Evaluation of soil moisture-based indices for quantifying agricultural drought in the southern Great Plains

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Introduction

- Measured soil moisture is not incorporated into drought indices commonly used to define agricultural drought.
- Soil moisture-based indices are a logical choice for monitoring agricultural drought as data become widespread.
- **But potential indices and their links to agricultural production remain understudied.**

Objectives

How are soil moisture based indices related to crop yield?

- Soil moisture-based drought indices were evaluated by quantifying their relationships with county-level cotton, hay, and wheat yield in **Oklahoma** and **the Texas Panhandle**.

Which index is preferred?

Agricultural drought indices should be…

1. Related to crop yield
2. Temporally comparable
3. Spatially comparable
4. Easy to understand

Methods

- Soil moisture-based indices were derived from data from the **Oklahoma** and **West Texas** Mesonet systems (Fig. 1).
- Candidate indices included:
  - **Matric potential (MP) and soil water storage (SWS)**, raw measures of soil moisture.
  - **Fraction of available water capacity (FAW)**, soil moisture standardized based on measured soil properties.
  - **SWS-anomaly and FAW-anomaly**, soil moisture standardized by long-term averages.
  - **Statistically standardized SWS and FAW (SSWS and SFAW)**, soil moisture standardized by fitting an empirical probability density function to long-term data and then transforming values to the standard normal cumulative distribution.
- Correlation was used to quantify soil moisture-yield relationships.

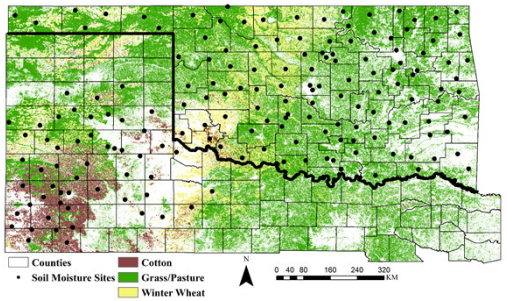

Figure 1. Map of the study area including locations of Oklahoma Mesonet and some West Texas Mesonet station locations as well as cotton, grasslands, and wheat land cover in Oklahoma and part of Texas in 2016.

Results and Discussion

Correlation timing varies by crop

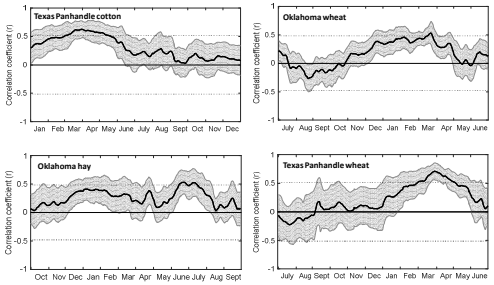

Figure 2. Average correlation (r) between SWS-anomaly (0-40 cm) and cotton, hay, or wheat yield in for counties in Oklahoma or Texas from 2000-2016. The shaded area around each line represents one standard deviation, and dashed lines are the limits of significant correlation ($P < 0.05$).

Yield of each crop was significantly related to drought indices. But the time of peak correlation varied by crop.

Standardization limits seasonality

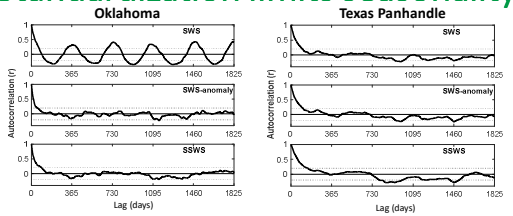

Figure 3. Correlograms for soil water storage (SWS), SWS-anomaly, and standardized SWS (SSWS) for the Marena Oklahoma Mesonet station near Stillwater, Oklahoma from 2000-2016 and the Reese Center West Texas Mesonet station near Lubbock, Texas from 2002-2016.

In Oklahoma, soil water storage (SWS) showed a clear annual cycle that was not present with standardize indices.
In the drier Texas Panhandle, no indices were seasonal.

Within a county, performance of drought indices was similar…

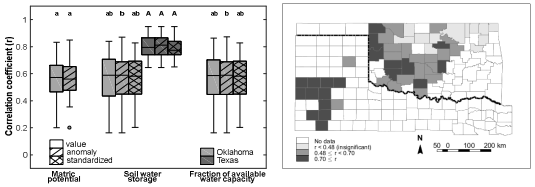

Figure 4. Correlation between drought indices and wheat yield for each county in Oklahoma and the Texas Panhandle from 2000-2016 (left). Map showing spatial gradient of correlation strength between Soil Water Storage and wheat yield.

For all crops, the strength of the drought index-yield relationship was the same for each index at the county level (Fig. 4 left).
For wheat, drought index-yield correlation strength generally decreased from west (drier) to east (wetter) (Fig. 4 right).

…BUT across counties, standardized indices were best.

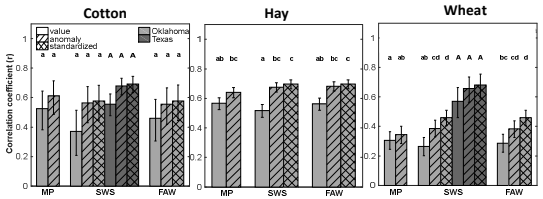

Figure 5. Correlation between drought indices and cotton, hay, and wheat yield across all counties in Oklahoma or the Texas Panhandle. Drought indices were calculated for the 0-40 cm soil layer for Matric Potential (MP), soil water storage (SWS), and fraction of available water capacity (FAW).

For a given index, the anomaly and statistically standardized values were generally more strongly related to crop yield than indices based on raw soil moisture.
For wheat, correlation strength was generally higher for the Texas Panhandle than for Oklahoma, possibly because parts of Oklahoma are less water limited.

Conclusions

Which index is preferred?

1. Related to crop yield?
   All indices were significantly related to cotton, hay, and wheat yields in Oklahoma and the Texas Panhandle.
2. Temporally Comparable?
   Unlike raw indices and FAW, **Anomaly and Statistically Standardized Indices** were not seasonal (more temporally comparable).
3. Spatially Comparable?
   All indices performed similarly within counties, but **Anomaly and Statistically Standardized Indices** were generally better in across county analyses (more spatially comparable).
4. Easy to Understand?
   Anomaly and statistically standardized indices each met the first three criteria, but **SWS-anomaly** offers the additional advantage of representing depth of soil water, therefore having familiar units (mm or cm).

Acknowledgements
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