Development and Evaluation of Soil Moisture-Based Indices for Agricultural Drought Monitoring

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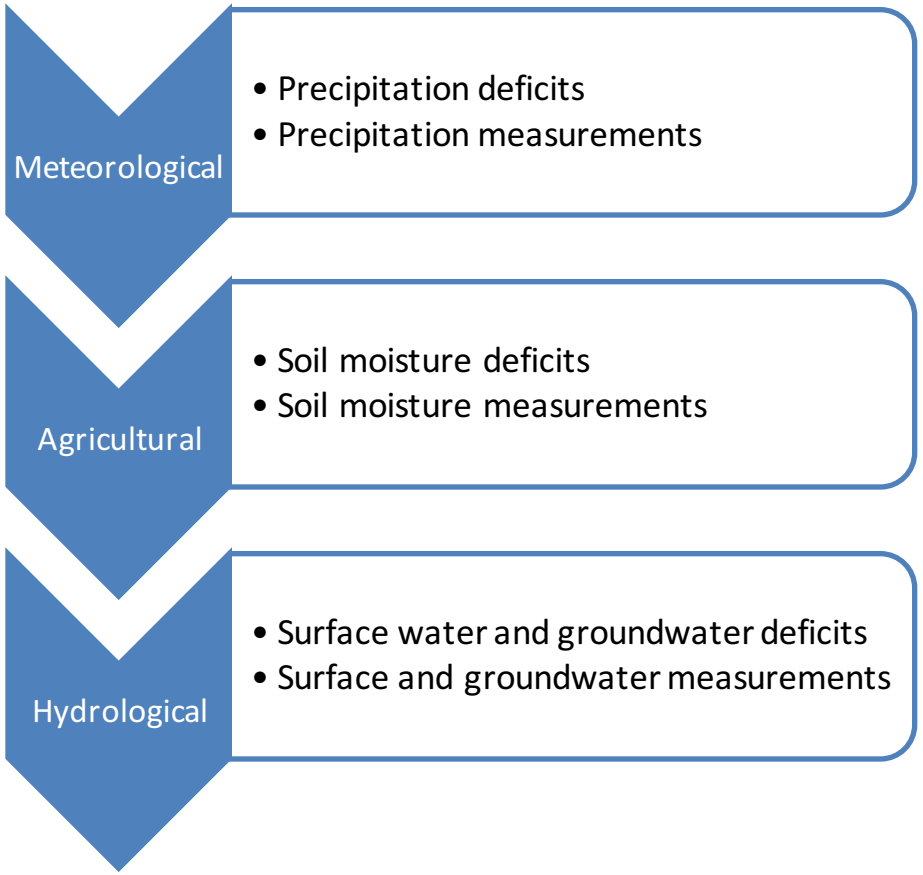
Drought classifications

- Severe impacts begin during agricultural drought
- Agricultural drought often foreshadows hydrologic drought
- Agricultural drought is defined by soil moisture



Pocasset, OK, Aug. 22, 2012 (Sue Ogrocki)

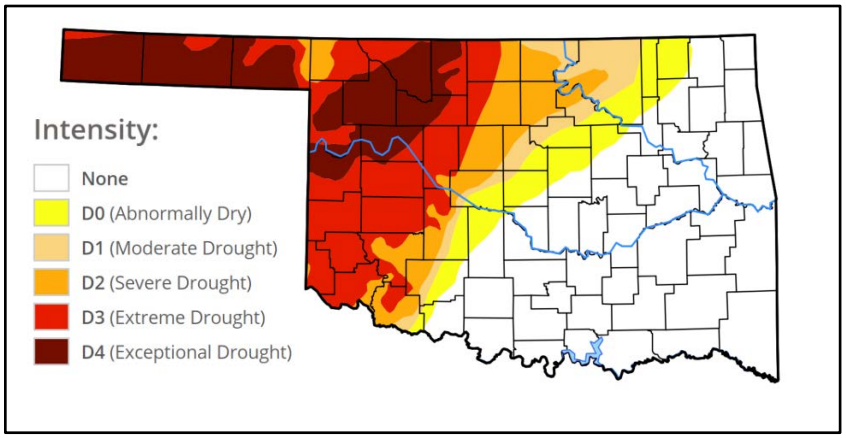
Texas Co., OK, Aug. 2012 (Mark Mabry)

Luther, OK, Aug. 4, 2012. (Jim Beckel)

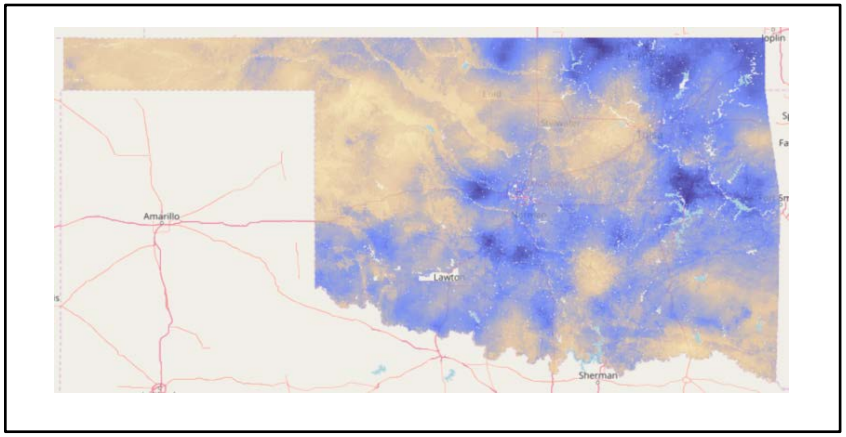
Kay Co., OK, Oct. 18, 2012. (AP)

Drought monitoring

- Common metrics:
  - Meteorological indices
  - Surface water monitoring
  - Remotely sensed vegetation indices
- Why not measured soil moisture?
  - Measurement challenges
  - Conceptual challenges
- Objective: identify effective agricultural drought indices based on soil moisture measurements

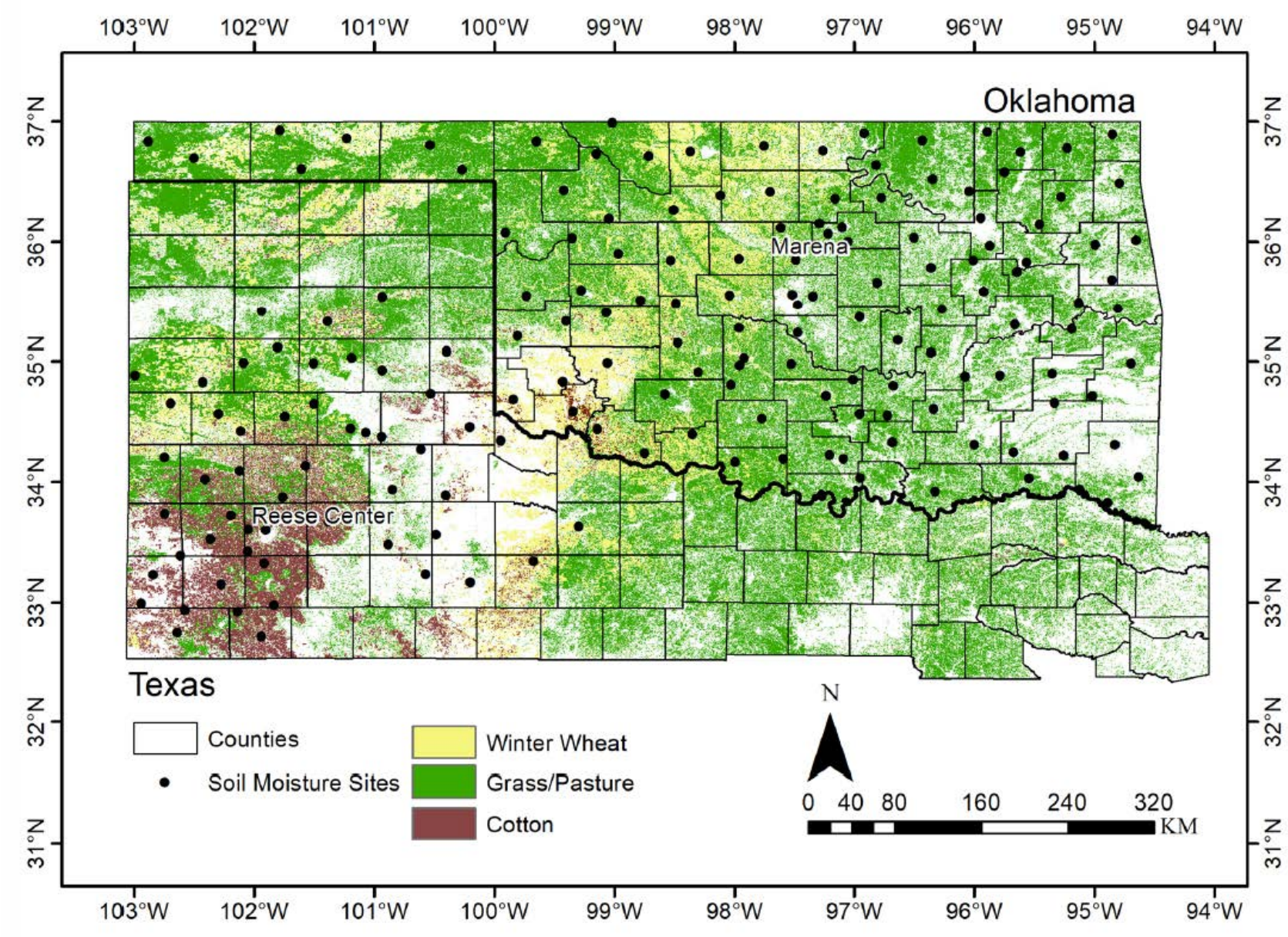


US Drought Monitor, May 24, 2018. Courtesy of NDMC-UNL.



Oklahoma automated in situ soil moisture mapping system, 5-cm depth, May 23, 2018.

Study region



Methods

Data

- Oklahoma Mesonet
  - Heat dissipation sensors
- West Texas Mesonet
  - Water content reflectometers
- National Agricultural Statistics Service
  - County non-irrigated yields
- Crop types
  - Winter wheat
  - Hay
  - Cotton

Limitations

- No sensors in cropland!
- Different sensor types
- No measured soil properties for West Texas Mesonet
- Limited NASS crop data availability

Candidate soil-moisture based indices

Variables

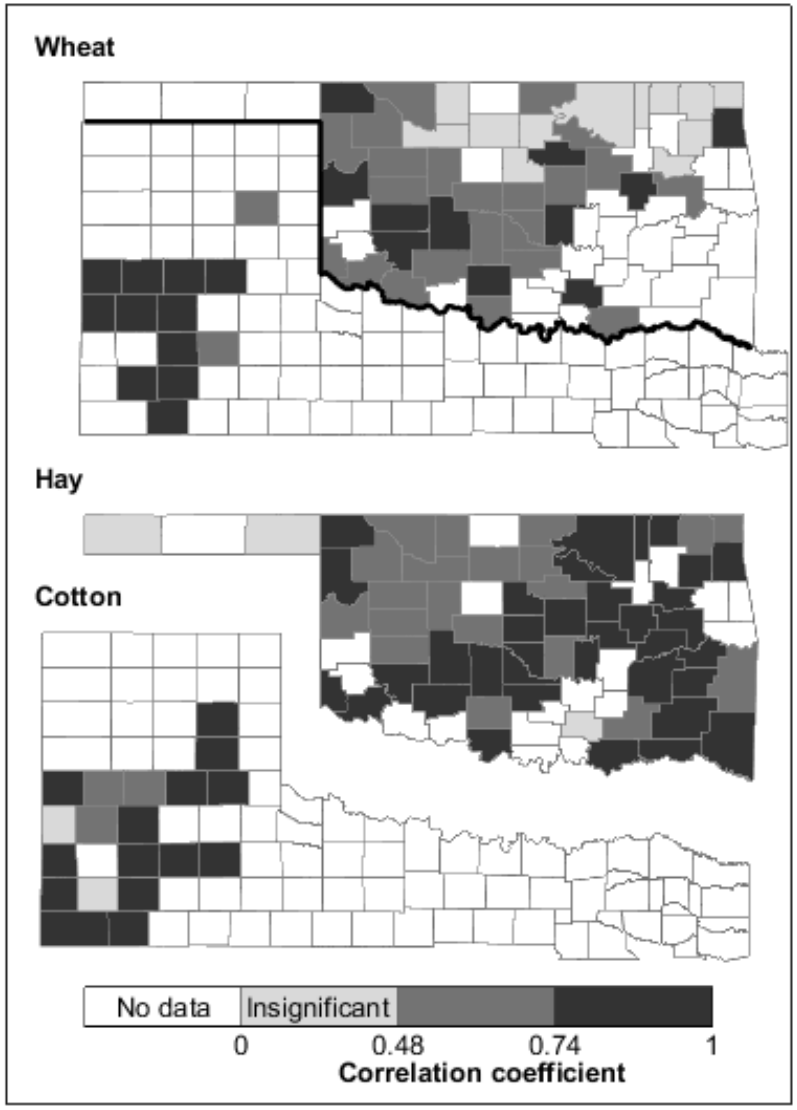
- Matric potential (MP): indicator of the potential energy of the soil water; kPa
- Soil water storage (SWS): volumetric water content X soil depth; mm
- Fraction of available water capacity (FAW): volumetric water content scaled between 0 (wilting point) and 1 (field capacity); unitless

Expressions

- Raw values
- Anomalies: current value minus mean value for this day of year
- Statistically standardized: empirical pdf fit for each day of year and used to estimate cumulative probability which is transformed to a standard normal value

Strong county-level correlations

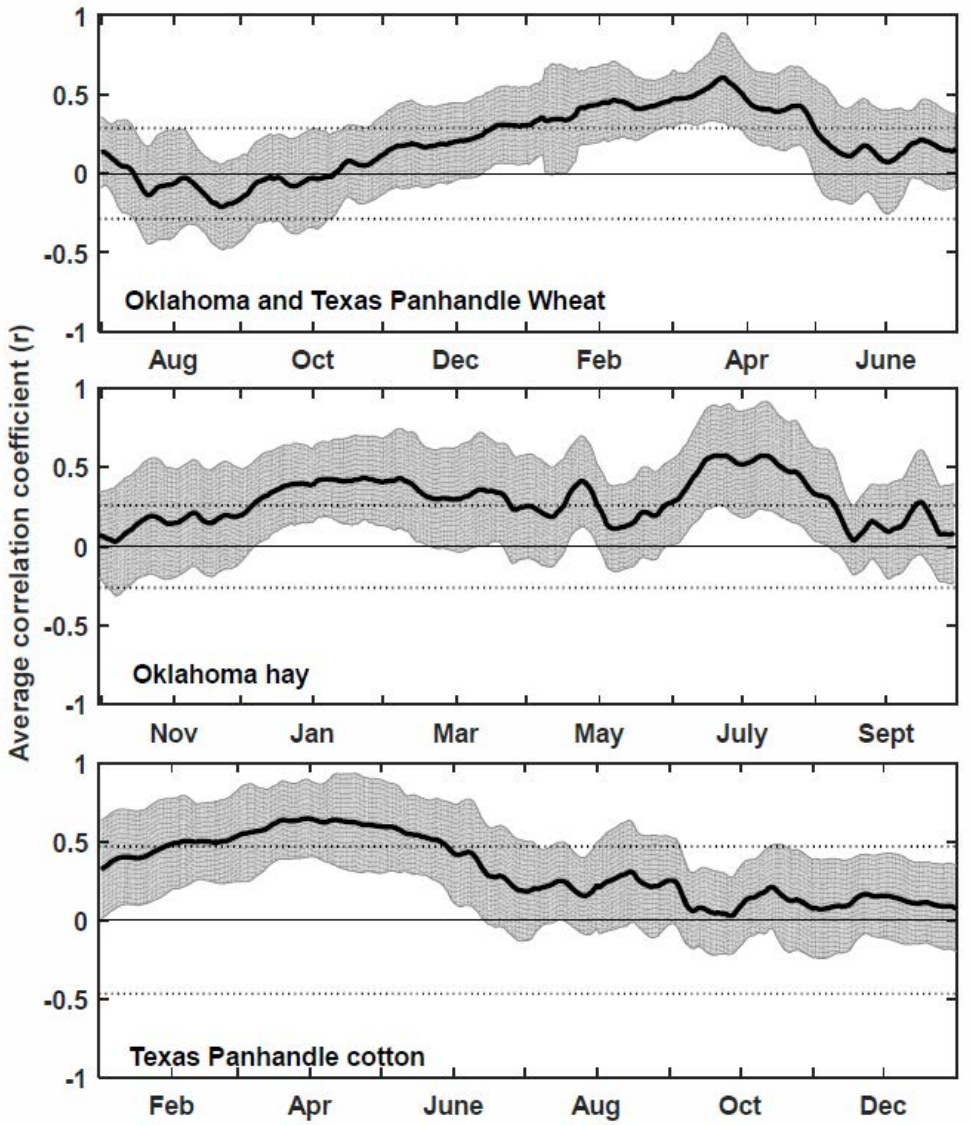
- Measured soil moisture positively correlated with crop yield
- Correlations stronger for warm-season crops than cool-season crops
- NE to SW trend in correlation strength for winter wheat



Maximum correlation coefficients (*r*) between soil water storage anomaly and wheat, hay, or cotton yield anomaly for individual counties in Oklahoma (2000-2016) and the Texas Panhandle from (2002-2016). The day of year on which maximum correlation occurred varied by county.

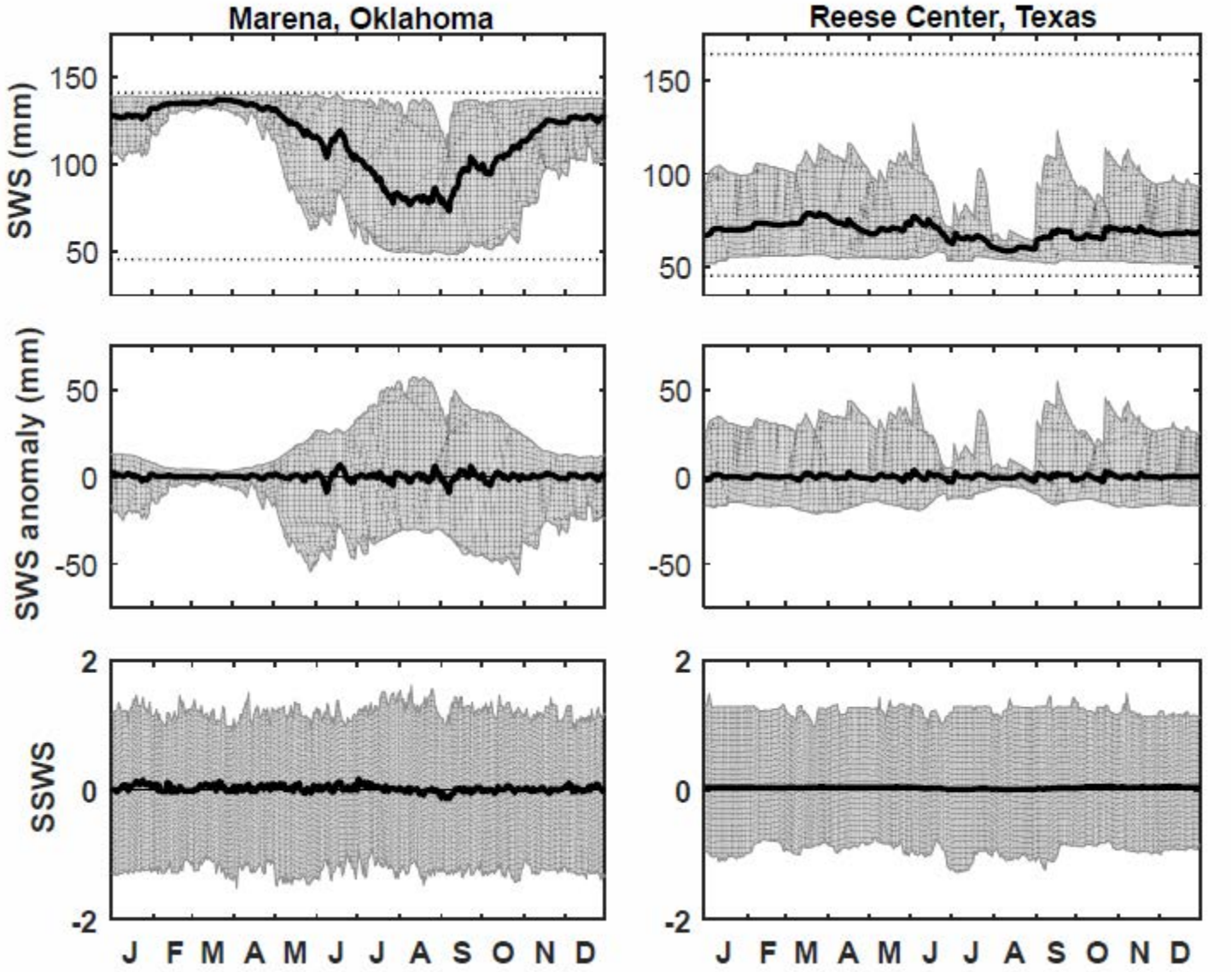
Long lead times

- Wheat yields most strongly correlated with soil moisture in late March
- Hay yields most strongly correlated with soil moisture in June and July.
- Cotton yields most strongly correlated with soil moisture in March and April



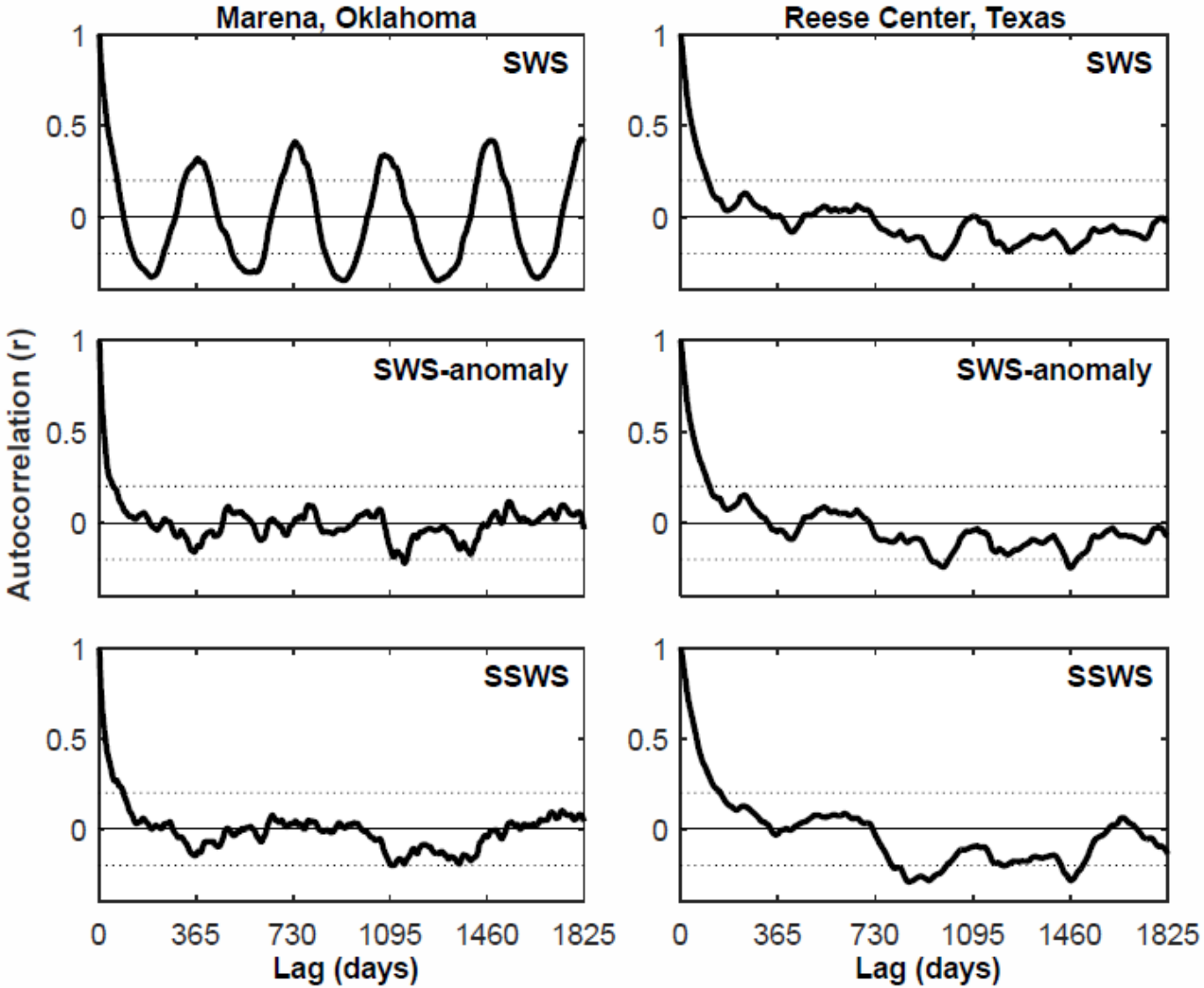
Average correlation (*r*) between SWS-anomaly and wheat, hay, or cotton yield anomaly for counties in Oklahoma (2000-2016) and the Texas Panhandle (2002-2016). The black line represents the across-county average correlation coefficient for each day of year for counties with significant soil moisture-yield anomaly relationships, and the shaded area around each line represents one standard deviation. The dashed lines are the limits of significant correlation ($P < 0.05$)

Seasonality differs across sites



Time series of 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. The solid black lines represent mean values for each day of the year, and the shaded region is the area between 10th and 90th percentile values. For SWS, maximum and minimum values are represented by dashed lines.

Standardization minimizes seasonality

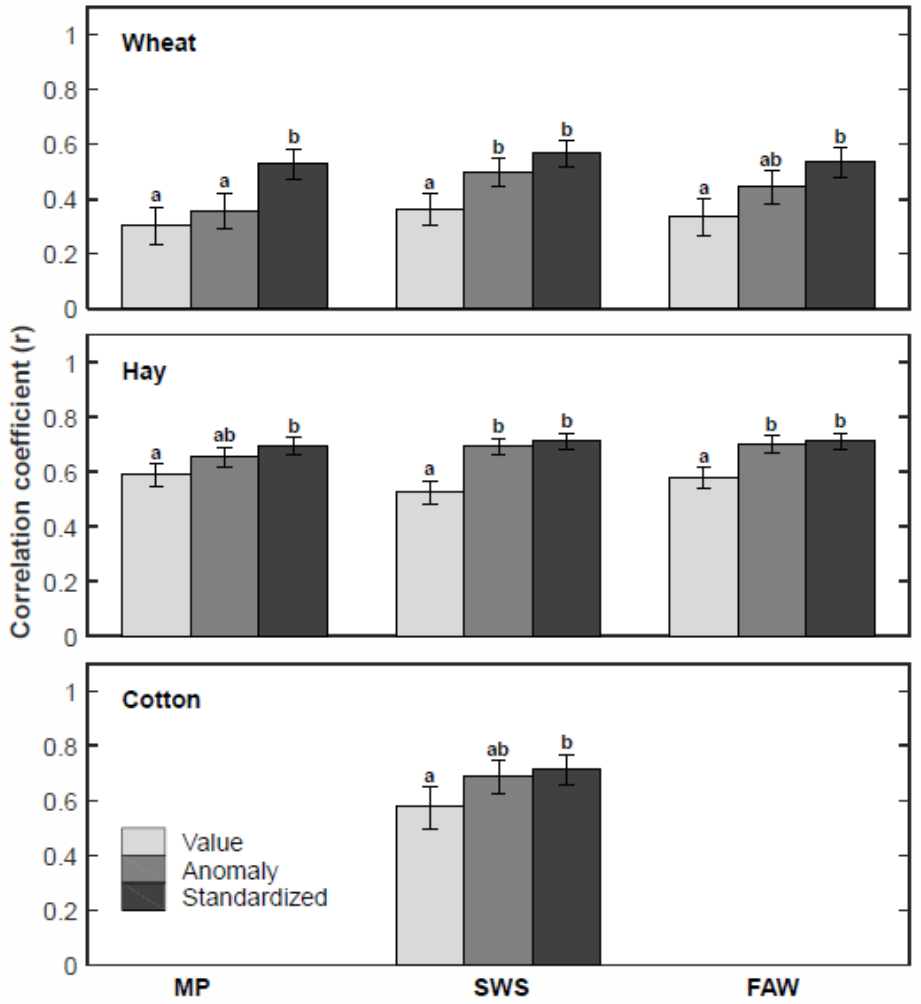


Correlograms for soil water storage (SWS), SWS-anomaly, and standardized SWS (SSWS) for the Marena Oklahoma Mesonet station near Stillwater, Oklahoma from 2000-2016 and the Reese Center West Texas Mesonet station near Lubbock, Texas from 2002-2016. Dashed lines are included at ±0.2 as an estimate of the limit of practically meaningful autocorrelation.

Standardization strengthens regional-level correlations

- Matric potential, soil water storage, and fraction of available water capacity similarly correlated with yields

- Statistically-standardized values more strongly correlated than raw values in 7 cases and than anomalies in 1 case



Correlation coefficients (*r*) between drought indices and wheat, hay, or cotton yield anomaly. County-level data for counties with significant soil moisture-crop yield anomaly relationships were combined into a single correlation analysis for each drought index-crop combination, and Oklahoma data were from 2000-2016 and Texas Panhandle data were from 2002-2016. Drought indices included matric potential (MP), soil water storage (SWS), and fraction of available water capacity (FAW), and *r* is shown for index values, anomalies, and statistically standardized indices. Error bars are 90% confidence intervals, and columns with different lowercase are significantly different at $P < 0.10$.

Summary

- Two promising indices
  - Soil water storage anomaly
  - Standardized soil water storage
- Soil property data essential for some purposes, but not necessarily for drought monitoring
- Strong potential for soil moisture measurements in drought monitoring

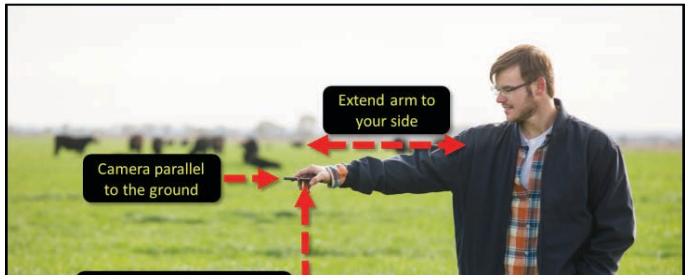
- Soil water storage anomaly
  - Depth units (mm or in)
  - Easier to construct
  - Easier to interpret
- Standardized soil water storage
  - Unitless
  - More difficult to construct and interpret
  - Slightly stronger correlations to yield

Acknowledgments and invitations

- Supported by:

SOUTH CENTRAL CLIMATE SCIENCE CENTER

- Special thanks to:
  - Oklahoma Mesonet staff
  - West Texas Mesonet staff
  - National Agricultural Statistics Service



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