Title: The Impact of Drought on Vegetation Water Use in Different Climatic Divisions across Oklahoma

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Students: Kul Khand

Student Status	Number	Disciplines
Undergraduate	0	
M.S.	0	
Ph.D.	1	Biosystems & Agricultural Engineering
Post Doc	0	
Total	1	

Principal Investigators: Saleh Taghvaeian, Assistant Professor, Oklahoma State University; Kul Khand, PhD Student, Oklahoma State University; Prasanna Gowda, Research Leader, USDA-ARS Grazinglands Research Laboratory, El Reno, OK.

Publications:

Khand, Kul; Saleh Taghvaeian; Ali Ajaz, 2017, Drought and its impact on agricultural water resources in Oklahoma. (Available in: http://pods.dasnr.okstate.edu/docushare/dsweb/Get/Document-10705/BAE-1533web.pdf), Oklahoma Cooperative Extension Service, BAE-1533.

Khand, Kul; Saleh Taghvaeian; Ali Ajaz; Prasanna Gowda, 2018, Evapotranspiration responses to droughts from croplands and grasslands in semi-arid and humid climates of Oklahoma, USA (manuscript in preparation).

Ajaz, Ali; Saleh Taghvaeian; Kul Khand, 2018, Development of agricultural drought indices by effective harnessing of soil moisture and weather data (manuscript in preparation).

Problem and Research Objectives:

Water use by vegetation is one of the major components of water budget, having a significant impact on water availability at variable scales. The state of Oklahoma lies in a transitional zone between eastern humid and western semi-arid climates. These climatic variations lead to differences in vegetation water use (also termed evapotranspiration) across the state. At the same time, the vegetation water use behavior is impacted by frequent droughts. Therefore, capturing water use variations in relation to climatic conditions and droughts can provide critical information for decision makers to optimize water management plans and conserve the finite water resources of Oklahoma. The main objective of this study was to analyze in-situ and remotely sensed data to study the interrelations between evapotranspiration (ET), droughts and climatic conditions, as well as their impacts on water resources.

Methodology:

The study has been conducted in three phases. At first, an initial study was conducted to synthesize the drought impacts on water resources in western Oklahoma. Three different sites were selected based on water resources: the Oklahoma Panhandle (Ogallala aquifer region), southwest region (Lugert-Altus Irrigation District), and central (the Rush-Springs aquifer) region. Groundwater level data from the USGS monitoring wells and the surface water level data were collected and analyzed to assess the impact of droughts on water resources.

In the second phase, meteorological and soil moisture data from Mesonet stations were used to develop drought indices. Daily meteorological data such as solar radiation, air temperature, wind speed and relative humidity were used to compute daily reference ET (ASCE-EWRI, 2005). These daily reference ET values were integrated with soil moisture data to develop two new drought indices: Soil Moisture Evaporation Index (SMEI) and Drought Duration Index (DDI). Five sites were selected in this study to capture climatic conditions across Oklahoma (Figure 1). SMEI and DDI were computed for the period of 2000 to 2017 and compared with previously developed drought indices and the US Drought Monitor.

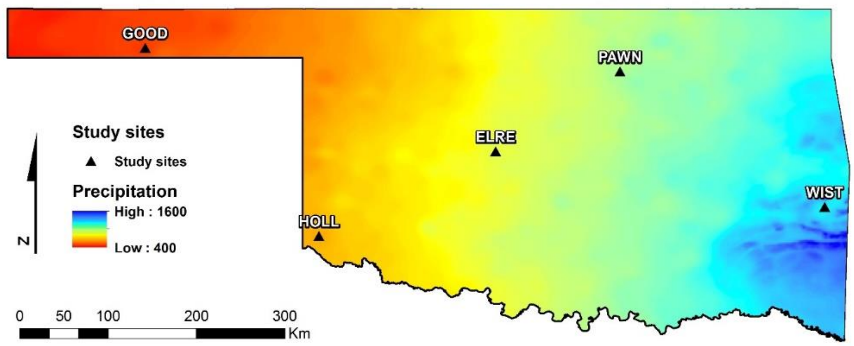

Figure 1. Location of five Mesonet study sites across Oklahoma

In the third phase, daily ET maps were generated using MODIS (Moderate Resolution Imaging Spectroradiometer) imagery. The Surface Energy Balance System (SEBS) model (Su, 2002) was implemented to compute daily ET maps with meteorological inputs from Mesonet stations. The ET results from croplands and grasslands were compared for different climate divisions across the state for the period of 2001 to 2014. The NLCD landcover (Homer et al., 2015) was used as a reference for distinguishing the different landcover types. Results from all three phases were integrated to analyze the impact of drought on water resources and vegetation water use across different climatic conditions.

Principal Findings and Significance:

Drought impacts on water resources: The Ogallala aquifer in the Panhandle regions is a major source of irrigation water and has been diminishing during the past few decades. Based on water level data collected from 42 monitoring wells across the Panhandle, water levels in the Ogallala aquifer declined 19 feet from 2001 to 2017 (Figure 2). About 50 percent of decline (9 ft) occurred in the recent drought between 2011 and 2015. The average decline rate during the drought period was 2.2 feet per year, which is 2.75 times greater than during non-drought years (0.8 feet per year).

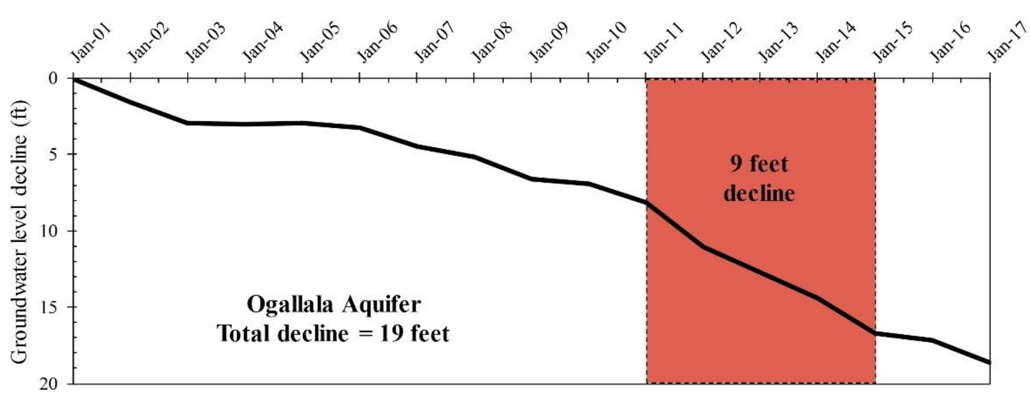

Figure 2. Groundwater level decline in the Ogallala aquifer of Oklahoma Panhandle

Rush Springs is the second most important aquifer within the state and provides irrigation water to several counties in western Oklahoma. This aquifer also experienced groundwater level depletion during droughts. The water level data from 12 monitoring wells showed that the water level in the Rush Springs aquifer dropped 10 feet during 2001 to 2017. About 70 percent of that decline was observed in recent drought between 2011 and 2015 (Figure 3). The average rate of water level decline during drought years was 1.8 feet per year, nine times the average decline rate in non-drought years (0.2 feet per year). Unlike Ogallala, the Rush Springs aquifer showed increases in groundwater level after rainy periods in 2005, 2007 to 2009 and 2015 to 2017.

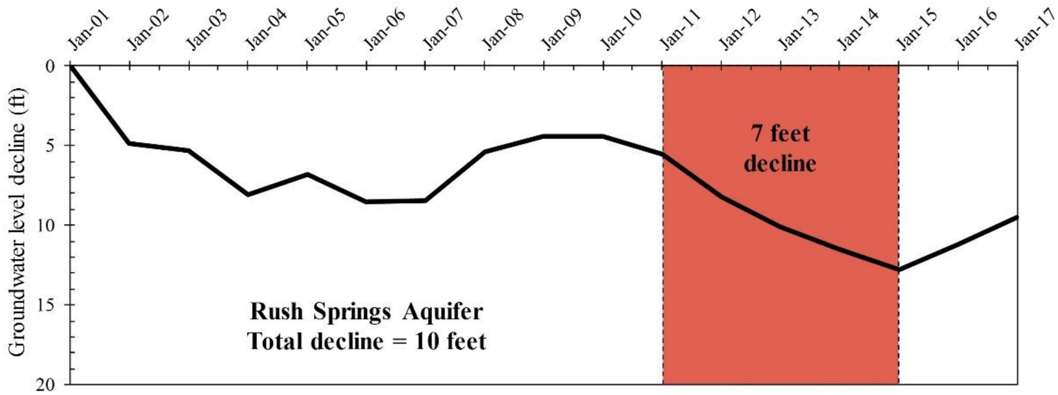

Figure 3. Groundwater level decline in the Rush Springs aquifer

Similar to groundwater resources, surface water resources were impacted by droughts. Lake Altus in southwest Oklahoma is a primary source of irrigation water for the Lugert-Altus Irrigation District (LAID). The lake was significantly impacted by the drought of 2011. Water storage in the lake was declined by about 70 percent in July 2011 compared to July 2010. Due to this decline, irrigation water was restricted to LAID, which ultimately decreased the irrigated area to near zero in 2011 (figure 4). In July 2014, water storage in Lake Altus was about 85 percent less than that in July 2010. After receiving rainfall in early 2015, the water level in July 2015 in Lake Altus overpassed the water level of that in July 2010 (Khand et al., 2017).

The study documented the vulnerability and resilience of water resources in response to recent drought. The Rush Springs aquifer, which is hydrologically connected to surface water resources showed a quicker response to the rainfall (Figure 3), indicating greater resilience to drought. However, the Ogallala aquifer did not show any response even after rainy periods, indicating sustainability issues for the long term.

The report on these results is published by the Oklahoma Cooperative Extension Service and is available online (http://pods.dasnr.okstate.edu/docushare/dsweb/Get/Document-10705/BAE-1533web2018.pdf).

Development of drought indices: Drought indices were developed to incorporate two components of drought severity: magnitude and duration. SMEI (soil moisture evapotranspiration index) to measure magnitude and DDI (drought duration index) to capture drought duration component. The SMEI and DDI results from 2000 to 2017 indicated the successful detection of droughts across different climates of Oklahoma. Comparison with existing soil moisture-based and meteorological drought indices showed good correlations.

The performance of the new indices for temporal and spatial tracking of drought was also studied. For temporal analysis, a Mesonet site (Goodwell) from Oklahoma Panhandle was selected for a drought period of 2011 to 2014. The SMEI and DDI were able to capture the magnitude and duration components of drought episodes as indicated by the US Drought Monitor and other indices (Figure 4).

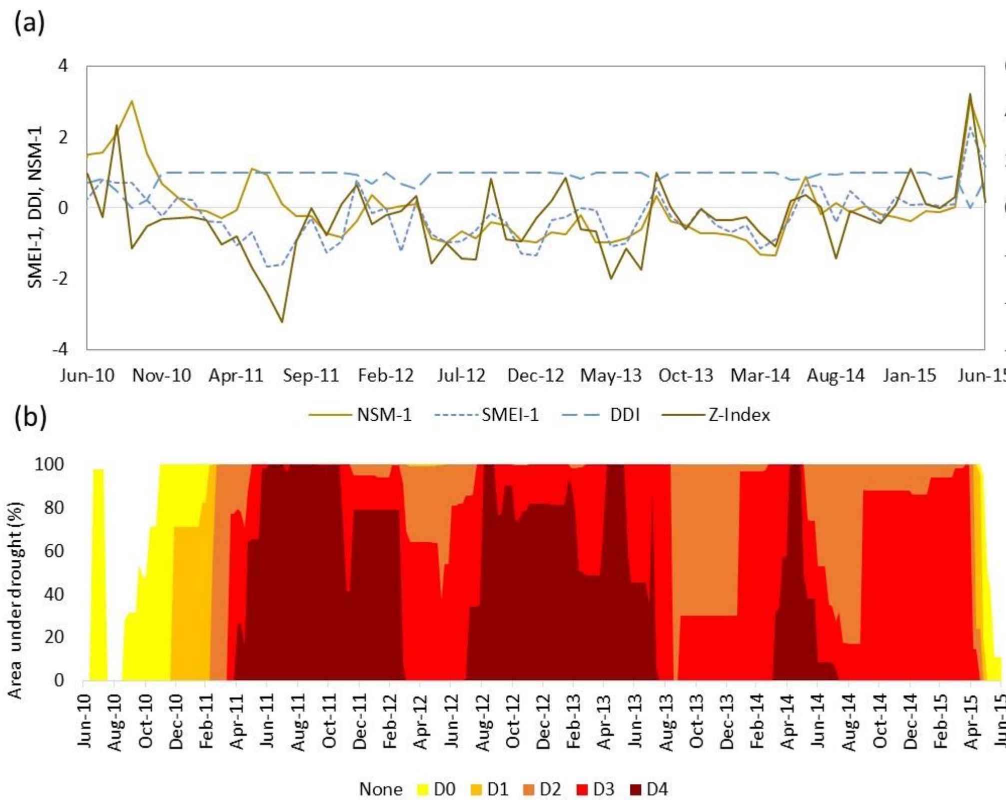

Figure 4. Comparison of SMEI and DDI with (a) soil moisture-based (NSM) and meteorological drought index (z-index), and (b) US drought monitor.

The spatial pattern of drought indicated by SMEI was similar to the US drought monitor, indicating successful incorporation of spatial variation of drought across the state. Application of soil moisture and meteorological data from Mesonet stations across the state was useful for tracking drought and for developing indices suitable for the climates of Oklahoma. The soil moisture and reference ET data could be further explored for predicting droughts and making timely decisions to minimize losses from droughts. The manuscript on this study is ready for submission.

Drought impacts on vegetation water use: The comparison of water use (ET) maps between July 2010 (no-drought) and July 2011 (drought) is shown in Figure 5. The results indicated the greater impact of drought on western parts of the state compared to the eastern parts. In the western parts of the state, grasslands and croplands are the dominant land covers. However, eastern part is mostly covered by forests. Based on these two months, forest indicated greater resilience to drought compared to croplands and grasslands.

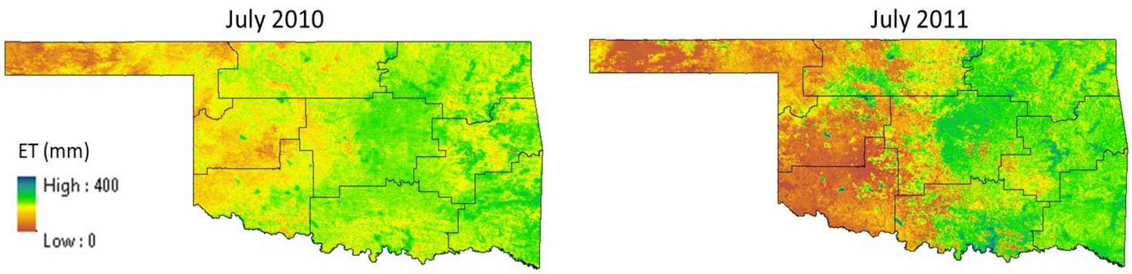

Figure 5. Monthly ET for July 2010 and 2011 across Oklahoma

Further analysis is being conducted and the results will be presented in upcoming meetings and reports. The final results and findings will be included in a manuscript that is expected to be submitted for publication by Summer 2018.

References:

Environmental and Water Resources Institute of the American Society of Civil Engineers (ASCE-EWRI). The ASCE Standardized Reference Evapotranspiration Equation; Report of the ASCE-EWRI Task Committee on Standardization of Reference Evapotranspiration; ASCE: Reston, VA, USA, 2005.

Su, Zhongbo, 2002, The Surface Energy Balance System (SEBS) for estimation of turbulent heat fluxes, Hydrology and Earth System Sciences, 6(1), 85-100.

Homer, Collin; Jon Dewitz; Limin Yang; Suming Jin; Patrick Danielson; George Xian; John Coulston; Nathaniel Herold; James Wickham; Kevin Megown, 2015, Completion of the 2011 National Land Cover Database for the conterminous United States-Representing a decade of land cover change information, Photogrammetric Engineering and Remote Sensing, 81(5), 345-354.

Khand, Kul; Saleh Taghvaeian; Ali Ajaz, 2017, Drought and its impact on agricultural water resources in Oklahoma. (Available in: http://pods.dasnr.okstate.edu/docushare/dsweb/Get/Document-10705/BAE-1533web.pdf), Oklahoma Cooperative Extension Service, BAE-1533.