Google Earth Engine Application for Mapping and Monitoring Drought Patterns and Trends: A Case Study in Arkansas, USA

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HIGHLIGHTS

- Arkansas experiences a higher frequency of droughts during March and August.
- Droughts are most frequent in eastern and southern Arkansas, especially in the Mississippi Alluvial Plain.
- Flash droughts strongly affect vegetation, with agricultural lands and grasslands being the most vulnerable.
- Short-term meteorological data shows more frequent droughts, while long-term trends suggest possible improvement in some areas.

ABSTRACT

Drought is a prolonged dry period that can severely impact the environment, human health, economies, agriculture, and energy resources. The primary objectives of this study are to: 1) quantify the variability and distributions of drought patterns in Arkansas, USA, 2) use remotely sensed indices to investigate the correlation between drought and vegetation cover in the area, and 3) develop a cloud-based user-friendly app to facilitate the assessment of drought impact in Arkansas over the past decades. In addition, a correlation analysis was also performed between the Vegetation Health Index (VHI) and meteorological indices to better understand the impact of meteorological drought on vegetation stress. The results indicate that drought is most prevalent during March and August months. The results of this study revealed that approximately 31% of the study area fell under the four drought classes (i.e., 1% Extreme drought, 4% Severe drought, 9% moderate drought, and 19% mild drought), with spring and the growing season experiencing moderate drought, particularly in agricultural areas, most notably within the Mississippi Alluvial Valley Plain at both state and county levels. In August, approximately 31% of the study area fell under the Four drought classes (i.e., 1% Extreme drought, 4% Severe drought, 9% moderate drought, and 19% mild drought), with spring and the growing season experiencing moderate drought, particularly in agricultural areas, most notably within the Mississippi Alluvial Valley Plain at both state and county levels.

INTRODUCTION

Arkansas is one of the south-central states that shows this vulnerability. Despite its humid subtropical classification, the state has a history of severe droughts. In recent years, the drought caused widespread crop failures, particularly for soybeans, rice, and cotton, leading to agricultural losses exceeding $128 million (University of Arkansas Division of Agriculture, 2012).

Figure. 1 shows the distribution of the main land cover in Arkansas, in the southern region of the United States.

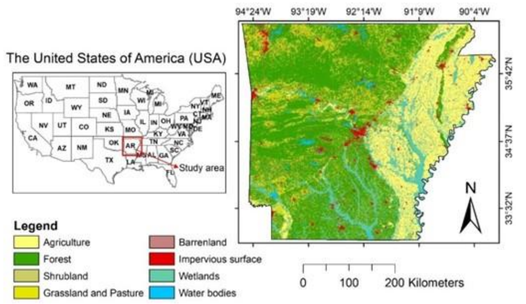
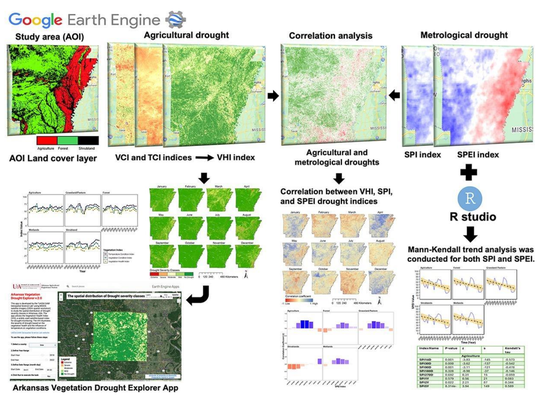


Figure 1. Location of study area based on the 2023 Cropland Data Layer (CDL)

MATERIALS AND METHODS

Graphical abstract

Arkansas has a humid subtropical climate with hot summers and mild winters, making it susceptible to drought. The mean annual temperature is 60.1°F (15.6°C), and the average annual precipitation is 50.5 inches (128.3 cm).



Data Sources and Description

The following table shows the data that were used in this study with its description (Table 1).

Table 1. Data sources and description.

Data Product	Data Type	Spatial Resolution (m)	Temporal Resolution	Date
MOD13Q1.0 61	NDVI	250	16 days	2000-present
MOD11A1.0 61	LST	1000	Daily	2000-present
USDA-NASS Cropland	Land Cover	30	Annually	2000-present
GRIDMET DROUGHT dataset	Drought Indices	4638.3	Daily	2000-present

Development of the Drought indices

The following table shows the drought indices that were developed in this study (Table 2).

Table 2. Summary of drought indices mentioned.

Drought index	Calculation formula
Temperature Condition Index (TCI)	$TCI = \frac{LST_{max} - LST_{pix}}{LST_{max} - LST_{min}} \times 100$
Normalized difference vegetation index (NDVI)	$NDVI = \frac{NIR - RED}{NIR + RED}$
Vegetation Condition Index (VCI)	$VCI = \frac{NDVI_{pix} - NDVI_{min}}{NDVI_{max} - NDVI_{min}} \times 100$
Vegetation Health Index (VHI)	$VHI = 0.5 \times (TCI) + 0.5 \times (VCI)$

Table 3. Drought classification based on VHI values (For more details check: Alzurqani et al., 2024).

Drought severity classes	Value (%)	Color scheme
Extreme	< 10	
Severe	< 20	
Moderate	< 30	
Mild	< 40	
No Drought	≥ 40	

Correlation Analysis

A Pearson correlation analysis was carried out between the Vegetation Health Index (VHI) and meteorological-based drought indicators aggregated at different time scales (Standardized Precipitation Index SPI

RESULTS AND DISCUSSION

Maps of drought spatial trends based on VHI

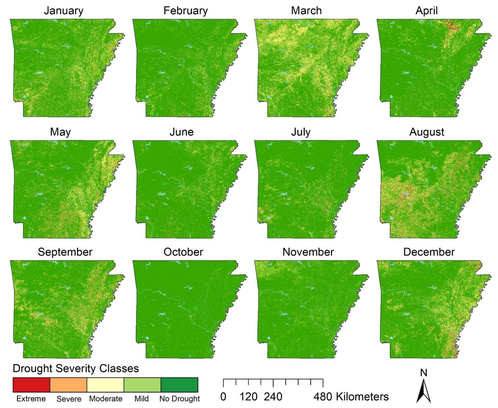


Figure 2. Monthly Drought severity classes for the vegetation health index (VHI) during the study period (2000-2022).

Correlation spatial and temporal analysis between VHI and SPI

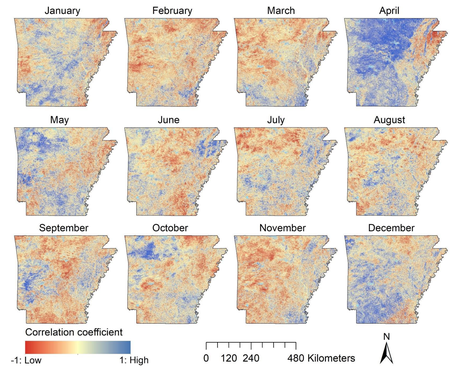


Figure 3. Monthly correlation coefficient between VHI and SPI (1 year) during the study period (2000-2022).

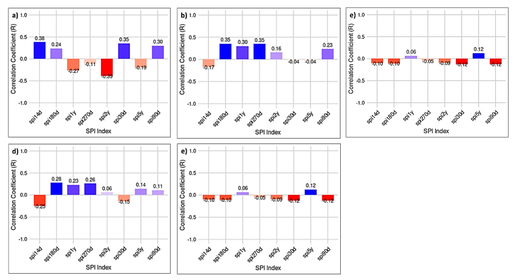


Figure 4. Annual correlation coefficient between VHI and SPI during the study period (2000-2022). a) is over Agriculture, b) over Grassland pasture, c) over Forest, d) over Wetlands and e) is over Shrubland.

RESULTS AND DISCUSSION

Mann-Kendall trend analysis

- Example of the RPNDVI shown the new residential development over time (Fig. 5)

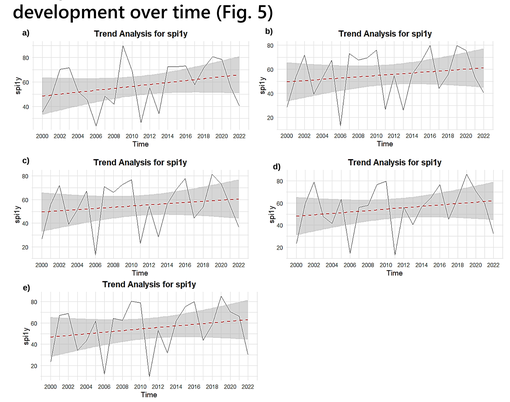


Figure 5. Mann-Kendall trend test for 1 year SPI, during the period 2000-2022. a) is over Agriculture, b) over Grassland pasture, c) over Forest, d) over Wetlands and e) is over Shrubland.

Table 1. Mann-Kendall trend for SPI over Agriculture

Annual	P-value	z	s	Kendall's tau
SPI14D	0.065	-1.88	-71	-0.281
SPI30D	0.001	-3.30	-125	-0.494
SPI90D	0.000	-4.04	-153	-0.604
SPI180D	0.027	-2.24	-85	-0.336
SPI270D	0.751	-0.34	-13	-0.051
SPI1Y	0.102	1.66	63	0.102
SPI2Y	0.004	2.88	109	0.431
SPI5Y	0.000	4 .41	167	0.661

CONLCUSIONS

- The state experienced a diverse drought landscape, with the southeast and northeast regions facing more severe conditions in December, while the southwest reached its peak drought levels in August.
- The analysis highlights strong correlations between the Vegetation Health Index (VHI) and the Standardized Precipitation Index (SPI) over 14, 30, and 90 days in agricultural areas. It also shows significant decreasing trends, which indicate the presence of drought conditions.

ACKNOWLEDGEMENTS

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