Analyzing drought conditions using NDVI in Coke, Texas

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ABSTRACT. In this research, drought in Coke County, Texas is analyzed using Normalized Difference Vegetation Index (NDVI) derived from remotely sensed Landsat data. Shrub, crop, and evergreen are focused to analyze their response to a drought event. The study reveals that pre-drought NDVI in 2009 is found to be higher than post-drought NDVI in 2011. The dominant vegetation, shrub, is most affected by drought, and the crop is least affected by drought. The study of dominant vegetation type can be used to monitor and study the severity and status of local drought.

1. INTRODUCTION
Drought is an event of an extended period of time, which can be a season, a year, or more, of insufficient rainfall (Ram Mohan Rao and Roy, 2012). It is the most complex environmental issue that affects not only agriculture, water resources, but also economy and ecosystem (Li et al, 2020). And it can be classified into four types: meteorological, hydrological, agricultural, and socioeconomic (Zhong, Cheng and Wang, 2020). Many studies analyze drought conditions using varies methods, such as the standardized antecedent precipitation evapotranspiration index (Li et al, 2020), the standardized precipitation index (Spinoni et al, 2020), the normalized difference vegetation index (NDVI) (Uttaruk and Laosuwan, 2019, Rimkus et al, 2017, Rotjanakusol and Teerawong, 2019), Standardized Precipitation Index, Streamflow Drought Index (Zhong, Cheng and Wang, 2020). NDVI determines the drought effects on vegetation (Rimkus et al, 2017). It is a measurement of the health of the plant based on how the plants reflect light. NDVI values decrease during the period of time without precipitation (Rimkus et al, 2017). Another reason for the decrease in NDVI values is the increase in dust in the atmosphere (Rimkus et al, 2017). Chlorophyll is a health indicator in plants, which can absorb visible light strongly, and the leaves can reflect near-infrared light (eos.com). When the plants become dehydrated or dead, the plants absorb more near-infrared light than reflect it. Therefore, the change in reflected near-infrared light can indicate the health of the plants.

Texas has been experiencing a severe drought condition for the past decades. In 2010, a severe drought was observed. It was significantly affected by the internal atmospheric variability that caused drying (Seager et al, 2014). This drought affected the health of the vegetation, such as, crops, shrubs, and trees. Therefore, NDVI is used to analyze the drought conditions in 2010 in Coke County, Texas. In the research, NDVI values of pre-drought in 2009 and post-drought in 2011 in Coke County are compared, and finding out which type of vegetation among crops, shrubs and evergreens is most susceptible to drought condition. The post-drought NDVI in 2011 is expected to be lower than the pre-drought NDVI in 2009.

2. STUDY AREA
Coke County, Texas is chosen as the study area to analyze the drought condition using NDVI values
(Figure 1). Coke County is located on the Edward Plateau in the center of Texas. The county was founded in 1889. And it was one of the 46 prohibition or entirely dry counties in Texas.

![Coke County, Texas](image)

According to 2010 U.S. Census, Coke County had a population of 3320, the total area is 2,400 km², and 40 km² of its area were covered with water. 90% of Coke County's agricultural income comes from cattle, sheep, goats, and horses. It is also the leading county of sheep ranching in the U.S. (Hunt, 2010). Therefore, the severe drought condition in 2010 had serious negative impacts on its agricultural income. And the drought condition has to be monitored and analyzed.

3. METHODOLOGY

3.1. NDVI

![Pre-drought in 2009 in Coke County](image)  ![Post-drought in 2011 in Coke County](image)

Figure 2a. Pre-drought in 2009 in Coke County  Figure 2b. Post-drought in 2011 in Coke County
The pre-drought and post-drought data are collected from Landsat, and they are viewed in ArcGIS 10.3.1 (Figure 2a-b). These two images are used to calculate NDVI using ArcGIS 10.3.1 and make comparison between pre-drought and post-drought.

NDVI is calculated using the difference of the spectral of vegetation. Healthy green leaves have a higher reflectivity in the near-infrared band (Keranen and Kolvooord, 2014). NDVI is calculated using the following formula:

\[
\text{NDVI} = \frac{(\text{IR} - \text{R})}{(\text{IR} + \text{R})}
\]

Where:
- \( \text{IR} \) = the DN value of a particular pixel in the infrared band, and
- \( \text{R} \) = the DN value of a particular pixel in the red band.

To calculate the NDVI values of the two images in 2009 and 2011, two functions in ArcGIS 10.3.1 are added to the MTL Landsat scene. One is named NDVI Function which is used to generate an image displaying greenness and relative biomass. Another is named Colormap Function which is used for easier comparison (Figure 3a-b).

ArcGIS uses a slightly different formula to calculate and display NDVI. Using the formula below, NDVI values range from 0 to 200:

\[
\text{NDVI} = \frac{(\text{IR} - \text{R})}{(\text{IR} + \text{R})} \times 100 + 100.
\]

\( \text{IR} \) = the DN value of a particular pixel in the infrared band, and
\( \text{R} \) = the DN value of a particular pixel in the red band.

The overall NDVI in 2009 is larger than it is in 2011, and the detailed changes of NDVI are in Table 1 and Figure 4 below.

Table 1. The NDVI statistics in 2009 and 2011

|                | 2009 NDVI | 2011 NDVI | % change  |
|----------------|-----------|-----------|-----------|
| Minimum        | 49        | 48        | -2.01     |
| Maximum        | 176       | 172       | -2.33     |
| Mean           | 122.26    | 106.39    | -14.92    |
| Standard deviation | 9.44     | 6.18      | -52.75    |
3.2. Isolate vegetation types

In order to isolate the vegetation types of the study area, a layer file is acquired from USGS National Land Cover Database. This layer file is named lc_2006 which classified the vegetation type, and there are 15 types of vegetation in Coke County (Figure 5).

Shrubs can be extracted by using the Raster Calculator, and the equation is "lc_2006" == 52 and name it shrubs. Crops can be extracted by using the Raster Calculator, and the equation is "lc_2006" == 82 and name it crops. Evergreens can be extracted by using the Raster Calculator, and the equation is "lc_2006" == 42 and name it evergreen.

Then, use Times Function in the Math toolset in the Spatial Analyst toolbox to create the vegetation type NDVI map in 2009 and 2011. Run the Times tool and multiply shrub by NDVI_2009. Name the output raster shrub_2009. Then run the Times tool and multiply shrub by NDVI_2011. Name the output raster shrub_2011. And repeat these steps for crop and evergreen. The result is shown in Figure 6 a-f.
Table 2 shows the detailed information of the changes of different vegetation in 2009 and 2011, which is collected from the layer file created.

| Vegetation Type | 2009 NDVI Values | 2011 NDVI Values | % Change |
|-----------------|------------------|------------------|---------|
|                 | min              | max              | mean    | st dev | min    | max    | mean    | st dev | % change mean | % change sd |
| shrubs          | 0                | 176              | 115.02  | 36.38  | 0      | 174    | 108.48  | 38.9   | -6                   | 6.5          |
| crops           | 0                | 175              | 123.87  | 31.97  | 0      | 173    | 123.82  | 31.01  | -0.04                | -3.1         |
| evergreens      | 0                | 169              | 113.59  | 33.73  | 0      | 167    | 111.45  | 31.88  | -1.9                | -5.8         |

4. **ANALYSIS**

4.1. **NDVI**

The red areas (see Figure 3a-b) in NDVI map represents water bodies. The post-drought water bodies are significantly smaller than the pre-drought water bodies. Drought significantly reduced the surface water area.

From the statistics of the NDVI in 2009 and 2011, the pre-drought NDVI in 2009 is higher than the post-drought NDVI in 2011. Although the maximum and minimum NDVI did not change a lot (both around -2%), the mean NDVI decreased almost 13%. The change in sd (-52.75%) indicates that the vegetation is more variable before drought than after drought. The graph of NDVI in 2009 and 2011 (Figure 4) agrees with the statistics of the NDVI in 2009 and 2011. NDVI in 2009 varies wider than in 2011. The statistics of NDVI and the declined surface water area reveal that the vegetation in Coke County becomes dehydrated or dead because of the occurrence of drought, which might cause a large number of decline in the agricultural and livestock yield.

4.2. **Isolate vegetation types**

After isolating the vegetation type, it is clear that the shrub is the most dominant land-cover type in the scene, and evergreen is the least dominant vegetation in the scene. By comparing the isolated vegetation type before and after drought in 2009 and 2011, crop has the least change among the three types of vegetation, and evergreen has the most change after drought event in 2010.

The statistics of NDVI of different vegetation types shows the detailed change. The shrub’s NDVI decreases the most (6%) than the crop and evergreen. And the crop’s NDVI decreases the least (-0.04%). The sd of shrub increases 6.5% which is the highest, which means the variation of its NDVI increase the most, and the sd of evergreen decreases 5.8% which is the lowest, which means the variation of its NDVI is the least.

5. **CONCLUSION**

The drought event in Coke County in 2010 decreased the area of the water bodies in 2011 compared to 2009. Drought also decreases the variation of overall NDVI in Coke County. In the three types of vegetation, shrub is affected by the drought the most, and crop is affected by the drought the least. As the dominant vegetation in Coke County is shrub, the health condition of shrub can reflect the drought severity in Coke County. In areas like Coke County whose dominant vegetation is shrub, the drought condition in such areas can be monitored and studied by the NDVI of shrub. In addition, this research provides a method using the NDVI of the local dominant vegetation to monitor and analyze the severity of drought.

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