

Statistical Analysis of Grassland Trends and Phenology using Satellite Time Series Imagery of the Flint Hills Ecoregion

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Abstract

The Flint Hills ecoregion is subject to a wide range of climate variation. This research study focuses on the counties of Elk and Pottawatomie within the Flint Hills and explores a method for analyzing vegetation condition and trends as an indicator of grassland health throughout the ecoregion. By utilizing remotely sensed time series imagery collected from 16-day MODIS NDVI composites over a timespan of 15 years and BFAST analysis methods we were able to analyze trends in overall grassland health and number breaks for this time period. In addition to trends and breaks, various phenometric parameters were extracted using TIMESAT. They included: start of season, end of season, season length, maximum NDVI, and small season integral. These phenometric parameters were analyzed for three years that had varying climatic conditions and fell within the 15 year time series. The years examined exhibited climatic conditions that were summarized as cool-wet (2008), hot-dry (2012), and normal (2005). The phenometric values assigned to each pixel were compared between the two counties using a Kolmogorov-Smirnov (KS) test. KS tests revealed the phenological patterns of the two counties were significantly different. Analysis of the entire time series revealed that a majority of the grassland pixels in the two counties saw negative grassland greenness trends over the time series. The number of breaks between the two counties also varied.

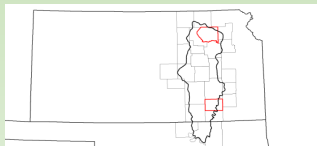


Fig. 1. Flint Hills ecoregion, Pottawatomie (north) and Elk (south) counties.

Objectives

Our study sought to understand how grassland vegetation dynamics within the Flint Hills ecoregion have changed over the past 15 years. We hypothesized that (1) the long-term trend in grassland greenness, a proxy for condition/health, has been stable throughout the Flint Hills and (2) the frequency of disturbances/breaks are similar throughout the Flint Hills.

In addition to vegetation dynamics, we wanted to understand if there were similarities in vegetation development between our two study areas. We hypothesized that phenometrics, key measures of vegetation development, occur at similar times throughout the Flint Hills.

Purpose

The Flint Hills ecoregion is a 1.6 million hectare (ha) expanse of land in eastern Kansas and north-central Oklahoma and it is home to one of the last remaining expanses of tallgrass prairie (Hutchinson et al., 2014). These grasslands offer a multitude of ecosystem services such as water retention, carbon storage, and livestock forage just to name a few. The study of vegetation dynamics helps us determine the impacts seen from variables such as climate change, land cover changes, land management practices, etc. Remote sensing is a cost effective method for examining vegetation dynamics on large spatial scales repeatedly over a period of time.

Materials & Methods

Study Area

Both of the counties used in this study, Elk and Pottawatomie, are located in the Flint Hills ecoregion of Kansas. While both counties are located in the same ecoregion, they represent northernmost and southernmost portions of the region and will likely display differences in vegetation dynamics

Image Data

Imagery data used for analysis were Moderate Resolution Imaging Spectrometer (MODIS) Normalized Difference Vegetation Index (NDVI) composites. The composites used were the maximum NDVI value collected within a 16-day temporal scale and had a spatial resolution of 231 x 231-meters pixels. A 16-day temporal scale means 23 images were taken each year. This study focused on a time period from January 1, 2001 to December 31, 2015. It was determined that only pixels (231 x 231-meters) consisting of more than 80 percent grassland according to National Landcover Database 2011 would be used.

Vegetation Dynamics

We used the Breaks For Additive Seasonal and Trend (BFAST) method to extract components of time series NDVI from MODIS imagery. The BFAST method enables the extraction of seasonal, trend, and noise components of NDVI grassland imagery for each pixel (Hutchinson et al. 2014). In addition to modeling trends, BFAST can also detect breakpoints including when they occur and the magnitude of the break (Hutchinson et al. 2014). A Chi-squared analysis was conducted to determine site differences (Elk vs Pottawatomie) for both trends and breaks during the time series.

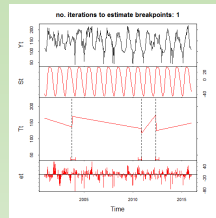


Fig. 2. One pixel broken into seasonal, trend, and noise components using BFAST.

Phenometrics

The program TIMESAT was used in our study to filter raw NDVI data and extract phenometrics of interest. Similar to what was done in Pockrandt, 2014, our study utilized the Savitzky-Golay TIMESAT filter in addition to parameters found optimal for our Flint Hills study area. The phenometrics that were extracted included: start of season, end of season, small seasonal integral, maximum NDVI, and season length. The Kolmogorov-Smirnov (KS) Test was used in the R statistical program to determine if phenometric results were significantly different between the two counties and across the three years that saw climate variations: 2005, 2008, and 2012.

Results

Vegetation Dynamics

We can see from figure, the overall trends of both study areas were overwhelmingly negative. Of the 16,415 pixels in Pottawatomie containing more than 80 percent grassland, 68.9 percent exhibited a negative trend over the 15 year study period. Over 59 percent of Elk county grassland pixels saw a negative trend over the study period.

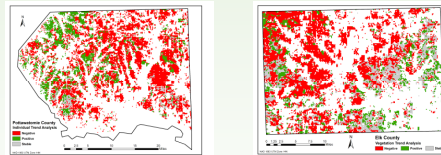


Fig. 3. Grassland vegetation trends over the 15 year time series.

Elk county saw a significantly larger number of pixels experience multiple breaks over the study period. Pottawatomie county saw 75 percent of its pixels experience zero breaks while Elk only saw 38 percent of its pixels experience zero breaks.

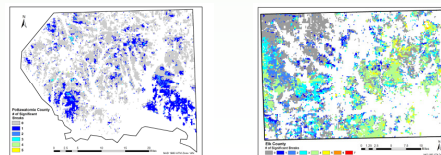


Fig. 4. Grassland breaks over the 15 year time series.

Phenometrics

The phenometrics that were examined included: start of season, or when grass first showed signs of green-up; end of season, when grass showed signs of senescence; season length, or the difference between start and end of season dates; maximum NDVI, when grass was showed maximum greenness; and small season integral, a measure of grassland productivity.

Utilizing TIMESAT and running KS tests for all phenometrics across the three years showed (table 1) that there are significant differences that can be observed between Pottawatomie and Elk counties. One phenometric parameter that shows significant differences between the counties is start of season (figure 4).

Parameter	Phenometric of interest	t-value	p-value
2005	Start of Season	0.1148	<0.05
2005	End of Season	0.1148	<0.05
2005	Season Length	0.1148	<0.05
2005	Maximum NDVI	0.1148	<0.05
2005	Small Season Integral	0.1148	<0.05
2008	Start of Season	0.0873	<0.05
2008	End of Season	0.0873	<0.05
2008	Season Length	0.0873	<0.05
2008	Maximum NDVI	0.0873	<0.05
2008	Small Season Integral	0.0873	<0.05
2012	Start of Season	0.1148	<0.05
2012	End of Season	0.1148	<0.05
2012	Season Length	0.1148	<0.05
2012	Maximum NDVI	0.1148	<0.05
2012	Small Season Integral	0.1148	<0.05

Table 1. D- and P-values for KS test of phenometric parameters.

Fig. 4. Cumulative distribution plot showing differences in start of season in 2008.

Conclusion

A broad view of phenometric data indicates that there are indeed differences in phenometric developed between Pottawatomie and Elk counties, this can be seen from statistical data presented in Table 1. Our group hypothesized that phenometrics occur at relatively similar times and see similar growth throughout the ecoregion, but this was not the case.

The number of breaks within the two counties were significantly different and the majority of pixels in the two counties have seen negative trends in grassland greenness over the 15 year time span from 2001 to 2015. This negative trend could be a result of multiple factors such as climate change, land use change, invasive species, etc. The declining health of grasslands in the Flint Hills has significant implications for livestock grazing, carbon storage, water cycling, and prairie preservation just to name a few.

The methods outline for this study allow ranchers, biologists, government agencies, and other interested parties the ability to continually track vegetation dynamics on large spatial scales within the Flint Hills. An understanding vegetation dynamics can be used to improve land management practices, assist policy decisions, and understand climate changes.

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