Time Series Analysis of Vegetation Dynamics and Burn Scar Mapping at Smoky Hill Air National Guard Range, Kansas using Moderate Resolution Satellite Imagery

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Abstract. Military installments are import assets for the proper training of armed forces. To ensure the continued viability of the training grounds, management practices need to be implemented to sustain the necessary environmental conditions for safe and effective training. This analysis uses satellite imagery over time to gain insight into vegetation conditions over a large military installment. MODIS imagery was collected multiple times a year for 11 years at Smoky Hill Air National Guard Range (Smoky Hill ANGR) and a comparison site in Kansas. NDVI was extracted and analyzed within R using the statistical package BFAST. Vegetation trends and disturbances were gathered from the BFAST analysis. It was found that Smoky Hill ANGR has more disturbances in vegetation than the comparison site, but has a higher percentage of positive vegetation trends. A combination of Landsat 5 TM and 7 ETM+ imagery was used over the same 11 years and a burn algorithm was run on the imagery. It was found that Smoky Hill is burned more regularly than the comparison site. Based on the findings of the trend and burn analysis more research needs to be done to determine if the burning explains all of the vegetation disturbances or if the military training is influencing the vegetation conditions at Smoky Hill ANGR.

Keywords. *Time Series Analysis, Burn Scar, BFAST, Remote Sensing, Military Installments.*

Indroduction

Sustainable use of military training grounds is a necessity for the continued viability of the installations for training. The Department of Defense (DoD) controls 19,421,540 acres of land within the United States (Gorte et al., 2012). Training activities on these 19+ million acres can have dramatic impacts on the environment (Shaw et al., 1989). The purpose of this study is to use the statistical package Breaks For Additive Seasonal and Trend (BFAST), within the statistical software program "R", to generate a time series trend analysis of the vegetation conditions at Smoky Hill Air National Guard Range (ANGR) and to use Landsat imagery to put together a burn history of the military installment.

Study Area

Smoky Hill ANGR is a 13,707.9 hectare range located south west of Salina, KS. Within the KSANG training area there is a 4,090.9 hectare Impact Area for air to ground training (Busby et al., 2007). Smoky Hill ANGR is located in the Smoky Hills ecoregion of Kansas (Hansen, 2012); it is a 2,028,996.7 hectare transition area from mixedgrass prairie in the west to tallgrass prairie to the east (Busby et al., 2007). A comparison site was picked out about 16.1 km north west of Smoky Hill ANGR.

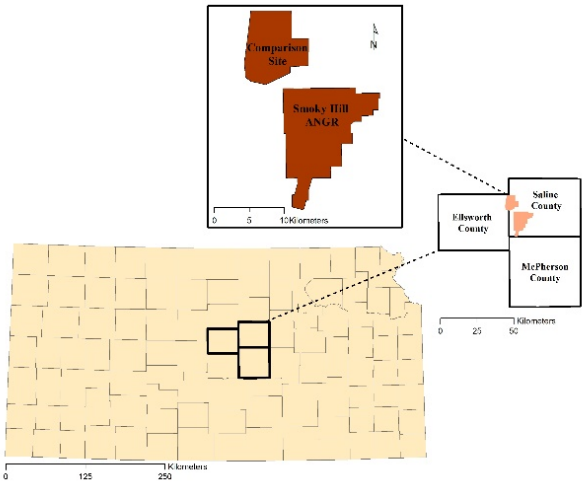

Fig 1. Smoky Hill ANGR is located in north central Kansas.

Data and Methods

Time Series Analysis

The imagery analyzed for the BFAST analysis was 16-day maximum value composite normalized difference vegetation index (NDVI) images (250 meter spatial resolution) recorded by the Moderate Resolution Imaging Spectroradiometer (MODIS) onboard the Terra satellite (Maccherone, 2012). A total of 23 MODIS 16-day maximum value NDVI composite images are produced each year. For this study satellite data collected during the period 2001-2011 was acquired, yielding a total of 253 individual composite images. Once downloaded, the MODIS imagery was re-projected, clipped, and the NDVI band extracted. A time series analysis was performed on the MODIS NDVI images for both Smoky Hill ANGR and the comparison site using the BFAST routine available with the "R" statistical environment.

Burn Analysis

For the burn analysis 30 meter Landsat 5 MSS/TM and Landsat 7 ETM was collected during the period 2001-2011, yielding a total of 253 individual composite images. The goal was to have at least 1 image a month for the 11 year time period totaling 132 images needed. All of the images were sorted into one of three categories: Burn Scar and Clear Image, No Burn Scar, Cloudy Image. Out of the 111 usable images only 60 had burn scars that could be classified. To detect the burn scars a Minimum Distance Supervised Classification was done using the red and NIR bands a method developed by Mohler (2011). The new classified images had two two pixel values, 1 for burned and 0 for unburned pixels. All the classified images were combined, using raster calculator, into a one year composite image that represented the 11 year time frame. The combined image has pixel values ranging from 0-11, the pixel value represents the minimum amount of times a pixel could have burned during the 11 years.

Results

Trend Analysis

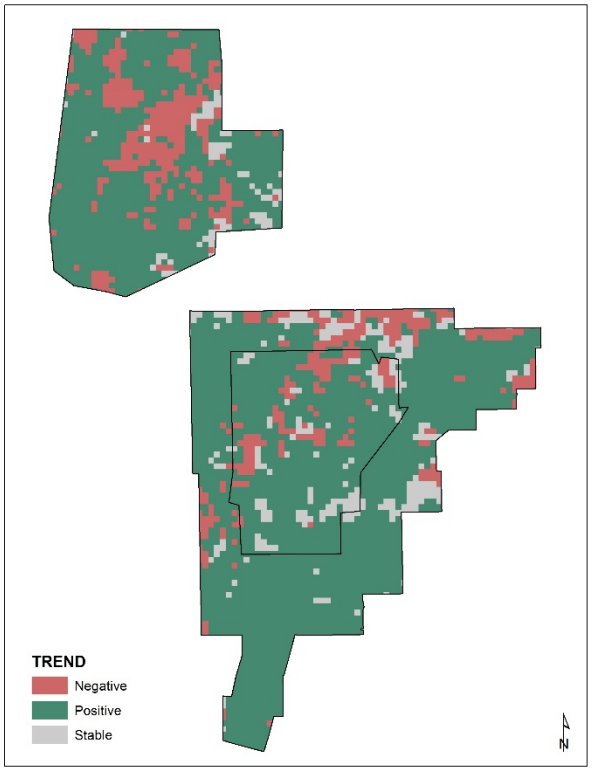

Fig 2. The overall trend is represented by the color of the pixel. Green is a positive trend, red is a negative trend, and gray is stable.

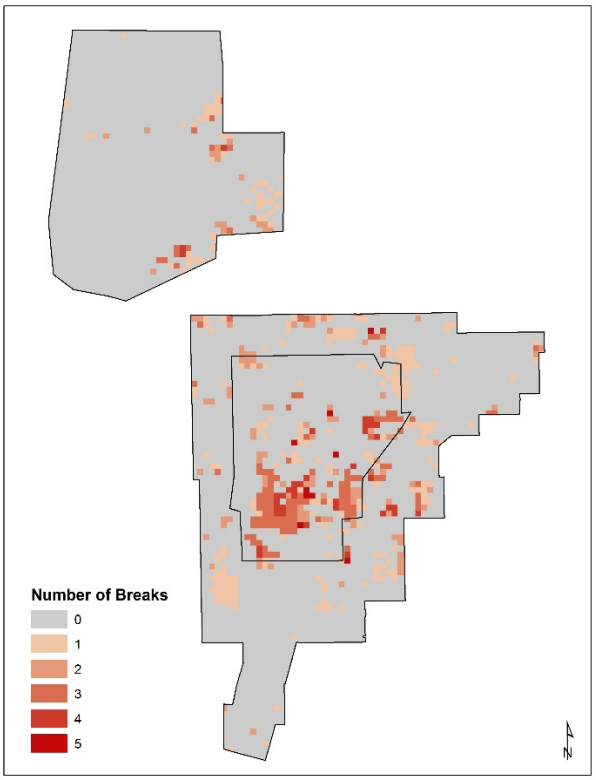

Fig 3. The number of times a pixel had a break in trend over the 11 year time period.

Analysis of the BFAST results show that a majority of the pixels for the Comparison Site, Smoky Hill ANGR, and the Impact Area are trending positive, showing an increase in greenness. Pixels that show a statistically significant ($\alpha = 5\%$) positive slope are represented as green, pixels that show a statistically significant ($\alpha = 5\%$) negative slope shown in light red, and stable pixels are shown in gray. Smoky Hill ANGR and the Impact Area have similar positive, negative, and stable pixel counts, around 78% positive, 12% negative, and 10% stable. The comparison site has 71% positive, 23% negative, 6% stable pixels. This map allows for Smokey Hill's land management team to access the vegetation trends across the whole range for the overall long-term vegetation conditions from 2001-2011. Areas in green represent an improvement in vegetation health, a greening up of vegetation over those 11 years and the light red represent a decrease in vegetation health, a browning in the vegetation and the stable vegetation is gray (Fig 2).

The second aspect analyzed with BFAST was the number of breaks from the trend over the 11 years, from 2001-2011. This shows how many disturbances occurred that caused a negative or positive response in the vegetation. The area with the largest percentage of pixels having at-least one break is the Impact Area with 26.7%. The entire Smoky Hill Range has 18.3% with at-least one break and the Comparison Site has only 6.22% with at-least one break. By looking at Fig. 3 it shows that most of the pixels that had more than one disturbance are within the Impact area. This can imply that there are disturbances to the vegetation within the Impact Area that aren't happening within the entirety of Smoky Hill or the Comparison Site.

Burn Analysis

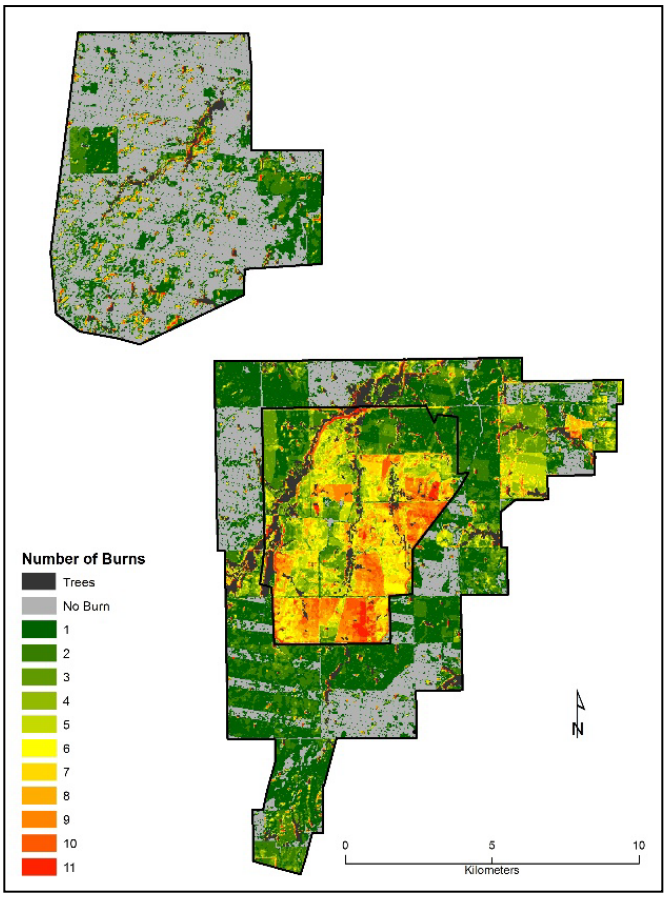

Fig 4. The burn analysis shows the minimum amount of times a pixel burned over an 11 year time frame.

The final image represents the fewest amount of times a pixel could have burnt during the 11 year time period from 2001 to 2011. Looking at Fig 4 you can see that the Impact Area has the highest frequency of burned pixels compared to Smoky Hill as a whole and the Comparison Site. The Impact Area only had 9% of the pixels that didn't record a burn over the 11 years. Compared to the entire Smoky Hill Range at 24% and the Comparison Site at 67% of pixels that hadn't been burnt.

The Impact Area has an even distribution of the amount of pixels that have been burnt from 0 to 11 times. In the other two areas the distribution is heavily skewed toward 0 to 2 burns. The entire Smokey Hill area had 64% of pixels burned 0 to 2 times and the Comparison Site had 92% of its pixels burned 0 to 2 times. Comparatively, the Impact Area had 27% of its pixels burned 0 to 2 times.

Conclusion

Military training grounds are important for many different reasons and assessing and managing the environmental conditions are imperative. BFAST and burn scar analysis used for this study are viable options for monitoring and assessing the vegetation conditions within Smoky Hill ANGR, Impact Area, and the Comparison Site. Now to summarize the findings of this study.

All three areas exhibit at least 70% of their hectares showing significate positive vegetation trends. There was more disturbances within the Impact Area compared to Smoky Hill ANGR and the Comparison site from 2001-2011. The disturbance response within the Impact Area was 76% negative (browning) compared to 52% for Smoky Hill ANGR and 30% for the Comparison Site.

The Impact Area was burnt more frequently than Smoky Hill ANGR and the comparison site. Smokey Hill ANGR had 63.6% of pixels burned 0 to 2 times and the Comparison Site had 92.2% of its pixels burned 0 to 2 times. Comparing that with the Impact area that had 26.6% of its pixels burned 0 to 2 times.

The Impact Area had more disturbances and was burned more frequently during the 11 year time frame from 2001-2011, compared to Smoky Hill ANGR and the Comparison Site. The Impact Area also had more negative responses to disturbances than either of the other study areas. Based on these results burns could be the cause of the increased disturbances found within the Impact Area, but the overall trend of the Impact Area is 70% positive, like the other two areas. The increased disturbances that result in a browning, in the Impact Area, are not causing a different overall greenness response in the vegetation from the other two sites. All three areas have the same percentage of hectares trending greener.

There are areas that should be looked at to further this research. Add the images from 2012-2016. In situ study on the vegetation composition within the Impact Area should be compared to the other two sites. To determine if the increased disturbances within the Impact Area are having an effect on the vegetation composition. Also, looking into the cause of the burning at Smoky Hill ANGR. To determine if the burning is an effect of training activities or if it is a management practice.

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