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Analyzing the Change in Yellowstone Fire Scars using TM and ASTER imagery, analyzed in ENVI

1. Abstract

The purpose of this paper is to investigate the ecological damage and healing progress of the 1989 fire scars in Yellowstone National Park. Using datasets captured by both Landsat and ASTER, this data was processed using ENVI software to determine the change over time. Composite color images, reflectance plots and density slices were among some of the chief tools used to make these determinations. Additionally, two unsupervised classifications were run and cross references to SWIR TM data to better help understand the boundaries of the fire scars. It was determined that the boundaries of the scars shrunk over time, highlighting new vegetation growth and ecosystem healing. TIR data from ASTER was also used to create a density slice to determine the hottest pixel in a given region. Using a slice based on the hottest recorded temperature in the image, it was determined that the hot pixels were located on the left-hand side (this can be observed in figure 7 below).

2. Introduction

In 1988, wildfires swept through almost 800,000 km^2 of Yellowstone National Park, leaving large fire scars. Using images captured by the Landsat Thematic Mapper (TM) and the Advanced Spaceborne thermal Emissions and Reflection Radiometer (ASTER), these fire scars have been able to be analyzed over time. Analyzing TM imagery from September of 1990 2000, and 2010, respectively, the progress of the recovery was able to be seen. Although not complete in the 2010 TM data, the scarring had improved greatly. This was able to be accomplished by using a series of image enhancements and spectral analyses in both VNIR and SWIR. In addition to this method, several unsupervised classifications were employed to help determine specific classes to aid in determining which regions were scarred. The classification methods and class meanings will be discussed in greater detail below.

Methods

3.1 Initial Analysis

This analysis was performed using ENVI software. A true color composite image based on the respective bands available was loaded into the software for preliminary analysis. Several stretches were run on the image. Subsequently, the metadata for the TM bands was examined to confirm the USGS projection, sensor, pixel units, number of bands, along with a number of other important metrics. In addition, the spatial resolution of the image was found to be 30 meters (TM resolution is 30 meters, with exception of its TIR band, which is 120 meters).

3.2 Spectral and Temporal Analysis

The converted reflectance bands were loaded in R, G, B using bands 7, 2, and 4, respectively. Additionally, the same band combination was loaded using the original TM bands. These screens were then linked, and their spectra were examined in both standard TM data and reflectance data. Four distinct pixels were located and analyzed in this fashion; subsequently, surface composition was assumed based on the respective spectra. The change over the 10-year period from 1990 to 2000 using TM and ASTER imagery, respectively. Two color composite images in R, G, B were loaded and observed to look for changes in the scar boundaries after a decade. Both the TM and ASTER images were loaded from converted SWIR reflectance bands.

3.3 Image Classification in SWIR and TIR

Two unsupervised classifications, along with a density slice were generated to detect general surface groupings, along with heat signatures. The first classification generated was ISODATA, set to have 5 classes as a maximum. The newly formed ISODATA band was then loaded in, revealing 3 discernable classes – blue green and red. These classes were algorithmically determined to have statistical significance. The ISODATA figure will be included below (see figure 1). Additionally, K – mean was run set to have a maximum of 5 classes. These classes were also algorithmically determined based on the center of each class and its statistical significance. This figure will also be included below (see figure 6). TIR data was also used to generate a density slice. Band 14 of the TIR file was used and the assumed emissivity was set to 0.99. These settings were saved and then used to generate a density slice to determine the temperature in each pixel (recorded in kelvin). The spectral plot for this pixel can be seen below (figure 2).

3. Results and Analysis

After performing several stretches on the image, it was determined that the image equalization was the most effective stretch for determining specific features in an image. This stretch made it much easier to distinguish finer geological features such as rivers and ridges. Linking the reflectance and standard TM data screens revealed that different scales are used for both reflectance and standard TM on the spectral plots. Reflectance is plotted against the percent of each wavelength that is reflected, while standard TM is plotted against DN values (both having wavelength on the x-axis). An example plot for both reflectance and standard TM will be included below (see figures 4 and 5, respectively). Using both the absorbance and reflectance plot in unison gave the unique advantage of confirming one against the other. Observing the 10-year change from the 1990 TM and 2020 ASTER imagery revealed that much of the damage done by the fire scars had been healed. While the growth was not absolute, it could clearly be seen that the boundaries of the scars had receded. Additionally, the ISODATA classification proved to be more helpful than K-mean in determining where the fire scarring occurred. Cross referencing the ISODATA classification with SWIR TM data it seemed that the red areas were indicative of the scarring. K-mean data was left as unconclusive as to which parts were representing the scarring. The TIR density slice was split into several bulk temperature classifications. After reducing the slice to only one classification based on the hottest temperatures recorded in the image, the hottest pixel was located toward the left-hand side. This final image will be included below (see figure 7).

4. Conclusions

Using remote sensing can be a very effective way to monitor ecological damage over time. Using the methods outlined in this paper, such as unsupervised classifications, density slices, and reflectance bands, the progress of ecological healing was able to be seen. The Yellowstone fire scar boundaries had shrunken since the initial burn. ISODATA statistics made it possible to cross reference the TM imagery in SWIR with the generated classifications to better determine fire scarring. Additionally, density slices could be used in the future to model and determine the spread of wildfires in order to help fight them more effectively.

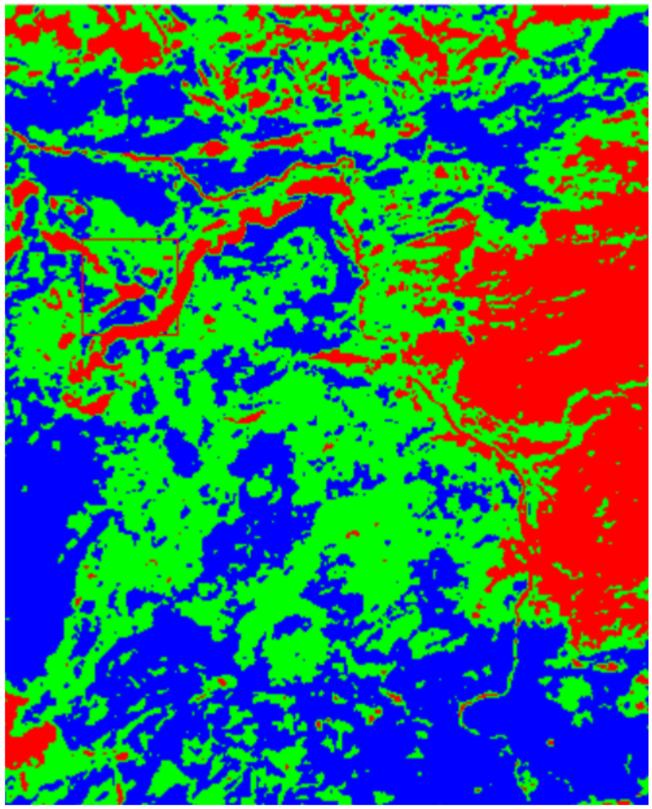

Figure 1 – ISODATA classifications

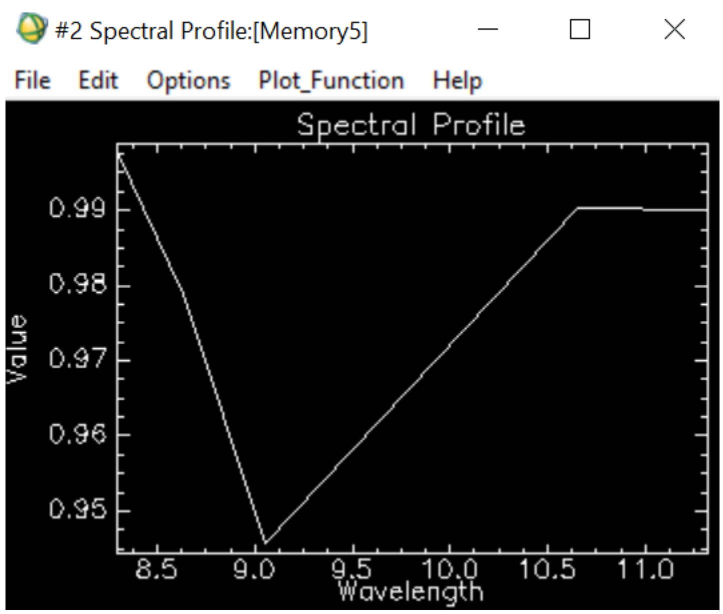

Figure 2 – Spectral profile for hottest pixel in TIR

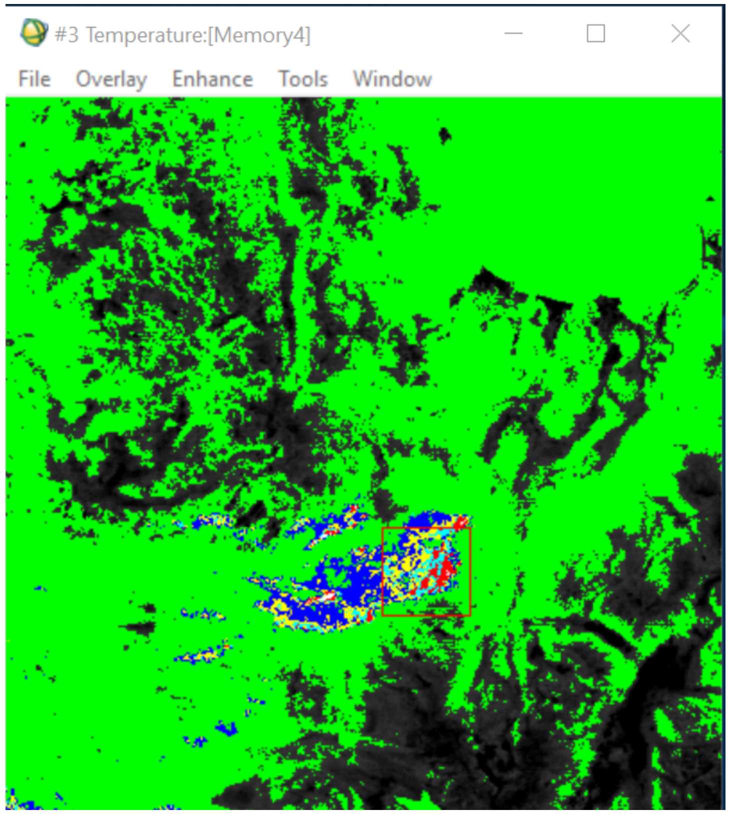

figure 3 – Density slice showing hot pixel in wildfire (EC)

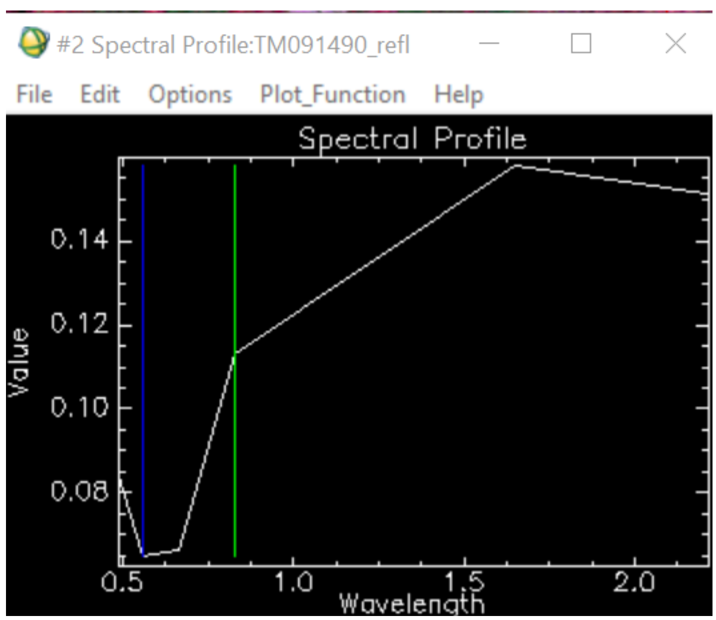

figure 4 – Spectral plot showing reflectance from Landsat data

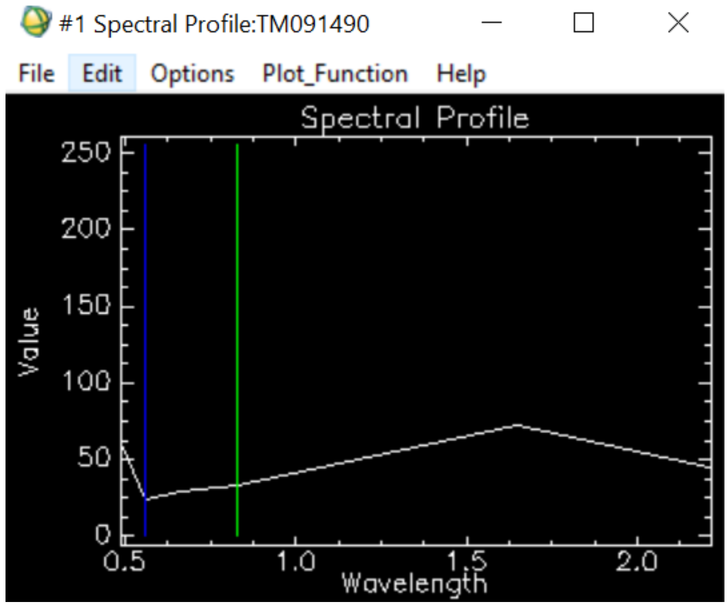

figure 5 – Spectral plot showing DN plot from Landsat data

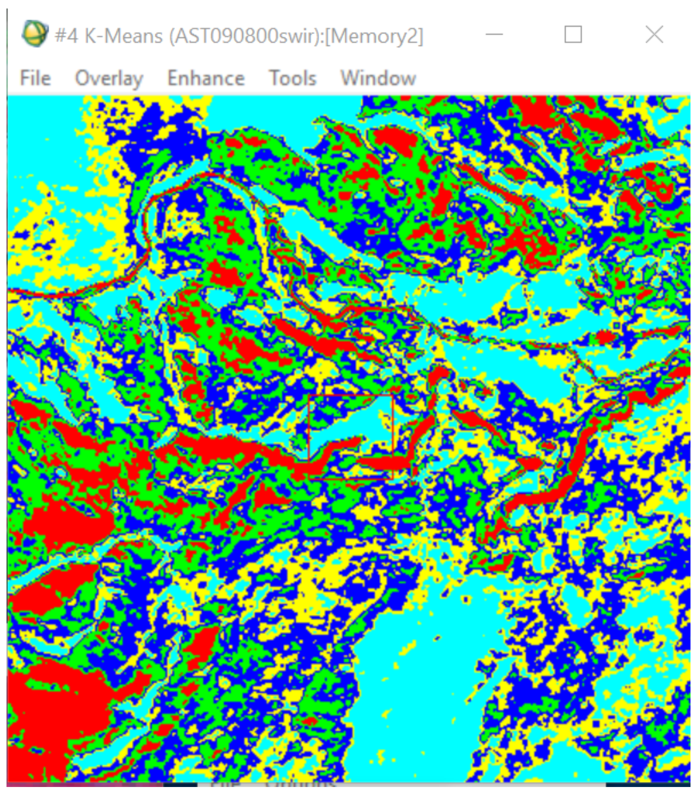

figure 6 – K-mean classifications

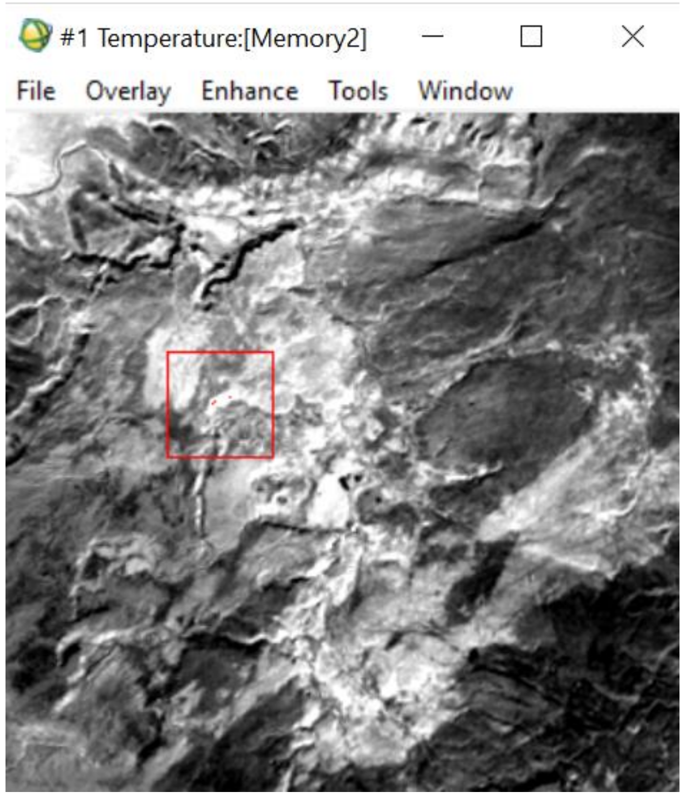

Figure 7 – TIR hottest pixel identified using density slice