Measuring the Change in NDVI in Various Regions of California After a Major Wildfire Event

Emma Reddy

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Department of Geography, McGill University

Mr. Patrick Osei Darko

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I. INTRODUCTION

The state of California has been the location of some of the most destructive wildfires in recent history. In the past, certain burns were beneficial to nature. Infrequent fires, every 30 to 150 years, largely benefit the adapted southern chaparral ecosystem, as the post-fire landscape encourages high reproductive success of the vegetation (California Chaparral Institute, n.d.). Additionally, the fires in the Sierra Nevadas help restore the forest floor, nourish soil, and kill disease (Sierra Nevada Conservancy, n.d.; Cal Fire, n.d.). California has engaged in fire suppression tactics that focused on reducing the area of burnt land. Instead, policies should aim to reduce the severity of fires and restore vegetation after a fire (Safford et al., 2022). Un-prescribed, more frequent, and more destructive fires that burn across all regions in California, instead of just those ecosystems adapted to it, cause large amounts of devastation and harm.

In 2020, nearly 4.5 million acres of land in California burned and were destroyed from wildfires (Kerlin, 2022). Between August 16th and 18th, a series of dry lightning strikes ignited close to 600 fires across northern California. Many of these fires developed into complexes, meaning they merged together into a larger event ("August 2020 California lightning wildfires", n.d.). Complexes are often named after their responding fire unit. Much of the state's dry vegetation and forests suffered during these fires.

This paper will be investigating the variation in the normalized difference vegetation index (NDVI) across three regions of interest in order to determine how a major wildfire event affects vegetation health over time. Each of these areas were burned due to fire complexes sparked by the mid-August lightning storms. I will monitor the NDVI over the course of 4 years, from 2018 to 2021, in order to get a complete understanding of how the vegetation health and the landscape may have changed before and after the perturbation.

II. DATA

I acquired satellite data via the Google Earth Engine (GEE) catalog. I used the United States Geological Survey Landsat 8 Level 2, Collection 2, Tier 1 satellite (image ID: LANDSAT/LC08/C02/T1_L2). This satellite data is already atmospherically corrected, so there was no need to complete any additional modifications on GEE. This satellite has a 16-day temporal resolution and a fine spatial resolution of 15 meters. This provided me with enough images to complete a thorough temporal analysis. The Operational Land Imager sensor provided me with the bands necessary for my NDVI calculations (United States Geological Survey, n.d.).

My areas of interest were chosen from the Cal Fire summary of incidents for 2020 (Cal Fire, 2022). I selected the three largest complexes that began on August 16th: the August Complex (in Mendocino Forest), the SCU Lightning Complex (in the Diablo Range; named for Cal Fire's Santa Clara Unit), and the CZU Lightning Complex (in the Santa Cruz Mountains; named for Cal Fire's San Mateo-Santa Cruz Unit).

III. METHODS AND PROCEDURE

Vegetation and burn indices have proven to be effective remote sensing tools in studying vegetation destruction and subsequent recovery from wildfires. Cuevas-Gonzalez et al. (2009) employed the use of NDVI in order to measure Siberian forest recovery from wildfires over the course of 13 years, and found NDVI to have decreased in the year following a burn. Similarly, Fairfax & Whittle (2020) discovered that beaver damming is an effective protection against wildfires, as areas around dams sustained higher NDVI values than those further away, following a wildfire event. NDVI is calculated using the following equation,

$$NDVI = \frac{NIR-R}{NIR+R},$$

where NIR is the near infrared band of the electromagnetic spectrum and R is the red band of the spectrum. NDVI is measured on a scale of -1 to 1. Values close to 1 signify healthy vegetation, as a plant producing more chlorophyll reflects more NIR and absorbs more red light. Values near 0 signal impervious surfaces, such as concrete, bare soil, or urbanized space. Finally, negative values are areas corresponding to water, such as a river or lake, or cloud cover ("Normalized difference vegetation index, n.d.).

I used GEE to complete my temporal analysis of NDVI, as it provides easy access to multiple years of satellite data. I began by mapping a true color map (using SR_B4, SR_B3, and SR_B2 for red, green, and blue bands, respectively) of California in order to find my areas of interest. Next, I compared my true color map to a map of the complexes in order to extract my areas of analysis ("2020 California wildfires, n.d.). Aftering creating a geometry (of approximately 12,500 acres in order to measure a significant area) to analyze and centering my map, I calculated the NDVI for an image collection with the following date range: January 1, 2018 (inclusive) until January 1, 2022 (exclusive). The NIR band on Landsat 8 is SR_B5, while the red band is SR_B4. After acquiring all values, each 16 days apart, I exported them to Google Sheets in order to graph the change over time.

IV. RESULTS AND DISCUSSION

The NDVI value, on average, decreased over time in each of the three areas of interest from 2018 to 2021.

The August complex site had the largest change in NDVI over time, with its trend line having a slope of -3.06E-4 (Figure 1). Less drastically were the CZU and SCU lightning complexes, with slopes of -1.36E-4 and -5.2E-5, respectively (Figures 2, 3).

The August complex had an R^2 value, or coefficient of determination, of 0.329, meaning the 32.9% of the variation in NDVI can be described by the change in time, which includes the major wildfire event. The CZU site had an R^2 value of 0.046, and the SCU site one of 0.031. These lower R^2 values suggest the wildfires have less of an impact on changing NDVI in these areas, meaning there may be other factors that contribute to this, such as increasing drought (Kimball, 2021).

Ultimately, however, there were large dips in NDVI values in August in all sites, and slight, subsequent increases, demonstrating the immediate and short-term consequences of a wildfire event on vegetation health.

V. CONCLUSION

There were multiple points on the final graphs that had low or negative NDVI values outside of the major fire event, likely due to cloud cover in the areas. Consistent cloud cover causes an underestimate in an area's average NDVI values (Comiso & Hall, 2014). If the low or negative values were removed, it is likely that the CZU lightning complex's R^2 value may have increased, since this is the area that had the most low or negative NDVI values.

Additionally, the areas of interest could have been decided by finding the normalized burn ratio for still images in September of 2020 using ENVI, instead of being visually chosen (Bright, 2019). This would have ensured that the analyzed areas had a majority of their land burned, which would confirm that the change in NDVI corresponds to the wildfire. In order to ensure the results from the areas chosen were not random, however, I completed a retest of the August complex site, choosing a different location within Mendocino Forest (Figure 4). The trend line for this retest site had a slope of -2.81E-4, and had an R^2 of 0.234. While both of these values are lower than the initial area, they are not so far off that they disprove the original conclusion.

This project could be continued through increased comparison and monitoring over time. Comparing burnt areas to those that have not burnt would provide a good understanding on how NDVI might have changed in California without a wildfire perturbation. Additionally, continuing this investigation while other fires occur would either help support or oppose my findings.

Understanding changing vegetative health levels is important for future conservation efforts in California. NDVI values experience a rapid decrease directly after major fire events. This rapid decrease is followed by a slower increase, likely caused by rain and natural vegetative healing. It is apparent that wildfire events, both large and small in overall area, have a non-negligible effect on an area's mean NDVI.

VI. FIGURES

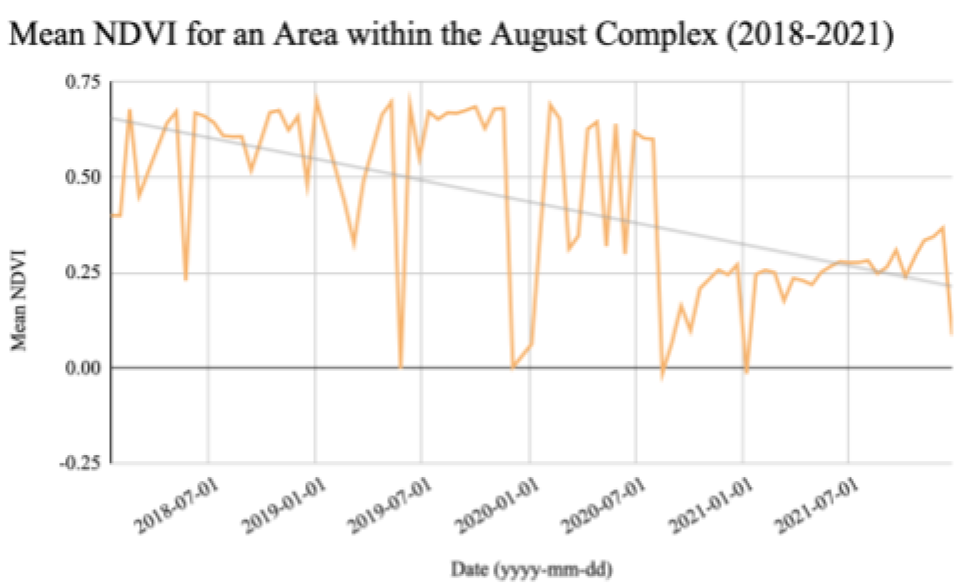

Figure 1. Change in NDVI over time for August Complex Site

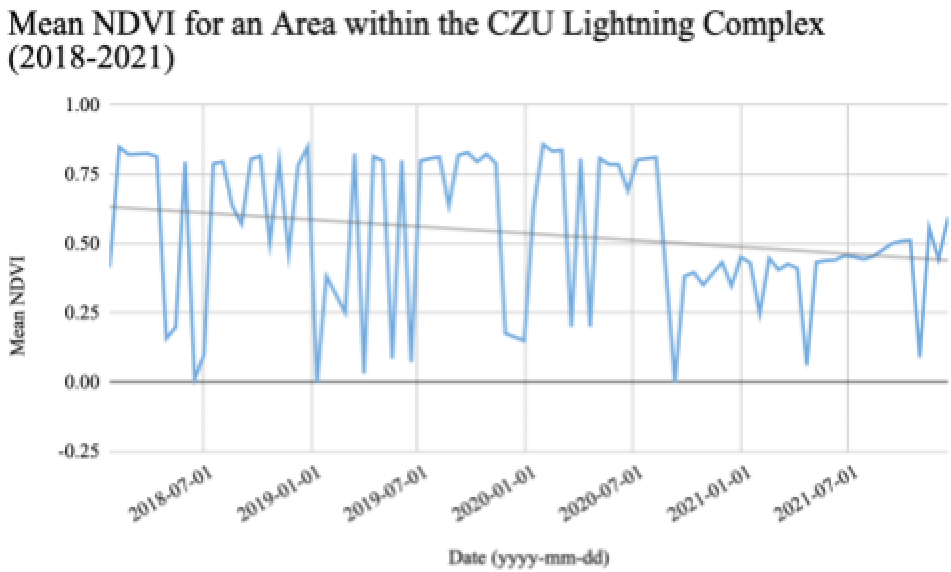

Figure 2. Change in NDVI over time for CZU Lightning Complex Site

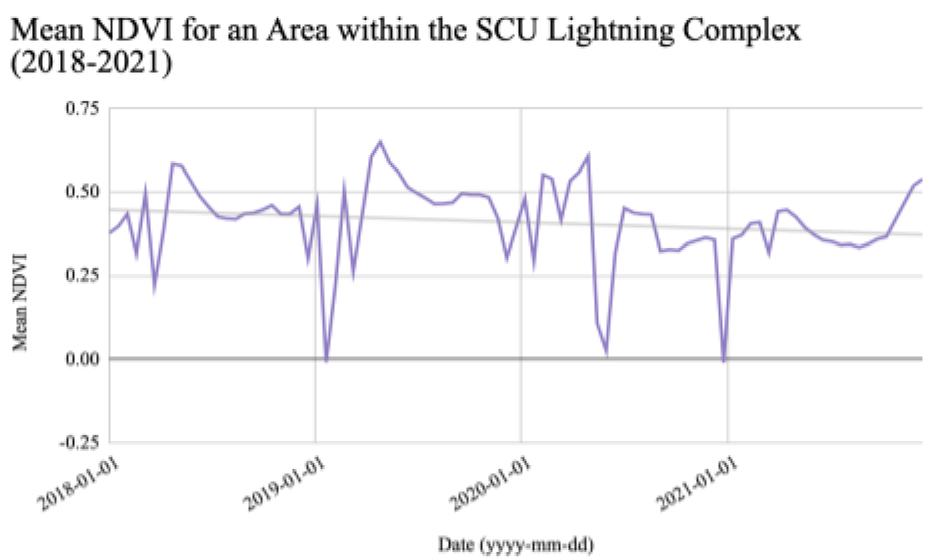

Figure 3. Change in NDVI over time for SCU Lightning Complex Site

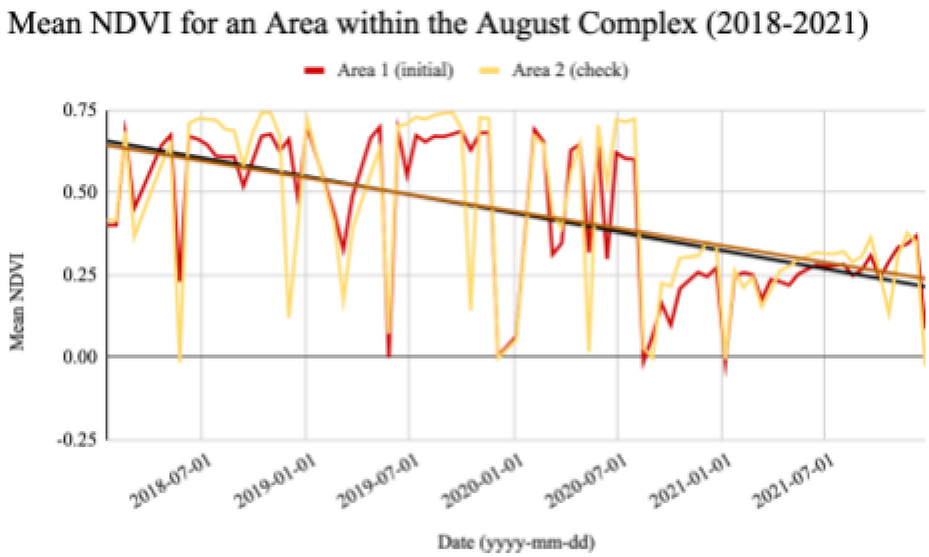

Figure 4. Change in NDVI over time for August Complex Site, retested

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