Final Project: LNU Lightning Complex

Eian J. Countryman

University of Iowa

Introduction to Remote Sensing

Professor Linderman

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Contents

1. **Introduction**

During the year 2020 California experienced numerous wildfires which were given large amounts of media coverage. The summer of 2020 was often described to be one of the worst wildfire seasons as of recent. Personally, I've never been able to fully comprehend the size of these wildfires as well and would like to better understand this phenomenon. The specific wildfire this report will be examining is the Lake Napa Unit (LNU) Lightning Complex in California that claimed the lives of six civilians. (2020) Multiple fires formed the LNU Lightning Complex that spanned the counties of Lake, Napa, Solano, Sonoma, and Yolo. (2020) The LNU Lighting Complex was geographically located in northern California, being approximately 50 miles to the west of Sacramento, California, and approximately 60 miles to the northeast of San Francisco, California. The fire was caused by lightning from remnants of the tropical storm Fausto. The LNU Lightning Complex started officially at 0400 hours on 17th August 2020 after multiple reports of lightning strikes with vegetation fires were received by the LNU Emergency Command Center (ECC). (2020)

Using imagery of an area from two or more time periods enables analysis of the changes to that area using change detection methods. There are two methods to change detection and they are a postclassification change detection and spectral change detection. The method used in this lab is a spectral change detection. A spectral change detection uses the spectral values of two or more images for processing and creation of an image. This method is often preferred to postclassification change detection due to the higher accuracy and the ability to use different processes to examine different types of changes. (Campbell, Ch. 15) A postclassification change detection uses two images that have been Land Use Land Cover (LULC) classified and compares areas that changed in classification. Temporally there are two methods to be used with change detection and they are bitemporal or multitemporal change detection. Bitemporal change detection is the method of using two images each from different points in time to determine changes. One might want to use this method to keep data volumes low and analyze changes that happen quickly such as dramatic single events. Due to this, the bitemporal method was used to examine the LNU Lightning Complex. Multitemporal change detection is the method of using three or more images each from different points in time to determine changes. One might want to use this method for analyzing slow rates of change, such as natural and socio-economic processes. Due to the nature of wildfires this was not a suitable method to be used. However, if one wanted to examine how the area burned by the wildfire rebounded then the use of this method would be ideal. The objective of this report is to examine the change to an area spectrally to better understand the effects of wildfires. Better understanding the spectral changes of a landscape enables the changes to the biophysical aspects to be examined. For example, the change from a vegetated surface to a bare earth is something we can analyze.

2. Data

All imagery data was acquired from the European Space Agency (ESA) and were all Sentinel 2 imagery. The first image was from 12 August 2020 with the second image from 27 August 2020 and the third image from 16 September 2020. All the images of California included the following:

- Projection: UTM, Zone 10
- Datum: WGS 84
- Pixel size X, Y: 20 meters
- Data type: unsigned 16-bit

The bands used from Sentinel 2 include:

B02	Blue – 490nm	10 m
B03	Green – 560nm	10 m
B04	Red – 665nm	10 m
B8A	NIR – 865nm	20 m
B11	SWIR - 1610	20 m
B12	MWIR – 2190nm	20 m

When the data was stacked into a multispectral image, they all became 20-meter resolution. All processes were conducted at 20m resolution. The Department of Forestry and Fire Protection created a “2020 FIRE SIEGE” report detailing every fire during the year 2020 in the State of California. The report includes statistics about each fire such as how many people died, structures destroyed, acres consumed, equipment used, and many others. The LNU Lightning complex claimed the lives of 6 civilians, consumed 363,220 acres, destroyed 1,491 structures, and required 2,839 personnel to subdue the fire. The start date is recorded as 17 August 2020 with the end date being mid-September (~14^{th}).

3. Methodology

The Sentinel 2 data obtained from the ESA were stacked individually to create 3 separate multispectral images. Each image was then adjusted in the model maker by dividing the Digital Number (DN) values by 10,000 to convert these values into reflectance values. To do any image processing using reflectance, such as a Normalized Difference Water Index (NDWI), we need reflectance values to ensure results are accurate. Using the adjusted images, a Normalized Difference Vegetation Index (NDVI) was then run on all images using the model builder. This was done to examine the vegetation levels from before the fire to the end of the fire. The formula for NDVI is ((Pnir – Pred) / (Pnir + Pred)). A Normalized Burn Ratio (NBR) was also run on each image in the same process of the NDVI except the formula for NBR is ((Pnir – Pswir) / (Pnir + Pswir)). The NBR is the same as a NDWI so the reason it was used was to examine the water content of the Area of Interest (AOI) before and after the fire. Using the NBR before and after photos a change detection was run using the formula of (NBRafter – NBRbefore) to determine, spectrally, the areas of change in water content. While running the change detection a highlight was added with a decrease percent of 10 to distinguish areas of major change. Finally, a change vector analysis was done using the NDVI and the NBR. The magnitude was first processed using the model builder and the following formula:

$$\sqrt{\left(NDVI_{after} - NDVI_{before}\right)^2 + \left(NBR_{after} - NBR_{before}\right)^2}$$

This formula calculates the amount or magnitude of change among the NDVI and NBR. The direction was calculated in the model builder while creating the final image. The formula used for the direction was: $AcrTan\left(\frac{NDVI_{after} - NDVI_{before}}{NBR_{after} - NBR_{before}}\right)$

The change vector image was then loaded into ArcGIS to change the colors identifying each quadrant. Each quadrant was identified as:

NDVI decreased, NBR increased	NDVI increased, NBR increased
NDVI decreased, NBR decreased	NDVI increased, NBR decreased

Finally, I used the tabulate area function to estimate the total burn area and compared it to the research data from CAL FIRE.

4. Results

Starting with the two multispectral images, they are *Figures 2 & 3*. These two figures show the RGB visualization (true color) of the extent of the LNU Lightning Complex. Next, the NDVI of before the fire and after are displayed in *Figures 4 & 5* which show changes from the wildfire in areas that go from light to dark. Following the NDVI, the NBR results are displayed in *Figures 6 & 7* which show the changes from the wildfire as areas that have been darkened. The results of the change detection of the NBR images are displayed in *Figure 8*. Dark areas in the figure represent areas of lost vegetation. Areas of major changed area highlighted in Figure 9. The results of the change vector analysis are displayed in *Figures 10 & 11* with one being grey scale and the other represented with color. The greyscale image defines areas of white having high amounts of change to the NDVI and NBR with areas in black having negligible change. The figure with color displays each quadrant, of four, in a separate color. Shown as:

(Orange) NDVI decreased, NBR increased	(Yellow) NDVI increased, NBR increased
(Blue) NDVI decreased, NBR decreased	(Green) NDVI increased, NBR decreased

The results from the tabulate area function calculated the burn area to be 707,414,400 sq meters which equates to 174,806 acres.

5. Discussion

The NDVI images (*Figures 4 & 5*) show important information about the area that was affected by the wildfire before it was burned. We can see that the burned area had high volumes of vegetation before the fires started. You can see areas that have changed but it is difficult to see to what extent. There is also some interference on the right side of the image showing the changed in the crop fields. From research this area is known to not be affected by the wildfire. However, the period in which the data covers is August to September, and it is very likely that crops are growing and or being harvested during this time. This interference is seen throughout all the images. The NBR images (*Figures 6 & 7*) show the extent of the fire clearly when compared to the NDVI. Because the NBR uses NIR and SWIR it does well in distinguishing burnt surfaces. This is due to the high reflectance of SWIR in areas recently burned with low reflectance of NIR due to the lack of vegetation. The ability to identify burned areas with NBR is only reinforced with the change detection seen in *Figure 8*. The areas that are black represent the burned areas. It is easy to differentiate the area that was affected by the wildfire as well as the severity based upon the darkness. Areas of black have severe burning while areas that are grey have lighter burning. The severity of burning is highlighted in *Figure 9* by showing the areas that changed significantly. The areas in red decreased dramatically due to the heavy burning. Areas of higher vegetation likely saw more severe burning due to the availability of fuel. Spectrally, these areas would change more than areas with less vegetation. For example, an area with lots of vegetation will have a high reflectance in NIR and low in SWIR. While areas with low vegetation will have low reflectance in NIR and higher reflectance in SWIR. The change caused by the fire would be more dramatic with areas of high NIR and low SWIR. As highlighted in *Figure 9*. Change vector analysis was a useful tool for examining the burned areas and identifying new information. Using the NDVI and NBR images I was able to do a two-band change vector analysis which is displayed in *Figures 10 & 11*. The analysis was very effective in identifying the burned areas. Unfortunately, Erdas doesn't allow me to change the colors of each quadrant, so I had to use Arc GIS to better display the separate quadrants. The orange pixels displayed represent areas where the NDVI decreased and the NBR increased, which many pixels were of the ocean. The yellow pixels displayed an increase in both NDVI and NBR which corresponded to freshwater bodies of water especially those within the burn area. My assumption is that these areas experienced algae blooms after the wildfire passed through. The blue pixels displayed represent areas where the NDVI decreased and the NBR increased. This corresponds to areas that were burned which makes sense because the loss of vegetation would cause the NDVI to decrease as well as the NBR. The green pixels displayed represent areas where the NDVI increased and the NBR decreased. This one was difficult to correlate with an area on the ground. I believe that the reason for this is because of the complicated formula used to do the change vector analysis. Erdas doesn't have an ArcTan function in the model maker, so a rudimentary formula was used to create ArcTan. The results from the tabulate area function are promising with the estimated burn area to be 174,806 acres compared to CAL FIRE's 323,220 acres which is within an order of magnitude. The difference in the numbers can be attributed to the fact that the area calculated in the study is only the areas that changed spectrally due to the wildfire. CAL FIRE is likely estimating acres affected using an alternate method that doesn't consider spectral data.

This project produced a significant amount of data that most certainly helped visualize the extent of the LNU Lightning Complex. It even produced quantifiable data that could be used either by those studying wildfires or organizations like CAL FIRE. There are parts of this project that worked well and parts that didn't. The NBR change detection as well as the change vector analysis worked well in visualizing the changes to the AOI. The NDVI alone wasn't helpful but when used as part of the change vector analysis it became a useful tool. Unfortunately, Erdas doesn't allow you the ability to change the colors of each quadrant in the change vector analysis which created a hassle of having to utilize two separate software to create a clearer result. Significant processing time could've been reduced if Erdas had this ability.

6. Bibliography

a. Figure 1 obtained via CAL FIRE, https://www.fire.ca.gov/media/hsviuuv3/cal-fire-2020-fire-siege.pdf

b. Figures 2-10 obtained via Erdas Imagine 16.7.0, 2022

c. Figure 11 obtained via ArcPro, ArcGIS Desktop 10.8.2, 2021

d. Sentinel 2 data of Northern California obtained via ESA, Copernicus: https://scihub.copernicus.eu/dhus/#/home

e. Campbell, James B., et al. *Introduction to Remote Sensing, Sixth Edition*, Guilford Publications, 2022. *ProQuest Ebook Central*, http://ebookcentral.proquest.com/lib/uiowa/detail.action?docID=7012355. Created from uiowa on 2022-09-13 20:11:47.

f. Morris, G. (2020). *Welcome to cal fire*. 2020 FIRE SIEGE. Retrieved December 12, 2022, from https://www.fire.ca.gov/media/hsviuuv3/cal-fire-2020-fire-siege.pdf

7. Appendix

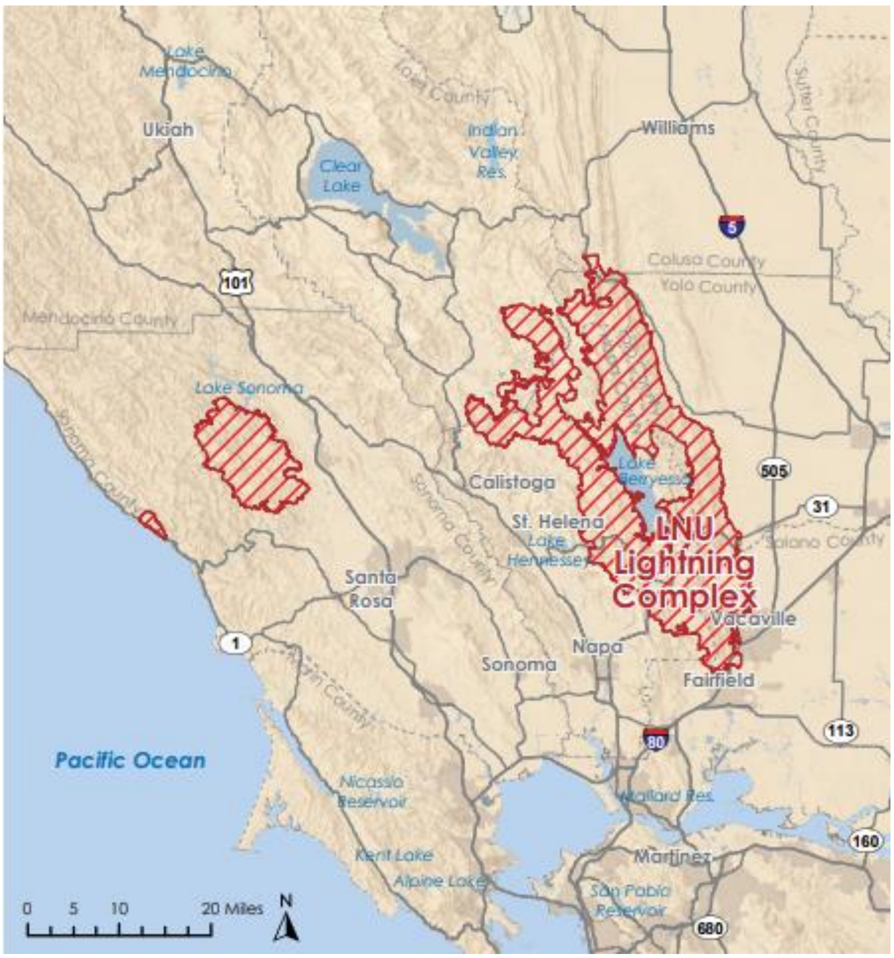
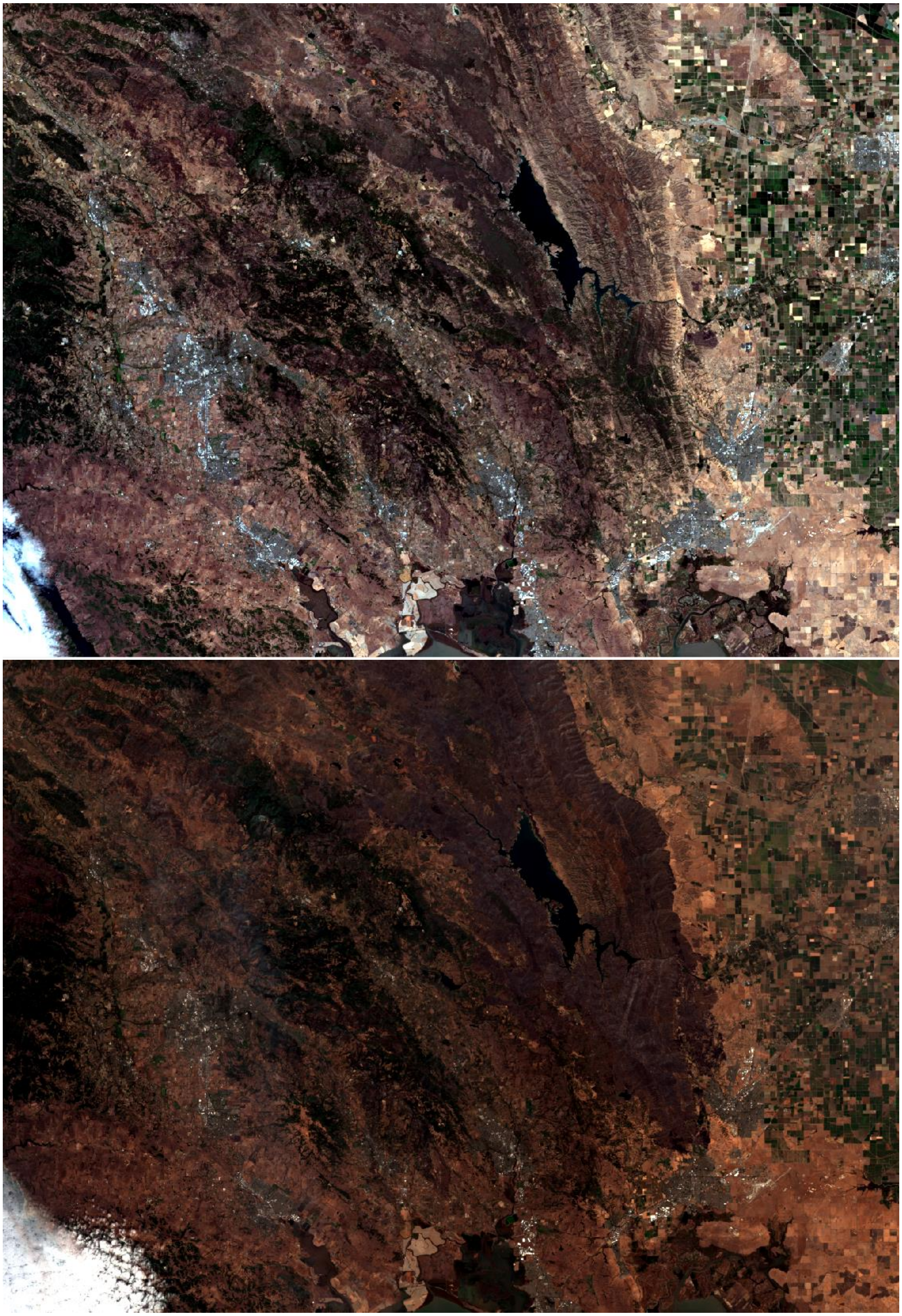
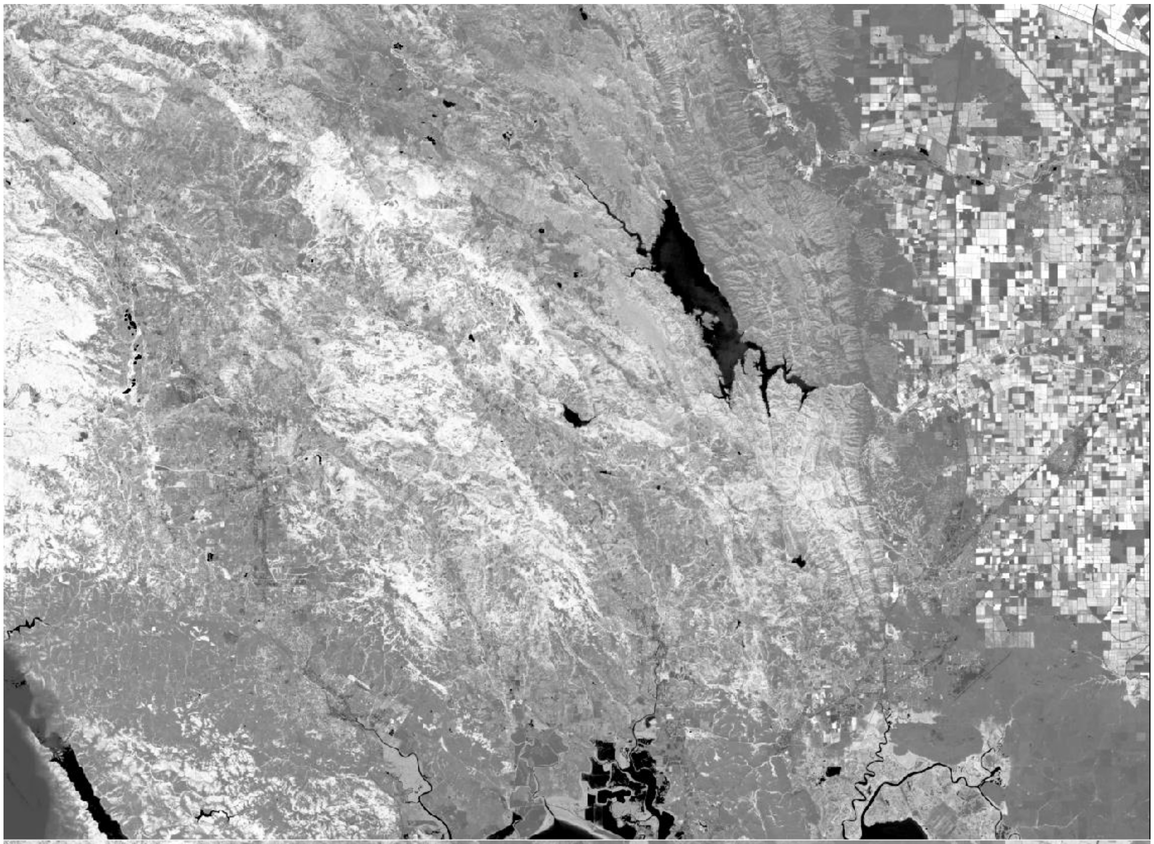
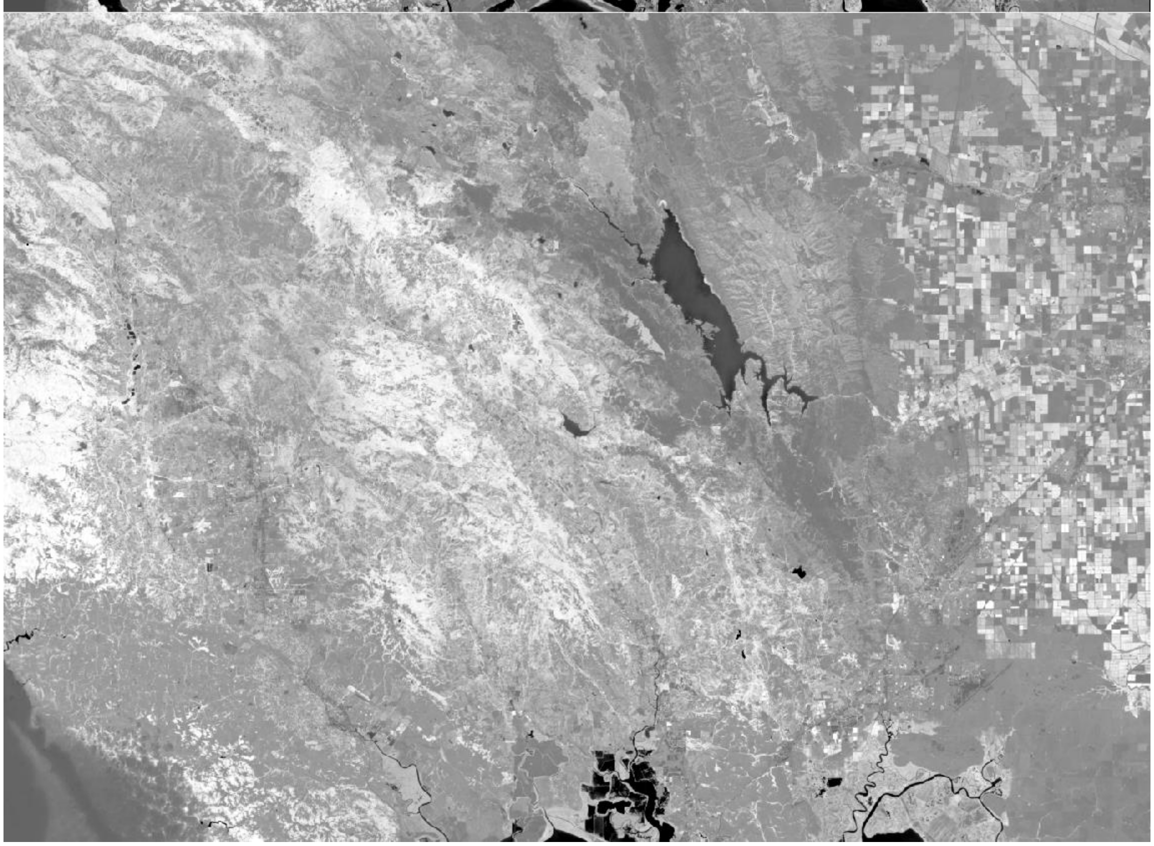


Figure 1 displays the fire extent of the LNU Lighting Complex.



Figures 2 (top) & 3 (bottom) display the before and then after of the LNU Lightning Complex.





Figures 4 (top) & 5 (bottom) display the NDVI of before and then after the fire.

Figures 6 (top) & 7 (bottom) display the NBR of before and then after the fire.

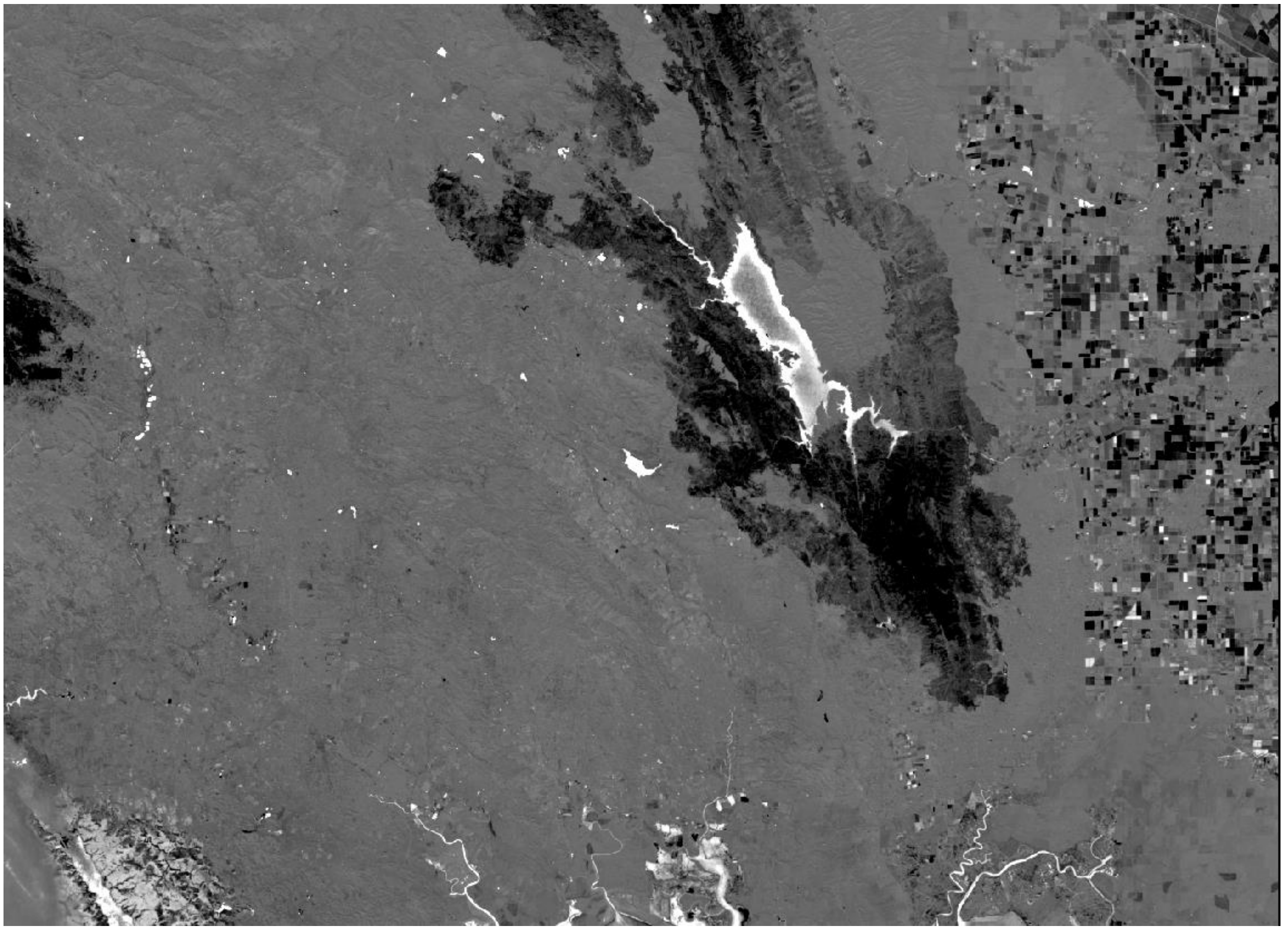


Figure 8 displays the change detection of the NBR from before to after.

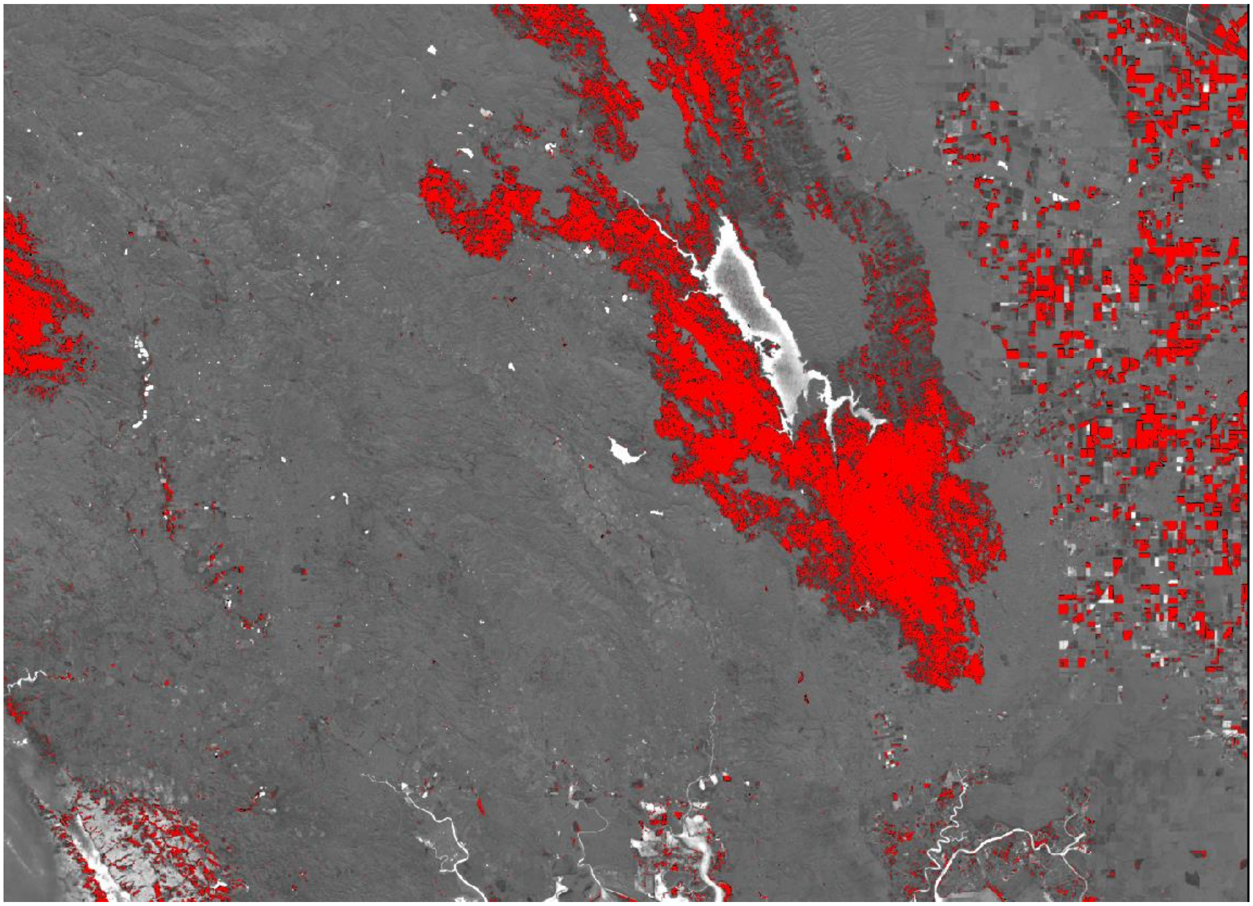


Figure 9 displays the change detection map with the areas of major change highlighted.

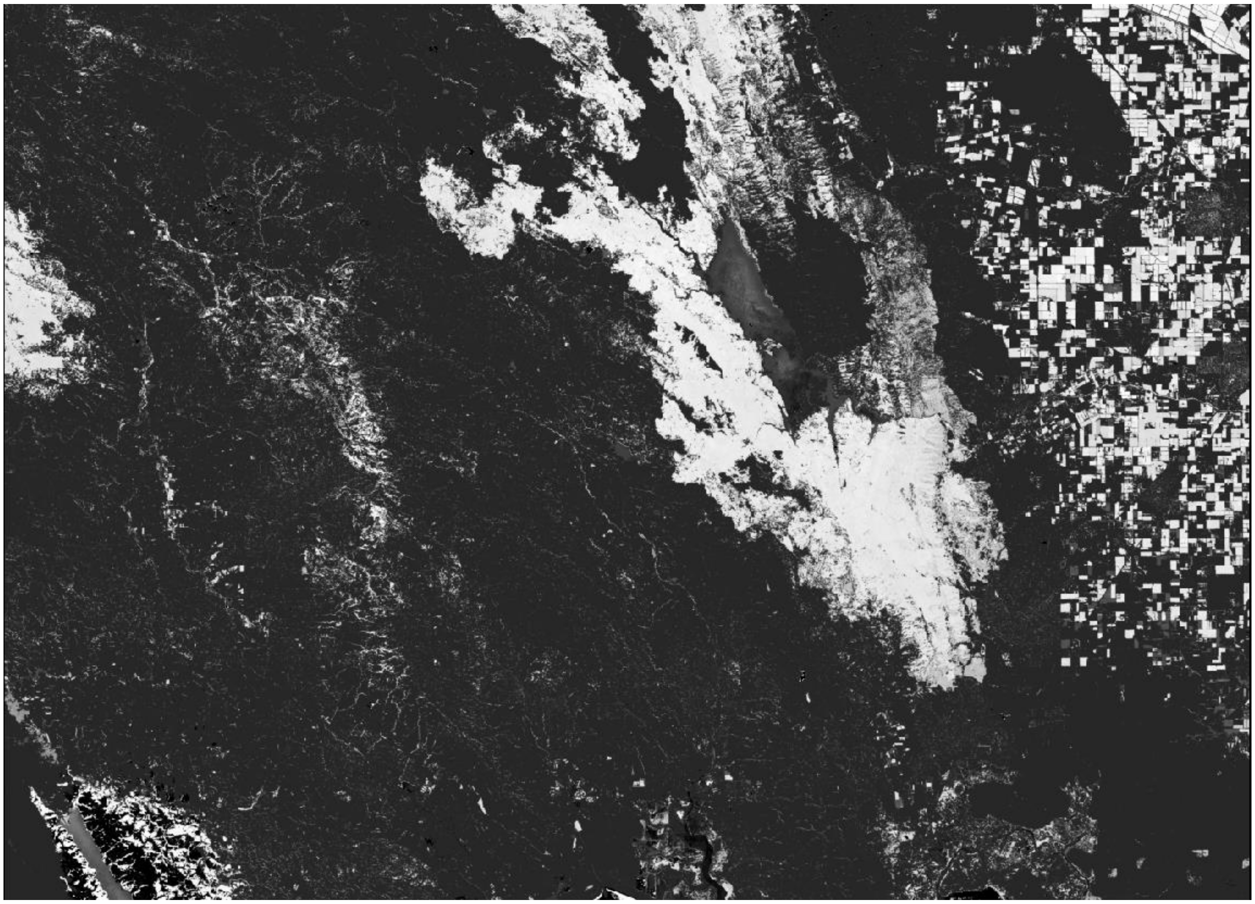


Figure 10 displays the change vector analysis results.

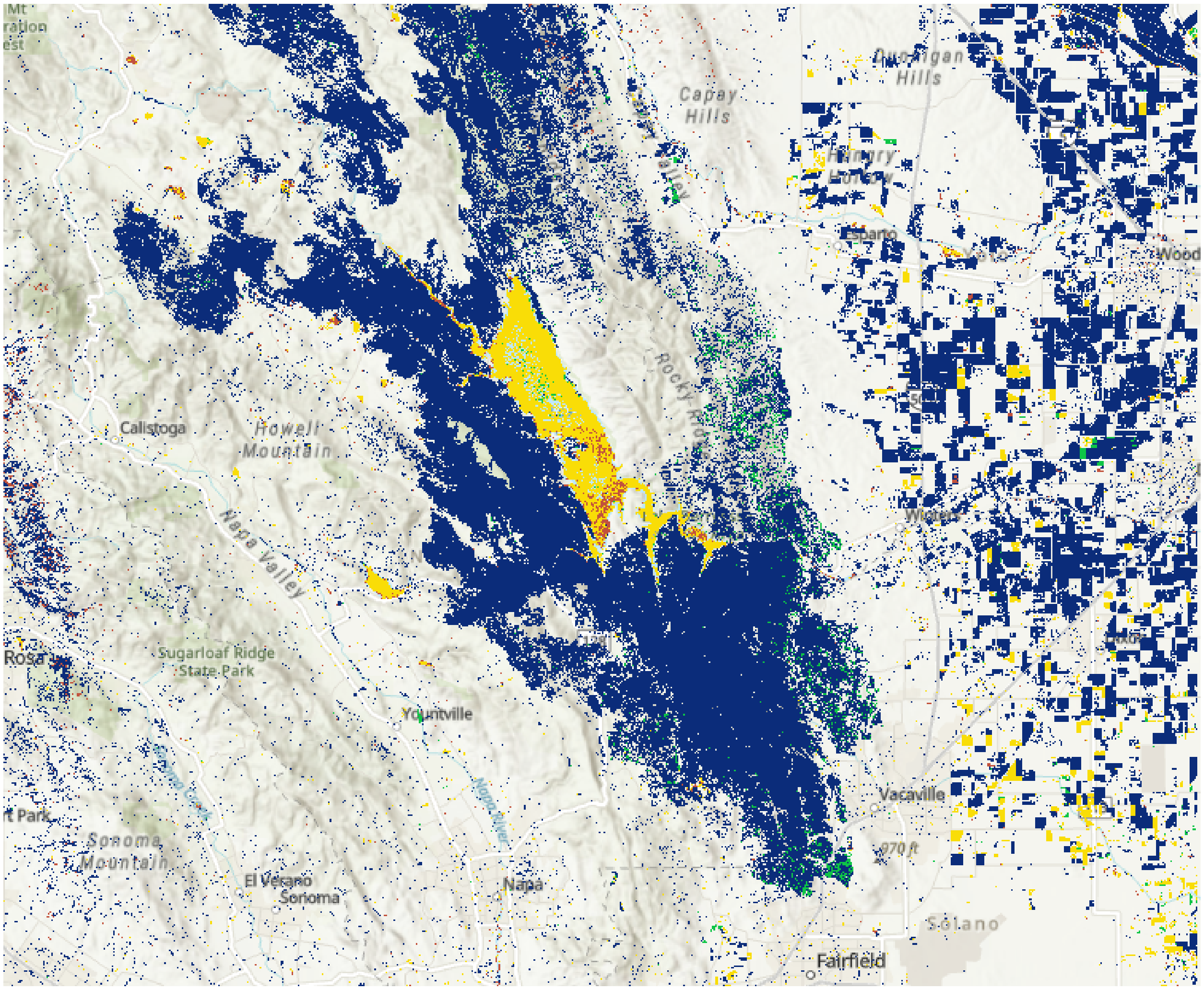


Figure 11 displays the change vector analysis in color.