Classification of Burned Area from Wildfire in Buena Vista, CA

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Abstract

Using Harmonized Landsat and Sentinel-2 (HLS) satellite imagery, this study examines the environmental effects of a recent wildfire in Tehama County, California, with an emphasis on the Ishi Wilderness Mountains and the Tehama Wildlife Area. To assess how the fire affected the landscape, pre- and post-fire photos were gathered and processed. Image bands from before and after the fire occurrences were stacked to create composite photos. The Maximum Likelihood Classification approach was used for supervised classification after training samples were developed to produce spectral signatures. The ISODATA approach was also used for unsupervised classification. Both burned and non-burned areas showed a considerable decline in vegetation when the Normalized Difference Vegetation Index (NDVI) and Normalized Burn Ratio (NBR) were used as categorization layers. The findings offer a spatial assessment of wildfire impacts and underscore the effectiveness of combining multiple classification techniques with vegetation indices in post-fire analysis.

Introduction

The California Park Fire in Tehama County, California has become the second-largest single wildfire in California's history. The fire began in Tehama County and spread north toward Shasta County and south toward Butte County. According to Cal Fire, the suspected cause of the park fire was arson. During its origin, this fire burned a large portion of the Ishi wilderness mountains and the Tehama Wildlife Area, two large nature and wilderness preserves in California. Now that the Tehama section of the park fire has been extinguished, restoration plans can be established and begun. For this reason, clear delineation of the burned area in the Ishi Wilderness and Tehama Wildlife Area is required to establish areas of focus for restoration. This project uses satellite imagery classification to determine the areas of Tehama County affected by the park fire. This classification could be used to help aid and inform restoration efforts.

Study Area

Northern California - Tehama County & Butte County.
The burned area of interest is located in the Ishi Wilderness and Tehama Wildlife Area, as well as the Western side of Butt Mountain. The study area includes the cities of Oroville, Chico, Red Bluff, and Redding.

Methods

Data used for the analysis was downloaded from NASA AppEEARS, using images obtained by Harmonized Landsat and Sentinel-2 (2015-12-01 to Present). Pre-fire data was downloaded between July 24 2022 and August 24 2022; the data was then inspected to find usable dates for our analysis. Data for post-fire was downloaded between July 24, 2024, and August 24, 2024, and the data was also inspected for usable dates. Images containing our study area were obtained by creating a shapefile of the AOI in ArcGIS Pro and submitting this shapefile to AppEEARS, which used the shapefile to select relevant images of the California park fire.

Our analysis began by downloading AppEEARS images of the Ishi Wilderness before and after the fire had occurred. Pre-fire and post-fire images were collected to identify and delineate areas of the wilderness affected by the fire. The HLS images were separated into individual band images, so the first step of the analysis involved stacking the images to create a true-color image of the area before and after the park fire. The Layer Stack tool in ERDAS Imagine was used to stack 12 image bands for pre- and post-fire images, resulting in 2 true-color images of the fire area before and after the fire.

The next step of analysis involved adding additional information to the pre- and post-fire images. Key indicators of fire occurrence are the Normalized Burned Area (NBR) index and the Normalized Difference Vegetation Index (NDVI). After images were stacked in ERDAS, NBR and NDVI were calculated for both stacked images using corresponding raster analysis tools. Upon completion, these tools each produced an image for the pre-and post-fire images. These NBR and NDVI images were then stacked onto the pre- and post-fire image stacks so that they were included as bands in the upcoming analysis. Using the newly stacked 2022 and 2024 images, now including NDVI and NBR values, supervised classification was performed on the 2022 and 2024 stacked images using Maximum Likelihood Classification (MLC). To perform this supervised analysis, Signature Editor was used to create spectral classes within both images; classes included forest, grass, crop, barren land, developed land, water, smoke, and burned land, with each class containing ≥10 spectral signatures. These information classes were used by the classification algorithm to classify the land-use types of both images. Upon seeing misclassified pixels in both images, unsupervised classification was also performed on both images using the ISODATA algorithm.

To analyze statistical results of the coverage of the fire, the supervised and unsupervised classification results created in ERDAS were first put into ArcGIS Pro to view respective attributes. Using the attribute tables, pixel counts were collected for pre- and post-fire images and calculations were performed to determine percentages of burned and non-burned areas.

Random points were then added to both maps to analyze NDVI and NBR values at these points, with the goal being to compare NDVI and NBR values in the burned area with those in the unaffected areas. The NDVI and NBR values at these points in both images were displayed as line graphs; a decrease in both NDVI and NBR can be observed from pre-fire to post-fire.

Results and Discussion

During our analysis, supervised classification using maximum likelihood yielded varying results compared to unsupervised classification using Isodata. We found that within the 2024 post-burn image, supervised classification identified 16.56% of the total pixels as being burned (see Figure 4). While unsupervised classification for the 2024 post-burn image identified 14.95% of the total pixels as being burned (see Figure 2). When looking at results found from normalized difference vegetation index and normalized burn ratio we find a decrease in both from between 2022 (pre fire) and 2024 (post fire) within the burned area extent. NDVI showed a decrease, with values between 0.2 to 0.8 in 2022 dropping to values between 0.1 to 0.2 in 2024 (see Figure 5). Some points showed more decrease than others. NBR showed decrease within the burned area, with values between -0.1 to -0.3 in 2022 dropping to values between -0.4 to -0.45 in 2024 (see Figure 7). NDVI was shown to stay fairly consistent from 2022 to 2024 outside of the burned area. With values ranging from 0.88 to 0.83 in 2022 and values from 0.88 to 0.84 in 2024 (see Figure 6). NBR showed a decrease from 2022 to 2024 outside of the burned area. NBR having values ranging from -0.1 to -0.25 in 2022 and values from -0.2 to -0.3 in 2024 (see Figure 8).

The results of this study demonstrate that there was a decrease in NDVI and NBR post fire within the Park Fire burned area extent. The decrease in NDVI shows a loss of vegetation within the burned area post-fire. NDVI values from 0.6 to 0.9 represent areas of dense vegetation while 0.1 or less represent sparse vegetation (USGS: science for a changing world, 2018). Our data shows evidence of dense vegetation pre-fire with values as high as 0.8 which drop to as low as 0.2 post fire, showing the loss of vegetation. NDVI values taken outside of the burned area consistently indicate dense vegetation and do not demonstrate the decrease as seen within the burned area. Low NBR values indicate "bare ground and recently burnt areas" (Office for Outer Space Affairs UN-SPIDER Knowledge Portal, n.d.). Our results show evidence of burned areas with the decrease of NBR. NBR values as high as -0.1 dropping to as low as -0.45 post fire within the burned area. We found that there was also a slight decrease in NBR values outside of the burned area. There may be several factors that contribute to this decrease such as low precipitation and dry conditions, further analysis would need to be conducted to confirm this. Results found during classification indicating the percentage of pixels identified as burned area may be inaccurate due to classification errors present in the images. Supervised classification results were found to have more errors than our unsupervised classification results, many of the errors present in pixels identified as urban and burned area. Both classification methods showed errors in the northeast portion of the image, classifying areas of barren land outside of the fire extent as burned.

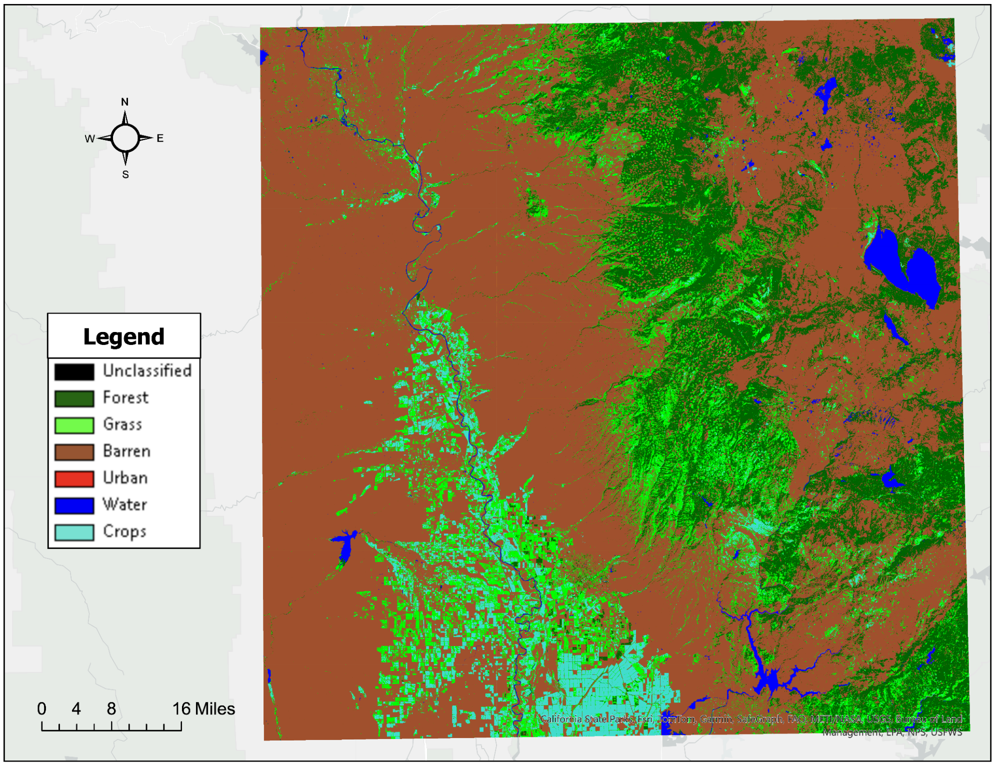

Figure 1. Pre-fire unsupervised classification results, using the Isodata method, from imagery collected on 8/19/2022.

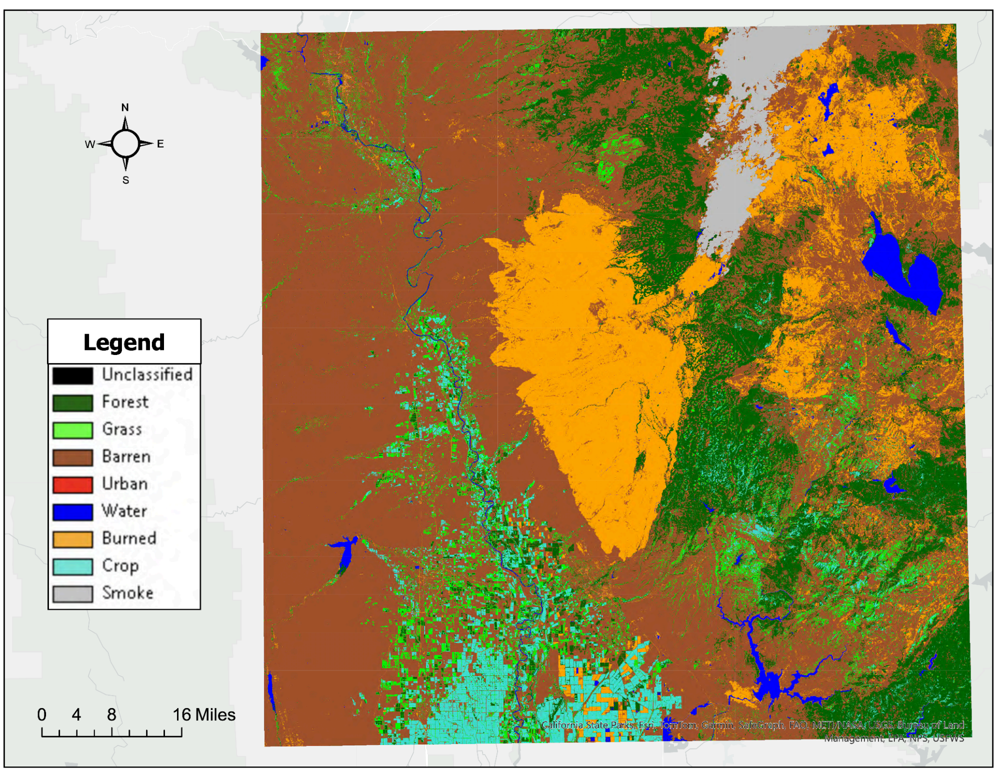

Figure 2. Post-fire unsupervised classification results, using the Isodata method, from imagery collected on 8/19/2024.

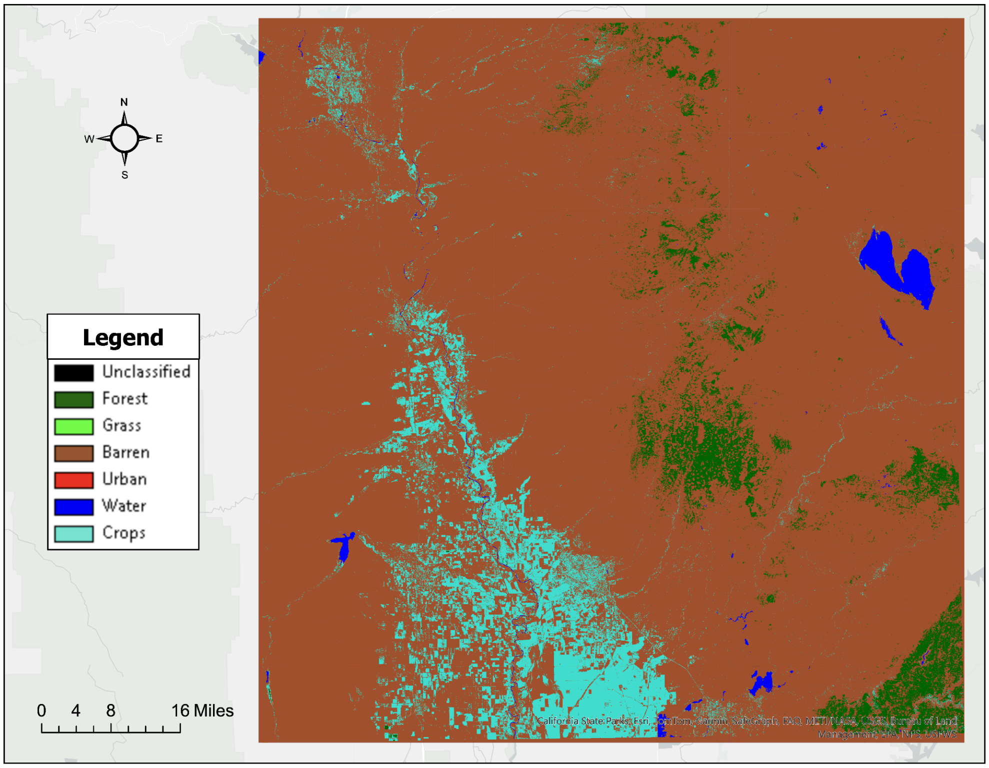

Figure 3. Pre-fire supervised classification results, using the Maximum Likelihood method, from imagery collected on 8/19/22.

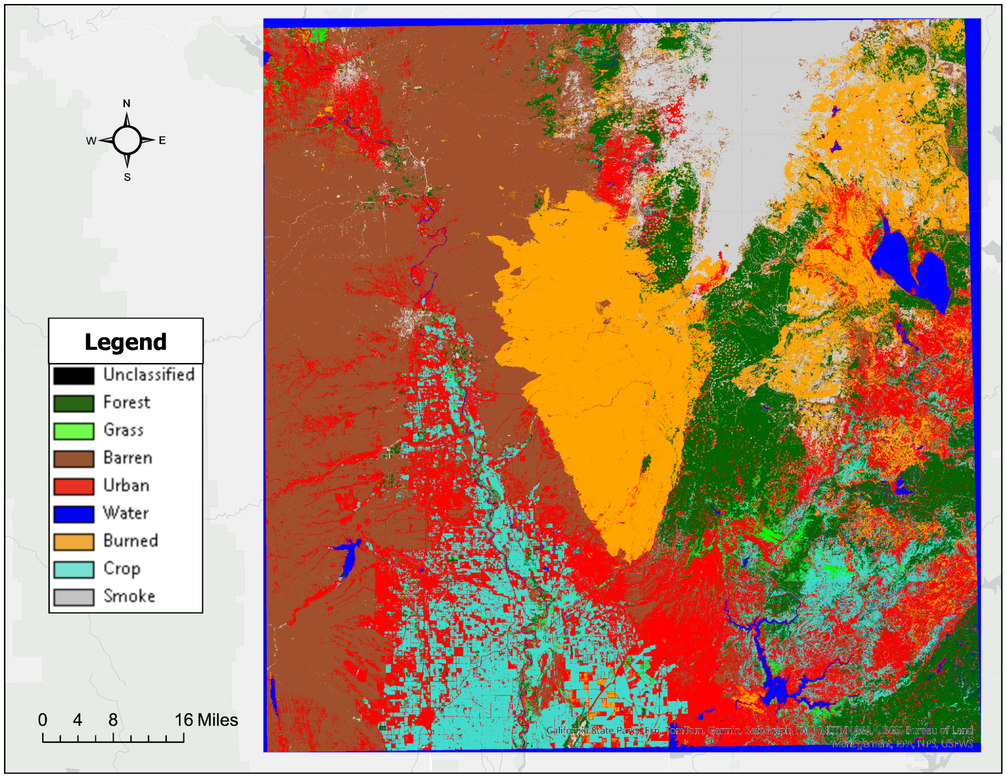

Figure 4. Post-fire supervised classification results, using the Maximum Likelihood method, from imagery collected on 8/19/2024.

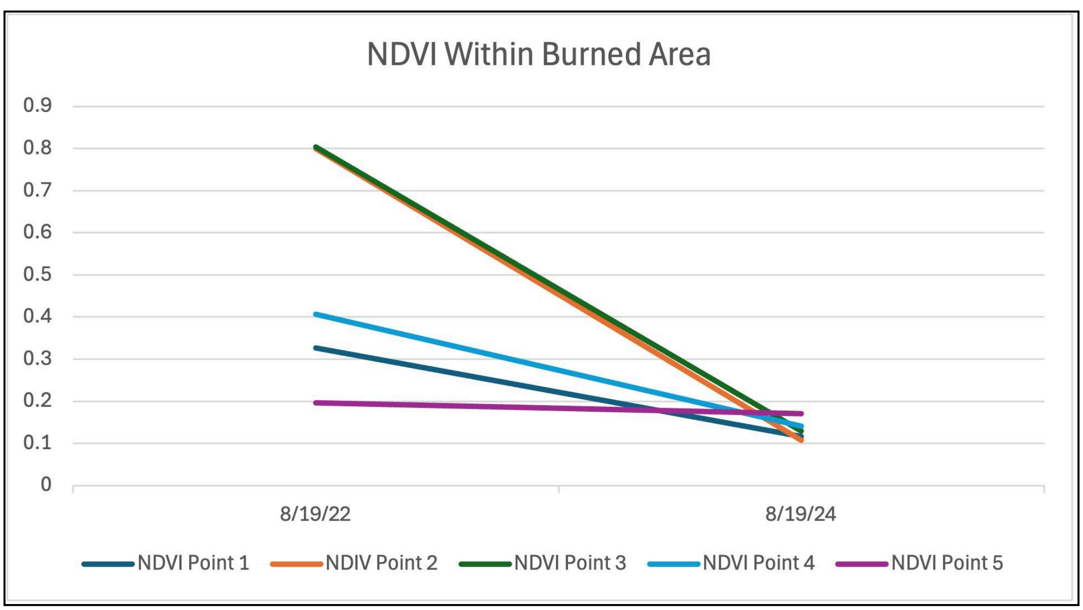

Figure 5. Normalized Difference Vegetation Index values of five random points within the Park Fire burned area extent from 2022 pre-fire and 2024 post-fire results.

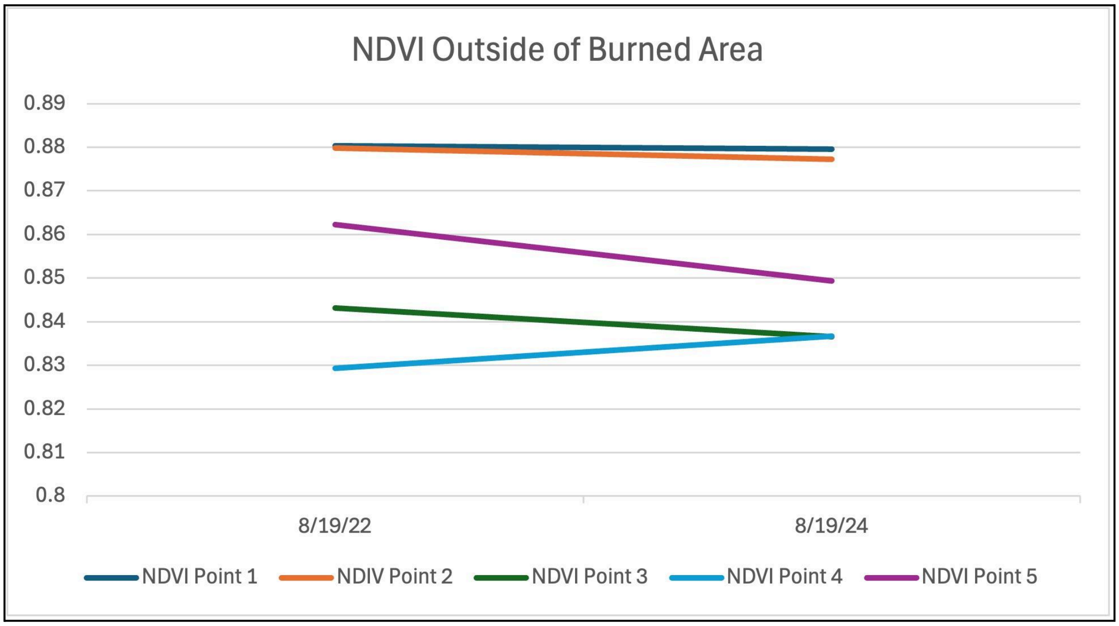

Figure 6. Normalized Difference Vegetation Index values of five random points outside of the Park Fire burned area extent (within forested land) from 2022 pre-fire and 2024 post-fire results.

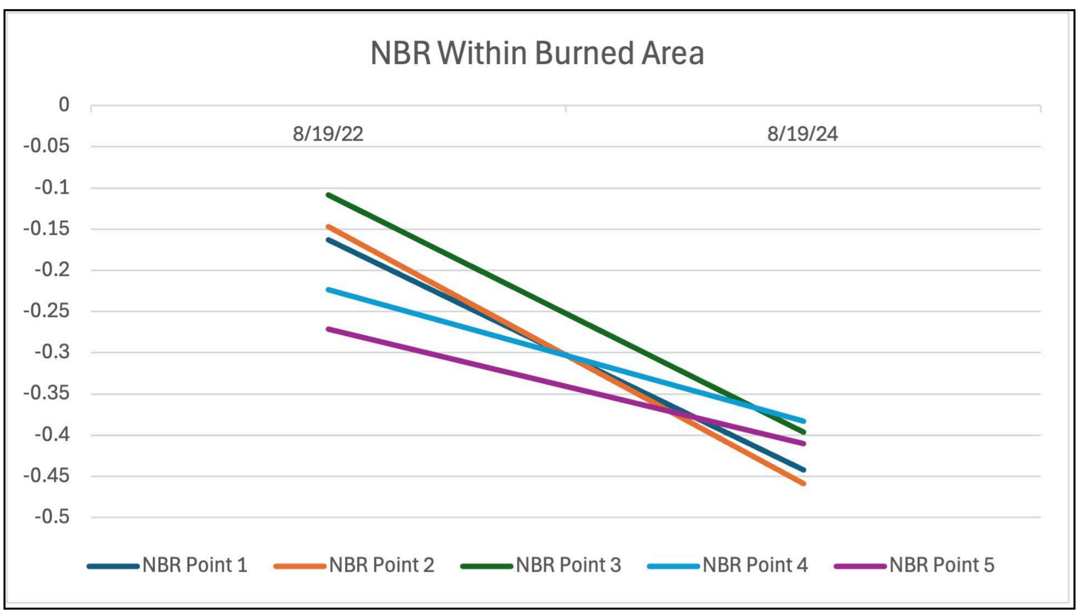

Figure 7. Normalized Burn Ratio values of five random points within the Park Fire burned area extent from 2022 pre-fire and 2024 post-fire results.

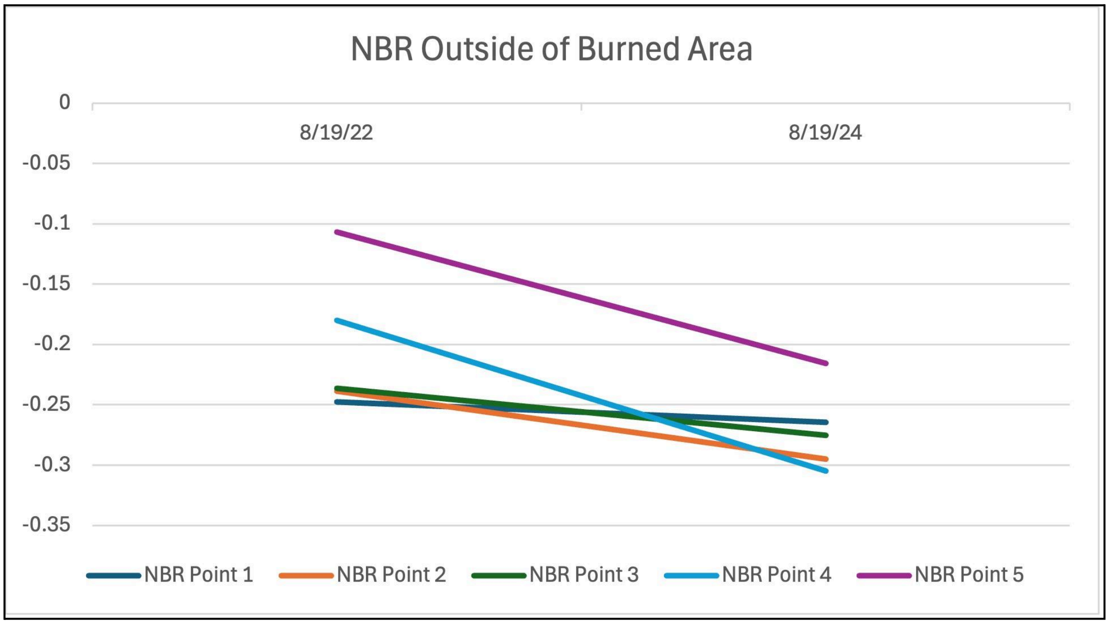

Figure 8. Normalized Burn Ratio values of five random points outside of the Park Fire burned area extent from 2022 pre-fire and 2024 post-fire results.

Conclusions

This study aimed to evaluate the areas of Tehama County, CA affected by the 2024 Park Fire. Specifically examining the landscape and environmental effects the fire had on the surrounding area. Our results show that Normalized Difference Vegetation Index and Normalized Burn Ratio both decrease within the burned area extent within post-fire imagery. This indicates a decrease in vegetation and provides evidence of burned/bare land within the post-fire results. Normalized Difference Vegetation Index outside of the burned area extent stayed consistent between pre and post-fire results indicating consistent levels of vegetation growth. We found a slight decrease in Normalized Burn Ratio outside of the burned area extent between pre and post-fire results, indicating the possibility of a decrease in precipitation between the two years. Results between both classification methods show that a low percentage of the overall classified image pixels were determined to be burned land. Inaccuracies within the burned land pixel percentages may be present due to classification errors present during analysis. These findings could be used to help aid and inform wildfire restoration efforts. Exploring additional future research may be beneficial in such efforts. Such as providing results from NDVI and NBR values across a larger pool of data within a wider period of time (Escuin, Navarro, & Fernández, 2007). Implications of such analysis could play a critical role in combating the increased occurrence of large wildfires within the state of California in recent years (Keeley, J. E., & Syphard, A. D, 2021). Our findings offer a thorough spatial assessment of wildfire impacts and underscore the effectiveness of combining multiple classification techniques with vegetation indices in post-fire analysis.

References

Escuin, Navarro, & Fernández. (2007, December 21). *Fire severity assessment by using NBR (Normalized Burn Ratio) and NDVI (Normalized Difference Vegetation Index) derived from LANDSAT TM/ETM images*. Taylor and Francis. https://www.tandfonline.com/doi/full/10.1080/01431160701281072?casa_token=UH0jzPl4hH0AAAAA%3Ah9-E9EsjKjNjnUc2V6Pbu5rQ-JHLGizaFhcGO-C3aTJew2ZHpNf6bC2cbt2g14y0UQe4yf8F5C_NP-k#d1e251

Keeley, J. E., & Syphard, A. D. (2021, August 25). *Large California wildfires: 2020 fires in historical context*. Springer Nature Link. https://link.springer.com/article/10.1186/s42408-021-00110-7

Normalized burn ratio (NBR). Office for Outer Space Affairs UN-SPIDER Knowledge Portal. (n.d.). https://un-spider.org/advisory-support/recommended-practices/recommended-practice-burn-severity/in-detail/normalized-burn-ratio

NDVI, the Foundation for Remote Sensing Phenology. USGS: science for a changing world. (2018, November 27). https://www.usgs.gov/special-topics/remote-sensing-phenology/science/ndvi-foundation-remote-sensing-phenology

Park Fire. Cal Fire. (n.d.). https://www.fire.ca.gov/incidents/2024/7/24/park-fire

Ramos, R., Downs, B., & Padilla, C. (2024, August 1). *Park Fire now one of the 5 largest wildfires ever in California; at least 209 homes destroyed*. CBS News. https://www.cbsnews.com/sacramento/news/park-fire-butte-county-updates/