Mapping the impact of wildfire on structures in the Palisades Fire, California

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Research Questions

- What is the severity of structural damage produced by the 2025 Palisades Fire in California using satellite data?
- What is the effect of using satellite imagery with different spatial and spectral resolutions?

Research Objectives

- To assess and map the spatial distribution and severity of structural damage caused by the 2025 Palisades Fire using remote sensing and GIS techniques.
- To provide new insight on the feasibility of remote sensing to map structural damage.

Introduction

Wildfires are uncontrolled fires that rapidly spread across landscapes, aided by dry vegetation, heat, and windy conditions (Thropp, 2024; WFCA, 2022; Wibbenmeyer & Tastet, 2025). Record-breaking fire seasons are becoming more frequent around the world, and causing remarkable effects on ecosystems, human life, and infrastructure (McWethy et al., 2019). The primary causes of wildfires include natural occurrences such as lightning and volcanic activity and human related causes such as discarded campfires, electrical malfunctions, and arson (NWCG, 2025). Wildfires have nearly doubled in the United States since 2005, with recent years experiencing the most severe wildfire seasons (Iglesias et al., 2022). California experienced one of its most extensive wildfire seasons in 2020, with more than 4.2 million acres consumed by fire (Thurman, 2022). The western United States was hit by disastrous wildfires fueled by record-high temperatures and drought in 2021 (Jain et al., 2024). California, known for being one of the most wildfire prone states in the U.S., has experienced a series of catastrophic fires (Keeley & Syphard 2021). Diverse climate, human-caused ignition events, vegetative fuels, and urban expansion contribute to the vulnerability of the state to devastating wildfires (Keeley & Syphard 2019). Los Angeles and its surrounding areas, including Pacific Palisades, have suffered significant damage from the large scale Palisades and Eaton fires (Woolcott, 2025). In 2025, the Palisades Fire emerged as one of the most destructive wildfires in the region, consuming thousands of acres and destroying over 5,300 structures (Castleman et al., 2025). This disaster underscores the urgent need for advanced techniques to assess wildfire damage and enhance mitigation strategies in urban areas susceptible to such risks (Seydi, 2025).

This study focusses on mapping of the structural damage caused by the 2025 Palisades fires, applying Remote Sensing and Geographic Information Systems. By integrating GIS with high resolution satellite imagery such as Sentinel-2 and PlanetScope, this analysis seeks to provide an accurate spatial distribution of the fire's effect, emphasizing areas on structural damage.

Study Area

The study area is Pacific Palisades which is a residential neighborhood located on the west side of Los Angeles, California, along the Pacific Ocean coast (Figure 1). It has a population of approximately 25,507 and a total area 62.97 km^2 (Wikipedia, Pacific Palisades, 2025). Pacific Palisades is largely urbanized, and well known for its natural landscapes, with expansive coastal and inland areas, including the Santa Monica Mountains, several natural parks, such as Topanga State Park, supplemented by numerous maintained city parks which are heavily forested and rich in biodiversity (Wikipedia, Pacific Palisades, 2025). The Palisades Fire started on January 7, 2025, in the Pacific Palisades area of Los Angeles. The Palisades Fire was a highly destructive wildfire that burned 23,448 acres (94.89 km^2), killed 12 people, and destroyed 6,837 structures, making it the tenth-deadliest and third-most destructive wildfire in California and the most devastating wildfire in the history of the city of Los Angeles (Wikipedia, Palisades Fire, 2025).

Methodology

Data

This study conducted was using four datasets. The first two datasets included pre-fire and post-fire satellite imagery from Sentinel-2 and PlanetScope. The third dataset is the fire perimeter data, and the fourth dataset consisted of structural and building damage data. The third and fourth datasets were sourced from LA County's website (Table 1).

Data Processing

Sentinel-2 Image Processing: Sentinel-2 image Preprocessing was performed in Google Earth Engine (GEE) and visualized and presented in ArcGIS Pro.

Sentinel-2 Image Processing in GEE:

- AOI Definition: A 10 km buffer around the center of the Pacific Palisades was used as the study area.
- Image Collection and Cloud Masking: Sentinel-2 Surface Reflectance (HARMONIZED) imagery was used. A cloud masking function was applied using the QA60 band to exclude cloudy and cirrus pixels. Reflectance values were scaled by dividing by 10,000.

- Pre-fire and post-fire Image Selection: Cloud-masked Sentinel-2 SR Harmonized images were processed for selecting pre-fire and December 18, 2024, was used and post-fire image the best post-fire image was March 8, 2025.
- Burn Ratio Calculation: The Normalized Burn Ratio (NBR) was computed for both pre-fire and post-fire images using the NIR (B8) and SWIR2 (B12) bands. The difference NBR (dNBR) was calculated to quantify loss and fire severity. dNBR was derived by subtracting post-fire NBR from pre-fire NBR (Key & Benson, 2006).
- Burn Severity Classification: dNBR values were classified into five categories based on standard thresholds ranging from enhanced regrowth to high severity (Key & Benson, 2006). Classes 0–4 were extracted and multiplied by pixel area to calculate burned area in square kilometers.
- Image Export from GEE: Images in Google Earth Engine were exported to Google Drive using the export task interface. Each image was prepared with defined parameters such as spatial resolution, export extent, and output format (GeoTIFF). In this study, the following images were exported:
    - Pre-fire and Post-fire Sentinel-2 image (RGB composite: B12 (Short-wave Infrared), B8 (Near-infrared), B4 (Red))
    - Pre-fire NBR – Normalized Burn Ratio before the fire
    - Post-fire NBR – Normalized Burn Ratio after the fire
    - dNBR – Differenced Normalized Burn Ratio
    - Burn Severity—Classified burn severity map

These exported images are used for post-processing, mapping, and reporting of wildfire impact.

Burn Visualization: All the raster outputs generated from Sentinel-2 image were exported, including pre-fire and post-fire image, pre-fire NBR, post-fire NBR, dNBR, and burn severity as GeoTIFF files. These files were saved to Google Drive and then downloaded to our local project directory. After downloading, the TIFF files were imported into ArcGIS Pro to produce maps with appropriate symbology for accurate comparison. Maps including pre- and post-fire image, NBR, dNBR, burn severity, and burned area were displayed with custom color palettes and a legend for interpretation. Structural and Building Damage data and fire perimeters were also downloaded from the LA County website and imported into ArcGIS Pro. Separate maps have been produced to show the extent of damage within the fire perimeter.

Planet Image Processing: The images were downloaded from PlanetScope. Images on the closest cloud free day before the fire and after the fire were used in the analysis. These ended up being December 18 for before the fire and February 8 for the image after the fire. Normalized Difference Vegetation Index (NDVI) was calculated from the red and Near-infrared bands to visualize the greenness of the vegetation. A difference map was generated between the first time point and the last time point to make a dNDVI map. Zonal statistics were calculated on the structure data from the County of Los Angeles with the difference in NDVI. The median change in NDVI for the buildings which were classified as destroyed by the County of Los Angeles is -0.05. All the other categories for damage and no damage had positive values for NDVI change.

Results and Discussion

Analysis of Sentinel-2 Data: A series of maps and graphs have been generated to depict the spatial and spectral changes in Pacific Palisades, California, before and after the wildfire. The pre-fire image shows the unburned landscape, while the post-fire image shows darker patches within the delineated fire perimeter, reflecting burned vegetation, structures, and surface change because of the wildfire (Figure 3). The Normalized Burn Ratio (NBR) maps illustrate vegetation conditions in the Palisades area before and after the wildfire event. NBR values range from -1 to +1, where higher values (closer to +1) indicate healthy vegetation and lower values (closer to -1) signify burned or barren land. In the pre-fire NBR map, most of the region exhibits dark shades, corresponding to NBR values close to 1, which reflect healthy, undisturbed vegetation cover. The post-fire NBR map reveals a dramatic shift, with lighter tones across large sections of the fire perimeter. The most severely affected zones are in the eastern, central and some parts of western regions, where vegetation loss is extensive (Figure 4). The dNBR values range from -2 to 1.63, where higher positive values (closer to 1.6, shown in dark tones) indicate severe vegetation loss and high burn severity. Lower or negative values (closer to -2, shown in lighter tones) indicate unburned areas or zones with vegetation regrowth (Figure 5). The analysis of burn severity classification reveals that a significant portion of the area underwent moderate to high burn severity (Figure 5).

The severity of building damage caused by the Pacific Palisades fire reflects that most of the buildings and structures of the central and southeastern part are severely affected compared to the western part of this area. The northeast and western parts represent damage from minor (green) to destroyed (red). Whereas the southeastern and south-central regions, which experienced high damage in urban neighborhoods and most buildings here are marked as destroyed, with some major or minor damage (Figure 6). A total of 6,665 buildings were highly damaged and categorized as destroyed (>50%) and 61 buildings damaged are marked as major damage (26–50%). On the other hand, 2,009 buildings experienced no damage. 660 buildings were classified as affected (1–9%), and 147 buildings were classified as having experienced minor damage (10–25%) (Figure 7). Maps of figure 8 reveal that different types of structures are damaged across the region like single-family homes, multi-family residences, commercial buildings, schools, and churches etc. The southern coastal area, particularly densely built residential neighborhoods, experienced the most structural damage. Meanwhile, the western and northern parts show minimal or no damage. The counts of the three largest categories of destroyed buildings include Single-family residence multi story (count 2720), Single-family residence single story (count 2326), and utility miscellaneous structure (count 1015), with less destruction on public and commercial infrastructure, providing a detailed spatial perspective on the disaster's impact (Figure 8).

Overall, pre-and post-fire NBR sentinel 2 image analysis depicts the drastic change in the vegetation cover throughout the Palisades area due to the wildfire. The burn severity classification confirms that large portions of the fire-affected region fall moderate to high burn severity. Most buildings were rated as destroyed, showing widespread destruction, particularly in highly populated southeastern and southern central areas. Urban regions were more severely affected than the scattered rural settlements in the north and west. Spatial damage type analysis suggests that residential buildings, both single family single and multi-story, suffered the most. The presence of damaged public and commercial buildings further suggests disruption of essential community facilities. The combined geospatial and statistical analysis exhibits extensive environmental damage and high structural loss due to wildfire.

Analysis of PlanetScope Data: The median NDVI change value from before and after the fire was calculated for each structure logged by the county of Los Angeles in the post fire building survey. Bar plots as shown in figure 10 were created to analyze the difference between structures that were classified as destroyed and not destroyed. The dataset includes other categories such as affected, minor damage, and major damage. The Planet data was not able to pick this up on damage to these other categories because most of these buildings still had a roof and the damage was internal. We combined the categories of No damage, affected, major, and minor into one class which is not destroyed for this analysis. The other class used is destroyed. We are using the first quartile threshold as the definition for whether a building was destroyed or not. This means 75% of destroyed buildings would be classified as destroyed in the analysis while the other 25% would not be classified as destroyed. We then looked at how many of the buildings that were manually digitized as not destroyed are above this threshold and found that 68% of not destroyed buildings would be correctly classified as not destroyed with this threshold. The other 32% would be incorrectly classified as destroyed. This is using non-null values of damage from the County of Los Angeles's dataset which consists of 11,731 buildings. Of these 11,731 buildings, 4,997 of them are not destroyed while the other 6,734 of them are counted as destroyed (Figure 10, and Figure 11).

PlanetScope vs Sentinel-2 data: There are pros and cons of using the PlanetScope and Sentinel-2 data for classification of building damage after a fire. Starting with Sentinel-2 data, the bands include the visible spectrum as well as Near-infrared and Shortwave Infrared. This is helpful because the Normalized Burn Ratio (NBR) uses the Near-infrared and Short-wave Infrared bands. The disadvantage of Sentinel-2 data is the resolution at which it is captured. The data is at a 10 m resolution meaning each pixel has the dimensions of 10 m by 10 m. The PlanetScope data is captured at a finer resolution of 3 m meaning each pixel has the dimensions of 3 m by 3 m. The disadvantage of the PlanetScope data is that it only has 4 bands which include the visible spectrum and the Near-infrared bands but not the Short-wave Infrared band. As a result, the PlanetScope analysis in this report uses Normalized Difference Vegetation Index (NDVI) change from before and after the fire while the Sentinel-2 analysis uses Normalized Burn Ratio which is an index designed for detecting fire scars. The PlanetScope data can better distinguish damage from one building to another while the Sentinel-2 data is better at distinguishing large patches of burned areas using NBR.

Conclusion

This analysis reveals the challenges in detecting building damage using remote sensing. Even with a 3 m resolution data product, it was challenging to determine which buildings were damaged in the fire event. By nature, remote sensing only detects the roof of a house which can frequently be intact when much of the inside of the structure has been destroyed by fire. It is slightly easier to determine whether a building's roof was destroyed because that is the part which the satellite is able to identify. Indices such as dNBR and dNDVI do a great job of detecting vegetation change before and after a fire, but urban environments are very complex. It is challenging to identify change in urban environments with remote sensing. Even if the 3 m PlanetScope data had a Short-wave Infrared band, it is likely that more valuable results would not have been able to be produced due to the challenges of remote sensing of change detection in urban environments. The immense change in vegetation cover of uninhabited areas was captured by the remote sensing products while the change of urban areas was harder to detect. The analysis of building damage count from Los Angeles County Palisades fire building dataset reveals that there are considerable number of structures, especially within southeastern, south central and central regions, that were destroyed. The findings emphasize the importance of incorporation of vegetation management activities and construction of fire-resistant buildings in hazardous areas can be an important aspect in mitigating potential losses.

Figures and Tables

Table 1: Data sets used for this study.

Satellite Sensor Types	Data Types	Date Range	Type	Source	Spatial Resolution
Sentinel-2	Pre-fire	December 18, 2024	Raster	Sentinel-2	10 m
	Post-fire	March 8, 2025	Raster	Sentinel-2	10 m
PlanetScope	Pre-fire	December 18, 2024	Raster	PlanetScope	3 m
	Post-fire	February 8, 2025	Raster	PlanetScope	3 m
	Fire Perimeter Data	January 21, 2025	Shapefile	County of Los Angeles	Vector
	Los Angeles (LA) County Boundary	November 13, 2015	Shapefile	Los Angeles GeoHub	Vector
	California State Boundary	July 17, 2024	Shapefile	Los Angeles GeoHub	Vector
	Structural/Building Damage Data	January 28, 2025	Shapefile	County of Los Angeles	Vector

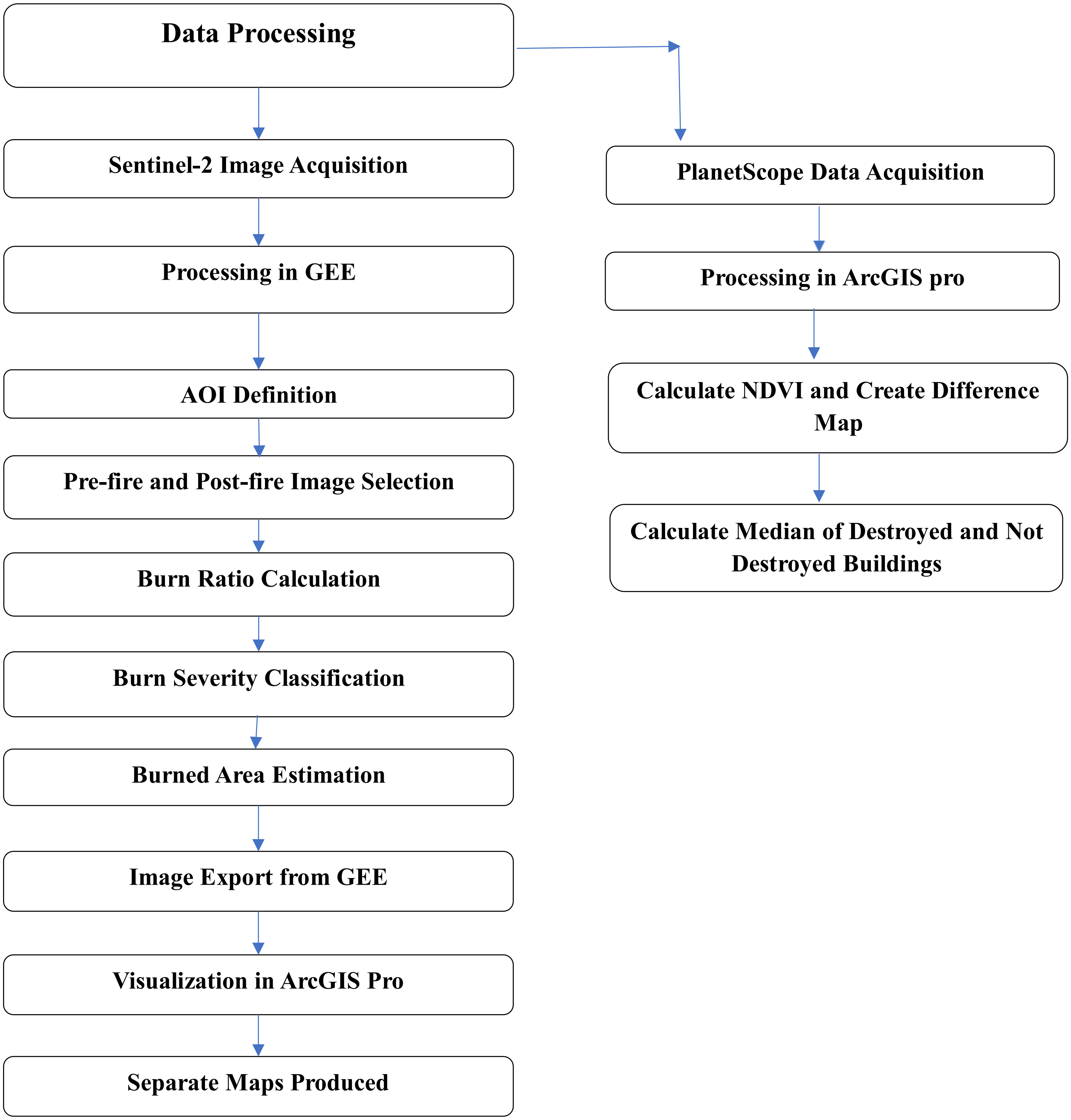

Figure 1: Working Flow chart

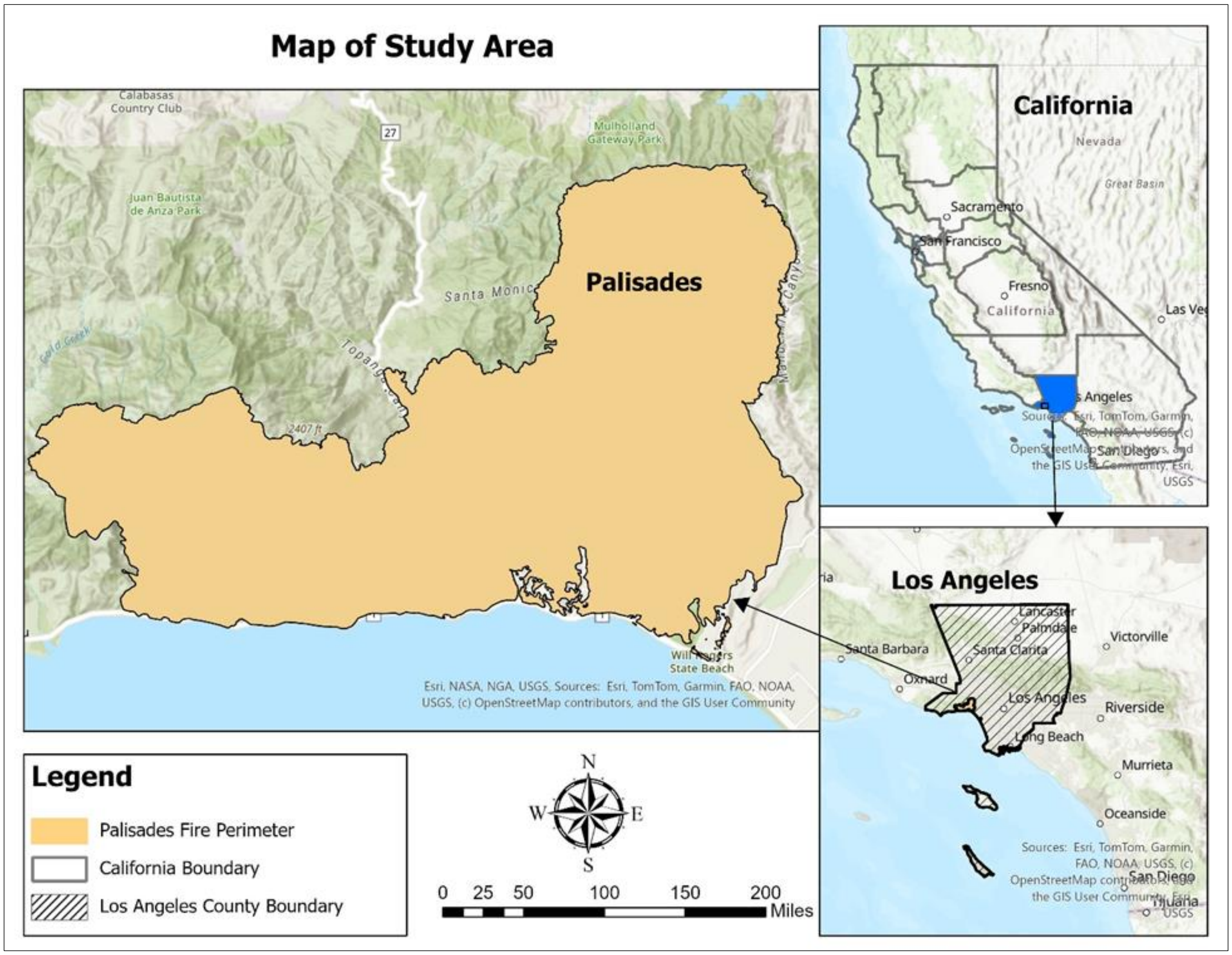

Figure 2: The study area is Pacific Palisades, California. The yellow polygon is the outline of the fire perimeter within Los Angeles County.

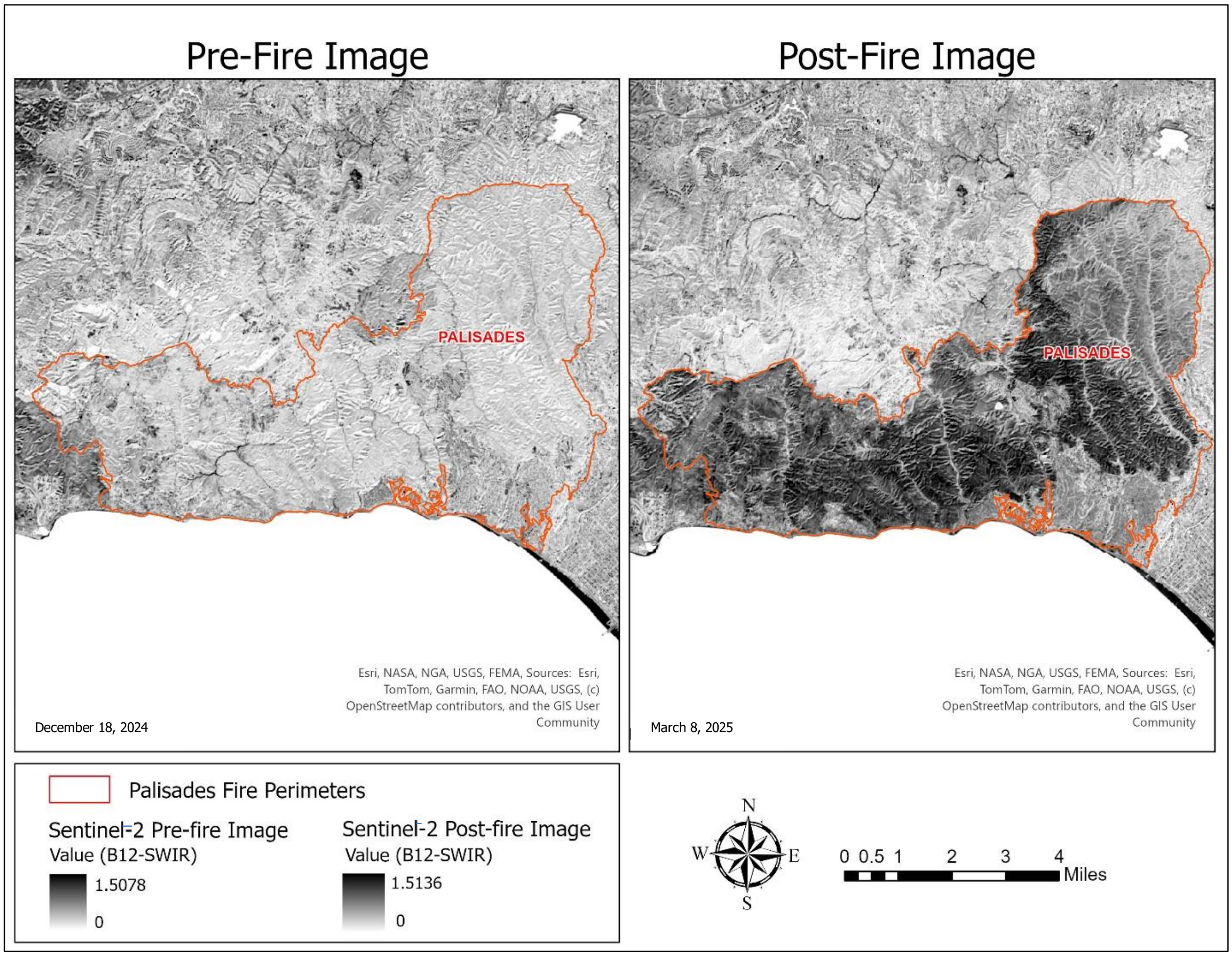

Figure 3: Pre-Fire and Post-Fire Sentinel-2 Images of the Pacific Palisades Fire Area.

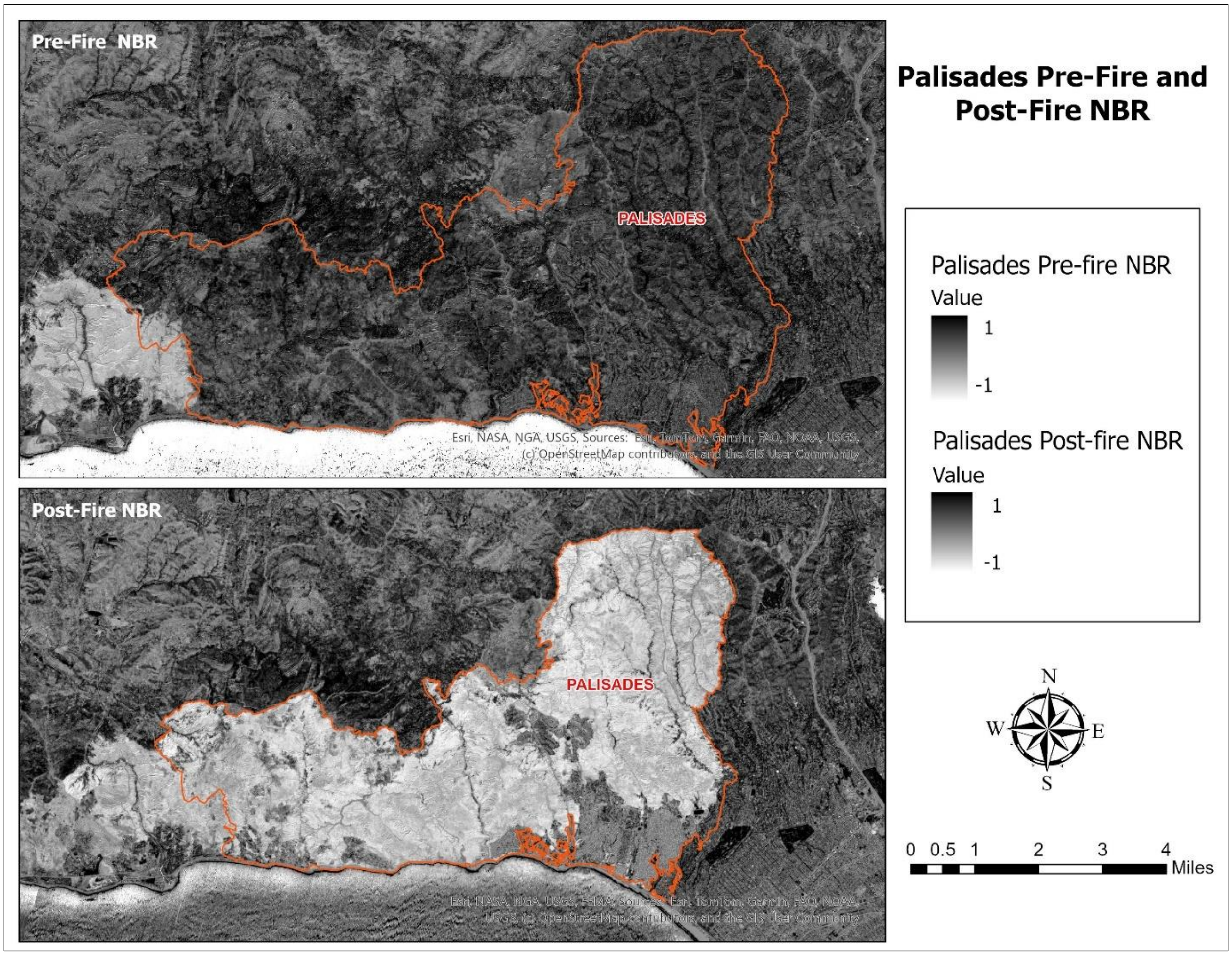

Figure 4: Sentinel-2 Pre-Fire and Post-Fire Normalized Burn Ratio (NBR) of the Pacific Palisades Fire Area.

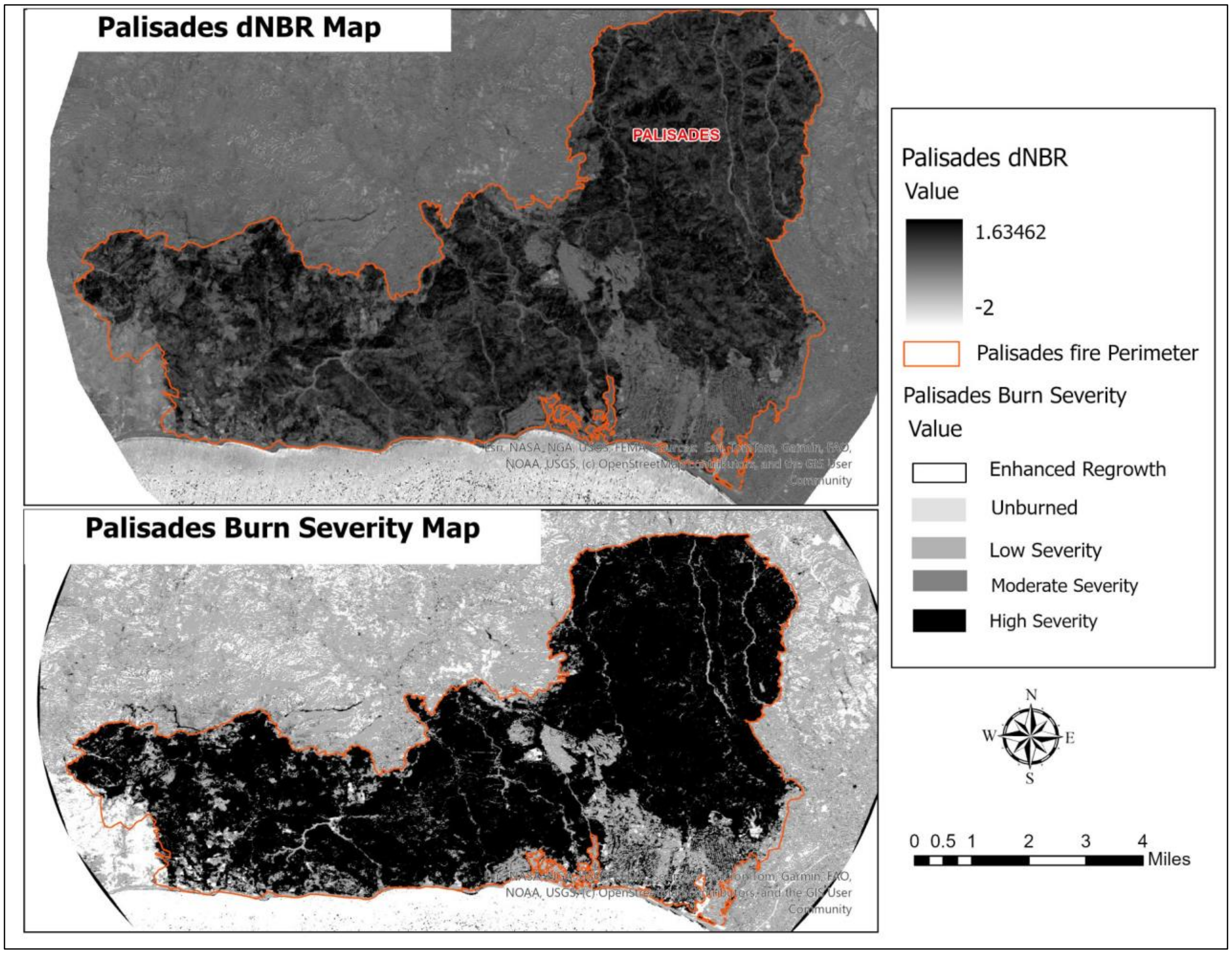

Figure 5: Differenced Normalized Burn Ratio (dNBR) and Burn Severity Maps (Sentinel-2) of the Pacific Palisades Fire Area.

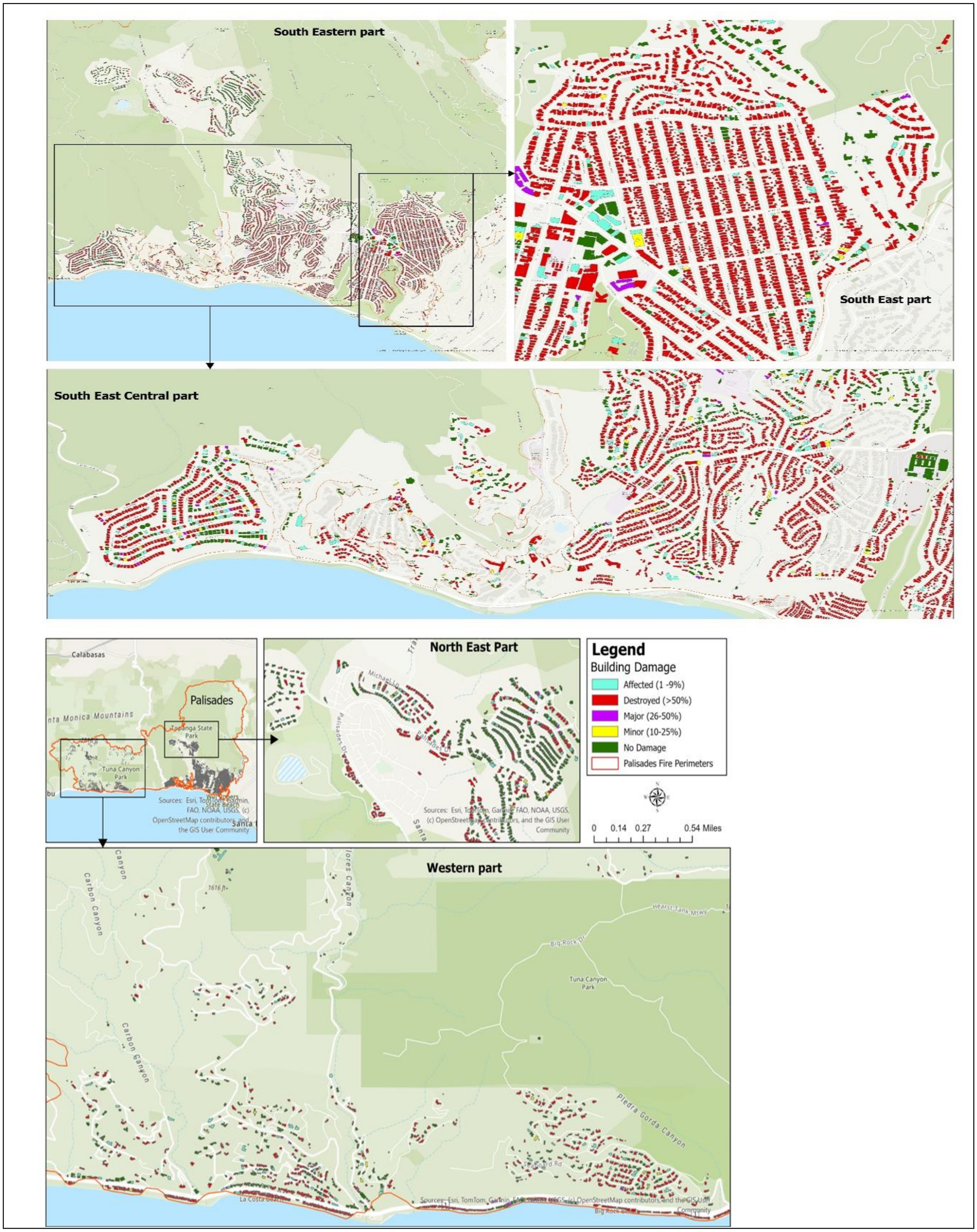

Figure 6: Spatial Distribution of Building Damage from the Pacific Palisades Fire.

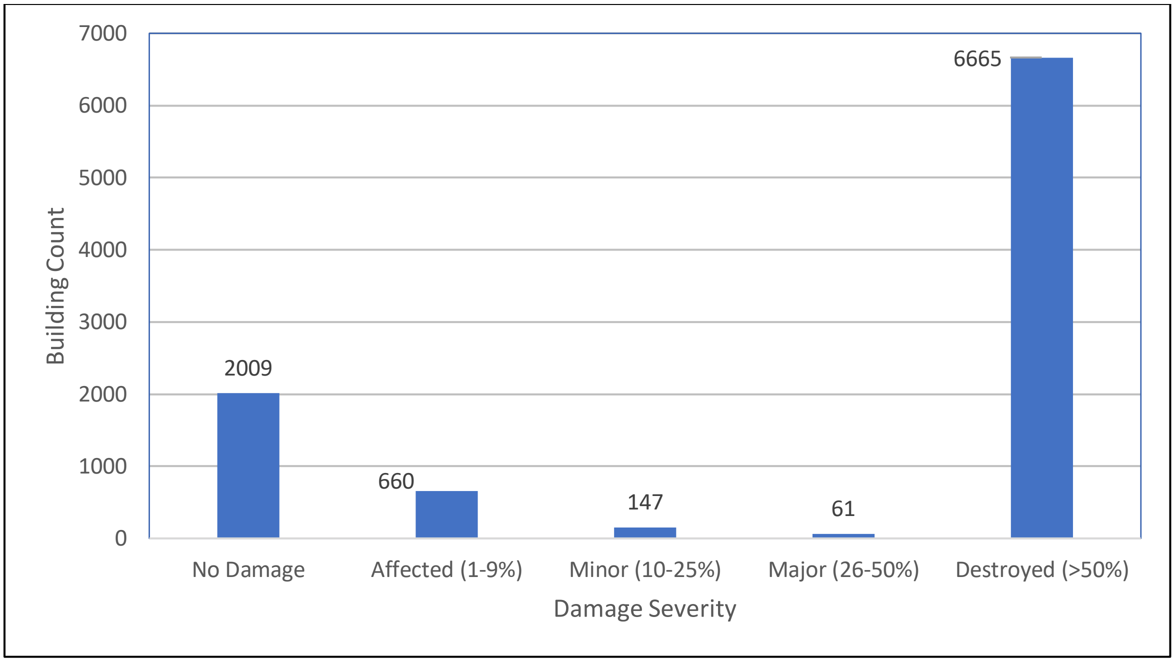

Figure 7: Building Damage Count from Los Angeles County Palisades Fire Building Dataset.

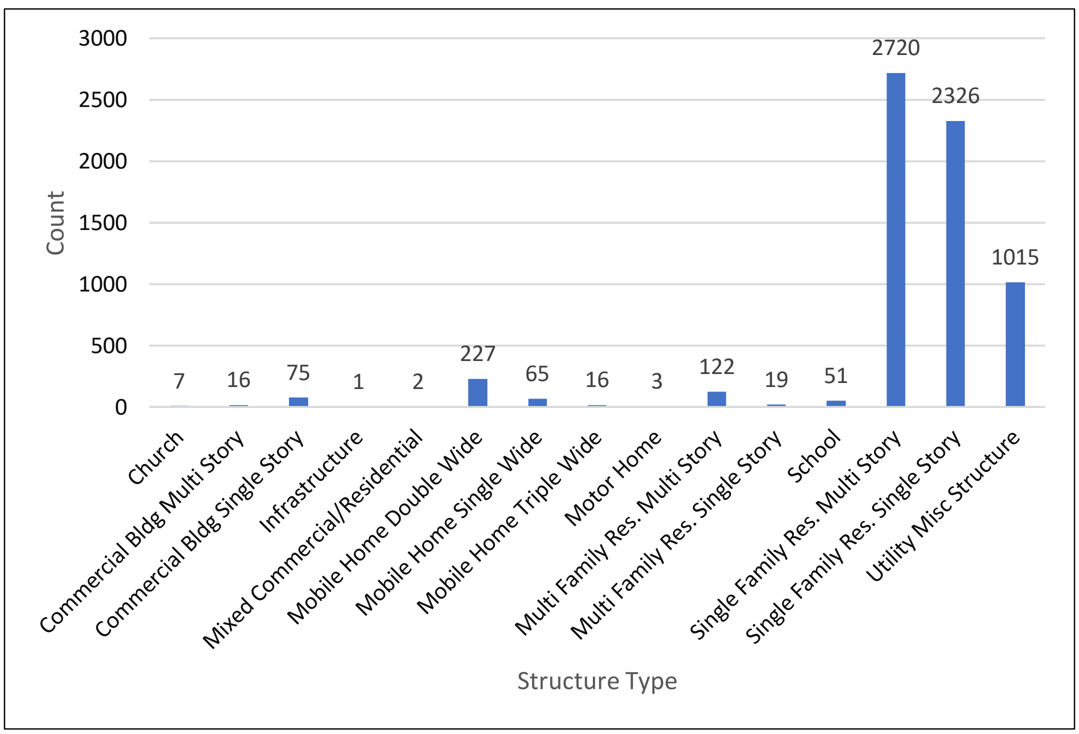

Figure 8: Count of structure types of Destroyed in Los Angeles County Palisades Fire Building Dataset.

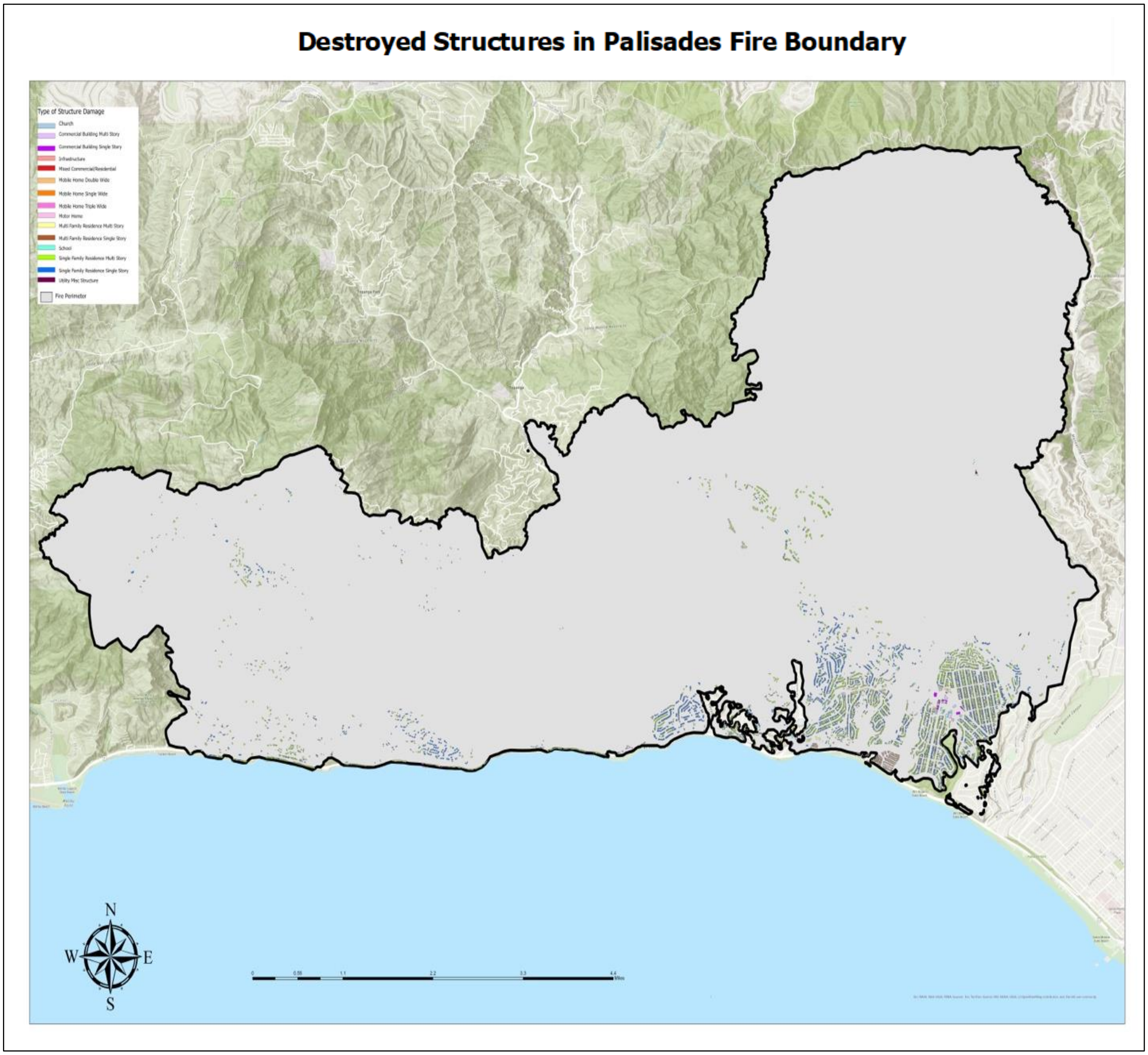

Figure 9: Map of Destroyed structure types (data from County of Los Angeles)

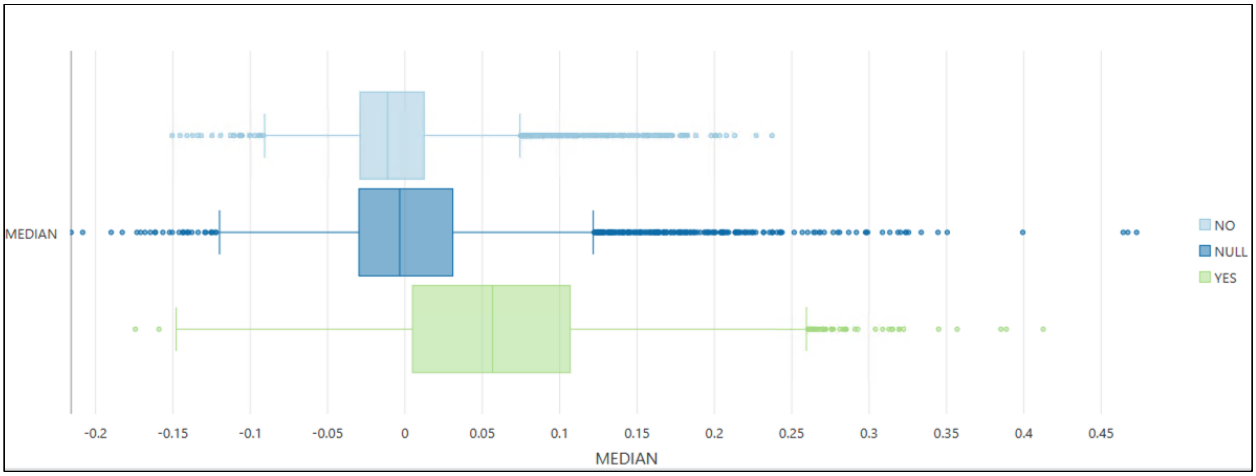

Figure 10: Distribution of Median NDVI change by destroyed, not destroyed, and null building status from PlanetScope data

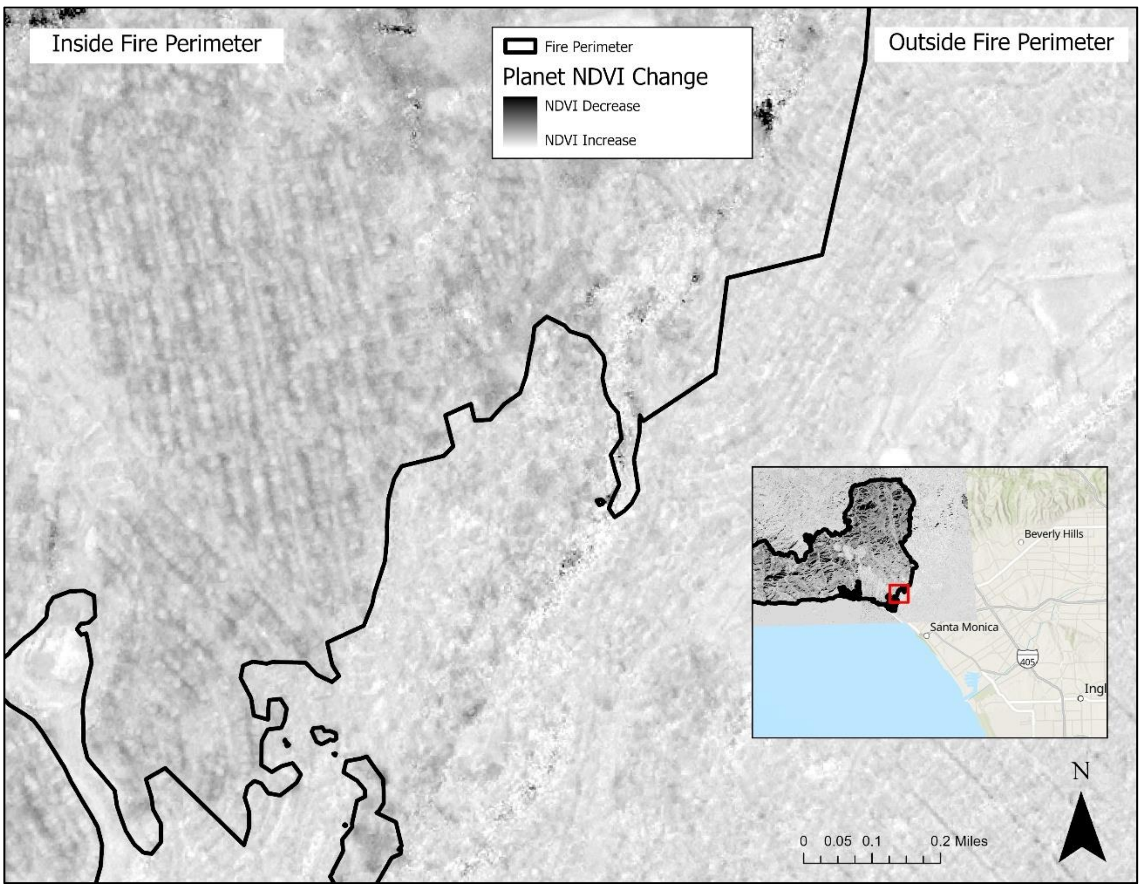

Figure 11: PlanetScope NDVI change pre-fire and post-fire

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