-Aren Page, Garrett LaRue, Garrett Godwin, Brian Wall, Daniel Hodges-

Abstract

Our project is designed to show how the 2013 Rim Fire in Stanislaus National Forest and Yosemite National Park, located in Tuolumne and Mariposa counties, CA affected the landscape and what resources were affected. This fire was one of the largest fires recorded in California, and the largest ever in the Sierra Nevada mountain range. In addition to showing how severe this fire actually was, we aim to address the common misconception that wildfires burn everything within their border, but are rather dispersed with varying intensity throughout the landscape.

To analyze the severity of the fire, we ran the Normalized Burn Ratio (NBR) which is designed to highlight the areas of a fire that have been burned with indexing the different ratings of severity of the burn. NBR is used for calculating two images, one being prior to the fire and the second image of immediately post fire. To enhance visualization of the NBR, we created Hillshades and Slope Rasters from a Digital Elevation Model. To visualize the spread of the fire and the area affected we acquired shapefiles that outlined the Region of Interest on a day by day basis starting from August 18, 2013 and continuing to the largest and fullest extent of the fire on September 26, 2013 as well as a parcels shapefile containing land use data.

Introduction

The 2013 Rim Fire was a 257,175 acre, or 402 mi^2 fire that burned actively from August 17, 2013 through October 24, 2013 in Stanislaus National Forest and Yosemite National Park, located in Tuolumne and Mariposa counties, CA. This fire was one of the largest fires recorded in California, and the largest ever in the Sierra Nevada mountain range and cost the state close to $127 million (Cal Fire 2013). This high cost was a result from all the resources damaged during the burn, all the workforce needed to clear the fire and the lack of tourism income which the sierras experience seasonally. Although this fire was devastating to a vast amount of land, the intensity of the burn was not as expected. It is common to believe that a wildfire burns in an even manner throughout the entire landscape, although this is not usually the case. A wildfire of this scale burns in a spotted manor amongst the encompassed burn area at varying intensity.

The rapid spread of the fire over such a large expanse of land was due to a combination of high winds and extreme drought conditions, as well as a delayed reporting of the fire's occurrence. The fire was ignited by a lone hunter who lit the fire from kindling. The fire spread easily due to high winds in the area which carried embers up the slopes of the landscape and ignited the dry fuels from Brush, Oaks, Pine, and other conifer stands (InciWeb 2013). These same dry conditions that allowed for the fire to ignite, and actively burned for several weeks, also allowed for the fire to smolder over winter and continue burning in some patches for months. Due to the extremely long residence time of the fire, it is likely that high amounts of heat caused severe damage to the roots, mycelium networks, and even seed banks within the soil (Sierra Conservancy 2017). Such high heats also caused volatilization of nutrient compounds that likely were carried away from the site via rainfall or as smoke during the initial burn period.

Even a fire in a remote area of mountain country can have huge impacts on the livelihoods of millions of Americans. The size and severity of the area burned was so immense, that astronauts could see the fire from space during the day, and the smoke plume traveled north over the rockies to Canada before traveling south to the Gulf of Mexico. The air quality impact from such a fire was severe, but the fire also burned through several hydroelectric power facilities and may have lasting impacts on the water quality of reservoirs in the region (SFPUC 2013). Tourism was affected negatively regions in iconic California destinations such as Lake Tahoe and Yosemite National Park. Other negative effects included loss of carbon sequestration, soil degradation, water regulation violations, pollination loss, habitat and biodiversity loss, property and aesthetic values, and recreational values diminished. (SFPUC 2013). One positive aspect of the fire is that the two Giant sequoia groves survived intact, and no one was killed during the blaze.

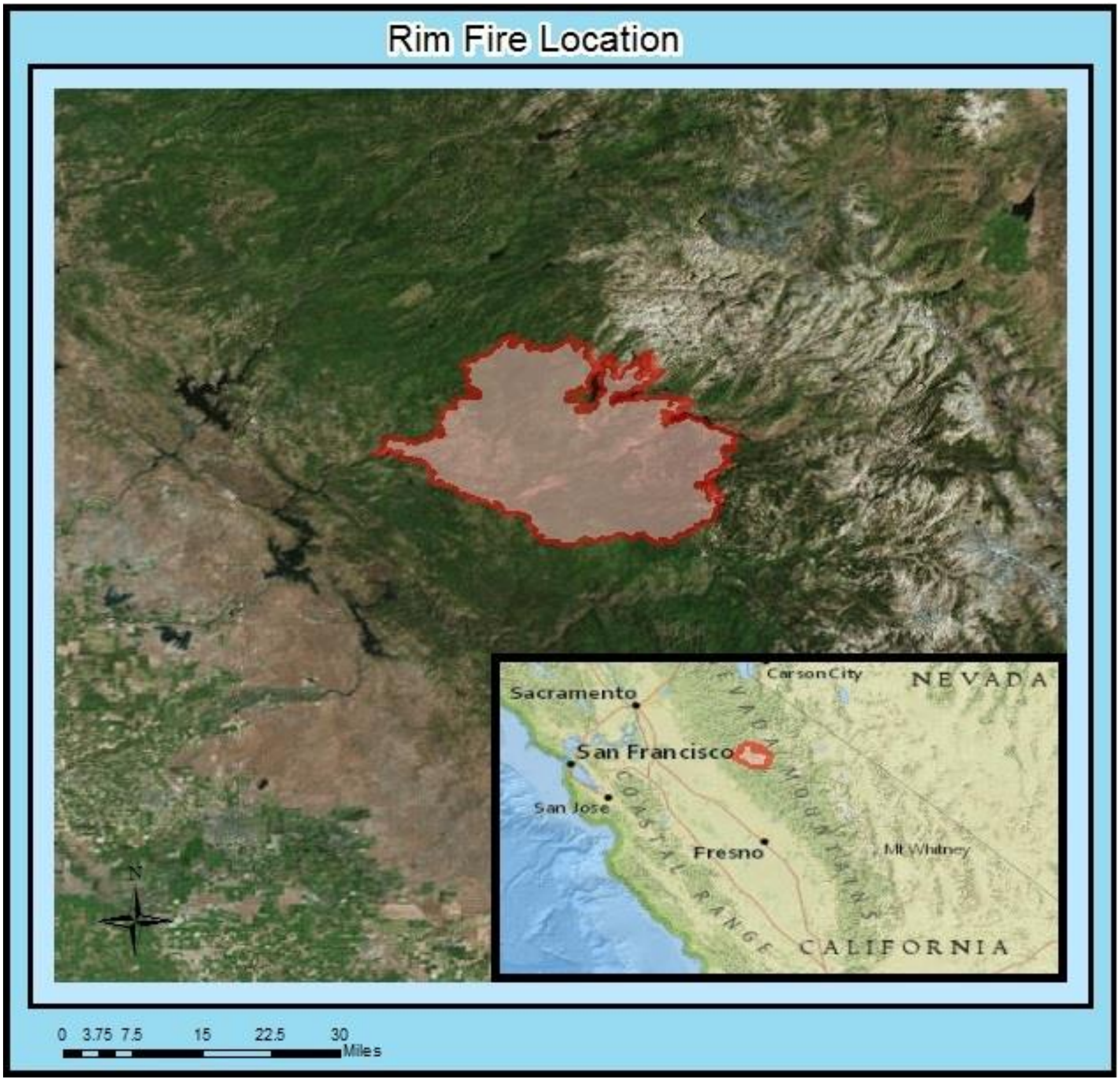

Figure 1: Rim Fire Location. Sierra Nevada mountains, CA.

Methods

The first step in analyzing the severity of the 2013 Rim Fire was to pinpoint the exact region of interest, or ROI. This was determined by downloading several boundary shapefiles from https://www.geomac.gov/ , that outlined the ROI on a day by day basis starting from August 18, 2013 and continuing to the largest and fullest extent of the fire on September 26, 2013. This final boundary layer will be used extensively to clip other data sets to the ROI. These boundaries were in the NAD_83 GCS and this became the default projection of all further analysis. The multiple boundary layers were compiled together to show the spread of the fire over the course of its burn.

The second step was to locate a digital elevation model, or DEM of the area so that further surface data could be gathered. The ROI was located on a transect of DEM images due it its select location and its immense size. Four DEMs were downloaded from https://nationalmap.gov/ and combined into one layer using the mosaic tool. From this DEM were were able to create a hillshade to enhance visualization of future maps, and a slope classification layer. The slope layer was reclassified into percent slope breaks of low, medium, and high slope at 15%, 30%, and 45% respectively.

Next we wanted to know about the land use of the area within the burn site. Parcels data was acquired from www.fs.usda.gov containing layers of land use. The parcels were clipped to the ROI boundary layer. In order to properly represent the land use, the unique attribute table was altered to add color values to each parcel.. This clipped parcels layer was then set against a basemap to better visualize the landscape.

To analyze the severity of the fire, we ran the Normalized Burn Ratio (NBR) which is designed to highlight the areas of a fire that have been burned with indexing the different ratings of severity of the burn.

NBR equation $NBR = \frac{\text{NIR} - \text{SWIR}}{\text{NIR} + \text{SWIR}}$ is used for calculating two images, one being prior to the fire and the second image of immediately post fire. The fires extent and severity is based upon taking the difference between these two index layers shown in the equation *dNBR* = PrefireNBR - PostfireNBR . We acquired Landsat 8 .geotiff images from https://earthexplorer.usgs.gov , which allowed us to view images of the pre and post fire ROI which also helped us visualize the impact of the fire. We used ENVI 64-bit to work with our pre and post fire images. In the layer manager, we selected each image individually, selected to change the RGB bands and in the following order choose: SWIR-Red, NIR-Green and Red-Blue, which allowed for the burn area to be clearly visible to work with. Next, we created NBR Raster's for both the pre-fire and post-fire images. Once accomplished, we created a differenced Normalized Burn Ratio Raster which shows with the higher pixel values being the brighter areas are indicating a higher burn severity. Once the differenced normalized burn ratio rasters were created, we used ArcMap to join the differenced normalized burn ratio image with the fire perimeter layer we had acquired and to create our fire burn severity map. We then reclassified the differenced normalized burn ratio values to match values that we had been acquired from GSP 216 Remote Sensing lab 8. We were able to go into the Attribute table of the severity layer and calculate the acreage of each burn severity layer using the pixel count to help us finish the final piece to our map.

Results

Our group set out to find what the slopes were like within the fire boundary as well as on the nearby landscape by creating a Digital Elevation Model (DEM) shown in **Figure 4** which also provided us with an image of where the watersheds were located in the fire boundary and in the nearby areas. We then wanted to find out what the Land use was within the fire boundary which was shown in **Figure 3.** This map turned out to have very interesting information showing most of the North and South sides of the fire being mainly composed of Pine and Pine Fir forested lands with a small portion to the Southeast side of the map being a True Fir forested land. There was five separate and certainly noticeable sections that were deforested lands which could be potential forested lands in the future. Another noticeable feature was that the grazing/farmland tied right into and more so overlapped with the watershed land which is non-forested land although the fire burned right through it.

Lastly, with our main goal of finding out the severity of the fire, we created a burn severity map shown in **Figure 5** by using the burn severity index to reference what was not burned to what was burned as well as the different scales of burn severity ranging from low-severity to high-severity burn. Once we had this map finalized as the sole main idea behind the project, we figured it would be cool to research and find data showing a day by day progression which is shown in **Figure 2**. As you can see from the daily fire spread map, we started out with a fire perimeter on August 19th which is when a good visible perimeter was present to us although the fire originally started on the 17th of August. Our daily fire perimeter progression map ranges from the 19th to the 25th which is when daily fire spread slowed down a significant amount and data was not collected till September 9th when the next good visual fire spread perimeter was taken for us to use. The last day we collected data was the full extent fire perimeter on September 26th when there was no more forward rate of spread being done to the landscape. To give everyone a perspective of where this fire occurred, we created a locator map shown in **Figure 1** above which shows that this fire was located north of Fresno, East of San Francisco and San Jose as well as Northwest of Mt. Whitney.

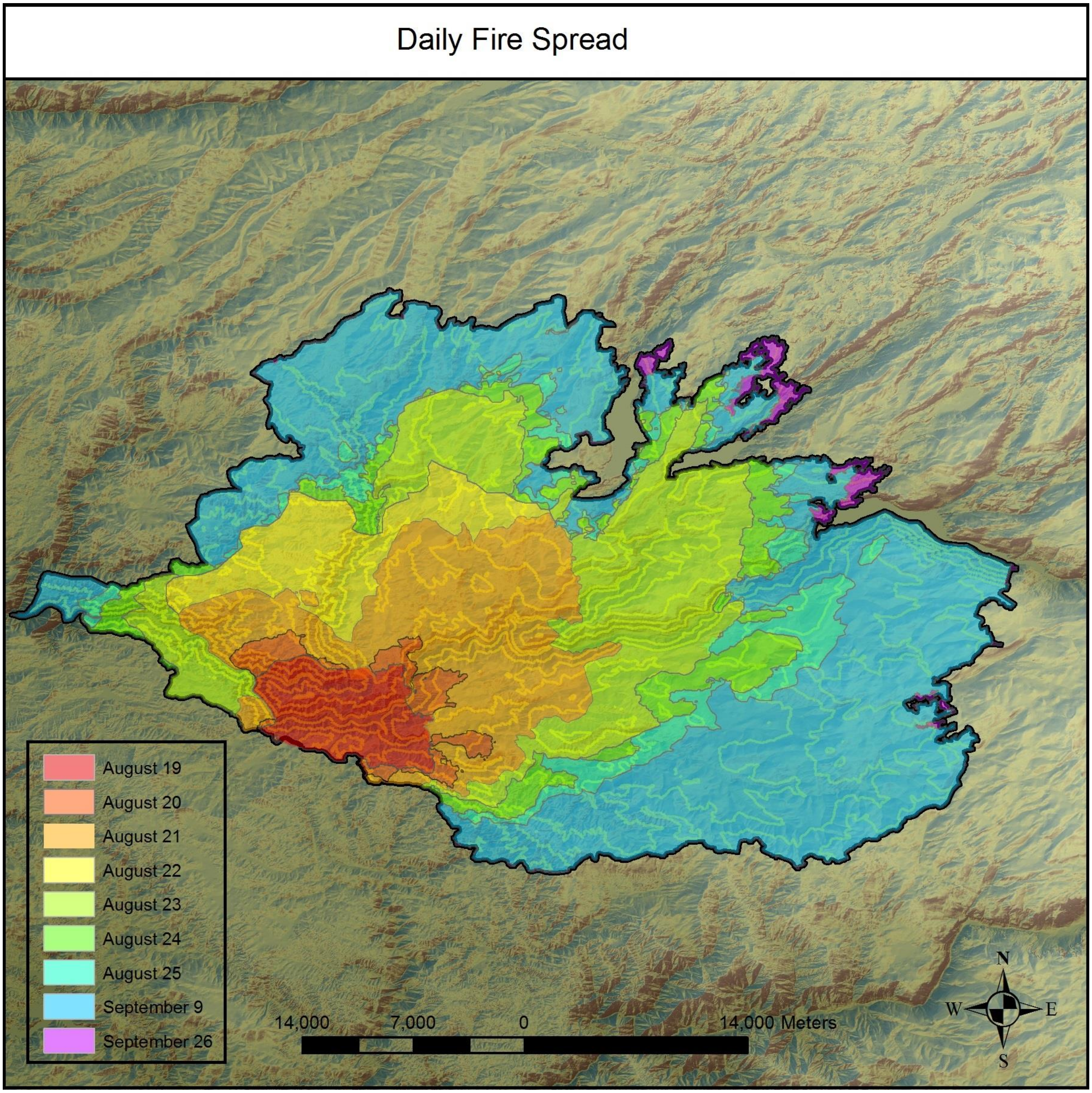

Figure 2: Daily spread of fire perimeter.

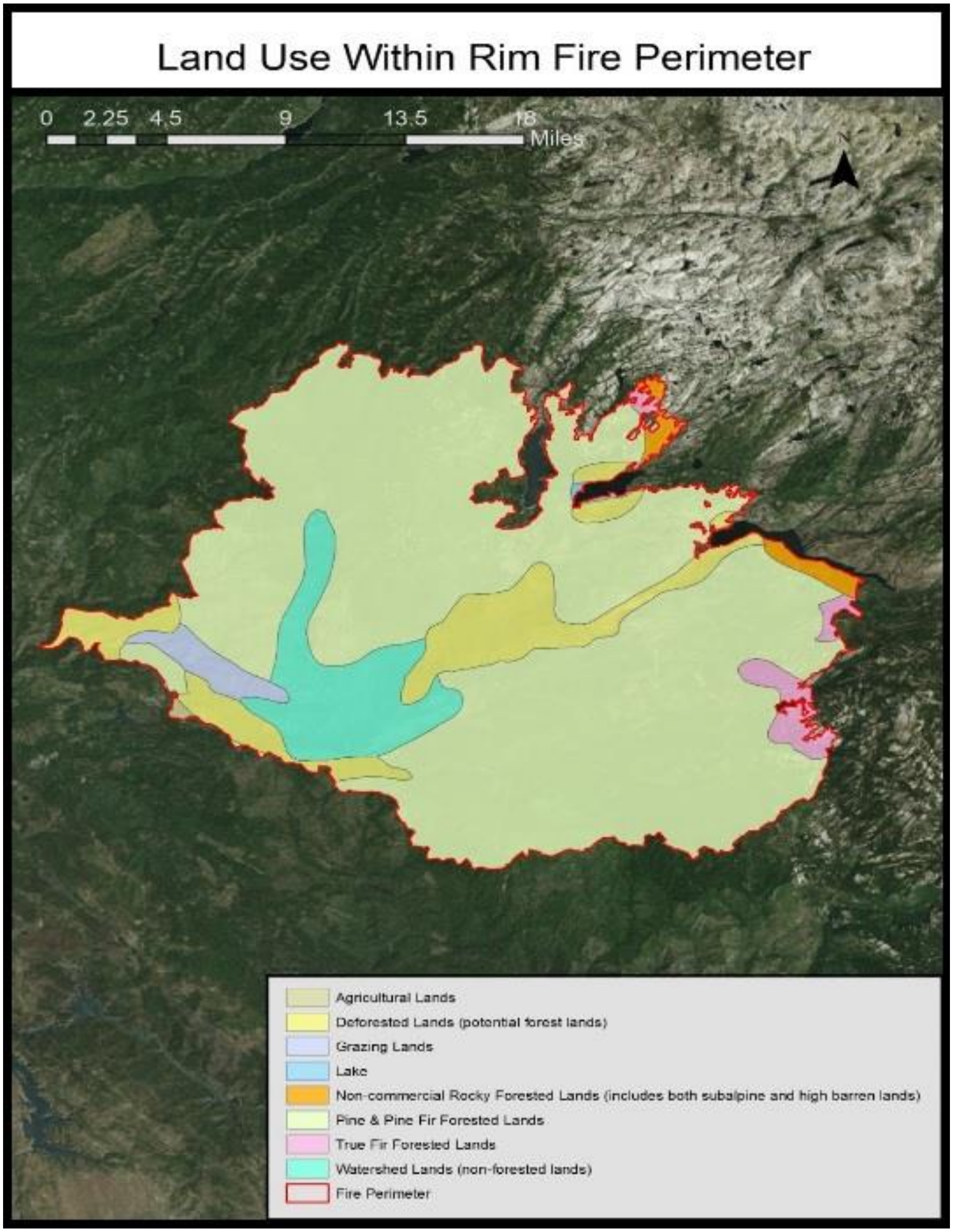

Figure 3: Land usage within Rim Fire Border

Land Use Type	*Acres^2 Per Parcel*			*Total Acres^2*
Grazing Lands	**34.857384**	**4304.852**	**0**	**4339.709163**
Deforested Lands (potential forest lands)	**288.742425**	**3897.488**	**14365.93**	**18552.15779**
Agricultural Lands	**312.937338**	**0**	**0**	**312.937338**
Lake	**320.099243**	**0**	**0**	**320.099243**
True Fir Forested Lands	**495.541359**	**908.9637**	**3886.747**	**5291.252354**
Deforested Lands	**923.509698**	**1313.528**	**5625.118**	**7862.1557**
Pine & Pine Fir and Forested Lands	**1624.505144**	**92534.1**	**102904**	**197062.5664**
Non-Commercial Rocky Forested Lands (includes both subalpine and high barren land)	**3263.546639**	**0**	**0**	**3263.546639**
Watershed Lands	**20386.19154**	**0**	**0**	**20386.19154**

Table 2 - Total square acres each land parcel contains within the fire border.

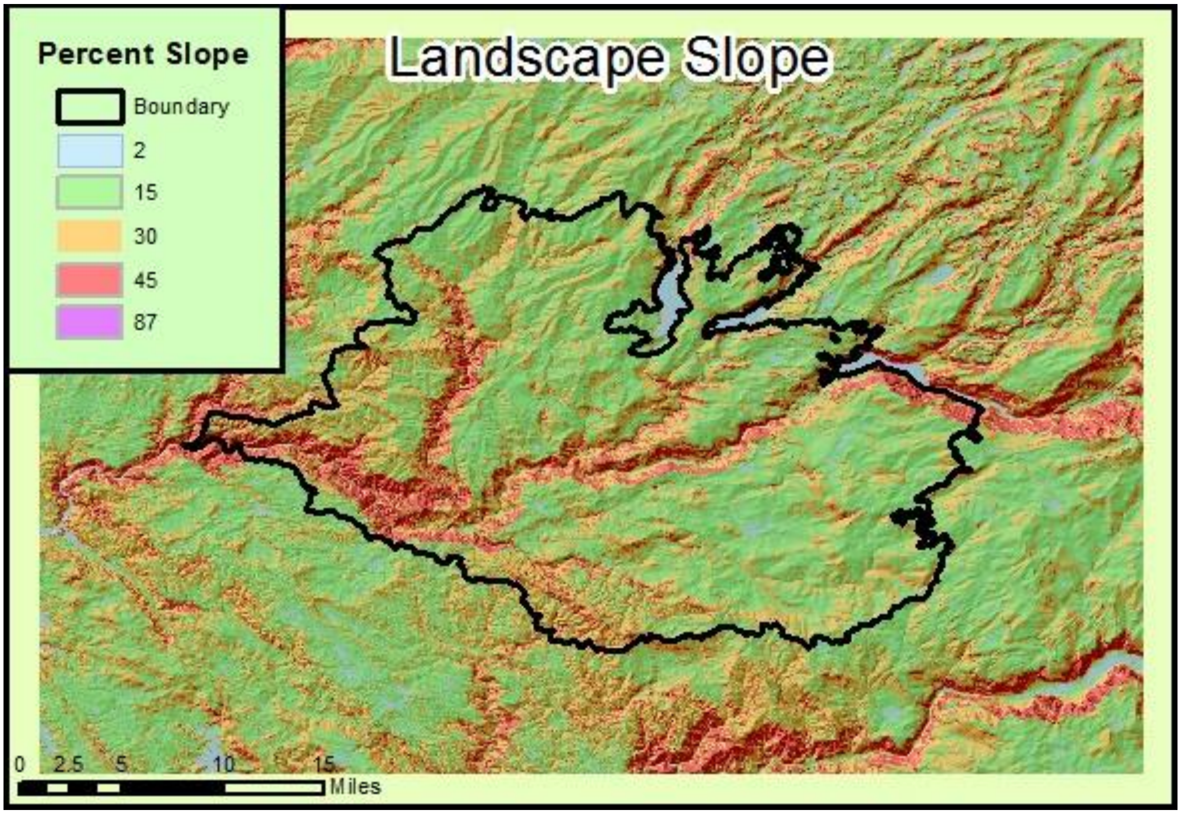

Figure 4: Slope percents of the landscape.

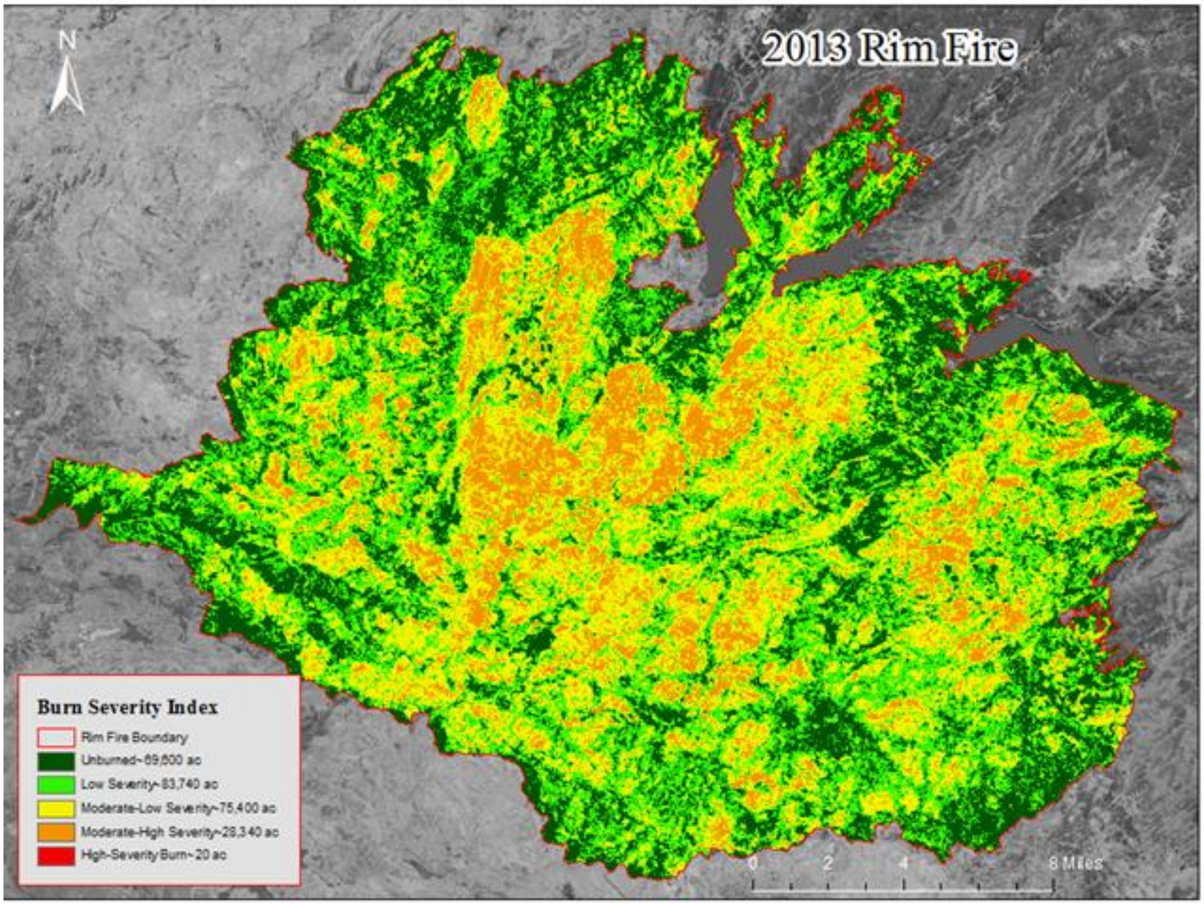

Figure 5: Fire Burn Severity.

Table 1: Land area classified by Burn Severity

Burn Severity Index	Pixel Count	Acres
Unburned	**313,198**	**69,653**
Low Severity	**376,554**	**83,743**
Moderate-Low Severity	**339,096**	**75,413**
Moderate-High Severity	**127,449**	**28,343**
High Severity	**93**	**20**
Total Acreage within burn perimeter		**257,174**
Amount of acreage burned		**187,521**

Severity of burn expressed as (%)		**72.92%**

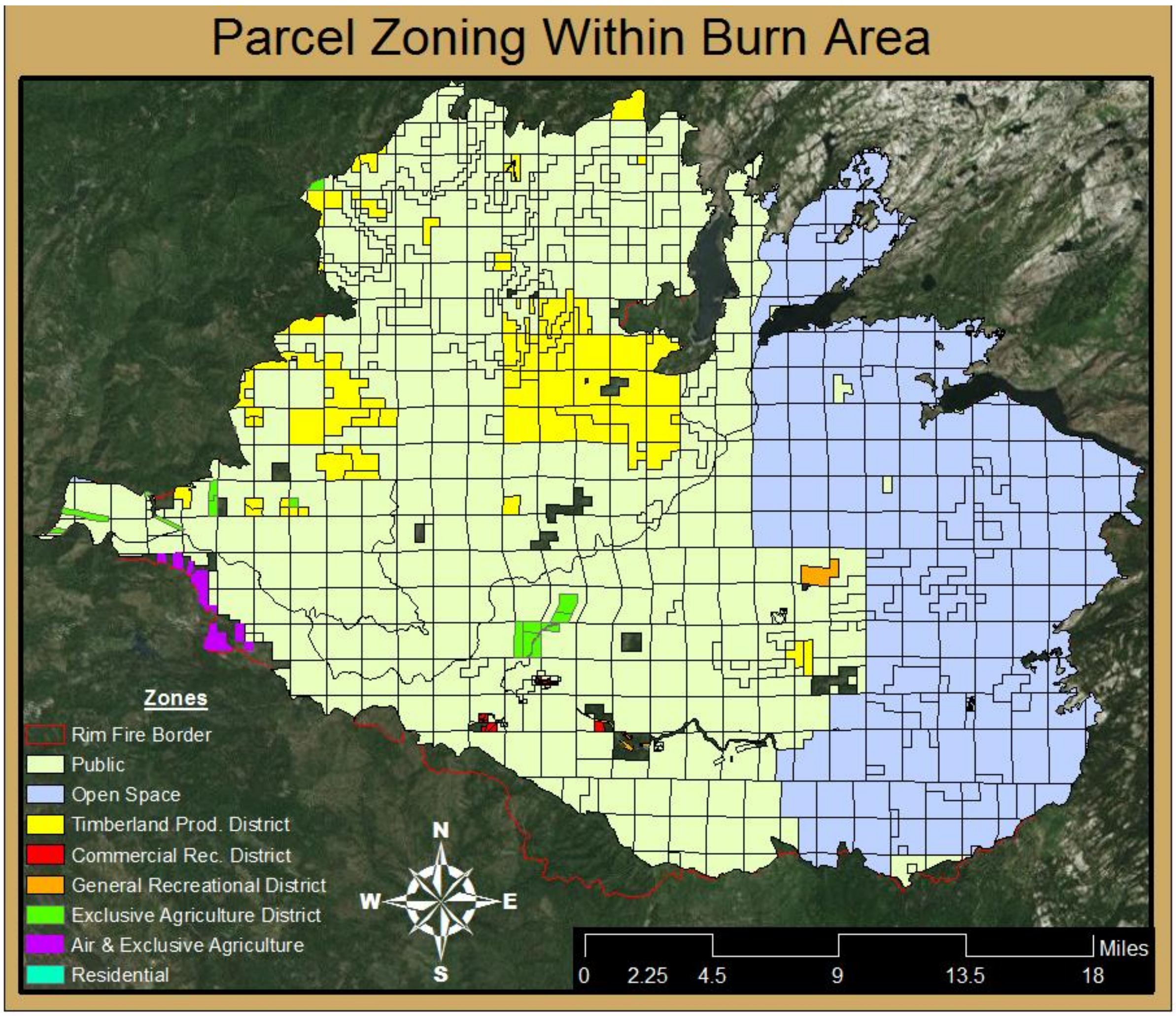

Figure 6: Parcel city zoning

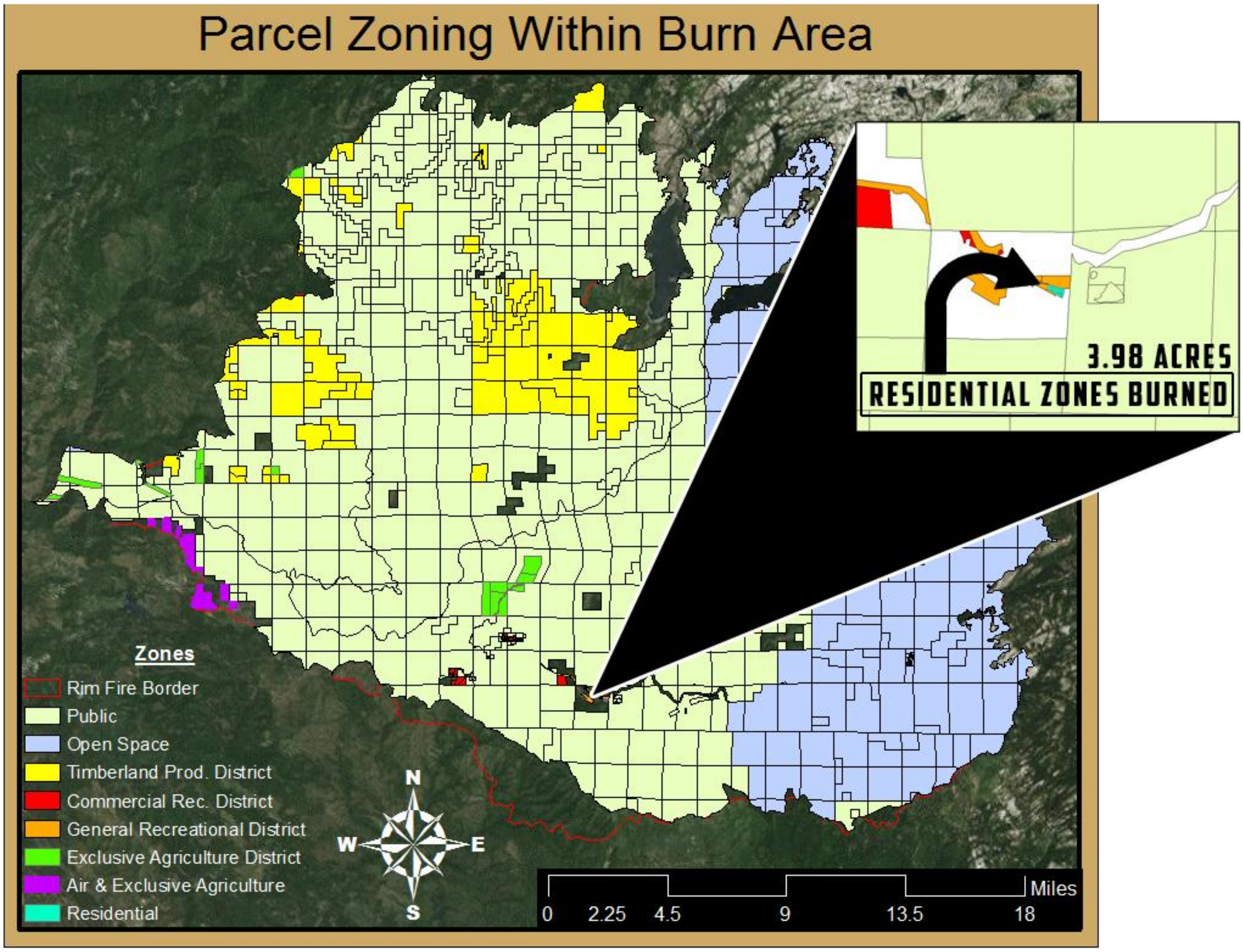

Figure 6: Parcel Residential zoning locater

Discussion

Our group was able to follow through with our initial goal of analyzing the severity of the 2013 Rim fire in a straightforward fashion. Data collection, manipulation, and analysis happened in a sequence that allowed for timely completion of tasks and ultimately achieving our goal. After determining the necessary shapefiles and rasters that we would need to proceed, we then located databases where this data could be easily accessed and acquired. These datasets included landsat images, boundary shapefiles, DEMs, and parcel and zoning shapefiles.We were able to successfully develop a burn severity map using the normalized burn ratio equations and analyze this, just as our original plan indicated. We used geotiff landsat images to achieve this analysis, but we had originally wanted to used NAIP images to developed a NDVI map to supplement the NBR. We were unable to located NAIP's in an effective manner, as the files were much to small, and dozens would need to be mosaiced together to analyze properly because the region of interest was so large in scale. Another issue our group ran into was acquiring LiDAR data about standing vegetation. Any LiDAR dataset that was acquired was missing key components of the attribute tables to encourage purchasing of the complete data. The landsat, boundary, zoning and parcel datasets were straightforward to obtain and manipulate. Working on google drive was helpful to coordinated group work, it was unfortunate that such an application for ArcMap does not yet exist to facilitate shared projects such as this.

Conclusion

Large scale fires like this one pose an enormous threat to the economic stability and public health of our state. This fire caused disastrous consequences to highly populated california regions and cost the state a tremendous amount of revenue. New methods of fire management are needed in order to prevent a large scale disaster such as this, in the future.

With the further understanding of how fires like this affect the landscape, we now can devise improved methods to manage the fire before it becomes out of hand. With **Figures 2 & 3** which we created, we can now see how fire travels amongst a landscape. It is easy to see that the fire spreads up slope to higher elevation, and burns hotter with drier fuel at high elevation. **Figure 5** shows us that the most intense burn severity is present at these exact regions. The fire stays lit in the areas away from low elevation and in pine fir forest that consists of easily burned material. **Figure 4** shows us how the fire affects different types of land, how the fire cannot burn as hot in areas such as watershed land or deforested areas.

Educating the public on how to manage our landscape to prevent fire damage is the primary goal of this project. With this understanding about fire behaviour, we can now estimate how a future fire will spread and therefore prevent it. Thus, creating better methods of fire management and prevention. These new methods could include prescribed burning in high risk areas or mandatory maintenance among dry forest.

Acknowledgements

Sara Hanna

Buddhika Madurapperuma

James Graham

Dr. Amy Rock

Dr. David Gwenzi

Bibliography

Works Cited

California, State Of. "California Statewide Fire Map." *Rim Fire General Information*. Cal Fire, n.d. Web. 27 Apr. 2017.

" Geospatial Multi-Agency Coordination." *GeoMAC Wildfire Application*. US Department of Agriculture, n.d. Web. 27 Apr. 2017.

The National Map. U.S. Geological Survey, n.d. Web. 27 Apr. 2017.

"The Rim Fire." *Sierra Nevada Conservancy*. State of California, 12 Apr. 2017. Web. 27 Apr. 2017. <http://www.sierranevada.ca.gov/our-region/rim-fire>.

Survey, USGS - U.S. Geological. *EarthExplorer*. N.p., n.d. Web. 27 Apr. 2017.

Garcia, Veronica. "Rim Fire." *InciWeb*. Incident Information System, 25 Oct. 2013. Web. 28 Apr. 2017. <https://inciweb.nwcg.gov/incident/3660/>.

"Watershed and Environmental Improvement Program 2013 Annual Report." San Francisco Public Utilities Commission, 11 Dec. 2013. Web. 20 Apr. 2017. <http://sfwater.org/index.aspx>.

"California Historic Vegetation " United States Department of Agriculture Forest Service

Web. 10 Aug. 2010. <https://www.fs.usda.gov/detail/r5/landmanagement/resourcemanagement>