Factors Contributing to Burn Severity in the Carr Fire

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Abstract:

It is clear that fire is a destructive force in California as well as the rest of the country, causing significant amounts of damage and even claiming lives, but lately the severity of these fires has begun to increase. ArcMap was used to determine what factors were key contributors to fire severity in the in the recent Carr Fire near Redding, California. Burn severity by land cover type within an area which experienced a fire tornado was also compared with the severity of the rest of the fire to analyze what was unique about this area. In assessing the accuracy of existing assumptions about fire severity in this particular event, we found there was only a small correlation between fire danger zones and areas that actually experienced severe burning, which may be a result of the fact that the severity of the Carr Fire created its own weather (Petras, 2018).

Introduction:

The Carr fire, in addition to burning over 190,000 acres of land, produced dramatic and devastating fire patterns such as a fire tornado in the community of Keswick. Since there was a fire tornado in this area, scientists are presented with an uncommon opportunity to study the effects of this relatively rare phenomenon, and a fire tornado of this size could present a wealth of interesting data. For this reason, the footprint of the Carr fire is focus of this project. Through remote sensing, and geospatial analysis, the goal of this project has been to make determinations about the factors that contributed to this fire compared to the area of the fire tornado specifically. The analysis examined the footprint of the fire in relation to bodies of water, urban areas and land cover type that help to determine the severity of a fire. Our analysis has focused on the areas that have been most damaged by fire to determine which, if any, surrounding factors contributed to the destruction in the area.

Decades of fire prevention have led to an abundance of fuel, which makes the forest abnormally flammable and creates fires that are significantly more destructive than they would be naturally (Johnson, 2003). This pattern has been continuing for a long time. In fact: in the 21-year period from 1945 to 1966, 64% of all fires on federally owned forests were caused by lightning and 36% were caused by man or had unknown causes. Thus for 21 years the fire rate was one per 38,287 acres per year. This comes out to just over 8,000 fires annually (Komarek, 1967). Now that fire has been suppressed and fuel has accumulated, 73,000 fires burn annually destroying 7 million acres of national land (USFS, 2018). This clearly illustrates that when fire was occurring naturally, there were fewer occurrences that were less intense and damaging, but humans have developed more fear than understanding regarding this topic and their fire suppression techniques have simply been leading to more fire in recent years.

This research begins to determine which factors contributed to the most damage in the Carr fire. The main focus of the analysis has been on land cover types as well as topographic factors that contributed most to fire severity. Topography is one of the most influential factors in affecting the way a fire behaves. South and south-western facing slopes typically have more sun exposure and as such will dry out much faster than north facing ones. Slope is also important in determining how quickly a fire can move up or down slopes, because a fire ignited at the bottom of a steep hill is likely to spread very quickly as it dries out nearby fuels with rising heat (USNP, 2017). Fire spread rates on slopes greater than 20 degrees can be more than 4 times the rate on flat terrain and wind typically travels uphill, adding to this effect (Lecina, 2014).

Methods:

A DEM for the Whiskeytown and Keswick area was acquired from OpenTopography.org. With that DEM, slope and aspect rasters were created to determine the slope and angle of each hill. Then, raster math was used to find the locations that are topographically fire prone due to having over a 20 degree slope and facing either south or south-west. The raster calculator was used to create these layers, which were multiplied together to find areas with both the appropriate slopes and aspects. A shapefile representing the boundary of the fire was then overlaid onto the DEM. This was acquired from the ESRI website. A layer containing rivers was taken from the California State GIS portal, and National Land Cover Database data was acquired from Earth Explorer, then clipped down to the extent of the fire perimeter. Land cover types were also reclassified down to four relevant categories being water, shrub, forest, and developed lands. The area in which the fire tornado occurred was digitized using google earth and field observations made during a trip in which fire experts with the Forest Service described some of the destructive effects of the fire tornado.

In order to create a Normalized Burn Ratio (NBR) map we used the raster calculator in ENVI. The NBR was performed by using the following equation on a post fire as well as a pre fire image gathered from USGS Earth Explorer: (Band 5- Band 7)/(Band 5+Band 7). Then, in order to determine the change in the two images, we subtracted the post fire image from the pre fire image. Lastly, a zonal histogram was created using the output created by the NBR in ENVI. A separate zonal histogram was also created for the area of the fire tornado for comparison to the rest of the fire. This data will enable us to see expected fire danger zones compared to the areas that actually had high severity burning. This allows us to assess the accuracy of a fire severity prediction model based on south facing and steep aspects in this particular fire.

Results

Figures 1 and 2 are both zonal histograms showing burn severity by land cover type. Figure 1 is the entire Carr fire area and figure 2 is focused on the fire tornado. These data were generated from the NBR which can be seen in figure 5. The NBR map was also used for comparison with our projected fire danger zones in figure 4 to assess accuracy. The results of this comparison are seen in figure 3.

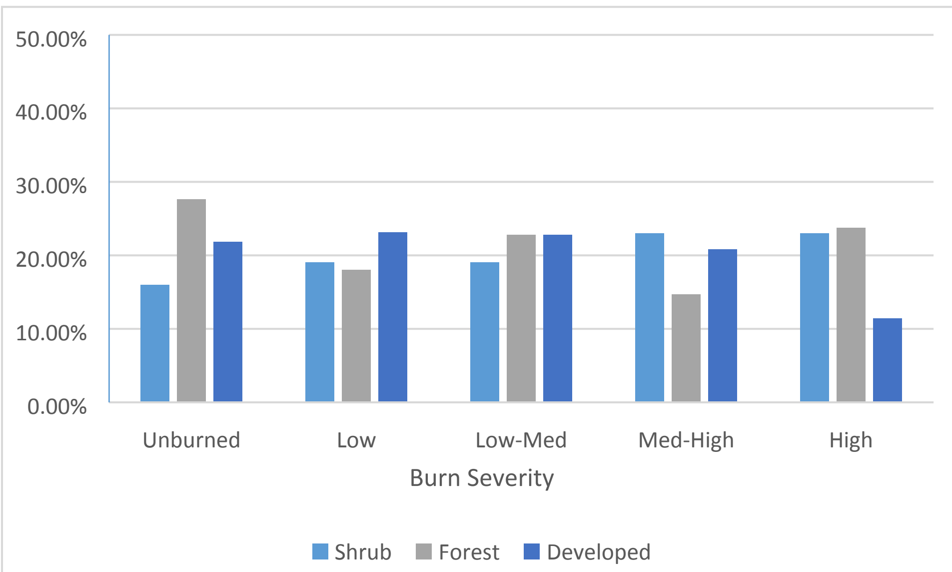

Figure 1. Burn severity by land cover type for the Carr Fire

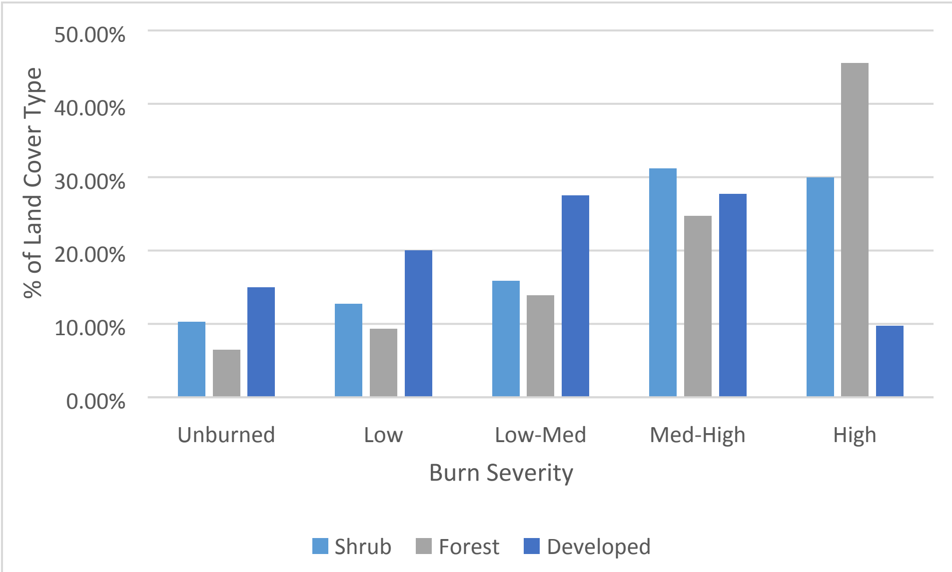

Figure 2. Burn severity by land cover type for the area of the fire tornado specifically

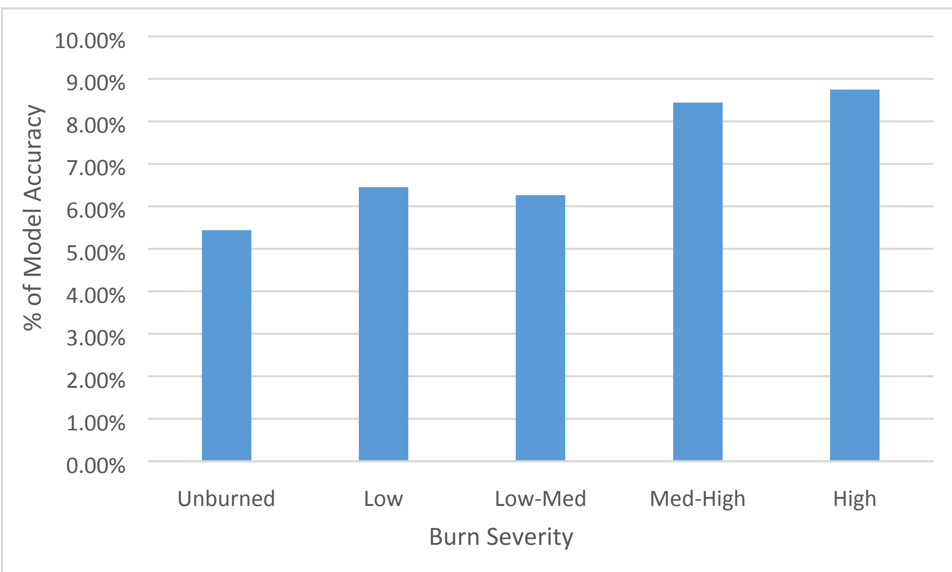

Figure 3. Accuracy of severity prediction model

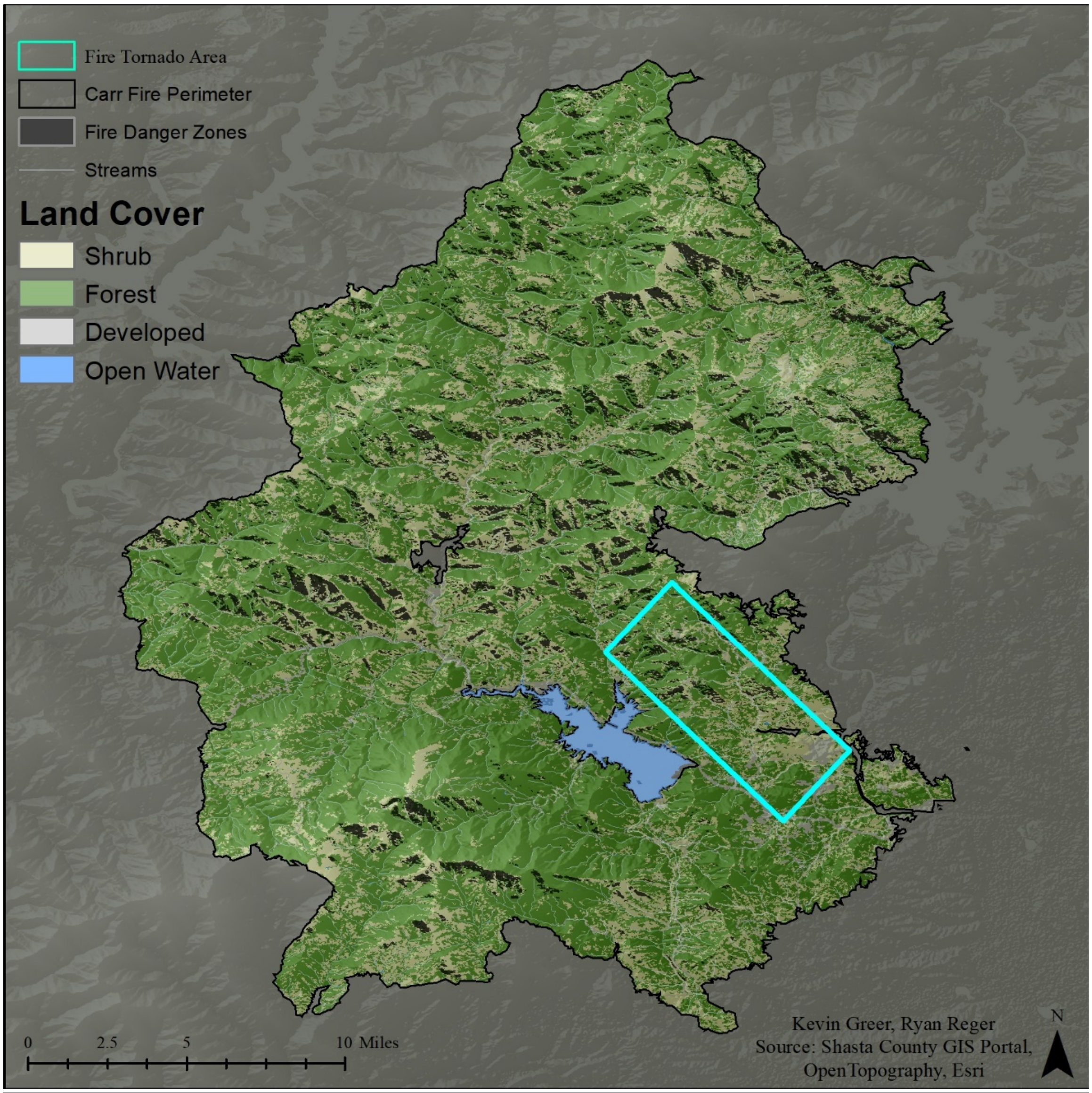

Figure 4. Map showing Fire Danger Zones within the Carr Fire perimeter

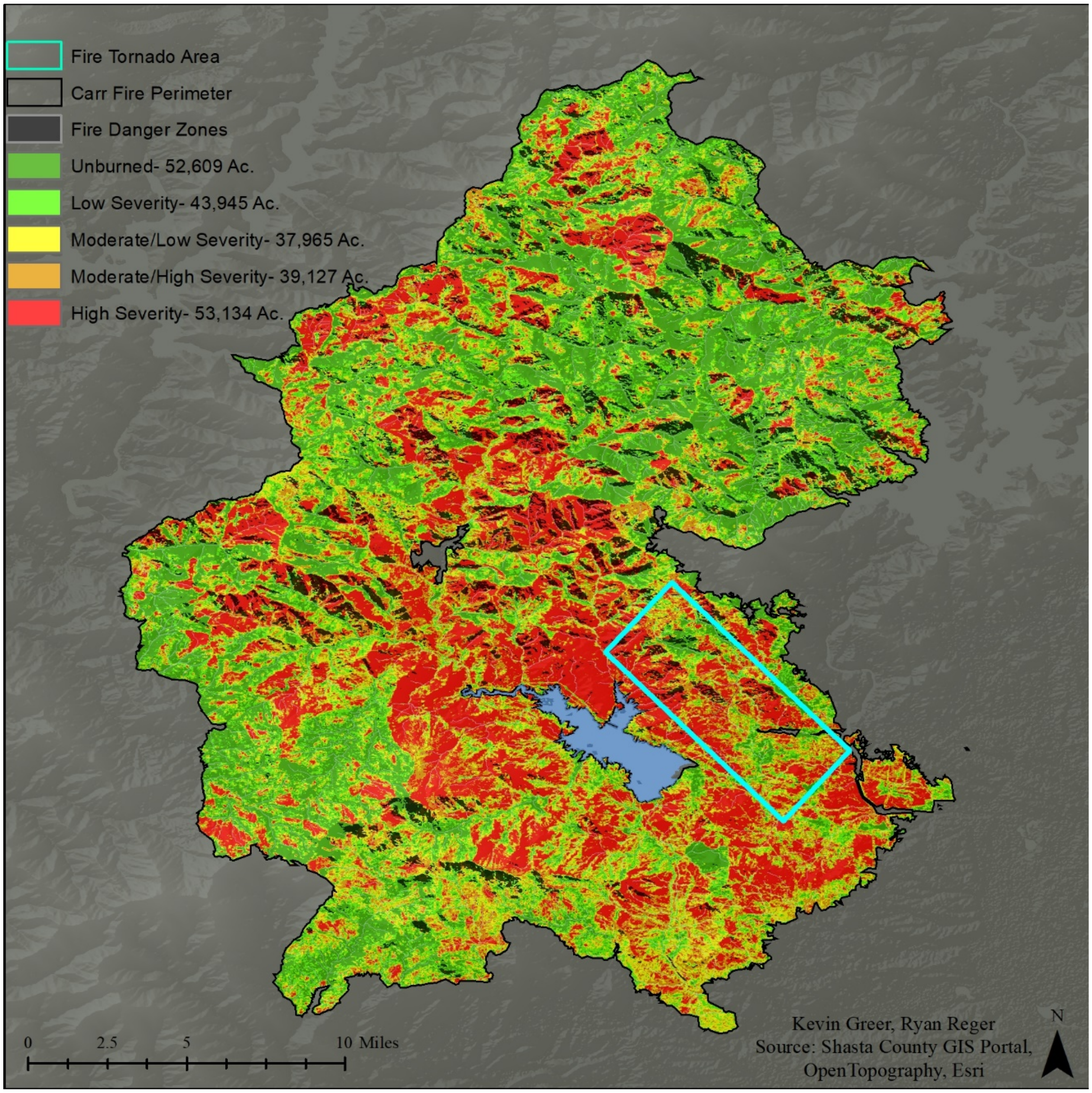

Figure 5. Normalized burn ratio map showing burn severity.

Conclusion:

In analyzing the results of these data, one of the most striking differences is visible in comparing figure 1 with figure 2. It is clear that forest and shrub fuels contributed more to high severity burning in the fire tornado area than they did in the rest of the Carr Fire, with roughly twice as much forest fuel. There was also more developed area in low-medium severity and medium-high severity areas here compared with the rest of the Carr Fire; and while there was less development in the high severity burn areas, it is worth noting that what development was present was almost entirely wiped out by the intensity of the fire tornado. These data suggest that more research on fire tornados in relation to land cover types may point to the broader hypothesis that generations of excessive fire prevention and inadvertent mismanagement may contribute to the frequency of fire tornados (Johnson, 2003).

Figure 3 shows some correlation between fire danger zones and areas that actually burned, especially in high severity burn areas. The relatively small correlation likely results from the fact that the the Carr Fire created its own volatile weather due to intense underlying climactic conditions such as drought, over 100 degree weather, and rapidly shifting winds. Rising heat from intense fire can form pyro-cumulus clouds which can increase risk of lightning and create strong down currents rendering some assumptions about fire behavior somewhat irrelevant and making predictions very difficult. These strong down currents also help to create unpredictable conditions such as fire tornados (Petras, 2018). This research suggests that fire prediction models within over forested areas must be refined and adapt to these unpredictable conditions brought on by an overabundance of fuel and a rapidly changing climate.

Works Cited:

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