Assessing the impacts of two stand-replacing wildfires on canopy cover and soil conditions in Bastrop County, TX

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GEO386G Final Project

Purpose and Introduction:

In the falls of 2011 and 2015, two stand-replacing wildfires swept through Bastrop County Texas, burning much of the "Lost Pines" ecoregion as well as the surrounding forest (figure 1). Together, the fires covered nearly 150 km^2 and severely impacted the ecosystem as a whole. Fires can have varying effects on forest ecosystems. In addition to the removal of biomass in the form of trees and shrubs, organic matter on the forest floor is volatilized. This can remove necessary nutrients from soil communities as well as increase soil temperatures and evaporation rates from the soil, further slowing down regeneration post-wildfire.

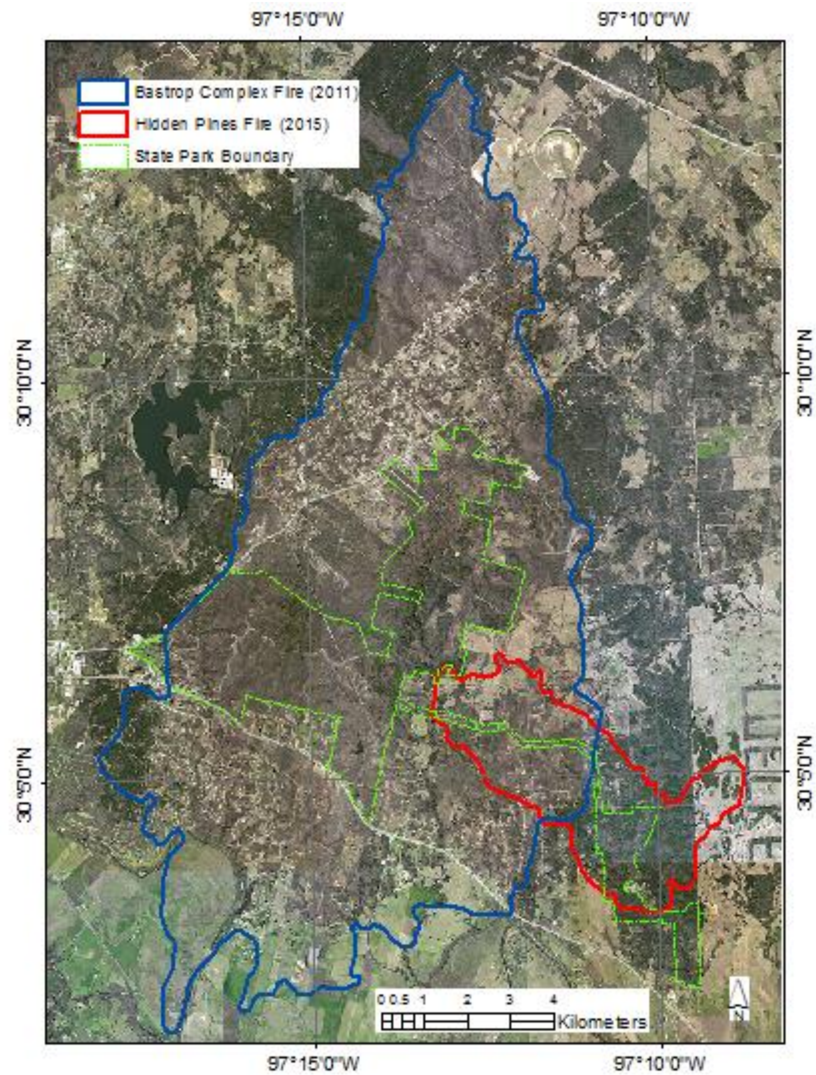

Figure 1: Outlines of the Bastrop Complex and Hidden Pines Fires

From data collected and analyzed over the past 9 months, it is clear that the burns are having lasting impacts on the soil ecosystems in the impacted areas, with dramatically spiking summer soil temperatures and sinking soil moisture contents. While it has been possible to make interpretations using this data about the general impact of wildfires on soil productivity, the scope of my overall thesis is limited due to the size of the burn areas and the time I can spend sampling. Using GIS, however, it is possible to extrapolate the data already collected to burned areas that have thus far been inaccessible due to my limitations. This project will attempt to combine spatial data downloaded from the internet, environmental data collected in the field and a few assumptions to infer the impact of the 2011 and 2015 wildfires on soil conditions during the summer of 2016.

These goals will be accomplished in three steps. First, the impact of the two fires on forest canopy coverage will be assessed and quantified by determining the total forested area before and after each fire and creating a forest coverage gradient which will show how much tree coverage the soils have. Second, under the assumption that canopy coverage is the most important factor influencing soil temperature and moisture content post fire, the previous data will be combined with collected data to estimate the impact on soil temperature and moisture. Third, using data downloaded from the USDA, moisture contents will be used combined with information about the permanent wilting points of different soil types in the region to determine the impact the fires have on plant growth throughout the burn areas.

Data collection:

Soil data were downloaded directly from the NRCS Web Soil Survey website, where they have polygon files as well as dozens of attribute tables with data associated with the soil types in the shape file. For the purpose of this project, only the table with "physical characteristics" was used.

http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx

The ArcGIS website has several layer packages that I used for this project. By searching for Bastrop Fire on their website, I was able to obtain published files of the fire outlines and canopy cover from before and after each fire.

http://www.argis.com

State park boundary data was downloaded directly from the Texas Parks and Wildlife Department website.

https://tpwd.texas.gov/gis/data

Base map imagery was downloaded from the Texas Natural Resources Information System website.

https://tnris.org/data-download

Unless otherwise noted, all data was originally in NAD83 datum. Any other data was originally in WGS84, which in Texas is identical. For the purpose of projection, any data in WGS84 was converted to NAD83.

Data preprocessing:

Soil polygon:

The soil polygon file downloaded from the USDA NRCS website was in the WGS 1984 spatial reference (Figure 2), so once it was added to a project in UTM zone 14N, it was exported with the spatial reference of the data frame (Figure 3).

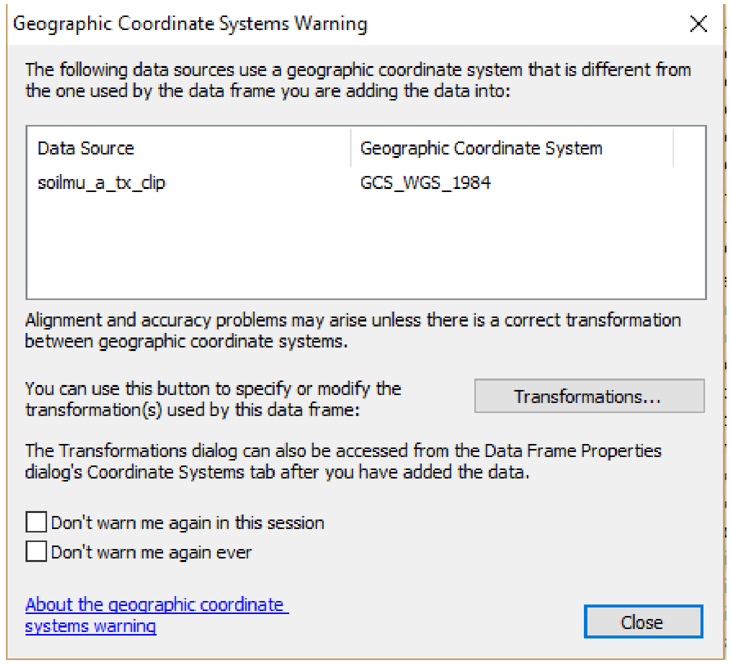

Figure 2: The soil file was originally in the wrong GCS

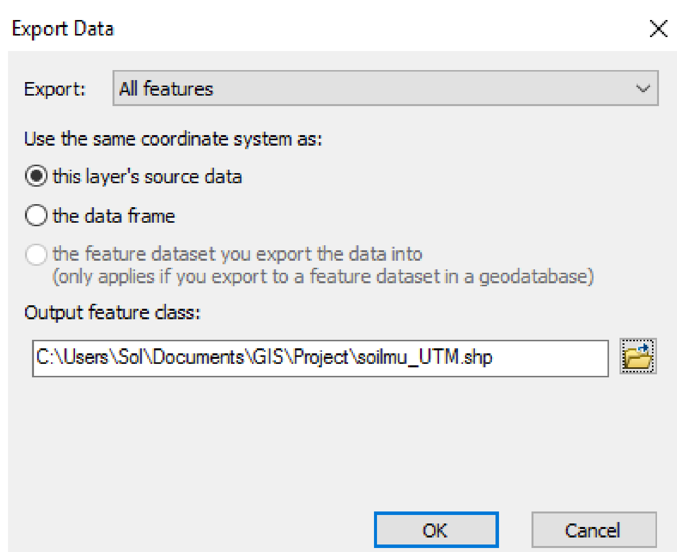

Figure 3: The soil file was exported with the same spatial reference as the data frame

The new file then needed to be clipped to the map area because the original file covered the entirety of Bastrop County (Figure 4).

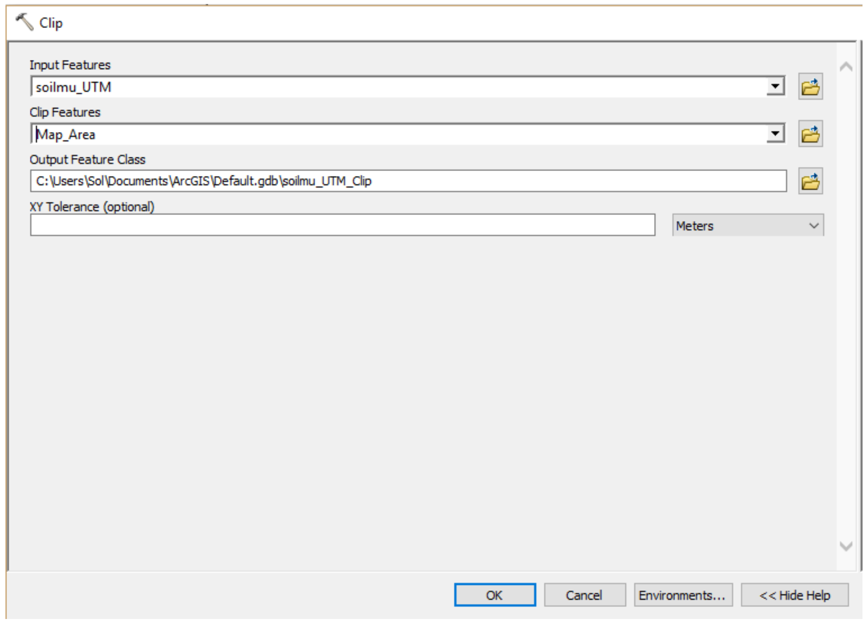

Figure 4: Clipping my new soil shapefile to the map area

I then joined the “physical properties” attribute table to the soil polygon (figure 5). The field used was “musym” which refers to the shortened name for each soil type, fields that were in each file.

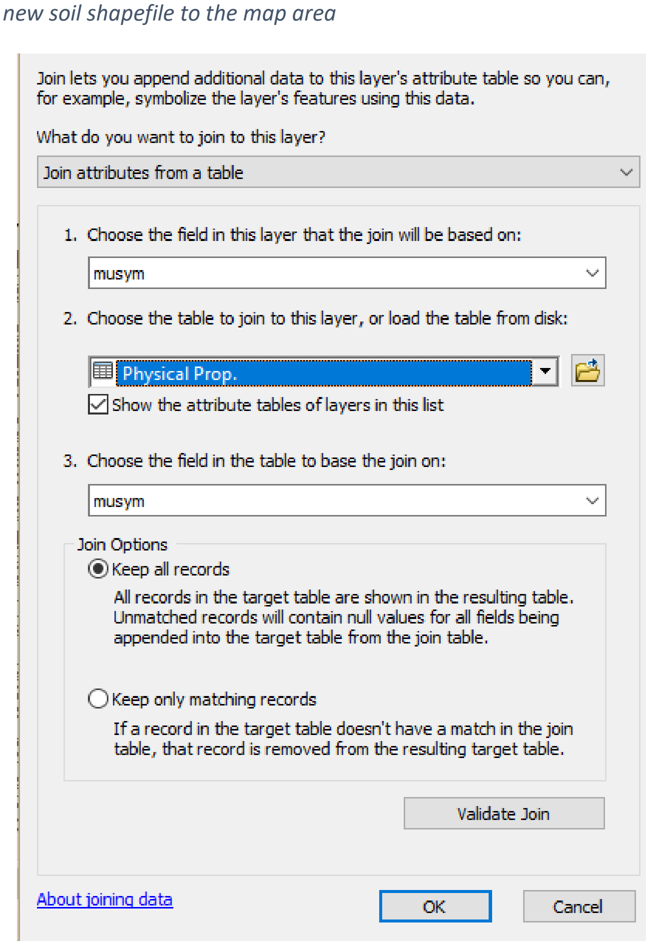

Figure 5: Joining the "Physical properties" attribute table to my clipped soil shapefile using the field "musym."

Since ultimately I want to be able to use this for spatial analysis using raster algebra, I created two rasters out of this polygon. The first used the field "permanent wilting point" to create a raster with values of the moisture content required for each soil type to sustain plant life (figure 6). The second used the field "percent sand" which created a raster with gradients based on the sand content of each soil type. I then reclassified this raster so that all soils with sand contents higher than 60% had a value of 1 and all soils with a sand content less than 60% had a value of zero (example of reclassification in figure 8). I did this because the soils that I sampled moisture content in had sand contents ~60% and I can assume that all soils with a higher sand content will have lower water retention during the summer. For all rasters that I created, I used a cell size of 5 x 5 meters so I could perform raster calculations and chose the cell center as the assignment type.

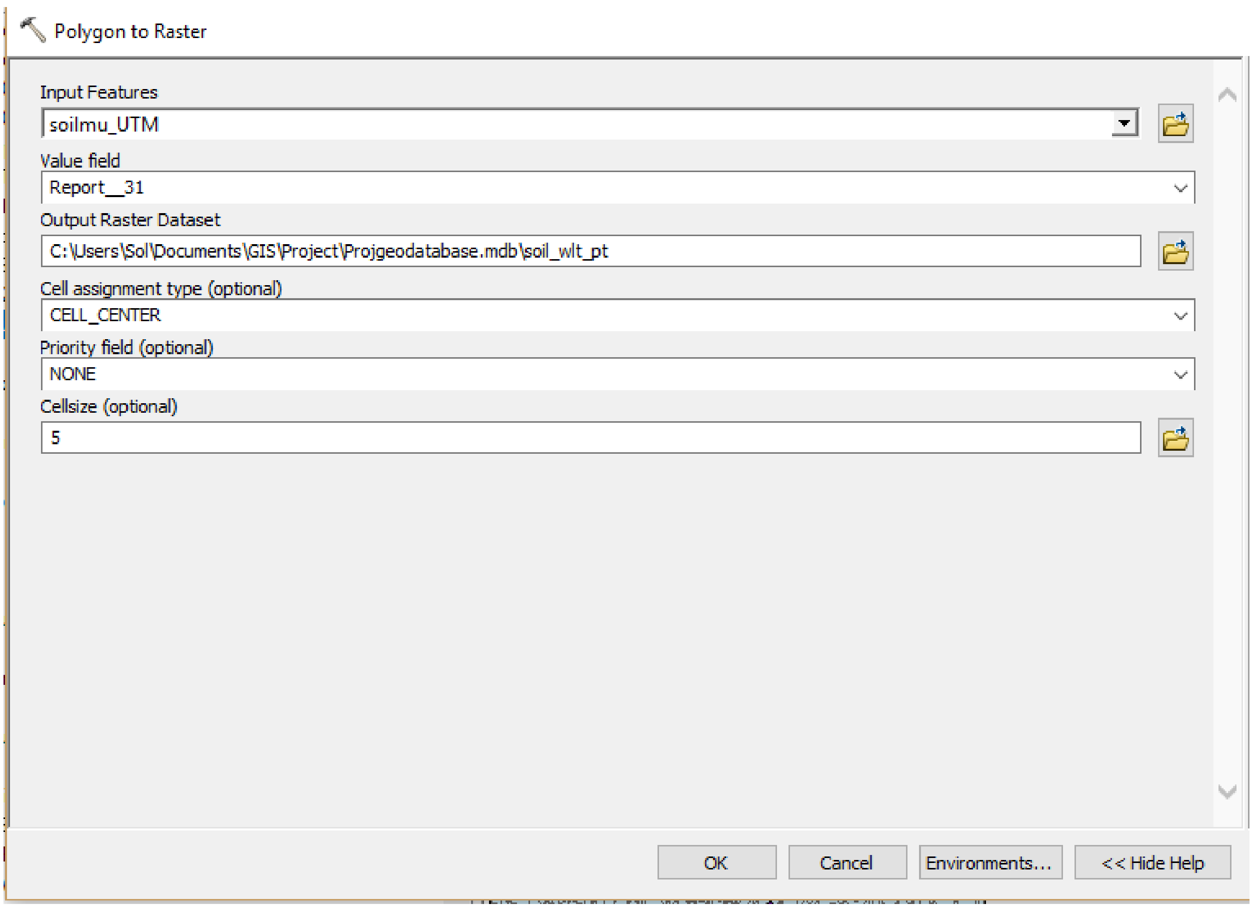

Figure 6: Converting the soil polygon to a raster based on the field "permanent wilting point" which in this table was labeled "Report_31."

Canopy coverage rasters:

Unfortunately, the canopy coverage rasters I downloaded could not be analyzed, only viewed, so I had to convert them into another raster that was usable. For my purposes, the easiest way to do this was to convert them into a .tiff by taking a screenshot and then georeferencing the image. I then converted the image rasters to float point files using "Raster to Float" conversion and converted the float point files back to a raster using "Float to Raster" conversion. Because the original file had only one color (for the green that signified canopy cover), all pixels that had tree coverage had identical RGB values. I resampled all rasters using “Resample” in data management so they would have 5x5 m cells (figure 7) and then reclassified using “Reclassify” in spatial analyst tools to create a binary raster where 1=tree and 0 = no tree (figure 8).

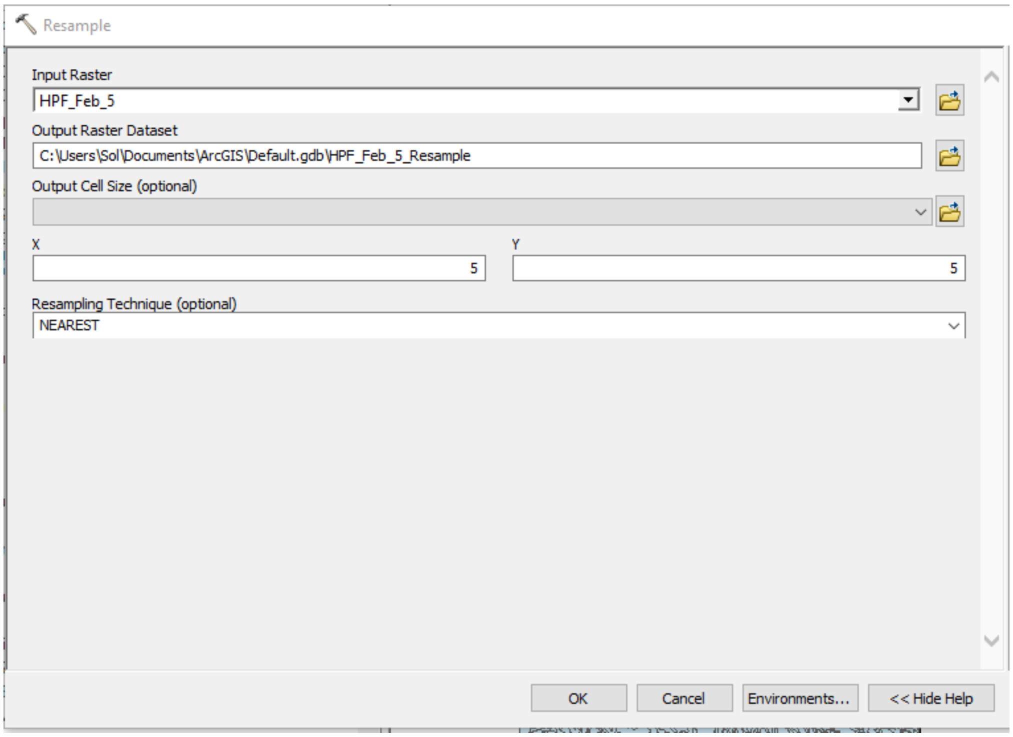

Figure 7:Resampling the new canopy coverage rasters so that all rasters had cell size of 5 x 5 meters

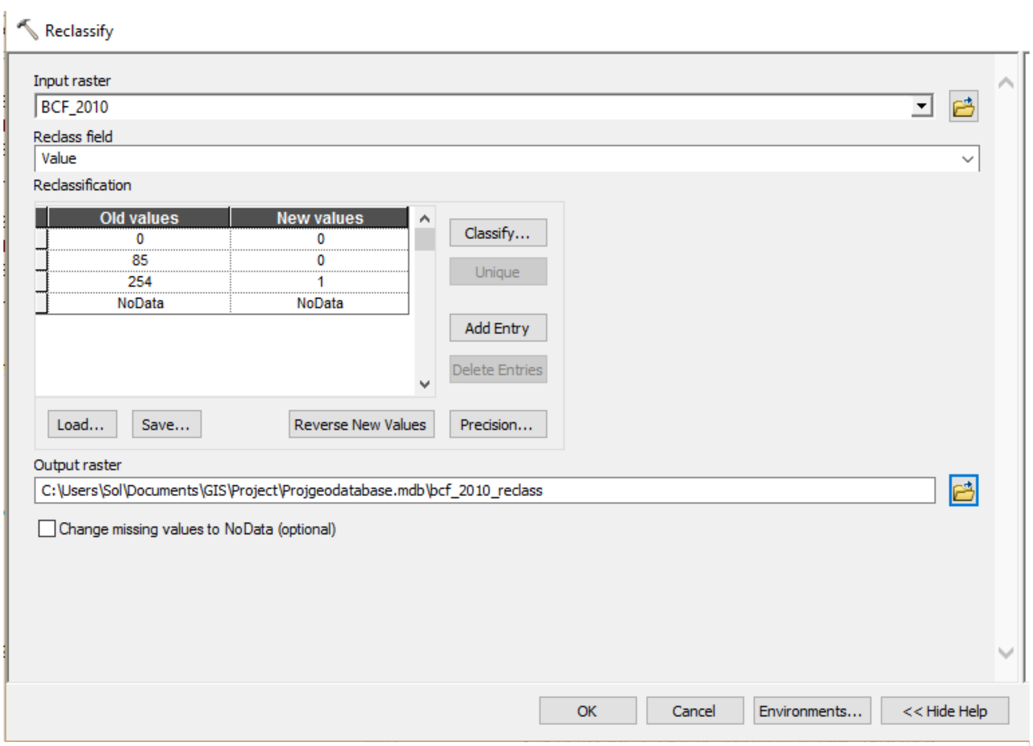

Figure 8: Reclassifying the canopy coverage raster into a binary raster

Data processing:

Canopy impact analysis:

Processing to determine the canopy change was very straightforward. First, I was able to create a new field in the attribute table called "Area" and use "Field Calculator" to determine the area of forested and unforested land before and after each fire. This was done by simply multiplying the "Count" field by 25 because I had previously set my cells to be 5x5 m (figure 9). I then created a figure using the base map from the TNRIS and the burn footprints and the canopy coverage layers from the ArcGIS website to show the canopy coverage before and after each fire (figures 10 and 11).

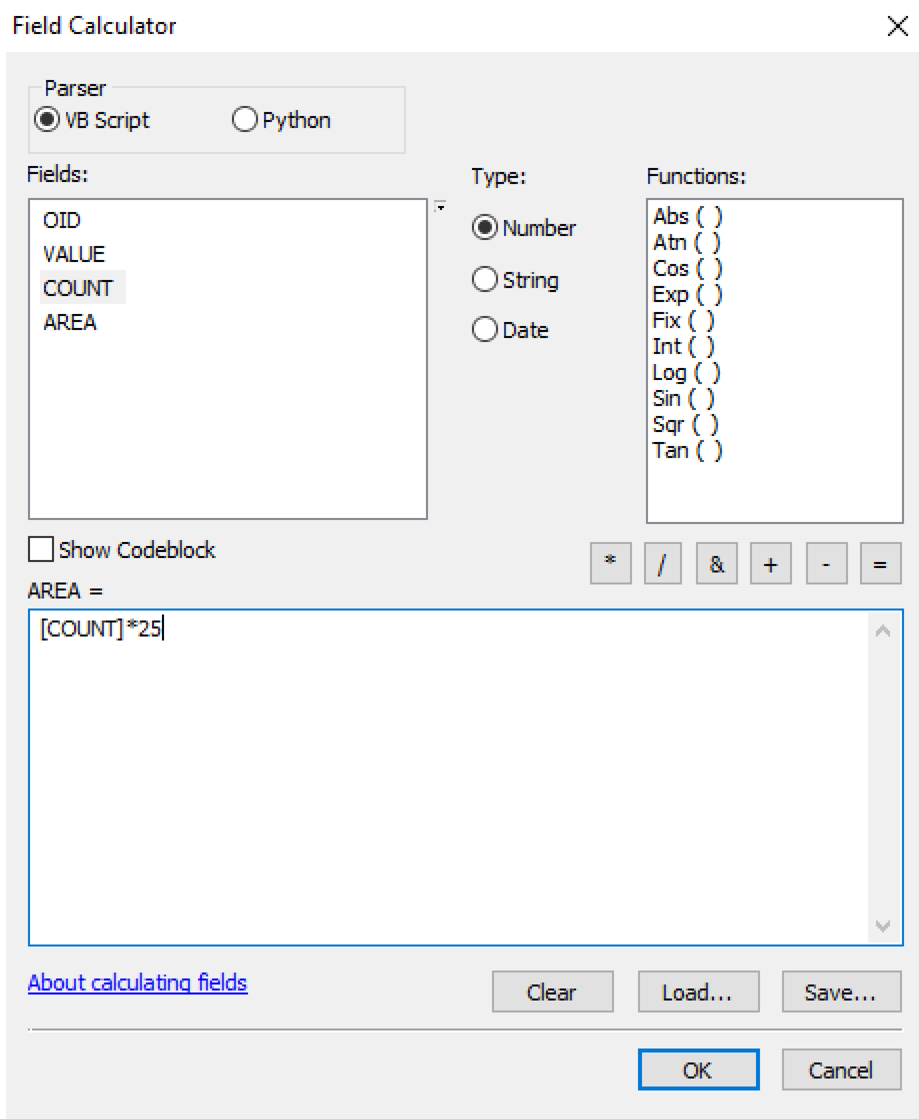

Figure 9: Creating a new field in canopy coverage rasters that calculates the area (in m^2) of forest coverage

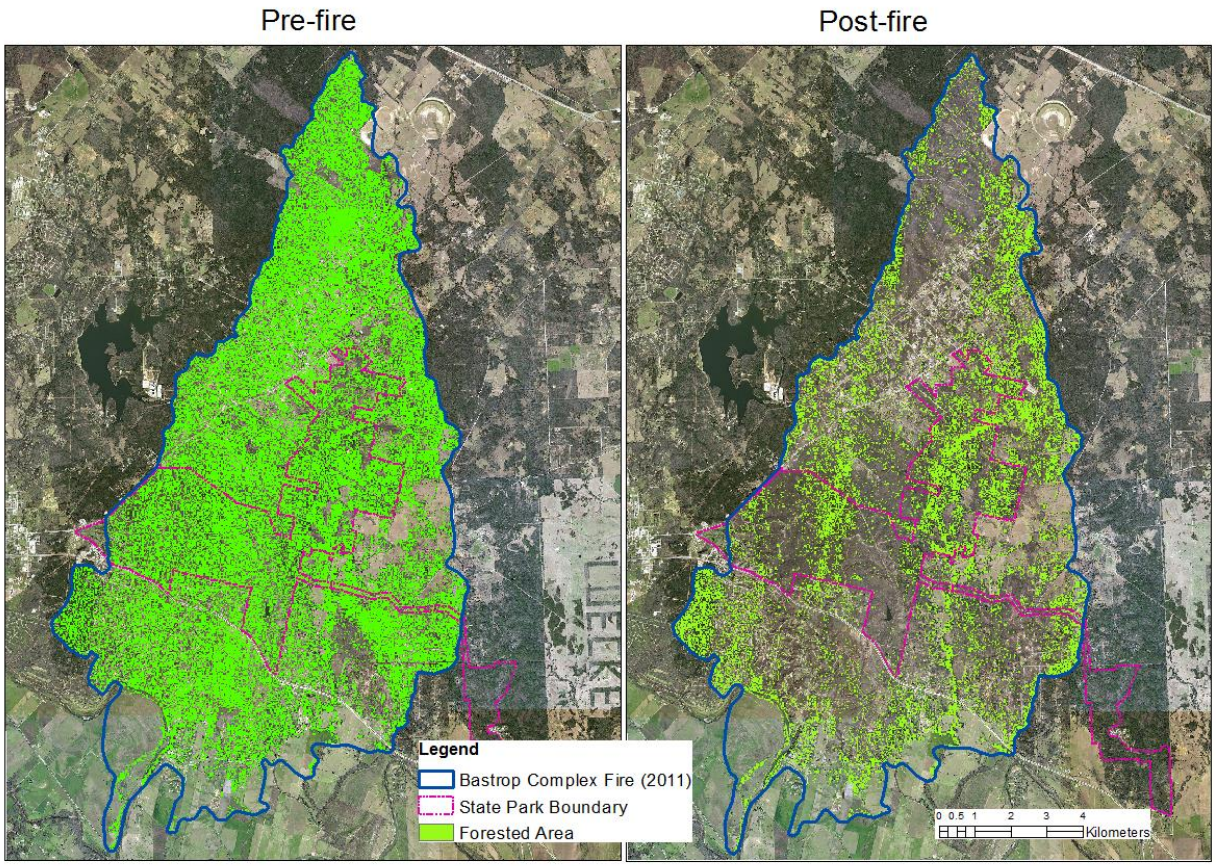

Figure 10: Canopy coverage maps before and after the Bastrop Complex Fire

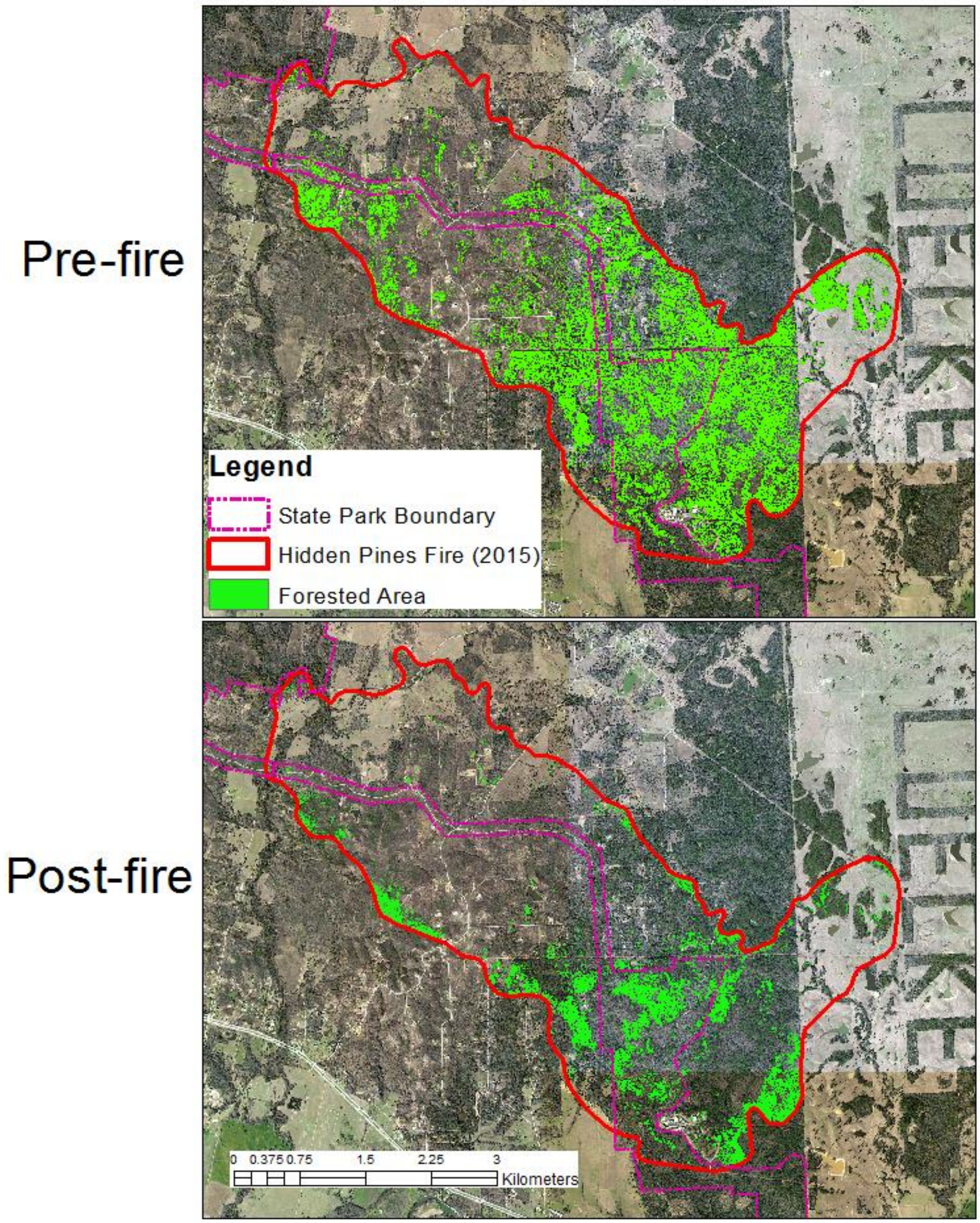

Figure 11: Forest canopy coverage before and after the Hidden Pines Fire

Soil impact analysis:

In order to determine the impact of the wildfires on the soil itself, it was important to analyze not just the canopy coverage itself, but the amount of shade that the canopy is providing the soil. As mentioned before, data suggests that during the summer and other dry seasons canopy coverage has the largest impact on soil temperatures and moisture content, but this is influenced by all the canopy around the soil, not just the trees directly above. It was possible to create a raster that provided this data using the "Focal Statistics" tool in neighborhood spatial analyst tools. I chose a somewhat arbitrary but likely liberal estimate for the horizontal distance away from each point where the canopy has an impact on soil shading. Using a 15 m radius I created a raster that shows the percentage of cells within a circle around a point that are forested (have a value of 1). The focal statistics tool calculates the mean of all the cells within that area and thus, one must simply multiple the new value by 100 to determine the % coverage (figure 12).

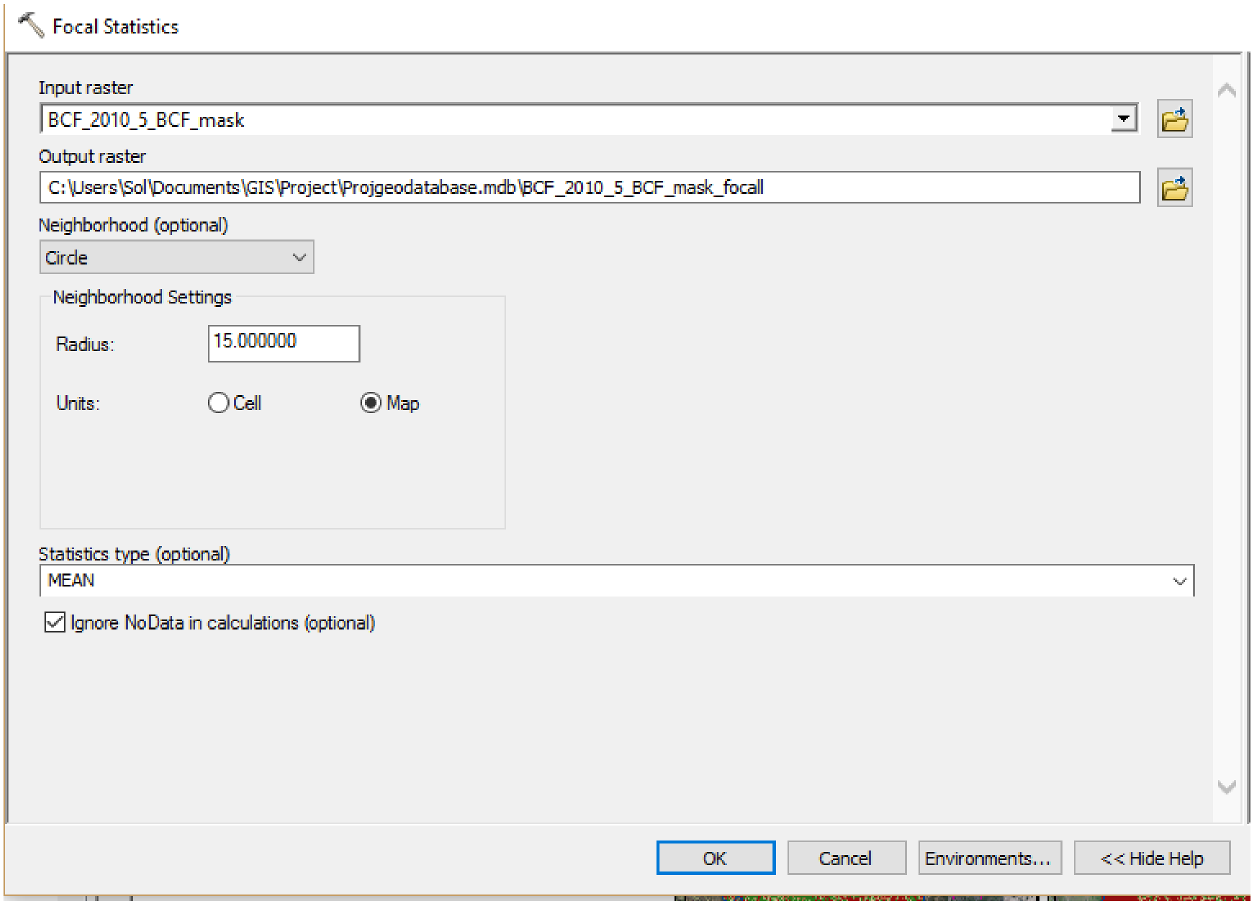

Figure 12: Creating a focal raster that determines the % shading of each 5 x 5 meter area of soil

I then made another arbitrary (but likely conservative) assumption that any area with <10% forest coverage will be impacted similarly to the data that I have collected (because the majority of my burned sites have <10% coverage). In order to use this, I reclassified the raster so that all cells with >10% forest coverage have a value of 0 and all cells with <10% forest coverage have a value of 1 (example of reclassification in figure 8). This way I could apply my data to the areas of each burn that have <10% forest coverage. I first did this with temperature, applying my data for each burn area to the pixels that had <10% forest coverage (figure 13).

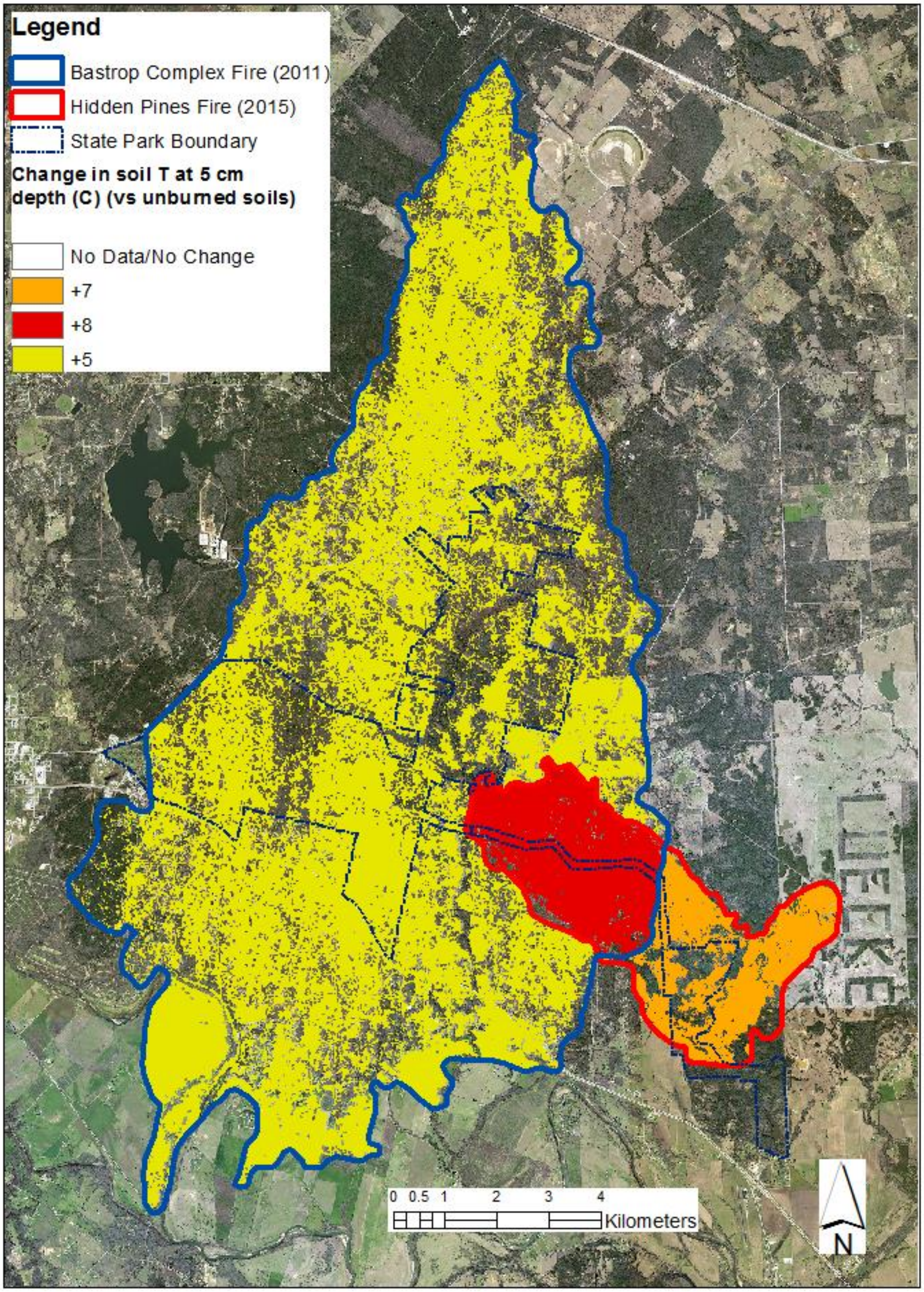

Figure 13: Map of the average soil temperature rise during July of 2016 at a depth of 5 cm

To determine the impact on soil moisture, I used the same binary raster with values of 1 for areas with <10% coverage, but because soil moisture is highly dependent on soil type, I only included soils that have >60% sand because, as I stated earlier, my samples had ~60% sand and one can assume that anything with a higher sand content will have lower water retention, so this is a conservative estimate. For this, I used "Raster Calculator" to create new rasters for each fire where I had both <10% forest coverage and >60% sand (figure 14). I then took all the moisture data I had, determined an upper bound

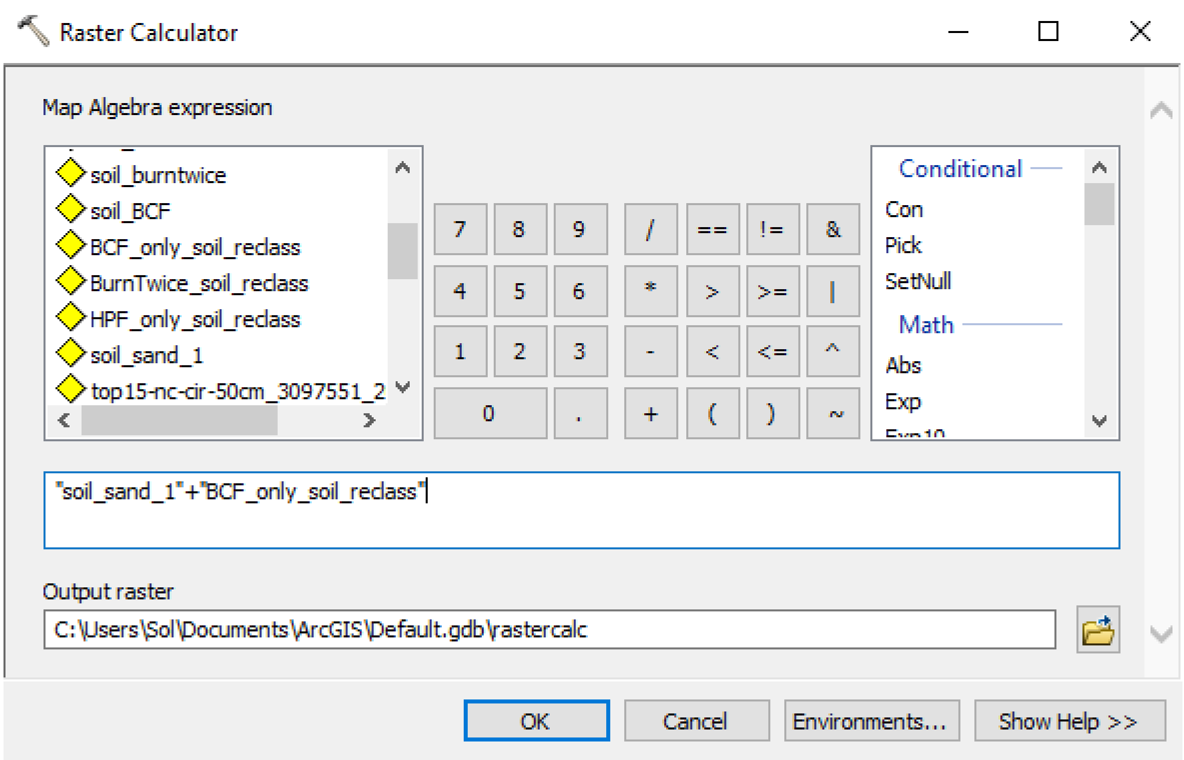

Figure 14: Raster calculator expression adding together rasters of sand content with rasters of % canopy coverage. If new rasters returned certain values (for >60% sand and <10% canopy coverage), they would be symbolized for the map

for a 95% confidence interval and applied that number as the likely upper limit for moisture content (figure 15).

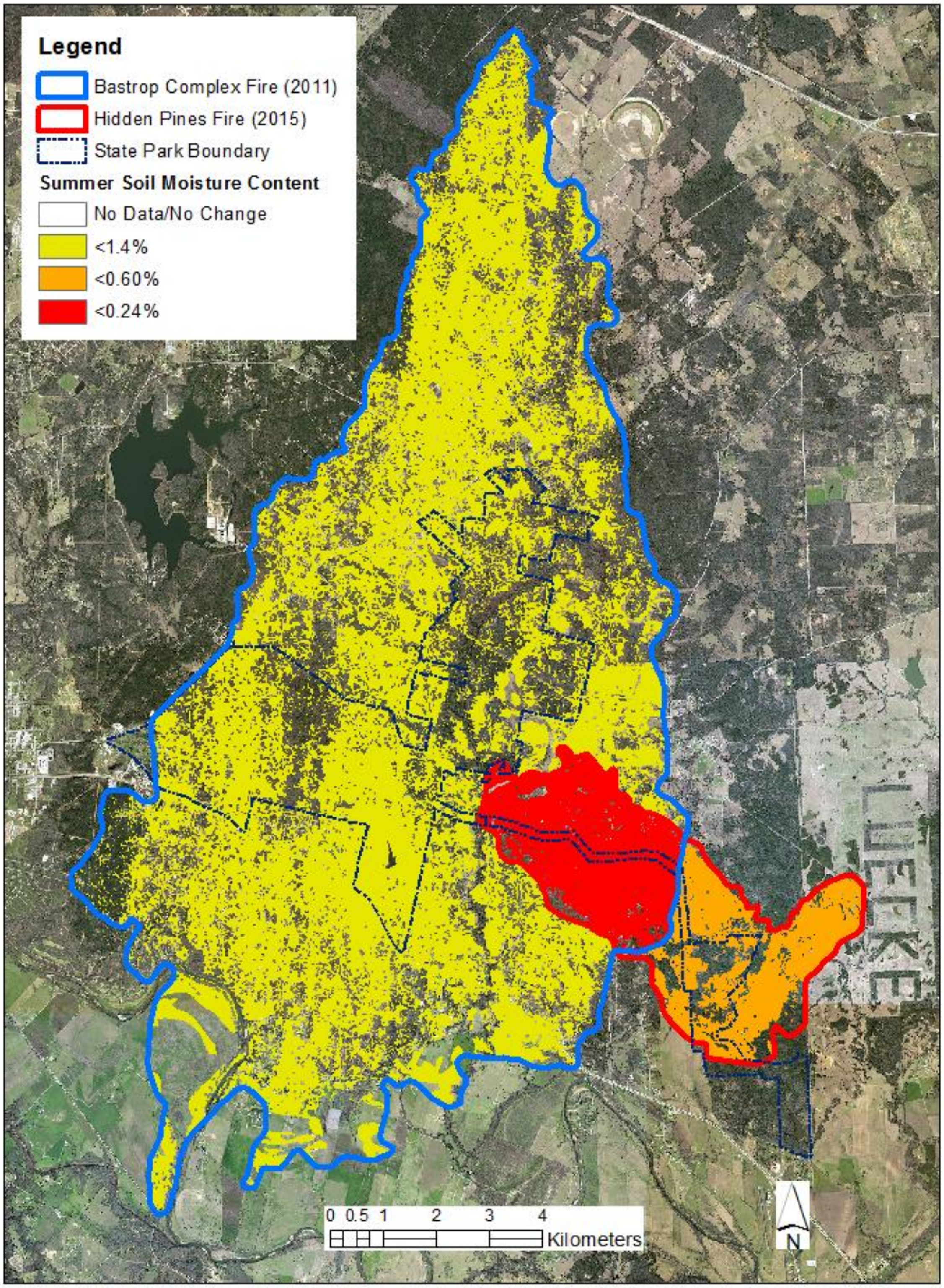

Figure 15: Map of likely soil moisture contents in July 2016 based on % sand, % canopy coverage and data collected in the field

Permanent wilting points:

The "permanent wilting point" of a soil refers to the water content threshold below which plants growing in the soil will wilt and be unable to recover with another wetting of the soil. Essentially it is a point where any further growth in that soil will require establishment by new plants, not the recovery of old ones. The soil data I downloaded from the NRCS had a field for the permanent wilting points of different soils in the region. As stated earlier, I created a raster with a gradient of permanent wilting points in order to perform this analysis. Using the data from the previous section and "Raster Calculator", I created new rasters that returned a value of 0 if the permanent wilting point of that soil was below the moisture content and returned a value of 1 if the permanent wilting point was above the moisture content (figure 16). I then used raster calculator again to determine where the soils that would likely be below the wilting point correspond with a sandy soil (and thus a soil that I can make

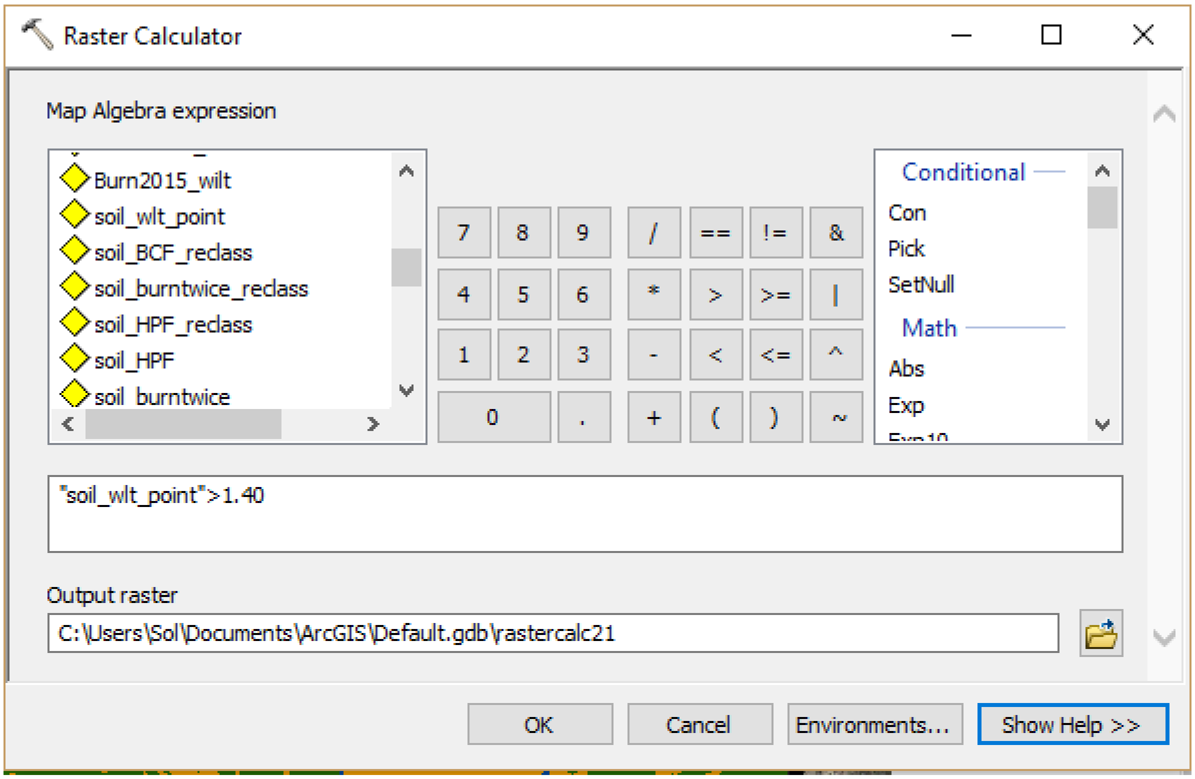

Figure 16: Raster calculator expression showing the way I created rasters that showed if the moisture content of an area of soil was likely below the permanent wilting point of that soil type

interpretations on). Finally, I used “Extract by Mask” to extract each raster by the burn area associated. The resulting figure shows where soils were likely be below the permanent wilting point (figure 17).

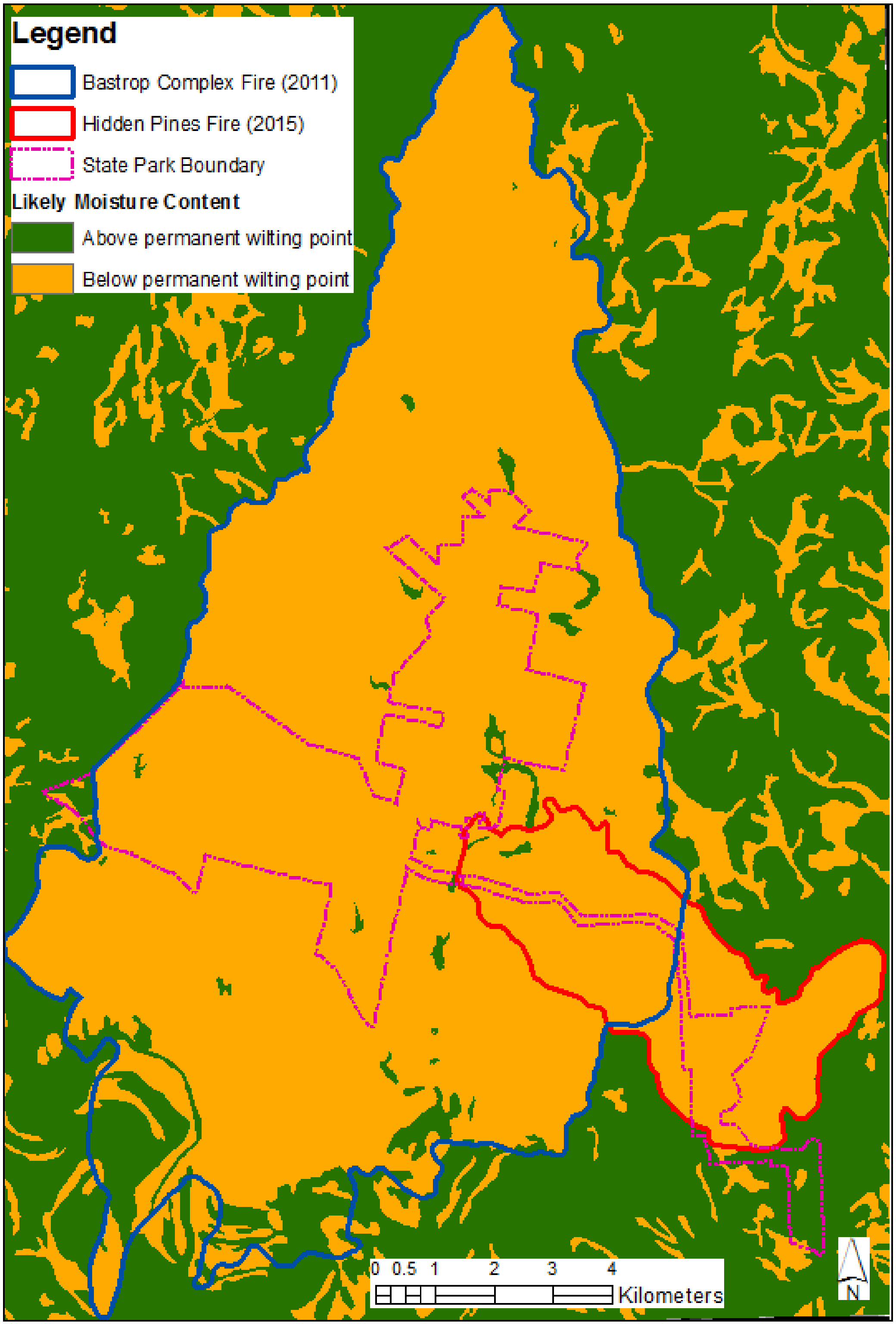

Figure 17: Map showing areas where the soils were above and below the permanent wilting points of that soil type, according to data collected in July 2016 and downloaded from the NRCS website

Results:

Canopy Loss:

As shown in table 1, a significant amount of forest canopy was lost during both fires.

Layer description	Area forested	Area unforested	% Forested	Forest lost
2010 pre-fire canopy	71,112,200 m^2	62,889,100 m^2	53%	N/A
2014 Bastrop post-fire canopy	26,478,750 m^2	107,522,550 m^2	20%	44,633,450 m^2
Feb 2015 Hidden Pines pre-fire canopy	4,931,600 m^2	13,227,950 m^2	27%	N/A
Nov 2015 Hidden Pines post-fire canopy	1,631,700 m^2	16,527,850 m^2	9%	3,299,900 m^2

Table 1: Areas of forested and unforested land within the burn area before and after each fire

The table shows significant forest loss, in the case of the Bastrop Complex Fire, 33% of the total land area was changed from forested to unforested. After the Hidden Pines Fire, the result was slightly smaller, but mostly because it was already largely unforested. Perhaps more dramatic are the two forest coverage maps I created (figures 18 and 19).

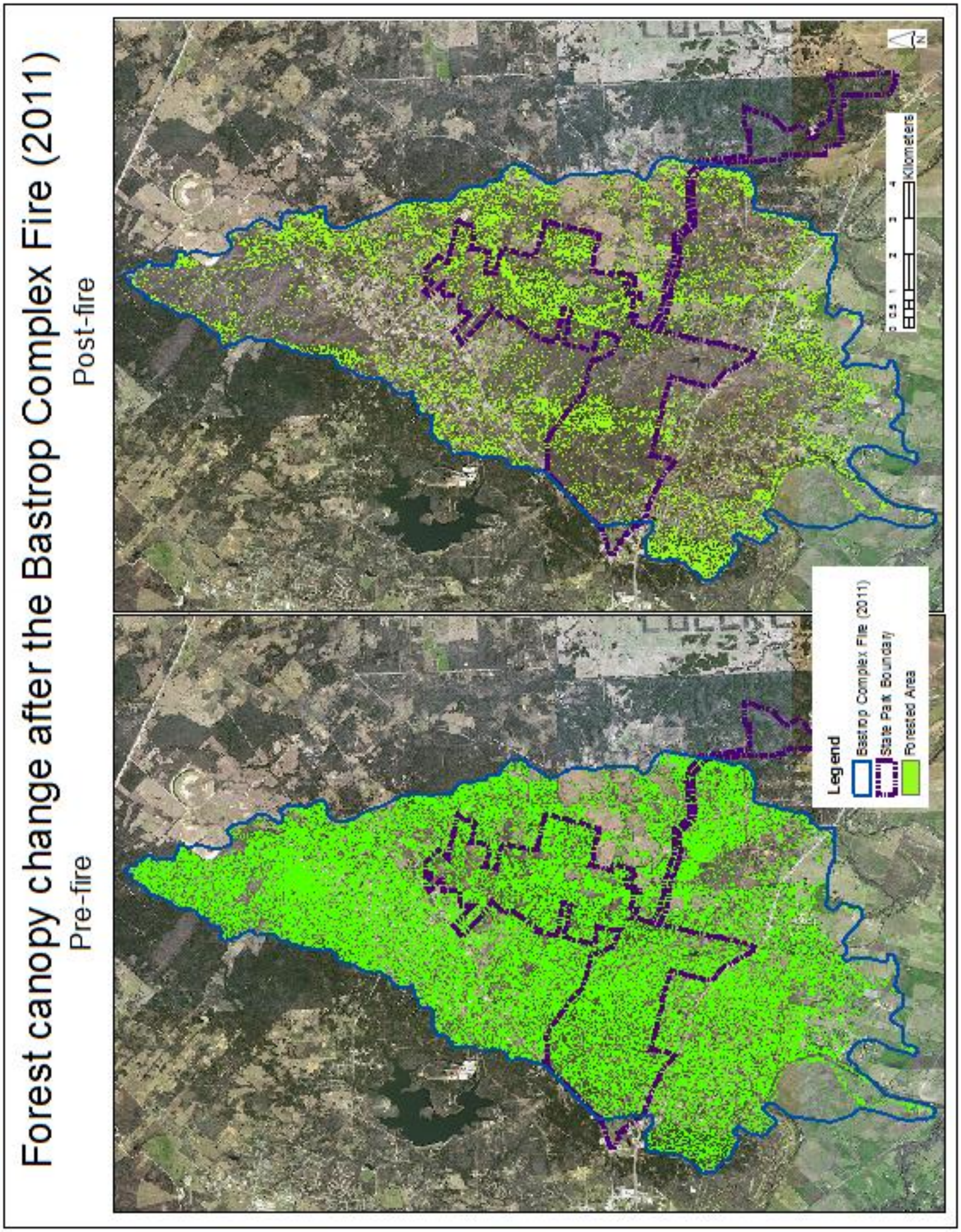

Figure 18: Final canopy coverage map for before and after the Bastrop Complex Fire

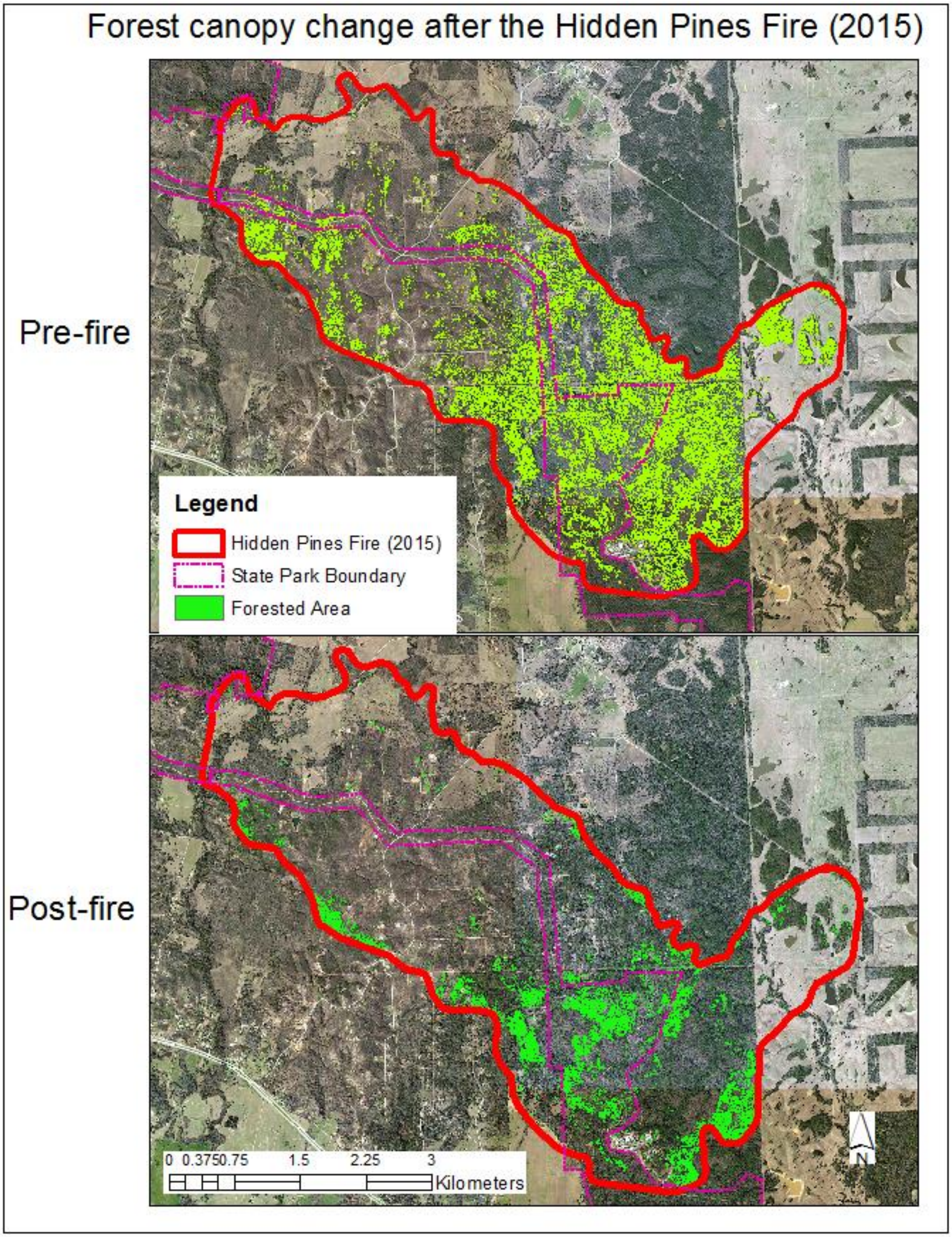

Figure 19: Final canopy coverage map for before and after the Hidden Pines Fire

Permanent wilting points:

Tables 2 and 3 show the effect of the fires on land area within each fire's footprint that likely dropped below the permanent wilting point for that soil type in July 2016. According to this analysis the percentages of land within the burn areas that were above and below the permanent wilting point will have roughly swapped due to the wildfire, with ~127 km^2 more land area dropping below the permanent wilting point. This could potentially have a dramatic effect on the regeneration of this ecosystem after the wildfires, since it is likely that after each summer much of the vegetation needs to completely reestablish because there wasn't enough water in the soils to sustain them over the hot months.

With Fires

Year burned	Area above permanent wilting point	Area below permanent wilting point
2015	6,050 m^2	9,340,775 m^2
2011	7,310,600 m^2	117,878,100 m^2
Both	91,600 m^2	8,720,975 m^2
Total	7,418,250 m^2	135,939,850 m^2

Table 2: Land area within each of the fire footprints that was likely above and below the permanent wilting points for those soils after the wildfires

Without Fires

Year burned	Area above permanent wilting point	Area below permanent wilting point
2015	9,069,950 m^2	276,875 m^2
2011	116,857,400 m^2	8,331,300 m^2
Both	8,630,875 m^2	181,700 m^2
Total	134,558,225 m^2	8,789,875 m^2

Table 3: Land area within each of the fire footprints that would likely have been above and below the permanent wilting points for those soils if the wildfire had not occurred

Once again, even more impressive is the visualization of this information, as seen in figure 20. This map shows the land area that was likely above and below the permanent wilting points for those soils types and it is obvious what impact the fires have on moisture contents and regeneration. One note on this figure, canopy coverage data was not available for land area outside of the burn footprints so the information on land outside of the footprints is only based on soil type and field data. However, control sites do span a variety of canopy coverage. That being said, it is likely that there are unburned areas with less canopy coverage than the field sites chosen for this project which may cause them to drop below the permanent wilting point.

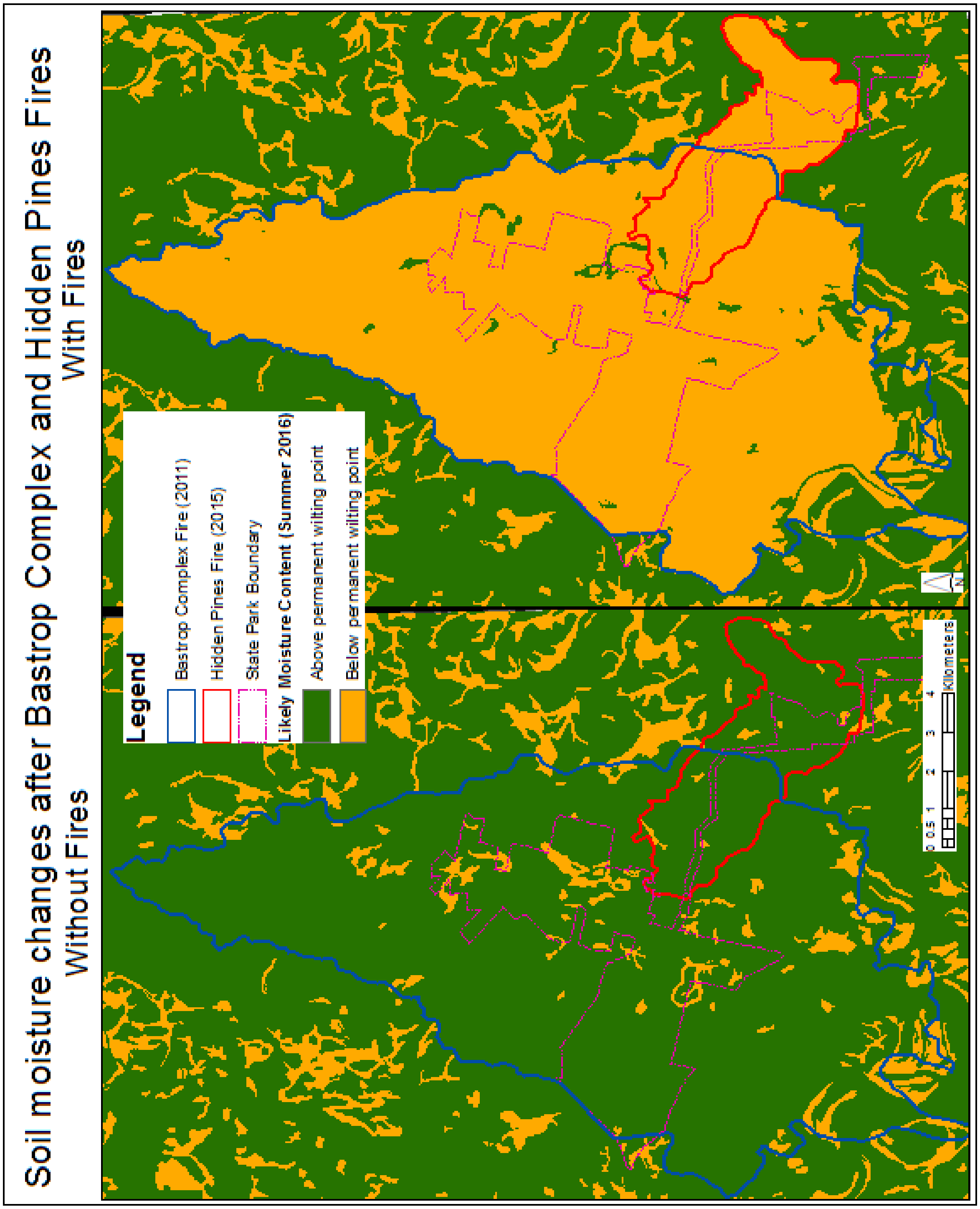

Figure 10: Map comparing the amount and distribution of soils that were likely above and below the permanent wilting point with or without the influence of the fire