John Sullivan

How have the spatial patterns of wildfire perimeters and the Wildland Urban Interface (WUI) in Oregon and Washington State shifted through time?

Advisor: Dr. Erica Smithwick

GEOG 596A
Penn State MGIS
April 21, 2021

Contents
1.0 Study Purpose .................................................................................................................. 1
2.0 Background ......................................................................................................................... 1
3.0 Project Scope and Approach ............................................................................................ 2
4.0 Objectives .......................................................................................................................... 2
5.0 Methodology ..................................................................................................................... 3
6.0 Results ............................................................................................................................... 14
7.0 Challenges / Limitations ................................................................................................. 21
8.0 Conclusion ......................................................................................................................... 21
References ................................................................................................................................ 22
Datasets .................................................................................................................................. 22
1.0 Study Purpose

There is not a good system, or organization of datasets, to educate people spatially and statistically about the dangers of moving into regions more prone to wildfire. Persons living in the Western United States are starting to see the impacts to daily life as wildfires begin to burn longer, hotter, and affect populations that move deeper into their destructive path. I aim to organize datasets that aid in the spatial and temporal analysis of vulnerable regions for people moving into the Wildland-Urban Interface (WUI) of Washington and Oregon, U.S. By identifying vulnerable areas, we can help residents allocate time, resources, and techniques available to fight a wildfire nearest to them. This topic is of interest to me because I live in Olympia, WA and have developed an appreciation for the forests and people that surround me. I would also like to draw attention to the risks associated with people moving into these regions given the increasing vulnerabilities of communities to wildfire.

2.0 Background

Climate change is causing the Earth to warm faster than we anticipated and has brought larger and more frequent fires to our forested ecosystems of western North America. This trend continues today with increases in a fire’s severity and areas burned (Cansler, 2014). The WUI is a regional classification, categorized using U.S. Census and USGS National Land Cover Data (NLCD), used to determine where people are living in relation to wildland vegetation. The fact that more and more people are building houses in these regions is cause for environmental concern. The main concern is that people are the number one cause for wildland fires, as well as habitat fragmentation, invasive species introduction, and biodiversity decline (Martinuzzi et al, 2020). For this study’s purpose I focus on wildland fire and how, through time, people are becoming more vulnerable to its destruction by living in the WUI. This study will:

- Compare areas where houses meet or intermingle with undeveloped wildland vegetation (WUI).
- Calculate focal areas for human-environment conflicts since the year 1990, which contained the most accurate census numbers and fire perimeters.
- Decennial census data from 1990, 2000, and 2010 will demonstrate how hundreds of thousands of people are moving into vulnerable regions.
- Compare how this study’s method of statically determining the number of people at risk and compare that with the WUI dataset.

According to the Department of Natural Resources (DNR), a forest fire is any non-structure fire in the wild that is either unplanned ignitions or planned ignitions that are declared wildfires. Large fires are defined as any wildland fire in timber 100 acres or greater and 300 acres or greater in grasslands/rangelands. This study has eliminated any reported wildfire that burned less than 100 acres (DNR, 2014). During 2020, Washington had the second worst year on record for wildfires, second to only 2015 for most acres burned in a single season this decade (Goodwin, 2020). Also, alarming is that the DNR Division for Wildfire reported that in 2020 they responded to 1,800 fires, and 40 percent of those were in the historically wetter Western Washington, and near some of the largest temperate rainforests in North America (Farley, 2020).
3.0 Project Scope and Approach

I will use a WUI polygon, provided by SILVIS LAB, to recategorized which populations are in vulnerable areas. Within the WUI layer, data is organized with Census results from 1990, 2000, and 2010. The attribution fields I will use to categorized which Census Blocks are at risk is based on what the WUI determines as low to high risk, the exact criteria are stated within the methodology section. I used this method because I would like to take into consideration low to high housing densities that are either intermixed or within a short distance to wildland vegetation. It is safe to assume that communities within 2.5 km of a large wildfire will either be forced to evacuate or face damage from being near a fire.

For the wildfire perimeter I will merge two polygons. One provided by the National Interagency Fire Center (NIFC) for Washington and the other by the Bureau of Land Management (BLM) for Oregon. These layers are crucial to this analysis because it will enable me to identify spatial patterns in how and why people in nearby WUI are vulnerable. Another source of my information comes from the U.S. Census Bureau, who produces a layer that is a unique number assigned to Census Blocks. A Block is the smallest geographic area for which the Census Bureau collects and tabulates Census data, and are formed by streets, roads, railroads, streams and other bodies of water, other visible and cultural features, and the legal boundaries (US Census Bureau, 2020). U.S. Census TIGER 2010 Block polygons are associated with housing and population density, while the WUI dataset incorporated spatial joins with these 1990, 2000, and 2010 Census Block housing densities.

4.0 Objectives

1. Identify areas where large populations and previous large forest fires merge.
2. Calculate the area and quantify over time how more people are moving into the WUI and previously burned fire perimeters.
3. Create temporal and thematic graphics depicting regions with heavy WUI populations near large forest fires.
4. Incorporate census data into the analysis to establish, through time, how many people are impacted.
5. Develop a robust ArcGIS Storymap detailing how these datasets correlate and have changed over time. This Storymap will give people something to use and share for educational purposes.
6. Organize all datasets into a 24 x 36-inch thematic map.
5.0 Methodology

I started by merging the two fire perimeter datasets in ArcPRO then used Microsoft Access to make some of the fields more manageable, such as the Year field being in Text format in one and numeric in another. I then combined this dataset with another provided by NIFC that had the more recent 2020 events. Figure 1 demonstrates how I exported the polygon to shapefile for use in Access. After merging fire perimeter polygons in ArcPRO, I imported the .dbf file into Access and converted the year’s text field to short integer. After I cleaned up some of the other fields I then reexported the .dbf to the same naming convention as the shapefile for incorporation and visualization in ArcPRO.

Figure 1

Figure 2 demonstrates how I was able to use structured query (SQL) functions to break up the fire polygon into five categories, four of which are a decade long. I left the year 2020 as its own layer because it helps demonstrate how bad that twelve-month period was. I left the
1980 fire incident perimeters strictly for visualization but removed them later when merging and dissolving the perimeters for comparison with Census numbers and WUI dataset.

Figure 2

Figure 3 is an example of how I spatially went through the datasets to delete redundant records of fires. Since a fire can cover the same region over the span of the 40-year time frame, I first used the select by location tool then manually by scrolling around the study area and toggling on and off layers to determine which perimeters overlapped.

Figure 3
All datasets used in this analysis were then clipped to the Census provided Washington and Oregon State polygon and use the NAD 1983 HARN StatePlane Washington South FIPS 4602 (US Feet) projection. I choose this projection because of its central location to the firepolygon_merge layer. The NLCD came from seven separate years and was clipped to a Washington/Oregon merged polygon. From these raster layers I will be able to demonstrate how the four categories of urban development are infringing on the same regions as previous wildfires, as seen in Figure 4.

Figure 4
For visual aesthetics I downloaded NaturalVue, SRTM2, and DTED1 image/elevation tiles from USGS EarthExplorer and used mosaic dataset processing methods such as building pyramids and calculating statistics. These will be useful when I put together thematic maps of the areas more prone to wildfire. Applying image tiles and using ArcPRO raster functions such as shaded relief maps can aid in not only the visual affects but also slope analysis of a fire’s destructive path. **Figure 5** demonstrates how some of the mosaic dataset and raster processing functions were applied to this dataset.

Figure 5
The datasets I am organizing also contain a WUI polygon to recategorized which populations are in vulnerable areas. I restructured the data within my own database to apply coded domains to certain fields. This is going to make adding or updating areas I identify as more vulnerable from more current landcover / LANDSAT8 images with band combinations for urban analysis. The attribution fields can be used to categorized which census blocks are at risk. Figure 6 is an example where I took into consideration low to high housing densities that are either intermixed or within a short distance to wildland vegetation.

Figure 6
Figure 7 utilizes the previously organized fire polygon perimeters to help visualize how these wildfires are burning more area as the decades progress. I left the most recent events underneath the older ones to demonstrate how wildfires are encroaching on areas previously untouched. These are a few of the layers I will load into ArcPortal and create a set of interactive storymaps to help educate viewers. After this I removed the 1980 incidents, then merged and dissolved the remaining perimeters into one final wildfire polygon encompassing all events from 1990 to 2020.
Figure 8 is a list of the final datasets; I clipped everything to the OR_WA_State polygon perimeter. The data can now be compiled for map production and analysis. I did a few queries in Access to demonstrate the types of information users will be able to find out now that the information is structured in a meaningful way. I first exported the tables for Blocks_2010_Merge, WUI_Merge1990_2010Change, and RAW_Fire_1980_2020 layers out of the geodatabase. Then I imported the .dbf into Access.

Figure 9 is an example of a query that can now be done on the raw fire data. Here I wanted to find the total amount of acres burned for the given year. I also changed the property sheet to format as fixed with zero decimal places for ease of viewing. Right away I can see that more acres are burning from wildfires in the 2000s.
Figure 10 depicts the Reclassify parameters I used and below is the Loop python script I developed to recode all rasters into a folder I called ‘Rasters’.

```python
# Import system modules
import arcpy
import env from arcpy.sa
import *
# Set environment settings
env.workspace = r"D:\PSU\Capstone\CapstoneData\CapstoneData.gdb"
# Set Local variables
outFolder = r"D:\PSU\Capstone\CapstoneData\Rasters"
# Check out the ArcGIS Spatial Analyst extension license
arcpy.CheckOutExtension("Spatial")
# Get a list of the rasters in the workspace
rasters = arcpy.ListRasters()

# Loop through the list of rasters
for inRaster in rasters:
    # Set the outputname for each output to be the same as the input
    outRaster = outFolder + "\" + inRaster
    # Process: recode
    out_raster = arcpy.sa.Reclassify(inRaster, "Value", "0 NODATA;11 NODATA;12 NODATA;21 1;22 2;23 3;24 4;31 NODATA;41 NODATA;42 NODATA;43 NODATA;52 NODATA;71 NODATA;81 NODATA;82 NODATA;90 NODATA;95 NODATA", "DATA")
    out_raster.save(outRaster)
    print('Done Processing')
```

Next I exported the four perimeter files (Figure 11) I will be using to mask my coded rasters to .shapefiles for incorporation into the below python Loop and Masking python script.

```python
# Import system modules
import arcpy
from arcpy import env
from arcpy.sa
import *
# Set environment settings
env.workspace = r"D:\PSU\Capstone\CapstoneData\Rasters"
# Set Local variables
inMaskData = r"D:\PSU\Capstone\CapstoneData\fireperm.shp"
inMaskData2 = r"D:\PSU\Capstone\CapstoneData\Buffer_2_5k.shp"
inMaskData3 = r"D:\PSU\Capstone\CapstoneData\Buffer_5k.shp"
inMaskData4 = r"D:\PSU\Capstone\CapstoneData\Buffer_10k.shp"
outFolder = r"D:\PSU\Capstone\CapstoneData\CapstoneData.gdb"
# Check out the ArcGIS Spatial Analyst extension license
arcpy.CheckOutExtension("Spatial")
# Get a list of the rasters in the workspace
rasters = arcpy.ListRasters()

# Loop through the list of rasters
for inRaster in rasters:
    # Set the outputname for each output to be the same as the input
    outRaster = outFolder + "\" + inRaster + "_p"
    # Process: Extract by Mask
```
Below is a list and description of the developed categories I reclassified from the NLCD. Impervious surfaces include roads, driveways, rooftops, and other compact surfaces that do not allow rain to infiltrate into the soil and groundwater.

**21 - Developed, Open Space**- areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.

**22 - Developed, Low Intensity**- areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20% to 49% percent of total cover. These areas most commonly include single-family housing units.

**23 - Developed, Medium Intensity**- areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50% to 79% of the total cover. These areas most commonly include single-family housing units.

**24 - Developed High Intensity**- highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80% to 100% of the total cover.
After doing some preliminary analysis on my raster mask output I discovered, for whatever reason, there was no change to the four develop NLCD categories between the years 2006 and 2008, then again between 2011 and 2013. Because of this, I chose to remove 2006 and 2011 from describing the change to urban development the NLCDs represent. I then calculated the acres – each X, Y cell size is 166.234375149578 feet, which equals 27633.87 feet squared and equates to 0.63438636364 acres per pixel. I then created another field to calculate the number of acres based on the count of pixels (see Figure 12).
I then created a new layer (Figure 13) by selecting the WUI_merge layer that intersect with the fire perimeter, and one that intersects with each fire perimeter buffer. The criteria for the WUI classes I took into consideration are as follows. Figure 14 depicts a merger of the following WUI categories by decade.

- **High_Dens:** Housing density $\geq 741.3162$ houses per square km
- **Med_Dens:** Housing density between 49.42108 and 741.3162
- **Low_Dens:** Housing density between 6.177635 and 49.42108
- **Intermix:** Wildland vegetation $> 50\%$
- **Interface:** Wildland vegetation $\leq 50\%$ and within 2.414 km of area with $\geq 75\%$ wildland vegetation

![Figure 13](image)

**Wildland Urban Interface Change 1990 to 2010**

![Figure 14](image)
6.0 Results

Of the 4,696 wildfire incidents I calculated from the merged Washington and Oregon BLM and NIFC datasets, 2,447 burned 100 or more acres. The year 2020 was particularly bad for the study area, though 2015 closely equaled it. The numbers demonstrate an alarming upward trend for incidents reported and acres burned. What the charts also show is that the worst years tend to come in waves, possibly equating to some type of cycle trending upward.
The table below was used to summarize the total amount of acres based on the four Developed Landcover Classifications from the NLCD for each buffer zone and year. The numbers illustrate how hundreds of acres are being developed in areas prone to wildfire. The large jump from 2001 to 2004 is likely equated to either a large population expansion or a change in how the landcover data was collected.

<table>
<thead>
<tr>
<th>Fire Perimeter</th>
<th>Year</th>
<th>High Intensity</th>
<th>Medium Intensity</th>
<th>Low Intensity</th>
<th>Open Space</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2001</td>
<td>2,069</td>
<td>6,232</td>
<td>23,985</td>
<td>103,217</td>
</tr>
<tr>
<td></td>
<td>2004</td>
<td>5,902</td>
<td>17,807</td>
<td>67,853</td>
<td>294,312</td>
</tr>
<tr>
<td></td>
<td>2008</td>
<td>5,997</td>
<td>18,152</td>
<td>68,011</td>
<td>294,453</td>
</tr>
<tr>
<td></td>
<td>2013</td>
<td>6,039</td>
<td>18,315</td>
<td>68,165</td>
<td>294,733</td>
</tr>
<tr>
<td></td>
<td>2016</td>
<td>6,121</td>
<td>18,577</td>
<td>68,383</td>
<td>294,922</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2.5 Kilometer Buffer</th>
<th>Year</th>
<th>High Intensity</th>
<th>Medium Intensity</th>
<th>Low Intensity</th>
<th>Open Space</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2001</td>
<td>10,929</td>
<td>46,101</td>
<td>148,862</td>
<td>379,356</td>
</tr>
<tr>
<td></td>
<td>2004</td>
<td>31,104</td>
<td>131,839</td>
<td>423,896</td>
<td>1,081,619</td>
</tr>
<tr>
<td></td>
<td>2008</td>
<td>33,368</td>
<td>139,886</td>
<td>426,743</td>
<td>1,084,259</td>
</tr>
<tr>
<td></td>
<td>2013</td>
<td>34,933</td>
<td>144,310</td>
<td>428,915</td>
<td>1,085,806</td>
</tr>
<tr>
<td></td>
<td>2016</td>
<td>35,913</td>
<td>148,051</td>
<td>431,487</td>
<td>1,085,707</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>5 Kilometer Buffer</th>
<th>Year</th>
<th>High Intensity</th>
<th>Medium Intensity</th>
<th>Low Intensity</th>
<th>Open Space</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2001</td>
<td>20,856</td>
<td>89,955</td>
<td>266,407</td>
<td>623,651</td>
</tr>
<tr>
<td></td>
<td>2004</td>
<td>59,625</td>
<td>257,249</td>
<td>758,798</td>
<td>1,778,629</td>
</tr>
<tr>
<td></td>
<td>2008</td>
<td>64,625</td>
<td>273,914</td>
<td>764,826</td>
<td>1,784,464</td>
</tr>
<tr>
<td></td>
<td>2013</td>
<td>68,612</td>
<td>283,721</td>
<td>769,646</td>
<td>1,787,937</td>
</tr>
<tr>
<td></td>
<td>2016</td>
<td>70,839</td>
<td>291,067</td>
<td>774,807</td>
<td>1,787,986</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>10 Kilometer Buffer</th>
<th>Year</th>
<th>High Intensity</th>
<th>Medium Intensity</th>
<th>Low Intensity</th>
<th>Open Space</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2001</td>
<td>36,010</td>
<td>151,768</td>
<td>436,979</td>
<td>993,106</td>
</tr>
<tr>
<td></td>
<td>2004</td>
<td>102,837</td>
<td>433,572</td>
<td>1,244,796</td>
<td>2,831,784</td>
</tr>
<tr>
<td></td>
<td>2008</td>
<td>111,535</td>
<td>461,460</td>
<td>1,255,685</td>
<td>2,842,499</td>
</tr>
<tr>
<td></td>
<td>2013</td>
<td>118,241</td>
<td>478,337</td>
<td>1,263,243</td>
<td>2,847,592</td>
</tr>
<tr>
<td></td>
<td>2016</td>
<td>122,021</td>
<td>490,706</td>
<td>1,271,725</td>
<td>2,847,519</td>
</tr>
</tbody>
</table>
According to the WUI dataset, numbers have steadily increased in all vulnerable categories, especially in the low-density intermixed category. Low density is usually the beginning stages that lead to medium to high density, so it is safe to assume thousands of people are moving into areas prone to wildfire more and more over the past three decades. The tables below reflect the number of BlockIDs that intersect the given perimeter category. Note the large jump in numbers when we incorporate the 2.5k buffer.
After looking at the number of Blocks that intersect the study areas fire perimeter, we can see that medium to high housing densities begin to take over low density as the perimeter buffer is expanded. This is another alarming example of how, within only a short distance, more people will be vulnerable to wildfires should they spread or massive amounts of people are forced to evacuate.
Next, I calculated the total acreage of WUI categories used in this analysis to see how that correlates with the four Developed Landcover acreage we clipped in the NLCD. Low Density Intermix is the dominate category within the fire perimeter, though Medium Density begins to show substantial risk looking at the 2.5k buffer.
When looking at the 5k and 10k buffer numbers we can see how High-Density housing begins to show substantial increases in acreage, while Medium and Low Density continues to climb as well.
Here we look at the Census numbers of total population and number of housing units. The numbers depict the large amount of people who are within a short distance to where a wildfire has burned since 1990. According to the 2010 Census, 123,182 people and 58,903 housing units are within the fire perimeter polygon. When we look just 2.5 kilometers out from the fire perimeter the numbers jump to 773,590 people and 347,583 housing units. That is a drastic increase, and only gets bigger as we look five and ten kilometers out.
7.0 Challenges / Limitations

- Census data does not entirely depict where and how people are living in the regions where humans meet nature.
- 2020 census data was not available for this analysis.
- There is not enough public knowledge or support to drastically change how and where we live. It is difficult to shift the way we live to mitigate the damage wildfires can cause.
- We are just starting to see how seasonal wildfires can damage our lives and economy. As we move into the 2021 summer months vulnerable populations need to actively embrace for contingency plans.
- This is a very complex problem with numerous variables involved to how or why a wildfire starts. Predictive models are not the solution, active education and prevention is what is needed to shift policy and the public’s mindset.
- Time is always an issue when we research and challenge complex problems such as climate change. This research covers a large geographic area, which may help sway policy at the federal or state level.

**Link to Storymap**

**Link to 24 x 36 inch Thematic Map**

8.0 Conclusion

The goal of this analysis is to help educate people about the dangers regarding the high numbers of people moving into regions prone to wildfire. I was able to determine that more people are moving into regions prone to wildfire and that wildfires are getting more severe and occurring all over Oregon and Washington. This study focused on the historic locations of wildfires in Washington and Oregon, which occurred mostly in the regions east of the Cascade Mountain Range. The greatest area of concern is that there are signs of wildfires creeping on the Western Cascade (more populated) slopes, as well as more people moving into the Eastern Cascade regions.

This analysis not only helps paint a picture of what has happened in each region but can also help allocate for additional resources and funding. Fighting a fire must be done on a more micro scale, so educating these large amounts of people living in vulnerable areas on how to fight future fires will help stop future destruction. There is currently a Bill (2413) in the WA State Senate to generate $63 million dollars yearly toward fighting fires. This will provide the needed funds to employ more fire fighters, analysts, and response stations (Holappa, 2020). The data presented in this study, as well as events occurring in California, tell us the Pacific Northwest is vulnerable to wildland fire. It is up to policy makers and the people moving into the WUI to prepare for the next large incident.
References


Datasets


