# Wildfires in Portugal Geospatial Analysis

*Capstone Project, GIS Specialization, U. of California, Davis, Coursera*

*by Helder Reis- 2019*

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# Methods

## Burned Area

A key part of the analysis was to determine the burned area using satellite images. Two bands are needed to calculate the NBR (Normalized Burn Ratio): the NIR (Near Infrared) and SWIR (Shortwave Infrared), using the formula: *NBR = (NIR-SWIR) / (NIR+SWIR)* . The delta NBR (dNBR) is used to determine the difference between pre and post fire NBR: *dNBR = PostfireNBR - PrefireNBR* .

Below table summarizes years, satellites and bands used:

| Years | Satellite | NIR Band (Wavelength) | SWIR Band (Wavelength) |
|---|---|---|---|
| 2001, 2009 | Landsat 5 | 4 *(0.76-0.90 micrometers)* | 7 *(2.08-2.35 micrometers)* |
| 2017 | Landsat 8 | 5 *(0.85-0.88 micrometers)* | 7 *(2.11-2.29 micrometers)* |

For each year I downloaded images from April/May for the pre-fire and October/November for the post fire, selecting the ones with lowest cloud cover.

Although Portugal is a fairly small country it still takes 8 Landsat images to cover the country (paths 203 and 204, rows 31 to 34). Therefore, **a total of 96 images were needed** (8 tiles x 2 bands x 2 times a year x 3 years), although for the process of selecting them I estimate to have downloaded 3 or 4 times those many.

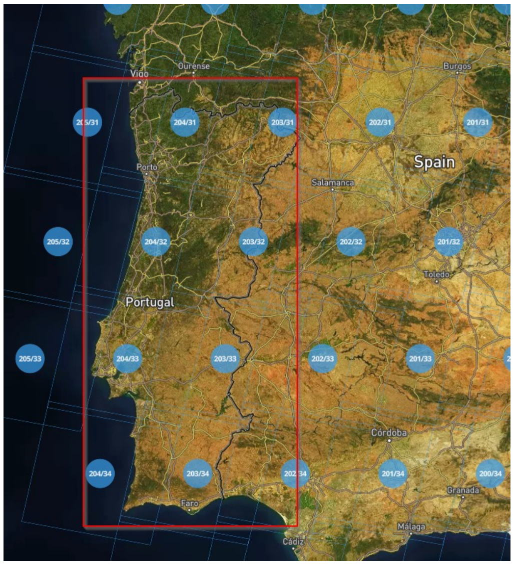



*Figure 1: Landsat Portugal tiles (source: remotepixel.ca)*

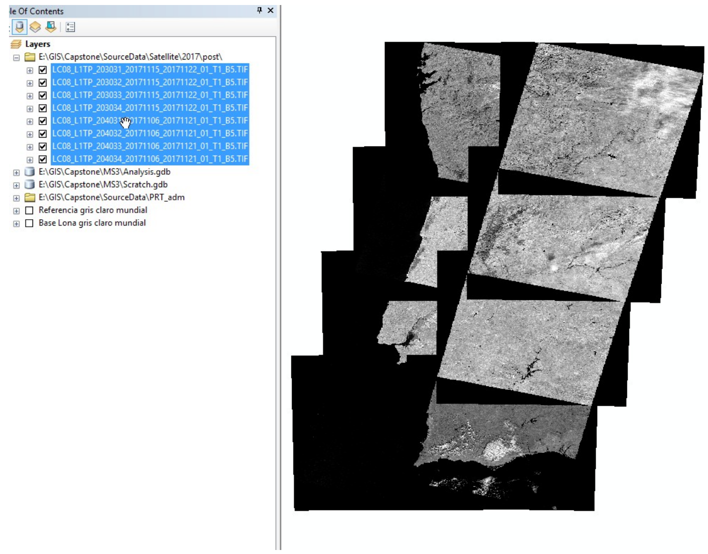


*Figure 2: 8 images put together. To avoid the black areas of each image the method used to mosaic overlapping areas was set to MAXIMUM.*

These were combined together to form 12 new rasters (*pre-fire 2001 NIR, pre-fire 2001 SWIR, post-fire 2001 NIR, post-fire 2001 SWIR, etc*) to be used as input for the dNBR model calculator for each year.

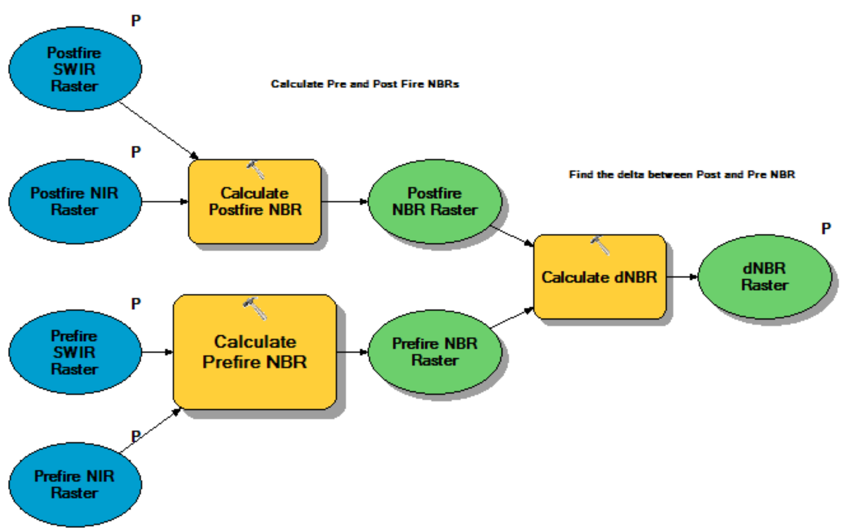



*Figure 3: Calculate dNBR Model*

The result were 3 dNBR rasters, one per year:

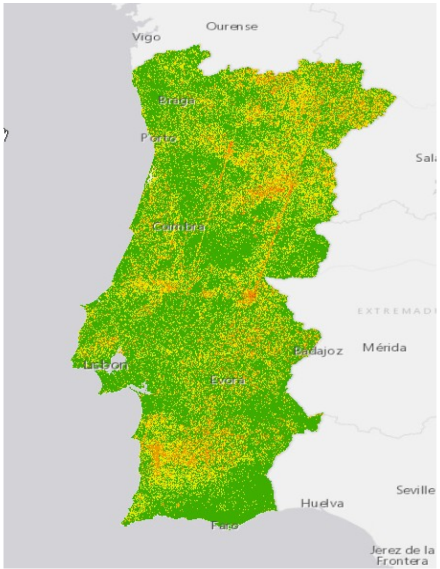



*Figure 4: dNBR 2001*

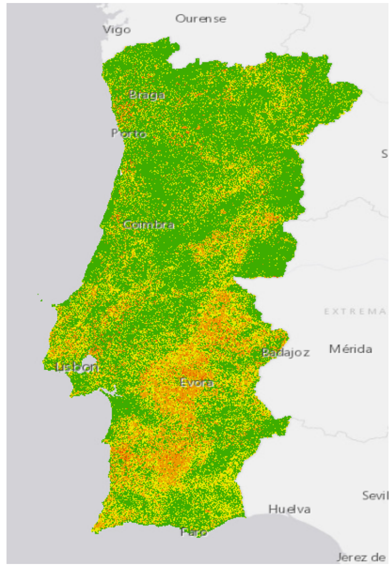



*Figure 5: dNBR 2009*

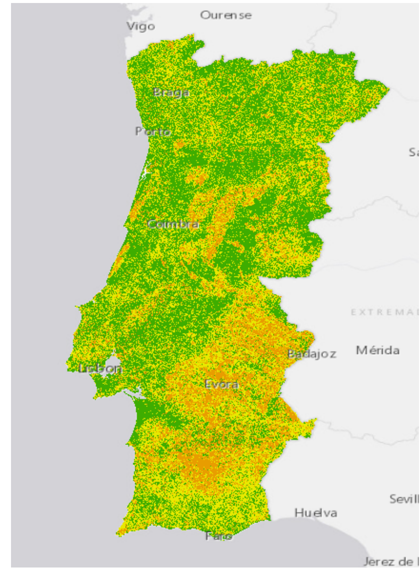



*Figure 6: dNBR 2017*

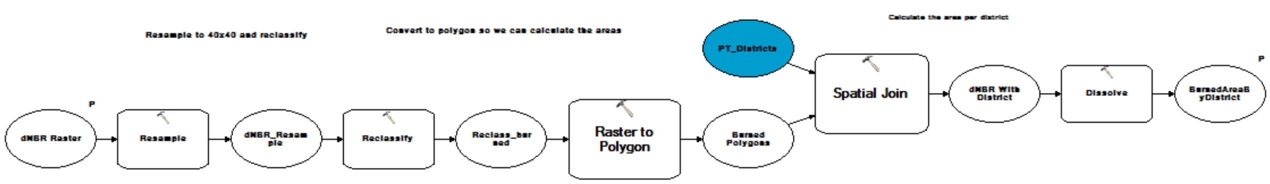
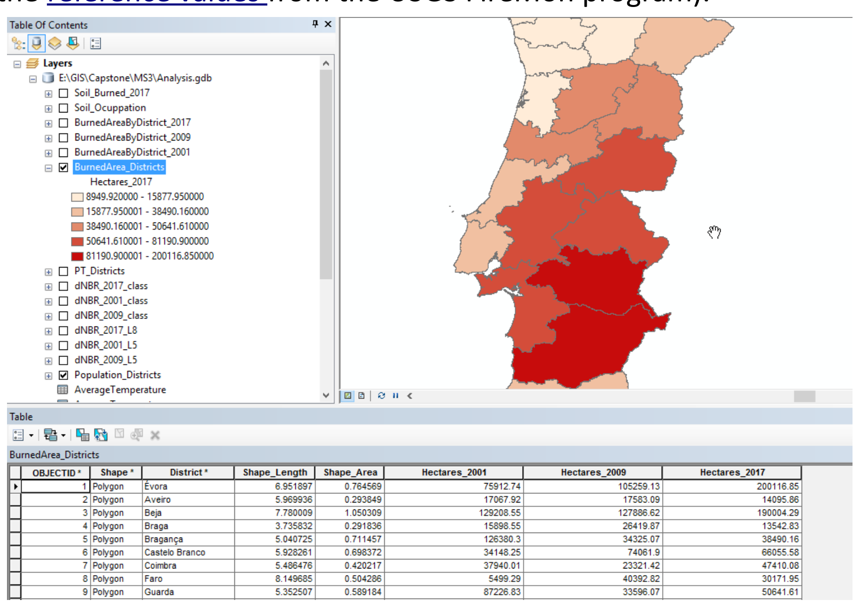



*Figure 7: Calculate Burned Area per District Model*

Using another model the raster was re-sampled to 40x40 meters and reclassified into low, medium and severely burned (using the reference values from the USGS FireMon program).

To focus on the major wildfires and minimize false positives, the burned areas were thresholded to values > .27 (medium-high severity), converted into polygons and then dissolved by district (there are 18 districts in mainland Portugal).




| OBJECTID * | Shape * | District * | Shape_Length | Shape_Area | Hectares_2001 | Hectares_2009 | Hectares_2017 |
|---|---|---|---|---|---|---|---|
| 1 | Polygon | Évora | 6.951897 | 0.764569 | 75912.74 | 105259.13 | 200116.85 |
| 2 | Polygon | Aveiro | 5.969936 | 0.293849 | 17067.92 | 17583.09 | 14095.86 |
| 3 | Polygon | Beja | 7.780009 | 1.050309 | 129208.55 | 127886.62 | 190004.29 |
| 4 | Polygon | Braga | 3.735832 | 0.291836 | 15898.55 | 26419.87 | 13542.83 |
| 5 | Polygon | Bragança | 5.040725 | 0.711457 | 126380.3 | 34325.07 | 38490.16 |
| 6 | Polygon | Castelo Branco | 5.928261 | 0.698372 | 34148.25 | 74061.9 | 66055.58 |
| 7 | Polygon | Coimbra | 5.486476 | 0.420217 | 37940.01 | 23321.42 | 47410.08 |
| 8 | Polygon | Faro | 8.149685 | 0.504286 | 5499.29 | 40392.82 | 30171.95 |
| 9 | Polygon | Guarda | 5.352507 | 0.589184 | 87226.83 | 33596.07 | 50641.61 |

## Climate and Population

From [PORDATA](PORDATA) I downloaded yearly average temperatures and total rainfall. Unfortunately the data was not available for all districts (only 7 out of the 18 mainland districts), and I couldn't find it in multiple other sources I looked for. This data was mostly handled in Excel to build charts. Fortunately the population information on PORDATA is very complete. I used total number of resident population, population density and age groups (to calculate percentage of people over 65). The data was dissolved by district and used for creating maps in ArcMap and also charts in Excel.

## Soil Occupation

I contacted the "Instituto da Conservação da Natureza e das Florestas" (Forest and Nature Conservation Institute) requesting the source data to the map of Soil Occupation I had found in their report, to this day I received no answer, even after following up. So I took a screenshot of the image from the pdf, saved it as TIFF, georeferenced it in ArcMap, then used Supervised Classification to produce a raster. I tried with different parameters (samples, reject fractions, etc) to minimize the errors but this is the best I could produce.

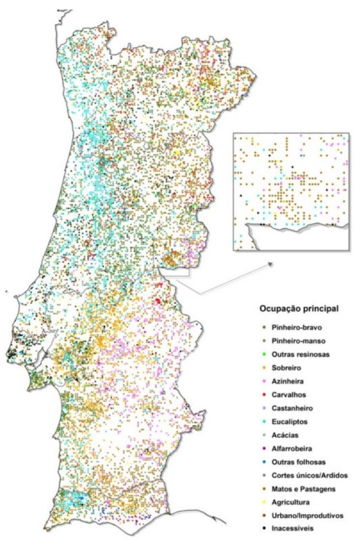



*Figure 8: Original image*

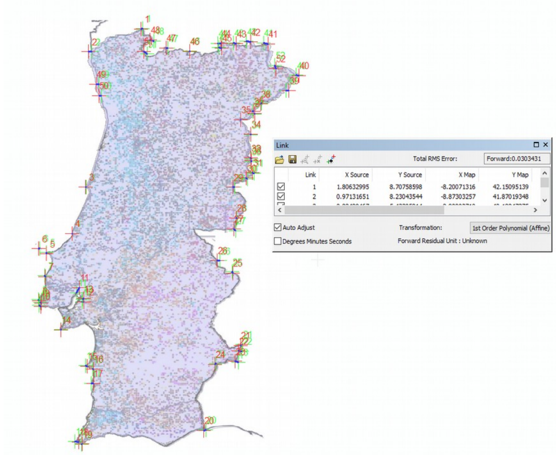


*Figure 9: Georeferencing in progress*

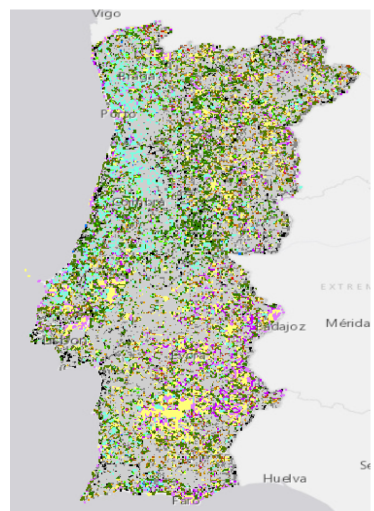



*Figure 10: Final classified image*

Visually the classified image somehow resembles the original but comparing the numbers, in the original the eucalyptus are is around 14% while in my version it is 6%. **The data quality is poor, does not reflect reality and therefore the results should be ignored** - nevertheless I decided to leave it in as an exercise.

## Others

As I feared in the project proposal, I was not able to find data on Forest Ownership, Criminal Activity and Emergency Response, so they are not part of this analysis.

# Results

## Burned Area

Here are the results of the estimated severely burned area (square kilometres):

*Table 1: Burned Area per year and district*

| District | 2001 | 2009 | 2017 |
|---|---|---|---|
| Aveiro | 17,067.92 | 17,583.09 | 14,095.86 |
| Beja | 129,208.55 | 127,886.62 | 190,004.29 |
| Braga | 15,898.55 | 26,419.87 | 13,542.83 |
| Bragança | 126,380.30 | 34,325.07 | 38,490.16 |
| Castelo Branco | 34,148.25 | 74,061.90 | 66,055.58 |
| Coimbra | 37,940.01 | 23,321.42 | 47,410.08 |
| Évora | 75,912.74 | 105,259.13 | 200,116.85 |
| Faro | 5,499.29 | 40,392.82 | 30,171.95 |
| Guarda | 87,226.83 | 33,596.07 | 50,641.61 |
| Leiria | 28,759.49 | 29,477.15 | 26,643.74 |
| Lisboa | 23,417.93 | 59,449.86 | 33,925.78 |
| Portalegre | 95,148.42 | 85,071.64 | 81,190.90 |
| Porto | 19,335.28 | 23,186.15 | 10,456.80 |
| Santarém | 61,054.12 | 70,924.91 | 62,565.55 |
| Setúbal | 35,340.71 | 62,247.71 | 59,035.80 |
| Viana do Castelo | 7,812.63 | 7,057.26 | 8,949.92 |
| Vila Real | 65,137.49 | 24,805.31 | 15,877.95 |
| Viseu | 61,228.66 | 24,637.92 | 42,233.00 |
| **TOTAL** | **926,517.17** | **869,703.90** | **991,408.65** |


*Figure 11: Districts in mainland Portugal (source: Wikipedia)*

# Climate

There seems to be a **positive correlation between the area burned and the yearly average air temperature** per districts/years:

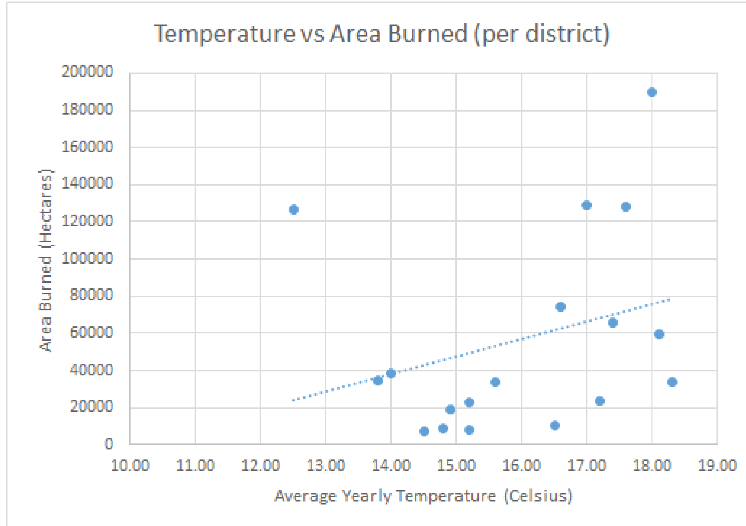
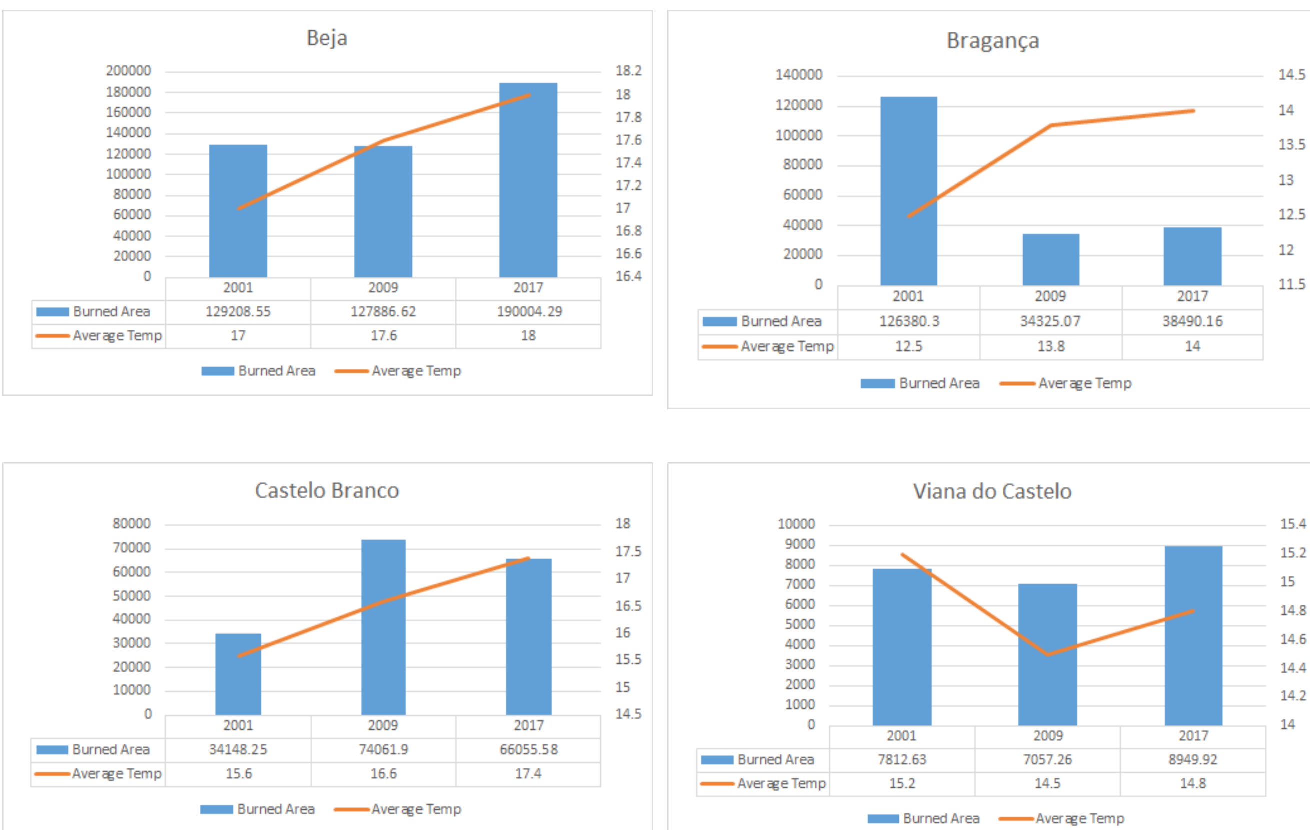



*Figure 12: Average Air Temperature Vs Area Burned*

However, looking at the temperature and burned area progression **in individual districts the correlation is not clear**:

*Table 2: Average Temperature Vs Area Burned per district*



There is also a **negative correlation when compared to the total yearly rainfall:**

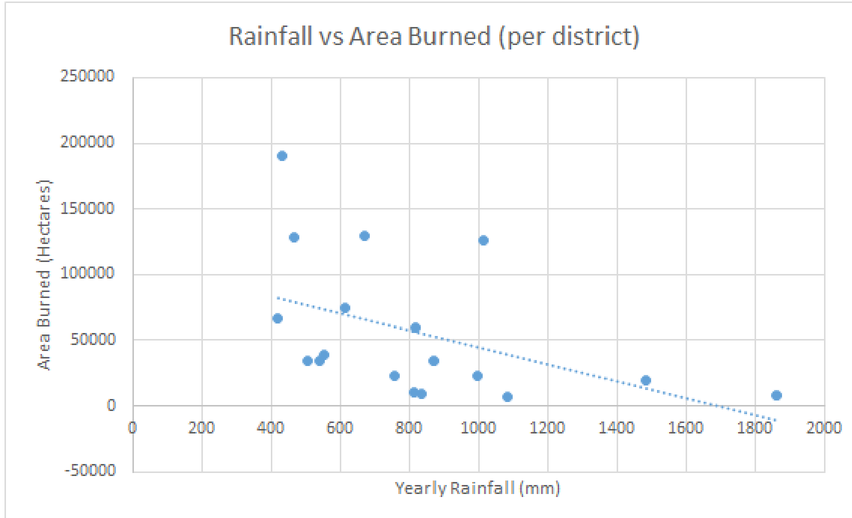
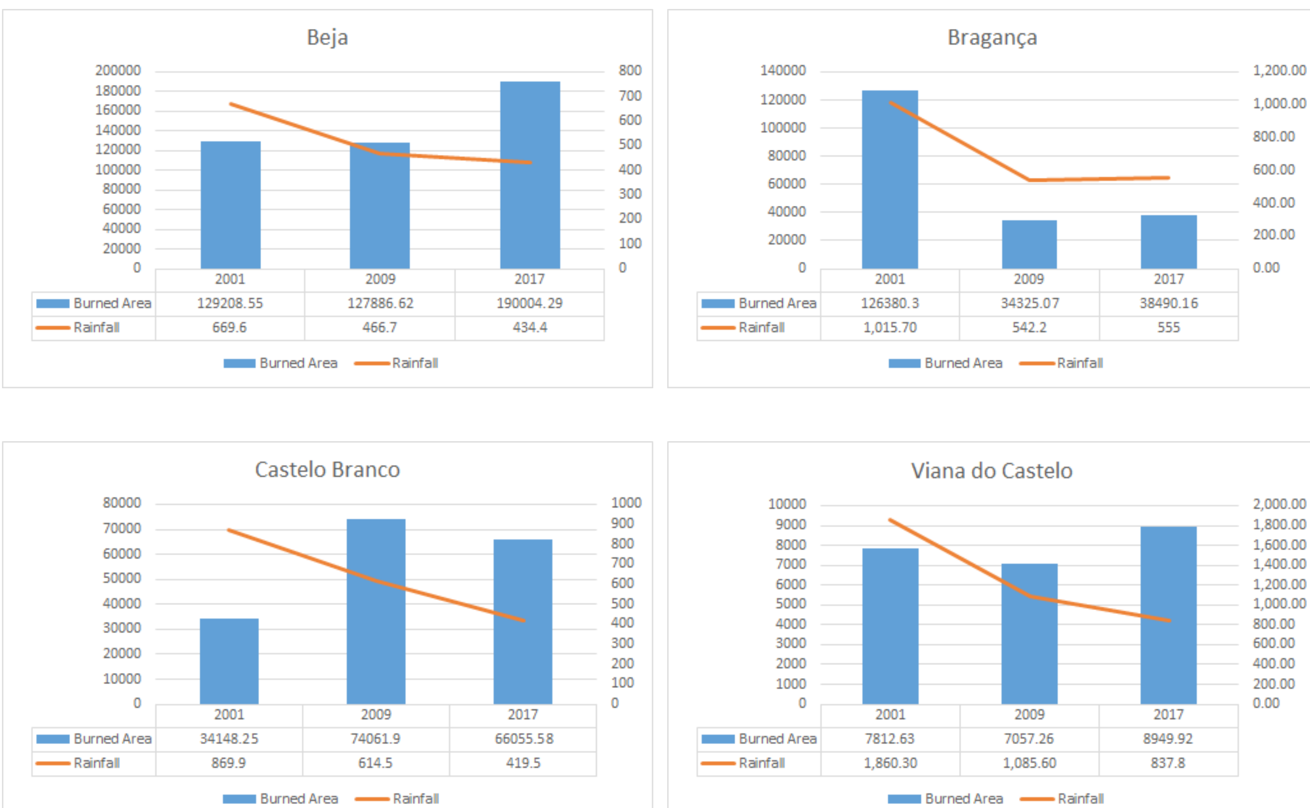



*Figure 13: Total Rainfall Vs Area Burned*

But again, when looking at the rainfall and burned area progression **in individual districts the correlation is not clear**:

*Table 3: Total Rainfall Vs Area Burned per district*



## Population

The correlation between the **area burned and the population density is a weak negative one**:

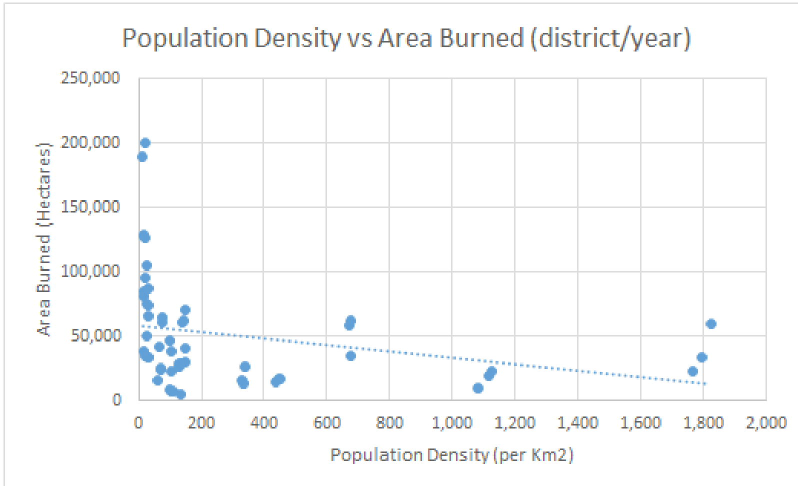
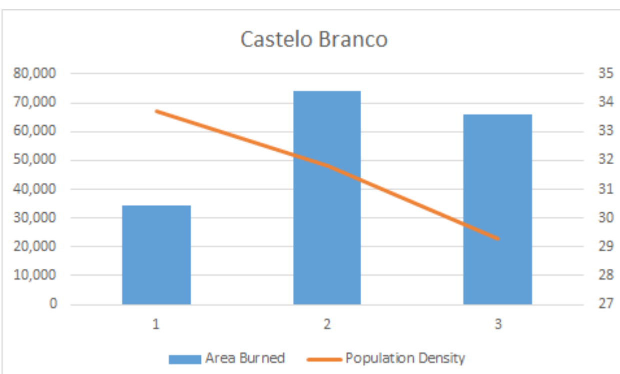
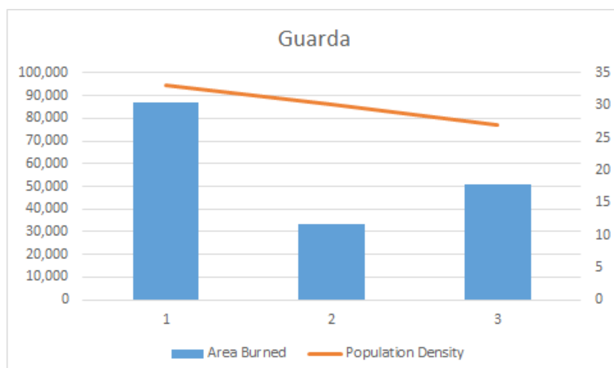


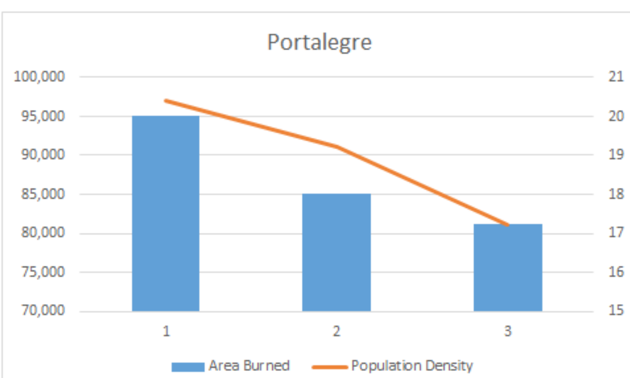

*Figure 14: Population Density Vs Area Burned*

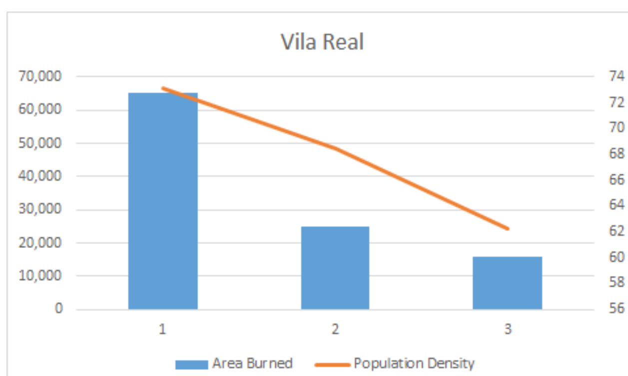
Also, since the hypothesis was that "areas where the population density has declined over the years have seen an increase in wildfires" I analysed the 4 districts with the biggest loss in population density between 2001 and 2017. **The results indicate no correlation in the observed cases:**

*Table 4: Population Density Vs Area Burned per district*



## Forest Type

Following is the result of comparing the burned area with the soil occupation (note: y axis is logarithmic):

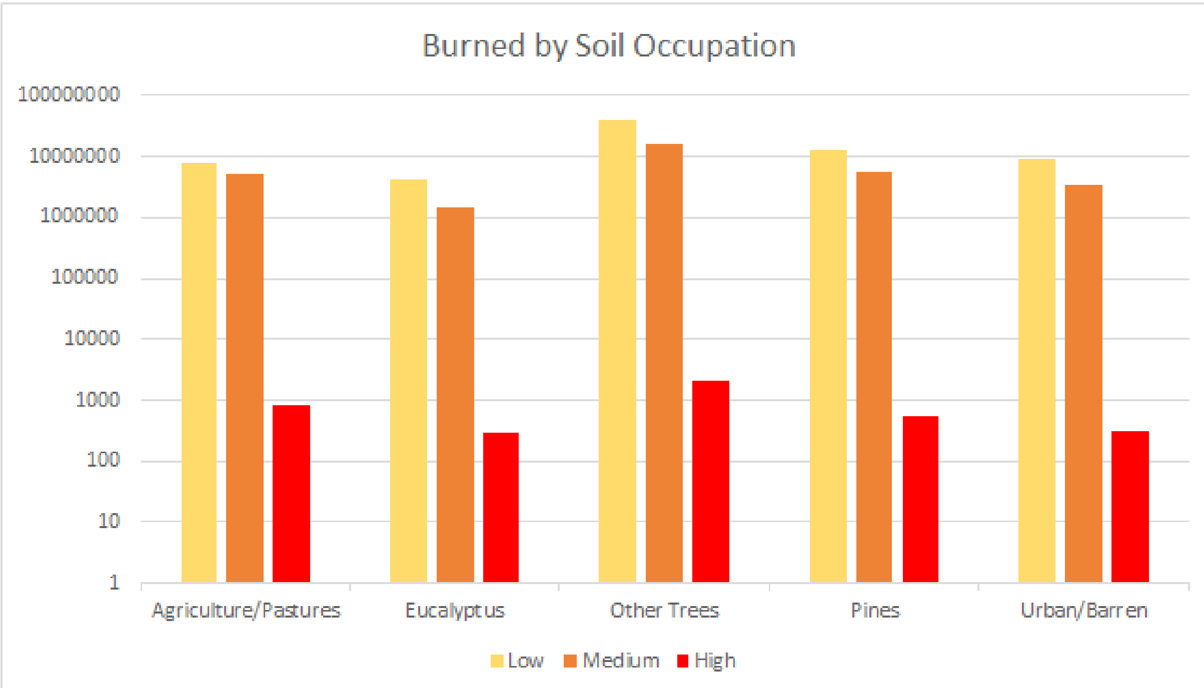



*Figure 15: Soil Occupation Vs Area Burned*

We expected to see higher values in eucalyptus areas, followed by pines and autochthonous trees, and that is not the case.

The results do not confirm the hypothesis but as mentioned above **the data is erroneous, so these results are invalid**.

# Discussion

The research question for this work was *"Can we find a correlation between these factors and the wildfires in Portugal?"*.

For some of the factors I couldn't find publicly available data (as I suspected), for others I was able to do some analysis and find some correlations with the available data which could be taken as a starting point for deeper analysis with much more data and resources (human and computational) than an academic project such as this can do.

Although the NBR calculations went quite well (after getting all the images, which took more time then expected due to cloud coverage and size of the files), I feel that there's a great number of false positives impacting the results, especially in the Alentejo area (south), which is mostly agricultural and not forest. Maybe the dry fields were identified as false positives, maybe it's because I merged images from different days with more or less sun, I'm not sure.

In my project proposal I had already mentioned 2017 as being especially tragic, the area burned in 2017 according to PORDATA was much more than 2001 and 2009, while in my calculations it was only slightly higher. Here's a table showing the difference, all values in Hectares:

| Year | My calculations | PORDATA |
|---:|---:|---:|
| 2001 | 926,517 | 117,420 |
| 2009 | 869,703 | 92,126 |
| 2017 | 991,408 | 539,921 |

They list their source as being the ICNF (the same I contacted about getting the source data for the soil occupation map), but I have no info on their methods. But it confirms my feeling of false positives in 2001 and 2009, although the model used was the same.

I also thought about removing "burned" areas less than 10.000 m2, since I could see in the satellite RGB images that they were false positives, but I had the feeling I was tampering with the data in order to get the results I expected, so I just thresholded it.

For the climate analysis I used yearly average air temperature and total rainfall, but there are many other factors one should consider: the number of heat wave days, the number of days without rain, the actual temperatures at the times the major fires started, etc. But again, the European Agency has a 400+ page report on this subject alone, I supposed a team of GIS Engineers would be needed to deeply analyse this.

Since I didn't get access to the underlying data for the forest type I did my best to replicate it, but the geoprocessing distorted it and the classification couldn't get to faithful results, despite my many tries. I wasn't sure if to leave it in this report or not, but decided to leave it since I spent quite some time working on it.

I also decided to do the graphs in Excel since it's more powerful and flexible than the graph tool in ArcMap, but the data is there and will be used to produce the maps.

Overall I learned a lot doing this analysis, which was my main objectives. I think that overall the methods used are valid if one can get the proper data.

Wildfires are a big problem and are only likely to get worse with climate change, I hope governmental agencies in Portugal and the rest of the world are working on this "for real" to find and mitigate their causes - I surely would love to find a job where I could be part of that effort.

Thank you for reading,

*Helder*