

Forest Fires in Portugal - What Are The Causes?

Practical Assignment of Data Mining I

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Chapter 1

Introduction

In this project, we try to find the best machine learning model that more accurately predicts whether a forest fire occurs negligently, intentionally, naturally or recurrently. From a database that was given to us, we divided the work into several parts.

The remainder of this report is organized as follows: in chapter 2, we describe the importance of predicting forest fires that are a big problem actually; in chapter 3 is described the causes of the occurrences that is the variable that the model will be predict and a table with all the variables of the original dataset; chapter 4 is dedicated to the exploration, cleaning and engineering of the data. Some graphics are plotted in this chapter and they help to visualize the origins and locations of the forest fires; the models used to test the dataset are described and compared in chapter 5; in chapter 6, We finalize with the main conclusions and the last chapter includes references.

Chapter 2

Problem Definition

Forest fires are a very important issue that negatively affects climate change. Typically, the causes of forest fires are those oversights, accidents and negligence committed by individuals, intentional acts and natural causes. The latter is the root cause for only a minority of the fires.

Their harmful impacts and effects on ecosystems can be major ones. Among them, we can mention the disappearance of native species, the increase in levels of carbon dioxide in the atmosphere, earth's nutrients destroyed by the ashes, and the massive loss of wildlife.

Data mining techniques can help in the prediction of the cause of the fire and, thus, better support the decision of taking preventive measures in order to avoid tragedy. In effect, this can play a major role in resource allocation, mitigation and recovery efforts.

Chapter 3

Forest Fire Dataset

The Institute for Nature Conservation and Forests ([ICNF](#)) is the governmental body responsible for the nature and forest policies, including the management of protected areas and state managed national, municipal, and communal forests of mainland Portugal. The ICNF has been maintained a database with data of all forest fires that occurred in Portugal over several years. The data set used in this study is a subset extracted from this database regarding the fires that occurred over 2015. It consist of **7511** records of fires and for each one, there is relevant information such as the GPS coordinates (latitude and longitude) where occur the fire, the date and time of fire alert, the date and time of the first intervention, and the date and time of fire extinction, besides the origin of the ignition, the affected area, and the cause type. The table 3 describes all variables contained in **Forest Fires** data set:

Table List of variables in **Forest Fires** data set.

| Variable | Type | Description |
|------------------|-----------|--------------------------|
| id | integer | id number |
| region | character | region name |
| district | character | district name |
| municipality | character | municipality name |
| parish | character | parish name |
| lat | character | latitude value |
| lon | character | longitude value |
| origin | character | how the fire started |
| alert_date | character | date when fire started |
| alert_hour | character | alert hour |
| extinction_date | character | date of the end of fire |
| extinction_hour | character | hour of the end of fire |
| firstInterv_date | character | date of intervention |
| firstInterv_hour | character | hour of intervention |
| alert_source | logical | alert source |
| village_area | numeric | village area affected |
| vegetation_area | numeric | vegetation area affected |

| Variable | Type | Description |
|--------------------|-----------|------------------------------|
| farming_area | numeric | farming area affected |
| village_veget_area | numeric | total village+veget affected |
| total_area | numeric | total area affected |
| cause_type | character | cause of the fire |

A classification for causes types are presented in table 3.2.

Table 3.2: Classifications of causes of forest fires.

| Cause | Description |
|-------------|---|
| Unknown | absence of sufficient objective evidence to determine the cause of the ignition of fire |
| Natural | lightning generated in thunderstorms |
| Negligence | the misguided use of fire in activities such as burning trash, mass burning of agricultural and forest fuels, fun and leisure activities; failure to properly extinguish cigarettes by smokers; the dispersal and transport of incandescent particles from chimneys; etc. |
| Intentional | incendiarism and arson, mostly resulting from behaviors and attitudes reacting to the constraints of agroforestry management systems and to conflicts related to land use |
| Rekindling | reburning of an area over which a fire has previously passed, but where fuel has been left that is later ignited by latent heat, sparks, or embers |

A glimpse of the structure of the **Forest Fires** data set is provided below:

Table: A glimpse of the structure of the data set.

```
## Rows: 7,511
## Columns: 21
## $ id          <int> 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 1...
## $ region      <chr> "Entre Douro e Minho", "Entre Douro e Minho", "T...
## $ district    <chr> "Viana do Castelo", "Porto", "Vila Real", "Vila ...
## $ municipality <chr> "Ponte de Lima", "Marco de Canaveses", "Boticas"...
## $ parish      <chr> "Serdedelos", "Vila Boa de Quires", "Cerdedo", "G...
## $ lat         <chr> "41:44:48.5663999999878'", "41:12:58.4280000000...
## $ lon         <chr> "8:31:12.32760000000027'", "8:12:28.3788000000002...
## $ origin      <chr> "fire", "fire", "fire", "firepit", "firepit", "f...
## $ alert_date  <chr> "2015-03-24", "2015-03-24", "2015-03-24", "2015-...
## $ alert_hour  <chr> "17:01:00", "17:10:00", "21:40:00", "16:00:00", ...
## $ extinction_date <chr> "2015-03-24", "2015-03-24", "2015-03-25", "2015-...
## $ extinction_hour <chr> "18:09:00", "18:47:00", "05:45:00", "17:00:00", ...
## $ firstInterv_date <chr> "2015-03-24", "2015-03-24", "2015-03-24", "2015-...
```

```
## $ firstInterv_hour    <chr> "17:10:00", "17:16:00", "22:00:00", "16:14:00", ...
## $ alert_source        <lg1> NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, ...
## $ village_area        <dbl> 2.50, 0.00, 0.50, 0.00, 0.10, 0.00, 0.35, 0.50, ...
## $ vegetation_area     <dbl> 0.000, 1.350, 38.000, 0.010, 0.000, 0.100, 14.82...
## $ farming_area        <dbl> 0.0000, 0.0000, 0.0000, 0.0000, 0.0000, 0.0000, ...
## $ village_veget_area  <dbl> 2.500, 1.350, 38.500, 0.010, 0.100, 0.100, 15.17...
## $ total_area          <dbl> 2.5000, 1.3500, 38.5000, 0.0100, 0.1000, 0.1000,...
## $ cause_type          <chr> "negligent", "negligent", "negligent", "negligen...
```

A summary for each variable present in dataset is provided below. The metrics displayed are: quantity and percentage of zeros, quantity and quantity and percentage of NA's, data type and quantity of unique values.

Table 4: A summary of variables of the dataset.

| ## | variable | q_zeros | p_zeros | q_na | p_na | q_inf | p_inf | type | unique |
|-------|--------------------|---------|---------|------|--------|-------|-------|-----------|--------|
| ## 1 | id | 0 | 0.00 | 0 | 0.00 | 0 | 0 | integer | 7511 |
| ## 2 | region | 0 | 0.00 | 501 | 6.67 | 0 | 0 | character | 10 |
| ## 3 | district | 0 | 0.00 | 0 | 0.00 | 0 | 0 | character | 19 |
| ## 4 | municipality | 0 | 0.00 | 0 | 0.00 | 0 | 0 | character | 297 |
| ## 5 | parish | 0 | 0.00 | 0 | 0.00 | 0 | 0 | character | 2270 |
| ## 6 | lat | 0 | 0.00 | 0 | 0.00 | 0 | 0 | character | 5858 |
| ## 7 | lon | 0 | 0.00 | 0 | 0.00 | 0 | 0 | character | 5867 |
| ## 8 | origin | 0 | 0.00 | 0 | 0.00 | 0 | 0 | character | 5 |
| ## 9 | alert_date | 0 | 0.00 | 0 | 0.00 | 0 | 0 | character | 317 |
| ## 10 | alert_hour | 0 | 0.00 | 0 | 0.00 | 0 | 0 | character | 1312 |
| ## 11 | extinction_date | 0 | 0.00 | 9 | 0.12 | 0 | 0 | character | 319 |
| ## 12 | extinction_hour | 0 | 0.00 | 9 | 0.12 | 0 | 0 | character | 1201 |
| ## 13 | firstInterv_date | 0 | 0.00 | 214 | 2.85 | 0 | 0 | character | 318 |
| ## 14 | firstInterv_hour | 0 | 0.00 | 215 | 2.86 | 0 | 0 | character | 1202 |
| ## 15 | alert_source | 0 | 0.00 | 7511 | 100.00 | 0 | 0 | logical | 0 |
| ## 16 | village_area | 5349 | 71.22 | 0 | 0.00 | 0 | 0 | numeric | 591 |
| ## 17 | vegetation_area | 2648 | 35.25 | 0 | 0.00 | 0 | 0 | numeric | 1052 |
| ## 18 | farming_area | 5976 | 79.56 | 0 | 0.00 | 0 | 0 | numeric | 650 |
| ## 19 | village_veget_area | 1413 | 18.81 | 0 | 0.00 | 0 | 0 | numeric | 1377 |
| ## 20 | total_area | 8 | 0.11 | 0 | 0.00 | 0 | 0 | numeric | 1781 |
| ## 21 | cause_type | 0 | 0.00 | 0 | 0.00 | 0 | 0 | character | 4 |

A sample the first observations is provided below:

```
## # A tibble: 6 x 21
##   id region district municipality parish lat lon origin alert_date
##   <int> <chr> <chr> <chr> <chr> <chr> <chr> <chr> <chr>
## 1 1 Entre~ Viana d~ Ponte de Li~ Serde~ 41:4~ 8:31~ fire 2015-03-24
```

```
## 2      2 Entre~ Porto      Marco de Ca~ Vila ~ 41:1~ 8:12~ fire  2015-03-24
## 3      3 Trás-- Vila Re~ Boticas      Cerde~ 41:3~ 07:5~ fire  2015-03-24
## 4      4 Trás-- Vila Re~ Montalegre    Gralh~ 41:5~ 7:42~ firep~ 2015-03-25
## 5      5 Trás-- Vila Re~ Valpaços      Alger~ 41:3~ 07:2~ firep~ 2015-03-12
## 6      6 Entre~ Vila Re~ Mondim de B~ Ermelo 41:2~ 07:5~ firep~ 2015-03-13
## # ... with 12 more variables: alert_hour <chr>, extinction_date <chr>,
## #   extinction_hour <chr>, firstInterv_date <chr>, firstInterv_hour <chr>,
## #   alert_source <lgl>, village_area <dbl>, vegetation_area <dbl>,
## #   farming_area <dbl>, village_veget_area <dbl>, total_area <dbl>,
## #   cause_type <chr>
```


Chapter 4

Data Preparation

Data preparation consists of the process of cleaning and transforming raw data in a form that can be used by machine learning algorithms. Next sections, we exploit the **Forest Fires** dataset in order to perform the steps of cleaning a transforming, when need.

4.1 Data Cleaning

4.1.1 Latitude and Longitude

The **Forest Fires** dataset store the latitude and longitude of the place where occurred the fire into variables `lat` e `lon` respectively. These values are in format of *Degrees°Minutes'Seconds"* and for the reason contain special characters `°`, `'`, `:` and `"`. Besides, there are wrong values into variables as dates between the coordinates and values with scientific notation E-12, E-11 and E-02. A sample of these inconsistencies is provided in the tables below:

```
## # A tibble: 1 x 2
##   lat                lon
##   <chr>              <chr>
## 1 41°41'25.82159999997'' 8°20'37.446000000002''
```

```
## # A tibble: 1 x 2
##   lat                lon
##   <chr>              <chr>
## 1 1900-01-01 14:19:38 07:30:27
```

```
## # A tibble: 1 x 2
##   lat                lon
##   <chr>              <chr>
## 1 38:36:5.11590769747272E-12 8:35:49.9999999999972
```

A cleaning and transformation steps were performed on `lat` and `lon` variables to remove the special characters and scientific notation. For the values wrongs where there is a date among the coordinates, it was performed an data imputation based on another observations that has the same `region`, `district`, `municipality` and `parish`. After the cleaning steps, the values were transformed from GPS coordinates to decimals coordinates in order to be able retrieve historical data from nearest weather stations using the [RNOAA](#) package

The data imputation and transformation generated 8 NA's in `lat` and `lon` variables for parishes listed below:

```
## # A tibble: 8 x 6
##   region district municipality parish lat lon
##   <chr>   <chr>   <chr>      <chr>   <chr> <chr>
## 1 Alentejo Évora    Mora        Cabeção   <NA> <NA>
## 2 Alentejo Évora    Montemor-o-Novo Cortiçadas de Lavre   <NA> <NA>
## 3 Alentejo Évora    Montemor-o-Novo Ciborro   <NA> <NA>
## 4 Alentejo Évora    Mourão      Granja    <NA> <NA>
## 5 Alentejo Évora    Évora       Horta das Figueiras   <NA> <NA>
## 6 Alentejo Évora    Montemor-o-Novo Cortiçadas de Lavre   <NA> <NA>
## 7 Alentejo Évora    Estremoz    São Lourenço de Mamporcão <NA> <NA>
## 8 Alentejo Évora    Mora        Brotas     <NA> <NA>
```

In order to fixing this, the latitude and longitude values for these parishes were imputed directly from the localization data retrieved from the internet.

4.1.2 District

Mainland Portugal is divided into 18 districts and the variable `district` from `Forest Fires` dataset refer the place where occurred the fires. As seen in table @ref(tab:summary_data), this variable has 19 unique values, so there are some inconsistent data. The table below display the unique values for this variable:

```
## [1] "Viana do Castelo" "Porto"          "Vila Real"      "Bragança"
## [5] "Braga"            "Portalegre"     "Santarém"       "Viseu"
## [9] "Guarda"           "Leiria"         "Castelo Branco" "Aveiro"
## [13] "Évora"            "Faro"           "Coimbra"        "Viana Do Castelo"
## [17] "Lisboa"           "Beja"           "Setúbal"
```

As seen in table above, there are two references for the same district: *Viana do Castelo* and *Viana Do Castelo*. So a step of cleaning was performed into this variable values.

4.1.3 First Intervention and Extinction

The variables `firstInterv_date` and `firstInterv_hour` store the date and time that occurred the first intervention by authorities after the fire alert. As seen in table 4, these variables have a total of NA's values equals 214 and 215, respectively. In order to reduce these quantity, a data imputation were performed based on values of `extinction_date` and `extinction_hour` assumption that if there are values for extinction date and time it because some intervention was realized. After data imputation the quantity of NA's was reduced to 7 in both variables as can be seen below:

| ## | variable | q_zeros | p_zeros | q_na | p_na | q_inf | p_inf | type | unique |
|------|-------------------------------|---------|---------|------|------|-------|-------|-----------|--------|
| ## 1 | <code>firstInterv_date</code> | 0 | 0 | 7 | 0.09 | 0 | 0 | character | 318 |
| ## 2 | <code>firstInterv_hour</code> | 0 | 0 | 7 | 0.09 | 0 | 0 | character | 1209 |
| ## 3 | <code>extinction_date</code> | 0 | 0 | 9 | 0.12 | 0 | 0 | character | 319 |
| ## 4 | <code>extinction_hour</code> | 0 | 0 | 9 | 0.12 | 0 | 0 | character | 1201 |

The remaining quantity of NA's values in `firstInterv_date`, `firstInterv_hour`, `extinction_date`, and `extinction_hour` represent 0.9% and 1.2% respectively of the total of observations. As these values are relatively low, these observations were removed from dataset.

Alert Source

As can be seen in table below, the variable `alert_source` has 100% of values with NA's, so this variable were removed from dataset.

| ## | variable | q_zeros | p_zeros | q_na | p_na | q_inf | p_inf | type | unique |
|------|------------------|---------|---------|------|------|-------|-------|---------|--------|
| ## 1 | <code>var</code> | 0 | 0 | 7502 | 100 | 0 | 0 | logical | 0 |

4.2 Data Transformation

In the Forest Fires dataset, the variables `region`, `district`, `municipality`, `parish`, `origin`, `cause_type` are with the data type as `<character>` when the appropriated should be a `<factor>`. Thus, a step to transform these variables into the most appropriated data type was performed.

Besides the variables aforementioned, others also were transformed. The variables `alert_date`, `alert_hour`, `firstInterv_date`, `firstInterv_hour`, `extinction_date`, and `extinction_hour` contains date and time data, and thus, these variables were appropriated merged and transformed in POSIXct object in order to able to handle it as a date. The variables `alert`, `firstInterv` and `extinction` were created based on corresponding variables, and the ones were removed from the dataset.

4.3 Feature Engineering

Weather Data

As additional information, let's use weather data in order to build features that can help the models obtain better accuracy. The weather data can be obtained from the National Oceanic and Atmospheric Administration (NOAA) Climate Data Sources using [RNOAA](#) package which provides free access to National Climatic Data Center's (NCDC) archive of global historical weather and climate data in addition to station history information. These data include quality controlled daily, monthly, seasonal, and yearly measurements of temperature, precipitation, wind, and degree days as well as radar data and 30-year Climate Normals.

For the propose this analysis, it was created 5 new features: `tavg`, `tavg15d`, `tmax`, `tmin`, and `prcp` based on the following weather measurements:

| Measurement | Description |
|----------------------|---|
| <code>tavg</code> | the average temperature of day (degrees C) |
| <code>tavg15d</code> | the average temperature of the last 15 days (degrees C) |
| <code>tmax</code> | the maximum temperature of day (degrees C) |
| <code>tmin</code> | the minimum temperature od day (degrees C) |
| <code>prcp</code> | the precipitation (mm) |

In order to retrieve the weather data it was considered the alert date of fire. The sample of the first rows of created features it provided in table below:

```
## # A tibble: 6 x 6
##   alert          tavg tavg15d  tmax  tmin  prcp
##   <dtm>          <dbl>  <dbl> <dbl> <dbl> <dbl>
## 1 2015-03-24 17:01:00 12.3   11.1  19.1  5.7  11.1
## 2 2015-03-24 17:10:00 15.1   13.3  21.6  5.7   3
## 3 2015-03-24 21:40:00 12.3   11.1  19.1  5.7   3
## 4 2015-03-25 16:00:00 13.7   11.5  16.2  11.5  0.4
## 5 2015-03-12 17:20:00 11.1    9.85  16.7  4.9   0
## 6 2015-03-13 14:48:00 12.7   11.4  16.2  9.6   0
```

After load weather data into **Forest Fire** dataset, some steps of data imputation were performed to reduce the quantity of NA's and zero values. The reasoning for imputation was calculate the value based on other variables. For instance, `tavg` variable with NA or zero value, check if there is values for `tmax` and `tmin` and calculate the average temperature. For `tmax` variable with NA or zero value, check if there is values for `tavg` and `tmin` and calculate the maximum temperature, and so forth. Below it provided the summary of the new features after the data imputation:

```
##   variable q_zeros p_zeros q_na p_na q_inf p_inf   type unique
```

| | | | | | | | | | |
|------|---------|------|-------|---|---|---|---|---------|------|
| ## 1 | tavg | 8 | 0.11 | 0 | 0 | 0 | 0 | numeric | 335 |
| ## 2 | tavg15d | 56 | 0.75 | 0 | 0 | 0 | 0 | numeric | 1549 |
| ## 3 | tmax | 133 | 1.77 | 0 | 0 | 0 | 0 | numeric | 325 |
| ## 4 | tmin | 133 | 1.77 | 0 | 0 | 0 | 0 | numeric | 323 |
| ## 5 | prcp | 4694 | 62.57 | 0 | 0 | 0 | 0 | numeric | 138 |

Based on Features

The variable `alert` provides relevant information for the goal of this analysis. The quantity of unique values for this variable is 7313. This quantity can represent noise for the predictive model. For this reason, it was created two new features based on it: `alert_month` and `alert_period`. The first one is a numeric variable with the month of a fire alert. The latter one is an ordinal feature with 4 values *Morning*, *Afternoon*, *Night*, *Dawn* with a slot of 6 hours each one. After creation of these new features, the `alert` variable was removed from dataset.

Another new feature called `duration` was created based on `alert` and `extinction` variables. Its value is the elapsed time between fire alert and its extinction. We consider that information can be useful help to predict the fire cause type as rekindling.

After this process of feature engineering the **Forest Fires** dataset now he has 24 variables as against 21 from the original dataset. A summary for the new dataset is shown the table below:

| ## | variable | q_zeros | p_zeros | q_na | p_na | q_inf | p_inf | type |
|-------|--------------------|---------|---------|------|------|-------|-------|----------------|
| ## 1 | id | 0 | 0.00 | 0 | 0.00 | 0 | 0 | integer |
| ## 2 | region | 0 | 0.00 | 501 | 6.68 | 0 | 0 | factor |
| ## 3 | district | 0 | 0.00 | 0 | 0.00 | 0 | 0 | factor |
| ## 4 | municipality | 0 | 0.00 | 0 | 0.00 | 0 | 0 | factor |
| ## 5 | parish | 0 | 0.00 | 0 | 0.00 | 0 | 0 | factor |
| ## 6 | lat | 0 | 0.00 | 0 | 0.00 | 0 | 0 | character |
| ## 7 | lon | 0 | 0.00 | 0 | 0.00 | 0 | 0 | character |
| ## 8 | origin | 0 | 0.00 | 0 | 0.00 | 0 | 0 | factor |
| ## 9 | firstInterv | 0 | 0.00 | 0 | 0.00 | 0 | 0 | POSIXct/POSIXt |
| ## 10 | extinction | 0 | 0.00 | 0 | 0.00 | 0 | 0 | POSIXct/POSIXt |
| ## 11 | village_area | 5342 | 71.21 | 0 | 0.00 | 0 | 0 | numeric |
| ## 12 | vegetation_area | 2646 | 35.27 | 0 | 0.00 | 0 | 0 | numeric |
| ## 13 | farming_area | 5968 | 79.55 | 0 | 0.00 | 0 | 0 | numeric |
| ## 14 | village_veget_area | 1412 | 18.82 | 0 | 0.00 | 0 | 0 | numeric |
| ## 15 | total_area | 8 | 0.11 | 0 | 0.00 | 0 | 0 | numeric |
| ## 16 | tavg | 8 | 0.11 | 0 | 0.00 | 0 | 0 | numeric |
| ## 17 | tavg15d | 56 | 0.75 | 0 | 0.00 | 0 | 0 | numeric |
| ## 18 | tmax | 133 | 1.77 | 0 | 0.00 | 0 | 0 | numeric |
| ## 19 | tmin | 133 | 1.77 | 0 | 0.00 | 0 | 0 | numeric |
| ## 20 | prcp | 4694 | 62.57 | 0 | 0.00 | 0 | 0 | numeric |
| ## 21 | cause_type | 0 | 0.00 | 0 | 0.00 | 0 | 0 | factor |
| ## 22 | alert_month | 0 | 0.00 | 0 | 0.00 | 0 | 0 | factor |

| | | | | | | | |
|-------|--------------|---|------|--------|---|---|---------|
| ## 23 | alert_period | 0 | 0.00 | 0 0.00 | 0 | 0 | factor |
| ## 24 | duration | 4 | 0.05 | 0 0.00 | 0 | 0 | numeric |
| ## | unique | | | | | | |
| ## 1 | 7502 | | | | | | |
| ## 2 | 10 | | | | | | |
| ## 3 | 19 | | | | | | |
| ## 4 | 297 | | | | | | |
| ## 5 | 2270 | | | | | | |
| ## 6 | 5805 | | | | | | |
| ## 7 | 6213 | | | | | | |
| ## 8 | 5 | | | | | | |
| ## 9 | 7185 | | | | | | |
| ## 10 | 7120 | | | | | | |
| ## 11 | 590 | | | | | | |
| ## 12 | 1051 | | | | | | |
| ## 13 | 650 | | | | | | |
| ## 14 | 1375 | | | | | | |
| ## 15 | 1779 | | | | | | |
| ## 16 | 335 | | | | | | |
| ## 17 | 1549 | | | | | | |
| ## 18 | 325 | | | | | | |
| ## 19 | 323 | | | | | | |
| ## 20 | 138 | | | | | | |
| ## 21 | 4 | | | | | | |
| ## 22 | 12 | | | | | | |
| ## 23 | 4 | | | | | | |
| ## 24 | 598 | | | | | | |

4.4 Data Analysis

Understanding the structure of the data, the distribution of the variables, and the relationships between them is fundamental to build a solid model.

Based on the dataset we plotted some graphics that helped us to get some conclusions and showed a general notion about the problem of the forests fires.

Figure 4.1 depicts the bar graphic of the distribution of forests fires during 2015. The x-axis represents the months along the year Of 2015 and the y-axis represents the total of fires that occurred by month.

This graphic showed us that july and august are the months with the largest occurrences and the period between march and september needs more attention. Probably we will consider the variable month as important to the analisis.

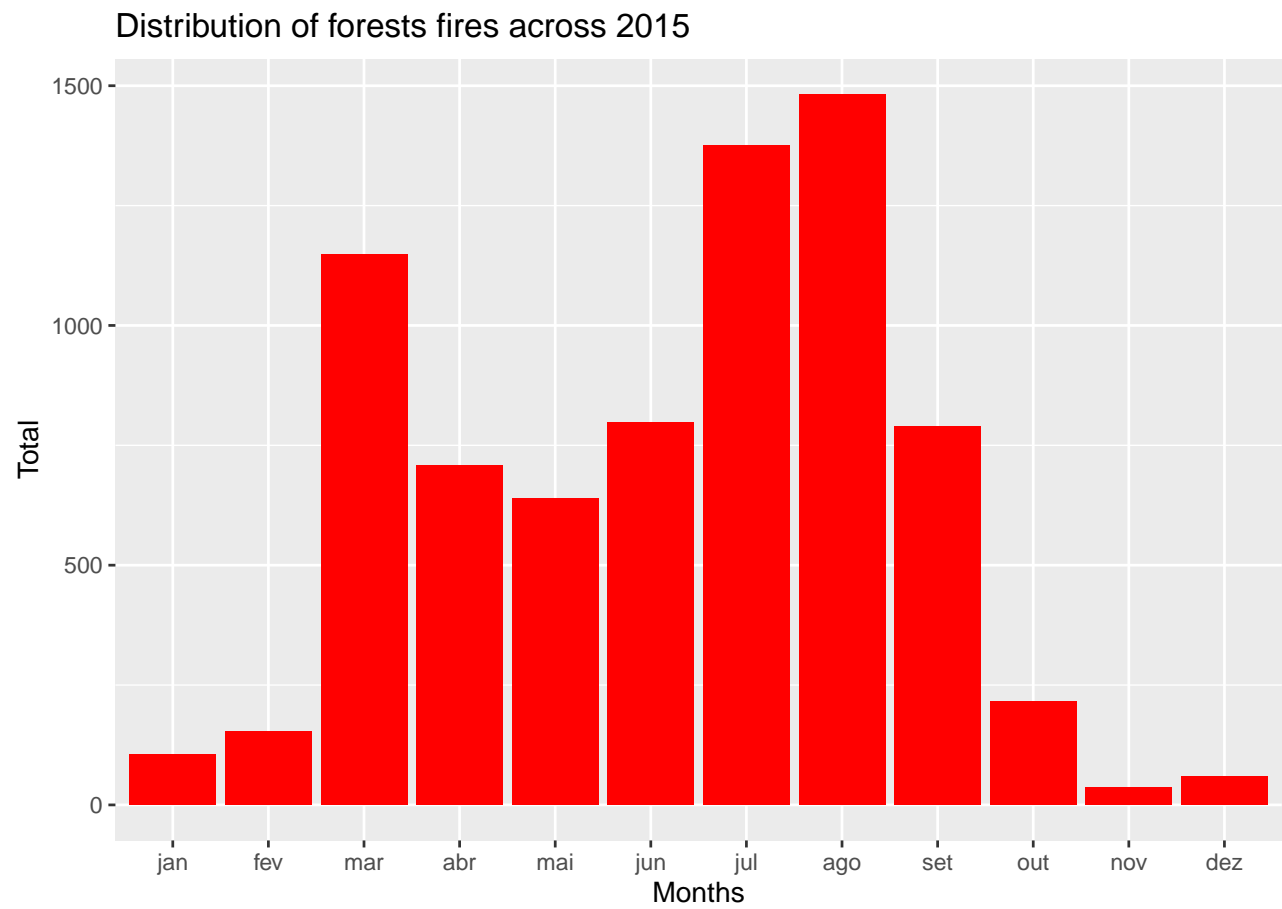


Figure 4.1: Barplot of the distribution of forests fires during 2015.

4.4.1 Region and District

These two variables represents the areas of the occurrences and we can observe by summary that the variable region has a lot of NA 's (501) that corresponds to 6,67% of the total of lines. The distribution of the occurrences by region can be observed in the grafic 4.2. The y-axis represents the regions and the x-axis represents the total of fires that occurred by region.

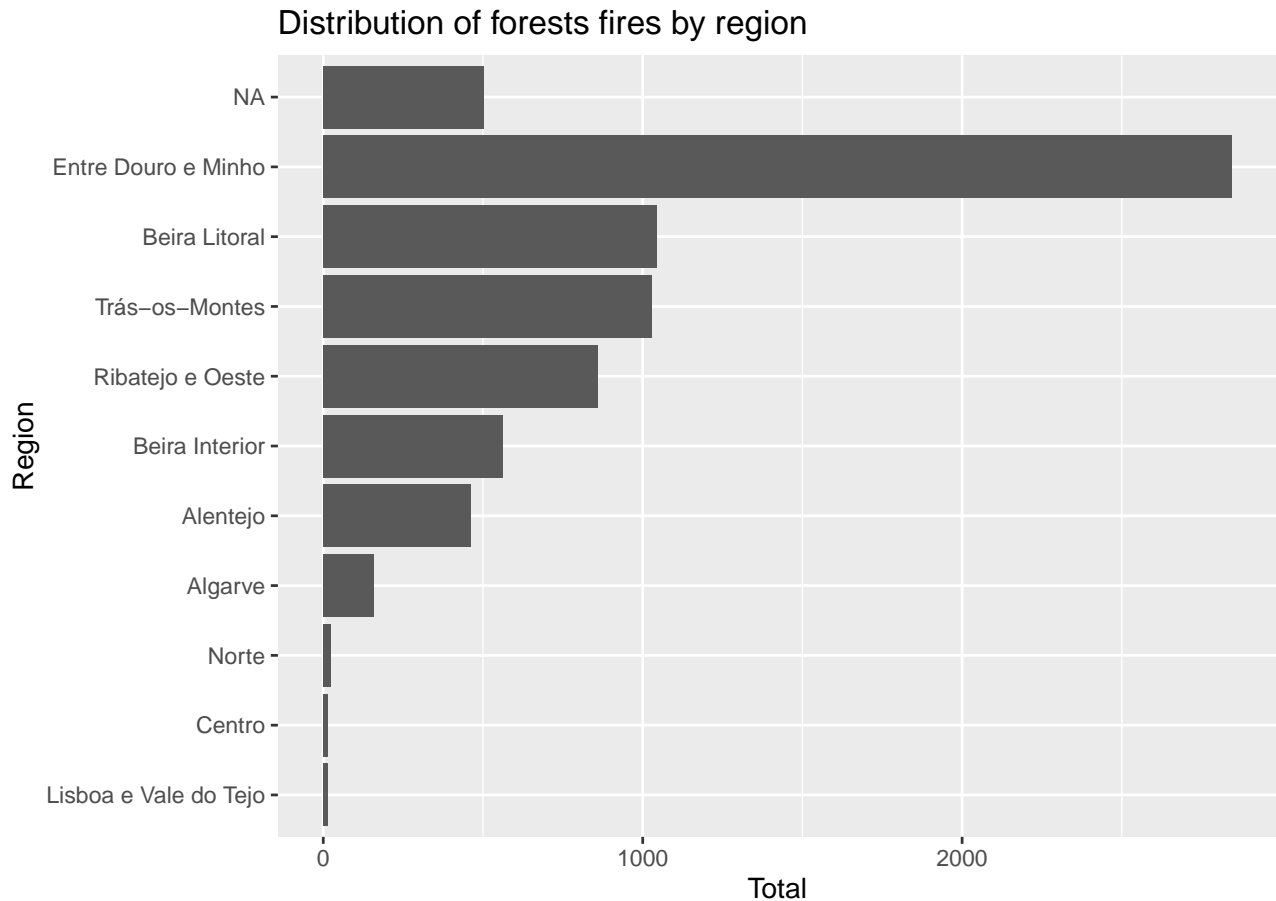


Figure 4.2: Barplot of the distribution of forests fires by regions.

Observing this grafic we saw that Entre Douro e Minho was the region with more forests fires and other regions like Centro, Lisboa and Norte were with minimum occurrences.

The relationship between region, month and causes is represented on figure 4.3. The x-axis includes the diferent regions, y-axis represents the months of ocurrences and the variable cause is showed by colours listed on the labels.

Another important graphic is the figure 4.4 that corresponds to the distribution of forests fires by district. The y-axis represents the districts and the x-axis represents the total of fires that occurred by region.

This graphic indicates that Porto and Viana do Castelo were the districts with more forests fires.

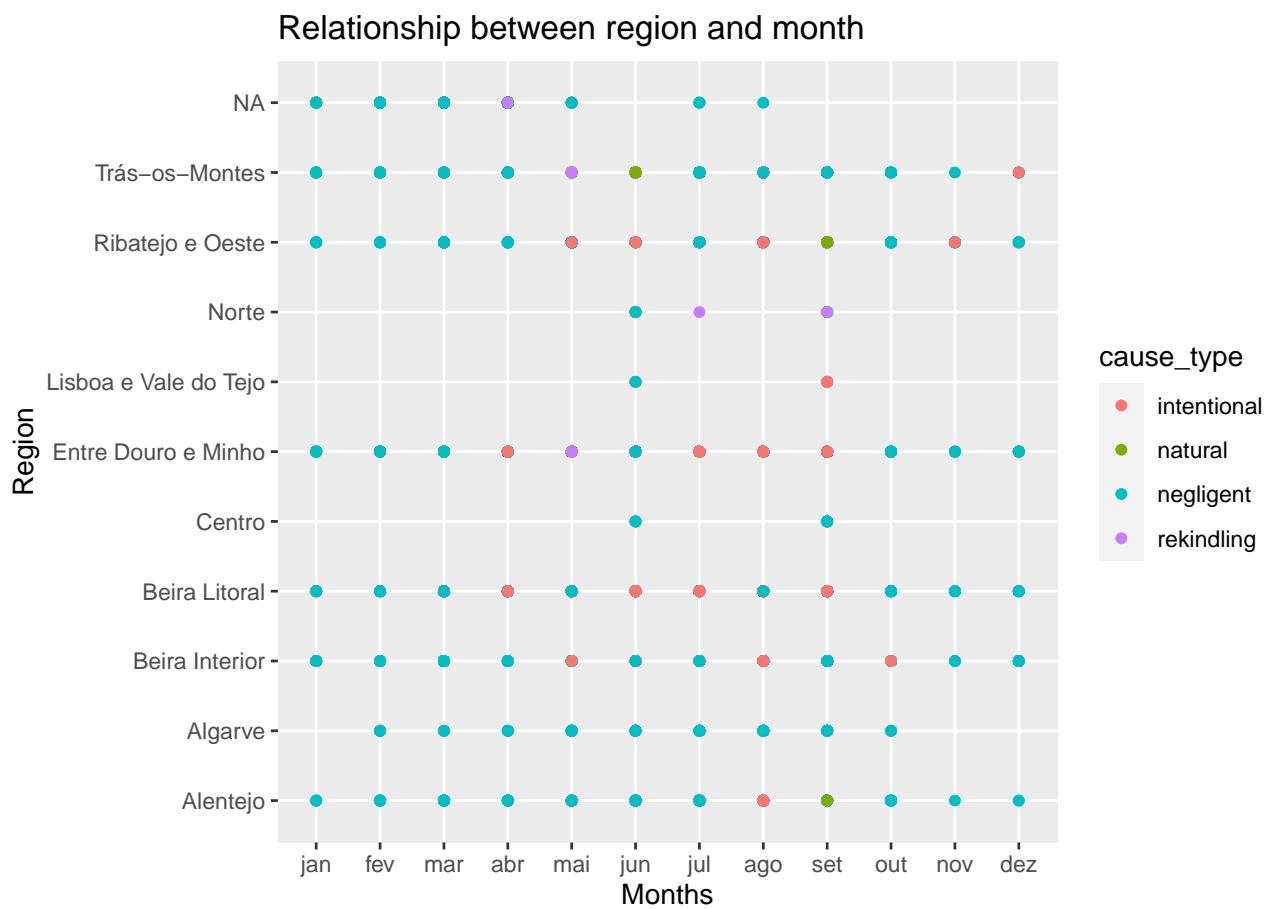


Figure 4.3: Distribution of forests fires relating region, month and causes.

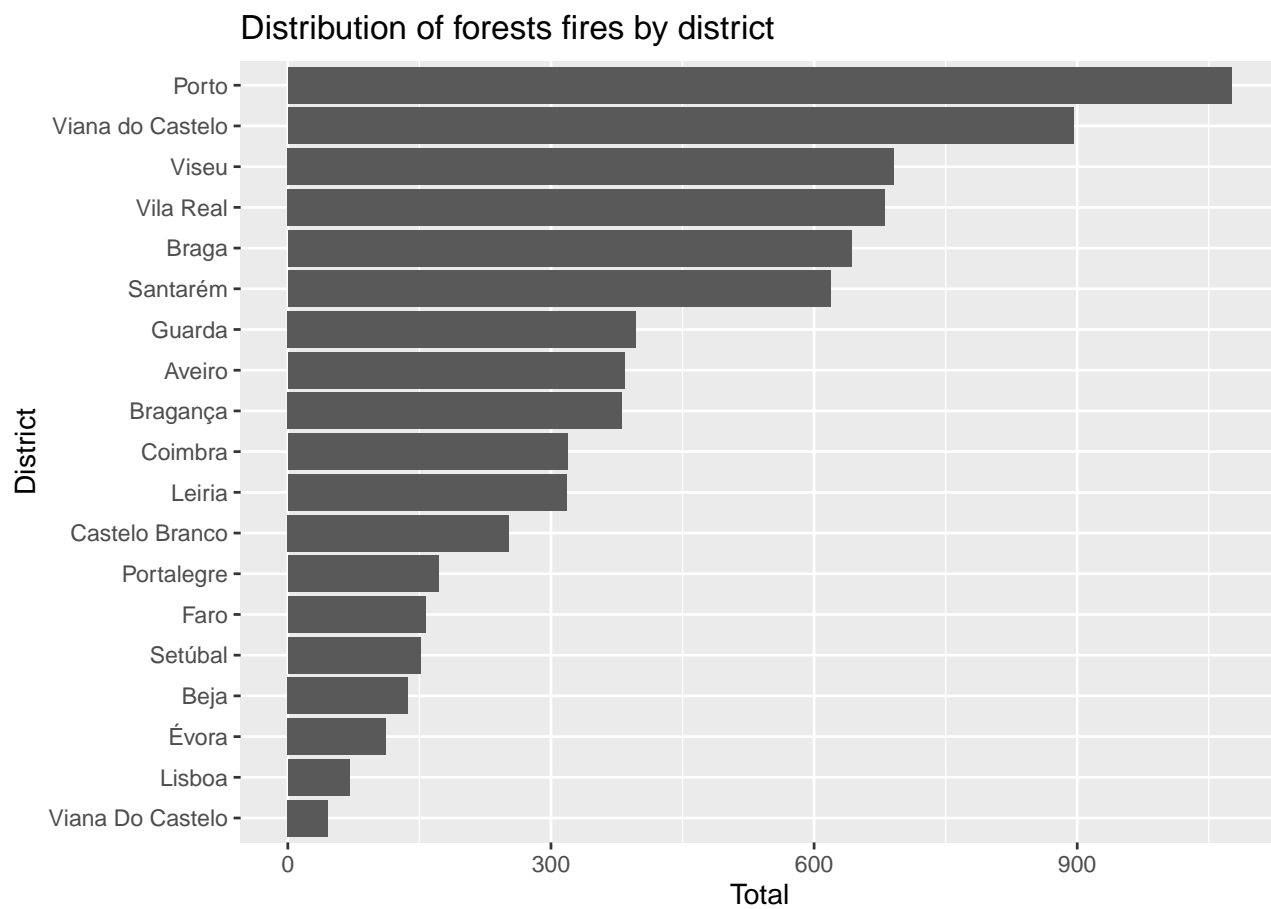


Figure 4.4: Barplot of the distribution of forests fires by districts.

The relationship between district, month and causes is represented on figure 4.5. The x-axis includes the different districts, y-axis represents the months of occurrences and the variable cause is showed by colours listed on the labels.

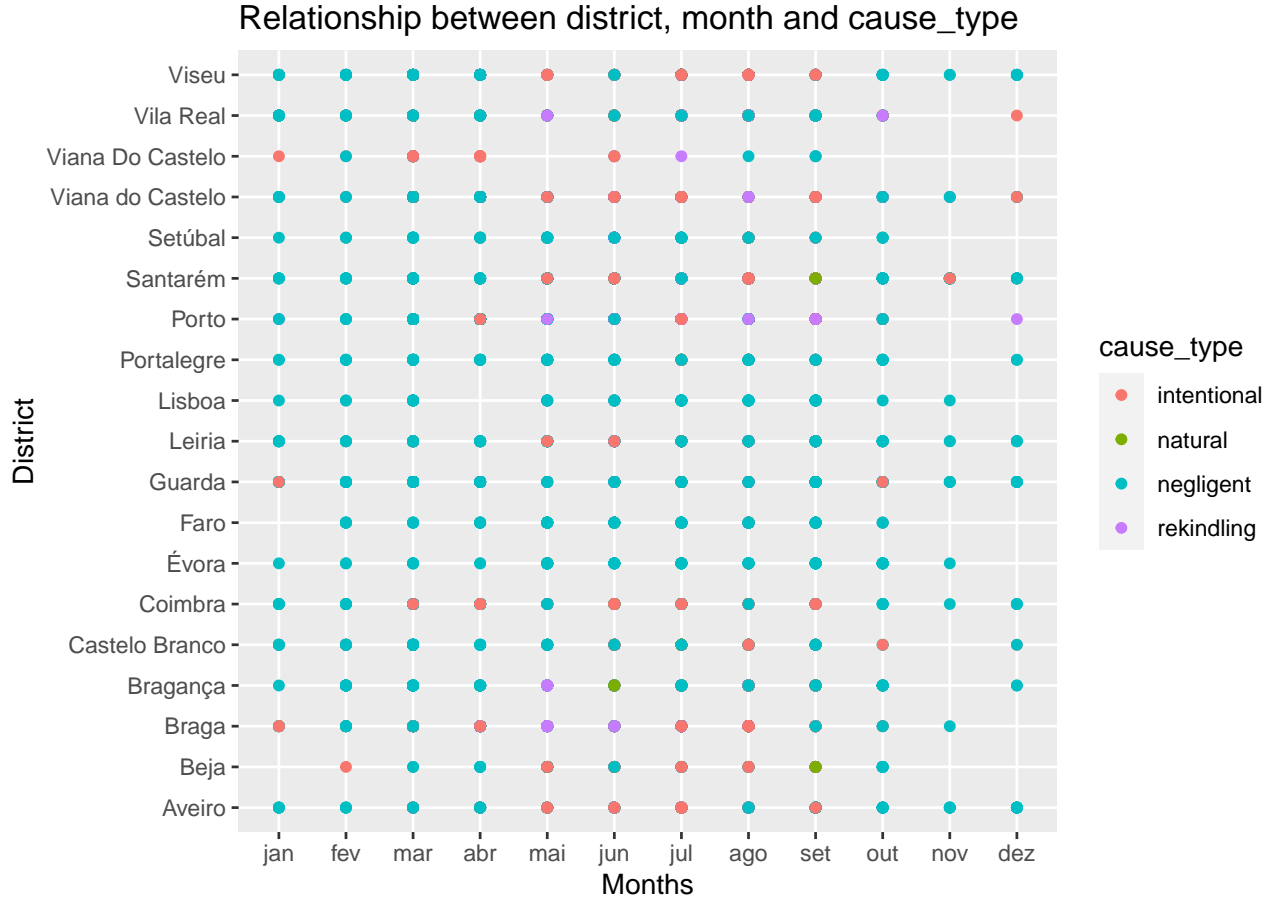


Figure 4.5: Distribution of forests fires relating district, month and causes.

4.4.2 Origin

Origin informs the reason that the fire started and apparently appears to be an important observation for evaluation. It can be observed in figure 4.6.

On the x-axis are listed the different origins and on y-axis represents the total of fires that occurred.

The firepit was the origin of the most forests fires comparing it with the other origins.

4.4.3 Cause type

This is the variable to be predicted by the model that will be chosen. It shows the four causes of the occurrences: intentional, natural, negligent and rekindling. They can be observed in the

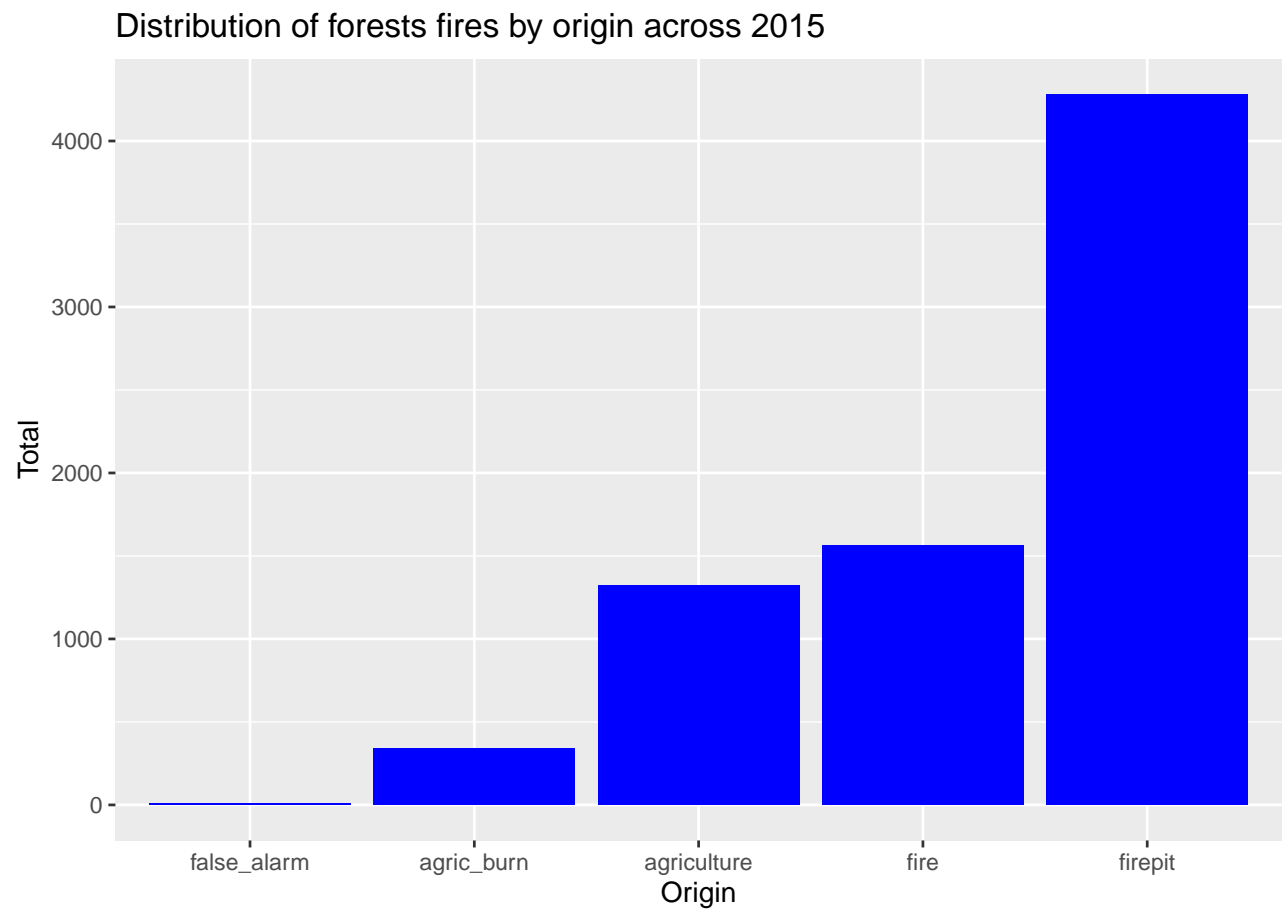


Figure 4.6: Barplot of the distribution of forests fires by origins.

graphic 4.7 below. On the x-axis are listed the different causes and on y-axis represents the total of fires that occurred.

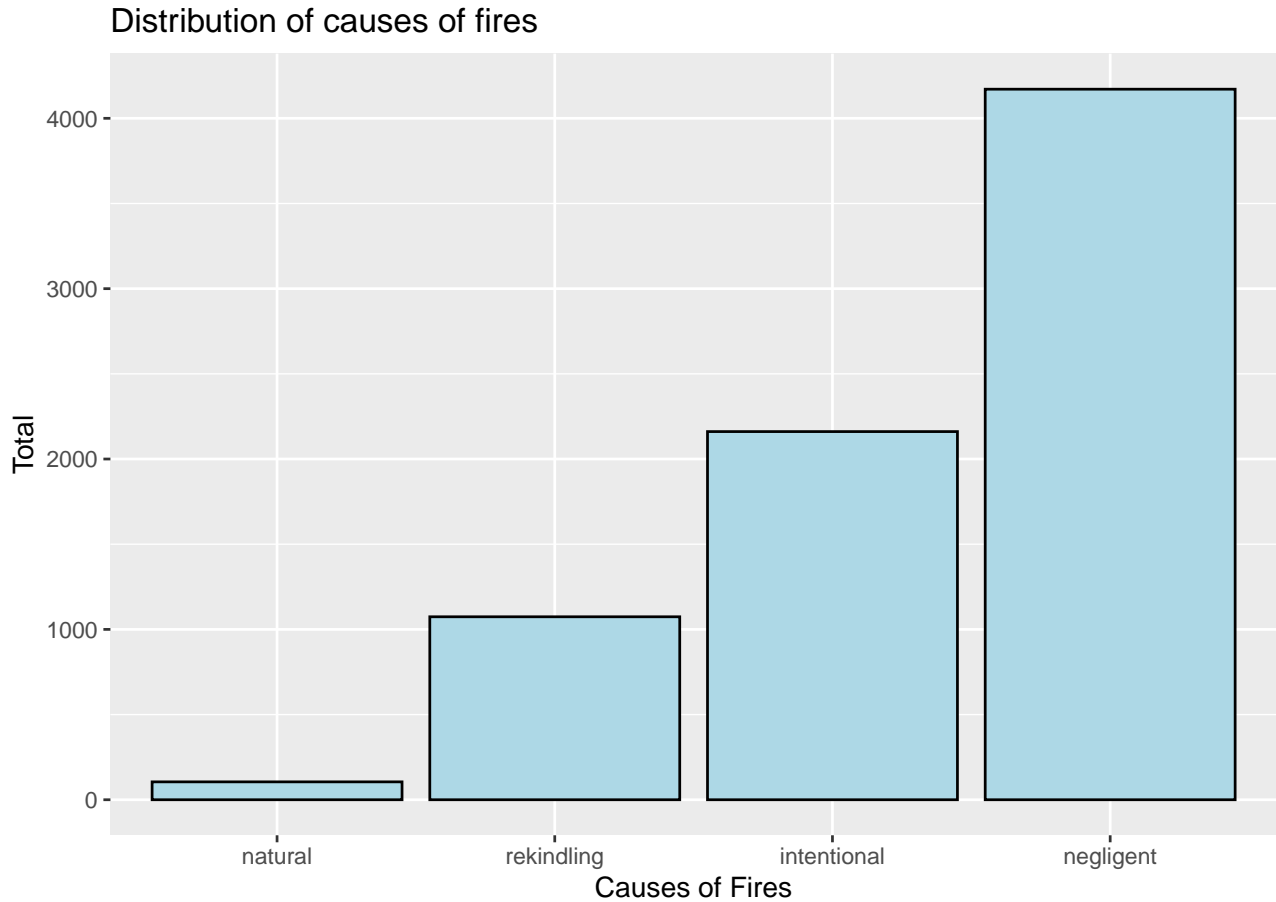


Figure 4.7: Barplot of the distribution of forests fires by causes.

A thing that calls our attention is the difference between the number of fires that were caused by negligence and by natural causes. The number of forest fires caused intentionally were almost the half of the negligent causes what is an alarmant number.

4.4.4 TAVG, TAVG15d, TMax and TMin

4.4.5 PRCP

4.5 Dimensionality Reduction

Dimensionality reduction consists of the process of reducing the number of features in a dataset in order to eliminate the noise and features redundancy and create a more compact projection of the data. After previous preprocessing steps performed, the **Forest Fires** dataset has now 24 variables and some of them are redundant or irrelevant to the context of this problem.

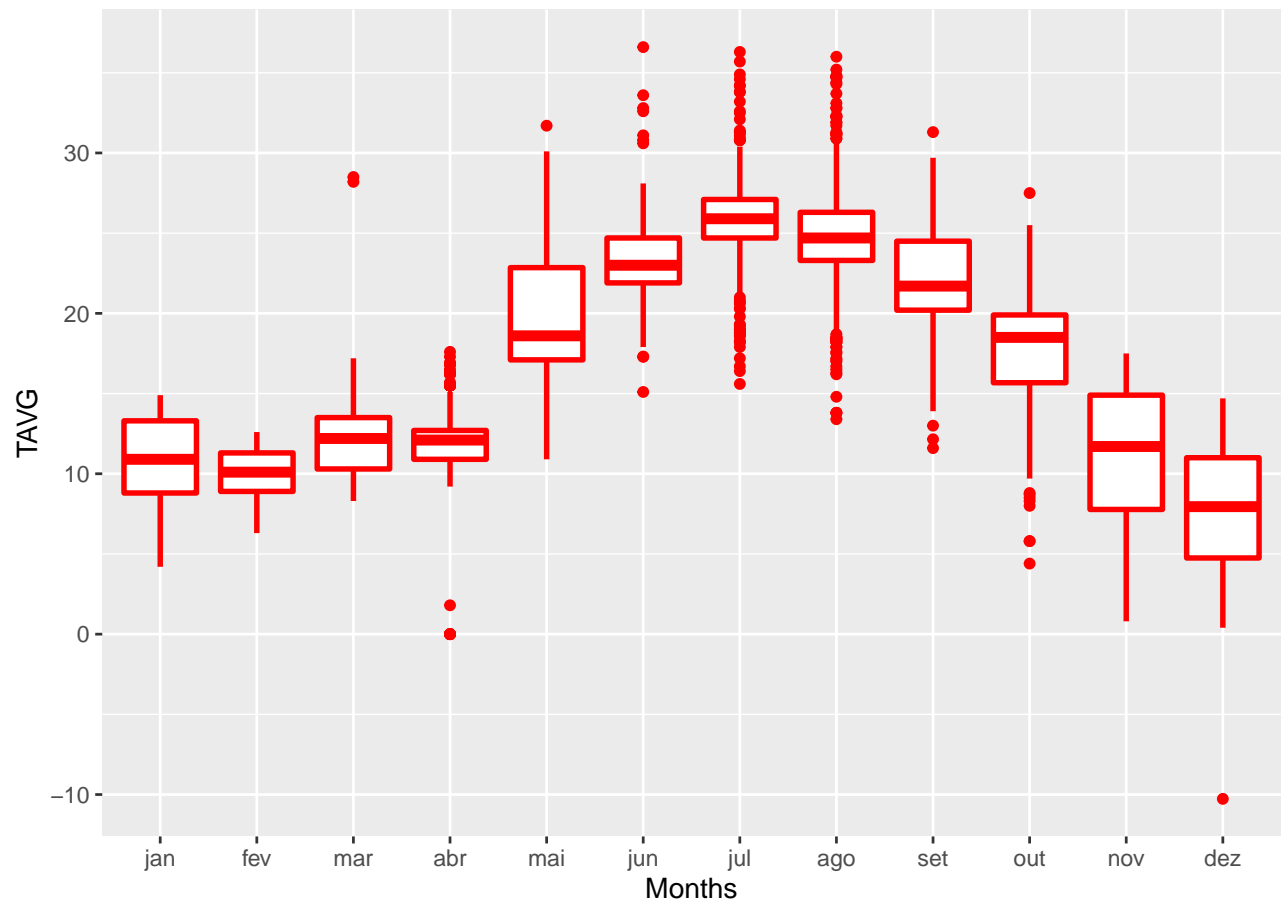


Figure 4.8: GeomPoint of Average Temperature by month

The variables `region`, `district`, `municipality` and `parish` has a high correlation once that one is a subdivision of another. A set of parishes is part of a municipality. In turn, a set of municipalities is part of a district. Thus, as the variable `region` has a lot of number of NA, and the variables `municipality` and `parish` are subdivisions of districts, they are irrelevant/redundant for the context and they were removed from the dataset.

The variables `village_veget_area` and `total_area` are redundants because contains a somatary of values of the variables `village_area`, `vegetation_area` and `farming_area`. Thus, they were removed from the dataset.

The variables `lat` and `lon` were important to retrieve the weather data from the nearest station. Once these data were inserted into the dataset, these variables became irrelevant to the context and they were removed from the dataset.

The variables `tmax` and `tmin` were important in order to performe data imputation into the `tavg` variable. After that they became irrelevant to the context and they were removed from the dataset.

The variables `id`, `firstInterv`, and `extinction` were considered irrelevants to the context once their values dont't provide useful information that can help to predict cause of forest fire, thus, these variables were removed from the dataset.

Thus, the dimensionality of the **Forest Fires** was reduced and has now 12 features considered relevants to the context. These variables are displyed below:

```
## [1] "district"      "origin"         "alert_month"    "alert_period"
## [5] "duration"      "village_area"   "vegetation_area" "farming_area"
## [9] "tavg"          "tavg15d"        "prcp"           "cause_type"
```

4.6 Feature Selection

Feature selection refers to techniques that select a subset of the most relevant features for a dataset.

Once made the dimensionality reduction, it needs to check which the previously selected variables are really relevant. For this, it was used the Recursive Feature Elimination (RFE), the most widely used wrapper-type feature selection algorithm.

RFE is popular because it is easy to configure and use and because it is effective at selecting those features in a training set that are more or most relevant in predicting the target variable.

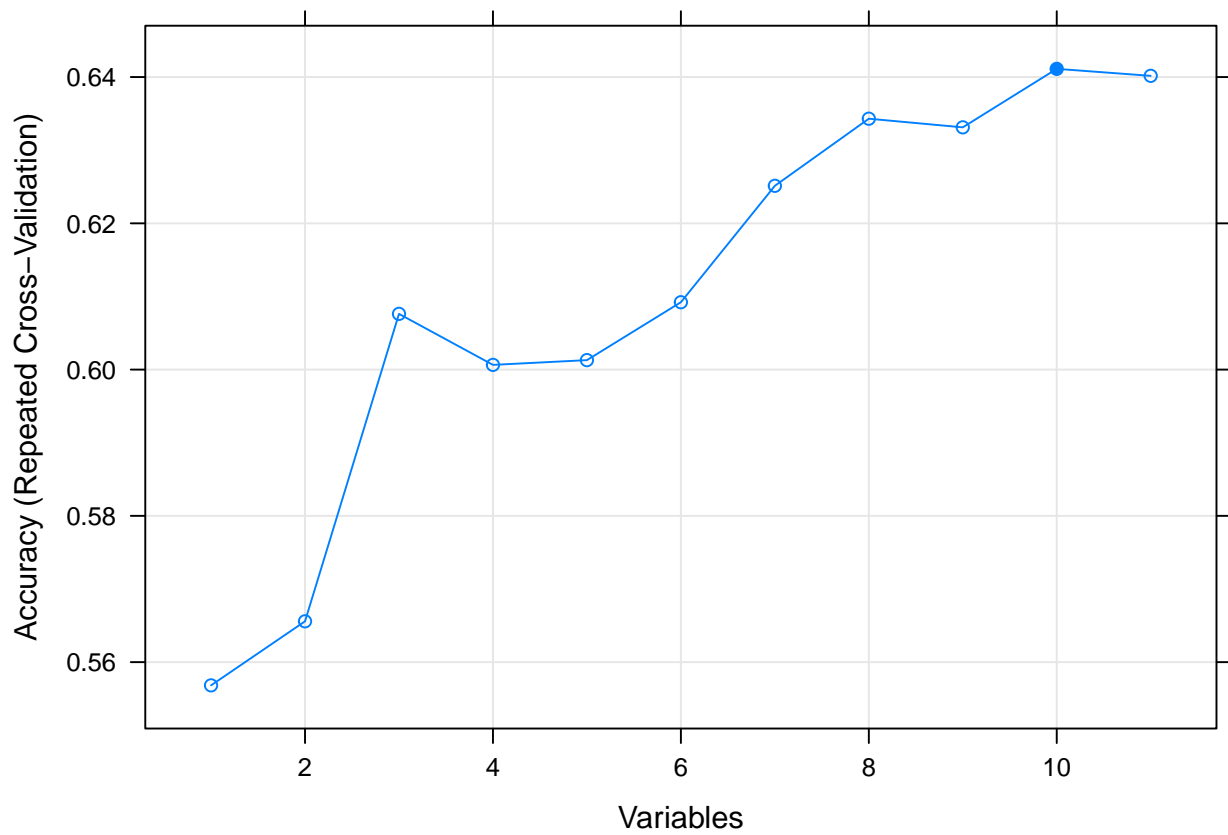
There are two important configuration options when using RFE: the choice in the number of features to select and the choice of the algorithm used to help choose features.

- **size**: a integer vector for the specific subset sizes that should be tested (which need not to include `ncol(x)`)
- **rfeControl**: a list of options that can be used to specify the model and the methods for prediction, ranking etc.

In order to performe the feature selection, it was used the RFE algorithm implemented by `caret` package. The hyperparameters values used was `size=c(1:11)` that correspond all the predictors features and `rfeControl(functions=rfFuncs, method="repeatedcv", repeats=5)` that mean the Random Forest method was use with 5 rounds of 10-Fold Cross-Validation.

The result of execution of RFE algorithm it provided below:

```
##
## Recursive feature selection
##
## Outer resampling method: Cross-Validated (10 fold, repeated 5 times)
##
## Resampling performance over subset size:
##
## Variables Accuracy   Kappa AccuracySD KappaSD Selected
##      1    0.5568 0.05332   0.008738 0.02409
##      2    0.5656 0.12550   0.015684 0.03324
##      3    0.6076 0.29187   0.017560 0.03127
##      4    0.6006 0.31349   0.019507 0.03202
##      5    0.6013 0.30798   0.025636 0.04427
##      6    0.6092 0.31493   0.018765 0.03178
##      7    0.6251 0.33683   0.016502 0.02639
##      8    0.6343 0.34991   0.016802 0.03035
##      9    0.6331 0.35030   0.017825 0.03092
##     10    0.6411 0.35921   0.016906 0.03076      *
##     11    0.6402 0.35563   0.015462 0.02840
##
## The top 5 variables (out of 10):
##      district, origin, alert_month, tavg15d, alert_period
```

The variables selected were:

```
## [1] "district"      "origin"        "alert_month"   "tavg15d"
## [5] "alert_period"  "tavg"          "village_area"  "farming_area"
## [9] "vegetation_area" "duration"
```

Chapter 5

Prediction Models

Predictive modeling is a technique that uses mathematical and computational methods to predict an event or result. The model is used to predict a result in some future state or moment based on changes in model inputs. The model parameters help to explain how the model inputs influence the result.

5.1 Distance-based Approach

5.1.1 K-Nearest Neighbor

Distance-based algorithms are machine learning algorithms that classify queries by computing distances between these queries and a number of internally stored exemplars. Exemplars that are closest to the query have the largest influence on the classification assigned to the query. The distance-based algorithm used in this study was the k-nearest neighbor algorithm (kNN).

5.2 Probabilistic Approach

Discriminant analysis is used to predict the probability of belonging to a given class (or category) based on one or multiple predictor variables. It works with continuous and/or categorical predictor variables.

Compared to logistic regression, the discriminant analysis is more suitable for predicting the category of an observation in the situation where the outcome variable contains more than two classes. Additionally, it's more stable than the logistic regression for multi-class classification problems.

5.2.1 Naive Bayes

According to Bayes' theorem, it is possible to find the probability that a certain event will occur, given the probability of another event that has already occurred. Naive Bayes is a particular class of Bayesian classifiers that predicts the probability that a case belongs to a certain class. Due to its simplicity and high predictive power, it is one of the most used algorithms. This algorithm assumes that there is no dependency relationship between the attributes. However, this is not always possible. The algorithm reads the database and builds a probability table. In Bayesian classification, the main interest is to find the posterior probabilities, the probability of a label given some observed features.

5.2.2 Logistic Regression

5.3 Mathematical Formulas

5.3.1 Linear Discriminants Analysis (LDA)

Linear discriminant analysis (LDA): Uses linear combinations of predictors to predict the class of a given observation. Assumes that the predictor variables (p) are normally distributed and the classes have identical variances (for univariate analysis, $p = 1$) or identical covariance matrices (for multivariate analysis, $p > 1$).

The LDA algorithm starts by finding directions that maximize the separation between classes, then use these directions to predict the class of individuals. These directions, called linear discriminants, are a linear combinations of predictor variables.

LDA assumes that predictors are normally distributed (Gaussian distribution) and that the different classes have class-specific means and equal variance/covariance.

Before performing LDA, consider:

Inspecting the univariate distributions of each variable and make sure that they are normally distributed. If not, you can transform them using log and root for exponential distributions and Box-Cox for skewed distributions. removing outliers from your data and standardize the variables to make their scale comparable. The linear discriminant analysis can be easily computed using the function `lda()` [MASS package].

5.3.2 Penalized Discriminants Analysis

5.4 Logical Approaches

5.4.1 Decision Trees

The Decision Tree classification method works as a tree-shaped flowchart, where each node indicates a test done on a value. The connections between the nodes represent the possible

values of the upper node test, and the leaves indicate the class to which the record belongs. After the decision tree is assembled, to classify a new record, just follow the flow in the tree starting at the root node until reaching a leaf. Due to the structure they form, decision trees can be converted into Classification Rules.

5.4.2 Tree Bag

5.5 Optimization Approaches

5.5.1 Neural Networks

A neural network is an adaptive system that learns using interconnected nodes or neurons in a layered structure that resembles the human brain. A neural network can learn from the data - so it can be trained to recognize patterns, classify data and predict future events.

A neural network divides the input into layers of abstraction. He can be trained using many examples to recognize patterns in speech or images, for example, just like the human brain does. Their behavior is defined by the way their individual elements are connected and the strength, or weights, of those connections. These weights are automatically adjusted during training according to a specified learning rule until the artificial neural network performs the desired task correctly.

5.5.2 SVM

It is used for both classification and prediction tasks. It consists of separating classes that can be separated by a straight line, called linearly separated classes. The model tries to trace the separation based on the best distance between the closest points. There are variations of SVM, such as the Kernell trick, which allows applying SVM to a set of nonlinearly separable data. Support vector machines for binary or multiclass classification.

Linear

Radial

Polinomial

5.6 Ensemble Approaches

5.6.1 Random Forests

Random forest is a supervised learning algorithm which is used mainly used for classification problems. This algorithm creates decision trees on data samples and then gets the prediction

from each of them and finally selects the best solution by means of voting. It gets a random sample with replacement from the training set, select some features at random and reduce dimensionality of the set, accordingly and train a tree model without pruning. It predicts the class obtained by majority vote averaging the output of each tree.

5.6.2 XGBoost

Chapter 6

Conclusions, Shortcomings and Future Work

Chapter 7

References

https://www.mathworks.com/?s_tid=gn_logo

(Citeable URL: https://ir.library.oregonstate.edu/concern/graduate_thesis_or_dissertations/zw12z7835)