FACULDADE DE ENGENHARIA DA UNIVERSIDADE DO PORTO

Sizing of forest fire initial attack suppression crews

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MESTRADO INTEGRADO EM ENGENHARIA ELECTROTÉCNICA E DE COMPUTADORES

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24 de Junho de 2019

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Abstract

Forest fires are a major problem in Portugal, consuming large hectares of the territory in recent years and threatening resources, houses and human lives. There is a structural problem of territorial organization that is being revealed as a serious threat to the safety of populations and the development of the country.

Through data of the critical phase of fires in Portugal, the goal of this dissertation is to compare the existing scenario of crews allocated in fire departments with new methods of allocation of teams but also see if the crews available nowadays are enough for the needs of the region. We specifically focus on the district of Porto and the Charlie phase of the years 2001 till 2012, but this can be replicated for past and future years and also to other regions. In order to do this, two factors were taken into account, the number of simultaneous occurrences in the area of intervention of each fire department and also the burned area in each occurrence. The data available was divided into two datasets, one with all the occurrences and the information about them and the other dataset with the area of intervention of each fire department. Both datasets were treated and then merged with the useful information for our problem. This final dataset had, for each occurrence, their location, type of fire, date and time information about alert and extinction, burned area and which fire department was in charge of them. An R code was then developed in order to tell us what was the number of simultaneous occurrences in each step of the period in analysis and what was the burned area per fire department area of intervention. With the results from this code, the allocation of the crews available on the district was made using two methods, first having into account the risk of simultaneous occurrences and then the risk of burned area potential per fire department. The results showed that the number of crews available in the district is not enough and that they could also be distributed differently.

We also decided to see if help between neighbor fire departments was possible, having made a case study with five fire departments of the district. After considering that help was possible, the number of crews available for each fire department to control the occurrences in their area was not only their crews but also the crews from the neighbor fire departments. This help between neighbors made that the lack of crews in the district could be filled if neighbor fire departments crews were available to help.

Resumo

Os incêndios florestais são um grande problema em Portugal, consumindo grandes hectares do território nos últimos anos e ameaçando recursos, casas e vidas humanas. Existe um problema estrutural de organização territorial que está-se a revelar como uma séria ameaça à segurança das populações e ao desenvolvimento do país.

Através dos dados da fase crítica dos incêndios em Portugal, o objectivo desta dissertação é comparar o cenário existente de alocação de equipas nas corporações de bombeiros com novos métodos de alocação de equipas mas também ver se as equipas disponíveis hoje em dia são suficientes para as necessidades da região. Concentramo-nos especificamente no distrito do Porto e na fase de Charlie dos anos 2001 a 2012, mas podendo replicar para os anos passados e futuros e também para outras regiões. Para isso, foram considerados dois fatores, o número de ocorrências simultâneas na área de intervenção de cada corporação de bombeiros e também a área ardida em cada ocorrência. Os dados disponíveis estavam divididos em dois conjuntos de dados, um com todas as ocorrências e as informações sobre elas e o outro conjunto de dados com a área de intervenção de cada corporação de bombeiros. Ambos os conjuntos de dados foram tratados e depois juntos com as informações úteis para o nosso problema. Este conjunto de dados final tinha, para cada ocorrência, sua localização, tipo de incêndio, data e hora de alerta e extinção, área ardida e qual corporação de bombeiros estava a cargo da ocorrência. Um código em R foi depois desenvolvido para nos dizer qual era o número de ocorrências simultâneas em cada step do período em análise e qual era a área ardida por área de intervenção de cada corporação de bombeiros. Com os resultados deste código, a alocação das equipas disponíveis no distrito foi feita através de dois métodos, primeiro tendo em conta o risco de ocorrências simultâneas e, em seguida, o potencial do risco de área ardida por corporação de bombeiros. Os resultados mostraram que o número de equipas disponíveis no distrito não é suficiente e que os mesmos também poderiam ser distribuídos de forma diferente.

Decidiu-se também ver se entreajuda entre corporações vizinhas era possível, tendo-se feito um estudo de caso com 5 corporações de bombeiros do distrito. Depois de considerar que a entreajuda era possível, o número de equipas disponíveis para cada corporação controlar as ocorrências na sua área de actuação não era apenas as suas equipas, mas também as equipas das corporações vizinhas. Essa entreajuda entre vizinhos fez com que a falta de equipas no distrito pudesse ser colmatada se as equipas das corporações vizinhas estivessem disponíveis para ajudar.

Agradecimentos

Em primeiro lugar gostaria de agradecer ao meu orientador, professor Abílio Pereira Pacheco, por toda a ajuda que deu, por ter estado sempre disponível e por sempre me ter incentivado a ir mais longe com esta dissertação. Um obrigado também ao meu co-orientador, professor Jorge Grenha, e ao Guilherme Torres e Afonso Ungaro pelo trabalho desenvolvido em conjunto na elaboração do código de simultaneidade e área ardida.

Em segundo lugar, ao engenheiro Paulo Bessa do AGIF por todos dados disponiblizados referentes às áreas de actuação das corporações do distrito do Porto, dados imprescindíveis para a realização deste trabalho. Um agradecimento também ao engenheiro Rui Almeida do ICNF pelos dados referentes às ocorrências no país.

O agradecimento mais importante vai para a minha família, principalmente aos meus pais. Obrigado por tudo o que me deram e pelo que fizeram para que eu sempre pudesse cumprir os meus sonhos. Sem eles nunca teria chegado onde cheguei.

Por último, e não menos importante, aos meus amigos que sempre estiveram presentes durante esta longa caminhada. Não irei agradecer um a um, mas eles sabem quem são.

Contents

List of Figures

List of Tables

Abbreviations and symbols

AFN	*Autoridade Florestal Nacional* - National Forest Authority
AGIF	*Agência para a Gestão Integrada de Fogos Rurais* - Integrated Management of Rural Fires Agency
ANPC	*Autoridade Nacional de Proteção Civil* - National Civil Protection Authority
BHE	Being Held
BV	*Bombeiros Voluntários* - Volunteer Firefighters
CA	Crews Allocated
EA	Extended Attack
ECIN	*Equipas de Combate a Incêndios* - Firefigthing Crews
EIP	*Equipas de Intervenção Permanentes* - Permanent Intervention Crews
ELAC	*Equipa Logística de Apoio ao Combate* - Logistic Crew for Suppression Support
DECIF	*Dispositivo Especial de Combate a Incêndios Florestais* - Special Firefighting Device
DON	*Diretiva Operacional Nacional* - National Operational Directive
ha	Unit of hectare
IA	Inital Attack
ICNF	*Instituto da Conservação da Natureza e das Florestas* - Nature and Forest Conservation Institute
INE	*Instituto Nacional de Estatística* - National Institute of Statistics
PR	Proportional Representation
RBA	Risk of Burned Area
RBAP	Risk of Burned Area Potential
RSO	Risk of Simultaneous Occurrences
UCO	Under Control
VCI	*Veículo de Combate a Incêndios* - Firefigthing Vehicle
VFCI	*Veículo Florestal de Combate a Incêndios*- Firefigthing Forest Vehicle
VLCI	*Veículo Ligeiro de Combate a Incêndios* - Light Firefigthing Vehicle

Chapter 1

Introduction

1.1 Context and motivation

This topic fits in the *Resolução do Conselho de Ministros* nº 159/2017, point b), and therefore, with the more immediate needs of the *Agência para a Gestão Integrada de Fogos Rurais* (AGIF), being also included in the initial goals of CoLAB ForestWISE (collaborative laboratory).

Forest fires are, unfortunately, well known for the population of Portugal. Every year, mainly in the Summer, the tv news go into this topic. The fires end up consuming large hectares of land and resources of our country, sometimes destroying houses and tragically taking lives. This is due not only to climate changes, but also to a failure in prevention, either in the cleaning of the forest or in the organization of the territory itself. Lastly, the lack of adequate training of those involved in suppression sometimes makes the situation worse.

The best way to fight a forest fire directly is in the moments following its ignition. After the growth of the fire, the direct attack is not effective, and so the firefighters need to be opportunistic, waiting for wind changes or other weather changes, etc. In this way, the initial attack (IA) is the most crucial moment of the suppression and must be in force and fast, being optimized to the best possible.

1.2 Dissertation approach

Initially, a simultaneity analysis of occurrences in a given area and in a given time interval will be done through a database with all historical occurrences. The objective is to determine the allocation of suppression crews (crews of five firefighters with a *veículo ligeiro de combate a incêndios* (VLCI)) to local firefighting centers in Portugal (e.g., fire departments), more specifically in the district of Porto, in order to obtain coverage of the occurrences, collectively, by the nearest and neighboring centers. Taking into account the historical occurrences, it is intended to compare the existing scenario (as-is) with a new scenario, optimized in order to minimize the number of suppression crews, maximizing the coverage of occurrences from the nearest (existing) local centers.

1.3 Dissertation outline

This dissertation starts with a review of literature about fire management, both prevention and suppression, the life cycle of a fire and also methods used in the allocation of seats. The third chapter explains all the manipulation done with the data that was available to extract the desired information to this work, a small case study and data analysis and also the methods that were used. In chapter four, the results are presented and then discussed and compared to the present. In the fifth and final chapter, conclusions are drawn and some limitations and future work are described.

Chapter 2

Literature review

2.1 Fire management

Fire Management is defined as all the activities that are concerned with the protection of people, property and forest areas from wildfire and also the use of prescribed burning to better manage the forest, all made in a way that considers environmental, social, and economic criteria (Merrill and Alexander 1987).

Social, economic and political institutions determine the objectives of fire management organizations. These programs are divided into two categories, prevention and suppression. They include measures to reduce the number of people-caused fires, detection systems that find fires while they are smaller and initial attack systems to contain them, preventing them from becoming larger and burning bigger areas, and also systems that try to minimize the damage from large fires that were not controlled by the initial attack (Martell 2001, Pacheco et al. 2012).

Fire management systems can be implemented in order to predict when and where those fires are more likely to happen, rearranging the available resources to the areas closer to that prediction (Martell 2001, Pacheco et al. 2015).

2.1.1 Fire prevention

Fire prevention consists of all the activities conducted in order to prevent wildfires from happening. As said previously, community prevention and fuel treatment are some of them (Pacheco et al. 2014).

Community prevention tries to teach people to avoid certain type of actions that can cause fire hazard and be the trigger for a wildfire, such as debris from bushfires or uncontrolled campfires (Torres 2016), and also raising awareness to the consequences of false alarms (Pacheco 2011). New measures and fines are also being put in place, demanding landowners to clean and take care of their terrains (Saraiva et al. 2007).

Forested areas occupy 59% of the national territory, the equivalent of 5,518,961 hectares, with 64% of those composed by trees areas (Pacheco 2011). With 93.4% of those forest areas being privately owned (Mendes 2006), and with a big part of them left to abandonment by the owners,

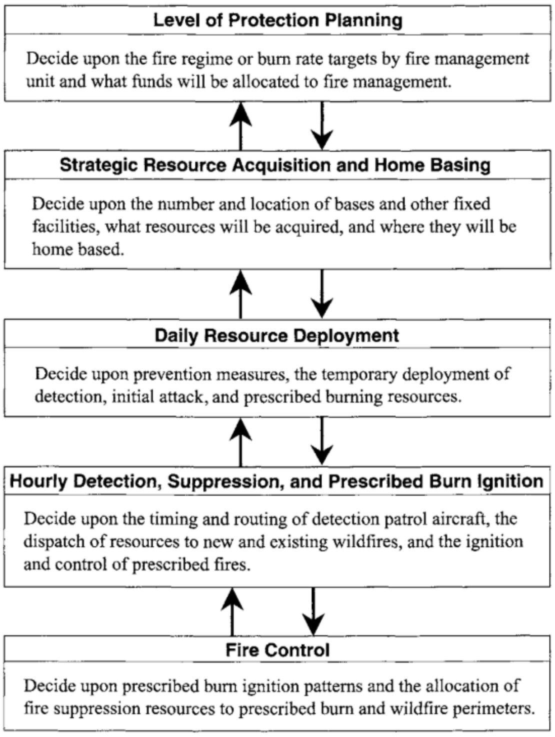

Figure 2.1: Fire management decision hierarchy from Martell 2001

fuel load increases and becomes a major problem, leading to an increase in the risk of forest fire (Carvalho et al. 2008). Therefore, fuel treatment becomes a part of fire management strategies (Pelaez 2018), aiming to reduce the occurrence of fires and their ability to spread, by changing the forest vegetation or fuel complexes (Martell 2001, Fernandes et al. 2016), either by having them manual, mechanical or chemical removed and also with the use or prescribed fire, which is a method used to manage the fire's intensity, size and frequency (Torres 2016, Pacheco et al. 2015).

Prediction of future fires is also an important prevention method (Martell 1982, Martell 2010) and has several factors in consideration, such as historical data and weather data, in order to determine if the conditions of past wildfires are or will be met in the future (Torres 2016).

2.1.2 Fire suppression

Fire suppression consists in all the actions used to extinguish or contain a fire (Pelaez 2018). After the fire is detected, resources are mobilized to the field and the initial attack starts (Torres 2016).

The initial attack is one of the most important components of fire management systems and is designed to start firefighting after the report of a forest fire, as quickly as possible (Martell et al. 1984, Martell 2015), preventing them from burning over large areas and minimizing the damaged caused by it (Pelaez 2018).

The first step after a fire is detected and reported is to decide what resources will be needed and dispatched to fight it. This takes into account several factors, including the location of the fire, its anticipated behavior and potential impact, and what suppression resources are available. After the resources are on the field, their objective is to stop the fire from growing and bring it to the state of being held (BHE) with the use of a control line around the fire's perimeter (Martell et al. 1984).

The initial attack outcome is not only influenced by the resources used, but also by the topology of the land where the fire is at, the weather conditions and the type of fuel in the ground (Martell 2007, Fernandes et al. 2016). The topology of the land will be one of the main factors while choosing the adequate type of transport for the firefighters (Bookbinder and Martell 1979). The response time is also crucial in the success of the initial attack. The faster the intervention is, the higher the probability of the fire being extinguished (Minas et al. 2012).

The attack can be direct or indirect. Direct attack is made at the fire perimeter and is used then the intensity of the fire is low and it is safe to fight it closely. When there are high value resources threatened by the fire, the direct attack can also be used. On the other hand, the indirect attack is made far away from the edge of the fire, and it consists of constructing fire lines, use of the topography or fuel breaks. It is used when the fire is more intense or is spreading fast (Torres 2016).

If the initial attack does not contain a fire, it is considered an escaped fire. It is declared as an extended attack fire and other actions are put in place. More resources are called to the field and can work for several days or weeks to extinguish the fire. With this in mind, we can see the importance of a good initial attack system (Martell et al. 1984).

An escaped fire is more dangerous because it can spread easily and to a bigger size. The combat of this kind of fire is different and has the goal of minimizing the damage it can make, sometimes taking more time to extinguish it, also depending on the arrival of favorable weather to the combat (Martell 2007). Extended attack is therefore considered opportunistic (Finney et al. 2009).

2.2 Fire life cycle

In Portugal, the 90 minutes after an alert are called the initial attack (IA) of a new occurrence (Pelaez 2018). Occurrence because it can be either a fire or a false alarm (Ahrens 2003).

Three VLCI from the three nearest local firefighting centers will be deployed and if an available helicopter or plane is in the radius of operation, it should also attend the fire (Autoridade Nacional de Protecção Civil 2019). In the location, the crew leader must prepare the plan for the fire suppression, having in mind the current fire behavior, local vegetation, values at risk, and the forecast weather. With the number and type of resources available, he must decide if more resources will be needed or not (Martell 2001).

If the fire is not controlled within the first 90 minutes, the leader must activate an extended attack (EA), as said previously. More resources are deployed to the field and the perimeter of action is expanded, with a command post set. The initial attack resources, especially the aerial ones, are sent back to recharge (Pelaez 2018).

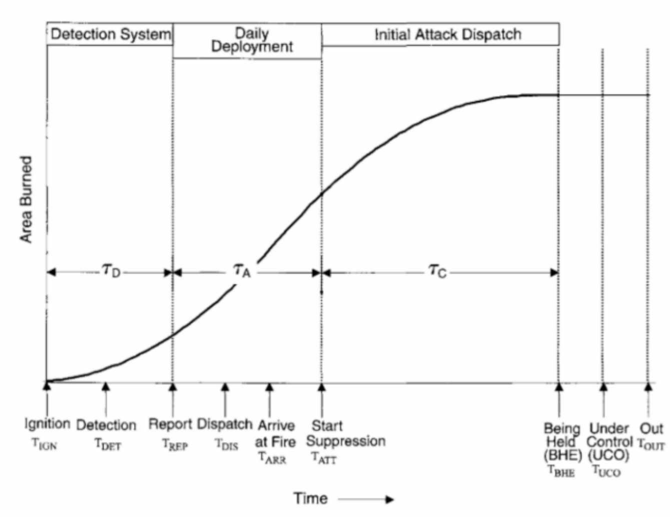

Figure 2.2: The life cycle of a forest fire from Martell 2001

As we can see in Figure 2.4, the initial attack is really fast and strong, followed by a gradual increase in resources at the EA, stabilizing when the fire is considered contained. Then, the number of resources start to decrease as the fire is under control (UCO) and declared out. After this, the firefighters still need to stay in the field for the mop-up, controlling the area and preventing rekindles (Pelaez 2018). If the fire is not correctly extinguished and rekindles occur, all the suppression goes again to the initial attack, unless the fire is still active in other areas of the combat (figure 2.3).

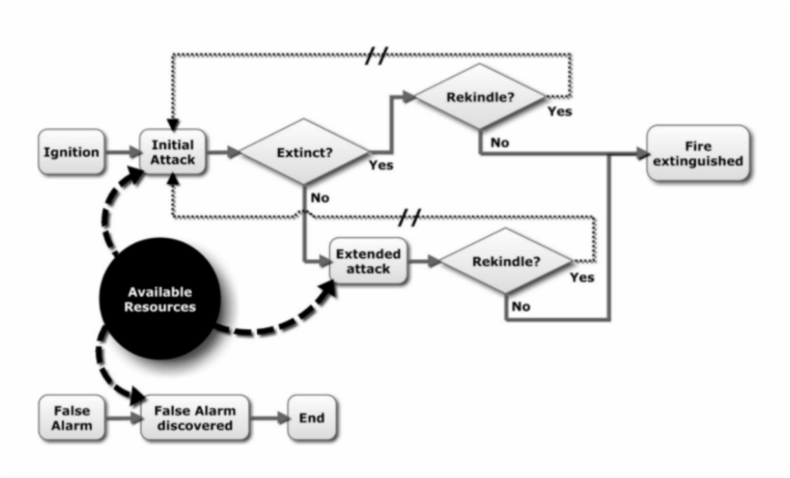

Figure 2.3: Conceptual model of the operation of a forest fire suppression system from Pacheco et al. 2014

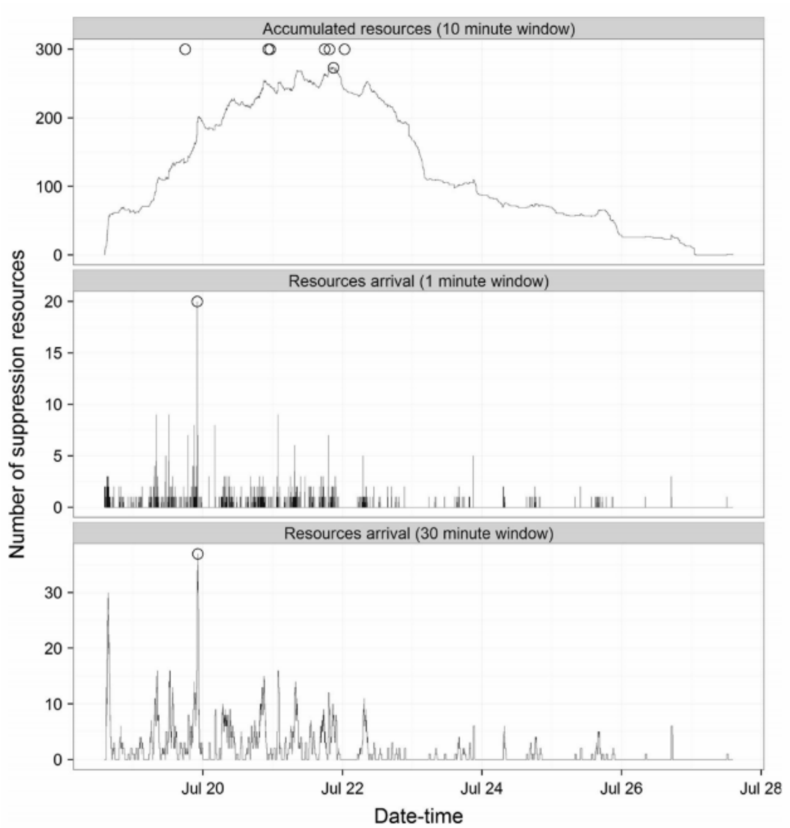

Figure 2.4: Accumulation and arrival of fire-fighting resources (vehicles, aircraft and personnel) from Fernandes et al. 2016

2.3 Portuguese fire suppression system

With an average of 28,500 fire ignitions per year, Portugal has the highest density of wildfire ignitions amongst southern Europe countries. This number is three times higher than Spain, France, Italy and Greece combined (Catry et al. 2009). The average burned area on the country has also increased 48.8% between 2002 and 2011 (Marchi et al. 2014). According to *Autoridade Florestal Nacional* (AFN), the Portuguese fire suppression system handled 32,357 occurrences in the year of 2010 (Pacheco et al. 2014).

Working on this area, Portugal has two major entities, *Autoridade Nacional de Proteção Civil* (ANPC) and *Instituto da Conservação da Natureza e das Florestas* (ICNF), previously called AFN. Since 2006, ANPC elaborates a document called *Directiva Operacional Nacional* (DON), which details, among other things, the number of resources and workforce, divided between fire departments and others, such as ICNF and police, and by seasons of fires as shown in Figure 2.5.

Phase	Periods
ALFA	01 January to 14 May
BRAVO	15 May to 30 June
CHARLIE	01 July to 30 September
DELTA	01 October to 31 October
ECHO	01 November to 31 December

Figure 2.5: Seasons of fires in Portugal

The Portuguese fire suppression system has at his disposal different kind of resources divided into four main groups. Aerial resources, ground forces, medical assistance and others, which includes resources that are not directly linked to the fire suppression but help during and after an occurrence. During the fire season, ANPC can also ask for reinforcements, either national or international, that can go from the army to private contracts (Pelaez 2018).

Ground forces commonly used vehicle is *veículo de combate a incêndios* (VCI), divided by *veículo florestal de combate a incêndios* (VFCI) and VLCI, and also rescue vehicles. VFCI are used by *equipa logística de combate a incêndios* (ELAC) crews (one vehicle and two elements) and can hold up to 4,000 liters, while VLCI are used by *equipa de combate a incêndios* (ECIN) crews (one vehicle and five elements) and can hold up to 400 liters. These two types of vehicles are assisted by support vehicles such as water tanks, logistic and tactical command vehicles and others. Track machines can also be used to facilitate access to the fire for the crews and also to create firebreaks (Autoridade Nacional de Protecção Civil 2019).

Aerial resources are divided into two groups, helicopters and airplanes. They usually help in the initial attack but can also be used in larger fires. Their faster reaction time, easier access to any area and the possibility to identify other ignitions are great advantages. However, they can't be used all the time, especially when weather conditions are not favorable or the smoke is dense. During the night, more specifically after the sunset and before dawn, their use is even forbidden, since they are not equipped to fly at night (Pelaez 2018).

2.4 Methods of proportional representation

A situation in which every party receives precisely the same share of the seats as it won of the votes, in a way it produces perfect proportionality, is very uncommon. Most of the times, disproportionality is inevitable (Gallagher 1991).

Each proportional representation (PR) method may produce significantly different seat allocations for the same distribution of votes because their conception of what proportionality means and how to minimize disproportionality differs. Even so, all of them try to reduce this disproportionality according to their principles and produce an outcome that is close to perfect proportionality as possible (Gallagher 1991).

D'Hondt method and Sainte-Laguë method are both a highest averages method used for allocating seats, being a type of party-list proportional representation. These methods differ from each other in the numbers they use as divisors, with D'Hondt method slightly favoring large parties over small ones and Sainte-Laguë method reducing the reward to large parties, generally benefiting middle-size parties at the expense of both large and small parties. The methods consider all of the available seats iteratively. For each one of them, it computes a quotient for all the parties based on the votes they received and the number of seats they have already taken. The seat is assigned to the party with the largest quotient, trying to maintain the overall proportionality. The number of seats taken by the chosen party is increased by one and the method repeats until all seats are assigned (Dang and Croft 2012).

Chapter 3

Data and methods

3.1 Study area

Portugal faces a structural problem of territorial organization, with the climate changes revealing that this is a severe threat to the safety of populations and the economic and social development of the country (Autoridade Nacional de Protecção Civil 2019).

The district of Porto is located in the North of Portugal, surrounded on the North by the district of Braga, on the East by the district of Vila Real, on the South by the districts of Aveiro and Viseu and on the West by the Atlantic Ocean. Of 18 districts in Portugal, Porto is the 17^{th} biggest and the most densely populated (Autoridade Nacional de Protecção Civil 2018).

The conditions for the development of forest fires are enormous, with forest areas occupying 48% of the district in a total of 111,347 ha, divided between 60,081 ha of stands and 40,089 ha of shrubs. 75% of this area is located in the interior of the district, further away from the seaside (Pacheco et al. 2014).

With 11,177 ha of burnt areas in recent years, the district has a historical trend of a very high number of forest fires (Pacheco et al. 2014). Adding to that the rural depopulation, the aging population, changes in the use and exploitation of forest areas, the abandonment of vast regions, the global warming and the continuous accumulation of materials in the soil, the conditions to bigger and more devastating fires are created (Autoridade Nacional de Protecção Civil 2018). In 2010, the district had 3,785 firefighting volunteers, with an average density of 30 ha of forest per volunteer. Even though the firefighters are more needed in the interior part of the district, the density of ha per volunteer was of 47, in contrast with the density of 14 ha per volunteer in the seaside (Pacheco et al. 2014).

We had information about the allocation of suppression crews in the district of Porto for the years of 2015 (appendix F) and 2018 (appendix G), and since the year 2015 was the one closer to the last year of our analysis and the number of crews allocated was similar for both years, we decided to compare our results with 2015.

There are 45 fire departments in the district, as shown in figure 3.1, and their number of ECIN and *equipas de prevenção permanentes* (EIP) crews are distributed as shown in table 3.1. This two types of crews were the ones that this dissertation focused on. We focused on the allocation of this type of crews for the Charlie phase, starting on July 1 and ending on September 30. Even though this phase stopped existing after the big fires of 2017, we will still consider it since this dissertation will only focus on data from 2001 till 2012.

Fire departments	ECIN	EIP	Crews allocated
BV Aguda	2	0	2
BV Amarante	2	1	3
BV Areosa	0	0	0
BV Avintes	2	0	2
BV Baião	2	0	2
BV Baltar	2	0	2
BV Carvalhos	2	0	2
BV Cete	2	0	2
BV Coimbrões	1	0	1
BV Crestuma	1	0	1
BV Entre-os-Rios	2	0	2
BV Ermesinde	2	0	2
BV Felgueiras	1	1	2
BV Freamunde	2	1	3
BV Gondomar	2	0	2
BV Leça do Balio	0	0	0
BV Leixões	0	0	0
BV Lixa	1	0	1
BV Lordelo	1	0	1
BV Lousada	1	0	1
BV Marco de Canaveses	2	1	3
BV Matosinhos-Leça	0	0	0
BV Melres	1	0	1
BV Moreira da Maia	0	0	0
BV Paço de Sousa	1	0	1
BV Paços de Ferreira	1	1	2
BV Paredes	2	0	2
BV Pedrouços	0	0	0
BV Penafiel	3	0	3
BV Porto	1	0	1
BV Portuenses	1	0	1
BV Póvoa de Varzim	1	0	1
BV Rebordosa	1	0	1
BV S. Mamede de Infesta	1	0	1
BV S. Pedro da Cova	2	0	2
BV Santa Marinha do Zêzere	2	0	2
BV Santo Tirso	1	1	2
BV Tirsenses	1	0	1
BV Trofa	1	1	2
BV Valadares	1	0	1
BV Valbom	2	0	2
BV Valongo	2	1	3
BV Vila das Aves	1	1	2
BV Vila do Conde	1	0	1
BV Vila Meã	2	1	3
Total	59	10	69

Table 3.1: Number of crews allocated in each fire department, year 2015 (adapted from appendix F)

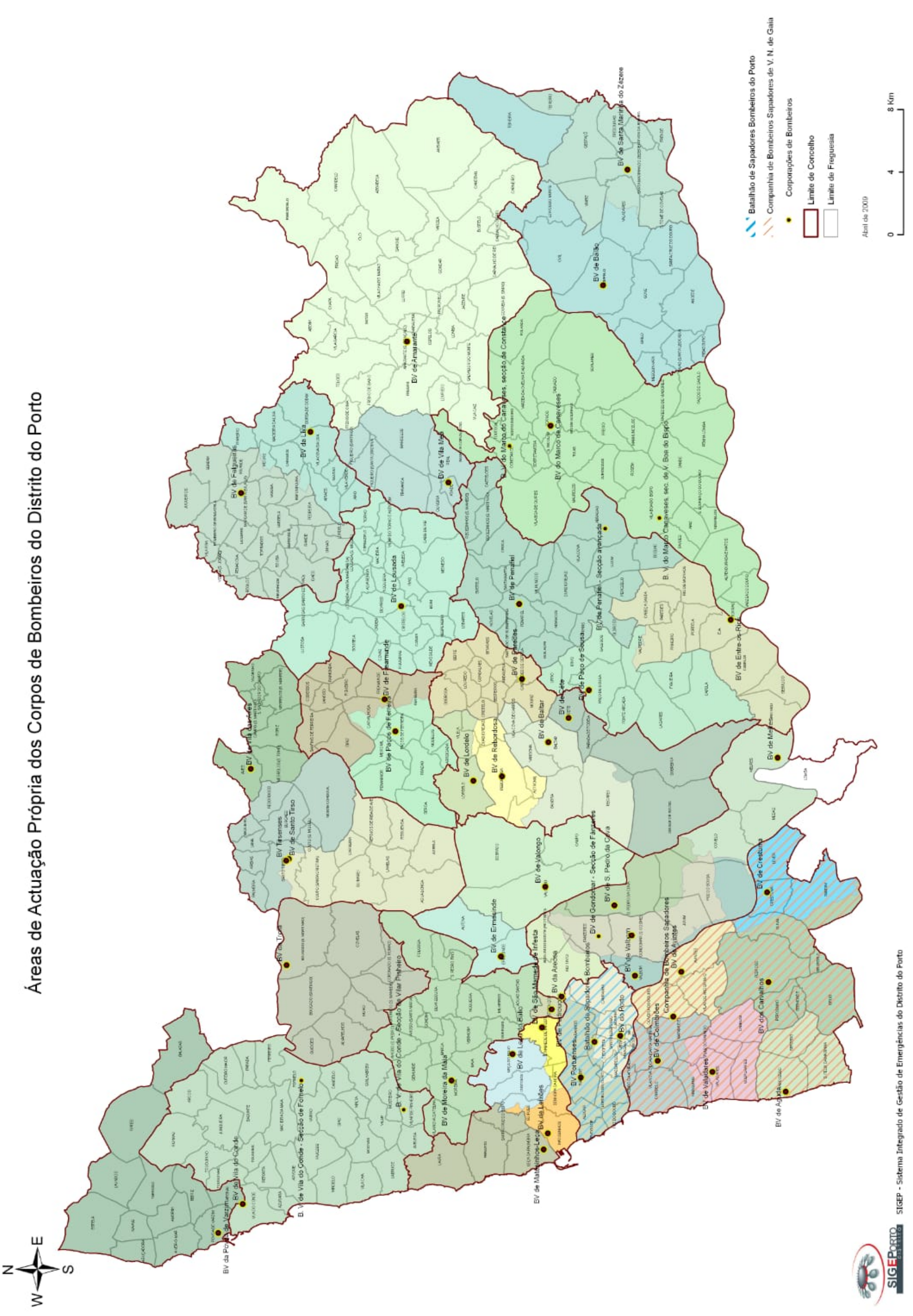

Figure 3.1: Intervention area of each fire department in the district of Porto, kindly given by engineer Paulo Bessa

3.2 Data

The data used in this work consisted of two different datasets, one with all the information related to the occurrences in Portugal from 2001 to 2015 (one file per year), provided in the website of ICNF (da Conservação da Natureza e das Florestas 2016), and the other one with the area of intervention of each fire department, provided by engineer Paulo Bessa.

The occurrences database had date-time (day and hour of alert and extinction) and geographical (district, municipality, parish, place, *Instituto Nacional de Estatística* (INE) code and coordinates) information and also data about the type of occurrence, its burned area discriminated by type (forest, shrubs, etc.) and the cause.

The area of intervention database had, for each parish, their INE code, municipality and the fire department that was in charge of occurrences in the area. This database was later joined with the first one using the INE code of the parish that was available in both datasets in order to know which fire department was in charge of each occurrence.

In 2013 and until 2015 there was a territorial reordering in Portugal, with the union of parishes creating new ones, and since the data available in the second dataset only included the area of intervention for each fire department before this union, the data used for the analysis had to be reduced only for the years of 2001 till 2012, included, which gave us a total of 12 years in analysis.

3.3 Methods

3.3.1 Data treatment and statistical analysis

A general analysis was performed for the years of 2001 till 2015 in collaboration with the authors in appendix A.1, using the software R Studio (RStudio Team 2015), which is a graphical user interface for the software R (R Core Team 2017), and Microsoft Excel.

All the data available had to be validated in the first place, what was made in the code presented in appendix B.1

- Total occurrences: 462,367
- Occurrences without date/time of extinction: 5,249
- Occurrences with negative duration: 1,245
- Occurrences without alert time: 1 (manually changed to 0h00)
- Valid occurrences: 455,872

In the 455,872 valid occurrences, some of their durations were considered invalid since in some cases the value was one year. To solve this problem, a histogram with the frequency of each duration was created.

Analysing the histograms presented in figures 3.2 and 3.3, the intervals where the frequency was 0 were [14.7;15.3] and [25.7;26.3]. With this information, the two possibilities were to cut durations superior to 15 or 26 days. The table 3.2 shows the number of occurrences cut for each option.

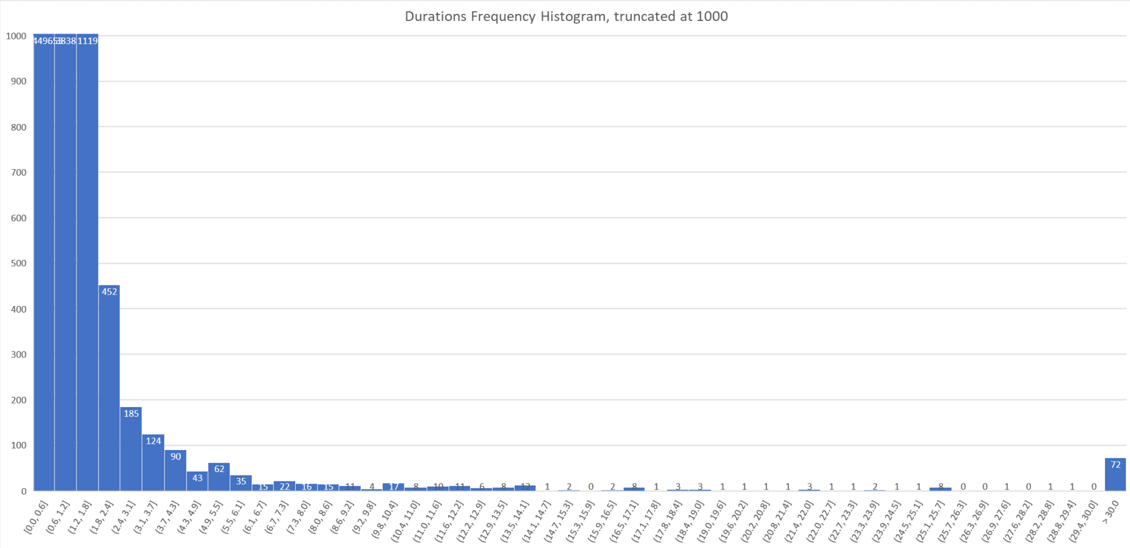

Figure 3.2: Durations frequency histogram, truncated at 1000 occurrences

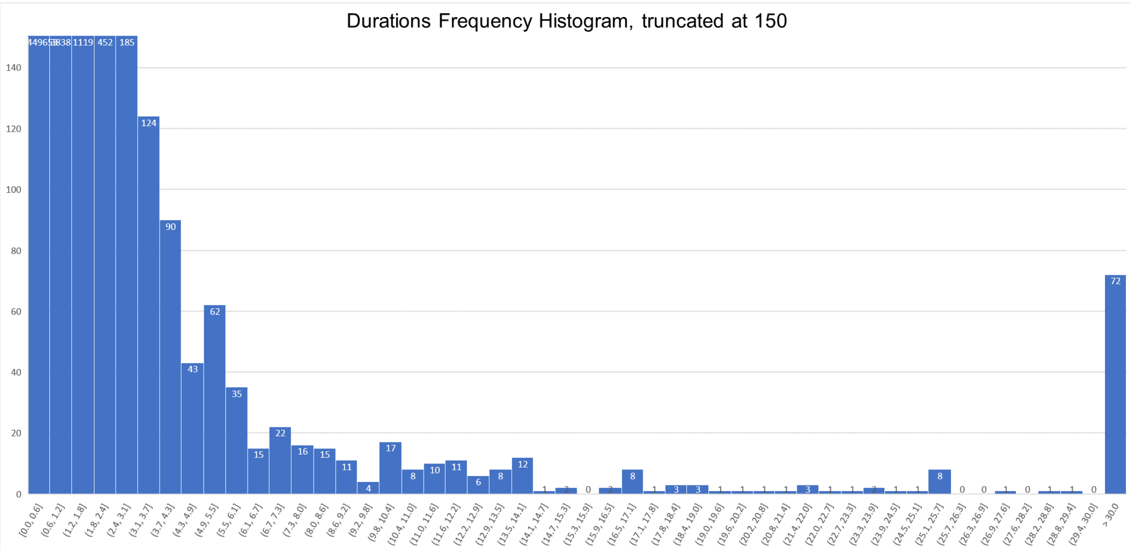

Figure 3.3: Durations frequency histogram, truncated at 150 occurrences

With this results and since the difference between the two options were not significant (just 40 occurrences in a total of 455,872), instead of cut durations at 15 days and cut correct values, we decided to be more conservative and cut durations at 26 days, thinking that durations until that value would be correct. This cut of 75 occurrences has an average of 5 occurrences cut per year.

After this, it was necessary to impute durations to the invalid data and data with durations superior to 26 days. For this analysis, it was necessary to obtain a simple relation between the duration of a fire and its total burned area. So, based on the analysis made by Torres et al. (2018), class intervals were made in which, for each class, the median of the duration of the occurrences

Cut (days)	Occurrences cut	Percentage in valid occurrences
15	115	0.03%
26	75	0.02%

Table 3.2: Number of occurrences cut

in that interval had to be superior to the class below, that is, for a higher burned area, higher the duration. For this to be true, small adjustments had to be made to his classes since his occurrence with the higher burned area was only 7,000 ha. The table 3.3 shows all the information obtained in this analyses with the new class intervals, information obtained in the code presented in appendix B.1.

Classes (ha)	Occurrences	Median (duration)	Median (days)	Median (hours)	Median (minutes)
0	76,002	0.0368	0	0	53
0 - 1	323,244	0.0569	0	1	22
1 - 10	45,994	0.1465	0	3	31
10 - 100	8,185	0.3181	0	7	38
100-1000	2,060	0.8420	0	20	12
1000 - 2000	179	15.493	1	13	11
2000 - 10000	121	38.882	3	21	19
10000 - 30000	13	59.375	5	22	30

Table 3.3: Classes of occurrences

After obtaining the new values and validating them, this durations were imputed to the invalid data and data with durations superior to 26 days. This imputation was then made in the code presented in appendix A.2, that is gonna be explained after, having imputed 6,569 occurrences (5,249 plus 1,245 occurrences with invalid data and 75 occurrences with a duration superior to 26 days), which was equivalent to 1.4% of the total occurrences (462,367).

Next, after all the data had been validated, it had to be processed in R Studio (appendix A.2). With the package "readxl" (Wickham and Bryan 2019), the information from all the years was imported from Excel to R. Since the name of the columns of the excel files were not the same for all the years, all of them had to be normalized. For this, the year 2015 was used as a base and the columns used are the ones presented in appendix C.

Since only the years of 2015 and 2014 had all these 39 columns in their excel files, in the rest of the years we included NA or "NULL" values for the new columns, depending on if the variable was numeric or text. With this being done, all the data were joined in a single data frame using the function rbind, joining all the rows of all files.

Then, the imputation of new durations was done to the invalid data and data with a duration superior to 26 days. This data had their date and time of extinction changed to NA and then the imputation function was used to change their duration according to their burned area class. All the data was then ordered by date and time of occurrence.

Since this dissertation was only focusing on the district of Porto and the years from 2001 till 2012, a second dataset was created from this one, using just the data from the district and this period. This changed the number of occurrences in our study from 462,367 to 80,762, an average of 6,730 occurrences per year. To this new dataset, it was joined the area of intervention dataset with the package "sqldf" (Grothendieck 2017), which gave us what fire department was in charge of each one of the occurrences. This ended all the processing that had to be done on the data.

Our goal was to optimize the initial attack, and since the IA in Portugal has 90 minutes to decide if the EA will be needed, the duration of the 93892 occurrences in the district of Porto was changed to 120 minutes in the code presented in appendix B.2, assuming that the initial attack is 100% efficient and that all occurrences were controlled in this period. This 120 minutes considered the 90 minutes of the initial attack plus 30 minutes of average travel time of the suppression crews to the local, since the beginning of the occurrence is at the time that the alert is made and not at the time that the crews arrive at the local.

After this, the code used to perform all the statistical analysis was done in appendix A.3 and in appendix A.4.

For the first code, the goal was to determine the number of simultaneous occurrences for each fire department. After declaring the period and step of the analysis, which for this dissertation was the Charlie phase of the years 2001 till 2012 with a step of three hours, a simultaneity cycle started to count how many occurrences were in each step of the period in analysis for each fire department. We used a three hours step because we considered the 120 minutes of occurrence duration plus 60 minutes for the crews to rest between occurrences, since they can't be immediately in a new occurrence after they finish fighting one. At the end of the cycle, the minimum, value at risk 5 (VaR 5), median, average, standard deviation, value at risk 95 (VaR 95), conditional value at risk 95 (CVaR 95) and maximum were calculated for each fire department. The value that was then used for all the work done with this analysis was the condition value at risk 95, that was called risk of simultaneous occurrences (RSO). The CVaR95 is the average of all the values higher than the VaR95 or quantile 95, which is the value that is greater than or equal to 95% of the data.

To show how the 3 hours step includes the time for the crews to rest, let's imagine 2 occurrences with a duration of 2 hours each, the second one starting when the first one ends. In this scenario, our code would say that for the first step we would have two simultaneous occurrences and for the second step 1 simultaneous occurrence. According to ANPC, 2 ECIN or EIP crews and 1 ELAC crew should go to every occurrence, so, in this scenario, we need to have 4 ECIN or EIP crews and 2 ELAC crews available. If we only considered a 2 hours step, for the first and second step we would have 1 simultaneous occurrence, what would tell us that only 2 ECIN or EIP crews and 1 ELAC should be available, which turns out to be an insufficient number of crews because they are not immediately available for the second occurrence when they control the first one.

For the second code, the goal was to determine the burned area per fire department. Using the same cycle as in the previous code, if the occurrence was inside the period of analysis, its burned area information was taken into account for the statistical calculations. The metrics calculated at the end of the cycle were the median, average, VaR95, CVaR95, maximum and total burned area per fire department. The value that was then used for all the work done with this analysis was the condition value at risk 95, that was called risk of burned area (RBA).

It is possible to have occurrences with different dimensions that may need more crews than others. The interior of the district has lots of forest areas and fires have space to expand, contrary to what happens in urban areas near the sea. Having this in mind, it was important to have into account not only the number of simultaneous occurrences but also the risk of burned area per occurrence in every fire department. To do this, the risk of burned area potential (RBAP) was calculated by multiplying the RSO with the RBA for each fire department. The RBAP (table E.3) is an estimation of how much can burn in the area of intervention of each fire department.

3.3.2 D'Hondt method and Sainte-Laguë method

D'Hondt method and Sainte-Laguë method are both methods of allocating seats in the parliament.

$$\frac{\mathrm{V}}{\mathrm{s}+1}$$

Figure 3.4: D'Hondt method formula

$$\frac{V}{2s+1}$$

Figure 3.5: Sainte-Laguë method formula

With:

- V being the number of votes the party received
- s being the number of seats the party has already taken

To exemplify how they work, figures 3.6 and 3.7 were made. Two hundred eighty thousand voters decided the allocation of four seats for four parties. Party A had 150,000 votes, party B had 80,000 votes, party C had 40,000 votes and party D had 10,000 votes. First, the number of total votes of each party is divided by 1, 2, 3 and 4 for the D'Hondt method and by 1, 3, 5, 7 for the Sainte-Laguë method. This difference in the numbers used comes because of the different denominator of each method formula. After the division, the four highest quotients are chosen and the respective parties get a seat. If two quotients have the same value, the seat will be given to the party with the lowest value of seats already taken. For example, in the figure 3.6, if one more seat would be given, that seat would go to the party C instead of the party B, even though both of them have a quotient of 4000.

The difference between this two methods is that D'Hondt method slightly favors large parties over small ones and Sainte-Laguë method reduces the reward to large parties, generally benefiting middle-size parties at the expense of both large and small parties.

Denominator	1	2	3	4	Seats Won
Party A	**150000**	**75000**	**50000**	37500	3
Party B	**80000**	40000	26667	20000	1
Party C	40000	20000	13333	10000	0
Party D	10000	5000	3333	2500	0
Total					4

Figure 3.6: D'Hondt method example

Denominator	1	3	5	7	Seats Won
Party A	**150000**	**50000**	30000	21429	2
Party B	**80000**	26667	16000	11429	1
Party C	**40000**	13333	8000	5714	1
Party D	10000	3333	2000	1429	0
Total					4

Figure 3.7: Sainte-Laguë method example

We decided to use these two methods of allocating seats to this problem. Instead of parties and their number of received votes, fire departments and their values of risk of simultaneous occurrences or risk of burned area potential were used. The number of seats to be allocated were substituted by the number of crews to allocate, which as seen in table 3.1, were 69 for the year of 2015, being this the number that was used in this problem. Using an excel simulator of the D'Hondt method created by de Magalhães (2011), the allocation was made adapting the simulator to this problem. This excel was then improved in order to also be able to do the allocation for the Sainte-Laguë method (Silva 2019).

3.3.3 Help between neighboring fire departments

It was intended to see if help between neighboring fire departments was possible. Instead of only having their own suppression crews for an occurrence in their area of intervention, fire departments had also available the crews of their neighbors. To do that, only the fire departments with areas of intervention in the central area of the district of Porto were taken into account for the allocation of crews, since the fire departments in the boarders of the district had neighboring fire departments in other districts of the country that weren't taken into account in this problem, what would mislead the number of crews available for the fire departments in the boarders of the district of Porto. To explain what is considered the central area, the figure 3.8 was made, in which the fire departments considered to be in the central area of the district are the fire departments A, B and C.

A small case study was done to see if this was possible, taking into account the simultaneous occurrences in the month of August of 2010, an average month of an average year. From the fire departments in the central area of the district, five were chosen for the case study. To see if help was possible, their number of simultaneous occurrences was analyzed in order to see how it changed during each day of the month compared to the day before. If for each step, the fire department being analyzed and its neighbors were changing all in the same way or if only one was

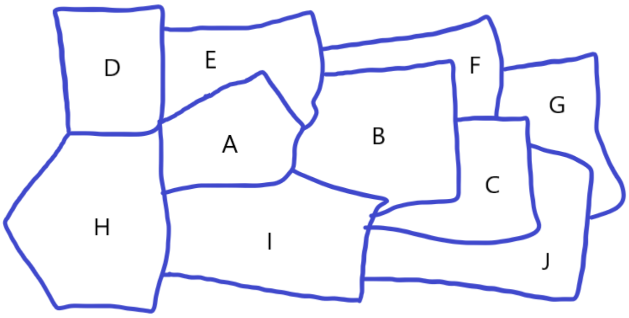

Figure 3.8: Example of fire departments in the district

different, it was considered that help was not possible. The figure 3.9 is a small example of how this was done, considering the fire department A and its neighbors from figure 3.8. The top part of the image represents the number of simultaneous occurrences for each fire department through a period. Even though these numbers of simultaneous occurrences are fictional for the example, the analysis in the down part of the image can still be made. For each fire department, we analyzed how the number of simultaneous occurrences was changing compared to the day before. Taking, for example, the BV A, in day 1 it had 1 simultaneous occurrence and in day 2 had 0. So, in the down part of the image, we have a -1 for BV A representing that the number of simultaneous occurrences in the day 2 decreased compared to day 1. This was done for BV A and its neighbors for all the period in the analysis. In this period, the number of simultaneous occurrences in fire department A was changing in the same way as its neighbors only 4 times (day 5, day 9, day 13 and day 24), which gave us an 87% of time that help was possible. Even though the fire departments of the boarders of the district (D, E, F, G, J, I, and H in figure 3.8) are not directly analyzed, their data is still used for the analysis of the fire departments in the central area and their suppression crews will be available for their neighbors. For the fire department A, the fire departments D, E, H and I were still used for its analysis.

After this analysis, an adjacency matrix was made (figure 3.10) based on the figure 3.1. For every position [x,y] of the matrix, the value was one if the fire department x and y were neighbors and 0 if not. For every row, if the value on the matrix was 1, the number of crews allocated to the fire department y were added to the fire department x. This was done for all the rows of the matrix until the new number of crews available to all the fire departments in the central area was known. If, for example, all the fire departments in figure 3.9 had 2 crews allocated, the new number of crews available for the fire department A would be 12, 2 crews allocated to itself plus 2 crews from fire department B, 2 from fire department D, 2 from fire department E, 2 from fire department H and 2 from fire department I.

	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14	Day 15	Day 16	Day 17	Day 18	Day 19	Day 20	Day 21	Day 22	Day 23	Day 24	Day 25	Day 26	Day 27	Day 28	Day 29	Day 30	Day 31	Minimum	VaR 5	Median	Average	Stantard Deviation	VaR 95	CVaR 95	Maximum
BV A	1	0	5	1	2	8	2	5	1	2	2	1	2	3	2	5	0	2	2	0	0	2	1	0	0	0	0	0	0	0	0	0	0	1	2	2	5	6	8
BV B	4	5	4	10	7	6	6	12	5	5	8	2	5	9	6	5	0	4	1	4	10	6	1	0	0	2	1	2	4	9	10	0	0	5	5	3	10	11	12
BV D	9	6	13	11	7	11	19	20	18	7	7	7	12	14	14	12	5	5	1	5	6	3	4	3	3	2	2	6	12	13	14	1	2	7	9	5	19	20	20
BV E	0	0	2	3	1	5	5	1	5	5	6	1	1	3	0	3	3	1	0	1	0	0	1	0	1	1	0	1	1	1	1	0	0	1	2	2	5	5	6
BV H	2	1	5	7	3	7	2	6	3	10	5	5	3	5	5	11	7	5	3	5	9	1	1	0	0	1	0	1	1	3	3	0	0	3	4	3	10	11	11
BV I	8	8	5	19	17	13	16	16	13	5	9	13	10	15	11	7	10	3	7	5	7	5	3	1	5	1	2	2	4	4	10	1	2	7	8	5	17	18	19

		Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14	Day 15	Day 16	Day 17	Day 18	Day 19	Day 20	Day 21	Day 22	Day 23	Day 24	Day 25	Day 26	Day 27	Day 28	Day 29	Day 30	Day 31
BV A			-1	1	-1	1	1	-1	1	-1	1	0	-1	1	1	-1	1	-1	1	0	-1	0	1	-1	-1	0	0	0	0	0	0	0
BV B			1	-1	1	-1	-1	0	1	-1	0	1	-1	1	1	-1	-1	-1	1	-1	1	1	-1	-1	-1	0	1	-1	1	1	1	1
BV D			-1	1	-1	-1	1	1	1	-1	-1	0	0	1	1	0	-1	-1	0	-1	1	1	-1	1	-1	0	-1	0	1	1	1	1
BV E			0	1	1	-1	1	0	-1	1	0	1	-1	0	1	-1	1	0	-1	-1	1	-1	0	1	-1	1	0	-1	1	0	0	0
BV H			-1	1	1	-1	1	-1	1	-1	1	-1	0	-1	1	0	1	-1	-1	-1	1	1	-1	0	-1	0	1	-1	1	0	1	0
BV I			0	-1	1	-1	-1	1	0	-1	-1	1	1	-1	1	-1	-1	1	-1	1	-1	1	-1	-1	-1	1	-1	1	0	1	0	1
Decreased	-1		3	2	2	5	2	2	1	5	2	1	3	2	0	4	3	4	3	4	2	1	4	3	6	0	2	3	0	0	0	0
Maintain	0		2	0	0	0	0	2	1	0	2	2	2	1	0	2	0	1	1	1	0	1	1	1	0	4	2	2	2	3	3	3
Increased	1		1	4	4	1	4	2	4	1	2	3	1	3	6	0	3	1	2	1	4	4	1	2	0	2	2	1	4	3	3	3
Times that help is not possible			0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

0 possible
1 not possible

Percentage of time that help is possible 87%

Figure 3.9: Fire department A and its neighbors

	BV AGUDA	BV AMARANTE	BV AREOSA	BV AVINTES	BV BAIÃO	BV BALTAR	BV CARVALHOS	BV CETE	BV COIMBRÕES	BV CRESTUMA	BV ENTRE-OS-RIOS	BV ERMESINDE	BV FELGUEIRAS	BV FREAMUNDE	BV GONDOMAR	BV LEÇA DO BALIO	BV LEIXÕES	BV LIXA	BV LORDELO	BV LOUSADA	BV MARCO DE CANAVESES	BV MATOSINHOS-LEÇA	BV MELRES	BV MOREIRA DA MAIA	BV PAÇO DE SOUSA	BV PAÇOS DE FERREIRA	BV PAREDES	BV PEDROUÇOS	BV PENAFIEL	BV PORTO	BV PORTUENSES	BV PÓVOA DE VARZIM	BV REBORDOSA	BV S. MAMEDE DE INFESTA	BV S. PEDRO DA COVA	BV SANTA MARINHA DO ZÊZERE	BV SANTO TIRSO	BV TIRSENSES	BV TROFA	BV VALADARES	BV VALBOM	BV VALONGO	BV VILA DAS AVES	BV VILA DO CONDE	BV VILA MEÃ
BV AGUDA	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
BV AMARANTE	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
BV AREOSA	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0
BV AVINTES	0	0	0	1	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
BV BAIÃO	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
BV BALTAR	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0
BV CARVALHOS	1	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
BV CETE	0	0	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
BV COIMBRÕES	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
BV CRESTUMA	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BV ENTRE-OS-RIOS	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BV ERMESINDE	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0
BV FELGUEIRAS	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BV FREAMUNDE	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0
BV GONDOMAR	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0
BV LEÇA DO BALIO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
BV LEIXÕES	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
BV LIXA	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
BV LORDELO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0
BV LOUSADA	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	1	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
BV MARCO DE CANAVESES	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
BV MATOSINHOS-LEÇA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
BV MELRES	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0
BV MOREIRA DA MAIA	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	1	0
BV PAÇO DE SOUSA	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BV PAÇOS DE FERREIRA	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0
BV PAREDES	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	1	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
BV PEDROUÇOS	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
BV PENAFIEL	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
BV PORTO	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0
BV PORTUENSES	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
BV PÓVOA DE VARZIM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
BV REBORDOSA	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0
BV S. MAMEDE DE INFESTA	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
BV S. PEDRO DA COVA	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
BV SANTA MARINHA DO ZÊZI	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
BV SANTO TIRSO	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	0	0	0
BV TIRSENSES	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	1	0	0
BV TROFA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	1	0
BV VALADARES	1	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
BV VALBOM	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
BV VALONGO	0	0	1	0	0	1	0	1	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0	1	0	0	0
BV VILA DAS AVES	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0
BV VILA DO CONDE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0
BV VILA MEÃ	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Figure 3.10: Adjacency matrix

Chapter 4

Results and discussion

This chapter presents the results obtained from the methods described in the previous chapter. First, the statistical data of simultaneous occurrences for each fire department is presented. Next, the allocation of crews using the D'Hondt method and Sainte-Laguë method, either with the variable used being the RSO or the RBAP. The number of crews available per fire departments is then analyzed having into account the help from neighbor fire departments. Lastly, all the previous points are analyzed in order to see how many crews are lacking in each fire department and how many crews more would be needed in the district if we consider help between neighbors.

4.1 Statistical analysis

As previously explained in 3, the analysis was made taking into account the Charlie phase of all the years from 2001 till 2012, with a step of analysis of three hours.

The results obtained in this analysis were used for the next sections of this chapter and can be found in appendix E.1 and E.3.

As mentioned in 3.3, every occurrence should have 2 ECIN or EIP crews and 1 ELAC crew for each occurrence, being the ECIN and EIP crews the ones we are focusing on this dissertation. Using the risk of simultaneous occurrences per fire department presented in appendix E.1, the number of necessary crews every fire department should have to be able to control their own occurrences was calculated by multiplying their RSO by two (table 4.1), being this the number equivalent to 2 ECIN or EIP crews per occurrence.

Comparing the number of necessary crews per fire department in table 4.1 and the real value of crews available in the district (3.1), it's clear that the system is deficient when it only has 69 crews and should have 206 to be completely perfect according to this analysis. Even if only one crew was necessary per occurrence, the 69 crews available would still not be enough.

Fire departments	Number of necesseray crews
BV Aguda	4
BV Amarante	6
BV Areosa	4
BV Avintes	4
BV Baião	4
BV Baltar	4
BV Carvalhos	6
BV Cete	4
BV Coimbrões	4
BV Crestuma	2
BV Entre-os-Rios	4
BV Ermesinde	4
BV Felgueiras	6
BV Freamunde	6
BV Gondomar	4
BV Leça do Balio	4
BV Leixões	2
BV Lixa	6
BV Lordelo	4
BV Lousada	6
BV Marco de Canaveses	10
BV Matosinhos-Leça	4
BV Melres	4
BV Moreira da Maia	6
BV Paço de Sousa	4
BV Paços de Ferreira	6
BV Paredes	6
BV Pedrouços	2
BV Penafiel	8
BV Porto	2
BV Portuenses	2
BV Póvoa de Varzim	4
BV Rebordosa	6
BV S. Mamede de Infesta	2
BV S. Pedro da Cova	4
BV Santa Marinha do Zêzere	4
BV Santo Tirso	6
BV Tirsenses	6
BV Trofa	4
BV Valadares	4
BV Valbom	4
BV Valongo	4
BV Vila das Aves	4
BV Vila do Conde	6
BV Vila Meã	6
Total	206

Table 4.1: Number of necessary crews per fire department according to their risk of simultaneous occurrences

4.2 Allocation of crews

Using the 69 crews available in the district, we decided to allocate them using the D'Hondt method and Sainte-Laguë method, with the RSO or the RBAP as variables, and compare them with the number of crews allocated per fire department in 2015.

The results for the allocation for both methods using the RSO and the RBAP are presented in table 4.2.

For the allocation using the RBAP, the Sainte-Laguë method showed a difference in relation to the D'Hondt method, where the fire department with the highest value of RBAP, BV Marco de Canaveses with a RBAP value of 25, has one less crew that was allocated to BV Vila do Conde. This was what we were expecting after what we saw in 3.3.2, saying that the D'Hondt method favours large parties, which gave BV Marco Canaveses 1 more crew when using this method.

Differently from what was expected after seeing 3.3.2, the Sainte-Laguë method gave the same results as the D'Hondt method when using the RSO for the allocation. This is due maybe to the fact that the RSO values for the fire departments are really close to each other and only varies from

Fire departments	Number of necessary crews	CA 2015	RSO		RBAP	
			Allocated crews (D'Hondt method)	Allocated crews (Sainte-Laguë method)	Allocated crews (D'Hondt method)	Allocated crews (Sainte-Laguë method)
BV Aguda	4	2	1	1	1	1
BV Amarante	6	3	2	2	3	3
BV Areosa	4	0	1	1	1	1
BV Avintes	4	2	1	1	1	1
BV Baião	4	2	2	2	1	1
BV Baltar	4	2	1	1	1	1
BV Carvalhos	6	2	2	2	3	3
BV Cete	4	2	1	1	1	1
BV Coimbrões	4	1	2	2	1	1
BV Crestuma	2	1	1	1	0	0
BV Entre-os-Rios	4	2	1	1	1	1
BV Ermesinde	4	2	1	1	1	1
BV Felgueiras	6	2	2	2	2	2
BV Freamunde	6	3	2	2	3	3
BV Gondomar	4	2	2	2	1	1
BV Leça do Balio	4	0	1	1	1	1
BV Leixões	2	0	1	1	0	0
BV Lixa	6	1	2	2	2	2
BV Lordelo	4	1	1	1	1	1
BV Lousada	6	1	2	2	3	3
BV Marco de Canaveses	10	3	4	4	9	8
BV Matosinhos-Leça	4	0	2	2	1	1
BV Melres	4	1	1	1	1	1
BV Moreira da Maia	6	0	2	2	2	2
BV Paço de Sousa	4	1	1	1	1	1
BV Paços de Ferreira	6	2	2	2	2	2
BV Paredes	6	2	2	2	2	2
BV Pedrouços	2	0	1	1	0	0
BV Penafiel	8	3	3	3	5	5
BV Porto	2	1	1	1	0	0
BV Portuenses	2	1	1	1	0	0
BV Póvoa de Varzim	4	1	1	1	1	1
BV Rebordosa	6	1	2	2	2	2
BV S. Mamede de Infesta	2	1	1	1	0	0
BV S. Pedro da Cova	4	2	1	1	1	1
BV Santa Marinha do Zêzere	4	2	1	1	1	1
BV Santo Tirso	6	2	2	2	2	2
BV Tirsenses	6	1	2	2	2	2
BV Trofa	4	2	1	1	1	1
BV Valadares	4	1	1	1	1	1
BV Valbom	4	2	1	1	1	1
BV Valongo	4	3	2	2	1	1
BV Vila das Aves	4	2	1	1	1	1
BV Vila do Conde	6	1	2	2	2	3
BV Vila Meã	6	3	2	2	2	2
Total	206	69	69	69	69	69

Table 4.2: Number of allocated crews per fire department according to their risk of simultaneous occurrences

1 to 5 (appendix E.1). This makes that the method doesn't clearly see a difference between large and medium/small fire departments.

The main difference comparing this two allocations using the RSO with the real value of crews available (CA) in the district in 2015 is that, for this two, no fire department have 0 crews allocated. Also, in the real case of 2015, no fire department had more than 3 crews allocated and for both of these cases BV Marco de Canaveses had 4. BV Marco de Canaveses is the fire department with the highest value of RSO, 5.

Looking to the map of the district, we see that the 3 fire departments with the highest value of RBAP (table E.3), BV Marco de Canaveses, BV Penafiel and BV Lousada, are all located far away from the seaside, in areas with a lot of forest areas and where fires have area to expand, where more crews should be allocated. This emphasizes what we were expecting, that we should consider not only the number of simultaneous occurrences but also their location and the risk of burned area potential of the fire department.

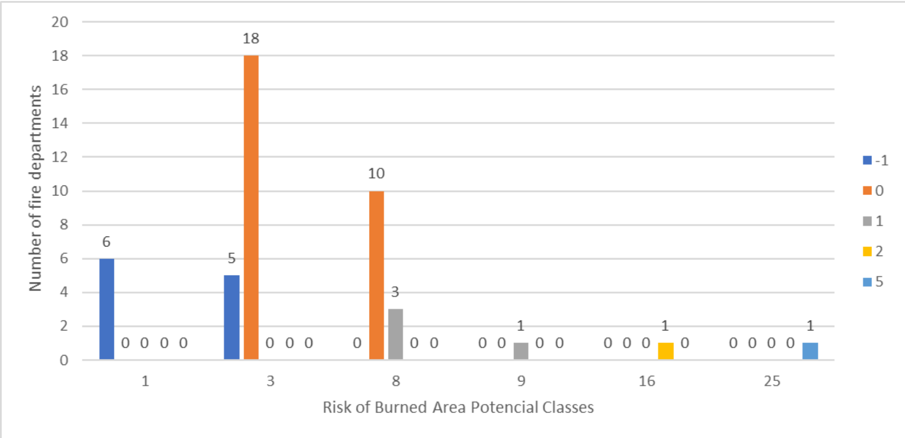

Figure 4.1: Changes in the number of crews comparing RBAP with RSO D'Hondt method

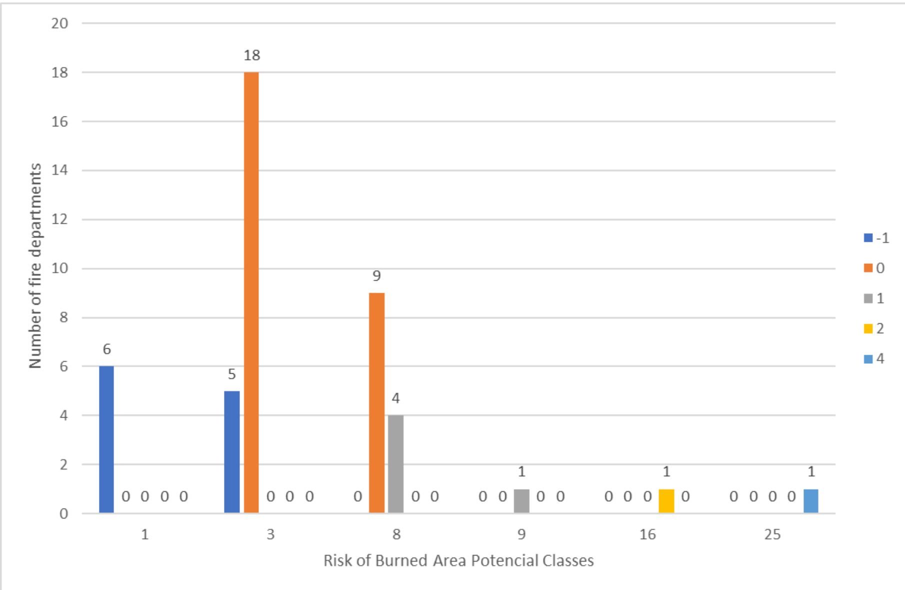

Figure 4.2: Changes in the number of crews comparing RBAP with RSO Sainte-Laguë method

4.3 Help between neighboring fire departments

Considering help between neighboring fire departments, we had to look only to the fire departments in the central area of the district for the reason we had already seen in 3.3.3. The number of fire departments in the analysis was reduced from 45 to 28 according to figure 4.3, with their names and number of neighbors presented in table 4.4. Even though BV Matosinhos-Leça, BV Leixões, BV Portuenses, BV Coimbrões and BV Valadares were not in the central area of the district according to what was explained in 3.3.3, they were still taken into account for this analysis since their East neighbor is the Atlantic Ocean and the problem of neighbors in other districts was not verified for them.

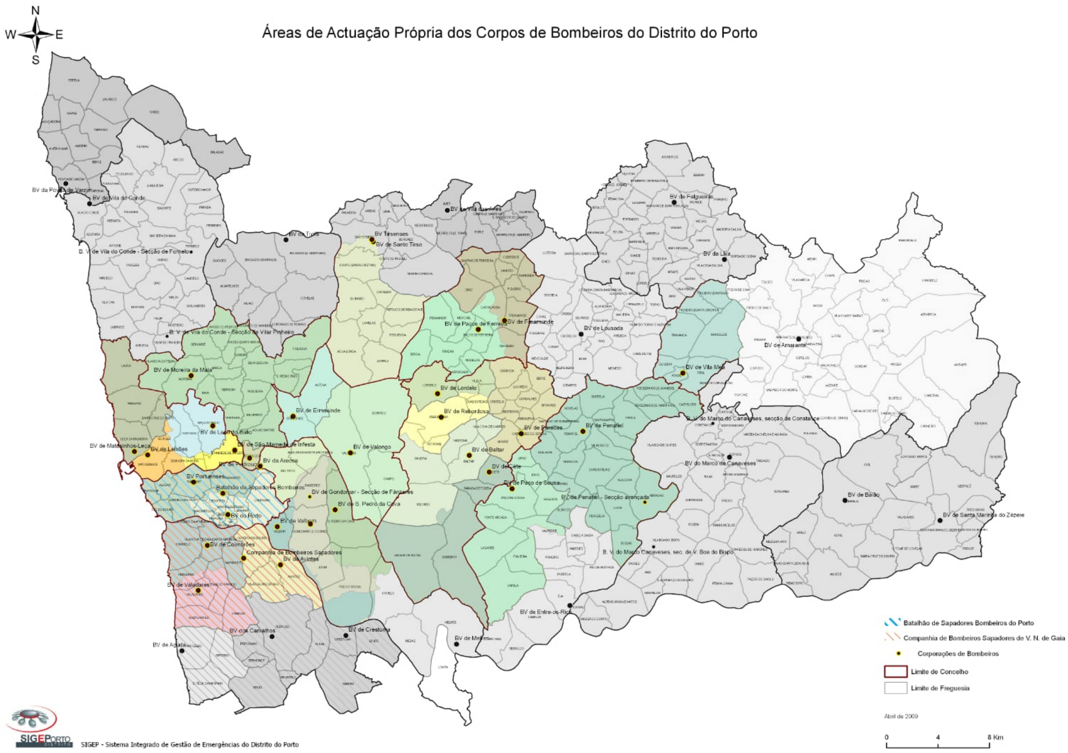

Figure 4.3: Fire departments in the central area of Porto (the colorful ones)

The five fire departments chosen for the case study to see if help between neighboring fire departments were BV Baltar, BV Paredes, BV Penafiel, BV Valongo and BV Paços de Ferreira (figure 4.6), with the simultaneous occurrences per day and their variation through the month for each one and their neighbors presented in appendix D. The percentage of time that occurrences were changing differently and that help was possible for each fire department in the analysis is presented in table 4.3.

We decided to do the case study again for BV Baltar and BV Paredes with a lower step, three hours since is the value we are using for our analysis. We know that when we decrease the value of the step, the number of simultaneous occurrences per step also decreases as we can see in figure

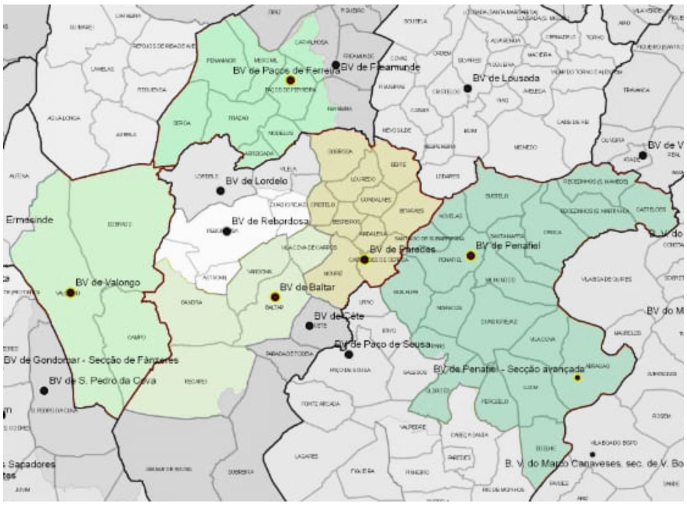

Figure 4.4: Fire departments used in the case study (the colorful ones)

4.5. Even though, for each step of three hours, the number of simultaneous occurrences varies only from 0 to 2, if we consider the one day step, we will have five simultaneous occurrences.

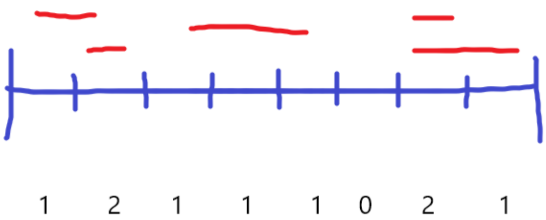

Figure 4.5: Occurrences (at red) during 1 day with a 3 hours step (number of simultaneous occurrences per step below each one)

This decrease with a lower step can make that equal variations in the number of simultaneous occurrences over the month for neighbor fire departments that were not visible in the one day step analysis show up, preventing help between them from being possible. Therefore, it was important to redo the case study with this in mind. The simultaneous occurrences per 3 hours step and their variation through the month for these two cases are presented in appendix D. The percentage of time that occurrences were changing differently and that help was possible for this two fire departments in the analysis is also presented in table 4.3. As we expected, the percentage of time that help was possible when considering the 3 hours step is lower.

After this analysis, we considered that help was possible and continued with our approach. Considering that all the neighbor crews would be available looked like to optimistic, so we also decided to see what would happen if only 50% of the neighbor crews were available. The crews available for these two approaches with the allocations made in 4.2 are presented in figure 4.6.

To explain how the value of crews available with help was obtained, let's take BV Porto as an example. According to the adjacency matrix in appendix 3.10, the neighbors of BV Porto are

Fire department	24 hours step	3 hours step
BV Paredes	100%	84%
BV Valongo	100%	-
BV Penafiel	93%	-
BV Paços de Ferreira	93%	-
BV Baltar	83%	57%

Table 4.3: Percentage of time that help is possible, August 2010

BV Areosa, BV Coimbrões, BV Portuenses and BV Valbom, with respectively 0, 1, 1 and two crews allocated in the year of 2015. Since in 2015 BV Porto had one crew allocated, the new number of crews available for them is 5. When having just 50% of neighbor crews available, if the number is decimal, it is rounded down. For example, the crews that BV Areosa, BV Coimbrões, BV Portuenses and BV Valbom had available for BV Porto in this situation were 0, 0, 0 and 1 respectively, giving BV Porto a total of 2 crews available.

Fire departments	Number of neighbors
BV Areosa	8
BV Avintes	4
BV Baltar	4
BV Cete	7
BV Coimbrões	4
BV Ermesinde	4
BV Freamunde	5
BV Gondomar	5
BV Leça do Balio	4
BV Leixões	4
BV Lordelo	4
BV Matosinhos-Leça	4
BV Moreira da Maia	9
BV Paço de Sousa	4
BV Paços de Ferreira	6
BV Paredes	9
BV Pedrouços	4
BV Penafiel	6
BV Porto	4
BV Portuenses	5
BV Rebordosa	4
BV S. Mamede de Infesta	6
BV S. Pedro da Cova	4
BV Santo Tirso	6
BV Valadares	4
BV Valbom	4
BV Valongo	10
BV Vila Meã	5

Table 4.4: Number of neighbors for each fire department of the central area of Porto

Taking into account the crews available with help using the RSO D'Hondt method, we can see in figure 4.7 that the number of neighbors doesn't have a direct connection with the number of crews available in each fire department. For a higher number of neighbors, fire departments don't necessarily have a higher of crews available. The crews available for each fire department are dependent on the number of crews allocated in their neighbors and not just the number of neighbors. As we see in figure 4.8, made from table 4.4, 15 out of 28 fire departments, 54%, have just four neighbors, so it is normal that the number of neighbors doesn't have as much influence as the number of crews allocated in the neighbors for the crews available for each fire department.

Crews per Fire Department with Help Between Neighbors	BV AREOSA	BV AVINTES	BV BALTAR	BV CETE	BV COIMBRÕES	BV ERMESINDE	BV FREAMUNDE	BV GONDOMAR	BV LEÇA DO BALIO	BV LEIXÕES	BV LORDELO	BV MATOSINHOS-LEÇA	BV MOREIRA DA MAIA	BV PAÇO DE SOUSA	BV PAÇOS DE FERREIRA	BV PAREDES	BV PEDROUÇOS	BV PENAFIEL	BV PORTO	BV PORTUENSES	BV REBORDOSA	BV S. MAMEDE DE INFESTA	BV S. PEDRO DA COVA	BV SANTO TIRSO	BV VALADARES	BV VALBOM	BV VALONGO	BV VILA MEÃ
Real Case, year 2015	0	2	2	2	1	2	3	2	0	0	1	0	0	1	2	2	0	3	1	1	1	1	2	2	1	2	3	3
Risk of Simultaneous Occurrences, D'Hondt Method	12	7	8	10	6	8	11	8	7	6	9	8	14	8	13	17	6	15	6	7	8	8	7	12	7	6	16	15
Risk of Simultaneous Occurrences, Sainte-Laguë Method	12	7	8	10	6	8	11	8	7	6	9	8	14	8	13	17	6	15	6	7	8	8	7	12	7	6	16	15
Risk of Burned Area Potential, D'Hondt Method	7	6	7	9	3	7	13	6	4	2	8	6	11	10	13	21	3	23	3	1	7	4	5	11	7	4	14	24
Risk of Burned Area Potential, Sainte-Laguë Method	7	6	7	9	3	7	13	6	4	2	8	7	12	10	13	21	3	22	3	1	7	4	5	11	7	4	14	23
Real Case, year 2015, 50%	4	3	5	7	2	4	6	5	0	0	4	0	3	5	6	7	0	7	2	1	4	1	5	6	4	3	10	6
Risk of Simultaneous Occurrences, D'Hondt Method, 50%	4	3	4	3	2	4	6	3	3	2	5	4	5	3	7	7	2	8	2	2	4	2	3	6	3	2	6	8
Risk of Simultaneous Occurrences, Sainte-Laguë Method, 50%	4	3	4	3	2	4	6	3	3	2	5	4	5	3	7	7	2	8	2	2	4	2	3	6	3	2	6	8
Risk of Burned Area Potential, D'Hondt Method, 50%	2	2	3	2	1	3	7	1	2	0	4	3	4	4	6	8	1	12	0	0	3	1	1	5	2	1	4	11
Risk of Burned Area Potential, Sainte-Laguë Method, 50%	2	2	3	2	1	3	7	1	2	0	4	3	4	4	6	8	1	12	0	0	3	1	1	5	2	1	4	11

Figure 4.6: Crews available with help between neighbors

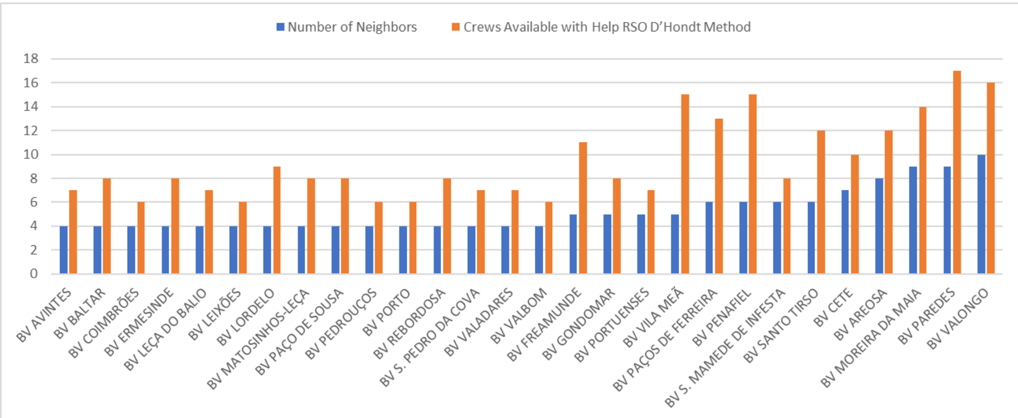

Figure 4.7: Number of crews available with help using the RSO D'Hondt method compared with number of neighbors per fire department (orderly growing by number of neighbors)

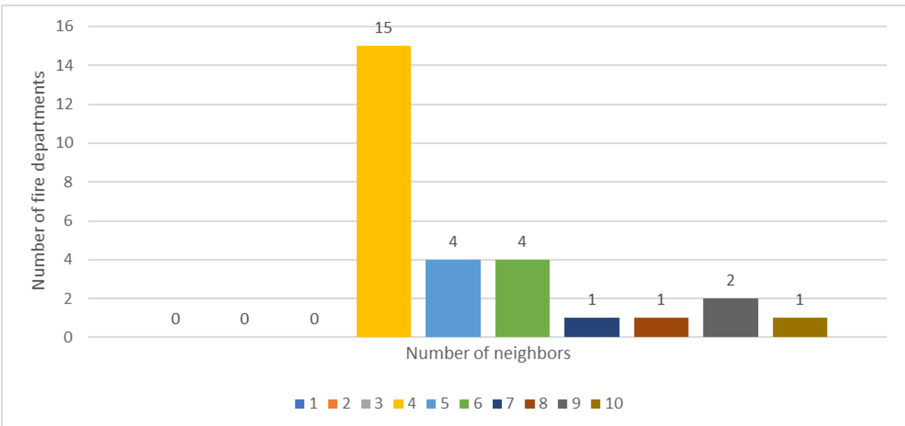

Figure 4.8: Number of fire departments per number of neighbors

4.4 Number of lacking crews

To see how many crews were lacking in each fire department, we subtract the crews that they had available in our methods by their number of necessary crews (table 4.1). To exemplify, let's look at two examples, BV Gondomar and BV Penafiel. In 2015, BV Gondomar had two crews allocated and the number of necessary crews for them was 4, so BV Gondomar has a value of -2 in figure 4.9, corresponding to 2 crews lacking. Considering help between neighbors for the RSO D'Hondt method allocation, BV Gondomar has eight crews available. Doing the subtraction again by four necessary crews, BV Gondomar has a value of 4, corresponding to 4 crews in excess (figure 4.10). In 2015, BV Penafiel had three crews allocated and the number of necessary crews for them was 8, so BV Gondomar has a value of -5 in figure 4.9, corresponding to 5 crews lacking. Considering help between neighbors for the RSO D'Hondt method allocation, BV Gondomar has 15 crews available. Doing the subtraction again by eight necessary crews, BV Gondomar has a value of 7, corresponding to 7 crews in excess (figure 4.10).

	BV AGUDA	BV AMARANTE	BV AREOSA	BV AVINTES	BV BAIÃO	BV BALTAR	BV CARVALHOS	BV CETE	BV COIMBRÕES	BV CRESTUMA	BV ENTRE-OS-RIOS	BV ERMESINDE	BV FELGUEIRAS	BV FREAMUNDE	BV GONDOMAR	BV LEÇA DO BALIO	BV LEIXÕES	BV LIXA	BV LORDELO	BV LOUSADA	BV MARCO DE CANAVESES	BV MATOSINHOS-LEÇA	BV MELRES
Risk of Simultaneous Occurrences	2	3	2	2	2	2	3	2	2	1	2	2	3	3	2	2	1	3	2	3	5	2	2
Necessary Crews per Fire Department	4	6	4	4	4	4	6	4	4	2	4	4	6	6	4	4	2	6	4	6	10	4	4
Cases Analysed																							
Real Case, year 2015	-2	-3	-4	-2	-2	-2	-4	-2	-3	-1	-2	-2	-4	-3	-2	-4	-2	-5	-3	-5	-7	-4	-3
Risk of Simultaneous Occurrences, D'Hondt Method	-3	-4	-3	-3	-2	-3	-4	-3	-2	-1	-3	-3	-4	-4	-2	-3	-1	-4	-3	-4	-6	-2	-3
Risk of Simultaneous Occurrences, Sainte-Laguē Method	-3	-4	-3	-3	-2	-3	-4	-3	-2	-1	-3	-3	-4	-4	-2	-3	-1	-4	-3	-4	-6	-2	-3
Risk of Burned Area Potential, D'Hondt Method	-3	-3	-3	-3	-3	-3	-3	-3	-3	-2	-3	-3	-4	-3	-3	-3	-2	-4	-3	-3	-1	-3	-3
Risk Burned Area Potential, Sainte-Laguē Method	-3	-3	-3	-3	-3	-3	-3	-3	-3	-2	-3	-3	-4	-3	-3	-3	-2	-4	-3	-3	-2	-3	-3

	BV MOREIRA DA MAIA	BV PAÇO DE SOUSA	BV PAÇOS DE FERREIRA	BV PAREDES	BV PEDROUÇOS	BV PENAFIEL	BV PORTO	BV PORTUENSES	BV PÓVOA DE VARZIM	BV REBORDOSA	BV S. MAMEDE DE INFESTA	BV S. PEDRO DA COVA	BV SANTA MARINHA DO ZÊZERE	BV SANTO TIRSO	BV TIRSENSES	BV TROFA	BV VALADARES	BV VALBOM	BV VALONGO	BV VILA DAS AVES	BV VILA DO CONDE	BV VILA MEÃ	**Total**
Risk of Simultaneous Occurrences	3	2	3	3	1	4	1	1	2	3	1	2	2	3	3	2	2	2	2	2	3	3	
Necessary Crews per Fire Department	6	4	6	6	2	8	2	2	4	6	2	4	4	6	6	4	4	4	4	4	6	6	206
Cases Analysed																							
Real Case, year 2015	-6	-3	-4	-4	-2	-5	-1	-1	-3	-5	-1	-2	-2	-4	-5	-2	-3	-2	-1	-2	-5	-3	-137
Risk of Simultaneous Occurrences, D'Hondt Method	-4	-3	-4	-4	-1	-5	-1	-1	-3	-4	-1	-3	-3	-4	-4	-3	-3	-3	-2	-3	-4	-4	-137
Risk of Simultaneous Occurrences, Sainte-Laguē Method	-4	-3	-4	-4	-1	-5	-1	-1	-3	-4	-1	-3	-3	-4	-4	-3	-3	-3	-2	-3	-4	-4	-137
Risk of Burned Area Potential, D'Hondt Method	-4	-3	-4	-4	-2	-3	-2	-2	-3	-4	-2	-3	-3	-4	-4	-3	-3	-3	-3	-3	-4	-4	-137
Risk Burned Area Potential, Sainte-Laguē Method	-4	-3	-4	-4	-2	-3	-2	-2	-3	-4	-2	-3	-3	-4	-4	-3	-3	-3	-3	-3	-3	-4	-137

Figure 4.9: Number of lacking crews per fire department

For the analysis without help (figure 4.9), all the fire departments had missing crews, with BV Marco de Canaveses being the one with the highest value of missing crews. The biggest difference in the RSO and RBAP methods is clearly visible also in BV Marco de Canaveses, that passed from being the fire department with the biggest amount of missing crews to the one with the lowest. This is due to the fact that BV Marco de Canaveses has the highest value of risk of burned area potential, since is a fire department in an area of the district with lots of forest for fires to expand. This emphasizes again what we were expecting, that we should consider not only the number of simultaneous occurrences but also their location and the risk of burned area potential of the fire department. On the other hand, the fire departments that had the lowest values of missing crews with RSO, 1 or 2 crews, increased their value of missing crews by one crew to fill this change of more crews in BV Marco de Canaveses.

In the analysis with 100% help (figure 4.10), the only cases that didn't have missing crews in any fire department were the ones made with the RSO. Even though the cases using RBAP had fire departments with missing crews, the total number of crews in the district were more than necessary, they were just bad distributed with fire departments with a lot of excess crews, especially the ones located in the interior of the district with lots of areas to burn, such as BV Paredes or BV Vila Meã.

Cases Analysed	BV AREOSA	BV AVINTES	BV BALTAR	BV CETE	BV COIMBRÕES	BV ERMESINDE	BV FREAMUNDE	BV GONDOMAR	BV LEÇA DO BALIO	BV LEIXÕES	BV LORDELO	BV MATOSINHOS-LEÇA	BV MOREIRA DA MAIA	BV PAÇO DE SOUSA
Real Case, year 2015	7	3	6	11	2	3	5	6	-3	0	5	-3	2	6
Risk of Simultaneous Occurrences, D'Hondt Method	8	3	4	6	2	4	5	4	3	4	5	4	8	4
Risk of Simultaneous Occurrences, Sainte-Laguë Method	8	3	4	6	2	4	5	4	3	4	5	4	8	4
Risk of Burned Area Potential, D'Hondt Method	3	2	3	5	-1	3	7	2	0	0	4	2	5	6
Risk of Burned Area Potential, Sainte-Laguë Method	3	2	3	5	-1	3	7	2	0	0	4	3	6	6
Real Case, year 2015, 50%	0	-1	1	3	-2	0	0	1	-4	-2	0	-4	-3	1
Risk of Simultaneous Occurrences, D'Hondt Method, 50%	0	-1	0	-1	-2	0	0	-1	-1	0	1	0	-1	-1
Risk of Simultaneous Occurrences, Sainte-Laguë Method, 50%	0	-1	0	-1	-2	0	0	-1	-1	0	1	0	-1	-1
Risk of Burned Area Potential, D'Hondt Method, 50%	-2	-2	-1	-2	-3	-1	1	-3	-2	-2	0	-1	-2	0
Risk of Burned Area Potential, Sainte-Laguë Method, 50%	-2	-2	-1	-2	-3	-1	1	-3	-2	-2	0	-1	-2	0

Cases Analysed	BV PAÇOS DE FERREIRA	BV PAREDES	BV PEDROUÇOS	BV PENAFIEL	BV PORTO	BV PORTUENSES	BV REBORDOSA	BV S. MAMEDE DE INFESTA	BV S. PEDRO DA COVA	BV SANTO TIRSO	BV VALADARES	BV VALBOM	BV VALONGO	BV VILA MEÃ	Total	Missing	Excess
Real Case, year 2015	8	12	0	7	3	2	3	0	6	6	4	2	15	8	126	6	132
Risk of Simultaneous Occurrences, D'Hondt Method	7	11	4	7	4	5	2	6	3	6	3	2	12	9	145	0	145
Risk of Simultaneous Occurrences, Sainte-Laguë Method	7	11	4	7	4	5	2	6	3	6	3	2	12	9	145	0	145
Risk of Burned Area Potential, D'Hondt Method	7	15	1	15	1	-1	1	2	1	5	3	0	10	18	119	2	121
Risk of Burned Area Potential, Sainte-Laguë Method	7	15	1	14	1	-1	1	2	1	5	3	0	10	17	119	2	121
Real Case, year 2015, 50%	0	1	-2	-1	0	-1	-2	-1	1	0	0	-1	6	0	-10	24	14
Risk of Simultaneous Occurrences, D'Hondt Method, 50%	1	1	0	0	0	0	-2	0	-1	0	-1	-2	2	2	-7	14	7
Risk of Simultaneous Occurrences, Sainte-Laguë Method, 50%	1	1	0	0	0	0	-2	0	-1	0	-1	-2	2	2	-7	14	7
Risk of Burned Area Potential, D'Hondt Method, 50%	0	2	-1	4	-2	-2	-3	-1	-3	-1	-2	-3	0	5	-27	39	12
Risk of Burned Area Potential, Sainte-Laguë Method, 50%	0	2	-1	4	-2	-2	-3	-1	-3	-1	-2	-3	0	5	-27	39	12

Figure 4.10: Number of lacking crews per fire department with help between neighbors

When considering 50% of help, all the cases had lacking crews in the district, even though some fire departments had excess crews. The RSO analysis is the one the lowest values of lacking crews in the district, 7 lacking crews, but we still think that we should consider the RBAP and not only the RSO.

Taking into account the number of crews available in excess with help also using the RSO D'Hondt method, we can see in figure 4.11 that with a higher number of neighbors, fire departments have in general a higher number of excess crews available.

After this, we decided to see, for the analysis using the Sainte-Laguë method with the RSO and RBAP, how many crews over the 69 available would be needed in order for the district to have enough crews when considering 50% of help.

Number of crews	Total	Missing	Excess
69	-7	14	7
70	-1	11	10
71	-1	11	10
72	2	8	10
84	52	0	52

Table 4.5: Number of total lacking crews in the district and missing and excess in fire departments considering the RSO Sainte-Laguë method with 50% help

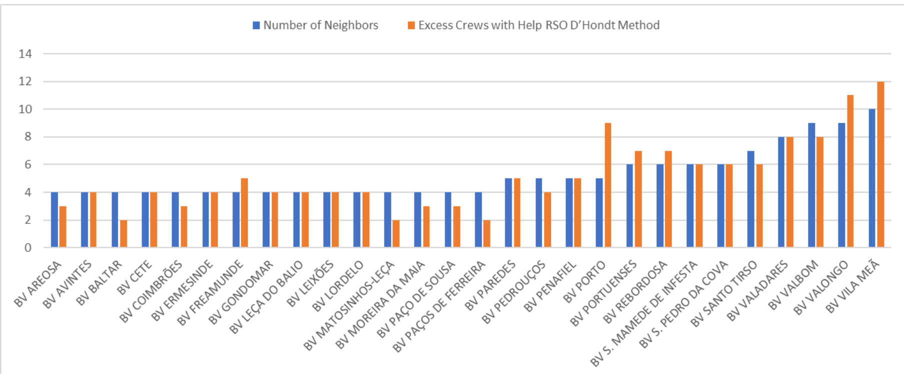

Figure 4.11: Number of excess crews available with help using the RSO D'Hondt method compared with number of neighbors per fire department (orderly growing by number of neighbors)

When considering the RSO (table 4.5), we should have 72 available to allocate in order for the district to have enough crews. This is just three more crews than what he had in 2015. But still, with this 72 crews, there are some fire departments with missing crews. In order for all fire departments to have enough crews, the number of teams to allocate grows to 84. When we increased the number of crews from 70 to 71, the number of total lacking crews stayed the same. This is due to the fact that this team was allocated to BV Vila Meã, a fire department that is not included in the central area of the district and that the only neighbor, BV Marco de Canaveses, is also not included in the central area. With this in mind, this crew allocated in BV Vila Meã will not have influence for the crews available in the fire departments in the central area of the district.

Number of crews	Total	Missing	Excess
69	-27	39	12
72	-25	39	14
84	-10	36	26
88	-2	32	30
89	4	32	36

Table 4.6: Number of total lacking crews in the district and missing and excess in fire departments considering the RBAP Sainte-Laguë method with 50% help

When considering the RBAP (table 4.6), the number of crews to allocate in order for the district to have enough crews grows a lot. If we consider the 72 crews from the RSO approach, the district still misses 25 crews. When we consider the 84 crews that made that no fire department had missing crews in table 4.5, we still have ten lacking crews in the district. Eighty-nine crews would be necessary in order for the district to have enough crews, which is an increase of 20 crews relatively to the 69 crews allocated in 2015.

With these values of crews previous analyzed, we also decided to see how changing the percentage of help from neighbors would influence the number of crews that are necessary for the district.

	number of crews			
% of help	69	70	71	72
50%	-7	-1	-1	2
60%	-7	-1	-1	2
70%	-4	2	2	5
80%	-2	4	4	7
90%	-2	4	4	7
100%	145	151	151	154

Figure 4.12: Number of lacking crews in the district when considering the RSO with help between neighbors, changing the total number of crews allocated and the percentage of help available

When considering the RSO (figure 4.12), we see that, even though we had previously said that 72 crews would be needed in order for the district to have enough crews with 50% of help, if we increase the percentage of help to 70%, 70 crews would be enough, which is just 1 more crew than the 69 allocated in 2015.

	number of crews				
% of help	69	70	71	72	89
50%	-27	-26	-26	-25	4
60%	-24	-23	-23	-22	9
70%	-11	-5	-5	4	39
80%	-6	0	0	9	60
90%	-4	2	2	11	65
100%	119	125	125	134	190

Figure 4.13: Number of lacking crews in the district when considering the RBAP with help between neighbors, changing the total number of crews allocated and the percentage of help available

When considering the RBAP (figure 4.13), we saw previously that 89 crews would be needed in order for the district to have enough crews with 50% of help, what was a clear increase of crews when compared to the 69 crews allocated in 2015. But if, once again, we increase the percentage of help to 70% as we did with the RSO, 72 crews would be enough, which is the same value as we got for the RSO when considering 50% of help. If we increase this percentage of help to 80%, the 70 crews that we got with the RSO for 70% of help would be enough for the district to have exactly the amount of crews that it needs. This analysis emphasizes again what we were saying, that we should consider the RBAP and not only the RSO.

In figure 4.14, we can see more in detail the influence of changing the number of crews and the percentage of help available on the number of lacking crews in the district when considering the RBAP. From this figure, we made the graphic in figure 4.15, that shows us what is the percentage of help that needs to be available in order for the district to have enough crews to control the occurrences happening, when changing the number of crews from the 69 allocated in 2015 to the 89 crews that we saw before that would make that the district has enough crews when considering 50% of help available. For example, between 72 crews and 85 crews, the percentage of help that needs to be available is always 67% for the district to have enough crews. What this shows us is that maybe is not worth it to have more than 72 crews if our goal is to have just 67% of help available. Allocating crews from 73 to 85 would give the same security level of help available as 72 crews and would be more expensive, so these decisions have to be really taken with considerable reflection.

	number of crews																				
% of help	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89
50%	-27	-26	-26	-25	-25	-25	-24	-23	-22	-21	-21	-17	-15	-11	-10	-10	-8	-5	-4	-2	4
51%	-27	-26	-26	-25	-25	-25	-24	-23	-22	-21	-21	-17	-15	-11	-10	-10	-8	-5	-4	-2	4
52%	-27	-26	-26	-25	-25	-25	-24	-23	-22	-21	-21	-17	-15	-11	-10	-10	-8	-5	-4	-2	4
53%	-27	-26	-26	-25	-25	-25	-24	-23	-22	-21	-21	-17	-15	-11	-10	-10	-8	-5	-4	-2	4
54%	-27	-26	-26	-25	-25	-25	-24	-23	-22	-21	-21	-17	-15	-11	-10	-10	-8	-5	-4	-2	4
55%	-27	-26	-26	-25	-25	-25	-24	-23	-22	-21	-21	-17	-15	-11	-10	-8	-6	-3	-2	-2	6
56%	-27	-26	-26	-25	-25	-25	-24	-23	-22	-21	-19	-15	-15	-11	-10	-8	-6	-3	-2	0	6
57%	-27	-26	-26	-25	-25	-25	-24	-23	-22	-21	-19	-15	-15	-11	-10	-7	-6	-3	-2	0	6
58%	-27	-26	-26	-25	-25	-25	-24	-23	-22	-21	-19	-15	-15	-11	-7	-5	-3	0	1	3	9
59%	-27	-26	-26	-25	-25	-25	-24	-23	-22	-21	-19	-15	-15	-11	-7	-5	-3	0	1	3	9
60%	-24	-23	-23	-22	-22	-22	-21	-20	-19	-18	-16	-15	-13	-9	-5	-5	-3	0	1	3	9
61%	-24	-23	-23	-22	-22	-22	-21	-20	-19	-18	-16	-15	-13	-9	-5	-5	-3	0	1	3	9
62%	-24	-23	-23	-22	-22	-22	-21	-20	-19	-18	-16	-15	-13	-9	-5	-5	-3	0	1	3	9
63%	-22	-21	-21	-20	-20	-20	-19	-18	-17	-16	-16	-15	-13	-9	-5	-5	-3	0	1	3	9
64%	-22	-21	-21	-20	-20	-20	-19	-18	-17	-16	-16	-15	-13	-9	-5	-3	-1	2	3	5	11
65%	-22	-21	-21	-20	-20	-20	-19	-18	-17	-16	-16	-15	-13	-9	-5	-3	-1	2	3	5	11
66%	-22	-21	-21	-20	-20	-20	-19	-18	-17	-16	-16	-15	-13	-9	-5	-3	-1	2	3	5	11
67%	-11	-5	-5	4	7	8	13	18	20	28	30	34	34	34	35	37	37	38	38	38	39
68%	-11	-5	-5	4	7	8	13	18	20	28	30	34	34	34	35	37	37	38	38	38	39
69%	-11	-5	-5	4	7	8	13	18	20	28	30	34	34	34	35	37	37	38	38	38	39
70%	-11	-5	-5	4	7	8	13	18	20	28	30	34	36	36	37	37	37	38	38	38	39
71%	-11	-5	-5	4	7	8	13	18	20	28	30	34	36	36	37	37	37	38	38	38	39
72%	-11	-5	-5	4	7	8	13	18	20	28	30	34	36	36	40	40	40	41	41	41	42
73%	-11	-5	-5	4	7	8	13	18	20	28	30	34	36	36	40	42	42	43	43	43	44
74%	-11	-5	-5	4	7	8	13	18	20	28	30	34	36	36	40	42	42	43	43	43	44
75%	-9	-3	-3	6	9	10	15	20	22	30	30	34	36	40	44	46	48	51	52	54	60
76%	-9	-3	-3	6	9	10	15	20	22	30	30	34	36	40	44	46	48	51	52	54	60
77%	-9	-3	-3	6	9	10	15	20	22	30	30	34	36	40	44	46	48	51	52	54	60
78%	-9	-3	-3	6	9	10	15	20	22	30	32	36	36	40	44	46	48	51	52	54	60
79%	-9	-3	-3	6	9	10	15	20	22	30	32	36	36	40	44	46	48	51	52	54	60
80%	-6	0	0	9	12	13	18	23	25	33	35	36	38	42	46	46	48	51	52	54	60
81%	-6	0	0	9	12	13	18	23	25	33	35	36	38	42	46	46	48	51	52	54	60
82%	-6	0	0	9	12	13	18	23	25	33	35	36	38	42	46	48	50	53	54	56	62
83%	-6	0	0	9	12	13	18	23	25	33	35	36	38	42	46	48	50	53	54	56	62
84%	-6	0	0	9	12	13	18	23	25	33	35	39	41	45	46	48	50	53	54	56	62
85%	-6	0	0	9	12	13	18	23	25	33	35	39	41	45	46	48	50	53	54	56	62
86%	-6	0	0	9	12	13	18	23	25	33	35	39	41	45	49	51	53	56	57	59	65
87%	-6	0	0	9	12	13	18	23	25	33	35	39	41	45	49	51	53	56	57	59	65
88%	-4	2	2	11	14	15	20	25	27	35	35	39	41	45	49	51	53	56	57	59	65
89%	-4	2	2	11	14	15	20	25	27	35	37	41	41	45	49	51	53	56	57	59	65
90%	-4	2	2	11	14	15	20	25	27	35	37	41	43	47	51	51	53	56	57	59	65
91%	-4	2	2	11	14	15	20	25	27	35	37	41	43	47	51	53	55	58	59	61	67
92%	-4	2	2	11	14	15	20	25	27	35	37	41	43	47	51	53	55	58	59	61	67
93%	-4	2	2	11	14	15	20	25	27	35	37	41	43	47	51	53	55	58	59	61	67
94%	-4	2	2	11	14	15	20	25	27	35	37	41	43	47	51	53	55	58	59	61	67
95%	-4	2	2	11	14	15	20	25	27	35	37	41	43	47	51	53	55	58	59	61	67
96%	-4	2	2	11	14	15	20	25	27	35	37	41	43	47	51	53	55	58	59	61	67
97%	-4	2	2	11	14	15	20	25	27	35	37	41	43	47	51	53	55	58	59	61	67
98%	-4	2	2	11	14	15	20	25	27	35	37	41	43	47	51	53	55	58	59	61	67
99%	-4	2	2	11	14	15	20	25	27	35	37	41	43	47	51	53	55	58	59	61	67
100%	119	125	125	134	137	138	143	146	150	158	160	164	166	170	174	176	178	181	182	184	190

Figure 4.14: Number of lacking crews in the district when considering the RBAP with help between neighbors, changing the total number of crews allocated and the percentage of help available

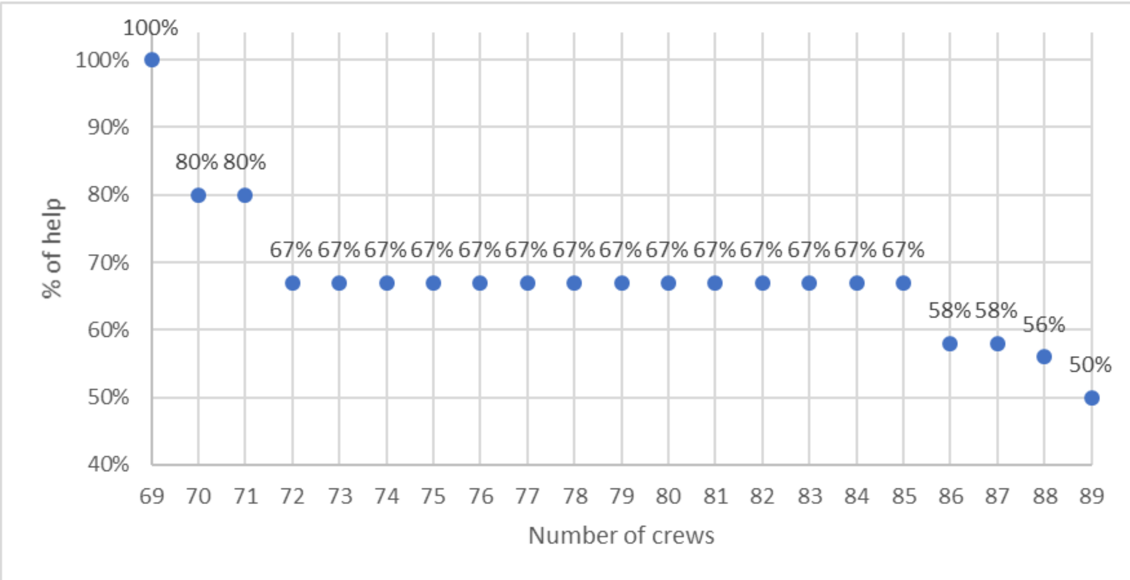

Figure 4.15: Percentage of help that needs to be available for each total number of crews allocated in order for the district to have enough crews to control the occurrences happening

Chapter 5

Conclusion

The goal of this dissertation was to compare the existing scenario of allocation of crews with a new one and see if the number of crews available in the district of Porto is enough. With the 69 crews available in 2015, two new methods of allocation were used in order to see if the allocation could be made in another way. After this, we considered that help between neighbor fire departments was possible and that each fire department had not only their own crews available but also the crews from their neighbors if they were needed.

The results that we got indicated that the number of crews available was not enough for each fire department to control their own occurrences and that the allocation of the available crews could be done differently also. Despite this, if help between neighbor fire departments was considered, the number of crews available was enough if we considered that help was available 100% of the time, just being bad distributed by the fire departments. Even though the analysis with the RSO seemed better when looking to the number of lacking crews, we still emphasize that the better analysis is the RBAP and that we shouldn't consider only the number of simultaneous occurrences but also the burned area.

5.1 Limitations and future work

One limitation in this dissertation was the fact that data from 2013, 2014 and 2015 had to be excluded because there was no information about the area of intervention of the fire departments for those years. After we get the data about that, this dissertation can be expanded for all the years.

The next step for this dissertation is to expand it to the rest of Portugal and see if it works, optimizing the system every year using the data from the previous year or years to do the allocation of crews. Other methods of allocation can also be tested.

Another approach that can be used for the problem is, instead of just saying that the crews available per fire department is their own crews plus the ones from neighbor fire departments, redo the simultaneity cycle in order to say that the number of occurrences for each fire department is not only the ones in their area of intervention but also the ones in the area of intervention of their neighbors, followed by a new allocation of crews with D'Hondt method and Sainte-Laguë method already with this difference in mind.

References

M. Ahrens. *The US fire problem overview report: leading causes and other patterns and trends*. Fire Analysis and Research Division, National Fire Protection Association, Quincy, Massachusetts, 2003.

Autoridade Nacional de Protecção Civil. Plano de operações distrital nº 01. Technical report, 2015.

Autoridade Nacional de Protecção Civil. Plano de operações distrital nº 01. Technical report, 2018.

Autoridade Nacional de Protecção Civil. Diretiva operacional nacional nº2. Technical report, 2019.

James Bookbinder and David Martell. Time-dependent queueing approach to helicopter allocation for forest fire initial-attack. *INFOR: Information Systems and Operational Research*, 17(1):58–70, 1979. doi: 10.1080/03155986.1979.11731717.

A. Carvalho, M. D. Flannigan, K. Logan, A. I. Miranda, and C. Borrego. Fire activity in Portugal and its relationship to weather and the Canadian Fire Weather Index System. *International Journal of Wildland Fire*, 17(3):328–338, 2008. ISSN 1049-8001. doi: 10.1071/wf07014.

Filipe Catry, Francisco Rego, Fernando Bação, and Francisco Moreira. Modeling and mapping wildfire ignition risk in portugal. *International Journal of Wildland Fire*, 18:921–931, 2009. doi: 10.1071/WF07123.

Instituto da Conservação da Natureza e das Florestas. Estatísticas, 2016. URL `http://www2.icnf.pt/portal/florestas/dfci/inc`.

Van Dang and W Croft. Diversity by proportionality: An election-based approach to search result diversification. pages 65–74, 08 2012.

Ricardo Campelo de Magalhães. Simulador do método de hondt, 2011. URL `https://limianoliberal.wordpress.com/2011/03/12/simulador-do-metodo-de-hondt/`.

Paulo Fernandes, Abílio P Pacheco, Rui Almeida, and João Claro. The role of fire-suppression force in limiting the spread of extremely large forest fires in portugal. *European Journal of Forest Research*, 135(2):253–262, Apr 2016.

Mark Finney, Isaac C. Grenfell, and Charles W. McHugh. Modeling containment of large wildfires using generalized linear mixed-model analysis. *Forest Science*, 55, 06 2009.

Michael Gallagher. Proportionality, disproportionality and electoral systems. *Electoral Studies*, 10(1):33–51, 1991. ISSN 02613794. doi: 10.1016/0261-3794(91)90004-C.

G. Grothendieck. *Manipulate R Data Frames Using SQL*, 06 2017. URL https://cran.r-project.org/web/packages/sqldf/index.html.

Enrico Marchi, Francesco Neri, Enrico Tesi, Fabio Fabiano, and Niccolò Brachetti Montorselli. Analysis of helicopter activities in forest fire-fighting. *Croatian Journal of Forest Engineering*, 35:247–257, 2014.

D L Martell, R J Drysdale, G E Doan, and D Boychuk. An evaluation of forest fire initial attack resources. *INFORMS Journal on Applied Analytics*, 14(5):20–32, 1984.

David Martell. A review of operational research studies in forest fire management. *Canadian Journal of Forest Research-revue Canadienne De Recherche Forestiere - CAN J FOREST RES*, 12:119–140, 06 1982. doi: 10.1139/x82-020.

David Martell. the Development and Implementation of Forest Fire Management Decision Support Systems in Ontario, Canada: Personal Reflections on Past Practices and Emerging Challenges. *Forestry & Natural-Resource Sciences Last Correction*, 3(1):18–26, 2010.

David Martell. A review of recent forest and wildland fire management decision support systems research. *Current Forestry Reports*, 1, 06 2015. doi: 10.1007/s40725-015-0011-y.

David L. Martell. *Chapter 15 - Forest Fire Management*, pages 527 – 583. Academic Press, San Diego, 2001.

David L. Martell. *Forest Fire Management*, pages 489–509. Springer US, Boston, MA, 2007. ISBN 978-0-387-71815-6. doi: 10.1007/978-0-387-71815-6_26.

Américo M S Carvalho Mendes. Forest owners' organizations in Portugal: Are the infant going to survive? *Small-scale forestry and rural development: The intersection of ecosystems, economics and society. IUFRO 3.08 meeting*, pages 289–304, 2006.

D F Merrill and Martin E Alexander. *Glossary of forest fire management terms*. Canadian Committee on Forest Fire Management, National Research Council of Canada, 1987.

James Minas, John Hearne, and John Handmer. A review of operations research methods applicable to wildfire management. *International Journal of Wildland Fire*, 21:189–196, 02 2012. doi: 10.1071/WF10129.

A. P. Pacheco. Análise de simulação de um sistema de supressão de incêndios florestais. Master's thesis, Faculdade de Engenharia Universidade do Porto, Porto, Portugal, 2011.

Abilio Pacheco, João Claro, and Tiago Oliveira. Rekindle dynamics: validating the pressure on wildland fire suppression resources and implications for fire management in portugal. volume 158, 05 2012. doi: 10.2495/FIVA120191.

Abilio Pacheco, João Claro, Paulo Fernandes, Richard de Neufville, Tiago Oliveira, J Borges, and José Rodrigues. Cohesive fire management within an uncertain environment: A review of risk handling and decision support systems. *Forest Ecology and Management*, 347:1–17, 07 2015. doi: 10.1016/j.foreco.2015.02.033.

Abílio P. Pacheco, João Claro, and Tiago Oliveira. Simulation analysis of the impact of ignitions, rekindles, and false alarms on forest fire suppression. *Canadian Journal of Forest Research*, 44 (1):45–55, 2014. ISSN 0045-5067. doi: 10.1139/cjfr-2013-0257.

Inês Maria Lage Mier Pelaez. Is there evidence of flexibility in the management of the portuguese firefighting helicopter fleet? (unpublished). Master's thesis, Faculdade de Engenharia Universidade do Porto, Porto, Portugal, 2018.

R Core Team. *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria, 2017. URL https://www.R-project.org/.

RStudio Team. *RStudio: Integrated Development Environment for R*. RStudio, Inc., Boston, MA, 2015. URL http://www.rstudio.com/.

Zita Saraiva, António Borges, and Sandra Fernandes. Controlo de matos e redução de combustíveis, prevenção de incêndios florestais. Technical report, Arbórea - Associação Florestal da Terra Fria Transmontana, 2007.

João Lourenço Silva. Simulador do método de sainte-laguë, 2019. URL https://paginas.fe.up.pt/~up201306121/trabalhosSiem/tese.html.

Hugo Torres, A. P. Pacheco, and João Claro. Dimensionamento do dispositivo de combate a incêndios rurais. unpublished, 2018.

Hugo Flávio da Silva Torres. Flexible design of a helipad network for a fleet of forest firefighting helicopters (unpublished). Master's thesis, Faculdade de Engenharia Universidade do Porto, Porto, Portugal, 2016.

Hadley Wickham and Jennifer Bryan. *Read Excel Files*, 03 2019. URL https://cran.r-project.org/web/packages/sqldf/index.html.

Appendix A

Colaboration code

The following code presented in this appendix was done in colaboration with Guilherme Torres and Afonso Ungaro.

A.1 Code manual

Análise de ocorrências simultâneas e da área ardida

Manual de utilização dos scripts

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2019-05-03

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Manual utilizador

Conteúdo

1. Pré-Processamento

1.1 – Como está dividido?

Este ficheiro está dividido em:

- Importação das bibliotecas e definição dos diretórios;
- Definição das funções a utilizar;
- Importação das tabelas de NUTS3 por Concelho e Corporações de Bombeiros por INE;
- Importação dos dados relativos aos 15 anos;
- Normalização das colunas para juntar todos os dados numa única dataframe;
- Normalização das variáveis espaciais (todos os nomes em maiúsculas e sem acentos);
- Correção das durações incoerentes e imputação de novas durações baseado nas classes de área ardida;
- Ordenação da dataframe por data de ocorrência;
- Adição das colunas das NUTS3 e das Corporações;
- Conversão em fator das variáveis espaciais, com o intuito de poder efetuar uma análise agrupada por fatores;
- Criação de dataframes de correção de erros;
- Exportação dos dados para os formatos .xlsx e RDS

1.2 – Como funciona?

- Instalação e inicialização dos packages:
  - para instalar fazer install.packages("<nome_do_package>")
  - para inicializar fazer library(<nome_do_package>)
- Definição das funções:
  - função acentos

```
acentos <- function(x) iconv(x,from= "UTF-8", to = "ASCII//TRANSLIT")
```

  - função imputar

```
imputar <- function(y) { #funcao para imputar data e hora de extincao a entradas com as mesmas invalidas
  x<-Lista_Total$`AA_Total (pov+mato+agric) (ha)`[y]
  if(x==0){
    z<-Lista_Total$DataAlerta[y]+Lista_Total$HoraAlerta[y]+0.0368 # Data extincao final (dia mais hora)
  }
  if(x>0 && x<=1){
    z<-Lista_Total$DataAlerta[y]+Lista_Total$HoraAlerta[y]+0.0569 # Data extincao final (dia mais hora)
  }
  if(x>1 && x<=10){
    z<-Lista_Total$DataAlerta[y]+Lista_Total$HoraAlerta[y]+0.1465 # Data extincao final (dia mais hora)
  }
  if(x>10 && x<=100){
    z<-Lista_Total$DataAlerta[y]+Lista_Total$HoraAlerta[y]+0.3180 # Data extincao final (dia mais hora)
  }
  if(x>100 && x<=1000){
    z<-Lista_Total$DataAlerta[y]+Lista_Total$HoraAlerta[y]+0.8420 # Data extincao final (dia mais hora)
  }
  if(x>1000 && x<=2000){
    z<-Lista_Total$DataAlerta[y]+Lista_Total$HoraAlerta[y]+1.5489 # Data extincao final (dia mais hora)
  }
  if(x>2000 && x<=10000){
    z<-Lista_Total$DataAlerta[y]+Lista_Total$HoraAlerta[y]+3.8881 # Data extincao final (dia mais hora)
  }
  if(x>10000 && x<=30000){
    z<-Lista_Total$DataAlerta[y]+Lista_Total$HoraAlerta[y]+5.9375 # Data extincao final (dia mais hora)
  }
    return(z)
}
```

Divididas as durações das ocorrências por área ardida em 8 classes;

Feita a mediana dos valores de duração de cada intervalo;

- Importação das tabelas de NUTS3 e Corporações de bombeiros a partir dos ficheiros Excel presentes na pasta “Import/”. No caso das NUTS3 estas foram obtidas a partir do nome dos Concelhos enquanto relativamente às Corporações foram obtidas a partir do código INE contendo a tabela também informações relativas à corporação de FreguesiaCB, ConcelhoCB, DistritoCB, INECB, LocalidadeCB, xCB, yCB, NomeCB e CodCB, INE.
- Importação dos dados:

```
#------------------------------------- < 2015 > -------------------------------------

Lista_Incendios_2015 <- read_excel("Dados/Lista Incendios_2015.xlsx",
                                   col_types = c("numeric", "text", "numeric",
                                                 "text", "text", "text", "text", "text",
                                                 "numeric", "numeric", "numeric",
                                                 "text", "text", "numeric", "numeric",
                                                 "numeric", "numeric", "numeric",
                                                 "numeric", "text", "text", "numeric",
                                                 "numeric", "numeric", "numeric",
                                                 "numeric", "numeric", "numeric",
                                                 "numeric", "numeric", "numeric",
                                                 "numeric", "text", "text", "text",
                                                 "text", "text", "text"))
```

Usada a função read_excel e replicada a ação para todos os 15 anos.

- Normalização das colunas:
  Para a normalização foi usada como base os nomes que existiam no ano de análise mais recente (2015). São eles:

- Ano
- Codigo SGIF
- Codigo_ANPC
- Tipo
- Distrito
- Concelho
- Freguesia
- Local
- INE
- x
- y
- lat
- lon
- DataAlerta
- HoraAlerta
- DataExtincao
- HoraExtincao
- Data1Intervencao
- Hora1Intervencao
- FonteAlerta
- NUT
- AA_Povoamento (ha)
- AA_Mato (ha)
- AA_Agricola (ha)
- AA_EspacosFlorestais (pov+mato)(ha)
- AA_Total (pov+mato+agric) (ha)
- Reacendimentos
- Queimada
- Falso Alarme
- Fogacho
- Incendio
- Agricola
- Perimetro
- APS
- Causa
- TipoCausa
- Regiao PROF
- UGF

Como apenas os anos de 2015 e 2014 tinham todos estes valores, nos restantes foram incluídos com valores NA ou "NULL" dependendo se a variável era numérica ou texto.

```
colnames(Lista_Incendios_2002) <- c("Ano", "Codigo SGIF", "Tip
Lista_Incendios_2002["lat"]<-c(NA)
Lista_Incendios_2002["lon"]<-c(NA)
Lista_Incendios_2002["Codigo_ANPC"]<-c("NULL")
Lista_Incendios_2002["Regiao PROF"]<-c("NULL")
Lista_Incendios_2002["UGF"]<-c("NULL")
```

- Junção numa única dataframe:
  Para a junção numa única dataframe e como anteriormente foram normalizados todos os nomes das colunas foi apenas necessário utilizar a função rbind() de modo a juntar todas as linhas.

- Normalização das variáveis espaciais:
  -Utilização da função acentos() para retirar todos os acentos;
  -Utilização da função toupper() para converter todas as letras em maiúsculas;
  - Correção dos erros de escrita dos concelhos de "Freixo de Espada à Cinta e "Sobral de Monte Agraço"

- Correção das durações incoerentes e imputação de novas durações:

  Baseado na análise dos dados presente no documento "Relatório Código.docx" foram consideradas incoerentes todas as durações superiores a 26 dias e inferiores a 0 dias.

A todos os dados que se encontravam nesta situação foi feita a imputação definida na função imputar valores estes que também estão descritos no documento acima indicado.

- Ordenação por data de ocorrência:

```
Lista_Total <- arrange(Lista_Total,DataAlerta,HoraAlerta)
```

- Criação de uma dataframe apenas com dados do distrito do porto:

```
linhas_lista2 <- as.numeric(nrow(Lista_snull)) #total de linhas da lista

Lista_porto <- Lista_snull

for(i in 1:linhas_lista2){

  if(Lista_porto$Distrito[i] !="PORTO"){

    Lista_porto$Distrito[i] <- NA
  }
}
```

Retiradas apenas as ocorrências referentes ao Distrito do Porto

- Adição das colunas das NUTS3 e das Corporações

```
Lista_porto_CB<-join(Lista_porto, imputacao_CB_filtrado, by = "INE", type = "left")
```

```
Lista_snull<-join(Lista_snull, imputacao_nuts, by = "Concelho", type = "left")
```

- Conversão para fator das variáveis espaciais:

```
Lista_snull$Distrito<-as.factor(Lista_snull$Distrito)
Lista_snull$Concelho<-as.factor(Lista_snull$Concelho)
Lista_snull$Freguesia<-as.factor(Lista_snull$Freguesia)
Lista_snull$NUTS3<-as.factor(Lista_snull$NUTS3)
Lista_snull$Ano<-as.factor(Lista_snull$Ano)

Lista_porto_CB$Distrito<-as.factor(Lista_porto_CB$Distrito)
Lista_porto_CB$Concelho<-as.factor(Lista_porto_CB$Concelho)
Lista_porto_CB$Freguesia<-as.factor(Lista_porto_CB$Freguesia)
Lista_porto_CB$NomeCB<-as.factor(Lista_porto_CB$NomeCB)
```

Fatorizam-se as variáveis espaciais, com o intuito de poder efetuar uma análise agrupada por fatores;

- Criação de dataframes de correção de erro:

```
erro1_resultados_distrito<-as.data.frame(levels(Lista_snull$Distrito))
colnames(erro1_resultados_distrito)[1]<-"Distrito"

erro1_resultados_concelho<-as.data.frame(levels(Lista_snull$Concelho))
colnames(erro1_resultados_concelho)[1]<-"Concelho"

erro1_resultados_freguesia<-as.data.frame(levels(Lista_snull$Freguesia))
colnames(erro1_resultados_freguesia)[1]<-"Freguesia"

erro1_resultados_NUTS3<-as.data.frame(levels(Lista_snull$NUTS3))
colnames(erro1_resultados_NUTS3)[1]<-"NUTS3"

erro1_resultados_CB<-as.data.frame(levels(Lista_porto_CB$NomeCB))
colnames(erro1_resultados_CB)[1]<-"CB"
```

De modo a corrigir o erro de termos um step inicial sem ocorrências foram criadas estas dataframes de base para colocar o nome das variáveis espaciais e a suas entradas a 0.

1.3– Que variáveis posso alterar?

Não existem variáveis passíveis de alteração, porém ao código podem ser adicionados novos dados anuais e novas regiões de análise.

1.4 – Como são guardados os dados?

Como output do script são gerados quatro pares de ficheiros:

Como ficheiros **.xlsx** foram guardados os seguintes:

Lista_Original.xlsx

Lista_Total.xlsx

Lista_snull.xlsx

Lista_porto_CB.xlsx

Como ficheiros **.rds** foram guardados os seguintes:

Lista_Original.rds

Lista_Total.rds

Lista_snull.rds

Lista_porto_CB.rds

2. Ciclo Simultaneidade

2.1 – Como está dividido?

Este ficheiro está dividido em:

- Importação das bibliotecas e definição dos diretórios
- Remoção de variáveis referentes a análises anteriores
- Definição das variáveis do ciclo de simultaneidade
- Execução do ciclo de simultaneidade
- Cálculo dos dados estatísticos
- Exportação dos dados para os formatos .xlsx e .pdf

2.2 – Como funciona?

O funcionamento em cada parte do código é o seguinte:

- Instalação e inicialização dos packages:
  - para instalar fazer install.packages("<nome_do_package>")
  - para inicializar fazer library(<nome_do_package>)
- Ciclo simultaneidade:
  - ciclo while controla se os valores estão dentro do step;
  - ciclo for percorre as linhas da lista que contém todos os anos;
- Correção de erros:
  - as data frames erro1_resultados_<regiao> permitem que seja escrito uma linha completa a zeros no caso de não haver ocorrências no primeiro step do ciclo
- Cálculo de estatísticas:
  - é calculado o <u>Máximo</u> dos valores obtidos no ciclo por região recorrendo à função max();
  - é calculado o <u>Mínimo</u> dos valores obtidos no ciclo por região recorrendo à função min();
  - é calculada a <u>Média</u> dos valores obtidos no ciclo por região recorrendo à função rowMeans();
  - é calculado o <u>Desvio Padrão</u> dos valores obtidos no ciclo por região recorrendo à função sd();
  - são calculados o <u>VaR 95, VaR 5 e Mediana (VaR 50)</u> dos valores obtidos no ciclo por região recorrendo à função quantile(x, probs) onde x é o array de valores e o probs é o valor do VaR respectivamente 0.95, 0.05 e 0.50.
  - é calculado o Conditional VaR 95 fazendo a média dos valores maiores ou iguais ao seu respectivo VaR 95.

2.3 – Que variáveis posso alterar?

- **Perl –** Software que permite guardar os dados em formato .xlsx sem recorrer ao Java. Necessário fazer o seu download em strawberryperl.com. A variável perl representa o diretório onde foi instalado o perl que por defeito está em:

```
perl <- "C:/strawberry/perl/bin/perl.exe"
```

- **Base_dir –** Variável que representa o caminho para a pasta onde está guardado o script R. Necessário alterar sempre que se alterar o computador onde se está a correr o script;
- **Base_export –** Representa o caminho para a pasta para onde serão feitas as exportações. Por definição é uma pasta dentro do Base_dir e por isso é criado o caminho a partir deste.

```
base_export<-paste0(base_dir, "Export/")
```

  Nota: A pasta para onde é definido o Export tem de existir pois o R não irá criá-la e se assim for retornará um erro;
- **Regiao –** Variável de extrema importância pois irá controlar toda a parte espacial da análise. Ter extremo cuidado a escrever o nome desta variável. Os seus valores possíveis são:
  - Distrito
  - Concelho
  - Freguesia
  - NUTS3
  - NomeCB

- **Variáveis temporais do ciclo –** Todas as variáveis temporais do ciclo como:
  - dia_inicio, h_inicio, min_inicio – Representam o dia e a hora de inicio da análise
  - dia_fim, h_fim, min_fim – Representam o dia e a hora de fim da análise
  - minutos_step – Define o tamanho de cada intervalo onde é estudada a simultaneidade de ocorrências. Tem por norma os valores de múltiplos de 60 minuto e como valores mais usuais 1440 (1 dia), 720 (12 horas) e 360 (6 horas).

```
dia_inicio <- "2011-01-01"      #ALTERAR AQUI DATA DE INICIO
h_inicio <- 0                   #ALTERAR AQUI HORAS DE INICIO
min_inicio <- 0                 #ALTERAR AQUI MINUTOS DE INICIO
dia_inicio<-as.Date(dia_inicio)
d_inicio<- ((as.numeric(dia_inicio)+25569)*86400) + (h_inicio*3600) + (min_inicio*60)

dia_fim <- "2016-01-01"         #ALTERAR AQUI DATA DE FIM
h_fim <-0                       #ALTERAR AQUI HORAS DE FIM
min_fim <- 0                    #ALTERAR AQUI MINUTOS DE FIM
dia_fim <- as.Date(dia_fim)
d_fim <- ((as.numeric(dia_fim)+25569)*86400) + (h_fim*3600) + (min_fim*60)
```

```
minutos_step<-60*6
```

2.4 – Como são guardados os dados?

Como output do script são gerados dois ficheiros:

1. Um ficheiro **.xlsx** com o nome definido pelas variáveis espaciais e temporais. Assim a estrutura do seu nome é:

<regiao>_<dia_inicio>_<dia_fim>_<step>horas.xlsx

Isto permite não escrever por cima de outro ficheiro com o mesmo nome e perder dados de análises anteriores.

Este ficheiro guarda os valores relativos às ocorrências simultâneas por step e por região definida (Distrito, Concelho, Freguesia, NUTS3) e também os dados estatísticos por região. Estes dados estatísticos são:

- Máximo;
- Mínimo;
- Média;
- Desvio Padrão;
- Mediana;
- VaR 95;
- VaR 5;
- Conditional VaR 95.

2. Um ficheiro **.pdf** com o nome definido pelas variáveis espaciais e temporais. Assim a estrutura do seu nome é:

<regiao>_<dia_inicio>_<dia_fim>_<step>horas.pdf

Este ficheiro guarda os gráficos relativos à variação temporal das ocorrências simultâneas para cada região de análise.

3. Área Ardida

3.1 – Como está dividido?

Este ficheiro está dividido em:

- Importação das bibliotecas e definição dos diretórios
- Remoção de variáveis referentes a análises anteriores
- Definição das variáveis do ciclo de área ardida
- Execução do ciclo de área ardida
- Cálculo dos dados estatísticos
- Exportação dos dados para o formato .xlsx

3.2 – Como funciona?

O funcionamento em cada parte do código é o seguinte:

- Instalação e inicialização dos packages:
  - para instalar fazer install.packages(“<nome_do_package>”)
  - para inicializar fazer library(<nome_do_package>)
- Ciclo de área ardida:
  - ciclo for percorre as linhas da lista que estão contidas dentro do intervalo de análise escolhido;
- Cálculo de estatísticas:
  - é calculado o Máximo dos valores obtidos no ciclo por região recorrendo à função max();
  - é calculada a Média dos valores obtidos no ciclo por região recorrendo à função rowMeans();
  - são calculados o VaR 95 e Mediana (VaR 50) dos valores obtidos no ciclo por região recorrendo à função quantile(x, probs) onde x é o array de valores e o probs é o valor do VaR respectivamente 0.95 e 0.50.
  - é calculado o Conditional VaR 95 fazendo a média dos valores maiores ou iguais ao seu respectivo VaR 95.

3.3 – Que variáveis posso alterar?

- **Perl –** Software que permite guardar os dados em formato .xlsx sem recorrer ao Java. Necessário fazer o seu download em strawberryperl.com. A variável perl representa o diretório onde foi instalado o perl que por defeito está em:

```
perl <- "C:/strawberry/perl/bin/perl.exe"
```

- **Base_dir –** Variável que representa o caminho para a pasta onde está guardado o script R. Necessário alterar sempre que se alterar o computador onde se está a correr o script;
- **Base_export –** Representa o caminho para a pasta para onde serão feitas as exportações. Por definição é uma pasta dentro do Base_dir e por isso é criado o caminho a partir deste.

```
base_export<-paste0(base_dir, "Export/")
```

Nota: A pasta para onde é definido o Export tem de existir pois o R não irá criá-la e se assim for retornará um erro;

- **Regiao –** Variável de extrema importância pois irá controlar toda a parte espacial da análise. Ter extremo cuidado a escrever o nome desta variável. Os seus valores possíveis são:
  - Distrito
  - Concelho
  - Freguesia
  - NUTS3
  - NomeCB
- **Variáveis temporais do ciclo –** Todas as variáveis temporais do ciclo como:
  - dia_inicio, h_inicio, min_inicio – Representam o dia e a hora de inicio da análise
  - dia_fim, h_fim, min_fim – Representam o dia e a hora de fim da análise

```
dia_inicio <- "2011-01-01"       #ALTERAR AQUI DATA DE INICIO
h_inicio <- 0                   #ALTERAR AQUI HORAS DE INICIO
min_inicio <- 0                 #ALTERAR AQUI MINUTOS DE INICIO
dia_inicio<-as.Date(dia_inicio)
d_inicio<- ((as.numeric(dia_inicio)+25569)*86400) + (h_inicio*3600) + (min_inicio*60)

dia_fim <- "2016-01-01"          #ALTERAR AQUI DATA DE FIM
h_fim <-0                       #ALTERAR AQUI HORAS DE FIM
min_fim <- 0                     #ALTERAR AQUI MINUTOS DE FIM
dia_fim <- as.Date(dia_fim)
d_fim <- ((as.numeric(dia_fim)+25569)*86400) + (h_fim*3600) + (min_fim*60)
```

3.4 – Como são guardados os dados?

Como output do script é gerado um ficheiro **.xlsx** com o nome definido pelas variáveis espaciais. Assim a estrutura do seu nome é:

<regiao>_AA.xlsx

Este ficheiro guarda os valores relativos à área ardida por região definida (Distrito, Concelho, Freguesia, NUTS3, NomeCB) e também os dados estatísticos por região. Estes dados estatísticos são:

- Máximo;
- Mínimo;
- Média;
- Desvio Padrão;
- Mediana;
- VaR 95;
- VaR 5;
- Conditional VaR 95.

4 – Como correr os scripts

Alguns scripts necessitam de inputs que são outputs de outros scripts. Assim, este ponto explica a ordem pela qual devem ser corridos os scripts:

1º - pre_processamento.R

2º - ciclo.R

3º área_ardida.R

A.2 Pre-processing

```
library(dplyr)
library(gtools)
library(readxl)
library(xlsx)
library(openxlsx)
library(plyr)
library(sqldf)

setwd("C:/Users/Jo o␣Silva/Documents/Dissertacao/Codigo")


acentos <- function(x) iconv(x,from= "UTF-8", to = "ASCII//TRANSLIT") #
    fun  o para retirar acentos e cedilhas

imputar <- function(y) { #funcao para imputar data e hora de extincao a
    entradas com as mesmas invalidas

  x<-Lista_Total$`AA_Total (pov+mato+agric) (ha)`[y]

  if(x==0){
    z<-Lista_Total$DataAlerta[y]+Lista_Total$HoraAlerta[y]+0.0368 # Data
        extincao final (dia mais hora)
  }

  if(x>0 && x<=1){
    z<-Lista_Total$DataAlerta[y]+Lista_Total$HoraAlerta[y]+0.0569 # Data
        extincao final (dia mais hora)
  }

  if(x>1 && x<=10){
    z<-Lista_Total$DataAlerta[y]+Lista_Total$HoraAlerta[y]+0.1465 # Data
        extincao final (dia mais hora)
  }

  if(x>10 && x<=100){
    z<-Lista_Total$DataAlerta[y]+Lista_Total$HoraAlerta[y]+0.3180 # Data
        extincao final (dia mais hora)
  }

  if(x>100 && x<=1000){
    z<-Lista_Total$DataAlerta[y]+Lista_Total$HoraAlerta[y]+0.8420 # Data
        extincao final (dia mais hora)
  }
```

```
  if(x>1000 && x<=2000){
    z<-Lista_Total$DataAlerta[y]+Lista_Total$HoraAlerta[y]+1.5489 # Data
       extincao final (dia mais hora)
  }

  if(x>2000 && x<=10000){
    z<-Lista_Total$DataAlerta[y]+Lista_Total$HoraAlerta[y]+3.8881 # Data
       extincao final (dia mais hora)
  }

  if(x>10000 && x<=30000){
    z<-Lista_Total$DataAlerta[y]+Lista_Total$HoraAlerta[y]+5.9375 # Data
       extincao final (dia mais hora)
  }
    return(z)
}

#------------------------------------------------------------------ <
    IMPORTACAO >
    ----------------------------------------------------------------------

#--------------------------------------- < TABELA IMPUTACAO NUTS >
    ---------------------------------------

library(readxl)
area_atuacao_CBPorto <- read_excel("C:/Users/Jo o␣Silva/Documents/
    Dissertacao/Codigo/Import/area_atuacao_CBPorto.xlsx")

area_atuacao_CBPorto = sqldf("
␣␣SELECT␣DICOFRE,␣CORPO_BOMB
␣␣FROM␣area_atuacao_CBPorto
␣␣WHERE␣FILTRAGEM␣=␣0
")


colnames(area_atuacao_CBPorto) <- c("INE", "NomeCB")

#--------------------------------------- < TABELA IMPUTACAO CORPORACAO DE
    BOMBEIROS > ---------------------------------------

library(readxl)
imputacao_nuts <- read_excel("Import/imputacao_nuts.xlsx")
```

```
#--------------------------------------- < 2015 >
    ---------------------------------------

Lista_Incendios_2015 <- read_excel("Dados/Lista␣Incendios_2015.xlsx",
col_types = c("numeric", "text", "numeric",
"text", "text", "text", "text", "text",
"numeric", "numeric", "numeric",
"text", "text", "numeric", "numeric",
"numeric", "numeric", "numeric",
"numeric", "text", "text", "numeric",
"numeric", "numeric", "numeric",
"numeric", "numeric", "numeric",
"numeric", "numeric", "numeric",
"numeric", "text", "text", "text",
"text", "text", "text"))


#--------------------------------------- < 2014 >
    ---------------------------------------

Lista_Incendios_2014 <- read_excel("Dados/Lista␣Incendios_2013_2014.xlsx",
sheet = "2014", col_types = c("numeric",
"text", "numeric", "text", "text",
"text", "text", "text", "numeric",
"numeric", "numeric", "text", "text",
"numeric", "numeric", "numeric",
"numeric", "text", "text", "text",
"text", "numeric", "numeric", "numeric",
"numeric", "numeric", "numeric",
"numeric", "numeric", "numeric",
"numeric", "numeric", "text", "text",
"text", "text", "text", "text"))

#--------------------------------------- < 2013 >
    ---------------------------------------

Lista_Incendios_2013 <- read_excel("Dados/Lista␣Incendios_2013_2014.xlsx",
sheet = "2013", col_types = c("numeric", "text", "text",
"text", "text", "text", "text", "numeric",
"numeric", "numeric", "numeric",
"numeric", "numeric", "numeric",
"text", "text", "text", "text", "numeric",
"numeric", "numeric", "numeric",
"numeric", "numeric", "numeric",
"numeric", "numeric", "numeric",
```

```
"numeric", "text", "text", "text",
"text", "text", "text"))

#---------------------------------------- < 2012 >
    ----------------------------------------

Lista_Incendios_2012 <- read_excel("Dados/Lista_Incendios_2011_2012.xlsx",
                                    sheet = "2012", col_types = c("numeric"
                                        ,
"text", "text", "text", "text", "text",
"text", "numeric", "numeric", "numeric",
"numeric", "numeric", "numeric",
"numeric", "numeric", "numeric",
"text", "text", "numeric", "numeric",
"numeric", "numeric", "numeric",
"numeric", "numeric", "numeric",
"numeric", "numeric", "numeric",
"text", "text", "text", "text", "text",
"text"))

#---------------------------------------- < 2011 >
    ----------------------------------------

Lista_Incendios_2011 <- read_excel("Dados/Lista_Incendios_2011_2012.xlsx",
sheet = "2011", col_types = c("numeric",
"text", "text", "text", "text", "text",
"text", "numeric", "numeric", "numeric",
"numeric", "numeric", "numeric",
"numeric", "numeric", "numeric",
"text", "text", "numeric", "numeric",
"numeric", "numeric", "numeric",
"numeric", "numeric", "numeric",
"numeric", "numeric", "numeric",
"text", "text", "text", "text", "text",
"text"))

#---------------------------------------- < 2010 >
    ----------------------------------------

Lista_Incendios_2010 <- read_excel("Dados/Lista_Incendios_2009_2010.xlsx",
sheet = "2010", col_types = c("numeric",
"text", "text", "text", "text", "text",
"text", "numeric", "numeric", "numeric",
"text", "numeric", "text", "numeric",
"text", "numeric", "text", "text",
```

```
"numeric", "numeric", "numeric",
"numeric", "numeric", "numeric",
"numeric", "numeric", "numeric",
"numeric", "numeric", "text", "text",
"text", "text"))

Lista_Incendios_2010[, c(11,13,15)] <- sapply(Lista_Incendios_2010[, c
    (11,13,15)], as.Date)

Lista_Incendios_2010[,c(11,13,15)] <- Lista_Incendios_2010[,c(11,13,15) ]
    + 25569

#---------------------------------------- < 2009 >
    ---------------------------------------


Lista_Incendios_2009 <- read_excel("Dados/Lista␣Incendios_2009_2010.xlsx",
sheet = "2009", col_types = c("numeric",
"text", "text", "text", "text", "text",
"text", "numeric", "numeric", "numeric",
"text", "numeric", "text", "numeric",
"text", "numeric", "text", "text",
"numeric", "numeric", "numeric",
"numeric", "numeric", "numeric",
"numeric", "numeric", "numeric",
"numeric", "numeric", "text", "text",
"text", "text"))

Lista_Incendios_2009[, c(11,13,15)] <- sapply(Lista_Incendios_2009[, c
    (11,13,15)], as.Date)

Lista_Incendios_2009[,c(11,13,15)] <- Lista_Incendios_2009[,c(11,13,15) ]
    + 25569

#---------------------------------------- < 2008 >
    ---------------------------------------

Lista_Incendios_2008 <- read_excel("Dados/Lista␣Incendios_2007_2008.xlsx",
sheet = "2008", col_types = c("numeric",
"text", "text", "text", "text", "text",
"text", "numeric", "numeric", "numeric",
"text", "numeric", "text", "numeric",
"text", "numeric", "text", "text",
"numeric", "numeric", "numeric",
"numeric", "numeric", "numeric",
```

```
"numeric", "numeric", "numeric",
"numeric", "numeric", "text", "text",
"text", "text"))

Lista_Incendios_2008[, c(11,13,15)] <- sapply(Lista_Incendios_2008[, c
    (11,13,15)], as.Date)

Lista_Incendios_2008[,c(11,13,15)] <- Lista_Incendios_2008[,c(11,13,15) ]
    + 25569

#---------------------------------------- < 2007 >
    ----------------------------------------

Lista_Incendios_2007 <- read_excel("Dados/Lista_Incendios_2007_2008.xlsx",
sheet = "2007", col_types = c("numeric",
"text", "text", "text", "text", "text",
"text", "numeric", "numeric", "numeric",
"text", "numeric", "text", "numeric",
"text", "numeric", "text", "text",
"numeric", "numeric", "numeric",
"numeric", "numeric", "numeric",
"numeric", "numeric", "numeric",
"numeric", "numeric", "text", "text",
"text", "text"))

Lista_Incendios_2007[, c(11,13,15)] <- sapply(Lista_Incendios_2007[, c
    (11,13,15)], as.Date)

Lista_Incendios_2007[,c(11,13,15)] <- Lista_Incendios_2007[,c(11,13,15) ]
    + 25569

#---------------------------------------- < 2006 >
    ----------------------------------------

Lista_Incendios_2006 <- read_excel("Dados/Lista_Incendios_2005_2006.xlsx",
sheet = "2006", col_types = c("numeric",
"text", "text", "text", "text", "text",
"text", "numeric", "numeric", "numeric",
"text", "numeric", "text", "numeric",
"text", "numeric", "text", "text",
"numeric", "numeric", "numeric",
"numeric", "numeric", "numeric",
"numeric", "numeric", "numeric",
"numeric", "numeric", "text", "text",
"text", "text"))
```

```
Lista_Incendios_2006[, c(11,13,15)] <- sapply(Lista_Incendios_2006[, c
    (11,13,15)], as.Date)

Lista_Incendios_2006[,c(11,13,15)] <- Lista_Incendios_2006[,c(11,13,15) ]
    + 25569

#--------------------------------------- < 2005 >
    ---------------------------------------

Lista_Incendios_2005 <- read_excel("Dados/Lista_Incendios_2005_2006.xlsx",
sheet = "2005", col_types = c("numeric",
"text", "text", "text", "text", "text",
"text", "numeric", "numeric", "numeric",
"text", "numeric", "text", "numeric",
"text", "numeric", "text", "text",
"numeric", "numeric", "numeric",
"numeric", "numeric", "numeric",
"numeric", "numeric", "numeric",
"numeric", "numeric", "text", "text",
"text", "text"))

Lista_Incendios_2005[, c(11,13,15)] <- sapply(Lista_Incendios_2005[, c
    (11,13,15)], as.Date)

Lista_Incendios_2005[,c(11,13,15)] <- Lista_Incendios_2005[,c(11,13,15) ]
    + 25569

#--------------------------------------- < 2004 >
    ---------------------------------------

Lista_Incendios_2004 <- read_excel("Dados/Lista_Incendios_2003_2004.xlsx",
sheet = "2004", col_types = c("numeric",
"text", "text", "text", "text", "text",
"text", "numeric", "numeric", "numeric",
"text", "numeric", "text", "numeric",
"text", "numeric", "text", "text",
"numeric", "numeric", "numeric",
"numeric", "numeric", "numeric",
"numeric", "numeric", "numeric",
"numeric", "numeric", "text", "text",
"text", "text"))

Lista_Incendios_2004[, c(11,13,15)] <- sapply(Lista_Incendios_2004[, c
    (11,13,15)], as.Date)
```

```
Lista_Incendios_2004[,c(11,13,15)] <- Lista_Incendios_2004[,c(11,13,15) ]
    + 25569

#--------------------------------------- < 2003 >
    ---------------------------------------

Lista_Incendios_2003 <- read_excel("Dados/Lista_Incendios_2003_2004.xlsx",
sheet = "2003", col_types = c("numeric",
"text", "text", "text", "text", "text",
"text", "numeric", "numeric", "numeric",
"text", "numeric", "text", "numeric",
"text", "numeric", "text", "text",
"numeric", "numeric", "numeric",
"numeric", "numeric", "numeric",
"numeric", "numeric", "numeric",
"numeric", "numeric", "text", "text",
"text", "text"))

Lista_Incendios_2003[, c(11,13,15)] <- sapply(Lista_Incendios_2003[, c
    (11,13,15)], as.Date)

Lista_Incendios_2003[,c(11,13,15)] <- Lista_Incendios_2003[,c(11,13,15) ]
    + 25569

#--------------------------------------- < 2002 >
    ---------------------------------------

Lista_Incendios_2002 <- read_excel("Dados/Lista_Incendios_2001_2002.xlsx",
sheet = "2002", col_types = c("numeric",
"text", "text", "text", "text", "text",
"text", "numeric", "numeric", "numeric",
"text", "numeric", "text", "numeric",
"text", "numeric", "text", "text",
"numeric", "numeric", "numeric",
"numeric", "numeric", "numeric",
"numeric", "numeric", "numeric",
"numeric", "numeric", "text", "text",
"text", "text"))

Lista_Incendios_2002[, c(11,13,15)] <- sapply(Lista_Incendios_2002[, c
    (11,13,15)], as.Date)

Lista_Incendios_2002[,c(11,13,15)] <- Lista_Incendios_2002[,c(11,13,15) ]
    + 25569
```

```
#--------------------------------------- < 2001 >
    ---------------------------------------

Lista_Incendios_2001 <- read_excel("Dados/Lista␣Incendios_2001_2002.xlsx",
sheet = "2001", col_types = c("numeric",
"text", "text", "text", "text", "text",
"text", "numeric", "numeric", "numeric",
"text", "numeric", "text", "numeric",
"text", "numeric", "text", "text",
"numeric", "numeric", "numeric",
"numeric", "numeric", "numeric",
"numeric", "numeric", "numeric",
"numeric", "numeric", "text", "text",
"text", "text"))

Lista_Incendios_2001[, c(11,13,15)] <- sapply(Lista_Incendios_2001[, c
    (11,13,15)], as.Date)

Lista_Incendios_2001[,c(11,13,15)] <- Lista_Incendios_2001[,c(11,13,15) ]
    + 25569

#------------------------------------------------------------ <
    NORMALIZAR NOMES DAS COLUNAS >
    -------------------------------------------------------------

colnames(Lista_Incendios_2015) <- c("Ano", "Codigo␣SGIF", "Codigo_ANPC", "
    Tipo", "Distrito", "Concelho", "Freguesia", "Local", "INE", "x", "y", "
    lat", "lon", "DataAlerta", "HoraAlerta", "DataExtincao", "HoraExtincao"
    , "Data1Intervencao", "Hora1Intervencao", "FonteAlerta", "NUT", "AA_
    Povoamento␣(ha)", "AA_Mato␣(ha)", "AA_Agricola␣(ha)", "AA_
    EspacosFlorestais␣(pov+mato)(ha)", "AA_Total␣(pov+mato+agric)␣(ha)", "
    Reacendimentos", "Queimada", "Falso_Alarme", "Fogacho", "Incendio", "
    Agricola", "Perimetro", "APS", "Causa", "TipoCausa", "Regiao␣PROF", "
    UGF")

colnames(Lista_Incendios_2014) <- c("Ano", "Codigo␣SGIF", "Codigo_ANPC", "
    Tipo", "Distrito", "Concelho", "Freguesia", "Local", "INE", "x", "y", "
    lat", "lon", "DataAlerta", "HoraAlerta", "DataExtincao", "HoraExtincao"
    , "Data1Intervencao", "Hora1Intervencao", "FonteAlerta", "NUT", "AA_
    Povoamento␣(ha)", "AA_Mato␣(ha)", "AA_Agricola␣(ha)", "AA_
    EspacosFlorestais␣(pov+mato)(ha)", "AA_Total␣(pov+mato+agric)␣(ha)", "
    Reacendimentos", "Queimada", "Falso_Alarme", "Fogacho", "Incendio", "
    Agricola", "Perimetro", "APS", "Causa", "TipoCausa", "Regiao␣PROF", "
    UGF")
```

```
colnames(Lista_Incendios_2013) <- c("Ano", "Codigo␣SGIF", "Tipo", "
    Distrito", "Concelho", "Freguesia", "Local", "INE", "x", "y", "
    DataAlerta", "HoraAlerta", "DataExtincao", "HoraExtincao", "
    Data1Intervencao", "Hora1Intervencao", "FonteAlerta", "NUT", "AA_
    Povoamento␣(ha)", "AA_Mato␣(ha)", "AA_Agricola␣(ha)", "AA_
    EspacosFlorestais␣(pov+mato)(ha)", "AA_Total␣(pov+mato+agric)␣(ha)", "
    Reacendimentos", "Queimada", "Falso␣Alarme", "Fogacho", "Incendio", "
    Agricola", "Perimetro", "APS", "Causa", "TipoCausa", "Regiao␣PROF", "
    UGF")
Lista_Incendios_2013["lat"]<-c(NA)
Lista_Incendios_2013["lon"]<-c(NA)
Lista_Incendios_2013["Codigo_ANPC"]<-c("NULL")


colnames(Lista_Incendios_2012) <- c("Ano", "Codigo␣SGIF", "Tipo", "
    Distrito", "Concelho", "Freguesia", "Local", "INE", "x", "y", "
    DataAlerta", "HoraAlerta", "DataExtincao", "HoraExtincao", "
    Data1Intervencao", "Hora1Intervencao", "FonteAlerta", "NUT", "AA_
    Povoamento␣(ha)", "AA_Mato␣(ha)", "AA_Agricola␣(ha)", "AA_
    EspacosFlorestais␣(pov+mato)(ha)", "AA_Total␣(pov+mato+agric)␣(ha)", "
    Reacendimentos", "Queimada", "Falso␣Alarme", "Fogacho", "Incendio", "
    Agricola", "Perimetro", "APS", "Causa", "TipoCausa", "Regiao␣PROF", "
    UGF")
Lista_Incendios_2012["lat"]<-c(NA)
Lista_Incendios_2012["lon"]<-c(NA)
Lista_Incendios_2012["Codigo_ANPC"]<-c("NULL")

colnames(Lista_Incendios_2011) <- c("Ano", "Codigo␣SGIF", "Tipo", "
    Distrito", "Concelho", "Freguesia", "Local", "INE", "x", "y", "
    DataAlerta", "HoraAlerta", "DataExtincao", "HoraExtincao", "
    Data1Intervencao", "Hora1Intervencao", "FonteAlerta", "NUT", "AA_
    Povoamento␣(ha)", "AA_Mato␣(ha)", "AA_Agricola␣(ha)", "AA_
    EspacosFlorestais␣(pov+mato)(ha)", "AA_Total␣(pov+mato+agric)␣(ha)", "
    Reacendimentos", "Queimada", "Falso␣Alarme", "Fogacho", "Incendio", "
    Agricola", "Perimetro", "APS", "Causa", "TipoCausa", "Regiao␣PROF", "
    UGF")
Lista_Incendios_2011["lat"]<-c(NA)
Lista_Incendios_2011["lon"]<-c(NA)
Lista_Incendios_2011["Codigo_ANPC"]<-c("NULL")

colnames(Lista_Incendios_2010) <- c("Ano", "Codigo␣SGIF", "Tipo", "
    Distrito", "Concelho", "Freguesia", "Local", "INE", "x", "y", "
    DataAlerta", "HoraAlerta", "DataExtincao", "HoraExtincao", "
```

```
    Data1Intervencao", "Hora1Intervencao", "FonteAlerta", "NUT", "AA_
    Povoamento␣(ha)", "AA_Mato␣(ha)", "AA_Agricola␣(ha)", "AA_
    EspacosFlorestais␣(pov+mato)(ha)", "AA_Total␣(pov+mato+agric)␣(ha)", "
    Reacendimentos", "Queimada", "Falso␣Alarme", "Fogacho", "Incendio", "
    Agricola", "Perimetro", "APS", "Causa", "TipoCausa")
Lista_Incendios_2010["lat"]<-c(NA)
Lista_Incendios_2010["lon"]<-c(NA)
Lista_Incendios_2010["Codigo_ANPC"]<-c("NULL")
Lista_Incendios_2010["Regiao_PROF"]<-c("NULL")
Lista_Incendios_2010["UGF"]<-c("NULL")

colnames(Lista_Incendios_2009) <- c("Ano", "Codigo␣SGIF", "Tipo", "
    Distrito", "Concelho", "Freguesia", "Local", "INE", "x", "y", "
    DataAlerta", "HoraAlerta", "DataExtincao", "HoraExtincao", "
    Data1Intervencao", "Hora1Intervencao", "FonteAlerta", "NUT", "AA_
    Povoamento␣(ha)", "AA_Mato␣(ha)", "AA_Agricola␣(ha)", "AA_
    EspacosFlorestais␣(pov+mato)(ha)", "AA_Total␣(pov+mato+agric)␣(ha)", "
    Reacendimentos", "Queimada", "Falso␣Alarme", "Fogacho", "Incendio", "
    Agricola", "Perimetro", "APS", "Causa", "TipoCausa")
Lista_Incendios_2009["lat"]<-c(NA)
Lista_Incendios_2009["lon"]<-c(NA)
Lista_Incendios_2009["Codigo_ANPC"]<-c("NULL")
Lista_Incendios_2009["Regiao_PROF"]<-c("NULL")
Lista_Incendios_2009["UGF"]<-c("NULL")

colnames(Lista_Incendios_2008) <- c("Ano", "Codigo␣SGIF", "Tipo", "
    Distrito", "Concelho", "Freguesia", "Local", "INE", "x", "y", "
    DataAlerta", "HoraAlerta", "DataExtincao", "HoraExtincao", "
    Data1Intervencao", "Hora1Intervencao", "FonteAlerta", "NUT", "AA_
    Povoamento␣(ha)", "AA_Mato␣(ha)", "AA_Agricola␣(ha)", "AA_
    EspacosFlorestais␣(pov+mato)(ha)", "AA_Total␣(pov+mato+agric)␣(ha)", "
    Reacendimentos", "Queimada", "Falso␣Alarme", "Fogacho", "Incendio", "
    Agricola", "Perimetro", "APS", "Causa", "TipoCausa")
Lista_Incendios_2008["lat"]<-c(NA)
Lista_Incendios_2008["lon"]<-c(NA)
Lista_Incendios_2008["Codigo_ANPC"]<-c("NULL")
Lista_Incendios_2008["Regiao_PROF"]<-c("NULL")
Lista_Incendios_2008["UGF"]<-c("NULL")

colnames(Lista_Incendios_2007) <- c("Ano", "Codigo␣SGIF", "Tipo", "
    Distrito", "Concelho", "Freguesia", "Local", "INE", "x", "y", "
    DataAlerta", "HoraAlerta", "DataExtincao", "HoraExtincao", "
    Data1Intervencao", "Hora1Intervencao", "FonteAlerta", "NUT", "AA_
    Povoamento␣(ha)", "AA_Mato␣(ha)", "AA_Agricola␣(ha)", "AA_
    EspacosFlorestais␣(pov+mato)(ha)", "AA_Total␣(pov+mato+agric)␣(ha)", "
```

```
    Reacendimentos", "Queimada", "Falso␣Alarme", "Fogacho", "Incendio", "
    Agricola", "Perimetro", "APS", "Causa", "TipoCausa")
Lista_Incendios_2007["lat"]<-c(NA)
Lista_Incendios_2007["lon"]<-c(NA)
Lista_Incendios_2007["Codigo_ANPC"]<-c("NULL")
Lista_Incendios_2007["Regiao␣PROF"]<-c("NULL")
Lista_Incendios_2007["UGF"]<-c("NULL")

colnames(Lista_Incendios_2006) <- c("Ano", "Codigo␣SGIF", "Tipo", "
    Distrito", "Concelho", "Freguesia", "Local", "INE", "x", "y", "
    DataAlerta", "HoraAlerta", "DataExtincao", "HoraExtincao", "
    Data1Intervencao", "Hora1Intervencao", "FonteAlerta", "NUT", "AA_
    Povoamento␣(ha)", "AA_Mato␣(ha)", "AA_Agricola␣(ha)", "AA_
    EspacosFlorestais␣(pov+mato)(ha)", "AA_Total␣(pov+mato+agric)␣(ha)", "
    Reacendimentos", "Queimada", "Falso␣Alarme", "Fogacho", "Incendio", "
    Agricola", "Perimetro", "APS", "Causa", "TipoCausa")
Lista_Incendios_2006["lat"]<-c(NA)
Lista_Incendios_2006["lon"]<-c(NA)
Lista_Incendios_2006["Codigo_ANPC"]<-c("NULL")
Lista_Incendios_2006["Regiao␣PROF"]<-c("NULL")
Lista_Incendios_2006["UGF"]<-c("NULL")

colnames(Lista_Incendios_2005) <- c("Ano", "Codigo␣SGIF", "Tipo", "
    Distrito", "Concelho", "Freguesia", "Local", "INE", "x", "y", "
    DataAlerta", "HoraAlerta", "DataExtincao", "HoraExtincao", "
    Data1Intervencao", "Hora1Intervencao", "FonteAlerta", "NUT", "AA_
    Povoamento␣(ha)", "AA_Mato␣(ha)", "AA_Agricola␣(ha)", "AA_
    EspacosFlorestais␣(pov+mato)(ha)", "AA_Total␣(pov+mato+agric)␣(ha)", "
    Reacendimentos", "Queimada", "Falso␣Alarme", "Fogacho", "Incendio", "
    Agricola", "Perimetro", "APS", "Causa", "TipoCausa")
Lista_Incendios_2005["lat"]<-c(NA)
Lista_Incendios_2005["lon"]<-c(NA)
Lista_Incendios_2005["Codigo_ANPC"]<-c("NULL")
Lista_Incendios_2005["Regiao␣PROF"]<-c("NULL")
Lista_Incendios_2005["UGF"]<-c("NULL")

colnames(Lista_Incendios_2004) <- c("Ano", "Codigo␣SGIF", "Tipo", "
    Distrito", "Concelho", "Freguesia", "Local", "INE", "x", "y", "
    DataAlerta", "HoraAlerta", "DataExtincao", "HoraExtincao", "
    Data1Intervencao", "Hora1Intervencao", "FonteAlerta", "NUT", "AA_
    Povoamento␣(ha)", "AA_Mato␣(ha)", "AA_Agricola␣(ha)", "AA_
    EspacosFlorestais␣(pov+mato)(ha)", "AA_Total␣(pov+mato+agric)␣(ha)", "
    Reacendimentos", "Queimada", "Falso␣Alarme", "Fogacho", "Incendio", "
    Agricola", "Perimetro", "APS", "Causa", "TipoCausa")
Lista_Incendios_2004["lat"]<-c(NA)
```

```
Lista_Incendios_2004["lon"]<-c(NA)
Lista_Incendios_2004["Codigo_ANPC"]<-c("NULL")
Lista_Incendios_2004["Regiao␣PROF"]<-c("NULL")
Lista_Incendios_2004["UGF"]<-c("NULL")

colnames(Lista_Incendios_2003) <- c("Ano", "Codigo␣SGIF", "Tipo", "
    Distrito", "Concelho", "Freguesia", "Local", "INE", "x", "y", "
    DataAlerta", "HoraAlerta", "DataExtincao", "HoraExtincao", "
    Data1Intervencao", "Hora1Intervencao", "FonteAlerta", "NUT", "AA_
    Povoamento␣(ha)", "AA_Mato␣(ha)", "AA_Agricola␣(ha)", "AA_
    EspacosFlorestais␣(pov+mato)(ha)", "AA_Total␣(pov+mato+agric)␣(ha)", "
    Reacendimentos", "Queimada", "Falso␣Alarme", "Fogacho", "Incendio", "
    Agricola", "Perimetro", "APS", "Causa", "TipoCausa")
Lista_Incendios_2003["lat"]<-c(NA)
Lista_Incendios_2003["lon"]<-c(NA)
Lista_Incendios_2003["Codigo_ANPC"]<-c("NULL")
Lista_Incendios_2003["Regiao␣PROF"]<-c("NULL")
Lista_Incendios_2003["UGF"]<-c("NULL")

colnames(Lista_Incendios_2002) <- c("Ano", "Codigo␣SGIF", "Tipo", "
    Distrito", "Concelho", "Freguesia", "Local", "INE", "x", "y", "
    DataAlerta", "HoraAlerta", "DataExtincao", "HoraExtincao", "
    Data1Intervencao", "Hora1Intervencao", "FonteAlerta", "NUT", "AA_
    Povoamento␣(ha)", "AA_Mato␣(ha)", "AA_Agricola␣(ha)", "AA_
    EspacosFlorestais␣(pov+mato)(ha)", "AA_Total␣(pov+mato+agric)␣(ha)", "
    Reacendimentos", "Queimada", "Falso␣Alarme", "Fogacho", "Incendio", "
    Agricola", "Perimetro", "APS", "Causa", "TipoCausa")
Lista_Incendios_2002["lat"]<-c(NA)
Lista_Incendios_2002["lon"]<-c(NA)
Lista_Incendios_2002["Codigo_ANPC"]<-c("NULL")
Lista_Incendios_2002["Regiao␣PROF"]<-c("NULL")
Lista_Incendios_2002["UGF"]<-c("NULL")

colnames(Lista_Incendios_2001) <- c("Ano", "Codigo␣SGIF", "Tipo", "
    Distrito", "Concelho", "Freguesia", "Local", "INE", "x", "y", "
    DataAlerta", "HoraAlerta", "DataExtincao", "HoraExtincao", "
    Data1Intervencao", "Hora1Intervencao", "FonteAlerta", "NUT", "AA_
    Povoamento␣(ha)", "AA_Mato␣(ha)", "AA_Agricola␣(ha)", "AA_
    EspacosFlorestais␣(pov+mato)(ha)", "AA_Total␣(pov+mato+agric)␣(ha)", "
    Reacendimentos", "Queimada", "Falso␣Alarme", "Fogacho", "Incendio", "
    Agricola", "Perimetro", "APS", "Causa", "TipoCausa")
Lista_Incendios_2001["lat"]<-c(NA)
Lista_Incendios_2001["lon"]<-c(NA)
Lista_Incendios_2001["Codigo_ANPC"]<-c("NULL")
Lista_Incendios_2001["Regiao␣PROF"]<-c("NULL")
```

```
Lista_Incendios_2001["UGF"]<-c("NULL")
#----------------------------------------------------------------- <
    JUNTAR TODOS OS ANOS NUMA UNICA DATAFRAME
    >-----------------------------------------------


Lista_Total<-rbind(Lista_Incendios_2015, Lista_Incendios_2014, Lista_
    Incendios_2013, Lista_Incendios_2012, Lista_Incendios_2011, Lista_
    Incendios_2010, Lista_Incendios_2009, Lista_Incendios_2008, Lista_
    Incendios_2007, Lista_Incendios_2006, Lista_Incendios_2005, Lista_
    Incendios_2004, Lista_Incendios_2003, Lista_Incendios_2002, Lista_
    Incendios_2001)


Lista_Total$Data1Intervencao<- as.numeric(Lista_Total$Data1Intervencao) #
    conversao para numerico
Lista_Total$Hora1Intervencao<- as.numeric(Lista_Total$Hora1Intervencao) #
    conversao para numerico



#---------------------------------------------------- < ORDENACAO TEMPORAL
     DE OCORRENCIAS >
    -----------------------------------------------------------------

Lista_Total$HoraAlerta[25457]<-0 # unico valor sem hora alerta passa a ter
     hora alerta = 0

Lista_Original<-Lista_Total

linhas_lista <- as.numeric(nrow(Lista_Total)) #total de linhas da lista

write.xlsx(Lista_Original, 'Export/Listas/Lista_Original.xlsx')       #
    guardar em excel
saveRDS(Lista_Original, file = "Export/Listas/lista_original.rds")    #
    guardar em formato RDS


for(i in 1:linhas_lista)
{
  Lista_Total$Distrito[i] <- acentos(Lista_Total$Distrito[i]) #retirar
      acentos e cedilhas dos nosmes dos distritos
  Lista_Total$Concelho[i] <- acentos(Lista_Total$Concelho[i]) #retirar
      acentos e cedilhas dos nosmes dos concelhos
```

```
Lista_Total$Freguesia[i] <- acentos(Lista_Total$Freguesia[i]) #retirar
    acentos e cedilhas dos nosmes das freguesias

Lista_Total$Distrito[i] <- toupper(Lista_Total$Distrito[i]) #nomes dos
    distritos todos em maiusculas
Lista_Total$Concelho[i] <- toupper(Lista_Total$Concelho[i]) #nomes dos
    concelhos todos em maiusculas
Lista_Total$Freguesia[i] <- toupper(Lista_Total$Freguesia[i]) #nomes dos
     freguesias todos em maiusculas

if(Lista_Total$Concelho[i]=="FREIXO ESPADA A CINTA"){    #correcao dos
    dois erros de escrita na base de dados
  Lista_Total$Concelho[i]<-"FREIXO DE ESPADA A CINTA"
}

if(Lista_Total$Concelho[i]=="SOBRAL MONTE AGRACO"){      #correcao dos
    dois erros de escrita na base de dados
  Lista_Total$Concelho[i]<-"SOBRAL DE MONTE AGRACO"
}

if(!is.na(Lista_Total$DataAlerta[i]) && !is.na(Lista_Total$HoraAlerta[i
    ]) && !is.na(Lista_Total$DataExtincao[i]) && !is.na(Lista_Total$
    HoraExtincao[i]))
{
      if( (((Lista_Total$DataExtincao[i]+Lista_Total$HoraExtincao[i]) -
          (Lista_Total$DataAlerta[i]+Lista_Total$HoraAlerta[i])) < 0) ||
          (((Lista_Total$DataExtincao[i]+Lista_Total$HoraExtincao[i]) - (
          Lista_Total$DataAlerta[i]+Lista_Total$HoraAlerta[i])) > 26))
      {
        Lista_Total$DataExtincao[i] <- NA
        Lista_Total$HoraExtincao[i] <- NA
      }



}


if(is.na(Lista_Total$DataExtincao[i]) || is.na(Lista_Total$HoraExtincao[
    i]) ){ #se data ou hora de extincao nao existirem correr funcao de
    imputacao com parametro de area total ardida e linha a imputar
  #imputar(i)

  Lista_Total$DataExtincao[i]<- imputar(i) %/% 1 #divisao inteira
  Lista_Total$HoraExtincao[i]<- imputar(i) %% 1 #resto da divisao
      inteira
```

```
  }
}

Lista_Total <- arrange(Lista_Total,DataAlerta,HoraAlerta)

Lista_snull <- Lista_Total

Lista_snull <- Lista_snull[!is.na(Lista_snull$DataAlerta),]      # Excluir
     NAs de DataAlerta
Lista_snull <- Lista_snull[!is.na(Lista_snull$HoraAlerta),]      # Excluir
     NAs de HoraAlerta
Lista_snull <- Lista_snull[!is.na(Lista_snull$DataExtincao),]    # Excluir
     NAs de DataExtincao
Lista_snull <- Lista_snull[!is.na(Lista_snull$HoraExtincao),]    # Excluir
     NAs de HoraExtincao

# 1,4% de NAs removidos

#---------------------------------------------- < Lista apenas com
    Distrito do porto >
    ---------------------------------------------------------


linhas_lista2 <- as.numeric(nrow(Lista_snull)) #total de linhas da lista

Lista_porto <- Lista_snull

for(i in 1:linhas_lista2){

  if(Lista_porto$Distrito[i] !="PORTO"){

    Lista_porto$Distrito[i] <- NA
  }
}


Lista_porto <- Lista_porto[!is.na(Lista_porto$Distrito),]

Lista_porto$Distrito<-as.character(Lista_porto$Distrito)
Lista_porto$Concelho<-as.character(Lista_porto$Concelho)
Lista_porto$Freguesia<-as.character(Lista_porto$Freguesia)
```

```
#---------------------------------------------- < FAZER IMPUTACAO DOS NUTS
     3 ATRAVES DO CONCELHO >
    -----------------------------------------------------------

Lista_snull<-join(Lista_snull, imputacao_nuts, by = "Concelho", type = "
    left")

#---------------------------------------------- < FAZER IMPUTACAO DAS
    CORPORACOES DE BOMBEIROS >
    -----------------------------------------------------------

Lista_porto_CB<-join(Lista_porto, area_atuacao_CBPorto, by = "INE", type =
     "left")

Lista_porto_CB$Distrito<-as.character(Lista_porto_CB$Distrito)
Lista_porto_CB$Concelho<-as.character(Lista_porto_CB$Concelho)
Lista_porto_CB$Freguesia<-as.character(Lista_porto_CB$Freguesia)
Lista_porto_CB$NomeCB<-as.character(Lista_porto_CB$NomeCB)


#---------------------------------------------- < CONVERTER DISTRITO,
    CONCELHO, FREGUESIA PARA FACTOR >
    ---------------------------------------------------------

Lista_Total$Distrito<-as.factor(Lista_Total$Distrito)
Lista_Total$Concelho<-as.factor(Lista_Total$Concelho)
Lista_Total$Freguesia<-as.factor(Lista_Total$Freguesia)

Lista_snull$Distrito<-as.factor(Lista_snull$Distrito)
Lista_snull$Concelho<-as.factor(Lista_snull$Concelho)
Lista_snull$Freguesia<-as.factor(Lista_snull$Freguesia)
Lista_snull$NUTS3<-as.factor(Lista_snull$NUTS3) #NUTS 3

Lista_porto$Distrito<-as.factor(Lista_porto$Distrito)
Lista_porto$Concelho<-as.factor(Lista_porto$Concelho)
Lista_porto$Freguesia<-as.factor(Lista_porto$Freguesia)

Lista_porto_CB$Distrito<-as.factor(Lista_porto_CB$Distrito)
Lista_porto_CB$Concelho<-as.factor(Lista_porto_CB$Concelho)
Lista_porto_CB$Freguesia<-as.factor(Lista_porto_CB$Freguesia)
Lista_porto_CB$NomeCB<-as.factor(Lista_porto_CB$NomeCB)
```

```
#-------------------------------------------------------------- <
    RESOLUCAO DE ERROS  >
    -------------------------------------------------------------------------


erro1_resultados_distrito<-as.data.frame(levels(Lista_snull$Distrito))
colnames(erro1_resultados_distrito)[1]<-"Distrito"

erro1_resultados_concelho<-as.data.frame(levels(Lista_snull$Concelho))
colnames(erro1_resultados_concelho)[1]<-"Concelho"

erro1_resultados_freguesia<-as.data.frame(levels(Lista_snull$Freguesia))
colnames(erro1_resultados_freguesia)[1]<-"Freguesia"

erro1_resultados_NUTS3<-as.data.frame(levels(Lista_snull$NUTS3))
colnames(erro1_resultados_NUTS3)[1]<-"NUTS3"

erro1_resultados_CB<-as.data.frame(levels(Lista_porto_CB$NomeCB))
colnames(erro1_resultados_CB)[1]<-"NomeCB"



#-------------------------------------------------------- < EXPORTAR DADOS
     PARA EXCEL >
    --------------------------------------------------------------------------


write.xlsx(Lista_Total, 'Export/Listas/Lista_Total.xlsx')     #guardar em
    excel
write.xlsx(Lista_snull, 'Export/Listas/Lista_SNull.xlsx')     #guardar em
    excel
WriteXLS(Lista_porto, 'Export/Listas/Lista_porto.xlsx')     #guardar em
    excel
write.xlsx(Lista_porto, "C:/Users/Jo o␣Silva/Documents/Dissertacao/Codigo
    /Export/Listas/Lista_porto.xlsx")
write.xlsx(Lista_porto_CB, "C:/Users/Jo o␣Silva/Documents/Dissertacao/
    Codigo/Export/Listas/Lista_porto_CB.xlsx")
saveRDS(Lista_Total, file = "Export/Listas/lista_total.rds")  #guardar em
    formato RDS
saveRDS(Lista_snull, file = "Export/Listas/lista_snull.rds")  #guardar em
    formato RDS
saveRDS(Lista_porto, file = "Export/Listas/Lista_porto.rds")  #guardar em
    formato RDS
saveRDS(Lista_porto_CB, file = "Export/Listas/Lista_porto_CB.rds")  #
    guardar em formato RDS
```

A.3 Simultaneity cycle

```
#CASO NAO ESTEJAM INSTALADOS INSTALAR AS 3 BIBLIOTECAS USANDO -> install.
   packages("nome_da_biblioteca")

#Possivel ter que instalar o perl a partir do site strawberryperl.com para
    usar WriteXLS

#PATH do perl

perl <- "C:/strawberry/perl/bin/perl.exe"

library(dplyr)
library(gtools)
library(WriteXLS)
library(readxl) #biblioteca para ler excel
library(xlsx)   #biblioteca para criar excel
library(lubridate) #biblioteca para usar data como data + HH:MM:SS
library(chron)  #biblioteca para converter para horas e minutos
library(PerformanceAnalytics) #biblioteca para analise estatistica do VaR
   (Value at Risk)
library(plyr)
library(R.utils)
library(expss)

setwd("C:/Users/Jo o␣Silva/Documents/Dissertacao/Codigo")

#----------------------------------------- < REMOVER RESULTADOS ANTERIORES
    > ---------------------------------------------

if(exists("resultados")){   # remover resultados anteriores se estes ainda
    existirem no workspace
  rm(resultados)
}

if(exists("resultados_final")){   # remover resultados anteriores se estes
    ainda existirem no workspace
  rm(resultados_final)
}

if(exists("resultados_estatisticas")){
  rm(resultados_estatisticas)
}

if(exists("resultados_geral")){
```

```
  rm(resultados_geral)
}

if(exists("aux")){
  rm(aux)
}

if(exists("aux2")){
  rm(aux2)
}

if(exists("estatisticas")){
  rm(estatisticas)
}

if(exists("base_res")){
  rm(base_res)
}

if(exists("base_distritos")){
  rm(base_distritos)
}


if(exists("nomes")){
  rm(nomes)
}

if(exists("total_colunas")){
  rm(total_colunas)
}

#---------------------------------------------------- < CODIGO
    SIMULTANEIDADE (VARIAVEIS)>
    ------------------------------------------------------------------

Data_Inicio  <- c() #Para dar nomes as linhas

# Apenas deixar uma das 4 seguintes linhas descomentada dependendo se a
    analise e para ser por Distrito, Concelho, Freguesia ou NUTS3

#base_res<- data.frame("Distrito"= character(), freq=numeric())
#base_res<- data.frame("Concelho"= character(), freq=numeric())
#base_res<- data.frame("Freguesia"= character(), freq=numeric())
#base_res<- data.frame("NUTS3"= character(), freq=numeric())
```

```
base_res<- data.frame("NomeCB"= character(), freq=numeric())


#ALTERAR NOMES DAS VARIAVEIS ACIMA

#CICLO

minutos_step<-60*3   #ALTERAR AQUI O STEP (EM MINUTOS)    < 1 hora = 60 >
     < 1 dia = 1440 > < 1 semana = 10080 >

step<-(minutos_step/1440) #Dividir por 1440 para dar o valor step em dias

sobre_step<-0 #Colocar aqui percentagem de atraso do step. Exemplo: 5

linhas_total <- as.numeric(nrow(Lista_otimo_CB)) # total de linhas do
    Excel

#---------------------------------------- < INSERIR DATA INICIO E DATA FIM
    NO FORMATO (AAAA-MM-DD) , HORAS E MINUTOS>
    ----------------------------------------------------------


d_inicio <- "2007-07-01"      #ALTERAR AQUI DATA DE INICIO
h_inicio <- 0                 #ALTERAR AQUI HORAS DE INICIO
min_inicio <- 0               #ALTERAR AQUI MINUTOS DE INICIO
d_inicio<-as.Date(d_inicio)
d_inicio<- as.numeric(d_inicio)+25569 + h_inicio/24 + min_inicio/(24*60)

d_fim <- "2007-09-30"         #ALTERAR AQUI DATA DE FIM
h_fim <- 24                   #ALTERAR AQUI HORAS DE FIM
min_fim <- 0                #ALTERAR AQUI MINUTOS DE FIM
d_fim <- as.Date(d_fim)
d_fim <- as.numeric(d_fim)+25569 + h_fim/24 + min_fim/(24*60)


#fator de correcao da contagem = 25569
#---------------------------------------- < CICLO SIMULTANEIDADE>
    ----------------------------------------------------------

d_in_step <- d_inicio

while((d_in_step+step) <= d_fim){

  resultados_geral <- base_res
```

```
d_fim_step <- d_in_step + step
contador<-0


for(i in 1:linhas_total) {
  # Apenas deixar uma das 3 seguintes linhas descomentada dependendo se
     a an  lise      para ser por Distrito, Concelho ou Freguesia

  #ifelse( test = ( (Lista_snull$DataAlerta[i]+Lista_snull$HoraAlerta[i
     ]) > d_fim_step ) | ( Lista_snull$DataExtincao[i] + Lista_snull$
     HoraExtincao[i] < d_in_step ), contador<-contador  , resultados_
     geral<-rbind(resultados_geral, count(Lista_snull[i,], "Distrito"))
      )
  #ifelse( test = ( (Lista_snull$DataAlerta[i]+Lista_snull$HoraAlerta[i
     ]) > d_fim_step ) | ( Lista_snull$DataExtincao[i] + Lista_snull$
     HoraExtincao[i] < d_in_step ), contador<-contador  , resultados_
     geral<-rbind(resultados_geral, count(Lista_snull[i,], "Concelho"))
      )
  #ifelse( test = ( (Lista_snull$DataAlerta[i]+Lista_snull$HoraAlerta[i
     ]) > d_fim_step ) | ( Lista_snull$DataExtincao[i] + Lista_snull$
     HoraExtincao[i] < d_in_step ), contador<-contador  , resultados_
     geral<-rbind(resultados_geral, count(Lista_snull[i,], "Freguesia"))
       )
  #ifelse( test = ( (Lista_snull$DataAlerta[i]+Lista_snull$HoraAlerta[i
     ]) > d_fim_step ) | ( Lista_snull$DataExtincao[i] + Lista_snull$
     HoraExtincao[i] < d_in_step ), contador<-contador  , resultados_
     geral<-rbind(resultados_geral, count(Lista_snull[i,], "NUTS3"))   )
  ifelse( test = ( (Lista_otimo_CB$DataAlerta[i]+Lista_otimo_CB$
     HoraAlerta[i]) > d_fim_step ) | ( Lista_otimo_CB$DataExtincao[i] +
     Lista_otimo_CB$HoraExtincao[i] < d_in_step ), contador<-contador  ,
      resultados_geral<-rbind(resultados_geral, count(Lista_otimo_CB[i
     ,], "NomeCB"))   )
}


Data_Inicio <- append(Data_Inicio,as.POSIXct(d_in_step*86400, origin = "
    1899-12-30", tz = "GMT") , after = length(Data_Inicio))

teste_seg<-d_in_step*86400

if(minutos_step!=120)
{
  if(teste_seg%%1 != 0)
  {
```

```
    teste_seg<-(teste_seg+1)%/%1
  }
}

intervalo<-as.POSIXct(d_in_step*86400, origin = "1899-12-30", tz = "GMT"
    )
intervalo<-as.character(intervalo)

#Alterar Distrito por Concelho, Freguesia, NUTS3 ou NomeCB dependendo da
     analise
if(nrow(resultados_geral)!=0){

  aux<- xtabs(formula=freq~NomeCB + freq, data=resultados_geral) #Fazer
      altera o se necessario

  aux<- as.data.frame(aux)

  ifelse(exists("resultados"),resultados<-cbind(resultados, aux$Freq),
      resultados<-aux)
}

if(nrow(resultados_geral)==0){
  if(!exists("resultados")){

    #FAZER IMPORT DESTAS DATA.FRAMES DE CORRECAO DE ERRO PARA O CASO DO
       PRIMEIRO INTERVALO SER VAZIO

    #escolher 1 dos 5 dependedo da an lise
    #resultados<-erro1_resultados_distrito
    #resultados<-erro1_resultados_concelho
    #resultados<-erro1_resultados_freguesia
    #resultados<-erro1_resultados_NUTS3
    resultados<-erro1_resultados_CB
  }

  resultados$freq<-0
}

colnames(resultados)[ncol(resultados)] <- intervalo


d_in_step <- d_fim_step-(step*sobre_step)

if(exists("aux")){
  rm(aux)
```

```
  }

}

#--------------------------------------------< CALCULAR DADOS ESTATISTICOS
    >-----------------------------------------------------------------------------------

estatisticas<-resultados
total_colunas<-ncol(resultados)

resultados_estatisticas <- data.frame(t(estatisticas[-1]))  #Transpor a
    dataframe (Colunas passam a linhas e vice-versa)
colnames(resultados_estatisticas) <- estatisticas[, 1]

resultados$Maximo<- NA
resultados$Minimo<- NA
resultados$Media<- NA
resultados$'Desvio␣Padrao'<- NA
resultados$Mediana <- NA
resultados$'VaR␣95' <- NA
resultados$'VaR␣5' <- NA
resultados$'CVaR␣95' <- NA

for(t in 1:nrow(resultados))
{
  resultados$Maximo[t]<-max(resultados[t,2:total_colunas])
  resultados$Minimo[t]<-min(resultados[t,2:total_colunas])
  resultados$Media[t]<-as.numeric(rowMeans(resultados[t,2:total_colunas]))
  resultados$'Desvio␣Padrao'[t]<- sd(resultados[t,2:total_colunas])
  resultados$Mediana[t] <- quantile(resultados[t,2:total_colunas], 0.5)
  resultados$'VaR␣95'[t] <- quantile(resultados[t,2:total_colunas], 0.95)
  resultados$'VaR␣5'[t] <- quantile(resultados[t,2:total_colunas], 0.05)

}

resultados_final <- data.frame(t(resultados[-1]))  #Transpor a dataframe (
    Colunas passam a linhas e vice-versa)
colnames(resultados_final) <- resultados[, 1]

ind_var<-nrow(resultados_final) #numero linhas do resultado

#ciclo para calculo do CVaR 95

for(z in 1:ncol(resultados_final)){
```

```
  max_var<-as.numeric(resultados_final[nrow(resultados_final)-2,z])

  x<-(resultados_final[1:(nrow(resultados_final)-8),z])
  x<-unlist(x, use.names = FALSE)
  x<-as.numeric(x)
  x<-x[x>=max_var]
  aux_cvar<-mean(x)
  resultados_final[ind_var,z]<-aux_cvar   #escrever o valor na data.frame


  rm(aux_cvar)
  rm(x)





  #x<-mean_col_if(ge(resultados_final[ind_var-2,z]),resultados_final[1:(
     nrow(resultados_final)-8),z]) #valores maiores que Var 95
  # x<-na.omit(x) #apagar valores nulos(menores que VaR 95)
  # x<-as.numeric(x) #converter para numerico
  # aux_cvar<-mean(x) #fazer a media dos valores selecionados
  # resultados_final[ind_var,z]<-aux_cvar   #escrever o valor na data.
     frame

  # rm(aux_cvar)

}

#----------------------------------------------------------------- <
   EXPORTAR DADOS>
   -------------------------------------------------------------

# Apenas deixar uma das 4 seguintes linhas descomentada dependendo se a
   analise e para ser por Distrito, Concelho, Freguesia ou NUTS3

#WriteXLS(resultados_final, "C:/Users/Jo o Silva/Documents/Dissertacao/
   Codigo/Export/Resultados_Distritoteste3.xlsx", perl = perl, row.names =
    TRUE)
#WriteXLS(resultados_final, "C:/Users/Jo o Silva/Documents/Dissertacao/
   Codigo/Export/Resultados_Concelho.xlsx", perl = perl, row.names = TRUE)
#WriteXLS(resultados_final, "C:/Users/Jo o Silva/Documents/Dissertacao/
   Codigo/Export/Resultados_Freguesia.xlsx", perl = perl, row.names = TRUE
   )
```

```
#WriteXLS(resultados_final, "C:/Users/Jo o Silva/Documents/Dissertacao/
    Codigo/Export/Resultados_NUTS3.xlsx", perl = perl, row.names = TRUE)
write.xlsx(resultados_final, "C:/Users/Jo o␣Silva/Documents/Dissertacao/
    Codigo/Export/Resultados/Resultados␣CB␣ ptimos /Final/Resultados_CB_
     ptimo _FaseCharlie2007_tresemtreshoras.xlsx", row.names=TRUE)

#---------------------------------------------< CRIAR E EXPORTAR OS
    GRAFICOS
    >--------------------------------------------------------------------------------

# Apenas deixar uma das 4 seguintes linhas descomentada dependendo se a
    analise e para ser por Distrito, Concelho, Freguesia ou NUTS3

#pdf(file="C:/Users/Jo o Silva/Documents/Dissertacao/Codigo/Export/
    Distritosteste3.pdf")
#pdf(file="C:/Users/Jo o Silva/Documents/Dissertacao/Codigo/Export/
    Concelhos.pdf")
#pdf(file="C:/Users/Jo o Silva/Documents/Dissertacao/Codigo/Export/
    Freguesias.pdf")
#pdf(file="C:/Users/Jo o Silva/Documents/Dissertacao/Codigo/Export/NUTS3.
    pdf")
pdf(file="C:/Users/Jo o␣Silva/Documents/Dissertacao/Codigo/Export/
    Resultados/Resultados␣CB␣ ptimos /Final/CB_ ptimo _FaseCharlie2007_
    tresemtreshoras.pdf")


for(d in 1:ncol(resultados_estatisticas))
{
  if(exists("aux2")){
    rm(aux2)
  }
  aux2<-data.frame("Ocorrencias"=(resultados_estatisticas[d])[,1], "
      Intervalos" = as.Date(rownames(resultados_estatisticas)))
  plot(aux2$Intervalos,aux2$Ocorrencias, main = colnames(resultados_
      estatisticas)[d], type = "l", xlab = "Intervalos", ylab = "
      Ocorrencias")

}

dev.off()
```

A.4 Burned area

```
#CASO NAO ESTEJAM INSTALADOS INSTALAR AS 3 BIBLIOTECAS USANDO -> install.
   packages("nome_da_biblioteca")

#Possivel ter que instalar o perl a partir do site strawberryperl.com para
    usar WriteXLS

#PATH do perl

perl <- "C:/strawberry/perl/bin/perl.exe"

library(dplyr)
library(gtools)
library(WriteXLS)
library(readxl) #biblioteca para ler excel
library(xlsx)   #biblioteca para criar excel
library(lubridate) #biblioteca para usar data como data + HH:MM:SS
library(chron)  #biblioteca para converter para horas e minutos
library(PerformanceAnalytics) #biblioteca para analise estatistica do VaR
    (Value at Risk)
library(plyr)
library(R.utils)
library(expss)
library(data.table)


setwd("C:/Users/Jo o␣Silva/Documents/Dissertacao/Codigo")


#----------------------------------------- < REMOVER RESULTADOS ANTERIORES
    > ---------------------------------------------

if(exists("resultados_geral")){
  rm(resultados_geral)
}

if(exists("base_res")){
  rm(base_res)
}

if(exists("resultados_aa")){
  rm(resultados_aa)
}

#----------------------------------------------------
   -------------------------------------------------------------------
```

```
regiao<-"NomeCB" # Escolher entre Distrito, Concelho, Freguesia ou NUTS3
           ATENCAO AOS ERROS DE TYPING!!!!!


if(regiao=="Distrito"){
  base_res<- data.frame("Distrito"= levels(Lista_snull$Distrito), freq=0)
}

if(regiao=="Concelho"){
  base_res<- data.frame("Concelho"= levels(Lista_snull$Concelho), freq=0)
}

if(regiao=="Freguesia"){
  base_res<- data.frame("Freguesia"= levels(Lista_snull$Freguesia), freq
      =0)
}

if(regiao=="NUTS3"){
  base_res<- data.frame("NUTS3"= levels(Lista_snull$NUTS3), freq=0)
}

if(regiao=="NomeCB"){
  base_res<- data.frame("NomeCB"= levels(Lista_otimo_CB$NomeCB), freq=0)
}


colnames(base_res)[2]<-"AA_Total␣(pov+mato+agric)␣(ha)"

linhas_total <- as.numeric(nrow(Lista_otimo_CB)) # total de linhas do
    Excel

#--------------------------------------- < INSERIR DATA INICIO E DATA FIM
    NO FORMATO (AAAA-MM-DD) , HORAS E MINUTOS>
    ---------------------------------------------------------


d_inicio <- "2001-01-01"      #ALTERAR AQUI DATA DE INICIO
h_inicio <- 0                 #ALTERAR AQUI HORAS DE INICIO
min_inicio <- 0               #ALTERAR AQUI MINUTOS DE INICIO
d_inicio<-as.Date(d_inicio)
d_inicio<- as.numeric(d_inicio)+25569 + h_inicio/24 + min_inicio/(24*60)

d_fim <- "2012-12-31"         #ALTERAR AQUI DATA DE FIM
h_fim <-24                   #ALTERAR AQUI HORAS DE FIM
```

```
min_fim <- 0                  #ALTERAR AQUI MINUTOS DE FIM
d_fim <- as.Date(d_fim)
d_fim <- as.numeric(d_fim)+25569 + h_fim/24 + min_fim/(24*60)


resultados_geral <- base_res
#------------------------------------------------------------ < CICLO
    SIMULTANEIDADE>
    -------------------------------------------------------------------------



  for(i in 1:linhas_total) {


    if(regiao=="Distrito"){
      ifelse( test = ( (Lista_snull$DataAlerta[i]+Lista_snull$HoraAlerta[i
          ]) > d_fim ) | ( Lista_snull$DataExtincao[i] + Lista_snull$
          HoraExtincao[i] < d_inicio ), contador<-contador  , resultados_
          geral<-rbind(resultados_geral, Lista_snull[i,c(5,26)])  )
    }

    if(regiao=="Concelho"){
      ifelse( test = ( (Lista_snull$DataAlerta[i]+Lista_snull$HoraAlerta[i
          ]) > d_fim ) | ( Lista_snull$DataExtincao[i] + Lista_snull$
          HoraExtincao[i] < d_inicio ), contador<-contador  , resultados_
          geral<-rbind(resultados_geral, Lista_snull[i,c(6,26)])  )
    }

    if(regiao=="Freguesia"){
      ifelse( test = ( (Lista_snull$DataAlerta[i]+Lista_snull$HoraAlerta[i
          ]) > d_fim ) | ( Lista_snull$DataExtincao[i] + Lista_snull$
          HoraExtincao[i] < d_inicio ), contador<-contador  , resultados_
          geral<-rbind(resultados_geral, Lista_snull[i,c(7,26)])  )
    }

    if(regiao=="NUTS3"){
      ifelse( test = ( (Lista_snull$DataAlerta[i]+Lista_snull$HoraAlerta[i
          ]) > d_fim ) | ( Lista_snull$DataExtincao[i] + Lista_snull$
          HoraExtincao[i] < d_inicio ), contador<-contador  , resultados_
          geral<-rbind(resultados_geral, Lista_snull[i,c(39,26)])  )
    }
    if(regiao=="NomeCB"){
      ifelse( test = ( (Lista_otimo_CB$DataAlerta[i]+Lista_otimo_CB$
          HoraAlerta[i]) > d_fim ) | ( Lista_otimo_CB$DataExtincao[i] +
```

```
        Lista_otimo_CB$HoraExtincao[i] < d_inicio ), contador<-contador
        , resultados_geral<-rbind(resultados_geral, Lista_otimo_CB[i,c
        (40,26)])  )
    }

 }

colnames(resultados_geral)[2]<-"freq"


#--------------------------------------------< CALCULAR DADOS ESTATISTICOS

    >---------------------------------------------------------------------------------


if(regiao=="Distrito"){
  area_ardida_stat<-ddply(resultados_geral,~Distrito,summarise,Maximo=max(
      freq), Media=mean(freq),Mediana=median(freq), VaR95=quantile(freq
      ,0.95), Total=sum(freq))
}

if(regiao=="Concelho"){
  area_ardida_stat<-ddply(resultados_geral,~Concelho,summarise,maximo=max(
      freq),media=mean(freq),mediana=median(freq), VaR95=quantile(freq
      ,0.95), Total=sum(freq))
}

if(regiao=="Freguesia"){
  area_ardida_stat<-ddply(resultados_geral,~Freguesia,summarise,maximo=max
      (freq),media=mean(freq),mediana=median(freq), VaR95=quantile(freq
      ,0.95), Total=sum(freq))
}

if(regiao=="NUTS3"){
  area_ardida_stat<-ddply(resultados_geral,~NUTS3,summarise,maximo=max(
      freq),media=mean(freq),mediana=median(freq), VaR95=quantile(freq
      ,0.95), Total=sum(freq))
}

if(regiao=="NomeCB"){
  area_ardida_stat<-ddply(resultados_geral,~NomeCB,summarise,maximo=max(
      freq),media=mean(freq),mediana=median(freq), VaR95=quantile(freq
      ,0.95), Total=sum(freq))
}
```

```
#--------------------------------------------------< CALCULAR CVaR 95
    >------------------------------------------------------------------------------------------


for(t in 1:nrow(resultados_geral)){



  if(regiao=="Distrito"){
    aux<-xtabs(formula=freq~Distrito + freq, data=resultados_geral[t,])
  }

  if(regiao=="Concelho"){
    aux<-xtabs(formula=freq~Concelho + freq, data=resultados_geral[t,])
  }

  if(regiao=="Freguesia"){
    aux<-xtabs(formula=freq~Freguesia + freq, data=resultados_geral[t,])
  }

  if(regiao=="NUTS3"){
    aux<-xtabs(formula=freq~NUTS3 + freq, data=resultados_geral[t,])
  }

  if(regiao=="NomeCB"){
    aux<-xtabs(formula=freq~NomeCB + freq, data=resultados_geral[t,])
  }

  aux<- as.data.frame(aux)

  t_aux <- transpose(aux)


  colnames(t_aux) <- rownames(aux)
  rownames(t_aux) <- colnames(aux)
  rownames(t_aux)[2]<-as.character(t)

  aux<-t_aux

  ifelse(exists("resultados_aa"),resultados_aa<-rbind(resultados_aa, aux
      [2,]), resultados_aa<-aux)


}
```

```
area_ardida_stat$CVaR95<-NA


for(z in 1:ncol(resultados_aa)){

  max_var<-area_ardida_stat$VaR95[z] #Valor de VaR 95 para o calculo do
      CVaR 95

  x<-(resultados_aa[2:nrow(resultados_aa),z])
  x<-unlist(x, use.names = FALSE)
  x<-as.numeric(x)
  x<-x[x>=max_var]
  aux_cvar<-mean(x)

  area_ardida_stat$CVaR95[z]<-aux_cvar

  rm(aux_cvar)
  rm(x)

}

#------------------------------------------------------------------ <
    EXPORTAR DADOS>
    --------------------------------------------------------------

#WriteXLS(area_ardida_stat, paste0(base_dir,"Export/AA/Resultados_",regiao
    ,"_AA.xlsx"), perl = perl, row.names = FALSE)
write.xlsx(area_ardida_stat, "C:/Users/Jo o␣Silva/Documents/Dissertacao/
    Codigo/Export/Resultados/ rea ␣Ardida/2001␣a␣2012/Resultados_CB.xlsx",
    row.names=FALSE)
```

Appendix B

Code

B.1 Data validation

```
library(dplyr)
library(gtools)
library(readxl)
library(xlsx)
library(openxlsx)
library(WriteXLS)

setwd("C:/Users/Jo o␣Silva/Documents/Dissertacao/Codigo")

aux<-Lista_Original

for(i in linhas_total){

  if( (is.na(aux$DataExtincao)) || (is.na(aux$HoraExtincao))){
    aux$DataExtincao[i]<- NA
    aux$HoraExtincao[i]<- NA
  }
}

aux <- aux[!is.na(aux$DataExtincao),]
aux <- aux[!is.na(aux$HoraExtincao),]

falta_extincao<- nrow(Lista_Original) - nrow(aux)

aux2<-aux

linhas_total_aux2<-nrow(aux2)

z<-1
```

```
while(z <= linhas_total_aux2){

  if((aux2$DataExtincao[z]+aux2$HoraExtincao[z]) - (aux2$DataAlerta[z] +
      aux2$HoraAlerta[z]) < 0)
  {
    aux2$DataExtincao[z] <- NA
    aux2$HoraExtincao[z] <- NA
  }
  z<-z+1
}

aux2 <- aux2[!is.na(aux2$DataExtincao),]
aux2 <- aux2[!is.na(aux2$HoraExtincao),]

duracoes_negativas<- nrow(aux) - nrow(aux2)

linhas_total_aux2<-nrow(aux2)

count_15<-0
count_26<-0

aux3<-aux2
t<-1
while(t <= linhas_total_aux2){

  if((aux3$DataExtincao[t]+aux3$HoraExtincao[t]) - (aux3$DataAlerta[t] +
      aux3$HoraAlerta[t]) > 15)
  {
    count_15<-count_15+1
  }

  if((aux3$DataExtincao[t]+aux3$HoraExtincao[t]) - (aux3$DataAlerta[t] +
      aux3$HoraAlerta[t]) > 26)
  {
    count_26<-count_26+1
    aux3$DataExtincao[t] <- NA
    aux3$HoraExtincao[t] <- NA
  }
 t<-t+1
}

aux3 <- aux3[!is.na(aux3$DataExtincao),]
aux3 <- aux3[!is.na(aux3$HoraExtincao),]

linhas_aux3<-nrow(aux3)
```

```
count_cl1<-0
count_cl2<-0
count_cl3<-0
count_cl4<-0
count_cl5<-0
count_cl6<-0
count_cl7<-0
count_cl8<-0

cl1<-c()
cl2<-c()
cl3<-c()
cl4<-c()
cl5<-c()
cl6<-c()
cl7<-c()
cl8<-c()

v<-1
while(v <=linhas_aux3){

  duracao<-(aux3$DataExtincao[v]+aux3$HoraExtincao[v])-(aux3$DataAlerta[v
      ]+aux3$HoraAlerta[v])

  if(aux3$`AA_Total (pov+mato+agric) (ha)`[v]==0){

    cl1<-append(cl1,duracao, after = length(cl1))
    count_cl1<-count_cl1+1

  }

  if(aux3$`AA_Total (pov+mato+agric) (ha)`[v]>0 && aux3$`AA_Total (pov+
      mato+agric) (ha)`[v]<=1){

    cl2<-append(cl2,duracao, after = length(cl2))
    count_cl2<-count_cl2+1

  }

  if(aux3$`AA_Total (pov+mato+agric) (ha)`[v]>1 && aux3$`AA_Total (pov+
      mato+agric) (ha)`[v]<=10){

    cl3<-append(cl3,duracao, after = length(cl3))
```

```
    count_cl3<-count_cl3+1

  }

  if(aux3$`AA_Total (pov+mato+agric) (ha)`[v]>10 && aux3$`AA_Total (pov+
      mato+agric) (ha)`[v]<=100){

    cl4<-append(cl4,duracao, after = length(cl4))
    count_cl4<-count_cl4+1

  }

  if(aux3$`AA_Total (pov+mato+agric) (ha)`[v]>100 && aux3$`AA_Total (pov+
      mato+agric) (ha)`[v]<=1000){

    cl5<-append(cl5,duracao, after = length(cl5))
    count_cl5<-count_cl5+1

  }

  if(aux3$`AA_Total (pov+mato+agric) (ha)`[v]>1000 && aux3$`AA_Total (pov+
      mato+agric) (ha)`[v]<=2000){

    cl6<-append(cl6,duracao, after = length(cl6))
    count_cl6<-count_cl6+1

  }

  if(aux3$`AA_Total (pov+mato+agric) (ha)`[v]>2000 && aux3$`AA_Total (pov+
      mato+agric) (ha)`[v]<=10000){

    cl7<-append(cl7,duracao, after = length(cl7))
    count_cl7<-count_cl7+1

  }

  if(aux3$`AA_Total (pov+mato+agric) (ha)`[v]>10000 && aux3$`AA_Total (pov
      +mato+agric) (ha)`[v]<=30000){

    cl8<-append(cl8,duracao, after = length(cl8))
    count_cl8<-count_cl8+1

  }
  v<-v+1
}
```

```
imputacao<-data.frame(Classes = c("0","0␣-␣1", "1␣-␣10", "10␣-␣100", "100-1000", "1000␣-␣2000", "2000␣-␣10000", "10000␣-␣30000"), Ocorrencias = c(count_cl1, count_cl2, count_cl3, count_cl4, count_cl5, count_cl6, count_cl7, count_cl8), Mediana = c(median(cl1), median(cl2), median(cl3), median(cl4), median(cl5), median(cl6), median(cl7), median(cl8)))

imputacao$Mediana<-round(imputacao$Mediana, 4)

write.xlsx(imputacao, 'Export/Tabelas/tabela_imputacao.xlsx')
```

B.2 Optimal result pre-processing

```
library(dplyr)
library(gtools)
library(readxl)
library(xlsx)
library(openxlsx)

setwd("C:/Users/Jo o␣Silva/Documents/Dissertacao/Codigo")

Lista_otimo_CB<-Lista_porto_CB

centoevinte_minutos<-120/(60*24)

linhas_lista_teste <- as.numeric(nrow(Lista_otimo_CB))

for(i in 1:linhas_lista_teste)
{

#if( (((Lista_otimo_CB$DataExtincao[i]+Lista_otimo_CB$HoraExtincao[i]) - (Lista_otimo_CB$DataAlerta[i]+Lista_otimo_CB$HoraAlerta[i])) > centoevinte_minutos) )
#{
  Lista_otimo_CB$DataExtincao[i] <- NA
  Lista_otimo_CB$HoraExtincao[i] <- NA
#}

if(is.na(Lista_otimo_CB$DataExtincao[i]) || is.na(Lista_otimo_CB$HoraExtincao[i]) ){ #se data ou hora de extincao nao existirem correr funcao de imputacao com parametro de area total ardida e linha a imputar
  #imputar(i)
```

```
  tempo<-Lista_otimo_CB$DataAlerta[i]+Lista_otimo_CB$HoraAlerta[i]+
      centoevinte_minutos

  Lista_otimo_CB$DataExtincao[i]<- tempo %/% 1 #divisao inteira
  Lista_otimo_CB$HoraExtincao[i]<- tempo %% 1 #resto da divisao inteira

}

}

write.xlsx(Lista_otimo_CB, 'C:/Users/Jo o␣Silva/Documents/Dissertacao/
    Codigo/Export/Listas/Lista_otimo_CB.xlsx')     #guardar em excel
saveRDS(Lista_otimo_CB, file = "C:/Users/Jo o␣Silva/Documents/Dissertacao
    /Codigo/Export/Listas/Lista_otimo_CB.rds")  #guardar em formato RDS
```

Appendix C

Normalized column names for ICNF data

- Ano
- Codigo SGIF
- Codigo_ANPC
- Ano
- Tipo
- Distrito
- Concelho
- Freguesia
- Local
- INE
- x
- y
- lat
- lon
- DataAlerta
- HoraAlerta
- DataExtincao

- HoraExtincao
- Data1Intervencao
- Hora1Intervencao
- FonteAlerta
- NUT
- AA_Povoamento (ha)
- AA_Mato (ha)
- AA_Agricola (ha)
- AA_EspacosFlorestais (pov+mato)(ha)
- AA_Total (pov+mato+agric) (ha)
- Reacendimentos
- Queimada
- Falso Alarme
- Fogacho
- Incendio
- Agricola
- Perimetro
- APS
- Causa
- TipoCausa
- Regiao PROF
- UGF

Appendix D

Case study

	2010-08-01	2010-08-02	2010-08-03	2010-08-04	2010-08-05	2010-08-06	2010-08-07	2010-08-08	2010-08-09	2010-08-10	2010-08-11	2010-08-12	2010-08-13	2010-08-14	2010-08-15	2010-08-16	2010-08-17	2010-08-18	2010-08-19	2010-08-20	2010-08-21	2010-08-22	2010-08-23	2010-08-24	2010-08-25	2010-08-26	2010-08-27	2010-08-28	2010-08-29	2010-08-30	2010-08-31	Minimum	VaR 5	Median	Average	Standard deviation	VaR 95	CVaR 95	Maximum
BV BALTAR	2	1	1	6	6	3	2	5	4	4	7	3	3	0	5	5	3	0	1	0	1	2	0	0	0	0	0	2	3	0	2	0	0	2	2	2	6	6	7
BV CETE	2	2	5	4	3	1	12	10	10	9	8	3	8	11	11	10	11	8	6	6	5	3	1	0	0	0	1	0	3	3	3	0	0	4	5	4	11	11	12
BV PAREDES	2	1	5	7	3	7	2	6	3	10	5	5	3	5	5	11	7	5	3	5	9	1	1	0	0	1	0	1	1	3	3	0	0	3	4	3	10	11	11
BV REBORDOSA	4	5	8	4	5	13	8	14	6	6	1	3	8	4	4	5	1	1	0	2	2	0	1	1	1	2	0	0	4	6	4	0	0	4	4	4	11	14	14
BV VALONGO	3	4	3	1	3	2	3	3	4	4	3	2	3	2	6	5	1	7	4	4	3	3	0	0	3	0	0	2	3	2	2	0	0	3	3	2	6	7	7

		2010-08-01	2010-08-02	2010-08-03	2010-08-04	2010-08-05	2010-08-06	2010-08-07	2010-08-08	2010-08-09	2010-08-10	2010-08-11	2010-08-12	2010-08-13	2010-08-14	2010-08-15	2010-08-16	2010-08-17	2010-08-18	2010-08-19	2010-08-20	2010-08-21	2010-08-22	2010-08-23	2010-08-24	2010-08-25	2010-08-26	2010-08-27	2010-08-28	2010-08-29	2010-08-30	2010-08-31
	BV BALTAR		-1	0	1	0	-1	-1	1	-1	0	1	-1	0	-1	1	0	-1	-1	1	-1	1	1	-1	0	0	0	0	1	1	-1	1
	BV CETE		0	1	-1	-1	-1	1	-1	0	-1	-1	-1	1	1	0	-1	1	-1	-1	0	-1	-1	-1	-1	0	0	1	-1	1	0	0
	BV PAREDES		-1	1	1	-1	1	-1	1	-1	1	-1	0	-1	1	0	1	-1	-1	-1	1	1	-1	0	-1	0	1	-1	1	0	1	0
	BV REBORDOSA		1	1	-1	1	1	-1	1	-1	0	-1	1	1	-1	0	1	-1	0	-1	1	0	-1	1	0	0	1	-1	0	1	1	-1
	BV VALONGO		1	-1	-1	1	-1	1	0	1	0	-1	-1	1	-1	1	-1	-1	1	-1	0	-1	0	-1	0	1	-1	0	1	1	-1	0
Decreased	-1		2	1	3	2	3	3	1	3	1	4	3	1	3	0	2	4	3	4	1	2	3	3	2	0	1	2	1	0	2	1
Maintain	0		1	1	0	1	0	0	1	1	3	0	1	1	0	3	1	0	1	0	2	1	1	1	3	4	2	2	1	1	1	3
Increased	1		2	3	2	2	2	2	3	1	1	1	1	3	2	2	2	1	1	1	2	2	1	1	0	1	2	1	3	4	2	1
Times that help is not possible			0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0	0	0	1	0	0
0	possible																															
1	not possible																															

Percentage of time that help is possible: 83%

Figure D.1: Simultaneous occurrences and variation of the number of occurrences, BV Baltar and its neighbors, August 2010, 1 day step

	2010-08-01	2010-08-02	2010-08-03	2010-08-04	2010-08-05	2010-08-06	2010-08-07	2010-08-08	2010-08-09	2010-08-10	2010-08-11	2010-08-12	2010-08-13	2010-08-14	2010-08-15	2010-08-16	2010-08-17	2010-08-18	2010-08-19	2010-08-20	2010-08-21	2010-08-22	2010-08-23	2010-08-24	2010-08-25	2010-08-26	2010-08-27	2010-08-28	2010-08-29	2010-08-30	2010-08-31	Minimum	VaR 5	Median	Average	Standard deviation	VaR 95	CVaR 95	Maximum
BV BALTAR	2	1	1	6	6	3	2	5	4	4	7	3	3	0	5	5	3	0	1	0	1	2	0	0	0	0	0	2	3	0	2	0	0	2	2	2	6	6	7
BV CETE	2	2	5	4	3	1	12	10	10	9	8	3	8	11	11	10	11	8	6	6	5	3	1	0	0	0	1	0	3	3	3	0	0	4	5	4	11	11	12
BV FREAMUNDE	3	1	4	2	4	2	5	4	3	4	3	3	2	3	3	1	3	2	0	0	1	3	0	0	0	0	0	1	0	0	6	0	0	2	2	2	5	6	6
BV LORDELO	1	2	3	1	0	1	2	3	2	8	5	3	6	3	2	3	2	1	0	0	1	0	0	1	2	0	0	0	0	2	0	0	0	1	2	2	6	7	8
BV LOUSADA	4	5	4	10	7	6	6	12	5	5	8	2	5	9	6	5	0	4	1	4	10	6	1	0	0	2	1	2	4	9	10	0	0	5	5	3	10	11	12
BV PAÇO DE SOUSA	0	0	2	3	1	5	5	1	5	5	6	1	1	3	0	3	3	1	0	1	0	0	1	0	1	1	0	1	1	1	1	0	0	1	2	2	5	5	6
BV PAÇOS DE FERREIRA	2	3	3	2	1	2	3	5	3	4	5	1	2	4	3	5	5	0	1	4	1	1	0	0	0	1	0	1	2	3	3	0	0	2	2	2	5	5	5
BV PAREDES	2	1	5	7	3	7	2	6	3	10	5	5	3	5	5	11	7	5	3	5	9	1	1	0	0	1	0	1	1	3	3	0	0	3	4	3	10	11	11
BV PENAFIEL	8	8	5	19	17	13	16	16	13	5	9	13	10	15	11	7	10	3	7	5	7	5	3	1	5	1	2	2	4	4	10	1	2	7	8	5	17	18	19
BV REBORDOSA	4	5	8	4	5	13	8	14	6	6	1	3	8	4	4	5	1	1	0	2	2	0	1	1	1	2	0	0	4	6	4	0	0	4	4	4	11	14	14

		2010-08-01	2010-08-02	2010-08-03	2010-08-04	2010-08-05	2010-08-06	2010-08-07	2010-08-08	2010-08-09	2010-08-10	2010-08-11	2010-08-12	2010-08-13	2010-08-14	2010-08-15	2010-08-16	2010-08-17	2010-08-18	2010-08-19	2010-08-20	2010-08-21	2010-08-22	2010-08-23	2010-08-24	2010-08-25	2010-08-26	2010-08-27	2010-08-28	2010-08-29	2010-08-30	2010-08-31
BV BALTAR			-1	0	1	0	-1	-1	1	-1	0	1	-1	0	-1	1	0	-1	-1	1	-1	1	1	-1	0	0	0	0	1	1	-1	1
BV CETE			0	1	-1	-1	-1	1	-1	0	-1	-1	-1	1	1	0	-1	1	-1	-1	0	-1	-1	-1	-1	0	0	1	-1	1	0	0
BV FREAMUNDE			-1	1	-1	1	-1	1	-1	-1	1	-1	0	-1	1	0	-1	1	-1	-1	0	1	1	-1	0	0	0	0	1	-1	0	1
BV LORDELO			1	1	-1	-1	1	1	1	-1	1	-1	-1	1	-1	-1	1	-1	-1	-1	0	1	-1	0	1	1	-1	0	0	0	1	-1
BV LOUSADA			1	-1	1	-1	-1	0	1	-1	0	1	-1	1	1	-1	-1	-1	1	-1	1	1	-1	-1	-1	0	1	-1	1	1	1	1
BV PAÇO DE SOUSA			0	1	1	-1	1	0	-1	1	0	1	-1	0	1	-1	1	0	-1	-1	1	-1	0	1	-1	1	0	-1	1	0	0	0
BV PAÇOS DE FERREIRA			1	0	-1	-1	1	1	1	-1	1	1	-1	1	1	-1	1	0	-1	1	1	-1	0	-1	0	0	1	-1	1	1	1	0
BV PAREDES			-1	1	1	-1	1	-1	1	-1	1	-1	0	-1	1	0	1	-1	-1	-1	1	1	-1	0	-1	0	1	-1	1	0	1	0
BV PENAFIEL			0	-1	1	-1	-1	1	0	-1	-1	1	1	-1	1	-1	-1	1	-1	1	-1	1	-1	-1	-1	1	-1	1	0	1	0	1
BV REBORDOSA			1	1	-1	1	1	-1	1	-1	0	-1	1	1	-1	0	1	-1	0	-1	1	0	-1	1	0	0	1	-1	0	1	1	-1
Decreased	-1		3	2	5	7	5	3	3	8	2	5	6	3	3	5	4	5	8	7	2	3	6	6	5	0	2	5	1	1	1	2
Maintain	0		3	2	0	1	0	2	1	1	4	0	2	2	0	4	1	2	1	0	3	1	2	2	4	7	4	3	3	3	4	4
Increased	1		4	6	5	2	5	5	6	1	4	5	2	5	7	1	5	3	1	3	5	6	2	2	1	3	4	2	6	6	5	4
Times that help is not possible			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
possible	0																															
not possible	1																															

Percentage of time that help is possible: 100%

Figure D.2: Simultaneous occurrences and variation of the number of occurrences, BV Paredes and its neighbors, August 2010, 1 day step

	2010-08-01	2010-08-02	2010-08-03	2010-08-04	2010-08-05	2010-08-06	2010-08-07	2010-08-08	2010-08-09	2010-08-10	2010-08-11	2010-08-12	2010-08-13	2010-08-14	2010-08-15	2010-08-16	2010-08-17	2010-08-18	2010-08-19	2010-08-20	2010-08-21	2010-08-22	2010-08-23	2010-08-24	2010-08-25	2010-08-26	2010-08-27	2010-08-28	2010-08-29	2010-08-30	2010-08-31	Minimum	VaR 5	Median	Average	Standard deviation	VaR 95	CVaR 95	Maximum
BV ENTRE-OS-RIOS	1	0	5	1	2	8	2	5	1	2	2	1	2	3	2	5	0	2	2	0	0	2	1	0	0	0	0	0	0	0	0	0	0	1	2	2	5	6	8
BV LOUSADA	4	5	4	10	7	6	6	12	5	5	8	2	5	9	6	5	0	4	1	4	10	6	1	0	0	2	1	2	4	9	10	0	0	5	5	3	10	11	12
BV MARCO DE CANAVESES	9	6	13	11	7	11	19	20	18	7	7	7	12	14	14	12	5	5	1	5	6	3	4	3	3	2	2	6	12	13	14	1	2	7	9	5	19	20	20
BV PAÇO DE SOUSA	0	0	2	3	1	5	5	1	5	5	6	1	1	3	0	3	3	1	0	1	0	0	1	0	1	1	0	1	1	1	1	0	0	1	2	2	5	5	6
BV PAREDES	2	1	5	7	3	7	2	6	3	10	5	5	3	5	5	11	7	5	3	5	9	1	1	0	0	1	0	1	1	3	3	0	0	3	4	3	10	11	11
BV PENAFIEL	8	8	5	19	17	13	16	16	13	5	9	13	10	15	11	7	10	3	7	5	7	5	3	1	5	1	2	2	4	4	10	1	2	7	8	5	17	18	19
BV VILA MEÃ	3	3	5	4	6	7	11	6	9	8	1	0	2	7	6	5	3	1	2	3	7	6	0	0	1	0	0	0	0	15	6	0	0	3	4	4	10	13	15

		2010-08-01	2010-08-02	2010-08-03	2010-08-04	2010-08-05	2010-08-06	2010-08-07	2010-08-08	2010-08-09	2010-08-10	2010-08-11	2010-08-12	2010-08-13	2010-08-14	2010-08-15	2010-08-16	2010-08-17	2010-08-18	2010-08-19	2010-08-20	2010-08-21	2010-08-22	2010-08-23	2010-08-24	2010-08-25	2010-08-26	2010-08-27	2010-08-28	2010-08-29	2010-08-30	2010-08-31
BV ENTRE-OS-RIOS			-1	1	-1	1	1	-1	1	-1	1	0	-1	1	1	-1	1	-1	1	0	-1	0	1	-1	-1	0	0	0	0	0	0	0
BV LOUSADA			1	-1	1	-1	-1	0	1	-1	0	1	-1	1	1	-1	-1	-1	1	-1	1	1	-1	-1	-1	0	1	-1	1	1	1	1
BV MARCO DE CANAVESES			-1	1	-1	-1	1	1	1	-1	-1	0	0	1	1	0	-1	-1	0	-1	1	1	-1	1	-1	0	-1	0	1	1	1	1
BV PAÇO DE SOUSA			0	1	1	-1	1	0	-1	1	0	1	-1	0	1	-1	1	0	-1	-1	1	-1	0	1	-1	1	0	-1	1	0	0	0
BV PAREDES			-1	1	1	-1	1	-1	1	-1	1	-1	0	-1	1	0	1	-1	-1	-1	1	1	-1	0	-1	0	1	-1	1	0	1	0
BV PENAFIEL			0	-1	1	-1	-1	1	0	-1	-1	1	1	-1	1	-1	-1	1	-1	1	-1	1	-1	-1	-1	1	-1	1	0	1	0	1
BV VILA MEÃ			0	1	-1	1	1	1	-1	1	-1	-1	-1	1	1	-1	-1	-1	-1	1	1	1	-1	-1	0	1	-1	0	0	0	1	-1
Decreased	-1		3	2	3	5	2	2	2	5	3	2	4	2	0	5	4	5	4	4	2	1	5	4	6	0	3	3	0	0	0	1
Maintain	0		3	0	0	0	0	2	1	0	2	2	2	1	0	2	0	1	1	1	0	1	1	1	1	4	2	3	3	4	3	3
Increased	1		1	5	4	2	5	3	4	2	2	3	1	4	7	0	3	1	2	2	5	5	1	2	0	3	2	1	4	3	4	3
Times that help is not possible			0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
possible	0																															
not possible	1																															

Percentage of time that help is possible: 93%

Figure D.3: Simultaneous occurrences and variation of the number of occurrences, BV Penafiel and its neighbors, August 2010, 1 day step

	2010-08-01	2010-08-02	2010-08-03	2010-08-04	2010-08-05	2010-08-06	2010-08-07	2010-08-08	2010-08-09	2010-08-10	2010-08-11	2010-08-12	2010-08-13	2010-08-14	2010-08-15	2010-08-16	2010-08-17	2010-08-18	2010-08-19	2010-08-20	2010-08-21	2010-08-22	2010-08-23	2010-08-24	2010-08-25	2010-08-26	2010-08-27	2010-08-28	2010-08-29	2010-08-30	2010-08-31	Minimum	VaR 5	Median	Average	Standard deviation	VaR 95	CVaR 95	Maximum
BV AREOSA	1	2	2	2	0	1	2	3	2	1	4	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	3	4	4
BV BALTAR	2	1	1	6	6	3	2	5	4	4	7	3	3	0	5	5	3	0	1	0	1	2	0	0	0	0	0	2	3	0	2	0	0	2	2	2	6	6	7
BV CETE	2	2	5	4	3	1	12	10	10	9	8	3	8	11	11	10	11	8	6	6	5	3	1	0	0	0	1	0	3	3	3	0	0	4	5	4	11	11	12
BV ERMESINDE	0	1	1	0	1	4	3	5	3	2	2	1	1	3	2	1	0	0	0	0	0	0	0	0	0	0	0	0	1	4	5	0	0	1	1	2	5	5	5
BV GONDOMAR	4	1	3	6	5	3	5	3	2	4	3	2	2	7	2	1	2	3	2	1	1	0	0	0	0	0	0	1	3	1	1	0	0	2	2	2	6	7	7
BV LORDELO	1	2	3	1	0	1	2	3	2	8	5	3	6	3	2	3	2	1	0	0	1	0	0	1	2	0	0	0	0	2	0	0	0	1	2	2	6	7	8
BV PAÇOS DE FERREIRA	2	3	3	2	1	2	3	5	3	4	5	1	2	4	3	5	5	0	1	4	1	1	0	0	0	1	0	1	2	3	3	0	0	2	2	2	5	5	5
BV REBORDOSA	4	5	8	4	5	13	8	14	6	6	1	3	8	4	4	5	1	1	0	2	2	0	1	1	1	2	0	0	4	6	4	0	0	4	4	4	11	14	14
BV S. PEDRO DA COVA	1	3	0	0	2	0	4	1	4	4	3	4	4	2	2	2	2	3	0	4	1	0	0	0	1	0	0	0	1	0	3	0	0	1	2	2	4	4	4
BV SANTO TIRSO	3	3	7	4	2	6	1	4	3	4	3	2	1	5	8	11	3	8	3	2	0	0	0	0	1	0	0	1	1	1	4	0	0	3	3	3	8	9	11
BV VALONGO	3	4	3	1	3	2	3	3	4	4	3	2	3	2	6	5	1	7	4	4	3	3	0	0	3	0	0	2	3	2	2	0	0	3	3	2	6	7	7

		2010-08-01	2010-08-02	2010-08-03	2010-08-04	2010-08-05	2010-08-06	2010-08-07	2010-08-08	2010-08-09	2010-08-10	2010-08-11	2010-08-12	2010-08-13	2010-08-14	2010-08-15	2010-08-16	2010-08-17	2010-08-18	2010-08-19	2010-08-20	2010-08-21	2010-08-22	2010-08-23	2010-08-24	2010-08-25	2010-08-26	2010-08-27	2010-08-28	2010-08-29	2010-08-30	2010-08-31		
	BV AREOSA		1	0	0	-1	1	1	1	-1	-1	1	-1	-1	0	0	1	-1	0	0	0	0	0	0	0	0	0	1	-1	0	0	0		
	BV BALTAR		-1	0	1	0	-1	-1	1	-1	0	1	-1	0	-1	1	0	-1	-1	1	-1	1	1	-1	0	0	0	0	1	1	-1	1		
	BV CETE		0	1	-1	-1	-1	1	-1	0	-1	-1	-1	1	1	0	-1	1	-1	-1	0	-1	-1	-1	-1	0	0	1	-1	1	0	0		
	BV ERMESINDE		1	0	-1	1	1	-1	1	-1	-1	0	-1	0	1	-1	-1	-1	0	0	0	0	0	0	0	0	0	0	0	1	1	1		
	BV GONDOMAR		-1	1	1	-1	-1	1	-1	-1	1	-1	-1	0	1	-1	-1	1	1	-1	-1	0	-1	0	0	0	0	0	1	1	-1	0		
	BV LORDELO		1	1	-1	-1	1	1	1	-1	1	-1	-1	1	-1	-1	1	-1	-1	-1	0	1	-1	0	1	1	-1	0	0	0	1	-1		
	BV PAÇOS DE FERREIRA		1	0	-1	-1	1	1	1	-1	1	1	-1	1	1	-1	1	0	-1	1	1	-1	0	-1	0	0	1	-1	1	1	1	0		
	BV REBORDOSA		1	1	-1	1	1	-1	1	-1	0	-1	1	1	-1	0	1	-1	0	-1	1	0	-1	1	0	0	1	-1	0	1	1	-1		
	BV S. PEDRO DA COVA		1	-1	0	1	-1	1	-1	1	0	-1	1	0	-1	0	0	0	1	-1	1	-1	-1	0	0	1	-1	0	0	1	-1	1		
	BV SANTO TIRSO		0	1	-1	-1	1	-1	1	-1	1	-1	-1	-1	1	1	1	-1	1	-1	-1	-1	0	0	0	1	-1	0	1	0	0	1		
	BV VALONGO		1	-1	-1	1	-1	1	0	1	0	-1	-1	1	-1	1	-1	-1	1	-1	0	-1	0	-1	0	1	-1	0	1	1	-1	0		
Decreased	-1		2	2	7	6	5	4	3	8	3	7	9	2	5	4	4	7	4	7	3	5	5	4	1	0	4	2	2	0	4	2		
Maintain	0		2	4	2	1	0	0	1	1	4	1	0	4	1	4	2	2	3	2	5	4	5	6	9	7	5	7	4	3	3	5		
Increased	1		7	5	2	4	6	7	7	2	4	3	2	5	5	3	5	2	4	2	3	2	1	1	1	4	2	2	5	8	4	4		
Times that help is not possible			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0	possible																																Percentage of time	100%
1	not possible																																that help is possible	

Figure D.4: Simultaneous occurrences and variation of the number of occurrences, BV Valongo and its neighbors, August 2010, 1 day step

	2010-08-01	2010-08-02	2010-08-03	2010-08-04	2010-08-05	2010-08-06	2010-08-07	2010-08-08	2010-08-09	2010-08-10	2010-08-11	2010-08-12	2010-08-13	2010-08-14	2010-08-15	2010-08-16	2010-08-17	2010-08-18	2010-08-19	2010-08-20	2010-08-21	2010-08-22	2010-08-23	2010-08-24	2010-08-25	2010-08-26	2010-08-27	2010-08-28	2010-08-29	2010-08-30	2010-08-31	Minimo	Minimum	VaR 5	Median	Average	Standard deviation	VaR 95	CVaR 95	Maximum
BV FREAMUNDE	3	1	4	2	4	2	5	4	3	4	3	3	2	3	3	1	3	2	0	0	1	3	0	0	0	0	0	1	0	0	6	0	0	2	2	2	5	6	6	
BV LORDELO	1	2	3	1	0	1	2	3	2	8	5	3	6	3	2	3	2	1	0	0	1	0	0	1	2	0	0	0	0	2	0	0	0	1	2	2	6	7	8	
BV PAÇOS DE FERREIRA	2	3	3	2	1	2	3	5	3	4	5	1	2	4	3	5	5	0	1	4	1	1	0	0	0	1	0	1	2	3	3	0	0	2	2	2	5	5	5	
BV PAREDES	2	1	5	7	3	7	2	6	3	10	5	5	3	5	5	11	7	5	3	5	9	1	1	0	0	1	0	1	1	3	3	0	0	3	4	3	10	11	11	
BV SANTO TIRSO	3	3	7	4	2	6	1	4	3	4	3	2	1	5	8	11	3	8	3	2	0	0	0	0	1	0	0	1	1	1	4	0	0	3	3	3	8	9	11	
BV TIRSENSES	5	0	3	2	6	5	5	6	5	4	4	1	4	3	3	3	7	2	2	3	2	0	0	0	1	0	0	0	3	1	2	0	0	3	3	2	6	6	7	
BV VALONGO	3	4	3	1	3	2	3	3	4	4	3	2	3	2	6	5	1	7	4	4	3	3	0	0	3	0	0	2	3	2	2	0	0	3	3	2	6	7	7	

		2010-08-01	2010-08-02	2010-08-03	2010-08-04	2010-08-05	2010-08-06	2010-08-07	2010-08-08	2010-08-09	2010-08-10	2010-08-11	2010-08-12	2010-08-13	2010-08-14	2010-08-15	2010-08-16	2010-08-17	2010-08-18	2010-08-19	2010-08-20	2010-08-21	2010-08-22	2010-08-23	2010-08-24	2010-08-25	2010-08-26	2010-08-27	2010-08-28	2010-08-29	2010-08-30	2010-08-31		
	BV FREAMUNDE		-1	1	-1	1	-1	1	-1	-1	1	-1	0	-1	1	0	-1	1	-1	-1	0	1	1	-1	0	0	0	0	1	-1	0	1		
	BV LORDELO		1	1	-1	-1	1	1	1	-1	1	-1	-1	1	-1	-1	1	-1	-1	-1	0	1	-1	0	1	1	-1	0	0	0	1	-1		
	BV PAÇOS DE FERREIRA		1	0	-1	-1	1	1	1	-1	1	1	-1	1	1	-1	1	0	-1	1	1	-1	0	-1	0	0	1	-1	1	1	1	0		
	BV PAREDES		-1	1	1	-1	1	-1	1	-1	1	-1	0	-1	1	0	1	-1	-1	-1	1	1	-1	0	-1	0	1	-1	1	0	1	0		
	BV SANTO TIRSO		0	1	-1	-1	1	-1	1	-1	1	-1	-1	-1	1	1	1	-1	1	-1	-1	-1	0	0	0	1	-1	0	1	0	0	1		
	BV TIRSENSES		-1	1	-1	1	-1	0	1	-1	-1	0	-1	1	-1	0	0	1	-1	0	1	-1	-1	0	0	1	-1	0	0	1	-1	1		
	BV VALONGO		1	-1	-1	1	-1	1	0	1	0	-1	-1	1	-1	1	-1	-1	1	-1	0	-1	0	-1	0	1	-1	0	1	1	-1	0		
Decreased	-1		3	1	6	4	3	2	1	6	1	5	5	3	3	2	2	4	5	5	1	4	3	3	1	0	4	2	0	1	2	1		
Maintain	0		1	1	0	0	0	1	1	0	1	1	2	0	0	3	1	1	0	1	3	0	3	4	5	3	1	5	2	3	2	3		
Increased	1		3	5	1	3	4	4	5	1	5	1	0	4	4	2	4	2	2	1	3	3	1	0	1	4	2	0	5	3	3	3		
Times that help is not possible			0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0	possible																																Percentage of time	93%
1	not possible																																that help is possible	

Figure D.5: Simultaneous occurrences and variation of the number of occurrences, BV Paços de Ferreira and its neighbors, August 2010, 1 day step

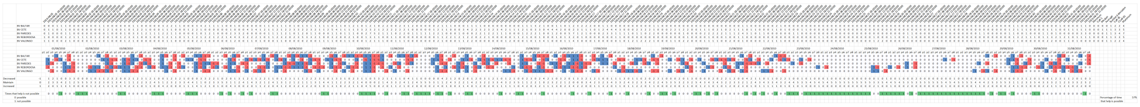

Figure D.6: Simultaneous occurrences and variation of the number of occurrences, BV Baltar and its neighbors, August 2010, 3 hours step

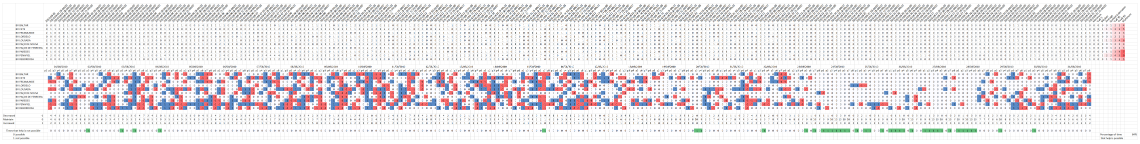

Figure D.7: Simultaneous occurrences and variation of the number of occurrences, BV Paredes and its neighbors, August 2010, 3 hours step

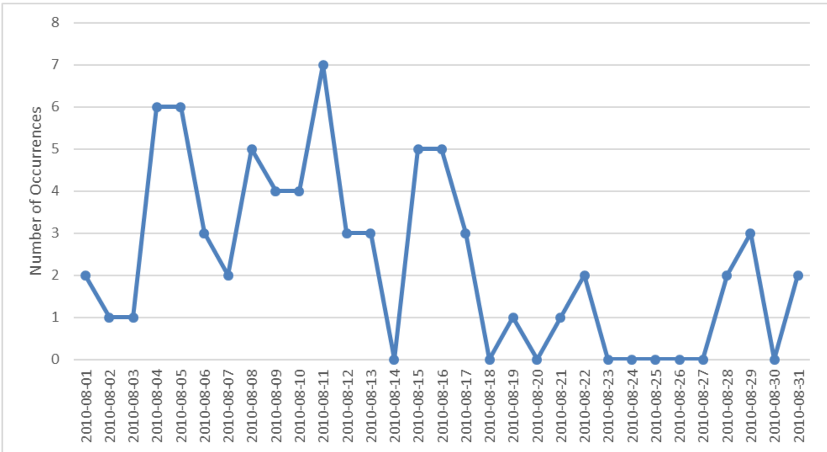

Figure D.8: Number of simultaneous occurrences in BV Baltar, 1 day step

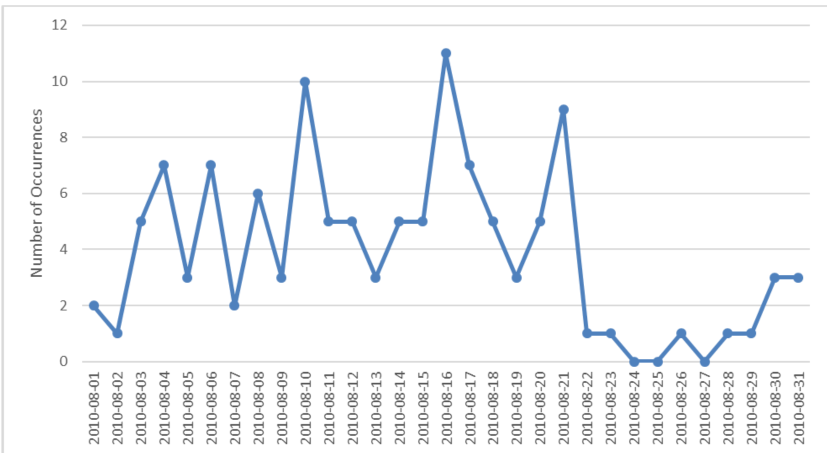

Figure D.9: Number of simultaneous occurrences in BV Paredes, 1 day step

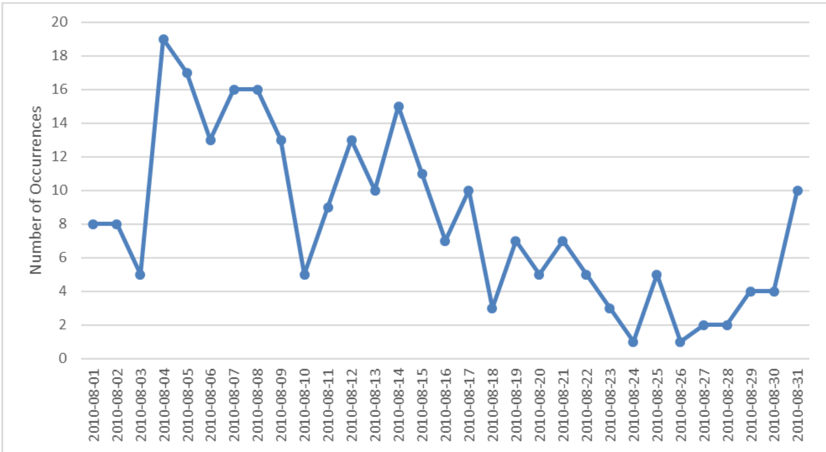

Figure D.10: Number of simultaneous occurrences in BV Penafiel, 1 day step

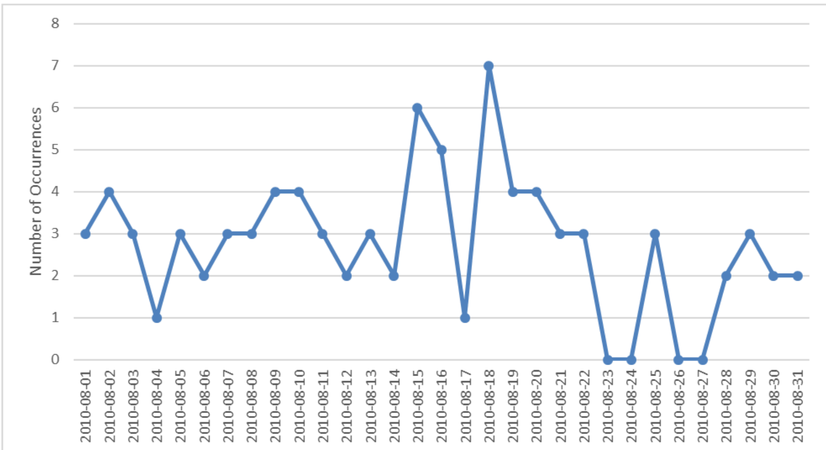

Figure D.11: Number of simultaneous occurrences in BV Valongo, 1 day step

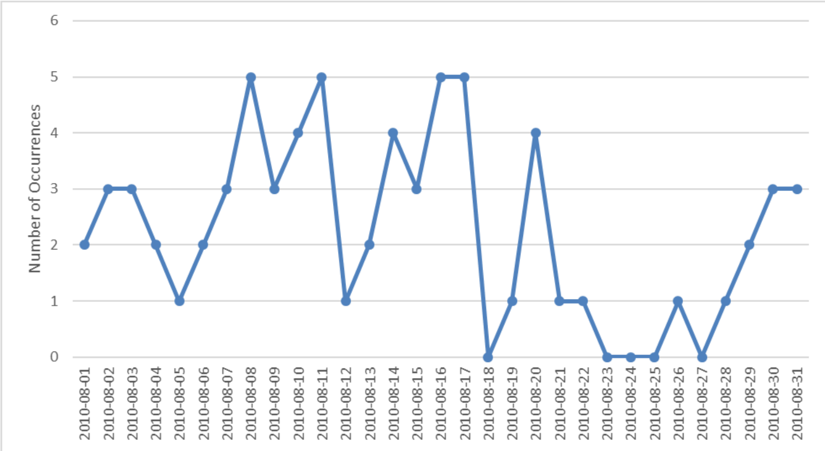

Figure D.12: Number of simultaneous occurrences in BV Paços de Ferreira, 1 day step

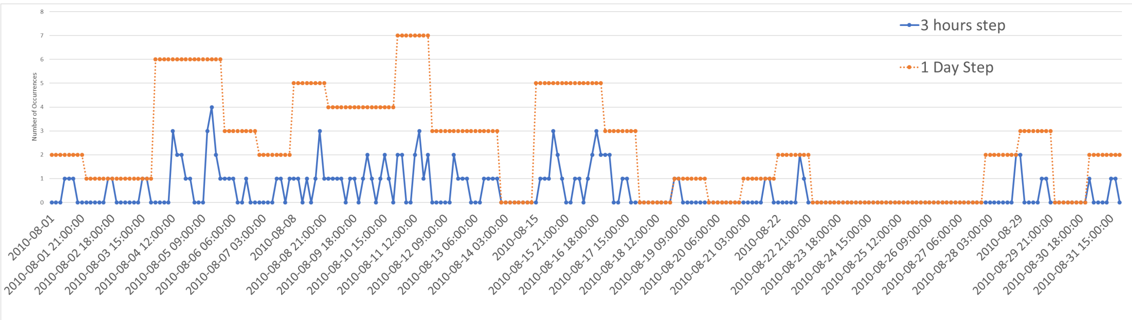

Figure D.13: Number of simultaneous occurrences in BV Baltar, 1 day and 3 hours step

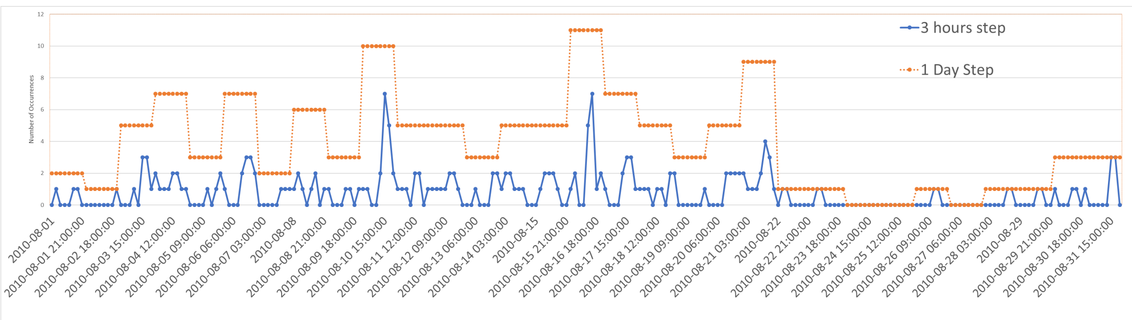

Figure D.14: Number of simultaneous occurrences in BV Paredes, 1 day and 3 hours step

Appendix E

Statistical analysis

E.1 Simultaneous occurrences, Charlie phase, 2001 till 2012, 3 hours step

Fire departments	Minimum	VaR 5	Median	Average	Standard deviation	VaR 95	CVaR 95	Maximum
BV Aguda	0	0	0	1	1	1	2	5
BV Amarante	0	0	0	1	1	2	3	7
BV Areosa	0	0	0	1	1	1	2	5
BV Avintes	0	0	0	1	1	1	2	6
BV Baião	0	0	0	1	1	1	2	8
BV Baltar	0	0	0	1	1	1	2	8
BV Carvalhos	0	0	0	1	1	2	3	9
BV Cete	0	0	0	1	1	1	2	5
BV Coimbrões	0	0	0	1	1	1	2	5
BV Crestuma	0	0	0	1	1	0	1	4
BV Entre-os-Rios	0	0	0	1	1	1	2	5
BV Ermesinde	0	0	0	1	1	1	2	5
BV Felgueiras	0	0	0	1	1	2	3	11
BV Freamunde	0	0	0	1	1	2	3	6
BV Gondomar	0	0	0	1	1	1	2	7
BV Leça do Balio	0	0	0	1	1	1	2	4
BV Leixões	0	0	0	1	1	0	1	2
BV Lixa	0	0	0	1	1	2	3	7
BV Lordelo	0	0	0	1	1	1	2	4
BV Lousada	0	0	0	1	1	2	3	15
BV Marco de Canaveses	0	0	0	1	2	4	5	12
BV Matosinhos-Leça	0	0	0	1	1	1	2	4
BV Melres	0	0	0	1	1	1	2	4
BV Moreira da Maia	0	0	0	1	1	2	3	8
BV Paço de Sousa	0	0	0	1	1	1	2	6
BV Paços de Ferreira	0	0	0	1	1	2	3	8
BV Paredes	0	0	0	1	1	2	3	8
BV Pedrouços	0	0	0	1	1	0	1	4
BV Penafiel	0	0	0	1	2	3	4	10
BV Porto	0	0	0	1	1	0	1	1
BV Portuenses	0	0	0	1	1	0	1	1
BV Póvoa de Varzim	0	0	0	1	1	1	2	5
BV Rebordosa	0	0	0	1	1	2	3	7
BV S. Mamede de Infesta	0	0	0	1	1	0	1	3
BV S. Pedro da Cova	0	0	0	1	1	1	2	8
BV Santa Marinha do Zêzere	0	0	0	1	1	1	2	5
BV Santo Tirso	0	0	0	1	1	2	3	6
BV Tirsenses	0	0	0	1	1	2	3	5
BV Trofa	0	0	0	1	1	1	2	5
BV Valadares	0	0	0	1	1	1	2	4
BV Valbom	0	0	0	1	1	1	2	6
BV Valongo	0	0	0	1	1	1	2	4
BV Vila das Aves	0	0	0	1	1	1	2	7
BV Vila do Conde	0	0	0	1	1	2	3	8
BV Vila Meã	0	0	0	1	1	2	3	6

Table E.1: Simultaneous occurrences, Charlie phase, 2001 till 2012, 3 hours step

E.2 Burned area, Charlie phase, 2001 till 2012

Fire departments	Median (ha)	Average (ha)	Var95 (ha)	CVaR95 (ha)	Maximum (ha)	Total (ha)
BV Aguda	1	1	1	2	7	148
BV Amarante	1	3	5	44	778	8323
BV Areosa	1	1	1	2	6	119
BV Avintes	1	1	1	2	10	147
BV Baião	1	5	10	74	780	7687
BV Baltar	1	3	2	37	792	3523
BV Carvalhos	1	1	1	5	161	1309
BV Cete	1	2	2	30	1132	2700
BV Coimbrões	1	1	1	3	15	155
BV Crestuma	1	1	2	10	66	280
BV Entre-os-Rios	1	2	3	21	266	2125
BV Ermesinde	1	1	1	13	343	845
BV Felgueiras	1	1	3	7	84	1631
BV Freamunde	1	1	1	5	48	612
BV Gondomar	1	1	1	3	30	423
BV Leça do Balio	1	1	1	2	15	74
BV Leixões	1	1	1	1	1	3
BV Lixa	1	1	3	8	85	1075
BV Lordelo	1	1	1	4	30	224
BV Lousada	1	1	2	7	141	2363
BV Marco de Canaveses	1	3	5	32	862	12344
BV Matosinhos-Leça	1	1	2	4	13	231
BV Melres	1	4	3	64	828	3603
BV Moreira da Maia	1	1	1	5	189	1282
BV Paço de Sousa	1	4	2	62	1874	5582
BV Paços de Ferreira	1	1	1	8	226	1170
BV Paredes	1	1	1	5	52	637
BV Pedrouços	1	1	1	1	1	14
BV Penafiel	1	2	3	24	1297	5641
BV Porto	0	1	1	1	1	1
BV Portuenses	0	0	0	0	0	0
BV Póvoa de Varzim	1	1	1	8	273	843
BV Rebordosa	1	1	1	6	106	797
BV S. Mamede de Infesta	1	1	1	2	5	43
BV S. Pedro da Cova	1	1	1	9	200	880
BV Santa Marinha do Zêzere	1	4	6	61	879	4426
BV Santo Tirso	1	2	3	23	662	2896
BV Tirsenses	1	1	3	16	321	2063
BV Trofa	1	2	3	19	282	2150
BV Valadares	1	1	1	2	18	96
BV Valbom	1	2	3	15	315	1413
BV Valongo	1	2	3	37	816	3088
BV Vila das Aves	1	1	2	9	81	970
BV Vila do Conde	1	1	1	5	85	1042
BV Vila Meã	1	1	3	9	171	1195

Table E.2: Burned area, Charlie phase, 2001 till 2012

E.3 Risk of burned area potential, Charlie phase, 2001 till 2012

Fire departments	Risk of burned area potential
BV Aguda	3
BV Amarante	8
BV Areosa	3
BV Avintes	3
BV Baião	3
BV Baltar	3
BV Carvalhos	8
BV Cete	3
BV Coimbrões	3
BV Crestuma	1
BV Entre-os-Rios	3
BV Ermesinde	3
BV Felgueiras	8
BV Freamunde	8
BV Gondomar	3
BV Leça do Balio	3
BV Leixões	1
BV Lixa	8
BV Lordelo	3
BV Lousada	9
BV Marco de Canaveses	25
BV Matosinhos-Leça	3
BV Melres	3
BV Moreira da Maia	8
BV Paço de Sousa	3
BV Paços de Ferreira	8
BV Paredes	8
BV Pedrouços	1
BV Penafiel	16
BV Porto	1
BV Portuenses	1
BV Póvoa de Varzim	3
BV Rebordosa	8
BV S. Mamede de Infesta	1
BV S. Pedro da Cova	3
BV Santa Marinha do Zêzere	3
BV Santo Tirso	8
BV Tirsenses	8
BV Trofa	3
BV Valadares	3
BV Valbom	3
BV Valongo	3
BV Vila das Aves	3
BV Vila do Conde	8
BV Vila Meã	8

Table E.3: Risk of burned area potential, Charlie phase, 2001 till 2012

Annex F

Plano de operações distrital N.º 01/2015

Ministério da Administração Interna

ANPC Autoridade Nacional de Protecção Civil

Comando Distrital de Operações de Socorro do Porto

PLANOP | **01** **2015**

Plano de Operações Distrital

Data: 30-04-2015 **Assunto:** Dispositivo Especial de Combate a Incêndios Florestais

ANEXO 3	**Meios dos Corpos de Bombeiros nas fases Bravo, Charlie e Delta**

Corpo de Bombeiros	MAIO			JUNHO			JULHO			AGOSTO			SETEMBRO			OUTUBRO		
	15 a 31			01 a 30			01 a 31			01 a 31			01 a 30			01 a 15		
	ECIN	ELAC	EIP	ECIN	ELAC	EIP	ECIN	ELAC	EIP	ECIN	ELAC	EIP	ECIN	ELAC	EIP	ECIN	ELAC	EIP
V. Porto							1			1			1					
V. Portuenses							1			1			1					
V. Aguda					1		2			2			2					
V. Avintes				1			2			2			2					
V. Carvalhos				1			2			2			2					
V. Coimbrões							1			1			1					
V. Crestuma				1			1	1		1	1		1	1				
V. Valadares					1		1			1			1					
V. Areosa								1			1			1				
V. Ermesinde					1		2			2			2					
V. Gondomar				1			2			2			2			1		
V. Melres				1			1			1			1					
V. São Pedro da Cova	1			1			2	1		2	1		2	1		1		
V. Valbom	1			1			2			2			2					
V. Valongo			1	1		1	2	1	1	2	1	1	2	1	1			1
V. Leça do Balio																		
V. Leixões								1			1			1				
V. Matosinhos-Leça								1			1			1				
V. Moreira da Maia		1			1			1			1			1			1	
V. Pedrouços																		
V. S. Mamede de Infesta							1			1			1					
V. Póvoa de Varzim				1			1			1			1					
V. Santo Tirso			1	1		1	1		1	1		1	1		1	1		1
V. Tirsenses	1			1			1	1		1	1		1	1				
V. Trofa			1	1		1	1	1	1	1	1	1	1	1	1			1
V. Vila das Aves			1		1	1	1		1	1		1	1		1			1
V. Vila do Conde				1			1	1		1	1		1	1				
V. Baltar				1			2	1		2	1		2	1		1		
V. Cête	1			1			2			2			2					
V. Entre-os-Rios				1			2			2			2					
V. Freamunde			1	1		1	2	1	1	2	1	1	2	1	1	1		1
V. Lordelo							1			1			1					
V. Paço de Sousa							1			1			1					
V. Paços de Ferreira	1		1	1		1	1		1	1		1	1		1			1
V. Paredes				1			2			2			2					
V. Penafiel	1			1	1		3			3			3			1		
V. Rebordosa							1			1			1					
V. Amarante	1		1	1		1	2	1	1	2	1	1	2	1	1	1		1
V. Baião	1			1			2	1		2	1		2	1		1		
V. Felgueiras			1	1		1	1	1	1	1	1	1	1	1	1		1	1
V. Lixa		1		1			1	1		1	1		1	1				
V. Lousada							1			1			1					
V. Marco de Canaveses	1		1	1		1	2	1	1	2	1	1	2	1	1	1		1
V. S. Marinha do Zêzere	1			1			2			2			2			1		
V. Vila Meã		1	1	1		1	2		1	2		1	2		1		1	1
Total Equipas p/ Mês	10	3	10	27	6	10	59	17	10	59	17	10	59	17	10	10	3	10
Total Operacionais	50	6	50	135	12	50	295	34	50	295	34	50	295	34	50	50	6	50

Página 36 de 61

Este documento tem carácter: **RESERVADO**

Figure F.1: Plano de operações distrital N.º 01/2015 from Autoridade Nacional de Protecção Civil 2015

Annex G

Plano de operações distrital N.º 01/2018

MINISTÉRIO DA ADMINISTRAÇÃO INTERNA

ANPC
AUTORIDADE NACIONAL DE PROTECÇÃO CIVIL

Comando Distrital de Operações de Socorro do Porto

PLANOP 01 2018
Plano de Operações Distrital

Data: 09-05-2018 **Assunto:** Dispositivo Especial de Combate a Incêndios Rurais

ANEXO 3	**Meios dos Corpos de Bombeiros nos Níveis II, III e IV**

Corpo de Bombeiros	MAIO – NÍVEL II 15 a 31			JUNHO – NÍVEL III 01 a 30			JULHO – NÍVEL IV 01 a 31			AGOSTO – NÍVEL IV 01 a 31			SETEMBRO – NÍVEL IV 01 a 30			OUTUBRO – NÍVEL III 01 a 15		
	ECIN	ELAC	EIP	ECIN	ELAC	EIP	ECIN	ELAC	EIP	ECIN	ELAC	EIP	ECIN	ELAC	EIP	ECIN	ELAC	EIP
V. Porto							1			1			1					
V. Portuenses							1	1		1	1		1	1			1	
V. Aguda					1		1	1		1	1		1	1		1		
V. Avintes				1			1			1			1					
V. Carvalhos				1			2			2			2			1		
V. Coimbrões					1		1			1			1			1		
V. Crestuma				1			1			1			1					
V. Valadares				1			2			2			2			1		
V. Areosa					1			1			1			1			1	
V. Ermesinde				1			2	1		2	1		2	1		1		
V. Gondomar				1			1			1			1					
V. Meires				1			1			1			1			1		
V. São Pedro da Cova	1			1			2			2			2			1		
V. Valbom	1			1			2			2			2			1		
V. Valongo		1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1
V. Leça do Balio																		
V. Leixões																		
V. Matosinhos-Leça				1			1	1		1	1		1	1		1		
V. Moreira da Maia		1			1			1			1			1			1	
V. Pedrouços					1			1			1			1				
V. S. Mamede de Infesta				1			1	1		1	1		1	1		1		
V. Póvoa de Varzim																		
V. Santo Tirso			1	1		1	1		1	1		1	1		1	1		1
V. Tirsenses			1	1		1	1	1	1	1	1	1	1	1	1	1	1	1
V. Trofa	1		1	1		1	2		1	2		1	2		1	1	1	1
V. Vila das Aves			1		1	1	1		1	1		1	1		1	1		1
V. Vila do Conde				1			1	1		1	1		1	1				
V. Baltar				1			2	1		2	1		2	1		1		
V. Cête	1			1			2			2			2			1		
V. Entre-os-Rios				1			2			2			2			1		
V. Freamunde	1		1	1		1	3		1	3		1	3		1	1		1
V. Lordelo				1			1			1			1			1		
V. Paço de Sousa					1		1	1		1	1		1	1				
V. Paços de Ferreira			1			1	1		1	1		1	1		1			1
V. Paredes							1			1			1			1		
V. Penafiel	1			1	1		2	1		2	1		2	1		1	1	
V. Rebordosa					1		2			2			2			1		
V. Amarante	1		1	1		1	1	1	1	1	1	1	1	1	1	1		1
V. Baião	1			1			2	1		2	1		2	1		1		
V. Felgueiras			1	1		1	1		1	1		1	1		1		1	1
V. Lixa		1		1	1		2	1		2	1		2	1		1	1	
V. Lousada				1			1			1			1			1		
V. Marco de Canaveses	1		1	1		1	2	1	1	2	1	1	2	1	1	1		1
V. S. Marinha do Zêzere	1			1			2			2			2			1		
V. Vila Meã		1	1	1		1	2		1	2		1	2		1	1	1	1
Total Equipas p/ Mês	10	4	11	30	10	11	57	18	11	57	18	11	57	18	11	30	10	11
Total Operacionais	50	8	55	150	20	55	285	36	55	285	36	55	285	36	55	150	20	55

Página 40 de 68
Este documento tem carácter: RESERVADO

Figure G.1: Plano de operações distrital N.º 01/2018 from Autoridade Nacional de Protecção Civil 2018