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Luciano Lourenço, Fantina Tedim e Cármen Ferreira

OS INCÊNDIOS FLORESTAIS. EM BUSCA DE UM NOVO PARADIGMA

II Diálogo entre Ciência e Utilizadores

Núcleo de Investigação Científica de Incêndios Florestais
Faculdade de Letras da Universidade de Coimbra
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Por motivos imprevistos, a publicação desta obra dilatou-se no tempo muito mais do que seria desejável. Apesar do desfasamento entre a entrega dos originais e a sua publicação, muitos dos assuntos mantêm-se, desafortunadamente, de grande atualidade.

NOTA DE ABERTURA

A primeira edição do "Diálogo entre Ciência e Utilizadores" decorreu na Faculdade de Letras da Universidade de Coimbra, a 16 de maio de 2014, e, logo nessa primeira reunião ,foi anunciada a realização de um segundo "Diálogo", que se iria realizar na Faculdade de Letras da Universidade do Porto, o qual se veio a realizar no ano seguinte, mais precisamente no dia 30 de setembro de 2015 e que se centrou na abordagem de "*Os incêndios florestais. Em busca de um novo paradigma*".

Como sucedeu com o anterior, também agora se dão à estampa as comunicações que nele foram apresentadas, de acordo com a sequência da respetiva apresentação, ainda que desta vez com um substancial atraso. Todavia, entendemos que isso é preferível à sua não publicação.

Assim, após a sessão de abertura, o primeiro painel, que deu "**A Palavra aos Académicos**", contou com quatro intervenções de especialistas, provenientes de três universidades distintas: Coimbra, Minho e Porto. Coube aos signatários abrir e fechar este painel, respetivamente, com o Prof. Doutor Luciano Lourenço, da Universidade de Coimbra, a proferir, nessa abertura, uma palestra sobre "*Incêndios florestais em Portugal continental. Degradação da paisagem ou reabilitação após as cinzas?"*.

Seguiu-se-lhe a intervenção do Prof. Doutor António Bento Gonçalves, da Universidade do Minho, que tratou da "*Intensidade, severidade e recorrência, três conceitos-chave no estudo dos incêndios florestais",* uma comunicação em coautoria com a Doutoranda Flora Ferreira Leite e o Prof. Doutor António Vieira, ambos da Universidade do Minho.

A continuação, a Prof.ª Doutora Adélia Nunes, da Universidade de Coimbra dissertou sobre a "*Tendência dos Incêndios florestais em Portugal continental (1980-2014): que ilações para o planeamento do território?"*.

Encerrou este painel a Prof.ª Doutora Fantina Tedim, da Universidade do Porto, com uma conferência sobre *"As causas e as motivações dos incêndios florestais na região norte de Portugal"*, realizada em coautoria com Vittorio Leone, Professor aposentado da Università degli Studi della Basilicata, de Potenza, Itália, com o Mestre Francisco Gutierres, do Centro de Estudos Geográficos da Universidade de Lisboa, e os Licenciados Fernando Correia e Catarina Magalhães, da Faculdade de Letras do Porto.

Depois de um breve intervalo, seguiu-se o segundo painel, dedicado à "I**nteração entre Académicos e Operacionais**", o qual contou com duas intervenções: A primeira delas, da autoria de Christophe Bouillon, do Irstea, Institut National de Recherche en Sciences et Technologies pour l'Environnement et l'Agriculture, e da Prof. Doutora Fantina Tedi, que se centrou no tema "*Os incêndios na interface urbano-florestal: questões metodológicas e de gestão"*. Seguiu-se-lhe a comunicação *"Os mega-incêndios em Portugal: desafios para a gestão"*, da autoria das Profªs. Doutoras Fantina Tedim, Carmen Ferreira e Helena Madureira, da Universidade do Porto, e dos Dr.s Alexandre Vasquéz Rodriguez e João Martins, mas que por não ter sido entregue para publicação, não pôde ser dada à estampa.

Após um intervalo para almoço, os trabalhos foram retomados ao início da tarde, com um painel em que foi dada "**A palavra aos Operacionais**", tendo o Coronel Luís Neri, Presidente do Serviço Regional de Proteção Civil da Madeira, dissertado sobre "*A interface urbano-florestal na RAM como ambiente de dificuldade extrema para a intervenção coordenada e racional dos corpos de bombeiros em incêndios florestais"*. Após esta intervenção, seguiu-se uma "*Sessão em grupos de trabalho*".

Depois de uma pausa para café, a reunião fechou com uma mesa redonda sobre "**A extinção e a prevenção: que equilíbrio possível?**", onde foram apresentadas as propostas e as conclusões de cada um dos grupos de trabalho, à qual se seguiu a sessão de encerramento, com que terminou esta reunião.

Estamos certos de que este segundo Diálogo terá dado um importante contributo para uma reflexão séria sobre os incêndios florestais em Portugal e, para que aqueles que não tiveram possibilidade de nele participar também possam usufruir dos assuntos aí tratados, publicamos as diferentes intervenções que, deste modo, não só perpetuam a realização desta reunião, mas também permitem disponibilizar para um público mais vasto os conteúdos dos assuntos então abordados.

Boas leituras!

Coimbra, 7 de setembro de 2018

Luciano Lourenço

Painel:
"A Palavra aos Académicos"

EVIDENCES ABOUT CAUSES OF WILDFIRES IN THE NORTHERN REGION OF PORTUGAL

AS CAUSAS E AS MOTIVAÇÕES DOS INCÊNDIOS FLORESTAIS NA REGIÃO NORTE DE PORTUGAL

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Abstract: This paper reports the results of an analysis of the causes of wildfires in the Northern Region of Portugal for the period 2012-2014. Data were analysed using descriptive statistics, GIS, cluster analysis and kernel density estimation. Analysis shows that the majority of wildfires have unknown causes, followed by those caused by negligence and those started deliberately. This research showed that the Northern Region is not a homogenous space in terms of the causes of and reasons for wildfires. Problems with misconceptions in ascribing causes are identified and discussed.

Keywords: Northern region, vandalism, causes of and reasons for wildfires.

Sumário: Este artigo apresenta os resultados da análise das causas dos incêndios florestais na Região Norte de Portugal, para o período de 2012-2014. Os dados foram analisados com recurso à estatística descritiva, SIG, análise de *clusters* e densidade *Kernel*. A análise evidencia forte expresão das causas desconhecidas, seguida por causas negligentes e intencionais. Esta investigação evidencia que a Região Norte não é um espaço homegéneo em termo de causas e motivos os incêndios florestais. Potenciais problemas na atribuição das causas foram identificados e discutidos.

Palavras-chave: Causas e motivos dos incêndios florestais, Região Norte, vandalismo.

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Introduction

Pyrogeography deals with the complex human–fire relationships across space and through time (Roos *et al., 2014)*, based on the understanding of drivers underlying spatial and temporal patterns of wildfires (Krawchuk and Moritz, 2014). One of its perspectives is related with the patterns of causes, since most of wildfires cluster in space and time (Butry and Prestemon, 2005; Genton *et al.*, 2006; Prestemon and Butry, 2005, 2008; Thomas *et al.*, 2011). Causes are more diverse than is often assumed, and fire initiation is neither random, nor, in some cases, meaningless as some papers suggest (Leone *et al.*, 2003; Lovreglio *et al.*, 2010), because most of the fires are result of human actions that have a conscient motivation or objective (Coughlan and Petty, 2012).

The level of knowledge of wildfire causes in Portugal still presents weaknesses, as for a relevant number of fires causes are unknown, aggravated by the lack of reliable data about causes and motives of wildfires in general, which is of paramount importance for directing prevention and risk communication to specific social targets or activities. Portuguese authorities recently improved wildfire outbreak investigation, reducing the percentage of unknown causes from 74 % in 1980-1988 (Ferriera de Almeida and Moura, 1992) to about 28 % in 2013 (ICNF, 2014). In the last years (2015 to 2017) the percentage of unknown causes ranged between 47 % and 53 % for the Portugal mainland. So, there is still a lack of knowledge regarding the roots of the wildfires problem in Portugal.

Overly simplistic explanations of wildfires encourage decision-makers to consider fire-fighting the main solution to harmful forest fires. The current wildfire policy in Portugal, mainly focused on suppression, has not been able to solve the wildfire problem or to contain it. The disastrous events occurred in 2017 confirmed this reality.

The suppression activity and the fixed structural prevention, completed by restrictive legal frameworks, seem inefficacious. An alternative and promising approach to contain the phenomenon is a more proactive model, based on wildfire suppression, integrated and reinforced by prevention. Collins (Collins, 2012) proposed to allocate 60 % of public funding to prevention and 40 % to suppression to control the fire problem in Portugal.

This paper is an explorative essay of pyrogeography, focused on the discussion of causes in the Northern Region of Portugal, with the purpose of understanding the weakness and strong points of the current knowledge of the wildfire causes in Portugal to inform wildfire prevention. Two main hypotheses are considered: *i)* a political and institutional pressure to decrease the importance of wildfire events with unknown cause can conduct to an artificial cause attribution showing that the main focus is the wildfire database and the institutional and political impacts more than the accuracy of the data to truly support sustainable prevention measures; *ii)* the high percentage of some causes in a municipality can be explained by a misunderstanding of their meaning, a lack of knowledge about the social and economic dynamics of the rural areas that can validate or not such causes, or misconceptions about wildfires. 61

Data and Methods

Study area

The Northern Region of Portugal (fig.1) with a surface of 21.285,88 km^2, had 3.689,173 inhabitants in 2011 (INE 2012), i.e. 23 % and 35 % of the total surface and population of the country, respectively. It is one of the most fire prone regions of the

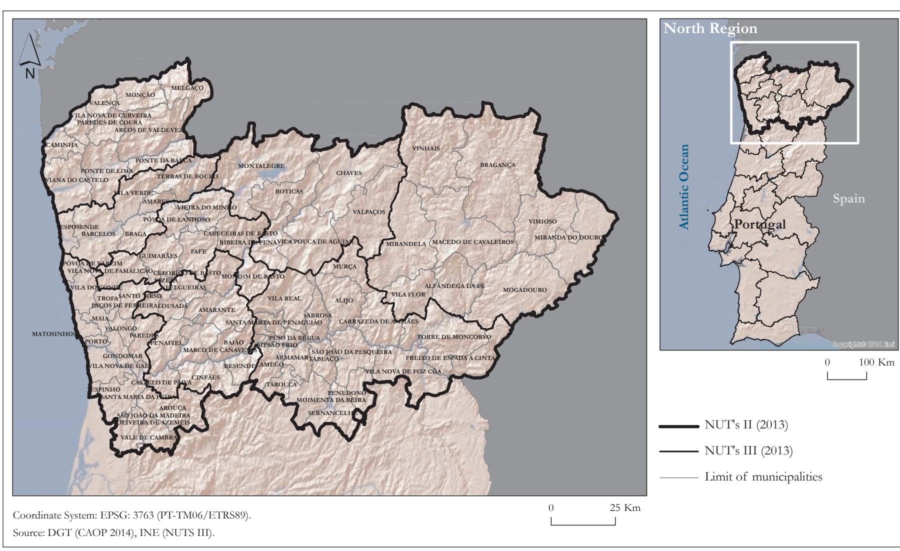

Fig. 1 - The location of the Northern Region (NUTS II) of Portugal and its administrative divisions (municipalities) and statistical unites (NUTS III).

***Fig. 1 -** Localização da Região Norte (NUTS II) de Portugal e a divisão administrativa (municípios) e unidades estatísticas (NUTS III).*

country (fig. 2). The annual average of fire density indicators (i.e. the number of events per 10 km^2; San-Miguel-Ayanz and Camia, 2009) for the period 2012 to 2014, puts into evidence the high fire proneness of the Region, with a value of 4,6 *vs* 1,7 for Portugal. The same happens with burned area (BA) per 10 km^2, which is respectively 24,6 ha for Northern Region and 10,2 ha for Portugal. As an average, the Region yearly exhibits 2,7 times more fire events and 2,4 times more BA than the whole country, in the reference period.

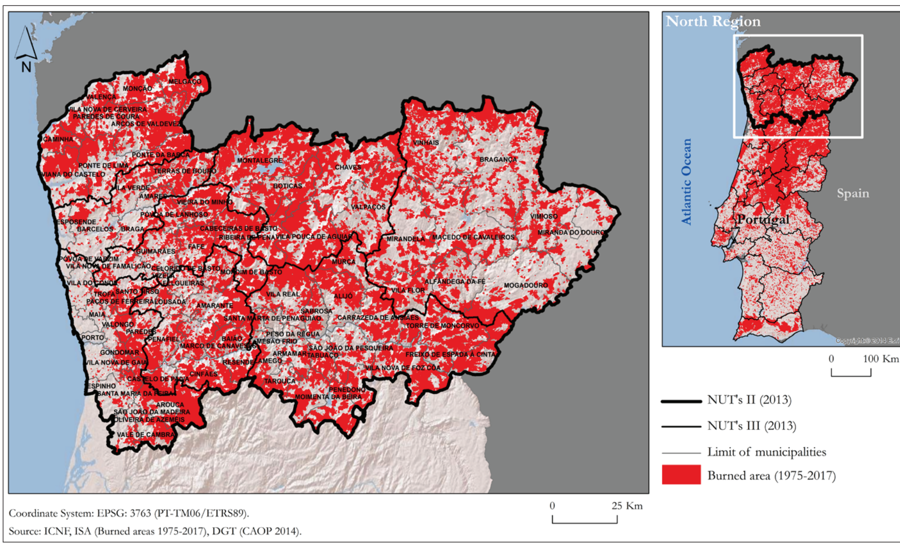

Fig. 2 - The Northern Region of Portugal is one of the most wildfire prone of the country. Burned area in Northern Region of Portugal between 1975 and 2017 (Source: 1975-1989, data from School of Agronomy (ISA - Instituto Superior de Agronomia); after 1990, data from Institute for Nature Conservation and Forests (ICNF - Instituto para a Conservação da Natureza e das Florestas).

Fig. 2 - *A Região Norte de Portugal é uma das áreas mais suscetíveis do país aos incêndios florestais. Área ardida na Região Norte de Portugal, entre 1975 e 2017 (Fonte: 1975-1989, dados do Instituto Superior de Agronomia (ISA); após 1990, dados do Instituto de conservação da Natureza e das Florestas (ICNF).*

Based on the Land Use and Cover Map for Portugal Mainland 2010 (COS2010 - Carta de Uso e Ocupação do Solo de Portugal Continental) (fig. 3), the land use is as follows: 7.087 km^2 (33,3 %) is Scrub and/or herbaceous vegetation (class 3.2); 5.089 km^2 (23,9 %) is Forest (class 3.1), with 2.279 km^2 of broad-leaved forest and 736 km^2 of Eucalypt forest, respectively; 2.487 km^2 (11,7 %) is Arable land (class 2.1); 2.316 km^2 (10,9 %)

is Permanent crops (class 2.2); 1.595 km^2 (7,5 %) is Heterogeneous agricultural areas (class 2.4); 1.183 km^2 (5,6 %) is Urban fabric (class 1.1); 222,6 km^2 (1,1 %) is Industrial, commercial and transport units (class 1.2); 94 km^2 (0,4 %) is Mine, dump and construction sites (class 1.3); 31 km^2 (0,1 %) is Artificial, non-agricultural vegetated areas (class 1.4); 66 km^2 (0,3 %) is Pastures (class 2.3); 926 km^2 (4,4 %) is Open spaces with little or no vegetation (class 3.3); 0,2 km^2 (0,0008 %) is Inland wetlands (class 4.1); 6 km^2 (0,03 %) is Maritime wetlands (class 4.2) and 165 km^2 (0,8 %) Inland waters (class 5.1).

The Northern Region of Portugal comprises 86 municipalities, but in this study Porto, an urban municipality with noconditions for the occurrence of wildfires, was excluded making 85 the total of municipalities studied. Those municipalities span from coastal ones with relevant population density and urbanization rate, to inner and remote rural municipalities, in a rough mountainous context, characterized by strong depopulation and ageing, as well as the decline of agricultural and forestry activities; all these conditions strongly influence the dynamic of fire occurrence and mainly the related causes and motivations.

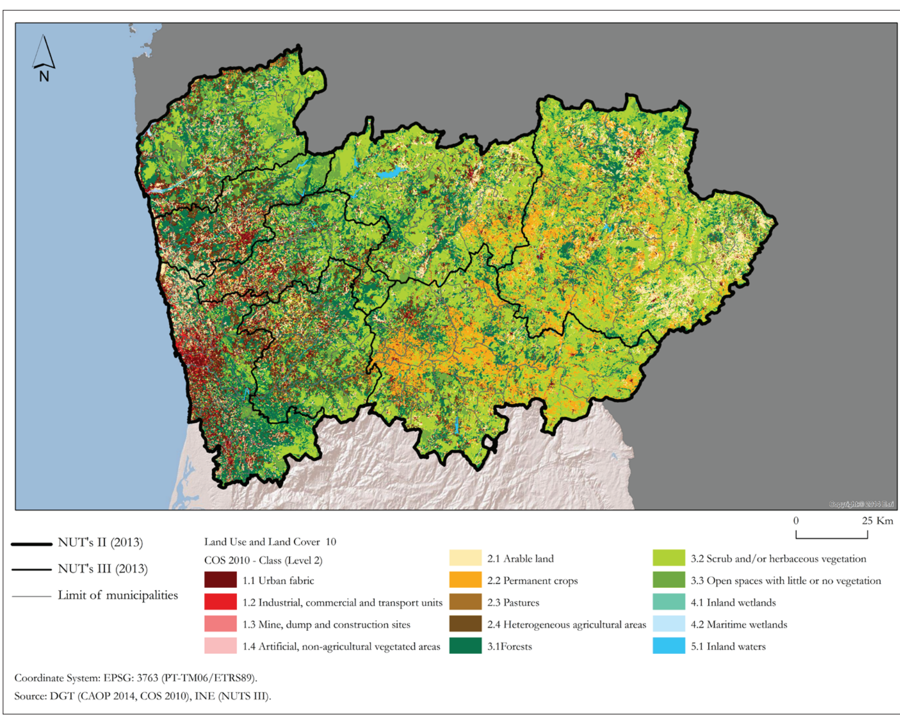

Fig. 3 - Land use and Land cover (level 2) in the Northern Region of Portugal, in 2010 (Source: COS2010).

Fig. 3 - *Uso e ocupação do solo (nível 2) na Região Norte de Portugal, em 2010 (Fonte: COS2010).*

Data sets and period of reference

This research is based on wildfire events for the period 2012 to 2014, characterized by a relevant inter-annual variability in terms of number of events and BA. In 2012 and 2013 the number of occurrences was high but similar (13.323 and 13.972, respectively), although the burned area was very different (43.233 ha and 106.563 ha, respectively). In 2014, the number of ignitions and burned area was very low (4.092 occurrences and 7.409,9 ha of burned area). We purposely limited our explorative survey to those years, but we are aware that a socio-ecological phenomenon such as wildfire, rapidly changes with time. Analysis has been carried out on a data base provided by the Institute for Nature Conservation and Forests (ICNF - Instituto para a Conservação da Natureza e das Florestas). After purging the database from occurrences with null burned area of forest and shrubs, 29.622 events were retained as valid; they represent our final source of information. Our research was therefore based on the causes related to such events.

In Portugal, wildfire causes are one of the parameters reported in the official ICNF database, which started in 1980. The Portuguese wildfire causes classification presents a 3-level hierarchical system, based on a three digits code. The higher level (first digit) groups the cause in six categories: 1 – *Negligent usage of fire*; 2 – *Accidental*; 3 – *Structural causes*; 4 – *Incendiary;* 5 – *Natural*; 6 – *Unknown*. The second level (two digits code) divides the high categories into smaller groups, identifying activities, and the third level (three digits code) corresponds to the official motives of fire outbreaks (ICNF, 2014).

In our analysis, 482 occurrences were categorized in general terms (one or two-digit code only), which do not identify the motives and behaviors behind the outbreak. This group does not include events categorized as 5 and 6 (*Natural causes* and *Unknown*) which for their nature do not admit or need a three-digit code. They were anyhow considered by the analysis. Since they represent only 1,6 % of the occurrences, they have a negligible impact on the final results, although at the municipality level the situation is rather variable. Though this situation affected 57,6 % of the municipalities, in most of them it represents less than 1 % of the events and only in five municipalities it presents values between 11,2 % (Vieira do Minho), and 33,3 % (S. João da Madeira).

Methods

Descriptive analysis of causes and motives of wildfires (2012-2014) was carried out at the municipality level in the North Region.

Spatial data in European Terrestrial Reference System 1989 (PT-TM06/ETRS89) were organized and processed in ArcGIS 10.5 software and integrated through thematic maps to put in evidence the spatial-temporal distribution of causes and motives of the wildfires.

The ignition points of all wildfires for the period 2012-2014 have been used to create a kernel density map for the whole region, so transforming the punctual information into a continuous density map of events realized to visualize the distribution of the ignition points. The Kernel Density Estimation (KDE) calculates a magnitude-per-unit area from point features using a kernel function to fit a smoothly tapered surface to each point. To deploy the kernel clustering method in Northern Region of Portugal, the ignition points from 2012 to 2014 have been registered according to their x and y location. The mentioned areas were analyzed using a cell size of 100 meters and a search radius of 3,218 m.

Finally, to show the different profiles of causality at the municipality level, a hierarchical cluster analysis was realized with SPSS software. This procedure attempts to identify relatively homogeneous groups of cases (municipalities) based on the more relevant fire causes (variables); the clusters were defined from the analysis of the Dendrogram using the Average Linkage within Groups. This hierarchical cluster analysis algorithm follows three basic steps: 1) calculate the distances between all group pairs and combines the two groups that are closest, 2) link the clusters, and 3) choose a solution by selecting the right number of clusters.

The method used for distance measuring was the Square Euclidian Distance. It is based on the Euclidian Distance between two observations, which is the square root of the sum of squared distances. Since the Euclidian Distance is squared, it increases the importance of large distances, while weakening the importance of small distances.

Thus, the procedure begins with as many clusters as there are cases (here: 85 which correspond to the municipalities under analysis). At step one, the two cases with the smallest squared Euclidean distance between them are clustered. Then the distances were once more computed combining the two that are next closest. The process continues until all cases are grouped into one large cluster. At the end we proceed to the individualization of 11 groups of clusters.

Wildfire occurrence at regional level

Main characteristics

In Northern Region of Portugal, the 29.622 events occurred in the period 2012-2014 affected about 156.975,16 ha. BA per event ranged from 0,0001 ha to 14.136 ha of the single largest wildfire. This fire occurred in 2013 and remains the largest one that occurred in the Northern Region of Portugal up to date.

The distribution per size class is markedly right-skewed, with the highest number of events in the minimum size class (<1 ha): 23.092 fires (78,0 % of the total number of events), but only for 2.982,80 ha of the BA (1,9 % of the total BA) (Table I). In about 95,8 % of wildfires the size was less than 10 ha and only explained 11,0 % of the BA. On the other hand, all wildfires encompassed in the size classes from 100 ha (i.e. large fires according to the standard of ICNF) onward, were reduced in number of events, only 241 (0,9 % of the total number) but affected 110.095,0 ha (70,2 % of total BA).

Table I - Wildfire incidents by size and burned area, in the Northern Region of Portugal, 2012-2014.

***Tabela I** - Número de incêndios na Região Norte de Portugal, segundo a dimensão e a área ardida, 2012-2014.*

Size (Ha)	**Fire events**		**Burned area (BA)**	
	No.	**%**	**Ha**	**%**
<1	23,092	78	2.982,80	1,9
1-4,999	4,495	15,2	8.907,87	5,7
5-9,999	793	2,7	5.329,71	3,4
10-24,999	575	1,9	9-117,33	5,8
25-49,999	269	0,9	9.224,61	5,9
50-99,999	157	0,5	11.317,25	7,2
100-249,999	137	0,5	21.301,42	13,6
250-499,999	59	0,2	20.594,37	13,1
500-999,999	28	0,1	21.806,23	13,9
1000-4999.999	16	0,1	32.257,48	20,6
≥ 5000	1	0,003	14.136,09	9
Total	**29,622**	**100**	**156.975,16**	**100**

Thus, confirming that the frequency-area distribution follows a power-law, with many small wildfires, few medium ones, and very few large ones, that account for most of the BA.

Wildfires occurrence followed a well-defined seasonal distribution (with a main peak in summer, from July to September), and a secondary peak in February-March; maximum number of fires and of monthly burned surfaces occurred from July to September for the three categories of land use (Table II).

Table II - Monthly distribution of number of wildfires and burned area by land use.
***Tabela II** - Variação mensal dos incêndios e área ardida segundo o tipo de utilização do solo afetada.*

Month	Fire events		Burned area (Ha)					
			Forest		Bushes		Agricultural lands	
	No.	%	Ha	%	Ha	%	Há	%
January	157	0,5	23.26	0,1	138,09	0,1	0,50	0,02
February	2.593	8,8	2.206,47	5,4	6.904,72	6,5	8,08	0,3
March	3.630	12,3	797,45	2,0	10.236,96	9,6	14,28	0,5
April	1.282	4,3	753,65	1,9	992,04	0,9	0,75	0,03
May	1.447	4,9	491,24	1,2	939,36	0,9	16,54	0,6
June	1.698	5,7	1.766,64	4,4	942,76	0,9	10,45	0,4
July	3.829	12,9	3.833,70	9,4	16.095,40	15,1	560,24	20,7
August	7.083	23,9	22.602,81	55,6	47.853,93	44,9	1.637,80	60,6
September	6.776	22,9	7.953,27	19,6	20.685,74	19,4	444,03	16,4
October	537	1,8	16,19	0,04	556,63	0,5	11,03	0,4
November	232	0,8	50,52	0,1	284,46	0,3	0,00	0,00
December	358	1,2	160,30	0,4	975,52	0,9	1,00	0,04
Total	**29.622**	**100**	**40.655,49**	**100**	**106.605,60**	**100**	**2.704,69**	**100**

The majority of BA is represented by bushes (106.605,60 ha, 71,1 % of the total BA) followed by forest (40.655,49 ha, 27,1 % of the total BA) and, at a distance, by agricultural lands (2.704,69 ha, 1,8 % of the total BA). It is very interesting that in the February-March peak most of the BA represented bushes, while during summer the amount of forest BA was higher. This presents a big challenge in a context of climate change as the existence of extreme weather conditions increases the likelihood of extreme wildfire events (EWE) and, consequently, increases the likelihood of disasters occurrence.

Wildfire causes and motives at regional level

General overview

The statistics of causes and the related motives (explained by the three digits code) with a minimum of 50 occurrences, were included in Table III. Total number of events and BA for each cause were reported.

The most important group was Unknown (34,2 % of events and 12,7 % of BA, respectively), which is not truly a cause or motive of a fire, but the absence of knowl-

Table III - Main causes of and reasons for wildfires in the Northern Region of Portugal, 2012-2014.
Tabela III - *Principais causas e motivos dos incêndios na Região Norte de Portugal, 2012-2014.*

Causes and motivations	Fire events		Burned area	
	No.	%	Ha	%
5 Natural causes	**61**	**0,2**	**61,71**	**0,03**
All negligent motives	**7.930**	**20,6**	**42.964,37**	**18,6**
145 Other bonfires	2.226	5,8	3.190,65	1,4
125 Renewing pastures	2.236	5,8	30.179,90	13,0
122 Clearing of forest áreas	1.469	3,8	3.288,28	1,4
121 Clearing of agricultural áreas	792	2,1	1.579,35	0,7
124 Burning remnants or agricultural waste	365	1,0	1.072,01	0,5
127 Cleaning paths, access and installations	150	0,4	574,00	0,3
129 Other vegetation burning	113	0,3	151,55	0,1
114 Waste from clandestine activities / illegal garbage dumping	114	0,3	168,41	0,1
126 Improving access to hunting and fishing areas	79	0,2	1.456,96	0,6
123 Clearing of urban áreas	44	0,1	50,48	0,02
128 Escaped preventive burning	52	0,1	127.53	0,06
All deliberate motives	**4.961**	**12,9**	**52.556,97**	**22,7**
448 Vandalism	3.875	10,1	38.941,71	16,8
449 Other deliberate fires	382	1,0	6.690,69	2,9
311 Conflits related whith hunting	70	0,2	985,01	0,4
All accidental causes	**160**	**0,4**	**2.628,93**	**1,1**
711 Rekindle	**3.340**	**8,7**	**29.487,53**	**12,7**
6 Unknown	**13.170**	**34,2**	**29.275,65**	**12,7**
Total	**29.622**	**100**	**15.6975,15**	**100**

edge of it. About 20,6 % of the fires can be attributed to negligent behaviors related with land management activities. Deliberate motives, although not very important in terms of number, explained a larger BA (12,9 % of events and 22,7 % of BA). Rekindle was also relevant (8,7 % of events and 12,7 % of BA) showing the need to enhance the activities of mop-up. The other causes and motives identified were just residual. The natural causes exhibited negligible values. So, clearly there was a dominance of wildfires of anthropic origin. As such, they will be discussed providing firstly detail on the four groups of analyzed causes, then details for all the most relevant motives we retrieved during the analysis inside the groups.

Unknown cause

Most of the wildfire events with *unknown* cause presented very small size (<1 ha) (Table IV) mainly because many of them were not considered in the investigation of causality. However, for some larger fires it was difficult to identify the cause.

Table IV - Wildfires with *unknown* causes per classes by size.
***Tabela IV** - Número de incêndios florestais de causas desconhecidas segundo a dimensão.*

Size (Ha)	Unknown causes			
	Fire events		BA	
	No.	%	Ha	%
<1	11.146	64,7	1.260,45	3,4
1-4.999	1.476	8,6	2.917,83	7,8
5-9.999	258	1,5	1.674,50	4,5
10-24.999	144	0,8	2.173,57	5,8
25-49.999	49	0,3	1.699,25	4,6
50-99.999	44	0,3	3.069,61	8,2
100-249.999	34	0,2	5.516,94	14,8
250-499.999	10	0,1	4.065,30	10,9
500-999.999	6	0,03	4.158,21	11,1
1000-4999.999	2	0,01	2.740,00	7,3
≥ 5000	0	0,0	0,0	0,0
Total	**13.169**	**100**	**29.275,66**	**100**

Wildfires with *unknown* cause were found all year long (Table V). However, the monthly distribution was markedly bimodal, with a major peak encompassing the critical summer period that occurred in August and September, gathering 5.915 events (44,9 % of the total number of events) and 19.917,39 ha, (43 % of the total BA). The number of fires was rather high in the other months, with a minimum between October and January; the same was observed for BA, with sustained values, always > 100 ha with the exception of January. The high percentage of *unknown* causes highlights some incapacity or difficulty to identify the causality of fire outbreaks, namely because of the high number of occurrences.

Negligent behaviors

Events set by the negligent use of fire, were characterized by a high number of small events (Table VI), as 90,0 % of them have size < 5 ha, representing 9,2 % of the BA. On the other hand, a few events larger than 100 ha were identified and although they represented only 1,0 % of the events, the BA of these fires was 25.164.98 ha, i.e. 58,6 % of the total BA. This confirms that a few large fires contributed to most of the BA and appears as a constant characteristic in the statistics of all countries (Gill and Allan, 2008; Cui and Perera, 2008; Gill and Allan, 2008; Moreno *et al.*, 2011; Oliveras *et al.*, 2014).

The distribution of negligent fires per month (Table VII) followed a typical bimodal distribution, as already observed. The main peak also occurred in August-September, with 3.032 events (38,2 % of the total number of events) and 26.257 ha of BA (62,5 % of the total BA); the maximum of occurrence was in August, with 1.629 events and 16.063,34 ha, respectively 20,5% of events and 37,4 % of BA. A secondary peak occurred in February-March, with 2.460 events (31,0 % of the total) affecting 11.081,83 ha (25,8 %). The distribution was coherent with the calendar of the activities in agriculture but was also arguably influenced by other activities in summer, such as the cleaning activities performed by people emigrated that come temporarily back home and that use the period of holidays to clean around the houses.

The most frequent motives of negligent fires, in decreasing order of importance of the number of events, were: *renewing pastures* (Code 125, 7,6 %); *other bonfires* (Code 145, 7,5 %); *clearing of forest areas* (Code 122, 5,0 %). All the other motives of negligent fires,

Table V - Wildfires with *unknown* causes per month.

***Tabela V** - Distribuição mensal dos incêndios florestais de causas desconhecidas.*

Month	Unknown causes			
	Fire events		BA	
	No.	%	Ha	%
January	70	0.5	21.92	0.1
February	1,018	7.7	2,355.31	8.1
March	1,407	10.7	4,214.61	14.4
April	507	3.9	343.25	1.2
May	665	5.1	466.29	1.6
June	1,019	7.7	517.10	1.8
July	1,926	14.6	767.61	2.6
August	2,935	22.3	12,028.12	41.1
September	2,980	22.6	7,889.27	27.0
October	298	2.3	117.43	0.4
November	123	0.9	193.68	0.7
December	221	1.7	361.06	1.2
Total	13,169	100	29,275.66	100

Table VI - Number of wildfires started through negligence, by size.

***Tabela VI** - Número de incêndios florestais de causas negligentes segundo a dimensão.*

Size (Ha)	Negligent behaviors			
	Fire events		BA	
	No.	%	Ha	%
<1	5.631	71,0	865,68	2,0
1-4.999	1.506	19,0	3.068,44	7,1
5-9.999	308	3,9	2.088,39	4,9
10-24.999	237	3,0	3.862,23	9,0
25-49.999	111	1,4	3.908,73	9,1
50-99.999	57	0,7	4.005,92	9,3
100-249.999	52	0,7	8.031,26	18,7
250-499.999	15	0,2	5.087,77	11,8
500-999.999	11	0,1	8.065,99	18,8
1000-4999.999	2	0,03	3.979,96	9,3
≥ 5000	0	0,0	0	0.0
Total	**7.930**	**100**	**42.964,38**	**100**

i.e. *cleaning paths, access and installations* (Code 127, 1,2 %), *other vegetation burning* (Code 129, 0,4 %), *waste from clandestine activities/illegal garbage dumping* (Code 114, 0,4 %), *improving access to hunting and fishing areas* (Code 126, 0,3 %), *clearing of urban areas* (Code 123, 0,2 %), and *escaped preventive burning* (Code 128, 0,2 %) presented a frequency <1,3 %.

Table VII - Number of wildfires started through negligence, per month.
Tabela VII - *Distribuição mensal dos incêndios florestais de causas negligentes.*

Month	Negligent behaviors			
	Fire events		BA	
	No.	%	Ha	%
January	69	0,7	89,28	0,2
February	1.134	10,9	3.942,10	9,2
March	1.326	12,8	7.139,73	16,6
April	461	4,4	732,37	1,7
May	453	4,4	613,85	1,4
June	319	3,1	328,21	0,8
July	777	7,5	2.611,19	6,1
August	1.629	15,7	16.063,34	37,4
September	1.403	13,5	10.194,57	23,7
October	175	1,7	441,68	1,0
November	88	0,9	118,56	0,3
December	96	0,9	689,50	1,6
Total	**7.930**	**100**	**42.964,37**	**100**

A more detailed analysis only for *other bonfires* and *renewing pastures* is provided as they are by far the most representative negligent motives. Wildfire events attributed to *other bonfires* were characterized for their very reduced size (Table VIII): 2.226 events, i.e. 99,9 % of their total, had less than 5 ha of surface, and 92,6 % had <1 ha. The maximum of size class was 500-999,999 ha, with only one event, and 732,0 ha of BA.

Also fires caused by *other bonfires* have a bimodal distribution with a marked peak in summer (July- September) gathering 1.639 events and 1.343,09 ha of BA (73,6 %), and a more attenuated secondary peak in February-March (Table IX), with only 333 events (15,0 % of total number) but a relevant BA (21,1 %).

Table VIII - Wildfires caused by *bonfires* by size.

Tabela VIII - *Número de incêndios florestais causados por outro tipo de fogueiras, segundo a dimensão.*

Size (Ha)	**Other bonfires**			
	Fire events		**BA**	
<1	**No.**	**%**	**Ha**	**%**
1-4,999	1.996	89,7	208,1	6,5
5-9,999	165	7,4	321,4	10,1
10-24,999	19	0,9	126,6	4,0
25-49,999	27	1,2	463,5	14,5
50-99,999	10	0,4	356,5	11,2
100-249,999	4	0,2	263,7	8,3
250-499,999	4	0,2	718,8	22,5
500-999,999	0	0,0	0,0	0,0
1000-4999,999	1	0,0	732,0	22,9
≥ 5000	0	0,0	0,0	0,0
Total	**2.226**	**100**	**3.190.6**	**100**

Table IX - Distribution of wildfires started by *other bonfires* per month.

Tabela IX - *Distribuição mensal dos incêndios florestais causados por outras fogueiras.*

Month	**Other bonfires**			
	Fire events		**BA**	
	No.	**%**	**Ha**	**%**
January	4	0,2	1,37	0,04
February	136	6,1	88,56	2,8
March	197	8,9	583,30	18,3
April	76	3,4	27,49	0,9
May	51	2,3	16,32	0,5
June	105	4,7	126,90	4,0
July	328	14,7	82,58	2,6
August	765	34,4	1.784,24	55,9
September	546	24,5	476,28	14,9
October	15	0,7	1,44	0,1
November	0	0,00	0,00	0,00
December	3	0,1	2,15	0,1
Total	**2.226**	**100**	**3.190,62**	**100**

More than 50 % of the wildfires related with *renewing pasture* presented more than 100 ha of BA but reduced number of total events (2,6 %) (Table X). An interesting point was, as previously stated, that most of the BA was explained by large fires. The fire events caused by renewing pastures also presented a dual distribution in the usual months (Table XI). The highest number of events and BA occurred in August although the use of fire during the critical period is forbidden.

Table X - Wildfires caused by *pasture renewal*, by size.
Tabela X - *Número de incêndios florestais causados por renovação de pastagens, segundo a dimensão.*

Size (Ha)	Other bonfires			
	Fire events		BA	
	No.	%	Ha	%
<1	961	42,94	229,39	0,76
1-4,999	760	33,96	1.622,18	5,38
5-9,999	204	9,12	1.379,36	4,57
10-24,999	149	6,66	2.430,72	8,05
25-49,999	67	2,99	2.365,40	7,84
50-99,999	40	1,79	2.743,16	9,09
100-249,999	33	1,47	5.019,55	16,63
250-499,999	13	0,58	4.380,12	14,51
500-999,999	9	0,40	6.029,99	19,98
1000-4999,999	2	0,09	3.979,96	13,19
≥ 5000	0	0,00	0,00	0,00
Total	**2.238**	**100,00**	**30.179,83**	**100,00**

Deliberate causes

Deliberate or malicious fires, i.e. intentionally caused by humans (Camia *et al*., 2013) were cause for a relatively reduced number of events, but had significantly higher burned areas in comparison with negligent fires. Deliberate fires thus clearly exhibit a higher "efficaciousness" in the sense of producing wider BA. The wildfires with more than 1.000 ha explained 35,5 % of the BA. The distribution of the number of events per classes of size (Table XII), was markedly right skewed: fires up to 4,99 ha represented 4.465 events (90,0 %) with a BA of only 2.679,44 ha (5,1 % of the total), whereas the size classes from 100 onward, the large fires, gather a total of 40.027 ha (76,16 % of BA), even though their number was much smaller.

Table XI - Distribution of wildfires per month caused by *pasture renewal.*

***Tabela XI** - Distribuição mensal dos incêndios florestais atribuídos a renovação de pastagens.*

Month	Renewing pastures			
	Fire events		BA	
	No.	%	Há	%
January	27	1.2	37,92	0.1
February	454	20,3	2.280,94	7,6
March	438	19,6	3.749,40	12,4
April	81	3,6	214,77	0,7
May	84	3,8	325,63	1,1
June	38	1,7	95,47	0,3
July	127	5.7	2.378,76	7,9
August	376	16,8	12.271,17	40,7
September	448	20,0	7.786,75	25,8
October	83	3,7	391,76	1,3
November	42	1,9	95,23	0,3
December	38	1,7	552.11	1,8
Total	**2.236**	**100**	**30.179,91**	**100**

Table XII - Wildfires deemed to have been started deliberately, by size.

***Tabela XII** - Número de incêndios florestais atribuídos a incendiarismo, segundo a dimensão.*

Size (Ha)	Vandalism			
	Fire events		BA	
	No.	%	Ha	%
<1	3.376	68,0	563,86	1,1
1-4,999	1.089	21,9	2.115,58	4,0
5-9,999	152	3,1	1.029,39	2
10-24,999	140	2,8	2.285,50	4,3
25-49,999	80	1,6	2.709,21	5,1
50-99,999	44	0,9	3.825,74	7,2
100-249,999	41	0,8	5.643,96	11
250-499,999	22	0,4	8.315,64	16
500-999,999	10	0,2	7.435,30	14,1
1000-4999,999	8	0,2	18.632,79	35,2
≥ 5000	0	0,00	0,00	0,00
Total	**4.962**	**100**	**52.556,97**	**100**

The distribution per month of deliberate fires (Table XIII) was bimodal; the main peak occurred in summer as expected, in August and September, which alone gathered 2.796 events (56,3 % of the total number of events) and accounted for 39.433.48 ha (92,5 % of BA).

Table XIII - Distribution of deliberate wildfires per month.
***Tabela XIII** - Distribuição mensal dos incêndios florestais atribuídos a incendiarismo.*

Month	Deliberate fires			
	Fire events		BA	
	No.	%	Ha	%
January	**17**	**0,3**	0,00	0,0
February	303	6,1	1,01	0,002
March	508	10,2	813,40	1,9
April	199	4,0	575,54	1,3
May	201	4,1	279,47	0,7
June	208	4,2	270,62	0,6
July	638	12,9	939,00	2,2
August	1.533	30,9	33.287,00	78,0
September	1.263	25,5	6.146,48	14,4
October	52	1,1	16,71	0,03
November	13	0,3	20,36	0,04
December	26	0,5	282,00	0,6
Total	**4.961**	**100**	**42.631,59**	**100**

Deliberate motives were a less multifaceted category than Negligent ones: the most frequent types of voluntary events were *vandalism* (Code 448, 13.1 %), and *other deliberate fires* (Code 449, 1,3 %).

Vandalism referred to malicious or mischievous fire setting that resulted in damage to property, but also to willful and malicious mischief or peer group pressure (Camia *et al.*, 2013). It is a rather poorly considered topic in literature. Burning of particular kinds, sometimes called vandalism, can easily be seen as arson. Many fires lit by children probably would fall into the *vandalism*, excitement, or no-apparent-motive categories (Muller 2009).

Vandalism is therefore an umbrella term used to capture a wide set of motives including willful mischievous destruction but also boredom relief (Holmes *et al.*, 2008; Meddour-Sahar, 2014), without really explaining their motive. The distribution of wildfire per month and per size did not present differences with the other causes. Most of the occurrences had <1 ha (67,6 %) and the events larger than 100 ha represented 1,6 % of the total (Table XIV).

Table XIV - Distribution of wildfires started through vandalism, by size.
Tabela XIV *- Número de incêndios florestais causados por vandalismo, segundo a dimensão.*

Size (Ha)	Vandalism			
	Fire events		BA	
	No.	%	Ha	%
<1	2.619	67,6	425,54	1,0
1-4,999	898	23,2	1.711,44	4,4
5-9,999	122	3,2	830,04	2,1
10-24,999	95	2,5	1.541,84	4,0
25-49,999	51	1,3	1.742,93	4,5
50-99,999	31	0,8	2.288,91	5,9
100-249,999	29	0,8	4.592,09	11,8
250-499,999	16	0,4	5.817,96	14,9
500-999,999	8	0,2	6.161,15	15,8
1000-4999,999	6	0,2	13.828,94	35,5
≥ 5000	0	0,0	0,00	0,0
Total	**3.875**	**100**	**38.940,83**	**100**

The monthly distribution of vandalistic fires was also bimodal (Table XV), with a marked peak in the critical period (July-September: 2.465 events, i.e. 63,6 %) of which 1.011 occurred in July (26,1 %). A less accentuated secondary peak occurred in February - March, with 481 events (12,41 % of the total number of events). BA clearly follows the same distribution, with a first peak in February-March, 4.676,98 ha (12,0 % of the total), followed by another peak in July-September (32.929,78 ha, 84,6 %) of which 25.119,01 ha burned in the month of July alone (64,5 % of the total BA). This distribution was similar to the one of other causes and motives with the exception of a higher percentage of BA in July during the period of analysis, which had not been previously observed.

Table XV - Distribution of wildfires started through vandalism, per month.
***Tabela XV** - Distribuição mensal dos incêndios causados por vandalismo.*

Month	Vandalism			
	Fire events		BA	
	No.	%	Ha	%
January	13	0,3	5,50	0,01
February	269	6,9	1.700,60	4,4
March	481	12,4	2.976,39	7,6
April	134	3,5	142,71	0,4
May	161	4,2	244,62	0,6
June	300	7,7	904,18	2,3
July	1.011	26,1	25.119,01	64,5
August	891	23,0	6.102,89	15,7
September	563	14,5	1.707,88	4,4
October	36	0,9	27,02	0,1
November	16	0,4	10,92	0,03
December	0	0,0	0,00	0,0
Total	**3.875**	**100**	**38.941,72**	**100**

Rekindle

Rekindle refers to a wildfire caused by re-ignition of a previous fire, due to latent heat or embers (Camia *et al.*, 2013). It can also result from an insufficient management of suppression aftermath, which is influenced by the high number of contemporary events, on which firefighter crews are called to intervene, with the consequent impossibility to efficiently make the necessary mop-up. The distribution in the number of events, with a huge mass in the small size class (<1 ha) is right skewed although with a very reduced BA (Table XVI).

The distribution per month of *rekindle* (Table XVII) was bimodal; the majority of events, as largely expectable, were concentrated in the three months of the critical period (July to September) which alone gathered 2.441 events (73,1 % of the total number of events) and 24.145,63 ha (81,9 % of BA). The maximum number of wildfires occurred in September and the maximum BA occurred in July. A relatively high number of fire events was also registered in March (379 events) with 3.098,37 ha of BA (10,5 % of the total BA). The distribution of wildfires per size and month did not present significant differences in comparison with other causes.

Table XVI - Distribution of wildfires caused by *reignition*, by size.

***Tabela XVI** - Número de incêndios florestais atribuídos a reacendimentos, segundo a dimensão.*

Size (Ha)	Rekindle			
	Fire events		BA	
	No.	%	Ha	%
<1	2.777	83,1	270,30	0,9
1-4,999	384	11,5	709,02	2,4
5-9,999	69	2,1	446,15	1,5
10-24,999	50	1,5	750,06	2,5
25-49,999	26	0,8	843,45	2,9
50-99,999	11	0,3	798,08	2,7
100-249,999	8	0,2	1,158.23	3,9
250-499,999	9	0,3	3.438,90	11,7
500-999,999	2	0,1	1.199,00	4,1
1000-4999,999	3	0.1	5.737,51	19,5
≥ 5000	1	0,03	14.136,09	47,9
Total	**3.340**	**100**	**29.486,79**	**100**

Table XVII - Distribution of wildfires caused by *rekindle* per month.

***Tabela XVII** - Distribuição mensal dos incêndios florestais atribuídos a reacendimentos.*

Month	Rekindle			
	Fire events		BA	
	No.	%	Ha	%
January	1	0,03	1,50	0,01
February	131	3,9	881,28	3,0
March	379	11,4	3.098,37	10,5
April	108	3,2	88,86	0,3
May	115	3,4	66,69	0,2
June	134	4,0	1.106,65	3,8
July	418	12,5	14.239,26	48,3
August	945	28,3	6.683,64	22,7
September	1.078	32,3	3.222,72	10,9
October	10	0,3	36,45	0,1
November	6	0,2	1,12	0,004
December	15	0,5	60,98	0,2
Total	**3.340**	**100**	**29.487,53**	**100**

The spatial pattern of wildfire causes and motives at municipal level

The kernel density map (fig. 4) made rather evident the concentration of wildfires in the western part of Northern Region of Portugal, and in some municipalities in the inner part of the territory.

Natural causes

Fire outbreaks related with lightning were mainly concentrated in some inner municipalities with rough territory and higher elevations, although no hotspots were evident. Only in 28 out of 85 municipalities fires were related with *natural causes* and in just seven municipalities this cause represented more than 2 % of the causes of ignition (fig. 5). No event of this type was registered in the coastal area. Most of the lightning episodes are not related with the presence of low-pressure systems but with regional or local summer convection; the changes of relief, in combination with the diurnal variations of solar heating of continental landmasses lead to fluctuations in temperature and provoke atmospheric instability (Royé *et al.*, 2018). In general, the fires originated by lightning presented small size. In the period of analysis, the largest fire provoked by *natural causes* burned about 12 ha.

Unknown causes

The spatial distribution of wildfires with *unknown causes* (fig. 6) showed that the knowledge about the causes was very heterogeneous in the Northern Region of Portugal. High percentage (>75 %) of wildfires with *unknown causes* mainly appeared in urbanized municipalities with a very extended and complex wildland urban-interface. Some of the municipalities in this situation presented a high number of occurrences (e.g. Gondomar and Vila Nova de Gaia) which made it difficult to investigate the possible cause of fire outbreaks.

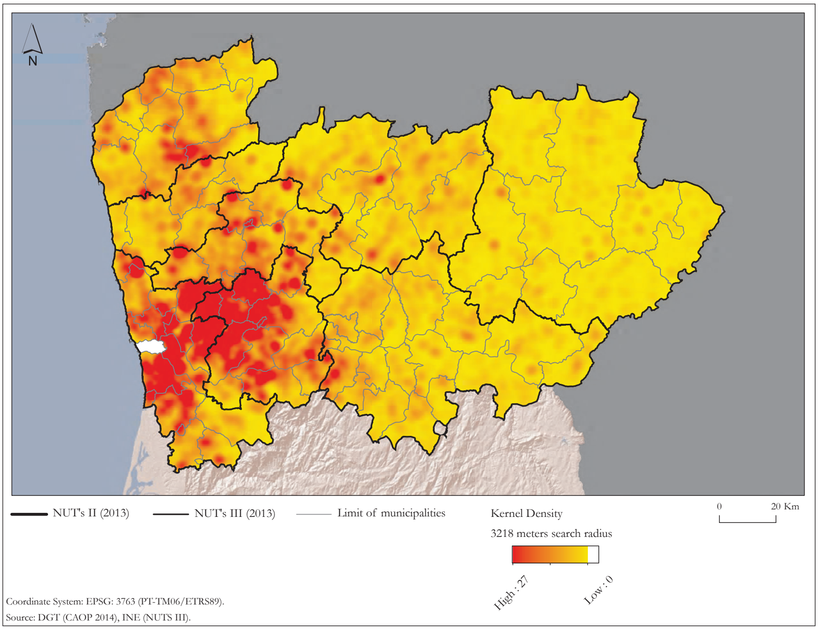

Fig 4 - Kernel density map of the wildfires in the Northern Region of Portugal, 2012-2014.

Fig. 4 *- Densidade de Kernel dos incêndios florestais na Região Norte de Portugal, 2012-2014.*

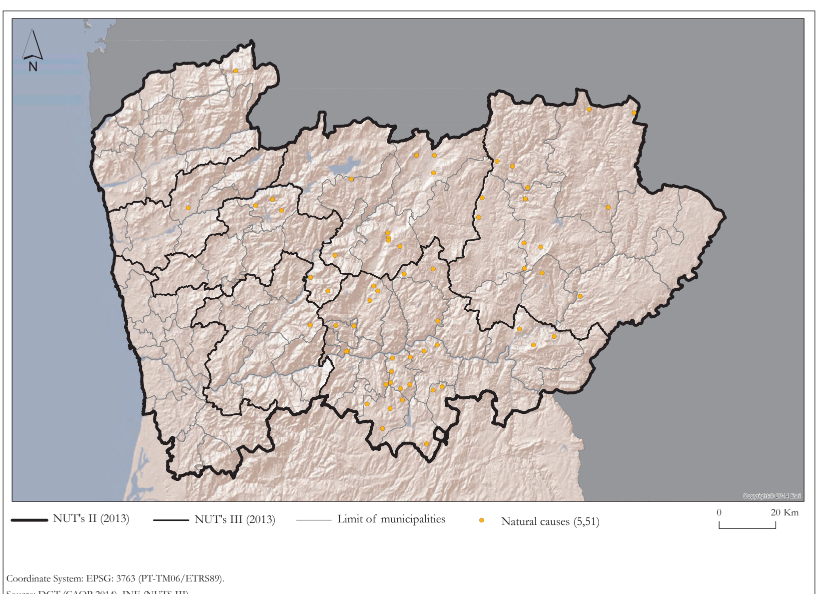

Fig. 5 - Wildfires arising from *natural causes per* municipality.

Fig. 5 *- Incêndios florestais de causa natural, por município.*

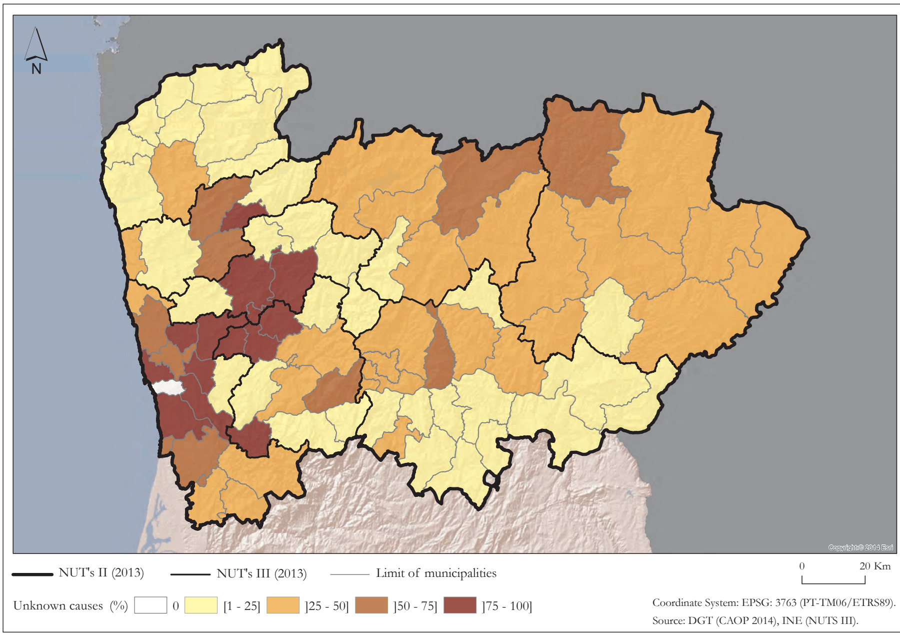

Fig. 6 - Wildfires arising from *Unknown causes per* municipality.

***Fig. 6** - Incêndios de causa desconhecida, por município.*

Negligent fires

Other bonfires

The occurrences related with *other bonfires* appeared spatially very concentrated, as 97 % of them were recorded in the two neighboring municipalities of Paredes and Penafiel (fig. 7). This atypical extreme concentration seems rather likely explained by difficulty in attributing a motive when investigating the causes of wildfires in these jurisdictions.

Renewing pastures

The use of fire in *renewing pastures* is a traditional management practice in areas where extensive cattle raising represents a primary economic activity. A flush of green vegetation for

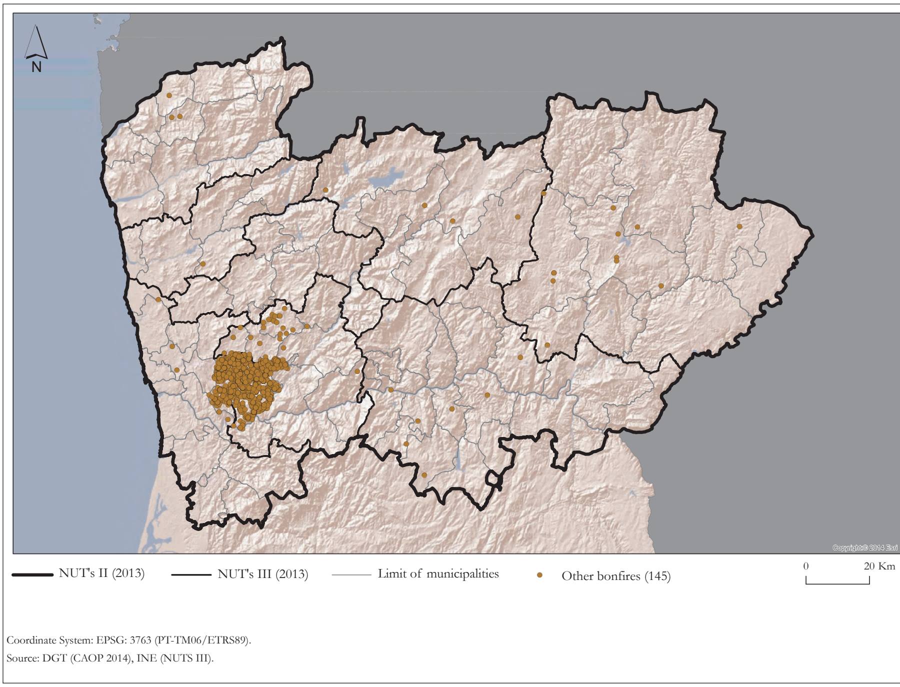

Fig. 7 - Wildfires caused by *other bonfires per* municipality.
***Fig.** 7 - Incêndios florestais provocados por outras fogueiras, por município.*

spring is expected having in mind the purpose of the practice. The existing legal framework (Decree law 156/2004, article 27th) enables the use of fire for pasture renovation after the *obtainment of a license from the local government and in the presence of competent person in prescribed burning or, in his absence, fire brigade or forest rangers* […] [stating that]: *the realization of renewing pasture is only permitted outside the critical period and with low fire danger index".*

Considering the traditional ecological knowledge of shepherds, the pasture renovations is generally made in small patches to avoid fire to escape; they need vegetation for the feeding of cattle and thus they avoid having cattle to walk for large distances.

The imposition of a restrictive legislation of fire use as a land management tool does not constitute an effective measure for the reduction of wildfires. Instead of coercive measures that have not been effective to promote a change in people's behavior, it might be better to enhance the engagement of people in wildfire prevention, through an interactive information and communication.

Renewal of pasture can be at the origin of wildfires if the fire escaped the control or if done in the critical period. However, it can significantly contribute to locally decrease fuel load, reducing fire risk in the same areas. The renewal of pasture should be seen as an activity able to reduce the occurrence of fires.

The fire associated with renewing pasture occurred mainly in mountain areas (fig. 8).

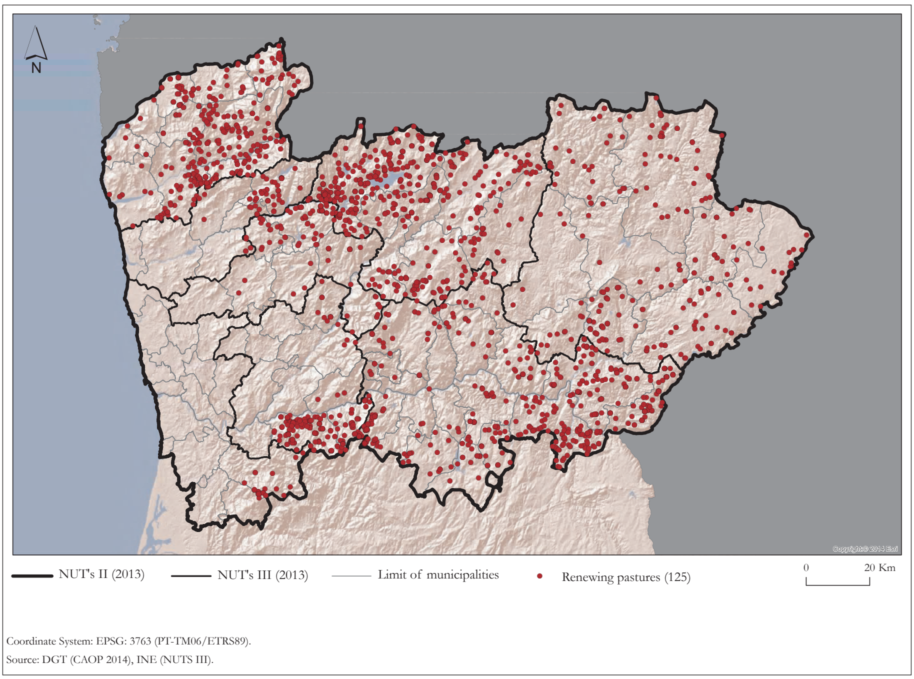

Fig. 8 - Wildfires caused by *pasture renewal per* municipality.

***Fig. 8** - Incêndios florestais provocados por renovação de pastagens, por município.*

Deliberate fires: vandalism

Vandalism has little to no importance in 23 municipalities. Differently, it explains at least 50 % of fire events that occurred in Arcos de Valdevez, Cabeceiras de Basto, Caminha, Celorico de Basto, Ponte da Barca and Viana do Castelo (fig. 9). In Northern Region of Portugal vandalism assumes an excessive representativeness with a high concentration in the district of Viana do Castelo and in the center part of the region, which may reflect a misclassification of the fire causality in these areas.

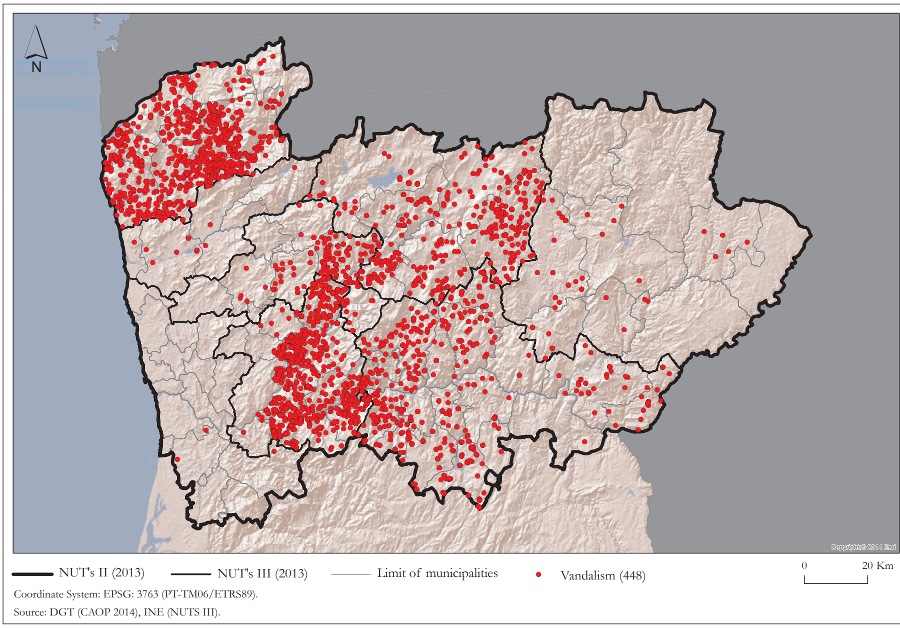

Fig. 9 - Wildfires started through *vand*alism per municipality.

***Fig. 9** - Incêndios florestais atribuídos a vandalismo, por município.*

Rekindle

Rekindle accounted for more than 25 % of the occurrences in Arouca, Barcelos, Melgaço, Monção, Póvoa do Varzim, Santa Maia da Feira, Terras de Bouro, Vale de Cambra, Valença and Vila Nova de Famalicão. This type of cause is not important in the east part of the region (fig. 10).

Classification of municipalities in terms of wildfire causes

In terms of the main cause of wildfire per municipality, significant differences were found (fig. 11). In 33 municipalities the first cause of wildfires was related with negligent behaviors in the use of fire and, fundamentally, with *renewing pasture* which was the first cause in 19 municipalities although activities related with cleaning forest or agricultural areas and other bonfires were also representative.

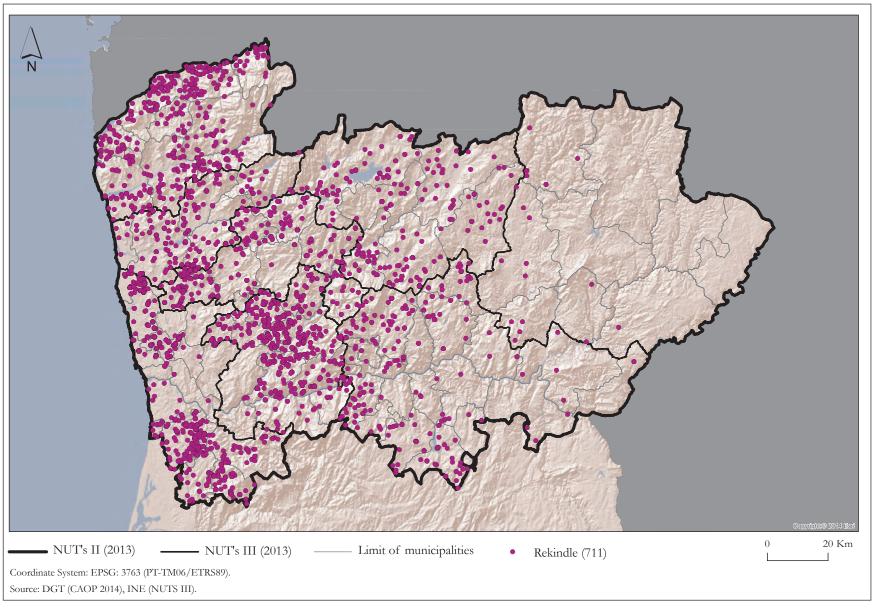

Fig. 10 - Wildfires provoked by *rekindle* per municipality.

***Fig. 10** - Incêndios florestais atribuídos a reacendimentos, por município.*

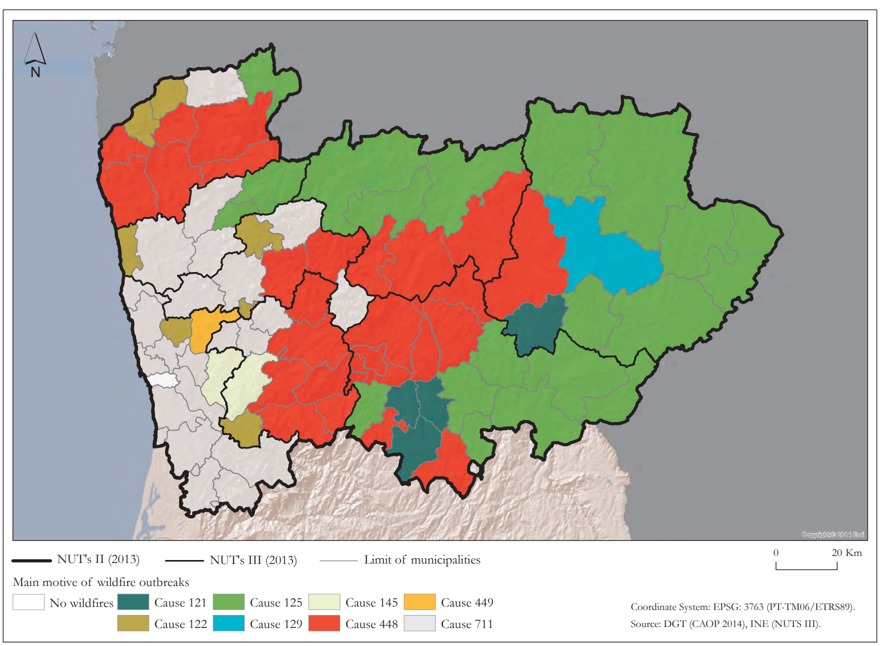

Fig. 11 - The main causes of wildfires *per* municipality.

***Fig. 11** - A principal causa dos incêndios florestais, por município.*

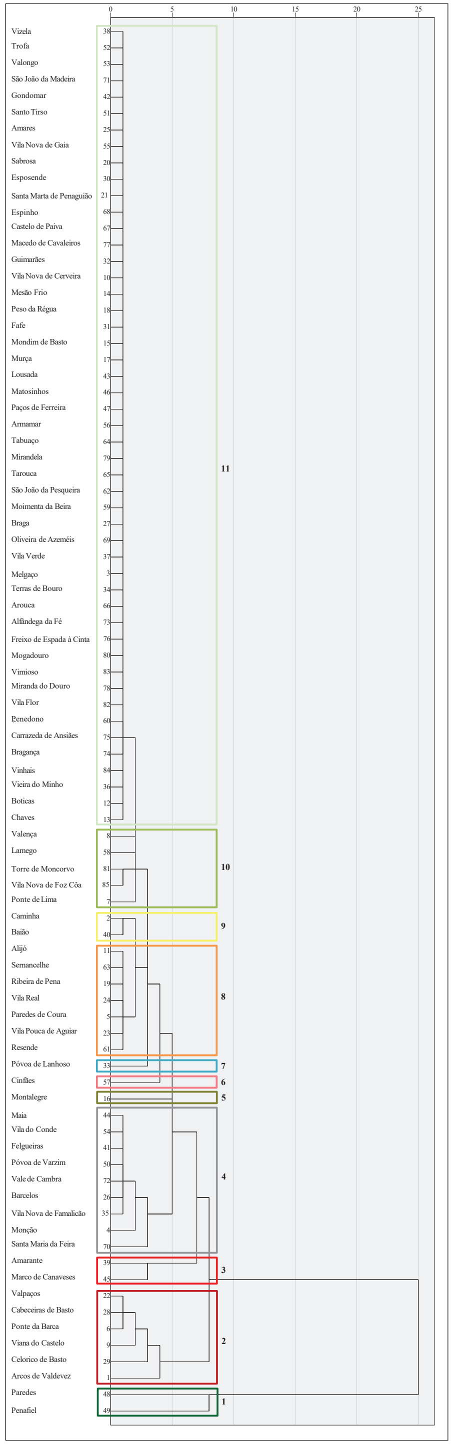

Fig. 12 - Classification of municipalities in terms of frequency and diversity of causes of wildfires.

Fig. 12 - *Classificação dos municípios em termos de frequência e diversidade das causas dos incêndios florestais.*

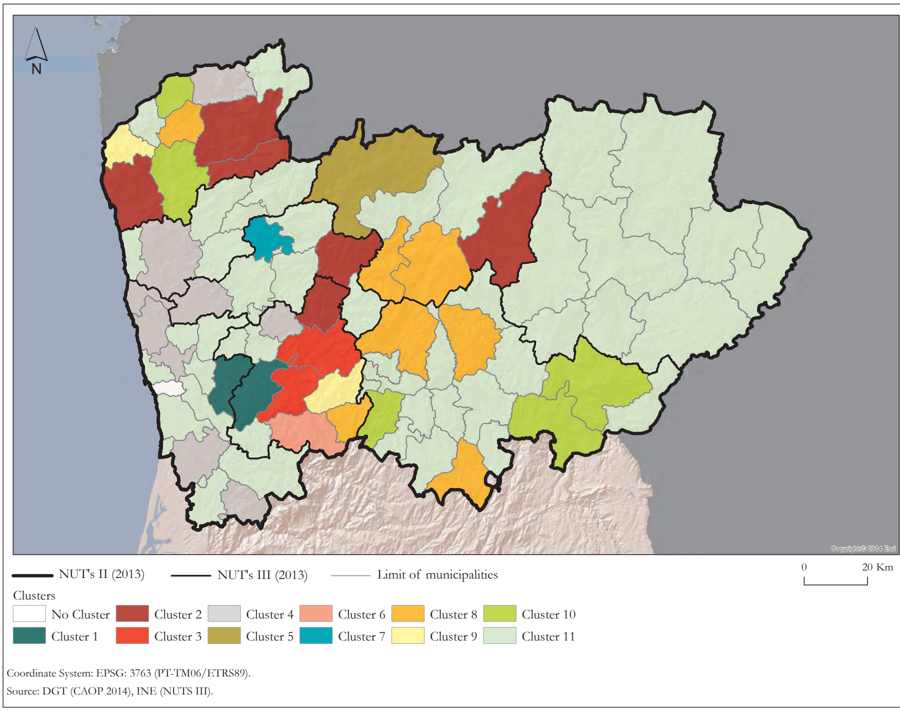

Fig. 13 - Geographical distribution of clusters.

***Fig. 13** - Distribuição geográfica dos clusters.*

Differently, in 28 municipalities *vandalism* and *other deliberate fires* appeared as the first cause of wildfires. Finally, in other 24 municipalities, *rekindle* was clearly the most representative cause of fire; in Póvoa do Varzim and Vale de Cambra it represented more than 45 % of the causes of fire occurrence.

The cluster analysis (fig.12 and fig.13) puts into evidence the heterogeneity of the municipalities considering the number of wildfires and the importance of the different causes. In the clusters 1, 5 and 7, the causes associated with negligent behaviors are more representative. On the contrary in the clusters 2, 3, 6, 8, 9 and 10 vandalism was insignificant. The cluster 11 presented a high diversity of situations although the number of fires with known causes can have very different profiles inside. In the cluster 4 wildfires due to rekindle had a high expression.

Discussion and conclusions

The Northern Region of Portugal is among the most wildfire prone areas in the country (fig. 2). This research showed that it is not a homogenous space in terms of causes and motives of wildfires. Some of the municipalities presented a dominant cause while others presented very complex profiles as there is a multiplicity of causes and motives to explain the wildfires outbreaks.

To develop efficacious prevention activities adapted to the characteristics of the territory, and sensitization campaigns able to change attitudes, behaviors, and awareness of people, it is of paramount importance to understand the roots of the wildfire problem, taking in due account that its origin is mostly anthropogenic.

The natural causes have residual importance in the Northern Region of Portugal and it is rather easy to identify fire ignitions caused by *lightning*. The only weakness regarding natural causes that should be evaluated is the accuracy of the information available, mainly related with the cover of the region by the *lightning* detector network.

The two main hypotheses considered in this study were validated. The relevant effort of Portuguese authorities in improving statistics to reduce the number of fires with *unknown causes* seems having produced scarce results in the Northern Region of Portugal. The percentage of *unknown causes* still represented about half of the occurrences, and its reduction is a true challenge. The reasons that explain the lack of knowledge about the causes can be: *i)* Lack of human resources to do the investigation; *ii)* Insufficient knowledge of the investigation teams to understand the causes and motivations; *iii)* The difficulty to apply the method of physical evidences (MEF- Método das evidências físicas) mainly due to the high number of events and to the objective difficulty of implementing the method in case of deliberate events. As a matter of fact, the MEF fairly works in case of involuntary fires but it is rather weak when applied to voluntary ones.

In the statistics regarding the Northern Region of Portugal some anomalous repetitions of minor motives or behaviors have been observed, typically in a restricted number of municipalities. For instance, *vandalism* appears so concentrated (fig. 9) in some municipalities in the central and North-west part of the Region, to depict something that could be geographically defined as *vandalism* districts. Considering that voluntary fires are a crime, the process of assessment of fire causes cannot ignore that crimes obey to general theories, one of which being the *routine activity theory* (Cohen and Felson, 1979), among the pillars of "environmental criminology". This theory states that three elements come together in any given space and time to produce a crime: *i)* an accessible target; *ii)* the absence of adequate surveillance; iii) the presence of a motivated offender (NSW Attorney General's Department, 2011). The anomalous concentration of events classified as *vandalism* more simply appears as a "guessed" fire cause, a result of a poor identification of context factors by the person who oversees assessing causes after each fire event.

Not surprisingly many municipalities have low values of *unknown* but high ones of *vandalism*; this transfer from one cause to another represents an attempt to clarify unknown causes which remained unresolved for the nature of the presumed motive. The reduction of the *unknown* causes rate cannot be obtained through streamlining the cause classification process. This procedure can have alleged statistical impacts but is not contributing to enhance prevention or worst is taking to the design of wrong strategies. Repeated misinterpretation of facts not only inflates the general statistics with incorrect information but is in evident contrast with the necessity of in depth knowledge of the phenomenon to lay down proper and efficacious prevention measures.

The *renewing pasture* motive observed in almost all the Northern Region of Portugal, on the contrary, well depicts (fig. 8) the possible unwanted or careless consequences of the use of fire as a tool of land management and represents an acceptable distribution of such motive in an area where husbandry still is an important economic activity, although with a deceasing trend.

In the current wildfire management policy focused on suppression (based on the paradigm of "war against fire") and, consequently, on a reactive approach, the accuracy of wildfire statistics is not a priority. However, the last wildfire events of 2017 and 2018 in Europe show that this type of policy needs to be gradually shifted to one that gives more emphasis to prevention and mitigation. Pedrógão Grande disaster (Portugal, June 2017) and the 2018 wildfires disasters in Greece show that the lack of prevention and people awareness about fires, create the conditions for the appearance of extreme wildfire events (Tedim *et al.*, 2018) and the occurrence of disasters. Reliable statistics on wildfires are the base of a more proactive approach.

The way to go over the weaknesses of the current practice of wildfire causes assessment does not require a change in the causes classification, although an harmonized classification is already available at European Union level (Camia *et al.*, 2013) and should be adopted by all member states. It does not imply that a national classification cannot be maintained, when it responds to the local landscape and social contexts were fires appear.

It is necessary a uniform training of the operational staff members, responsible for the after-fire reports where the causes of each event are proposed. Staff members responsible for causes assessment should be more aware of the crucial importance to produce good and reliable statistics.

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NOTAS FINAIS

Com estas Notas Finais, pretende-se reunir, em poucas páginas, as principais ideias/contributos dos capítulos que integram este livro, em busca de um novo paradigma para o grande problema que todos os anos o nosso país enfrenta, especialmente durante o verão, e que são os incêndios florestais.

No primeiro capítulo deste livro, intitulado "*Incêndios florestais em Portugal Continental. Degradação da paisagem ou reabilitação após as cinzas?*", Luciano Lourenço, autor do mesmo, refere que os incêndios florestais têm contribuído para a contínua degradação da paisagem do espaço florestal em Portugal, consequência do desinvestimento que tem vindo a ser feito no setor florestal. Para além de nos evidenciar as características das diferentes "gerações" de incêndios, que desde a década de setenta do século passado têm ocorrido em Portugal; de nos mostrar como se alteraram as espécies arbóreas da nossa floresta na sequência desses mesmos incêndios e de nos fazer refletir sobre os impactos no solo das primeiras chuvas após a destruição da vegetação pelo fogo, remete-nos o autor para o objetivo central do seu texto falando-nos sobre a reabilitação e recuperação de áreas ardidas, na esperança de se poder encontrar, com estes exemplos, medidas e/ou soluções que uma paisagem devastada pelo fogo nos exige. A intervenção de emergência que o Gabinete Técnico Florestal do Município de Seia faz, em 2010, na Mata do Desterro é, assim, o primeiro caso referido de reabilitação de uma área ardida explicado pelo autor. Como exemplo de recuperação de áreas degradadas após incêndio, destacamos a referência ao Projeto de rearborização que ocorreu nos anos oitenta do século passado, na serra das Caveiras, situada em áreas dos municípios de Góis e Pampilhosa da Serra, que nos remete para a necessidade da gestão/manutenção desses espaços. Destaque também para a referência à recuperação da área queimada na envolvente de Piódão, Plano de recuperação esse que não foi alheio à visibilidade que esta aldeia histórica tem a nível nacional.

Já os autores António Bento-Gonçalves, Flora Ferreira-Leite e António Vieira, no seu texto sobre "*Frequência, intensidade e severidade, três conceitos-chave no estudo dos incêndios florestais*", pretendem refletir sobre a importância destes três conceitos na definição de um outro que lhes anda associado e que é o conceito de regime de incêndio. Este conceito é considerado pelos autores, como fundamental para a compreensão do comportamento dos incêndios e seus efeitos sobre os ecossistemas. A falta de consenso, que dizem existir, sobre as definições de frequência, intensidade e severidade, torna urgente a discussão e clarificação destes conceitos-chave pela comunidade académica, no estudo da problemática dos incêndios florestais. Neste sentido, os autores apresentam a sua abordagem a estes conceitos, contribuindo assim para um debate que consideram necessário para a consensualização dos mesmos.

Adélia Nunes, no seu capítulo "*Tendência dos incêndios florestais em Portugal Continental (1980-2014): que ilações para o planeamento do território!*", tem como objetivo analisar a distribuição espacial e a tendência da evolução temporal dos incêndios florestais, no período referido e à escala do município. É feita uma análise dos fatores/elementos responsáveis pela desigual incidência nos diferentes municípios, bem como uma reflexão sobre as medidas levadas a cabo e políticas implementadas com vista à redução do número de ignições e área queimada. A autora refere a já conhecida dicotomia Norte/Centro *vs* Sul do país relativamente ao número de ocorrência e área ardida, mas alerta para que não se deve negligenciar as tendências positivas assinaladas pelos municípios alentejanos que, num futuro próximo, podem revelar-se preocupantes, na sequência de abandono de áreas marginais e do aumento de material ignisc ível. Refere ainda que as medidas relacionadas com o planeamento e as políticas florestais existentes no período em análise não foram eficazes, pois não se verificou uma redução significativa quer do número de ignições quer de área ardida a nível nacional. Acrescenta que são necessários planos de desenvolvimento rural mais abrangentes, centrados na prevenção e na educação.

O capítulo quarto, intitulado "*Evidences about causes of wildfires in the Northern Region of Portugal*" de Fantina Tedim, Vittorio Leone, Francisco Gutierres, Fernando J. M. Correia e Catarina G. Magalhães, centra-se, tal como o título indica, no estudo das causas dos incêndios florestais na região Norte de Portugal para o período 2012-2014. Para este período, foram analisadas as causas de 29622 eventos, destacando-se as "causas desconhecidas", seguidas das "causas por negligência" e "causas intencionais". Referem os autores que os incêndios com "causas desconhecidas" ocorrem, normalmente, em áreas com dimensões inferiores a 1ha e, apesar de se verificarem em todos os meses do ano, acentuam-se, sobretudo, nos meses de agosto e setembro. Noventa porcentos dos incêndios com "causas por negligência" ocorrem em áreas cujas dimensões são inferiores a 5 ha, no entanto, não será de desprezar aqueles que apresentam uma área superior a 100 ha e que correspondem a mais de metade do total de área ardida (58,6 %). Os incêndios com "causas intencionais" são em número reduzido, mas a área ardida apresenta maior dimensão quando comparada com os incêndios de "causas por negligência". É sobretudo nos meses de verão, concretamente em agosto e setembro, que ocorre um maior número de incêndios com "causa por negligência" tal como seria expectável. Os autores concluem que a região Norte de Portugal não apresenta homogeneidade em termos de causas dos incêndios, acrescentando que se alguns municípios apresentam uma causa dominante, outros há que em que as causas são múltiplas. Na opinião dos autores é importante que a classificação da causa do incêndio seja treinada e harmonizada pelos operacionais responsáveis por essa classificação, de forma a criar uma base estatística mais confiável.

Christophe Bouillon e Fantina Tedim, autores do capítulo intitulado "*Os incêndios na interface urbano-florestal: questões metodológicas e de gestão*", começam por referir o conceito de interface urbano-florestal, para que melhor se entenda esse território de risco face à ocorrência de incêndios florestais. A localização desse território e a sua composição determinam as características particulares em relação ao risco de incêndio. Um incêndio florestal que ocorra numa área de interface apresentará características específicas. São territórios, por vezes, densamente povoados, com muitas casas, acessos nem sempre fáceis, muitas vezes com caminhos estreitos e nem sempre adequados para veículos de emergência. Os meios aéreos são, assim, um complemento essencial ao combate. Deste modo, segundo os autores, uma interface urbano-florestal que apresente um enquadramento paisagístico adequado e adaptado à não propagação do fogo bem como a partilha das melhores práticas entre vizinhos, minimiza o risco de incêndio nesse território. Os autores consideram que o cidadão deve participar da governança local, criando grupos de residentes que possam estar mais atentos ao problema do fogo. Do ponto de vista prático, o habitante pode ser também um vigilante, capaz de favorecer uma transmissão rápida e precoce da informação no caso de acontecer um incêndio no perímetro da área onde vivem. Tal como o texto refere, os cidadãos são os melhores observadores do seu território.

Ainda dentro da temática dos incêndios que ocorrem em áreas de interface urbano-florestal, também Luís Guerra Neri apresenta um capítulo que se intitula "*O interface urbano-florestal na Região Autónoma da Madeira como ambiente de dificuldade extrema para a intervenção coordenada e racional dos Corpos de Bombeiros em incêndios florestais*". A procura de novas soluções para uma resposta eficaz aos muitos incêndios florestais que têm ocorrido na ilha da Madeira, tendo em conta a segurança da população, bens e ambiente, é o objetivo deste texto. O autor dá-nos conta das várias ações que os responsáveis pelo socorro e emergência da Região Autónoma da Madeira (RAM) têm vindo a desenvolver, no sentido de minimizar a intervenção em áreas de difícil acesso/combate, e que passam por um aumento de ações de formação, pela aquisição viaturas e de equipamento individual completo para os bombeiros, bem como pela melhoria da gestão de operações com aquisição de rádios, com qualidade, que permitam facilidade nas comunicações. Luís Neri refere a importância da prevenção e dá-nos conta de algumas medidas, passivas e ativas, que foram e estarão a ser tomadas para diminuir o risco de incêndio florestal na RAM. Tendo em conta este objetivo, o Plano Operacional de Combate a Incêndios Florestais 2015 (POCIF 2015), pretende reforçar o Dispositivo de Resposta Operacional Regional (DROR), que se refletirá, sobretudo, nos Corpos de Bombeiros, com a criação das Equipas de Intervenção Florestal (EIF), de forma a contribuir para uma maior eficácia do dispositivo em prontidão.

No último capítulo, Cármen Ferreira, Helena Madureira e Fantina Tedim, dão-nos a conhecer as interações e diálogos que ocorreram durante as sessões de trabalho entre os académicos e os operacionais, que se revelaram bastante enriquecedoras e que, mais uma vez, evidenciaram a importância da continuidade deste Diálogo entre as partes, que se espera continuar num futuro próximo.

Para concluir estas Notas Finais, resta-nos agradecer a todos aqueles que estiveram connosco nesta partilha de saberes e desejar que continuem a fazer-nos companhia num novo “Diálogo entre ciência e utilizadores” que se espera para breve.

Porto, 26 de julho de 2019.

Cármen Ferreira

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Apoios:

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