Super Case Study

4

Forest fires in Portugal in 2017

Online Version

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1 Introduction

Fire is an integral agent of forest ecosystem dynamics in many climate-diverse regions of the world, but especially in Mediterranean-type climate regions and dry-season climates in general, where weather conditions make it easy for wildfires to ignite and spread.

These Mediterranean ecosystems have been shaped by a coupled socioecological system of fire and humans (Moritz et al., 2014), creating a vast array of highly human-modified landscapes (Pausas et al., 2009) to make the use of forest and wilderness areas more profitable. In some regions of Europe, farmland and lower-biomass shrubland were replaced by fire-prone conifer or eucalyptus species of higher economic profitability, increasing the risk of fire, especially in areas where fuel management is not in place. However, many of the areas that were intensively managed in recent decades for forest resource extraction and fuel production are currently depopulated or abandoned, posing a high risk of wildfires as fuels have accumulated, and leading to new and more complex scenarios for fire management (Montiel Molina and Galiana-Martín, 2016; Castellnou et al., 2019).

In addition, climate change is affecting forest ecosystem dynamics, altering species succession and often making ecosystems more vulnerable to wildfires, and has caused changes in fire regimes, lengthening the fire season and altering fire size, intensity and frequency. Areas that were traditionally fire prone have experienced an increase in critical fire events that challenge traditional wildfire management practices, such as in recent fire seasons in Portugal (2003, 2005, 2013, 2016, 2017, 2018), Spain (2006, 2009, 2012), Italy (2007) or Greece (2007, 2018).

It is therefore essential to reassess wildfire dynamics and risks at the European and global scales, taking into account the effects of climate change, including droughts and the growing frequency and intensity of extreme heatwaves. These effects are not only changing fire regimes but may drive critical fires that exceed anything currently known. Landscape changes, derived from growing population and urban sprawl, and the use of unappropriated policies have also contributed to a more fire-prone landscape by increasing afforestation and reforestation with fire-prone species, enlarging the wildland–urban interface (WUI), in which fires threaten human lives and assets.

Portugal, like other Mediterranean countries affected by wildfires (e.g. Spain, France, Italy or Greece), has focused on enhancing wildfire-fighting capabilities, often neglecting wildfire prevention. Although the overall burned area in the EU has shown a slight decrease since the 1990s, the number of intense and critical fires has not decreased, with extreme fire episodes still happening every year. In recent years EU Member States have suffered critical wildfires that have caused the loss of human lives, in addition to substantial economic and environmental losses.

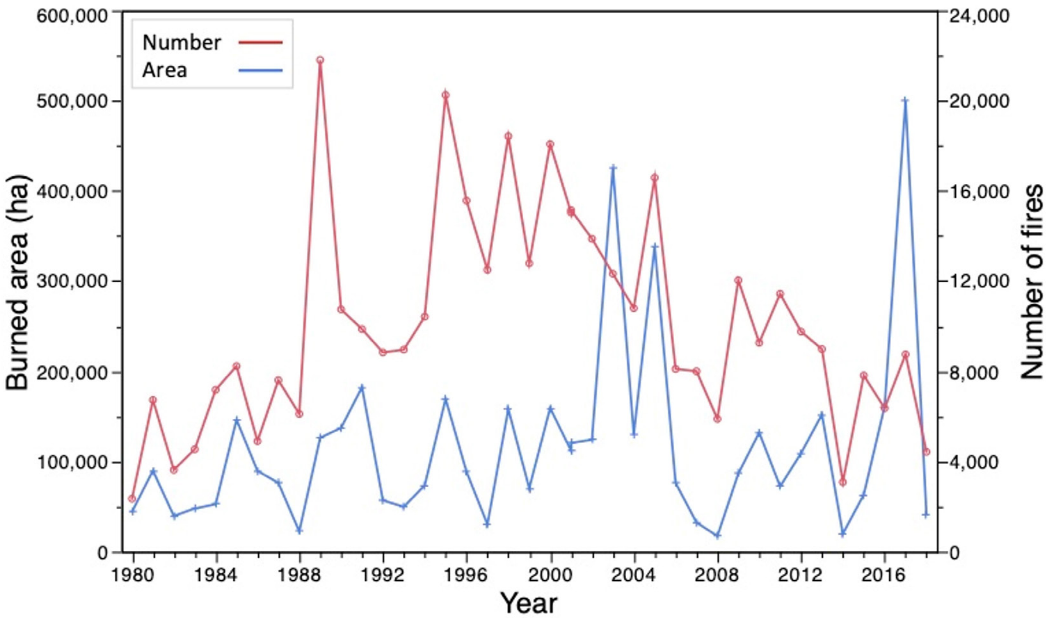
2 Background of fires In Portugal

Within the EU, Portugal is one of the Mediterranean Member States that periodically suffer serious damage from forest fires.

Trends in wildfires in the country in the last two decades show a decrease in the number of fires, although they show high variability in the area burned each year. Furthermore, Portugal suffered a critical concentration of multiple fire events in the last few years, which hampered the efficient extinction of the wildfires. This phenomenon has been observed in the most critical fire episodes in Europe in recent decades. Nearly two thirds of the area burned in Portugal in 2016 was the result of fires that occurred in the space of 10 days.

The year 2017 presented extreme meteorological conditions, with a severe heatwave and extreme atmospheric instability in June and the influence of Hurricane Ophelia and record breaking-drought in October. These extreme conditions led to a multiplicity of wildfires, many active fire fronts and explosive fire behaviour, contributing to the catastrophic fires in the central and northern regions of the country, with heavy impacts on human lives and assets. These critical fire episodes, often referred to as megafires or extreme wildfire events (EWEs) have been documented in several scientific publications (e.g. San-Miguel-Ayanz et al., 2013; Tedim et al., 2018). Figure 1 shows the numbers of fires and extent burned areas in Portugal each year from 1980 up to 2018 (ICNF, n.d.). Almost 3 million ha has been burned in Portugal since 1980. This corresponds to nearly one third of the total area of the country.

Figure 1. *Burned area and number of fires in Portugal between 1980 and 2018..* ***Source:*** *ICNF, n.d.*
Note: *Fire occurrences smaller than 0.1 ha and agricultural burned area were excluded to guarantee consistency across the time series.*



3 Analysis of fire events

Two major events occurred in June and October affecting central region of Portugal.

3.1 June events: the fire of Pedrógão Grande

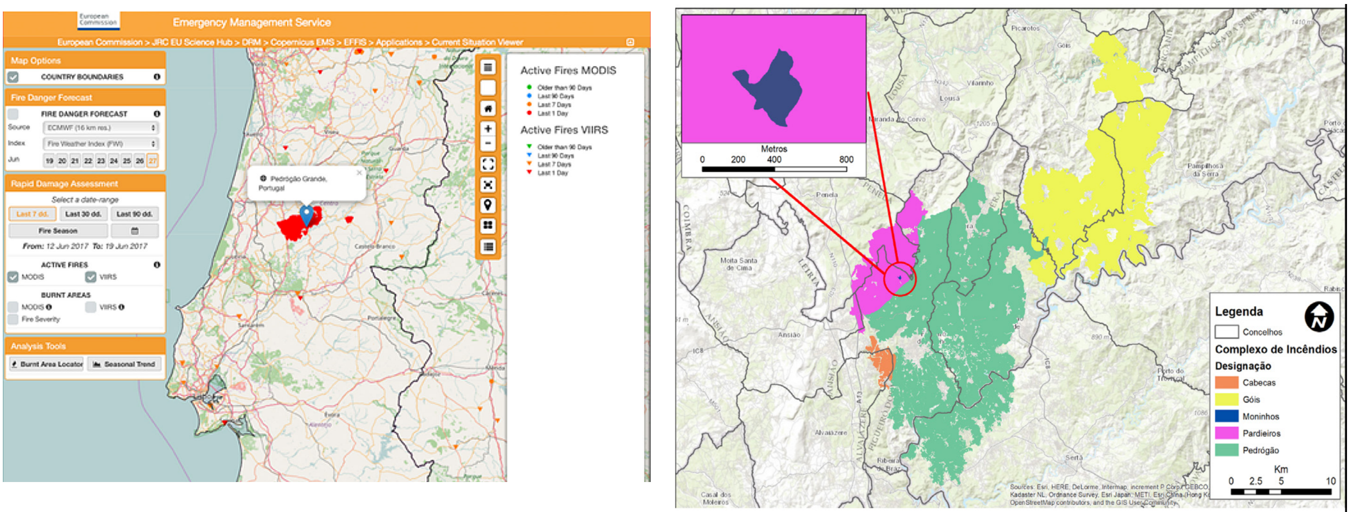
In the afternoon of 17 June, a series of forest fires broke out in Portugal, including two outbreaks near Pedrógão Grande (PG) and Góis, south-east of Coimbra, which extended to Castanheira de Pêra, Figueiró dos Vinhos, Pampilhosa da Serra and Penela. Viegas et al. (2017) and Guerreiro et al. (2017) produced detailed reports on these fires. The locations of the origins of these fires, their times of alert and of conclusion and the burned areas are given in Table 1 and their final perimeters are shown in Figure 2. Of this complex of fires, the most important was the one that started at two different points along a 25 kV electrical line, because the tragic loss of 66 lives that it caused. The locations of the fires and the map of the final perimeters are visible in Figure 2.

Table 1. *Data on the Pedrógão Grande complex of fires.* ***Source****: EFFIS, n.d., and Viegas et al., 2017.*

Place	Alert	Conclusion	Burned area (ha)
Escalos Fundeiros e Regadas	14.43, 17 June	23.49, 22 June	24 164.6
Fonte Limpa – Góis	14.48, 17 June	19.30, 22 June	16 119.2
Moninhos – Figueiró dos Vinhos	15.41, 17 June	18.38, 17 June	7.1
Cabeças – Alvaiázere	20.41, 17 June	10.35, 20 June	637.9
Pardieiros – Penela	21.15, 17 June	00.48, 21 June	4 399.8
Total			***45 328.6***

Figure 2*. (A) Maps of the locations in the European Forest Fire Information System (EFFIS) and (B) map of the final perimeters of the Pedrógão Grande complex of fires.* ***Source****: EFFIS, n.d., and Viegas et al., 2017.*

A) B)



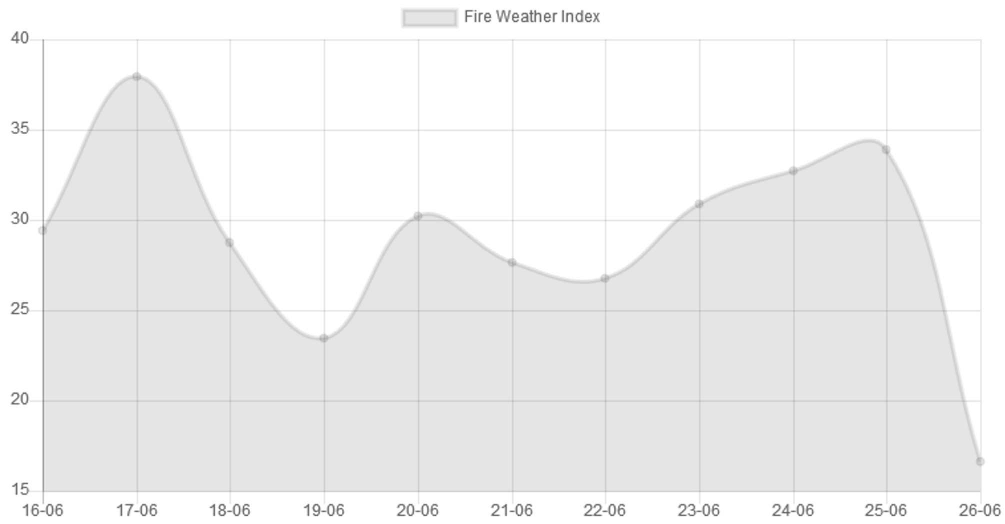
a. Conditions in Pedrógão Grande

The area of PG fire has a complex orography, covered by forest composed mainly of pine and eucalyptus plantations. The population density is about 30 persons/km2, who live in small towns, villages or houses scattered in the landscape. A good network of roads serves the region but fuel management was mostly absent.

A severe drought characterised 2017, with drought code values around 300 in the central region of Portugal in mid-June, well above the average value of 180 for that time of year. In mid-June, a series of days with maximum temperatures above 40 °C contributed to the Fire Weather Index (FWI) reaching record values of around 40, whereas the average is around 10. Therefore, fire danger in the region was extreme and the moisture content of fine dead fuels measured at the nearby station of Lousã was around 7 % (Viegas et al., 2017), which is consistent with extreme fire danger.

European Forest Fire Information System (EFFIS) predictions for 17 June showed very high fire danger conditions in these areas, which would expedite the spread of fires, which would burn with very high intensity, given the large accumulation of fire fuels in those areas (Figure 3). On the same day, a convective thunderstorm system developed in the region to the south-east of the area of PG, producing a large number of lightning strikes, some of which caused fires. During the afternoon, this system travelled towards the north-west and started influencing the area of the fire around 15.00. At one stage it was assumed that the fires of PG had been caused by lightning, but this hypothesis was discarded later (Viegas et al., 2017). Although this thunderstorm did not cause the fire, it affected its development in an unusual and unexpected form.

Figure 3. *FWI time series from 16 to 26 June 2017 in the area near Pedrógão Grande.* ***Source****: EFFIS, n.d.*

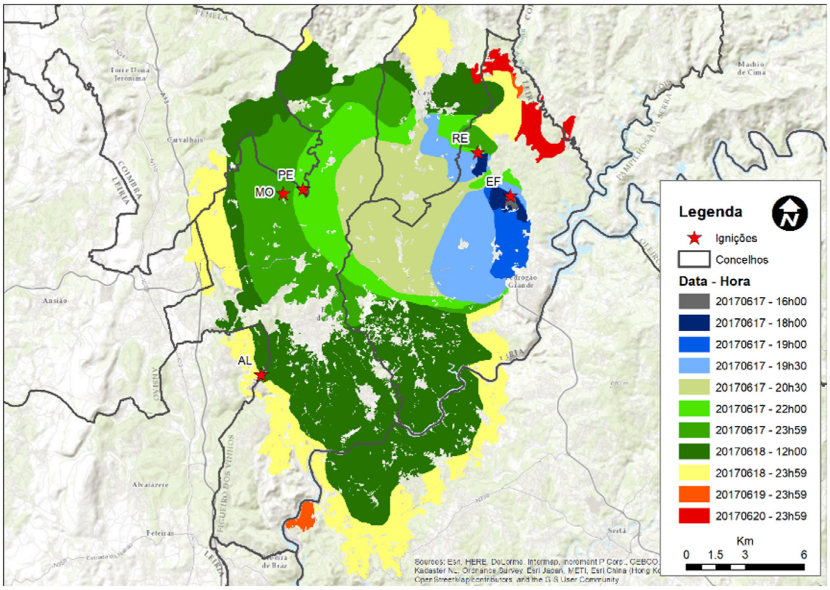


b. Evolution of the fires

The fires of PG had two separate origins, as shown in Figure 4: one around 14.43 at Escalos Fundeiros, and the second at 15.30 near Regadas, 3 km from Escalos. Both ignition points were located below a 25 kV electrical line. Evidence of contact between the line and vegetation was found, and it was declared the major cause by Viegas et al. (2017) but not proven by Guerreiro et al. (2017). Given the almost simultaneous occurrence of four fire ignitions in the same area, firefighting resources were dispersed and, owing to the very difficult terrain and meteorological conditions, control was not achieved during the first few hours.

Around 18.05, a strong interaction between the thunderstorm and the two fires of Escalos Fundeiros and Regadas, including a near 90° rotation in wind direction, caused their very rapid spread through a large area to the south-east of where they started, making the control of both fires virtually impossible. Between 19.30 and 20.30, the fire spread very rapidly in a roughly circular area with a diameter of 10 km. During this critical period, the fire spread at an estimated average rate of 5 km per hour, with fireline intensity up to 60 MW/m, and burned 7000 ha (Guerreiro et al., 2017). The fire trapped hundreds of persons who lived in this region or were travelling through it, and 66 lost their lives, many of them when trying to run away from the fire.

Figure 4. *Evolution of the Pedrógão Grande fire* ***Source****: Viegas et al., 2017*
Note*: red stars represent the ignition points.*



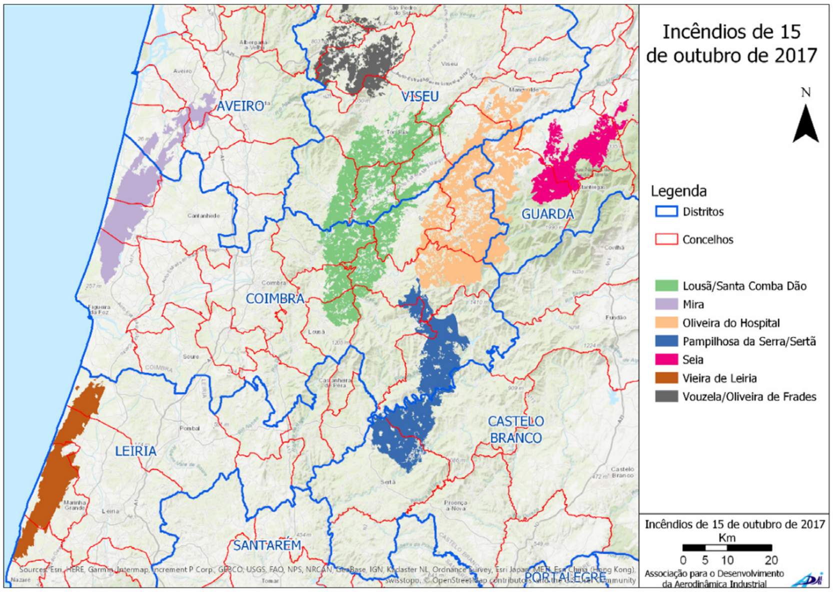
3.2 October fire events: the second disaster

After 17 June several serious fires occurred in Portugal, mainly in its central region, but the worst situations occurred on 15 October and the following days. During this period, a second disaster hit Portugal, with a much larger loss of forested area (but also shrubland and agricultural areas) and property, and the loss of 51 lives. It also affected some protected areas managed by the Portuguese government. These fires were studied by Guerreiro et al. (2018) and by Viegas et al. (2019). On 15 October more than 500 fires started and several of them developed into major fires burning a very large area (244 000 ha) in a relatively short period of less than 10 hours and causing devastation in a much wider area than the fires of PG. According to Viegas et al. (2019), there were seven major complexes of fires, which are listed in Table 2. Most of them had more than one ignition and were the result of several fires spreading in the same area. The time of alert indicated in Table 2 corresponds to the earliest ignition of a given complex. The burned areas of these seven fire complexes are shown in Figure 5.

Table 2. *Data on the main forest fire complexes on 15 October 2017.* ***Source****: Viegas et al., 2019.*

Designation	Time of alert (h)	Burned area (ha)	Fatalities
Seia	06.03	17 003	1
Lousã	08.41	54 407	15
Oliveira do Hospital	10.26	51 429	23
Sertã	12.02	30 977	2
Leiria	13.51	20 014	0
Quiaios	14.36	23 844	0
Vouzela	17.21	15 959	10
Total		***213 633***	***51***

Figure 5. *Map with the areas burned by the seven major fire complexes that occurred on 15 October 2017 in central Portugal.* ***Source****: Viegas et al., 2019*

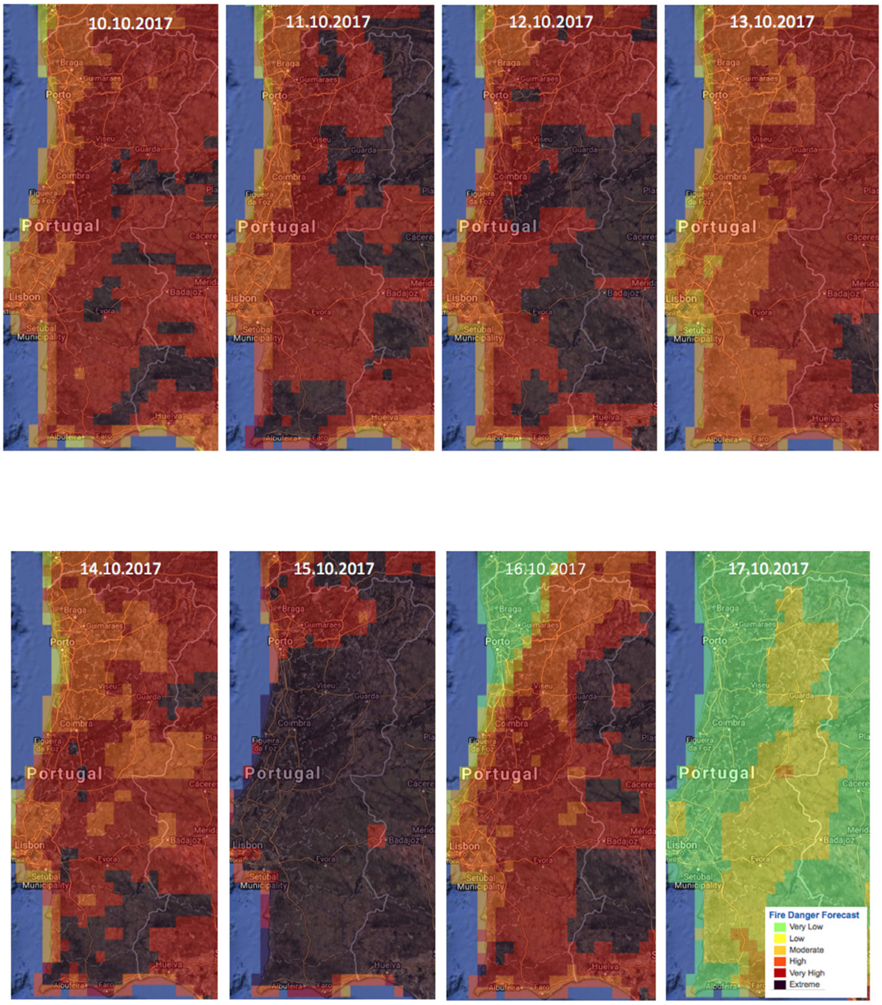


a. Conditions in central and northern Portugal

The very dry conditions that were felt throughout the summer of 2017 continued in mid-October with the drought code for Coimbra reaching record values of 800, well above the average value of 400 for the time of year. The FWI conditions prior to and during the wildfires are presented in Figure 6. This shows very high and extreme cumulative fire danger conditions prior to the days in which the fires spread and during the weekend of 14 October. The storm winds from the hurricane Ophelia induced a very strong southerly wind that blew hot and dry air from North Africa over the major part of the territory, increasing fire danger during 14 and, especially, 15

October. For example, the overall average value of the FWI for Portugal was 62 on 15 October and in Coimbra it reached an all-time record value of 82, making it impossible to control fires that escaped the initial attack. On 17 October there was precipitation in most of the country, decreasing the fire danger and helping to control most fires on 18 October, with only minor fires still burning north of Figueira da Foz. Critical fire events burning in extreme fire danger conditions, such as those described in this report, can only be extinguished when the weather conditions improve and fire danger decreases.

Figure 6. *Fire danger conditions (Fire Weather Index) in Portugal prior and during fire events,* ***Source****: EFFIS n.d.*



The information on fire danger conditions provided by EFFIS indicates the capacity of a fire to ignite and spread, linked to the resources required for fire control. Fire danger above an FWI value of 50, which was predominant in the whole Portuguese territory during 15 October, implies that fires cannot be controlled by either ground or aerial firefighting. They launch burning material that produces spot fires, up to 3 km ahead of the fire front in the 15 October events (Guerreiro et al., 2018), posing a major threat to firefighting crews, and increasing the number of simultaneously active fire fronts. For the Portuguese Institute for Sea and Atmosphere, the extreme fire behaviour classification starts at FWI = 38.

b. Evolution of fires

The five major EWEs of 15 October reached maximum rates of spread in excess of 3 km/h and up to 9 km/h. Between 16.00 on 15 October and 04.00 on 16 October the area burned by these fires in an hour ranged from 7 000 to 14 000 ha (Guerreiro et al., 2018). Firestorm conditions were felt at night after the cyclone winds had dissipated; they were caused by fire–atmosphere interactions and, possibly, interactions between fires. As in the PG fires, the most severe fire behaviour coincided with the timing of most human fatalities and occurred when air temperature was decreasing and relative humidity was increasing. In these fires a much smaller proportion of persons lost their lives while running away from their houses. As the fires spread mostly at night, many persons were surprised by the fire and did not have time to react.

4 Impacts

The Portuguese government reported about 21 000 wildfires in 2017, which burned an area of 539 920 ha of forests, shrubland and agricultural land causing 117 deaths (116 civilians and one firefighter).

One hundred and fifty municipalities were affected in the centre and north of the country, causing huge losses of private and public property, including buildings and industrial infrastructures, energy network infrastructure, roads, telecommunications, forestry and agriculture resources. The Portuguese government estimated the total cost of the damage by fires in 2017, between June and October, to amount to approximately EUR 1.5 billion, divided into physical damage (97 %) and intervention costs (3 %) (San-Miguel-Ayanz, 2018). Table 3 shows the estimated costs provided by the Portuguese government by type of damage.

Table 3. *Total estimated costs costs provided by the Portuguese government..* ***Source****: San-Miguel-Ayanz, 2018*

EFFECTS	
DAMAGE TYPE	**COST (MILLIONS EURO)**
Network infrastructure (Water/waste water, transport, bridges, energy, telecom, etc)	94.4
Public assets (airports, ports, hospitals, schools, etc.)	2.3
Business (Commercial and industrial activities)	311
Agriculture	209.7
Forestry	634
Residential (private homes and assets)	102
Cleaning up	63.9
Cost of emergency operations/rescue services	39
Total	***1456.3***

The June fires (including PG) burned around 49 000 ha (2 555 ha of Natura 2000 protected areas), caused the deaths of 66 people, injured many others and resulted in enormous damage to human infrastructure and the environment, affecting large forest areas, and more than 500 houses and rural infrastructures. One salient aspect of this event was that many of the victims who died were not usual residents of the region, as was also the case in Mati (Greece) in July 2018; this lack of familiarity with the countryside in general and such large-scale forest fires in particular may have had implications for their behaviour and response to the events. This aspect also suggests that assessment of potential or actual population exposure requires geospatial data that go beyond resident population and further detail population distribution in the daily (day/night) and seasonal cycles. Such data are now available for the EU-28 as part of the JRC's enhancing activity and population mapping project (Batista e Silva et al., 2016).

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The second critical episode took place on 15 October, with multiple simultaneous fires that resulted in the deaths of 51 people. In the period of 14–17 October a total of 32 wildfires were mapped by EFFIS, and resulted in a total burned area of 296 613 ha (44 200 of Natura 2000). The wildfires affected mainly the central region of the country. The damage costs estimated by the Portuguese government were approximately EUR 500 million and EUR 1 billion for the June and October fires respectively. Table 4 provides information on the environmental damage by Corine land cover class (Copernicus, 2020) and the amount of pollutants emitted by both events in the study period. They are responsible for 60 % of all the CO2 emissions released by all the fires during the 2017 fire season and around 15 % of Portugal's total CO2 emissions for the year reported by the Portuguese Environmental Agency.

Table 4.*Environmental damage due to the fires in 2017 (June and October).* ***Source***: *EFFIS, n.d.*

CORINE Land Cover	JUNE		OCTOBER	
	Area (ha)	%	Area (ha)	%
Broad-leaved forest	7 075.15	14.31	16 916.83	5.70
Coniferous forest	8 284.85	16.76	69 165.01	23.32
Mixed forest	10 461.72	21.16	39 709.71	13.39
Sclerophyllous vegetation	0	0	209.91	0.07
Transitional vegetation	16 815.74	34.02	78 400.75	26.43
Other natural land	2 390.25	4.84	30 849.75	10.40
Agriculture	3 602.05	7.29	55 463.54	18.70
Artificial surfaces	194.09	0.39	3 530.94	1.19
Other land cover	608.23	1.23	2 366.97	0.80
Total	***49 432.08***	***100***	***296 613.4***	***100***
NATURA 2000	***2 555.18***	***5.17***	***44 200.3***	***14.9***

Table 5. *Amount of pollutants emitted by the fires in 2017 (June and October).* ***Source***: *EFFIS, n.d.*

Type	Quantity (tonnes)	
	JUNE	OCTOBER
Carbon dioxide	775 512	4 156 584
Carbon monoxide	38 258	193 427
Methane	1 978	9 853
Particulate matter 2.5 m	3 676	18 511
Particulate matter 10 m	4 338	21 852
Non-Methane hyfrocarbons	1 564	7 908
Volatile organic compounds	1 886	9 546
Nitrogen dioxides	2 736	13 485
Organic compounds	2 116	10 769
Elemental carbon	234	1 216
Particulate matter	5 952	30 221

5 Response

In the critical period of the fire season (July–September), the Portuguese Special Firefighting System integrated 9 740 operational staff, 2 065 vehicles and 48 aircraft, mainly during the Charlie Phase (1 July to 30 September).

All the available resources in Portugal responded to the critical fires in 2017. In the critical period of the fire All the available resources in Portugal responded to the critical fires in 2017. These resources were supported by the Intervention and Relief Group (GIPS) of the National Republican Guard, the Institute for Nature Conservation and Forests and the Association of Pulp Industries, with a total of over 2 300 personnel. Aerial forces intervened in 7 457 firefighting missions totalling over 9 000 hours, which was a much higher figure than those of previous fire campaigns.

On 18 June, Portugal requested support to fight the fires through the Emergency Response Coordinating Centre of the Directorate-General for European Civil Protection and Humanitarian Aid Operations (ECHO), and resources were provided by France (two Canadair planes and one Beech reconnaissance aircraft), Spain (two Air Tractors) and Italy (two Canadair planes). ECHO sent a liaison officer to arrive in the country in the afternoon of that day. Spain made four additional Canadair craft available through its bilateral agreement with Portugal, and Morocco provided one Canadair craft. According to Portuguese authorities, the PG fire was under control on 21 June. These fires were extinguished by 23 June.

Several official emergency actions were taken at the political level, such as activating the civil protection emergency plans of several municipalities and declaring a state of public disaster for the adoption of preventative measures by the Portuguese Council of Ministers. Additional emergency measures were taken during the critical phase, mainly at the health and social protection level, relocating the population affected, reorganising and repositioning critical infrastructures, etc

6 Lessons learned

Changes on the operational level (civil protection structure and operational/ firefighting response) and in the spatial planning of the territory (fuel management measure, protection of residential and industrial areas, forestry public investment) were proposed.

The tragic dimension of the fire events of 2017 in Portugal, both in terms of loss of human lives and in terms of economic and social harm, has also brought into question misguided current fire management policies focused only on reactive fire suppression. The effects uncovered the structural and operational vulnerabilities of the current system of fire prevention and suppression. The firefighting trap policies contributed to continuous fuel accumulation and landscape fuel continuity, leading to increased fire hazard and risk (Moreira et al., 2020). This led to several official actions and a renewed effort to address this issue.

Technical reports were requested by the government to analyse both fire episodes (June and October). The Assembly of the Republic created an independent technical commission to study the events and to recommend solutions, and consequently government reforms were announced (see for example Guerreiro et al., 2018). Recommendations on the operational level (civil protection structure and operational/firefighting response) and on the spatial planning of the territory (fuel management measures, protection of residential and industrial areas, public investment in forestry) were included in these technical reports (Guerreiro et al., 2017, 2018).

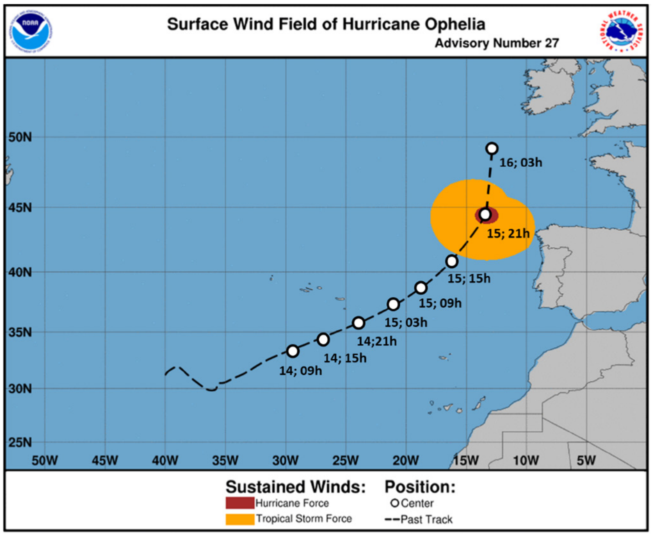
The commission also suggested the creation of the Agency for the Integrated Management of Rural Fires (AGIF), a public institute that coordinates all entities whose missions contribute to dealing with rural fires, such as the Institute of Nature Conservation and Forests, the National Authority for Emergency and Civil Protection, the National Republican Guard, the armed forces, fire brigades and all private agents (Resolution 12/2018). A Technical Independent Observatory was created by the National Assembly to support its members in the assessment of the system and in the preparation of legislation on the issue. Following Resolution 12/2018, the System for Integrated Management of Rural Fires was established under AGIF coordination, with the purpose of protecting the population, territory and assets from forest fires. Among other resolutions from the Council of Ministers of Portugal, a programme for the regeneration of the pine forests of Inner Portugal (Resolution 1/2018) was adopted, pointing out the need to make available information derived from Earth observation, including forecasts of meteorological fire danger and maps of structural fire danger.

Realising the need for preparedness and self-protection in the new reality of rural fires, a programme designated as “Aldeia segura, pessoas seguras” (Republica Portuguesa, n.d.) was adopted to increase the risk awareness, preparedness and coping capacity of settlements and populations in rural areas, including a focus on fire prevention, warning, evacuation of settlements and preparation of shelters. Many of these resolutions were adopted and are being put into practice. For example, extensive programmes of fuel management around houses and settlements have been performed throughout the country, and improved vigilance and self-preparedness on the part of the population are now observed. In addition, a national research programme was promoted, specifically to fund research initiatives applied to forest fire research, enhancing the availability of information and tools for fire managers to assess and understand fire regime, dynamics and post-fire recovery (Guerreiro et al., 2018; Viegas et al., 2017).

7 Discussion

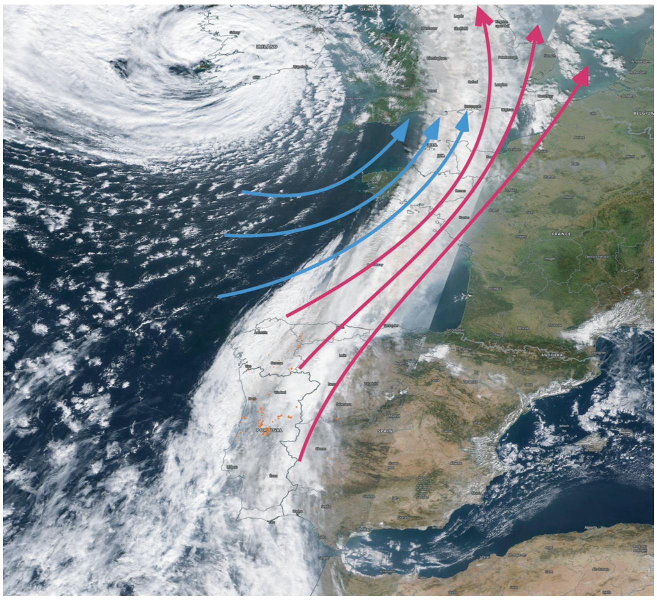
The existing scientific literature on critical fire events, known as megafires or EWEs, shows the limited effectiveness of firefighting against high-intensity and fast-spreading wildfires.

Figure 8. *Trajectory of Hurricane Ophelia, fuelling wildfires in Portugal and blowing the smoke plume north.*
Source*: NOAA National Hurricane Center, 2017*



The JRC analysis of fire danger conditions prior and during the wildfire events in the period 14–16 October 2017 in Portugal shows an unprecedented weather situation in which any ignited fire would spread with high intensity and speed. Very strong winds created by hurricane Ophelia, associated with extremely low relative humidity in the existing fuels, led to wind-driven wildfires. Those were the initial major causes of the very fast spread of the wildfires and the catastrophic damage they brought about. The existing scientific literature on critical fire events, megafires or EWEs, shows the limited effectiveness of firefighting against high-intensity and fast-spreading wildfires. These extreme events can only be controlled when weather conditions improve, which happened on 17 October, when the fire danger conditions decreased dramatically (see Figure 2).

Figure 9. *Burned scars of the fires in Portugal and Spain superimposed on NASA Terra satellite images*
Source*: NASA Worldview, 2020*



At least one of the fires in October was caused by electrical lines but the major causes were fire use (36.0 %), arson (35.7 %) and rekindling (10.7 %); these percentages refer to the total number of fires in the period 14–15 October for which a cause could be determined. The shape of the fire perimeters indicates wind-driven fires with elongated scars following the direction of the predominant wind when fires ignited; these wind were generated by hurricane Ophelia.The effect of the hurricane , which created very strong winds from south to north, as far as Ireland and the United Kingdom, is shown in Figure 8 and 9. The images show the unusual trajectory of Ophelia, the fire scars in Portugal and northern Spain, and how the smoke plume was pushed north along the coast of France into the British Isles.

8 Conclusions

The results of the analysis of the very large fires that occurred in Portugal in 2017 show how predominant critical weather conditions during a short time period can trigger extreme wildfire events, causing enormous economic damage and human casualties.

These fire events are a serious challenge to societies, as they exceed the control capacity in critical weather conditions, causing destruction and fatalities because of their high intensity, erratic behaviour and strong spotting activity (Tedim et al., 2018).

This type of event is rare, but the fires in central Portugal in 2017 should not be viewed as isolated events. Similar clustering of large fire events has been observed in recent fire seasons in Portugal (2003, 2005, 2013, 2016), Spain (2006, 2009, 2012), Italy and Greece (both 2007). Forest fires such as the 2017 disasters are rather complex events arising from the interplay between social and natural conditions, processes and factors throughout the wildfire temporal cycle. Some of the major factors that potentially increase the frequency of these major disasters are the following.

- Changes in forest and fuel management, land use and land cover (both natural and human-made, e.g. afforestation, fire-prone forests of eucalyptus and pine). Land use management is critical in hindering critical fires, through land use planning to avoid continuous forest landscapes, and through fuel treatment to reduce the amount of fuel and decrease wildfire intensity and spread.

- Spatial planning and governance mechanisms (land tenure and land use conflicts, sharing responsibilities, coordination).

- Changes in the socioeconomic dynamics, such as the increasing depopulation of rural areas. For instance, population density in the Pedrógão region went from 34.1 individuals per square kilometre in 2001 to 26.8 in 2018 (PORDATA, 2019), leading to farmland abandonment and contributing to increased fuel continuity, making it easier for fires to ignite and spread.

- The increase in the wildland–urban interface, where fires are highly damaging to human lives and assets. This has been dramatic in the last decades.

- Climate change, with higher temperatures and longer drought periods influencing wildfire dynamics, leading to longer and more intense fire seasons.

These extreme events seem to be inducing a vicious circle, contributing to land use changes and depopulation of rural areas, which increase the propensity for more frequent, larger and more destructive fires even in areas that years ago were not fire prone. Considering current trends in Europe (and especially in Portugal, where most fires are caused by humans), the hazard component appears to be a rather inflexible part of the risk equation, with a negative future outlook. Promoting a shift from suppressing fires, which often burn on continuous fuel layers of fire-prone vegetation, to mitigation, prevention and preparation measures can surely contribute to better control of EWEs, reducing the socioeconomic and ecological effects of fire (Moreira et al., 2020). The management of fuels, including the deliberate use of fire or using it for grazing or for energy to reduce fuel loading are possible solutions to develop. In addition, the vulnerability component poses important challenges such as the ageing of population, which has various implications for prevention, preparedness and response measures (i.e. firefighting) in rural areas.

This leaves most of the reduction in risk and impacts to be achieved by managing fuels and by reducing vulnerability (when possible) and, especially, decreasing direct human exposure to fire, in order to prevent human casualties. This requires a special focus on early warning and self-protection measures, but also Investment in fire prevention, both in education campaigns and engagement of local communities, making them more resilient and ready to defend themselves from the effect of extreme fires, and in forest management (fire use regulation).

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