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CIVIL PROTECTION SPECIAL FORCE



Intervention report

EAUF 02 FEPC

Location: Tojeiro

Parish: Marmeleite

Municipality: Monchique

District: Faro

Coordinates:

Latitude: 37°15,4916N

Longitude: 8°40,2742W

Date: 17/07/2021

Team: EAUF 02

Occurrence number: 2021080029244

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Timetable of Team activation:

EAUF 02				
Team composition: Fábio Silva, H. Gonçalves, P. Barreto, H. Garcia				
Activated by: CNEPC ¹		Activation GDH ² : 171653JUL21		Exit GDH: 171705JUL21
Arrival in theatre GDH: 171944JUL21				
COS ³ on arrival in theatre: CODIS ⁴				
Time of evolution of the fire at the arrival of the Team: 6 hours and 18 minutes				
Surrender	Yes		No	X
Total hours of rest: 6 hours				
Demobilised by: CODIS				
Demobilisation GDH: 182018JUL21				Departure from theatre GDH: 182018JUL21

¹National Command for Emergency and Civil Protection; ²GDH – Group/date/hour reference; ³Commander of Rescue Operations; ⁴District Operational Commander

Geographical framework

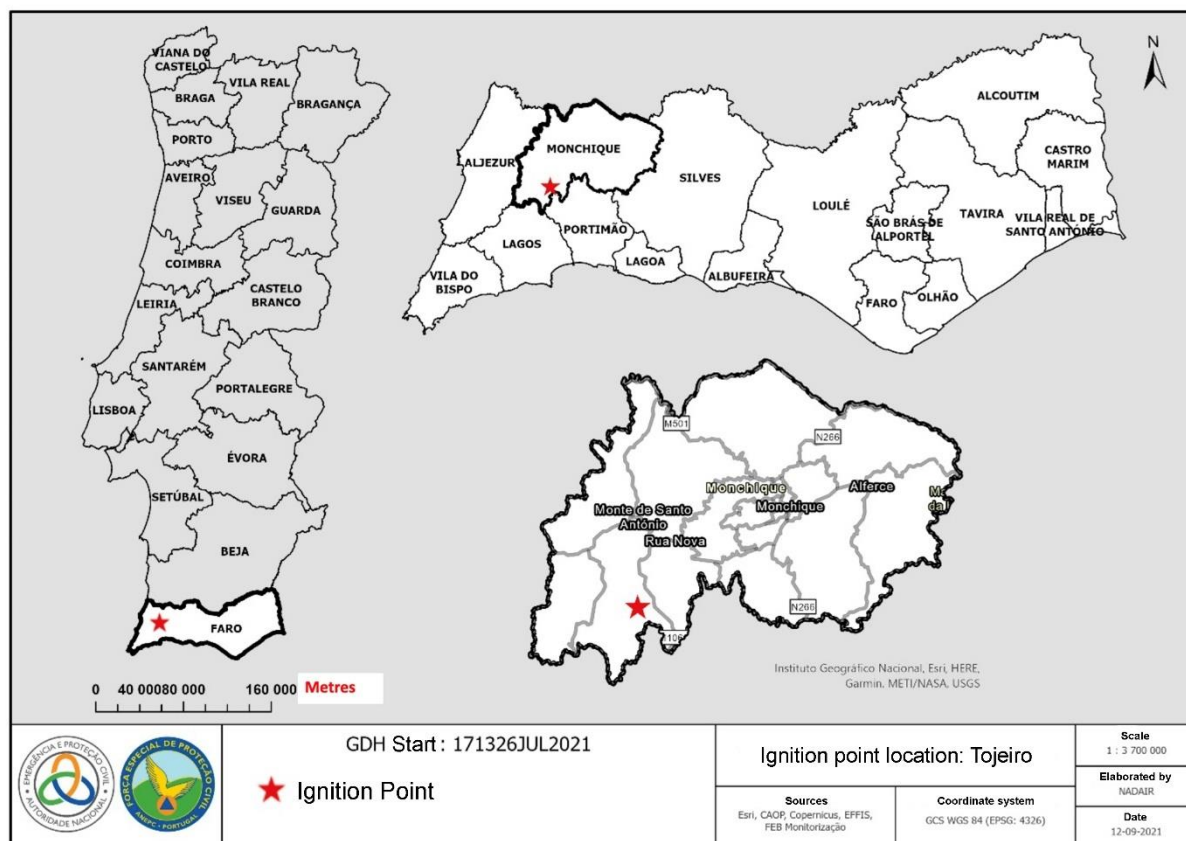


Figure 1 - Location of the ignition point of the rural fire at the Tojeiro site (DGT, 2020; NAD-AIR, 2021).

The rural fire was started at 1.26 p.m. in Tojeiro, parish of Marmeleite, municipality of Monchique, district of Faro.



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Figure 2 – The initial fire zone at 3.58 p.m. Photo taken by ANEPC, AVRAC.

The 3/3 CPS alignment shortly after its start gave a fire behaviour outside of its fighting capacity, much due to the dryness index even on the north-facing slopes, combined with a rather irregular terrain orography, characteristic of the Algarve region, and the type of existing fuels with high thermal loads, such as scrubs and Eucalyptus forests.

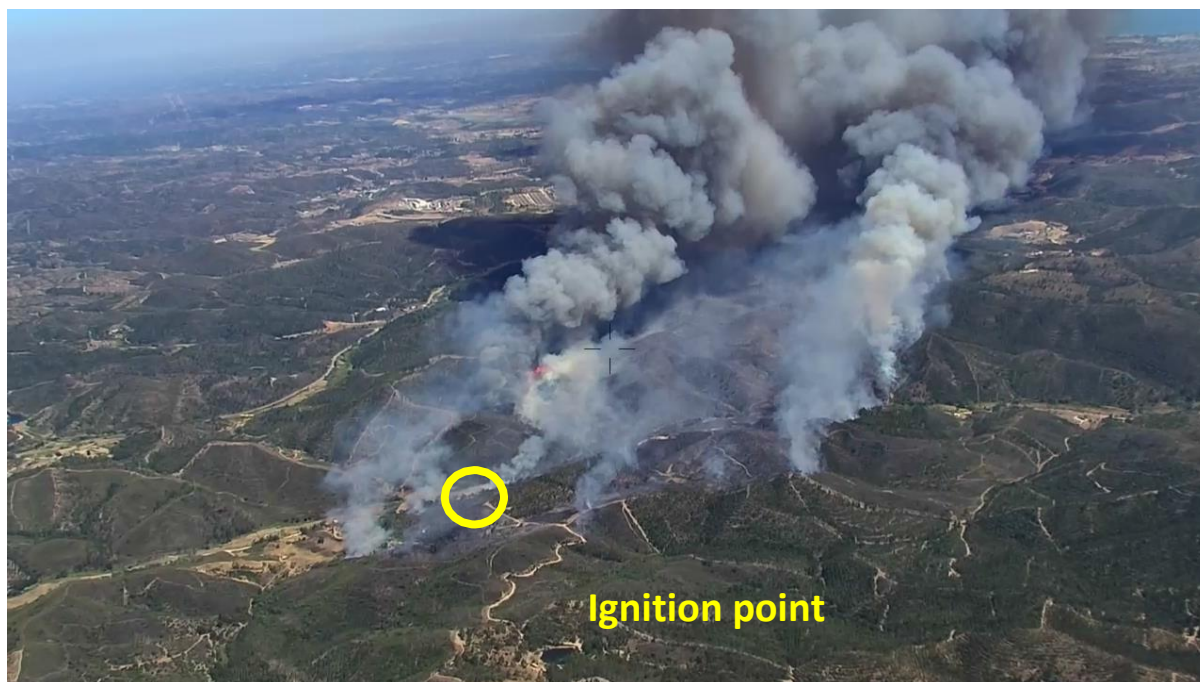


Figure 3 – The initial fire zone at 3.59 p.m. Photo taken by ANEPC, AVRAC.

Climatology

As shown in Figure 4, observing the meteorological evolution that precedes the fire from the National point of view, the month of July 2021 in mainland Portugal was classified as cold and dry according to the Portuguese Institute for Sea and Atmosphere (IPMA). The average value of the mean air temperature (21.54°C) was 0.63°C lower than in previously recorded years (1971-2000) and the fifth-lowest value since 2000 (the lowest was 21.15°C in 2018). Air temperature values lower than those currently recorded have occurred in 30% of the years since 1931. The average minimum air temperature (14.59°C) was the third-lowest since 2000 (the lowest was 14.38°C in 2009), with an anomaly of -1.03°C. Minimum air temperature values lower than those currently recorded have occurred in 20% of the years since 1931.

Highlights of the month include:

- Maximum temperature: more than half of the month with temperatures below or close to the average monthly value and above-average values only occurred in the periods from 9 to 11 July 2021 and 14 to 18 July 2021.
- Minimum temperature: temperatures below or close to the average monthly value during most of the month, with above-average values recorded from 16-18 July 2021.

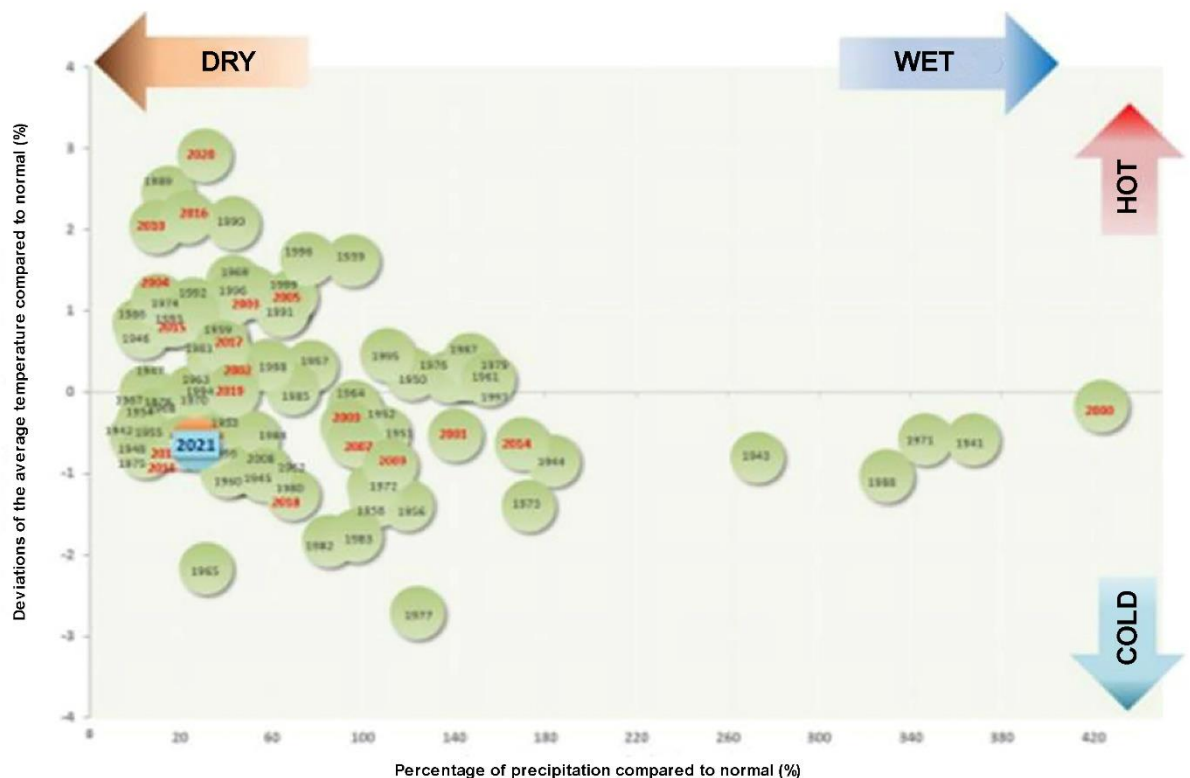


Figure 4 - Graph of the climatological analysis for July 2021 (IPMA, 2021a).

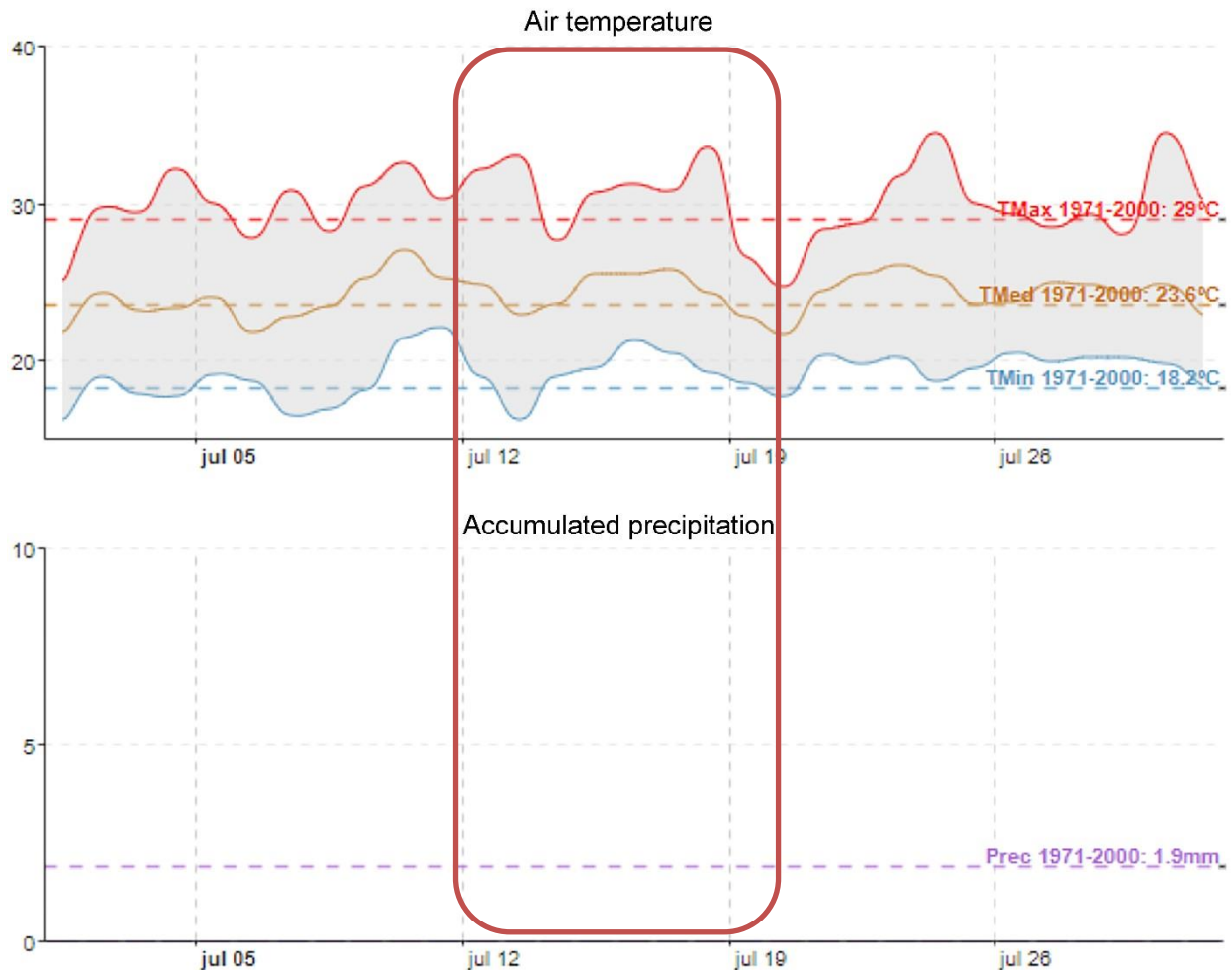


Figure 5 – Climate Normals for Faro station (closest) for the fire period (IPMA, 2021b).

Meteorology

As shown in Figure 6, the area where the fire occurred was experiencing a moderate drought, with no precipitation for a long period until the date of the fire. The water percentage in the soil decreased at the end of July, compared to the end of June, throughout the territory. The Northeast region, the region of Lisboa e Vale do Tejo, and the coast of Alentejo and Algarve should be highlighted since all locations had water percentages in the soil below 20%, with many places very close or equal to the permanent wilting point.



Figure 6 – Drought Index in July 2021 (IPMA, 2021c).



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Analysing the region of Algarve (Figure 7), the data revealed very high Fire Weather Index (FWI) values on 17 July 2021, indicating an extreme risk of fire, and above normal for this area at this time of year. Moreover, Figure 8 demonstrates that the addition to high FWI values, there was also an Initial Spread Index (ISI) with values above normal (75-90% percentile) and an average Drought Code (DC) that was high (689) but is within the normal values for the period under review.

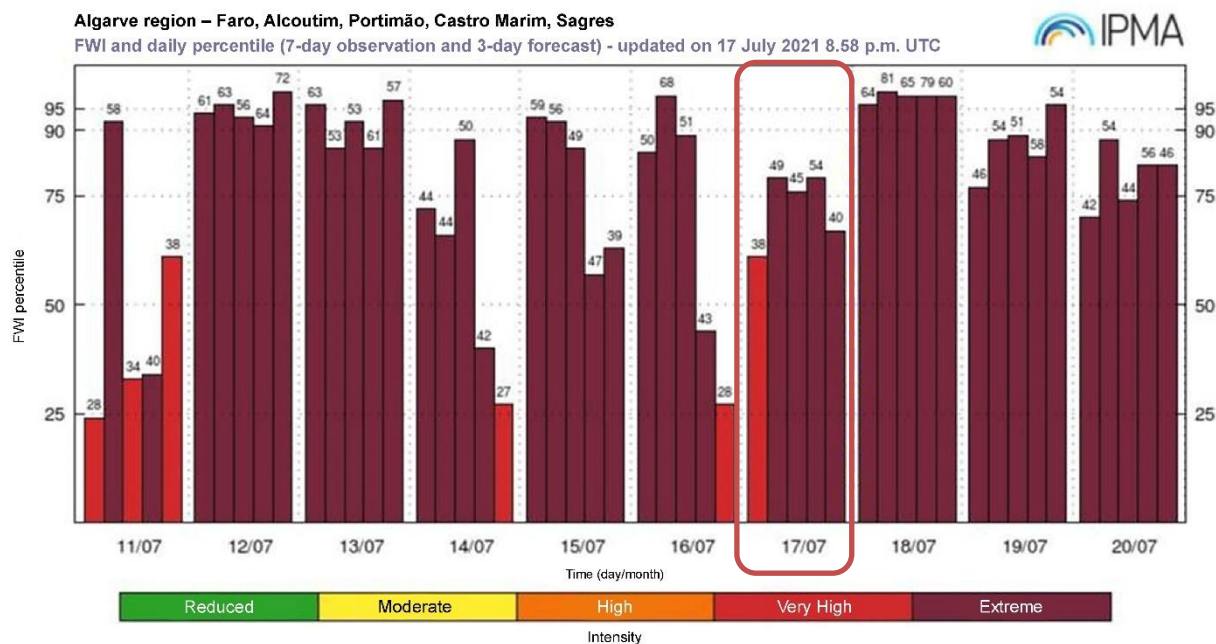


Figure 7 - FWI and daily percentile (7-day observation and 3-day forecast) for the Algarve region (IPMA, 2021c).

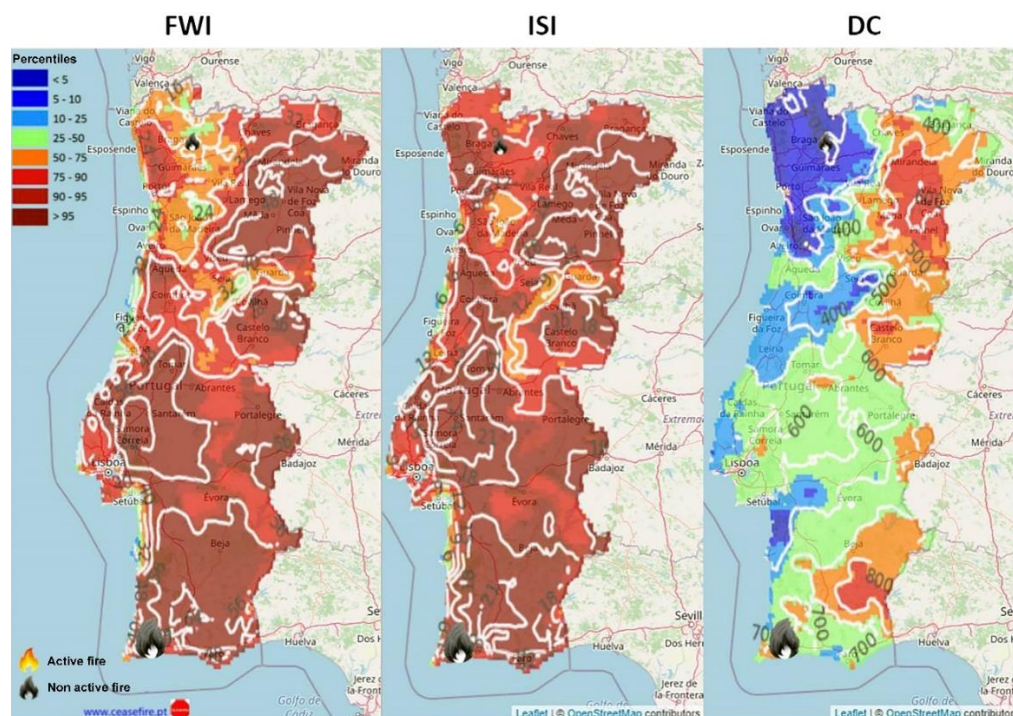


Figure 8 - FWI, ISI and DC percentiles on 17 July 2021 (CeaseFire, 2021).



The Rural Fire Information Management System (SGIF) register for the day and location of the fire is presented in Table 1. The data confirmed indexes propitious to the occurrence of fires of extreme intensity, with initial propagation speeds greater than 600 m/h, secondary outbreaks, difficulty in the aftermath, and consequent difficulty in combat, with all the conditions for ignition to become a large fire.

Table 1 – Average values of the Canadian forest fire weather index system at the fire location on 17 July 2021 (SGIF, 2021).

Average temperature (°C)	Average Relative Humidity (%)	Average wind Intensity (units)	Average precipitation (mm)	Average FFMC
33.3434066772461	24.349250793457	12.4065074920654	0	94.3000030517578
Average DMC	Average DC	Average ISI	Average BUI	Average FWI
169.399993896484	688.799987792969	16.5699996948242	209.800003051758	53.8499984741211

NOTE: Daily average values.

FFMC (93-95) – (High to very high-intensity fire, likely to spread through trees canopy. Rapid ignition of projected sparks.)

DC (>500) – (Flameless combustion is persistent. Aftermath and extinction are increasingly difficult and laborious. It is essential to monitor all the edges of the fire.)

BUI (>100) – (Very high consumption of all fuel categories.)

ISI (>15) – (Fast or very fast-spreading fires (above 600 m/h), which generally involve the canopy of the trees, except in stands with marked vertical discontinuity.)

FWI (>39) – (Active canopy fires are expected. The speed of spread, the potential for secondary outbreaks, and the likelihood of fire crossing obstacles are extreme. It is not possible to attack the head of the fire. The action of ground assets must be limited to the rear and flanks of the fire. Indirect attack using fire can be effective.)

Given the indicators predicted and verified, it is also confirmed that the district of Faro was one of the districts identified as a critical area for forest fires, having been placed in a state of Special Red Alert within the scope of the Special Rural Fire Fighting Device (DECIR).

	17JUL21	18JUL21
AVEIRO		
BEJA		
BRAGA		
BRAGANÇA		
CASTELO BRANCO		
COIMBRA		
ÉVORA		
FARO		
GUARDA		
LEIRIA		
LISBOA		
PORTALEGRE		
PORTO		
SANTARÉM		
SETÚBAL		
VIANA DO CASTELO		
VILA REAL		
VISEU		

Figure 9 - Special Alert State in the districts in Portugal for 17 and 18 July 2021.



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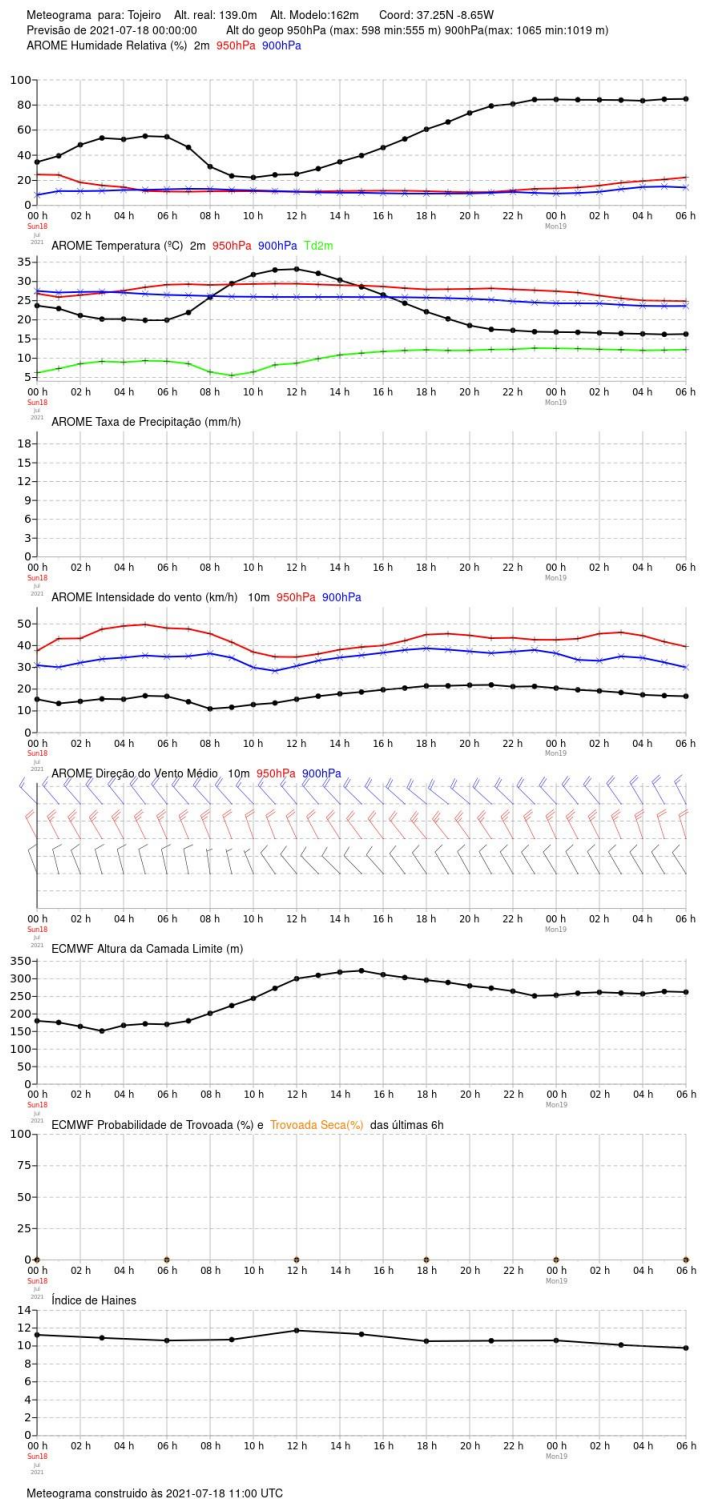
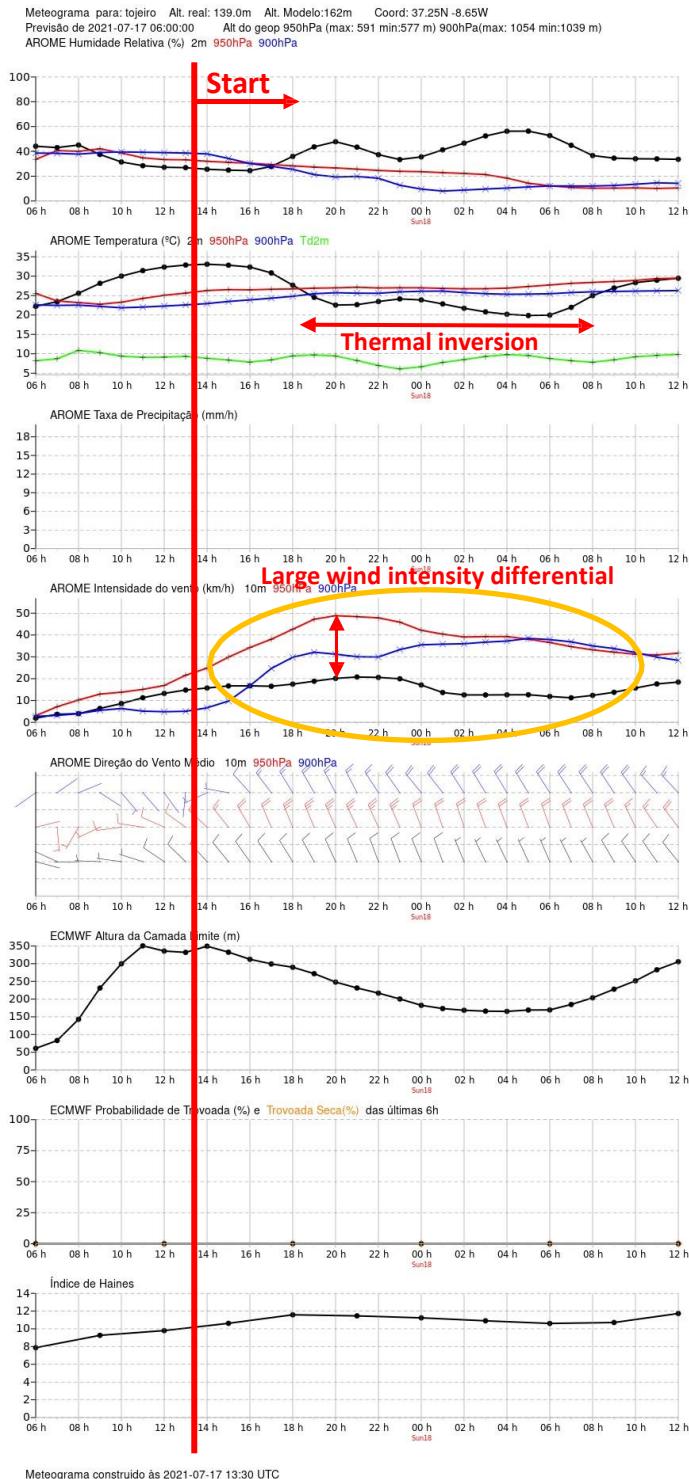


Figure 10 - IPMA Meteograms for the locality of Tojeiro, referring to 17 July 2021 (left image) and 18 July 2021 (right image).

On 18 July, the forecast was a maximum temperature (surface) of 34°C by 2 p.m., a decrease to 20°C by 4 a.m., and then returning to 34°C by noon on 19 July. The dew point temperature was forecast to be 12°C by 4 p.m., increasing to 16°C by midnight on 18 July. Relative humidity (surface) by 2 p.m. was around 25%, with a weak recovery at night, not exceeding 60% on the night of 17 July to 18 July.



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The constant wind from the northwest was between 15 and 20 km/h during the day (wind at 10 m) and was felt with greater intensity at the site. The differential between the surface and 950 hPa layers progressively increased in the afternoon, reaching a peak between 7.30 p.m. and 8.00 p.m. with intensity differences exceeding 30 km/h. This situation intensifies the surface wind by creating a vacuum on the ground with air masses sucked by the strong displacement in the 950 hPa layer. Still, regarding the wind, a possible wind rotation to the west was sensed at 7.30 p.m., which turned out to be temporary, and the prevailing wind throughout the fire period was from the northwest, maintaining the initial dynamics.

Concerning convectivity, the only index that showed (moderate) values was the Haines index, which reached a maximum value of 11 by the end of the day.

Despite being predicted to be dry and with a weak recovery, the night would present a thermal inversion between 7.00 p.m. on 17 July and 8.00 a.m. on 18 July. Allied with a decrease in wind intensity, it became a great opportunity to fight and suppress the fire.

It should be noted that these values come from a meteorological forecast and that with the fire present and the energy released, it could greatly alter the local dynamics of meteorological behaviour.

Synoptic situation

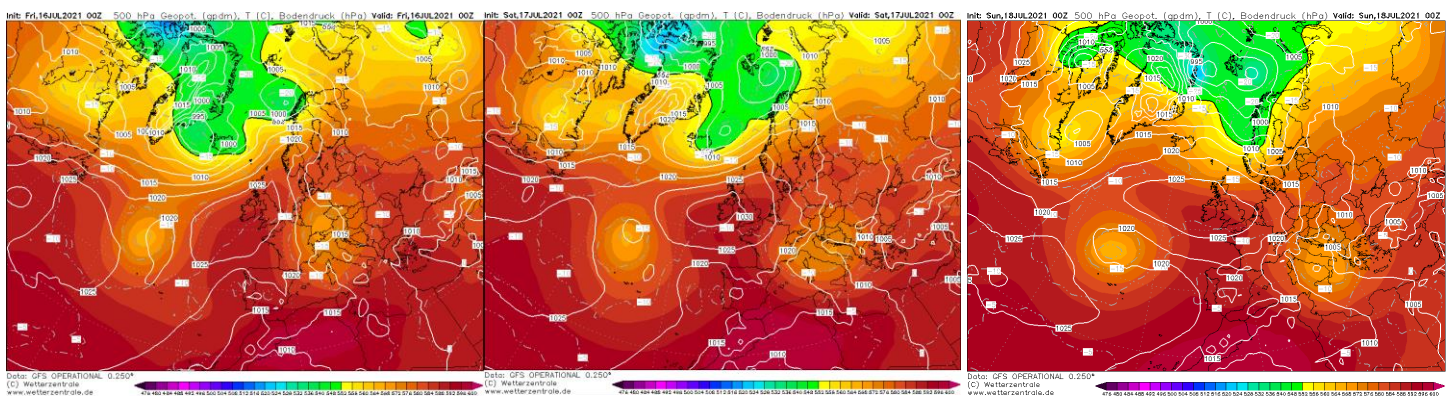


Figure 11 - Synoptic charts 500 hPa, 16, 17 and 18 July 2021 (Wetterzentrale, 2021), adapted by Hugo Gonçalves, GAUF – FEPC.

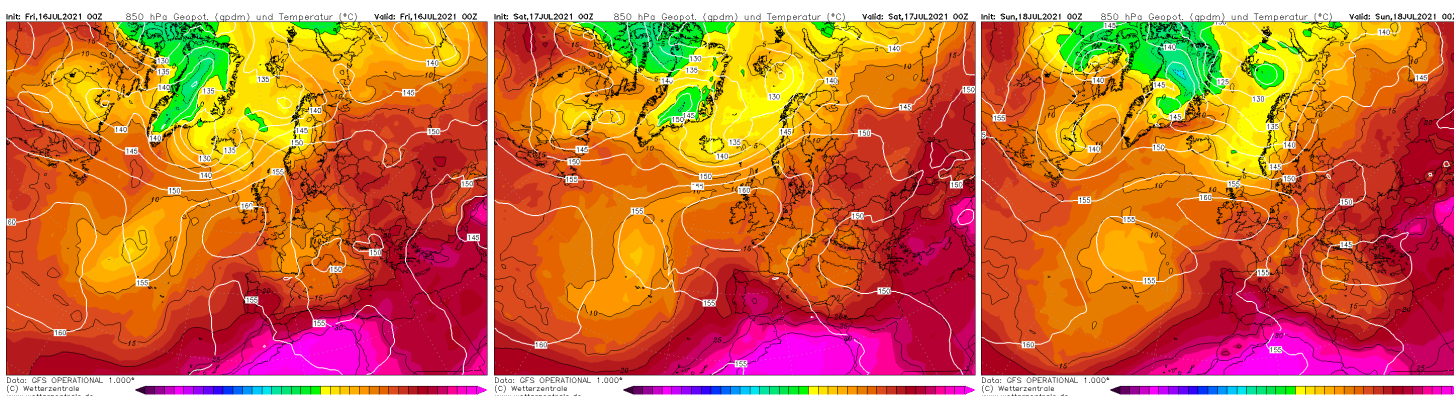


Figure 12 - Synoptic charts 850hPa, 16, 17 and 18 July 2021 (Wetterzentrale, 2021), adapted by Hugo Gonçalves, GAUF – FEPC.

Anticyclone over the British Isles and depression valley extending from North Africa to the north-western Iberian Peninsula.



Topography

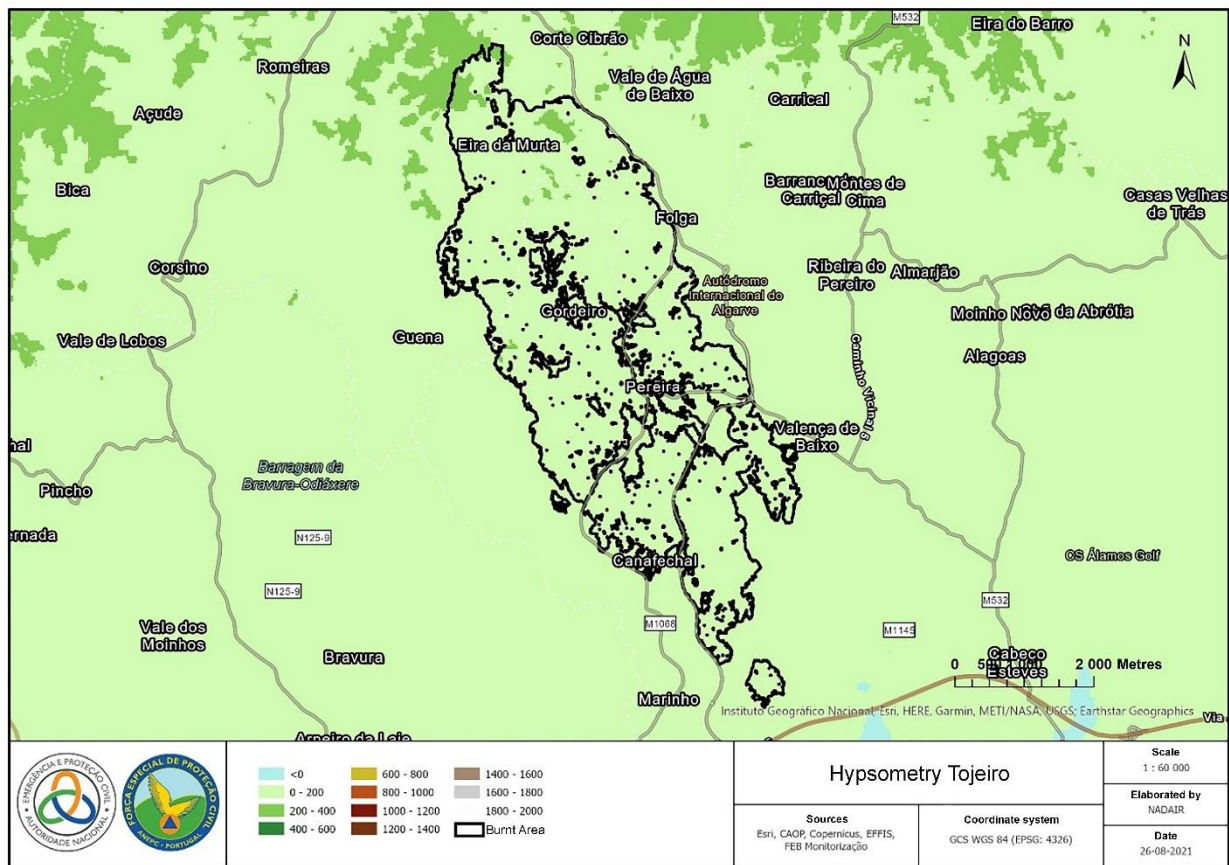


Figure 13 - Hypsometric chart (NAD-AIR, 2021).

Approximately 98% of the fire occurred in an area with altitudes of less than 200 m, and the remaining 2% was between 200 and 400 m (Figure 13). Notably, the higher altitude locations were identified in the initial zone of the fire, corresponding to places where there was a higher concentration of areas with slopes greater than 40% (Figure 15) and a higher concentration of slopes oriented to the west and south (hot and very hot, respectively) (Figure 16). Thus the potential for propagation increased, especially in the early stages.



Figure 14 - Three-dimensional image of the initial zone of the fire and its orography (local characteristic) (NAD-AIR, 2021).



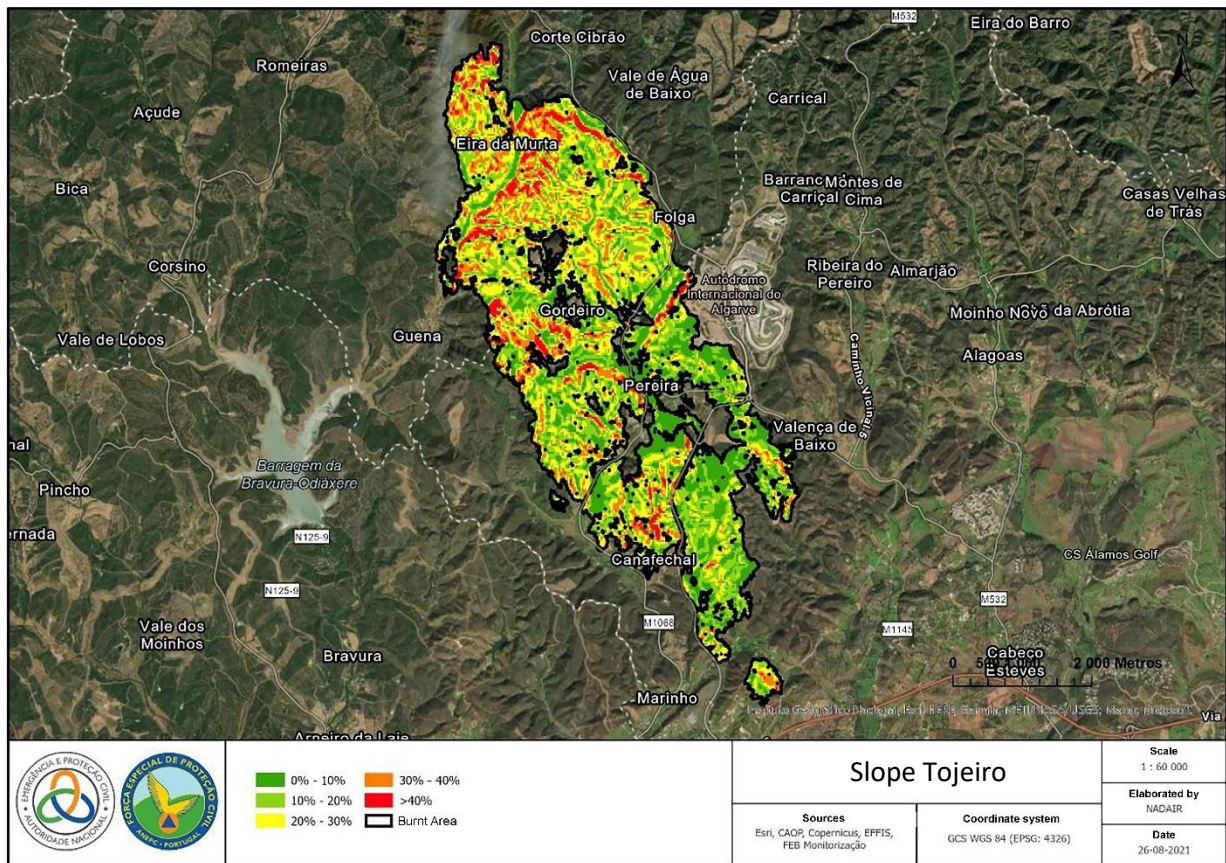


Figure 15 – Slope chart (NAD-AIR, 2021).

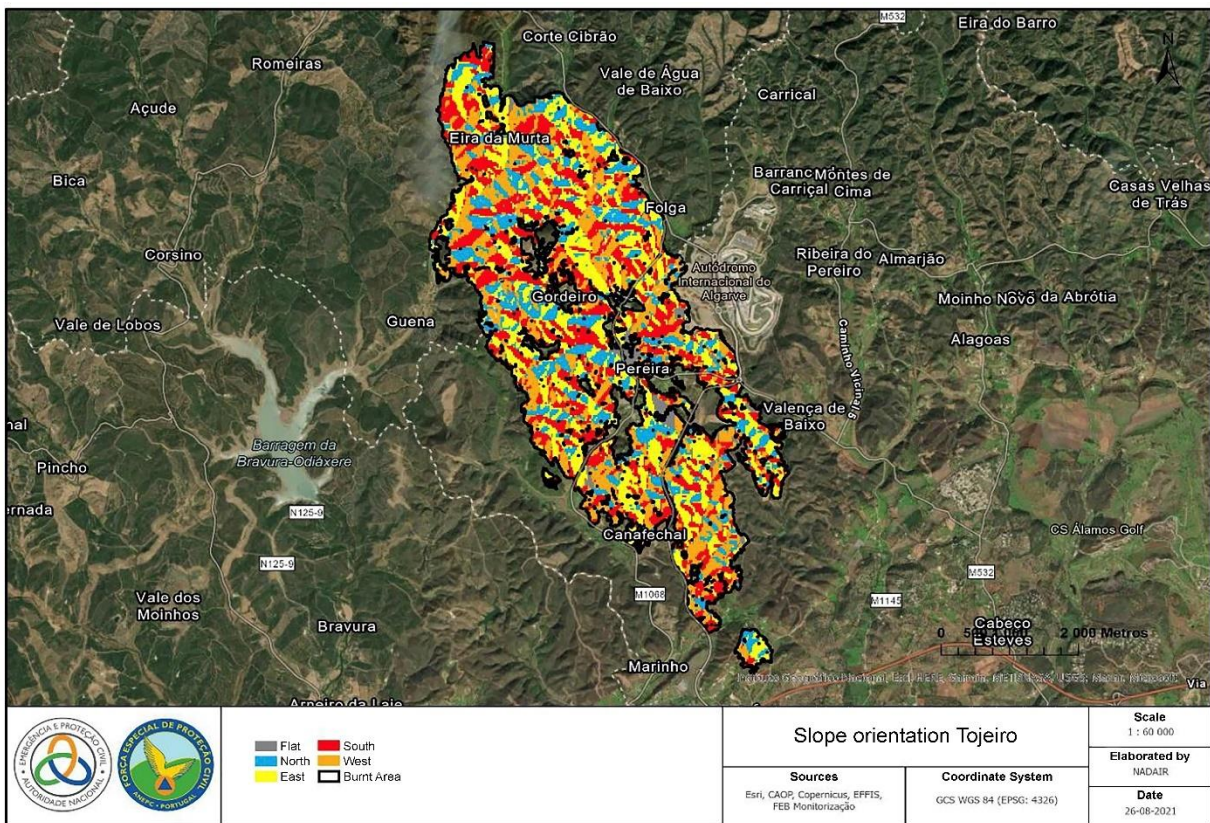


Figure 16 - Slope orientation chart (NAD-AIR, 2021).



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As can be seen in Figures 17 and 18, approximately 50% of the total area of the fire presents hot and very hot slopes. There was an equal percentage (50%) for slopes greater than 20%, highlighted by an area, of approximately 20%, with a slope greater than 30%. In this sense, it is a characteristically irregular area.

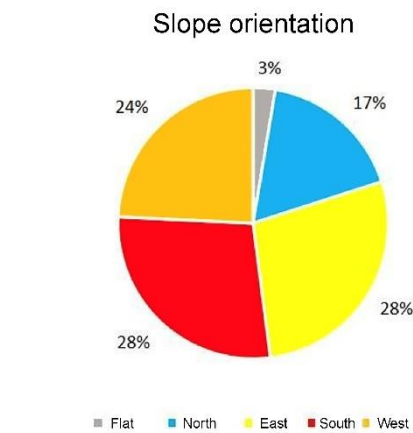
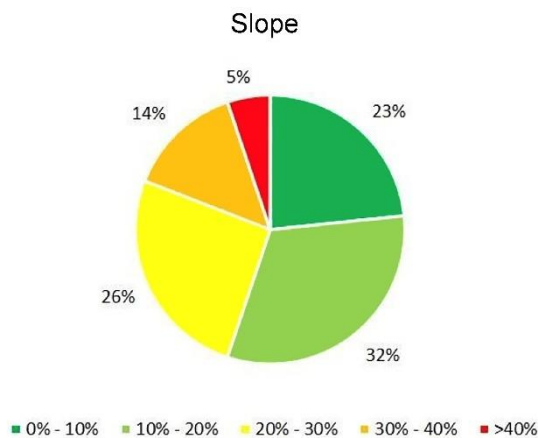


Figure 17 - Distribution of slopes by percentage (NAD-AIR, 2021).

Figure 18 - Distribution of slope orientation by percentage (NAD-AIR, 2021).

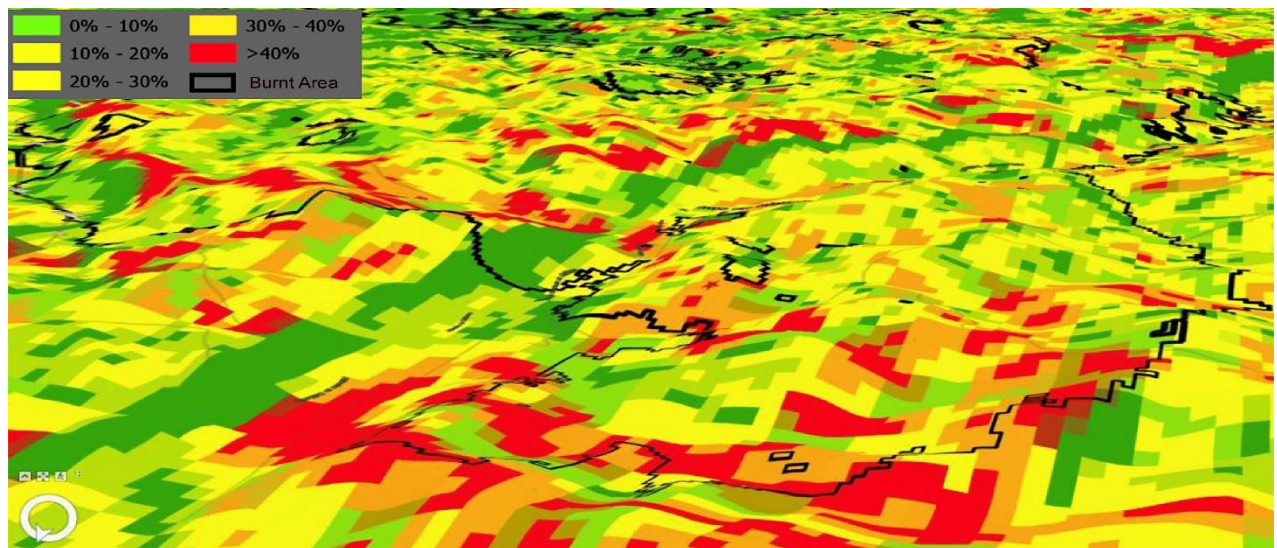


Figure 19 – Three-dimensional image of the area where the fire started, coinciding with the areas of greatest slope (Slope Raster Chart) (NAD-AIR, 2021).

Combustible materials (fuels)

The area covered by the fire reached forests and bushes, accounting for 91% of the total burnt area (46% and 45%, respectively) (Figure 21). This spread contributed to a constant thermal load along its path, evidenced by copious amounts of fine dead combustible material. In some cases, the creation of two simultaneous situations: high velocity of propagation with a high thermal load occurred.

Only 2% of the fire's area corresponded to pure pasture, 1% was artificial territories (near the Autódromo Internacional do Algarve area), and 6% were agricultural areas. Adjacent to these affected agricultural areas, large islands with the same type of occupation did not burn (southwest of the Autódromo) (Figure 20).



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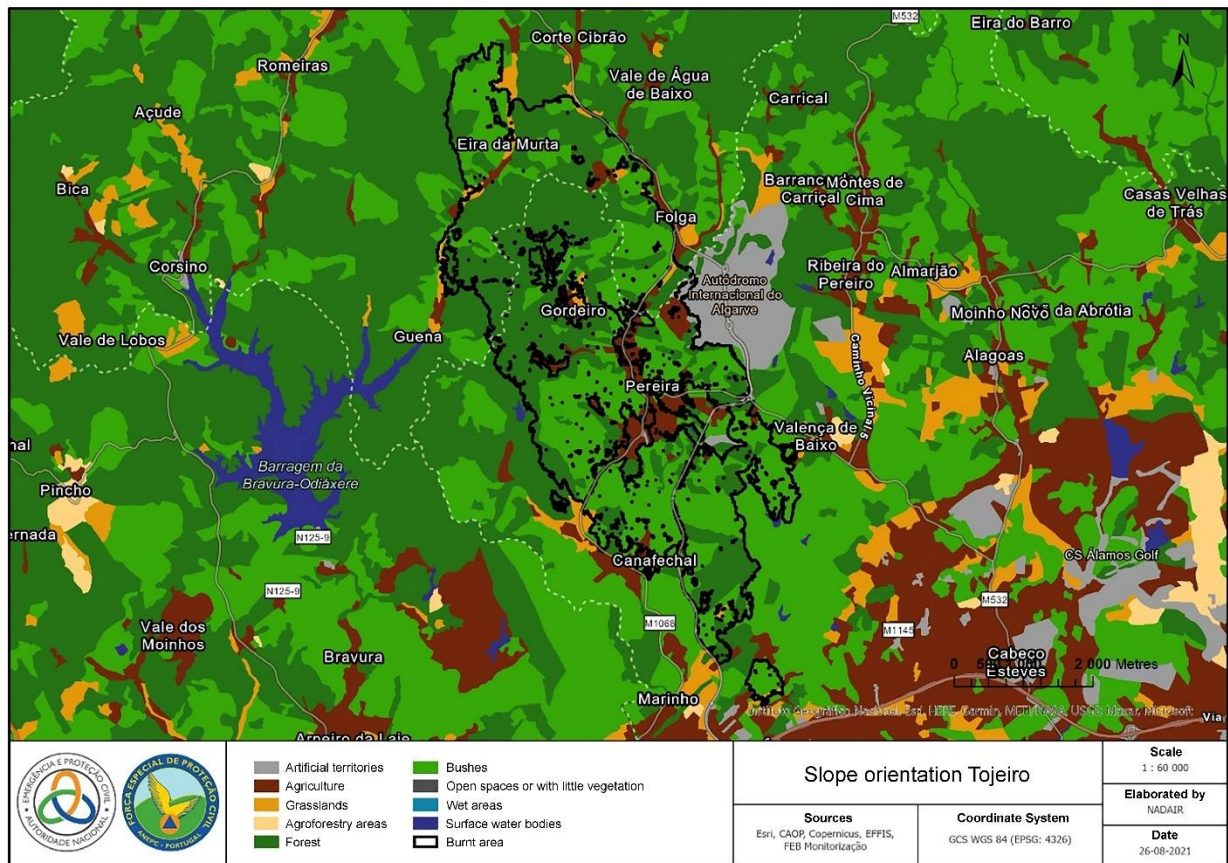


Figure 20 – Land use and occupancy chart (n1) (DGT, 2018; NAD-AIR, 2021).

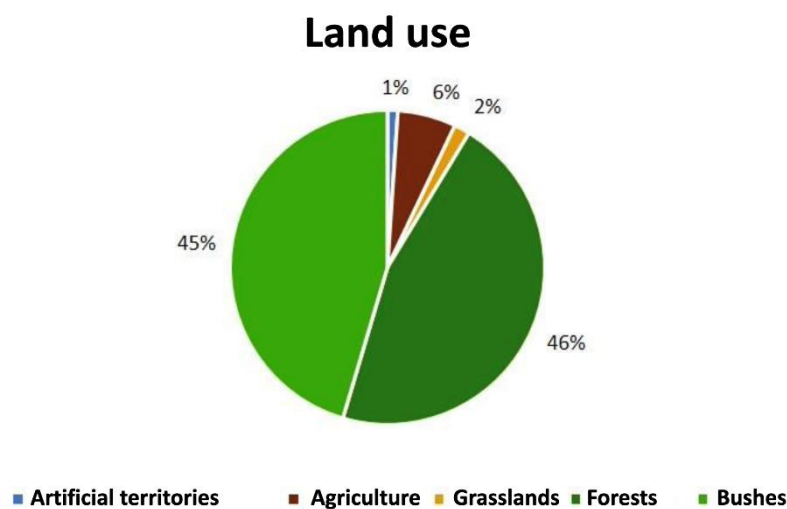


Figure 21 - Distribution of land cover by percentage (DGT, 2018; NAD-AIR, 2021).

Regarding level 4 of COS2018 (DGT, 2018), in relation to forests, the most affected forests were those of eucalyptus, stone pine and cork oak (near the area at the beginning of the fire) with 22.7%, 14.1% and 8.9% respectively, having the maritime pine and other hardwood forests, an irrelevant value within the affected area (Figure 22).

Land use (level 4)

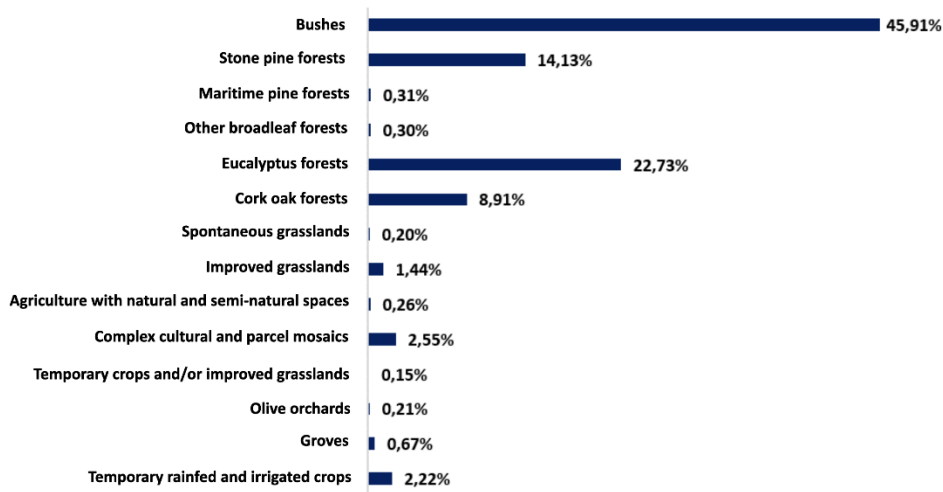


Figure 22 – Distribution of land cover by percentage (DGT, 2018; NAD-AIR, 2021).

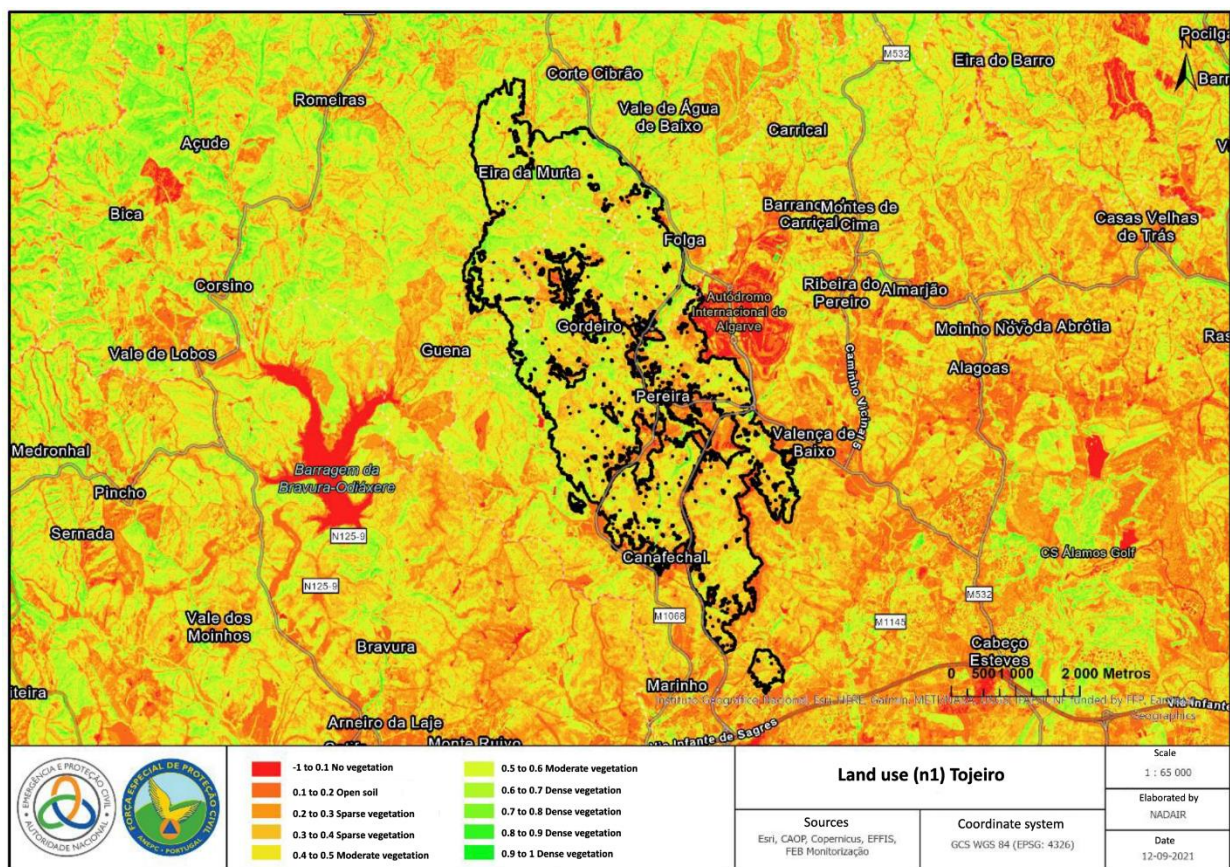


Figure 23 - Normalised Difference Vegetation Index (NDVI) (NAD-AIR, 2021; Sentinel Online - ESA, 2021).

Through the Normalised Difference Vegetation Index (NDVI), we verified that the fire area with more islands coincides with the area that has less dense/shallow or even non-existent vegetation. In the initial zone of the fire, half of the site had more vegetation and was denser, thus creating the highest thermal load at the beginning. Upon closer examination of this map, it is quickly verified that the Autódromo served as a great barrier and that the first third of

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the right flank almost opened through the beginning of a finger formation. It should be noted that this flank had great potential in case there were meteorological conditions for that. It is also verified that most of the head of the fire stalled in an area with little or no vegetation, which corresponds to the Institute for Nature Conservation and Forests (ICNF) fuel management strips, despite covering a large area with less fuel. Most of the 33% of sparse vegetation and 5% of open ground were in the second half of the fire, a factor that may have facilitated the combat, together with the lower existing slope.

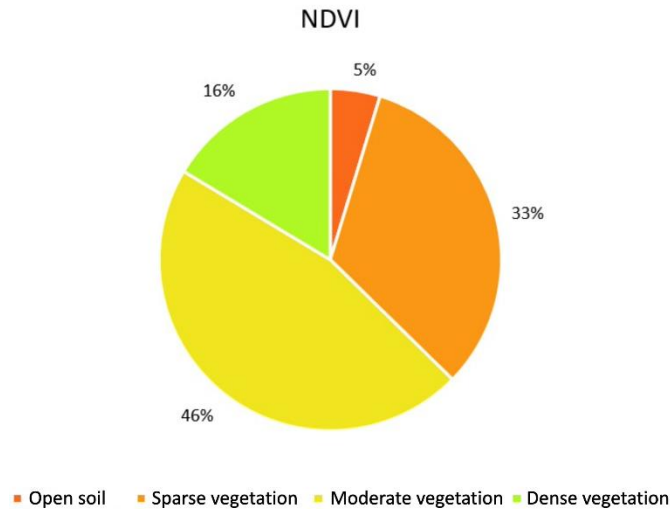


Figure 24 - Distribution of NDVI classes by percentage (NAD-AIR, 2021; Sentinel Online - ESA, 2021).

History of fires

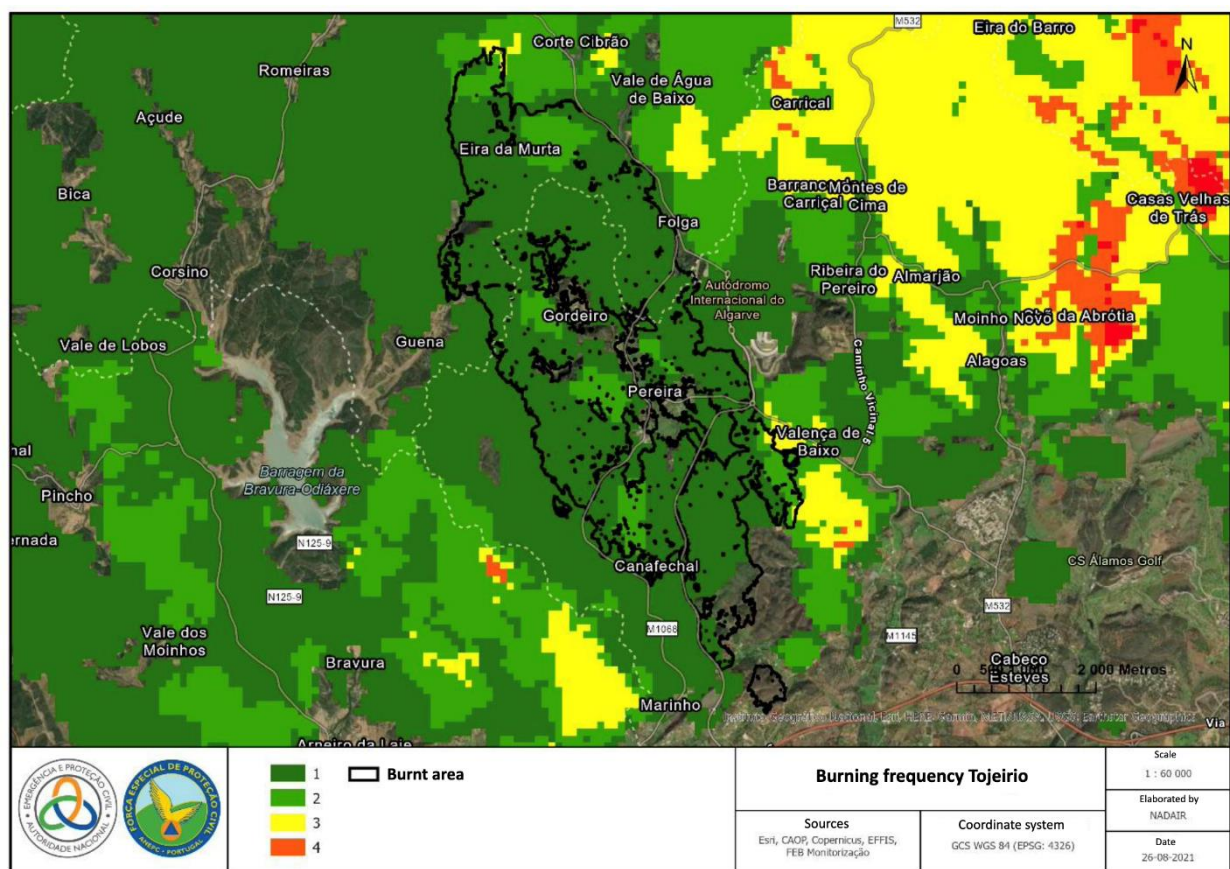


Figure 25 – Number of times burnt between 1975 and 2020 (ICNF, 2021a).



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Although within the perimeter, there is a fire history of having burned at least once, it is generally verified that it is an area where several fires have already occurred, and the presence of the same is recurrent. There has been a repetition of fires, up to four times, in some locations between 1975 and 2020 (ICNF, 2021a).

Thus, the calculation performed for the probability of fire recurrence at that site is represented in Figure 26.

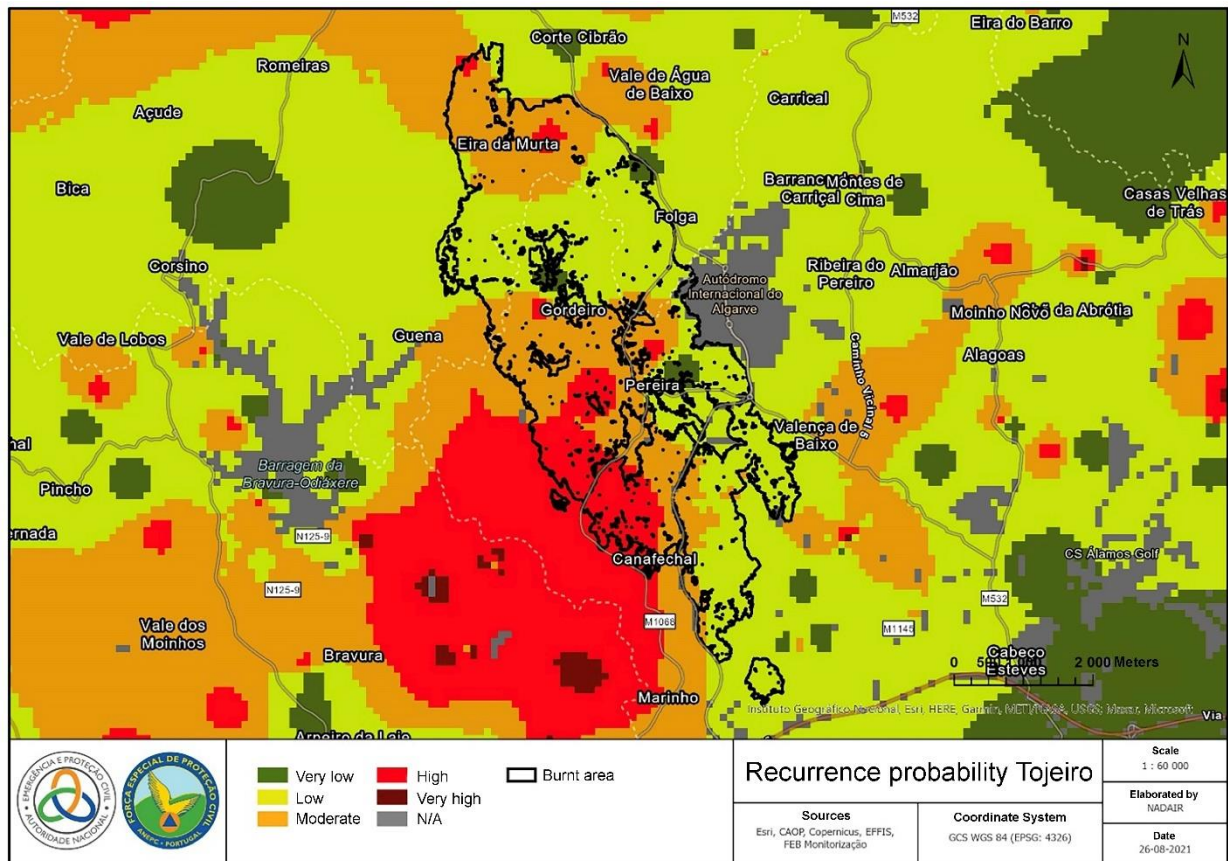


Figure 26 - Probability of fire recurrence in 2021 (NAD-AIR, 2021).

A large part of the second half of the fire, against the right flank and the ignition site, presents a moderate, high and very high probability of fire recurrence for 2021, i.e., higher than 50%, 70% and 90%, respectively.

Using this map, combining the probability of burning with the existing fuel accumulation, one obtains a fire exposure map, which looks at how exposed the area is to the occurrence of rural fires. Both maps (probability and exposure) are underpinned by fire history.

It can be seen from Figures 27 and 28 that more than 50% of the final perimeter of the fire is in the highest exposure classes in 2021 (high and very high). Only 7% of the burnt area is in the two lower classes. Much of the highest class is on the right flank with a constant concern of possible opening.

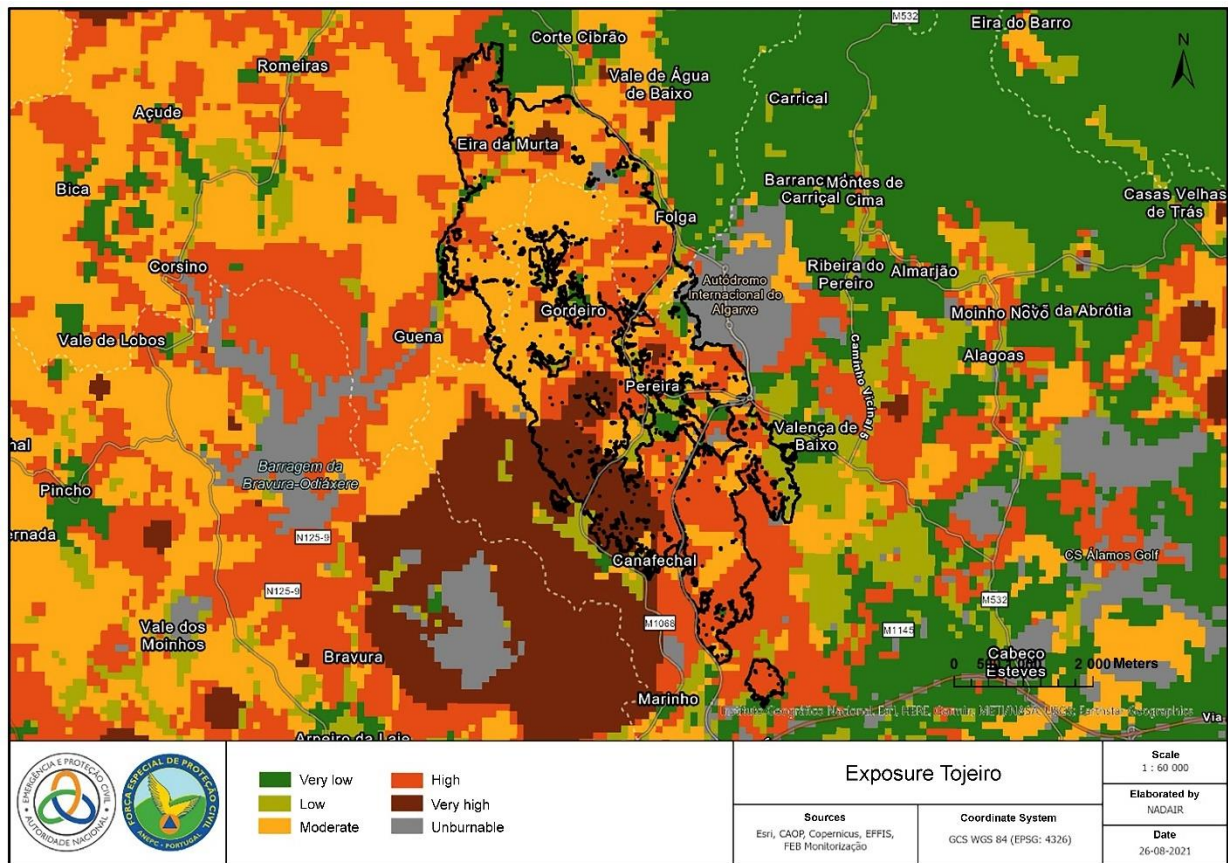


Figure 27 - Rural fire exposure chart.

Exposure (recurrence + fuel accumulation)

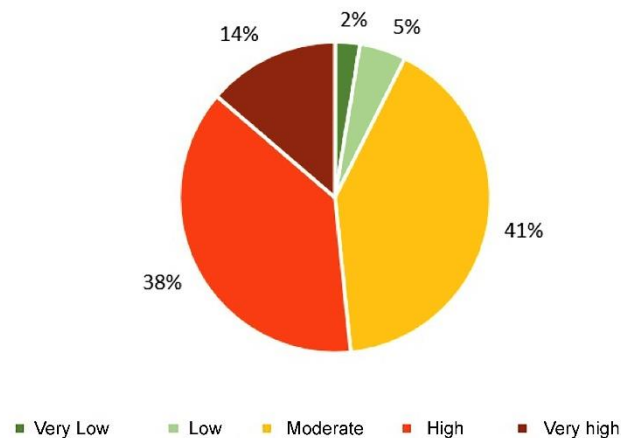


Figure 28 - Distribution of exposure classes by percentage.

General analysis of the fire

The fire had in its beginning a stronger behaviour due to previously described factors such as the rather irregular orography, steep slopes, fuel types and CPS alignment (2/3 and 3/3). It was typically a wind fire, strongly influenced by the 950 hPa layer, which presented wind speed differences sometimes higher than 30 km/h than the surface forecast.





Figure 29 – Behaviour of the fire column at about 90 minutes when the fire was still strongly influenced by the irregular orography and steep slopes in the initial phase.

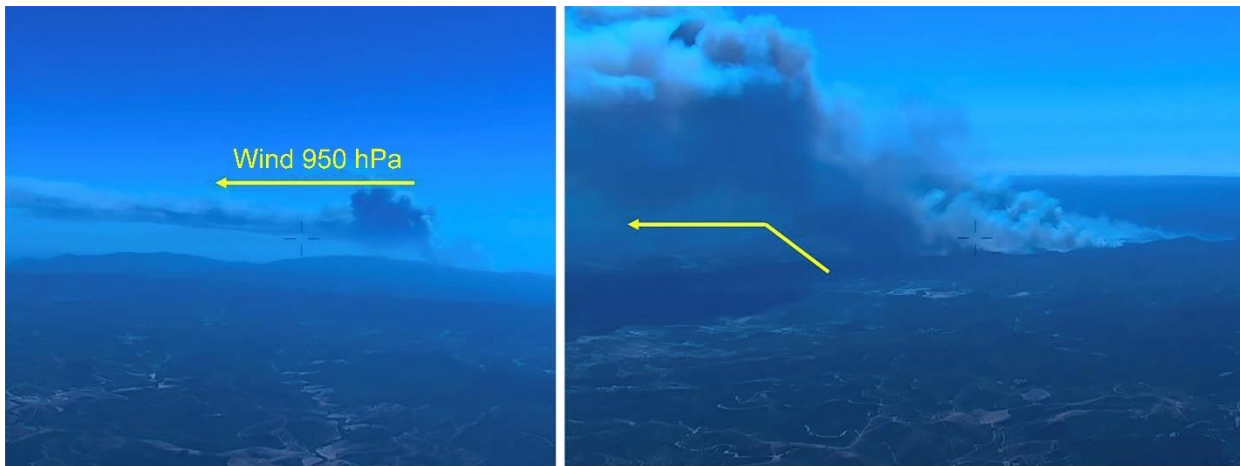


Figure 30 - Photos captured by ANEPC, AVRAC, at 3.45 p.m. (2h20min of fire).

The 950 hPa layer with much more intense wind dispersing the smoke column is shown in Figures 29 and 30. However, this differential of wind intensity values between the 950 hPa layer and the surface created a vacuum on the ground causing the wind intensity values to be higher than the predictions (Figure 31), consequently influencing the speed of fire spread. This differential of intensities between layers increased during the afternoon of 17 July, reaching its peak just before 8.00 p.m., when the fire also reached its highest velocity of propagation, above 2000 m/h, with lots of secondary outbreaks and the highest rate of expansion, above 300 ha/h.



Figure 31 – Image demonstrating surface wind/fire behaviour. (Source: fire brigade operative).

Overall, considering propagation velocities, expansion rates, orography analysis and observation of the fire column (colour and inclination), it appears that in an initial phase, the fire burned with a lower propagation velocity but with more flame intensity, opening in different directions (mainly in the south/southeast). With the increase of wind in altitude and lower slopes, the fire started to have a higher propagation speed and greater flame length.

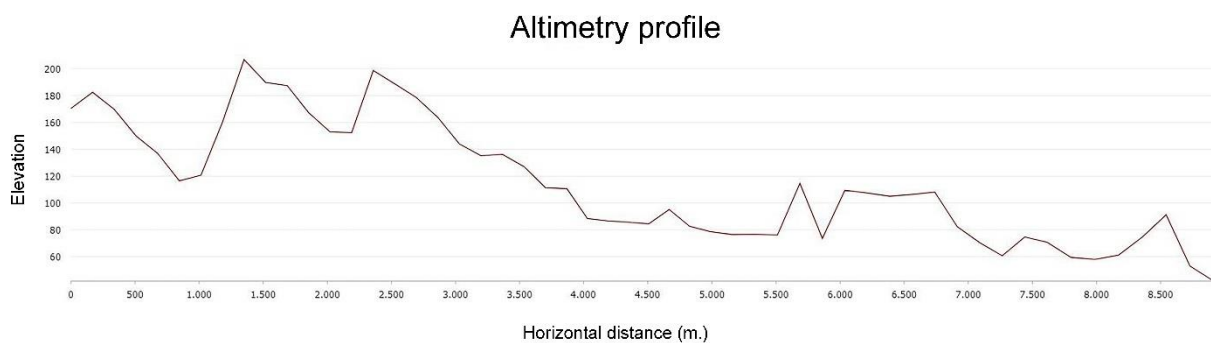


Figure 32 - Altimetry profile of the main axis of fire propagation.



Figure 33 - ATI photo in the initial area of the fire (Source: ATI photos from the Monitorisation Special Fire Brigade).

Figure 33 illustrates the lower wind intensity and higher flame intensity in the early phase, coincident with the information on the fire intensity in the simulation (Figure 34). Therefore, the head of the fire was out of fighting capacity during most of the afternoon.

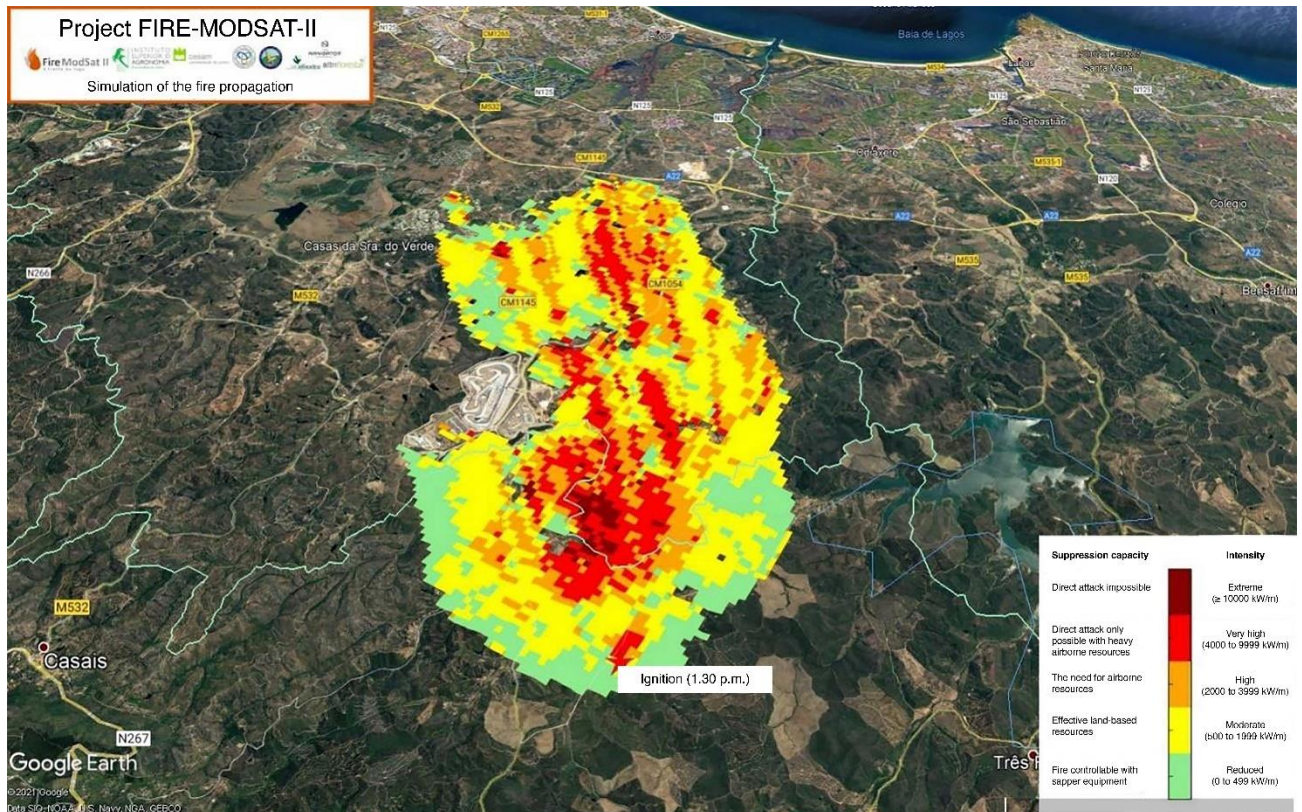


Figure 34 - Simulation of fire intensity (Benali, A., Sá, A.C.L., Briquemont, F., Pereira, 2021).

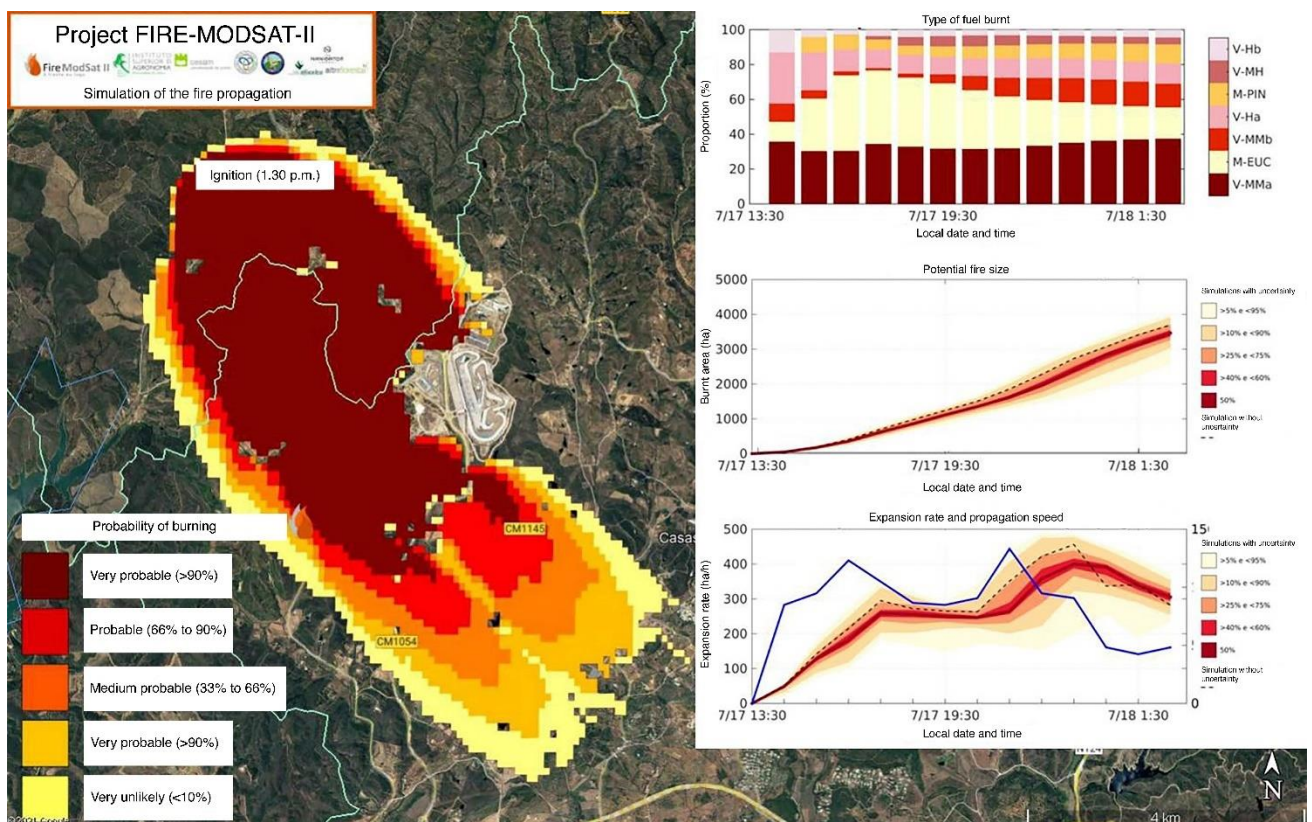


Figure 35 - Simulation of the fire perimeter at 8.30 p.m. (7 hours) and the data related to the analysis of the total simulation made until 1.30 a.m. (without counting the firefighting) (Benali, A., Sá, A.C.L., Briquemont, F., Pereira, 2021).

The fire took only about 7 hours to cover about 9 km from the ignition point (11.3 km taking into account the slopes) (without counting the last secondary outbreak), with a behaviour similar to a wind fire and substantial propagation by the projection of incandescent particles. Despite small variations in wind direction, especially in the late afternoon (sea breeze), which foresaw the possibility of the left flank opening, it was the north/northwest wind that was the most dominant, leading the fire until the end, becoming preponderant to close both flanks, being the right one more important, due to its greater opening due to the existence of more fuel and less access. The head of the fire, in turn, was dominated by the combat and many discontinuities, such as the primary strip network system for fuel management (Figure 36). Even though the best conditions were not the best, it was where the fire slowed and stopped, allowing a more effective combat and improvement of consolidation with tracked machines.

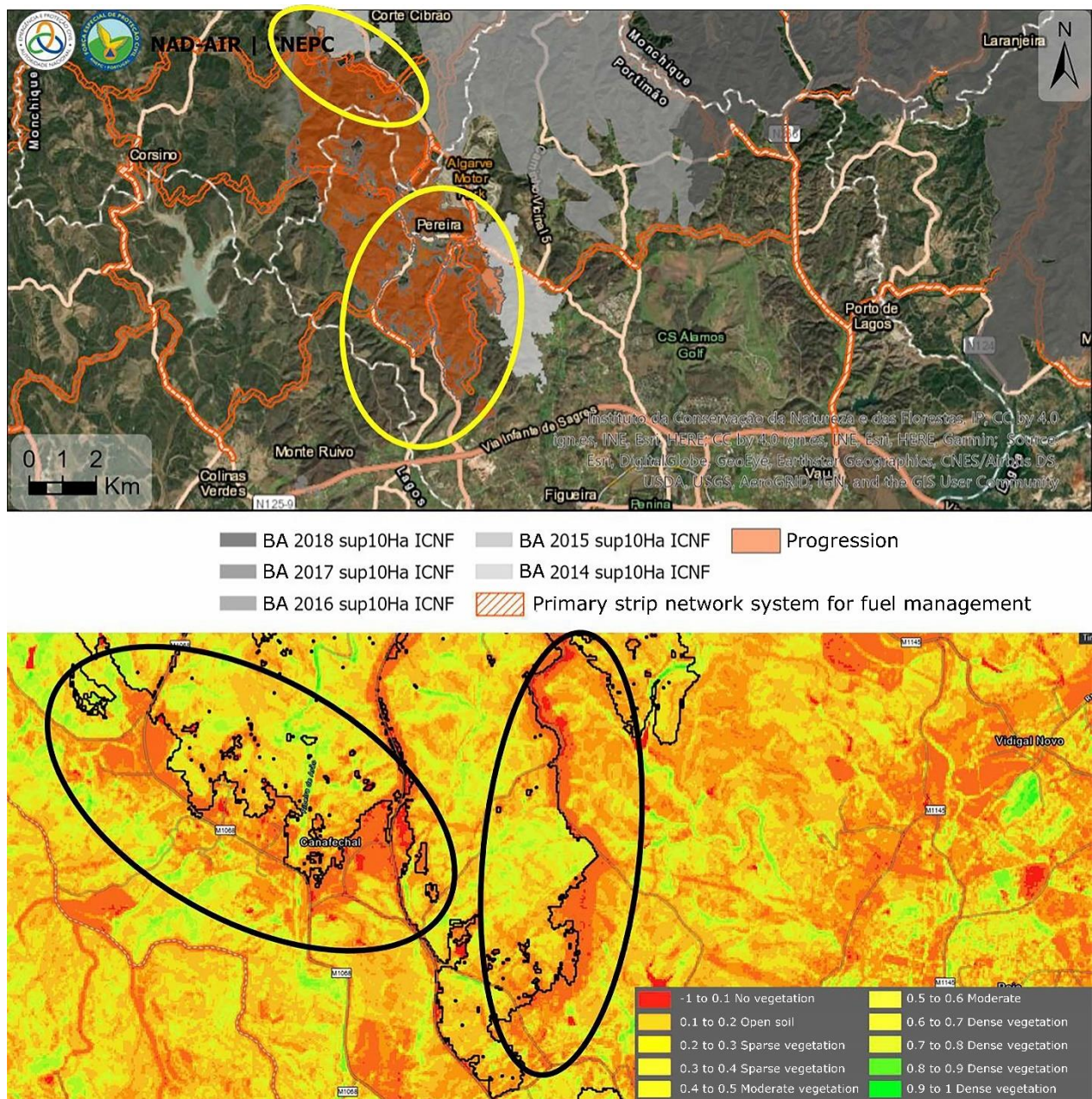


Figure 36 – In the upper part of the figure, areas of greater discontinuity with the primary strip network system for fuel management. In the lower part of the figure, the NDVI in the area where the fire head has stopped, with most of the locations having little or no vegetation (ICNF, 2021b; NAD-AIR, 2021).

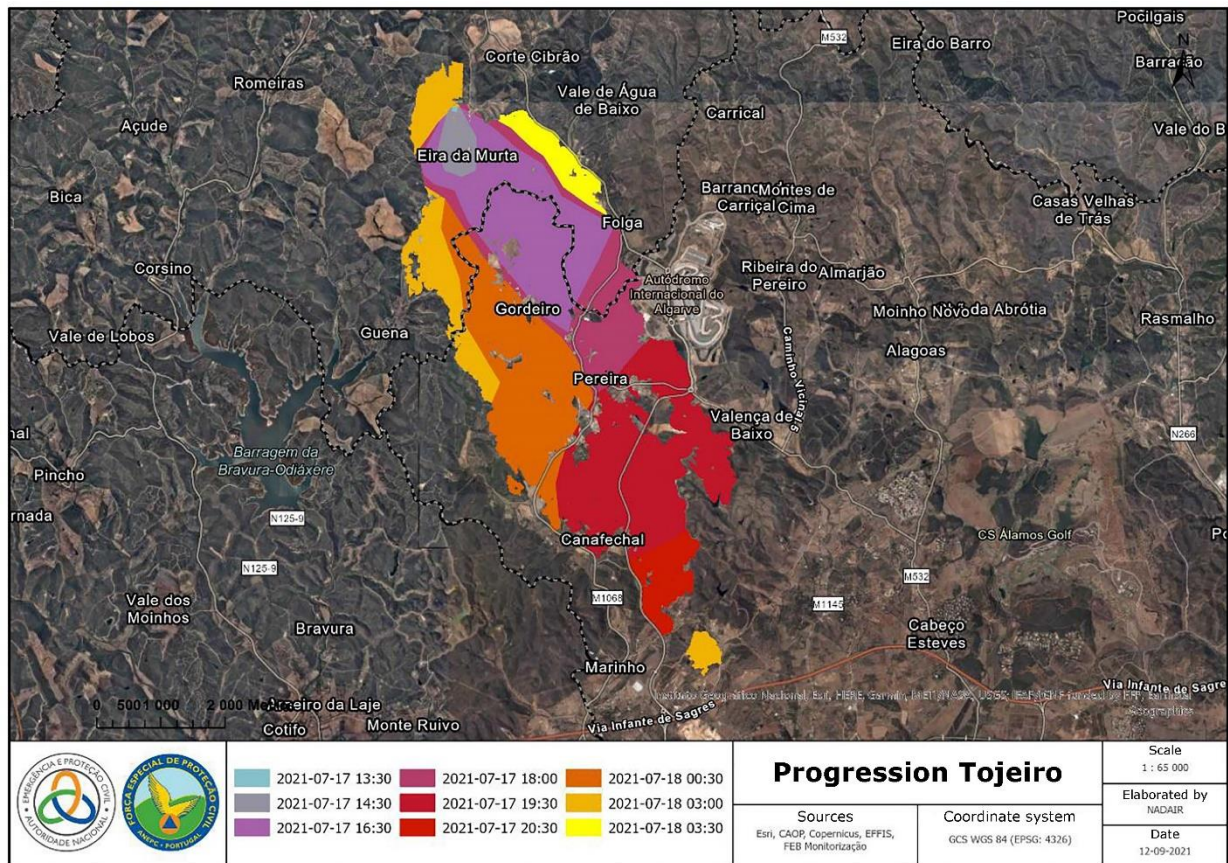


Figure 37 - Hourly fire progression (NAD-AIR, 2021; NASA, 2021a; Sentinel Online - ESA, 2021).

The reconstruction of the fire's progression (Figure 37) shows that it had several periods of propagation speed and expansion rates. These features are especially evident in areas with higher slopes and an abundance of biomass before the Autódromo between 2.30 p.m. and 4.30 p.m. (mentioned previously), reaching a propagation speed of almost 2000 m/h immediately after the Autódromo and exceeding 2000 m/h between 6.00 p.m. and 7.30 p.m. (Figure 38). The period between 7.30 p.m. and 9.00 p.m. was already where the fire head stalled, at the intersection of the primary strip network system for fuel management.

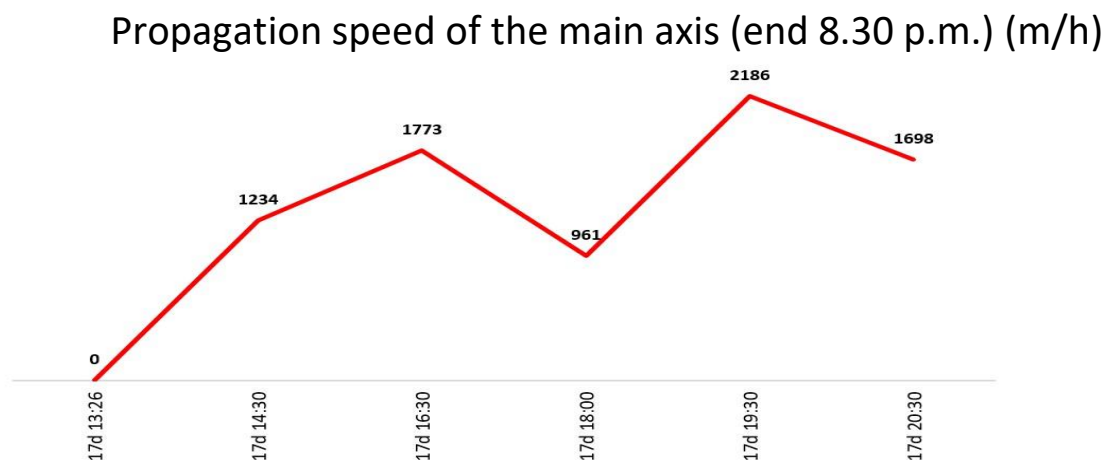


Figure 38 - Estimated velocity of the fire's propagation, until the head is dominated by the fire management strips (without accounting for the secondary outbreak) (NAD-AIR, 2021).



Regarding the flanks, they kept opening proportionally even after the head of the fire was dominated, causing the fire to continue its expansion until the early morning of 18 July. The flanks were the subject of much analysis, and a timely and well-planned intervention avoided a larger opening and/or stronger starts during the night and the following day (19 July).

Estimated fire expansion rate until dawn on 18 July 2021

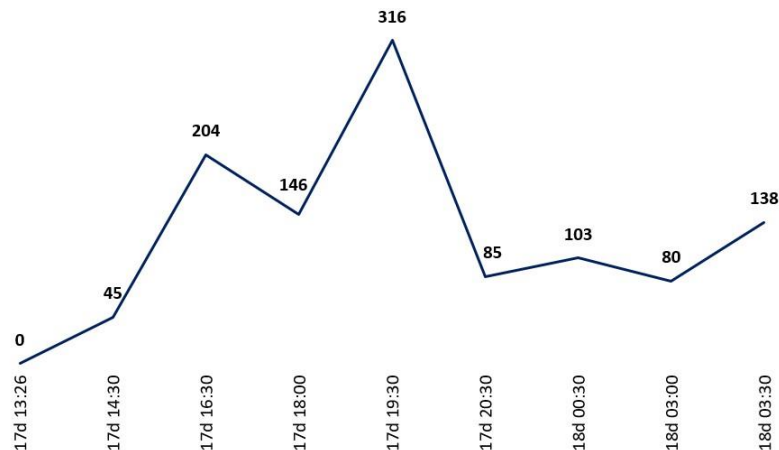


Figure 39 - Estimated fire expansion rate until dawn on 18 July 2021 (NAD-AIR, 2021).

The fire had two moments where the expansion rate was higher, coinciding with the peaks of propagation speed and the steeper slopes, more fuel, and higher intensities (simulation) between 2.30 p.m. and 4.30 p.m. In the second peak, between 6.00 p.m. and 7.30 p.m., there was an increase in wind coinciding with the time when there was a greater differential in wind intensity between the surface layer and the 950 hPa layer, thus enhancing the fire. In total, 42Tj of energy was released, verifying that the highest energy release values were observed during periods with higher propagation speeds and expansion rates.

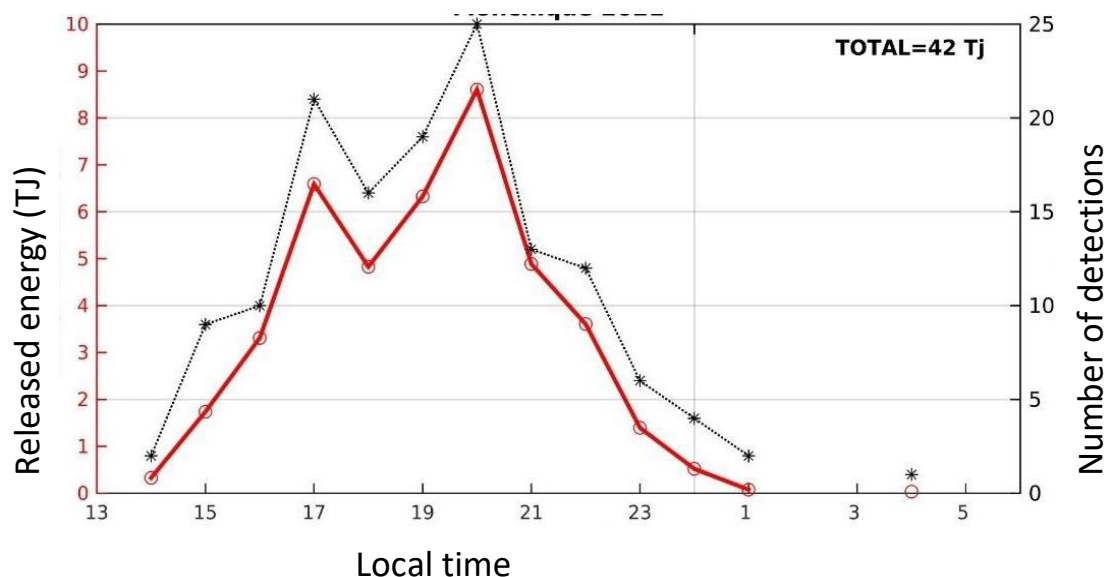


Figure 40 - Remote detection of energy released during the fire (Benali, A., Sá, A.C.L., Briquemont, F., Pereira, 2021).



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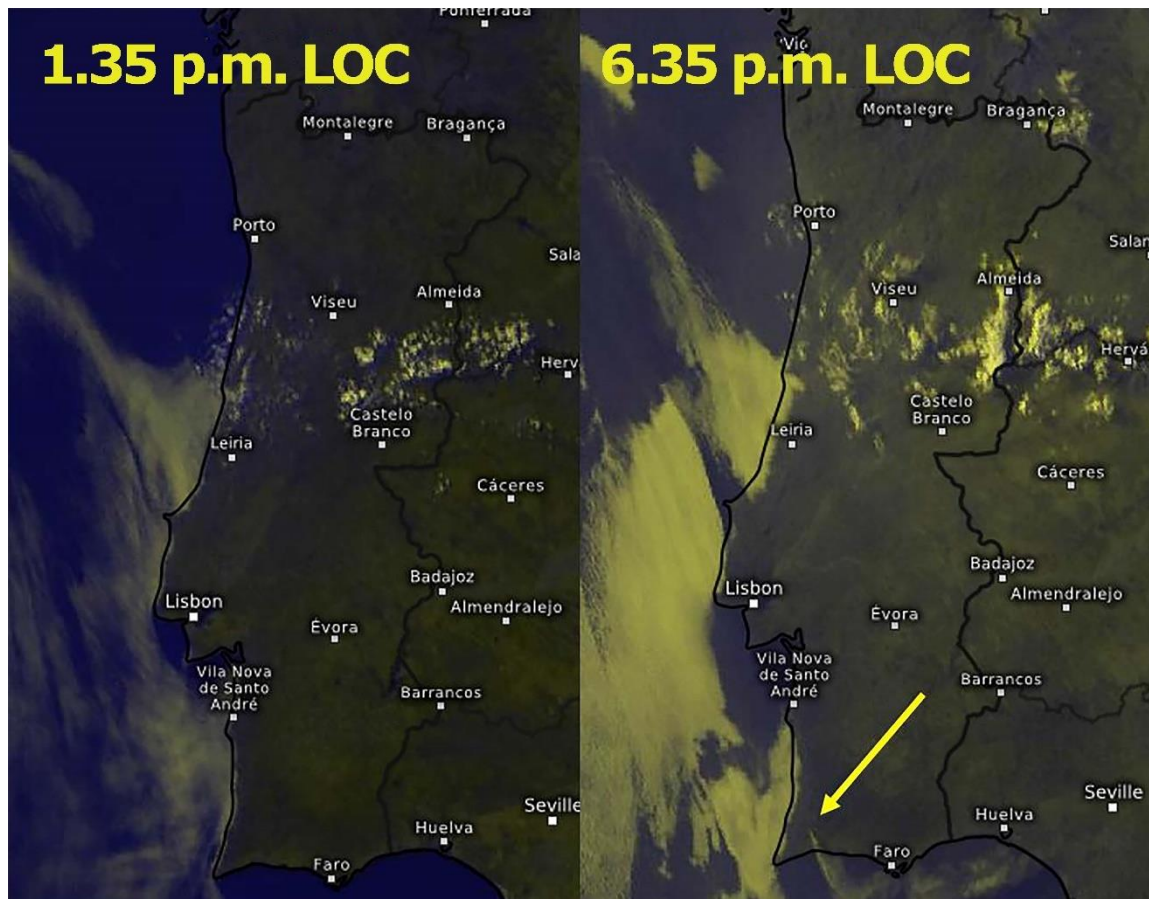


Figure 41 – Identification of the fire (visible smoke column) at 6.35 p.m. via satellite (Weather.us, 2021).

Acting proposals

When the team arrived in this theatre of operations, the fire was already attained a high propagation speed, with rapid propagation through particle projection, mainly in the head of the fire. There were many roads parallel to the flanks, and the head of the fire was heading, out of extinction capacity, to places with less combustible materials. Thus, it was proposed to reposition the combat means in front of the head of the fire in areas of discontinuities and urban-forestry interface, where it would be within the capacity of combat, and use tracked machines and tactical fire in the tail of the fire on both flanks, to prevent their opening.

On the left flank, the aim would be to take advantage of the M1068 road to close this flank so that it would not give rise to a secondary fire on the opposite side of the road. A new strong progression would emerge that overtook the Autódromo, as it ended up serving as a barrier. The right flank contained the highest amount of biomass per hectare, with the appearance of some fingers in its progression, and the same working method was proposed with tracked machines and the use of tactical fire to consolidate it effectively and prevent its opening, restricting it to the place where it was located.

Concerning the tail of the fire, it was still burning freely, and it was decided to utilise the same manoeuvres after controlling the right flank. Thus, the whole perimeter would be closed with a defined strategy to be followed until 7.00 a.m. on 18 July, when a new increase in temperature, wind intensity and eventual thermal inversion (expected for 8.00 a.m.) would occur.



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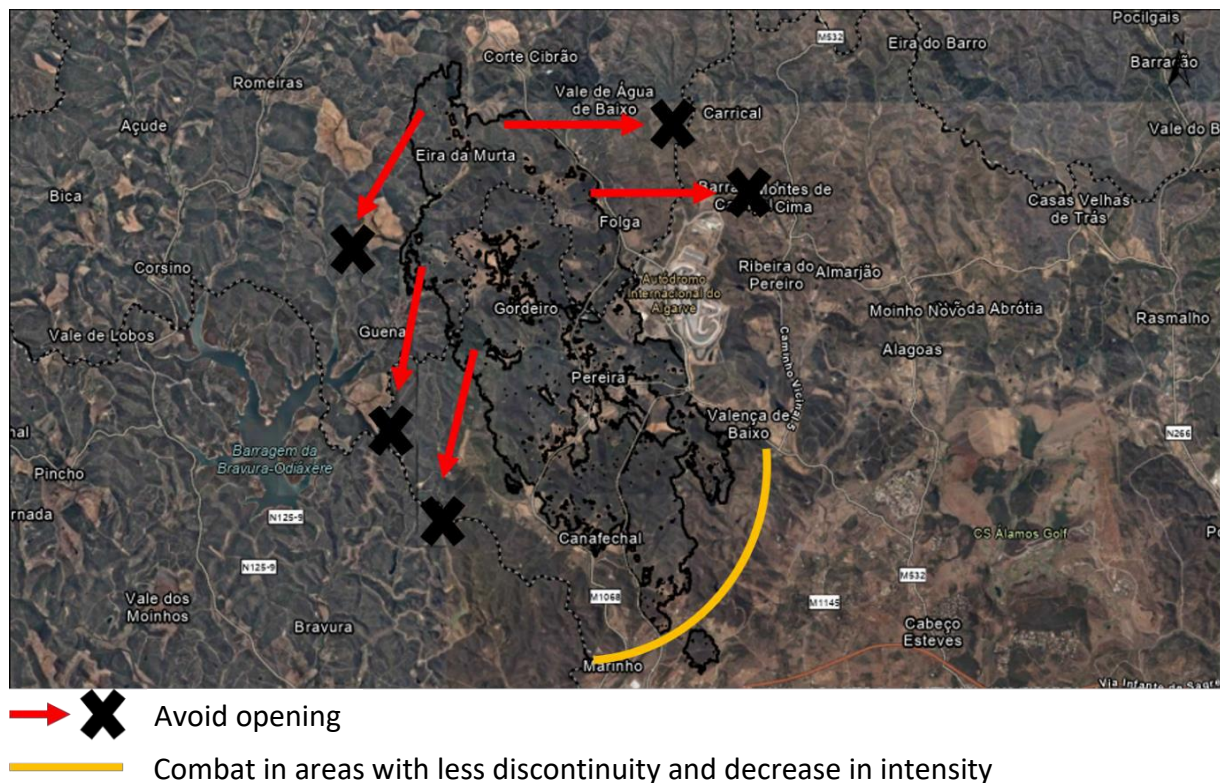


Figure 42 - Areas and objectives of the acting proposals.

Work carried out by the team

The first objective of this team was undoubtedly the recognition of the fire perimeter to analyse it in the best way. While this work was being developed, the responsible technician (ADOP FEPC Fábio Silva) went to the Command Post to start the work and support the decision-makers to outline the appropriate strategy. It was possible to make two passes in the area of the head of the fire that helped the perception of the fire's behaviour and speed of spread to support the placement of means on-site.

After elaborating the strategy, the team divided up to carry out simultaneously the tactical fire actions on the left flank and those on the right flank and later on the tail. The team had three tracker machines that supported the execution of fire management strips and consolidation of the manoeuvres carried out. Each element (2) executing the manoeuvres had a combat group at its disposal for support and vigilance. The two remaining elements (including the technician responsible) went to the tail area for a better reconnaissance because it is a more complex area, with steep slopes and few access points, where machine operators do not enter, at least not while it was at night. In the event of increased fire intensity, a strip with track machines was placed away (opposite ridge) from the tail of the fire to act as a barrier. This arrangement also provided access to land vehicles and prevented having to halt the manoeuvres that were already being carried out on the flanks (from front to back). With the rising of the day, it was possible to identify places in the tail of the fire for entry and exit of the track machine, facilitating the placement of a fire management strip closer to the active zone, attenuating the risks associated with this type of operation.

All the actions proposed in the Command Post were accepted, commissioned, and successfully executed within the foreseen schedule (7.00 a.m. on 18 July), and the fire was considered dominated by 7.15 a.m. of the same day. After these actions, the team returned to the Command Post for briefing and subsequent rest.

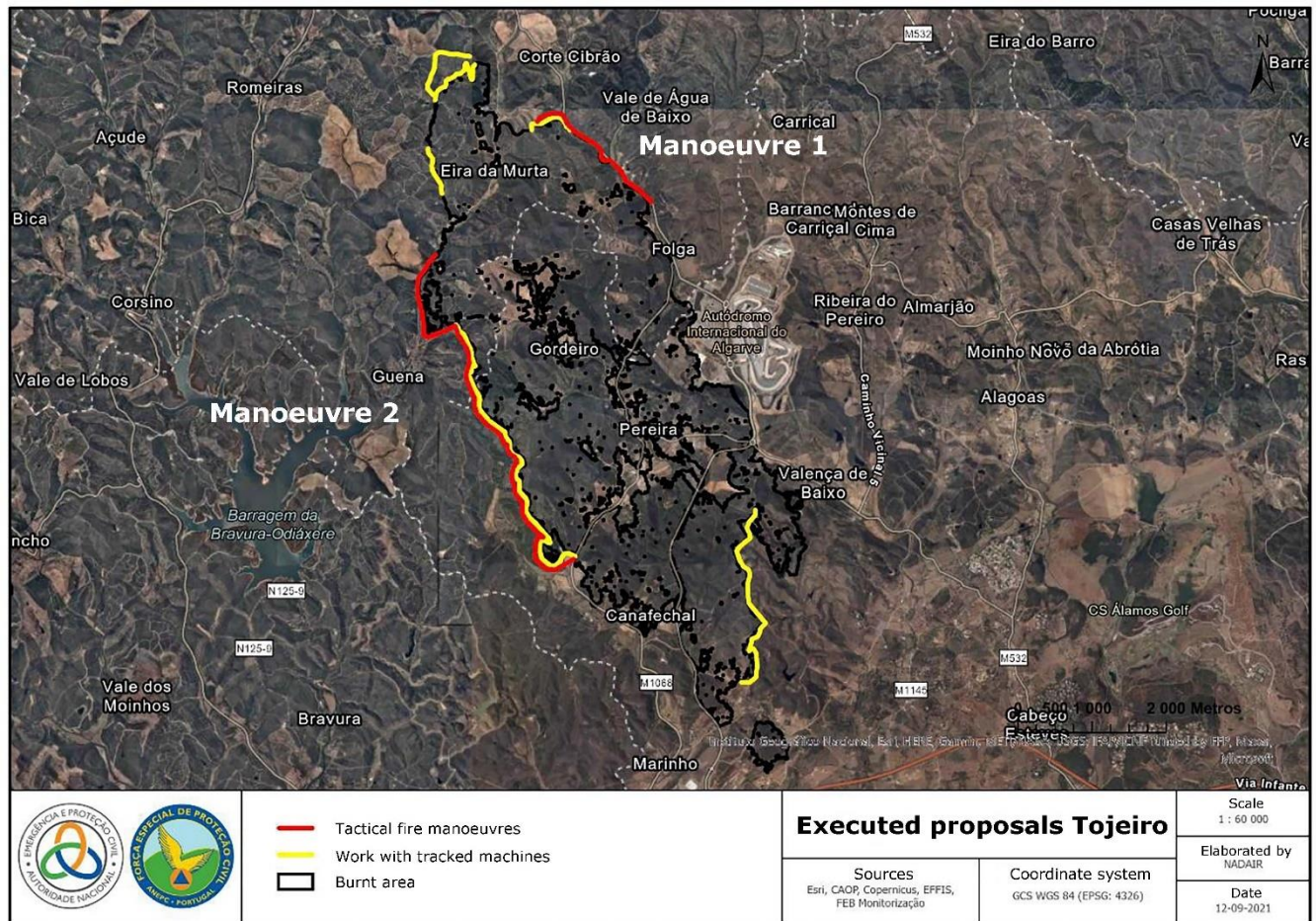


Figure 43 - Executed proposals (NAD-AIR, 2021).

Suppression fire manoeuvres

Description	Tactical fire manoeuvre 1
Objective	Prevent left flank opening before the Autódromo
Type	Tactical fire
Proposed extension	2150 metres
Extension undertaken	2150 metres
Area consumed (approx.)	50 hectares
Coordinates of the start	37°12.3080'N 8°39,4072'N
Coordinates of the end	37°14.5061'N 8°40,6753'N
Date/start time/end/total	17JUL21 / 10.30 p.m. / 6.49 a.m. / 8.19 a.m.
Secondary outbreaks	No
Success	Yes

Table 2 - General data on the use of fire manoeuvre 1.



Description	Tactical fire manoeuvre 2
Objective	Prevent opening of the right flank
Type	Tactical fire
Proposed extension	5934 metres
Extension undertaken	5934 metres
Area consumed (approx.)	60 hectares
Coordinates of the start	37°14.9072'N 8°38,7141'N
Coordinates of the end	37°15.4767'N 8°39,7247'N
Date/start time/end/total	18JUL21 / 12.00 p.m. / 7.00 a.m. / 7.00 a.m.
Secondary outbreaks	No
Success	Yes

Table 3 - General data on the use of fire manoeuvre 2.

The tactical fire manoeuvres totalled some 8 km, fulfilled their initial objective of preventing flank openings, and were an effective overnight job.

Estimation of the final perimeter of the fire

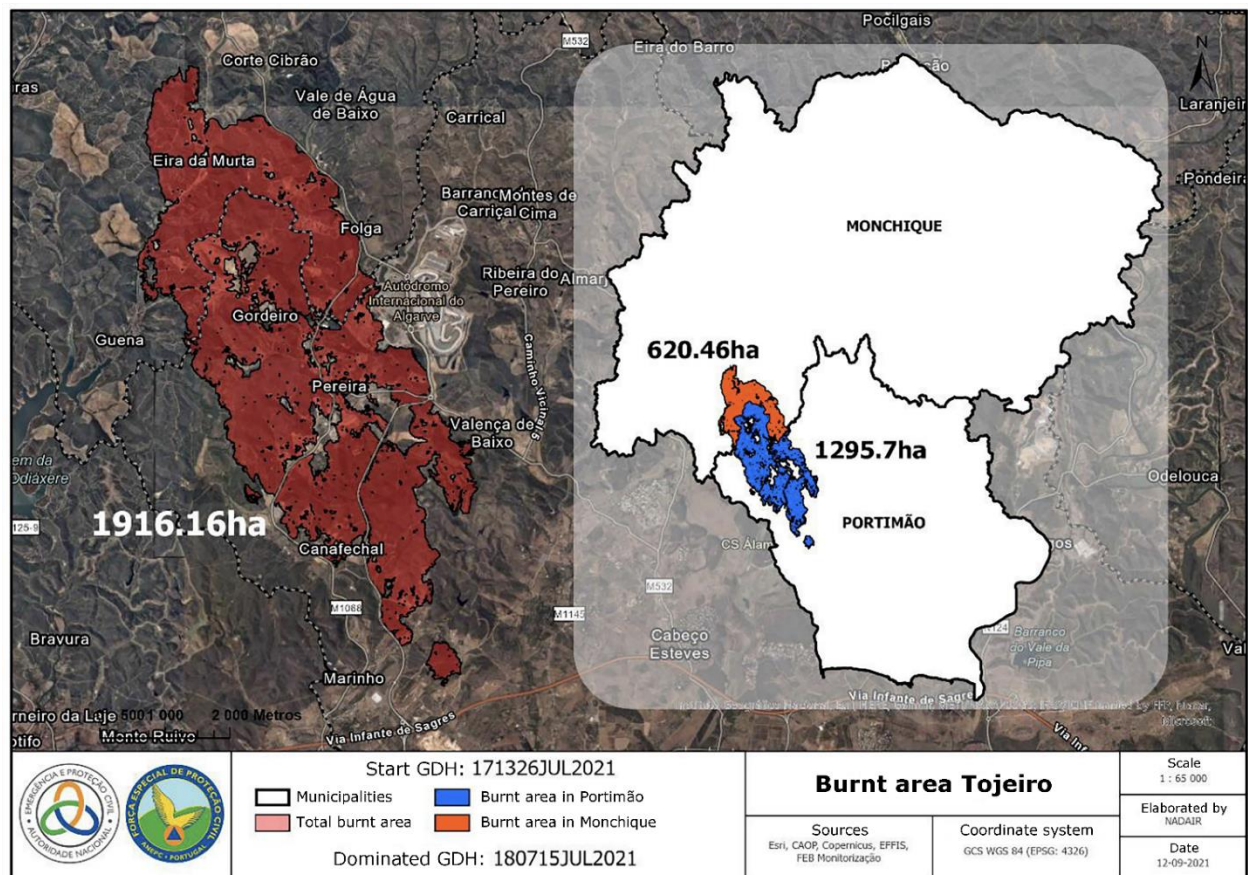


Figure 44 - Total estimated burnt area, and by municipality (NAD-AIR, 2021; Sentinel Online - ESA, 2021).

As shown in Figure 44, the fire affected two municipalities (Monchique and Portimão) with a burnt area of 620.46 ha and 1295.7 ha, respectively.

Concluding remarks

All the articulation made in the Operational Command Post was preponderant for the success of the rapid extinction of this fire. The final perimeter of the fire, which does not present a triangular shape often caused by strong pulls from the flanks, suggests that the tactical fire manoeuvres and the use of tracked machines were crucial for the operation's success.

The primary strip network system for fuel management also proved to be extremely important for the success of the fight, as it allowed the reduction of fuel and the safe access to the head of the fire by the combat operatives.



Figure 45 – Primary strip network system for fuel management, in the area of the head of the fire, captured by AVRAC on the morning of 18 July 2021.

The final average main axis spread speed, applying the three-dimensional distance, was about 1600 m/h, while the average rate of expansion until the head of the fire became dominated was about 175 ha/h, and the final average rate of expansion until the fire was dominated was about 136 ha/h.

As for the severity, only 4% of the fire was in areas where the severity was high. However, its distribution focuses more on the first half, where it was prone to greater fire intensity. Concerning low and low-moderate classes, these were observed more in the last third of the fire perimeter, an area with more discontinuities and less fuel load.

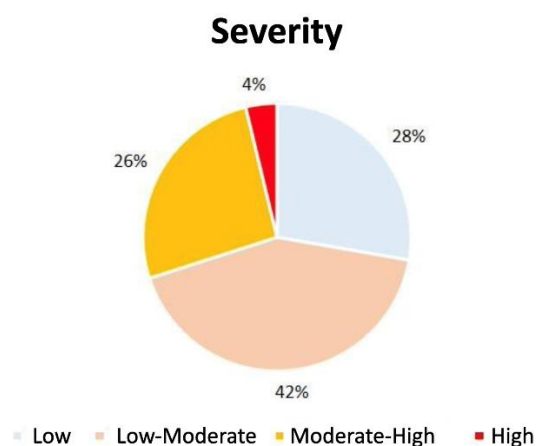


Figure 46 - Distribution of Severity classes by percentage (NAD-AIR, 2021).



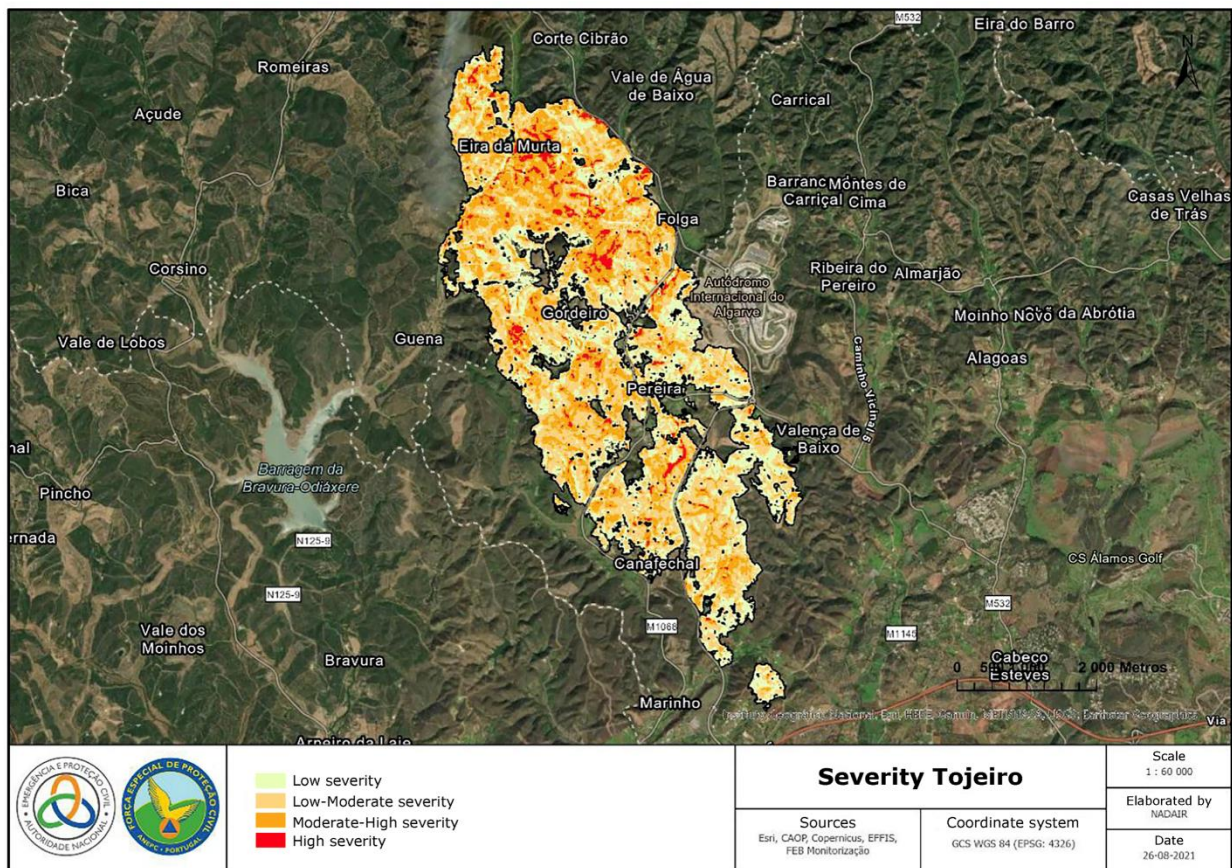


Figure 47 – Severity map (NAD-AIR, 2021; Sentinel Online - ESA, 2021).

The NAD-AIR also conducted an INFOP during this fire, which has been disseminated for operational knowledge and is available in Appendix 1 - INFOP conducted by the NAD-AIR during the fire.

Castelo Branco, 23 September 2021

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References

- Benali, A., Sá, A.C.L., Briquemont, F., Pereira, J. M. C. 2021. Simulação incêndio de Monchique DATA.
- Campbell, D. The Campbell Prediction System The Campbell Prediction System (CPS). Available from: www.dougsfire.com.
- CeaseFire. 2021. Histórico. Available from: https://www.ceasefire.pt/IDL_M_fireIV.php?&datinfo=2021-07-17&info=DC
- DGT. 2018. Carta de Uso e Ocupação do Solo de Portugal Continental. Available from: <https://www.dgterritorio.gov.pt/Carta-de-Uso-e-Ocupacao-do-Solo-para-2018>
- DGT. 2020. Carta Administrativa Oficial de Portugal - CAOP 2020 | DGT. Available from: <https://www.dgterritorio.gov.pt/Carta-Administrativa-Oficial-de-Portugal-CAOP-2020>
- ICNF. 2021a. Territórios ardidos. Available from: <https://sig.icnf.pt/portal/home/item.html?id=983c4e6c4d5b4666b258a3ad5f3ea5af>
- ICNF. 2021b. Rede Primária FGC. Available from: <https://sig.icnf.pt/portal/home/item.html?id=151ed5df1e9f4357bc4ecfde2be04e5f>
- IPMA. 2021a. IPMA - Resumo boletim clima. Available from: <https://www.ipma.pt/pt/oclima/monitoriza.mensal/>
- IPMA. 2021b. IPMA - Monitorização diária. Available from: <https://www.ipma.pt/pt/oclima/monitoriza.dia/>
- IPMA. 2021c. IPMA no apoio ao Sistema Nacional de Protecção Civil. - IPMA. Available from: <http://multisites.ipma.pt/anpc/>
- NAD-AIR. 2021. NAD-AIR.
- NASA. 2021a. Fire Map - NASA | LANCE | FIRMS. Available from: <https://firms2.modaps.eosdis.nasa.gov/map/#d:24hrs;@0.0,0.0,3z>
- NASA. 2021b. EOSDIS Worldview. Available from: [https://worldview.earthdata.nasa.gov/?v=-106.36577841515475,-46.546875,97.64702841515475,53.015625&l=MODIS_Terra_Thermal_Anomalies_All\(hidden\),MODIS_Aqua_Thermal_Anomalies_All\(hidden\),VIIRS_SNPP_Thermal_Anomalies_375m_Night,VIIRS_SNPP_Thermal_Anomalies_37](https://worldview.earthdata.nasa.gov/?v=-106.36577841515475,-46.546875,97.64702841515475,53.015625&l=MODIS_Terra_Thermal_Anomalies_All(hidden),MODIS_Aqua_Thermal_Anomalies_All(hidden),VIIRS_SNPP_Thermal_Anomalies_375m_Night,VIIRS_SNPP_Thermal_Anomalies_37)
- Sentinel Online - ESA. 2021. Available from: <https://sentinels.copernicus.eu/web/sentinel/home>
- SGIF. 2021. Sistema de Gestão de Informação de Incêndios Florestais. Available from: https://fogos.icnf.pt/sgif_app/MostraMapasGraficossrch.asp
- Weather.us. 2021. Satellite HD, Europe and Africa. Available from: <https://weather.us/satellite/europe-africa/satellite-hd-15min.html>
- Wetterzentrale. 2021. Wetterzentrale - Top Karten - GFS Europe 06Z. Available from: <https://www.wetterzentrale.de/topkarten.php?map=1&model=gfs&var=1&time=0&run=06&lid=OP&h=0&tr=3&mv=0>



Appendices



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Occurrence number
2021080029244

Locality
Tojeiro

Date
17/07/2021

Appendix 1 – INFOP (Operational Information) conducted by NAD-AIR during the fire.



INFOP – Operational information
National Command of Security Operations
Decision Support Unit - Rural fire analysis

03
2021

1 – OCCURRENCE DATA

Occurrence	Date	District	Municipality	Local
202108002944	17/07/2021	Faro	Monchique	Tojeiro

2- METEOROLOGIA

-Temperature (surface): Maximum temperature of 34 °C by 3.00 p.m. with decrease to 20 °C by 4.00 a.m. on 18 July -2021, dew point temperature of 12 °C by 16:00 with increase to 16 °C by midnight on 18 July 2021.

-Relative humidity (surface): by 2,00 p.m. a RH of about 25% with a weak recovery from 7.00 p.m. onwards with a maximum peak at 4.00 a.m. on 18 July 2021 with a recovery to 60%-70%.

-Wind: Constant wind from the Northwest and at 10 m this will be around 15 km/h with gusts that can reach up to 40 km/h

3- PREDICTION

Topographic fire which in its initial phase aligned itself with the wind direction (NW) having gained a strong increase in its initial propagation speed.

With the direction of propagation aligned with the wind, the most exposed right flank may carry out tail to head pulls.

In situations of full alignment with the slope it is estimated that the fire increases in intensity and speed, however, this will be an opportunity for suppression when it is against the slope.

4 – PRIORITIES

P1 - Dominance of the head of the fire and its consolidation if possible. (Canafechal road).

P2 - Dominance and consolidation down to mineral soil of the entire right flank (exposed to the wind). If possible with the use of tracked machines from tail to head of the fire to prevent flank pull-offs from the rear to the head.

P3 - Dominance of the left flank and consequent consolidation with the use of tracked machines from the tail to the head.

5 – SAFETY RECOMMENDATIONS

Ensure the correct implementation of safety protocols (LACES, 10 safety situations, 18 situations scream danger).

Ensure hydration of operatives during combat manoeuvres and avoid possible heat strokes.

Redouble attention to the circulation of combat vehicles on paths in the middle of the slope.

Not neglect the implementation of mitigation protocols for COVID-19.

6 – PHOTOS



Annexes - Please refer to the annexes ...



Página 1 de 2



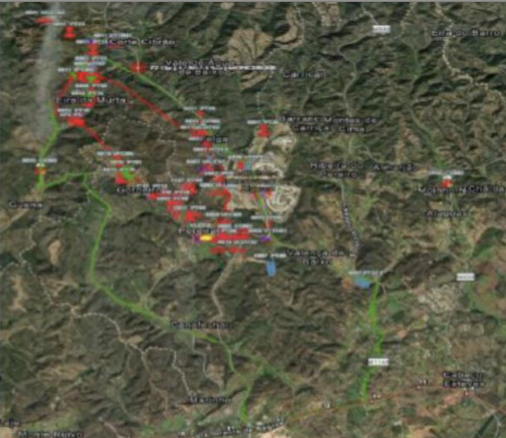
INFOP – Operational information
National Command of Security Operations
Decision Support Unit - Rural fire analysis

03
2021

7 – Map of the current situation



8 - Prediction Map



GDH: 171730JUL21

Prediction validity: 6 h 12 h 24 h outro

INFOP: Tojeiro 03/2021





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