AFAN

D2.5.

Guidelines on the use of tools, science and best practices for fire analysis

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List of Acronyms

BDIFF	Database on Forest Fires in France
DDT (M)	Departmental Directorate for the Territories and the sea
DREAM	Societa Cooperativa Agricolo Forestale - D.R.E.AM. ITALIA
ENSOSP	Ecole Nationale supérieure des Officiers de Sapeurs-Pompiers
GIS	Geographic Information System
FBP	Forest Fire Behaviour Prediction
FWI	Forest Fire Weather Index
INT-CFRS	Catalan Fire and Rescue Service
ONF	National Institute of Geographic and Forestry Information
PCF	Pau Costa Foundation
PPR	Natural Risk Prevention Plan
SDIS	Departmental Fire and Rescue Service
SWFRS	South Wales Fire and Rescue Service

Executive Summary

The current climatic conditions are conducive to an increase in the number of forest fires, their intensity and the area burnt.

All European countries are concerned, and their demographic density makes it necessary to improve the firefighting strategy and to enhance fire extinguishing capacities.

Human and technical resources are limited and must be distributed over the areas concerned within a national territory but also within the European Union and even worldwide.

At all decision-making levels, it is necessary to have forest fire analysts to anticipate the spread of fires, to help prioritise operational actions and to optimise human and technical resources.

The forest fire analyst relies heavily on his or her experience of fires but also on the training received. The analyst anticipates the spread of the fire, identifies the areas at risk, and among other tasks advices the incident commander at a manoeuvre, tactical and strategical level (see Deliverable 2.2 for further details).

To do this, the analyst has scientific and technical tools that validate the proposed actions. The present document compiles a series of tools, science and good practices that are used to perform fire analysis tasks. The items compiled in this document are non-exhaustive. The workshops organised by the AFAN project, were used to compile information for this document.

Finally, the workshops show that each country has different types of fire analysis cells, and they apply similar practices.

1

1. Introduction

Apart from fire ignitions or small fires where extinction is spontaneous (the local means are enough), the fight against forest fires requires more and more expertise. Fire fighters and foresters must optimise the means at their disposal.

In Europe, over the period 1980-2017, an average of 457,289 ha of forest (source: EU-EFFIS) were destroyed by forest fires in Spain, Italy, Portugal, Greece and France. In 2017, 178,234 ha burned in Spain, 540,630 ha in Portugal and around 100 people died in the Iberian Peninsula, mainly in Portugal. Thus, in 2020, about 340,000 hectares of forest burned in the whole of the European Union. The most affected countries are Romania, Portugal, Spain and Italy.

In 2021, more than 500,000 hectares were burnt, 61% of which was forest. Fires are no longer limited to the southern countries but represent a growing threat to Central and Northern Europe.

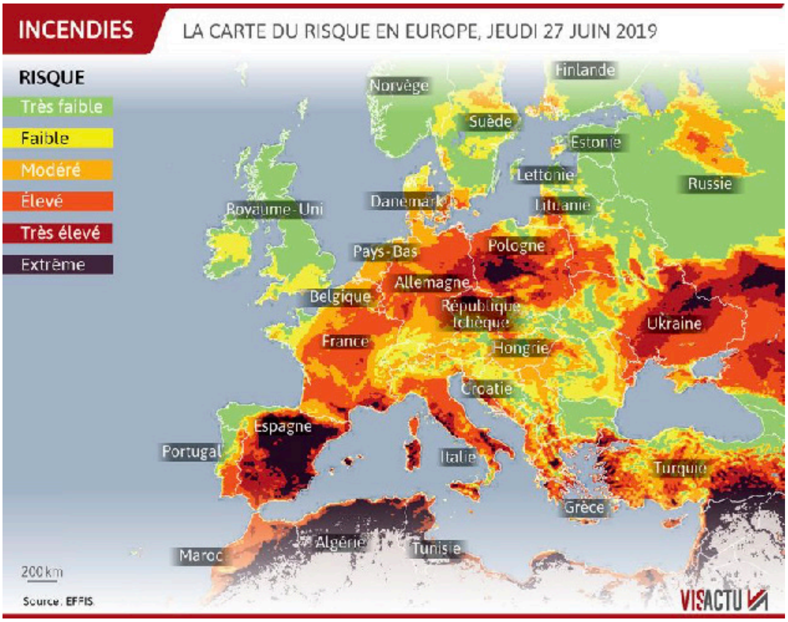

Figure 1.Climate change affects the duration and severity of the fire season forcing the European Commission to change its strategy. Source: EFFIS.

On 24 February 2021, the European Commission adopted the Communication 'Forging a climate-resilient Europe – the new EU Strategy on Adaptation to Climate Change'. The Strategy outlines a long-term vision for the EU to become a climate-resilient society, fully adapted to the unavoidable impacts of climate change by 2050. This strategy aims to reinforce the adaptive capacity of the EU and the world and minimise vulnerability to the impacts of climate change, in line with the Paris Agreement and the proposal for a European Climate Law.

Climate change is changing weather conditions; vegetation is becoming drier. Higher temperatures encourage plants to transpire and the water content of the soil to decrease. As the vegetation dries out, the risk of fire outbreaks is higher (Figure 1). The absence of rain, combined with an early rise in temperature, increases the fragility of the massifs. The risk period becomes longer and more intense.

In addition to the impact on people and property, wildfires have short- and long-term impacts to the fauna and flora of the affected areas. Thus, any fire has an immediate impact on the main functions of the forest:

- Economic: loss of timber value and production, impact on economic and tourist activities.
- Environmental: potential damage to biodiversity and landscapes, regulation of the water regime, water quality, air purification, carbon storage.
- Social: recreational activities, hunting.
- Trigger of other risks: rock fall, landslides, erosion, torrential floods, avalanches in the mountains.

During wildfires, air and land-based fire-fighting resources are spread over large areas. With the wildfire threats increasing in Europe due to climate change, many countries with very large human and technical resources are adapting and optimising their commitment by implementing fire analysis.

Within the framework of the AFAN project, analysts from different countries (e.g. Wales, Spain, Italy and France) were able to exchange views during different workshops (Spain, Italy and France), webinars, and important documents, which can be found on the website (https://fireanalysisnetwork.eu/). These documents give a good understanding of what fire analysis is. The present document complements the list of outcomes, by describing different tools, science and best practices used in fire analysis.

The knowledge of these factors is essential for meaningful analysis. Tools, good practices and applied science are the expression of these factors.

The development of knowledge improves the expertise of wildland fire analysts.

2

2. Analysis tools

The fire analysts from the different countries that have been consulted to create this document use approximately the same tools. On the other hand, they do not use the same method, which depends on the available resources, ancestral habits and also on the mastery of techniques.

Different countries develop their own analytical tools. They respond specifically to their expectations and the implementation is limited to national boundaries. They are not accessible to all.

However, there is a certain similarity between countries. Within the European Union, they all benefit from the results of programmes dealing with wildfires, climate change, weather forecasts, etc.

The examples listed below are identified during the workshops organised during the AFAN project. In addition, a database with tools, science and best practices as developed during the project, accessible through the AFAN website. In order to feed the database, a questionnaire was sent to more than 150 correspondents, wildfire experts and decision makers in the operational chain of command, mainly from European countries. Without being precise, they all use the same type of tools.

2.1 Examples of wildfire event databases

2.1.1 The wildfire database (BDIFF)

Name	The forest fire database
Region of implementation	French national level
Year of creation	2006
Description	Application of fire history: date, location, area
For who	Analysts, forest engineers, public authorities, urban planners
For what (analysts' point of view)	Combined with historical weather conditions, this BDIFF application allows to improve the prevention system and to anticipate the spread from an existing model
Link	https://bdiff.agriculture.gouv.fr/incendies (accessible by means of a login)
Main characteristics of the tool	Improving the prevention system: The fire history gives indications of the shortcomings to be corrected. It allows for the establishment of more optimal prevention tactics through the installation of water supply points, access roads, turning areas and also the establishment of urban planning rules integrated into the environment. Anticipate the spread: The fire analyst knows in advance the potential area affected by the fire. The impact of the terrain becomes a constant. The analyst can therefore focus more on the atmospheric and meteorological conditions and the type of vegetation. As well as the anticipation the areas at risk or those that require reinforced means. Hosted by the National Institute for Geographic and Forestry Information (IGN) of France. Since 1992, it has been collecting, at the national level, all information on wildfires and, in particular, the causes of these fires. These data, made available to the public, are declarative data filled in by a network of contributors under the national supervision of the ministries in charge of forests and the Interior of the French government. It identifies the areas impacted by wildfires.

2.1.2 The Prometheus Database

Name	The Prometheus database
Region of implementation	French Mediterranean area
Year of creation	1973 and upgraded in 2011
Description	Recording of fires: date, location, area, nature of the cause, origin of the alert, type of damage.
For who	Firefighters, analysts, foresters, public authorities, town planners, gendarmerie and police.
For what (analysts' point of view)	To have a reliable statistical tool that allows spatial and temporal comparisons and a better understanding of the causes.
Link	https://www.promethee.com/incendies

2.2 Examples of Meteorological Tools

2.2.1 Hazard Map - GIS

Name	GIS
Region of implementation	Worldwide
Year of creation	1980 then developed to the present day
Description	Mapping wildfire risks according to meteorology and vegetation conditions.
For who	Firefighters, analysts, forest engineers, public authorities.
For what (analysts' point of view)	Knowing the risk areas and anticipating fire behaviour.
Link	https://www.promethee.com/incendies
Main characteristics of the tool	There are different types of fire danger maps, each depending on the scale, the formula used for the calculation and expertise of the region where this tool is implemented. The objective of this tool is to anticipate fire conditions and to prepare command centres to deal with a potentially tense situation. This forecasting tool is the result of the expertise of meteorologists combined with that of fire managers in the field (Figure 2). This map is used to identify risk areas and to adapt the operational system in terms of land and air resources.

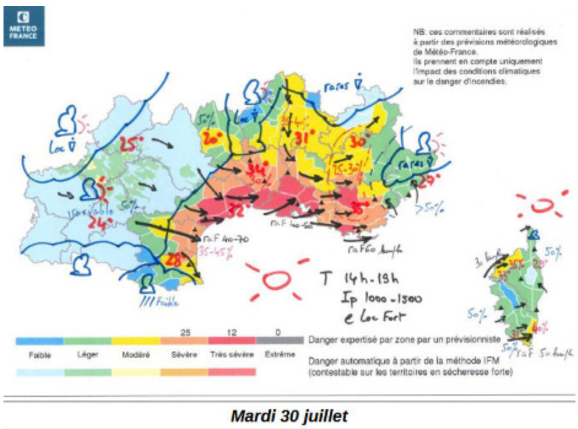

Figure 2: Example of a hazard map created of Tuesday 30 July 2021 in the French Mediterranean area. Source: Zonal Command post.

2.2.2 Measurament tools

2.2.2.1 Weather Portable Station

Name	Kestrel 5500 Fire Weather Meter Pro
Region of implementation	Europe
Year of creation	Unknown
Description	Portable weather station.
For who	Forest engineers, firefighters, hikers.
For what (analysts' point of view)	This portable tool collects local data very accurately (Figure 3). These data are essential for defining the spread of the fire and its speed and the humidity. Precise knowledge of the meteorological conditions at the site of the fire will enable the analysis of the fire to be refined and the spread and speed of the fire to be defined more accurately.
Link	https://kestrelmeters.com
Main characteristics of the tool	Accurate, multilingual mobile phone. When the fire breaks out and analysts intervene, they use a tool to know the local situation. The majority of countries turn to a portable tool such as the one developed by the company Kestrel. It is the most rustic. It provides accurate data close to the site of the fire. Like a small mobile weather station, it gives wind speed, temperature, humidity, and other information depending on the tool you use.

Figure 3. Weather mobile measurement tools.
Source: raphaelsupplisson.wixsite.com

2.2.2.2 Weather Mobile station mounted on vehicle

Name	Weather Mobile station mounted on vehicle.
Region of implementation	France
Year of creation	Unknown
Description	Portable weather station.
For who	Forest engineers, firefighters, analysts.
For what (analysts' point of view)	Another tool used in the field is the weather station installed directly on the command post or on an analyst vehicle (Figure 4). Such a vehicle allows for mobility and immediate weather information on the incident. On large fires, the mobile station can measure the weather conditions on different areas. The analyst adapts and refines his work thanks to the data.

Figure 4. Weather mobile measurement tools in vehicle.
Source: raphaelsupplisson.wixsite.com

2.3 Fire behaviour analysis tools

2.3.1 Campbell Prediction System (CPS)

Name	Campbell Prediction System
Region of implementation	South of Europe, Canada, USA, Australia.
Description	CPS is a tool that allows analysts to justify the logic of analysis and also the language to express it from a scientific basis.
For who	Firefighters
For what (analysts' point of view)	The Campbell Prediction System (CPS) is a practical way to use on-scene fire behavior observations to determine fire behavior strategies and tactics.
Link	http://emxsys.com
Main characteristics of the tool	It is one of the resources used to determine control strategies and tactics based on fire behaviour. It involves using observation of fire behaviour to predict and anticipate danger points, firefighting opportunities and control threshold.

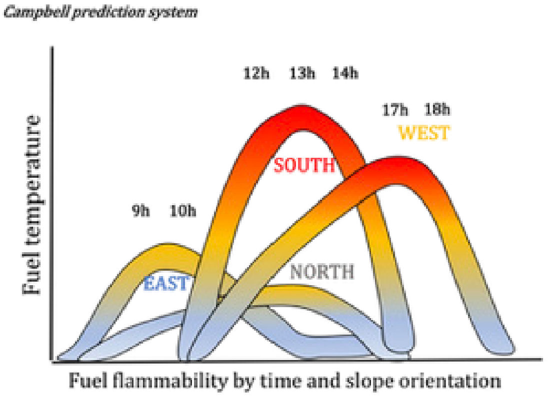

Figure 5. Campbell Prediction System Explanation.
Source: http://cps.emxsys.com/chapter-12-cps-rx-alignment-of-forces/

2.3.2 Examples of simulation softwares

Name	FireTactics
Region of implementation	France
Year of creation	1990
Description	Based on a propagation model developed by JC.Drouet-Elliptical contagion model-Input data: relief, vegetation, meteorological conditions. In includes 5 vegetation models and it is used in the framework of risk studies, for experience feedback, in the framework of firefighting. It can be used in real time. ater requirements, number of firefighting machines.
For who	Firefighters, American Air Force.
For what (analysts' point of view)	To simulate the spread of wildfire.
Link	researchgate.net
Main characteristics of the tool	In the field, FireTactic® allows you to: make topographic sections of the terrain, position or radio position vehicles, make SITACs and print them out for reinforcements, simulate the contours of the fire based on the weather, relief, vegetation, urban areas, etc... (JC Drouet algorithm) and integrate dynamic fire barriers. As a fire is the result of several complex physical phenomena, no study has yet led to a complete understanding of the concepts involved. Experiments on this subject are few and far between and there are a few software programs that simulate the evolution of forest fires (such as Farsite or FireTactic). As these programs are intended to help professionals, they are not easily accessible. They are not widely used in command posts. The propagation plumes are still too far from reality.

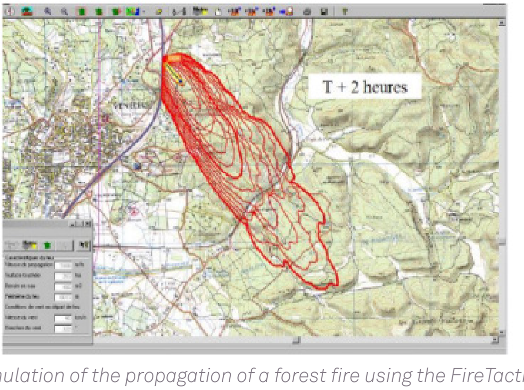

Figure 6. Simulation of the propagation of a forest fire using the FireTactic software. Source: https://www.valabre.com.

2.3.3 SandBank

Name	Sandbank
Region of implementation	Italy
Description	The characteristics of the terrain are reproduced on sand to facilitate the study of propagation
For who	Forestry agencies, firefighters.
For what (analysts' point of view)	The propagation is anticipated and makes it possible to define the sensitive zones, the zones more favourable to extinction.
Main characteristics of the tool	The sandbank facilitates observation and changes the perspective with which wildland firefighters at all levels approach the analysis of fire behaviour, designing a learning environment that promotes the assimilation of concepts. There are different types of sandbanks: – Playful with miniatures, simulating the location of machines and poles. – Virtual, using an overhead projector to simulate the spread of fire in the field. Depending on the software used, it is possible to position machines virtually or via miniatures. In the field, the coordinator can draw the situation in the field during a briefing. In any case, the sandbox is meant to be educational in order to better represent the situation. The tool can be modelled at will. In Tuscany (Italy), DREAM uses the sandbank to: – Lessons learned: to understand fire behaviour and propagation patterns – To simulate scenarios and carry out exercises during training sessions

Figure 7. Sandbank use for training by DREAM Italy, Tuscany. Source: DREAM

2.4 Enviromental scanning tool

Name	Environmental scanning tool
Region of implementation	Europe
Description	Consist on: 1) Teams that take samples and identify the water stress of the sample. These data are used to produce the hazard map. The photographs make it possible to visualise the state of the plants over a large part of the territory. 2) A platform that receives photographs taken by walkers and professionals and allows the state of the vegetation to be frozen and its capacity to burn to be visualised.
For who	Forest engineers have the best network on the ground and the best knowledge of the vegetation.
For what (analysts' point of view)	It is a tool to explore plant drought conditions, from the actual water content in plants, it gives information on fuel availability. Therefore, it can be a tool to build fire risk maps or to assess expected fire behavior.

2.5 Analysis of the mapping

2.5.1 Copernicus

Name	Copernicus
Region of implementation	Europe
Year of creation	1998
Description	Satellites pictures
For who	Crisis manager
For what (analysts' point of view)	It allows to know the situation on the ground: burnt surface, contour of the fire, impacted areas.
Link	https://www.copernicus.eu/fr
Main characteristics of the tool	Copernicus is based on four "pillars": A space component consisting of satellites for observing the ground, the oceans and the atmosphere, which, with the help of different types of instruments (camera, synthetic aperture radar, spectrometer, altimeter, radiometer), collects data on the entire planet (source: Copernicus website). The Copernicus services exploit this satellite data and process it for use by the recipient services. They archive data that is several decades old, making it possible to make comparisons and, for example, to measure the regression of the Amazon forest, the impacts of global warming, etc. Maps are created from images, features and anomalies are identified and statistical information is extracted.

Figure 8. Greece, fire damage on the island of Evia seen by the Sentinel-2 satellite. Source: Copernicus

2.5.2 Spatial data portals

2.5.2.1 Geoportal

Name	Geoportail
Region of implementation	France
Year of creation	2006
Description	Online mapping
For who	Firefighters, authorities.
For what (analysts' point of view)	taking into account the actual mapping for example to facilitate the access.
Link	https://www.geoportail.gouv.fr/
Main characteristics of the tool	Created in 2006, Geoportail is a website that allows you to benefit from the online mapping of the French territory. It is freely accessible and used for operational purposes but also for urban planning. It provides a map in different modes, which gives the status of the terrain, vegetation cover, access, urban and peri-urban areas. The resulting analysis will allow the identification of areas to be protected and the capacity for intervention.

Figure 9. Roquebrussanne city in the Var department (France). Source: Geoportal

2.5.2.2 Open SIS

Name	OpenSIS
Region of implementation	France
Year of creation	2017
Description	Location of the different types of vegetation and all static means involved in the fight against forest fires (at the regional level)
For who	Firefighters, forest engineers.
For what (analysts' point of view)	It allows the identification of effective control areas. With the help of a fire analysis, the emergency operations commander has a tool that refines his operational plan. The analysts are able to identify the areas that can be protected or the most effective extinguishing areas.
Link	https://www.opensis.fr
Main characteristics of the tool	Created in 2017, it lists in each French department the type of vegetation in a given sector, the water points, and all the static means of defence against forest fires. It is an operational tool that is not accessible without a right. This site lists up to 36 types of vegetation defined in consultation with the firefighters and foresters, 7 categories of massifs: coniferous forest, deciduous forest, open forest, etc. It enables the propagation of fire to be anticipated, as well as the phases of acceleration or deceleration.

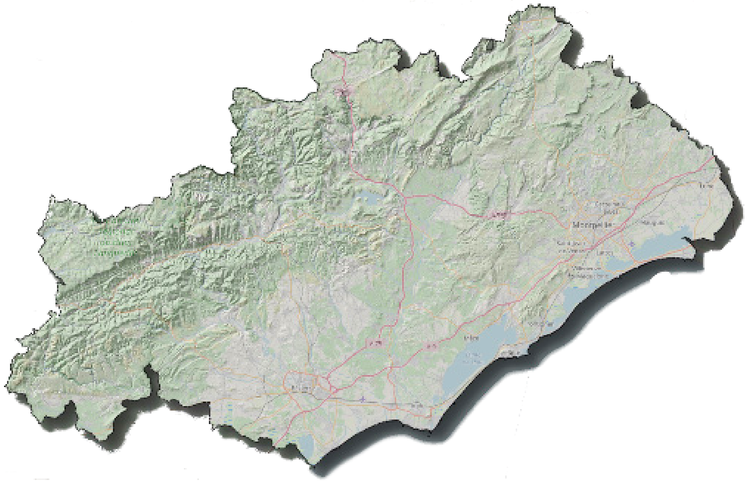

Figure 10. Example of Open SIS.
Source: https://www.opensis.fr/34/index.php/view/

2.5.2.3 Open DFCI

Name	Open DFCI
Region of implementation	France
Year of creation	2017
Description	Placing on a map all the tactical means involved in the fight against forest fires.
For who	Firefighters.
For what (analysts' point of view)	Identification of optimal control areas.
Link	https://opendfci.fr/map/
Main characteristics of the tool	The OpenDFCI platform makes it possible to disseminate the shared and updated zonal database of DFCI equipment to the various actors involved in preventing and fighting forest fires, in the form of a homogeneous map of the French Mediterranean region. Updated annually, this application develops its own location system, which is easy and common on the French territory. In addition to the relief, accesses, vegetation cover, water points, turning areas, etc. are identified. It is a tool that facilitates the management of operational resources.

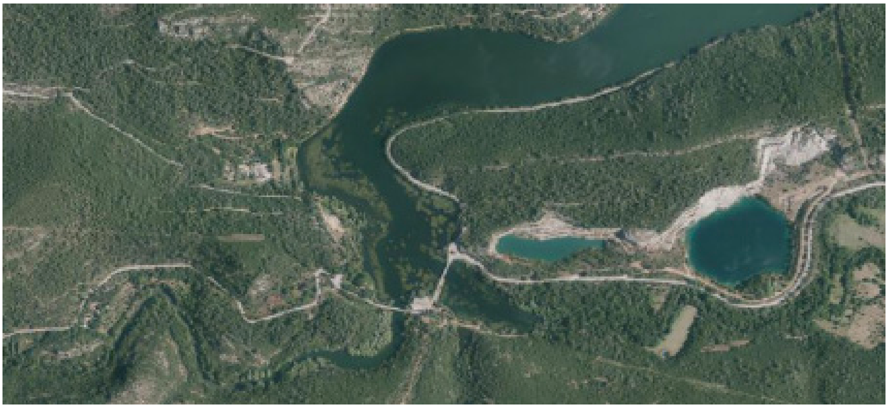

Figure 11. Example of image provided by the platform.
Source: https://opendfci.fr/map/

2.5.2.4 Operational Mapping (multiple sources)

Name	Operational Mapping (multiple sources)
Region of implementation	Europe
Description	Satellite pictures
For who	Firefighters, decision makers.
For what (analysts' point of view)	Location of the fire.
Main characteristics of the tool	Operational mapping is a tool for assistance and decision-making. It allows an event to be visualised in a given territory and time. The interest is to present a realistic vision of the event as well as of the operation. There are four main objectives: – To provide information on the event in space and time. – To show all the information that supports decision-m – To show the evolving data such as the fire perimeter or the stakes. – Indicate possible intervention scenarios. Operational mapping is used either on paper or on digital media and is updated by a fire officer in charge of anticipating the incident. Information such as roads, structures, fuel breaks, water points, topography, vegetation groups are displayed on a 1:25,000 scale map and are available in both paper and digital format. The only difference between the two is that the digital format allows distances and areas to be measured in a more interactive way. However, fire analysts prefer to work on the digital format because they can draw the perimeter of the fire and annotate the necessary information on the ground. During the incident, the map is updated by the incident commander himself and his team at the incident command post. Digital maps allow for better analysis of the terrain where the fire is moving. They are also useful for deciding on strategies and tactical deployment: access roads, anchors, spread trigger points and fire operations opportunities.

3

3. Good practices

3.1 Fire fighting and defensibility

Analysts use tools, including the examples given in the previous chapter.

The analyst must interpret his or her knowledge to ensure the defensibility of areas affected by forest fires.

Defensibility is a concept specific to wildfire risk, as it takes into account the possibilities of intervention by the emergency services, whose role is paramount in crisis management. Defensibility corresponds to the capacity of an area to be defended. It is assessed according to the following three criteria:

- Access: the ability of the emergency services to access the buildings to be defended in safety. Accessibility depends on the architecture, size and signage of the access roads, but also on their vegetation environment;

- Hydrants or fire defence reserves: they determine the possibility for the emergency services to replenish their water supplies. This resupply must be able to take place as soon as possible and in safety.

- Brushwood clearing on the fuel breaks located on either side of the access roads contributing to the defensibility of the zone: it conditions the intensity of the fire front threatening these access roads and then the constructions.

Good practices are those that allow for the avoidance or resolution of a fire.

Whatever the practices, they all have a positive impact on the fight against forest fires.

They are often linked to the technical and human capacities of the territory. The analyst needs access to a number of different types of information:

3.2 Realisation of the Forest Fire Weather Index

Name	Forest Fire Weather Index
Region of implementation	France, Canada
Year of creation	1970
Description	The forest fire weather index is an estimate of the risk of forest fire occurrence.
For who	Decision makers, firefighters, forest engineers, meteorologists.
For what (analysts' point of view)	Identify areas at risk from wildfires and the means to be used.
Link	http://cwfis.cfs.nrcan.gc.ca
Main characteristics of the tool	This index was first developed in Canada in the late 1970s. The Forest Fire Weather Index (FWI) is an estimate of the risk of forest fire occurrence calculated by several meteorological services; it defines a level of risk linked to the nature and structure of the vegetation stands, to the exposure to wind and sun, and to the water reserve capacity of the soil.

3.3 Study of the vegetation

Depending on the type of vegetation, resistance to fire is more or less important. Species endemic to southern European countries are less sensitive and more resistant to water stress, for example. In addition, diseases make the plants more vulnerable.

The type of vegetation and its condition influences the behaviour of the fire and affects the degree of resistance and the spread rate. Apart from the endemic species, the different types of vegetation react radically to extreme weather conditions. Lack of water dries out plants considerably, killing the most fragile species and creating flashpoints.

Under the effects of wind, for example, flaming pinecones blow away and create hot spots in the vegetation that are conducive to inflammation.

3.4 Development of forest fire defense mesures

As part of prevention, equipment is installed to slow down the spread of fire, secure the means of responders, and prohibit fire at sensitive sites. This information is colected and displayed on an information map (e.g. OPEN SIS).

There are different techniques and tools to carry out the planning of preventive actions, including pre-emergency planning, and fuel management. Two examples are the use of the polygon method[1], and prescribed burning[2], respectively.

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1 Based on, among other things, the relief, fire history, exposure, and type of vegetation, this method identifies risk areas and places that are suitable for extinction (https://fireanalysisnetwork. eu/relevant-fire-analysis-re sources-translated-to-english/).

2 Prescribed burning: by using technical fire make it possible to protect sensitive sites, to facilitate access to the herds and to train the responders to the specificities of fire. The acquisition of experience improves the anticipation of propagation and provides analysts with the general context of the fire.

3.5 Lessons learned

Feedback is an approach aimed at detecting and analysing anomalies, deviations and any event, whether positive or negative, by looking for the causes and the sequence of events and by learning from them. We must remember our strengths and weaknesses so that we do not repeat our mistakes.

1. Feedback is very difficult to carry out for various reasons:

- Technical: the people who were active during the forest fire have given back their knowledge completed by their experiences. They refuse to be questioned. The Emergency Commanders are the most experienced, the most competent and the highest in the hierarchy. Their decisions were the best at the time they were made.

- Legal: Victims and/or their insurers are always looking for someone to take responsibility for the costs involved. Identifying weaknesses means identifying mistakes, those responsible, those guilty.

2. Training must be improved and tools developed to help with decision-making or resolution.

- Firefighters must be confronted as often as possible with professional scenarios to develop reflex actions that will allow them to act quickly and effi- ciently but also to save their lives or those of their fellow fighters.

- These activities highlight the shortcomings in procedures and tools, which are therefore gradually being improved.

4

4. Examples of European Science applied to fire analysis

4.1 Examples of applied research

1. **Dr. Theodore M. Giannaros** (Greece) studies the relationship between weather and fire and in particular pyro convective phenomena.

A megafire is a fire that destroys a very large area, typically over 1,000 or 10,000 hectares (https://fr.wikipedia.org/megagafeu).

These phenomena are not limited to other continents. I remind you of the fires in Greece, Portugal and Sweden.

2. **Professor Frédérique Giroud** (France) of the Entente research centre, in partnership with the fire brigade, foresters and industrialists, is developing a retardant product that reduces the burning capacity of plants without harming them.

It is a chemical product designed to slow down the spread of fires. The term includs substances that act both chemically and physically (such as fire retardant foams and gels). In short, it makes trees more resistant to fire and prevents them from burning. It can be applied either by air or land.

3. **Marc Castellnou** (Spain) in the Catalan Fire and Rescue Services, developed the fire polygon methodology.

Analysts draw polygons according to the relief, the speed of propagation and the future operational capacities. They identify the points of passage of the fire and the areas at risk. The analysis allows the optimisation of the use of operational means or methods of fighting (tactical fire) and decision-making at strategical level.

Published article[3]: Empowering strategic decision-making for wildfire management: avoiding the fear trap and creating a resilient landscape. Fire Ecology. 2019.

3 https://interior.gencat.cat/web/.content/home/030_arees_dactuacio/bombers/foc_forestal/jornades_recerca_cooperacio_internacional/articles_de_recerca_en_foc_forestal/articles_incendis_forestals/2019_Castellnou_empowering-strategic-decision-making-for-wildfire-

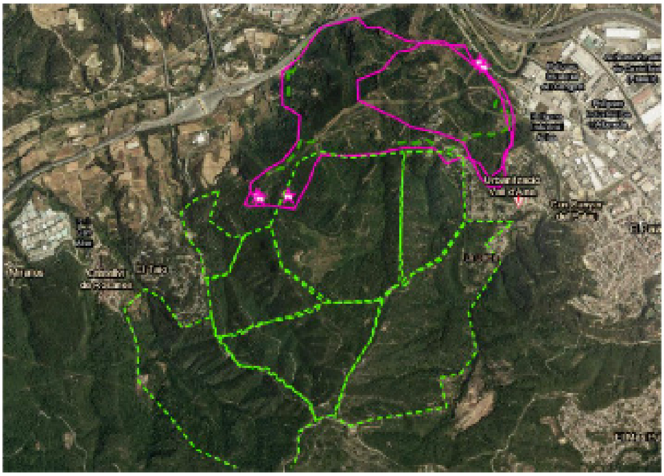


Figure 12. Fire perimeter (purple) and potential fire polygons (green) of the Castellví de Rosanes fire drawn during for the 3rd operational period from the beginning of the fire (14/07/2021 early morning). Source: INT-CFRS.

This method of analysis allows for involvement in territory planning well in advance of the fire and also during response phase through the incident action plan.

4.2 Vector simulators

The best-known vector simulators used by the fire community and some government agencies are PROMETHEUS and FARSITE.

Both incorporate data in raster form regarding local vegetation, wind and terrain conditions.

However, they differ in their behaviour and fuel models.

4.2.1 Farsite

Name	FARSITE
Region of implementation	USA
Year of creation	1998
Description	FARSITE includes existing fire behavior models for surface, crown, spotting, point-source fire acceleration, and fuel moisture.
For who	Firefighters
For what (analysts' point of view)	simulator that takes into account many of the analyst's referent elements.
Link	https://www.fs.usda.gov/treesearch/pubs/4617
Main characteristics of the tool	Created in 1998 by Mark A;Finney. FARSITE (Fire Area Simulator) simulator incorporates several sub-models of fire behaviour: Van Wagner's (1977) model for crown fires, Rothermel's (1972, 1991) model for surface fires, Albini's (1979) model for fire jump and Nelson's (2000) model for the evolution of the water content of plants. The main inputs to the FARSITE simulator are in the form of files relating to local terrain (elevation, slope, exposure) and vegetation characteristics (canopy cover, fuel model), plant moisture content and weather conditions (wind, temperature, precipitation and relative humidity). The user also has the option of adding inputs related to the action of aerial and terrestrial control methods.

4.2.2 Prometheus

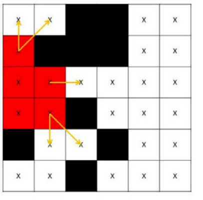
Name	Prometheus
Region of implementation	Canada
Year of creation	2014
Description	Model that takes into account the different types of vegetation.
For who	Firefighters, forest engineers.
For what (analysts' point of view)	Studies of the spread by type of vegetation.
Link	https://firegrowthmodel.ca/pages/prometheus_software_e.html
Main characteristics of the tool	Prometheus is a Canadian wildland fire growth simulation model released on September, 2014. The Prometheus simulator simulates fire spread by combining the equations derived by Richards (1999), based on the Huygens principle, with the Canadian Forest Fire Behaviour Prediction (FBP) system, which combines wind, moisture content and 16 vegetation types. The FBP system is based on certain assumptions, such as a uniform and continuous canopy, a simple and uniform topography or a constant and unidirectional wind, all of which limit its field of application. The inputs to the simulator are less complete than those of FARSITE, with in particular a base of 16 fuels adapted to the FBP system. An alternative method, developed by Balbi (2007, 2009, 2010) and recently extended to large-scale real-time simulation by Santoni (2011), decomposes the flame front into a succession of segments. The propagation then takes place, at each time step and for each point connecting the segments, according to a direction defined by the composition between wind and slope, and at a speed based on a simplified modelling of the different physical mechanisms involved in a fire.

4.2.3 Forefire

Name	Forefire
Region of implementation	France
Year of creation	2009
Description	Ssimulator which describe the inter-action between the fire and the atmosphere.
For who	Firefighters
For what (analysts' point of view)	Identify the interactions on the fire to determine the rate of spread or the areas involved.
Link	http://forefire.univ-corse.fr/
Main characteristics of the tool	Created in 2009 in France, the simulator developed by the Sciences Pour l'Environnement from the Université de Corte laboratory, called FOREFIRE, has been coupled to a meteorological model in order to describe the fire/atmosphere interaction. The first results are encouraging (Filippi et al., 2011). Other, less common, models are also used as a decision support tool and have the same operating principle. These include the Portable Fire Growth Model (Shamir, 2006), SiroFire (Gould, 2007) and Phoenix (Tolhurst, 2006).

4.3 Raster Models

Name	Raster Model
Region of implementation	USA
Year of creation	1990
Description	Model that superimposes different information on the same map.
For who	Firefighters
For what (analysts' point of view)	The analysis benefits from a lot of information that impacts its interpretation. It analyses the connection between these pieces of information to obtain the most likely propagation.
Link	https://desktop.arcgis.com

Main characteristics of the tool	Raster models are based on the description of the vegetation cover as a set of regularly or irregularly shaped sites, over which fire propagates according to specific contamination rules or probabilities of occurrence. Among the raster models developed and used in the fire community are the IGNITE model (Green et al., 1990); DYNAFIRE (Kalabokidiset al, 1991); FireMap (Ballet Guertin, 1992, Vasconcelos and Guertin, 1992); the model presented by Karafyllidis and Thanailakis (1997), and further developed by Berjack and Hearne (2002); Geofogo, developed by Vasconceloset al., 1998; FireStation, by Lopez, 1998; Extended Swarm, by Li and Magill, 2001; FlamMap, developed by Finney, 2006.  *Figure 13. Schematic diagram of propagation in a raster model* *Source: Valabre* The simplest of these models is the percolation model, in which propagation is from near to near, as a burning site can only affect its nearest neighbours. The evolution of the state of a site (healthy, on fire, burnt) depends on the state of the neighbouring sites and on transition rules which can be stochastic or deterministic. Different types of neighbourhoods are used: the Von Neumann neighbourhood with 4 neighbours, the Moore neighbourhood with 8 neighbours, or more rarely a combination of these neighbourhoods with 12 neighbours. Depending on the neighbourhood considered, the percolation (threshold, size and number of clusters) and propagation properties differ. The propagation will also depend on the doping, defined as the ratio of the number of combustible sites to the total number of sites. A percolation model is very simple to implement, but it does not allow for the inclusion of long-range effects beyond the nearest neighbours, such as flame radiation, hot gas convection or fire jump projections (De Gennes, 1976). They also do not allow the reproduction of the fractal properties observed in large fires. This information comes from the thesis presented by Matthieu De Gennaro to obtain the university degree of doctor of the University of Aix-Marseille Discipline: Energetics Modelling of the propagation of large forest fires and development of an operational tool to assist in tactical fire fighting.

5

5. Conclusions

For the analysis of fires, the analysts use different tools adapted to the needs of their territory, as well as their experience and knowledge acquired over the years, and which is of great value to obtain a good result.

The knowledge of the territory, the available tools and the experience acquired, allow a more accurate and precise analysis.

These tools, developed based on empirical models, are very useful and allow remote analysis.

The use of the tools they require a lot of knowledge and experience (see AFAN deliverable n°2.2: Guidelines of fire analyst competencies and skills).

Forest fire analysts have the tools to carry out an effective analysis that will contribute understand fire behaviour during wildfire events, to plan prevention actions, and to anticipate possible future forest fires. However, websites need to be updated regularly and are only photographs at a given time. Artificial intelligence will undoubtedly be able to fill these gaps.

The use of adequate tools, science and best practices makes it possible to actively participate in the reduction and extinction of fires. However, the application of these measures is still too long to reduce the time needed to extinguish fires and the area affected. It can only be applied to large fires.

Many researchers are working on programmes to develop a better understanding of the phenomena, a better understanding of the environment, to develop passive extinction tools, etc.

These studies must be shared with as many people as possible. They must be included in the various platforms, and they must lead to operational implementation.