Interreg Sudoe

EUROPEAN UNION

climalert

European Regional Development Fund

CHAPTER 3.3: Implementation of the operational system for the assessment of early warning and proactive actions in forest fires

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1. Introduction

Southern Europe, due to its weather, soil, botanical and human characteristics, is a singular area for the occurrence of forest fires, particularly in the Mediterranean arch composed by France, Greece, Italy, Portugal, Turkey, and Spain, where more than 80% of the total burned area in the continent burns each year (WWF, 2019).

Experts have indicated that the characteristics and dynamics of forest fires are changing in Southern Europe, with one of the main causes behind this transformation being climate change. The new dynamics are modifying the general regime of the fires, which are becoming more intense and virulent, and therefore in most cases cannot be extinguished.

This new generation of forest fires is named sixth-generation fires, and the results are devastating for the environment, the economics of the affected area, as well as the population and their possessions.

The regions analyzed within the Climalert project, due to their geographical location, which is framed within the Mediterranean arch and located in Southeastern Europe, have the appropriate characteristics for being affected by a sixth-generation forest fire.

The establishment and development of indices, models, and quantitative and qualitative information at different work scales that allow establishing early warning levels, is an indispensable and fundamental commitment for the making of proactive decisions when faced with different emergencies that occur in the territory, especially in the area analyzed in the present document, the forest fires.

The combination and integration of shared-use platforms of appropriate meteorological models with forest fires indices increase the precision of the results, anticipating the occurrence of the phenomenon and therefore helping with the taking of appropriate actions to minimize environmental and economic losses and save human lives.

The present document analyzes these indices, models and quantitative and qualitative information related with forest fires, which together with climate and meteorological models, are necessary in the SUDOE area for establishing early warning levels that will help improve proactive decision-making, thereby helping to take preventive actions before the incident occurs.

2. Development of regional and local climactic-metorological data

The implementation of meteorological services with worldwide, European and national coverage is fundamental for increasing the safety of the people and their belongings, as well as for the creation of prediction models that allow establishing early warning systems for proactive decision-making.

The inclusion of these services as supplementary information to a common platform for the management of different emergencies has become vital for all the European countries and the world as well.

The information from the national and worldwide meteorological stations are, in most cases, insufficient for evaluating the preciseness of the meteorological conditions of forest areas that have little homogeneity in their underlying surface and very variable topographical and surface characteristics.

The great challenge is to bring together and reduce the scale for making meteorological decisions in order to achieve that the predictions and models derived from them are more local in nature and focused towards the emergency for which one wishes to have an advantage in its prediction.

Faced with this challenge, this section describes 2 proposals for the acquisition of meteorological data related with the prevention and extinguishing of forest fires at the local and regional level, utilizing the Region of Murcia as an example, as it belongs to the SUDOE area. The products derived from the acquisition of the local meteorological data, incorporated to global meteorological models, will project and improve the early warning predictions and proactive decision-making at the regional and local level.

2.1. Proposal 1. Creation of a regional forest meteorology network.

As of today, Spain relies on meteorological records and prediction models created by the National Meteorological Agency (AEMET). However, the data obtained from its network of observations do not contain, due to its geographical location (urban and agricultural areas, mainly), sufficient data for modelling the conditions that could be found within these areas and forest areas.

Numerous Autonomous Communities, such as Andalusia, Catalonia and Galicia, have opted for developing their own network for acquiring meteorological data within the most important or vulnerable forest areas. This regional-local network, together with the State Meteorological Agency, will provide the managers with more tools for the prevention of forest fires, and as a result, proactive decision-making.

The objective of the regional-local network is the monitoring of the sensitive areas and forest areas in the Region of Murcia. To characterize the specific climactic conditions in the forest stands, and to avoid errors due to the spatial variability of the meteorological data, stations must be installed within the forest area to be monitored.

The main characteristics which the network must characterize are those defined by the Service of Forest Health and Biological Equilibriums (SSF) from the Ministry of Agriculture, Food and Environment of Spain:

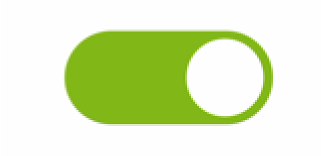
In general, the measurements (except for soil temperature, soil moisture and precipitation), can be collected above the canopy of the surrounding mass or in a uncovered area next to the plot (in general less than 2Km), and with the same orientation, altitude and slope conditions.

The deforested area will have a radius that is equal to or greater than twice the height of the surrounding mass. The temperature of the soil, the moisture in the soil, and precipitation, will have to be measured in the plot (Recording of Meteorological data, Service of Forest Health and Biological Equilibriums (SSF)).

The equipment and sensor must be consistent with the requirements from the World Meteorological Organization (WMO), and if possible, also compatible with the National Meteorological service. The stations are almost continuously acquiring data, and the storage of the data will not be longer than an hour (Meteorological Data Acquisition. Forest Health and Biological Equilibriums Services (SSF)).

As for the variables that should be considered, the SSF establishes the following 2 types:

- **Compulsory:**
  Precipitation. Air temperature. Air moisture. Wind speed. Wind direction. Solar radiation.



- **Optional:**

  LTV b radiation. Soil temperature. Soil water. Translocation and surface runoff.

2.2. Proposal 2. Creation of a network for the prediction and monitoring of regional storms.

The implementation of a network for the prediction and monitoring of storms aims to monitor the regional territory (Region of Murcia) that is sensitive to storm formation and to possible lighting events that could provoke the occurrence of forest fires.

Monitoring the formation of and tracking the storms will help with knowing in advance when an electrical storm is approaching, favoring the making of decisions and taking of preventive actions that can protect people and facilities against forest fires, as well as improving the early warning predictions and proactive decision-making at the local and regional level.

Among the main characteristics that the storm prediction and monitoring network should have, we find:

Reading of the changes in the electromagnetic field in a radius not wider than 30Km.

Provide information on the existence of the risk of lightning strikes before the first discharge (15/20 minutes).

Provide information about when the danger has passed and the storm is no longer active.

Obtain precise measurements about the intensity of the electric field.

Continuous working of the sensor, without the need to re-start the electronic equipment used for measuring.

Display the data obtained through a common platform on the internet.

According to the IEC 62793: 2016 – UNE-EN IEC 62793: 2019 standard, and having in mind the different phases of the storm, the detectors utilized for storm prediction will be classified in the following manner:

Class A: Detects the storm during its entire lifetime (from Phase 1 to Phase 4).

Class B: Detects IC (intracloud) and CG (cloud-to-ground) lightning (from phase 2 to phase 4).

Class C: Detects CG (cloud-to-ground) lightning (from Phase 3 to Phase 4).

Class D: Detects CG (cloud-to-ground) lightning (Phase 3) and other electromagnetic sources with limited efficiency.

In this way, the objective of the Region of Murcia would be the implementation of Class A sensors for the complete monitoring of the storm cycle, in its two types:

- **Fix network of sensors on ECO mesh panels:**

To determine the formation of electrical storms for the prevention of forest fires.

To determine the possibility of lightning strikes by the storms that are formed in the Northeast area of the region for the prevention of forest fires.

To determine the formation of electrical storms for work accident prevention of the personnel in charge of the fixed surveillance mesh (ECO mesh panel) of the Region of Murcia and in particular the ECOs placed in the Northeastern areas of the region.

- **Portable model**

To determine the formation of electrical storms for assisting in forest fire extinguishing tasks.

To determine the possibility of lightning strikes from the storms that are formed for assisting in forest fire extinguishing tasks.

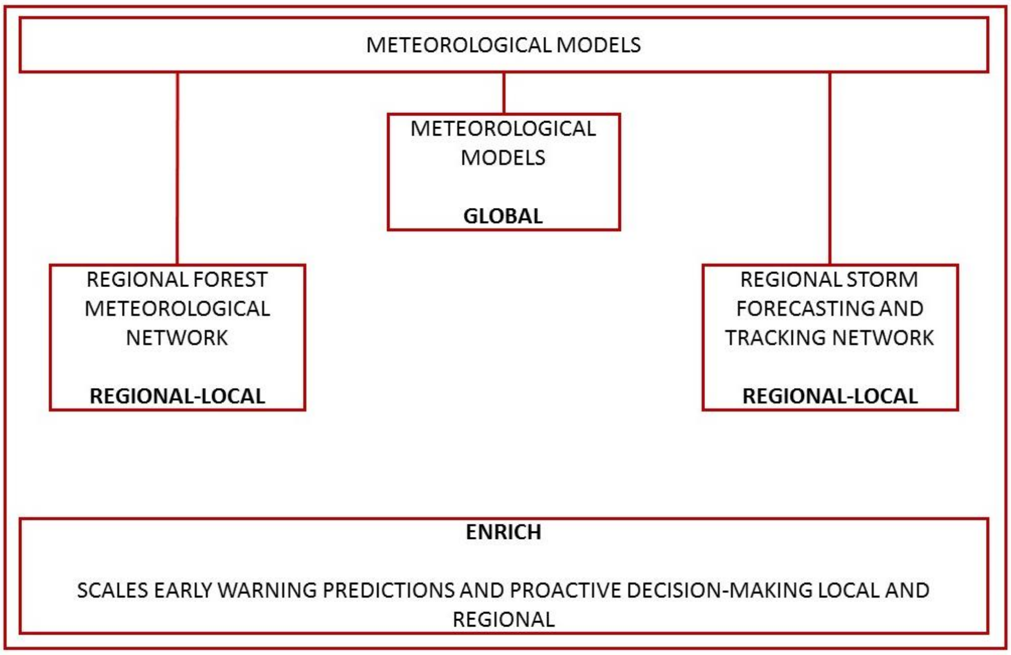


Figure 1. Implementation of Meteorological Models.

3. Development of warning indices

Acquiring data or establishing factors that help with specifying evidence or signs to evaluate, and analyzing and understanding situations based on habitual parameters of occurrence, are considered forecasting indices. These indices are utilized by every knowledge-based discipline to establish patterns of behavior that allow us to construct models for improving the early warning predictions and proactive decision-making.

To improve the management of early warning and proactive decision-making related with the forest fires in the SUDOE area, 3 forecasting indices are analyzed:

1. **Danger or Risk of Forest Fires Index.**
2. **Vulnerability Index.**
3. **Difficulty in Fire Extinguishing Index.**

3.1. Danger or Risk of Forest Fires Index

Establishing the risk or danger of forest fires in a territory is based on different parameters that are interconnected, which altogether determine numerical values of danger or risk of forest fires for the different areas into which the territory has been divided, helping to improve the early warning predictions and proactive decision-making.

For example, the Region of Murcia, for the calculation of this index, uses the methodology defined in the INFOMUR PLAN 2020 as a reference, defining the risk of a forest fire as: “the probability that a fire will start in an area” (INFOMUR PLAN 2020).

This methodology is based on the calculation of three sub-indices:

Frequency of forest fires – index of causality of forest fires – index of the danger derived from the fuel.

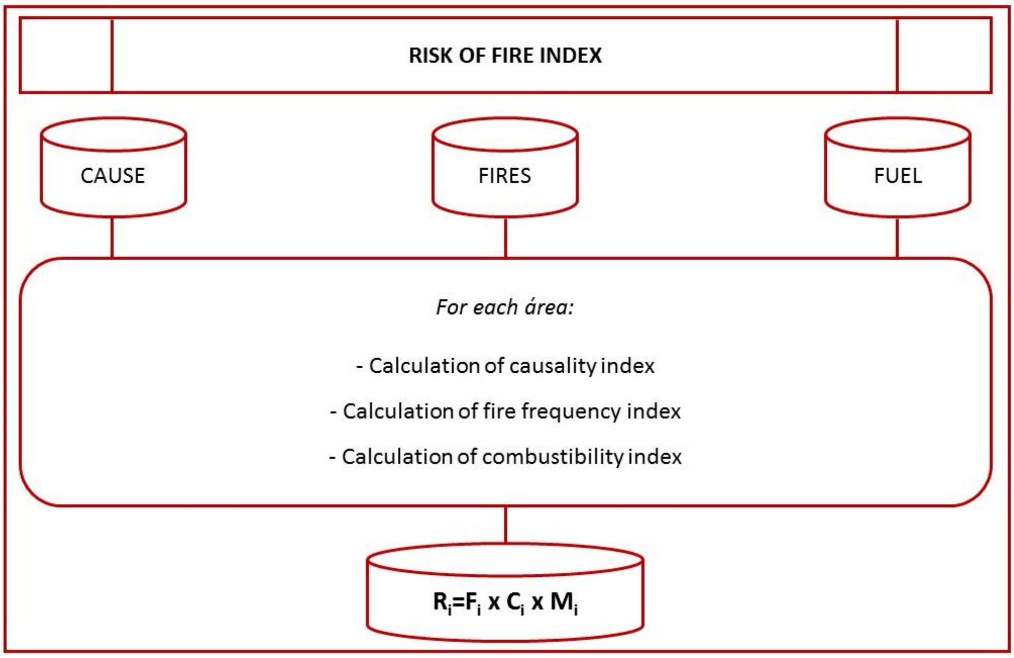


Figure 2. Risk of Forest Fires.

However, this risk of forest fires index can be implemented by adding new factors which will enrich the results obtained and will help to improve the early warning predictions and proactive decision-making.

Using as the reference the Special Plan of Emergencies for Forest Fires in Catalonia (INFOCAT PLAN), the following factors are considered important for their future analysis prior to their addition to the calculations established in the INFORMUR PLAN:

Slope of the terrain – Combustibility – Flammability – Insolation – Winds – Water Deficit

The study and combining of both methodologies will provide the optimum result for calculating the danger or risk of forest fires.

3.2. Vulnerability Index

Knowing the dangers provoked by forest fires to the vulnerable elements of the territory, according to their nature, is indispensable for improving the early warning predictions and proactive decision-making.

This is why differentiating the most vulnerable elements within the territory, and being able to categorize them according to different levels of action by considering their vulnerability against forest fires, is basic for managing any type of emergency in a coordinated and equilibrated manner.

Thus, establishing a territorial relationship between the vulnerable elements in a space and the index of danger or risk of forest fires will provide managers with enough information for making proactive decisions against the occurrence of the fire event.

Obtaining a map that shows the index of vulnerability signifies the use of a methodology that includes at least the following factors (INFOMUR PLAN 2020 and INFOCAT PLAN):

- Population:
  Including the population centers, industrial areas, housing developments, farmhouses, camping areas, historical elements… All of elements related with a population.
- Infrastructures:
  This group includes the highways, motorways, asphalted roads, and railway networks. Also included are elements corresponding to service networks such as electricity, etc.
- Protected spaces:
  Protected Natural Areas, Places of Importance for the Community, Special Bird Protection Areas, etc.
- Especially dangerous elements.
- Fuel modeling.

The final result will show elements that are grouped according to class type, as a function of the degree of vulnerability of each element to a forest fire. The result will be a very helpful instrument for determining the proactive actions needed against the threat of a forest fire.

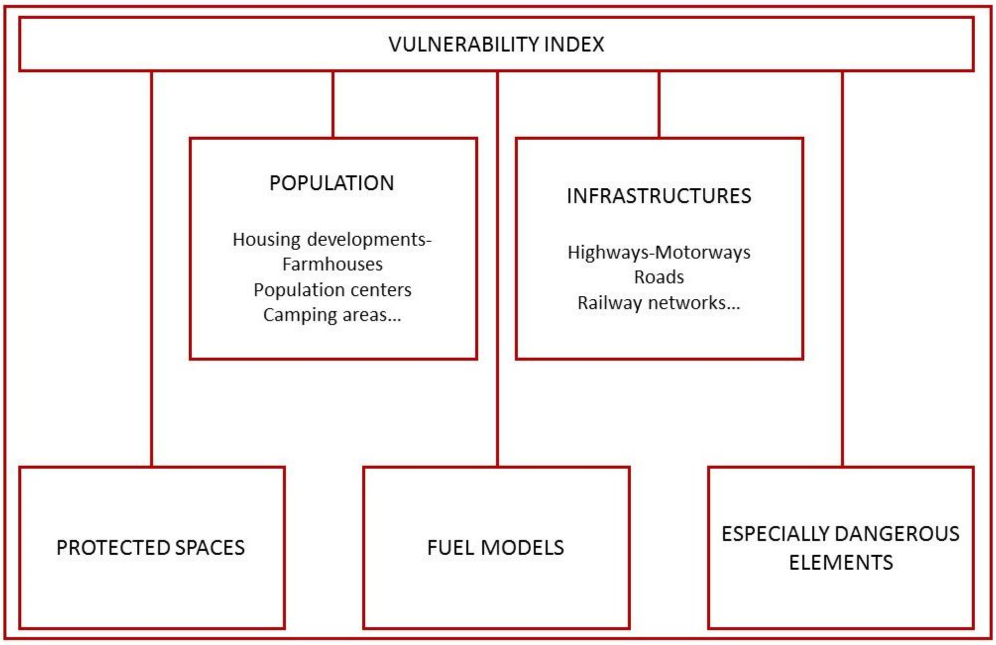


Figure 3. Calculation of Vulnerability Index.

3.3. Extinguishing Difficulty in Fire Extinguishing Index (IDEIF-IDEX)

The difficulty in extinguishing forest fires is understood as the ability to control a forest fire and avoid its spread. This term is dealt with by various authors (Vélez et al., 2000), (Chuvieco, Martín Isabel, 2004), (Alonso-Betanzos, 2003).

Thus, the difficulty in extinguishing forest fires index is the ability of a territory to act against a forest fire with conventional methods. It is a territorial planning model that includes aspects of the physical medium, such as the existing fire extinguishing infrastructures, and the accessibility to the terrain (Galina F., Toraño A. and Suárez Torres J., 2007).

The forest fire extinguishing model (IDEIF-IDEX) is based on a hierarchal scheme comprised of 3 levels of variables that organize the entire process in a rational manner to differentiate all the components or tasks affected and to itemize their relative importance.

The first level corresponds to the general grouping of the processes, the second level is comprised by the indices that model the process (formulation), and the third level is shaped by the variables that comprise the indices.

First level:

Extinguishing maneuvers – Speed of arrival– Propagation.

Second level:

Penetrability – Mobility – Opening of the Lines – Availability of Water Resources – Accessibility – Dangerousness.

Third level:

Variables that comprise each of the indices of the previous level. Scheme 4.

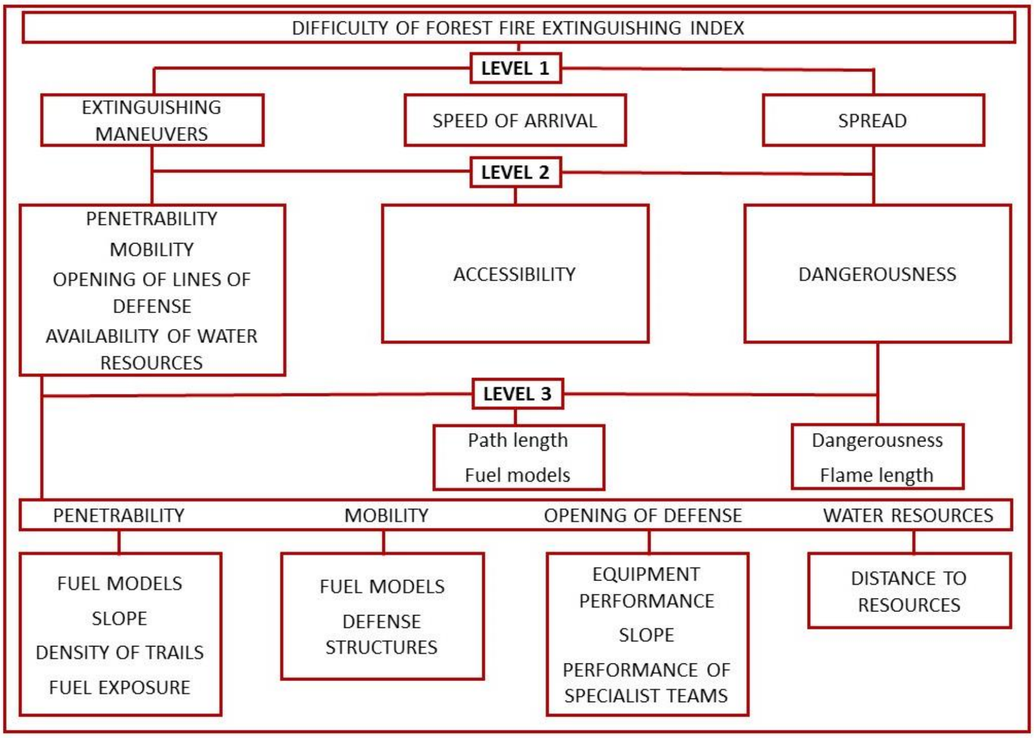


Figure 4. Calculation of the Difficulty of Fire Extinguishing Index.

The result of the Difficulty in Extinguishing Forest Fires Index (IDEIF - IDEX), will provide the organizations in charge of the emergency systems with a key tool for establishing proactive assessments of the forest fire that are managed at each moment in time, such as, for example:

1. Difficulty in fire extinguishing.
2. Improvement in the arrival time, through accessibility.
3. Recommendations for action can be established in those areas that are more difficult, as a study can be conducted about the possibility of creating more firebreaks which will either decrease the difficulty in fire extinguishing in an area, or limit the areas with the highest indices, thereby avoiding the spread of fires that originate from them.
4. Improve geolocation and operational prioritization during the fire extinguishing maneuvers.

4. Fuel modeling

Knowledge about forest fuels and their distribution is fundamental for modelling any variable related with the behavior of the fire in the territory.

A forest fire is mainly a space-related event, so that knowledge of the geographical location and connectivity between the diverse types of fuels is necessary for understanding the potential behavior of the fire.

To obtain information about the spatial configuration and connectivity between the fuels, continuous and repeated inventories of the fuels should be conducted at the regional and local level.

Obtaining a good map of the fuel models present in each surface will help with distinguishing in advance those zones or areas that are more sensitive and therefore prone to being affected during the occurrence of a forest fire.

The traditional methods utilized for the review and creation of maps related to the fuel models are not economically feasible.

These technologies have enough capacity for offering information about the spatial distribution and the continuity of the different types of fuels, promoting a better assessment of the risk of forest fires and the decrease of its environmental impact, for people and their belongings.

Along these lines, we find the analysis techniques of remote sensing, in particular for the mapping of fuel models, with 2 systems of essential and reference remote sensing available: Image spectrometry and LiDar.

Image spectrometry analyses the spectrum dimensions, which is sensitive to species discrimination, the types of surface and the moisture of the fuels.

LiDar analyzes the spatial information, describing the geometric properties of the natural and artificial surfaces.

Both systems are adequate and complementary, and they are therefore indispensable for mapping the different and heterogeneous types of fuels, especially within the Mediterranean environment (European Forest Institute, Discussion Paper 15, 2009).

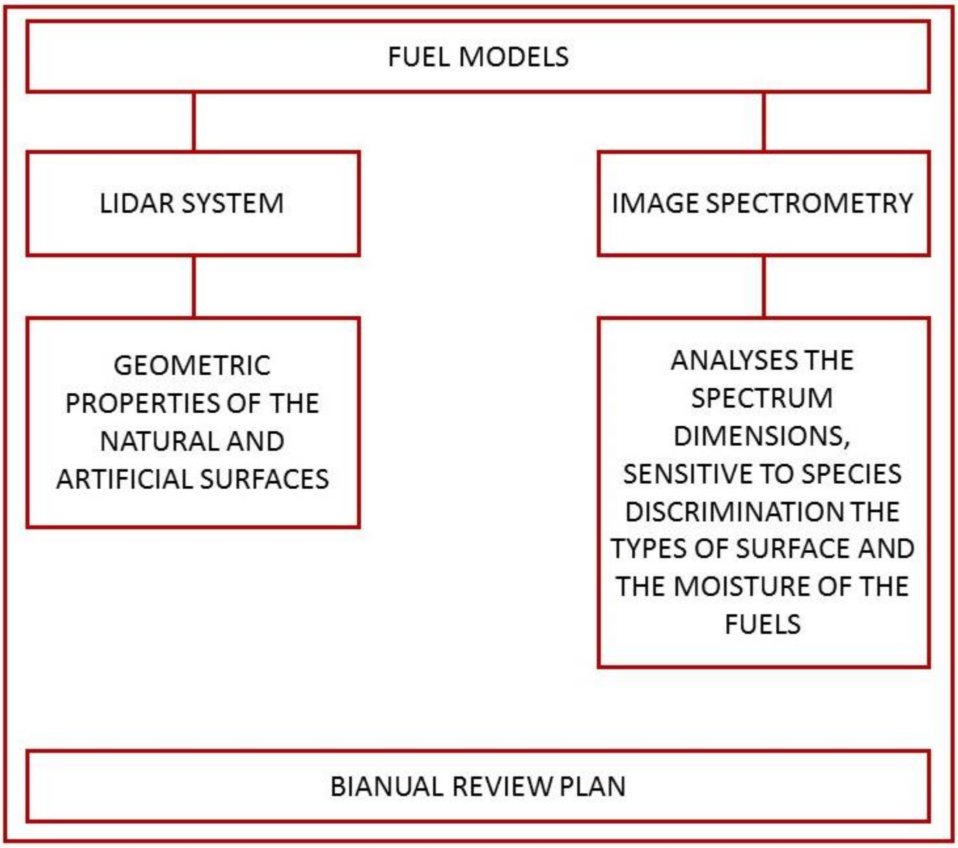


Figure 5. Mapping of Fuel Models

5. Models of strategic areas of action

This new concept has appeared from the need to optimize resources and prioritize the economic investment at the landscape scale and focus our attention to areas and places in our mountains where the prevention and restoration activities are a priority, providing support to the fire extinguishing crews by providing them with areas of opportunity where they can slow down the spread of fires that show patterns of not being extinguishable.

Along this line, we find two fundamental figures for the creation of the models:

1. **The Strategic Management Points (SMP).**
2. **Operational Perimeters of Control (OPC).**

5.1. The Strategic Management Points (SMP)

The most accepted definition of SMP is that proposed by Costa et al. (2011):

"Locations of the territory in which the modification of the fuel and/or the preparation of the infrastructures, allow the fire extinguishing services to execute attack maneuvers to limit the potential of a Great Forest Fire".

The Strategic Management Points (SMPs) are therefore fire extinguishing infrastructures for dealing with a reference fire (simulated or based on the analysis of fire history (standard fire)), whose design is integrated into a strategy and tactics that are predetermined by the type of fire extinguishing system. These are associated to places with characteristics that are appropriate for the deployment of extinction maneuvers that are known, safe, agreed-upon and sized for this purpose by the fire extinguishing system.

The objective and specific objectives of the SMPs can be diverse and depend on the landscape that were making plans on. Nevertheless, in most proposals, the following common points usually exist:

- To establish fire extinguishing plans before the forest fire and to decrease the uncertainty of the strategies, tactics, extinguishing operations, thereby increasing the safety of the fire extinguishing teams.
- To reduce the potential of fire spread, compartmentalizing or isolating areas that could be potentially affected by the fire.

- To improve the protection of belongings and people.
- Protecting the elements found in highly vulnerable landscapes.

The modeling of the SMPs and their addition to the emergency maps, results in and influences the appropriate programming for simulated-simulation exercises in a classroom or in the field for fire extinguishing personnel or those related to the management of these types of emergencies, such as for example for the design of evacuation zones, confinement, escape routes, safe zones, etc…).

5.2. Operational Perimeters of Control (OPC)

Defined area units of the forest landscape, whose contour shapes a perimeter that serves to delimit the territory in which the fire is manifested in its spatial spread, in a different manner as compared to the spread into neighboring area units, also has differences in the net exchange in the value of the resources, as well as in the operational strategies of fire extinguishing.

As a function of the above, it is observed that the acts of defense could be differentiated and dependent on the priorities of the management of the forest landscape at this site.

Along the boundary line which defines the contour, we can find or define spaces which provide evident opportunities for controlling the spread of the fire (Potential Control Locators, PCL). Each SMP can be conceptually assimilated to the idea of "fire basin", following the similarity of a river basin as related with the runoff, but inverting the movement (O'Connor C.D., Thompson M., Rodríguez and Silva Fco. 2016).

The addition of these two management figures to the emergency maps could provide elements of analysis for early warning evaluation that will result in the improvement of the proactive decision-making, among which we find:

- The evolution potential of forest fires.
- Priority of action against simultaneous forest fires.
- Creation of early warning alerts for the population through digital channels, SMS, Telegram, etc.

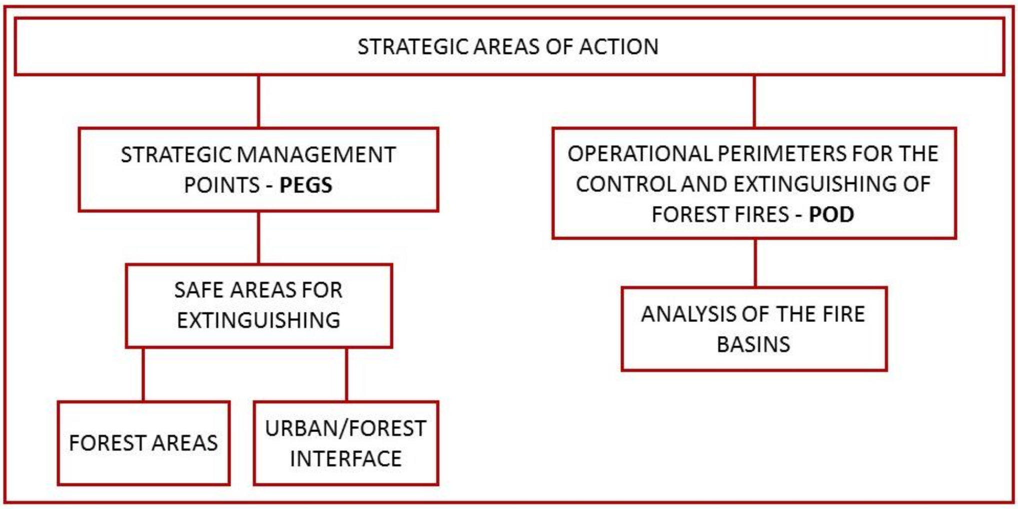


Figure 6. Strategic Areas of Action.

6. Regional database of forest fires

The new technologies have brought with them the ability to acquire data in real time in a manner that is fast, easy and unlimited.

The generation of large amounts of data from diverse sources about any event or incident occurring in the territory creates difficulties for the appropriate analysis of data during the event or after it.

Forest fires are no exception to this dynamic, and the information obtained during an event of this phenomenon comes from diverse channels, social networks, volunteers, press releases, etc.

However, only the information and data collection from the technical personnel who are undertaking the fire extinguishing tasks will be utilized as the basis for the management of the forest fire in real time and the analysis after it is extinguished.

Along this line, and with the support of the new technologies for the acquisition of information on forest fires, the creation of a Regional Database of Forest Fires is suggested, with the following main objectives:

- To define a regulated and common procedure for the administration of and access to the data.
- Databases that are accessible from a common platform.

- Location and geo-referenced perimeters of the forest fires.
- To specify the qualitative and quantitative data needed from the field.
- Delivery formats for providing information.
- Type of reports created after the fire.
- Classification of forest fires, for lessons learned analysis.

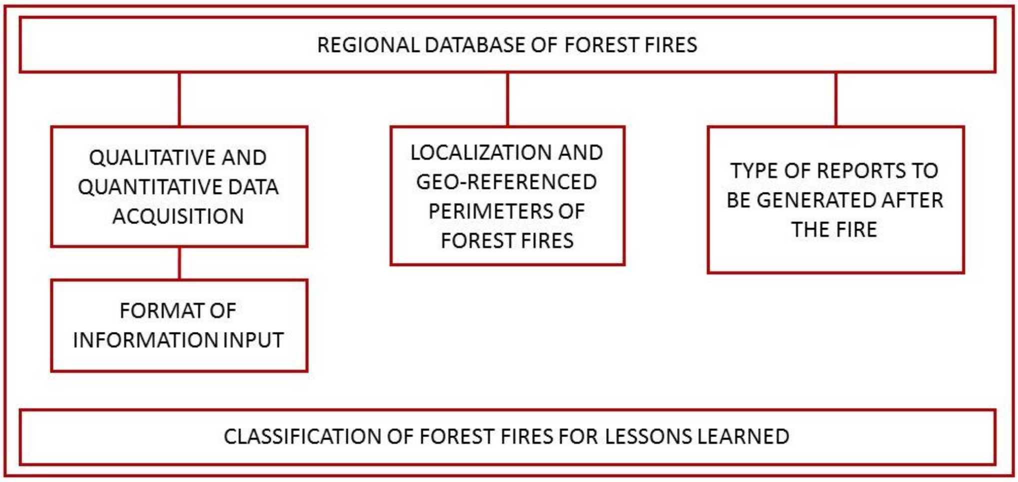


Figure 7. Regional Database of Forest Fires.

7. Modeling of the urban/forest interface

"In the Mediterranean area, as well as in other areas, we find a type of forest fires that are increasing in intensity and virulence, thereby increasing the frequency and persistency of episodes of risk and the entry into non-habitual areas, such as the urban-forest interface, resulting in a change in paradigm of forest fires. The characterization and identification of these Urban/Forest Interface (UFI) are key for dealing with the problem".

Conclusion of the Euromediterranean Workshops on Forest Fires (2014).

Pau Costa Foundation.

The **Urban/Forest Interface (UFI)** is an *area where the interaction Man - Forest – Mountain is materialized in interactions and exchanges between housing developments, installations, and the forest terrain* (Díaz, J.M. 2018).

The forest fires in the **Urban/Forest Interface (UFI)** are becoming an ever more complex problem due to the severe marks left on the environment and the effects produced in populated areas, which represent a significant threat to many communities.

From the overall point of view of management, knowing the Urban/Forest Interface areas with higher priorities of action signifies important savings in economic and human resources, as well as an improvement in the territorial organization. On the other and, acting on areas with higher priorities will avoid most of the negative effects caused by the fire on these spaces, such as the loss of human life and the loss of personal belongings.

The regions within the SUDOE area are affected by this change in the trend and frequency of forest fires, as well as their behaviors. The changes in the dynamics of the behavior of the forest fires, together with the field/city migration processes, along with the existence of an unorganized process of city growth by the occupation of natural spaces or border areas, turn the SUDOE area into a territory where the risk of a fourth generation fire or a fire in the Urban/Forest Interface, is real, and therefore the danger to the population and their goods exists.

It is necessary to reflect on the circumstances surrounding the cruel scenario presented, where the potential loss of human life and properties due to these forest fires is increasing.

Faced with this perspective, the creation of tools that allow the modeling of the Urban/Forest Interface is needed to reduce the effects of the fire on the infrastructures found in the territory, at the same time that these tools could help improve the early warning forecasting and making of proactive decisions.

Modeling of the Urban/Forest Interface for the prevention and extinction of forest fires is based on calculation methodologies. For its modeling in the SUDOE area, the methodology by (Díaz J.M., 2018) will be used as its starting base.

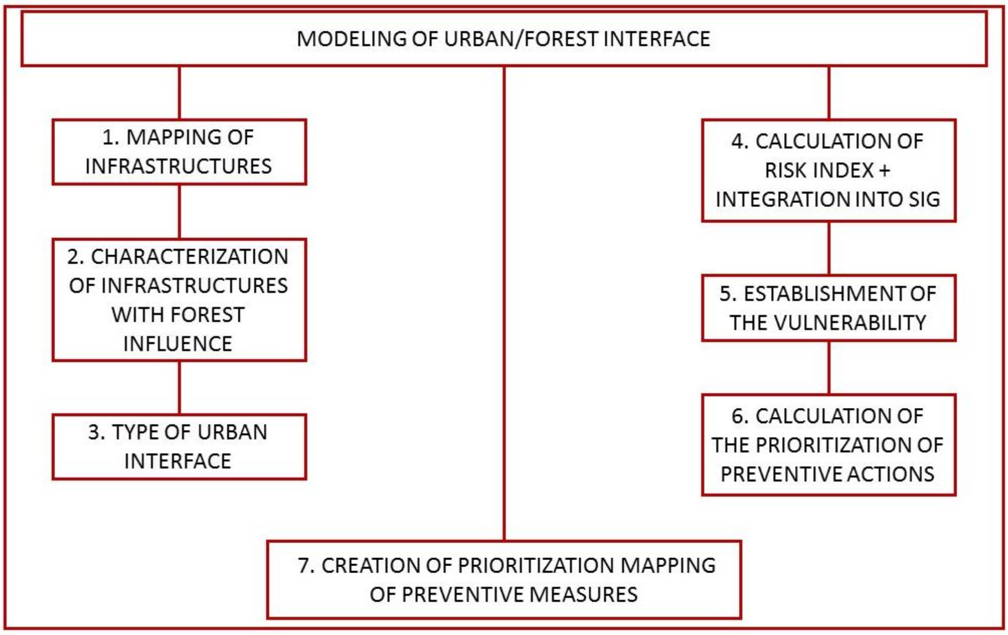


Figure 8. Modeling of the Urban/Forest Interface.

8. Preventive thematic mapping

Along with the different base layers utilized for the creation of preventive thematic mapping, as well as those obtained starting with the execution of each of the points described in this report, the addition of the following thematic cartography is considered significant to optimize the system:

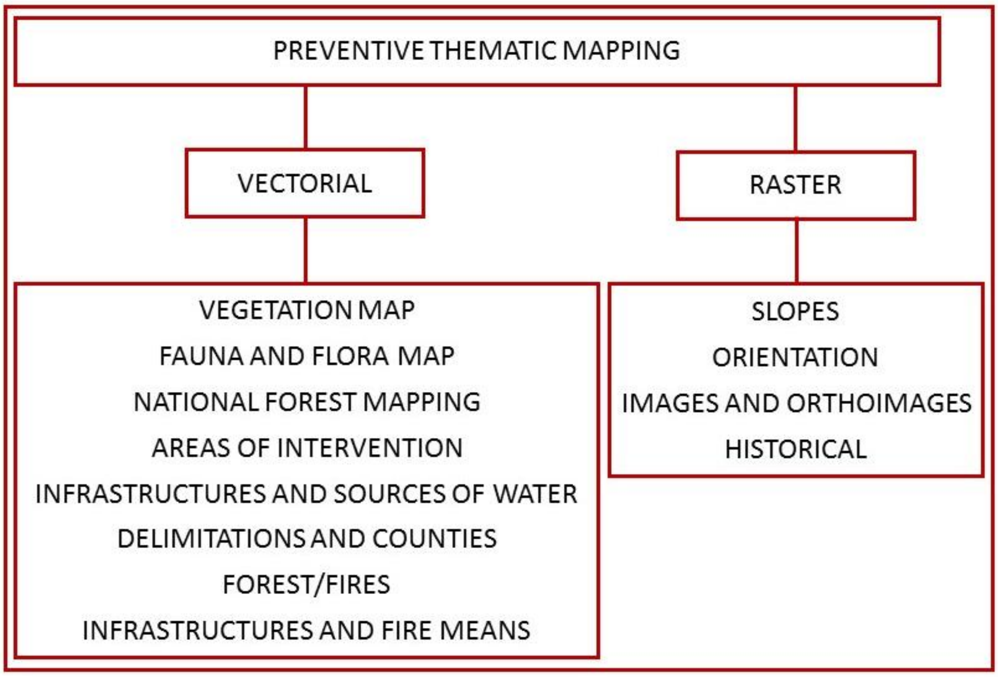


Figure 9. Preventive Thematic Mapping

9. Relevant global models to be incorporated

Together with the existing global meteorological models, it is important to incorporate the following predictive models, which together with those obtained starting with the creation of this report, will comprise a high value predictive tool for the assessment of danger forecasting and the performing of proactive actions during forest fires.

9.1. Duff Moisture Code.

This is a variable from the system of classification of the environmental index of fires designed and adopted by the Canadian Forest Service.

The Duff moisture code (DMC) is a numeric classification of the mean moisture content of the compacted organic layers of moderate depth.

9.2. Initial Spread Index.

This is a variable from the system of classification of the environmental index of fires designed and adopted by the Canadian Forest Service.

The Initial Spread Index (ISI) is a numeric classification of the expected rate of fires spread. It combines the effects of wind and the Fine Fuel Moisture code (FFMC) on the rate of spread without the influence of variable quantities of fuel

9.3.Rate of spread.

The rate of spread is the numeric qualification of the expected rate of spread of the fire. Also, it provides information on the effect of the wind on the spread time, as a multiplicative factor applied to the potential rate of spread in flat terrain without wind conditions (static input parameter) which takes into consideration the effect of the wind speed and direction on the rate of spread.

9.4.Fire Weather Index.

This is a variable from the system of classification of the environmental index of fires designed and adopted by the Canadian Forest Service.

The Fire Weather Index (FWI) is a numeric classification of the intensity of the fire, dependent on the weather conditions. It is a good indicator of the fire danger, as it contains a component of fuel availability (drought conditions) and a measure of ease of propagation.

9.5. Drought code

This is a variable from the system of classification of the environmental index of fires designed and adopted by the Canadian Forest Service.

The Drought Code (DC) is a numeric rating of the average moisture content of deep, compact organic layers. This code is a useful indicator of seasonal drought effects on forest fuels and the amount of smoldering in deep duff layers and large logs.

9.6. Buildup index.

This is a variable from the system of classification of the environmental index of fires designed and adopted by the Canadian Forest Service.

The Buildup Index (BUI) is a numeric rating of the total amount of fuel available for combustion. It combines the DMC and the DC.

10. Simulators of fire behavior

The Royal Academy of the Spanish Language (RAE) defines simulator as:

"Set of people or things prepared for a purpose which reproduces the behavior of a system in specific conditions, generally applied towards the training of those who must utilize that system".

Throughout history, the fight against forest fires has been incorporating the development of computer programs to its analysis techniques, which are able to simulate fire behavior under specific conditions (temperature, wind, fuel, fire extinguishing techniques…), with the main objective being the training of technicians and forest brigades for improving the understanding of the behavior of the fire and as a result to optimize the making of decisions for each phase of the forest fire.

Along this line of progress and development, the addition of computer programs for simulating the behavior of a fire provides a great visual help for understanding and knowing the possible and potential development that could be reached by specific forest fires.

There are many types of simulators, which through the use of mathematical and empirical models, represent the behavior of evolution, both spatial (spread) and temporal (arrival time) of the fire, among which we can find (Silva, 2017):

Dynafire – Firemap – Pyrocart – Firestation – Geofogo – Embyr – Wildfire – SiroFire – Farsite – Flammap - Visual Seveif - Visual Peligro - Visual Fuego - Propagator

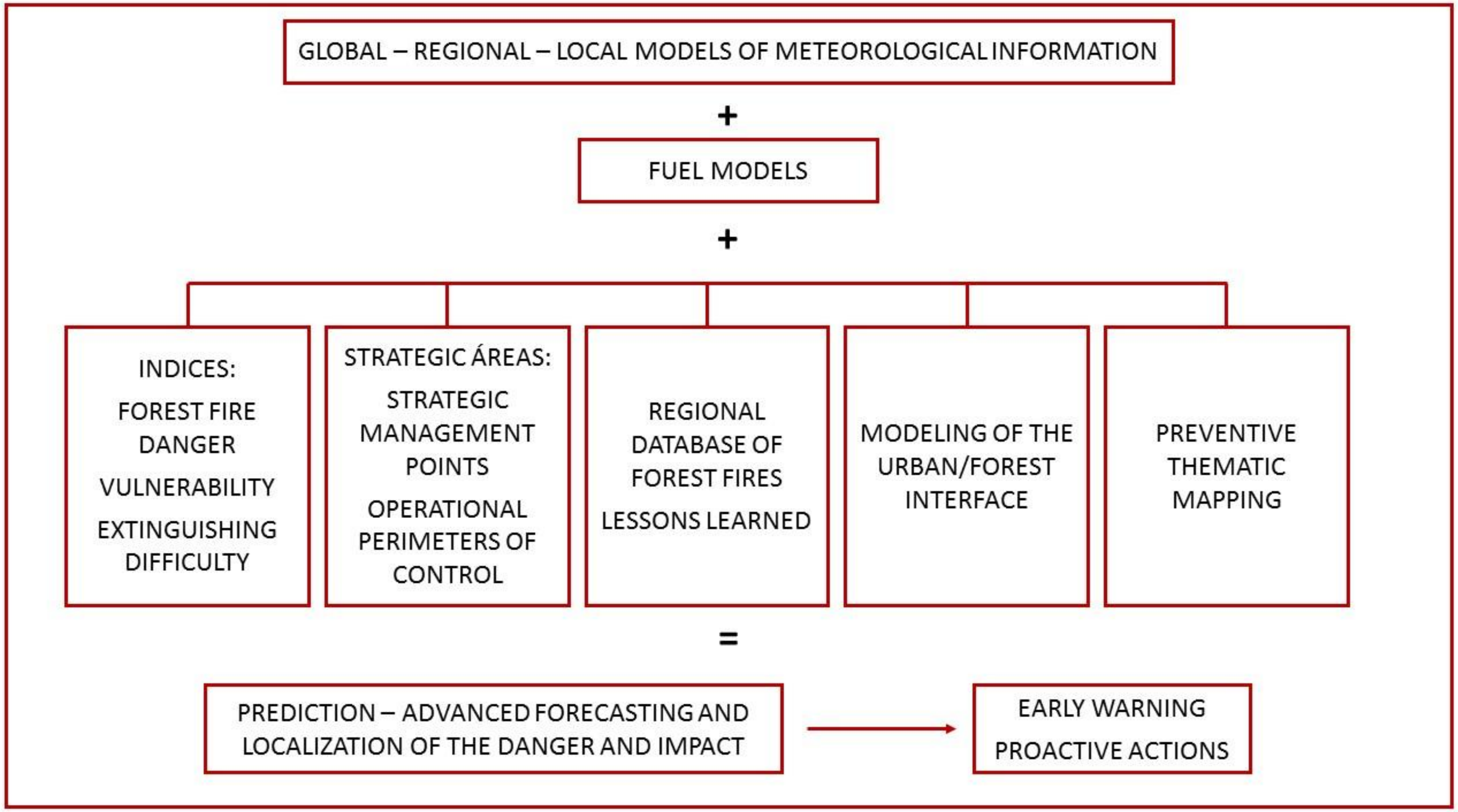


Figure 10. General Scheme of the Operational system for the assessment of early warning and proactive actions in forest fires.

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