

International Handbook on Forest Fire Protection

*Technical guide for the countries
of the Mediterranean basin*

MINISTÈRE DE
L'AMÉNAGEMENT DU
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L'ENVIRONNEMENT
(FRANCE)

Département Gestion des territoires
Division Agriculture et Forêt Méditerranéennes

Groupement d'Aix en Provence
Le Tholonet - BP 31
13612 – Aix en Provence cedex 1
France

F.A.O. (FOOD AND
AGRICULTURE
ORGANIZATION OF THE
UNITED NATIONS)

Preface

Forest fires represent a considerable threat to the Mediterranean forests. It is estimated that about 50,000 fires occur each year in the Mediterranean basin and affect more than 600,000 ha.

To face this permanent threat, the Mediterranean countries have mobilized and organized for a long time increasingly efficient forest fire prevention and suppression systems. Thus, gradually, according to their culture, their means and their national preferences, the Mediterranean countries have developed a considerable knowledge, tools and adapted methodologies, typical for each country.

Unfortunately, this information remains scattered and is even sometimes not written down. The exchange of information and experiences between countries constitute an effective mean to contribute to the reinforcement of forest fire prevention and suppression. Handbooks of great utility were already elaborated on forest fires, such as for example the “Technical Guide” written in 1989 by French Mediterranean foresters from Cemagref (France), a public research institute of for agriculture and environment, or the “Handbook on forest fire control, a guide for trainers”, published by the Finnish organisation for international development (FINNIDA, Finland) in 1993. But these publications, either do not reflect the special problems of the Mediterranean basin, or restrict themselves to only one country, not taking into account regional diversity.

Thus, under the influence of the network for “Forest fire protection” of the FAO Committee on Mediterranean Forestry Questions of the FAO Silva Mediterranea and thanks to the financial support of France, in particular by the Ministry for Land Management and Environment (Ministère de l'Aménagement du Territoire et de l'Environnement), the FAO asked the Cemagref to produce a practical tool, up-to-date and complete, which is able to improve the training in forest fire prevention and suppression, and would be valid for all countries of the region. This work is conducive to the overall objective to reinforce the national capacities of forest fire prevention in Mediterranean basin. Cemagref has not spared any effort to gather all available bibliographical information by contacting all the Member States of the FAO Silva Mediterranea, and paying visits to several of them.

The guide is structured in eight broad chapters which cover all problems of forest fires in the Mediterranean region: basics of forest fire, databases, fire causes, risk analysis, prevention (dealt with in two chapters: prevention of fire starts and the control of fire spread), suppression, and post-fire activities. The reader will find comprehensive and practical information, as well as methodologies. The guide is didactically targeted to a wide range of users. Moreover, this technical guide has a flexible and adaptable design: each country may improve or alternate the guide by adding national specificities.

The FAO warmly thanks all people who took part directly or indirectly in the elaboration of this guide. Special thanks go to the Cemagref, for its excellent work, to the countries of the area, which were implied in this work by accommodating the personnel of the Cemagref and for communicating relevant information, and to the Government of France which financed the work. Our thanks go also in particular to Mr. Pierre-Yves Colin, Ms. Marielle Jappiot and Ms. Anne Mariel, all three researchers at the Cemagref, which were backstopping the study from the initial phase until the final preparation of the guide. At the FAO, this work was conceived within the framework of the activities of the FAO Committee on Mediterranean Forestry Questions and in particular of the network for “Forest Fire Protection”. The secretariat of this Committee, headed by Mr. Michel Malagnoux, coordinated this work. Mr. Pascal Martinez, first associated and then as consultant to the FAO, followed and impelled with much efficiency and perspicacity the realization of the work and facilitated the communication with the Cemagref.

Jean Clément
Director, Forest Resource Division
FAO Forestry Department

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Introduction to the Handbook and to the mediterranean context



A Handbook on Forest Fire Protection for the Mediterranean basin

Objectives

The Handbook on Forest Fire Protection, serving as a technical fire guide, has the three following objectives:

- Give an overview of the present knowledge in the field of forest fire in the Mediterranean basin;
- Provide a practical technical document designed as a helping tool;
- Serve as a basis for the exchange of ideas within the Mediterranean basin.

This Handbook was prepared with the support from the Trust Fund Project “Forest Fire Co-operation in the Mediterranean Basin” (GCP/REM/056/FRA), financed by France in the Framework of the Mediterranean Forestry Action Programme (MED-FAP). Thirty one member countries are concerned, of which five member countries have been selected as a priority for the project by the FAO, i.e., for this technical guide: Cyprus, Lebanon, Morocco, Tunisia, and Syria.

From 1989 to 1992, the French research institute CEMAGREF (Centre national du Machinisme Agricole, du Génie Rural, des Eaux et des Forêts, Aix en Provence) has edited seven volumes of a “Handbook for the French Mediterranean Forest” (Guide technique du forestier

THE MEDITERRANEAN FORESTRY ACTION PROGRAMME (MED-FAP)

Initiated by the FAO in 1992, this programme has the objective to initiate activities to fight against different forms of degradation of the Mediterranean forest (desertification, erosion, fire, etc.). It provides a general conceptual framework from which each concerned country defines its strategies to reach the envisaged objectives. The bases of the MED-FAP remain relevant for the new frame of forestry action plans that are presently promoted by the international community.

The concerned countries are: Albania, Afghanistan, Algeria, Saudi Arabia, Bahrain, Bulgaria, Cyprus, Egypt, United Arabian Emirates, Spain, Ex-Yugoslavia, France, Greece, Iraq, Iran, Israel, Italy, Jordan, Kuwait, Lebanon, Libya, Malta, Morocco, Oman, Portugal, Qatar, Romania, Syria, Turkey, Tunisia, Yemen.

méditerranéen français), covering the special problems of the French Mediterranean forest.

The volume “Forest Fire Protection” (Protection des forêts contre les incendies) has not only been appreciated in France, but also abroad. The Food and Agricultural Organization of the United Nations (FAO) therefore encouraged the publication of an international handbook, based on the French volume and adjusted to the conditions of other countries of the Mediterranean basin.

The handbook will consist of two parts which will be implemented successively:

- Creation of an international document synthesizing the forest fire problem for the entity of the Mediterranean countries, i.e., the present guide. The CEMAGREF was charged with this first phase.
- Preparation of specific national guidelines for each country. This is a long-term project which will be realized by the individual countries.

Development of this Handbook

COLLECTION OF INFORMATION

Indispensable for setting up a state-of-the-knowledge synthesis on forest fires is the collection of information. This has been accomplished in different ways:

- Search of documentation by key words in existing databases: FAO references, global databases (Agris, Agricola, Cab, Enviroline, Pascal, Ntis);
- Field trips to six different countries (Cyprus, Morocco, Portugal, Syria, Tunisia, Turkey);
- Attempt to establish contacts by mail with all countries concerned (limited response).

CREATION OF A DATABASE

Based on this information collection CEMAGREF created a database using the software EndNotes which allowed to integrate more than 300 documents into a structured documentation for the development of the



Handbook on Forest Fire Protection. Each document was read, analysed for its usefulness for the guide, and finally catalogued with the help of a form (title, author, publishing date, abstract, etc.).

This database can be accessed at the CEMAGREF research unit "Mediterranean Agriculture and Forestry" (*Agriculture et Forêt Méditerranéennes*) in Aix en Provence.

ASSESSMENT OF THE COLLECTED INFORMATION

Within the 31 countries concerned by the programme MED-FAP, the collection of information is very heterogeneous with regards to quantity and quality. The documents are numerous from countries to which a field trip was done. In contrast, for some countries, it was difficult and even impossible to collect information (absence of bibliographical references, no reply mailed requests).

Fires have a different importance varying from country to country. For some countries fire constitutes a problem with major impacts requiring high attention (Algeria, Bulgaria, Cyprus, Spain, France, Greece, Iran, Israel, Italy, Morocco, Portugal, Syria, Tunisia, Turkey).

COUNTRIES THAT COULD NOT BE DOCUMENTED

Afghanistan, Saudi Arabia, Bahrain, United Arab Emirates, Ex Yugoslavia, Iraq, Iran, Jordan, Kuwait, Libya, Oman, Qatar, Romania, Yemen.

In other countries having small forested areas fire represents a marginal or even non-existing problem (Saudi Arabia, Bahrain, Egypt, United Arab Emirates, Kuwait, Libya, Malta, Oman, Qatar). For instance, in Egypt all forest areas are artificial and irrigated, and forest stands do not exceed a size of 80 hectares.

Structure of the Handbook

The Handbook on Forest Fire Protection is organized in eight major themes:

- Basics of Forest Fire
- Databases
- Fire causes
- Risk analysis
- Prevention to avoid fire ignition
- Fire danger rating systems to reduce delay times
- Fire suppression
- Post-fire activities

Each subject is presented by:

- An introductory leaflet presenting the principles of the dealt subject
- Several practical leaflets providing technical information

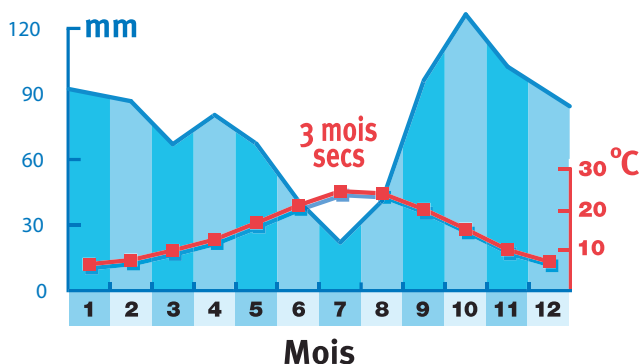
Each leaflet is organized in the same way:

- "Why?" asks for the reason to take such action
- «How?» presents a synthesis with illustrated «boxes» showing examples of adopted solutions

Forest Fires in the Mediterranean basin

The Mediterranean Context

CLIMATIC CONDITIONS



histogram (temperatures/precipitation) of Mediterranean type

The Mediterranean climate is very particular and characterized by:

- hot and dry summer seasons, and
- overall dry condition.

Nevertheless a high variability can be observed from country to country:

- The dryness can be more or less marked in length and intensity. For example, Syria lacks rain during a major part of the year due to the effects of a mountain chain stretching along the coast line.
- The wind can equally be an essential component of this climate. In France it is the *Mistral* or the *Tramontane*; in Israel, in Lebanon or in Syria it is the *Khamsin*, a dry warm wind; at the coast of North Africa blows the *Sirocco*, originating in the Sahara.

This variability exists also between regions of one country as a result of topography, distance to the sea, altitude, and wind exposition. For instance, in Lebanon, the north of the Bekaa plain suffers from a strong dryness caused by a mountain chain (Western Chain) preventing any precipitation whereas the south of this plain is characterized by a lower relief and receives more precipitation.

All in all, the climatic conditions are strongly

favouring the occurrence of forest fires: High temperatures, the absence of precipitation, and regular occurrence of strong winds increase the desiccation of the vegetation and favour ignition risk and fire spread.

SOCIAL ENVIRONMENT AS A DETERMINING FACTOR

In addition to the particular climatic features the socio-economic conditions are determining factors of forest fire occurrence:

Population pressure

Depending on local to regional utilization and functions of forests, people affect forests in different ways:

The forest as a resource for subsistence.

In certain countries (Albania, Morocco, Syria, Tunisia, Turkey), the forest is a source of direct and indirect subsistence for the rural population (firewood, construction wood, non timber forest products, e.g., fruits, and for pasture land and animal husbandry).

The Moroccan forest suffers from a very strong human pressure. For the Rif region the average consumption of firewood varies between four to six tons per home and year. The forest is divided into zones with user rights that are attributed to *douars* (villages) and are legally recognized. These user rights are very constraining for the forest service which is responsible for forest management and the authorization and regulation of livestock grazing, collection of fuelwood for local use,



Country	Forest area		Definition of a forest
	1000 ha	Percentage of territory	
Albania	1 242	45.3	*
Algeria	4 366	1.8	Total of woody and other vegetation with an average height >7 m.
Saudi Arabia	1 601	0.7	*
Bulgaria	3 800	34.4	*
Cyprus	175	18.9	Natural and artificial tree formations, <i>garrigue</i> , <i>macchia</i> , heath, both in public or private ownership
Spain	30 490	61.0	Areas that are wooded or covered with non-cultivated species (trees, shrubs, <i>macchia</i> , grass, etc.)
France	15 075	27.7	Wood formations with a canopy cover of more than 10 %, plantations, heath, <i>macchia</i> , <i>garrigue</i>
Greece	5 754	44.5	Wood or bush formations, pastures
Iran	18 043	11.0	*
Iraq	1 550	3.5	*
Israel	109	5.4	*
Italy	8 063	27.4	*
Jordan	146	1.6	*
Lebanon	84	8.2	Vegetation including shrubs, and coppice and high-forest trees that can only be used for wood industry and fire wood
Libya	779	0.4	*
Morocco	4 718	6.7	Naturally or artificially wooded formations, matorral
Portugal	2 976	32.5	Land of more than 0.2 ha where trees cover more than 10 % of the surface
Romania	6 340	27.6	*
Syria	429	2.3	Natural or artificial vegetation formations that are state property
Tunisia	831	5.3	Naturally or artificially wooded area, <i>garrigue</i>
Turkey	20 199	26.0	Tree or brush formations with varying density and of natural or artificial origin
Yemen	4 060	7.7	*
* no definition reported			

Source: Mediterranean Forestry Action Programme - F.A.O., 1993

and the cutting of construction wood for the needs of a family. The user-rights benefits equal half of an average Moroccan salary.

This results into a strong human pressure, exerting positive impacts on the one side (clearing of the understorey) and, on the other side, negative impacts (reduction of the forested area, increase of fire risk).

The forest environment as attractive lifestyle alternative for urban populations. In France constructions multiply in the forest, the population often seeks the peace and quietness of nature. In Greece the growth of the city Athens is characterized by the construction of



dwellings at the forest edge. The expansion of the forest/ urban-interface increases the risk of fire ignition and the vulnerability of these residential areas.

The forest as conversion area. The increase of areas for cultivation is detrimental to forests. Frequently fires are set intentionally at the forest edge in order to reduce the forested area. This is the case in Morocco or in Syria.

Photographs illustrating the forest as a conversion area

The forest as recreational area. Forests frequently





visited by tourists are subjected to increased risk of fire occurrence, especially in the summer season.

The impact of the population pressure is particularly strong where the legal framework is less elaborated or enforced, e.g., absence of forest demarcations, lack of law enforcement capabilities.

Rural exodus

Whereas much of the forest is reduced in the South and East of the Mediterranean basin, forest and other woody vegetation spreads into abandoned agricultural areas in the North. These new types of woodlands and forest have a high fire hazard due to the dominance of pioneer species. Their expansion favours the formation of large fuel complexes by interconnecting formerly fragmented forest patches, thus increasing the risk of catastrophic large fire events.



Political context

It has been observed that intentional burning of forests are an expression of political instability, e.g., during election periods or in land-use and ethnic conflicts.

TOTAL FOREST AREA

It is very difficult to estimate the forested area of a country, since the definition of a forest rather varies from country to country. This absence of a common definition makes it difficult to compare data between countries of the Mediterranean basin.

The following table provides some figures about forests in some countries of the Mediterranean basin. Where available a definition of “forest area” is given:

Forest Fires in the Mediterranean Basin

DEFINITION OF FOREST FIRES

This definition varies from country to country and in function of its forest definition, but also of additional criteria, e.g., the location of the fire ignition and its distance to the forest, type of ownership, fire size, etc.

Bulgaria: all fires that occur in a forest, plantations, orchard and pastures.

Cyprus: fire originating within state forests or on private land at a distance less than one kilometre from a state forest.

FIRE STATISTICS

Spain: fire that spreads in forested areas or vegetation covers of non-cultivated species.

France: fire that affects a forest, heath, *garrigue*, or *maccia* with a size of at least one hectare and of one owner regardless of the burned area. The term “affect” implies that at least parts of the shrubby or woody layer have been destroyed.

Greece: vegetation fire outside agricultural areas.

Italy: all vegetation fires are considered as “forest” fires.

Lebanon: fire affecting the forest, *garrigue*, grazing zones for life stock, agricultural areas, or orchards.

Morocco: fire affecting forest formations and matorrals belonging to the state forest property or being under forest management.

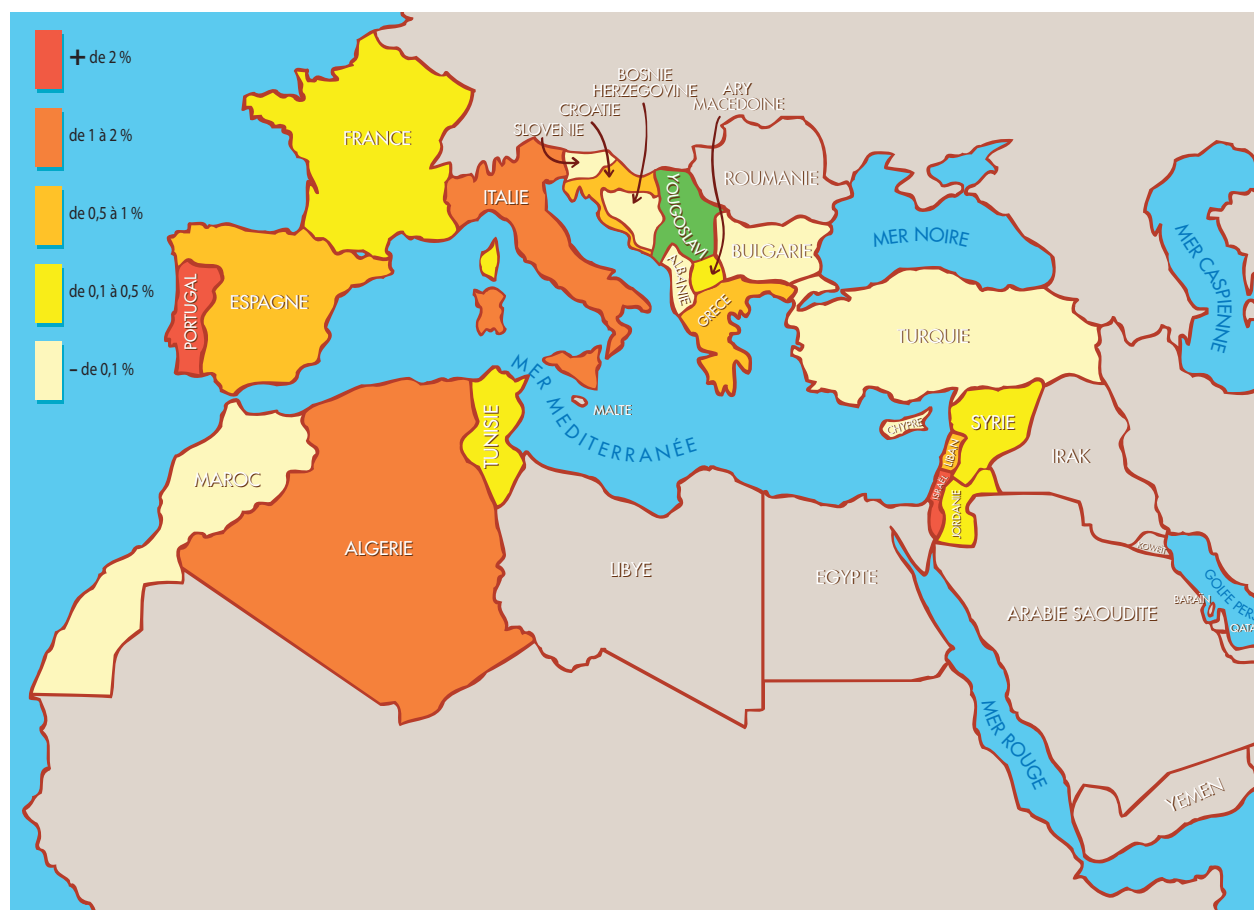
Portugal: fire affecting a forested area that is not agricultural or urban.

Tunisia: fire affecting natural or artificial forests with a size of more than four hectares.

Country	Period	Average area burned per year (ha)	Percentage of national forested area affected by fire (%)
Algeria	81-96	49 130	1.13
Albania	88-97	136	0.01
Bulgaria	95-98	2 550	0.07
Cyprus	81-97	130	0.07
Spain	81-97	211 635	0.69
France	81-97	32 456	0.22
Greece	81-97	48 003	0.83
Israel	81-97	3 407	3.13
Italy	81-97	132 305	1.64
Jordan	81-85	299	0.20
Lebanon	96-97	734	0.87
Libya	81-85	16	-
Morocco	81-97	3 459	0.07
Portugal	81-97	83 143	2.79
Syria	81-97	1 312	0.31
Tunisia	81-97	1 468	0.35
Turkey	81-97	14 662	0.07

Source: Mediterranean Forestry Action Programme (FAO 1993)

These few examples illustrate well the high variability of forest fire definitions. Therefore comparisons between countries have to be done with precaution.



1

Basics of forest Fire



Index

Introduction

A forest fire involves combustion of organic material (fuel) that releases a large quantity of energy.

The combustion energy is transferred from the burning fuel to unburned fuels ahead of the fire front. This phenomenon ensures the fire spread.

The fire start depends on the flammability of the vegetation. The fire spread depends on a number of variables, including fuel characteristics (size, moisture content and arrangement), weather and topography.

1.1 Combustion and released Energy



Combustion

Definition: A combustion is a fast and exothermic oxidative reaction that releases heat, requiring an oxidizing agent to burn the fuel. In the case of a forest fire this oxidizing agent is the air in the atmosphere with the vegetation being the fuel.

The combustion requires the presence of three elements: (a) fuel, (b) oxidizing agent, and (c) initial energy. The process develops in three phases: (a) evaporation of water in the fuel, (b) emission of flammable gas by pyrolysis, and finally (c) ignition. The ignition is ensured by an external energy source. In the following process one part of the released combustion energy is reabsorbed by the fuel in order to sustain the combustion. In the case of a forest fire the released energy is absorbed by the vegetation ahead of the flaming front, which causes the fire propagation.

- Low woody material with a height of less than two meters;
- High woody material with a height of more than two meters.

The horizontal and vertical structure can be continuous or discontinuous (e.g., distribution in small clusters or patches; lack of understorey).

Microstructure

The spatial arrangement of the fine fuels (leaves, needles, and branches) influences the fire intensity: Loosely packed fine fuels have better contact with oxygen and ease the combustion process as compared to densely packed heavy fuels.

CHEMICAL COMPOSITION

A plant is composed of organic matter and water.

Fuel

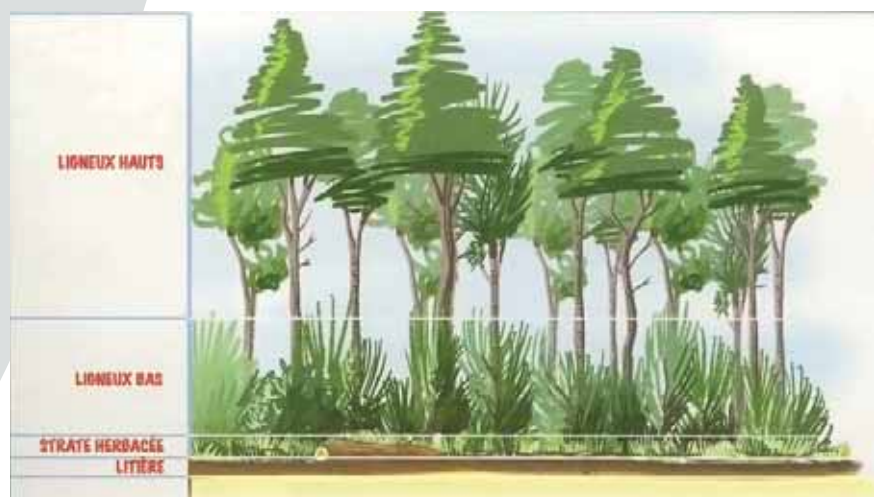
Structure

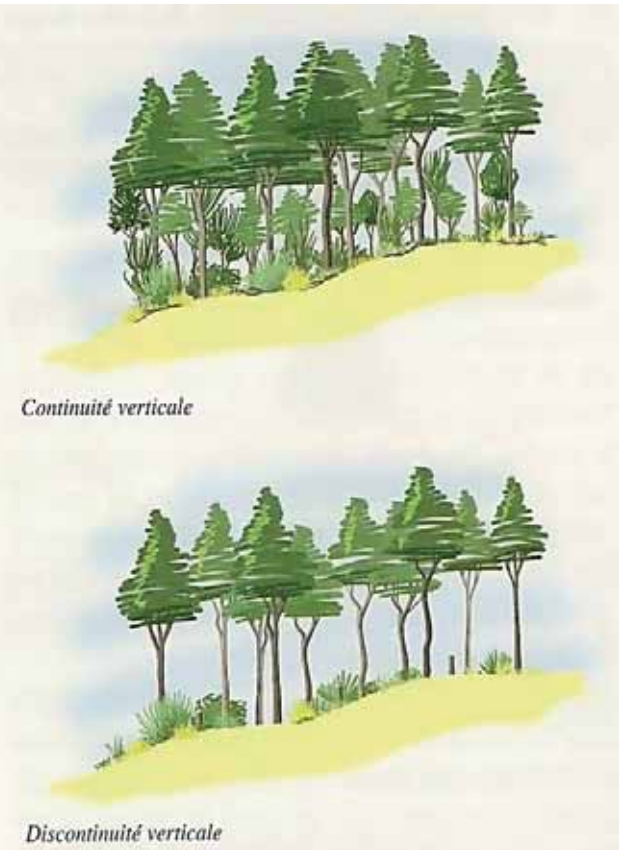
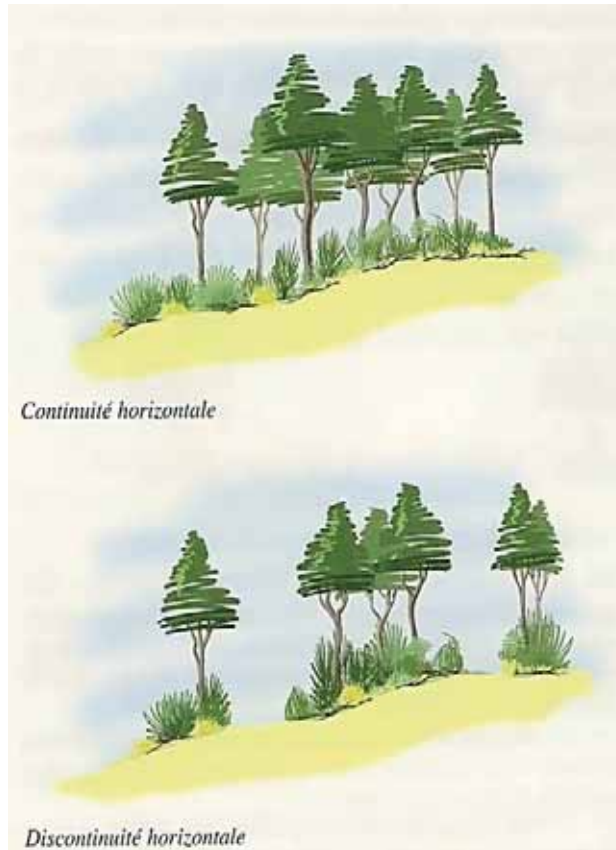
Macrostructure

This is the horizontal or vertical and spatial distribution. Models allow to describe this distribution.

E.g.: in France four vertical strata are discerned:

- Litter, often not very thick in the Mediterranean region;
- Grass stratum, very flammable in the dry season;



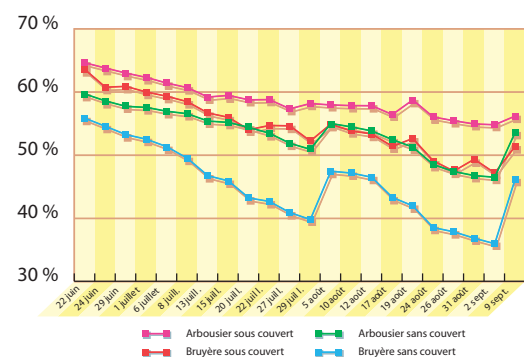


Water content

A condition *sine qua non* for the begin of combustion is dehydration of the vegetation by evaporation of water, followed by thermal degradation (pyrolysis) and release of flammable gases. This physical mechanism requires a high amount of energy due to the high latent heat of the water. Thus, vegetation with a high water content is not very flammable and combustible.

The water content varies in function of the species, but also in function of the phenology, the physiological plant condition and the climatic influence.

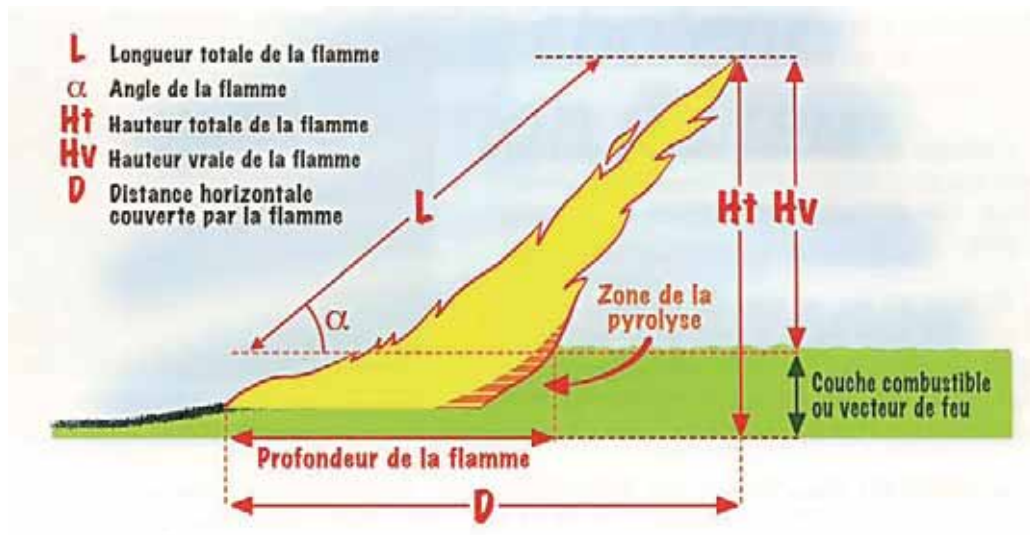
Teneur en eau



Examples with figures

Dry material is composed of organic matter and minerals. Only the organic matter burns, releasing the necessary energy for the fire propagation. Thus, a plant

with high mineral content has a reduced heat yield and is less combustible.



COMBUSTIVE AGENT (OXYGEN)

In the case of forest fires oxygen is abundant in the atmosphere. Ignition and combustion depend strongly on this element. In order to ignite flammable gases (the product of pyrolysis) and maintain a flame, there has to be an oxygen content of at least 15.75 % in the air; average oxygen content of the air is ca. 20 %. The wind plays an essential role for the fire spread because it supplies oxygen to the active fire.

ENERGY SOURCE

The capacity of a fuel to catch fire depends on its characteristics, the energy source and the exposure time

- A weak energy supply allows the ignition of grass, whereas the energy supply has to be much higher for the ignition of wood.
- In order to ignite dry vegetation by a glowing ember the presence of wind is required.
- An electric arc cause by a broken power line or by lightning provides sufficient energy for ignition of dry vegetation



Released Energy – Fire Intensity

Some definitions ...

Total fuel load. This is the quantity of all above-ground combustible materials. Fuel load is usually measured in grams of organic matter (dry weight) per square meter, or tons per hectare. During a forest fire only a fraction of the total fuel is consumed.

Available fuel. The portion of the total fuel that actually burns or would actually burn under specified burning and fuel conditions.

Energy release. The computed total heat release per unit area, expressed in kilojoules per square meter (kJ/m^2)

Fire front or flaming front. The part of a fire within which continuous flaming combustion is taking place. Unless otherwise specified, the fire front is assumed to be the leading edge of the fire perimeter.

Rate of spread. This is the speed of advance of the fire front. It is strongly correlated to the wind speed. It is



computed in meters per second or in km per hour.

Fire line intensity. This is the released energy per time unit and per length of the fire front and calculated in kilowatts per meter of the fire front (kW/m).

This fire line intensity equals the product of available combustion energy and the fire rate of spread. In Canada and France one distinguishes between different fire categories:

- Fireline intensity less than 2 000 kW/m: fire control possible with ground forces only;
- Fireline intensity between 2 000 and 4 000 kW/m: aerial suppression forces are necessary for the control of the fire head;
- Fireline intensity higher than 4 000 kW/m: frontal attack on the fire head often impossible; indirect attack on flanks necessary.

Example: A vegetation type consisting of a continuous layer of short, fine and dry grasses with an available fuel load of 200 g per square meter (=2 tons



per hectare) and burning with a rate of spread of 0.5 m/sec (= 1.8 km/h) has a fire line intensity of 2 000 kW/m. (the heat value of the fuel is 20 kJ/g).

Other examples of released energy - comparing elements

1

1.2 Heat transfer and fire spread

The mechanisms of fire spread are distinguished in three phases:

- Combustion of vegetation material with heat emission;
- Heat transfer towards the fuel ahead of the fire front by conduction, thermal radiation and convection;
- Heat absorption by the plant before the flaming front and its ignition.

Types of Heat Transfer

Heat transfer is an energy exchange process between two points in space that occurs when a temperature difference exists between these two points. It is maintained by the three fundamental physical processes: conduction, radiation and, convection.

CONDUCTION

The conduction is the result of molecular movement. It is related to the composition and the temperature of the environment. It can only happen in a material that is solid, liquid or gaseous. The heat spreads from the warm to the cold body.

In practice the conduction is negligible during the spread of a vegetation fire, since it accounts only for 5 % of the heat transfer. The only exception is a ground fire or a peat fire where conduction is the predominant heat transfer. On the other hand, the solid particle conduction explains the different behaviour of fuels as a function of their depth.

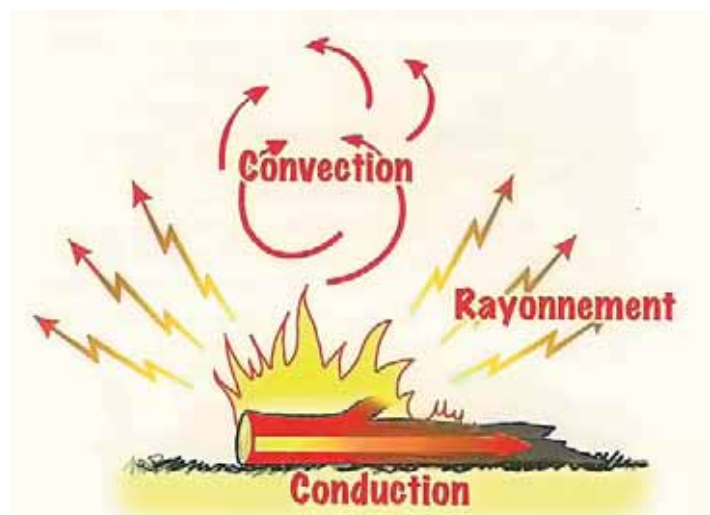
THERMAL RADIATION

Radiation is a type of energy transfer in form of electromagnetic waves with or without particles. All bodies with an absolute temperature above 0 K (= -273°C) emit an electromagnetic radiation, where the radiation frequency is a function of the temperature. The quantity of the transferred energy from one body to another body augments with the increase of the temperature difference between these two bodies. Heat transfer during a forest fire is mainly by electromagnetic infrared radiation.

The radiation flux between a pinpoint flame and another point is inverse proportional to the square of the distance. Thus, it reduces very rapidly with distance. However, a fire front is not a point source of energy but an extended radiating front. At a distance to the fire front of less than 10 to 20 times of the flame height, the absorbed radiation by an object varies therefore inversely proportional with the distance of this object to the flaming front. The radiation is extremely intense at close proximity to the fire front. At a distance 5 to 10 times the flame height, the radiation is much less intense.

In practice it is especially the radiation at short distance that is causing the temperature increase and the drying of the fuel ahead the flaming front, thus maintaining the spread of the fire.

The thermal radiation can reach several Watts per cm². For example, with a fire front of 5 m height



and a length of 50 m the following energy is measured perpendicular in the middle of the fire front:

- 6.2 W/cm² at a distance of 0 m
- 5.2 W/cm² at a distance of 1 m
- 1.4 W/cm² at a distance of 10 m
- 0.7 W/cm² at a distance of 20 m
- 0.4 W/cm² at a distance of 30 m
- 0.2 W/cm² at a distance of 50 m

For comparison:

- In the Sahara Desert in summer time and clear weather the solar radiation on the surface equals 0.1 W/cm² and the temperature of the sand reaches 80°C.
- The pain threshold of naked skin is 0.2 W/cm².
- The threshold causing death within 1 to 2 minutes is 0.7 W/cm².

CONVECTION

Convection is a heat transfer by macroscopic movements of a fluid (gas in the case of a fire) whose mass transports the containing heat. In vegetation fires, combustion produces hot gases which mix with the also heated ambient air. These hot gases are lighter and go up quickly. They bring a great quantity of heat to fuels located above (crown), desiccate them and raise their temperature up to the ignition point. The wind, by pushing hot gases ahead of the flaming front -even in the lower layers of the vegetation - accelerates the fire spread.

The variations of the topography also influence the displacement of hot gases. For an upslope fire, the convection ahead of the fire front is more marked with increasing slope steepness; it is the opposite in a downslope fire. The convection is the dominating process of heat transfer in the forest fires spread. In addition, the moving gases often transport burning materials ("firebrands"), which can fall down up to several hundred meters in front of the fire and ignite new fires ("fire spotting").

Types of Fire Spread

Except for ground fires, a vegetation fire is propagated mainly by convection and radiation. Fire spotting can accelerate the fire spread.

Various types of fires are distinguished in accordance with the layers they are spreading:

- Ground fires burn in organic material of the soil layer (e.g. a peat fire) and usually do not produce a visible flame. They can penetrate in very deep organic deposits and smoulder several decimetres under the surface. They are relatively rare in the Mediterranean region.
- Surface fires burn the low and contiguous



layers on the ground (litter, grass, undergrowth). They are the most common.

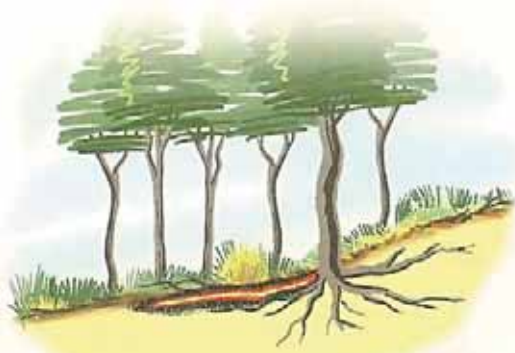
- Crown fires set ablaze the tree tops and spread quickly. There are two types:

1. Independent crown fires, which spread in the crown independently from a surface fire.
2. Dependent crown fires, which spread in the tree tops only because of the heat released by the surface fire. They are «passive» if they contribute less to the propagation than the surface fire and «active» in the contrary case.

Fire spotting is caused by flying sparks or embers (firebrands) ahead of the flaming front. These particles, lifted up in the convection column and transported by the wind, can be the cause for a second fire in front of the first fire. Large firebrands can burn a long time and be transported very far (up to 10 or 20 km in exceptional cases). Very many fire spots can lead to multiple fire starts within a small area and thus create an extremely dangerous blow up. Fire spotting can occur on short or long distances according to the environmental conditions.

The rates of fire spread are extremely variable. A fire in a peat swamp advances only by a few meters in several weeks. The rate of spread of a surface fire or a crown fire depends on the characteristics and the state of the vegetation, the slope and the wind speed.

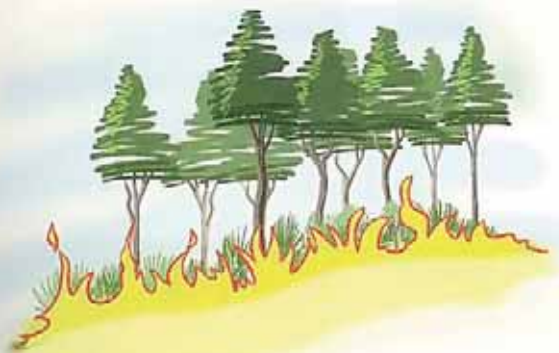




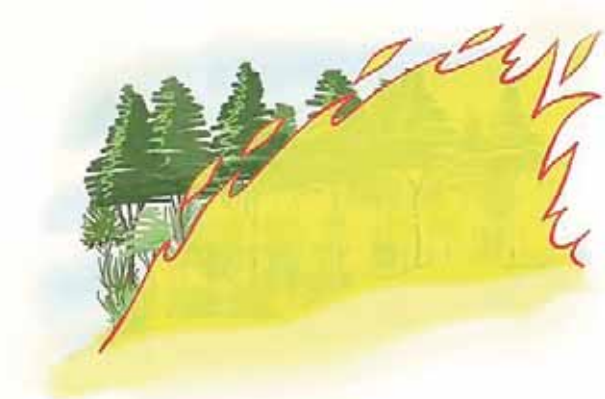
Feu de sol



Feu de cimes



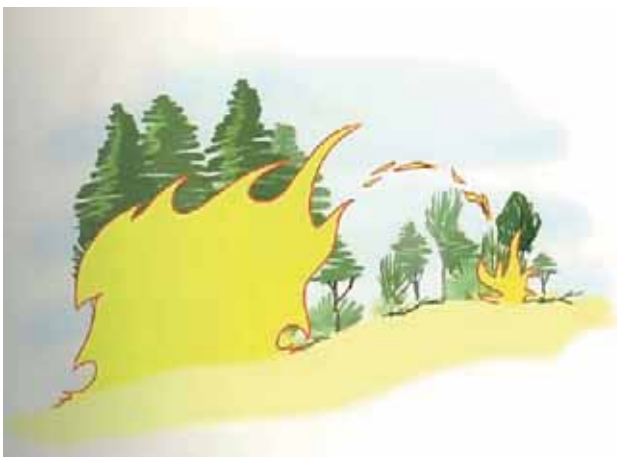
Feu de surface

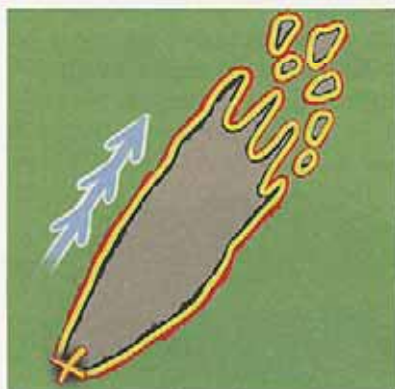
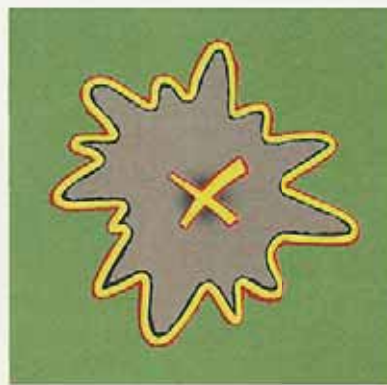
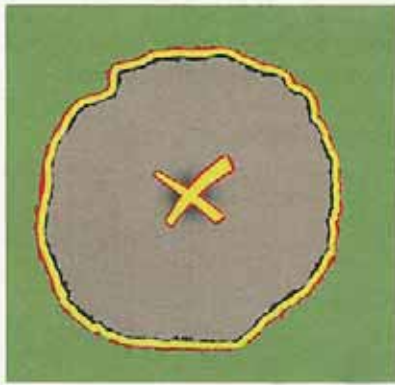


Feu total

- The rate of fire spread is higher in low and continuous fuel types where the biomass is small (grass, heath, open garrigues), sometimes exceeding 10 km/h.
- In stands with a dense understorey, this speed decreases because the vegetation forms a screen obstructing the wind and the heat transfer. Under these conditions the spread rate is 5 to 6 km/h. On the other hand, more biomass is burned.
- Fire storms often move at speeds ranging from 5 to 10 km/h.

Example: In France, fires are regarded as rapid starting from a propagation velocity of 1 km/h, the equivalent of 0.28m/s.





1

1.3 Flammability, combustibility

Flammability and combustibility characterize the reaction of the vegetation during a fire:

- Flammability influences the ignition.
- Combustibility, or fire intensity in relation to vegetation characteristics, influences the fire spread.

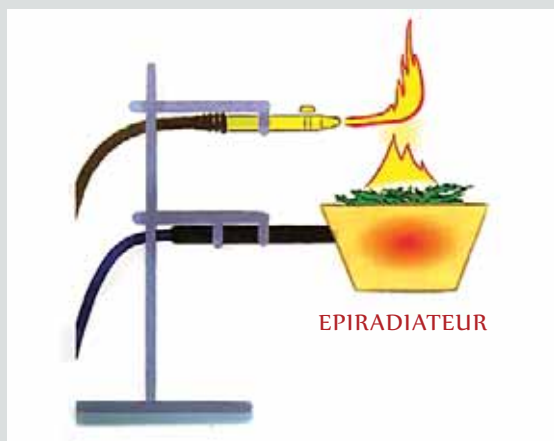
These two concepts can be defined for a plant (branch, leaves, bark fragment), for a species or for a vegetation formation.

Flammability

Flammability qualifies the proneness of the fuel to ignite under heat. It characterizes the quantity of energy necessary to the desiccation of the plant and the pyrolysis.

One of the methods employed to estimate this flammability consists in measuring the following parameters of vegetation samples that are subjected to thermal radiation:

- The time of ignition, corresponding to the



This apparatus is composed of an electric resistance, providing a constant calorific flow, embedded in a block of silica, itself included in a ceramics cup. A standardized sample of the vegetation is deposited in the cup for the flammability measurement. Under the effect of heat, the sample is desiccated and emits gases in the following pyrolysis. These ignite in contact with a gas burner located at a few centimetres above the cup.

exposure time necessary to the appearance of a flame. This factor can be measured using a stop watch.

- The frequency of ignition, i.e., the number of samples where a flame appears, in relation to the total number of samples.

The average values of these two parameters allow to classify the plants according to their flammability.

Combustibility

Combustibility is the **fire intensity related to the characteristics of the vegetation**. It describes the fire intensity that a vegetation formation can build up, without taking into account the topography and the wind.

It characterizes the proneness of the vegetation to burn by releasing sufficient energy and to induce, by heat transfer, the ignition of the next plants.

The combustibility of vegetation is correlated to (a) the amount of biomass combusted, (b) the heat content of the particular species burned, (c) the spatial structure, and (d) the water content (i.e., the season).

The Importance of these Parameters

The flammability of a plant varies according to its parts. The bark of the Aleppo pine does not have the same flammability as its needles. The fire in a pine forest starts in the litter, made up mainly of dry needles. The

risk analysis of an ignition in such a stand requires the knowledge of the flammability of these needles.

A vegetation formation is made up of plants. The flammability and the combustibility of a stand depends on its species composition and their structural arrangement, as well as their water content. These two parameters are thus variable according to the vegetation formation, but also according to the season.

Flammability and combustibility are important for estimating the fire hazard of a forest:

- The study of flammability starts with the analysis of the risk of a fire occurrence, either temporal (follow-up in time), for example, resulting to a preventive mobilization of fire fighting forces at days with high risk, or spatial.
- The combustibility study allows to define fuel types in function of fire behaviour models.

The methodology of the fire risk analysis is more precisely developed in Theme 4 (Risk Analysis).

High flammable species	Medium flammable species	Low flammable species
<i>Calluna vulgaris</i>	<i>Arbustus unedo</i>	<i>Buxus sempervirens</i>
<i>Erica arborea</i>	<i>Cistus albidus</i>	<i>Cytisus multiflorus</i>
<i>Eucalyptus sp.</i>	<i>Cistus salviifolius</i>	<i>Daphne gnidium</i>
<i>Genista hirsuta</i>	<i>Juniperus oxycedrus</i>	<i>Halimium commutatum</i>
<i>Pinus halepensis</i>	<i>Ononis tridentata</i>	<i>Olea europea</i>
<i>Quercus ilex</i>	<i>Pinus pinaster</i>	<i>Pistacia lentiscus</i>
<i>Thymus vulgaris</i>	<i>Quercus faginea</i>	<i>Rhamnus alaternus</i>
<i>Ulex parviflorus</i>	<i>Rhamnus lycioides</i>	<i>Rubia peregrina</i>

Flammability: Spanish classification for some species

Source: Instituto Nacional de Investigaciones Agrarias (INIA)

Databases - information systems

2

Surface
annuelle moyenne
brûlée (en ha)

250 000
200 000
150 000
100 000
50 000
0

Espagne

Italie

Portugal

Algérie

Grèce

France

Turquie

Maroc

Israël

Bulgarie

Tunisie

Syrie

Liban

Jordanie

Albanie

Cypr

Part de la surface
forestière brûlée (en %)

3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0

Index

Principles

- The collection of observations on forest fires over a long period provides essential information for the development of fire fighting and prevention policies:

- It is essential to obtain reliable figures and statistics on fires in order to improve the understanding of the phenomenon, to prioritise technical and economic choices for fire prevention and suppression, and to evaluate the effectiveness of these.

- It is necessary to know the causes of forest fires as well as the motivation of arsonists, and to inform, warn and support the persons in charge.

- The analysis of past fires makes it possible to determine the spatial and temporal characteristics of the fire risk, in order to implement devices for effective prevention and suppression. However, it is necessary to keep in mind that an approach based only on the

past is dangerous without an extrapolation to the present situation in which land use with its particular vegetation and human activities could have changed.

- The building and the management of a database make it possible to gather the information collected by different actors.

- The analysis of this information is a part in the improvement of the fire risk management.

- The international co-operation in database management facilitates the exchange of information on forest fires between countries.

2.1 Building and management of a database

Before building a database on forest fires, it is essential to define the objectives of this database. The information to be collected is then selected according to the pursued objectives.

- The analysis of the collected information requires a filing and management system for this information to ensure its future use. This is the objective of a database.

Characteristics of databases

A database is a whole of homogeneous, coherent and representative data files. It must be easily usable, by combining flexibility, simplicity, ease of use and reliability. A database must at the same time preserve a continuity in time and be evolutionary, suitable for adaptations. It must be updated and be regularly used, in particular by those which feed it. In the contrary case, it loses its reliability.

A data collection and processing that is to the maximum decentralized, allows to implicate the field staff and to obtain an information management system with the following advantages:

- Adaptation to the encountered diversity of situations and still preserving the national standardization. Central services coordinate the work and ensure the regularity and the continuity of the data in time, in order to have the statistical series that are necessary for the analysis.
- Greater reliability of collected information and better sensitivity for local decisions.
- Integration of statistics in service operations.

Choice of data to be collected

NATURE OF THE DATA

the information to be recorded is determined by the pursued objective and the questions to be answered. The information must be collectable with the necessary and sufficient precision so that the answer is useful. Moreover it is necessary to avoid any redundancy of information.

It is necessary to define:

- **Obligatory data.** This is substantial identification data, collected for all fires, including for example the date and time of alarm and the end of the intervention, the ignition place, and the fire size. These data must be complete, i.e., be indicated for all fires.

- **Optional data.** This is additional information that can be collected for all fires or only some: exceeding a certain size, concerning certain forests, having certain origins, etc.

Property of data: the information collected must be clearly defined and measuring units specified. Thus, burned surfaces can correspond to the surfaces actually burned by the fire or to the area affected by the fire, but this must be clearly specified. The data must moreover be reliable.

Some definitions...

Data: characterized by a sign and a code, it is collected without preliminary reflection on its interest and precise objective.

Information: collected according to a precise objective, it has an interpretation model.

Data bank: coherent set of interdependent data.

Database: data bank associated with a management software, it is characterized by:

- Its information
- Its structuring
- Types of user queries
- Possibilities of creation and update of information

Information system: database where each information is present only once.

Homogeneity: indicates temporal continuity of the information. Information must be collected with the same definitions and method during the entire life-span of the database.

Coherence: it must be possible to link and compare the data, and the data must thus be recorded in the same way, for example, in the same unit system.

Evolutionary: a database must be able to adapt to the evolutions of data processing.

Flexibility: characterizes the facility with which modifications can be taken into account.

NB: because of the everyday usage of the term «data», it will be used also wrongly here to indicate data and information. For the same reason, the expression «database» will be used wrongly to indicate databases and information systems.

Data collection and integration of information in the database

The collection of data can be made according to the following methods:

- By the intermediary of a form filled out by hand, the forest fire report.
- Directly on a data-processing tool, like the cartographic data collected by GPS.
- By procurement of existing and already on the spot stored data, using a data-processing tool, like the data of operation bases. This procedure avoids a double data entry.

The data collection must follow some rules:

- If possible, it must be collected as soon as possible after a fire.
- Various people can take part in the recording of information (fire fighters, foresters, police officers, gendarmes, etc.). The role of each one will have then to be specified, and the variables recorded by the same person will be linked as much as possible.
- The form must be simplified to the maximum in order to be filled out easily and errorless.
- The form must be written in the language of the operator.
- The reliability of the data must be controlled.

* All forms must be checked upon their arrival at the next hierarchical level in order to make sure that there are no missing data or visible anomalies. The incomplete or erroneous forms are immediately returned back to the person who must complete it.

* It is possible to ask for a reconfirmation of information when a fire has certain characteristics. Example: In France, for any fire of more than 100 ha a confirmation request is sent to the person having provided the information.

* It is necessary to control 5 to 10 % of the forms, selected randomly, by a field trip to verify the facts. Therefore, it is necessary to fill out a blank form without knowing the content of the original form, then to compare the two forms in order to control the quality of the information collected initially. This control makes it possible to check that instructions are comprehensible, that they were understood and that the work is correctly done.

* If the form is incomprehensible, it is necessary to edit it again.

* If instructions are badly understood, it is necessary to conduct again a staff training.

* Incidentally, if work is of poor quality, the too negligent personnel can be sanctioned.

DATA CODING

it is preferable to enter information as plain text and to avoid the use of codes for many reasons:

- The codes are an error source during data acquisition in the field or data entry into the computer.
- The significance of the code is likely to be

forgotten in the future.

- It is easy to enter data by crossing out the list items, either in the field or during the data entry.
- The information content of the data files is then clear and perennial.

DATA STORAGE AND DATA MANAGEMENT:

The collected data are recorded on computer in order to be analyzed. For the database management a software application can be used which is developed from a programming tool or a standard software, such as:

- A basic data manager, for example, Paradox or Microsoft Access ®.
- A spreadsheet having the functions of a basic data manager, for example, Lotus or Microsoft Excel ®.

The developed software must allow automatic plausibility checks.

DATA ENTRY METHODS

if the collection of information is initially taken from a forest fire report, the data entry form on the computer screen should resemble the handwritten form as much as possible to facilitate this data entry.

The recording of the data can be carried out at various hierarchical levels:

- By the personnel close to the field, as in France.
- At the central level, like in Turkey.

During the data entry, the use of automatic plausibility checks allow to detect:

* Anomalies, i.e., information corresponding to not plausible facts:

– Dates or schedules, for example, a fire start on September 1 and its suppression on August 31.

– On the geographical localization (area, province, community). For example, an error message appears if the community does not exist in the province.

* Improbabilities, i.e., information corresponding to facts possible but very different from common facts:

– Time of intervention, for example, less than 5 hours.

– Surface burned compared with the duration of fire, for example, a two hour old fire cannot have burned 1000 ha.

The recorded data must also be checked, for example, in one of the following ways:

- Make a double data entry by two operators and to compare the two files;
- Print data and compare them with the original forms.

– In the case of a detected error or missing data, additional information is requested from the operator.

Different back-up copies of files must be made on various saving devices (diskettes, hard disk, CD-Rom).

2.2 Use of a database

The analyses of the information stored in the database allow:

To clarify phenomena (burned surfaces, nature of the fire causes) and their evolutions over time.

To explain these phenomena and evolutions.

To have objective elements thus to formulate fire prevention policies, early warning, preparedness and to support fire suppression.

To inform all hierarchical levels.

To communicate with the population through the media.

Used software

After collection the data is examined to provide statistical results (tables, graphs, maps) and analyses.

The use of an office software facilitates the interpretation of information:

- Excel© is powerful for the creation of graphs.
- Access© allows many queries.

A word processing software (for example, Word© or Word Perfect©) allows to write reports by including graphs resulting from a spreadsheet and the tables resulting from a basic data manager.

If a standard office automation software is used to develop the management software management, the interpretation of information can be carried out directly without transfer. In the contrary case, the used management software must make it possible to transfer the data towards the office automation software.

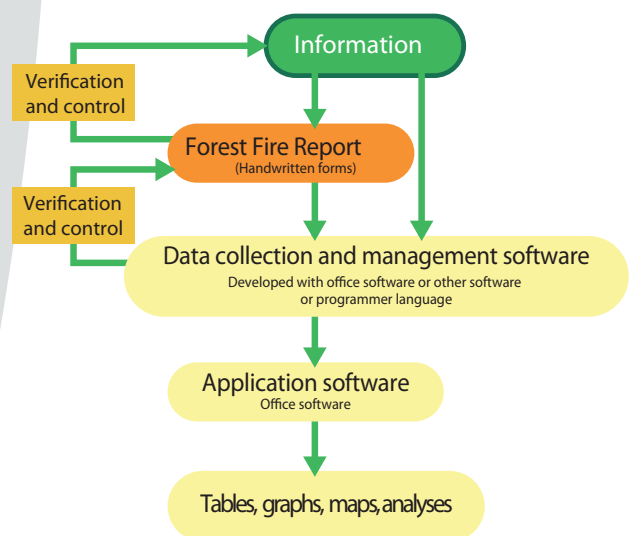
The possible processing

A simple processing makes it already possible to obtain interesting results, which can be presented in the form of tables:

- General statistics (number of fires and surfaces burned per year)
- Monthly distribution by week day
- Distribution by surface classes
- Distribution by causes
- Distribution by geographical entities, according to administrative or forest units.

The creation of graphics, more understandable than tables, often facilitates the analysis. On the other hand, graphics in general do not allow to present as many data as in a table.

The distribution curves of the numbers and surfaces burned during month of the year allow to visualize the dangerous summer months.



The cartography allows to visualize the distribution of fires, their origin, etc. (cf. chapter 4.3).

More complex data processing can combine several files. It can be judicious to regroup the data with the information from other databases, in particular geographical and socio-economic information systems for the understanding of fire causes or the study of burned areas and fire weather. The database on forest fires can be compared with databases of forest inventories, with the objective, for example, to interrelate burned surfaces with the existing forest cover types.

Case studies make it possible to complete the analysis based on the entire data set. It is then a question of carrying out the precise examination of the events on a very carefully selected sample of fires, in particular by reconstituting the facts accurately.

Program processing

The information collected in the database allows to study a multitude of relations between certain fire characteristics. The analyses carried out are intended to clarify:

- When and where fires start;
- Their number and burned area;
- Fire fighting techniques;
- Similarities between fires (dates, places, causes, etc.);
- Exceptional fires.

The analysis of the results can take the following shape.

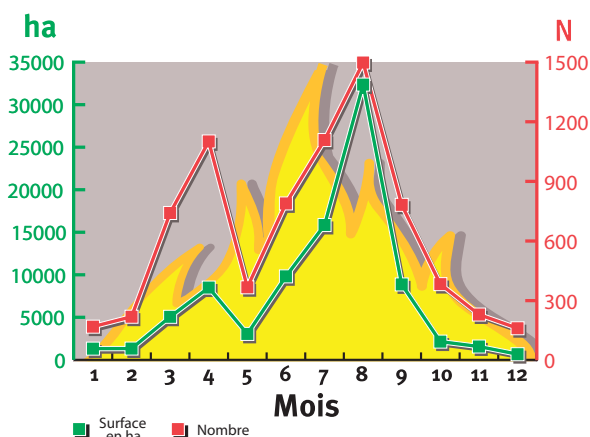
ANNUAL ANALYSES

Data in relation over time:

To analyse the evolution with time:

- Number of fires and burned areas
- Example: Numbers of fires, total, maximum, and average burned areas by fire, by year, by month, day or hour
- Times of first intervention and time of extinction
- Example: Times of intervention, in minutes, by day of the week.
- Fire causes.

Mois	Nombre de feux (N)	Surface totale S (ha)
janvier	169	1 316,87
février	219	1 324,23
mars	741	5 058,80
avril	1 101	8 495,75
mai	367	3 045,37
juin	789	9 813,27
juillet	1 108	15 849,04
août	1 498	32 359,65
septembre	782	8 862,97
octobre	383	2 141,66
novembre	230	1 594,69
décembre	161	660,09
Totaux	7 548	90 522,39



Nombre de feux et surface brûlée, par mois - Source : Chevrou, 1999

- Example: Fire causes by year

Data in relation to the place:

To analyse the relations between the place of ignition (area, province, community) and:

- The number of fires
- Example: Number of fires per region
- Burned surface
- Example: Total, maximum, and average burned surfaces by fire and by region
- Evolution over time of the fire number and burned surfaces
- Example: Number of fires and total, maximum, and average burned surfaces by fire, area, year
- Fire causes
- Example: Fire causes by area

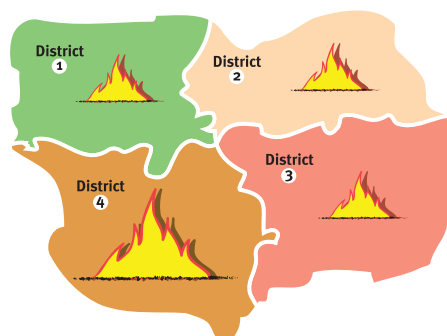
Data in relation to elapsed time:

Relation analysis of burned surfaces and:

- Intervention times
- Example: Number of fires in % per class of surface and class of intervention time
- Suppression time
- Example: Number of fires in % per class of surface and class of extinction time

Analysis of results obtained previously in relation to the availability of the fighting capacity according to the date of the first alarm.

District	Nombre de feux (N)
District 1	1 489
District 2	1 403
District 3	1 451
District 4	3 205
Totaux	7 548



Nombre de feux et surface brûlée par district - Source : Chevrou, 1999

The French database: Prométhée («Prometheus»)

The database Prométhée is a statistical tool for forest fires. It assists to the planning of actions to be carried out and the assessment of their effectiveness. Created in 1973, this program covers 15 Départements of the South East of France.

The information stored in Prométhée is organized along the four following categories:

- Identification of the fires
- Conditions during fire start and fire propagation
- Operational means implemented and tactics used
- General characteristics of the burned zone

The fire characteristics (date and hour of alarm, location and burned area) are reported each evening by the Center of Départemental Fire Operations and Rescue. The three other categories, representing the complementary data, are provided by foresters, fire fighters, gendarmes and police officers. The information

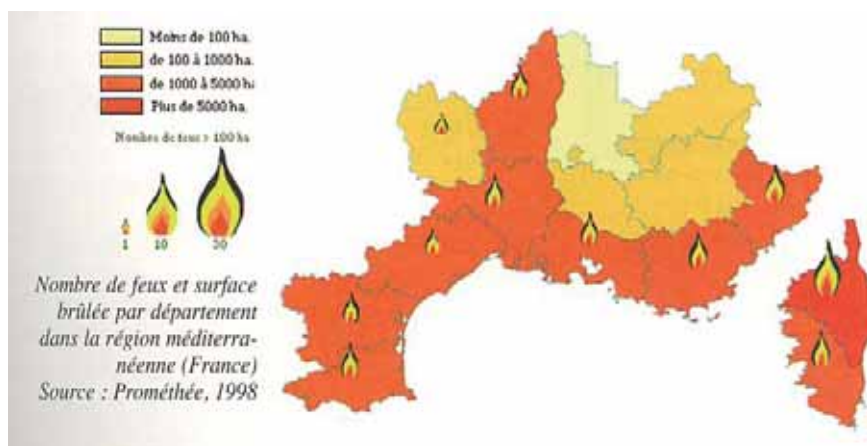
is entered directly into the Prométhée database, without passing by the intermediary of a forest fire report.

Départemental coordinators, nominated by the Préfet (governor), are in charge of the follow-up and meet frequently. They have the responsibility for the data-gathering in their Département. They are the essential link between the different services in charge of the data acquisition. They ensure the homogeneity of the data collection for the entire French Mediterranean region, which is carried out by field personnel.

The conclusions drawn from Prométhée increased considerably the knowledge on forest fires in France and determined the strategy development and prevention techniques, fire danger rating system and fire fighting for about fifteen years.

Example: evolution in the fire prevention measures, decentralization of water bombers, definition of reconnaissance flight routes, etc.

Internet Site: <http://www.promethee.com/promethee/>



Data in relation to the burned vegetation

Relation analysis between:

- Number of fires and burned surfaces and vegetation types

Data in relation to the fire causes

Relation analysis between:

- The frequency of fires of accidental or negligent cause and week day
- The frequency of arson fires and week day
- The frequency of arson fires and hour of first alarm

In relation to the meteorological conditions

Relation analysis between:

- Number of fires and burned area and maximum air temperature
- Number of fires and burned area and maximum wind speed

Analysis of exceptional fires

Fires showing exceptional characteristics with regards to the burned surface, the date, the place, the cause, the delay time or the time of extinction must be analysed in order to know how and why that fire occurred in order to, for example, improve the organization if the fire was a catastrophic event.

Database in Turkey

Each fire is recorded at the level of an Under-district on forms which are reported up all hierarchical levels until the General Forestry Directorate, where the forms are entered in an computerized database. There are very few computers at the level of Regional Directorate, Districts and Under-Districts.

In total, four reports can be written for the same fire, according to the evolution of the fire:

- The first report informs on the ignition.
- The second report specifies the fire evolution, if the fire is not contained within 6 hours. A report of this type is then filled out every 6 hours until the suppression of the fire.
- The third report describes the characteristics of the extinguished fire.
- The last report, called «forest fire report», synthesizes all information; it is the final version, which will be used for the data entering.

There exist two databases:

- An operational database that allows to analyse the course of fire fighting operations and to improve interventions. It is created from the information of the first three types of reports.
- A statistical database that is build on the synthesizing last report, the «forest fire report».

PARTICULAR STUDIES TO BE REPEATED EVERY FOUR YEARS APPROXIMATELY:

Analysis of relations between the burned surfaces and the management conditions of the forest (existence of a management or a forest fire protection management plan, implemented or not implemented).

Information feedback

In the case of a centralized data processing, a top-down information feedback motivates the field officers and their personnel in charge of data acquisition by showing the importance of their work. It justifies the prevention measures taken in the field, for example, the building of infrastructures for fire suppression. This information feedback can be done with an annual report synthesizing and analysing the data of the past year for each administrative unit in order to personalize the results.

In conclusion, the correct operation of a database is based on some simple rules:

- communicate bottom-up and top-down (through all hierarchical levels) and to the public (media);
- simplify;
- be pragmatic;
- ensure a rigorous updating.

FIRE REGISTRATION RECORD

1	Information on Forest Fire Location			3	Information on Forest Fire Time			Date	Time
A	Regional Direct			a	Fire Announcement (detection) Time				
B	Forest District			b	Initial Attack Time				
C	Forest Subdistrict			c	Control Time				
D	Code num of Fore.			d	Extinction Time				
E	Location			e	Forest fire Duration				
F	Number of Forest Stand			4	Number of Fire in District or Subdistrict		Fire number of Forest District Direc..		
G	City			5	Name of Fire Chief				
H	Town			6	Messenger of Fire				
I	Village			7	Fire Occurrence Point				
2	Fire Causes are Certain or Prob ?			8	Suppression Method				
9	Forest Fire Cause	Lightning	Unknown	Arson	Negligence		Accident		
10	Meteorological Information	Rel Humidity %	Wind Speed Km/s	Wind Direction	Max. Air Temp.	Rainfall mm	Days since Last Rain		
11	Topographic Information	Elevation	Slope	Aspect	Place	Wide Valley	Narrow Creek	Dry Creek	Slope Ridge
12	Source of Ignition	Grass	Shrub	Litter	Kidding	Wood	Slash	Residue	Other
13	Burned Forest Area	Management form	High Forest (Ha)	Degraded High Forest (Ha)	Coppice Forest (Ha)	Degraded Coppice Forest (Ha)	Maquis (Ha)	Reforestra. (Ha)	Total
A		Stand Type							
B		Tree Species							
C		Surface Fire							
D		Crown Fire							
		Total							
14	Number of Seedlings below 7,9 cm height that died in the fire								
15	Value of trees less than 8 cm in diameter in the K.G.H. Log Pole In Wood Pa.Wood Sp. Wood Fuelw								

2.3 *international cooperation*

According to the principle that each country can benefit from the experiences of its neighbours, it is important to establish a co-operation in the field of forest fires by collecting comparable standardized information. International organizations, like FAO, need rather homogeneous and reliable indicators in order to play their role in information exchange and the enhancement of development.

In 1990 the first Ministerial Conference on the Protection of Forests in Europe was held in Strasbourg. On this occasion 27 states and the European Community expressed the need to facilitate and promote the exchange of information between countries in order to improve prevention strategies. The creation of a decentralized data bank on forest fires meets this need.

In 1991 the FAO and the International Centre for Advanced Mediterranean Agronomic Studies organized the first think tank workshop on databases, which was open to all countries of the Mediterranean basin. Another workshop followed in 1993.

In 1997 the F.A.O. Committee Silva Mediterranea has launched a new activity to extend the database on all Mediterranean countries of the Mediterranean basin, in the framework of the French project "Information Exchange and strengthening of national management capacity and forest fires risk analysis"¹. Two workshops, held in 1997 and 1998, enabled representatives of five priority countries, like Algeria and Turkey, to exchange their work and to receive a practical training on the creation, the management, and the use of databases.

Data of European countries are gathered and analysed by the European Commission. This data synthesis is now available for all Mediterranean countries.

The information exchange between countries requires to analyse the definitions of the expression "forest fire" in each country. Without imposing an international definition, differences and specificity of definitions must be integrated when data are compared.

Decentralized database on forest fires

THE OBJECTIVES

– To improve the knowledge of the phenomenon for the whole of the Mediterranean basin, i.e., initially to

count and quantify the fires

- To facilitate and promote the exchange of compatible data and of experiences with forest fires in order to establish prevention policies without replacing the various national systems by a universal and standardized system
- To compare prevention and suppression methods used in each country
- To cooperate in the case of catastrophic fire events
- To improve the operation of national systems for data processing, the reliability of the data and quality of national data banks
- To setting up of a common fire danger rating system

THE PRINCIPLES

A common core ("socle minimum") of information on forest fires defines the obligatory information that has to be collected on each fire (cf. below). The signatory state, having decided to adhere to the network, commits itself to collect this minimum information on forest fires, and to hold the information of this minimum base at the disposal to each other member of the network.

Each country has its own definition of a forest and a forest fire. It is necessary to compare the definitions and to support its convergence. The heterogeneity of these definitions is not an obstacle for the collaboration, but their harmonization will be on the contrary a consequence of the co-operation.

The integrated data must follow some principles:

- All vegetation fires and not only forest fires are considered
- Each country keeps and clarifies its definition of a vegetation fire
- The recorded data should allow comparisons between countries

The data that is preserved on hand-written forms prior to the installation of the database, can be integrated into this database.

¹ In French: Échange d'informations et renforcement de la capacité nationale de gestion et d'analyse du risque d'incendie de forêt.

THE MINIMUM CORE OF INFORMATION

The minimum core of information on forest fires consists of ten characteristics that are collected for each officially reported fire:

- Date of first alert
- Time of first alert
- Date of first intervention
- Time of first intervention
- Date of extinction
- Hour of extinction
- Location of fire ignition (state, area, province or department, community)
- Total burned area
- Localization of the burned area on forest and non-forested territory
- Fire cause

The interpretation

The interpretation of the information of a database was presented in chapter 2.2

It should be noted that the numerical data of a common minimum basis make it possible to calculate various values:

- Number of forest fires and burned area expressed absolute or as a percentage
- Average sizes of a fire (burned surface / number of fires)
- Time of intervention (date and hour of first intervention - date and hour of alarm)
- Times of extinction (date and hour of extinction - date and hour of alarm)
- Speed of fire spread: surface burned / time of extinction
- Variations of local or temporal averages to the general average
- Extreme values (maximum and minimum)
- Classes of burned area (sizes), intervention times (elapsed times), speed

These values allow to analyse a multitude of relations between fire characteristics.

Fire causes

3



Principles

The causes of forest fires are multiple, and their distribution varies from country to country and within one country, but also over time. The determination of fire origins is the basis for any effective prevention policy.

- Fires in the Mediterranean basin are by a large majority of human origin, i.e., caused by accident, negligence or intention.*
- The fire-cause investigation is an essential task of forest fire protection. In order to know the real cause of a fire, various procedures are executed according to the country. Thus specialized teams are charged with this task, using sophisticated methods.*

3.1 Fire origins

The origin of a fire is often difficult to determine due to the absence of material evidence. The result is that the percentage of undetermined causes can be very high.

This percentage related to the number of fires in the average reaches 32 % in Spain, 33 % in France, 26 % in Greece, 31 % in Portugal and 48 % in Turkey.

The cause of a fire can be known with different degrees of certainty.

In France, the certainty of the cause is indicated using one of the following descriptions: certain, very probable, probable, undetermined. Before 1996, only the gendarmerie (French national police) could investigate the cause of a fire, and only these causes were considered unquestionably as “known” with proven evidence. Since 1996, other services (municipal police, foresters, firefighters) can also provide information which they have on the nature of the cause and its degree of certainty. The causes considered as “known” are causes that are unquestionable, very probable, or probable. These new rules have permitted to better understand fire origins, and the rate of certain causes increased from approximately 30 % before 1996 to approximately 70 % currently.

Natural causes

Vegetation does not self-ignite, even during droughts. The most important natural cause is lightning. This phenomenon, very widespread in boreal forests (“dry storms”), is relatively rare in the Mediterranean area where it accounts for only 1 to 5 % of all ignitions.

Exceptions can however be observed, particularly in Spain, where, in certain areas, lightning accounts for 30 % of fire starts (Aragon: 38 % and Castile-La Mancha: 29 %).

Human causes

They are the major factor for forest fire ignition. For

all Mediterranean countries there can be differentiated between involuntary and voluntary causes. The balance between these two causes depends closely on the social, economic, political, and juridical context in each country.

INVOLUNTARY CAUSE

This is the principal cause for forest fires in most Mediterranean countries.

Negligence

Negligence results from carelessness vis-a-vis the fire hazard and is correlated with the visitor frequency in the forest or its immediate surroundings. The type of carelessness depends on the activities in the forest and its immediate surroundings.

Fire causes	Examples
Farming activities	Within the forest: collection of honey with smoke, clearing for ploughing In its periphery: pastoral fires, burning of vegetation residues
Forest work	Charcoal production (charcoal kiln), debris burning after clearing
Tourists	Picnic, cigarettes
Hunters	Driving animals for hunting, campfires
Dwellings	Garden fires, barbecues



In each country the distribution of causes is very different:

- For countries where the economy is based on agriculture and where the pressure of the rural population is strong, agricultural and forest works represent one of the most important causes (E.g., up to 65 % in Syria). Under these conditions, fire starts are very often at the limits of a forest.

- In countries with a strong urban growth, the construction of dwellings in the forest or its edge creates the so-called wildland/urban interfaces which is very favourable to fire starts, e.g., the urbanization at the periphery of Athens.

- In countries with a highly developed tourist industry, numerous fire causes are related to the public (e.g., 13 % in Cyprus). Certain causes are very specific to certain countries.

Military exercises cause 15 % of all fires in Cyprus. This is also an important fire cause in Israel.

Accidents

Accidental fires are much less frequent than fires due to negligence.

Traffic in the forest or its periphery: the forest/road interface are zones with a strong probability of a fire start. The projection of fire sparks during the passage of a railway train, or by the muffler of a vehicle (car, motor bike, etc.) can cause a fire. It is the same for not well maintained agricultural and forest machines.

Power lines: strong winds can cause electric arcs between swaying lines and set vegetation at fire.

Garbage dumps: either authorized or clandestine, in any case, garbage dumps constitute a potential fire source by ignited papers or internal combustion caused by fermentation.



VOLUNTARY CAUSES (ARSON)

Their percentage is very variable from country to country: 4 % in Tunisia, 30 % in Greece, 53 % in Sardinia (Italy), and up to 67 % in Spain.

Pyromania

Certain individuals set a fire out of pleasure, as a game, to draw attention, to see fire engines in action, etc. This pyromania is more or less morbid, according to the degree of responsibility feeling of the individual. This cause plays, however, only a limited role, even if there is often a tendency, in the case of an uncertain fire origin to blame a pyromaniac.

Revenge

Fire can be a tool of revenge caused by a controversy with the administration (hunters) or a neighbour, social exclusion (dismissed worker), expropriation, etc.

When the forest is at stake

Political stakes: in countries marked by political instability, the forest can be at serious risk.

Economic stakes: arson fires can bring a direct material profit (improvement of pastures, wood utilization, etc.) or indirect by land appropriation. These acts with criminal motivation are thus all the more frequent when the legislative framework is badly defined (absence of land register or demarcation of forests, quasi non-existent law enforcement and punishment).

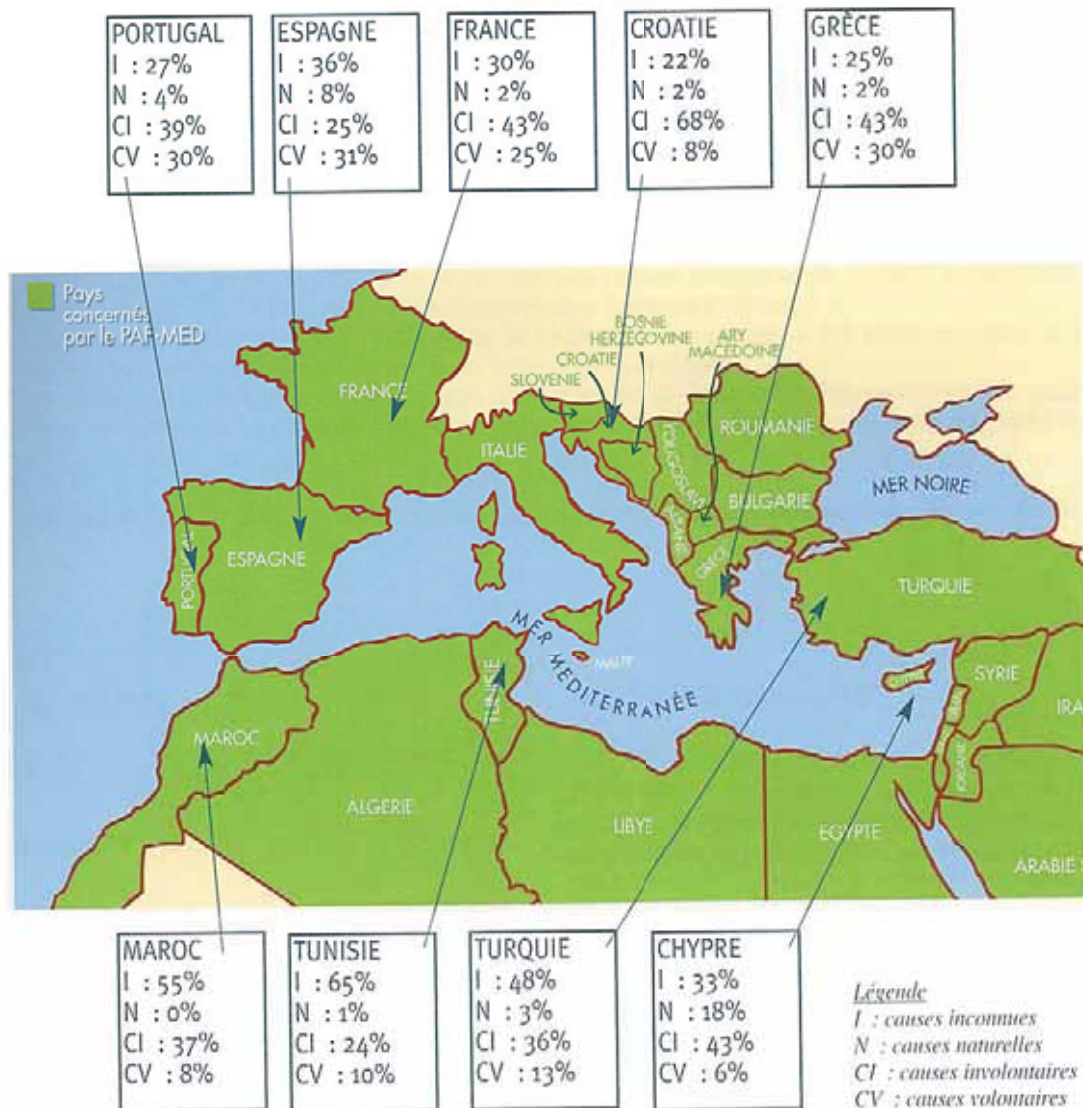
Examples:

- This phenomenon accounts for nearly 10 % of fire causes in Syria: with a demographic growth rate largely exceeding

that of available arable land, the local population pressure to acquire new agricultural land is very strong. The inhabitants burn debris at the forest edge, hoping that the fire spreads to the forest stands.

– In Greece, in particular in the periphery of Athens, cases of arson aiming at land appropriation are frequent because of the urban local population pressure and not very scrupulous real estate developers (transformation of the burned forest areas into construction land).

Social stakes: this is a very particular, specific case in Italy, and especially in Sardinia. The cases of arson are very frequent, particularly in zones having a high unemployment rate. To start a forest fire can be a way of creating new jobs (detection, suppression, rehabilitation of burned areas, etc.). One speaks about a “fire industry”.



3.2 *Investigation of causes*

A sustainable success in the combat against forest fires requires the investigation and analysis of fire origins. The knowledge of the causes allows a better targeting of actions to be initiated for fire prevention (information, awareness raising, risk analysis, regional planning, etc.), and to limit possible criminal acts by bringing culprits effectively to trial.

In many Mediterranean countries, the fire-cause investigation is still little developed, even not existing, and the portion of unknown causes is high. Taking into account the absence of evidence, the origin of a fire is often investigated in a very subjective way when analysing fire characteristics (point of origin, date, hour, etc.). Unfortunately by prejudice fire origins are often blamed on scapegoats, hindering investigators to find the real cause.

In Spain and Portugal, where the fire-cause investigation has gained from strong efforts for a few years, the share of unknown causes strongly decreased:

- In Spain, a training course for the investigation of causes was initiated in 1991. The rate of unknown causes dropped from 48 % in 1990 to 18 % in 1995.
- In Portugal, the method of the physical evidence (cf. below) was tested for the first time in 1990. The rate of unknown causes dropped from an average of 74 % for the years 1980 - 1988 to an average of 31 % for the years 1990 - 1996.

The analysis of information collected on causes requires a coherent classification of these causes.

Methods of fire-cause investigation

INFERRING FROM FIRE CHARACTERISTICS

The data collected on a fire can provide additional information specifying the context of the fire start. This method is simple but risks sometimes to provide subjective results.

POST-FIRE INVESTIGATION

After a fire, a survey can be carried out to determine the fire origin. This investigation has the advantage of being more thorough than a simple deduction from collected fire characteristics. Nevertheless, this remains difficult, since the absence of material evidence allows not always to conclude on true causes. Thus, many investigations do not lead to any hints and causes remain unknown.

EVIDENCE METHODS

The investigation of fire causes is a difficult exercise which does not always lead to a result by the intermediary of a traditional investigation. Evidence methods have been used for a few years, but they require at the same time much time and know-how. These methods are used by specialized fire-cause investigation teams, whose members, especially trained, devote themselves full-time to this task.

Specialized investigation teams

The implementation of physical evidence methods for investigation requires:

- To call in personnel especially trained for this purpose
- To create partnerships between services in charge of fires

METHOD OF PHYSICAL EVIDENCE

This method, developed in the United States, is used in Spain and in Portugal.

Principle

The method has 3 successive phases:

- Localization of the point of the fire origin by reconstruction of the evolution of the fire contours. The traces, called physical indicators, left by the fire on stones, trunks, posts, vegetation, etc., are analysed.
- Thorough analysis on the site of the initial fire area, identifying the heat source that caused the fire.
- Identification of the cause and the person responsible for the fire, based on the material evidence and the testimony of witnesses.

Fire reconstruction and localization of the starting point

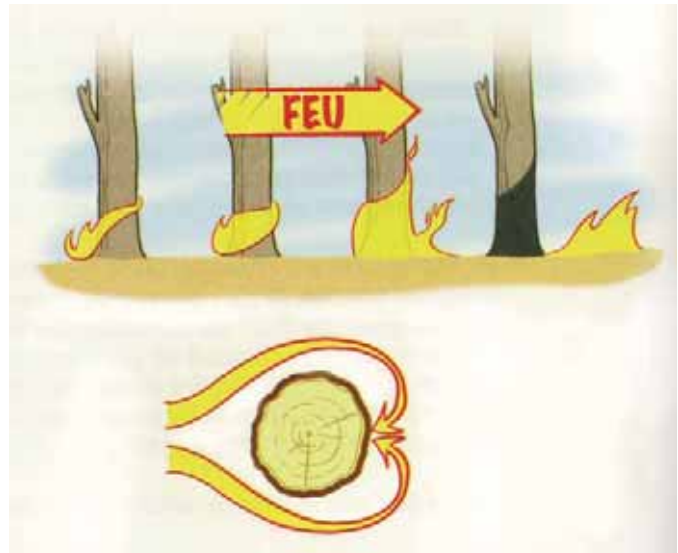
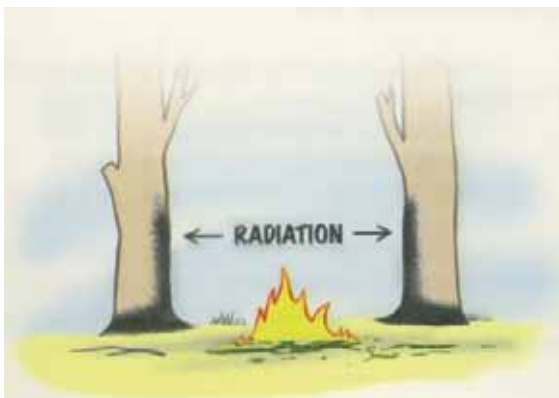
The use of theoretical fire spread models permits to reconstruct the evolution of fire contours and to locate roughly the starting zone. The physical indicators allow to establish direction vectors and the direction of the fire progression and thus to specify the area of the fire origin.

The types of evidence left by a fire are numerous, and each one provides information on one or more fire characteristics: propagation direction, rate of spread or fire intensity. Two examples are presented here:

Charring models

There are traces left by a fire on tree stems. Their shape varies according to the direction of the fire propagation and the wind direction.

- When the fire starts, it develops by radiation, and the trees surrounding the point of the fire start show the same charring height. Under influence of wind and with increasing wind speed the flames tilt and produce more intensively charred stems in the downwind direction

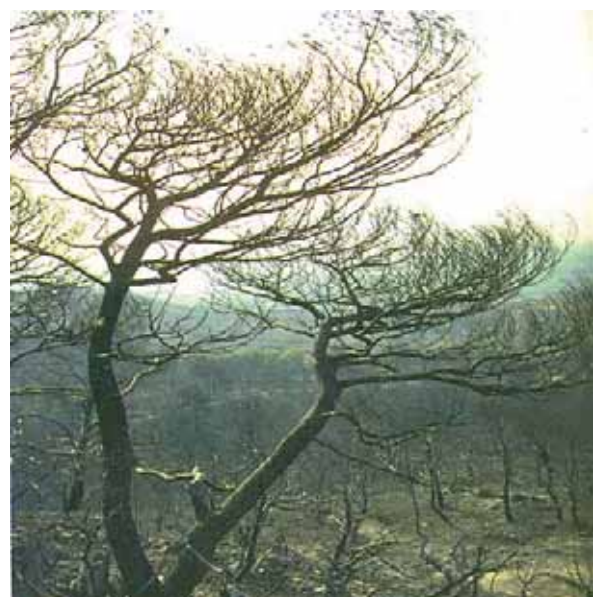


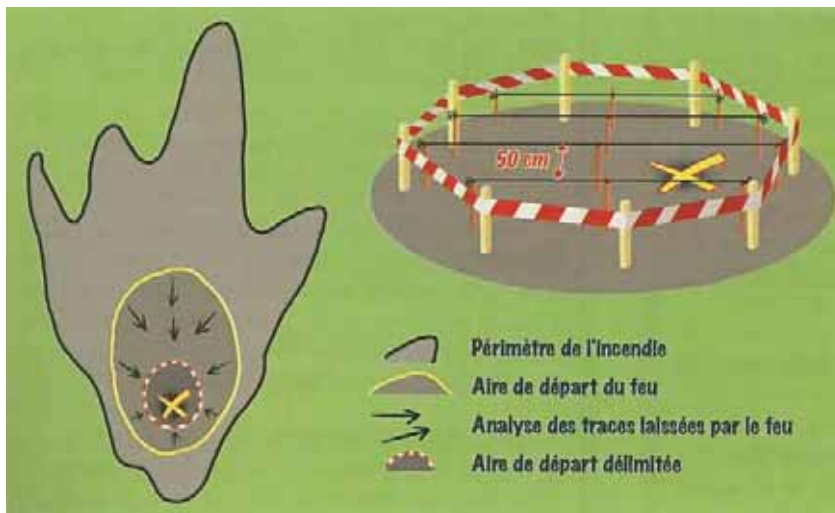
- When the fire increases in size, the heat is transferred by radiation but also by convection. Charring marks are lower on the trunk side directed towards the approaching fire (upwind side) and higher at the downwind (lee) side.

«Freezing» of branches

Under the effect of hot convection currents pushed by the wind, the fine tree branches of trees and undergrowth take and then preserve a flag shape directed in the wind direction, i.e., the direction of fire propagation. This „freezing“ effect more distinct with increasing spread rate of the fire.

Near the point of the fire start, the fire affects more the branches close to the heat source (usually branches of the lower parts of the tree) where charring marks can be observed.





- Fire starting point located at the shade of trees
- Very visited place
- Existence of zones cleared of undergrowth
- Tire tracks
- Cigarette butts
- Reminders of food
- Ant paths
- Reminders of a campfire, sometimes surrounded by a circle of stones
- Presence of a grill or a spit
- Fire start late in the day

Parallel, an investigation with the help of witnesses provides information on:

The number and the description of the people present at the beginning of the fire

The description and registration of passing or parking vehicles

Other observations related to the fire incident

The circumstances at the fire origin are deduced by comparing the results of the physical investigation with the testimonies.

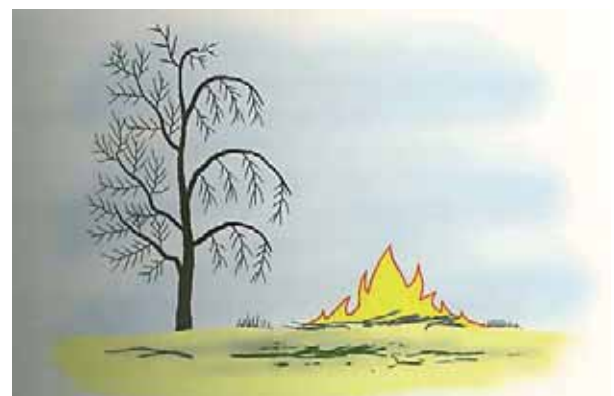
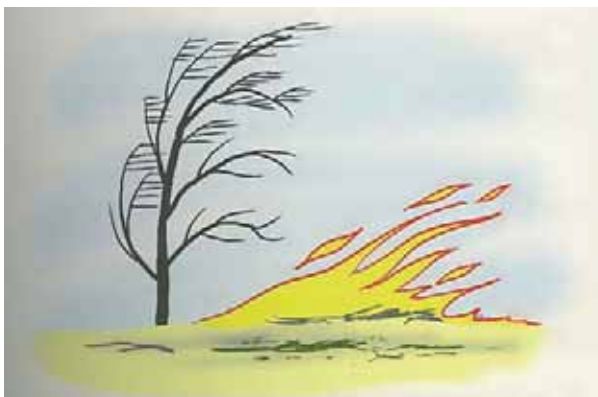
The physical evidence method does not allow to find out the cause of all fires. However, it allows to inquire in an exhaustive way fires which are representative for the entire statistical population. When sufficient numbers of samples have been collected necessary for significant results, it is possible to extrapolate the results by evaluating general tendencies of the principal clusters of fire causes.

Identification of the ignition source

The location of the ignition is validated by interrogating the fire fighting personnel and other witnesses. It is then delimited by a flashing ribbon and is demarcated by tracts of 50 centimetres width, using tape and cords. Each tract is analysed in detail, in order to determine the ignition source.

Identification of the fire cause

A possible cause of the fire is determined by checking indicators that may provide suitable information. The checklist presented below would be used to investigate a fire caused by recreational activities:



Classification of causes

The objective of the cause classification is to process collected data.

The adopted typology of causes must remain close to the reality in the field and must allow to plan preventive actions. If possible, classifications of the type “miscellaneous” or “other” should be avoided.

SPAIN

Forest Fire Investigation Teams

The investigation teams have a triple role:

- *Determination of fire causes by using the method of physical evidence*
- *Identification of risk situations, control of actions taken to avoid risks and evaluation of the effectiveness of those*
- *Informing of the population about fire prevention techniques*

These teams are composed of at least three people, each of them being in charge of a precise task when investigating a fire cause:

- *The first collects the material evidence on the ground*
- *The second collects testimonies*
- *The last coordinates the team and integrates information*

These three people write for each fire a technical report on the investigation.

Each team has a fire investigation kit with a series of tools and equipment (portable meteorological equipment, camera, video camera, steel tape, report paper, signal tape, etc.).

The personnel of the investigation brigades is composed of foresters, civil guards, and police force members of the autonomous regions. The training, initiated in 1991, has a duration of 5 days (30 teaching hours). The courses include the following topics: fire behaviour, localization techniques of the fire starting point, fire-protection, field work, and socio-economic context of forest fires. Video cassettes provide a support to the staff training.

A coordinator of all brigades analyses the information of all investigated fires, determines the main tendencies of the causes, informs political leaders of the obtained results and advises them on actions to be taken to prevent fires.

FRANCE

Multi-Disciplinary Team at départemental level

In France, any fire of more than 100 ha is the subject of an investigation, carried out by a multi-disciplinary team composed of a firefighter, a forester, a gendarme, and a police officer.

There is a team in each French département. The team members receive training courses and use the «Handbook for fire-cause investigators».

The investigation takes in average three hours for each fire. The starting point is localized with a minimum precision of 30 m, if possible of 5 m. All possible fire causes located in the determined fire start zone are investigated (dwellings, high voltage power lines, garbage dumps, remainders of ignition devices, etc.).

The multi-disciplinary team collaborate with:

- *The Scientific Police Laboratory of Marseilles*
- *The Institute of Criminal Research of the National Gendarmerie*

The teams update the database Prométhée, in particular by providing information which they have on the nature of the cause. On the other hand, the data entry of information about arsonists is an exclusive responsibility of the national and municipal police forces.

Extrapolation of known causes

The discriminative analysis allows to extrapolate the known causes to the entire statistical fire cause population.

This classification system was introduced in 1990 to the French region Provence-Alpes-Côte d’Azur.

Principle: The principle is, for a given fire, to seek similarities with fires of known causes. It is a question of determining major fire types (characterized by the fire start point, the hour, the date, etc.) representative for certain causes (agricultural work, lightning, etc.).

Method: Fires with a certain cause are thus divided by chance into two groups: (1) base data for building a model; (2) test data for model validation. If the forecast is reliable, the method is applied to fires of undetermined cause.

Results: The obtained results do not allow to determine precisely each fire origin. However, the total cause distribution is satisfactory.

PORTUGAL

Forest Fire Investigation Teams

Since 1989, forest fire investigation teams are charged during the summer to determine fire causes by using the method of physical evidence. These investigation teams are composed

of two or three foresters. They work in collaboration with the criminal police.

Because of the great quantity of fires, all fires cannot be the subject of an investigation. The least significant or most difficult accessible fires are not always studied.

In 1998 a total of 66 teams, with a higher number in the north of the country, investigated 3.6 % of all fires.

The training program of foresters and technicians goes back to 1991. An annual session provides a continuing education to the members of the investigation teams and trains new personnel in the fire-cause investigation and the interrogation of people.

After 10 years of experience, the forest fire investigation teams are now well trained and in 80 % of the analysed fires the causes were clarified.

Outside the fire season, the investigation teams fulfil additional tasks:

- Identification of dangerous situations (e.g., trees too close to a power line, too high fuel loads)
- Monitoring of risk zones
- Awareness raising and education of the population
- Verifying of statistics and validation of fire numbers
- Mapping of burned areas
- Damage estimates

Before the introduction of the fire-cause investigation many fires were allotted to criminal acts. Today, a better knowledge of the causes often allows to allot these fires to other origins.

Various tendencies can be distinguished, for example:

- Distinct difference between criminal fires and fires caused by agricultural or forest work, so especially concerning the season (respectively in summer at the end of afternoon / in winter or fall in the middle of the day), as well as localization (respectively in the vicinity of an access path / near an isolated dwelling).
- Easily recognizable lightning-caused fires: typical in August, they are often very far away from any access paths.

FRANCE

Classification of causes in the database Prométhée

A new cause classification in the Prométhée database was adopted in 1997. The principles are similar to the classification in Portugal. Types of causes are divided into five families, each one of these families being subdivided in categories and each category can be more detailed:

- Natural causes (lightning)
- Accidental causes related to installations (categories: power line, railroad, vehicles, garbage dump)
- Arson (categories: conflict, land speculation, pyromania)
- Involuntary causes (negligence) related to professional work (categories: forestry, agriculture, industrial work, resumption of fire)
- Involuntary causes (negligence) related to private individuals (categories: work, leisure, throwing away of burning objects).

There is no heading «miscellaneous». On the other hand, the certainty of the cause classification is indicated: unquestionable (1), very probable (2), probable (3), or unknown origin (4).

PORTUGAL

Classification of causes

It is a dichotomous classification with three levels, organized in five main groups of causes:

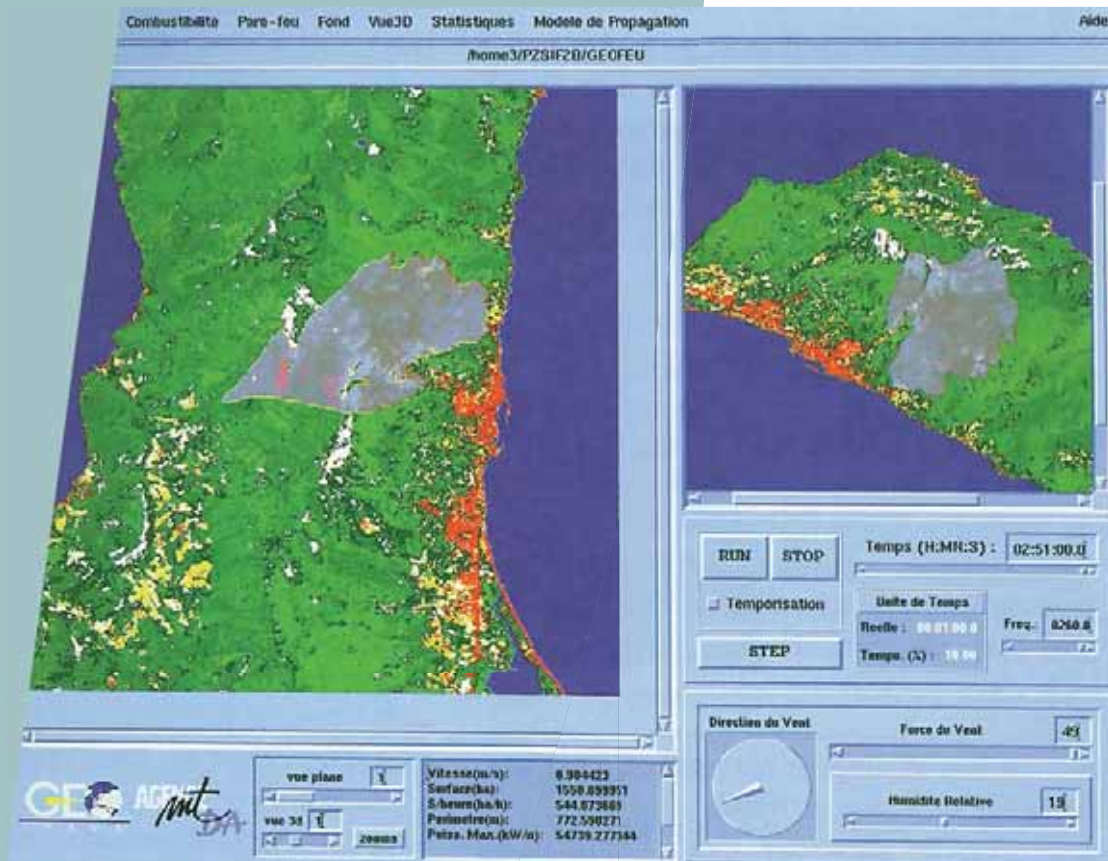
- Fire use
- Accidental
- Structural
- Arson fire
- Natural

Example:

- 2. Accidental causes
 - 2.1. Transport and communication
 - 2.1.1. Power lines
 - 2.1.2. Railroad
 - 2.1.3. Mufflers
 - 2.1.4. Traffic accidents
 - 2.1.5. Others

Fire danger and risk analysis

4



Principles

The term **FIRE HAZARD** describes the fuel complex (the combustible materials), defined by volume, type, condition, arrangement, and location, that determines the degree both of ease of ignition and of fire suppression difficulty.

VULNERABILITY defines the threat to property which is at stake in the area concerned ("values at risk": dwellings, buildings, heritage). This aspect will not be approached in this guide.

It should be noted that the forest, being both a fire vector (fuel) and a fire victim, is simultaneously subject to the risk and the vulnerability. This is also the case for humans who with their activities can start a fire as well as suffer the negative impact of the phenomenon.

In general, the disciplines which conduct research on natural or technogenic hazards (e.g., flooding, earthquakes, major technological accidents, etc.) call a **DANGER** the product of the arising probability of a phenomenon (risk) and the value of the damage (vulnerability).

However, as generally accepted concerning forest fires, the term risk is used in this guide in the sense of ignition probability, and the term danger in the sense of its given definition (see above).

It is necessary to distinguish the concepts of fire danger evaluation and forecast:

- To evaluate a danger, is to assess both fixed and variable factors of the fire environment that determine the ease of ignition, rate of spread, difficulty of control

- To forecast a danger, is the effort to determine a period or time when the phenomenon could occur.

- The fire danger varies in time in accordance with weather and vegetation conditions. This is the **TEMPORAL FORECAST** of the danger.

The fire danger is not homogeneous for the whole territory. Its intensity depends of natural environmental conditions and the land use. The **spatial evaluation** takes this aspect of fire danger into consideration.

It should however be noticed that:

- The temporal danger is not inevitably identical for the entire area looked at. This area can be divided into zones which each has its own temporal fire danger level.

- The spatial danger is analysed on a well defined date, and can evolve over time (new human activities, change of vegetation stress, etc.).

4.1 Fire Danger Rating: Prediction of critical periods

During the whole fire season the prevision of periods with a high fire danger allows to mobilize all fire fighting capacities in time at days with a high fire danger by providing an estimation of the danger level. The preventive mobilization of means favours the early detection and a short delay of the initial attack on new fires, thus limiting their spreading. A fire danger rating, broadcast daily, allows also to raise the awareness of the population or to restrict the access into the forest during the summer or at days with a high fire danger.

The start and the spread of a fire is mainly influenced by the moisture content of the surface fuels (litter and herbaceous layer), as well as from the moisture content of the shrubby vegetation, and by the wind speed. Various parameters allow to evaluate the litter moisture content: air temperature and moisture, precipitation, cloud cover. The combination of these parameters allow to compute a fire danger index.

Risk Factors

CLIMATE FACTORS

Daily observations of weather stations

The daily observations of weather stations provide the necessary weather parameters to the forecast litter moisture and wind speed.

Example of provided data: quantity of the last rainfall, numbers of days without rain since the last rain, air temperature maximum of the forecast day, wind direction and speed.

With the help of field samples and measurements in the laboratory, the flammability of litter and plants or their moisture content (cf. chapter 1.3) can be evaluated.

Calculation of the soil water reserve

The calculation of the soil water reserve allows to estimate the water content of the vegetation during the fire season. However, a difference exists between the moisture content of the vegetation and the water kept in the ground.



Use of remote sensing

Remote sensing allows to evaluate the vegetation moisture content. Its use is however limited because the results still require to be validated, especially for the temporal follow-up of the live fuel moisture content. The research is directed today towards the use of radar data.

Noteworthy is the network INRA / ONF (France) for the measurement of the moisture content of plants. It will allow the calibration of satellite data. These measurements also improve

the rough results of calculations of the soil water content.

Use of simulation

Atmospheric models can simulate wind conditions, if the orography and the weather characteristics of the zones with a high fire danger are

PORTUGAL

MEMO: a prognostic meteorological model for the prediction of air mass movements after Miranda et Borrego (1994)

It is possible to simulate the movement of air masses in complex terrain.

Principle: in the study zone, the air flow is

influenced by phenomena of various scales in relation to the topography. The model generates forecasts of air flows ten meters above ground level, at three different scales: 5 x 5 km², 2 x 2 km², 1 x 1 km².

Application: the model MEMO described the weather situation during the fire of Poiares by using only the weather data of the radiosonde of Lisbon.



known.

The soil water reserve

The soil water reserve corresponds to the available water quantity for plants in the ground. It is expressed in millimeters of water. The lower the reserve is, the more is the plant under water stress, and the higher is the fire danger.

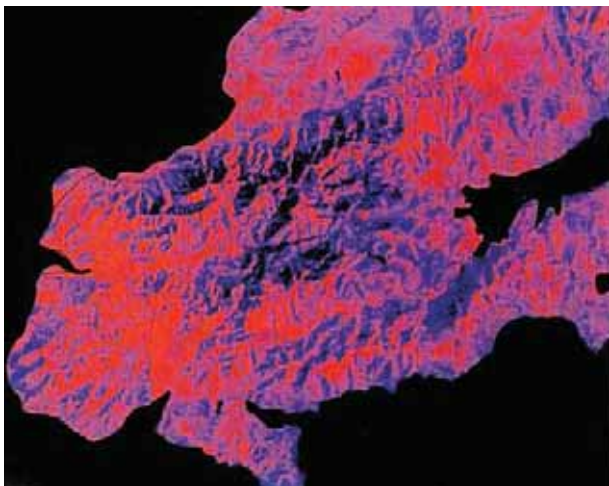
Fire danger rating

Fire danger rating on the base of meteorological data is more precise when it is expressed on the base of weather forecast of the previous evening or on the very same day. Long-term forecasts are also possible.

There are many calculation methods which give either a numerical index directly or an alarm level which increases with the danger conditions. Generally, the numerical index is also translated, for practical reasons, into a danger scale with 3 to 6 levels.

Operational applications

By communicating these indices to persons in charge of firefighting, a preventive mobilization of firefighting capacities is possible.



FRANCE

Calculation: The soil water reserve is fed by daily precipitation and is reduced by the real evapotranspiration of plants (RET), calculated with a formula based on the average air temperature (Thornthwaite). The soil water reserve can be calculated daily with the following formula:

$$Rd = Rd-1 + RAINd-1 - RET$$

Rd : daily water reserve j

Rd-1 : water reserve of the previous day

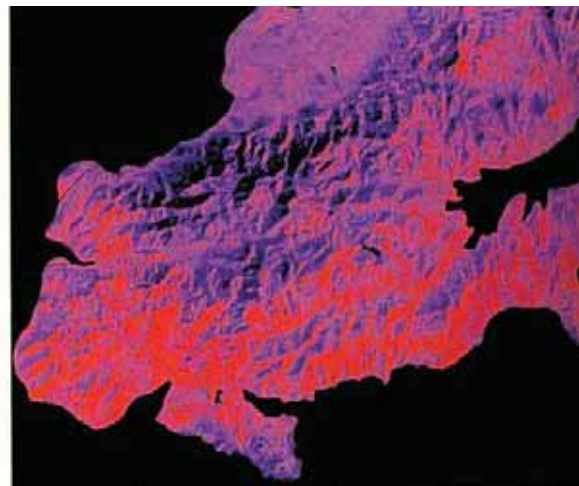
RAINd-1 : precipitation of the previous day

RET : real evapotranspiration

Some numbers: in the French Mediterranean region, the maximum reserve is arbitrarily set to 150 mm. Fires become dangerous when the soil water reserve is lower than 50 mm. Below 30 mm and with strong winds, the probability of having catastrophic fires is high. This is the value in summer. In winter, the value is 45 mm.

Example: in France, during summer, an expert of the weather service Météo-France joins the CIRCOSC (Centre Interrégional de Coordination Opérationnelle de la Sécurité Civile) each day. The départements in the South of France are divided into 90 zones characterized by similar climatic conditions. A daily danger rating with five classes (varying from low to very high) is provided for each zone. The expert uses an adaptation of the Canadian methodology, an estimated propagation velocity (formula by J.C. Drouet) and other more subjective elements.

The index depends on the quality of the weather forecasting. Errors in the wind forecast can thus have serious consequences on the deployment of fire fighting forces.



TUNISIA

Special weather report on the forest fire risk (DMRIF)

The National Institute of Meteorology publishes daily, between 1 May and 31 October, a special weather bulletin "forest fire danger".

The bulletin content: This bulletin consists of 2 parts:

- a table showing the weather data of the previous day for each province;
- a table showing the weather data of the day, as well as the alert level (DMRIF) with four levels (none, low, rather high, high).

Calculation of the DMRIF: Forest Fire Danger Weather Level

Parameters

- R = Reserve of soil water content (mm)
- Vm = Average wind speed (m/s)
- Nd = Number of days without rain since the last rain
- Tmax = Maximum air temperature in the shade (°C)
- Q = Quantity of the last rain (mm)
- Equations
- If the number of days since the last rain is higher than six
- $DMRIF = -131,7 * R + 5,9 * Vm + 26,8 * Nd + 1,4 * Tmax - 32,8 * Q$
- If the number of days since the last rain equals six or is lower
- $DMRIF = -26,3 * R + 4,6 * Vm + 0,5 * Tmax$

Addressees:

- The General Forestry Directorate
- The Directorate for Civil Defence
- The meteorological subdivisions
- The regional centres of meteorology and telecommunication

SPAIN

Method of fire danger calculation

The method employed is not cumulative. It uses tables indicating alarm levels. The 1st table provides the probability of a fire start as a function of shading (4 classes), temperature (9 classes) and fine fuel moisture content (16 classes). The 2nd table indicates the level of alarm according to the probability of a fire start (4 classes) and the wind speed (4 classes) by distinguishing between drying and not-drying winds.

The following levels of alert exist:

PRE-WARNING: Low or moderate. No special precautions taken.

WARNING: Moderate danger. Fire fighting capacities are ready to be mobilised.

ALARM: High danger. Vigilance intensified

EXTREME ALARM: Extreme danger. High probability of frequent and large fires, and fire spotting.

FRANCE

Use of the Canadian Forest Fire Weather Index (FWI) System

In spite of its origin on the other side of the Atlantic, the Canadian Forest Fire Weather Index (FWI) System has applications in the Mediterranean region.

The Canadian Forest Fire Weather Index (FWI) System consists of six components that account for the effects of fuel moisture and wind on fire behaviour.

The first three components are fuel moisture codes and are numerical ratings of the moisture content of litter and other fine fuels, the average moisture content of loosely compacted organic layers of moderate depth, and the average moisture content of deep, compact organic layers.

The remaining three components are fire behaviour indices which represent the rate of fire spread, the fuel available for combustion, and the frontal fire intensity; their values rise as the fire danger increases.

The Fine Fuel Moisture Code (FFMC) is a numerical rating of the moisture content of litter and other cured fine fuels with a weight of approximately 250 g / m². This code is an indicator of the relative ease of ignition and flammability of fine fuel.

The Duff Moisture Code (DMC) is a numerical rating of the average moisture content of loosely compacted organic layers of moderate depth with a weight of approximately 5 kg / m². This code gives an indication of fuel consumption in moderate duff layers and medium-size woody material.

The Drought Code (DC) is a numerical rating of the average moisture content of deep, compact, organic layers with a weight of approximately 25 kg / m². This code is a useful indicator of seasonal drought effects on forest fuels, and amount of smouldering in deep duff layers and large logs.

The Initial Spread Index (ISI) is a numerical rating of the expected rate of fire spread. It combines the effects of wind and the Fine Fuel Moisture Code on rate of spread without the influence of variable quantities of fuel.

The Buildup Index (BUI) is a numerical rating of the total amount of fuel available for combustion that combines the Duff Moisture Code and the Drought Code.

The Fire Weather Index (FWI) is a numerical rating of fire intensity that combines the Initial Spread Index and the Buildup Index.

The calculation of the indices is done using mathematical functions. Each index has a characteristic

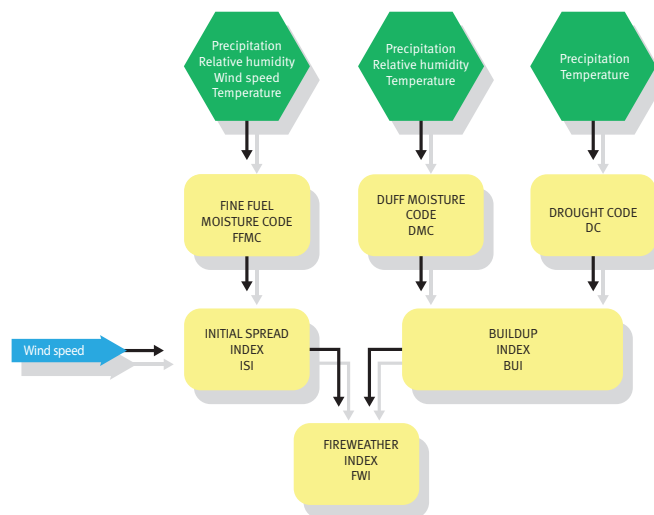


Figure: Components of the Canadian Fire Weather Index System

scale. The function accounting for the wind in the I.S.I. is simple exponential which doubles the value of the I.F.M. for each 19 km/h increase of the wind speed.

Fire danger	FWI scale
Extreme	30 and more
Very high	17 to 29
High	9 to 16
Moderate	5 to 8
Low	2 to 4
Very low	0 to 1

The ISI and the BUI are particularly recommended for general needs in fire control, since they inform directly about the rate of fire spread and the quantity of available fuel. Whereas the six standard components provide numerical ratings of relative wildland fire potential and informs the general public by an overall fire danger rating. The danger classes used in Canada are the following:

The FWI system is standardised for the entire country but the range of forest fire weather conditions is certainly not uniform. Thus it is logical that each territorial organization establishes its own fire danger rating system, fixing for their area a suitable scale.

4.2 *Spatial Fire Danger Rating: cartography*

Being dynamic, the fire danger rating varies over time. Therefore for well targeted and adapted actions, it is thus crucial to know the zones with a high fire danger. These zones correspond partly to the territory where one or more of the following characteristics prevail: high probability of fire occurrence; conditions of the natural environment favorable to fire spread; high potential fire loss.

The **spatial evaluation** of the fire danger proposes a zoning of the territory. The cartography is the translation of this zoning into a map.

It is a decision-support tool for the:

- choice of sites to be equipped in priority with fire fighting infrastructures, the selection and the location of fire fighting equipment;
- landscape management: management of wildland/urban interfaces and the consideration of the fire threat in urban planning;
- fire fighting: better knowledge of sectors with difficulties for fire operations.

In the following of this chapter, only the spatial evaluation of forest fire risk will be dealt with. The risk analysis will not be covered here.

The spatial evaluation of the fire danger risk requires a knowledge of the spatial variation of the factors which contribute to fire occurrence, fire spread, and fire danger.

Generally, the contribution to the fire risk by each environmental factor is translated into a primary risk index. Then a general danger evaluation is based on several indices corresponding to various contributing risk factors.

The risk factors

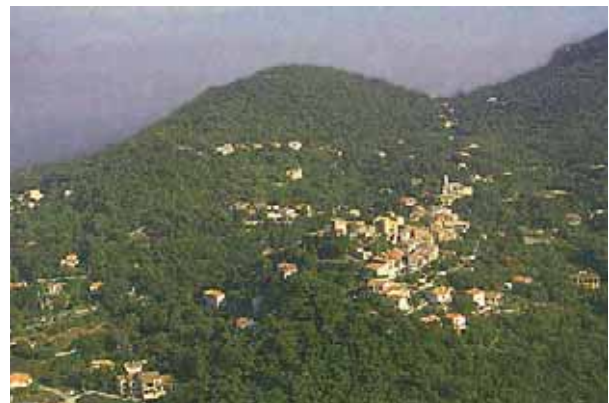
Factors that determine the fire start can be distinguished by anthropogenic origin (cf. chapter on fire causes), and by the natural environment which determines the conditions favourable for the start and spread of a fire. The contribution of these factors to the risk can be estimated based on the observation of historical fires and experiences of field staff, or experimental data.

ANTHROPOGENIC FACTORS: HUMAN ACTIVITIES AND INSTALLATIONS

A risk index can simply correspond to the presence of activities (for example, apiary or pastoralism) or infrastructure such as roads, railroads, power lines, dwellings, etc., or can take into account the distance compared to these installations. These factors can be mapped, for example, based on the interpretation of aerial photographs or by terrestrial inventory.

NATURAL ENVIRONMENTAL FACTORS: CLIMATE, VEGETATION, AND TOPOGRAPHY

Among the climatic components wind plays a significant role for fire spread.



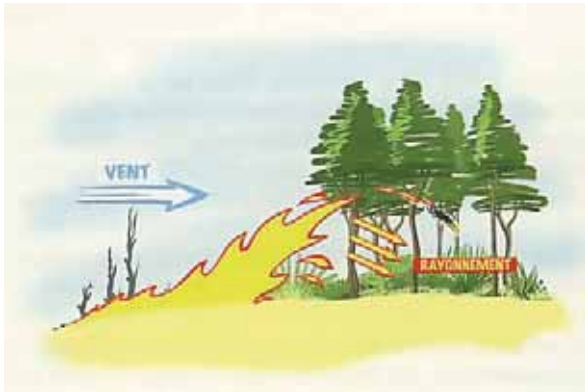
Wind

The local wind depends on the zonal wind, the topography, and the roughness of the vegetation.

Parameters: direction and speed

Modelling and cartography:

- Cartography of the local wind based on the experience of field personnel and measurements in situ



- Interpolation of data from weather stations
- Digital simulation: wind modelling using mathematical equations and computations
- Physical simulation in the laboratory: measurements on a hydraulic model by simulating the air flow by a water flow

Vegetation

Parameters: composition, moisture content, and structure (vertical and horizontal distribution)

Analysis and cartography: allows to identify fuel types of different combustibility. The cartography can be carried out from:

- Field data
- Interpretation of aerial photographs or satellite imagery
- Example: vegetation indices provided by satellite NOAA-AVHRR. The most widespread is the NDVI (Normalized Difference Vegetation Index) index that is correlated with the leaf area, the primary net productivity, and the biomass. The fire danger zones correspond to areas with a significant decrease of the NDVI over time.
- This index is calculated starting from the red (R) and near infrared (NIR) channels: $NDVI = (NIR - R) / (NIR + R)$

Topography

Parameters: slope and aspect

Development and cartography: a Digital Ground Model (DGM) can be build based on

- Digitised perimeter lines and landmarks
- Stereoscopic interpretation of satellite imagery
- The DGM, calculated by computer, overlays the territory with a grid, giving altitude, slope, and aspect.

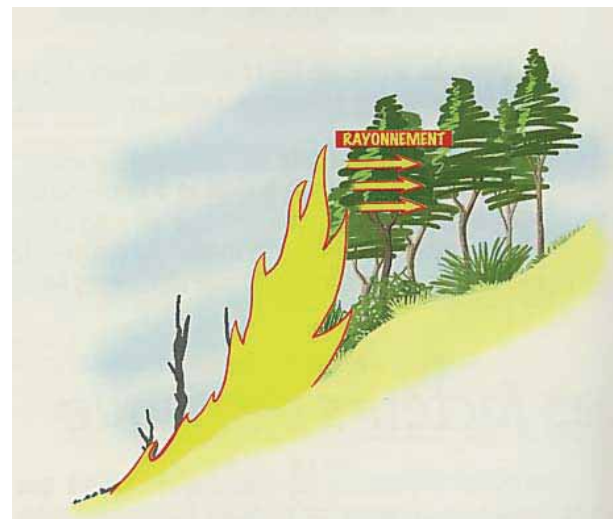
Evaluation methods for spatial risk rating

Some methods distinguish between the risk of a fire start and the propagation risk. Other methods consider only one single risk which combine these two components. Some are based on a purely empirical approach such as the interrogation of field experts (foresters, firefighters). The majority adopts a more deterministic approach using, either a combination of risk factors in the form of indices, or mathematical propagation models (cf. chapter 4.3).

ANALYSIS OF THE SPATIAL VARIABILITY OF THE FIRE START RISK

Various methods have been developed:

- The most simple way consist of mapping points of past fire starts over a given period.
- Based on the knowledge of fire causes, it is



possible to defer on a map the elements linked to human activity which are generally the cause for a fire. These elements can be weighted according to their contribution to the risk in the past.

ANALYSIS OF THE SPATIAL VARIABILITY OF THE PROPAGATION RISK

There exist different concepts based on:

- Observations made on past fires allowing to determine qualitatively zones which were affected regularly by large fires. However, data on historical fires consider spatial structures of the past and does not inevitably apply to the present or future. Thus, formerly separated forest stands can be linked by natural regeneration. An extrapolation to the present considering

the distribution of the current vegetation is necessary.

- The calculation of indices accounting for the danger contribution of natural environmental and human risk factors.
- The use of a flaming front propagation model.

The usage of Geographical Information Systems (GIS)

Geographical Information Systems (GIS) are powerful tools which allow to manage geographical data as well as to link descriptive data for spatial analysis. GIS enables the user to identify spatial relations between maps.

Capacities and functions of the GIS:

- Storage of great quantities of information
- High speed of calculations
- Updating facilitated
- Calculations of new variables: distance to the nearest road, distance to a water point, etc.
- Selection, crossing of data, etc.
- Integration of satellite data

Many risk mapping methods use GIS as tools for storage, management, and geographical information processing.

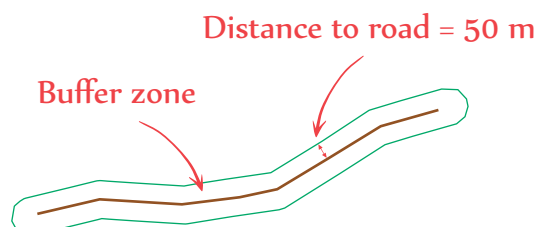
The approach is generally the following:

- Acquisition of the spatial data and attributes
- Data management
- Handling and analysis of data (queries, risk indices)

Mapping of the query results

Buffer zones

Some GIS software permits to map buffer zones on both sides of lines such as roads, railroad tracks or powerlines. This can be used to define and to map areas automatically where the potential for a fire start is higher.



E.g., cartography of surfaces which border the road network on a 50 m depth.

Combination example for GIS maps

The spatial data used in a GIS can be structured in two very different formats:

- Raster format: the study zone is presented in the form of cells juxtaposed in a grid
- Vector format: it describes the real world based on nodes (points) and lines

2 schemes of superposed layers

The superposition of map layers is an operation that consists of determining which geographical

ITALY

AN EXAMPLE OF AN APPLIED METHOD TO AN AREA (TUSCANY – ARGENTARIO MOUNTAIN)

The risk factors are mapped at a scale of 1:15.000, with a grid of 1 km.

ELEMENTARY FACTORS AND INDICES:

Burned surfaces: each pixel corresponds to a percentage of burned surface, to which an index (from 1 to 5) is given.

Road network: three highway types are distinguished (suitable for motor vehicles and maintained, suitable for motor vehicles and not maintained, not suitable for motor vehicles). For each pixel, the length and the type of highway is given.

Aspect (orientation of slopes compared to dominant winds): four aspects, based on perimeter lines, are chosen. The monthly frequency of the wind from June to September in each direction is calculated. It is then correlated with the four cardinal directions in each pixel.

Vegetation (flammability / combustibility): a note is allotted to various vegetation formations, according to the dominant vegetation in the pixel:

Leave trees = 1

Coppice = 2

Vineyards, olive trees = 3

Reforestation of coniferous trees and dense macchia > 2m = 4

Prairies, steppe, garrigue, open macchia < 2m = 5

Climate: interpolation of the temperature and precipitation data between two weather stations

Calculation of the dryness (ombrothermic diagram).

INTERMEDIATE INDICES AND FINAL INDEX

Index AFI (Annual Fire Index): it is the sum of the five noted preceding factors from 1 to 5, itself subdivided in 5 classes

Frequency F: number of annual fires / total number of fires over 30 years (divided into 5 classes)

Risk index = AFI + F. This index itself is subdivided in 5 classes.

FRANCE

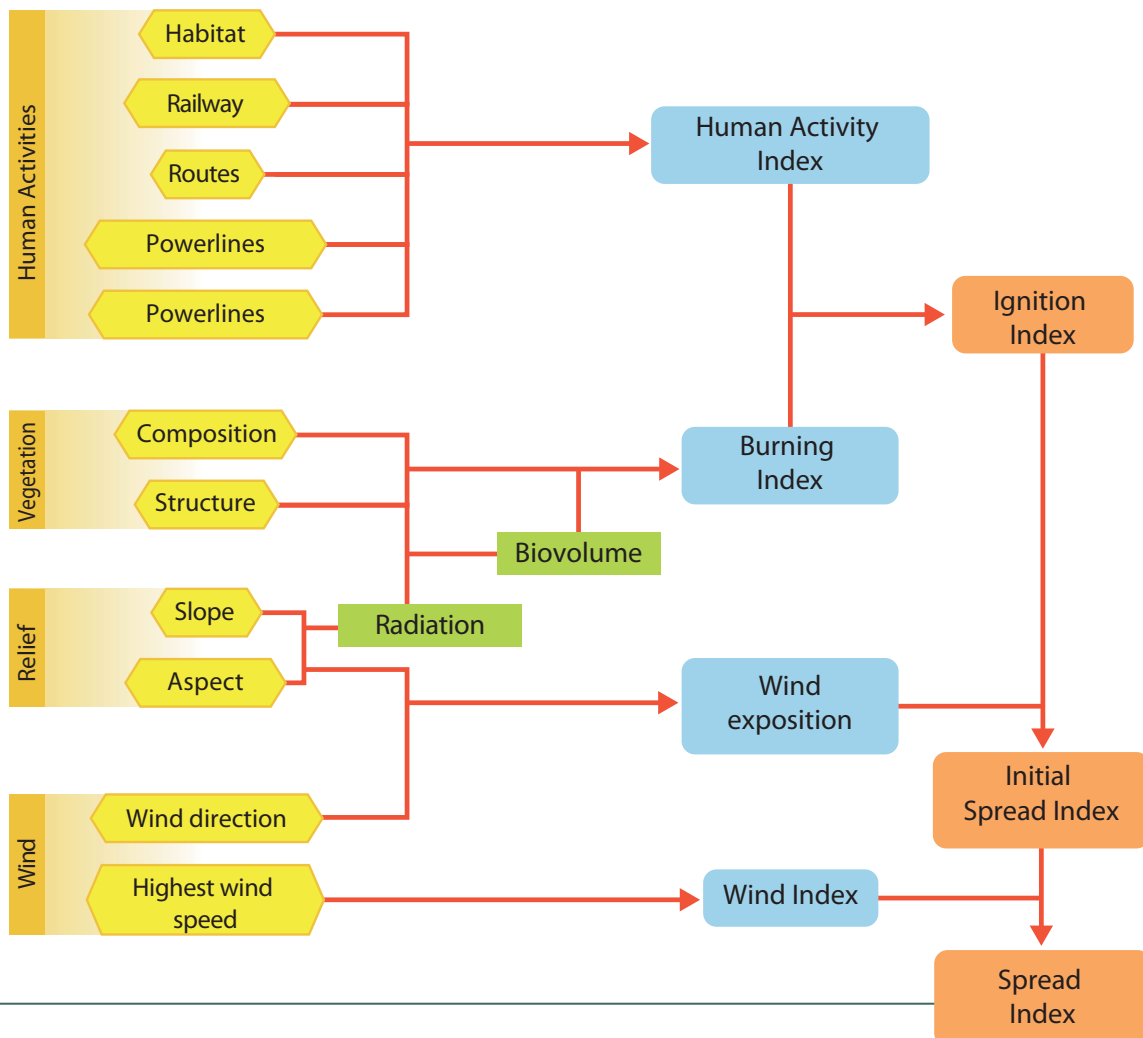
Example of the method developed by CEMAGREF

The risk factors are mapped at a scale of 1:5000, with a grid of 250 meters, for the entire Maures mountains (135 000 ha in the département Var). The method is based on a detailed analysis of each factor.

The **FIRE START INDEX** combines the various anthropogenic factors (human activity and installations). Those are mapped and a zone of influence of 50 m around each element is calculated (cf. GIS functions). A note is then allotted inside these zones.

The **PROPAGATION INDEX** combines three intermediate indices:

– a burning index representing the variations



of composition and structure (vertical layers, canopy closure) of the vegetation

– an index combining the relief with the wind direction

– an index translating the wind speed in the form of 6 classes

In each box, classes are defined and points are given to each class. The indices for fire start or fire spread result from the sum of final points.

There exist other index methods, for example, the method developed by the French National Forest Service (ONF) in the département Alpes Maritime where three intermediate indices are calculated (vegetation, human activities, topography) and are combined into one index.

Other methods use fire spread simulation models (Agency MTDA), cf. chapter 4.3.

elements exist at the same place.

A crossing of several vector maps result in a high number of smaller and smaller polygons.

The nature of raster maps allows numerous

and rapid overlaying. It permits, for example, to combine several risk indices intermediary based on a mathematical formula.

ITALY

Use of historical data for the overall description of a territory

The national territory is described by seven statistical parameters based on historical data. These parameters reflect the potential fire danger of the studied geographical areas.

Statistical parameters

Contribution to analysis of study zone

Total number of fires per year within an administrative area	Informs about the concentration or dispersion of fire
Number of fires per year larger than a defined threshold for each administrative area	Informs about the concentration of exceptional fires
Number of fires per year in relation to total number of fires over a ten-year period	Indicates if the fire phenomenon is continuous or episodic
Average fire size in administrative area	Describes the size of the fire phenomenon, but is heavily influenced by extreme values
Median of burned area within an administrative area	Expresses the fire size below or above which there is an equal number of fire incidents
Maximum fire size	Reflects the most difficult conditions for fire extinction
Average of relation between burned area and fire duration	Reflects the conditions for the spread of the fire front.

MOROCCO

in cooperation with Andalusia - Analysis of the fire start risk

Data: relief, climatic data over the last 20 years, data on fires over the last 10 years.

The data are deferred on maps at a scale of 1:50 000, with a grid of 5 x 5 km. For each grid square fire frequency, causes, infrastructure, and fuel types are given.

Results: two risk types are studied, the historical risk (based on statistics) and the potential risk, calculated based on vegetation, wind, and topography, using American formulas, adapted to Andalusia.

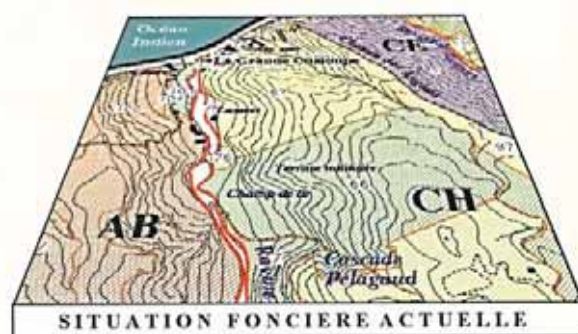
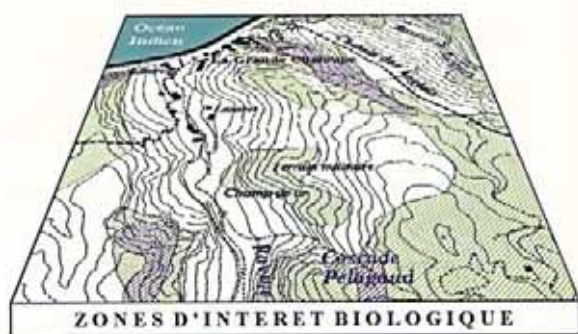
Application: a regional master plan for the forest management against forest fires is written. It evaluates the need for equipment according to the predicted risk, directs the choice of this equipment and establishes a set of priorities.

PORTUGAL

Fire starts

In Portugal, since 1990, the geographical coordinates of fire starts and to their associated causes are recorded, the first being recorded on topographic maps at a scale of 1:25 000.

From these data and parameters, like the biomass, the vegetation cover, and the distance to roads and human installations, an empirical GIS model is developed (see below the paragraph «GIS usage»): it spatially estimates probabilities of a fire start. To develop this model, it was necessary to analyse the relations existing between the starting of a fire and the analysed parameters.



4.3 *prediction of the fire spread*

The simulation of forest fires, i.e., the prediction of the development of the fire front and fire perimeters, as well as of fire characteristics (intensity, flame length), aims to improve fire forecasting and fire suppression:

- Use for certain spatial evaluation methods of the risk
- Installation of fire suppression support infrastructures (roads, fuel breaks, water points...).
- Staff training
- Preventive mobilization (preparedness)
- Support of persons in charge of the fire suppression, in real time, for strategic choices. The estimation of the fire size at the time of attack and the prediction of the evolution of the fire front are important information for the deployment of suppression forces.

The operational objective of the fire models, i.e., the use in real time, within a tactical framework, is not reached yet. Indeed, taking into account the complexity of the forest fire phenomenon, due to interactions between various factors of the natural environment and between the fire and these factors, and taking into account the current calculation power of computers, the calculating times are much too slow today.

The simulation is a support tool for the human decision-making. Under no circumstances it can replace the human decision.

It is necessary to distinguish several model types:

Local models.

– The local fire spread models are tools which predict the local rate of spread, i.e., the direction and the speed of the fire front in a specific location.

– The **local fire behaviour models** are tools which calculate, for a given point of the fire front, the direction and the speed of the fire spread as well as fire intensity according to certain local vegetation conditions (fuel type, moisture content, density, height), topography, and atmosphere (air temperature and humidity, direction and force of the wind). The American model BEHAVE is a well known and widely applied example of such a model.

– The **systems of fire prediction** are simulation tools which predict the fire perimeter as a function of time, knowing the propagation velocity in some perimeter points. These prediction systems use two different methods:

* Simple methods not using complex calculations. They provide successive positions of the fire front by ellipses or segments whose dimensions depend on the wind and the average vegetation type.

* Complex computer-developed simulation methods using the power and the speed of the various calculations. It is possible to simulate fire starts and to observe where and how fire is propagating. These tools allow to manipulate certain parameters or to simulate the effects of new preventive fire infrastructures, e.g., fuel breaks, etc.

A fire prediction system requires for its functioning a local fire spread or fire behavior model.

All these tools use mathematical models which must, in theory, take into account the local vegetation and its moisture content, the local wind and the topography. Some of these parameters are difficult to know and to describe which means to integrate in the fire spread or behaviour models, and in the forecast systems. In practice, the simplest models regard these data (vegetation, moisture content, wind, topography) as constants in space and time, which is appropriate for certain sites and certain weather conditions.

Local models

LOCAL FIRE SPREAD MODELS

These very simple models are based on weather conditions (wind speed and direction) and on field observations of the spread rate, and the direction of the fire progression upon arrival of fire crews or the ongoing fire suppression. An extrapolation starting from accumulated observations allows to predict the fire spread in a coarse way.

LOCAL FIRE BEHAVIOUR MODELS

The first fire behaviour models were developed in North America. They implement complex functions provide as output the energy of combustion and the fire spread in function of various parameters. They simplify the forest fire phenomenon with regards to atmospheric conditions and the distribution of the vegetation.

The three model families

Three approaches of modelling can be distinguished: the purely empirical method (or statistical), the purely physical method (or deterministic), and an intermediate method (or semi-empirical).

Statistical models

They are based on the observation of experimental or real fires. Their principle is to build, by regression, mathematical relations between the explanatory variables taken into account (e.g., vegetation, wind) and the observed results considered for the model (fire intensity and fire spread). These models do not allow to predict characteristics of a real event, but provide the average value of the characteristics of all the possible events which could be obtained or observed for the same values of the variables. These models are often used to predict the daily fire danger (this is the case for France). Only the Canadians use them to predict the rate of fire

spread with the Canadian Forest Fires Danger Rating System (CFFDRS).

Deterministic models

They are based on assumptions concerning the physical and chemical phenomena which determine fire behaviour and translate them into mathematical equations. The method is contrary to the preceding one. This approach has been applied very little for forest fire modelling because of the complexity of calculations required. In addition the models cannot be integrated easily into operational systems. On the other hand, this approach carried out in the long term would allow a precise and quantitative analysis process implemented at the time of a vegetation fire. Albini (1985) proposed a model based on the heat transfer by radiation which considers the thermal radiation as the mode dominating the heat transfer. The model requires as input the flame temperature and the slope in degrees.

THE ROTHERMEL MODEL (USA)

The Rothermel model is a semi-empirical model whose original formulation goes back to 1972. It is the base of many current systems of prediction (FARSITE, CARDIN...). This model is based on the energy transfer of the spread seen as a succession of ignitions.

Assumption

The assumptions restricting the field of application of the model are the following:

- The fire is described on the level of the fire front, presumably linear and infinite.*
- The fuel is uniform, only one layer of fuel made up of a single type or of a homogeneous mix of types of particles is considered.*
- A stationary mode of spread is reached, which implies stationary conditions (slope, wind).*
- The transport of solid particles is not considered.*

A certain number of assumptions relating to the mechanisms of action (heat transfer, effects of water and minerals, effects of the wind and slope...) are also preset.

The prediction of the fire behaviour on a slope and with wind is deduced from the fire rate of spread without wind or slope, which depends only on the fuel characteristics. The slope and wind effects are added to those of the fuel.

Input variables

These are values taken from parameters describing fuel and spread conditions:

- Physical and chemical characteristic of fuel particles*
- Fuel moisture content*

- Fuel bed characteristic (thickness, dry load...)*
- Slope*
- Wind speed and direction*

The predictions provided by this model do not use direct information of the phenomenon.

Intermediate parameters

The necessary intermediate parameters for the modelling, which appear neither at the entry nor at the output of the model, are entirely provided by using experiments in the laboratory on the test bench. These experiments were initially undertaken on litter then extended to other low layers (herbaceous layers). The Rothermel model thus predicts only the behaviour of a fire burning on contiguous surface layers.

Model output

The model predicts the rate of spread, the fire residence time, the depth of the zone in rapid combustion and the fire intensity.

Evolution

– This model was then adapted by various authors to other conditions:

- BROWN Model (1982): extension to the shrubby layers*
- FRANDSEN and ANDREWS Model (1979): extension to a non-uniform fuel*
- ALBINI Model (1982): extension to non-stationary conditions*

The Rothermel model was computerized and the software BEHAVE developed which allows to enter the input variables and to obtain directly the output variables.

Intermediate models

The approach, located between the two preceding ones, relies at the same time on observations of experimental or real fires, or of laboratory experiments. It must also partially take into account the physical and chemical mechanisms of fire behaviour. Thus, there is a whole range of intermediate models whose experimental and theoretical contents are more or less important. These models allow to predict certain aspects of the phenomenon and are simple enough to be introduced into prediction systems. They take only partially account of topographical effects on the fire spread. The Rothermel model (1972) is an example of a semi-empirical model.

Modelling of spot fires

Spot fires are projections of incandescent or ignited woody particles likely to light new areas ahead of the flaming fire front. Albini (1979) proposes a model predicting the maximum distance traversed by an ignited particle which is based on estimates of the wind profile and the burn duration of the spotting particles. The model allows then, knowing the flame height, to determine the trajectory of a particle which just extinguishes in contact with not burning fuels.

Experimental data

The development of models requires to collect data from fire observations, which can be carried out under various conditions.

Wildfire evaluation

On one side, vegetation fires provide some of the necessary data for the development of statistical models and, on the other side, these fires are only used for model validation. When vegetation fires burn large areas with a uniform vegetation under rather constant wind conditions, these fires allow a reliable description of the fire rate of spread and the overall conditions. This is often the case for large fires in central and eastern Canada.

Contrary to this, in the case of Mediterranean fires, the observations drawn from fires are much more specific in space and time, and are accompanied by a great uncertainty on weather conditions and local fuel characteristics and topography.

Experimental fires in the field

Experimental field fires allow to choose and to know certain conditions governing fire: topography, fuel type, weather conditions. The fire will be rather well described if working on limited size (smaller than 1 ha) and with a landscape supporting the observations.

Prescribed burning intended to maintain natural landscapes and on larger areas can also provide observation material.

Experimental fires in laboratory

These fires are conducted on test benches whose size does not exceed a few square meters. The fuel characteristics can be chosen and described with precision. Particular devices allow to vary the slope or to create an artificial wind. Various types of sensors (video camera, thermocouples...) are used to measure the characteristics of the fire behaviour.

Fire prediction systems

To forecast the fire behaviour over time certain information is absolutely necessary:

- Different input parameters: vegetation maps, topography, wind
- A local fire spread or fire behaviour model.
- A fire is started at a given point and the fire spread is observed.

According to the complexity of the input variables and the local models, one distinguishes simplistic and complex systems.

FRANCE

Experiments in the laboratory: the burning-bench of INRA

The various models use experimental data either as input to the model or to validate it.

PRINCIPLE: fires are reproduced on reduced scale in order to control their propagation and to facilitate the observation of combustion. The slope of the test bench can be varied.

HARDWARE: a regular fuel bed is constructed on a burning table (rectangular shape, max. width 3 m, length variable).

MEASUREMENTS: the fire rate of spread and the flame geometry are generally measured.



SIMPLE SYSTEMS: ELLIPSE, OVAL, AND “CÔNE DU VAR”

The fire simulation can be carried out in a very simplified way by using:

- an average vegetation of the studied zone, a uniform and constant wind direction and wind speed
- a hand drawing on a map of the successive fire positions (represented by a successive series perimeters of same geometrical form, only different in length)

These simple models assume a homogeneous fuel, a rather regular terrain and uniform and stationary wind conditions, i.e., which do not vary over time.

The drawn geometrical forms reflect a more or less realistic shape of the fire front which is derived on field observations. Various simple geometrical models are presented below. Their parameters depend a priori on the local conditions and must thus be collected locally.

The ellipse model

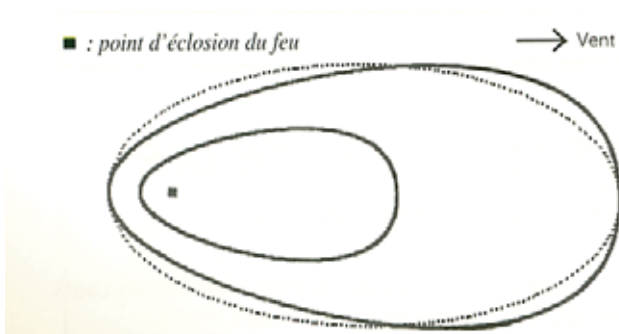
This is the most simple model. It uses different fire rates of spread for the head, flanks, and the back of the fire. The characteristics of the ellipse are:

- The ignition point is located on one of the two foci
- The large axis is directed parallel to the wind direction
- a: long axis
- b: short axis
- v: rate of spread of the fire head
- w: rate of spread of the fire back
- u: rate of spread of the flanks
- s: fire area
- t: time passed since ignition

The results are:

- $a = (v + w)t$
- $b = (2ut)$
- $S = \pi/2(v + w)ut^2$

A successive fire perimeter can be drawn which are ellipses having one of their two foci on the ignition point.



The oval model

The oval is obtained by a deformation of the ellipse with the same flatness. The characteristics of the oval are:

- The ignition point is located in the centre of the oval, which is one of the 2 foci of the ellipse with the same long axis and the same flatness
- The long axis is directed parallel to the wind direction
- a: long axis of the oval
- b: maximum width of the oval
- b/a: flatness of the oval
- T: time passed since ignition

The results is:

- $a = c_1 t$
- $b = c_2 t$

c_1 is a coefficient which depends on wind force, vegetation type, fuel moisture content, air temperature and humidity, and topography.

The ration $b/a = c_2 / c_1$ depends on the wind force. It varies between 0.5 for strong winds and 1 for no wind, resulting in a circle.

A successive fire perimeter can be drawn which are ovals having all their centres (foci) located at the ignition point.

The model “Var cone”

It was invented by French firefighters of the *département* Var. It has been used for the training of firefighters and fire suppression strategies. The “Var cone” represents the average perimeter of a forest fire based on the observation of many fires in the field.

The perimeter is represented:

- Against the wind from the ignition point: a half-circle of 250 m radius centred on the ignition point, which represents the maximum advance of the fire backwards.
- With the wind from the ignition point: two lines forming between them an angle of 42 degrees, whose bisect is parallel to the wind direction.

This model does not represent the spread of the fire front between the two lines. However, it can be completed by a front that is determined by line segments indicating the shape and speed of advance being constant during the fire.

COMPLEX MODELS

On the other hand, fire simulations can be carried out in a much more elaborated way, if:

- Detailed maps of vegetation, topography, and wind are available;
- The applied local fire behaviour model is complex and requires the use of computers;

- The fire spread is visualized on a computer screen.

The input variables must be organized in a well structured database to allow fast simulations. A user-friendly interface with many functionalities allows to carry out simulations under good conditions. These complex systems of prediction are called **simulation software**. The quality and the speed of simulations depend on the used model, of the structure of the database, and the power of the computer.

The input variables

Some application methods of the input variables for the behaviour models and the prediction systems are presented below.

Topography

The relief can be mapped in the form of a digital field model, in vector format or raster format.

Vegetation

The forecast of the fire behaviour by simulation requires to know the fuel in a detailed way. Since fuel characteristics cannot be inventoried with precision in each point of the studied zone, it is necessary to use a **fuel typology**.

Many simulators use the input variables of the 13 North American fuel models with different fire behaviours associated (speed and flame length). According to Albini, certain grassy formations are traversed by fire at the speed of 20 km/h. In France, the average spread rate of large fires is at ??? km/h.

These fuel models are adapted to the vegetation of the country.

Example: in Spain, the DGCN adapted the 13 North-American fuel models to the Mediterranean forest. A photographic key allows to determine the fuel model present on the zone to study.

Example: in Italy, the indigenous vegetation was compared with the fuel types of BEHAVE from which were retained: n°2 which is rather widespread in the

UNITED STATES

The Fire Area Simulator FARSITE

FARSITE uses the Rothermel model. Its functioning requires the use of a Geographical Information System (GIS).

Necessary data:

- Obligatory spatial data:
- Altitude
- Slope
- Aspect
- Fuel types (standard fuel models 1 to 13 or several customized models).
- Forest cover (in % or according to 4 categories).

Weather data:

- Temperature and humidity (daily maximum and minimum) for the calculation of the fuel moisture during the simulation
- Wind (hourly speed and direction)

The simulation of the passage of a crown fire requires:

- The height of the green crown base
- The total tree height
- The crown density (mass/volume)
- The simulation of fire spotting requires additional specific inputs

Principles of operation

Under uniform and homogeneous conditions and under the influence of a constant wind, a fire is propagated, in theory, like an ellipse increasing in each point with a constant speed starting from the ignition point. In practice, the software takes into account only the principal axis of the ellipse.

Between one moment t and a moment $t + t$, the infinity of points which form the ellipse comprise like as many burning points and are at the origin of an infinity of small ellipses of which the external perimeter forms an ellipse with $t + t$.

When these conditions are not homogeneous any more, or when the wind is not constant, it is considered that the local conditions are locally uniform.

The fire perimeter, irregular, is then given in theory by an infinity of ellipses which correspond each one to the fire spread according to local conditions, but in practice only by the end of the principal axes of these ellipses.

FARSITE calculates the position of these points and connects them to a new fire line.

The results

The fire simulation results are presented, as a choice of the operator, in the following forms:

- Fire development maps, two or three dimensional
- Table or graphics of the fire area as a function of time
- GIS files of the fire characteristics

The 2nd version of FARSITE is available on the Internet site: <http://www.montana.com/sem>

Another simulator, IGNITE (Australia) is available on the Internet site: <http://www.csu.edu.au/firenet/ignite.html>

Mediterranean bio-climate, and nº9 encountered in the Apennines and the Alps. These models allow to individualize vegetation covers where the direct attack of a fire is possible, according to the following parameters: fire line intensity, flame length and height, fire rate of spread, depth of the fire front.

The **moisture content** of the vegetation can be modelled by considering the initial water reserve in the ground and the accumulated precipitation.

Wind

The wind mapping can be obtained by digital simulation taking into account the wind synopsis, topography and vegetation roughness. If not available, maps can be drawn based on field measurements.

Examples for the application of local models and prediction systems

PROTECTION ANALYSIS OF VALUES-AT-RISK

The fire model (as simple as BEHAVE) will indicate the fire intensity near the values to be protected, and the width of the zone cleared of undergrowth which will not be crossed by thermal radiation. It is possible to chart this result for the entire territory.

IGNITION ANALYSIS

The model, which can be very simple, will indicate the burned surface at the arrival of first suppression forces; the access time which can be calculated using a GIS. This result can be mapped for the whole territory to deduce the sites and the type of infrastructures for forest fire protection (access roads, fire breaks, automatic watering systems, lookout posts, etc.).

Prediction systems can support the decisions for establishing fire protection infrastructures. The simulation steps can be:

- Entering of parameters of the studied territory
- Selection of weather conditions favourable to fire, including historical extreme values in order to determine short (10 years), medium (30 years), and long-term risks (100 years)
- Ignition point selection
- Visualization of the fire spread and information on its characteristics
- Repetition of the simulation for all possible ignition scenarios
- Simulation of the building of access road or fire breaks with the objective to study their impact on the fire and fire suppression (delay time, fire fighting conditions and security, etc.)

SPAIN

THE FIRE SIMULATOR CARDIN

CARDIN is a prediction system which simulates the fire behaviour with a digital image in raster format. This software is a prototype based on the Rothermel model. The fire behaviour is analysed pixel by pixel: when a pixel is set on fire, the model calculates the rate of spread in 8 directions.

INPUT VARIABLES

- Fuel model. For each pixel is allotted one of the 13 North-American vegetation types, adapted to the vegetation in Spain.
- Fuel moisture content divided into 5 categories:
 - * Dead, very fine
 - * Dead, average
 - * Dead, thick
 - * Herbaceous alive
 - * Woody
- Roughness: effect of deceleration of the wind measured in 6 m height, and given in 4 classes
- Topography (slope and aspect).
- Speed and direction of the wind: measured at 6 m above ground-level, the constant wind being assumed in the studied zone.

CARDIN allows the digitalisation of topography and fuel with an independent system: DIGICAR.

MODEL RESULTS

- It gives the profile and the perimeter of a fire.*
- It is possible to change certain data during the simulation.*
- Disadvantage: only one wind speed is considered.*

– These simulations then allow to determine the nature and the situation of the most effective and efficient equipment.

Generally, simulations are carried out systematically for the studied territory with an ignition point every 50 to 500 meters in two perpendicular directions. The results for each ignition point are calculated in square cells (with a size of 0.25 to 25 ha). Thus a map, more or less coarse according to the size of the cells, is obtained. These results will represent certain risk types, for example, the value of the damage caused by the fire in each square (risk induced by this fire), or the degree of exposure of the values-at-risk in a square (risk undergone by these values).

5

Fire prevention: Avoid any fire occurrence

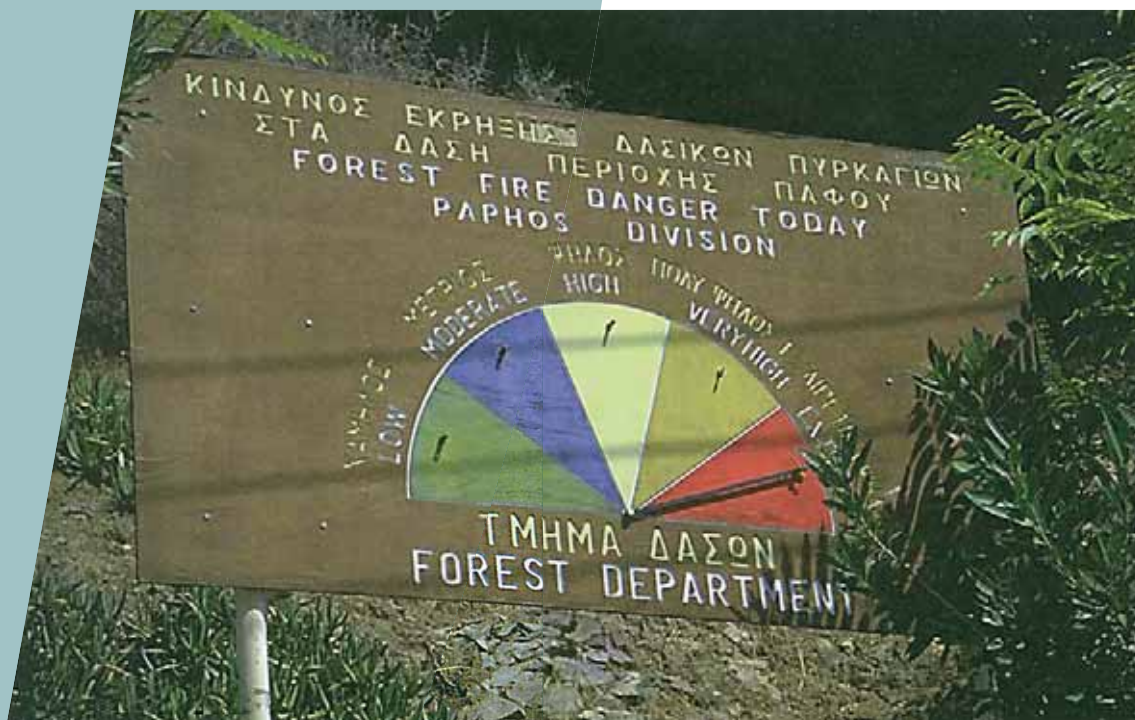


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Chapter 5.1 - Education and sensitisation

Chapter 5.2 - The legal framework

Introduction

We call prevention all actions aiming at preventing any fire occurrence.

Actions of prevention include:

- Fire-cause investigation*
- Education and sensitising of the public: since fire origins are mainly related to human activities, it is necessary to inform and sensitise the various population groups who can generate fires, such as farmers, forest workers, local inhabitants, tourists, industrial companies, and small enterprises*
- Inspection of buildings and facilities likely to cause fire ignition (power lines, lanes, garbage dumps...)*
- Fire law enforcement: dissuasive surveillance, definition of a dissuasive and repressive legislative framework*
- Forest access regulations*

Actions of education and sensitising allow an awareness raising for the fire hazard and a better knowledge of the fire danger. It is necessary to aim well at the target groups and to choose diligent means and actions to be implemented.

– A legal framework - preventive and repressive - is the essential complement of the preceding actions.

According to the existing fire risk and available economic resources for financing prevention activities and fire suppression, various strategies can be adopted:

– Avoid all ignitions and protect all zones threatened by fire.

– Develop a strategy of the “acceptable minimum”, realizing the technical and financial impossibility of protecting the entire territory against fire.

Example: Italy has defined zones where fires can burn (alpine pastures, fields abandoned by farmers...), and others where it must be controlled or avoided at all costs (in priority inhabited zones, industries...).

5.1 Education and Sensitization

One of the major objectives of awareness raising is to explain why the Mediterranean forest should be protected, and how to protect it. The purpose of education and sensitising is not to provide scientific knowledge to the citizens, but to give them a desire for acting to protect the forest and for taking the responsibility.

Forest fires are mainly caused by human activities, due to negligence, accidents, or incendiary acts. Therefore, it is essential with regards to prevention, to create awareness that forest fire protection is the business of all. This awareness-building process builds on public education and sensitisation of people.

The responsibility to inform, communicate, and train is in the hands of forest fires experts and decision makers.

An effective communication program must answer the three following questions:

- Who is the target group?
- What message is to be passed?
- Which media should be used?

Each answer is closely linked to the two other questions.

Training allows to look further into scientific, technical, and practical details, or teaching techniques.

But before beginning any public relation campaign, it is important to analyse the preceding actions and to evaluate the short, average and long-term impacts of messages on the target groups as a feedback for new campaigns.

Analyse preceding actions

To evaluate the impact of communication campaigns, two methods are possible:

- Campaigns with objective verifiable criteria for evaluation of previous achievements (e.g., reduction of fire occurrences or area burned in the period following the communication campaign in comparison to a reference period).
- Campaigns with an interest in the communication itself: is the message received, understood, appreciated?
 - During the campaign design, pre-tests gather first reactions for documentation of a restricted population sample of the target group, using qualitative interview techniques. (E.g., is the message comprehensible? Which visual elements are observed attentively?) The feedback is used to modify documents. These pre-tests are more a help for the campaign design than an analysis of existing situations.
 - The impact test samples from a targeted population variables like “recognition percentage” of the campaign, the remembered content... These methods assess the members’ memory of the sample population.

The target groups

Good communication needs a good knowledge of the targeted groups and their information level, opinions, attitudes, motivations, and values... A feasibility study is essential for assessing better the behaviour and the sensitivity of the public with respect to the forest, fires, prevention, and suppression.

TARGETED SENSITISATION

It is always more effective to target only one population group. This allows to adapt the public awareness campaigns according to the characteristics of the group of individuals. Different target groups can be distinguished:

- Children and teenagers within the education system, teenager movements, or holiday centres. The children are privileged interlocutors because they are sensitive to the safeguarding of the forest. They can transmit the message to their parents:
 - Persons in charge for the regional planning (local counsellors, officials...)



- Farmers or foresters working in or near the forest
- All the people residing in forests and its edges
- Forest owners
- Tourists

MASS SENSITIZATION

The general public represents the entire population and the individual can only be targeted via a group within this population.

Public awareness campaigns for the entire population appeal to the responsibility of the general public in order to avoid any act of imprudence. These campaigns are more effective if they take place when conditions are such that the public constitutes a risk for the forest.

The messages

The information about the Mediterranean forest is mainly related to fire. First, people have to be convinced that forest protection is essential. Second they have to be informed how to participate in forest fire protection:

- The message must be adjusted to the targeted public.
- The communication must carefully avoid to

MOROCCO

Committee for vigilance and immediate suppression in

Presentation: Created on the initiative of the National Forestry Service at the beginning of the 1980s, these committees consist at least of 2 representatives of the State, an elected official, and an honourable village representative ensuring the link to the population. They are organized according to the administrative hierarchy (community, region, province) and intervene on well defined territories (administrative limits).

Objectives: These committees call upon the civic responsibility and the participation of inhabitants. The purpose is:

- *Sensitising of the population in their area of intervention*
- *Mobilization and the immediate intervention of the population in the event of fire*
- *Raising of responsibility feeling of inhabitants towards forest resources*

Operation: Each year, a document (approved by the National Forestry Service) is compiled to define the committee (members, means available, objective to reach). It acts, while ensuring the renewal of the members of the committee, to maintain a certain continuity in the objectives. In the longer term, the goal is to train professionals for fire fighting.

bring misleading messages to people by spreading simplistic formulas, whereas the reality is often quite complex, asking for a long-term campaigning until the concept being accepted.

- Not only simple messages should be chosen, since citizens are ready to accept that the problems are rather complex.

- The forest functions have to be defined: place for livelihood, resources for rural population, wood production, public recreation, landscape element, part of balanced ecosystems...

- It should be avoided that the population sees the forest only as a fuel complex burned by fire in the dry season, but to sensitise people for the benefits of forested land. It is the green forest, the living forest which is essential.

Messages can be conveyed by impressive images. The options include:

- A forest engulfed in flames, a catastrophe, a spectacle if the message shows some pictures of a fire and ongoing fire fighting. A fascinating image.
- A fire-killed forest, images of black trunks and ash, destined to disappear. A shocking image.
- A well preserved green forest, synonymous for life quality, beauty, and future. An aesthetic, sensitive, and encouraging image.

The messages include:

- Utility message - to prevent the forest from burning - targeting groups of individuals identified as persons in charge of fires (farmers, shepherds, foresters, hunters...); mainly informing about laws, regulations, prohibition, and training.
- Shock message – to recognize that fire is a catastrophe - destined to the general public. The aim is to make people reject fire and make the population attentive towards fire. The effect is mainly of short-term.
- Educational message - to love, to know, to protect - destined to children and the general public; teaching the functioning of the forest and to provide information to build up a positive long-term attitude.

The vectors

Actions of education and sensitisation can be direct (advertisements) or indirect (participation in forest work). These actions use various vectors (media, ground patrols, panels, public meetings...) and can be organized by various speakers such as representatives of the state or local communities, non-governmental organizations, voluntary associations...

The vector is a tool which strongly depends on the target and the message.

MASS MEDIA

Television, radio, and press can be a good

means to transmit a message, in the form of advertising films, specialized emissions, newspaper articles...

E.g.: Turkey calls upon personalities known to give more weight to these media messages. In Cyprus, a fire danger index is shown with the weather forecast.

On the other hand, the use of the media, in particular of television, has disadvantages:



- The impact of the image can be too attractive, thus being more fascinating than inspiring a desire for preventing.
- The message aims the general public and is not focused at all.

The information passes can be passed to journalists who have necessarily to be interested and who have to be provided with:

- A press release with short information. It is a short text (approximately thirty lines) which:
 - * Goes directly to the essential message
 - * Answers basic questions (Who? What? Where? How? Why?)
 - * provides additional information in order of decreasing importance
- A press kit with more detailed information. The information is presented in form of few leaflets (maximum 12 pages) structured as follows:
 - * A synopsis
 - * A synthesis in 2 or 3 leaflets
 - * Short texts dealing with various topics: technical, economical, social, practical...

It is useful to build up a network of partners, contact in advance journalists of local daily newspapers, regional weekly magazines, local radio stations, regional television, as well as regional reporters of the national press.



SPAIN

RURAL PUBLIC AWARENESS CAMPAIGNS

The use of fire is an agricultural tool for the Spanish rural population. The objective of the public awareness campaign intended for these rural populations is to show that misused fire carries damage to farmers and stockbreeders, and to explain how to use it well. This campaign started in 1988.

Material and methods currently used for rural awareness raising are:

- A booklet entitled «All against fire», giving recommendations to carry out agricultural and pastoral fires.
- A play, represented shown in very many villages since 1991.
- A video entitled “Prevention of fires caused by agricultural and pastoral burning”.

OTHER DIRECT VECTORS

Many vectors can be used to carry out a public relation campaign:

- Posters
- Patrols on foot, horse...
- Conferences
- Exhibits
- Written documents (booklets, books for children, specialized reviews...)
- Audio-visual documents
- Botanical paths
- Guided tours
- Special advertising gadgets

The sensitising of children can be done by conferences in schools, by the creation of clubs working

TUNISIA

FOREST ASSOCIATIONS OF COMMON INTEREST (ASSOCIATIONS FORESTIÈRES À INTÉRÊT COLLECTIF - AFIC)

Created on the initiative of the Ministry of Agriculture in 1996, these associations aim at organizing forest users and link them to the authorities. They have the task to ensure:

- The agro-silvo-pastoral management of private land within state forests;
- The organization of paid activities for the local population in the forest surroundings: grazing management, water point management, bee-keeping...

The AFICs seek to reconcile the interests of the population within the forest with these of the administration by integrating forest dwellers into the forest development and conservation management.

TURKEY

PARTICIPATORY PROGRAM APPROACH

ORIGIN: *This program (currently in progress) is a component of a project set up in February 1998 by the F.A.O. (TCP/TUR/6713A), dealing with:*

- management of forest fires
- communication technology for fire control
- databases
- forest fire protection
- participation of population and rural development

This project is managed by three international consultants originating in France, the United States, and India, and by five Turkish experts in charge.

Within the framework of the last topic (participation of the population), four villages were selected as pilot zones.

PRINCIPLE: *This program of participatory approach breaks up into two stages:*

- Definition of the socio-economic profile of the village (activities, production, level of education...)
- Proposal for an adapted strategy: installation of projects answering special needs of the village and support the participation of the population by ensuring a certain income (e.g., organized forest fuel reduction, extracting wood for construction and cooking; afforestation with obligation of stockbreeders to avoid forest damage by grazing; education of the population in schools, mosques...)

for the protection of forests, by the edition of specialized reviews, plays...

Specific information campaigns can target tourists by presentations in hotels, panels written in several languages...

Public relation campaigns targeting the general public can take various forms:

- Specialized patrols charged to inform and to sensitise the public in forest and in periphery.
- Panels prohibiting to start camp fires in the forest, to picnic, and to smoke, or panels to sensitise people for the fragile forest ecosystem.
- Intervention in the everyday life by information campaigns on the market, during religious services... or the distribution of posters and stickers.

INDIRECT ACTIONS

The participatory approach can also be a good means of sensitising:

- The participation of the population in afforestations can raise the awareness for the need of preserving and regenerating the forest.
- Forest work by young people (undergrowth clearance, pruning) offers teenagers a possibility to discover the natural environment.

Moreover, the participatory approach allows to establish or reinforce relations of confidence between the forest managers and the local population.

Training

The training allows to acquire thorough knowledge about fires and the close connections to human activities. It can be carried out targeting:

- Young people, during their education, by the way of specific training kits
- Teachers, who will sensitise then their pupils
- People working in the forest: precautions to be taken during the use of equipment, activities to be performed, use of certain less dangerous exploitation techniques...
- Elected officials of local communities
- Personnel working in fire prevention and suppression
- E.g., in Turkey, workers in charge of fire detection and suppression receive three weeks of training
- People volunteering for forest fire protection

FRANCE

Training of volunteers from Forest Fire Community Committees (Comités Communaux Feux de Forêts - CCFF)

DEFINITION: under the authority of the Mayor the CCFF is founded by a meeting of volunteers of the community (officials, farmers, hunters, forest owners...), supporting the protection of the forest and their environment.

ROLES: *A CCFF can intervene in various fields:*

- Sensitising and education of the population in raising the knowledge and the respect for the forest
- Participation in the development of the fire risk map for the community forest
- Surveillance
- Initial attack on starting fires
- Assistance of fire crews by guiding them, by ensuring their supply...

TRAINING: *Each person wishing to participate in a CCFF must follow a formal and practical training, followed by a knowledge test in order to evaluate his/her capacities to be a committee member. This formation consists of:*

- Basic training: forest organization, principles of forest fire protection, meteorology, organization of rescue operations...
- Specialized training: first aid, surveillance (patrolling/look-out), map reading, communication...

5.2 The legal Framework

To sensitise and to inform is not always enough; it is also necessary to enforce. The definition of a legal framework, at the same time preventive and repressive, regulating human interventions in the forest or its periphery (agricultural work, picnic, constructions in the forest...) allows to reduce the risks of fire ignitions.

Preventive legislation

CONTROL OF HUMAN ACTIVITIES

The agricultural, pastoral, or forest activities in the forest or in the vicinity must be controlled, even prohibited when the fire danger is high.

LAND USE

The cutting of the territory into properties (land register) must be consigned on official documents and be demarcated clearly on the ground, particularly when there are state forests. This allows to discourage any attempt at land appropriation (real estate speculation, clearings for the extension of agricultural zones...).

REGULATIONS FOR ACTIVITIES IN AGRICULTURE OR FORESTRY

IN MOROCCO, from July 1st to October 31st:

- Fire prohibited.
- Incineration of the undergrowth, grass, standing crops prohibited to private individuals on areas located at less than 4 km to the forest.

IN CYPRUS:

- All year long, prohibition to start a fire in the forest and up to 1 km from the forest.
- Prohibition for farmers to burn from March 31st to November 30th.

REGULATION OF FOREST ACCESS

IN SYRIA, the license plates of all vehicles in the forest are controlled.

In France and in Cyprus, many access roads into forests are closed for public traffic by a system of barriers opening with a master key; each person in charge (surveillance, suppression...) has a double key.

FRANCE

RISK PREVENTION PLANS (PLANS DE PRÉVENTION DES RISQUES (PPR))

CONTEXT: In France, the Forest Law allows to ensure the protection of the forest and threatened goods, but it is the Law for Urban Planning which regulates the right to build, based on the Land-use Plan (POS¹). The latter defines construction zones, in particular according to the natural risks. However, the fire component is not taken into account. The PPR, founded by the law no. 95-101 of February 2nd, 1995, is an opposable constraint for town planning open to third parties. It is annexed to the POS.

OBJECTIVES: The PPR consists in delimiting:

- Zones directly exposed to the fire risk.
- Zones where certain land-uses could worsen existing risks or cause new risks.

The purpose of this zoning is to regulate projects for new installations (dwellings, factory sites...) and to define prevention and protective measurements for existing constructions.

MEANS: The mapping of the risk includes three phases:

- Preliminary analysis of the study zone, in particular using statistical data, allowing to define a risk zone.
- Evaluation of existing risk levels based on: vegetation, climate, topography, human activities.
- Determination of the human, socio-economic, and environmental stakes.

RESULTS: The territory covered by the PPR is cut into three zones:

- Red zone, all new construction (dwelling, complex tourist, industrial building...) must be prohibited.
- Blue zone, new constructions are authorized under conditions.
- The “white” zone does not have a particular constraints.

¹ In French: Plan d’Occupation des Sols (POS).

To constraint the scattering of constructions in the forest (dwellings, tourist residences...), it is essential to regulate the use of land, in particular by prohibiting to build in zones with a high fire hazard.

VEGETATION CLEARING

Vegetation clearance and including maintenance can be made compulsory in zones with a high fire hazard: around dwellings or constructions, garbage dumps, along roads and tracks, railroad tracks, power lines.

E.g., in Morocco, dwellings, buildings, or building sites located in the forest or at less than 200 m of the forest limit must be surrounded by a fire break of 25 m without vegetation.

Repressive legislation

Enforcement aims at deterrence: persons responsible for fire starts must be identified, judged, and convicted. The sentence is variable according to the degree of the responsibility of the culprit and the damage generated: it can go from a fine to prison.

Law enforcement

The existence of a legal framework allowing to regulate human activities in the forest or its periphery is not enough. In practice, it is necessary that laws

are applied, and a control is necessary to take care of this enforcement. It can be carried out by a forestry police (Syria), by forest district guards (Tunisia), or by surveillance teams (committees for vigilance and immediate suppression in Morocco).

Even if the repressive legislation envisages sanctions for the persons causing the fire, their application can be a problem:

- The identification of fire causes is difficult; that of the arsonist is even more difficult.
- For an arson fire, the degree of responsibility of an individual must be investigated beyond any doubt: morbid pyromania or deliberated act?
- For an involuntary fire, it is sometimes difficult to judge the degree of responsibility of the arsonist: imprudence or accident?

THE SANCTIONS...

In Lebanon, the law no. 558 of July 1996 protects the forest against any aggression: any person causing a fire is sentenced between one to five years prison and fined five to twenty million Lebanese Pounds.*

In Morocco, in Syria, the author of an arson fire is judged for crime. Moreover, in Syria, the sanctions are heavier in years when fires are numerous.

*Equivalence * one Lebanese Pound = \$ (1 USD = 1505 LBP)*

6

Fire prevention: contain the fire spread



Principles

The fire ignition proves the failure of the prevention activities.

The prevention is defined in this handbook as all preliminary actions carried out to prevent fire occurrence as well as to reduce fire consequences. There exist two types of prevention approaches:

- Measures preparing fire suppression, such as:

- * Controlling the fire at its initial stage by rapid initial attack; and

- * Containing the spread of the fire which could not be suppressed by initial attack.

- * Pre-suppression measures by fuel management (fuel reduction, fuelbreak construction).

In practice, these two approaches are closely interdependent. Indeed, the reduction of fire intensity due to fuel modification facilitates the work of the fire crews and increases fire safety.

RAPID (INITIAL) ATTACK

For fire fighting, time is essential, especially when the climatic conditions are critical. The speed of intervention on a starting fire determines the evolution of this fire. At the beginning an easily controllable fire turns into a catastrophic fire when the intervention (response) time is too long. The intervention time beyond which the fire becomes not easily controllable depends on the specific conditions in each country, in particular with regards to vegetation, climate, topography, and available fire fighting resources.

E.g., the subjectively estimated threshold is 10 minutes for France and 15 minutes for Greece.

The reduction of intervention times is based on some principles:

- The installation of a surveillance network allowing to detect any fire start quickly. This surveillance can also have a dissuasive and repressive role and thus limit the number of ignitions.

- Preparedness of first intervention capacities: mobilisation and standby of ground and aerial fire fighting means allowing a rapid response (e.g., ground or aerial patrols with fire fighting equipment, fire fighting crews stationed in the forest).

- The improvement of accessibility (strategic access roads, dirt roads).

- A good knowledge of the terrain (access, fire spread prediction, etc.), supplemented by an effective signposting on the ground and updated maps.

- Establishment of an information and dispatch centre for fire surveillance, fire suppression and co-ordination of operations.

LIMIT THE FIRE SPREAD

The failure of the initial attack opens the way for the fire spread, which can then become catastrophic.

Thus, prevention measures and preparedness are crucial to enable the fire crews to attack the fire under the best conditions for effectiveness and security:

- Definition of adapted fire fighting strategies, installation and organization of human resources, and fire fighting equipment;

- Implementation of field installations: principal roads, secondary roads, zones prepared for fire fighting, water points.

VEGETATION TREATMENT

Undergrowth clearing and adapted silviculture operations reduce fire intensity and spread, and damage caused by wildfires.

UNDERGROWTH CLEARING

Fire intensity is closely related to the quantity of combustible phytomass (fuel load). The fire spread depends partly on the spatial continuity between plants.

Clearing of undergrowth involves the reduction and/or spatial (horizontal, vertical) separation of the lower vegetation layer, i.e., the layer which determines fire intensity and spread. It is also important for the creation of safe and accessible operation zones, e.g., fuelbreaks.

Silviculture

Silvicultural measures (selection of tree species, thinning, modification of stand structure) contribute to the reduction of fire spread and fire effects on trees.

6.1 Fire detection

It is essential to set up an effective surveillance network which allows to reduce the time between the ignition and the detection of the fire. It focuses particularly on all activities which can cause a fire.

The surveillance is based on the combination of various observation and detection means, either mobile or fixed, terrestrial or aerial.

The combination of the surveillance and the first intervention, performed by the same team having terrestrial or adequate aerial support, proves particularly effective for quick intervention on a starting fire during days at very high risk.

Fixed observation

It is preferable that the fixed observation is ensured based on specific infrastructures: fire lookout towers. The absence of these installations renders the surveillance more difficult.

The tower must be located on open high point with a good visibility on the surrounding area. Their number can be variable, in particular according to the topography which can strongly limit the visibility, but essence is to ensure the best possible surveillance coverage of the territory.

These towers must be protected from fire (undergrowth clearing, watering system).

The surveillance quality of a watchtower network depends mainly on three factors:

- The location of the stations;
- The equipment specifications (technical quality and equipment of the stations);
- Rules for safeguarding the network efficiency (quality of the personnel, work specifications).

DESIGN OF AN OPTIMAL NETWORK OF FIXED FIRE WATCHTOWERS

The network of fire watchtowers must allow, for the greatest possible number of fire starts:

- A fast alert;
- An accurate localisation of the fire (with a precision of one kilometre).

In order to achieve this:

- The area covered by the network must include the maximum of the zones at risk.

- It is necessary to seek an overlapping coverage of the zones at risk by two or three towers to allow a fast and precise localisation of the fire by triangulation.

Study of the environment according to the fire phenomenon

Before any choice of building sites for the fire watchtowers, it is important to study the area in order to be able to delimit the zones to be covered by the network. The delineation is determined by various considerations:

- Mapping of the fire danger (risk and vulnerabilities), and in particular the ignition risk.
- Analysis of the fire fighting constraints (topography, distance to fire centres, forest fire protection equipment, etc.).
- Analysis of alternative means of alarming (fire reporting). An effective vigilance by the population in certain zone (revealed, for example, by the study of filed fire reports) allows to accept a less dense coverage of these zone, especially when this economises on needed investments (villages located at the end of steep-sided valley where the visibility from lookout towers is difficult).

First selection of available installation sites

An inventory of all the points likely to be of an interest is made starting from the topographic map of the zone that has to be covered by the network.

After field visits a first ranking is carried out in order to preserve a number of points still higher than that which will have to be finally retained.

Background types	Observation direction	Very clear weather		Average clear weather		Hazy		Foggy	
		Midday	8 hrs to 16 hrs	Midday	8 hrs to 16 hrs	Midday	8 hrs to 16 hrs	Midday	8 hrs to 16 hrs
Dark background (dark pines)	With the sun	23.3	24.1	17.7	18.5	12.8	12.8	8.0	8.0
	Against the sun	22.5	22.5	16.9	16.9	12.0	12.0	8.0	8.0
Clear backgrounds	With the sun	22.5	23.3	16.9	17.7	12.0	12.8	8.0	6.0
	Against the sun	19.3	18.5	14.5	14.5	10.4	10.4	7.2	6.4
Very clear backgrounds (dry grass)	With the sun	21.0	22.5	16.1	17.7	11.2	12.0	7.2	8.0
	Against the sun	15.3	14.5	12.0	11.2	8.8	8.8	5.6	5.6

Establishment of the zones seen from each selected station

The sight range

For a given zone, it is initially advisable to determine the limit of the visible area, i.e., the acceptable maximum distance for discovering smoke during periods with a high fire danger. This one is a function of:

- Factors related to the fire guard (eye acuteness, experience, state of tiredness, work attention, etc.).
- Atmospheric factors:
 - * Fog, urban and domestic smoke as well as dust, which decrease the visibility
 - * The sun position. The more the observer faces the sun, the more appears the smoke clear to him. The maximum distance to which a small smoke column can be seen depends more on the clearness contrast between smoke and its background than the colour contrast.

The table below shows the limiting distances for secure visibility (70 % of the real sight range of the observer) in kilometres. It is based on studies made with smoke-producing substances reproducing the equivalent smoke of a 18 m² litter fire of *Pinus ponderosa* on a dry day in the midst of summer.

With increasing darkness and uniformity of the background a small smoke plume is detected easily due to high contrast.

Although it is more unpleasant and fatiguing for the human vision to inspect a landscape against the sun, the observation under these conditions is more effective.

Other factors affect smoke detection:

- The wind tilts and disperses the fume of starting fires; this complicates the localization;
- The height and the density of the forest cover influence the appearance time of the smoke into the sight of the observer.

The sight (visibility) range limit will in general be fixed between 20 and 25 km, but can also be reduced to 10 km for zones with bad visibility conditions (fog, clear background, etc.).

Eye level of the observer

It is the height of the observer above ground-level which minimises blind zones. This height is a primarily function of the height of the lookout tower cabin. In hilly terrain, this height influences little the visibility of more distant zones but can be essential for zones located below the tower.

Mapping of visible and hidden zones

When the tower location and the tower height are determined, it is advisable to determine the observation coverage and blind spots. That can be done by:

- Using a topographic map with contour lines (e.g., maps at a scale of 1:50,000 with contour lines every 10 m):
 - * Draw section lines from the tower location (e.g., every six degrees one line, totalling 60);
 - * Determine for each section the visibility limits as well as blind spots for the observation from the lookout tower;
 - * Draw these limits on a map and interpolate between sections.

- Using a computer and a digital terrain model.

Determination of the optimal network

The contours corresponding to each site considered are compared. The final choice of the installation points for the fire lookout towers is complex and the decision will be the result of a compromise taking into consideration:

- Examples for the coverage for the land under forest fires protection are:
 - * 80 to 90 % in very high risk zones
 - * 75 to 85 % in high risk zones
 - * 50 to 60 % in moderate or low risk zones
- The simultaneous coverage by two or three fire lookout towers.

The use of data processing and a geographical information system (GIS) allows to synthesise the studies carried out for the considered sites.

E.g., Turkey has a very important network including 783 fire towers, which meets the requirements of a mountainous topography (forest surface: approximately 20 million hectares).

EQUIPMENT SPECIFICATIONS

Fire lookout types

The choice of the installation type depends on the:

- Needed eye-level height above ground-level for the observer;
- Equipment that the observer uses;
- Possible choice to lodge the guard on the spot;
- Available budget.

Three types of possible stations of watchtower are enumerated below:

- Caravan. Bad visibility - Possibility of lodging the observer.
- Pylon with platform at the top. Good visibility - Good possible equipment if the platform is large and roofed - Possibility of placing the observer in installations annexes
- Solid tower. Good visibility - Good possible equipment - Possibility of lodging the observer - High cost.

Certain constructions have a double utility. E.g., in Syria, the bottom of the tower is reserved for the forest police, which control illegal activities and the top for fire detection. The fire protection operational centres also have a lookout room on the highest floor of the building.



Tower equipment

The observers can have the following localization and detection equipment:

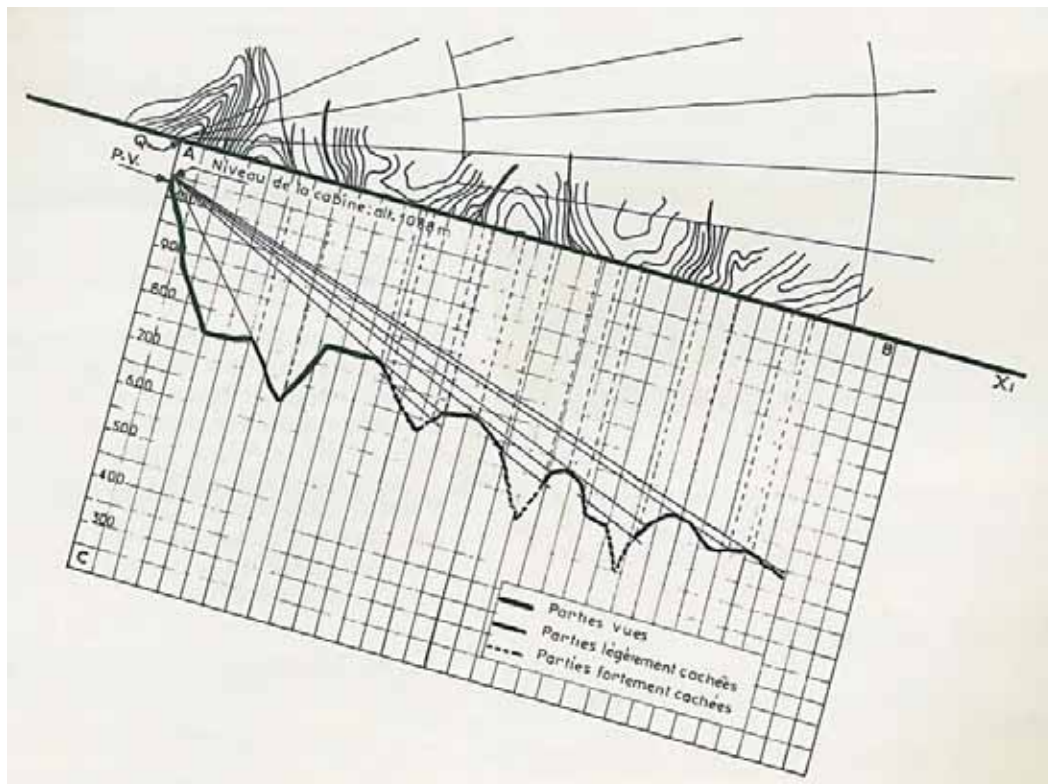
- Maps indicating visible and hidden zones;
- Binoculars;
- Instruments to measure the azimuth (compass, alidade, etc.) allowing to locate the fire location.

It is obligatory that each tower is equipped with communication tools (radio or telephone) in order to transmit quickly any fire occurrence to the fire management centre.

SURVEILLANCE RULES

Mobilization

First of all, the fire surveillance must be assured during the period with the highest risk (e.g., three months





in France, seven months on Cyprus); for zones with a high fire risk outside the general fire season, it can be judicious to operate some towers all year long (e.g., Turkey).

The duration of a surveillance day depends on the available human and material resources and the temporal distribution of the fire occurrence. The surveillance can be carried out in day time or 24 hours a day, but the night visibility is very reduced.

Organization

The personnel of the lookout towers consists of two to three people working in shifts. In some cases, the tower provides lodging to ensure permanence. The surveillance can be ensured in two different ways but which can be complementary by personnel having:

- a very good knowledge of the area, able to locate very precisely smoke without having recourse to sophisticated hardware (nevertheless binoculars are strongly recommended);
- the localisation and detection equipment described above.

Terrestrial mobile observation

A terrestrial mobile observation supplements usefully the surveillance from fixed lookouts. They are patrols on foot, bicycle, horse, or vehicle. Their role is the fire detection, education of the public, control of human activities which can increase the fire risk, enforcement, and dissuasion. The patrols have a radio to inform the responsible organisation.

In the case of equipped patrols, the patrols carry tools for a first intervention (water tanks, motor-driven pumps, etc.).

The effectiveness of the initial attack depends not only on early detection, but also of the quality of the alarm message. The patrols are more effective than untrained volunteers if its personnel is professional and has a basic knowledge of fire behaviour. The alarm message then has much more of detailed information (slope, vegetation, smoke column, necessary fire fighting equipment, etc.).

Aerial observation

There exist two types of surveillance using aerial platforms:

- **Aerial reconnaissance.** The airplane has only the task of detecting fires and to alert the fire fighting services;
- **Aerial reconnaissance with water tanks.** The planes have a water tank and combine surveillance and initial attack. These reconnaissance planes (e.g., Tracker S2F) are equipped with a small water tank and able to intervene directly on the fire immediately after detection.

This type of surveillance remains little developed in the Mediterranean basin. The reserves come from the inherent cost of this detection system. The armed aerial reconnaissance is nevertheless very useful for the zones that are not accessible on the ground.

Automated systems

This type of surveillance, thanks to the development of new technologies, starts to develop. It is used either in backing up the fire lookouts or in an autonomous way.

There are three principal types of hardware:

- **“Visible” cameras.** The reception of images is carried out by a camera operating in the visible spectrum. The images are transmitted to the observation post. The fire detection is made on a screen by an observer or automatic image comparison. The disadvantage is that this hardware can be used only day light.
- **Video sensors.** The system is composed of several CCD video cameras and a central processing unit able to identify the “signature” of the smoke of forest fire. At night or day, it provides the functions of smoke detection on an area of approximately 3 000 ha and rapid information transfer to one or more control stations.
- **Infrared sensors.** A sensor operates in the thermal infra-red field (wavelength from 10 to 12.5 mm). The detection is made by automatic image comparison. These sensors have the advantage of being usable during the night, but the costs of installation are high.

All these apparatuses function only in direct aiming. The often irregular topography of the edges of the Mediterranean basin forces to multiply the sensors if one wants to cover the territory correctly.

Intervention of the population

The participation of the population in the fire detection can be of a great help. A toll free phone number is at the disposal of the public linked directly to the forest fire management centres, the forest services or the police.

FRANCE

AIR PATROL WITH WATER DROPPING FACILITIES

Each year, ten air routes are selected and for each are specified the cruising length, the plane type (Tracker S2F, Fokker, Hercules C130 or the scooping plane CL 415), and the flight time.

The aerial patrol is started only at days with a very high fire danger. Its high cost (25 000 FF by plane/hour) is to be considered relative with the results obtained: 75 % of the detected fires are extinguished by this device when applied immediately.

Sticker Turkey (177); other numbers for other countries (18 in France and now the 112 on all GSM networks)

Fire localisation

The people informing the fire services of a fire start must specify the fire localisation as precisely as possible. The use of a co-ordinate system by the responsible authorities allows to synthesise the localisation in the form of a code and to be avoid vague descriptions.



ITALY AND SPAIN

SURVEILLANCE BY INFRARED DETECTORS

This type of surveillance is developed in Italy (Province of Turin, Sardinia) and in Spain (Andalusia) to mitigate the staff shortage.

The radiation emitted by the hot bodies is raised by an infra-red sensor placed on a tower with a height of approximately 30 m. The sensor rotates at a speed of 360 degrees/min. It memorises several successive images of the territory. The comparison of these successive images allows to know if the emission of infra-red signals has increased in a given point. The alarm mechanism is started at a certain threshold.

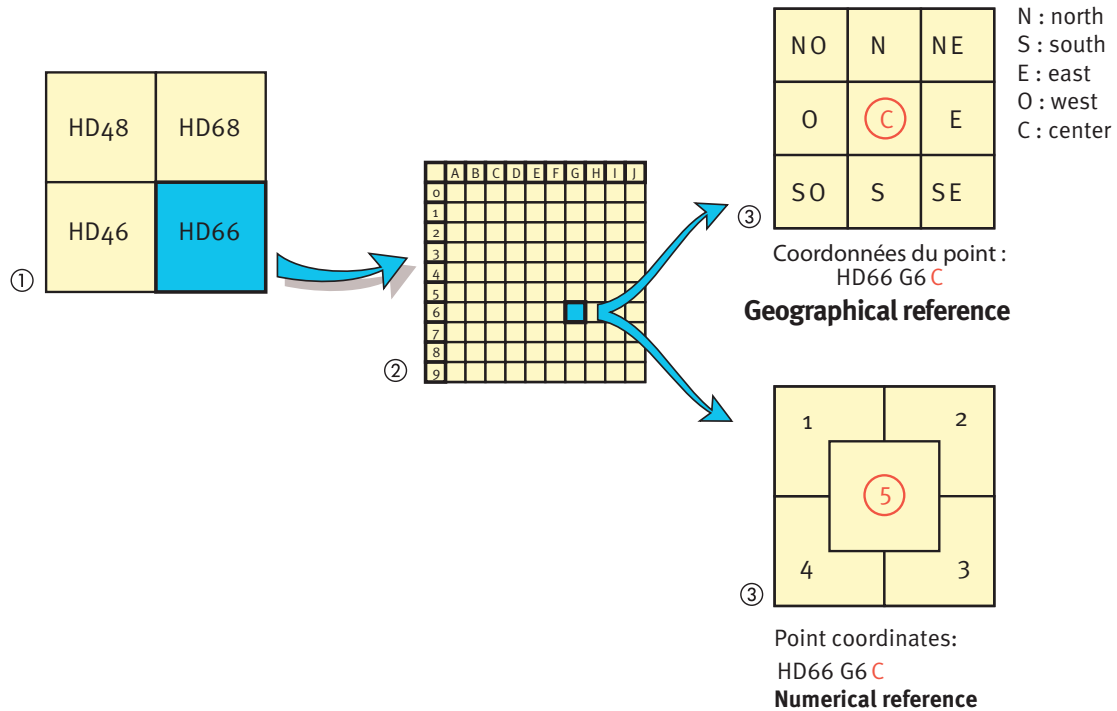
These devices can announce fires of a few m² at a distances of more than 10 km. Their performances are however reduced if the vegetation is too dense, and if an obstacle (rock, hill, etc.) is located between the detector and the place of the fire occurrence.

FRANCE

MAPS WITH GRID REFERENCE SYSTEM

To locate a fire, France is using a grid system:

- The territory is divided into squares (grid cells) covering a surface of 400 km²; each square is located by two letters and two digits (1);
- Each unit is divided once again into 100 squares of 4 km², to be defined a letter (abscissa) and a number (ordinate) (2);
- Lastly, each subdivision is divided into 5 or 9 squares (3).



6.2 Localized Undergrowth clearing

Localized undergrowth clearing allows to secure values at risk and to create fire fighting zones for the rescue squads.

Fire safety strips along roads

The strips along public roads are cleared of vegetation:

- To secure transit.
- To avoid the start of a fire («anti-cigarette-strips»).

If maintenance is insufficient and regrowth of



the herbaceous layer develops the functioning of safety strips decreases.

The objectives of clearing safety strips along roads and forest fire protection roads include:



- To maintain safety conditions sufficient for the traffic of fire fighting vehicles and surveillance. The width of cleared ground depends on the vegetation height, and it is at least 5 m on both sides of the road

- To establish intervention zones in the case of a fire occurrence. The minimal width of the strips cleared of vegetation is then 25 m on both sides of the way.

Taking into account the topographic conditions



and wind pattern of the site, undergrowth clearing can be asymmetrical. For example, the width cleared of undergrowth must be larger on side of the prevailing wind or below a road located on a slope.



Around dwellings

Dwellings in the forest represent a double risk:

- They constitute a potential sources for a fire start (cooking fires, barbecues, burning of wood debris from undergrowth clearing, garden fires, etc.);
- When a fire occurs in a forest, they can be directly threatened.

To protect dwellings, it is necessary to clear the undergrowth in their neighbourhood.

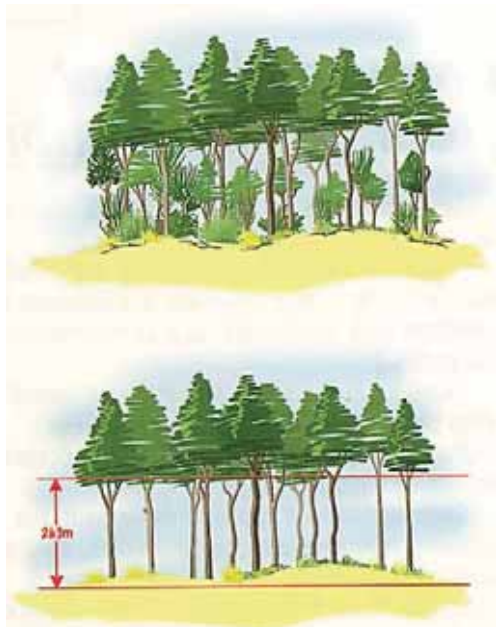
This instruction also applies to industrial areas, very sensitive to fires, as well as to recreational areas (campsites, picnic areas, etc.).

The scattering of dwellings within the forest constitutes an important problem, even when ground clearance is carried out correctly. It indeed causes the dispersion of fire fighting means which prioritise the protection of human lives and their values at the costs of the forest. Moreover, the access roads to these dwellings are often dead ends, and the entrance and the exit road can be cut by the fire.

Forest-agricultural interface

The agricultural activities in the forest periphery constitute a potential ignition source (debris and field burning, etc.). It is thus necessary to limit the risk of a fire spread towards the forest and to reduce the combustible biomass in periphery of the forests.

E.g., on Cyprus, at the beginning of June, strips of 30 to 50 m width are burned at the forest edge and then with the crusher to clear the ground.



Other important zones

Garbage dumps, power lines, and railroad tracks also constitute potential fire sources. It is thus advised to create a zone cleared of undergrowth near these installations, when close to a forest.

E.g., in Morocco, the National Electricity Company must ensure ground clearance under power lines and the National Railroad Company has the same obligation along their railway tracks.



6.3 *spatial planning*

The creation of large-scale spatial discontinuity of fuel complexes combining undergrowth clearance, forestry activities, and agricultural or pastoral activities (fuelbreaks and firebreaks) aims at the establishment of:

- fire fighting support zones;
- prepared fire lines, where fires can be more easily contained.

These discontinuities can be installed in the forest periphery (at the forest / urban interface) or inside the forest.

These discontinuities allow to stop low- and medium-intensity fires. However, high-intensity fires may jump over these fire protection belts. Strong winds reduce the effectiveness of these discontinuities because flying embers carried by the wind easily cross over (spotting) and light a second fire (spot fire) on the other side.

Firebreaks

Firebreaks in a strict sense are linear discontinuities where the vegetation is absent or reduced to a low herbaceous layer. These breaks must be located at forest / urban interfaces or on ridges for a better effectiveness. They are built with the bulldozer or by hand and must have a minimal width of 20 m to allow transport and intervention of fire crews, while ensuring their safety. These discontinuities have nevertheless disadvantages:

- They are easily jumped over by a fire. Their width is very insufficient to prevent that a fire does not spot beyond the break.
- They require a very regular maintenance at 1- to 4-year intervals to control or even to eliminate the vegetation by hand, bulldozers, or phytocides (herbicides).
- They are very sensitive to erosion, especially when slopes are steep because of absence or reduction of vegetation. The maintenance techniques accentuate this.
- The absence of wind breaking vegetation increases the fire acceleration by winds.
- They have a negative landscape impact.

Fuelbreaks

The objective of fuelbreaks is to create a discontinuity of the vegetation cover, to decrease the fire intensity, and to allow the direct attack by fire crews.

FUELBREAKS WITH A TREE COVER

With a minimal width of 100 m, the purpose of breaks with a tree cover is to limit the fire spread by reducing the contact between plants, while creating:

- Horizontal discontinuity: separating trees by thinning, elimination of the understorey by undergrowth clearing.
- Vertical discontinuity: suppression of the interface crown/understorey by pruning and undergrowth clearing.

With a reduced tree cover density the vegetation re-growth is rapid and therefore the maintenance must be regular.

Certain compartmentalization is done with different intensities:

- A centre area being the privileged fuel treatment zone.
- The boundary area, contiguous with the centre area, which is a zone simply grazed by animals without special labour activities. It is a part of an improved forest fire control by fuel load reduction at the edges of the firebreak.

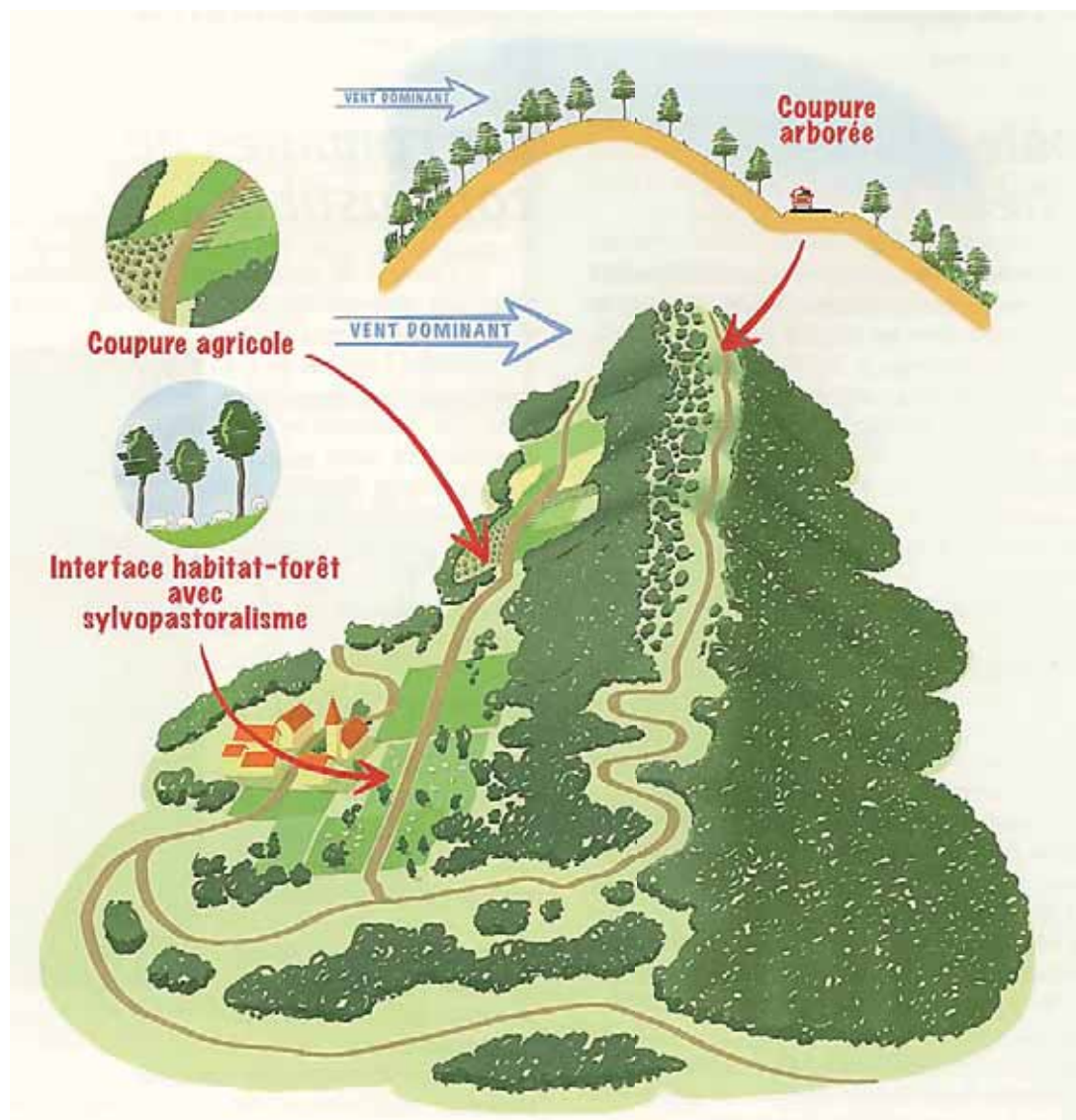
For forestry techniques and undergrowth clearance, see chapter 6.3 and 6.1.B



AGRICULTURAL BREAKS (GREENBELTS)

The creation of spatial discontinuities can also be a result of agricultural land use (e.g., vineyards, orchards, olive groves, etc.), which, if they are regularly maintained, constitute obstacles for fire spread. The limits between agricultural land (slope, ditches, etc.) must be cleared of undergrowth in order not to function as “igniter cords” allowing the fire passage.

Firelines that are constructed are described in chapter 6.6.



Fuel reduction

6.4 techniques

The choice of the fuel reduction technique depends on the state of general conditions of the vegetation and its natural environment:

- First opening (severance cutting) or maintenance.
- Vegetation type and density.
- Topography and terrain type.

Two phases of fuel removal can be distinguished:

- The initial operation (opening of the vegetation): This is often an expensive operation because the fuel load can be high.
- Thereafter, undergrowth clearance for maintenance intended to limit the re-growth of the vegetation. This work must be carried out regularly, with a frequency varying in function of the vegetation density and the applied technique. This operation is less expensive per treatment, taking into account the slower plant growth but it requires a continuous budgeting.

When the fuel load is high, for example, at the initial opening, it is advisable to carry out a manual or mechanical undergrowth clearing, or to use prescribed burning. If the fuel load is low, other techniques can be applied: herbicides or silvo-pastoralism.

The various techniques of undergrowth clearing are described below. They can be combined with, for example, a mechanical opening followed by silvo-pastoral maintenance.

The periodicity of the treatments depends on the speed of vegetation re-growth, management objectives (tolerated maximum biomass loads), and financial capacities. For each technique a short description and a comparison of advantages and disadvantages is presented below.

Manual undergrowth clearing

Hardware: hand-tools (brush hook) or with an engine (tree dozer, slicer)

Periodicity of treatments: every 3 to 4 years

Advantages

- Quality work that allows selectivity and thus the protection of regeneration.
- Low impact method, if it is used on a regular basis.
- Can be used under difficult topographic conditions and on very stony soils.

Plants that are less flammable can be favoured at the expense of flammable species.

Disadvantages

- Poor yield especially under difficult conditions.
- High costs if hand labour is expensive.
- Debris must be burned or crushed.

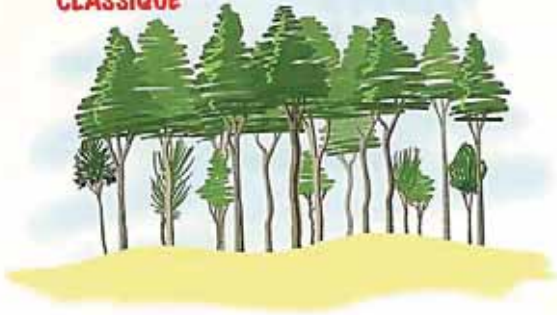
This technique is favoured by countries where hand labour costs are relatively low.



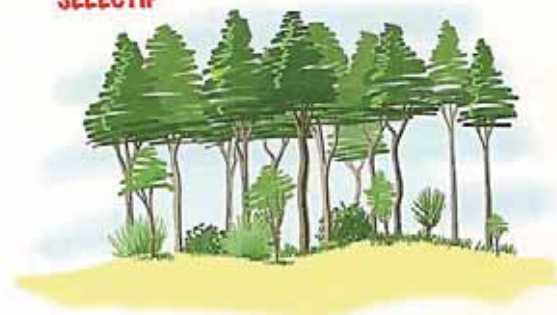
Manual fuel reduction by brush cutter on a terrace (France)



DEBROUSSAILLEMENT CLASSIQUE



DEBROUSSAILLEMENT SELECTIF



Mechanical ground clearing

Hardware: modified / converted farm tractors or public work machines

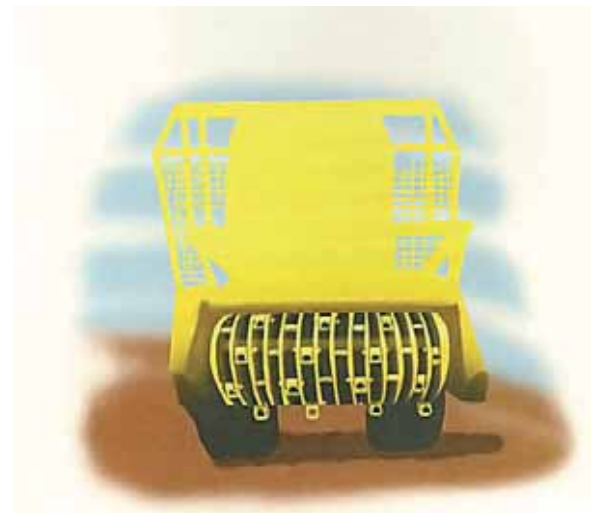
Periodicity of interventions: every 3 to 4 years

Advantages

- Rapidity.
- Advantageous cost/benefit relation in easily accessible terrain.

Disadvantages

- The equipment requires high investments and its maintenance is costly.
- The environmental conditions (topography, soil type, tree density) can be an obstacle for using the equipment.
- The heavy equipment has a negative impact on the soil by compaction; nevertheless an impact is limited on cleared zones, representing only a small percentage of the forested area.
- The de-rooting exposes the bare soil causing erosion on steep slopes.
- The debris must be burned or crushed/shredded.
- Coppicing species which are usually very flammable are favoured.



Broyeur à axe horizontal

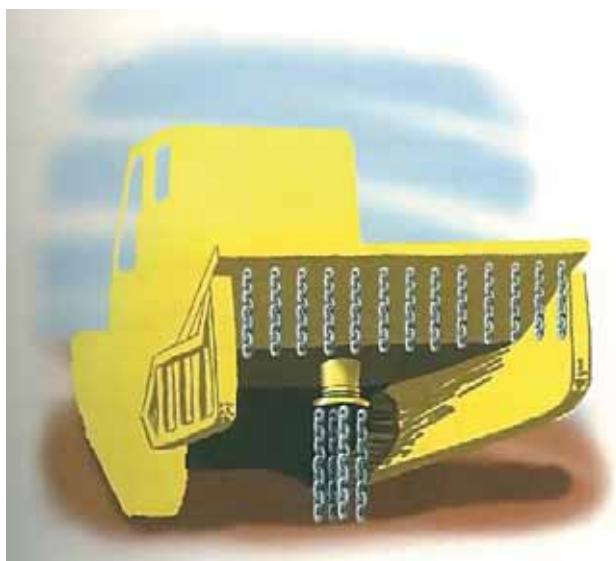


Râteau fléco



Chemical fuel reduction

Undergrowth clearing can be carried out by spraying herbicides or growth inhibitors. The use of these chemicals is an interesting alternative for areas where a mechanical maintenance is not possible (steep slopes, rocky terrain, etc.). Furthermore, when only limited funds are available for a too costly mechanical clearing. The applied substances function in general systemic, since they penetrate primarily by the foliage or the root systems and are transferred systemically (transported by the sap) to other parts of the plant. They have a persistence varying from a few hours (e.g., glyphosate) to a few months (hexazinone).



According to their nature, they contribute to:

- **selective destruction of flammable species** with a progressive death of plants such as grass, weeds, semi-woody and woody plants. This destruction (to be practised outside the season with a high fire danger) imposes a pruning of the trees parts above ground before summer. This intervention is interesting for perennial vegetation since it prevents any sprouting. Follow-up costs for maintenance are reduced. Moreover, the killing of the plant while letting untouched the root system protects still the soil against erosion.
- **growth depression of the vegetation** with a temporary reduction of the woody increment and the foliar development, inhibition of germination or destruction of seeds in the course of germination. This reduces the fuel load (products classified under growth depressant substances or sprout inhibitors).

Prior to use of these chemical substances in forest fire protection, it is advisable to consult all legal restrictions.

Judicious combinations of products and mode of



Rotor à chaînes



Rotor à couteaux

application will allow to:

- Find technical solutions adapted to the conditions: selection of the product according to the objective and the conditions for application;
- Treat any terrain: substances chosen according to the accessibility and the surface of the area to be treated;
- Apply quickly the treatment: use of the more adapted substances.

Intervention types

Note: The active substances proposed here are only examples. The user will have to refer to the pesticide product labels provided to choose the adapted dose.

For further information with regard to efficiency spectrum, selectiveness, and special products commercially available please read:

Cemagref-INRA, 1987, Note Technique N°53, Application des traitements par produits chimiques – Phytocides en sylviculture

- ACTA, (yearly updated index of herbicides)

FRANCE

USE OF THE CHEMICALS FOR BRUSH CLEARING

The French regulation stipulates that:

– *Only approved commercial chemicals can be used for the permitted use (categories “forests” or “non crop zones”) for firebreaks without any vegetation. The approval is given in each country by the Ministry of Agriculture and Fishing within the European legal framework.*

– *The treatment has to be executed by companies licensed for this type of work where the personnel is guided by certified personnel (certificate of application and distributor of agro-pharmaceutical products).*

Some examples of herbicides		
Penetration over leaves (photosynthesising organs)	GLYPHOSATE, is a broad-spectrum, non-selective systemic herbicide used for control of annual and perennial plants including grasses, sedges, broad-leaved weeds, and woody plants fosamine ammonium, growth depressant	
Penetration over the root system	propyzamide, absorbed by weed roots and translocated upwards; it works by inhibiting cell division and photosynthesis, hence the rate of weed growth can define the speed of kill. diuron or aminotriazole, herbicides restricted to non-cropland, noxious over root system for forestry trees	
Mixed penetration	hexazinone, a triazine herbicide used against many annual, biennial and perennial weeds as well as some woody plants; it is mostly used on non-crop areas; selective use for conifers, especially pine trees during the growing season	
...ways of application:		
<ul style="list-style-type: none">• Water hose with adjustable jet stream nozzle• Compressed air sprayers• Mechanical and power sprayers• Helicopter spraying, only used for fire breaks		
INTERVENTION TYPES		
Intervention type	Anti-cigarette strips	Fuel breaks in fuel types with trees
Objectives	Strips, cleared completely from weeds and herbs, at least in season with a high fire danger.	Limit the vegetation biomass (fuel loads) of herbaceous and woody strata below dangerous levels.
Treatment and precautions	<ul style="list-style-type: none">• Spraying over large area for an efficient dispersion• Local treatment with active emulsions (currently illegal) in the case of woody vegetation which is dispersed over an area To be avoided: <ul style="list-style-type: none">• Creation of a continuous dead vegetation cover prone for fire ignition and build-up of large fires.• Creation of vegetation-free strips along creeks and ditches.	Selection of treatment: <ul style="list-style-type: none">• Growth inhibitors for less flammable vegetation in order to reduce its biomass.• Selective use for specific products or mode of treatment in a targeted and local manner. This treatment can destroy: Two herbaceous and woody strata at the same time; <ul style="list-style-type: none">• Only one single stratum.
Product type	It is possible depending on the situation to combine: <ul style="list-style-type: none">• A sprout inhibitor (little soluble) propyzamide• a herbicide (penetrating into the first leaves and shoots): aminotriazole glyphosate• a herbicide: TRICLOPYR (ESTER OR AMINE) fosamine ammonium• phytohormones: 2,4-D or fluroxypyr• a graminicide: dalapon	Against woody and semi-woody species: triclopyr, fosamine ammonium , glyphosate Against herbaceous dicotyledons: <ul style="list-style-type: none">• 2,4-D, fluroxypyr, glyphosate, triclopyr Against graminaceae: <ul style="list-style-type: none">• dalapon, glyphosate
Frequency of treatment	Yearly	Between 1st and et 2nd treatment: <ul style="list-style-type: none">• 2 to 4 years
Season of treatment	Propyzamide: in November – December Dalapon: start of growing season Phytohormone, triclopyr and aminotriazole: in growing season Glyphosate and fosamine ammonium: after growing season and one month before senescence	Between 2nd and et 3rd treatment: <ul style="list-style-type: none">• 3 to 5 years
Accompanying treatments	The first treatment causes a substitution of the flora, e.g., the graminaceae replace the destroyed previously cleared brushes. A second treatment can be envisaged to obtain a bare soil.	The treatments can be combined with grassing, prescribed fire, or sowing of less flammable species.
Products to be avoided	Active soluble and/or persistent products (piclorame-dicamba) since the risk of transfer is very high on bare soils. Active toxic products for the aquatic fauna along water surfaces (triclopyr ester)	Idem; although the risk of transfer of active substances is lower thanks to the vegetation cover.

Prescribed burning

This technique uses fire to eliminate and contain the vegetation in a confined area. It remains generally little developed in the Mediterranean basin, except:

- In France where 3,000 ha were cleared of undergrowth in this way in 1999.
- In Portugal where this method was very much used in the years 1980 (more than 2,000 ha of maritime pine stands were treated in the area of Minho) and, after

a period of less demand, a renewed interest is currently experienced.

Obstacles for the application of this technique are:

- The psychological reservation caused by the simple fear of fire or fear of the effects on forest stands.
- Lack of specific training in prescribed burning in some countries.
- Problems of legal liability in the event of an accident (fire escape).

Prescribed fire can be used for periodic fuel reduction as well as for first undergrowth clearing, even when the fuel load is high. It is the case, for example, for vegetation openings:

- For forest fire protection management in dense *macchia* formations which can reach up to 2.5 m height or in dense *garrigue* with kermes oak of 1 m height.
- For pasture management in different types of heather formations.

Periodicity of interventions: every 3 to 4 years

Advantages

- No topographical restrictions.
- Efficient on woody vegetation.
- Reduction of fine and medium fuels.
- Eliminates dead ground fuel (e.g., pine needles).

Disadvantages

- Requires specialists.
- Surveillance obligatory.
- Negative impact on young plants or trees with a fine bark, except when a thermal thinning is required.
- Climatic conditions have to be considered.

HOW TO USE PRESCRIBED BURNING?

Conditions for application

Prescribed burning requires the selection of weather conditions and fuel moisture adapted to the burn site topography, vegetation characteristics, and planned type of fire control in order to prevent a fire escape outside the defined zone and to protect, when existing, the tree canopy. For example:

- On a slope with eastern aspect an east wind results in a down-slope fire against the wind.
- Under a tree canopy, a strong wind will often be preferred for keeping down the hot plume of a fire backing into the wind and to support its dispersion and to prevent that the smoke column does stagnate too long within tree crowns.

Site preparation

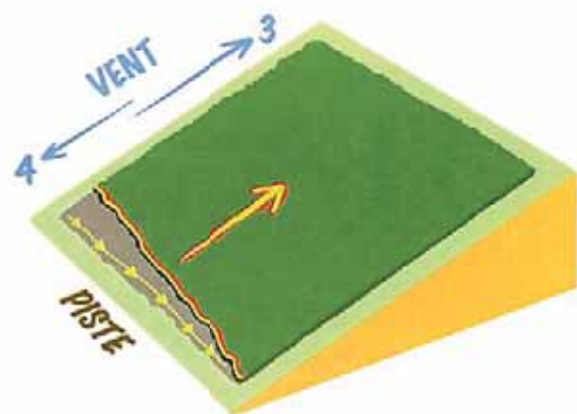
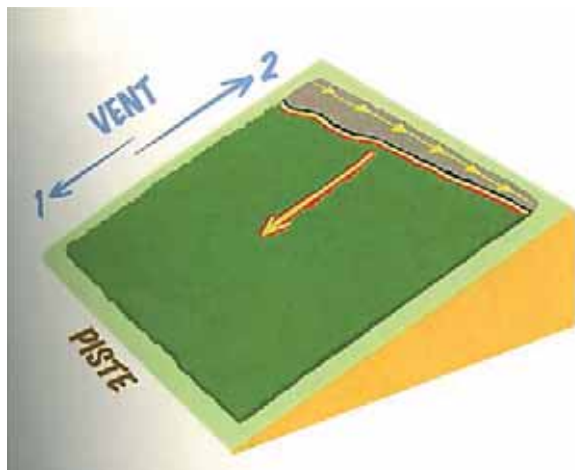
During a prescribed burning the fire must be contained within a well defined area. It is thus necessary to delimit the perimeter of the burn site:

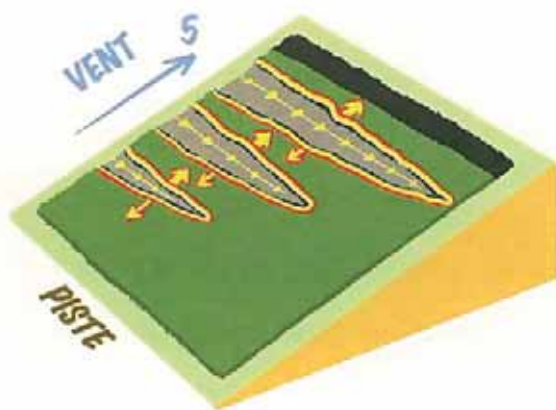
- Either by existing barriers (road, creek, cultivation, rock zone, etc.)
- Or by artificial barriers created especially through undergrowth clearance or ground cleaning, and whose width is related to:
 - * Position of the barrier.
 - * Topography, vegetation, weather conditions, fire control fire envisaged.

E.g., for a prescribed downslope backfire (against the wind and top down) it is sufficient to rake a litter free strip of 50 cm as a control fireline.

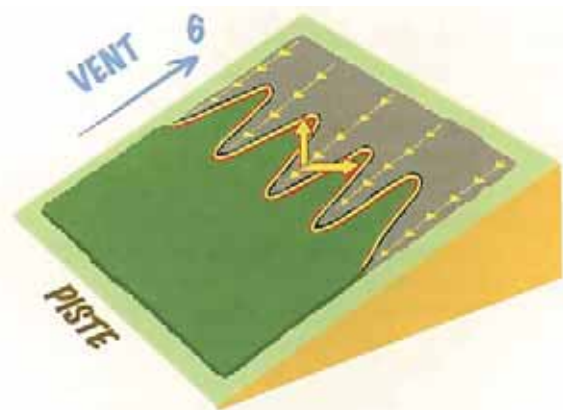
It is also advisable for limiting the physiological damage on stems as well as on the landscape, to protect the tree bottom, in particular those trees with a fine bark, by using one of the following methods:

- The protection most commonly used is the raking of litter at the foot of trees down to the bare soil,

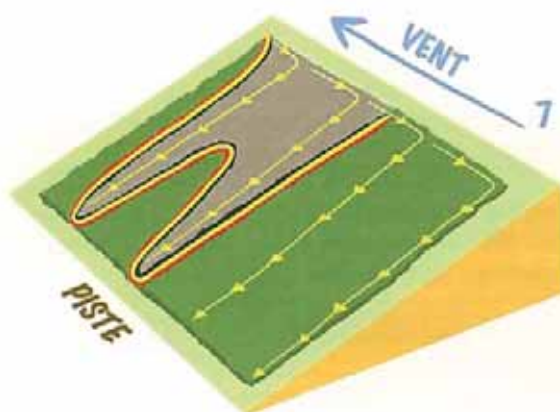




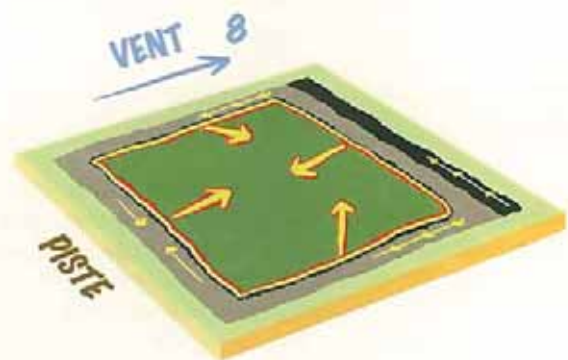
5 Feu par courbes de niveau successives



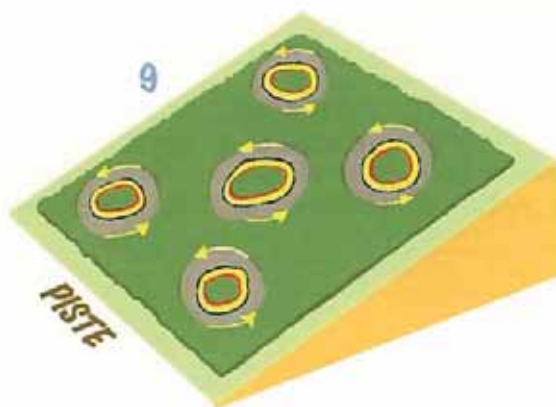
6 Feu par lignes simultanées dans la pente (en rateau)



7 Feu par lignes successives dans la pente



8 Feu périmétral



sufficiently to keep the flames far from the stem. The width of this raking is at least 50 cm but can reach 3 m downhill of the tree foot; in the event of an high intensity fire, the upslope directed flame is more destructive.

– It is also an option to humidify the trunk (by possibly adding a foaming product) using a backpack pump when the fire is not very intense, or with a water lance in the case of an intensive fire.

Before ignition, it is essential to check the control lines. The weak points are to be supervised particularly.



Fire control... some examples

Downslope fire against wind: because of safety measures, the burning is generally led against natural fire dynamics: the ignition starts on the highest point and against the wind.

Strip fire on successive strips along contour lines: the fire is lit on successive strips (from top to bottom) following contour lines. This technique allows to burn larger areas, but the fire intensity is increased, which requires the creation of adapted barriers. It applies, for example, to heather and *macchia* when prescribed fires are carried out under wet conditions.

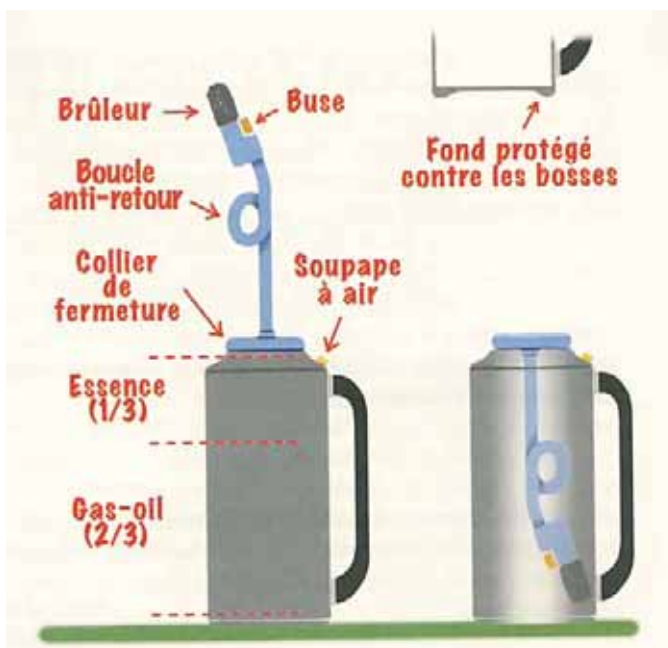
THE DRIP TORCH

Designed in the USA and imported from North America (the European market is still too narrow), the drip torches are the essential tool of a perfect fire control. The drip torch has a fuel capacity of 5.7 l, a seamless aluminium fount, a double bottom and a full length handle, a fuel trap on spout and check valve in cover prevent flashback into fount.

This equipment, used for a long time, is highly reliable and robust. Only the spout is clogged after long use. Indicated to function with kerosene in North America, the torches have been used in Europe without incident for 15 years with a mixture of gasoline 30-50 % and diesel to 70-50 %, mix rate: 1/3 gasoline - 2/3 diesel is most convenient, most usual and the least expensive.

When using the gasoline/diesel mixture, it is advisable to be vigilant, and:

- Always to fill fully the drip torch tank or to open it far from any fire source: burning in progress, hot ashes, or a burning cigarette.
- To make sure before and after use that the lid is correctly closed.
- To protect the torch from any radiation exposure of dynamic fires and the sun (particularly spring to autumn) in order to avoid the piston effect caused by gas dilation in the container.



Silvo-pastoralism

The silvo-pastoralism uses forest areas for cattle raising. In many countries, it is a technique usually used by the local population. However, if it is not controlled, the pasture becomes the enemy of the forest by damaging the regeneration and frictions on the tree stems... On the other hand, this activity, if it is well managed, can be of a great effectiveness in the maintenance of forest areas. This is controlled pasture because the pasture zones and range are well defined and limited.

The silvo-pastoralism introduced for forest fire protection can only succeed if the forest areas which are to be maintained, are well integrated within all available pastoral resources of the stockbreeder. He/she will always prefer the health and the correct feeding of his/her herd to actions of undergrowth clearance. Thus, it is necessary to integrate the zones for undergrowth clearance in the stockbreeder's breeding system, based on baseline studies, and not to start *a priori* with a zone definition that are to be maintain, hoping that the stockbreeder accepts heavy constraints modifying and disturbing his/her pre-existent system breeding.



The controlled pasture with heavy animals can be used for an initial undergrowth clearance, but only combined with other forage zones in fuelbreaks and some environments (e.g., white oak with a sparse shrub layer, high coppice of holm oak).

Advantages

- Control of the vegetation.
- Management of existing resource.
- Revalorisation of breeding and abandoned landscapes in some countries.
- Maintaining of human activity in the forest.

Disadvantages

- Requires a protection of the regeneration against browsing.
- Irregularity of resources: food complements are sometimes necessary (e.g., pastoral improvements by sowing).
- Necessity to eliminate plants refused by animals.
- Negative environmental impact:
 - * Soil settlement, especially in the case of heavy animals.
 - * Erosion risk when the pressure of the animals is too strong.

Combination of methods

The various methods can be used successively to improve the effectiveness of undergrowth clearance. Two combinations for the opening then maintenance of the fuelbreaks with a tree cover are presented below.

ISRAEL

SILVO-PASTORALISM

Israel encourages the silvo-pastoralism as much as possible to reduce the fuel load in the forest.

The pasture control is conducted in two ways:

- *Pasture licenses are handed out for the herd and the grazing zone.*
- *Fences are installed by the Forestry Department.*

Mechanical undergrowth clearance and controlled pasture. The opening of the environment is carried out by a mechanical undergrowth clearance, accompanied, if possible, by stump removal. The controlled pasture limits then the re-growth of the vegetation, regularly browsed. A pastoral improvement (e.g., by sowing without further site preparation) constitutes a food enrichment for the animals. A manual undergrowth clearance eliminates the plants refused by the cattle. This combination allows to reduce the frequency of interventions.

Prescribed burning and controlled pasture. The environment is opened by burning, then maintained by animals, intensive pasture at the beginning of the summer season. The refused plants also can be eliminated by burning.

6.5 *preventive silviculture*

The objective of a preventive silviculture is to obtain a composition and a structure of forest stands with the objective to:

- reduce the fire spread and fire intensity;
- limit the tree damage caused by the fire passage.

These two objectives are closely interdependent. All measures aiming at reducing the fire intensity try to limit the damage caused to trees. If the fire remains a surface fire and does not turn into a crown fire, the crowns will be less affected and chances of survival increase for a greater number of trees in the stand.

There are only a few studies on preventive silviculture in Mediterranean forests. Forest management has to cope with a low profitability of forest stands and strongly depends

- on available financial means;
- on revenues and products which can be drawn from the forest.

In this context, only a few examples for preventive silviculture will be presented.

What types of forest stands

The stand characteristics with a potential effect on fire sensitivity are:

- Structure: existence of vertical or horizontal discontinuities.
- Canopy density, directly and by its action on the vegetation of the lower layers.
- Species.

STRUCTURAL DISCONTINUITY

Breaking the continuity between surface (ground) and crown

The presence of a single tree layer, isolated from the ground, without intermediate layers, avoids the fire spread from the surface to the crown layer. Suppressed or sick trees and low tree branches can be eliminated by thinning and pruning.

Mosaic of different stands

A mosaic (1 to 5 ha) of even-aged stands and different species, by creating ruptures inside the forest (spatial discontinuity), seems to be the most appropriate way to limit the vulnerability of large forests to the fire

passage. These mosaic stands must have a sufficient depth so that the fire will lose power when entering. The minimal size of a mosaic is a function of topography and stand type.

For instance, coppice forests with their dense clumps and the consequences of the selection management system (uneven-age management) develop characteristics of multiple-layered vegetation formations that support the spread of wildfires.

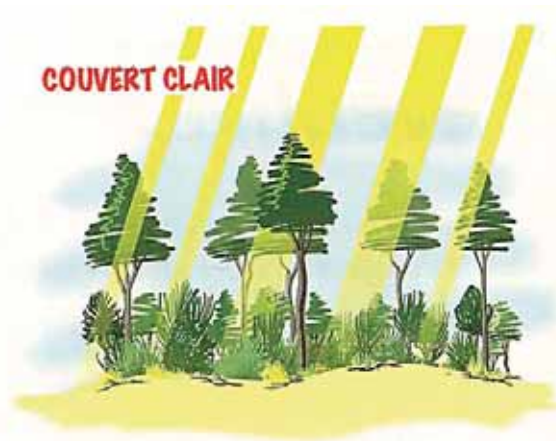
In order to decrease the risks of fire spread, a vigorous coppice forest can be converted into a stand on stocks (standards): for each clump, one preserves only one or two maiden. This conversion requires frequent interventions however to limit shoots and sucker branches.

CANOPY DENSITY

A thick and shady forest canopy:

- Reduces fire spread in the low layers by:
 - * Limitation of the vegetation desiccation and acceleration of the decomposition of organic matter due to aerial moisture increase in the understorey (moist microclimate).
 - * Reduction of the shrubby fuels and better natural pruning because of a photosynthesis reduction below the canopy level.
- Supports the fire spread in the crown layer.

The creation and the maintenance of a dense canopy allows to limit the intensity of surface fires



but increases the risk of crown fires. To avoid the development of a mass fire, the effect of a dense canopy therefore must be supported by a cleared understorey. A dense canopy is obtained by:

- The choice of Mediterranean species having a dense foliage. In fact, the quality of the foliage of a species depends on the soil fertility on which it grows. The Aleppo pine, whose foliage is generally light, has a dense foliage which covers the ground well when it is growing on a fertile soil. The umbrella pine generally has a dense foliage, but it requires fertile soils.
- A dynamic silviculture with sufficiently strong thinning, with a canopy being closed again by the development and closure of crowns. A dense canopy should not be synonymous with badly cleared up tight stands and strong density, with many trees suppressed and dying.

With the beginning of the stand regeneration the young regeneration favours the spread of fires. In order to avoid the loss of regenerated areas by fire it is recommended to increase the rotation cycle of the overstorey seed trees.

The tree density must be higher at the forest edge that is exposed to strong winds in order to form a windshield.

Stands with a dense canopy cannot be obtained everywhere in the Mediterranean basin. On the one hand the environmental conditions have to be favourable (sufficient fertility), on the other hand it has to be compatible with the forest management objectives and the financial means.

In the particular case of fire and fuelbreaks, the recommended tree density is much lower (not “touching” crowns) to avoid the fire spread between crowns, as well as allowing the movement and interventions of fire crews. This opening of forest stands supports the vegetation development on the ground. The operations for undergrowth clearance must be much more frequent.

SPECIES COMPOSITION

With regard to the fire spread the species composition plays a much less important role than the structure.

Diversity. The species mixture allows to reduce the sensitivity of a forest to fire. It is necessary to choose species which have the same growth characteristics in order to avoid the formation of several arborescent layers creating a vertical continuity.

Species with strong juvenile growth. They ensure a fast reconstitution of the canopy, therefore limit the vegetation development on the ground. They are moreover very competitive compared to the shrubby vegetation.

Less flammable species and less fuels. They must be favoured at the time of forestry interventions in the existing stands like during afforestations (cf. table below).

Species resisting the fire passage. Stands made up of trees with a sufficiently thick bark will resist better to surface fires which will have only a low or average intensity. The cork oak is particularly resistant, except when it was harvested recently.

Silvicultural operations

THINNING

In the specific context of forest fire protection, the principal objective of thinning is the reduction of fuel loads; sometimes the secondary objective is the improvement of wood production.

Nature

Preventive thinning is first of all selective: the suppressed trees are removed, and, in certain cases,

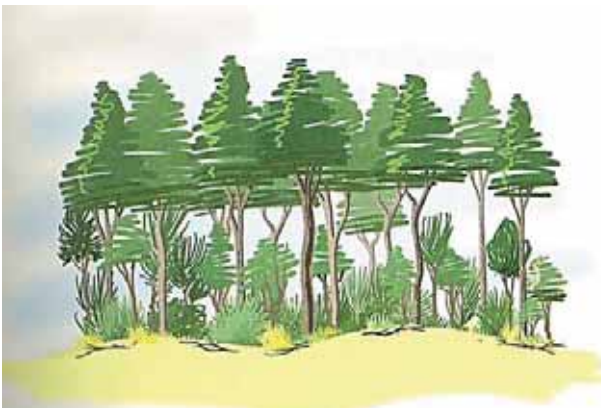


elite trees for production are selected. It can be also sanitary when it allows the elimination of dying trees.

Type

A vigorous crown thinning is conducted:

- if the remaining stems will respond to the thinning operation by developing their crowns, thus quickly reconstituting the canopy;



- in the case of a fuelbreak, where the objective is to obtain a distance between crowns.

In the contrary case, a low thinning allows to eliminate the overtopped trees.

The choice of selecting the individual trees to be preserved can be made in accordance with the objective of production objectives (plus trees) and forest mechanization (alignments to allow the passage of machines for maintenance and harvest). However, the remaining lines of trees constitute an “ignition cord” for the fire spread.

Intensity

The thinning intensity can be strong if the fast reconstitution of the canopy is possible. For fuelbreak construction and maintenance the intensity of thinning must create sufficient space between the individual trees.



Periodicity

It is variable according to the species, but generally, the thinning are made every 10 to 15 years, when the stands are 20 to 30 years old. Ideally the rotation (time between two interventions) is reduced in order to intervene more frequently but less intense.

However, that is often not always economic, taking into account the low profitability of forest stands.

CLEANING

Cleaning aims to reduce the density of the stems in a regeneration area in favour of residual tree support. Except in the case of a fuelbreak, it must be carried out in a moderate way because it supports the development of understorey.

PRUNING

This operation consists in cutting the lower tree branches with the following objectives:

- In the case of forest fire protection, it is especially important to create a discontinuity between the upper tree canopy and the lower layers. All trees must be pruned up to a height of two meters. In general this measure is expensive.

- Improvement of the accessibility of the stands.
- In a production forest the pruning improves the wood quality by eliminating the nodes.

SLASH MANAGEMENT

Accumulated thinning and pruning slash supports fire spread and intensity and therefore must be eliminated by chipping or other means.

6.6 Infrastructures for Fire Fighting support

The objectives for construction of infrastructures for fire suppression include:

- Facilitate access for fire crews in order to reduce the travel time to reach the fire (access roads).
- Facilitate the intervention of fire crews (fire fighting support zones, water points).

The design and construction of these infrastructures must provide working conditions for rescue squads with a maximum of safety.

Access roads can also be used for surveillance (patrols, some with slip-on tank units).

Access roads

Fire fighting vehicles use the entire accessible road system to reach a fire, to position themselves on strategic points, or to supply water: road network, gravel and dirt roads for different use (forest fire protection, public circulation, forestry development, etc.).

The roads fulfil the following functions:

- Allow the movement of fire engines (fast access to fire and water supply).
- Secure in some cases protected zones where fire crews can fight fires.
- Assure the circulation of surveillance patrols within a forest fire protection program.

ROAD NETWORK

The road network must be cleared of undergrowth along the sections located near forests (cf. chapter 6.1).

TRACKS

Tracks are very important for forest fire protection. Connected to the road network, they must allow movements and the fight inside a forest or in its periphery and that with full safety. One distinguishes various types of tracks, according to their principal function:

- Transit ways and access ways to the forest. They are primary forest roads allowing vehicles with full water load to access quickly the important zones of the forested area.
- Their infrastructure must allow fast movement of the fire engines: moderated slope, low banking, sufficient width to allow the passing of vehicles or passing zones in a sufficient number and regularly spaced, places of reversal.
- They are flanked on both sides with a strip

SOME PARTICULARITIES

IN ISRAEL, firebreaks were replaced by a very dense network of roads, because the manual maintenance of firebreaks is very expensive. The roads thus serve simultaneously as traffic roads, spatial compartment, and access for forestry development. For maintenance mechanical and chemical undergrowth clearances (herbicides) are used.

IN TURKEY, certain tracks, called «protected roads» also play the role of a firebreak (width: 10 to 20 m). They are in general bordered of *Cupressus sempervirens* or leafy trees (*Quercus* sp., *Acer* sp., etc.)

- Either to protect the access by the choice of less flammable species or building shelterbelts,
- or to create attack zones exposed to a lower fire intensity.

Maintained regularly by bulldozer, these protected roads sustain unfortunately a very strong erosion due to a steep slope and the absence of vegetation, which restricts in some cases the passage of fire engines.

IN SYRIA, in the event of large fires, new tracks are opened with bulldozers; afterwards these tracks are destroyed or integrated into the management plan.

cleared of undergrowth ensuring the safety of the traffic.

- Firelines that allow to fight against a fire of moderate intensity.

- * They are more extensively managed than transit ways.

- * Nevertheless, the undergrowth clearance of fire strips must be carefully planned and carried out.

SOME PARTICULARITIES...

***IN ITALY,** impermeable fabric cisterns, strengthened by tubular metal structures, have the advantage of being easily handy (reduced capacities: 2 to 25 m³), but are also much more fragile.*

***IN TURKEY,** mobile cisterns are drawn by tractors belonging generally to the local population, which plays an active role in fire fighting.*

– Secondary roads (tracks) allow to approach an initiating fire or a low intensity fire.

* Their length must be less than 1,000 m. They can be opened by bulldozers.

* They are bordered on each side by security strips cleared of undergrowth.

Dead end roads are to be avoided in order to ensure the evacuation of crews under all circumstances. Any dead end must be indicated and must have a turning platform cleared of vegetation.

Many tracks have multiple uses: forestry development, linking roads between villages, access to dwellings, tourism. This multi-functionality increases the fire risk related to human activities in the forest. To limit the visiting of forests, certain tracks located in sensitive zones can be prohibited for public access during the fire season, even all year long.

ESTABLISHMENT OF TRACK NETWORKS

Two essential elements have to be taken into consideration for road construction:

- Topography;
- Fire scenarios.

In flat terrain, the road network can form a regular squaring. In relief zones, roads will be built according to the diagram below. In certain cases the establishment of a track network can also take into account the landscape constraints.

Network density

There is not standard for the road density. This depends on the fire sensitivity of the zone, the values-at-risk, but also of financial constraints, because the building of any infrastructure is expensive.

Support zones - defense lines prepared in advance

Localized undergrowth clearances (for example along tracks) or on large areas (fuelbreaks) represent essential fire fighting support zones since the fuel load is here much lower.

SPATIAL COMPARTMENTALIZATION

Within large forested or otherwise vegetated areas spatial discontinuities must be created by firebreaks or fuelbreaks to provide secure support zones for fire attack (cf. chapter 6.3).

REINFORCEMENT OF FIRE FIGHTING ZONES

Certain tracks used for fire fighting and completely cleared of undergrowth on both sides can be reinforced by a second line of attack. It could be, for example, a secondary road located on the windward side, building a first shield against the fire.

IN ADVANCE PREPARED FIRELINES

An in advance prepared fireline (LICAGIF¹) allows to create a containment line by concentrating fire fighting means along access lines (road or track) ahead of the fire front, with the aim of stopping the fire spread on this line or at least breaking up the fire in smaller fires.

Establishment

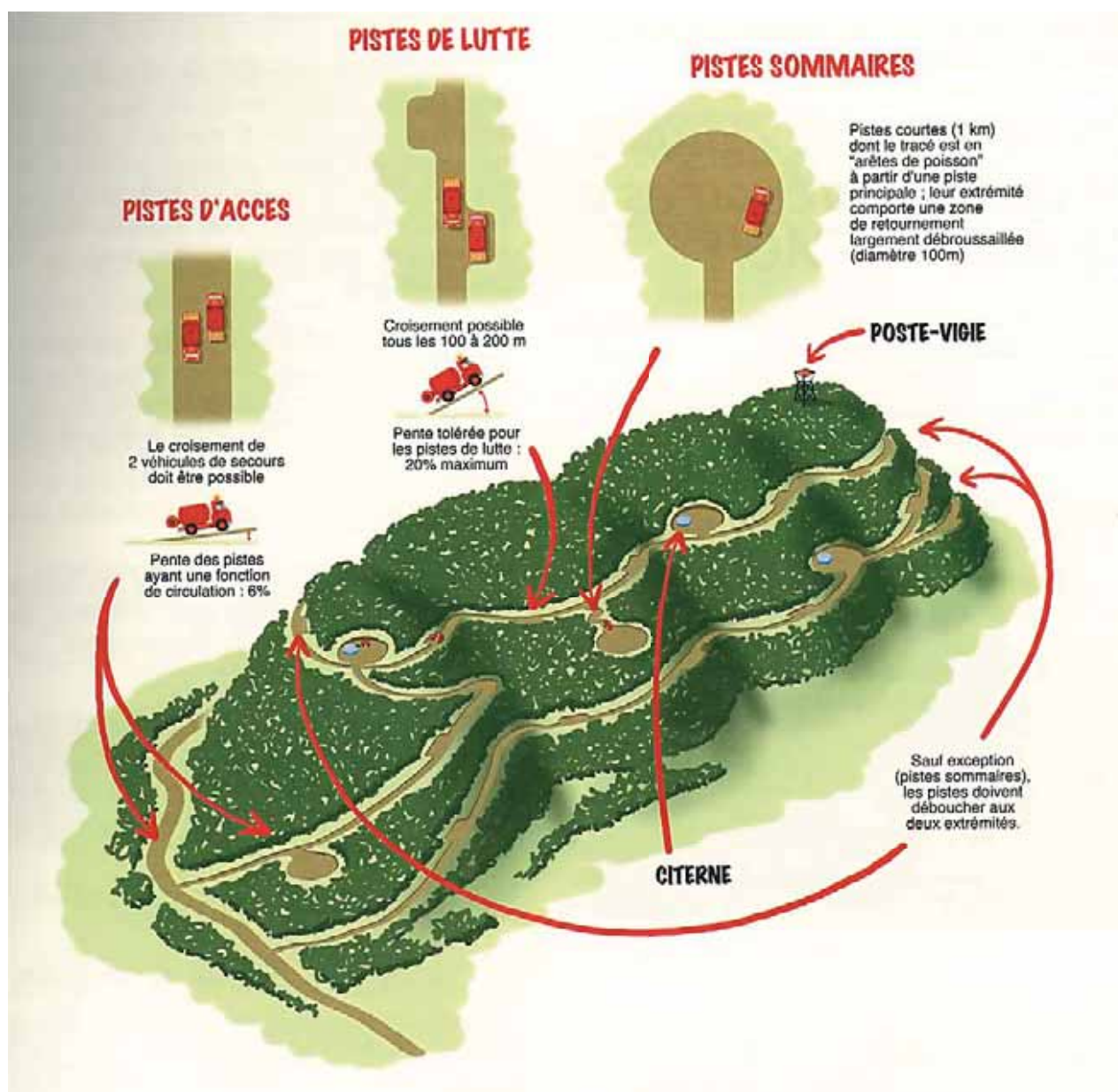
To stop large fire fronts, the LICAGIF must build a connection between other strategic areas impassable for fire: rocks, water surfaces, other LICAGIFs.

FRANCE

STANDARDIZATION OF FOREST FIRE PROTECTION ROADS (DFCI)*

*The Delegation for the Protection of the Mediterranean Forest** introduced a standardisation of forest fire infrastructure «DFCI» in function of existing accessibility and safety. With regard to roads, which must absolutely be signposted and clearly identified, three categories were defined: the first two are described in the table below; the third category encompasses tracks not meeting the conditions of the categories 1 and 2.*

Some tracks, forbidden to public access, are closed using keys of which doubles are distributed to personnel involved in fire fighting and fire prevention (e.g., surveillance patrols).



FRANCE

INDICATIVE DENSITIES

Type of network

Very dense network (fire risk and values-at-risk high)

Intermediate network
(average risks and values-at-risk)

Not very dense network
(weak risks, limited values-at-risk)

Recommended density

Fire fighting track: 2 km for 100 ha
Access track: 0.5 km for 100 ha
Zones cleared of undergrowth: 12 ha for 100 ha

Fire fighting track: 1 km for 100 ha
Access track: 0.25 km for 100 ha
Zones cleared of undergrowth: 6 ha for 100 ha

Fire fighting track: 0.5 km for 100 ha
Access track: 0.125 km for 100 ha
Zones cleared of undergrowth: 3 ha for 100 ha

Source: Cemagref, Aix en Provence

The establishment of this infrastructure on ridges is aimed to slow down fire spread and intensity in these sectors. The choice of mountain ridges on which these defence lines will be constructed is based on fire scenarios and strategic options for fire fighting.

Elements of the LICAGIF

The circulation track is a traffic axis along which fighting means will be concentrated. It is selected according to the topographical and the meteorological characteristics of the sector.

The width of undergrowth clearance on both sides of the circulation track is defined:

- according to the nature of the vegetation and the topography of the sector,
- as an operational minimum allowing fire fight from the track, and
- so that personnel and equipment are never directly exposed directly to fire radiation.

The minimum width is 100 meters.

The maintenance of a tree canopy aims to create a barrier in order to limit the chances of fire spotting and to “slow down” winds on the LICAGIF. Moreover, it allows a better integration of the defence line into the typical landscape characteristics

Water supply is secured by setting up closed

metal cisterns with a capacity of 30 m³ along the road approximately every 700 to 1,000 meters.

Vegetation free strips create a complete fuelbreak between the vegetation and the LICAGIF area. These will facilitate the maintenance of the zone in which undergrowth is cleared with prescribed fires and which could possibly be used as backfire line.

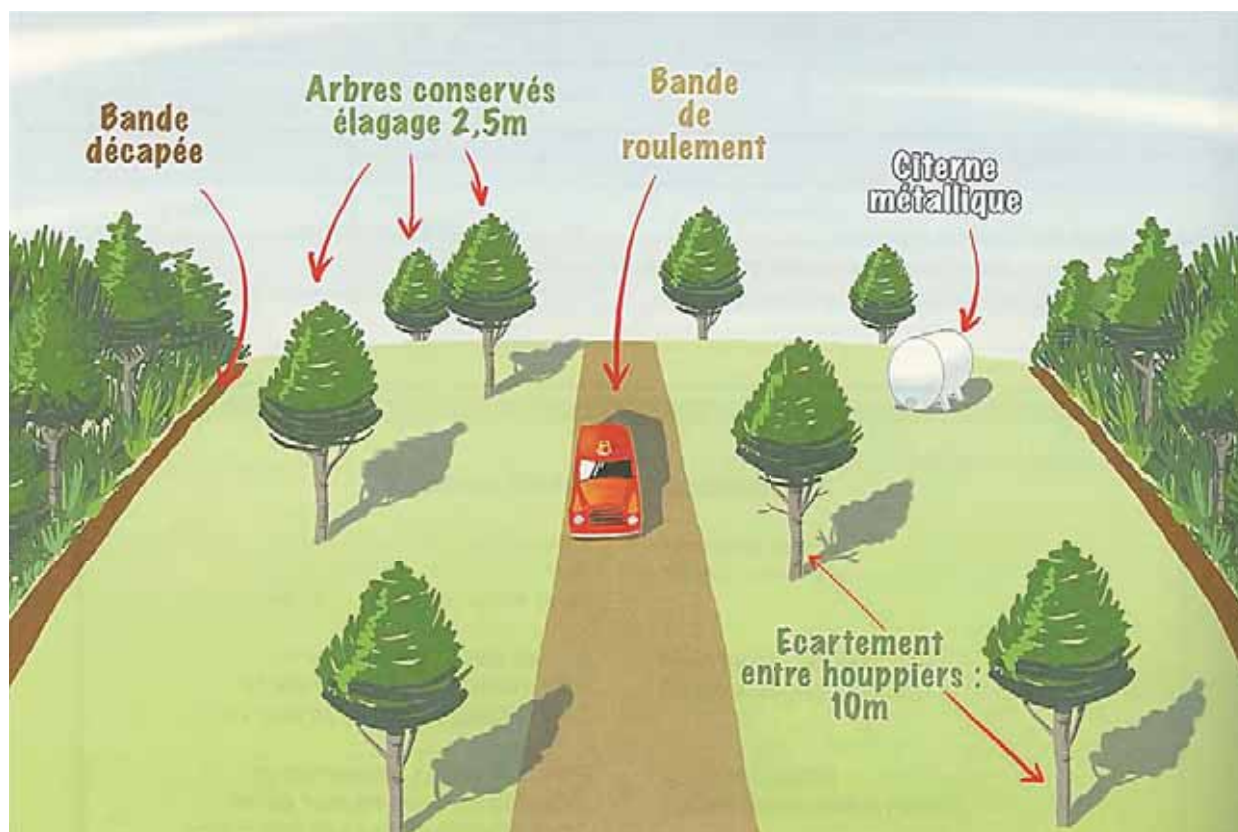
Access to the LICAGIF

The last success factor of the containment line is the possibility of concentrating rapidly and in full safety all types of fire engines. It is thus necessary to have a coherent strategic road network that takes into consideration fire fighting plans by:

- integrating any existing road axis (main road, secondary road, communal road, track), if required to be supplemented by new tracks,
- managing safety of personnel and equipment (cf. chapter on roads and tracks).

Water points

Since the water storage capacities of fire engines is limited, it is necessary to include the use of artificial or natural water resources. These water resources must be distributed in a sufficient number to reduce transport distances.



WATER RESERVOIRS

These are large water bodies, e.g., natural (lakes) or artificial (water reservoirs). They must be arranged locally to allow the operation of fire engines on the ground and are very useful for the supply of air tankers. Air tankers (scooping planes) require a minimum water surface of 2,000 m length, 100 m width, and 2 m depth.

CISTERNS

Fixed cisterns are built of concrete or metal, can be constructed underground or on the ground. In general cisterns, with a varying capacity of 10 to 150 m³, are fed naturally (spring water, rainwater collected with an *impluvium*, etc.) or artificially. The charging of fire engines must be carried out using motor-driven pumps or by benefiting from the topography to give sufficient pressure to the water. Some cisterns can be especially equipped for the supply of helicopters, for example, using a trap door on the cistern's top for the supply by aspiration.

Mobile cisterns have a much lower capacity than fixed cisterns; these cisterns, constructed of metal or sometimes of impermeable fabric, have the advantage to bring the water point close to the fire fighting zone.

Swimming pools can be used locally by the fire fighting services to refill water tanker and by owners to protect their dwelling.

E.g., in Turkey, some hotels use the swimming pool water and a motor-driven pump to protect the establishment in the event of a fire.

POTABLE WATER SUPPLY NETWORK

The potable water supply network can be used by fire engines via fire hydrants, which have the advantage of providing water under pressure. When several water tankers are supplied, the pressure strongly decreases. In Syria, the water tower providing drinking water to the village is generally located close to the fire protection centre.



CISTERN NETWORK DENSITY

The number and site of cisterns depend on the fire hazard, topography, cistern size, the capacities of available vehicles, and the distance to the next water point.

A cistern of 60 m³ every 4 km road seems sufficient. Along a fuelbreak, one cistern every 1 to 2 km is calculated.

MAINTENANCE

The water points must be regularly controlled (filling, operation, access), each week in a period of high risk, and a report of state must be sent to the responsible services (forester, firemen).

Water sprayers

Water sprayers create a cloud of fine water droplets which limit the fire spread. The cloud of small water particles attenuates the heat radiation emitted by the fire and reduces the temperature. Consequently the heat-generated drying process and pyrolysis are reduced in front of the fire. Fine water droplets can be generated by fixed or mobile metal pipes, fire engines with sprayer guns, special nozzles connected to hoses and pressurised hand-held fire extinguishers.

This technique can also be used as a prevention measure in order to reduce the fire ignition risk when climatic conditions increase the fire danger.



SOME PARTICULARITIES

IN ISRAEL, firebreaks were replaced by a very dense network of roads, because the manual maintenance of firebreaks is very expensive. The roads thus serve simultaneously as traffic roads, spatial compartment, and access for forestry development. For maintenance mechanical and chemical undergrowth clearances (herbicides) are used.

IN TURKEY, certain tracks, called "protected roads" also play the role of a firebreak (width: 10 to 20 m). They are in general bordered of *Cupressus sempervirens* or leafy trees (*Quercus* sp., *Acer* sp., etc.)

- Either to protect the access by the choice of less flammable species or building shelterbelts,
- or to create attack zones exposed to a lower fire intensity.

- Maintained regularly by bulldozer, these protected roads sustain unfortunately a very strong erosion due to a steep slope and the absence of vegetation, which restricts in some cases the passage of fire engines.



CYPRUS

WATER POINTS

CONCRETE CISTERNS, with a capacity of 90 m³ are built near water springs which ensure the filling. They are connected downstream to various water points sign-posted by the letter **H**, closed with a special key of which a double is given only to fire crews. Using the slope, water has sufficient pressure and no pumps are needed.

This water reserve is supplemented by **FIRE HYDRANTS** installed on drinkable irrigation or water pipelines, and **ARTIFICIAL PONDS**.

On average, a water cistern or water point can be found every 6 km; these water reserves ensure the supply of the fire engines on the ground primarily, and even of helicopters. There are no planes equipped for fire fighting.



6.7 Land management plan

All activities in establishing infrastructures to support fire forecasting, prevention and fire fighting, will inevitably lead to failure if not properly planned. A Regional Fire Management Plan is a document for a specific forest that:

- defines and plans actions and infrastructures required to meet the fire fighting strategy and the particular requirements of the forest owner;
- assures coherence between these activities and the general management plan of the territory.
- The regional fire management plan is based on the analysis of the variables of the natural environment (climate, topography, vegetation) and anthropogenic components (settlements, attitudes, stereotypical behaviour, land use).

Delimitation of the intervention perimeter

Since the fire risk in a forest does not know administrative boundaries, it is necessary to define a risk zone, i.e., a continuous zone inside which the phenomenon fire must be studied in order to apprehend its physical dimension.

The risk zone will be easy to delimit in an area having an average forest coverage of less than 40% where forest areas are generally well separated from each other. In the contrary case, various methods can be used to establish risk zones.

- Search for almost insurmountable obstacles

by analysing historic fire events and weather data on the dominant wind direction (sometimes it is possible to find obstacles that a fire did never cross over or has very low chances to ever cross).

- Increase the study area to avoid the phenomenon of artificial boundaries.

Collaboration

The need to harmonize activities within a defined risk zone implies that various stakeholders collaborate for the elaboration of a fire management master plan.

The dialogue between the administration, forest fire protection organizations, and forest users is essential to establish an optimal fire protection plan of the zone at risk; often this will be based on compromises.

MOROCCO

MASTER PLAN FOR FOREST FIRE PROTECTION IN THE RIF

This plan, elaborated since 1998, is the result of the cooperation between the Rif area (Tétouan, Larache, and Chefchaouen) and the autonomous government of Andalusia (Spain).

OBJECTIVE: *The purpose of this plan, which relates at the same time to fire prevention and the fire control, is:*

- *To analyse and evaluate the need for basic equipment in function of values-at-risk.*
- *To organize the installation of fire fighting support structures (access roads, water points, fire fighting equipment, etc.) among the various involved partners.*
- *To establish a set of priorities among forest areas in function of their vulnerability and stakes.*
- *This prioritisation determines the intensity of operations to be carried out for the forest fire protection (equipment, intervention forestry, assignment of the*

fire fight equipment, etc.).

MEANS: *This plan recommends the creation of a Regional Centre of Operations and, for each province, Provincial Centres of Operations, that are divided into Territorial Units of Fire Monitoring and Suppression. Centres of Operations have the role:*

- *To assign and coordinate the use of the human resources and equipment which is granted.*
- *To ensure the follow-up of interventions.*
- * *To facilitate the staff training.*

IMPLEMENTATION. *It was started at the beginning of the year 1999, with the:*

- *Equipping of the coordination room of the Regional Operations Centre of Chefchaouen.*
- *Construction et equipping of a lookout tower.*
- *Installation of a water point of 50 000 litres.*
- *Rehabilitation of tracks on a length of 20 km.*
- *Training of 20 persons, engineers, and fire crews members.*

Elaboration of a fire management plan

ANALYSIS OF THE STUDY ZONE

A fire management plan for the territory requires a good knowledge of the environment and an analysis of its ecological (climate, relief, type of vegetation...) and socio-economic (uses of the forest, occupation of the ground, etc.) components. The study of historic fires allows to determine the forest fires risk.

FIRE SCENARIOS

Taking into account the results of the analysis, scenarios are given by defining the most probable causes of ignition and characteristics of fire propagation. To model these scenarios, it is essential to feed in practical knowledge, i.e., real fire situations experienced by fire crews during past fire events. The fire rate of spread can be estimated with the help of fire propagation models.

PROPOSAL FOR PREVENTIVE ACTIONS

For each scenario, it is necessary to propose various actions allowing to:

- Reduce the ignition risk.
- Limit the burned area.
- Limit the damage caused by fires.

FRANCE

STAKEHOLDERS FOR THE FOREST FIRE PROTECTION MANAGEMENT PLAN (PLAN D'AMÉNAGEMENT DES FORÊTS CONTRE L'INCENDIE - PAFI)

This plan is elaborated by a study group consisting in general of representatives from:

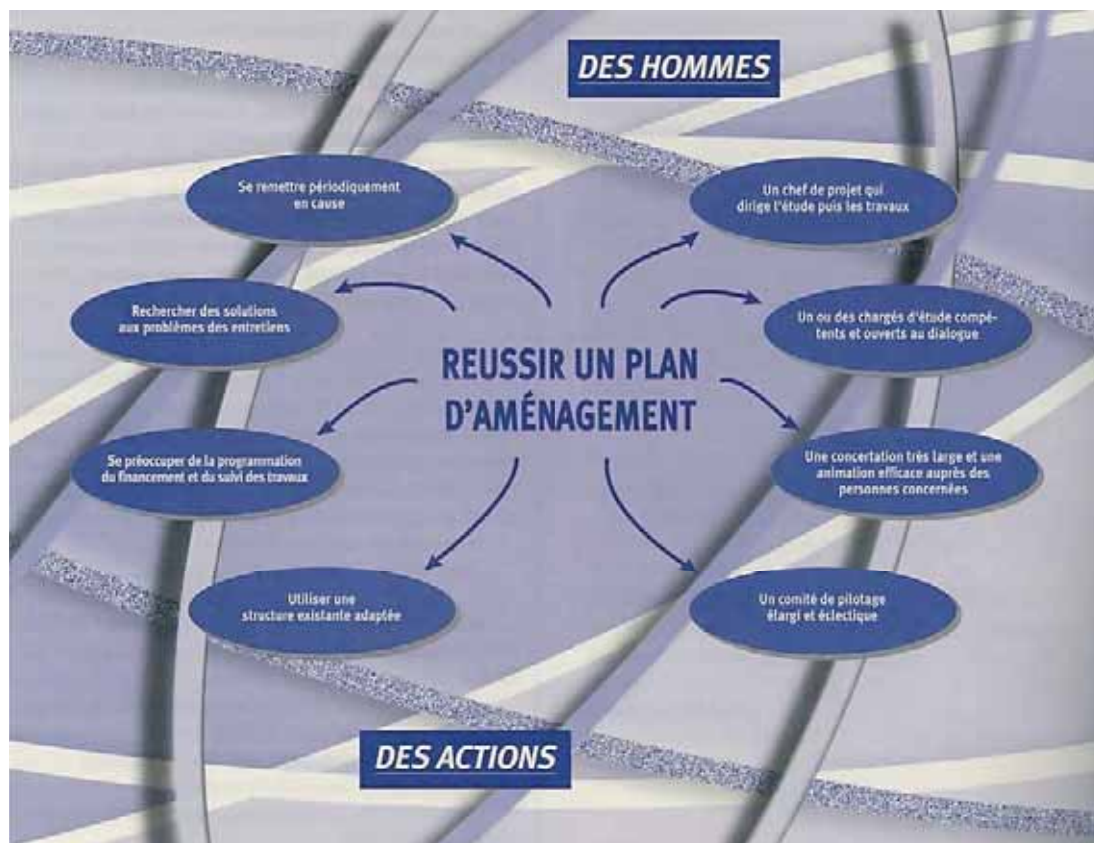
- Municipalities concerned (mayor, assistants, local council members)
- Departmental and local fire and rescue services
- Forest services
- Private owners
- Community committees for forest fires
- Forest users
- Scientific institutions

These various actions may include:

- Sensitising of the population and its participation in preventive activities in the forest.
- Installation of preventive infrastructures (lookout towers, tracks, water points, fuelbreaks, etc.).
- Interventions in forest stands (undergrowth clearing and other forest operations, etc.).

SYNTHESIS

Based on different scenarios and selected preventive actions, the best compromise has to be found, ensuring the coherence and the effectiveness



of prevention system. This choice is of course strongly dependent on financial constraints.

Implementation of the study

When the final document is completed and approved, it is necessary to implement the proposals formulated in the study, i.e.:

- To plan the actions and the work envisaged.

- To allocate the financial means.
- To execute the actions and to build the infrastructure in the field; to maintain this infrastructure.

It is also important to question certain elements of the infrastructure plan in order to take account of new situations. In particular, after a fire in the zone, it is recommended to take advantage of the experiences gained and to improve the infrastructure for forest fire protection. This experience feedback is done in consultation with the actors and the witnesses of the fire.

ITALY

Forest fire protection plan

Definition and objectives

The forest fire protection plan describes spatial and temporal activities for fire prevention, fire suppression, and forest rehabilitation, which have to be implemented in order to reduce negative impacts of forest fires. They are elaborated for large areas, e.g., regions of a country.

General principles

The forest fire protection plans are based on the description of the territory and the fire behaviour prediction. The fundamental principles are:

- *Taking into account tolerable damages.*
- *Consideration of fire prevention, suppression and forest rehabilitation, and the search for an equilibrium and coherence between these three activities.*
- *Comparison of prediction with field observations.*
- *Integration of scientific and technical innovations.*

Setting up

In order to define tolerable damages, the term “acceptable annually burned area” has been introduced: This is the maximum burned area which is tolerated for the territory with a forest fire protection plan and which can be actually achieved due to fire prevention and suppression activities. If the probability of serious fire damages is high, it is necessary to reduce the acceptable annually burned area. Obviously, this increases the costs for prevention activities.

To assess the acceptable annually burned area the following activities are necessary:

- *Delineation of the forested areas where a fire would cause less damage. It is agreed to accept fires in these areas.*
- *In these zones, the potential fire behaviour is evaluated.*
- *The decision is taken to accept the fire just as it is or to intervene with the intention to modify the fire intensity and to reduce the damage.*

The structure of the forest fire protection plan

Homogeneous zones have to be defined for the formulation of objectives. The steps for zoning are the following:

– **ZONES TO BE INCLUDED IN THE PLAN:** *During this first step the zones which have to be included are defined. Historical fire data are taken into account.*

– **ZONING BY CURRENT SITUATION:** *Delineation of homogeneous zones in function of the repercussions of the fire problem or where to begin the planning. These homogeneous zones are characterised by the fire danger (as a result of numerous factors which influence the fire start and fire spread) and the fire severity (defined as fire effects on an area). They build the basis for different activities.*

– **ZONING BY OBJECTIVES:** *This zoning is fundamental for the plan since it describes the objectives to be achieved in relation with the activities to be conducted for the different areas of the territory. For each homogeneous entity described in the zoning of the current situation the fire behaviour and the foreseeable effects are described. The acceptable maximum burned area as well as maximum fire severity is determined. It is necessary to be concrete, distinguishing between achievable results and more far reaching results outside the planning period of the forest fire protection plan.*

– **DESCRIPTIONS OF ACTIVITIES:** *For each zone, as a result of the previous zoning by objectives, activities, intervention areas, and necessary equipment are described in detail.*

Users and operational use of the forest fire protection plan

Users are persons in charge of operational planning, fire prediction, and forest fire management. The plan describes the activities in fire prevention, fire detection, fire suppression, and prescribed fires. The plan must be well structured to meet the requirements of forest fire suppression: deployment of forest fire suppression capacities. It has to enable the user to determine the intervention priorities between various forest areas and to inform the user on the most efficient suppression techniques.

SYRIA

EXAMPLE OF AN INTEGRATED FIRE PROTECTION MANAGEMENT PLAN

LOCALIZATION. This management plan was implemented in the community of Om-Altoyour, at 30 km from the city of Lattaquié on the coast.

Characteristics of the studied zone. It is a zone very representative for forest fires problems in Syria:

- Its ecological characteristics make it very sensitive to fire, in particular because of pure stands of *Pinus brutia*.

- The pressure of the local population on the forest is very high.

- *Pinus brutia* constitutes an important firewood resource.

- The economic development is low and is primarily based on an agriculture using traditional techniques that are not very profitable and require large areas and land converted from forest. All in all, the growth rate of the population (3.5% on a national scale) largely exceeds the availability of arable lands.

The majority of the fires results from agricultural activities (64.5%).

PROPOSALS FOR AN INTEGRATED INSTALLATION.

Taking into consideration the characteristics of the studied zone, various preventive actions integrating the socio-economic problems were proposed:

- To decrease the fire hazard of the pure forest stands by supporting the mixture of species which will have in the long term to replace the single species stands of *Pinus brutia*, and by creating discontinuity in the canopy.

- To increase the income of the local population and to decrease its dependence on agricultural activities. The forestry operations can thus provide temporary employment. The introduction of multiple-use forest species diversifies the resources.

E.g.: *Ceratonia siliqua* is used for its medical values, melliferous plant, and food supply (for human and animal consumption).

These various operations sensitise inhabitants for the need for forest protection. It is a question of finding compromises between forest fire protection and the socio-economic development of the local population.

Project FAO - GCP/INT/539/ITA

TUNISIA

A forest fire protection management plan of a pilot forest area

LOCALIZATION: This management is currently implemented in the forest of Dj. Mansour which is situated on the border between the Gouvernorates Zaghouan and Siliana.

CHARACTERISTICS OF THE STUDIED ZONE: Three forest areas with stands dominated by Aleppo pine on approximately 7,000 ha. Large fires are generally propagated by the effect of the Sirocco, a hot and dry wind blowing from the Southwest.

MANAGEMENT PROPOSALS:

The management proposals target the implementation of the following principles:

- Reason the management at the scale of the entire forest region instead of the level of the individual forest areas; ensure the perfect coherence of the infrastructure;

- Disconnect the concept of segregating infrastructures of that of compartimentisation of forests with respect to fire;

- Prioritise the treatment of fuelbreaks in accordance with functional criteria: strategic breaks, security strips along roads, forest urban interface, agricultural breaks;

- Improve the circulation of fire engines on the fuelbreaks;

- Develop the use of tree as wind break for preventing crown fires;

- Test the technique of undergrowth clearance as alternative to manual work (crushing, clearing, weed killer, possibly prescribed burning, etc.) for the zone where the work force is rare;

- Evaluate systematically social consequence of technical reorientation.

The suggested management meets two broad aims:

- To facilitate rapid initial attack.

- To establish support zones for fighting fires that could not be extinguished by initial attack.

The fuelbreaks for attacking incipient fires will be primarily strips cleared of undergrowth along roads where many ignitions were noted during last years. To build up support zones, old firebreaks located on strategic axes will be widened by strong thinning along these, followed by periodic undergrowth clearance.

This pilot project is accompanied by the installation of a research team intended to follow and evaluate the new selected options.

Project FAO GCP/REM/056/FRA

7

Fire Fighting



Contents

- Chapter 7.1 – Strategy*
- Chapter 7.2 – Fire fighters*
- Chapter 7.3 – Fire fighting equipment*
- Chapter 7.4 – Communication*

Introduction

The ignition of a human-caused fire marks the failure of the prevention activities. The fire fighting capacities, organized beforehand for the forecast, must then be put into action. The quality of the forecast system is determining for the success of the suppression operations.

The reaction to the fire depends on the importance of the fire. The number of deployed forces increase with the size and the virulence of the fire.

- *The firefighters can be of very diverse origin: professional firefighters, foresters, volunteers, rural population. The quality and training of the personnel is a significant success factor for forest fire suppression.*

- *The fire fighting equipment is very diversified: at an early stage, a fire can be controlled using rudimentary tools (shovels, fire beaters) provided that it is not too intense (not very abundant vegetation, low fuel loads and low wind speeds). Very often, it is necessary to intervene directly with machines designed specifically for wildland fire fighting: vehicles with a small water tank for the first intervention, then tankers, water bomber planes...*

However, to be effective, the deployment of means must take place according to:

- *a strategy, which defines the general rules (principles, objectives) on which are founded the fire fighting operations*

- *attack tactics adapted to the local context (characteristics of the environment, forces available, weather conditions).*

The good course of the fire fighting actions requires:

- *A clearly defined line-of-command.*
- *Coordinating structures ensuring the coherence of operations, fire intervention tactics, the organization of the equipment, logistics, public relation. These structures can be developed as the fire increases in size.*

Fire fighting is a difficult, tiring and dangerous operation. Thus it is necessary to take care of safety (individual protective equipment), food supply and resting (recovery) of the staff.

The weather conditions influence much the fire behaviour. Weather data must be collected and analysed during the operations in order to forecast wind speed and direction, temperature or humidity. Approaching cold weather fronts are to be observed particularly, because they generate sudden variations of these parameters.

The experience feedback, i.e., the analysis of fire fighting actions and their impact on the fire progress, allows to improve interventions on later fires

Fire fighting actions (tactics of ground attack, use of aerial forces) are not described in this handbook.

7.1 Strategy

In order to be effective, forest fire fighting must be implemented according to a strategy defined at the national level, and whose objectives are the following:

- To formalize fundamental principles and principal objectives regulating fire fighting; principles and objectives which will guide then the persons in charge for the design and implementation of the operational fire fighting activities.
- To serve as common reference for all firefighters.

The definition of a fire fighting strategy is based on the analysis of:

- Fire risk;
- Forest fire effects;
- Principles of fire fighting that have been proven useful;
- Available capacities and techniques.

The fundamental principles

The strategy of fire fighting is based on fundamental principles where all operations have to fit in. These principles can relate to the fight alone or connect fire fighting to the complex of forest fire protection, thus harmonized within an overall solution concept.

The principal objectives

Fire fighting strategies generally define two principal objectives:

- Control the fire at initial stage;
- Contain the spread and extent of fires which could not be suppressed at initial stage.

These objectives will be all the more easier to be met when they will be integrated into a general fire protection policy (principle of a general solution quoted above) with its primary objective to prevent all fire occurrence.

The fire fighting infrastructure, which was presented in chapter 6, supports the achievement of these two objectives.

CONTROL OF FIRE OCCURRENCE AT INITIAL STAGE

When a fire is detected, the first attack must allow to control it as long as the burned surface is small and the fire intensity is still controllable. The success of this operation depends on the speed, the force and the quality of the initial attack.

The preventive mobilization, i.e., the anticipated installation of the adapted fire fighting capacities, is a very effective tool to ensure the success of the first attack. The initiation of the preventive mobilization and its intensity level depend on the estimate of the fire risk, by using, for example, the daily results of a weather risk index. The preventive mobilization can include:

- A terrestrial coverage (patrols with light vehicles for first intervention, preventive intervention dispatching, initial attack groups, etc.)
- An aerial coverage (aerial patrols with air tankers).

The effectiveness of preventive mobilization depends mainly on:

- The deployment of means and timing.

FRANCE

THE «ANTICIPATION» PRINCIPLE

The rationale for a general forest fires protection strategy, planned by the Directorate of Civil Security, sets «anticipation» as absolute rule with regard to forest fire fighting.

Indeed, the evolutionary time and space aspect which characterizes the origin and occurrence of the fire risk, makes it a phenomenon particularly difficult to comprehend and to fight.

This rule imposes two fundamental options for the orientation of design as well as for the operational application:

- *To seek to solve the fire problem as early as possible.*
- *To be constantly and under all circumstances ahead of all events.*

YOU HAVE TO ANTICIPATE FOR A BETTER CONTROL OF THE SITUATION

- Its capacity of a fast initial response to the event.

SPAIN

PHASES OF INITIAL ATTACK

INDICATIONS PROVIDED BY THE PEOPLE HAVING DETECTED A FIRE:

- Precise fire localization;
- Optimal access way to that point;
- Estimation of the fire area and its perimeter during detection;
- Fuel type burning;
- Wind speed;
- Dwellings and structures threatened by the fire;
- Name of the person who detected the fire.

ACTIONS OF FIRE CREWS MOVING TOWARDS THE FIRE.

The fire boss of each fire crew which moves towards the fire must instruct his/her crew members what they know of the zone of the fire:

- Fuel and topography.
- Access roads and paths.
- Natural and artificial fire barriers.
- Forest ownerships.
- Recent fires in the zone and their cause.
- Fire behaviour during a recent fire.

The teams also must:

- determine direction, speed and variability of the wind;
- study the smoke characteristics.

ACTIONS WHILE ARRIVING ON THE FIRE AREA.

While arriving at the fire scene, it is necessary to overlook the situation for a better understanding. The following points have to be checked:

- Starting point and most probable fire cause.
- Area and perimeter of the fire.
- Values-at-risk (houses, installations, forests).
- Meteorology (wind).
- Fire behaviour (wind speed, flame height, spot fires).
- Fire type.
- Fuel type.
- Topography.
- Barriers (roads, rocks, lakes or rivers, cultivated zones).

DECISIONS TO BE TAKEN.

- Where to start the attack.
- Type of attack: direct, indirect, backfire.
- Localization and width of the fire line, and means to build it.
- Reinforcements to be called in.

In France, the initial attack of incipient fires has, under all circumstances, priority before all other intervention forms, and all adequate means must be allocated for this purpose.

The effectiveness of the first attack depends on the information collected at the time of the alarm and the preparation of the fire crews.

CONTAINMENT OF FIRES WHICH COULD NOT BE SUPPRESSED AT THE INITIAL STAGE

When the initial attack failed and when weather conditions are difficult, then the starting up fire can reach a critical phase, generally characterized by a true fire explosion and a random spread for which the initial means are not sufficient.

The deployment of large fire fighting forces, difficult to coordinate, does not obtain satisfactory results. Other techniques must then be considered and implemented.

FRANCE

FIGHTING AGAINST CATASTROPHIC FIRES

The commander of fire operations prefers mobile and aggressive attacks of the fire. It includes the use of combined air-ground strikes. These massive and dynamic interventions, placed at the right moment and point, interrupt the fire propagation, which must be repeated and exploited until the final fire extinction, using the standard fire fighting equipment.

This option requires of the fire operations chief a complete knowledge of the present situation and a permanent anticipation of the fire spread. Then, within the shortest time delay, the so-called «shock crews» are deployed, having the right impact on the fire.

Human resources

7.2 management

Fire suppression often requires the mobilization of many fire fighters. The local population participates sometimes in the fire fighting. However, it is necessary that personal specialized in fire fighting is responsible for the fire operations. This personal indeed has a good knowledge of fire suppression, has specific equipment, is organized in operational command structures and develops a fire fighting strategy adapted to the fire context.

Forest fire suppression requires two types of firefighters:

- Specialists (professional firefighters and foresters).
- Local population.

Fire fighting personal

SPECIALIZED PERSONAL

Varying in different countries, various actors intervene for forest fires suppression:

- The professional firefighters, who also intervenes on urban fires,
- The foresters, who fight only forest fires.

The specialized personnel receives a training.

NOT SPECIALIZED PERSONNEL

Local population

In some countries, the local population takes an active part in fire fighting in an obligatory or spontaneous way.

Volunteer associations

Sometimes, forest workers, for example those working in forest exploitation or cork harvesting, are called in to support fire fighting activities. However, the involvement of the local population must be limited because people are not trained and their equipment is often rudimentary. They generally have no protective equipment.

CYPRUS

For the period with a fire risk, the forest service employs 140 seasonal workers to train the fire crews led by permanent staff. Teams of 10 to 15 persons are stationed in the forest centres. When the risk is low, this personnel is tasked with various maintenance work. In winter, the permanent staff works on building sites (roads, forestry work, etc.).

MOROCCO

The command and the responsibility for the forest fire suppression is in the hand of the administrative authority (Governor), which supervises the personnel of the National Forestry Commission, the Civil Protection, and sometimes the Royal Army Forces. In practice, the units of the National Forestry Commission direct the operations on the ground.

There is a brigade of fire fighters for each province, equipped with four-wheel-drive fire fighting vehicles. These brigades and the forest service units are in pre-alarm during the period with high risk.

FRANCE

The fire and rescue organizations intervene on all types of accidents including urban small fires and major forest fires.

There are also forest fire rangers, employed by the départements, whose roles are the following:

- Working in landscape management;
- Detection and suppression of starting fires.
- In some départements they reinforce forest fires suppression units.

PORTUGAL

The 40 000 fire fighters, 95% volunteers, are grouped in 450 corporations distributed over the whole territory with at least a corporation in each community. Each corporation is led by a commander, also a volunteer. These firefighters intervene on all types of fires. The 5% of professionals are stationed in some larger cities (Oporto, Lisbon, Coimbra) and intervene only on urban fires.

The regional structure of the National Fire Service is responsible for the coordination of the 450 corporations and the equipment management.

SPAIN

SELECTION

The selection of the forest personnel for fire crews is carried out according to following criteria:

– Age: 18 to 60 years in general, and 22 to 45 years for the special brigades.

– Former experience.

– Medical examination: absence of cardiac and pulmonary problems.

– Physical fitness.

– Physical examination.

** Sufficient working capabilities: muscle power, resistance, agility, reflexes, balance.*

** Lung capacity: For an individual, it is the maximum oxygen capacity which can be collected, (respiratory system) and transported (circulatory system) to the muscles. The training bank test is used. The candidate steps up and down from a training bank (40 cm top for the men, 33 cm for the women) 22,5 times per minute, at the rate/rhythm of a metronome. The cardiac pulsation is measured after the effort. The cardiac pulsation, the age and the weight of the individual allow to determine his/her aerobic capacity.*

– Theoretical and practical tests. A theoretical (suppression activities, organization, protection of forest ecosystems) and a practical test (tool handling) allow to complete, if necessary, the selection test.

First training and fitness aptitude certification

During the first two contract weeks, the selected candidates must attend at least 20 hours class on the following subjects:

- Ecosystems protection and fire effects;*
- Fire behaviour*
- Suppression techniques;*
- Opening of defence lines;*
- Handling of tools;*
- Radio communication;*
- Safety;*
- Helicopter transport;*
- Coordination and operation of the brigade.*

During these first two weeks, psycho-technical tests evaluate the general intelligence, the speed and the understanding capabilities of commands of the selected people.

At the end of these first two weeks, a certificate of aptitude for the work fire suppression is issued, by taking account the behaviour in progress, the results of the psycho-technical tests and the capability for team work.

TRAINING DURING THE CONTRACT

During their contract, the days without fire, the fire fighters must follow a daily training, including at least one hour:

- gymnastics;*
- march in the forest with their equipment or physically challenging forest work;*
- theory on the fire suppression.*

Reinforcements

When a fire size increases and becomes uncontrollable, other types of personnel can intervene as reinforcements.

Individual protective equipment

This equipment must ensure the protection of the firefighter without reducing his/her mobility which is necessary for fire fighting or to escape a possible dangerous situation.

Organization and coordination

Forest fire fighting sometimes involves different categories of people, professionals or volunteers. It is important that the service in charge of fire fighting

MOROCCO

The population can be recruited (labour forced) by the Governor. It has rudimentary fire fighting equipment. This population, in spite of some reservations, is motivated by vigilance committees and the immediate fire suppression.

TURKEY

The population of forest villages must participate in fire fighting under the responsibility of foresters. It has some light equipment such have shovels, beaters, etc. All men between 18 and 50 years can be forced, which represents a potential of 760 000 people.

FRANCE

The Communal Committees on Forest Fires (CCFF) are volunteer crews organized under the authority of the mayor of the community. Their role is stated in local decrees and the mayor chairs the committee.

The members of the CCFF receive a specific training (cf. chapters 5.2 and 5.4). In the event of a fire, they are at the disposal of the fire operations chief. Their role is then to help the fire crews deployed on the fire with the objective:

- To facilitate the arrival of the professional fire brigades, by guiding them;*
- To ensure supply, if necessary*
- To participate in the rescue of people in danger.*

FRANCE

The military can be used as reinforcement for local fire crews being in fire fighting operations as well as for early fire detection. Two types of military units must be distinguished:

- *The UIISC², a special unit for civil defence, placed at the disposal to the Minister of the Interior. They are units specialized in the field of the civil defence and for this reason they are equipped with forest fire equipment;*
- *Other military units, less qualified and less well equipped, which can take part in the final mop-up as a reinforcement of fire crews.*

PORTUGAL

The firefighters of the corporations only fight against small fires.

The National Service of Civil Protection (SNPC) intervenes only on larger fires.

In the case of large fire events, the forest service and the army are mobilized by the intermediary of the SNPC.

TUNISIA

Three types of personnel can intervene on forest fires: foresters, soldiers and firefighters. According to the size of the fire, other services can intervene, such as the Ministry of Transport (using heavy construction engines) or the Ministry for Public Health (rescue and safety). Personnel of the National Guard can also be called to fight against fires.

is clearly identified, and that command lines and responsibilities are well defined.

RESPONSIBILITY FOR FIRE FIGHTING

Forest fire fighting is under the responsibility of the administrative authority, which delegates it to the qualified service. Thus three models of responsibility are distinguished:

- **“Integrated forester” model.** The services for forest management are responsible for the fire suppression. They coordinate possible intervention of other services (e.g., firefighters intervening normally only on urban fires).
- **“Fire and rescue” model.** The general services for fire suppression and rescue deal with all the types of disasters, including forest fires. All other services are placed under their authority.
- **“Mixed” model.** Various services can intervene independently. This organization causes

SPAIN

SAFETY EQUIPMENT OF THE FOREST FIRE FIGHTING PERSONNEL

Obligatory equipment

- *A light and adjusted helmet, out of plastic or light metal, yellow or orange.*
- *A shirt and trousers, or an overall, yellows or oranges, out of non-flammable fabric, weight lower than 300 g, long sleeves fitted to the wrists, with zipper and pockets.*
- *Solid leather boots, fitted to the ankles, with striated non-skid rubber soles, insulated inner soles against heat when walking on a flaring ground.*

Recommended equipment

- *Gloves, out of leather or wool, doubled with flexible fabric.*
- *Anti-smoke glasses with a large vision field, chock resistant, not flammable, head fixed with an elastic tape*
- *Fabric accessories belt.*

Complementary equipment

- *Drinking canteen of 1 litre, made of aluminium*
- *Lantern*
- *Whistle*

This equipment must be fire proof, convenient, light, durable. The clothing must allow the evacuation of perspiration.

problems, because it is difficult to define the limits of responsibilities and to coordinate the various actions carried out during the fire suppression. For an effective system, coordination structures have to be determined.

The level of responsibility depends on the fire evolution: when the fire becomes bigger, the next higher hierarchical levels are requested for support, level by level up.

ORGANIZATION OF FIRE SUPPRESSION CAPACITIES

The level of responsibilities involved depends on the development of the fire: when the fire becomes bigger, the higher hierarchical levels are involved level by level up.

Optimal average density of fire fighting personnel

Spain uses the following densities as indicative figures:

- *In zones with a moderate risk, at least one fire protection brigade of 7 to 10 members for 10,000 ha.*
- *In zones with a high risk: one brigade for 5,000 ha.*

TURKEY

The forest fire protection is under the authority of the General Directorate of Forestry. The organization corresponds to the forest management by area (Regional Forest Directorate, Districts and Under-districts).

A Forest Fire Information and Suppression Centre informs the Regional Forest Directorates about the fire risk, and organizes and coordinates the fire suppression activities. In the case of large fires, it ensures the coordination between the forest areas concerned. It deploys on a national level the available suppression capacities of the General Directorate of Forestry.

FRANCE

The command and coordination responsibilities and structures are:

– At the national level: the director of Defence and the Civil Defence, with the Ministry for the Interior, using the Operational Decision-Support Centre.

– In the southern zone (all departments of the Mediterranean zone): the Préfet of the southern zone, using the Inter Regional Centre for Operational Coordination of Civil Defence².

– At the level of the départements: the Préfet of the département, using the Departmental Operational Centre for Fire and Rescue³.

The Inter Regional Operational Coordination Centre for Civil Defence has several missions:

– Fire danger forecast.
– Installation of prevention and suppression infrastructures (anticipation, distribution of the suppression capacities, etc.).

– Operational coordination.
– Information management.

PRINCIPLE OF ONE INCIDENT COMMANDER

The Commander of the Operations of Help (COS), being a fire brigade officer, ensures under the authority of the Préfet or the mayor, the engagement of all fighting capacities, including national, placed at his/her disposal.

The role of the Préfet is essential and the intervention of all forces, regardless their administrative origin, is ensured under his/her responsibility. Thus, even the light aerial means, financed by the local communities, are put under this authority.

ITALY

Foresters, carabinieri (national police) and communities can intervene on a fire but the Corpo Forestale (forest service) is responsible for the command and coordination of all fire operations. The Corpo Forestale is under the Ministry for Agriculture and Forestry.

This service has a central coordination structure and operational structures distributed in all regions. Each region develops its own intervention plan. There are 15 operational centres located in the regional capitals and 44 specialized intervention groups, positioned on strategic points.

SYRIA

The forest services have the responsibility for forest fire protection.

Fire suppression is based on temporary recruitment, from June to October, of unskilled workers. This personnel is organized in fire crews of twenty members placed under the authority of a crew chief. The fire crews themselves are under the responsibility of a permanent employed engineer of the Department of Forestry.

The fire crews can be:

– Isolated intervention groups, having each at least one vehicle with a (slip-on) tank.

– Stationed in forestry police stations.

– Stationed in specialized fire protection centres. The workers are then recruited all year long and take part in other tasks outside the fire season (surveillance, phyto-sanitary treatment of plants, seed collection, etc.).

Since 1996, Syria established one or two specialized fire protection centres. The personnel of a fire protection centre consists of 65 people divided as follows:

– A director who is permanent employed engineer of the Department of Forestry

– An assistant director, also permanent engineer of the Department of Forestry

– Sixty workers divided into three intervention groups of 20 people each

– Three group chiefs (high school diploma or bachelor)

In all cases, the workers are recruited among the population of the neighbouring villages. Thus they know very well the area. A group has a 24 hrs shift, the two others rest at home. In the event of an alarm, the shift group leaves for fire fighting. If needed, the two other groups are alerted, which requires only one hour since the workers live in the vicinity.

The densities depend on the available financial means.

MANAGEMENT TOOLS

Especially designed dated-processing tools can support the management of forest fires. They are still little developed in Mediterranean countries.

TUNISIA

The Civil Protection is responsible for any disaster. On the operational level, an incident command committee is created on the fire scene. This committee is chaired by the governor, and includes a representative of the Civil Protection (Ministry of the Interior), a representative of the General Directorate of Forestry (Ministry of Agriculture) and a representative of the National army (Ministry for National Defence). These representatives are in charge of the situation evaluation and the decision-making. A close cooperation between these three bodies allows a more effective forest fire fighting. This committee elaborates an operation system which defines the role of each intervention force and the means to be set up. The incident command committee ensures also the relay with the central authorities.

Each representative is also in charge of the supervision and the direction of his/her forces.

Ten Centres for Forest Protection (CPF) are located in the zones at risk. Each is staffed with a commanding technician or engineer and ten forest firefighters.

During period with a high fire risk (from early May to end of October), a permanent staffing is assured 24 hrs in all CPFs. For that, two crews take turns, one from 07:00 hrs to 19:00 hrs, the other from 19:00 hrs to 07:00 hrs, while a third team is resting.

FRANCE

THE COMPUTERIZED SYSTEM FOR OPERATIONAL COMMUNICATIONS OF THE CIVIL SECURITY (SYSTÈME INFORMATISÉ DE COMMUNICATIONS OPÉRATIONNELLES DE LA SÉCURITÉ CIVILE - SICOSC)

It is a decision-support system for forest fires management in the 15 departments of the southern zone. It enables all partners of the Interregional Centre of Operational Coordination of the Civil Security (CIRCOSC) to know constantly the «general environment», i.e., the fire risk and operational situation for the entire southern zone.

OBJECTIVES:

– Assistance for anticipation. During a disaster declaration, the system helps to determine the zones which are placed under high surveillance.

– Coordination support. During rescue operations, the system contributes to the optimal assignment of the means to the incident.

– Prioritisation support. The system makes it possible to treat on a hierarchical basis the events when there is inadequacy between means and needs

– Information support. The system allows the compilation of received information, their rational interpretation and their synthesized diffusion.

FUNCTIONALITIES:

– Intranets are introduced to the various services of the Civil Defence. This function allows to diffuse the daily risk forecast and to communicate information on the ongoing fire fighting operations.

– Databases, which contains the files of all fires, used for the feedback of experience.

– Visualization - mapping.

THIS SYSTEM IS CONSISTS OF:

– A communications server.

– A database server

– SUN workstations located at the CIRCOSC.

– Desktops distributed to the Départemental Operational Centres for Fire and Rescue (CODIS).

– A local access network and lines towards outside connecting the servers to the workstations, the desk tops, National Meteorology and all Civil Defence partners of CIRCOSC.

7.3 Fire Fighting equipment

Terrestrial or aerial forest fire suppression requires equipment adapted to the:

- fire type: surface or ground fire
- development phase: ignition, large uncontrolled fire
- environmental conditions: access, topography

Terrestrial equipment

DIRECT FIRE INTERVENTION

Standard equipment

These are shovels, hoe-rakes (pulaski), fire beaters, pickaxes, which is only used during the initial attack, but seldom after the ignition, when a fire is still small or fires of low intensity or for mop-up. Those hand tools is used in France in zones difficult to access, for example by crews transported by helicopters.



MOROCCO ACQUISITION OF BACKPACK SPRAYERS

In Morocco, the mobile intervention unit of the barracks of Rabat Salé bought 40 backpack units with a capacity of 16 l, provided with a sprayer. The range of those is 4 to 5 m, the best effectiveness being obtained for 1.50 m.



Backpack sprayers

These are also reserved for low intensity fires or first intervention, because the water reserve is small and the range of sprayers is limited to 5 m.

Initial attack vehicles

Used for prevention surveillance, these cross-country vehicles are provided with a water tank allowing an immediate first intervention on starting fires. Taking into account this double function, the characteristics of this type of equipment is a compromise between:

- Mobility allowing an effective surveillance and a fast access on the spot of ignition.
- Sufficient water capacity to suppress fires with a first intervention or to slow down them in waiting for reinforcements.

FRANCE

Vehicles for initial attack

Nicknamed wrongly «Dangel» in reference to the initial constructor, these yellow off-road vehicles are equipped with:

- A water tank of 600 l
- A motor-driven low pressure pump
- A lance with a minimal diameter of 23 mm, ensuring a flow from 80 to 200 l/min



Water tankers

These are cross-country vehicles specifically equipped for fire suppression, equipped with pumps, lances, and high capacity water tanks. The tanks are variable in size according to the type of equipment, the whole set-up has to reconcile, as for the vehicles for initial attack, mobility to reach fire, functionality during the fire fighting activities, and an optimal water tank size.

- On one hand, the higher the water capacity, the more the mobility of the vehicle is reduced. Thus, it is necessary to choose the water capacity adapted to the access conditions of the forest area.

- On the other hand, a water lance can only fight approximately ten meters fire line. Therefore, it can be advantageous to deploy several average sized trucks (2,000 l) with one or two lances or heavier trucks (4,000 to 6,000 l) with 4 or 5 lances. Very big engines (10,000 l and more) can be used for restocking smaller trucks or be equipped with several water lances.

It is advised to equip these vehicles with self-protection systems; various techniques can be employed, for example a good heat insulation of the driver cab or a watering by outside spraying the vehicle.

INDIRECT INTERVENTION

Opening of access roads and vegetation strips: machines of public works such as the bulldozers can be used during fire fighting to build provisional tracks providing access to the fire, to limit the spread of the fire front by removing any vegetation on a strip (fireline) in front of the fire. The equipment for forest exploitation such as chain saws are also used to establish these firelines before the advancing fire front.

Transport of fire crews: this can be assured, when the fire fighting vehicles are not available in sufficient quantity, by not equipped “ordinary” vehicles: pick-ups, minibus.

In Turkey, for example, a part of them is rented from companies during the fire season.



SYRIA

Fire engine of large capacity

The fire protection centre of Rabi'a (province of Lattakia, on the coast) has a water tanker of German origin with a capacity of 17,000 l. This truck is equipped on the top of cistern with a water gun having a maximum range of 50 m, and with 6 pipes of 20 m length that can be put end to end, with an effective range of 10 m. Lance and gun can function simultaneously on the same pump.

Syria owns other older tankers with a capacity of 8 000 to 12 000 l. Originally without pumping system, they were later equipped with a pump by the fire fighting services.



FRANCE

A VEHICLE RANGE OF VARYING CAPACITY

Three types of fire engines are used in France:

- Average engine: 2,000 l
- Heavy engine: 4,000 l
- Very heavy engine: from 6,000 l (to 11,000 l)

Detail of the equipment (lances, pump)

SPAIN

FIREFIGHTER 55

Firefighter 55 is a crawler-mounted assembled mobile unit intended for the extinction of all surface fires, particularly useful in rough terrain and difficult access. Its principal characteristics are:

- Capacity: 11,300 l water.
- Armoured body.
- Total weight with full water load: 45,000 kg.
- Air-conditioned cockpit.
- Water cannon with a range of 60 m.

Monitoring of weather parameters: small portable weather stations measuring in real time humidity, temperature, wind direction and force allow to follow the

evolution of the weather conditions in order to organize the fire suppression.

Aerial equipment

TYPE OF EQUIPMENT IN USE

Helicopters and airplanes are very useful for fire suppression, like for the tactical support of fire crews on the ground or, when the access conditions to the fire are difficult on the ground.

Helicopters

They can be used for personnel transport or active fighting such as dropping water (in French so-called “water bomber helicopters” or HBE¹). There are several back-up systems for water re-filling:

- Bucket suspended on a winch below the helicopter. The filling is done by immersion in water. The

bucket is difficult to fill and to handle and, during transport, under the effect of swinging, much from water is lost.

- A plastic bag fixed beneath the helicopter, filled with a hose, connected to a tanker or of a fixed water point.

- Combination of the two preceding techniques. A bucket is fixed on a reinforced chassis, and is equipped with a pump and a filling hose. This system allows to carry until 5,000 l.

Having a great flexibility, helicopters have the advantage of being able to operate independently of an airport for the water supply, which can be carried out by aspiration in hovering above a water point, when the



HELICOPTERS: SOME TECHNICAL CHARACTERISTICS

ÉCUREUIL (B1)

TYPE: single-engine helicopter

TASK: Aerial reconnaissance of fires, guidance of ground forces, transport (personal and material), evacuation of people, marking for aerial path-finding.

ORIGIN: France (Aérospatiale)

CRUISING SPEED: 210 km/h

OPERATIONAL FLIGHT AUTONOMY: 2:00 hrs

CAPACITY: 800 l

SUPPLY: pumping in hover (40 s)



PUMA (SA 330)

TYPE: twin-engine helicopter

TASK: transport of the fire crews into zones difficult to reach for ground rescue forces.

ORIGIN: France (Aérospatiale)

CRUISING SPEED: 240 km/h

OPERATIONAL FLIGHT AUTONOMY: 2:15 hrs

CAPACITY: 2,400 l

SUPPLY: by pumping in hover (1 min 10 s)



SOKOL

TYPE: twin-engine helicopter

ORIGIN: Russia

CRUISING SPEED: 235 km/h

OPERATIONAL FLIGHT AUTONOMY:

CAPACITY: 1,500 l

TRANSPORTED PERSONNEL: 11

MI-8

TYPE: twin-engine helicopter

ORIGIN: Russia

CRUISING SPEED: 200 km/h

OPERATIONAL FLIGHT AUTONOMY:

CAPACITY: 2,500 l

TRANSPORTED PERSONNEL: 22

KAMOV

TYPE: twin-engine helicopter

ORIGIN: Russia

CRUISING SPEED: 230 km/h

OPERATIONAL FLIGHT AUTONOMY:

CAPACITY: 4,500 l

TRANSPORTED PERSONNEL: 16

¹ In French: Hélicoptère Bombardier d'Eau

AIR PLANES: SOME TECHNICAL CHARACTERISTICS

Canadair (CL 415)

MAIN TASK: direct attack.

ADDITIONAL TASKS: spotter plane with water tank, builds firelines with retardants.

TYPE: twin-engine turboprop jet seaplane

ORIGIN: Canada

CRUISING SPEED: 330 km/h

OPERATIONAL FLIGHT AUTONOMY: 3:30 hrs

CAPACITY: 5,800 l

SUPPLY: by scooping (10 to 12 s) or on ground (3 min)
scooping distance: 800 m



Fokker 27

MAIN TASKS: support of fire suppression, builds firelines with retardants, liaison (winter).

ADDITIONAL TASKS: spotter plane with water tank, transport (personnel and equipment).

TYPE: twin-engine turboprop jet

ORIGIN: Netherlands

CRUISING SPEED: 370 km/h

OPERATIONAL FLIGHT AUTONOMY: 3 hrs

CAPACITY: 5,600 l

SUPPLY: on ground (3 min)



Tracker (S2F)

MAIN TASK: spotter plane with water tank.

ADDITIONAL TASKS: direct attack, builds firelines with retardants

TYPE: twin-engine turboprop jet

ORIGIN: USA

CRUISING SPEED: 360 km/h

OPERATIONAL FLIGHT AUTONOMY: 3:30 hrs

CAPACITY: 3,280 l

SUPPLY: on ground (1 min 30 s)



Hercules C130

MAIN TASK: builds firelines with retardants

ADDITIONAL TASKS: spotter plane with water tank, support of fire suppression.

TYPE: four-engine turboprop jet

ORIGIN: USA

CRUISING SPEED: 420 km/h

OPERATIONAL FLIGHT AUTONOMY: 4h

CAPACITY: 11,400 l

SUPPLY: on ground (10 min)

Dromader

TYPE: single piston-engine plane

ORIGIN: Poland

CRUISING SPEED: 205 km/h

OPERATIONAL FLIGHT AUTONOMY: 3 hrs

CAPACITY: 2,200 l

SUPPLY: on ground

Air Tractor AT-802 A

TYPE: single-engine turboprop jet

ORIGIN:

CRUISING SPEED: 310 km/h

OPERATIONAL FLIGHT AUTONOMY: 5h

CAPACITY: 3,500 l

SUPPLY: on ground

water reserve is located under the flight engine. Their capacity is, however, reduced, if compared to planes.

Airplanes

Fixed-wing airplanes are used for surveillance, for example as reconnaissance plane which is equipped with water tanks (cf. chapter 5.4.A), and for active fire suppression. Faster than helicopters, they also have a much bigger water reserve (3,000 to 6,000 l), which allows to increase their intervention capacity on a fire. With the exception of amphibious planes (Canadair), airplanes are strongly dependent of an airport for the refilling of their water tanks.

The water supply of the Canadair planes requires a water stretch of 2,000 m length by 100 m of width by 2 m depth, having a refilling (scooping) distance of 800 m.

Planes used in agriculture (Thrush Commander, Grumman Agcat, Air Tractor, Dromader) are used in some countries like Spain. These planes have low requirements for airport infrastructures. A non-tarred air strip of 500 to 800 m length is sufficient. However, these airplanes are limited by their load capacity.

METHODS OF USE

In the Mediterranean basin the use of aerial fire fighting means is still restricted as compared to other countries. The necessary investments for the acquisition of such equipment (more than 100 million francs for a Canadair CL 415) and the significant intervention costs constitute a considerable financial obstacle. Certain countries circumvent this difficulty by renting planes or helicopters from other organizations, like the army

SPAIN

Collaboration agreement

A collaboration agreement between the Ministry for Defence and the General Management for Nature Conservation (DGCN) of the Department of Environment regulates the management and the use of amphibious planes, Canadair - 215 or others, for forest fire suppression:

– The planes are the property of DGCN. Eventually the acquisition of new planes will be at its charge.

– The planes are permanently used for forest fire suppression.

– The fire suppression operations, the crew training and the maintenance of planes are executed by the Air Force Group 43 (air base of Torrejón de Ardoz - Madrid).

– The planes will be used as airtanker, to conduct surveillance, reconnaissance and transport.

– Each year, the DGCN pays the amount of expenses related to the flight of the aircraft and the training of crews.

FRANCE

Management of aerial forces

HELICOPTERS. *They can depend on:*

– Civil Defence; they belong then to the government and are managed by several air bases distributed on the national territory and are used by the Civil Defence for many tasks (medical transport, forest fires, etc.).

– Local communities, which only decide about their use in the event of a forest fire. These are then light flight engines, since the heavy machines of the type Puma remain inaccessible to the budget of these communities. During forest fire suppression operations, they are put under the command of the Commander for the Rescue Operation.

AIRPLANES. *With the exception of some light engines belonging to the départements, the planes are:*

– Financed by the Government, the Ministry for the Interior, the Direction for Defence and Civil Defence, the Air Force Command.

– Managed by the air base of the Civil Defence (Airport Marseilles Provence). The base has the responsibility for the planes, the pilots, the technical part and maintenance. The pilots are placed under the authority of the commander of the base.

– Employed by the CIRCOSC. The commander of the base places the planes at the disposal of the CIRCOSC, which decides on their use.

In the summer season, certain planes are stationed nearer to the risk areas:

– either a priori on four air bases (Ajaccio, Bastia, Carcassonne and Cannes), or
– step by step in function of the alert level.

A simultaneous use of aerial means of national and local authorities require a strict application of common rules:

– At the arrival of airtankers of the Civil Security, the incident commander initially disengages the départemental air means.

– When national airplanes are in the operation zone, the air coordinator can authorize the combined actions of all aerial means but separated temporally or spatially.

There are agreements with neighbouring countries (Italy, Spain) for the use of the national aerial means.

or the police, or from private companies. International co-operation allow certain countries not having the necessary financing for the acquisition of aircrafts to call for air support of adjacent countries.

The air means can also be used outside the fire

TURKEY

Hiring of helicopters

Turkey rents helicopters of Russian origin (MTI), allowing the transport of personnel (15 people) and water dropping with a capacity of 3 tons. This equipment is rented during 3 months. The hiring cost is 200,000 USD the unit, for 100 hours use; the additional use is invoiced with 2,000 USD per helicopter and day.

MOROCCO

Aerial forces

In Morocco the use of the aerial forces began in 1998, by an agreement between the National Forestry Commission and the Royal Gendarmerie, which placed part of its planes at the disposal of forest fire protection. This equipment was rented on a 300 hours base, for a total of two million dirhams. the planes used are Turbo Trash, of a capacity of 1,500 to 2,000 l, with a flight autonomy of two hours.*

Morocco also signed an agreement with Spain: the centre for aerial fire suppression of Cadiz has an operating range of 200 km, which covers part of the north of Morocco. This international co-operation was already tested several times, in particular with Spanish airtankers in the Rif area.

** equivalent dirhams - USD*

risk season for other interventions (transport of people, equipment or food in the case of natural disasters, conflicts, etc.).

Chemical additives

These are chemicals that are added to water to improve its physical and chemical extinguishing properties. The following additives are distinguished:

- **Dampening agents.** By decreasing the surface tension of water, a greater diffusion and better penetration is ensured. They are used however little, because of to their performances more limited compared to the other products

- **Short-term retardants.** These are principally foaming agents which by their physical action increase the quantity of water retained by the vegetation. The mixture of water with the foaming agent is done during the flight using a foam container and a pump that allows a flow that is programmed in accordance with the weather conditions and the vegetation density (proportion ranges between 3 to 6 per thousand). Its employment is generally limited by winds higher than 40 km/h. It is not advisable for direct attack.

- **Long-term retardants.** A product is classified a long-term retardant when its duration of effectiveness reaches 2 to 6 hours, even several days if no rain comes to wash the treated zone. Its active part is due to the presence of a chemical compound (fireproofing salt) which is degraded under the action of heat according to endothermic reactions. Mixed with water in proportions of about 20%, the product is primarily dropped from the air, for building up retardant barriers before the fire front in order to limit fire spread and to narrow the fire front. The better performance of the retarding product, compared to water, varies by a factor of superiority from 4 to 9 according to the type of plane.

These chemicals can be used aerial (plane, helicopter) as well as terrestrial (tanker, vehicle of first intervention).

7.4 Communication systems

An effective high quality communications network allows a good communication and coordination between the various actors of fire prevention and suppression. If well organized, it allows to reduce delay times until initial attack.

The transmissions system for information generally used for forest fire protection is the radio operator system. However, a particular telephone network is sometimes also used.

In any transmission network, the quality of the procedures and their precise definition are essential, so that only information circulates that is necessary, clear, precise, and concise.

Radio

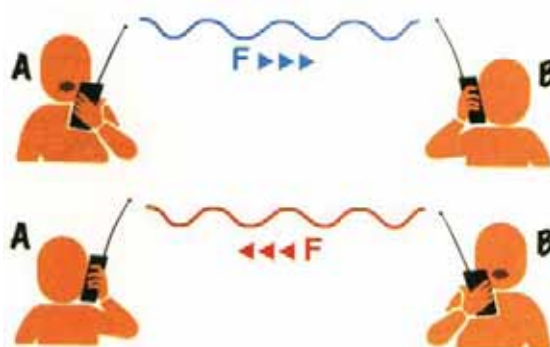
CHOICE OF THE FREQUENCIES

The most used frequencies vary from 30 MHz (low frequencies) to 3 000 MHz (very high frequencies).

The waves having the lowest frequencies have the best direct carrying distance but they are less easily reflected and less penetrating.

TYPES OF NETWORKS

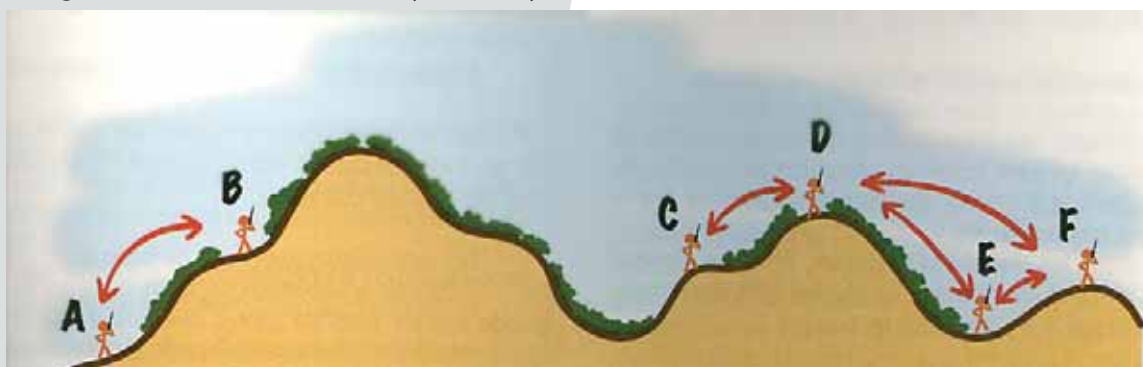
Simplex network: it functions only on one frequency (emission and reception) and does not require a relay. The installation cost of such a network is reduced, but the range of the communications is very limited by



Réseau simplex

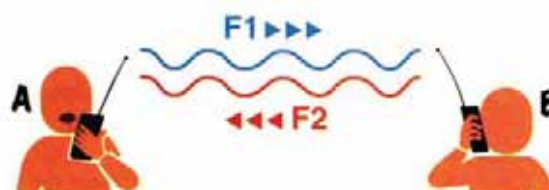
Temps T1 : A émet et B reçoit sur la fréquence F

Temps T2 : B émet et A reçoit sur la fréquence F



the relief. In practice, the network simplex is used only in complement of another communication system (e.g., Tunisia, Syria).

Duplex network: emission and reception can simultaneously take place on two different frequencies constituting a channel. This type of network makes it possible to establish communications between a central station and several private radio stations. However, the



Réseau duplex

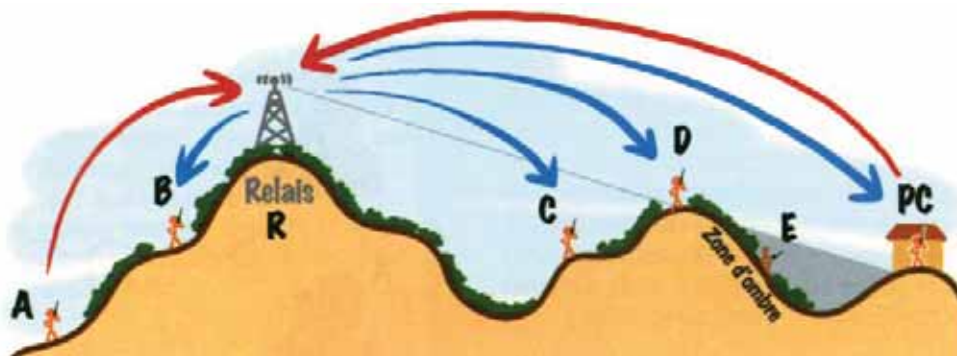
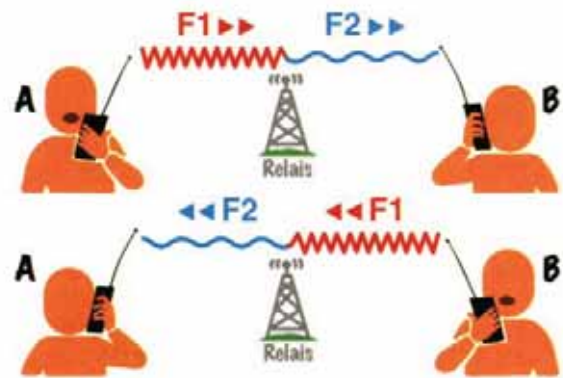
Temps T1 : A émet sur F1, B reçoit sur F1

Temps T2 : B émet sur F2, A reçoit sur F2

latter cannot communicate directly between them and must always pass by the central station.

Semi-duplex network: emission and reception are done successively on two different frequencies, by means of a relay which reverses the frequencies. The advantage of this type of network is to ensure a permanent and optimal cover of the territory, insofar as the relays are established judiciously. However, the installation cost of such a system is comparatively much higher, and there remain obscured zones in which the communication is impossible.

This mode of transmission is used the most in the Mediterranean basin.



NETWORK HARDWARE

Automatic relays

These are stations which retransmit the frequencies that they receive. They are necessary as soon as the area to cover is too big or that the relief is too steep.

For semi-duplex networks, automatic relays must function in duplex, in order to retransmit immediately the received emissions.

Stations

Stationary radios: in general stationary and powerful equipment is linked to offices, (with an antenna on the roof of the building), they are the main points of the exploitation of the network.

Mobile radios: with a power of 10 to 15 Watts, these mobile stations can be installed in a vehicle and be fed by the battery of this one.

Portable radios: they have the advantage of being light and easily to operate, therefore they are very practical on the ground; their principal weakness is the

power limitation (2 to 5 Watts), which makes them much less powerful than from mobile stations. Provided with an autonomous battery, they cannot function more than 24 hours.

DESIGN OF A SEMI-DUPLEX NETWORK

Installation of an automatic relay

The range of the relays is in general approximately 30 km. It can be much more significant if the relay is located on a high point.

The relays will be established in order to:

- To cover with a minimum of relay the greatest possible area (a cover of 95 % must be regarded as excellent). The relays will be established on high points.
- Minimize the installation costs (access, energy supply).

There is an advantage if there exists a certain overlapping of zones covered by the relays, because that provides some security in the event of breakdown of one of them.

Distribution of the stations

The stationary radios will be located at the level of headquarters, coordination centres or communication units having the goal to centralize various calls.

With regard to mobile or portable stations, the personnel ensuring the surveillance (lookout towers, patrols...) must be equipped in priority.

When the fire danger is high, it is advised, in order to avoid the saturation of the network or confusion, to set up specialized cells tasked to handle the communications coming from the personnel ensuring the surveillance (e.g., communication centres in Turkey).

If the equipment is insufficient or defective to ensure a total cover of the territory, it is necessary to resort to indirect communications (from station to station), but this requires much more time.

Telephone

TELEPHONE NETWORK

The national telephone network can be used to transmit information, but its use for the surveillance remains generally limited, because it can saturate very quickly in the event of significant fire risks.

A specialized telephone network can supplement the radio operator network.

E.g., in Cyprus, the forest service has its own telephone network with a manual switching standard, effective and free of charge except for maintenance costs. This network connects the various forest units, divisions to the lookout towers. Moreover, phone terminals connected to the forest office are at the disposal of the public in the forest, and particularly close to picnic areas.

MOBILE PHONES

This mode of communication is increasingly used by persons in charge of forest fire protection. However, it does not ensure a total coverage of the territory. Moreover, the operational standard can sometimes be saturated at the time of a fire occurrence.

CALL FREE NUMBER

A call free number can be placed at the disposal of the public (cf. chapter 5.4.A).

Standard operation procedures

To successfully use a communication network requires not only powerful hardware but also a rigid operation procedure and operating discipline, and security of correct use.

The procedure must be simple, clear, effective and be especially followed. The communications must be short. With the beginning of each call, the speaker must announce him/herself on the network by his/her specific code. It is thus advisable to create a code table which will have to be rigorously respected. Clear codes are often retained: generally, the function is followed a geographical place, person names have to be avoided.

RADIO CONNECTIONS IN MOROCCO

DISTRIBUTION OF THE HARDWARE:

STRUCTURE	HARDWARE
Regional Directorate of Forestry (DREF)	1 stationary station + 1 mobile station
Arrondissement (Province)	1 stationary station + 1 mobile station
Centre for Forestry Development (CDF)	1 stationary station + 1 mobile station
Sub-Centre for Forestry Development (SCDF)	1 mobile station
Forest District	1 portable station

Moreover, all foresters at all levels have one portable radio station.

COMMUNICATIONS: there are three frequencies: provincial, inter-provincial and regional.

- The forest districts have only access to the frequencies of their province, therefore to the SCDF, to the Arrondissement (Province) and to the Regional Directorate of Forestry (DREF).
- The SCDF have access to frequencies of the other provinces.
- The Arrondissement (Province) can use the three frequencies.

1 In French: Unités d'Instruction et d'Intervention de la Sécurité Civile

2 In French: Centre Inter Régional de Coordination Opérationnelle de la Sécurité Civile (CIRCOSC)

3 In French: Centre Opérationnel Départemental Incendie et Secours (CODIS)

8

Post-fire



8.1 – Fire effects on the environment

8.2 – Diagnosis of forest stands after fire

8.3 - Rehabilitation

Introduction

When the last embers are finally extinct, the damage caused by the fire can be fully assessed. Its consequences are most serious when fires destroy inhabited structures, forest areas serving as a resource for the local population, large areas, or if the fire burned near a city or tourist area. Very often, in the Mediterranean region, inhabited zones are threatened by fires which let the population feel the fire risk.

The population, elected officials, and the media usually demand that actions are taken in order to repair what was destroyed and to make sure that fires do not reoccur. These requests are legitimate, since the social impact of fires and their psychological impact should not be neglected. However, too hasty and unwise actions should be avoided. On the contrary, it is necessary to take time to define what it is necessary to do and what is not, what is urgent and what can wait.

- Most urgent is the control of erosion risks. A quick diagnosis allows to define the necessary work load and to take actions in the weeks after the fire.*

- The control of plant health risks is also part of short-term actions. The damaged or weakened trees must be monitored. It is essential that effective measures (cutting and burning) are taken as soon as a risk of an epidemic is detected.*

- It also can be interesting to cut quickly the standing dead trees, when the selling of blackened wood is feasible.*

- Finally, a fast cutting back of most deciduous trees supports coppicing.*

All other actions can wait.

Then the question arises what should be done with the burned area. Is it necessary:

To reconstitute the initial state (restoration),

Or, on the contrary, to benefit from the fire and to reorganise the landscape (refitting or rehabilitation).

The activities for landscaping do not relate only to the forest, but the entire area burned by the fire. Here also a situation analysis precedes all restoration or rehabilitation actions. Various studies support the decision-making process:

- The feedback of experiences, which allow to analyse the means of prevention, forecast and fire fighting to be implemented and to learn the lessons (existence of potential fire sources, lack of fire equipment or fire management, non-operational command structures...).*

- Monitoring of spontaneous regeneration of forest vegetation.*

- Scientific analysis: investigations of soils, meteorology, ecology...*

- Analysis of economic and social forest functions (wood production, resources for rural population, landscape, public recreational areas).*

With regard to the rehabilitation of vegetation, the persons in charge must give each other the time of a detailed situation analysis, and in particular the natural regeneration capacity of the vegetation. Natural regeneration, if possible at all, should be given preference to artificial afforestation, except in some particular cases.

The lessons learned from these studies allow, if necessary, to adjust the landscape management plan, or to revise the existing management plan. This plan defines new management guidelines which decrease the fire hazard, while preserving forest functions.

8.1

Fire effects on the natural environment

Fire Effects on the Forest Stand

Damages caused by the fire

The passage of a fire results in the more or less serious deterioration of vital parts of the plant, such as foliage, stem and roots, resulting in a loss of tree vitality which can cause death.

The deterioration degree is a function of the combined damage of various tree parts (foliage, stem, roots), resulting from fire type (surface or crown fire) and fire intensity, as well as the species' fire sensitivity. A rapid passing fire causes much less damage than a slow fire with longer "residence time".

EFFECTS ON THE FOLIAGE

The destruction of leaves or needles by a fire reduces temporarily the photosynthetic activity. The deterioration of the buds stops any growth of the branch.

The resistance of these vital parts to heat is variable according to the species: in some cases, a layer of protective cells covers the needles (e.g., waxes) or the buds (e.g., scales). The development

stage of the plant also conditions its resistance to thermal stress.

Visually, fire effects on the foliage result in crown scorch (browning). Browning is followed by the loss of leaves and needles.



EFFECTS ON THE STEM

The bark protects sub-cortical tissues (phloem and xylem) responsible for the diameter growth and the sap circulation. These are more or less modified according to the heating of the stem at the time of the fire passage. The slightly damaged tissues are regenerated by the sapwood, with appearance of an healing mark. On the other hand, the destruction of the phloem prevents the storage of photosynthesis assimilates in the roots and the tree survival time is then one to two years (use of reserves accumulated before fire). If even the xylem is destroyed, any communication between



the foliage and the root system is interrupted, and the tree dies within a few weeks.

The fire resistance varies according to species, in particular in function of bark thickness. In the case of the cork oak, the sapwood is protected by cork, building a thick bark which serves as insulating thermal material (except if the tree was harvested recently), which makes this species one of the least sensitive to fire. The destroyed branches are replaced by new branches developed from dormant buds.

EFFECTS ON ROOTS

The deterioration of the root collar (buttress) reduces the vigour of the tree, often resulting in death. The heating of the ground at the time of the fire passage can also be responsible for the tree weakening, affecting the root tips located in the upper soil layer.

Ground fires kill roots and trees.

Phyto-sanitary risks

The deterioration of vital parts results also in a weakening of the entire tree, which becomes vulnerable to parasitic or fungi attacks. The burned forest stands can then become potential hearths of contagion of the adjacent vegetation.

Effects on the regeneration of a forest stand

REGENERATION TYPES

The regeneration of a forest stand can be done in two ways: (a) germination (characteristically coniferous trees) or the re-sprouting of coppice. Many deciduous trees and a very small number of coniferous trees (*Juniperus* spp., *Thuja* spp., *Pinus canariensis*) have the capacity to coppice. These are shoots on stocks with underground parts that have survived the fire. Aerial parts of certain tree species resprout; for instance, *Quercus suber* rebuilds relative easily its crown after the passage of a moderate fire.

FIRE EFFECTS ON REGENERATION

The heat of fire favours the regeneration of certain forest species. This is the case for *Quercus coccifera* (France, Italy), *Quercus calliprinos* (Syria), *Pinus brutia* (Syria, Lebanon) and *Pinus halepensis*:

– For *Quercus calliprinos* and *Quercus coccifera*, the stand opening and the absence of competing vegetation supports the regeneration by coppicing. Nevertheless, if a fire is too strong, the capacity of resprouting decreases and even disappears, following the more or less irrevocable deterioration of the sapwood.

– For *Pinus brutia* and *Pinus halepensis*, a moderate fire supports the regeneration by accelerated maturation then bursting of the cones and release of seeds in the weeks following the fire. On the other hand, an intense fire causes the death of nearly all seeds. The embryo dies following the bursting of the tegument under the heat effect.

Impacts of Fire on the Environment

EFFECTS ON SOIL

The passage of a fire effects the structure and composition of the soil.

Soil structure

Fire induces a reduction in the stability of aggregates leading to a particulate structure. This transformation involves the reduction of the water retention capacity and the rate of water infiltration because the soil pores are filled with particles.

Soil composition

The fire results in a fast mineralisation of biomass, litter, and humus, which short-circuits the normal biological cycle, to the detriment of decomposing agents of the ecosystem. Despite a short-term fertilizing pulse the medium-term fertility is reduced. Fire also induces a loss of minerals to the atmosphere. The burning of organic matter releases nitrogen. Other less volatile minerals are involved in the form of very fine particles in the convection column, and are exported several kilometres from their place of origin.





– However, ashes coming from the combustion of the vegetation are at the origin of contributions out of nitrogen, potassium and phosphorus, in a form where it can be assimilated by plants. This compensates for the losses of these elements in the ground. In the surface ground, the cation exchange capacity is reduced.

Micro-organisms

Sterilisation starts between 50 and 125°C, and generally effects the first five or the first ten centimetres of the ground. In fact, the surface layers, which are richest in organic matter and most active biologically, are damaged. Micro-fauna is destroyed and recovers only slowly.

Erosion

The exposure of the soil following the fire as well as the structural modifications induced by the fire increase very strongly erosion risks. These depend on:

- **Slope** - the steeper the slope is, the more significant the risks of gully erosion.
- **Geological and pedological nature of the ground** - Clay soils are very sensitive to erosion.
- **Distribution and intensity of precipitation** - Violent rains on an cleared ground can generate considerable damage on the spot and downstream (floods, flow mud...).

EFFECTS ON VEGETATION DYNAMICS

In almost all cases, after a fire, the vegetation recovers quickly to its initial state, without human intervention.

However, recovery of the vegetation cover depends on the fire severity and frequency.

– Following a moderated fire, the vegetation cover gradually reconstitutes, by resprouting, germination, or starting from underground parts that survived (bulbs, rhizomes). The ecosystem evolves to a state, which is comparable to the initial floristic stadium before the fire, gradually in structure, quasi immediately in composition, successively losing pioneering transitory plants which disappear slowly.

– An intense fire reduces the regeneration capacities: heat can destroy the underground parts or seeds necessary for survival, and thus strongly limit the regeneration of the vegetation. It results in a floristic impoverishment.

– Repetitively occurring fires lead to a significant floristic impoverishment. Many plants do not have time to mature for sexual reproduction before the passage of a new fire. The species with the highest capacities of dissemination and heat resistance (*cistus*, *calycotomus*) constitute then the dominant species of the vegetation cover.

EFFECTS ON THE FAUNA

The fire affects in different ways the various faunistic groups: some do not survive because they are burned or asphyxiated by the fume (weak individuals); others escape fire (birds) or find shelter, e.g., in the ground. Survival chances depend on the fire severity (ground heating can be very high and animals do not survive), but also of the time period (season) the fire is occurring (e.g., the damage is higher at the time of bird nesting). Fire disturbs, moreover, in an indirect way the biological cycles of animals. Repeated fires may cause faunistic impoverishment by killing animals or extortion due to reduced food resources, destruction of habitats, etc.



EFFECTS ON THE LANDSCAPE

Fire may cause a significant change of the landscape by transforming the life conditions of the population into a charred environment. Low vegetation seems to cope easier with the impacts of fire than forest trees.

ECONOMIC LOSSES

The various elements which constitute the costs of a fire are:

- **Direct costs** - fire fighting activities, destroyed equipment (dwellings, infrastructures, vehicles), destroyed forests.
- **Indirect costs** - loss of the uses, restoration of the vegetation and the landscapes, influence on the economy of tourism and the recreational activities.

It is very difficult to evaluate the economic losses caused by fire due to the problem to properly estimate the indirect costs.

Examples:

- In France, the Mediterranean forest has a relatively low direct economic value, since forest products are often not used. On the contrary, in the surroundings or tourist areas the landscape change through fire induces economic losses which are poorly known and linked to an “affective” value to the natural landscape destroyed by the fire.

- In Morocco and in Syria, the forest is a subsistence resource for the local population. Therefore, economic losses caused by the passage of a fire are considerable.

8.2 Post-fire Diagnosis of a Forest Stand

After a fire, it is useful to select trees for elimination in order to ensure the renewal of the forest stand with the help seed-bearing trees and to improve the ground protection. If the extreme cases are easy to recognise, it is more difficult to predict the future of trees with little damage, apparently untouched and partly with a recovered tree crown after the fire. Therefore, it is of primary importance to develop a post-fire diagnosis tool with the objective to have indicating criteria for tree survival or death. In practice, few studies were carried out in the Mediterranean basin on this subject.

Assessment of crown damage

The assessment can be carried out in two ways:

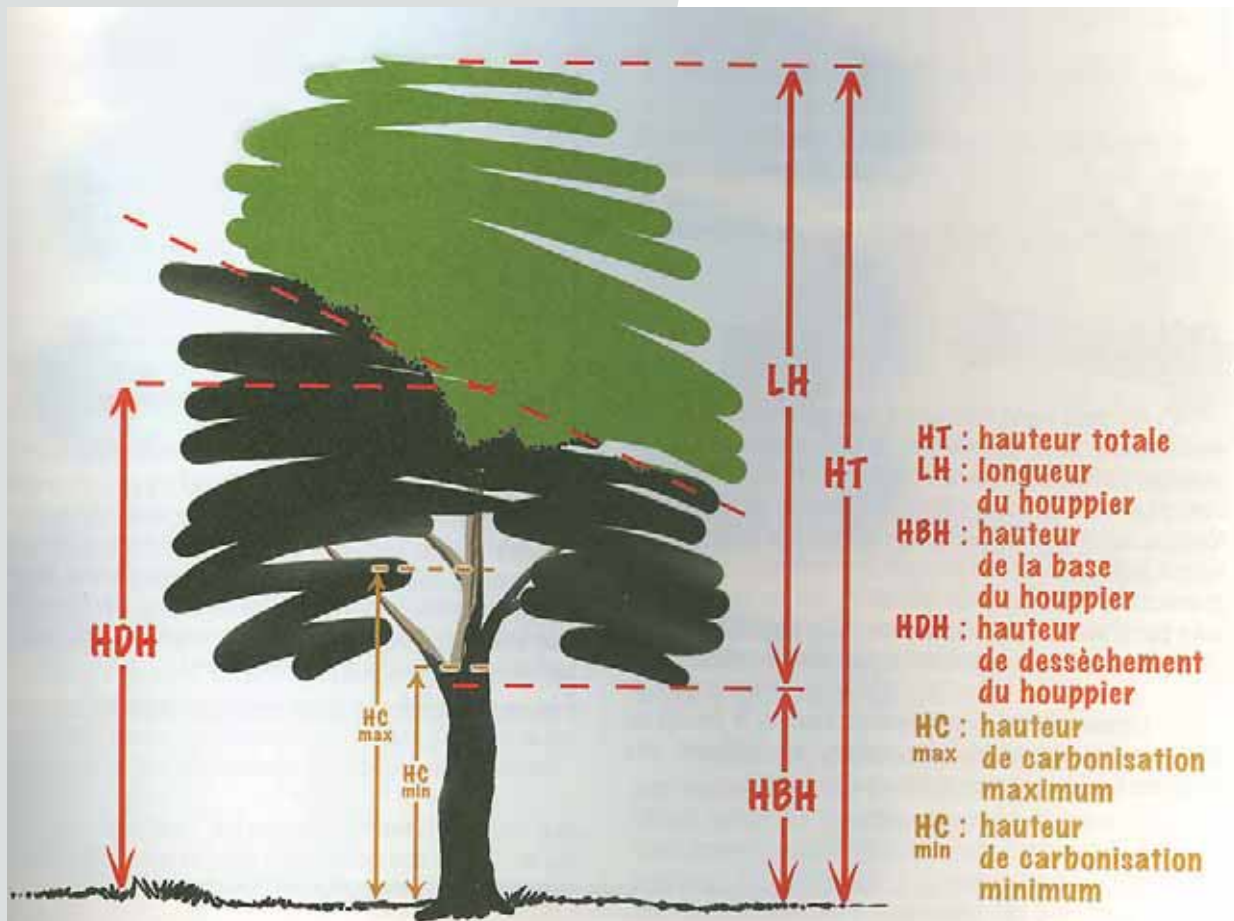
- Visual estimation of the crown volume percentage turned red.
- Measuring the height of dried crown. It can be related to the total tree height or be used to calculate the proportion of desiccated volume.

It seems that the best prediction is the visual estimate; this method is, however, very subjective and causes strong heterogeneity between notes assessments of different observers.

Estimation of stem damage

This estimate can refer to:

- Protection criteria of sub-cortical tissues. The



NORTH AMERICA

Which variable to chose for the diagnosis?

Cognisant the fact that little work has been done in the Mediterranean basin, we give here some examples drawn from North-American studies.

Species	PRIMARY CRITERIA	OTHER CRITERIA	REFERENCE
Pinus concorta	Percentage of dried crown	Charring ratio	Peterson, 1986
Pseudotsuga menziesii	Percentage of dried crown	Intensity of insect attack	Peterson, 1986
Pinus ponderosa	Diameter at 1.30 m height	Percentage of dried crown Season	Harrington, 1993

thicker the tree bark, the lower the damage to the tree. By correlating the thickness of the bark to the diameter at 1,30 m height, it is feasible to assess the tree damage.

- Damage descriptors of the stem: height or depth of charring.

- Damage descriptors for the cambium:

- * Chemical tests with fluoro-chrome or ortho-dolidine, specifying exactly the state of cambium but having disadvantage of being destructive.

- * Bio-electric measurements: The electric resistance of cambium (ERC) can be measured using a vitalo-metre; a low ERC translates into little cambium tissue damage.

Estimation of root damage

The root damage is very difficult to estimate because of the underground position of these parts. The degree of ground charring is assessed by a charring degree, which serves as an indicator for the intensity of deterioration.

Conclusion

It can be concluded that there is great diversity of descriptors to assess the damage generated by the passage of a fire. The choice of the criteria assessing deterioration is all the more difficult since there is a great variability of reaction to fires varying from species to species. The parameters to be retained for the diagnosis can be different according to the forest species. This variability, moreover, is accentuated by other factors, like the physiological state of the tree at the time of the fire occurrence, the site characteristics...

Essential is, however, to facilitate the work of the manager in charge of the diagnosis, by using easily measurable variables on the ground.

FRANCE

Example of post-fire diagnosis for Aleppo pine and umbrella pine (INRA Avignon)

The umbrella pine is overall more resistant to heating than the Aleppo pine because its bark, in particular at the stem base, is thicker.

FOR THE ALEPPO PINE, the combination of burned foliage volume and the diameter at 1,30m height, which are parameters easy to measure in the field, give an estimate of the mortality after the fire.

Example: for a tree with a 20 cm diameter and whose foliage was burned off more than 60%, the death probability is higher than that of survival (with the critical threshold of survival fixed here at 0.5).

FOR THE UMBRELLA PINE, only the volume of the burned foliage allows to judge the tree survival. The bark is indeed thicker (in particular at the foot of the tree), and the damage caused by fire is less serious on the stem.

Example: pines whose foliage crown volume was charred more than 92% have a greater probability to die than to survive.

It is only a probability, and not a certainty. In addition, the manager must fix the critical threshold of probability: if he/she wishes to minimise the risk of differed mortality (e.g., landscape constraints), he/she will reduce the value of this threshold; if, on the contrary, he/she wants to preserve all trees likely to live (example: optimisation of natural regeneration), this threshold will have to be increased, but the plant health risks will be higher.

8.3 Rehabilitation of forest stands

At short-term

The emergency activities aim at controlling erosion risks with their irreversible consequences.

The deterioration of the vital tree parts following the fire passage involves more or less irreversible damage. It might be preferable to cut the dead trees:

- For plant health and landscape reasons.
- For selling the wood, if possible. The commercial value of dead trees finances sometimes the cutting costs. However, the use of these charred forest products is very limited: use for fascines, firewood, charcoal.
- For security reasons. Thus, the wood of the Aleppo pine breaks quickly and, only two or three years after the fire, stems of the dead trees can be toppled over by wind.

The cutting back of charred deciduous trees supports the re-shooting (Holm oak, cork oak).

At long-term

In most cases, the ecosystem (fauna and flora) recovers spontaneously.

However, rehabilitation work of forest stands after fire are necessary in the following cases:

- To protect the forest of high human pressure:
 - * Risk of use of the burned area for cultivation or pastoralism.
 - * Risk of land squatters - When the legislative framework is badly defined (absence of delimitation of the forest or absence of enforcement), local population or realtors could bring the land in their possession.
- To restore social functions quickly:
 - * To reassure the local population, when it uses forest resources.
 - * Existing serious landscape constraints, or when the forest plays a major role for public recreation.
- When the stand has a protective function, e.g., against protection against falling rocks.
- To reconstitute a degraded ecosystem - The fire, when it is intense or repeated, degrades in a more or less irreversible way the ecosystem by erosion and impoverishment of fauna and flora. To stop this degradation requires to reconstitute the vegetation cover by regenerating forest stands.

Rehabilitation at short-term

EROSION CONTROL - “FASCINAGE” (FASCINE LINES)

The first weeks which follow a fire, erosion risks are sometimes very high due to the absence of a vegetation cover. A steep slope and violent rains make the ground all the more sensitive to erosion. A fast intervention in the weeks following the fire is thus necessary if there are reasons to fear a strong erosion (fires in the summer season on a steep slope and vulnerable sandy or clay soils).

The fascine lines help to limit erosion. The burned trees are cut back to 50 cm or 1 m above ground, which allows to preserve trunks as anchor piles. The cut down vegetation is placed after pruning parallel to the contour lines, left on the spot leaning against trunks. This technique thus allows to build “barriers” limiting material erosion. It has, moreover, the advantage of cleaning the disaster zone while using charred material. On the other hand, it is labour intensive, since all operations are performed manually. However, this work is not necessary if the erosion risk is low (spring fires, moderated slope, grounds resisting well erosion).

E.g., Greece did use this technique following the 1998 summer fires near Athens. Locally, France uses this technique to limit the erosion risks burned areas with very steep terrain, where storms at summer end can have catastrophic consequences.



CUTTING OF BURNED TREES

It is advisable to cut down only trees which are not likely to recover and to survive. The preserved trees constitute a seeding sources favouring an inexpensive natural regeneration. They contribute to the protection of soils which have been exposed by fire, and to the safeguarding of the landscape.

CUTTING BACK AND PRUNING OF BURNED DECIDUOUS TREES

To be effective, these interventions must be carried out before the end of the winter following the fire.

The cutting back is to remove the entire tree until its stock which is still alive and where coppice shoots will grow. The cutting back close to the ground facilitates the re-sprouting by stock shooting. A cutting back a few centimetres above ground-level is on the other hand very harmful.

The pruning is the removal of certain branches. This technique can be applied to the cork oak, when it is very damaged by fire. All branches of small diameter are cut and the crown re-growth is supervised.

ITALY

Monitoring of the vegetation dynamic with satellite imagery

In Italy, law 47/75 prohibits the construction after fire and modification of the statute of the burned area until the vegetation is re-grown. Therefore, the study of the vegetation dynamics in burned zones is important, at the same time to define the interventions intended to accelerate the recovery of the vegetation, and to program the future management of the territory.

Remote sensing is used to map the burned zones.

Three Landsat satellite images are used: before the fire, two afterwards. Two channels are combined for an vegetation index:

– Channel TM₄ (near infra-red): sensitive to the internal structure of the foliage structure.

– Canal TM₅ (average infra-red): sensitive to the water content.

The fire passage induces a reduction in the response of the vegetation to channel TM₄.

Contours of burned surfaces can be extracted automatically with filters. Total burned surface areas can also be calculated based on this cartography.

This cartography must be followed-up by ground-truthing and an analysis of aerial photographs.

Rehabilitation at long-term - Regeneration of forest stands

The passage of a fire can provide the opportunity for reconsidering the management and offers the opportunity for a total adjustment of total burned area, like writing a new regional plan. The contemplation relates to the whole fire-touched area, including the forest area, with the following management objectives:

– To redefine the objectives of medium- and long-term forest management, and means of achieving these goals.

– To define necessary actions so that the risk that such a disaster reproduces is very strongly reduced.



In general, after a fire, a spontaneous vegetation, virtually identical to the one which was burned, will re-grow more or less quickly. However, various constraints can make an artificial afforestation preferable to natural regeneration.

THE NATURAL REGENERATION.

The natural regeneration must be favoured where possible. It requires a low initial investment. This regeneration can result from coppice rejections, tree suckers, or seeds originating from survived trees.

Where pressures are strong on the natural regeneration, the protection of the regeneration zones strongly advised, in particular against cattle and game.

When natural regeneration is insufficient, it can be supplemented by artificial enrichments.

E.g., in Tunisia, most of the time, the burned zones are fenced for 7 to 10 years in order to allow natural regeneration to reach a height above browsing line.

MOROCCO

Plant production

Reorganisation of seedbeds

The seedbeds of small and average size which existed in each district of the north of the country (Rif area) were gradually closed during the 5 last years. Only 3 large seedbeds of the administration in Morocco remain:

- Chefchaouen (production of resinous seedlings),*
- Azrou (production of cedar mainly),*
- Marrakech (production of thuja).*

Seed collection

The harvest of seeds is done from certified stands. A catalogue indexes the 19 areas of seed sources. An area of seed source can comprise several species types. There exists a catalogue per species, which lists all certified stands for each species.

The administration of the National Forestry Service asks for and fixes the number of seedlings to be produced with the seedbed for the next year. The harvest of seeds is carried out according to these needs.

Regional seed station of Aïn Rami (Chefchaouen)

The industrial seedbed of Chefchaouen provides seeds to the northern zone of the country (area of Rif) until Oujda. The mainly produced species are coniferous trees: Aleppo pine, maritime pine, Canaries pine, umbrella pine.

Two million seedlings are produced annually. Stocks of resinous seeds amount up to 100 kg.

Here also plants in plastic containers are produced. Compost is collected in the forest and then filtered. The watering of the seedlings is automatic and is done in the morning and evening. The seedlings prepared for afforestations are less than one year old. The seedlings remain to a maximum of 6 months in seedbed (summer).

The seedbed employs 60 workers, six semi-skilled workers, one technician, and three engineers.

Besides the plant production, this seedbed works on three broad research topics:

- Production of seeds (seed harvest),*
- Genetic improvement,*

Improvement of farming techniques of seedlings in seedbed. Studies are undertaken on the breeding of seedlings out of containers under shade (in particular Aleppo pine and cork oak). The current tendency consists in giving up gradually the polyethylene bags, difficult to decompose, in favour of rigid wall containers.

The seedbed promotes these techniques in forest nurseries in the Eastern Rif.

TURKEY

Seed origin

The seedbeds are in majority public. The seed production has two origins:

- from good quality stands, where the seed-bearing trees can be located by white painting marks.*
- from seed-bearing trees obtained by seed-crossing.*

ARTIFICIAL REGENERATION

Artificial regeneration is used especially in countries where a strong population pressure is a serious threat and where a conversion of burned forest areas to other uses or appropriation of encroaching dwellers has to be avoided.

E.g., in Morocco, each burned zone is fully replanted within five years after the fire event.

In Syria, each burned zone is reforested immediately in order to use the next rain.

TUNISIA

Tree nurseries in Sers

Pilot tree nursery

- 500 000 seedlings per year.*
- Seeding in containers, sun-protected in summer, automatic watering 2 times per day at a rate of 10 minutes each time.*
- New compost manufactured of 50% crushed Acacia cyanophylla, 45% of crushed Aleppo pine bark, and 5% of cork bark grains.*
- Computerised management.*

This pilot seedbed produces many seedlings of Pinus halepensis, plants for pastoral improvements (Acacia cyanophylla, Medicago arborea and Atriplex numiliara) as well as eucalyptus.

Traditional tree nursery

- 2 500 000 seedlings per year (production potential of up to 4 million seedlings).*
- Plants raised in polyethylene bags.*
- Compost: vegetation soils + sand.*

This seedbed provides seedlings of Pinus halepensis, Cupressus sempervirens, Acacia aurida, Ceratonia siliqua, Fraxinus oxyphylla, Sophora japonica, Milia azerida, and many plants for ornament and line-planting.



Reforestation

SYRIA

OBJECTIVES: to limit erosion risks and to stop encroaching by local population

SPECIES: Pinus pinea, Pinus halepensis, Pinus brutia, Robinia pseudacacia, Ceratonia siliqua, Cedrus libani, Abies cilicica,...

PREPARATION AND PLANTING:

- Cutting of burned trees.
- On steep slopes: seed sowing or distribution of branches carrying cones.
- On less steep slopes: creation of terraces and plantations; use of seedlings raised in plastic bags
- In dry zones, the young plantations are irrigated.

DENSITY: 1 500 to 2 000 trees/ha in flat terrain on fertile soils, 600 to 1000 trees/ha in mountain terrain

PROTECTION: surveillance ensured by a guard recruited among inhabitants

FINANCING: work financed by the Forestry Department

THE REFORESTATION IN MOROCCO...

OBJECTIVES: to limit erosion risks and to support the local population, for whom the forest area is an important means of subsistence.

SPECIES: Pinus halepensis, Pinus pinea, Pinus pinaster...



PREPARATION AND PLANTING: cut of charred trees in the year following the fire; undergrowth clearance in the event of pushes back of the matorral when the plantations take place a few years after the fire; plantation on strips following the contour lines in the case of hilly terrain; work of the ground on squares of 50 x 50 cm along strips; use of seedlings raised in plastic bags; planting takes place between February and December, sometimes until end of March.

DENSITY: 1 100 trees/ha

PROTECTION: fencing for six years

FINANCING: work financed by the administration of National Forest Service (average cost: 6 000 DH/ha)

TURKEY

OBJECTIVES: to limit the risks of erosion and to avoid the appropriation by the local population

SPECIES: Quercus sp., Pinus nigra, Pinus brutia mixed with Cedrus libani or Cupressus sempervirens ; at the edge of the plantation, more fire resistant species (only Cupressus sempervirens or mixed with other leafy trees: Quercus sp., Acer sp...)

PREPARATION: cut of the burned trees and soil preparation with a bulldozer

DENSITY: variable density according to the species (2m x 3m for Cedrus libani, 3m x 1.5m for Pinus nigra)



PROTECTION: surveillance of the plantation by guards

FINANCING: ensured by the General Directorate for Reforestation and Erosion Control

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