EFI Discussion Paper 15, 2009

Living with Wildfires: What Science Can Tell Us

A Contribution to the Science-Policy Dialogue

Yves Birot (ed.)

EUROPEAN FOREST INSTITUTE

Living with Wildfires: What Science Can Tell Us

A Contribution to the Science-Policy Dialogue

Yves Birot (ed.)

European Forest Institute
Discussion Paper 15, 2009

EUROPEAN FOREST INSTITUTE
MEDITERRANEAN REGIONAL OFFICE – EFIMED

GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN

FIRE PARADOX

phoenix

EUROPEAN FOREST INSTITUTE

ISBN: 987-952-5453-29-4 (printed)
ISBN: 978-952-5453-30-0 (online)
ISSN: 1455-6936

Living with Wildfires: What Science Can Tell Us

Author: Yves Birot (ed.)

Publisher: European Forest Institute
Torikatu 34
FIN-80100 Joensuu
Finland

Editor-in-Chief: Risto Päivinen

Tel: +358 10 773 4300
Fax: +358 10 773 4377
Email: publications@efi.int
WWW: http://www.efi.int/

Cover photo: Paulo Fernandes
Layout and printing: Kopijyvä Oy

Editor’s contact information

Yves Birot
yves.birot@wanadoo.fr

Table of Contents

Contributing Authors and Drafting Committee 5

Introduction 7

1. Forest Fires at a Glance: Facts, Figures and Trends in the EU 11

2. Why and How Do Woodlands Burn? What Is the Resulting Impact?

   2.1 The Causing Factors: A Focus on Economic and Social Driving Forces 21
   2.2 Fire Start and Spread 27
   2.3 Wildfires Impact in 3D: Environment, Economy, Society 33

3. Acting on Wildfires Risks: What Practices, Strategies and Policies?

   3.1 Assessing Wildfire Risk in Time and Space 41
   3.2 Managing Wildfire Risk: Prevention, Suppression 49
   3.3 What to Do After Fire? Post-Fire Restoration 53
   3.4 Economics of Wildfires 59
   3.5 Policy Analysis Reveals the Need for New Approaches 63

4. Meeting a New Challenge: Expected Increase and Expansion of Wildfires as Related to Climate Change

   4.1 Impacts on Potential Wildfire Risk Due to Changes in Climate 71
   4.2 The Need for Strategies Anticipating Climate… and Other Changes 75

Conclusions 79

Contributing Authors and Drafting Committee

Contributing authors

Yves Birot, EFIMED, Avignon, France
Laurent Borgniet, CEMAGREF, Aix-en-Provence, France
Andrea Camia, European Commission Joint Research Centre, Ispra, Italy
Jean-Luc Dupuy, INRA, Avignon, France
Paulo Fernandes, University of Tras-os-Montes and Alto Douro, Vila Real, Portugal
Johann Georg Goldammer, Global Fire Monitoring Centre, Freiburg, Germany
José Ramon Gonzalez-Olabarria, EFIMED, Barcelona, Spain
Mireille Jappiot, CEMAGREF, Aix-en-Provence, France
Corinne Lampin-Maillet CEMAGREF, Aix-en-Provence, France
Robert Mavsar, EFIMED, CTFC, Barcelona, Spain
Cristina Montiel-Molina, University Complutense, Madrid, Spain
Francisco Moreira, ISA, Lisbon, Portugal
José Manuel Moreno, University of Castilla-La Mancha, Toledo, Spain
Francisco Rego, ISA, Lisbon, Portugal
Eric Rigolot, INRA, Avignon, France
Jesus San-Miguel, European Commission Joint Research Centre, Ispra, Italy
Ramon Vallejo, CEAM, Spain
Ricardo Velez, Ministry of Environmment, Madrid, Spain

Drafting committee

Yves Birot, EFIMED, coordinator, France
Marc Castellnou, GRAF, Generalitat de Catalunya, Spain
Johann Georg Goldammer, Global Fire Monitoring Centre, Freiburg, Germany
Francisco Moreira, ISA & EFI Project Centre PHOENIX, Lisbon, Portugal
Davide Petenella, University of Padova, Italy
Francisco Rego, ISA & FIREPARADOX, Lisbon, Portugal
Eric Rigolot, INRA & FIREPARADOX, Avignon, France
Jesus San-Miguel, European Commission Joint Research Centre, Ispra, Italy
Gavriil Xanthopoulos, National Agricultural Research Foundation, Athens, Greece

Introduction

Yves Birot

Contrary to other natural hazards such as earthquakes or windstorms, wildfires are certainly among the most predictable ones. Therefore, it is a phenomenon which, in principle, should leave modern societies some degrees of freedom and margins of manoeuvre for implementing efficient counteracting strategies. However, this opportunity has not been properly used. Over the last decades, wildfires have proven to be a subject of growing concern for the Mediterranean Region. Woodlands, rangelands, maquis and garrigues in rural areas or at the interface with urban areas still continue to burn with significant environmental, social and economic impacts, in particular in case of increased frequencies of fires. Although the European statistics show that in average policies and measures related to fire prevention and suppression have been efficient, extreme climatic conditions (in 2003 in western Europe, and in 2007 in eastern Europe) result in catastrophic fires, such as those undergone by Portugal and Greece. The impacts of such disasters are tremendous, also at the political level. Although the occurrence of severe wildfires has been affecting mainly the northern rim of the Mediterranean Basin, some significant changes in climate and land use are already taking place and will most likely result in an expansion of fire threatened areas. For example, Syria, Lebanon and Algeria have recently been exposed to catastrophic wildfires. In a near future, new areas in the north will face a shift to Mediterranean-like ecological conditions, which raises the question of how to anticipate these evolutions.

As any risk, wildfires cannot and should not be eradicated, and anyhow, managing fire risk through prevention and suppression has a cost. Therefore, in the context of finite financial resources and increased areas subject to fire, the appropriate response cannot be just to continue business as usual, as it will require a dramatic increase in the means and equipments allocated to fire management. The issue at stake is rather to set up integrated strategies and policies that provide "reasonable" trade-offs between environmental, social and economic elements, and allow us to live with wildfire risk. This new approach definitely calls for a profound rethink of these strategies and policies at national and European level, by tackling the problem in all dimensions, including a clear identification of civil protection and forest protection objectives, as they have been in the past quite often mixed up. There is a need for moving from short term driven policy of fire control, mainly based on huge technological investments, to a longer term policy of removing the structural causes of wildfires.

Science's traditional mission has been – and still is – to advance knowledge as a support to innovation. Today, the mission is also to provide expertise in the policy making processes. The science community feels that it can and should contribute to feed the debate on wildfire by providing research results and ideas as background material for future options in strategies and policies. Wildfire related research has been very active in

Living with Wildfires: What Science Can Tell Us
Yves Birot (ed.)

Europe over the last two decades, in particular thanks to a number of EU funded projects (Framework Programmes for RTD), so that a structured research community and new expertise and competence have emerged. Time has come to make this knowledge more digestible and available to policy and decision makers, and beyond to the whole society. This is the ambition of the current paper.

The document is not a state of the art report covering, in an exhaustive manner, all issues related to wildfires. It focuses rather on a limited number of selected key topics on which scientists have some messages to deliver, and which should be considered in future policy making processes. The overall objective of this discussion paper is to provide understanding for managing.

This discussion paper is divided in four sections. The first one presents some statistical figures on wildfire and underlines the trends. The second section deals with two basic questions which should form the background of any rational strategy: why and how do woodlands burn? what is the resulting impact? Practices and strategies for acting on fire risk, including the economic and policy dimensions, are presented in the third section. In the last part, the emphasis is put on the challenges linked to increased and new wildfire risks related to climate change, and ways to cope with them.

1. Forest Fires at a Glance: Facts, Figures and Trends in the EU

1. Forest Fires at a Glance: Facts, Figures and Trends in the EU

Jesús San-Miguel and Andrea Camia

A forest fire is any uncontrolled fire that affects, at least partially, forest and other wooded land areas. The European Forest Fire Information System (EFFIS) established in 2000 by the EU provides the data from national and international sources on forest fires.

This chapter gives an overview of forest fires using facts and figures mainly from the Mediterranean region. Statistics on forest fires have been compiled by the Mediterranean countries since the 1980s. However, the methods and parameters of data collection systems varied a lot among the countries. In 1992, following the EEC Reg. 2158/92, later on complemented by EC 804/94, the Mediterranean countries started the collection of the so-called "core information on forest fires", which included, the following parameters: (1) date and time of the fire start, (2) date and time of the fire extinction, (3) location of the fire, and (4) presumed cause of the fire. This core information was then included, if not existing, in the national forest information systems and was provided to the European Commission. This data, as well as that collected since the establishment of the European Forest Fire Information System (EFFIS) in 2000, constitute the basis of the analysis provided in this chapter.

The EFFIS EU Fire Database contains data on the last 22 years for the largest EU Mediterranean Countries, that is, from West to East, Portugal, Spain, France, Italy, and Greece. Data for Cyprus is only available for the last 8 years, and will be not considered in the overall analysis as the weight in terms of number of fires and total burnt area at the EU Mediterranean level is relatively small.

Absolute frequency of forest fires shows a noticeable increase during the last decades

---

Overall, the number of fires has increased in the EU Mediterranean region during the last decades (Figure 1). However, this might be due to a real increase of fire events or to the improvement of data collection mechanisms in the Mediterranean countries. Frequency of forest fires can be provided in absolute values, that is, just the number of fires by administrative region (e.g. country) as illustrated in Figure 2 for the period 1980–2006.

Living with Wildfires: What Science Can Tell Us
Yves Birot (ed.)

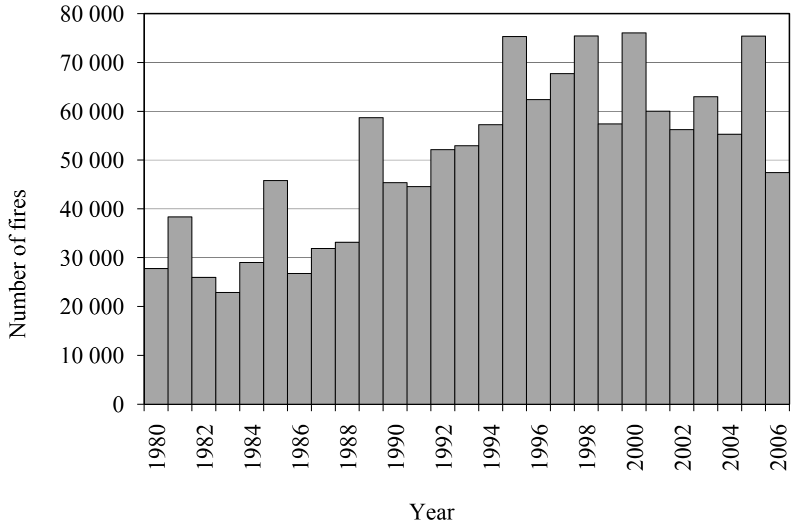

Figure 1. Number of fires in the Mediterranean region.

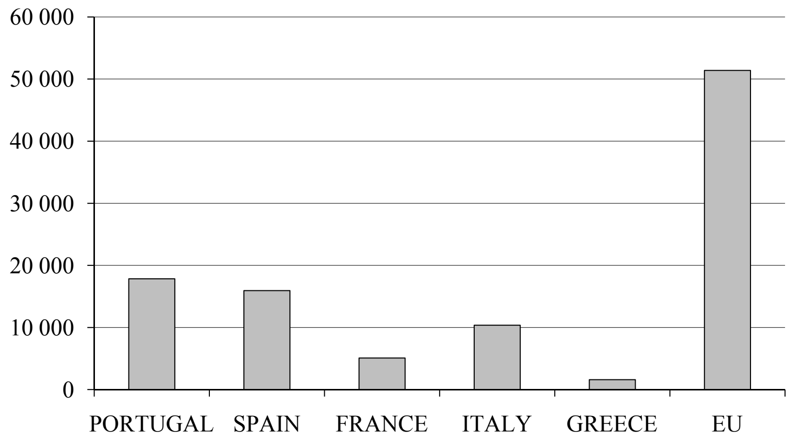

Figure 2. Average number of fires in each of the EU Mediterranean countries in the period 2000–2006.

However, larger countries may have higher number of fires. Therefore, the number of fires and the impact of these should be related to the total forest or wildland area in the country.

Spatial distribution of forest fires in Europe shows their important occurrence in the Mediterranean region, but also in central and northern Europe.

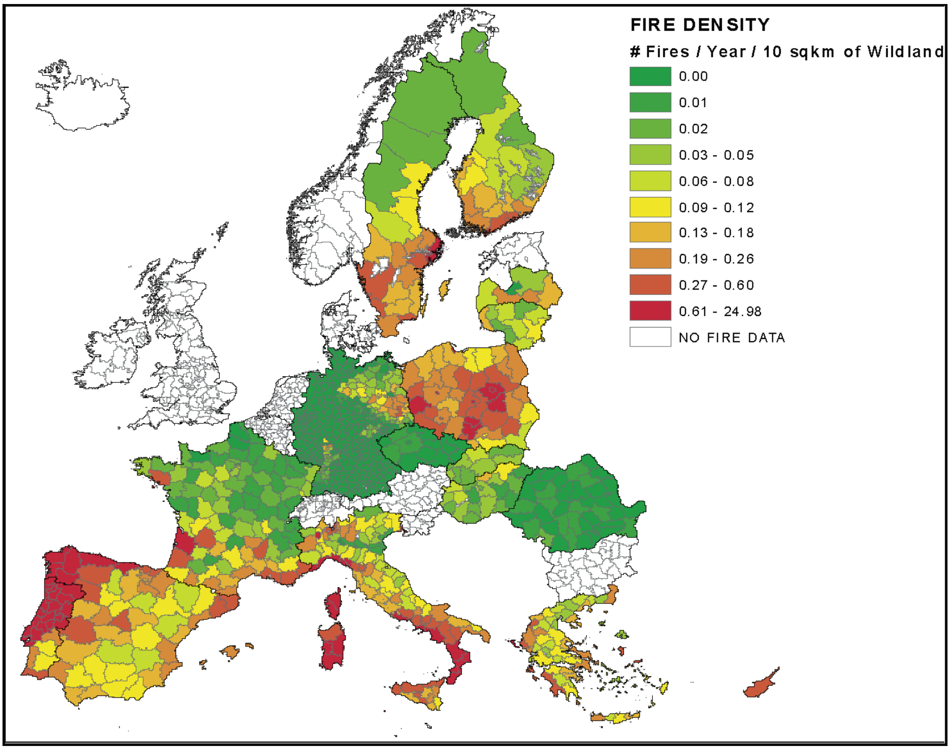

Figure 3. Average annual distribution of the number of fires in the EU by province.

About 95% of the forest fires in Europe are caused by people. Therefore it is important to show the variability of forest fire statistics, not only at the country level, but at the regional and provincial levels. A standardized figure of ‘fire density’, i.e. number of fires by 10 square km of wildland area in the country can be used for this purpose. Figure 3 shows this fire density map by province for those European countries for which data are available in EFFIS. The figure shows that forest fires are a recurrent phenomenon in the EU Mediterranean countries, and that they also occur with a relative high frequency in other central and northern European countries. Figure 3 shows the average annual distribution of the number of fires for the EU by province, which provides a good overview of the spatial distribution of fires in Europe. This data suggest that the pattern of forest fires is not related only to climatic conditions, but also to socio-economic causes that affect fire ignitions (see Chapter 2.1).

Temporal patterns of forest fires occurrence in the Mediterranean shows a major peak in summer, and secondary peaks in spring and autumn.

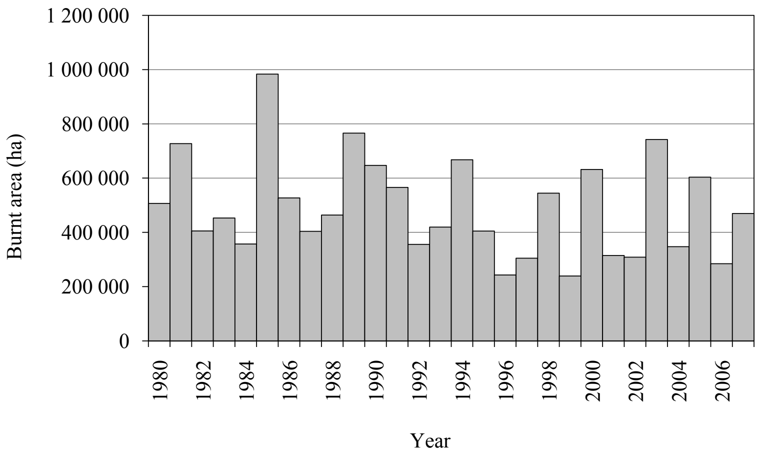

Figure 4. Burnt areas in the EU Mediterranean region.

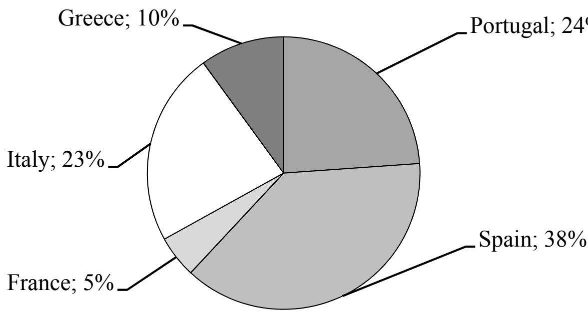

Figure 5. Distribution of burnt areas in the EU Mediterranean countries.

Forest fires in the Mediterranean region have three peaks of activity, the largest one in the summer, that is, during June, July and August, sometimes extending until September. The second peak of activity is in the spring, partly due to seasonal agricultural practices, straw burning, shrub clearing etc. Finally, a third peak is on the mountain regions in the winter. This is often due to dry periods and early snow melting in February and March, associated to the Foehn effect, which results on dry wind coming down a mountain and warming up as it descends.

On average, 500 000 hectares of Mediterranean forests burn every year, mainly located in Spain, Portugal, France, Italy, and Greece. Large fires (> 50 ha) account for 75% of the total burnt area while they represent only 2.6% of the total number of fires.

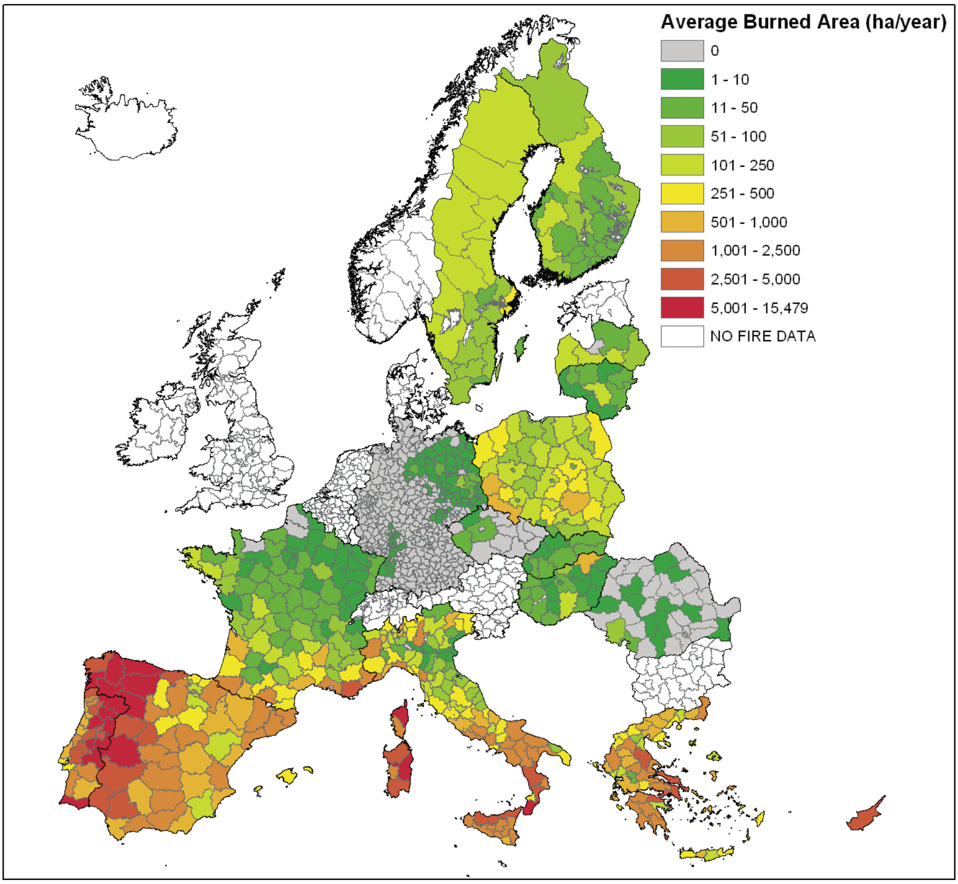

Figure 6. Map of burned areas in the EU by province.

On average, about half a million hectares of forested areas are burnt every year in the Mediterranean region, as illustrated in Figure 4.

The patterns of burnt areas in the Mediterranean region change yearly, as they are closely related to weather conditions in the region. Most of the burnt areas in the EU Mediterranean region are located in Spain, Portugal, and Italy, with smaller areas in Greece and France (Figure 5). The map of average burnt area by province in the EU (Figure 6) shows the spatial distribution of the burnt areas in the Mediterranean region, and provides a basis for comparison with the rest of Europe.

Most of the burnt areas in the Mediterranean region result from fairly large fires, that is, larger than 50 ha. They are responsible for approximately 75% to 80% of the total area burned every year. In the period considered (1980 to 2006) these fires were responsible for 74.6% of the total burned area in the region, even though these were only 2.6% of the total number of fires.

The number of very large fire (> 500 ha) remains stable over time.

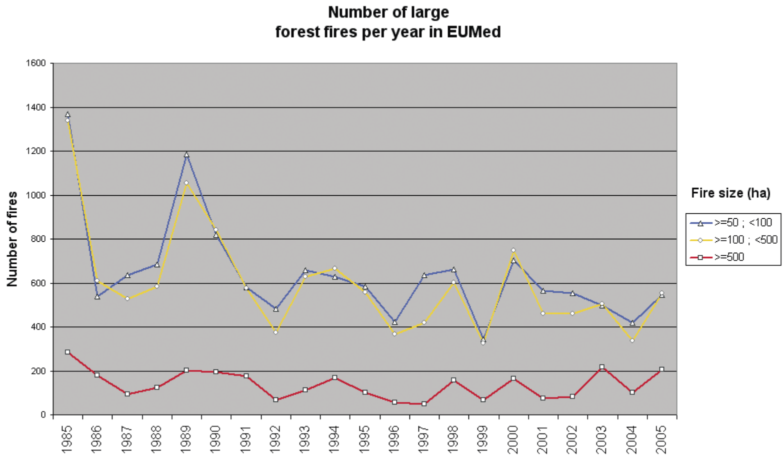

Figure 7. Trends of forest fires by fire size in the EU Mediterranean region.

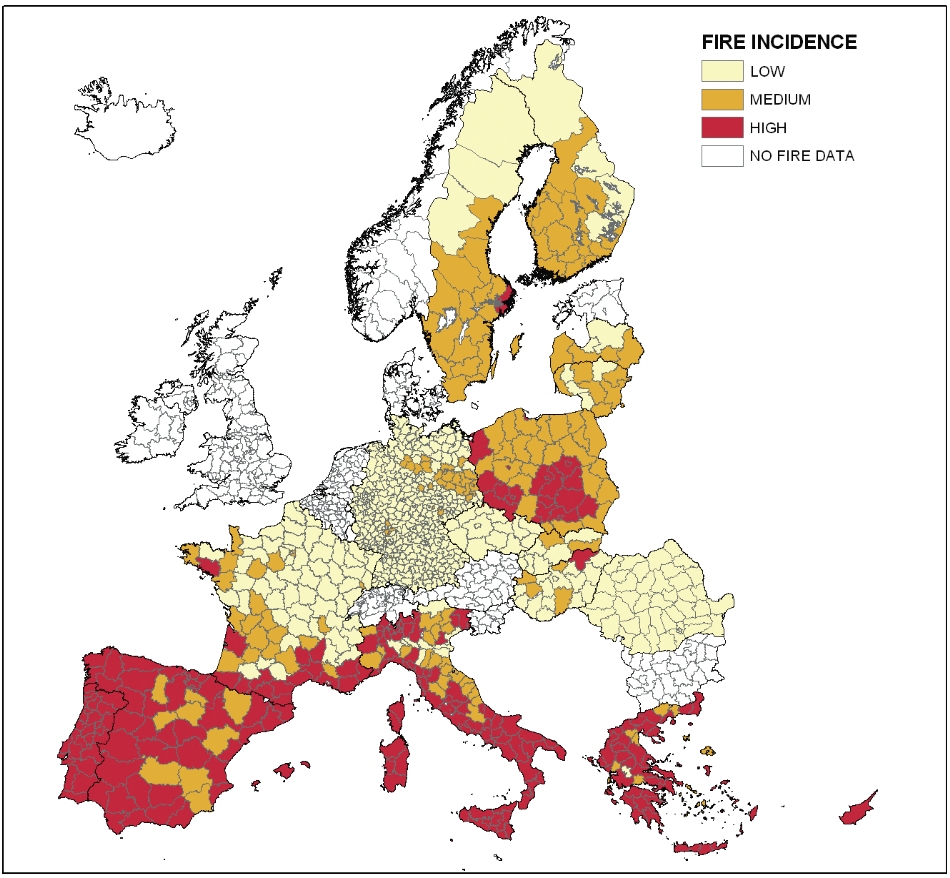

Figure 8. Fire incidence map for the EU.

Figure 9. Raging fires in Greece (Aug. 2007). Credit: NASA

It is important to note that although the total number of fires in the region shows an increasing trend, the number of very large fires, i.e. those burning 500 ha or more, remains stable over time (Figure 7).

Forest fire incidence appears, not surprisingly, fairly high throughout the Mediterranean region, but also in western France, Poland and further north: Finland and Sweden.

In order to analyze the impact that forest fires have in the Mediterranean region, both the number of fires by wildland area and the total burnt area by wildland area were summarized, forming a forest fire incidence index. This index identifies areas in which fire incidence is high because either the number of fires is high (although the total burnt area may be low due to efficiency in fire prevention and preparedness), or the burnt area is high, which could be due to a high or low forest fire frequency. Figure 8 shows fire incidences in the EU in the form of a map.

Recommended reading

Barbosa, P., Palumbo, I., Kucera, J., Camia, A., San-Miguel-Ayanz, J. and Schmuck, G. 2008. Assessment of forest fires impact and emissions in the European Union based on the European Forest Fire Information System. In: Bytnerowicz, A., Arbaugh, M., Riebau, A. and Andersen, C. (eds.), Wild Land Fires and Air Pollution. Elsevier.

Camia, A., Amatulli, G. and San-Miguel-Ayanz, J. 2007. Forest Fires and Climate in Southern EU: Preliminary Analysis of Current Trends. JRC Scientific & Technical Reports. 26 p.

Kohl, M., San-Miguel-Ayanz, J. and Camia, A. 2007. Forest Damage (Indicator 2.4), in Kohl, M. and Rametsteiner, E. (eds.) MCPFE/UNECE/FAO State of Europe's Forests 2007 - The MCPFE report on sustainable forest management in Europe, Criterion 2. Maintenance of Forest Ecosystem Health and Vitality. Pp. 25–29

San-Miguel-Ayanz, J., Camia, A., Liberta, G. and Boca, R. 2007. Analysis of Forest Fire Damages in NATURA 2000 Sites During the 2007 Fire Season, JRC Scientific & Technical Reports. 36 p.

Schmuck, G., San-Miguel-Ayanz, J., Barbosa, P., Camia, A., Kucera, J., Amatulli, G., Boca, R., Schulte, E. And Dierks, H. 2007. Forest Fires in Europe 2006 - EUR 22931 EN, JRC37598.

2. Why and How Do Woodlands Burn? What Is the Resulting Impact?

2.1 The Causing Factors: A Focus on Economic and Social Driving Forces

Ricardo Vélez

Major social and economic changes in land use have affected the wildland/rural interface as well as the wildland/urban interface resulting in an increased amount of biomass (fuel), higher exposure to man induced fire, and conflicts.

In the Mediterranean region, direct causes of fire, i.e. the ignition, are in 90% of cases related to human activities (agricultural and forestry operations, garbage dumps, power lines, accidents) and behavior (recreation, delinquency, unawareness, smoking) while natural factors such as thunderstorm lightning play a minor role. Important indirect causes affecting the occurrence, behaviour and effects of wildfires are related to climatic factors such as high temperatures and long dry periods altering the water status in plants, and strong winds accelerating the combustion and propagation processes. Today, improved tools for assessing the risks linked to these factors are available and used at an operational scale. However, we do not have any means to control or influence the climate, at least in the short run. Other major fire causes are related to the fuel (i.e. the vegetation) characteristics in terms of biomass and its spatial distribution, as well as to its exposure to fire. These elements are to a large extent driven by social and economic forces. Therefore, it is particularly relevant for policy- and decision makers to look at them, because these are the factors they can act on.

The current situation in the European Mediterranean woodlands is characterised as follows: i) depopulation of rural areas because of better employment opportunities in urban areas and average overaging of the remaining people; ii) abandonment of traditional uses in rural environments as a result of depopulation; iii) tendency of reduced use forests use as a raw material producer, or at least to be reduced noticeably; iv) tendency of abandonment of traditional uses such as grazing and firewood use; v) tendency of increase of recreational use of wildlands; vi) continuous growth of the forest-urban interface. These unplanned circumstances have led to the resurfacing of old conflicts between people, as well as to news ones, which are manifested in various ways. Fire has become an increasingly violent means in these conflicts, as will be discussed next.

Conflicts at the wildland/rural interface are mainly related to: rural abandonment, inconsistent policies on land management (fire use and grazing), and the designation of protected areas for nature conservation.

Living with Wildfires: What Science Can Tell Us
Yves Birot (ed.)

Abandoning the land. The conflict arises as a result of rural activities ceasing on marginal lands, either spontaneously or encouraged by the EU policy to reduce agricultural surpluses. Abandonment of land cultivation results in an invasion by forest species, a process which would lead to forest formation. This generates the most dangerous types of light fuel accumulations with a high level of continuity in the horizontal and vertical distribution of the fuel, in which ignitions can easily spread, take on high speeds and intensities and are extremely difficult to control. In these areas, lightning is a major cause of fires. For instance, in the increasingly deserted mountainous areas of Central Spain the number of lightning fires amounted up to 25% of the total during the years 1996 to 2005 with a maximum of 52% at the Teruel province. The continuing trend of land-use and forest abandonment (or non-management by their owners who are non-residents and do not have an active interest to manage the forests due to low profitability) is worsening the situation.

Grazing land and the use of fire. The conflict arises as a consequence of the traditional use of fire to maintain pastures and get rid of ligneous vegetation. In general, the legislation of all Euro-Mediterranean countries forbids the use of open fires and agricultural burning inside and in the vicinity of forest areas (e. g. 200 m in France, 300 m in Portugal and 400 m in Spain). Outside this area, a permit must be requested from forest services, which will be granted depending on the fire danger index. In general, there are rules establishing the fire season during which permits are not granted for any reason. Nevertheless, this preventive legislation is indirectly countered by regulations for protecting people living in the mountains. The EC incentive policy consists of subsidies per head of sheep and goats with no relation to the area of land on which these animals will graze. In addition, they are allowed to migrate seasonally to new pastures. The people who turn to these subsidies are those who know how to apply for them and are often from the urban environment. Afterwards, they use shepherds to look after their livestock. The lack of relationship between landowner and use of the land, leads to shepherds applying fire in a more uncontrolled fashion, thus causing wildfires. The conclusion is that this conflict is neither sufficiently discussed nor clarified to public opinion, thereby producing a lack of attention from administrations to prevent undesired effects from the incentives mentioned.

Designation of protected areas for nature conservation. The conflict arises from the limitations these designation brings to local communities. When a region is declared specially protected (national park, natural park, etc), certain restrictions arise directed towards conservation or restoration of natural resources. This has an immediate influence on the lives of local communities and may clash with their uses and customs. Confrontation can occur, of which the forest fire is a symptom. The tendency in protectionist policy is to recognise these potential conflicts and take compensatory measures which should be extended to the area of influence of these protected regions. The conclusion is that this conflict will tend to spread, even though it may be controlled by good management of protected regions.

"Slash and burn" for agricultural purposes or systematic burning of agricultural waste. The first conflict arises out of the use of fire to eliminate forest vegetation and its subsequent replacement by agricultural crops. However, there is a current tendency of decrease of this conflict due to lack of demand to establish new agricultural cultivation areas. Only in places where irrigation is possible, which is usually highly profitable in Mediterranean countries, can this kind of land demand still be seen. Obviously, the extent of irrigated lands is highly limited in space because of water availability. In addition, EC

policy for preventing surpluses (CAP) aimed at reducing agricultural surpluses is deterring further settlements on forestland which are usually low productivity type lands due to their quality or slope. The second conflict is about the use of fire to get rid of harvest residues (stubble burning) and prepare the land for further sowing that is a traditional operation on cereal cultivation land. It is also performed to remove underbrush and weeds and anything that interferes with farming. These practices are presently forbidden by the EC which does not allocate CAP subsidies after fire. That is why these conflicts have a decreasing impact. Nevertheless it is not evident that they are about to disappear. For instance, at the Northwest of the Iberian Peninsula a new interest in cultivating a certain variety of grapes that are producing a high-priced type of wine led recently to a wave of fires for vegetation clearing. Another problem derived of land abandonment is the closing of lanes, trails and secondary roads invaded by the natural vegetation. Setting fire to open them is a new cause of rural origin.

Unbalanced management or suppression vs. fuel management. Governments tend to increase the budgets for suppression resources. This is resulting in reduced availability of financial resources for fuel management. The real success of those strong suppression systems have a paradoxical effect, that is, they keep vegetation unburned – a development that contributes to dangerous fuel accumulations. Silviculture, intensive land-use, including the application of sound, benign, sustainable and safe use of controlled fire in agricultural and pasture management (see Chapter 3.5), however, would contribute to easing the situation.

Conflicts at the wildland/urban interface are mainly related to increased and uncontrolled urbanization in wildland areas; recreational use and poor waste management practices are also significant.

Land use change into urban use. The conflict arises with the rapid spread of urban areas, which occupy bordering agricultural land and then move into more remote forest lands. Currently available individual and public commuting transport to urban areas implies that an even greater proportion of land has urban development potential. Some people say that targeted burning of vegetated lands would make it easier to get permissions for land use change to allow construction of residential areas. However, this has not been proven in any case. It is therefore a subject for investigation to ascertain whether or not this is true. Nevertheless, the main issue is the steadily growing interface between wildland and urban areas, in particular with the development of diffuse individual house construction, in relation to loose policies in the approval of building permit. Relationships can be established between spatial repartition of fire ignition points and wildland urban interfaces. Several studies have shown that around three quarters of fire ignition points are located in the interfaces and the majority of them are located in interface type characterised by high aggregation of vegetation and high density of houses. Moreover, when fires break out, priority in fire suppression will be logically given to the protection of people and houses, leaving the forest to be burnt (see also Chapter 3.1).

Expansion of recreational uses in the forest area. The conflict arises as a result of forest areas being invaded for recreational activities such as hiking and hunting. The ever growing presence of people in the forest turns into a higher likelihood of negligent use of fire in open air cooking or by smokers. Some hunters may even use it to force animals to show themselves. The current tendency is to enforce regulations, intensifying surveillance and limiting travelling in the forest. Another practice, typical till the 1980s, i.e. building barbecue areas in the forest, is being abandoned. Those areas already in existence are being dismantled and open air fires within forest areas are being banned. This conflict is growing in importance but can be contained with means such as education and deterrent surveillance.

Garbage disposal by fire. This conflict is acquiring a growing importance with the amount of waste being produced in urban areas. The enormous amounts of rubbish in the larger cities have given rise to heavy investment in processing equipment. However, in medium to small towns, it is still piled up and eliminated by burning. Fire escapes can turn into a forest fire. This is a conflict requiring greater attention from local authorities, who are the people really responsible for this problem.

Other conflicts and causes are not directly related to the use of land but rather to human behavior (revenge, delinquency, pyromania) or improper management.

Revenge may be directed at individuals or at society and fire is one of the many means used. The reasons vary from the frustration of a hunter not able to find a place to hunt to quarrels between private citizens. Acts of terrorism can also be included in this category, although there is not much reliable information available. Delinquency is often linked to the use of fire to hide another offence or to help in perpetrating it by poachers, smugglers and hooligans. Intentional fires may be set by temporary forest workers who want to preserve their jobs. Other causes are related to poor management practices such as military exercises, public works with explosives, badly maintained power lines and vegetation management. Pyromaniacs are also reported to cause wildfires, although their role is often exaggerated.

Conclusion: there is a large room for innovative and improved policies related to land use, agriculture, urbanization and education.

Recommended reading

Caballero, D., Beltran, I. and Velasco, A. 2007. Forest Fires and Wildland-Urban Interface in Spain: Types and Risk Distribution. In: Proceedings of the 4th International Wildland Fire Conference, Sevilla, Spain, 13–18 May 2007. http://www.fire.uni-freiburg.de/sevilla-2007.html

Lampin, C., Jappiot, M., Borgniet, L. and Long, M. 2006. Cartographie des interfaces habitat-forêt: une approche spatiale pour estimer le risque d'incendie de forêt. Revue internationale de géomatique. European Journal of GIS and Spatial analysis. Information géographique et gestion des risques 16(3–4): 321–340.

Ministry of the Environment 2006. Los incendios forestales en España, Decenio 1996–2005, Madrid, Spain.

Velez, R. 2002. Causes of forest fires in the Mediterranean Basin. In: Arbez, M., Birot, Y. and Carnus, J-M. (eds.). Risk Management and Sustainable Forestry. EFI Proceedings 45, 2002. European Forest Institute.

Velez, R. 2007. Experiences in Spain of Community Based Fire Management. In: Proceedings of the 4th International Wildland Fire Conference, Sevilla, Spain, 13–18 May 2007. http://www.fire.uni-freiburg.de/sevilla-2007.html

2.2 Fire Start and Spread

Jean-Luc Dupuy

Fire start and spread are governed by the physico-chemical processes of pyrolysis, heat transfer and combustion

---

Fire ignition, which is the initiating step of the combustion of a fuel, can occur only when a heat source, a fuel and an oxidizer are all present at the same time in the same physical space. In the particular case of woody fuels – solid fuels – heat transferred from the source to the vegetation makes the temperature of the fuel rise and beyond some threshold called ignition temperature (about 300°C), the vegetation releases flammable gaseous fuel – this the pyrolysis process – at a high rate. The gaseous fuels react with oxygen – this is the flaming combustion process – releasing a huge amount of heat. Basically fire spread is possible when fire ignition has occurred and when the amount of heat transferred from the pre-existing fire to neighbouring fuel is high enough to cause its ignition. The rate of fire spread – the speed of the fire – depends on the strength of the heat source, on the efficiency of the heat transfer processes, and on the energy required to raise the temperature of the fuel to the ignition temperature. Heat transfer processes are radiation and convection. Fire spread may be enhanced due to the transport of firebrands to some distance of the fire. These firebrands may ignite the fuel at the point they reach and a secondary fire, called a fire spot, appears. Spotting can occur several hundred meters from the main fire front. Pine and oak stands are susceptible to produce fire brands causing spotting far from the fire front.

Fire spread is not only the propagation of fire following the terrain slope, but also the propagation of fire from surface fuels (litter, grass, shrubs) to crown fuels (foliage of tree crowns). Fire that burns only surface fuels is called a surface fire and fire burning also tree crowns is called a crown fire.

Understanding how woodlands burn amounts to understand how the basic processes of pyrolysis, combustion and heat transfer are affected by the different environmental factors.

Knowledge of theses effects and their quantification has been the purpose of many scientific investigations based on observations, experiments and models. Forest fuel moisture and wind are probably the most obvious factors affecting fire spread. Since the water content of the fuel must be evaporated before ignition can occur and since boiling of water requires a huge amount of energy, fuel moisture content is the most important

Living with Wildfires: What Science Can Tell Us
Yves Birot (ed.)

parameter influencing fire start. Moisture content also influences fire spread. This is why so many efforts have been made to measure or predict the moisture content of vegetation as influenced by meteorological conditions and biological cycles. In free-burning wind-driven fires, the wind bends the flames towards the unburned vegetation. This enhances the heat transfer to the unburned fuel. It has been observed that the rate of fire spread is more or less proportional to wind speed at least for low to moderate wind speeds and for surface fires. The terrain slope also affects fire spread and a steep relief is known to cause very dangerous situations for fire-fighters. The amount of forest fuel and its distribution in the vegetation layer is also a factor affecting fire spread. In addition, the fire power, often called 'fire intensity', is directly influenced by the amount of fuel.

Fire modelling: a powerful technology for the simulation and prediction of fire spread

The scientific observation of fires in natural conditions is a hard task. As for many environmental phenomena, fire modelling has been a way to reduce the amount of observations necessary for understanding and predicting fire behaviour. Two modelling approaches have been developed, empirical and physically-based. Empirical models for fire spread are established on the basis of a reasonable number of fire observations and predict the rate of spread of a fire. Usually, simple mathematical formulas give the fire rate of spread as a function of a small number of parameters (wind, fuel height, fuel moisture, and sometimes slope). The Australian or the Canadian models used by forest and fire managers are well-known empirical models and scientists have recently developed similar models in Spain and Portugal. Physically-based models are based on the principles of physics and attempt to quantify the basic mechanisms of fire. However, only in the last decade, a full representation of wildfire physics has been able to predict fire spread. The so-called coupled atmosphere-fire models enable three-dimensional simulations of fire spreading at the scale of a pine stand (< 20 ha); however, this approach requires the use of super-computers. They provide predictions of all fire characteristics. Simplified versions of this kind of model can also simulate fire at larger scales (10 km^2), but important research effort is still necessary on this topic. Empirical or physically-based models have been also developed for fire spotting.

Fire behaviour is predictable but only in average.

Scientific investigations of fire behaviour have established significant correlations between the key influencing factors – wind, fuel properties, slope – and fire rate of spread. This is why empirical models are successful for operational predictions of fire spread in the range of environmental conditions that served to establish them. Fire is also governed by the laws of physics and as such is not a completely random process. These facts mean that some aspects of fire are predictable at some scales. This is essential to decide strategies of fire prevention and mitigation.

The question of fire behaviour predictability however remains important. Fire observations done by experts of wind flows and recent advances in coupled fire-atmosphere modelling have revealed that wind turbulence plays a dominant role in erratic fire behaviour often observed in the field. In addition the turbulence level, which measures the amount of local wind fluctuations, is increased by buoyancy effects. Hot gases in a fire plume are less dense than ambient air and rise vertically in the atmosphere by virtue of the Archimedes principle; the driving force is called the buoyancy force and the upward vertical motion of hot gases is accompanied by downward vertical motion of fresh air. This physical situation is very unstable and explains why fires releasing a high power are susceptible to exhibit very erratic and dangerous behaviour. A simple physical criterion based on the relative force of wind and buoyancy has been proposed to identify such unstable situation, but the prediction of the criterion itself remains delicate.

It is well known in the field of fluid mechanics that turbulence effects are only predictable in average. That means that one must expect great variations in fire behaviour from one time to another and from one point to another. Fire practitioners or fire fighters operating at ground level are primarily concerned with these effects, which are mainly significant at local scales (< 1 km). The natural heterogeneity of vegetation or the mechanism of spotting are additional sources of fire behaviour variability.

Wildfires are difficult – sometimes impossible – to control and rules for danger evaluation in real fire fighting conditions should be established.

Wildfire science has established methods to compute fire intensity. A wildfire releasing ten thousand kilowatts per meter of fire front length is not unusual in severe weather conditions corresponding to a dry summer and a windy day. A 100 m portion of such a fire line releases a power comparable to the one of a nuclear power station in order of magnitude and could evaporate a 20 m^3 volume of water each minute. Crown fires commonly exhibit huge intensities, several thousands of kilowatts per each meter of fire front length have been reported. These facts remind that wildfire is a dangerous phenomenon and is difficult to control. The transition of a surface fire to crown fire potentially increases the danger and the difficulty of fire fighting. The natural variability of fire behaviour, which was mentioned above, is also an additional factor to the danger and difficulty of fire fighting. Establishing simple criteria or rules for the assessment of danger level for fire fighters or fire practitioners could be helpful for fire safety. Rules should use simple observations of environmental conditions and actual fire behaviour. These facts also reveal the benefit one can expect by reducing the amount of fuel, which is expected to reduce the fire intensity

Adequate management of wildland fuel should reduce fire intensity and severity and physically-based models should help the decisions making process

Contrary to wind, slope and with some exceptions to fuel moisture content, the amount of vegetation and its distribution may be influenced or even controlled by human activities. The reduction of the amount of biomass is almost the only way to reduce the potential

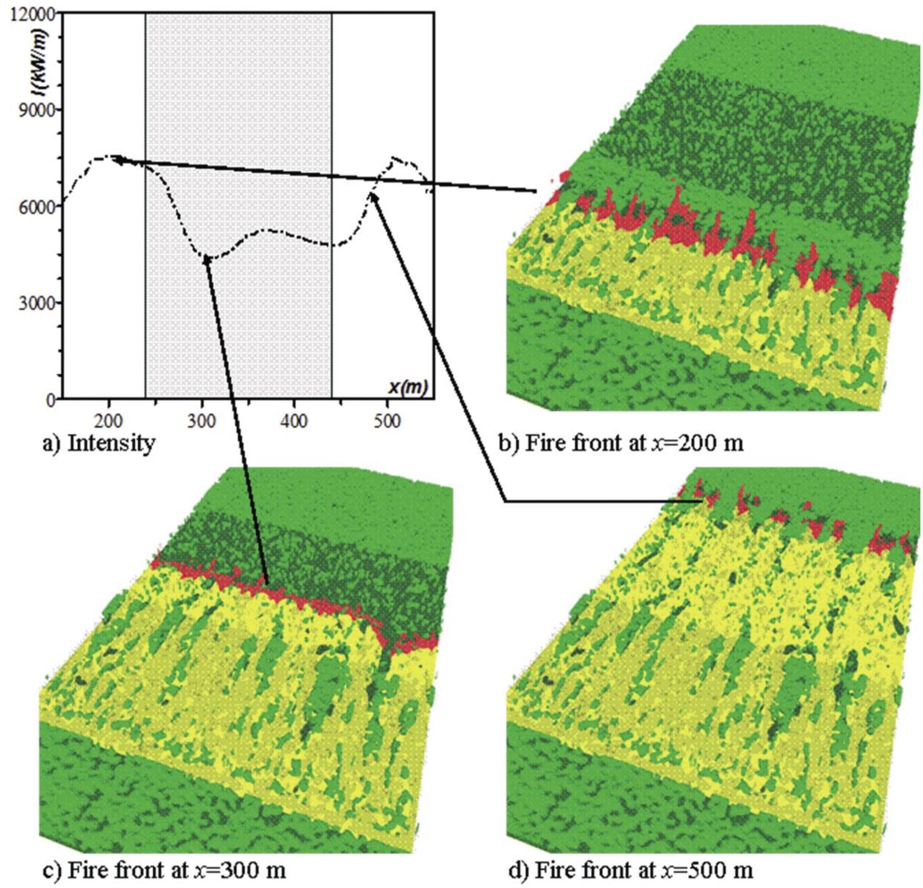

Figure 10. Numerical simulation of a fire spreading over a fuel break in a Pinus halepensis stand, using the coupled fire-atmosphere model FIRETEC (INRA – LANL joint work, Pimont et al. 2008). Cover fraction of trees on the fuel break is 25%. The fire spreads along the x-axis and the fuel-break extends from x=240 m to x=440 m. Flame contours in red are deduced from computed isotherms. Green and yellow colour contours are used respectively for tree canopy and surface fuels (shrubs, grasses) representations (iso-contours of computed biomass density).

for fire spread and damages. The extensive use of prescribed burning has been developed for a long time in North-America or Australia to this aim. It has started to be developed in some Mediterranean regions of Europe during the last decades and is often applied to forest areas specifically devoted to fight fire. These areas are often called fuel-breaks. Many questions arise from forest and fire managers on the efficiency of surface fuel reduction on tree survival, on the dimensions and the position of a fuel break in a forest, or on the effect of clearing on fire intensity. To date answers have been usually given from the expertise of wildfire specialists, but not from specific tools based on sound science.

Also it is usually impossible to test the different hypotheses through experimental fires in severe conditions, since one should accept to burn forested areas with high tree mortality level. Coupled fire-atmosphere models should give relevant answers in the near future. A simulation of a fire spreading over a fuel-break is shown as an illustration of the use of a coupled-fire atmosphere model (Figure 10). Similar simulations using varied vegetation patterns on the fuel-break have been done in both *Pinus halepensis* and *Pinus pinaster* pine stands [3]. These simulations revealed that: (i) fire behaviour strongly depends on the species due to different foliage densities, (ii) a 25% cover of trees on the fuel break decreases significantly fire intensity as compared to the untreated pine stand (75% cover fraction), but 50% is not efficient, (iii) it is more efficient to let a small number of large tree clumps than a large number of dispersed trees. These predictions have been obtained very recently and must be confirmed by deeper investigations. They are given here as a demonstration of the potential of these new tools. Effort should be done to transfer these new technologies for applications to forest and fire management.

Physically-based models of fire spread can predict the effects of new environmental conditions of burning expected from global change.

The global change will cause important changes in the environmental factors that influence fire start and spread. Changes in vegetation characteristics are particularly expected. First consequences have been observed with the sudden decline of some conifer forests in the south of Europe. An immediate consequence is the sudden reduction of moisture content of the vegetation. One can also expect that some species not yet adapted to heat and dryness will adapt to new climate conditions by reducing their moisture content or more likely by producing dead parts, as some Mediterranean species already do. Tree species are known to have large ability to adaptation. One can eventually expect that by migration new mixtures of plant species take the place of species no longer adapted to their environment. In order to assess the consequences of these changes on fire behaviour, empirical models will be of small value since they are based on fire observations made in existing vegetations. On the contrary recent physically-based models are powerful tools to explore new scenarios.

Recommended reading

Albini, F.A. 1993. Dynamics and modelling of vegetation fires: observations. In: Crutzen, P.J. and Goldammer, J.G. (eds.)Fire in the environment: the ecological, atmospheric, and climatic importance of vegetation fires. Report of the Dahlem Workshop held in Berlin, 15–20 March 1992.

Johnson, E.A. and Miyanishi, K. (eds.). 2001. Forest fires: behaviour and ecological effects.

Pimont F., Dupuy, J-L. and Linn, R.R. 2008. Impact of fuel-break structure on fire behaviour simulated with FIRETEC. Proceedings of Forest Fires 2008, International Conference on modelling, Monitoring and Management of Forest Fires, 17–19 September 2008, Toledo, Spain.

2.3 Wildfires Impact in 3D: Environment, Economy, Society

Yves Birot and Robert Mavsar

Impact of wildfires on nature and society must be assessed over a long period after occurrence with full appraisal of how humans, goods and services are affected.

Wildfires have a temporal impact ranging from the combustion period up to a few decades afterwards. They affect not only the forest and woodland ecosystems, but also the adjacent systems (agricultural, urban, transport and power lines networks, etc.) and the civil society (resident or non resident) in many aspects: human life and health, wellbeing, employment, economic and social activities, etc. The nature and availability (when possible) of wildfire impact information provides a foundation for the understanding and incorporation of this information into wildfire policies, risk assessments, and management practices. A rigorous impact assessment should therefore be a pre-requisite and consider the whole set of all relevant wildfire impact categories, as listed in Table 1.

However, the level of quality and availability of information is very variable from a category to another so that there is no "full picture" of impacts, not even at a country scale. Some documented examples are presented in this chapter.

Wildfires have an important impact on air pollution with consequences for human health, and on greenhouse gases (GHGs) balance.

Air pollutants and particles are released to the atmosphere during the combustion process (and later for some of them), affecting air quality and human health in particular for populations downwind located. Significant correlations between forest fire activity and air pollutants (ozone, carbon monoxide, nitrogen monoxide, particulate matters) concentrations in the atmosphere have been reported. New findings in the Mediterranean and in the US have pointed out the role of wildfires in the release of large amounts of mercury compounds (about 40% of the total emissions). Recent investigations have shown that large wildfires, such as those in Portugal (2003) may account for the emission of a high proportion of GHGs (Figure 11) compared to the transport and industry/services sectors leading to undermining the efforts for complying with the commitments linked to the Kyoto protocol. However, on average, forest fires in the European Union provide a minor contribution, if compared to industrial emissions.

Living with Wildfires: What Science Can Tell Us
Yves Birot (ed.)

Table 1. Wildfire impact categories: ■ economic, ▲ social, ● environmental.

Damage to homes and structures ■ ▲
Air pollution & public health impacts ■ ● ▲
Evacuation of adjacent communities ■ ▲
Destruction of cultural and archaeological sites ▲ ■
Impact on transportation flow and networks ▲ ■
Damage to soils, watersheds and water supply ● ■ ▲
Damage to adjacent agricultural systems ■ ▲
Cost of fire suppression ■
Damage to timber resources & other forest products, and future production losses ■ ▲
Insurance and taxation cost ■
Damage to recreation facilities ■ ▲
Alteration of biodiversity & wildlife habitat ● ■
Carbon emission ● ■
Costs of rehabilitation and restoration ■

Wildfires result on short run in increased water peak flows and soil erosion causing serious problems, but a progressive return to normal after a few years is usually observed, once a new plant cover has been established

In hilly and mountainous watersheds post-fire heavy rainfalls (a frequent case in the Mediterranean) result in marked modifications of the water cycle with increased peak flows and annual water yield, and activation of soil erosion processes leading to heavy soil losses. On a short run (2–3 years), this may cause serious damage such as floods, mud flow affecting human habitats, and related systems (road, agriculture, water resources, etc,), but also the woodland ecosystems with a regressive evolution of soil physical and chemical properties whose recovery is extremely slow. In serious cases, a quick intervention after fire for controlling these associated risks must be implemented (see Chapter 3.3). However, these phenomena have usually a temporary nature, and will decrease with the reconstitution of the ground cover (see below), provided the fires are not too frequent. The speed of this process can be reduced by limiting factors (low fertility, drought).

Large wildfire is a major disturbance to habitats, tree and plant, animal and microbial communities and population, and biodiversity in general. However, natural recovery processes may usually, on a long run, overcome the situation and impression of catastrophe prevailing after fire, subject to the level of resilience of ecosystems prior to fire, and a low hazard frequency (> 30 years).

Plant community resilience after fire is determined by species' ability to regenerate through two main mechanisms: growth of new sprouts (resprouter species) and

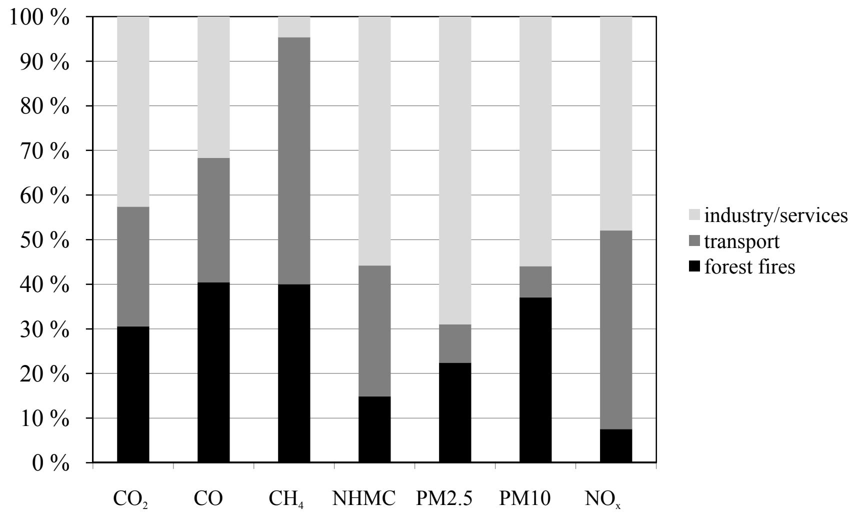

Figure 11. Comparison between anthropogenic and forest fires emissions (%) in Portugal, for 2003. CO_2: carbon dioxide, CO: carbon monoxide, CH_4: methane, NMHC: non methane hydrocarbons, PM 2.5 & PM10: particulate matters (particles < 2.5 μm and <10 μm), NO_x: nitrogen oxides (after: Miranda et al. 2007).

germination from surviving seed banks or from seeds arriving from neighbouring populations (seeder species). Evolutionary and paleological studies suggest that fires are natural in the Mediterranean Basin. Natural selection pressure exerted by fire has shaped over millenaries the current Plant Functional Types, which make most of Mediterranean forest ecosystems (especially oak forest and shrubland) capable to reconstitute themselves after fire. However, natural fire frequency (mainly caused by thunderstorm lightning) is believed to be in the order of magnitude of a few decades, while human activities (farming, grazing,) and human induced fires have, in the history and until now, have been accelerating disturbing factors, in particular during the 20th century. Today the frequency, size and intensity of wildfires have dramatically increased in some areas; they may affect the resilience of some ecosystems (e.g. pine forest) and lead to a regressive evolution.

Large wildfires may also in some cases lead to the extinction of local populations and thus to an erosion of genetic resources as exemplified by natural populations of *Pinus nigra* ssp. *clusiana* in southern France. They can also jeopardize the investments devoted to nature conservation as experienced on the Natura 2000 network in Spain (Galicia) and in Greece. In a simplified manner, one can state that wildfires are not threatening so much the “ordinary biodiversity” but rather the “extraordinary biodiversity” such as remarkable habitats, species or populations.

All in all, “although many Mediterranean basin plants have traits to cope with fire, a large number of the ecosystems currently found in this region are strongly altered, and may suffer disasters. Post-fire disasters are not the rule, but they may be important under conditions of previous human disturbances.” (Pausas et al. 2008)

Wildfires cause marked economic, social and human impacts.

The social and economic impacts caused by wildfires are of major importance. For example, the wildfires which in 2005 destroyed vast forest areas in Portugal caused almost 800 million € worth damages and took 13 lives. Even worse were the disastrous fires that stroke Greece in summer 2007, which caused 64 casualties and resulted in over 5 billion euro in damages. Even if these two cases represent extreme fire events, they may serve as examples of the magnitude of the socio-economic impacts of wildfires.

However, even if these values appear very high, it should be mentioned, that in most cases the only represent a part of the total value of losses. The values of the damages reported by the official statistics, in most cases, only include the value of lost market goods and services, while the value of lost non-market goods (e.g. biodiversity, carbon fixed, recreation spaces, natural beauty, cultural and historical value of natural spaces) are not considered.

In addition to the damages caused by wildfires, a significant amount of money is invested in prevention and suppression measures. As an example, the five Mediterranean countries which belong to the EU (Greece, France, Italy, Portugal and Spain) invest more than 2.5 billion euro each year in prevention and suppression, of which 60% is invested in equipment, personnel and forest fire suppression operations, and the rest is used in preventive work.

It should be noted that due to poor quality and availability of data, the estimation of the total socio-economic impact of forest fires in Europe is very difficult. Even on the national level the data is, in most cases, of low quality and very often not existing. However, an interesting attempt has been made by Portugal by presenting a matrix of forests’ values, which shows that the negative externalities due to wildfires account on average for 38% of total forests’ value.

Costs appear as consequence, response and in anticipation of wildfires

The economic losses due to wildfires are various and can be generally divided into those which occur as a consequence and response to wildfires and those related to the anticipation of wildfires.

Losses as a consequence of wildfires are incurring from the direct or indirect exposure of goods to fire. Under this category we can list losses of forest goods and services (e.g. timber, mushrooms, berries, places for recreation and tourism activities, landscape beauty, watershed protection, biodiversity), property (e.g. houses, cars, production capacities), infrastructure (e.g. power lines, roads, rail), human health (morbidity and mortality) and other losses (e.g. closure of roads, losses in production due to power cuts). These losses are mainly borne by the owners or users of the damaged good or service.

Further, as a response to wildfires, in general, extinction (man power and equipment) and restoration activities are launched. These activities produce costs that for the most part are borne by the society.

On the contrary, the costs in anticipation of wildfires are predominantly those which incur due to measures aimed at the prevention of wildfires and protection of property and people. These measures include fire prevention (e.g. removal of fuels by prescribed burning, thinning, fire breaks), wildfire related education and training, maintenance of fire fighting and other fire related equipment, fire safety measures in structures and infrastructure.

It is difficult to generalise, which type of the economic losses have the highest share, since this depends on the characteristics of the wildfire, and on the policy and fire management context. By characteristics it is referred to the size of the wildfire, the intensity (e.g. more intense wildfires are considered to generate more severe damages) and the location of the fire. Especially the location of the fire plays a very important role. For example fires occurring in the wildland-urban interface may cause very high property and infrastructure damages and have severe impacts on human health, but cause less ecological damages.

Recommended reading

Cinnirella, S., Pirrone, N., Allegrini, A. and Guglietta, D. 2008. Modeling mercury emissions from forest fires in the Mediterranean region. Environmental Fluid Mechanics 8(2): 129–145

González-Cabán, A. 2007. Wildland Fire Management Policy and Fire Management Economic Efficiency in the USDA Forest Service. In: Proceedings of the 4th International Wildland Fire Conference, Sevilla, Spain, 13–18 May 2007. http://www.fire.uni-freiburg.de/sevilla-2007.html

Mayor, A.G., Bautista, S., Llovet, J., and Bellot, J. 2007. Post-fire hydrological and erosional responses of a Mediterranean landscape: seven years of catchment-scale dynamics. Catena 71:11, 68–75

Ministerio de Agricultura. 2007. National Forest Strategy –Portugal. Government Order No 114/2006.

Miranda, I., Monteiro, A., Martins, V., Carvalho, A., and Borrego, C. 2007. The 2003 fire season in Portugal: impacts on air quality. Seventh Symposium on Fire and Forest Meteorology, 23–25 October 2007, Bar Harbor, Maine, USA.

Morton, D.C, Roessing, M.E., Camp, A.E. and Tyrrell, M.L. 2003 Assessing the Environmental, Social, and Economic Impacts of Wildfire , GISF Research Paper 001, Forest Health Initiative. Yale University, School of Forestry and Environmental Studies, Global Institute of Sustainable Forestry http://www.itcnet.org/includes/downloads/alandeconomicimpactsofwild.pdf.

Pausas, J.G., Llovet, J., Rodrigo, A. and Vallejo, R. 2008. Are wildfire a disaster in the Mediterranean basin? A review. International Journal of Wildland Fire. In press.

Pettenella, D. 2007. Economic estimation of forest fire damage in N-E Italy. Proc. 4th International Wildland Fire Conference. Sevilla, Spain, 13–17 May. 2007. http://www.fire.uni-freiburg.de/sevilla

3. Acting on Wildfires Risks: What Practices, Strategies and Policies?

3.1 Assessing Wildfire Risk in Time and Space

Marielle Jappiot, José Ramón González-Olabarria,
Corinne Lampin-Maillet and Laurent Borgniet

Short term risk refers to fire ignition and fire behaviour as influenced by quickly evolving factors related to climatic conditions or plant (fuel) status. Medium term risk refers to fire ignition and propagation as influenced by structural factors with slow change over time.

Short term risk assessments, through efficient operational indices based on weather and fuel characteristics, allow organizing the activity of fire pre-suppression, detection and suppression, and updating decisions (level of alert, management of fire fighting on the flaming front) in relation to changes in the fire risk level.

The weather can be considered as the most significant component for fire ignition and propagation and the assessment of the impact of meteorological factors on daily fire occurrence and behaviour has always been a key point for researchers. Vegetation characteristics are also important to consider. Short-term fire risk is assessed through indices based on daily and even hourly measures of vegetation moisture content and/or of meteorological variables influencing fire behaviour (air temperature, relative humidity, wind, precipitation). These indices considers the risk from the point of view of flammability/ignition ability depending on the fuel conditions (moisture content, temperature) and on the fuel type (continuity, compactness and on whether it is live or dead fuel). The main purpose of such indices is to provide information, in advance or instantaneously, concerning fire ignition or spread probability. Some indices are based on meteorological data only (in this case, the moisture status of the vegetation is estimated indirectly), others are based on vegetation stress related data, while a third type combines both weather and plant data. A number of these indices have been developed in Europe and elsewhere; reflecting the specific needs of each country with different risk management systems, depending on end-users (fire-fighters, foresters, etc).

At the EU level, the Joint Research Centre of the E.C. has developed within the European Forest Fire information System (EFFIS) a Fire Danger Forecast module which generates daily maps of 1 to 6 days projected fire danger level in EU using weather forecast data. The module is active from 1st of March to 31st of October and is fed with meteorological forecasted data received daily from French and German meteorological services. After a test phase of 5 years, during which different fire danger methods have been implemented in parallel, in 2007 the EFFIS network has finally adopted, with some slight changes, the Fire Weather Index (FWI) developed in Canada as the method to assess the fire danger level in a harmonized way throughout Europe. Fire danger is mapped throughout the E.U.

Living with Wildfires: What Science Can Tell Us
Yves Birot (ed.)

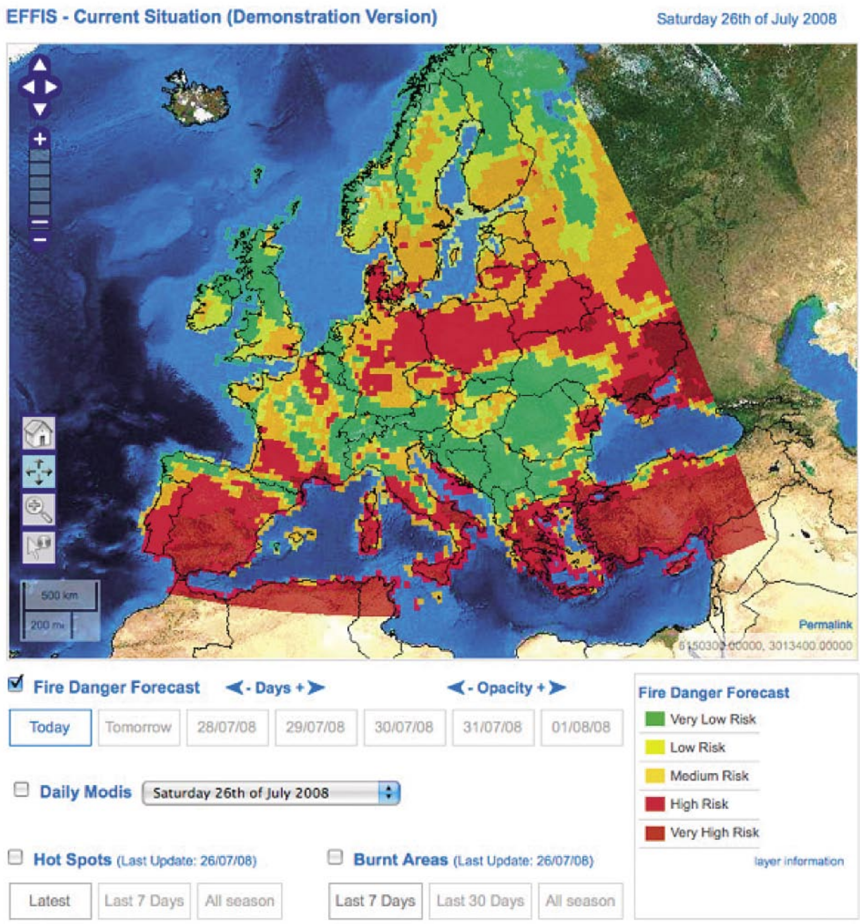

Figure 12. Map of fire danger forecast over Europe on 26 July 2008; EC Joint Research Centre.

with 5 classes, identical for all countries, and with a spatial resolution of about 45 km (French data) and 36 km (German data).

Research efforts now concentrate on the essential task to better identify characteristics of shrub layers, principal vector of fire and on the estimation of its water related status (water content):

- By direct measurement of water content, using a network of sampling stations;
- By numeric simulation of the global vegetation stress trend, using climatic observations (for a network of meteorological stations);
- By the assessment of plant water content, derived from radiations measured by space borne remote sensing (daily and medium resolution).

Medium term fire risk includes fire hazard and vulnerability, both influenced by human activities and land use. Its assessment considers: i) the probability of ignition occurrence related to human settlements and socio-economic indicators, and of fire spread; ii) potential damage related to fire intensity and vulnerability (incl. the value). Assessment methods are still under development.

Wildland fire risk can be defined as the expected loss due to wildland fires on a certain area and period of time. This concept encloses two different components: on the one hand, the probability that a wildfire affects the area during that period of time: fire hazard, and on the other hand, the potential damage that the fire will cause once it occurs: vulnerability. Medium term fire risk considers these two components over periods larger than a 1-year basis (2 to 10 years). The study of medium term fire risk requires information about the fire regimes in a determined region, trying to understand the factors that determine the landscape-scale spatial fire patterns.

The probability of fire occurrence, considered as an independent component, is influenced by: the probability of ignition occurrence, and the probability of fire spread across the landscape. In the Mediterranean basin, ignition is mainly related to human causes. However, human actions are rather erratic and unpredictable, and information about specific human activities at regional or national scale is seldom available. For this reason, most of the studies dealing with the effect of human activities on the probability of occurrence or frequency of fire ignitions in a certain area rely mainly on cartographic data on human settlements (e.g. roads, houses, power lines, rail roads, campgrounds, etc.), and/or general socio-economic indicators in the area (e.g. population density, presence of agricultural lands, rent distribution, level of unemployment, etc.). Some studies may include additionally climatic related variables to improve the accuracy of the models.

Fire spread estimations can be accurately obtained with currently existing simulators. However, for a medium term perspective, the use of regional scales and fire regimes is a more appropriate approach than single event studies. The medium term analysis of fire spread is based on static variables such as: topography, average weather conditions, living fuel dynamics, and spatial connectivity of fuels including landscape configurations. New satellite images with very high spatial resolution can provide a large amount of spatial explicit information useful for fire behavior prediction (see recent advances in remote sensing).

The assessment of potential damage takes into account: the intensity of fire, the vulnerability of the elements analyzed, and the value of those elements. Fire intensity depends on weather conditions (wind, moisture of fuels), topography (slope, aspect), and fuel loading and structure. Vulnerability to fire depends on the capacity of a structure (tree, house etc.) to sustain a certain level of heat intensity during a certain period of time without being seriously damaged. Other relevant aspect is the resilience or self-recovery capacity after fire. Forest and fuel management can play a major role in reducing the potential fire intensity and increase the forest resistance to fire, by reducing fuel loads and continuity (vertical and horizontal), and selecting more resistant forest structures.

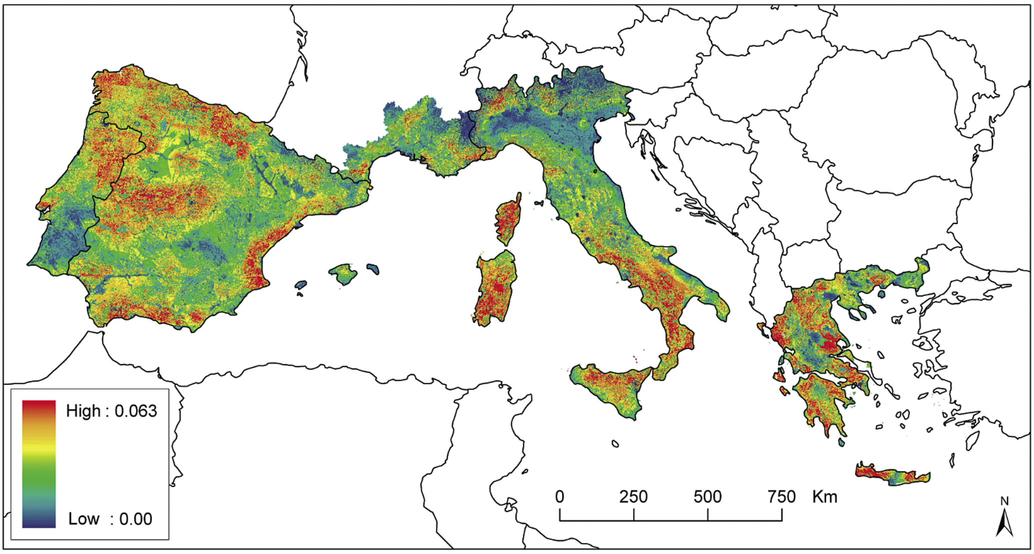

Figure 13. Wildland Fire Danger Assessment for 10 August, 2004 (EC project "Forest Fire Spread and Mitigation – SPREAD", contract number EVG1-CT-2001-00027).

Fire risk spatial indices constitute powerful operational tools for fire suppression and/or fuel management objectives.

The use of fire risk indices and associated maps across a territory can provide useful information about sensitive areas where additional efforts on fire prevention have to be implemented. The development of an effective fire risk index requires considering all the elements involved, such as, the susceptibility of a structure (forest, human-made structure etc.) to be affected by fire, its vulnerability to fire, and its value. Good examples of the methods to assess fire risk in different countries of the European Union have been obtained in the SPREAD project (Figure 13).

New methods of risk assessment are needed for the Wildland Urban Interface whose extension raises many concerns in regard to wildfire, and calls for better management. Harmonized methods based on spatial and temporal inventories and surveys are under development.

There is a growing concern regarding the issue of Wildland Urban Interface (WUI) as its extension results in increased wilfire risks. Therefore, it is crucial to have rigorous assessment of risks in such a context. WUIs are characterized by the combined presence of houses and dense forest in the same area. They can be characterized through the spatial arrangement of houses and vegetation. This coexistence of human settlements and forest carries an intrinsic increase of fire risk. On the one hand, the prevalence of human activities in areas without fuel (vegetation) control constitutes a permanent source of potential fire ignitions. On the other hand, once a fire occurs, WUIs may potentially be affected by severe losses, not only economic but also in terms of human lives. This high potential risk sometimes leads to derive the fire suppression means from their initially planned tasks and to allocate them to the WUIs. As WUI areas in Europe and especially in the Mediterranean region are composite systems with very complex spatial patterns, which are threatened more and more by forest fires over the last decades, many scientists and fire managers have emphasized the importance of a detailed spatial assessment of these sensitive areas.

One way of dealing with the difficult issue of fire risk in WUI is to implement an extensive inventory of WUIs, their location, surrounding forest characteristics, road network, fire defence infrastructures, etc. This kind of inventory will help to identify risky WUIs in terms of fire exposure, defensibility or evacuation facilities. These data can be used to design and implement preventive actions to correct the weaknesses. Moreover, such inventories will provide a valuable amount of information, which can be converted into thematic maps. They can be used also by fire-fighters during fire extinction, with an increased effectiveness and safety when working on WUIs. To develop such tools, a European method for characterizing and mapping WUIs in Mediterranean countries has been developed in the context of the Fireparadox project. It takes into account some approaches already developed in European countries.

The final objective of Wildland Urban Interface management (WUI) in relation to fire risk, should be to develop a set of strategies that increase the safety of the local communities, including landscape design, fire-safe construction recommendations, fire-response planning (defence and evacuation) and fire-wise education (people should understand that they are living in a risky place and they have the responsibility of take actions to defend themselves).

Promising technological advances in the capture and processing of satellite images pave the way to a future, effective and economically viable data frame for assessing fire risk (at short and medium-term) and monitoring the effectiveness of fuel treatments.

Fire is a spatially explicit event, so the knowledge of the spatial configuration and connectivity of different types of fuels is a key element to understand the potential behaviour of fire if it occurs. Obtaining information about the spatial configuration and connectivity of fuels requires continuous and repeated inventories at regional scale, not economically feasible with traditional forest inventories.

Remote sensing offers the potential to provide spatially distributed information on fuel types important for the assessment of fire risk and to mitigate the impact of wildland fires. Data of the two remote sensing systems, imaging spectrometry and LiDAR, are well suited to map the diverse and heterogeneous fuel types, especially within the complex

Figure 14. Two examples of WUI: dense (left) and isolated (right) dwelling in a forest landscape. Source: Cemagref/ C. Tailleux

Table 2. Mapping fuel types at landscape level based on airborne LiDAR and imaging spectrometer data over a Mediterranean site south of Aix-en-Provence Comparison of accuracy of Imaging Spectrometry and LiDAR used jointly and separately.

Remote sensing input	Overall accuracy	Kappa coefficient
IS & LiDAR	75.4%	0.716
IS	69.15%	0.645
LiDAR	31.73%	0.226

Mediterranean environment. The classification of fuel types is specifically dependant on the height, density and the surface type of the fuel. LiDAR observations sample the spatial information dimension describing the geometric properties of natural and artificial surfaces. Imaging spectrometry on the other hand samples the spectral dimension, which is sensitive for discrimination of species, surface types and fuel moisture. The observations of these two remote sensing systems can mutually complement each other and are thus indispensable for comprehensive and specific fuel type mapping (Table 2). Spatial distribution of land cover together with additional properties on the fuel structure and condition can be further translated into fuel models important for the parameterization of forest fire behaviour models.

Recommended reading

Andersen, H.E., McGaughey, R.J. and Reutebuch, S.E. 2005. Estimating forest canopy fuel parameters using LiDAR data. Remote Sensing of Environment 94: 441–449.

Blanchi, R., Jappiot, M.and Alexandrian, D. 2002. Forest fire risk assessment and cartography. A methodological approach. Proceedings of the IV International Conference on Forest Fire Research, 18–20 November 2002, Luso, Portugal.

EFFIS www.effis.jrc.ec.europa.eu

Illera, P., Fernandez, A. and Delgado, J.A. 1996. Temporal evolution of the NDVI as an indicator of forest fire danger. International Journal of Remote Sensing 17: 1093–1105.

Koetz, B., Morsdorf, F., Curt, T., Van der Linden, S., Borgniet, L., Odermatt, D., Alleaume, S., Lampin, C., Jappiot, M. and Allgöwer, B. 2007. Fusion of Imaging Spectrometer and LiDAR Data Using Support Vector Machines for Land Cover Classification in the Context of Forest Fire Management. In Schaepman, M.E., Liang, S., Groot, N.E. and Kneubühler, M. (eds.) 10th Intl. Symposium on Physical Measurements and Spectral signatures in Remote Sensing. Intl. Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. XXXVI, Part 7/C50.

Lampin-Maillet, C., Jappiot, M., Long, M., Morge, D. and Ferrier, J.P. 2008. Characterization and mapping of dwelling types for forest fire prevention. Computers, Environment and urban systems. doi:10.1016/j.compenvurbsys.2008.07.003.

3.2 Managing Wildfire Risk: Prevention, Suppression

Éric Rigolot, Paulo Fernandes and Francisco Rego

The trend in undergoing larger and more damaging wildfires is the end result of unbalanced policies that are effective in fire suppression but are undersized in regard to fuel management and its generalization.

Contemporary land use trends promote biomass accumulation and landscape-level continuity of highly flammable fuel types, thus favouring large and severe fires. The situation is aggravated in many European countries by fire policies, which are centred in fire pre-suppression and suppression and ignore or assign a minor role to stand and fuel management. Fire-fighting technology can cope with just a small fraction of the potential intensity of a wildfire driven by extreme weather and propagating in favourable terrain and heavy fuel. The limits of fire suppression are especially evident when the wildland-urban interface absorbs the available resources to protect houses and infrastructures. The results of the current fire management policy can be deceptively encouraging on the short-term but will not lead to sustained decreases in area burned and will increase the relative importance of large fires. Several recent cases substantiate this paradox: Catalonia (1986–1993), Galicia (1994–2005), and Greece (2001–2006) were regarded as examples of success and in each case catastrophic fire seasons followed those periods.

Fuel management addresses directly the root of the fire problem, because modified fuels change fire behaviour. When properly designed and implemented, fuel management increases the weather threshold for effective fire suppression, and this is even more relevant in a climate change scenario. Three basic strategies are available, respectively isolation by fuel breaks, area-wide fuel modification, and fuel type conversion.

Fuel isolation is the most commonly used strategy in Europe and materializes as strategically-placed linear fuel treatments of variable width that are expected to confine wildfires by expanding the safety and effectiveness of fire suppression operations. Fuel isolation presupposes the sacrifice of vegetation in-between fuel breaks and its success is often compromised by spotting.

Area-wide fuel modification creates a landscape mosaic of treatments in highly flammable vegetation types. Within each treatment unit, fuel quantity is reduced and its structural arrangement is changed by increasing discontinuity and compactness. Reduction in the overall impact of fire and increased extinction capacity are attained over the landscape, but the required effort and scale of intervention are usually impracticable because resources allocation is strongly shifted towards fire suppression.

Fuel conversion replaces hazardous vegetation types by less flammable types with a proven mitigating effect of fire behaviour, namely dense broadleaved woodland. This strategy is constrained by the species available for conversion and site conditions but can take advantage of natural succession towards mixed forest and maturity.

In the European context of cultural and fragmented landscapes it is advisable to combine the strategies of fuel isolation, area-wide fuel modification and fuel type conversion. Successful landscape fuel management requires careful spatial planning, i.e. consideration of the size, location, orientation and shape of the treatments.

The main target of preventive silviculture is crown fire avoidance by treating surface fuels and promoting low density and vertically discontinuous stands. Enhancement of individual tree vigour and growth is advisable in order to increase fire resistance.

Stand management against wildfire in flammable forest types should adopt the following operational sequence:

a. Reduce surface fuels to limit potential fire intensity.
b. Prune trees and eliminate ladder fuels to restrain the likelihood of vertical fire development.
c. Thin the stand to minimize the probability of fire transmission within the canopy.

Fuel treatments are generally unnecessary in vegetation types whose flammability is naturally low, such as riparian areas, broadleaved deciduous woodland and short-needled conifers. Contrarily to drier forests, the overstorey should be dense in order to maximise shade, moisture and wind sheltering.

Land managers can resort to a variety of fuel treatments, namely prescribed burning, mechanical treatments, controlled grazing and phytocides. These techniques differ on their conditions of use and targeted fuel category or layer, and have distinct environmental effects, impacts on fuels and costs:

1. Prescribed burning has economical and effectiveness advantages, can simultaneously fulfil other management objectives, and is the preferred (or the only) option for area-wide fuel management. Its major limitation – the need to comply with a restricted weather and fuel moisture window – is also what minimizes concerns such as the risk of escape, smoke production or negative ecological effects. It demands increased public awareness, training and planning. The use of prescribed burning to emulate natural processes has also its place, especially in the frame of close-to-nature forestry and in areas with a conservation status.
2. Mechanical treatments are varied and consequently have quite different effects on fuel hazard, depending on the degree of physical modification (removal, piling, mastication). Costs can consequently be very high but will be similar to prescribed fire in the case of harrowing. The use of heavy equipment can potentially damage the soil and is restricted by terrain slope.

Figure 15. Fuel break management through pastoralism. Credit: INRA.

3. Controlled grazing has a selective and scattered impact on fuels which is dependent on the silvopastoral system and forage preferences of grazing animals. Grazing provides a financial return and increases the length of time between consecutive mechanical or burn treatments.
4. Phytocides increase flammability on the short-term and motivate environmental concern but have a long-lasting effect on understorey vegetation.

The most effective results are likely to be attained through operational sequences that combine two or more fuel treatments.

Bioenergy development holds promise for cost effective fuel management.

The use of forest biomass is a promising option to promote fuel treatments and reduce the net costs of stand pruning and thinning, especially in view of the current trend in oil prices. Biomassing may resort to understorey vegetation and even trees in excess, but also raw material produced by forest exploitation.

Forest biomass in the form of wood pellets, wood chips and wood logs used directly for combustion for heat recovery, is more sustainable and cost effective when a local fuel source is used.

Further research and development on bioenergy should be encouraged to convert lignocellulosic materials to fuels, which currently faces technical barriers that restrain economical viability. Second generation technologies should expand the type of feedstock utilising broader lignocellulosic sources.

Mega fires may spread over any vegetation type, implying that fire management planning should consider the territory as a whole.

Recent experiences of mega fires in Portugal and Greece showed that extreme fire events are hardly selective and may spread over almost any type of vegetation, including agriculture areas and ornamental vegetation in peri-urban areas. Policies and regulations dealing with wildland fires issue should also be considered by the agricultural and urban sector.

Perception of the mitigating effect of fuel management can be poor under extreme, i.e. windy and dry, fire weather, because large fires will still develop. Although this indicates the limitations of fuel management it does not diminishes its value or relevance, because it is unrealistic to expect that fuel management halts fire spread.

An objective analysis of the results brought by fuel management should be focused on fire intensity and severity within the burned area, not on fire size. Success of a fuel management program is gauged by (i) expansion of fire suppression options and effectiveness, and (ii) reduction of the environmental and socio-economical impacts of fire.

Nevertheless, the level of protection required by highly-flammable industrial plantations in more aggressive fire environments might be so high that the incurred expenditures will rise to unreasonable levels, thus precluding effective stand management practices.

Current fire policies privilege fire suppression, but this does not mean the most adequate fire-fighting techniques and tools are used in Europe. The basic knowledge of wildland fire fighting has been mostly lost or abandoned and replaced by civil protection rationales. A much stronger effort should be devoted to perimeter control strategies, which implies increased use of hand-tools crews and mechanized equipment, and indirect attack methods (backfiring) to be used when the capacity of extinction is reached. This requires important developments in legislation, outreach and training (namely in understanding fire behaviour).

Recommended reading

Agee, J.K. and Skinner, C. 2005. Basic principles of forest fuel reduction treatments. Forest Ecology and Management 211: 83–96.

Countryman, C. 1974. Can Southern California Wildland Conflagrations be Stopped? Gen. Tech. Rep. PSW-7. Berkeley: USDA Forest Service.

Fernandes, P. and Botelho, H. 2003. A review of prescribed burning effectiveness in fire hazard reduction. International Journal of Wildland Fire 12: 117–128.

Finney, M. 2004. Landscape fire simulation and fuel treatment optimization. In: Hayes, J.L., Ager, A.A., Barbour, R.J. (eds.). Methods for Integrating Modeling of Landscape Change: Interior Northwest Landscape Analysis System, USDA Forest Service Gen. Tech. Rep. PNW-GTR-610, Portland, OR. Pp. 117–131.

Graham, R., McCaffrey, S. and Jain, T. (eds.). 2004. Science Basis for Changing Forest Structure to Modify Wildfire Behavior and Severity. Gen. Tech. Rep. RMRS-GTR-120. Fort Collins: USDA Forest Service.

3.3 What to Do After Fire? Post-Fire Restoration

Francisco Moreira and Ramon Vallejo
(with input from the PHOENIX network)

Forest planning should include the identification of forests vulnerable to wildfire.

Forest planning and management should include the identification of forest stands vulnerable to a fire event. The more fire-vulnerable forests are those that will not recover the same composition if affected by a medium or high intensity wildfire, or frequent fires, particularly if they have an important conservation value, and especially those areas that show high risk of soil erosion and runoff that may produce flash floods and damages downstream. Therefore, the identification of vulnerable areas, prior to the occurrence of wildfires, should be a major priority in forest planning. Tools for achieving this objective include modelling plant regeneration and erosion risk, topographic, soil type, forest species composition and vegetation cover maps.

Not all burned forests require restoration.

Fire is not always a disaster for ecosystems and landscapes. Wildfires have been natural disturbances to ecosystems in the Mediterranean region before human widespread influence. Therefore, plants have developed adaptive strategies to survive the passage of fire, e.g. storing seeds in pine cones and in the soil seed bank, or retention of surviving belowground structures that allow the plant to resprout. In addition, fires may promote nutrient cycling and generate habitat for fire-dependent species. No ecosystem remains bare of plant cover for very long after a fire. In most cases ecosystems regenerate naturally after a fire without the need for human intervention, especially in low severity fires and resilient ecosystems (that have the ability to recover their original structure after a disturbance such as fire). However, the resilience after fire of forest ecosystems is markedly reduced by frequently repeated wildfires or when combined with other disturbances, that may lead to a non reversible degradation, at least at human scale.

Sometimes, natural regeneration may not suite management objectives, e.g. some pine stands showing excessive regeneration or invasive exotic species being promoted by fire, hence requiring post-fire intervention. Natural regeneration after fire will depend on characteristics of the fire regime (e.g. recurrence, intensity, and season) and stand factors (e.g. site quality, pre-fire vegetation), thus the monitoring of regeneration is important as a basis for management decisions. In some situations, the lack of natural regeneration may

Living with Wildfires: What Science Can Tell Us
Yves Birot (ed.)

Figure 16. Resprouting trees quickly regenerate after fire. Cork oak is one of the most adapted tree species to fire.

even provide opportunities to increase landscape heterogeneity that may be beneficial in terms of biodiversity and decreased susceptibility to future fire events.

It is not necessary to cut all burned trees immediately after fire.

Rapid salvage harvesting of burned trees is often suggested to optimise timber value, because the later the extraction is performed, the lower the economic value of the logs. But the potential ecological impacts of removing recently burned trees should be taken into account. Unless expensive log extraction methods are applied (e.g. cable), log hauling may produce heavy soil erosion, often at higher levels than the erosion induced by the fire itself. This is especially the case for erodible soils, where log extraction is recommended after plant regeneration is sufficient to protect the soil surface (usually the spring after a summer fire). Therefore, prior identification of vulnerable soils is critical to decide on the timing and method of log extraction.

Leaving snags (standing dead trees) in the forest stand may trigger bird-mediated seed dispersal for forest species and enhance ecosystem recovery. Dead wood is a habitat for many insects and other species of interest for biodiversity conservation. In addition, species with serotinous cones will continue to experience seed fall for months after a fire, thus contributing to natural regeneration. Immediate post-fire logging is usually claimed to be necessary to avoid the outbreak of pests (especially bark beetles) from the charred wood to nearby unburned forest. This risk depends mostly on the severity of the fire. In low to moderate severity fires, the weakened surviving trees are the most prone to suffer wood-boring pests, and so the stands should be carefully monitored and eventually treated to avoid pest outbreak. Burned dead trees in high severity fires have a much lower risk of attracting bark beetles.

Figure 17. Most often, post-fire pine germination is excessive in Aleppo pine (and other Mediterranean pines). Assisted natural regeneration is advisable in these cases to reduce intra-specific competition and enhance tree growth and forest recovery.

Emergency measures to decrease soil erosion and water runoff hazards should be taken only in high risk areas.

In the short-term, post-fire rehabilitation measures may be required in order to avoid or mitigate irreversible damages to ecosystems, structures and settlements. This implies a rapid diagnosis of ecosystems and landscapes prone to severe soil erosion and runoff. High risk areas are those that have experienced another fire event recently, areas affected with higher fire severity, on steeper slopes, with erodible soils, and with a low rate of plant cover regeneration. These areas can be identified with GIS information on topography, soils and vegetation, plus field or remote sensing assessment of fire severity coupled with previous knowledge of vegetation responses to fire.

Logs and branches from the extraction may be used to form contour strips to mitigate hill slope erosion. Applying mulching and log dams shortly after a fire have proven to be the most effective in mitigating soil degradation and excessive runoff on slopes showing a high risk of erosion. However, care must be taken when applying log dams, as this technique may not be effective at all if incorrectly implemented.

Reforestation is not necessarily the best post-fire response, and should include a careful selection of species and techniques.

There is strong political pressure for reforesting or afforesting burned areas in the Mediterranean region as soon as possible after a wildfire. However, reforestation/ afforestation are usually not so urgent after a fire, and may not be advisable in many

Figure 18. The use of tree shelters is recommended to improve the micro-environment of seedlings in plantations to face drought and grazing.

cases. Furthermore, if it must be carried out, the selection of species and techniques for reforestation should be carefully evaluated. Active restoration techniques such as planting are very expensive. Furthermore, activities associated with soil preparation for planting may increase the risk of soil erosion. Direct seeding is less costly, bur the success is usually very low, and thus cost-effectiveness is also low. Therefore, these active techniques should only be considered when other options are not feasible and if there is a specific objective of recovering the forest, e.g. in areas where no natural tree regeneration is expected, and where there are no mature trees in the vicinity that might naturally colonise the site in the medium term.

Other applications of financial and human resources may be much more effective, in particular by taking advantage of regeneration from seeds left in the ground by burned vegetation, or from resprouting of burned trees and shrubs. In addition to the low costs of these assisted natural restoration techniques, plant survival and growth rates are higher when compared to active restoration. Consequently a higher and faster-growing vegetation cover is achieved with significant implications for preventing soil erosion. Thus, we advocate a much more frequent use of assisted natural restoration, based on natural regeneration management that, depending on the objectives, may involve thinning, the selection of shoots, and the control of unwanted vegetation. The costs associated with the management of natural regeneration can be much lower when compared to active restoration, meaning that with a similar amount of funding available a much larger area can be effectively treated. The selection of active or natural restoration will depend on the type of pre-fire vegetation, regeneration rate, and restoration objectives.

Not all areas are suitable for afforestation with all species, and for some areas afforestation/ reforestation should not be carried out at all. The selection of forest species and reproductive material should take into account ecological restrictions, including those related to expected climate changes, the objectives of post-fire restoration including environmental aspects (biodiversity) and technical limitations. In many burned areas in arid lands with degraded soils tree survival possibilities will be very low and so it is preferable to use shrubs for objectives other than wood production. In many situations, reforestation with native hardwoods is preferable to using conifers or eucalyptus, particularly when the objective is to increase fire resistance and resilience. Native deciduous oaks, in particular, have several advantages including (a) being more fire-resistant; (b) being more fire-resilient (often showing remarkable resprouting abilities, which do not occur in conifers); (c) decreasing the fire intensity of an advancing fire front, a feature that can be used in fire-fighting strategies. However, one should keep in mind that the success rate of planting hardwoods can be rather low in harsh conditions.

A precaution principle for optimising natural genetic resources would be using native reproductive material. The afforestation/ reforestation with alien species and populations should be avoided, particularly in areas with a high biodiversity value, or where the local populations are exposed to risks of hybridization with the introduced populations. When needed, planting non native reproductive material, should always be based on a well established scientific background.

Large monospecific plantations created in the past have proven to simplify the landscape and facilitate the propagation of wildfires and pests. When deemed necessary, small afforestation patches are recommended, as they improve landscape diversity, fire resistance, and biodiversity, while costing less than large plantations. These small patches would act as dispersion nuclei for the introduced species in the long term.

Wildfires constitute opportunities for the planning and effective management of landscapes more resistant and resilient to wildfires.

Existing forests are the result of management decisions that were taken in the past, with traditional objectives such as water management or timber values. Today, objectives have to take into account new societal needs such as biodiversity, climate change mitigation or recreational value. Forest restoration should always include fire-prevention and increasing resilience principles in fire-prone regions. The fact that a large area was burned should be taken as an opportunity to change land use rules to create more resistant (less fire prone, i.e. with lower combustibility and fire propagation) and resilient (with higher regeneration ability) landscapes to fire. Basic principles of landscape management include increasing landscape heterogeneity and increasing landscape barriers or filters that inhibit the spread of fire.

Certain land use or land cover types (e.g. shrublands, conifer plantations) in a landscape are more susceptible to fire than others (e.g. deciduous or riparian forests, agricultural areas) because of differences in vegetation structure, moisture content, and fuel load composition. This causes differential combustibility, fire intensity and rate of fire spread across different land cover types. This knowledge can be applied in landscape-scale fuel breaks, designed to (a) effectively breaking up the continuity of hazardous fuels across a landscape, with the objective of reducing the occurrence of large wildfires, (b) reduce the intensity of wildfires, providing broad zones within which fire fighters can conduct suppression operations more safely and efficiently, (c) provide various non fire-related benefits (e.g. habitat diversity, landscape scenery).

Existing studies in the Mediterranean region showed that annual crops (including pastures), permanent crops and silvo-pastoral and agro-forestry systems, are highly effective as landscape fuel breaks. Thus a high priority should be given to the maintenance and implementation of agricultural and pastoral activities in fire-prone landscapes, particularly if spatially organized in wide strips of at least 1 kilometre.

Recommended reading

Alloza, J.A. and Vallejo, V.R. 2006. Restoration of burned areas in forest management plans. In: Kepner, G., Rubio, J.L., Mouat, D.A. and Pedrazzini, F. (eds.). Desertification in the Mediterranean Region: a Security Issue. Pp. 475–488.

Moreira, F., Rego, F. and Ferreira, P. 2001. Temporal (1958–1995) pattern of change in a cultural landscape of northwestern Portugal: implications for fire occurrence. Landscape Ecology 16: 557–567.

Pausas, J.G. et al. 2004. Pines and oaks in the restoration of Mediterranean landscapes of Spain: New perspectives for an old practice – a review. Plant Ecology 171: 209–220.

Vallejo, V.R. and Alloza, J.A. 1998. The restoration of burned lands: The case of eastern Spain. In: Large Forest Fires. J.M. Moreno ed., Pp 91–108.

Vallejo, V.R., Aronson, J., Pausas, J. and Cortina, J. 2006. Restoration of Mediterranean Woodlands. In: Van Andel, J. and Aronson, J. (eds.). Restoration Ecology. The New Frontier. Pp. 193–207.

3.4 Economics of Wildfires

Robert Mavsar

Economics is an essential part of proactive fire management.

In the past, economics was mainly aiming at assessing the direct or (in few cases) indirect losses caused by forest fires. However, if it should become an essential tool of proactive fire management, it has to go one step forward. Proactive fire management is acting in the sense of fire prevention, rather than extinction. Thus it is taking decisions where to take management measures to prevent wildfire events in the future. The resources, needed for such intervention, are limited and they should be allocated in the most efficient way. Therefore, decision makers should look for solutions where the expected benefits per invested euro are the highest. As benefits, we consider the values of goods and services (e.g. forest) which could be damaged if a wildfire would break-out. Thus, in a modern approach, wildfire economics should give the answer about the values we are protecting, rather than only about the values lost. This is important since not all forests hold the same value for the society. Having the information on their value and importance might facilitate the decision where to invest in prevention and where to relay on extinction measures. However, one should be aware that such decisions are not only taken upon the information on possible economic impacts, but also ecological impacts should be considered.

Full economic impacts of wildfires should be estimated.

Even if the damages caused by wildfires are often counted in millions of euro, they can still be considered as underestimated. There are several issues, explaining why, and some of them are discussed in this chapter.

Market vs. non-market

In most cases the damages reported by official statistics include only the value of lost market goods and services, which have established markets and market prices. However, wildfires cause significant damages to the affected ecosystem and its processes, which are essential in providing also other benefits for the society. For example, a forest is not providing only timber and non-timber products which can be sold on the market,

Living with Wildfires: What Science Can Tell Us
Yves Birot (ed.)

but also a wide range of other goods and services (e.g. recreation, purification of water, CO_2 sequestration and fixation, biodiversity, natural beauty). There is no doubt that the society also receives benefits from enjoying these “other” goods and service (also called non-market). Therefore also their value must be considered when estimating the total economic impacts of wildfires.

Short term vs. long term impacts

The most obvious are the immediate impacts of a wildfire which include the impacts in the period between the occurrence of the wildfire and the restoration of the burned sites. Nevertheless, there might be also economic and social impacts beyond this time span. For example, large wildfires might cause disturbances of regional market of products and services (e.g timber, recreation and tourism).

For example, if a forest fire significantly changes the aesthetics of a recreation area, it can have a positive short term effect on the number of visitors (e.g. people are curious to see the damages caused by the forest fire), but could cause a negative long term effect (e.g. recreationists prefer other sites until the burned site is fully recovered).

Sectoral vs. intersectoral impacts

The estimation of economic impacts of wildfires is mostly limited to the sector level (e.g. forestry). But wildfires might also provoke impacts in other sectors. For example, a very often cited example is lower number of tourists during a wildfire event in the region or loss of production time due to participation of volunteers in fire suppression operations. There might be also other examples which might turn up and are even more difficult to estimate (e.g. lower estate prices due to repeated fire events in the area). Not necessary these impacts are always negative, but nevertheless they have to be considered.

Standardisation of the assessment of economic and social impacts of wildfires and the improvement of data availability.

Another issue to be considered in the future is the standardisation of the framework for the assessment of economic and social impacts of wildfires and the improvement of data availability.

To minimize the negative economic and social impacts of wildfires, efficient wildfire related policy and management measures at different levels should be developed and implemented. To take decisions on the most efficient alternatives, reliable and comparable information should be provided. The current reporting system on the European level, the so called European Forest Fire Information System (EFFIS), also includes a module on fire damage assessment, which assesses the size of the burnt area and provides the breakdown by cover type, and in the case of Natura 2000 the impact to dwelling species. However, it lacks any assessment of economic or social impacts, though a socio-economic module is under preparation and should be fully implemented in EFFIS around 2010.

Even if the economic and social impacts of different wildfire events might differ considerably, still a standard economic framework should be applied. A possible framework could be the Cost-benefit analysis (CBA). By comparing the costs and benefits measured in monetary terms, the CBA is a technique for the assessment of the relative desirability of competing alternatives (events, projects or policy measures). For example, it can be used to evaluate the overall economic impact of a forest fire or different fire management measures. The assessment involves the comparison of the current situation to one or more alternatives.

A further feature of the CBA is that it can be conducted from different perspectives. A private CBA considers the costs and benefits of which are imposed onto or accrue to a private agent (e.g. forest owner). In turn a social CBA attempts to assess the overall impact of a project on the welfare of the society as a whole. At the same time the CBA is flexible enough to adapt to a wide range of different situation.

Within the frame of the CBA, it would be advisable to establish a standard (basic) set of costs and benefits that should be reported and recommendations regarding their estimation could be given (e.g. which valuation method to apply). This would enable to compare the economic and social impacts of different fire events and to provide sound damage estimates on national or even European level. This data would serve as good indicators for the assessment of the effectiveness of the applied wildfire related policies and management measures.

Forest fires and society – a multiple relation

Society can, on one side, be considered as the victim of wildfires, suffering significant welfare losses, while on the other side, the society is also influencing the risk of wildfire occurrence or even directly provoking them.

Yet, there is another aspect of the relation society-wildfire which has to be considered. The fire management measures, implemented to decrease the occurrence probability of wildfires or to restore burned areas, are mainly based on the decision of forest managers, generally omitting the public perception on these measures. However, the decisions on forests fire management issues do influence, not only the forest as a natural resource and provider of various benefits, but also affect society's well-being. It might occur that certain population groups established strong preferences regarding the acceptability of certain measures or policies. Therefore, it is important to take these preferences into account, when designing and implementing fire management policies. Understanding the public's perception can (i) help the administration recognize when policies or actions may get public support, (ii) warn the administration when certain activities or policies might be opposed by the public, (iii) help to develop information or education campaigns, which might help to get public support for a certain policy or action.

Recommended reading

González-Cabán, A. 2007. Wildland Fire Management Policy and Fire Management Economic Efficiency in the USDA Forest Service. Paper presented at the Wildfire 2007, 4th International Wildland Fire Conference, 13–17 May 2007, Sevilla, Spain. http://www.fire.uni-freiburg.de/sevilla-

3.5 Policy Analysis Reveals the Need for New Approaches

Cristina Montiel and Jesús San-Miguel

The European Union (EU) does influence and complement national policy processes related to wildfires, through various instruments: i) prevention legislation, ii) information system on forest fires (EFFIS), iii) related initiatives dealing with Rural Development and disaster prevention and response.

Even though the wildland fire issues, as threats affecting forests, are mainly dealt within national forest policies in Mediterranean countries, the issue of forest fires has been on-board of the political agenda of the EU since 1980s. This process lead to the establishment of European Union (EU) forest fire prevention legislation in 1992 (EEC 2158/92[1] and EC/308/97[2]) encouraging Member States to establish forest fire prevention plans. This regulation was complemented with the European Commission Regulation EC 804 of 1994[3], which provided resources for the development of information on forest fires in the Member States (see Chapter 1). Although the mentioned regulations expired in 2002, a new regulation on the monitoring of forest and environmental interactions was established by the EU in 2003 and was referred to as "Forest Focus" (EU Reg. 2152/2003[4]). This new regulation followed the initiatives of the EU towards developing comprehensive information systems at the European level. It included the operation of the European Forest Fire Information System (EFFIS), already created by the EC Joint Research Centre in 2000, and the further development of this system regarding the assessment of fire severity, the socio-economic impact of forest fires, as well as, the analysis of forest fire causes. Forest Focus expired in 2006, although the activities of EFFIS continue through the collaboration of the EC with the Member States. Additional initiatives on prevention and response to forest fires in the EU are on-going within the EU Rural Development Regulation and the recent EC communications on disaster prevention and response[5] in the EU.

Among the national policy instruments for wildland fire management, forest fires prevention actions should be cross-sectoral, involving different stakeholders and public policies (forest owners, civil protection, rural development, spatial planning, and forest services).

Although the European legislation has contributed to homogenize the national legal frameworks, there are still important differences among the countries, namely concerning terminology. First of all, there is a wide range of definitions of forest, adapted to each

1, 2, 3, 4, 5 See EC & EU related texts in the references at the end of this Chapter.

Living with Wildfires: What Science Can Tell Us
Yves Birot (ed.)

Table 3. Typology of policies addressing directly or indirectly the issue of wildland fires.

National Forest Plans (NFP)	Wildfire topic is usually included in NFP as a specific operational programme or as a part of a wider one. The most frequent measures considered are: fuel management; enhancement and conditioning of preventive and defensive infrastructures; public awareness and information campaigns; and detection and extinction systems.
Wildfire Defence and Protection Plans	These specific planning documents are generally developed in the context of civil protection and emergencies, and determine the necessary actions to carry out when a wildfire event occurs. They classify and map risk, identify and set the fire risk seasons, and set the protocol to be followed in order to face a wildfire emergency.
Territorial policies	*Spatial planning policies:* An inadequate urban or regional planning may aggravate the effects of wildland fires. On the contrary, a correct land use organization may minimize the harms. *Agricultural and rural development:* Its potential in solving the wildland fire problem is most important in those measures aimed at guaranteeing the maintenance of viable local communities in both the social and economic sense. *Energy policies:* The use of biomass could provide a solution for reducing the risk for wildland fire initiation and propagation. Nature protection: e.g. designated areas of high biodiversity value to be protected from fire.

ecological and socioeconomic context. Besides, the term forest fire is very often used for those wildfires occurring on a broad land use category referring to forest stands, shrublands and even grasslands. Actually, woodlands are a very complex land use category, especially in the Mediterranean countries, which includes forests and other wooded lands. In fact, the term wildland is used to refer to natural landcover or uncultivated lands. Therefore, wildland fire, seems less restrictive and more appropriate than forest fire referring to the Mediterranean region.

There are two main types of planning documents relevant for wildland fire management: the National Forest Plans and the Wildfire Defence and Protection Plans (Table 3). Nevertheless, apart from sectoral policies which have the responsibility for wildland fire management (forest and civil protection), it is important to consider other public policies with influence in structural causes affecting wildland fires, which are out of the sectoral scope and are basic for wildfire initiation and propagation.

In this respect, the existing European Union funds (e.g. structural funds and rural development funds) should be made available for national, regional and sub-regional prevention measures in the countries.

Territorial policies have a great potential for addressing the structural causes of wildland fire initiation and propagation, as very often, they cannot be properly addressed with conventional approaches. Analysing social, ecological and economic conditions which contribute to set the wildfire risk can found such policies and help in acting on the way land is managed.

Territories can be defined as elements of various areas featuring some environmental, economic and social commonalities or homogeneity. Territories can be aggregated and up-scaled into larger units, up to a national and even transnational level. Many issues such as fire, water flow, biodiversity, agriculture, recreation, etc., and even post-fire restoration should be considered at the territory or landscape level, as it is the pertinent scale where functions and processes take place. Acting on functionalities should be a main objective of territorial policies. In the last few years, wildland-urban interface protection has also become a planning issue within preventive policies as result of catastrophic fire disasters affecting human properties and lives. Managing such areas requires careful planning but also cooperation of forestry and fire-fighting agencies as well as local communities. Territorial policies, although they are not easy to design and implement, can be very effective, with their cross-sectoral nature and the way they influence land use planning and management, and spatial organisation (fuel-breaks, migration corridors and transport networks, urbanisation).

An effective coordination among the different bodies dealing with wildland fires at national and regional level is needed..

The forest policy process and the institutional framework existing in the different countries influence the way in which wildland fires are managed. On the other hand, the structure of national governance is crucial. The degree of decentralization determines where responsibilities are allocated and how they are developed. It is usually on the regional or local scales where wildfire plans are formulated and implemented because it is the operative level. Sometimes, problems of coordination are compounded for the countries which have federal systems (multilevel governance frequently leads to time-consuming processes and sub-optimal results) or are undergoing decentralization trends.

A comparative assessment of wildfire policies in Southern Europe shows that the main focus is on emergency suppression measures instead of the promotion of long-term prevention actions, and a lack of articulation between civil protection and forest protection.

Wildland fire issues are given a different consideration in the national policy instruments depending on the risk severity of wildfires in the national contexts and the different political and administrative systems existing in each country. Forest Plans usually include preventive and curative actions to mitigate wildfire hazard, while Civil Protection policies aim to protect human lives and goods. Although European countries have very different institutional arrangements for organizing forest fire prevention and suppression (including the involvement of the civil society), some common patterns can be recognised in the Mediterranean region, which is the most wildfire-prone zone, with a long history and challenge to develop wildfire's related legislation and policy, and a high investment in fire protection. In general, the political efforts have recently evolved towards a fire policy centred in emergency suppression measures, based on more and more sophisticated

Table 4. Strengths and weaknesses of wildfire policies in the Mediterranean region.

Strengths	Weaknesses
• All the countries have specific policies for wildland fires. • Development of geographical information systems for decision making. • Political will on coordination between the administrative organisms and different agents participating in fire management actions, especially in extinction, even if results are not yet evident in all countries. • Improvement of the extinction efficiency	• The awareness of policy-makers towards fires has derived from catastrophic incidents instead of being a proactive action. • Wildfire policies are usually suppression-oriented actions at the expense of prevention • Lack of efficient participatory processes for groups of stakeholders which may contribute to fire management motivated by self-interest in areas threatened by fire. • Traditional burning practices were made illegal without prior educational programs.

equipments with high costs – and sometimes influenced by industrial lobbies – instead of the promotion of long-term preventive actions. A summary of strengths and weaknesses of wildfire policies in the Mediterranean region is presented in Table 4.

A legal and policy framework should support the wise use of fire as a way of managing preventive and defensive structures

A key issue in wildfire management is the planning of preventive and defensive structures (see Chapter 3.2). There are mainly two different spatial models for it, namely the lineal and the mosaic models. The combination of fuel-break areas with the traditional lineal fuel-breaks is the option that is being adopted in most countries. The standard approach for its maintenance is mechanization. Most countries are also promoting a combination for silvicultural treatments and livestock grazing, as well as the use of biomass, for reducing fuel accumulation.

France, Portugal and Spain are the most advanced countries in the introduction of prescribed burning and also the regulation of traditional fire use practices in their legal and policy frameworks.

The development of such an approach requires paying attention to the elements as follows:

- Regulation of fire use practices vs. punitive regime: Legislation has been characterized as a punitive regime in wildfire issues. That should evolve towards a regulative regime from a preventive approach, especially concerning prescribed burning and traditional fire use practices.
- Professional and technical use of fire vs. fire exclusion: Wildfire policies adopted by most European countries over the last century have been based on fire exclusion regardless of their specific context. At present, professional training should be a priority for the organization of hand-crews to develop preventive action at the ground level.
- Regarding fire use techniques, there is a need of a basic framework on backfiring techniques and a more detailed description of conditions to develop prescribed burning.

Concluding remark: although fire suppression is deeply rooted in most countries, a national forest fire policy should consider all aspects of wildfire management as a whole and with a long-term view. A global and territorial approach, through the connection of the forest fire policies with the territorial policies (i.e. spatial planning, rural development, energy policy), is needed to address the structural causes of wildfire events.

Recommended reading

Aguilar, S., Galiana, L. and Lázaro, A. 2007. Analysis of wildfire risk management from a territorial policies perspective: strengths and weaknesses in the European and national framework. In: 4th International Wildland Fire Conference, Seville-Spain, 13–17 May 2007 www.wildfire07.es

European Commission/Union texts related to wildfires

[1] Council Regulation (EEC) No 2158/92 of 23 July 1992 on protection of the Community's forests against fire, Official Journal L 217, 31/07/1992. Pp. 0003–0007.

[2] Council Regulation EC/308/97 of 17 February 1997 amending Regulation EEC/2158/92 on protection of the Community's forest fire, OJ L 51 21.02.97. p. 11.

[3] Commission Regulation EC/804/94 of 11 April 1994 laying down certain rules for the application of Council Regulation EEC/2158/92 as regards forest fire information systems, Official Journal L 93 12/04/94 p. 11

[4] Regulation (EC) No. 2152/2003 of the European Parliament and the Council of Nov. 2003 concerning monitoring of forests and environmental interactions in the Community (Forest Focus), Official Journal L 324/1, 11/12/2003 p 1.

[5] EC Communication to the European Parliament and the Council on Reinforcing the Union's Disaster Response Capacity, COM(2008) 130 Final, Brussels, 5.3.2008.

FAO 2007. Fire management - global assessment 2006. FAO Forestry Paper 151. Rome, 2007. 156 p. http://www.fao.org/docrep/009/a0969e/a0969e00.HTM

Herrero, G., Lázaro, A. and Montiel, C. 2008. A comparative assessment of the European forest policies and their influence in wildfire management. 3rd Symposium on fire Economics, Planning and Policy: Common Problems and Approaches, Carolina, Puerto Rico, April 29–May 2, 2008, www.fireeconomics.com

Schmuck, G., San-Miguel-Ayanz, J., Barbosa, P., Camia, A., Kucera, J., Amatulli, G., Boca, R., Schulte, E. and Dierks, H. Forest Fires in Europe 2006. EUR 22931 EN, JRC37598. http://effis.jrc.it/documents/2006/ForestFiresInEurope2006.pdf

San-Miguel-Ayanz, J., Schmuck, G., Flies, R., Schulte, E. and Seoane, I. 2005. Towards a forest information system for Europe. Database and Expert Systems Applications, 2005. Proceedings. Sixteenth International Workshop on Inst. For Environ. & Sustainability, European Comm. Joint Res. Centre, Italy. Pp. 669–673.

4. Meeting a New Challenge: Expected Increase and Expansion of Wildfires as Related to Climate Change

4.1 Impacts on Potential Wildfire Risk Due to Changes in Climate

José-Manuel Moreno

The climate of southern Europe and the Mediterranean (SEM) is projected to warm more than the global average, particularly in the summer. Precipitations are projected to decrease, particularly in the summer. Warming and precipitation reductions are projected to increase with increasing greenhouse gasses emissions

---

Annual temperatures are projected to increase in SEM more than the global average (for the A1B scenario and the period 2080–2099, the projected global warming is 2.8ºC, whereas for the SEM is 3.5ºC). Warming will be largest towards the south and more inland than around the coast, and will be highest in summer (4.1ºC, for the same scenario and period). Maximum temperatures are likely to increase more than average or minimum temperatures. Warming will be greater with increased greenhouse gasses emissions. Annual precipitation is very likely to decrease in most of SEM, and the number of wet days is very likely to decrease.

Precipitation changes will not be homogeneously distributed between seasons, with summer precipitation tending to experience the greatest reductions (24% reduction in summer vs. 12% reduction in the annual total for the same period and scenarios as above). Precipitation changes will vary throughout the region, and the greater reductions are likely to occur more towards the south (Figure 19). Other changes for SEM include decreases in relative air humidity and cloud cover, particularly in summer; no significant changes in 10 m mean annual wind speed are expected, except for a light increase in summer.

Temperature variability and extremes are projected to increase, with heat waves increasing in intensity, duration and frequency. The number of dry spells and droughts are projected to increase.

Inter-annual temperature variability is likely to increase in summer is most of Europe. This means that, if during a given period the maximum temperature of a set of the warmest years exceeds the mean of the period by a certain value, in the future this value will be even greater, and will be added to the larger mean that is expected due to warming. This variability also extends to daily temperature variability, with the highest maximum temperature increasing more than the median maximum temperatures. Changes in synoptic patterns are projected to produce heat waves of increasing intensity, duration

Living with Wildfires: What Science Can Tell Us
Yves Birot (ed.)

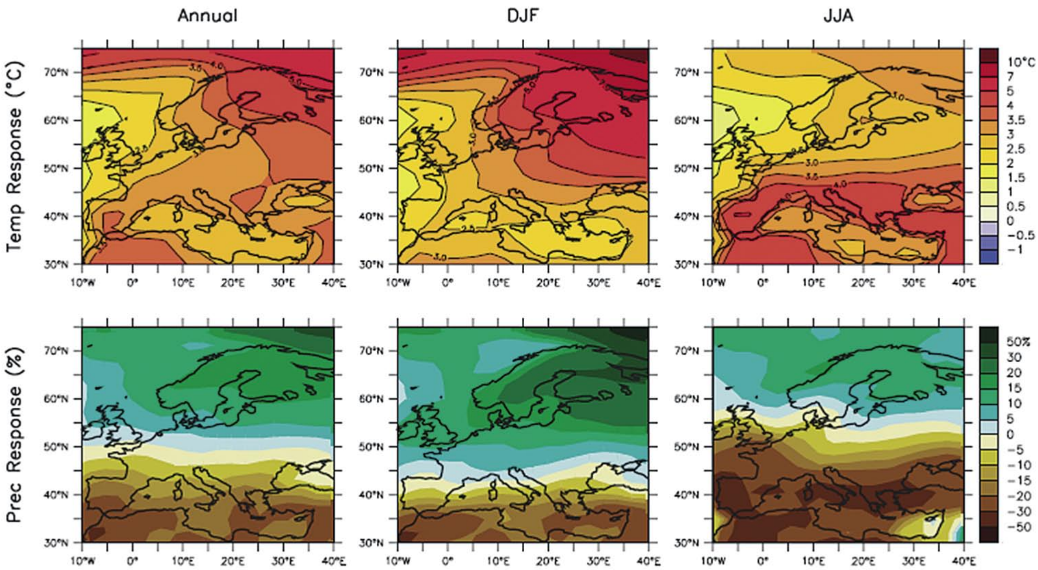

Figure 19. Simulated temperature and precipitation changes over Europe for the A1B scenario. Top row: annual mean, winter (DJF), summer (JJA) temperature change between 1980 to 1999 and 2080 to 2099, averaged over 21 models. Bottom row: same as top, but for fractional change in precipitation. Source: IPCC 4AR 2007.

and frequency much through SEM and Central Europe. There is uncertainty with regard to extreme, summer, short-term precipitation in the Mediterranean and Central Europe. Much larger changes are expected in the frequency of precipitation extremes; for SEM, large increases in the frequency of low summer precipitation are projected. The number of dry spells and the risk of drought is likely to increase in SEM and Central Europe (100-yr droughts are expected to occur under certain scenarios by the end of the century every 10-yr or less), notably in southern Europe.

Landscape hazardousness is likely to increase due to plant water stress and mortality, and to further abandonment of low productive areas.

Land-use change is expected to continue, with additional marginal areas under the future conditions being abandoned, which means additional land to be colonized by vegetation. Climate change is likely to reduce nutrient turnover and nutrient availability, reduced soil moisture and, ultimately, reduced growth and primary productivity. Plant water stress is very likely to increase, and so it is for plant (including trees) mortality, thus potentially increasing fuel hazardousness in many areas. Recurrent droughts, particularly in places where until now were not frequent, may add to this. Large (more than 40%) plant species losses are projected to occur based on several scenarios, which mean a reduced potential for regeneration in the event of fire.

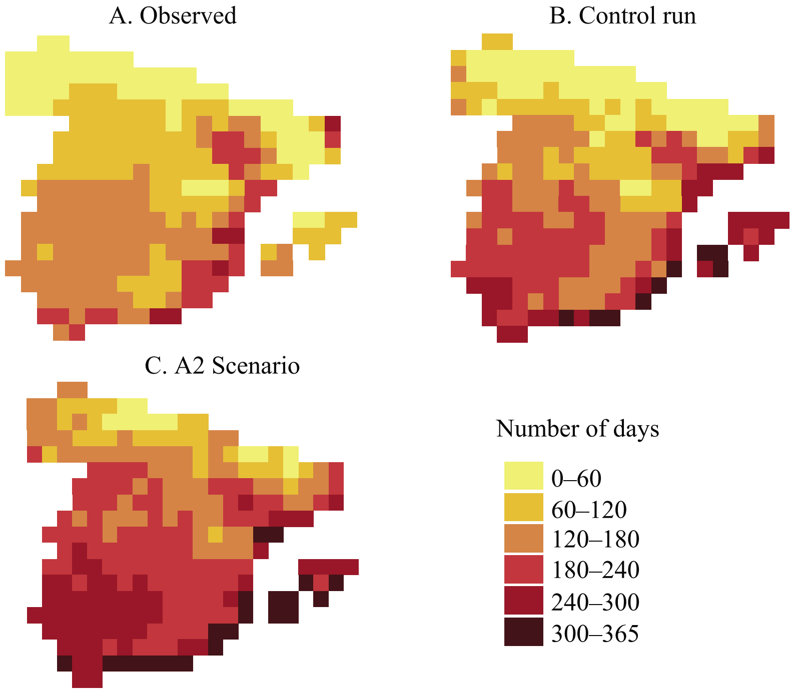

Figure 20. Observed (A) and modeled (B, C) Period of Alert (number of days comprised between the first and last day during the year in which FWI≥15 continuously for a week) in Spain. Observations are based on the (MARSSTAT database from the JRC of the EC at Ispra (IT), and the period 1975–2004. Modeled data are the median of the control runs (B, 1961-1990) and the A2 scenario (2071–2100) of 9 regional climate models (data source INM, Madrid). From Moreno et al. 2008.

Climate change will very likely increase the length and severity of the fire season, as well as the extension of areas of risk. Extreme conditions are likely to increase in many areas and with it the probability of large fires. Recurrent droughts and reduced precipitation are likely to imperil ecosystem regeneration after fire.

Increased temperatures and reduced precipitation are very likely to cause increases in fire danger conditions in current areas and extend these conditions to areas in which fires were now not frequent or absent. The fire season will be longer and more severe (Figure 20). Increased dry spells and droughts, and higher temperatures, particularly maximum temperatures, will very likely increase the frequency of extreme fire danger conditions and with it the probability of fire, particularly of large fires. The postfire regeneration potential of many areas will very likely suffer from reduced precipitation and increased probability of drought. If, as it happened in the past, drought is concomitant with large and widespread fires, this means that the potential for recovering after fire of large extensions might be in peril, thus adding capacity to vegetation change. Increased frequency of fires may cause many wooded areas to become shrublands.

Recommended reading

Alcamo, J., Moreno, J.M., Nováky, B., Bindi, M., Corobov, R., Devoy, R.J.N., Giannakopoulos, C., Martin, E., Olesen, J.E. and Shvidenko, A. 2007. Europe. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Pp. 541–580.

Moreno, J.M., Zavala, G., Martín, M. and Millán, A. 2008. Forest fire risk in Spain under future climate change. In: . Settele, J. and Kühn, I. (eds.)Atlas of Biodivesity Risks- From Europe to the Globe, from Stories to Maps.

Moriondo, M., Good, P., Durao, R., Bindi, M., Gianakopoulos, C. and Corte-Real, J. 2006.Potential impact of climate change on fire risk in the Mediterranean area. Climate Research 31: 85–95.

Pausas, J.G. 2004. Changes in fire and climate in the eastern Iberian Peninsula (Mediterranean basin). Climatic Change 63: 337–350.

4.2 The Need for Strategies Anticipating Climate… and Other Changes

Yves Birot and Éric Rigolot

Looking out in front of the headlights: foresight studies are needed.

Policies related to wildfires have very often been designed in a situation of reactive posture, generally after the occurrence of some major disasters. As wildfire risk is most likely going to increase and expand to new areas, it is time to break out the reactive mode and to anticipate change and deal with emerging issues in advance, so that it becomes possible to act on and address problems in time to avert a crisis. Foresight studies are the adequate tool that allows not to predict but to shed light on a future characterised by uncertainty. They can greatly assist policy and decision making processes. Foresight on wildfire should take into account both the areas where there is today a "fire culture" and established policies on fire management, and new areas where wildfire risk is expected. Even though climate change is an important driving factor, other factors such as changes in land use and society have to be jointly considered.

Foresight can be seen as the art of knowledge, and defined as a systematic and participatory process of gathering future intelligence and building a medium-to-long-term vision, aimed at present day decisions and mobilizing joint actions. Usually, a full foresight exercise comprises the following components: i) structured anticipation and projections of long-term social, economic, scientific and technological developments and needs, carried out through trends analysis, elaboration of scenarios, projections on the future; ii) interactive and participative methods involving a broad diversity of stakeholders, and aimed at reaching a consensus; iii) elaboration of a shared guiding strategic vision, including business perspectives, and iv) implications for today's decisions and actions, as well as for policy and strategy formulation targeted to the preferred futures. Foresight studies can be carried out at the local, regional, national or trans-national level.

Foresight studies on wildfire related issues should have an important focus on the structural causes of fires: they should consider inter alia the elements as follows:

- analysis and projections of variation in ecological conditions: climate trends and extreme events, impact on woodland ecosystems and their dynamics, modification in fire regimes with a tentative mapping of new areas under fire threat.
- societal changes reflected by demography and population transfer: from North to South (summer vacation migrations), from rural to urban areas (wish of urbanized people to live in nature rather than with nature), recreation habits and conflicts between users, urbanisation patterns. There are also specific aspects linked to fire prevention and fight-

Living with Wildfires: What Science Can Tell Us
Yves Birot (ed.)

ing: urban communities are less favourable to the wise use of fire (prescribed burning or backfire), while fire fighters coming from urban areas – unless carefully trained – are less comfortable and efficient in fighting fires in wildland areas.

- economic aspects linked to agriculture, forestry, tourism, bioenergy development and the use of forest biomass, etc.
- policy aspects in particular those related to integrated land use planning, and the need to consider cross-sectoral policies.

Foresight studies should also consider or reconsider the whole set of values and assets to be protected. For obvious ethical reasons, human lives have a top priority, followed by human goods. However to what extent should the society pay 100% of costs generated for protecting those who, knowing the fire risk, have deliberately chosen to live in nature rather than with nature? The forest lands having a protective role against sand dune shift, erosion, runoff), should also receive some priority in fire protection. Moreover, the other values of the forest that we want to bequeath to next generations, should they be goods or services, should be better evaluated. In particular, biodiversity (genes, species, populations, ecosystems) and habitat aspects should be highlighted.

"Learning to live with fire", a new approach for civil protection.

It is strongly believed that one cannot get rid of fire, at least in the Mediterranean environment, with a human dominated fire regime. Civil protection objectives should shift to a new approach, helping citizens to learn to coexist with wildfires by a better awareness and preparation before the fire season, including home protection by mitigation actions at the WUI, and safer behaviour during the emergency situations to preserve lives and assets. In addition to this, we must rethink the fighting fire practices at the WUI and clarify towards the residents the evacuate or stay tactics.

International cooperation should be strengthen between European member states and extended to North-African and Middle East Mediterranean countries. Within the framework of the European mutual assistance between governments in case of emergency situation during the fire season, the European Commission Monitoring and Information Centre (MIC), should be able to activate in addition to conventional fire fighting resources which includes mainly air tankers, experts specialized in fire behaviour analysis and a light international intervention force specialized in fire use in fire fighting.

These actions should be implemented with a better knowledge, preparation and planning of the interactions between wildfire consequences with other natural hazards (drought, heat waves, torrential rains).

Towards an integrated fire management policy

Living with fire implies to properly evaluate the potential environmental, social and economic damage of undesirable fire (large and intense), but also the benefits of using low intensity and/or targeted fires such as prescribed burning, or even backfires in fire suppression operations. It is meaningful and realistic to envisage a combination of fire

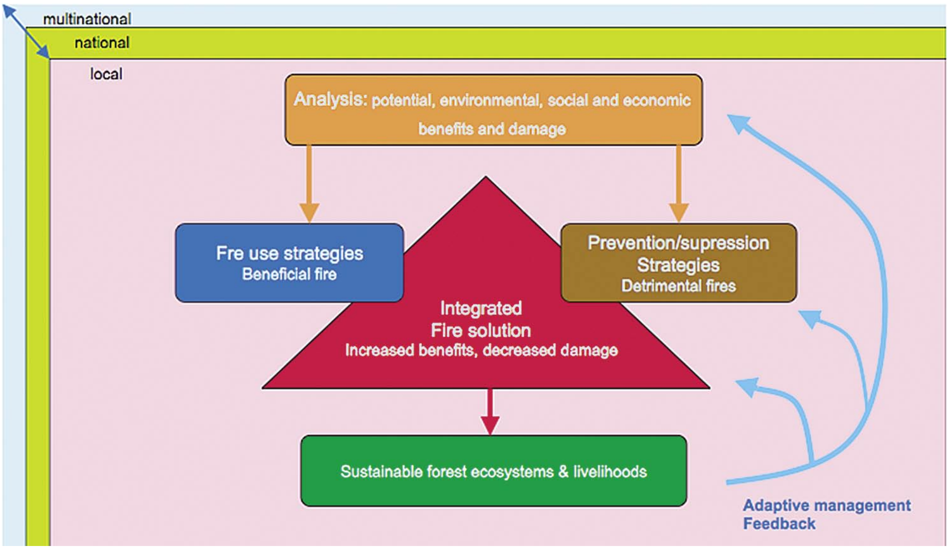

Figure 21. Integrated Fire Management; a conceptual framework (after Myers 2006).

use strategies and prevention/suppression strategies in proportion and intensity adequate to the local conditions (different scales). Such integrated solutions consist of appropriate assessments, goal setting, public policies, education, fire management technologies, and evaluation. Increasing the benefits through the use of fire and decreasing damage from undesirable types of fires can provide sustainability to ecosystems and livelihoods.

> *"Integrated Fire Management is defined as an approach to addressing the problems and issues posed by both damaging and beneficial fires within the context of the natural environments and socio-economic systems in which they occur, by evaluating and balancing the relative risks posed by fire with the beneficial or necessary ecological and economic roles that it may play in a given conservation area, landscape or region." (Myers 2006).*

It is seen as the best approach for removing the structural causes of wildfires.

A long lasting strategy must be based on a renewal of academic and professional training systems at the National and European levels because IFM principals must be early taught to future forest and fire managers

---

Any fire policy should be continuously monitored and evaluated in regard to effectiveness; this is even more true for the new policies which will be applied to extended geographic areas.

A key basis for developing a successful forest fire policy is to understand that many of the elements involved have a dynamic nature. Climate as pointed out above, with its steady trends and extreme events is of course crucial to consider, as well as the evolution in ecosystems composition and functioning, and the modification in fire regime. Societies also evolve and move, and new realities appear, including conflicts. Needless to say that scientific knowledge and technologies are progressing, feeding innovation. It is most likely that in the future, funding capacities will change. They could not match the funding needs in relation to increased fire risk, if the current fire strategy is continued and not adapted to the new context. Administrations and public agencies may also change. In a complex issue like wildfire, in which a large number of factors are inter-playing with a significant level of uncertainty, designing and implementing strategies require a periodic assessment. Therefore public policies must be regularly evaluated and adjusted accordingly in the long-term if needed.

Recommended reading

Aguilar, S., Galiana, L. and Lázaro, A. 2007 Analysis of wildland fire risk management from the territorial policies perspective:strenghts and weaknesses in the European regulatory framework. In: Proceedings of the 4th International Wildland Fire Conference, Sevilla, Spain, 13–18 May 2007. http://www.fire.uni-freiburg.de/sevilla-2007.html

Myers, R.L. 2006 Living with Fire – Sustaining Ecosystems & Livelihoods Through Integrated Fire Management; Global Fire Initiative.

Pelli, P. 2008. Review on Forest Sector Foresight Studies and Exercises. EFI Technical Report 29. www.efi.int

Xanthopoulos, G. 2007. Forest fire policy scenarios as a key element affecting the occurrence and characteristics of fire disasters. In: Proceedings of the 4th International Wildland Fire Conference, Sevilla, Spain, 13–18 May 2007. http://www.fire.uni-freiburg.de/sevilla-2007.html

Conclusions

Johann Georg Goldammer, Éric Rigolot and Yves Birot

The role of science

Fire needs to be understood in all its aspects (fire occurrence, fire behaviour, fire ecology, social sciences) in order to develop sound, sustainable and visionary integrated fire management policies and strategies:

- Science may contribute to define new fire management strategies by creating the scientific and technical foundation for implementing the concept of integrated fire management.
- Science should contribute to understand the proper fire regime suitable to each ecosystem.
- Socio-economic and anthropological analysis of traditional use of fire should lead to a better understanding of the context and the main drivers of fire use in rural communities and to adapt laws, develop informed policies, and create institutional frameworks to enhance a wise and integrated use of fire in all the segments of the society.

The current developments are promising. After the dormancy of wildland fire science in Europe had been broken more than a quarter of a century ago, the formerly widespread ignorance of the role of human-set fires in the dynamics, biodiversity, productivity and stability of cultural landscapes of Europe has been overcome. With the impetus given by the New World, particularly through the influence of North American concepts of fire ecology and fundamental fire science, a new wildland fire science identity and remarkably increasing fire research capabilities have evolved all over Europe. Starting with the exploration of basics of fire ecology, physics and chemistry of the European biota, European fire science is now exploring the rapidly changing socio-cultural environment in Europe and its implications on the increasing vulnerability of the post-modern societies and the natural space in Europe to wildland fire.

The need of science and technology transfer, capacity building and governance in fire management

Any progress in developing fire management solutions that would meet the contemporary and – even more important – the future problems of wildland fire in Europe will be highly dependent of the success of science and technology transfer. In vast areas of Europe the sectoral responsibilities for fire management are shared by services that persevere in the

Living with Wildfires: What Science Can Tell Us
Yves Birot (ed.)

mid to late 1900s – not only from the point of view of capacities of human resources, but also with regards to technological approaches.

The transfer of science-based concepts to fire management in Europe is a tremendous challenge. Whereas the general public and decision makers are often rather impressed by "high-tech solutions", e.g. by automated fire detection and monitoring systems, or the use of aerial assets for firefighting, including the vision of establishing a pan-European aerial fire strike force, still too little attention is given to tackle the underlying causes of the increasing severity of wildfires and vulnerability of society.

As future solutions in fire management need to address the phenomena of changes at landscape level, the required capabilities and skills of fire managers are becoming more complex. Currently the fire suppression capabilities that are still prevailing in most countries of Europe, especially in Central, Western, Northern and Eastern Europe, are conventional fire control technologies and techniques designed for structural or hazardous material firefighting. The need for reforms and innovations, however, have been identified. The EU Leonardo Programme is currently sponsoring the research and review of competency-based wildfire training systems to identify best practice examples from Europe and around the world, to be applied in Europe. The research project EuroFire, which is developed in partnership with the International Association of Fire and Rescue Services (CTIF), a major global professional and lobby organization, is producing competency-based basic training materials specifically for use in European countries.[1] The key target end-user groups for the EuroFire project are: fire-fighters, the rural and land-based sector, sectoral organisations and education and training institutions. EuroFire is also working with the parallel EU-sponsored Fire Paradox Project to share resources, support distribution of the material and encourage feedback.[2]

Besides the need for further development of vocational training in wildland fire management in Europe, reforms of public policies are overdue. The current view to solve the European wildland fire problem by conventional and high-tech fire suppression approaches must be complemented by trans-sectoral policies of integrated fire management. The UN Fire Management Voluntary Guidelines, which have been developed by a group of international experts and reviewed by a global stakeholder consultation, provide a framework that can be used as a guide for developing national or even pan-European integrated fire management policies.[3]

Networking and international cooperation in wildland fire science and fire management

Finally, there is a need of enhancing international cooperation in wildland fire science and management. The rationale for this does not only lie in the similar nature of the problem of land-use and socio-economic changes all over Europe, but also of biophysical changes related to climatic evolution. Over the past years considerable progress has been made in cooperation in wildland fire science through a number of EC-sponsored pan-European

1 www.euro-fire.eu
2 http://www.fireparadox.org/
3 http://www.fao.org/forestry/guidelines/en/

research projects as well as the participation of European fire scientists in international programmes. This has allowed overcoming a prevailing situation of fragmentation of often small-sized research teams by developing a real scientific community. To meet the coming challenges, it is important to keep this capacity.

Moreover, there are border-crossing and global aspects of the fire problem that need to be tackled by fire science, such as the trans-boundary air pollution during extended wildfire episodes that is threatening human health and security, or the role of fire emissions on the composition and functioning of the global atmosphere. Other unresolved problems that need to be addressed by research and development include fire management on lands contaminated by heritages of armed conflicts, major disasters and environmental pollution. This is especially the case in Eastern Europe where large areas are covered by land mines and unexploded ordnance or contaminated by radioactive pollution as a consequence of nuclear accidents (Chernobyl accident).

Cooperation in technology transfer and fire management is becoming imperative vis-à-vis the sheer magnitude of the wildland fire problem and the financial implications that some countries may not overcome individually.

In Europe an increase of international cooperation in aerial firefighting is observed. During some recent fire crises, e.g., in Greece and neighbouring Balkan countries in 2007, the resources shared were mainly fixed- and rotary-wing aircraft. Calls for aerial assistance are common and seem to bring immediate solutions and relief. The reality, however, sometimes is quite different – and here one must be sceptic and self critical. During the recent years it was repeatedly observed that aerial assets, which were brought from Central European countries to the South and Southeast of Europe, provided enormous moral support to the countries in need. However, evaluation on the ground revealed that a large number of missions and sorties provided brilliant pictures for the media but were rather inefficient in bringing down the fires. While the European Commission is taking first steps to enhance the preparedness and smooth cooperation in international aerial firefighting – the FIRE-4 project – there is still a lack of internationally agreed standards for multinational firefighting operations on the ground – a prerequisite to involve aerial assets.

Europe should orient itself by expertise and progress made at international level. The International Wildland Fire Summit of 2003, an informal international event held in conjunction with the 3rd International Wildland Fire Conference, addressed international cooperation in fire management.[4] The Summit recommended that solutions for cooperation must be based on practical and realizable approaches and instruments leading to common strategies, frameworks for implementation and financing mechanisms. Most crucial is the development of mechanisms that will result in concrete action, including both informal and formal agreements at bilateral and international levels. The agreed "Strategy for Future Development of International Cooperation in Wildland Fire Management" provided a number of recommendations aimed at harmonization and standardization of approaches and enhanced international cooperation. Two of the Summit outputs are particularly practical and ready for implementation:

- An international agreement template which can be used by agencies wishing to form a cooperative or mutual aid arrangement with one or more other countries for cooperation in wildland fire management;

4 http://www.fire.uni-freiburg.de/summit-2003/introduction.htm

- A recommendation that an Incident Command System (ICS) should become the international standard for wildland incident management in international or interagency agreements and exchanges.

In the context of disaster risk reduction and civil protection the management of wildland fire crises is only one arena in which countries are challenged to develop agreed standards and protocols for enhancing the efficiency and the effectiveness of cooperation. A common wildland fire management terminology, agreed competency-based standards, and agreements that regulate responsibilities and liabilities of cooperating parties are prerequisite for improving governance of major disasters, both for providing and receiving assistance. Here the "Rosersberg Initiative" aims at strengthening international preparedness and response to environmental emergencies – an initiative that is quite relevant for the international wildland fire community.[5]

Recommended reading

Goldammer, J.G. 2000. Global transitions of fire and fire management: Retrospectives and perspectives. In: Moser, W.K. and Moser, C.F.(eds.) Fire and Forest Ecology: Innovative Silviculture and Vegetation Management 1-9. Proc. Ann. Tall Timbers Fire Ecol. Conf. 21. Tall Timbers Research Station, Tallahassee, Florida.

Goldammer, J.G., Statheropoulos, M. and Andreae, M.O. 2009. Impacts of Vegetation Fire Emissions on the Environment, Human Health and Security – A Global Perspective. In: Bytnerowicz, A., Arbaugh, M., Riebau, A. and Andersen, C. (eds.). Wildland Fires and Air Pollution. doi:10.1016/S1474-8177(08)00001-6.

5 The Rosersberg Initiative was launched by the international Advisory Group on Environmental Emergencies (AGEE) in 2007 and is currently addressing three thematic areas, (a) Advocacy and Capacity-Building; (b) Strengthening International Governance Systems; and (c) Operational Aspects of Providing and Receiving Assistance. For more information see: http://ochaonline.un.org/ToolsServices/EmergencyRelief/EnvironmentalEmergencies/RosersbergInitiative/tabid/2647/language/en-US/Default.aspx

Science can help in designing better strategies and policies allowing living with fire risk. The recent results of forest fires research should be available to policy and decision makers, and beyond to the whole society. This EFI Discussion Paper focuses on a limited number of selected key topics related to wildfires on which scientists have key messages to deliver, and which should be considered in future policy making processes.

This Discussion Paper is divided in four sections. The first one presents some statistical figures on wildfire and underlines the trends. The second section deals with two basic questions which should form the background of any rational strategy: why and how do woodlands burn? What is the resulting impact? Practices and strategies for acting on fire risk, including the economic and policy dimensions, are presented in the third section. In the fourth part, the emphasis is put on the challenges linked to increased and new wildfire risks related to climate change, and ways to cope with them.

The authors represent eminent European scientists, covering a broad range of expertise and scientific disciplines, with up to date scientific information.

ISBN: 987-952-5453-29-4
ISSN: 1455-6936