OPERATIONAL TOOLS AND GUIDELINES FOR IMPROVING EFFICIENCY IN WILDFIRE RISK REDUCTION IN EU LANDSCAPES

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FIREfficient
Operational tools for improving efficiency in wildfire risk reduction in EU landscapes

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Foreword

Under future climate change scenarios, all EU countries may undergo increased risk of wildfires, and therefore civil protection and global emergency management will become increasingly important. This expected trend, will affect areas that historically have not experienced significant impact from wildfire events and a large proportion of damage is likely to be related with high-severity of fires. These typologies of fires affecting forests nowadays are not just a factor of risk for forest but a global emergency involving forest values, civil protection and land planning.

The need to adapt wildfire risk management strategies to the changing context of risk is urgent and not always easy due to the fact that frequency of extreme events in a particular region is low. Actions should focus on reducing the likelihood of the occurrence of extreme wildfires and the severity of damage and impacts on people and ecosystems if extreme wildfires do occur.

In parallel, wildfire risk management strategies are being significantly improved in terms of efficiency and operational impact. Innovative knowledge and practices in fire management and fire behavior assessment offer a powerful tool for improving cost-effective emergency response, which enhances the effective integration of wildfire risk into land planning or allows better defining the role of the actors responsible for reducing wildfire hazard and risk in the landscape (from forestry to land planners and homeowners in urban interface). In this book we aim to show that resilience of forests to wildfires can be improved through proper risk governance, good forest management and landscape planning activities.

This publication has been developed in the frame of the European project FIREfficient (*Operational tools for improving efficiency in wildfire risk reduction in EU landscapes*). The project seeks to build capacity for land planners through enhancing the transfer to them of best practices and lessons learned in wildfires. An extended version of each chapter can be found out in the project website and the Lessons on fire platform created with the project.

The Editors

Sota els efectes dels escenaris futurs de canvi climàtic, tots els països de la Unió Europea poden experimentar un augment significatiu del risc d'incendis forestals i, en conseqüència, la rellevància de la protecció civil i de la capacitat de gestió global de l'emergència seran cada vegada majors. Aquesta previsible tendència afectarà zones que històricament no han experimentat impactes significatius d'episodis d'incendis forestals, i una proporció molt important dels danys estaran relacionats amb incendis severs i d'alta intensitat. Aquest tipus d'incendis que típicament afecten als terrenys forestals actualment, no són només un factor de risc pels boscos, sinó una emergència global que afecta tan als valors mediambientals, com a la protecció civil i a la planificació del territori.

En aquest marc és urgent adaptar les estratègies de gestió del risc d'incendis forestals a aquest context de risc canviant. Tanmateix, això no és fàcil de portar a terme ja que la presència d'episodis extrems d'incendis en una regió concreta és baixa. Les accions s'haurien de dirigir, per una banda, en reduir la probabilitat d'ocurrència dels grans incendis forestals i, per l'altra, en reduir la severitat dels danys i impactes sobre la població i els ecosistemes en cas que esdevinguin.

En paral·lel, les estratègies de gestió del risc d'incendis han millorat significativament els darrers anys en termes d'eficiència i impacte operatiu. El coneixement i pràctiques més innovadores sobre gestió de focs i d'anàlisi dels patrons de propagació d'incendis ofereixen una eina molt útil cara a millorar la cost-eficiència de la resposta en cas d'emergència així com d'integrar el risc d'incendi en la planificació del territori. Permeten, alhora, definir millor el paper dels diferents actors relacionats amb la mitigació del risc dels incendis forestals al territori (des dels gestors forestals fins als planificadors del territori o els propietaris dels habitatges a les zones d'interfase urbano-forestal). Aquest llibre pretén mostrar que la resiliència dels boscos als incendis forestals pot ser millorada a través d'una bona governança del risc, i la gestió forestal i planificació dels usos del territori adient.

Aquesta publicació ha estat desenvolupada en el marc del projecte Europeu FIREfficient (*Operational tools for improving efficiency in wildfire risk reduction in EU landscapes*). El projecte pretén fer accessible el coneixement expert d'incendis forestals als planificadors del territori a través de la identificació i transferència dels nous coneixements, eines i lliçons apreses al voltant de diversos aspectes dels incendis forestals. A la web del projecte així com a la plataforma Lessons on fire es poden trobar una versió ampliada de cada capítol.

Bajo los efectos de los escenarios futuros de cambio climático, todos los países de la Unión Europea pueden experimentar un aumento significativo del riesgo de incendio forestal y, en consecuencia, la relevancia de la protección civil y de la gestión global de las emergencias derivadas será cada vez mayor. Esta predecible tendencia va a afectar a regiones que históricamente no han experimentado impactos significativos de episodios de incendios forestales, y una proporción muy importante de los daños estarán relacionados con incendios severos y de alta intensidad. Esta tipología de incendios que típicamente afectan a los terrenos forestales actualmente, no solo representan un factor de riesgo para los bosques, sino una situación de emergencia global que involucra tanto los valores medioambientales, como a la protección civil y al planeamiento territorial.

La necesidad de adaptar las estrategias de gestión del riesgo a estos tipos de incendios, es una urgencia ineludible a la par que compleja debido a la baja frecuencia con la que se dan los eventos extremos en una determinada región. Las acciones a implementar deberían ir dirigidas a reducir, por un lado, la probabilidad de ocurrencia de les incendios forestales extremos y, por otro, en reducir la severidad de los daños e impactos sobre las personas y ecosistemas si dichos incendios ocurrieran.

En paralelo, las estrategias de gestión del riesgo de incendios han mejorado significativamente los últimos años en términos de eficiencia i operatividad. El conocimiento y las prácticas más innovadores en gestión de incendios y en análisis de los patrones de propagación de incendios ofrecen una herramienta muy útil para mejorar la coste-eficiencia de la la respuesta en caso de emergencia, así como de integrar el riesgo de incendios en la planificación del territorio. Permiten, a su vez, definir mejor el papel de los diferentes actores relacionados con la mitigación del riesgo de incendios forestales en el territorio (des de los gestores forestales hasta los planificadores del territorio o los propietarios de la viviendas en zonas de interfase urbano forestal). Este libro pretende mostrar que la resiliencia de los bosques a los incendios forestales puede ser mejorada a través de una buena gobernanza del riesgo, y la gestión forestal y planificación de los usos del territorio adecuada.

Esta publicación se ha desarrollado en el marco del proyecto Europeo FIREfficient (*Operational tools for improving efficiency in wildfire risk reduction in EU landscapes*). El proyecto pretende hacer accesible el conocimiento experto de incendios forestales a los planificadores del territorio a través de la identificación y transferencia de los nuevos conocimientos, herramientas y lecciones aprendidas alrededor de diversos aspectos de los incendios forestales. A la web del proyecto y en la plataforma Lessos on fire se puede encontrar una versión ampliada de cada capítulo.

Die vorhergesagten Klimaszenarien lassen für alle EU Länder ein erhöhtes Vegetationsbrand-Risiko erwarten, so dass die Rolle des Zivilschutzes und ein umfassendes Krisenmanagement umso wichtiger werden. Dieser Trend wird auch und gerade Regionen betreffen, die historisch keine Feuer-Erfahrung besitzen; gleichzeitig wird die Mehrzahl aller Schäden bei sehr intensiven und großen Bränden entstehen. Diese Art von Wald- und Vegetationsbränden sind nicht einfach ein forstliches Risiko, sondern vielmehr eine globale Krise für Wald-Ökosystemdienstleistungen, Zivilschutz und Landschafts- und Landnutzungsplanung. Die Notwendigkeit Feuermanagementstrategien an den sich verändernden Risikokontext anzupassen ist dringlich, gleichwohl jedoch erschwert durch die geringe Frequenz von Extremereignissen am jeweils gleichen Ort.

Adaptionsmaßnahmen sollten darauf zielen die Wahrscheinlichkeit des Auftretens von extremen Feuerereignissen zu verringern und den Schaden und die negativen Effekte auf Ökosysteme und Menschen zu minimieren, wenn es zu Großbrandlagen kommt.

Parallel haben sich die Europäischen Feuermanagementstrategien in den vergangenen Jahren signifikant verbessert und ihre Effizienz deutlich gesteigert. Innovatives Wissen, neue operative Praktiken und Wissen um Feuerverhaltensfaktoren bieten interessante Möglichkeiten in Waldbrandmanagement und -Bekämpfung. Diese Erfahrungen erlauben und fordern die Einbindung von Feuer-Risiko in die Landschaftsplanung und ermöglichen in der Risikominimierung die Rollen und Verantwortlichkeiten der einzelnen Akteure in der Landschaft zu definieren. Dies reicht vom Förster und Landwirt über den Landnutzungsplaner bis zum semi-urbanen Hausbesitzer. Mit diesem Buch möchten wir aufzeigen, dass es möglich ist die Resilienz von Wäldern gegenüber dem Risiko von Wildfeuern zu steigern. Gutes Risikomanagement, vernünftiger Waldbau und Landschaftsplanung die den Faktor Wildfeuer berücksichtigt sind hier wichtige Bausteine. Diese Veröffentlichung wurde im Rahmen des EU Projektes FIREfficient (Operational tools for improving efficiency in wildfire risk reduction in EU landscapes) entwickelt.

Das Projekt möchte Landschaftsplaner und Landnutzungsplaner im Thema Wildfeuer Handlungskompetenzen und Wissen vermitteln und fördert den Austausch von guter fachlicher Praxis und „lessons learned" im Bereich Wildfeuer. Eine ausführliche Version aller Kapitel kann auf der Projektwebsite, als auch über „Lessons on fire platform" gelesen und abgespeichert werden.

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INTRODUCTION: WILDFIRE RISK MANAGEMENT ACROSS EUROPE, FACING COMMON CHALLENGES AND OPPORTUNITIES

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1. Introduction: wildfire risk management across Europe, facing common challenges and opportunities

By Tim Green, Alexander Held and Marc Castellnou

1.1. Concepts and lessons learned in wildfires and risk planning and management at EU level

Wildfire are affecting us all across Europe

Wildfires are a phenomenon that threaten lives and have major economic and ecological consequences at local, regional, national and global scales. The long-term average of annual burnt area in Europe (1980-2014) is about 500 000 ha with about 85% of the burnt area occurring in the EU Mediterranean area (SAN-MIGUEL-AYANZ et al., 2013), However, large wildfires are not only an issue for Mediterranean areas. In 2014, the largest single fire event in Europe occurred in Sweden affecting 12 807 ha in Västmanland County (JRC, 2015).

The number, frequency and intensity of fires, as well as the damage caused by fires, are increasing across Europe. This trend is expected to continue and we must be prepared. There are a number of reasons for the increasing occurrence of wildfires in Europe in recent decades. These include: land abandonment; changing patterns of human settlements; and changing climate. Farmland abandonment may affect an area of 12 600 000-16 800 000 ha in the European Union by 2030 (KEENLEYSIDE and TUCKER, 2010). There may be benefits to this abandonment in terms of habitat restoration, but it also means that trees and shrubs will grow on previously farmed land and so the amount of fuel, and therefore the risk of fire, will increase in these areas. It is also predicted that fire season severity and fire season lengths will increase along with the predicted climate change (FLANNIGAN et al., 2013).

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The fire management approaches that have been applied across Europe in the past decades are not solving the increasing wildfire problem. Up to now,, the policy strategy across Europe has mainly consisted of controlling and suppressing fires. We have become very effective in controlling small and medium intensity fires, and yet, we have to admit, there are big and intense fires that escape beyond our control until the fire runs out of fuel or the weather changes allowing us to regain control of the situation. This small proportion of large fires causes the vast majority of severe impacts and losses. In 2007, fires in Greece affected 270 000 ha of forest, olive groves, and farmland, killed 64 people, and destroyed more than 1000 homes and 1000 other buildings. Estimates of damage ranged up to €5 billion (MAVSAR et al., 2010).

Every time a wildfire is contained (more often than not meaning creating a control line around a fire that was not going to burn beyond an acceptable limit) and nobody dies, the success is attributed to skill ("good safe firefighting"). On the other side, when a fire escape beyond our control, or someone gets hurt or dies, the failure is attributed to "bad firefighting". Of course, the reality is far more complicated.

Changes in the climate and changes in vegetation characteristics may be reasons for the increasing frequency and intensity of wildfires, but let us also consider the organizational set-up of planning and fire management in Europe to analyze why the change towards landscapes that are more resilient (Box 1) seems to be so difficult. Gaps in coordination between the planning agencies, land managers and civil protection agencies is one reason why the incidence of large wildfires is on the rise, and why the consequences have been so devastating. There has also been a trend to increase resources used for fire suppression – by using more fire fighters, fire trucks, fire hoses, helicopters, water bombers, look-out towers, satellite detection, fire-spread models, fire weather index, etc. as well as investing in newer and more sophisticated technology. Public opinion often demands that resources be spent in response to dramatic, high profile events – such as fighting large fires. Of course this is needed, but there is usually not the same demand for investment in more strategic and long-term prevention activities reducing landscape vulnerability. Low probability but high impact events are often low on the list of priorities until they occur.

Adjustments but little substantive change

There have been some fantastic advances in how we respond to wildfires in Europe, but still the catastrophic fires keep occurring. Some of the amazing adjustments include: the development of special wildfire crews, air tankers and helicopter use across borders, the European Forest Fire Information System EFFIS, the Emergency Response Coordination Centre ERCC (previously Monitoring and Information Centre MIC), numerous checklists, innovative fire shelters or fire curtains, dedicated research and computer models. Recent additions include HRO (High Reliability Organization) training, wildfire simulators, European forest risk platforms, social media communication tools among others.


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However, the policy of fire exclusion and control was set more than 100 years ago, and we have yet to look back. It is based on two big assumptions:
1. We can control fire.
2. We can do it safely.

Are these assumptions true? Might it actually be harmful to maintain these beliefs? Is there another solution? We know that we can reduce the severity and impact of inevitable vegetation fires. It means focusing on measures to reduce the likelihood of wildfires occurring, reducing the severity of damage and impacts on people and the environment if they do occur, and assisting with fire suppression activities.

Fire intensity is directly related to the amount of available fuel. The only realistic way to avoid large, high intensity vegetation fires is to keep vegetation fuel levels down to manageable levels. Low fuel levels mean mild fire intensity, easy and safe controllability and low levels of damage. Beyond mechanical tools and grazing for reducing broad-scale fuels, prescribed burning under mild weather conditions is part of a realistic solution. Prescribed burning is the planned use of low intensity fire, under mild weather conditions, to reduce fuel loads over broad areas of vegetated land. It is done so that when wildfires do occur, they are of lower intensity and are much easier, and very much cheaper and safer, to control. This connection between fuel load and fire intensity is now relatively well understood across Europe. Reduction of fuel loads requires active management of (vegetation) fuels on a range of scales, from broad scale fuel reduction (for instance through prescribed burning) in some landscapes to removal of vegetation and other combustible materials around buildings and infrastructure.

Land-use planning for reduction of fuel loads is vitally important. Prescribed burns, for example, need careful planning in order to maximise the discontinuities in the fuel loads and minimise the inconvenience to the public. Of course, active management of fuels by fuel reduction burning and other measures (e.g. pruning, thinning or removal of ground vegetation) and the related land-use planning is not something that can be embarked upon overnight. It requires careful research into fire behavior in a variety of fuel and vegetation types across Europe; unfortunately there is still not much research in most European countries. It also requires understanding of the Fire Types concept, the use of Strategic Management Points*,* fire behavior influencing factors or the Campbell Prediction System (CPS) (see chapter 3.2). Ideally this understanding is not only from theoretical training but supported by experience and exposure to real situations to raise an even higher awareness level for the respective landscape planner on the complex topic of land use planning for fire management. Large wildfires are a rare event and it is unlikely that any individual will gain experience of such an event. In order to increase preparedness for these events we need to provide opportunities for experts to define and exchange skills and experience and visit areas where these events are occurring or have just occurred.

Because these large wildfires are a relatively recent and rare phenomenon, preparation for these events is an issue that has often been neglected in forest and spatial planning. While most forests in Europe have a management plan, it is not clear to what extent fire is routinely considered as part of the plan (FOREST EUROPE, 2011). One positive example of integrating preparation for wildfires is a small program that has been established by the Forestry Commission of the UK. The Forestry Commission has issued a good-practice guide for building wildfire resilience into forest management planning (FC, 2014).

People with experience of fire management and fire fighting are making very clear demands for greatly increased fuel management programs to prevent catastrophic fires happening. With these requests comes the need for adapted land and urban planning, to allow for a new approach in fire management, complementary to fire suppression. To achieve progress in this direction we need to understand what are the hindrances that prevent us from applying new methods and approaches. We need to make tools available to overcome these obstacles and allow for real change to improve the efficiency in wildfire risk reduction across Europe, across the different countries, cultural and societal variations, vegetation and fire types. We need to define and describe commonly agreed competencies and standards across Europe, both in fire management organizations as well as in the planning sector.

Box 1. **Definitions of relevant risk management related concepts.**

Hazard: A hazard is a dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage. http://www.unisdr.org

Preparedness: The knowledge and capacities developed by governments, professional response and recovery organizations, communities and individuals to effectively anticipate, respond to, and recover from, the impacts of likely, imminent or current hazard events or conditions. http://www.unisdr.org

Recovery: The restoration, and improvement where appropriate, of facilities, livelihoods and living conditions of disaster-affected communities, including efforts to reduce disaster risk factors. http://www.unisdr.org

Resilience: Resilience is: (1) the ability to bounce back from a crisis to the initial state, altered perhaps but essentially unscathed; (2) the capacity of a system to: “continually change and adapt yet remain within critical thresholds” (FOLKE et al., 2010); (3) the capacity to “absorb a spectrum of shocks or perturbations and to sustain and develop its fundamental function, structure, identity and feedbacks as a result of recovery or reorganization in a new context” (CHAPIN et al., 2009); (4) the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions (http://www.unisdr.org). Sub-systemic resilience may be part of the problem rather than part of the solution if it hinders the adaptability and transformability (see below) of the system – examples of problematic resilience include vested economic interests, bureaucratic red tape and entitlement thinking etc.
Resilience has two components: **adaptability:** the capacity of the system as a whole to maintain core functions and values under changing circumstances. For the system as a whole to be adaptable, sub-systems need to be transformable, and **transformability:** the capacity to transform the stability landscape itself in order to become a different kind of system, to create a fundamentally new system when ecological, economic, or social structures make the existing system untenable (FOLKE et al., 2010).

Response: Response is the aggregate of decisions and measures taken to: (1) contain or mitigate the effects of a disastrous event to prevent any further loss of life and/or property; (2) restore order in the immediate aftermath of the disaster; and (3) re-establish normality through reconstruction and rehabilitation shortly thereafter. http://www.businessdictionary.com/

Risk: (1) Risk is the ‘*effect of uncertainty on objectives*’. In this definition, uncertainties include events (which may or may not happen) and uncertainties caused by ambiguity or a lack of information. It also includes both negative and positive impacts on objectives (ISO, 2009a, 2009b). (2) Risk is the potential of losing something of value, weighed against the potential to gain something of value. Risk can also be defined as the intentional interaction with uncertainty. Risk perception is the subjective judgment people make about the severity of a risk, and may vary from person to person. http://www.businessdictionary.com/

Risk assessment: The determination of quantitative or qualitative estimate of risk related to a concrete situation and a recognized hazard. *Quantitative risk assessment* requires calculations of two components of risk *(R):* the magnitude of the potential loss *(L)*, and the probability *(p)* that the loss will occur. **Acceptable risk** is a risk that is understood and tolerated usually because the cost or difficulty of implementing an effective countermeasure for the associated vulnerability exceeds the expectation of loss.
Risk assessment consists of an objective evaluation of risk in which assumptions and uncertainties are clearly considered and presented. Part of the difficulty in risk management is that measurement of both of the quantities in which risk assessment is concerned – potential loss and probability of occurrence – can be very difficult to measure. The chance of error in measuring these two concepts is high. Risk with a large potential loss and a low probability of occurrence, is often treated differently from one with a low potential loss and a high likelihood of occurrence. In theory, both should be of near equal priority. https://en.wikipedia.org/wiki/Risk_assessment

1.2. Towards an effective integration of key knowledge, tools and best practices of wildfire risk management into land-use planning

Updating knowledge and approaches

Across Europe we experience a number of different climate zones and are exposed to the related vegetation fire regimes. Across the continent, the combination of a policy of fire exclusion, increasing efficiency of fire control and changing land use has led to an ever increasing fuel load and to an increasing risk of mega fires. If you add in the predicted effects of climate change, the situation is expected to get even worse.

> ***If the fire suppression approach is not delivering the desired results, it is time to consider new approaches, namely the acceptance of fire disturbance and the approach of managing fuel loads to mitigate the effects of unwanted fires, to complement the fire suppression.***

Promising research into various aspects of fire behavior and fire management, as well as capacity building and collection of good practices has been carried out in many EU projects such as FIREPARADOX, FUME, FireSmart, EuroFire, FUELMAP, eFIRECOM, Cost Action FP0701, and, FIREfficient[1]. Organizations like the Pau Costa Foundation (PCF), Global Fire Monitoring Centre (GFMC), European Forest Institute (EFI) and many others are making knowledge available; providing training and capacity building, hosting workshops and fostering exchanges of experts between institutions and countries. There is also a raft of projects[2] dealing with disaster risk reduction and relevant for fires: MOVE; ENHANCE; CapHazNet; CONHAZ.

> ***With all the existing knowledge, why is it that in Europe the application of existing knowledge is only patchy and not widespread? This question does not only refer to the land-use planning process, it also refers to land-use practices and the public opinion of fire management issues.***

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Across Europe, land-use planning policy and budget decisions concerning fire management are often discussed and decided upon under the demands of an urban population with an urban mindset. Few decision-makers in land planning and management have experienced wildfire and the related dangers and losses. Responsibility for fire management is generally given to the civil fire services. That the mindset, training and approach of a civil fire service ("putting out fire") does not and cannot reflect land management issues is a factor that needs attention. A civil fire service planning and decision-making will almost always think of suppression first, then firefighter safety, and only then about preventative measures like fuel reduction and land management.

> ***Fire intensity is directly related to the amount of available fuel. Low fuel levels mean mild fire intensity, easy controllability and minimal damage.***

An integrated approach to wildfire management, involving fire prevention as well as fire suppression is needed. All stakeholders, not just the civil fire services, should be involved and making well-informed decisions.

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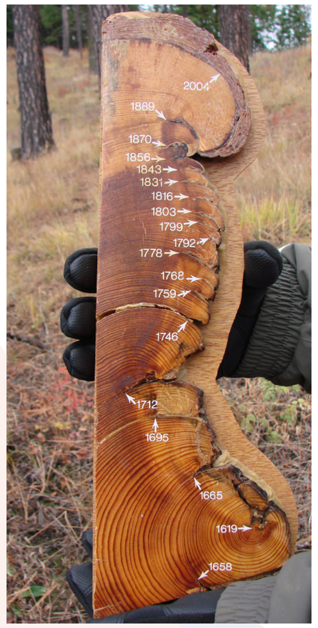
[1] FIREPARADOX: http://www.fireparadox.eu/, FUME: http://fumeproject.uclm.es/, FireSmart: EuroFire: http://www.euro-fire.eu/, EFIRECOM: http://efirecom.ctfc.cat/CA FP0701: http://uaeco.edu.gr/cost/, FIREfficient: http://firefficient.ctfc.cat/

[2] MOVE: http://www.move-fp7.eu/, ENHANCE: http://enhanceproject.eu/, CapHazNet: http://caphaz-net.org/, CONHAZ: http://conhaz.org/



Presence of natural fires in the ecosystem. Author: Eduard Plana Bach

Obstacles to implementation of an integrated approach

What do we mean by change and what is the difference to the current fire policy of fire control and suppression? We think we are on the safe side to describe a holistic fire management approach on a European scale based on three main cohesive objectives. A Cohesive Vegetation Fire Management Strategy is a strategy involving all stakeholders (including the urban and spatial planners) and across all landscapes, using the best science, to make meaningful progress towards three goals:

1. Fire Resilient Landscapes.
2. Fire Adapted Communities.
3. Safe and Effective Wildfire Response.

With the **Vision:** *To safely and effectively extinguish fire when needed; use fire where allowable; manage our natural resources; and to live with wildfire.*

Preservation of forests can be seen as a prerequisite for climate change mitigation. Forest fire management and the planning and inclusion thereof, in land-use practices play a vital role. The Intergovernmental Panel on Climate Change (IPCC, 2007) formulates this very clearly:

> *"Even the strictest mitigation measures will not be able to avoid further negative effects of climate change in the next decades. Therefore, adaptation measures - especially for managing short term consequences – are essential."*

A major activity line of appropriate adaptation measures according to the IPCC (2007) are "Initiatives and measures to reduce the susceptibility and vulnerability of natural and human systems against actual or expected impact of climate change." With this, the link and connection to risk management (and the planning thereof) becomes obvious. The focus on risk management is consistent with the statements of the Special Report of the IPCC – Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX)[3] (IPCC, 2012). This report clearly demonstrates the relationship between climate changes on the one hand and risk on the other. There should be a focus on incorporating risk management so that it becomes a central issue that is addressed as a matter of routine at national level, and even at global level. Again, land use planning plays an integral part. Adaptation measures to expected climate change that includes appropriate preparation for large wildfires in land use planning, only happen partially and to a relatively low extent.

> ***Why is it that available knowledge does not find application in land-use planning to a wider extent?***

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[3] The work presented here is based on an analysis of the IPCC SREX report and research conducted within several studies in forest risk management networks, such as the PUMA(1) network and the FRISK GO(2) project

(1) www.waldwissen.net/waldwirtschaft/schaden/fva_ratgeber_forstliches_krisenmanagement_startseite/index_DE
(2) www.friskgo.org

Box 2. **Conceptual barriers for an effective Integration of wildfire risk into land planning.**
Economic Barriers
1 – **Liquidity problems**: While adaptation measures are often linked with high investment costs, the potential benefits from the investments often occur only in the long term in the form of reduced risks.-

Environmental Barriers
2 – **Current forest growth dynamics in conflict with adaptation goals**: Due to the long-term nature of forestry production the current characteristics of forests may not be suited to the expected conditions under a changed climate.
3 – **Long-term production**: Many of the adaptation measures (tree species selection, management measures) can only be initiated or implemented in the early development phases of a forest. In a significant proportion of stands there may be no possibility or only very marginal adaptation planning that can be implemented.

Information Barriers
4 – **Incompleteness of knowledge**: There are many knowledge gaps. For instance, in the context of planning for fire management there are uncertainties in climate predictions and the response of vegetation and fuel response to changes in climate. Assessment of the economic effectiveness of various risk mitigation measures is hampered by incomplete knowledge.
5 – **Limited use of the most up-to-date information**: Even when stakeholders have sufficient information they may not act because large wildfires only happen very rarely and there are already current work conditions are already demanding enough.
6 – **Aging of Knowledge**: Accumulation of knowledge may be overtaken by the speed of change.
7 – **Quality of knowledge presentation**: New knowledge may be presented in a form which is not or only partially in a usable format for the average user – for instance, when knowledge is not transferred from the scientific sphere to other stakeholders (forest owners, forest managers, land-use planners, etc.).
8 – **Technical availability**: Availability of information may be restricted especially during acute crisis situations where there may be periods of high demand. The involvement in technically powerful, independent and well-known information platform (e.g. a forest risk facility such as proposed by FRISK-GO) has a high priority.

Psychosocial barriers
9 – **Lack of lighthouse events**: Visible but non-dangerous events often do not provide sufficient impulse for action. Sometimes, only large catastrophic events provide that impulse to act.
10 – **Underestimation of risk**: There is a tendency to underestimate risks especially when the impact or frequency of events has a high natural variability.
11 – **Postponing decisions under uncertainty**: Individuals and organizations may defer decisions under conditions of uncertainty
12 – **Time lag between cause and effect**: Due to the longevity of forest production, the effects of adaptation measures (let alone the planning of the measures) only become visible or effective in forest ecosystems with a high time delay. The effects of either action or inaction in forest ecosystems are usually only marginal in the short term. Negative consequences in the next 10-20 years will therefore only be visible to a very limited extent.
13 – **Low perception of the effectiveness of protective measures**: It is not possible to exclude the risk of natural events. A success thus manifests itself often only in a reduction of impact or severity compared to a potentially greater impact from failure of risk management measures. The motivation to implement protective measures can therefore be low.
14 – **Creeping normalcy**: The long-term trends are barely noticed, and the altered state is perceived as the new normal. This means that an incentive for action often only occurs when the rate of change has reached a tipping point (a point of no return).

Political barriers
15 – **Samaritan's Dilemma**: The expectation of assistance from the state after a disaster (such as a large wildfire) may reduce the motivation of individuals to take adaptive and preventive measures.
16 – **Politician's Dilemma**: A potential conflict exists between the short-term political interests of politicians and governments (at all levels) and what is in the long-term interest of society.
17 – **Conflicting interests between minimizing risk and other management objectives**: There are many demands from different stakeholders placed on forests. One of these is too minimize the risk of disasters occurring – for example by reducing the fuel loads in forests susceptible to forest fire or by managing forests in mountainous areas to protect settlements from the risk of avalanche or flooding. Optimum management for these objectives may conflict with other management objectives, such as maximizing timber production, or biodiversity.
18 – **Targeted disinformation**: Strategies for mitigation of disaster risk, and also partly adaptation strategies, are often associated with risks of additional costs or reduced yields. Avoidance of action may therefore be in the economic interests of some parties. It is well-known that lobbyists operate targeted efforts to apply political pressure.

Based on an analysis of the SREX report and other reports we can identify 18 barriers that hinder implementation of adaptation measures in land-use planning with regard to the forest sector. The barriers are grouped into five categories: Economically justified barriers - Environmental barriers - Information barriers - Attitude and behavioral barriers (psychosocial component) - Political barriers. There is overlap and interconnection between the different barriers. The large number of barriers identified (see Box 2) shows that the so far rather slow implementation of adaptation happens for a variety of reasons. A considerable number of these explanatory factors are psychological. We have sufficient information and knowledge to make more rational decisions about adaptation measures than we do at the moment. It is, therefore, highly unlikely that significant adaptation success can be achieved only by the further extension of our knowledge and making the knowledge more available. We also need to develop methods for awareness raising that overcomes the psychological barriers. Implementation of adaptation measures "is still in its infancy".

Pinus ponderosa forest managed by prescribed burning in NW USA. Author: Eduard Plana Bach

What can be done?

Before we can expect changes in operations and the planning process, there is a need for global and European leadership on fire management issues. Many organizations are dealing with wildfire issues, but none has the authority or agreement by the others to provide such credible and accepted leadership. We need to agree at a high level on a unified vision of a good practice fire management with cohesive strategic goals.

To find out more see:
Report on challenges for wildfire risk integration into land planning. FIREfficient Project. Deliverable 8.
http://firefficient.ctfc.cat/, http://www.lessonsonfire.eu

U.S. Federal forest managed with prescribed burning for biodiversity conservation purpose in Florida. Author: Eduard Plana Bach

2.

CROSS-SECTORAL DIMENSION OF WILDFIRE RISK; DEALING WITH SOCIETY, LAND-USE MANAGEMENT AND ECONOMY

Author: Eduard Plana Bach

2. Cross-sectoral dimension of wildfire risk; dealing with society, land-use management and economy

2.1. Wildfire risk communication and governance: managing societal involvement and multi-stakeholder cross-sectoral planning

By Eduard Plana, David Martín, Marc Font, Marta Serra and Domingo Molina

2.1.1. The socio-environmental dimension of wildfire risk: moving towards a firewise planning

Wildfire risk planning mission is increasingly intricate as land-use planning tool that should be able to keep pace with rapid rates of social and environmental changes. As wildfires are likely to be more severe, homes become less defendable, and the solution becomes more complex because we must take into consideration nature and humans. Changes in land use and climate change bring alterations on fire regimes; extreme fire behaviors appear in areas not historically affected. This has significant relevance in terms of culture of fire because of the lack of social background knowledge of coping with fires. This situation aggravates and diversifies the range of associated impacts and meets a vulnerable society that is not prepared to deal with such a magnitude of risk. The success of adaptation to this new dimension of risk is largely induced by social factors such as fire risk perceptions, capacities to face increasing levels of risk or identification of relevant social actors to come into play. This implies a higher degree of social and political commitment to enhancing a proper risk governance[4], and societal and institutional involvement an achieving an efficient wildfire risk management and mitigation.

Potential for disaster risk decreases as communities or societies expand their capacity to cope with the related negative consequences (UN/ISDR, 2009). Thus, risk can be attenuated leading communities to minimize their biophysical and social vulnerability (CUTTER, 1996, Figure 1). That vulnerability reduction is achieved by considering simultaneously the combination of two determinant factors: on one hand the agroforestry and livestock activities, which promote a landscape mosaic of different land uses; and on the other hand, the urban and spatial dimension, which includes urban settlements and infrastructures at risk, as well as the social capacity to undertake self-protective measures. Together, both factors will affect the overall vulnerability of the territory.

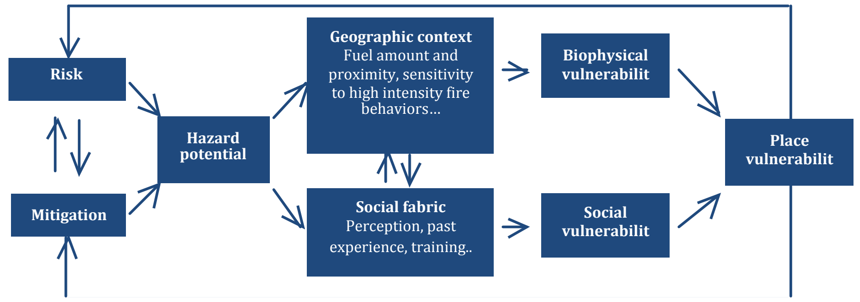


Figure 1. Hazards of place model of vulnerability. Source: Adapted from CUTTER, 1996.

Because extreme wildfires are relatively rare events, policy makers and citizens very often underestimate the risk and its awareness levels. Likewise, as a consequence of the widespread mind-set held by urban societies, the distinctive role of fire as a part of the traditional management decays, and in some societies any use of fire or even fire as a natural component of the ecosystem is criminalized. There is also misunderstanding of wildfire risk in rural communities, in which the same traditional use of fire may occur as a common practice and management tool, but in a context of increased fire risk (especially due to the high fire spread capacity).

The urban areas in contact with the forest areas, the so-called **wildland urban interface** (WUI) is one of the most controversial and problematic issues for fire suppression and emergency services. Human life and urban houses are the focal point of these services, and fire suppression in urban areas becomes more complex and

[4] Understanding governance as the processes of interaction and decision-making among the actors involved in a collective problem that lead to the creation, reinforcement, or reproduction of social norms and institutions (HUFTY, 2011).

expensive compared to the forest areas. People living in WUI areas should assume some responsibility for protecting their property, but they usually are unaware of fire behavior or even the preventive and protective actions they may take (KRUGER et al., 2003; NELSON et al., 2003; AGRAWAL and MONROE, 2006; BLANCHARD and RYAN, 2007; GILL and STEPHENS, 2009).

Firewise planning (Figure 2) is a valuable service that landscape architects and designers can offer to homeowners, incorporating the needs of two factors: (1) the home's structure (analyzing it as available fuels); and (2) the home's surroundings (offering a defendable and fire safe space) (KRUGER et al., 2003; XANTHOPOULOS, 2004; MOLINA-TERRÉN, 2009; NFPA, 2015). Policy-level decisions, such as providing financial incentives to conduct urgent changes in existing settlements developments ("pre-existences") and creating technical building codes for future area development are fire-safe practices (MCCAFFREY, 2004).

These technical building codes should consider:

1) The potential impact of radiant heat of an encroaching wildfire on the different types of structures, thereby prescribing an adequate safety distance between the vegetation and the building;
2) potential emission of spot fires into the WUI area and spread capacity among gardens and house; as well as,
3) leaving sufficient space for fire suppression services on public roads, property access roads and fire trails, as well as for civilian evacuations.

Commonly, government departments with authority to draw up planning documents will be willing to approve all these technical instructions and convert them into mandatory technical regulations.

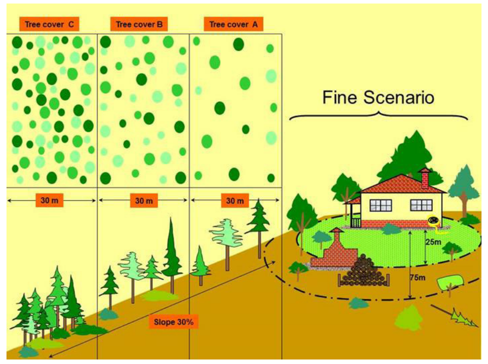


Figure 2. Firewise planning: model of defendable space around a house.

Author: Pau Costa Foundation

In summary, emergency, agroforestry and spatial/urban planning policies should provide a coherent framework for integrating wildfire risk management into the land planning framework. The policies should consider structural factors linked with expected global change, and traditional suppression and prevention policies should be complemented with the land-use patterns and social perception and demands assessment (Figure 3).

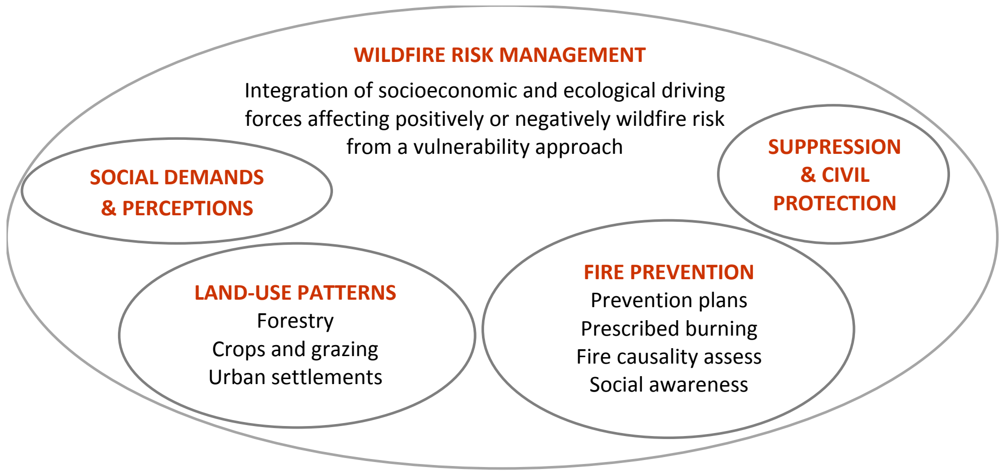


Figure 3. Components of an integrated approach of Wildfire Risk Management.

2.1.2. Social factors influencing individual attitudes and public support towards wildfire risk mitigation strategies

Wildfire suppression has been the dominant rationale for many years. Consequently, policies which envisaged a total suppression of fire were produced and strongly endorsed by the public, in name of the belief that all fire can be solved with technology issues such as bigger fire extinction resources. However this is a myth that can induce to communities at risk into a false feeling of security and avoid any prevention measure. It is human nature to deflect responsibility for negative events (COHN et al., 2008), which makes easier to attribute the disaster culprit on a public deficiency management of the forest and for instance belittle the inherent risk which entails the fact of owning a home in the WUI. In the opposite, moving forward towards a better social understanding of the role of fire in the ecosystems should favors long-term cross-sectoral strategies based upon fuel management at landscape level, and better knowledge of risk exposure should promotes attitudes of self-protection and shared responsibility (PLANA, 2011b).

Psychological variables, related to public beliefs and attitudes, appear to be the most significant factor of public policy support to wildfire management strategies (ABSHER and VASKE, 2007). The main factors affecting the ability to undertake an individual action can be summarized in the perceived effectiveness of actions to reduce the risk; confidence in the capacity to correctly carry out actions; the perceived responsibility for fire risk management; and trust and credibility to the institution promoting actions (MARTIN et al., 2007).

Experience of wildfire is an important component in the risk awareness level, in this sense however, the consequence that past experiences with wildfire galvanize people's reactions leading to undertake fire management practices is not that straight forward (WINTER and FRIED, 1998; CUTTER et al., 2003; BLANCHARD and RYAN, 2007; COHN et al., 2008). According to SIMS and BAUMAN (1983), as the influence of experiencing a wildfire increases the level of awareness and risk perception works for a relatively short period after the disaster occurs, mitigation measures and legal change should be established immediately following the event.

If individuals would take responsibility for fire, things would be easier, but before transferring all the responsibility to the individual level, we should answer about "who is the actual risk owner?" public authorities got the corresponding taxes and gave the corresponding administrative permits to build up a house into the forest (this can change with updating the legal frames, but the "pre-existences" are resulting from the old one). It is important to mention that wildfire management is a non-excludable good. This means that every single resident has the right to be provided with the same service, or, as a paradox, good compensations expected from insurance coverage may disincentive individuals to assume more responsibility in their own safety (GARDNER and EL-ABD, 1984; HEMENWAY, 1987; CORTNER et al., 1990; WINTER and FRIED, 1998).

2.1.3. Guidelines for cross-sectoral wildfire risk planning and societal involvement

Here follows a list of major issues to be considered to enhance the cross-sectoral risk planning meanwhile involving individuals as an active component of the mitigation strategies:

✓ **Expanding the scale of the approach to wildfire risk management and promoting partnership working**

Wildfire risk needs to be approached as a "multi-scale issue" by bringing it across land planning scales: from the territorial level to forest stand and home levels. It also needs to be regarded as, as a "multi-stakeholder issue" including all public and private actors involved in the causal chain of preparedness, response and recovery stages. Finally it has to include a "cross-sectoral approach", where policies regarding forests, agriculture, urban and spatial planning, tourism, energy and other relevant sectors are integrated) (PLANA, 2007).

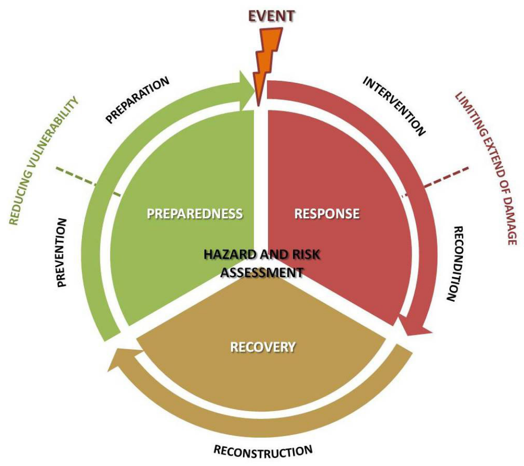


Figure 4. Components of the risk cycle (defined in Box 1). Source: Adapted from PLANAT, 2011.

eFIRECOM expert exchange meeting in a WUI area. Author: Eduard Plana Bach

The diversity of stakeholders who are affected by fire and could have been differentiated so far (fire departments, local governments, emergency management agencies, forest management departments, planners, homeowners' associations, volunteers ...) must come together to deal with the wildfire risk management. A political arrangement on land-use planning for promotion of operational cooperation among public and private stakeholders and the coordination between agencies is needed; as it has been achieved in some countries (Box 3).

Box 3. **The example of partnership working: Wildfire Groups in the UK (MCMORROW, 2011; GAZZARD, 2015).**
Wildfire groups[5] (also called Fire Operations Groups - FOG) were born in 1996 (after a serious moorland fire happened in UK) and are responsible for building wildfire mitigation and adaptation into land management and emergency planning. They are not widespread all across UK, but they have been created where there is a need to focus on landscapes at risk from wildfire. The membership varies depending upon local circumstances, but it is generally composed by Fire and Rescue Services (FRS), major Private and Public Landowners, Countryside Associations, Water Companies and the Ranger Services. This particular forum with many different representatives allows fire related issues to be addressed that individual agencies would otherwise not address. Therefore, by promoting joint working and collaboration, joint ownership of the causal chain "preparedness-response-recovery" actions is achieved. Likewise, wildfire groups fill a gap in current legislation that otherwise would limit Fire and Rescue Services competences on being responsible for making land management more resilient to wildfire. For example, the local fire groups formed by agencies and rural landowners work alongside each other to share equipment and training, and even develop joint working management practices and prescribed burning plans.

Development of fire plans and maps for specifically designated rural areas is required by wildfire groups. Such fire plans may include contact details of key people able to assist during the emergency; location of equipment; prioritization of key infrastructure and landscapes to be protected; location and seasonality of nearby water resources; information on access to be used in the case of a fire event. Commonly the ranger service plays a key role in the wildfire groups orchestrating organizational procedures like the secretariat or the meetings, and supporting firefighters during the fire emergency.

Furthermore, fire groups are also intended to build a strong network that encourages and allows local communities (rural and urban) to actively participate in protecting their environment and economy from the effects of wildfires. Education programs and initiatives are developed to provide advice and support on wildfire issues to help people understand the importance of fire prevention and thus contribute to raising awareness of wildfires. They include the production of fire awareness promotional material for the local community and visitors on the impacts of wildfire and landscape management, including managed burning.

✓ **Reducing uncertainty and making wildfire risk planning robust**
As much as we reduce uncertainty our decision-making process is more consistent. The new knowledge about wildfire patterns prediction offers accurate information but poses new challenges for an effective integration of wildfire risk into land planning (section 2.2). Consistent economic arguments show wildfire risk mitigation measures as the best and most cost-effective option (section 2.2).

Official risk mapping and regulations should be able to give legal coverage to fire risk planning, which in turn will provide the tools for implementing operative and management indications. Levels of hazard and vulnerability should be assessed as objectively as possible for helping the decision-making process in land planning. Providing normative range to risk planning will be necessary to ensure that the provisions are transferable to the territorial and urban planning as binding regulations (this legal status is necessary as far as activities and uses regulation affects property rights). The common forest scaled planning model from national-regional-local levels offers a coherent framework in which to assess fire risk in a top-down approach; this helps to overlap the administrative boundaries limitations as wildfire risk need to be analysed under criteria related to the physical limits of existing massifs (PLANA, 2011a).

[5] Inspired by the experience of the flood action groups (see for instance: http://www.nationalfloodforum.org.uk/)

✓ **Promoting local governance and management of risk**
Local administrations play a key role within the hierarchical system of wildfire risk planning in so far as they are required to establish the link between the homeowners (fire risk planning at property level) and the upper territorial level. At the local level, the planning process can be used as a tool for promoting stakeholders awareness and risk culture as well as for defining the boundaries of the responsibilities among stakeholders, and building trust and credibility between them. Clearly defined administrative processes should allow municipalities to be acquainted with specific policy and legal instruments designed to implement specific restrictions and actions. As well as applying property taxes to make residents pay for ongoing maintenance of the defendable perimeter.

✓ **Promoting more disaster resilient communities**
At a community level, partial as well as individual perception of the risk – understanding this as the level of own exposition to the hazard – influences the cooperation capacity in prevention and self-protection actions. Therefore, fire education and outreach programs designed to change people's attitudes, behavior and level of knowledge offer an opportunity to increase awareness regarding the shared responsibility in managing risk (MCCAFFREY, 2004).

Author: Eduard Plana Bach

Participation programs constitute a great chance to foster contacts among neighbors. This in turn helps to form a sense of community (MCDANIEL, 2014) and brings people to understand that fire hazard is a problem that affects everyone, and which can only be tackled through cooperative working. By means of community participation in decision-making processes, creating debate about which level of vulnerability can be assumed, and what alternatives exist to mitigate the risk, a better consensual and jointly responsible development and implementation of management actions can be achieved (PEREIRA et al., 2014). When part of the solution comes from the local community, social acceptability is higher as is the level of social commitment and activism (HERAS, 2006). The inclusion of forest landowners' associations into WUI communities could allow all factors affecting the risk management and assessment to be addressed. Furthermore, linking local and scientific knowledge contributes to provide a broader understanding of natural/social systems by giving rise to an interactive and two-way learning processes (Box 4) (REED, 2008; PAVEGLIO et al., 2009).

Box 4. **Example of residents' involvement in fire management: Firewise communities in USA**
The National Firewise Program is an initiative from the National Fire Protection Association in the USA that provides homeowners with the knowledge and techniques necessary to create a home environment safe from wildfire. If homeowners get involved and meet the requirements standards set by the program, they are given national Firewise community recognition. Some of the local solutions that the Firewise Program considers are homeowner education, fire department response, prescribed fire, structural retrofits or design of open spaces. Recognized Firewise communities are awarded so they can prove the benefit of their efforts. In addition, they may receive preferential consideration for medical grants and funding for continuing their work, understanding that it must be a continuing process.

Table 1. Recognition standards for becoming a Firewise community.

RECOGNITION STANDARDS	ACTIONS
1.- Community Hazard Assessment	Create a plan in coordination with local fire officials which identifies locally achievable solutions that the community is able to implement. An inventory of the area will be necessary in order to determine the potential impact of the fire (what areas need to be treated?).
2.- Creation of a local Firewise task force and an action plan	Be responsible for maintaining the Firewise community program, monitoring its progress and reporting its tasks. The recommendations are approved by the WUI specialists who may work with the community to identify project implementation funds. It should involve homeowners, fire professionals, planners, land managers, urban, foresters, who are all expected to take part in the development of the WUI plan.
3.- Organise a Firewise communities' USA day	The event should be designed to increase awareness among communities about fire ecology, Firewise techniques, landscaping demonstrations or provide opportunities for homeowners to share information and skills.
4.- Financial commitment	Participating communities invest a minimum of $2 annually per person for local Firewise community efforts. These funds stay in the community and they are not necessarily cash. Small neighbourhoods achieve their minimum investment through municipal employers or volunteers using municipal or other equipment.
5.- Annual report and renewal application	The local Firewise community need to submit an annual report documenting complaints with the program. In addition, each year, every recognized community must renew its commitment to Firewise program by reapplying and documenting its continuing efforts to reduce wildfire hazard. Communities are granted after implementation plan has been presented to the local Firewise representatives and at least one Firewise project has been completed.

Source: National Fire Protection Association (http://www.firewise.org/)[7] (NFPA, 2015) (SHIRALIPOUR et al., 2006).

✓ **Promoting an effective wildfire risk communication**

Adapting the wildfire risk related message to different groups and specific social contexts can help to make the communication process more successful. In fact, small communities within a rural culture may be easier to reach than larger communities (MCDANIEL, 2014). In accordance with this, educational programs should be target specific groups such as property owners, year-round residents, chambers of commerce, local realtors or schools (GARDNER et al., 1985; MCCAFFREY, 2004; MACGREGOR et al., 2008; SHINDLER et al., 2009; MCDANIEL, 2014). At this stage, distinction should be made between risk communication (warning homeowners about a potential future damage and preventive actions) and crisis communication (during an event) (STEELMAN and MCCAFFREY, 2013).The goal of the message should not just be that people become aware of risk, but also that this risk could pose significant and severe consequences for them (MACGREGOR et al., 2008). Furthermore, the aim of the communication processes must also enable communities to meet the wildfire challenge by providing the appropriate capability and tools to effectively undertake fire prevention actions. Pedagogical techniques are also a fundamental ingredient in the communication process. As a core premise, communication must be conducted without provoking alarm, in a way that does not frighten or disconcert people. The general misperception of reality in many ways (reluctance to cut trees, false feeling of security, etc.) demonstrates how important it is to educate while communicating, attempting to make people understand that there is a better approach for actual fire hazard and risk prevention planning.

The lack of trust and credibility constitutes the main barrier to effective risk communication (SLOVIC, 1999; VOGT et al., 2005; MCCAFFREY, 2006; STEELMAN and MCCAFFERY, 2013). According to MCDANIEL (2014), interactive events such as workshops, field trips or demonstration sites, can support openness and transparency as they are a chance for experts to justify and clarify their actions as well as for public to make their voice heard. Moreover, the credibility of the information provider and the clarity of the message will influence the acceptability of the message and increased likelihood to conduct fire mitigation practices (MCCAFFREY and OLSEN, 2012).

Final remarks

✓ Especially in the current global change context, wildfire risk assessment and management analysis needs to ensure there is room for interpretations coming from social science disciplines aimed at tackling the new forms of interaction between fire and society. Social questions such as people's perceptions, beliefs and attitudes toward fire impacts appear to be key issues since they play a decisive part in determining the success or failure of fire management programs.

✓ The synergistic effect of the partnership working can encourage learning and exchange of knowledge, which must be robust, homogenous, harmonic and transferable to the interested parties. Learning to live with fire appears to be the most effective strategy all across the world. Designers, developers or builders working in WUI areas have the opportunity to offer residents a home designed and constructed with Firewise features.

[7] <Firewise Communities USA – Recognition Program> http://firewise.org/usa-recognition-program.aspx?sso=0

✓ Communication processes must be driven at the local level to actively engage homeowners in planning processes and increase their understanding about the public liability to create and maintain defendable spaces around their properties. Interactive approaches encourage two-way exchange in such a way that they can promote better understanding between the parties and trust in those who implement a practice resulting in a greater acceptance of risk reduction measures.

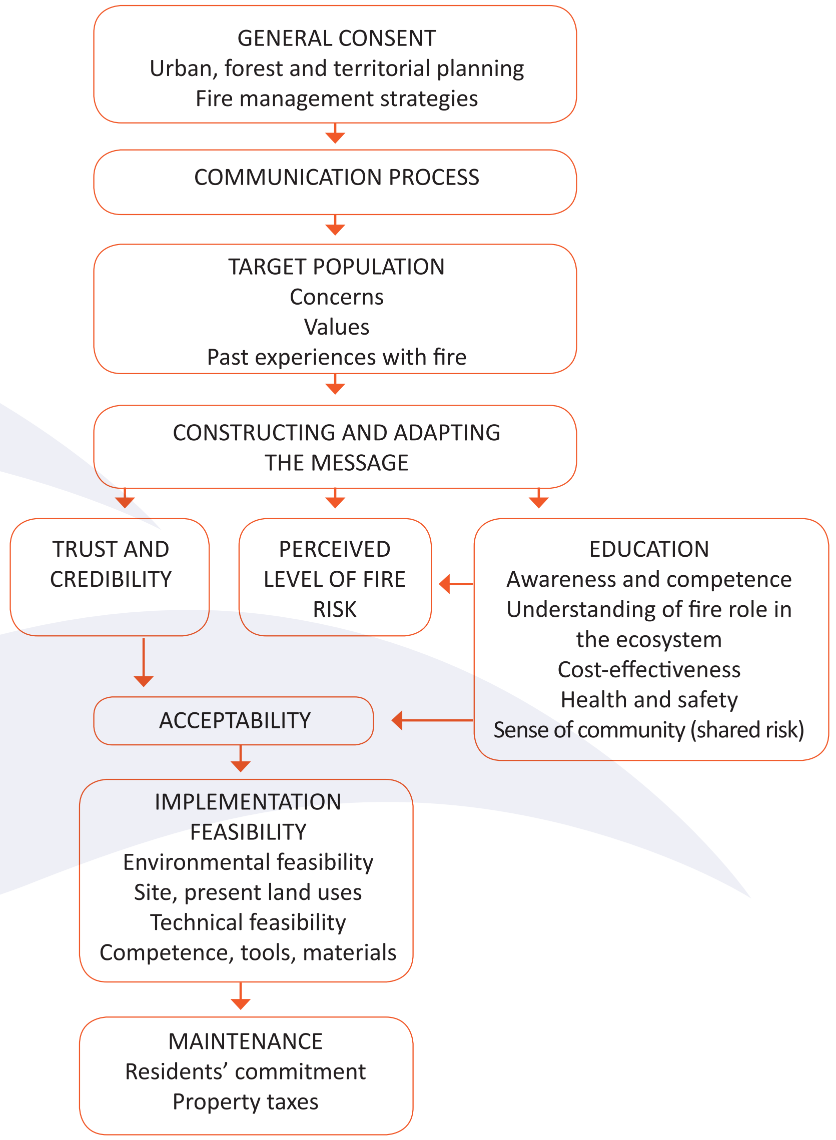


Figure 5. Sequence of stages in the process of communication and factors that influence public acceptance of fire management.

To find out more see:
Report on Social factor and territorial dimension of wildfire risk management: managing societal involvement and cross-sectoral planning. FIREfficient Project. Deliverable 15.
http://firefficient.ctfc.cat/, http://www.lessonsonfire.eu

Author: Eduard Plana Bach

2.2 Cost effective assessment of wildfire risk mitigation strategies

By Eduard Plana and Marc Font

2.2.1 Understanding the economy of wildfire risk management

The understanding and assessment of socio-economic impacts of wildfire should be considered as an essential part of the wildfire risk planning and management (KLINE, 2004; MORTON et al., 2003). A positive economic balance between the impacts of the perturbation and the avoided costs through the implementation of the preparedness and response actions should favor a better social justification of the efforts done, especially when cross-sectoral and long-term mitigation strategies are needed. In that sense, the cost effective assessment of risk management within a natural hazard context aims to provide a basis and support for better decision making (WORLD BANK and UNITED NATIONS, 2010; IPCC, 2012; SHREVE and KELMAN, 2014). This kind of assessment not only can, as mentioned, encourage the implementation of the mitigation strategies but also support the less costly and/or more effective approaches.

The main negative economic effects of wildfires are those related to the direct impacts on the forest goods and environmental services supply such as wood production, soil erosion, increased risk of foods or avalanches (EMELKO and SHAM, 2014), loss of landscape quality and tourism revenue, disruption of wildlife habitat (hunting) and costs of restoration. Other important external impacts on transport, water resources, air quality and health should also be considered. On the other hand, special attention should also be focused on those vulnerable elements of the landscape, such as houses and infrastructures, and the people living or staying there.

The United Nations Office for Disaster Risk Reductions (UNISDR) defines the natural disaster risk as the exposure or chance of loss due to a particular hazard **for a given area and reference period**. In the context of risk management, the benefits of the mitigation strategies implemented arise only in case of events occurring, a part of those indirect benefits coming from having the area safety. This poses additional challenges for including disaster risk reduction into economic appraisals as the occurrence of the risk event needs to be identified and involves a solid risk assessment in terms of recurrence and severity as the basis for assessment of the cost and benefits of the mitigation strategies.

In that sense, in contrast with other natural risks such as floods or snow avalanches, there are some characteristics of wildfires which make the development of a traditional economic risk assessment difficult. The spatial definition of wildfire intensity and the affected area is a complex task due to the uncertainty about where the fire will start (ignition point) and where and how it will spread. Indeed, fire could run through a fuel available landscape under specific weather conditions, but it is currently not possible to define how both factors (landscape and weather) will affect fire intensity at a local level. Also, because human activities are the main fire causality factor, determining when and where fires occur, which difficult the concretion of the wildfire return period. The occurrence of future fires is partly determined by the suppression efficiency of past fires and the fuel distribution at landscape level (which changes over time). Finally, the level of severity around the burnt area and the proportion and distribution of unburnt area will have economic consequences, for instance, in the seed dispersion of the replacement forest species which will directly affect the costs of restoration. The economic assessment of wildfire risk is made even more uncertain by the existing knowledge gaps between:

a) Many natural hazards linked with loss of forest cover (e.g. floods, soil stabilization or snow avalanches);
b) Climate change and land-use changes (and the synergistic combination of their effects) which adds significant levels of uncertainty regarding current wildfire patterns, and also as a reference for the future.

In addition, other important considerations needed to perform a cost effective assessment of wildfire risk mitigation strategies are:

- Wildfire impact is strongly influenced by the fire severity according to the ecosystem fire ecology and fire resilience, as well as for the spatial and temporal dimension considered (burnt surface and its frequency). The degree to which forest goods and services are affected will change according to fire intensity. High intensity fires can collapse the ecosystem functionality (even indirect ecosystem functions such as flood or avalanche protection) because of the loss of the forest cover, while low intensity fire can offer benefits in terms of forest health and wildfire risk reduction through regulating tree competition, restoring habitats or controlling fuel loads, for instance. High fire recurrence with several events at the same site can also decrease the regeneration capacity of vegetation, even in the long term. In forests with low amounts of ladder fuels, fire can promote a forest structure that is resilient to fire, ensuring its future viability. All in all, paradoxically, a mosaic of burnt and unburnt areas, limits the fire spread capacity of future events in the medium term periods and at the landscape level, because the burnt gaps create a natural fuel discontinuity which helps to prevent fire propagation.

- Cost are easily calculated when impacts affect elements with a direct market effect (e.g. house prices) or indirect effect (e.g. estimation of customers in a rural tourism site in a burnt area, or increase of avalanche defensive measures in a mountain, due to the loss of protection forest). However, not all fire impacts can be easily calculated by means of traditional cost (monetary) estimation methodologies (MORRISON, 2009; MORTON et al. 2003). This is, for example, the case for various environmental and social services where there is no measurable market price. However, there are various methods used in environmental economics (hedonic price, travel cost, contingent valuation, etc.) to determine how such services are integrated into the decision making process.

- The cost owner has to be clearly identified and properly considered in a cost–benefit assessment, because for each cost owner profile (public or private) different cost types could be accounted. For instance, losses in wood production are borne by the forest owner, while losses in environmental services provided by forests affect as well to society. The cost of suppression measures, and even prevention measures, are in most cases covered by the public administrations.

- All efforts to reduce vulnerability have a direct effect on the efficiency of the wildfire event suppression and emergency management as protection of citizens and infrastructures is the priority. This shows how every risk phase (preparedness - response – recovery, see figure 4 in chapter 2.1) is strongly related to the others, and the improvement in one component will also affect, to varying degrees, the other phases (for instance, reducing fuel around the houses will also reduce the fire suppression efforts). Considering the cross-sectoral and long-term dimension of wildfire risk management, from forest policies promoting fuel remove to risk culture promotion into wildland urban interface (WUI), for instance, understanding how the relationships among risk components works can help to identify the less costly and most effective approaches.

- It is expected that fuel treatment over the long term should result in less fire suppression costs, lower personal and property damages, and in major socio-economic and environmental benefits as well as in creating landscapes resilient to future wildfire events. The more intensive the fuel treatment, the greater the effects in reducing wildfire risk (RUSSELL et al. 2004, KLINE 2004, GRAHAM et al. 2004). The alternatives should be balanced according to the risk management objective: *Defensive* – from high intensity in WUI buffer zones; *Pre-suppression* – creation of Strategic Management Points and fuel management areas to decrease the spot fire distance (see chapter 3.2); or *Tolerance* – with low intensity management in large forest areas looking for forest structures to avoiding crown fires (see chapter 3.1).

2.2.2 Methodological steps and considerations for a cost effective assessment of fuel treatments at landscape level

Cost–benefit analysis (CBA) is a common evaluation tool used in the risk management framework to support the assessment of alternatives in terms of public budget allocation (KOPP et al., 1997; WETHLI, 2014). CBA can be used to measure the change with and without a specific action to be implemented, comparing the costs of the planned project with its benefits (commonly calculated in terms of avoided costs in the case of risk management). When relevant impacts cannot be expressed in terms of market price an alternative is to limit the approach to an assessment of cost-effectiveness, which shows how to achieve a given benefit, measured in physical terms, at the lowest cost measured in monetary terms. In all cases, it is recommended to list all environmental changes in a quantitative manner.

In this section, specific considerations to undertake a CBA on wildfire risk management and fuel treatments at landscape level are described following seven common methodological steps to carry out a CBA (CTFC, 2008):

Lineal preventive infrastructures are not always the most cost-effective.
Author: Eduard Plana Bach

1. Set the framework for the analysis to define the project (or policy or event) and the state before implementation compared to the state after implementation. Two fundamental approaches are:

a) To justify the fuel treatment done in a delimited area, comparing fire impact with or without fuel treatment (FINNEY, 2001). Benefits understood as avoided costs (damages caused plus extinction costs) are compared with the cost of fuel treatment. This option clearly assumes that the fire event exists.

b) Comparing the effects of different strategies of wildfire risk management (*Defensive*, *Pre-suppression*, *Tolerance* or mix of), balancing the investments and the results achieved in each case. This option needs a territorial/regional approach where usually the different policies are developed. An example could be to compare the options of investments in: house protection and defense; fuel treatments in strategic areas; or fuel management at the landscape level (PLANA, 2010).

In all cases, results of the CBA will be affected by the so-called assessment variables, such as: cost of fuel treatment type (e.g. mechanical, prescribed burning, thinning, grazing, mix of); forest market condition (e.g. existence or not of a biomass market); fire recurrence (return period) and severity (precise estimation of potential losses depending on severity); goods and services value (for instance, fire affecting forest land versus WUI areas). These variables could be included in the sensitivity analysis (step 6) which permits more flexible integration from the perspective of different scenarios.

For *option a* the study area for the CBA should be defined based on the fire pattern behaviors and the fire types (chapter 3.2). For *option b*, the CBA study area should be the region or territory to be addressed. Regarding the time frame of the CBA, this should be as long as to recognize the effects of the fuel treatment. In this way, it should be possible to compensate for the difficulties in identifying the stochastic probability of a future fire event, assuming one or several events along the period of the project implementation.

2. Identify the relevant mitigation project impacts, identifying whose costs benefits should be recognized. Considering the relevance of wildfire impacts in forest services and the typically public intervention in the suppression tasks, it is recommended to undertake a social CBA application instead of a private one in which only cost and benefits directly affecting the forest owner are considered. Within fuel treatment scenarios, the cost of the total potential affected surface should be considered, independently of whether at the end of the considered time frame, the area has burned or not. Impacts of forest fires beyond the boundaries of the study area could also be considered (for instance, health problems in surrounding cities). Both the treatment service life as well as the necessary time to move from the initial scenario to the optimal conditions (final scenario with increased resilience to fire impacts) has to be considered even simulating fire events during the transition. The more we can identify indirect and environmental impacts, the more able we are to integrate the social benefits of the project into the CBA accountability.

3. Quantification and monetization of cost and benefits, assessing how costs and benefits will change along each year of the CBA referenced period. Difficulties in how to monetize the environmental services will directly affect CBA of wildfire risk, as forest policies are usually based on the benefits that forests offer society. An alternative to deal with these difficulties is to consider ecosystem functionality (protection, recreation, landscaping, water cycling …) rather than environmental externalities. Other general considerations when calculating costs and benefits are:

- Consider the relative prices of forest and other agricultural products, which do not always increase over time (and are not affected in the same way by inflation – understood as the loss in the value of money over time or the increase in prices over time).
- Consider the public subsidies and taxes and how they affect the **shadow prices** (used when imperfect competition prevail in the market or the market is regulated).
- Separate clearly additional cost from the **sunk** cost (money that has been spent or irrevocably committed before the start of the mitigation project. These costs would exist both with and without the project.
- Fire suppression costs per hectare can change a lot according to the final burnt area, usually being much higher for small fires than for large fires. Calculating values of costs and benefits for different fire sizes (e.g. 0-1 ha; 1-5 ha, etc.) will allow more detailed analysis than just calculating average values over an entire area.

4. Discount costs and benefits, converting future costs and benefits into present value. This step is used to ensure that the future costs and benefits of the evaluated alternatives can be compared. The longer the time reference of the analysis, the more uncertain is the social discount rate. Fuel treatments at landscape level take time as the forest management may easily need some decades to be visible (for instance, converting high vulnerable uneven-age dense stands to less vulnerable open even-aged stands). Although discount rates of 2-7% are often used in CBA, the majority of studies regarding disaster risk reduction use discount rates of 10-12% (SHREVE and KELMAN, 2014).

5. Calculate the CBA performance indicators, computing indicators subtracting costs from benefits to analyze the project viability and performance. The studied policy or project is considered efficient if benefits are greater than costs. CBA indicators most commonly used are Net Present Value (which compares whether the projected earnings generated by a project or investment exceeds the anticipated costs) and Benefit–Cost Ratio (which compares the amount of monetary gain realized by a project versus the amount it costs to execute the project). Indicators will be sensitive to the intrinsic value of those goods and services to be protected; therefore, the difficulties in identifying the total economic value of forest land can bias the alternative comparison, especially in *option b* where WUI values are easier to monetize.

6. Perform sensitivity analysis, checking the accuracy of the estimates and assumptions determining the critical variables for which the CBA is most sensitive. Beyond the discount rate, this also includes: *variable-by-variable analysis* – isolating the effect of a change in one variable on the performance indicators; and *scenario analysis* when factors affecting cost–benefit flows do not operate independently (see step 1). Uncertainties related to the climate change scenarios can be analyzed at this stage, for example, by introducing different fire regimes.

7. Make a recommendation, assessing all results and accounting for other qualitative and context considerations. Commonly, economic efficiency considerations should not be the sole criterion for evaluating policies, but rather they should be part of a larger decision. This has particular relevance in the case of CBA of wildfire risk mitigation strategies considering the limitations in estimating costs and benefits and fire event distributions. In this sense, it is strongly recommended to integrate CBA results with qualitative appraisals – at social, cultural and environmental level – moving towards a multi-criteria approach.

Final remarks

- ✓ Regarding the cost effective assessment of wildfire risk mitigation strategies, it should be taken into account that there is not a unique accountability for forest fires impacts;
  - Understanding how fire severity affects (positively or negatively) the ecosystem functionality is crucial in correctly identifying and quantifying the impacts (positive and negative).
  - Social perceived impacts should be distinguished from the environmental impacts. The severity of these impacts can vary from low to high.
  - Not all impacts can be calculated from a monetary point of view.
  - It is important to consider the positive impacts of fire as well as the negative impacts – taking into consideration each timeline, spatial and cross-sectoral dimension.
  - The assessment should be done from each cost “property” perspective.
- ✓ A relevant weakness in using CBA for fuel treatment management at landscape level is the assumption of the fire event, as their occurrence is difficult to forecast in terms of recurrence and area affected from a probabilistic perspective (compared to floods or avalanches). All in all, the results of the analysis offer

complementary information for the policy makers assuming the existence of the fire event. In that sense, the probability that a landscape is burned should be properly argued, although the particular site or zone, particular date or period and particular likelihood or period range cannot be totally defined. Two main drivers affecting the level of wildfire risk (climate change and land use changes), should be considered within the CBA as future scenarios can determine the economic balance of risk mitigation strategies, considering their long-term effects.

To find out more see:
Report on Wildfire risk mitigation: Protocol for a cost effective assessment on fuel treatments at landscape level. FIREfficient Project. Deliverable 14.
http://firefficient.ctfc.cat/, http://www.lessonsonfire.eu

Investing in supersion should be balanced with investment in fuel loads accumulation at landscape level. Author: Eduard Plana Bach

3.

KNOWLEDGE AND TOOLS FOR REDUCING FOREST LANDSCAPE VULNERABILITY TO WILDFIRE

Author: Pau Costa Foundation

3. Knowledge and tools for reducing forest landscape vulnerability to wildfires

3.1 Reducing vulnerability to wildfires at forest stand level

By Míriam Piqué, Teresa Valor and Mario Beltrán

3.1.1 Forest management effects in fire behavior

While extinction systems are able to fight fires of low to medium intensity, which are the majority, the few fires of high intensity and extreme behavior (large forest fires, LFF) often exceed the capacity for extinction, affecting large areas of forest. The real challenge in order to reduce the negative effects of the LFF is to strengthen the prevention measures. Such prevention should be understood as an active performance through spatial planning, proper management of forests and the efficiency of management fire during extinction. At this stage, it is important to consider the main factors that influence the behavior and spread of a fire (topography, meteorology and fuel) (ROTHERMEL, 1983, Figure 6). Since vegetation is the only factor that can be altered to influence the characteristics of forest fires (GRAHAM et al., 2004) and prevent them from becoming LFF, there is a need for a more widespread practice of preventive silviculture that modifies forest structures stands in order to make them more resistant to high intensity fire, reducing the amount and continuity of fuel and encouraging the growth and development of trees.

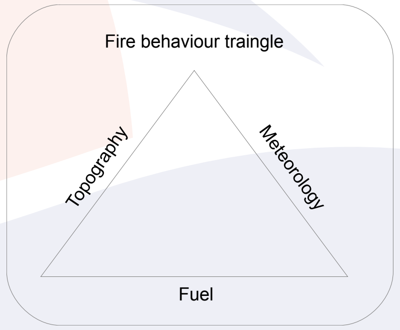


Figure 6. Fire behavior triangle (ROTHERMEL, 1983).

Author: Eduard Plana Bach

3.1.2 Vulnerability to crown fires at stand level: crown fire hazard assessment

There are different forest fire types depending on the fuel layer involved in its spread (figure 7):

a) **ground fires** – in which duff, organic soils and roots are consumed (FRANDSEN, 1987);

b) **surface fires** – in which needles, leaves, grass, dead and downed branch wood and logs, low brush and short trees are implicated in the combustion; and

c) **crown fires** – in which canopy fuels are involved (VAN WAGNER, 1977).

Furthermore, crown fires are divided into three categories:

a) **passive crown fires** – individual or small groups of trees torch out but flames are not maintained in canopy);

b) **active crown fires** – surface and canopy fuel stratum burn and crown fire spread depends on the heat released by the surface fuel layers); and

c) **independent crown fires** – fire spreads in the canopy independently of the heat released from the surface fire), which occur rarely and under extreme conditions (VAN WAGNER, 1993).

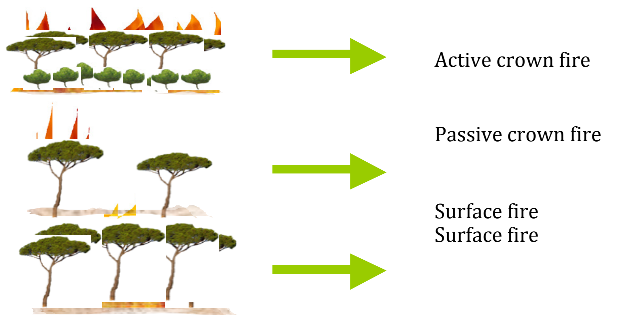


Figure 7. Types of fires in relation to the fuel involved in the propagation.

Undoubtedly, from all these types of fires, active crown fires are the ones that poses the greatest threat to the extinction systems and fire managers (ALBINI and STOCKS, 1986), often spreading rapidly (WADE and WARD, 1973) and burning with greater intensity and spreading faster than surface fires (ROTHERMEL, 1983). Traditional extinction with water or frontal interventions are impossible to undertake in these types of fires because fire behavior characteristics are extreme, i.e. high heat intensity, long spotting distances (see Figure 8) and long flame lengths and rates of spread (SCOTT and REINHARDT, 2001). So then, prediction of the conditions under which crown fires initiate and propagate are thus of primary concern in fire management.

To avoid active crown fires a good step forwards is an active forest management with the goal to create forest structures that inhibit the development of crown fires and facilitate the fire extinction tasks, acknowledging the major role of fuel distribution in fire behavior and regime. In this sense, the role of fuels and forest structure is very important in reducing the risk of transition of surface fires to active crown fires (FERNANDES, 2009; ÁLVAREZ et al., 2012; FERNANDEZ-ALONSO et al., 2013).

However, for integrating the risk of LFFs into the forest planning and management it is necessary to have tools that help to identify the degree of vulnerability of forests to crown fires, and by means of forest management to promote more fire resistant and resilient forest structures.

There are fire simulator software such as NEXUS (SCOTT and REINHARDT, 2001) or FlamMap (FINNEY, 2006) that evaluate whether within a stand an ignition will develop into a crown or a surface fire, and therefore the effectiveness of silvicultural treatments in preventing crown fire. However, there has been little practical application of such software because they require variables that are not usually measured in conventional forest inventories (CRUZ et al., 2003).

Furthermore, there are few crown fire hazard assessment tools that can be used to evaluate whether a forest stand with a given structure will generate crown fires, and therefore to estimate the effectiveness of silvicultural treatments with the objective of fire prevention.

Crown fire hazard assessment tools give information on the structural characteristics of the forest stand and its relationship with the vulnerability to generate and active high intensity crown fires. Therefore, they are useful in assessing crown fire potential behavior and guiding forest management to reduce the risk of crown fires. They are used to identify how vulnerable a forest stand is to generation and propagation of crown fires in relation to the structure and other ecological conditions. Such tools are useful in classifying priority areas where silvicultural treatments should be implemented in order to reduce the risk of LFFs.

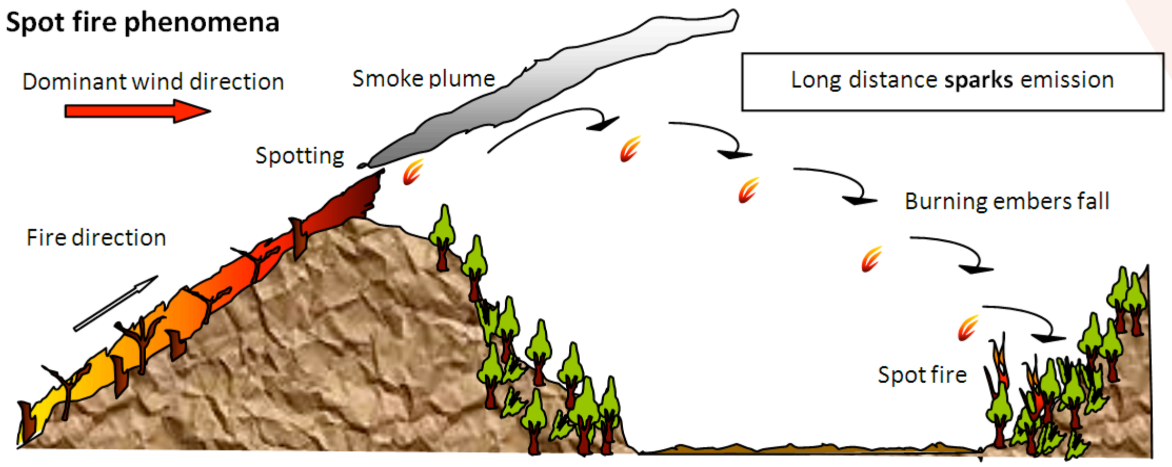


Figure 8. Spot fire phenomena mechanism. Source: PLANA and BARRIGÓN, 2007.

The previous fuel reduction in a planned SMP avoided spot fires in Ódena wildfire (Spain, July 2015). Author: Eduard Plana Bach

Tools for assessing crown fire hazard from forest stand variables of easy measurement

In practice, users of fire simulation models need a good knowledge about the assumptions made in the models to accurately gather data to characterize canopy and surface fuels. To overcome these difficulties other types of tools such as nomographs or classification keys have been devised. Worldwide, nomographs are created to provide managers with an easy way to assess the likelihood of crown fire initiation. They determine the critical values of flame length and spread rate of surface fires, needed for the transition from a surface fire to a crown fire. There are few tools for European conditions. For example, nomographs for *Pinus halepensis* have been devised using the VAN WAGNER (1977) initiation model and BYRAM'S (1959) surface fire model (DIMITRAKOPOULOS et al., 2007). Also, for *Pinus halepensis* forests ALVAREZ et al. (2012) classify forest structures into fuel types as a function of crown fire potential (forest structures identified depend on canopy closure, number of tree layers, percentage of the different tree layers and overall tree density). FERNÁNDEZ-ALONSO et al. (2013) develop a classification criterion of the potential of pine stands to sustain different crowns fire types, based on stand-level variables (basal area and dominant height). The likelihood of crown fire occurrence was simulated using the logistic crown fire initiation model proposed by CRUZ et al. (2004).

Heuristic and expert opinion approaches have also been used to appraise crown fire potential. FAHNESTOCK (1970) designed two keys for determining rate of spread and crowning potential. The second key for determining crown fire potential is based on forest cover, crown density and the presence or absence of ladder fuels. Later, MENNING and STEPHENS (2007) developed a ladder fuel hazard assessment flow chart (LaFHA). The aim was to rank to what extent a surface fire is able to climb to the canopy, by quantifying ladder fuels in a defined area. The LaFHA approach evaluates ladder fuels by estimating clumping of low aerial fuels and maximum gaps in vertical fuel ladders. More recently, PIQUÉ et al. (2011) developed a key to determine quickly the vulnerability of a forest stand to generate crown fires (CVFoC).

The CVFoC helps the manager identify appropriate treatments to modify stand structure in forests that are vulnerable to crown fires and develop forests that are more resistant (Box 5). PIQUÉ et al. (2011) identified structural types for *Pinus* spp. and *Quercus* spp. forests based on forest variables (Figures 9 and 10) as: surface covers of different layers of fuel (aerial, ladder, and surface) and vertical projection distances between them. The forests were classified according to vulnerability to active crown fires: A - high vulnerability; B - medium vulnerability; and C - low vulnerability.

Box 5 .**General applications of the crown fire hazard assessment tools.**
Assessment of crown fire occurrence sensitive at stand level and ranking the risk of a surface fire to climb to the canopy and develop into a crown fire.
Improve knowledge about which forest structures are vulnerable to development of crown fires, both for fire prevention purposes and fire fighting operations.
Provide practical information to forests managers about what are the optimum forest structures, and therefore, what are the most efficient silvicultural treatments to reduce risk of crown fires and facilitate fire extinction tasks.
Evaluate the effectiveness of different fuel treatments aiming at crown fire hazard reduction.
For areas with a high risk of forest fires due to climatic or socioeconomic factors, to identify priority areas more vulnerable to crown fires, where appropriate forest management should be implemented in order to reduce risk of LFF.

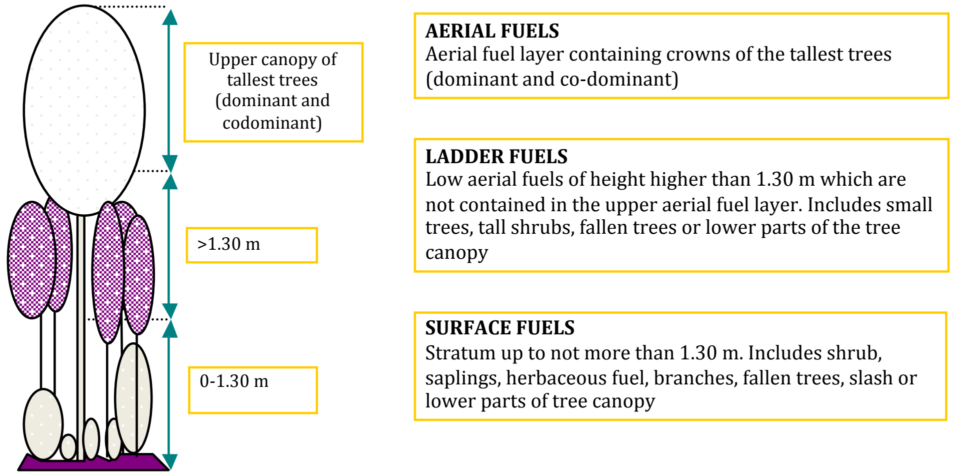


Figure 9. Classification of fuel layers used in crown fire hazard chart (CVFoC). Source: PIQUÉ et al. 2011.

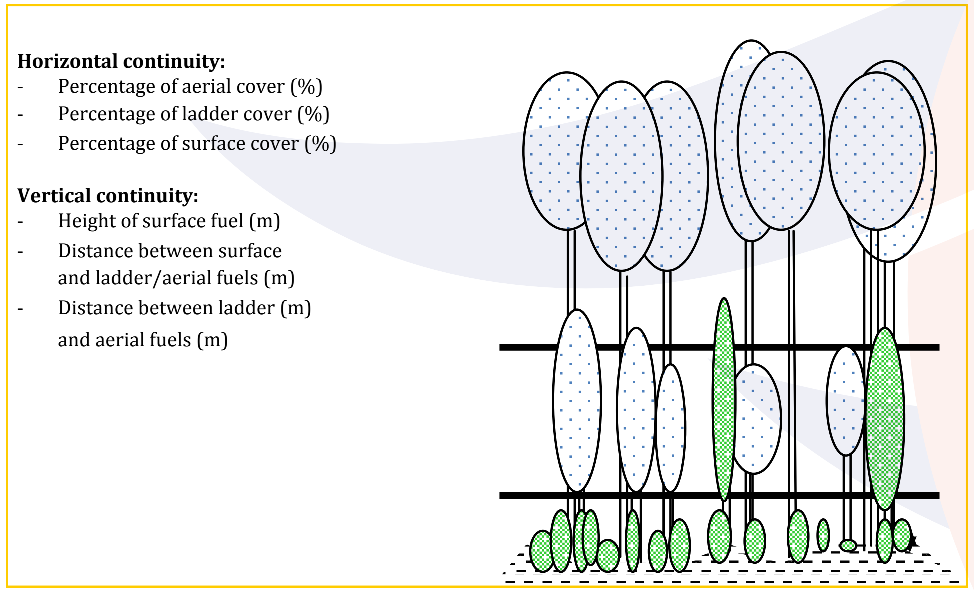


Figure 10. Forest variables used in crown fire hazard chart (CVFoC). Source: PIQUÉ et al., 2011.

For example, PIQUÉ *et al.* (2011) identified 38 structural types in *Quercus spp*. forest (5 type A, 16 type B and 17 type C), and 31 structural types in *Pinus spp*. forest (5 type A, 14 type B and 12 type C) (Figures 10 and 11).

Figure 11. Example of structural types of *Quercus ilex* (left) and *Quercus pubescens* (right) according to their vulnerability to develop crown fires. Codes according to PIQUÉ *et al.* (2011): A - high vulnerability; B - medium vulnerability; C - low vulnerability.

Figure 12. Example of structural types of *Pinus sylvestris* according to their vulnerability to develop crown fires. Codes according to PIQUÉ *et al.* (2011): A - high vulnerability; B - medium vulnerability; C - low vulnerability.

These tools present some advantages over the use of fire simulation models for assessing crown fire hazard. Users do not need expert fire behavior knowledge, and they are faster and simple for using in the field. It is important to note that when applying these tools it is likely that the fuel management operations do not prevent a forest fire from occurring, but they will reduce the risk of a high intensity fire. Furthermore, as long as the ignition occurs in the managed area, crown fires can be avoided in most cases and fires may only burn the surface fuel layer. In any case it is important to point out the role of weather in fire behavior, and that under extreme weather conditions or fires environments fuel plays a minor role in fire behavior.

3.1.3 Silvicultural treatments and management guidelines for fuel reduction

Fuel treatments

Fuel management strategies aim to contain or modify fire behavior by isolating, modifying or converting fuel (PYNE et al., 1996). Fuel isolation management aims to control fire in an area, making direct attack easier. Forests where fuels have been modified or converted might serve also to enclose fire, but their primarily objective is to modify its behavior.

Linear fuel treatments are the prevailing option in the forest fire prevention (XANTHOPOULOS et al., 2006), but their performance in face of fire is uncertain. Consequently, the most recommended in fire prevention is a fire-smart silviculture for more efficient LFF risk reduction (FERNANDES, 2013), following four fuel treatment principles and priorities to increase resistance to fire (AGEE and SKINNER, 2005; GRAHAM et al., 2004):

1. Decrease the accumulation or modify the structure of surface fuels to limit potential fire intensity, hence decreasing tree injury and facilitating effective fire suppression;
2. Raise the canopy base by pruning the trees and remove ladder fuels, minimizing the likelihood of vertical fire development, i.e. passive crown fire;
3. Thin the stand to decrease foliage density, impeding the transmission of fire between adjacent trees, i.e. active crown fire;
4. Maintain large trees of fire resistant species.

Treatments such thinning, pruning or the removal of surface fuels (using prescribe fire or mechanical tools) are advised. The effectiveness of these treatments in reducing fire hazard has been largely demonstrated in experimental fires and wildfire case studies using simulation models, mostly for dry conifers of the western USA (CAREY and SCHUMANN, 2003; GRAHAM et al., 2004; PETERSON et al., 2005). Nevertheless, how long treatments last for different types of ecosystems and fire regimes has not been studied in depth.
Thus, the main stand level management measures proposed for reducing the risk of LFFs is to encourage development of landscapes that are less vulnerable (more resistant and resilient) to LFFs, by applying

silvicultural models and silvicultural treatments for structuring the forest cover.

The strategy to reduce or remove fuel from the understory and dominant trees by clearings and by thinning of the stands is one of the most used treatments with the aim of preventing forest fires. However, this measure is very costly and therefore impractical to perform at larger scales. Thus, the challenge for efficient LFF prevention could be based on the following principles (PIQUÉ, 2012):

- Treatments that actually cause changes in forest structure and influence fire behavior in the desired way;
- Treatments that reduce forest fuel in strategic areas facing the prevention and suppression of forest fires at the mountain scale (see chapter 3.2);
- Treatments that take into account the natural dynamics and are based on adaptive management;
- Minimum intervention treatments – treatments should be low cost and the effects should last a long time.

Silvicultural treatments for promoting forest structures resistant to crown fires

Forests with little accumulation of fuel and forest structures with vertical discontinuity with respect to vegetation strata, and horizontal discontinuity with respect to the canopy and understory cover, are more resistant to spread of crown fires spread and are less intense. This is demonstrated in many studies and it has been found that altering fuel loads and fuel continuity through silvicultural treatments, causes a decrease in the vulnerability to crown fires (FULE et al., 2001; BROWN et al., 2004; AGEE and SKINNER, 2005; JOHNSON et al., 2007).
There are numerous publications that provide managers with information on how to create crown fire resistant forest structures using silvicultural treatments (JOHNSON et al., 2007; SERRADA et al., 2008). At the stand level, as FERNANDES and RIGOLOT (2007) suggested the sequence of treatments to reduce the vulnerability of a stand to crown fire would be:

- Reducing surface fuel load to limit the potential intensity of the surface fire;
- Removal of ladder fuels and pruning to reduce the likelihood of fire climbing to the canopy;
- Thinning to minimize the likelihood of fire spread through crowns.

In addition to the operations mentioned above, the following could be added (PIQUÉ, 2012):

- Silvicultural treatments to reduce resource competition and to promote growth and vitality of the tree species;
- Extend cut rotation so that the forests are more mature, to conform forest structures with vertical discontinuity.

Thus, the reduction of the vulnerability in most of forest stands would be achieved combining common actions of improvement stands treatments: thinning, pruning and shrub clearings. Depending on the initial situation of the stand (mainly in terms of the forest structure and the tree development), different treatments may be required to make forests more resistant to crown fires. It is important, as long as the stand is being managed, to advance in the development of the canopy, searching for high trees and elevated crowns from the floor, which will contribute to stand crown fire resistance and to reduce the need for future treatment.

Figure 13, show an example of treatments to reduce vulnerability to crown fires in different forest stands using Crown fire hazard charts (CVFoC) elaborated by PIQUÉ et al. (2011).

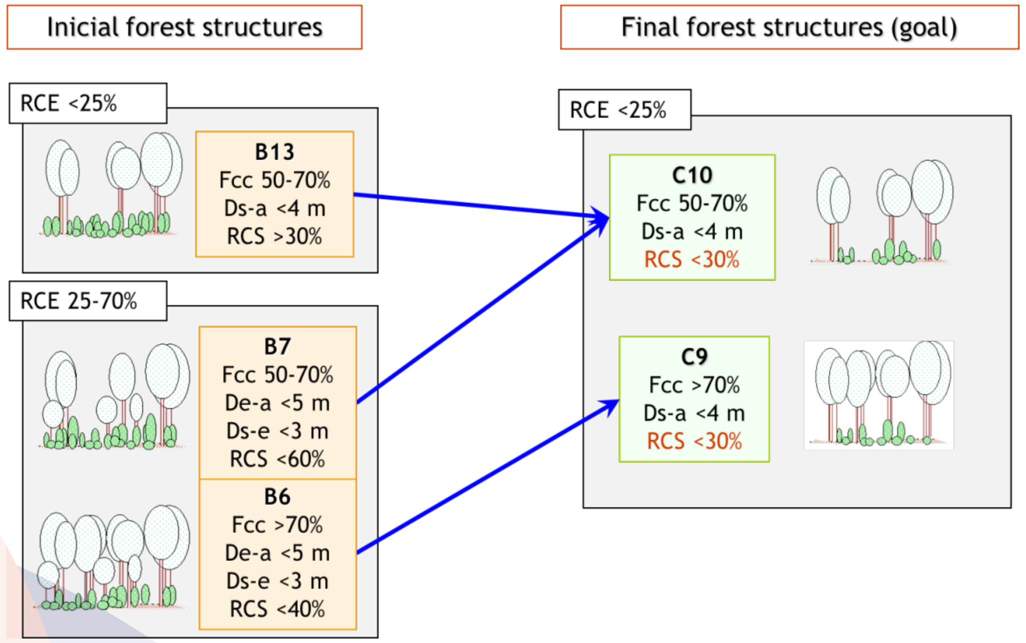


Figure 13. Initial forest structures and objective structures identified by the CVFoC, where B: forest type of medium vulnerability to generate crown fires and C, forest type of low vulnerability (PIQUÉ et al. 2011). RCE – Percentage of ladder cover; Fcc – percentage of aerial cover; Ds-a – Distance between surface and aerial fuels; Ds-e – Distance between surface and ladder fuels; RCS – percentage of surface cover.

Box 6 . Silvicultural treatments prescribed for managing forest stands to reduce the vulnerability to crown fire.

• Reduction of ladder fuels (<25%)
  – Eliminate understory taller than 1.3 m
  – Eliminate dominant trees with elongated crowns
  – Keep small trees (priority Quercus spp.), where there are no other trees around and no problem of vertical continuity
• Reduction of surface fuels (<30%)
  – Selective clearings
• Management of slash originating from the treatments
  – Cut the slash with diameter > 5 cm in pieces 0.8-1 m long. Distribute the slash on the floor
  – Prescribed burning

Slash treatment: Where silvicultural treatments generate a large amount of slash, they should be treated to prevent fuel accumulation on the surface; treatments should not interfere with forest regeneration and also facilitate a rapid incorporation of the organic matter into the soil. Different techniques are suitable and effective for slash treatment of forest interventions, as long as the constraints of their application are taken into account. Even so, the cost of treatments remains high and the costs often vary substantially between treatments, and therefore, it is necessary to evaluate techniques in terms of their cost and effectiveness in each area or region.

The most common techniques of slash treatment to be considered include:

- Cutting larger pieces of slash so that they are arranged on the floor as flat as possible.
- Piling slash. It may be especially necessary in regeneration felling, where it is necessary to leave the maximum soil and light available for the new shoots and seedlings. In the case of selective felling in uneven-aged stands or in regeneration felling in even-aged stands, care should be taken not to cover any coppice shoot in order to allow good resprouting. However, it can be an expensive treatment and in some areas this treatment also favors the appearance of bramble patches.
- Cutting up with chainsaw. Slash should not exceed 0.8-1 m in length and must be arranged on the ground not exceeding a height of 0.5 m.
- Piling and burning the slash to ensure a complete removal of dead fuel that remains on the ground.

Another option would be slash burning but a high degree of skill and experience is required.

- Chipping or grinding slash *in-situ* with a mobile chipper or shredder. The chips help control the growth of shrubs and keep some moisture in the soil, and decompose more quickly. It is a high cost option and accessibility for machinery limits its use.
- Chipping or grinding at road side. Slash is manually removed by winch or skidder. It is an expensive option.

Reducing the amount of fuel through the use of prescribed fire: Prescribed burning could be integrated as another silvicultural tool to reduce the amount of fuel and create forest structures less vulnerable to LFF. Careful planning and supervision by experts is needed.

In general, prescribed burning aims to reduce fuel loads to avoid creating intense and devastating fires and facilitate extinction tasks. However, it can also have other silvicultural objectives such as shrub clearing, slash removal, reducing competition for resources (light, water, nutrients), or improving pastures. In any case, prescribed burning must always be carried out by trained and qualified staff with adequate safety measures.

In northern Europe, prescribed burning is most often used in temperate heathland environments for improving pasture and habitat management for iconic species (e.g. red grouse, *Lagopus lagopus scotica*). Regular prescribed burning is applied to heather (*Calluna vulgaris*) moorlands across northwestern Europe. A number of studies focus on the effects of prescribed burning in England (YALLOP et al., 2006); Scotland (DAVIES et al., 2009); Germany (KLEIN et al., 2009); and Norway (NILSEN et al., 2005). In the UK alone, it is estimated that 120–360 km2 of heather-dominated moorland is burned each year (YALLOP et al., 2006), with over 3,600 km2 of UK moorland managed by prescribed burning on a rotational basis. Whilst some efforts have been made by Fire Operations Groups (see Section 2.1.3) to undertake prescribed burning with the support and oversight from Fire and Rescue Services, the majority of prescribed burning is still undertaken by land managers/farmers without this support.

Figure 14. Up left: Prescribed burning in *Quercus faginea* stand with the aim to reduce fuel load and improve pastures (Catalonia, 2008). Up right: Slash burning in *Pinus nigra* stand with the aim to reduce fuel load and reduce vulnerability of forest stand to large forest fires (Catalonia, 2015) Down: Prescribed burning in a northern European setting

Landscape level measures: Reducing vulnerability to large forest fires

At the stand level, treatments are sometimes unsatisfactory because fires spread beyond the stand-scale creating their own fire environment. Additionally, at the landscape level, fuel treatments might be insufficient or located in wrong places (AGEE and SKINNER, 2005). Both, the temporal and spatial scale of treatments are a difficult issue when planning fuel management strategies. The modification or conversion of fuel in a stand cannot alter fire size per se but it can change the fire behavior and might reduce, in most of the cases, its severity.

There are case studies of the effects of fuel treatments on large fire growth do exist (e.g. FINNEY et al., 2007). However, understanding of the effects of fuel treatments at the scale of the landscape is mostly theoretical and relies heavily on fire simulation modeling (FINNEY, 2001). The long-term, cumulative impacts of fuel management on fire incidence depend on how the rates of treatment effort and fuel re-accumulation interact with each other (FINNEY et al., 2007; KING et al., 2008). Therefore, it is not always easy to justify the investment in forest management-fire prevention (see chapter 2.3) and often considerable effort is needed for fuel treatment to really influence fire behavior and reduce the fire hazard. In this sense, an alternative is to carry out treatments in strategic areas facing the prevention and suppression of forest fires at the landscape scale (see chapter 3.2).

Among the measures to be integrated into forest management to prevent LFF, those related to the landscape level are of great importance. In this regard, COSTA et al. (2011) differentiate three types of actions or measures to be applied at landscape level for reducing fire hazard:

a) **Punctual specific actions of defence against fire** associated with fire suppression operations: determined according to the characteristics and pattern of spread of the different types of fires that may occur in an area, especially the most dangerous. These actions relate to Strategic Management Points (SMP), bands of low fuel or auxiliary bands anchored to paths (see chapter 3.2).

b) Actions for the **formation of a matrix of forest cover with a structure that hinders the development and spread of LFF,** and also contribute indirectly to increase fire fighting opportunities and capability.

c) Actions to **promote** landscape-scale **heterogeneity,** in terms of structure and species.

To find out more see:
Report on review and evaluation of knowledge, and Report on Training activities on the use of crow fire hazard charts.
FIREfficient Project. Deliverable 7 and Deliverable 11.
http://firefficient.ctfc.cat/, http://www.lessonsonfire.eu

3.2 Reducing vulnerability to wildfires at landscape level

By Jordi Pagès, Andrea Duane, Marc Castellnou, Lluís Brotons, Edgar Nebot

3.2.1 Wildfire risk approach at landscape level

The purpose of the present chapter is to present a conceptual framework to incorporate wildfires risk in landscape management decision-making. The framework aims at facilitating the implementation of operational management actions and landscape-fuel treatments, and thus should allow the reduction of landscape vulnerability to large wildfires.

State of the art in Europe

In terms of wildfires, there is neither legislation nor a common historical view at the EU level. The national and local legislation has focused on resolving fire conflicts in the territory wildfires were just a local problem. Commonly in Europe, wildfire risk planning has been approached from the point-of-view of urban and territorial planning, mostly identifying certain risk zones where infrastructure and building construction is not allowed. Mainly, wildfire risk planning has been centered on wildfire urban interfaces (WUI). Although many other risks (such as earthquakes or floods) have been incorporated in urban and spatial planning, wildfires have historically received less attention. As mentioned in chapter 2, this has been usually a result, among other reasons, of the low perceived risk associated with fires in many regions, and for the difficulty associated to its low predictability and stochastic behavior.

Fire budgets: Current status and insights: Public investment in forest management, fire prevention and fire-fighting are closely linked. The recent trend in many Mediterranean countries seems to favor investments in wildfire prevention and extinction. Nowadays the largest part of investment dedicated to prevention is bound to build infrastructure to support fire extinction, rather than to managing fuel loads at stand and landscape scale. Paradoxically, studies show that only investing in extinction support infrastructures tends to perpetuate large wildfires more than prevent them in high fire recurrence areas. This is because fire suppression effectiveness on small fires enhances the homogenization of fuels across the landscape and promotes large fires. In contrast, forest management investment (with a fuel reduction associated) is one of the suitable actions capable of reducing large wildfires incidence (LOEPFE et al., 2012).

Fire prevention and extinction competences among administration departments: Wildfire risk issue involves multiple departments in fire management, in the active prevention (actions that are used directly to improve efficiency in suppression activities such as building water tanks, low fuel area, safety zone or roads) and passive prevention (actions promoting fuel reduction), and extinction wildfire management. In Europe, from a public administration point of view, the three most common departments involved in land planning and emergencies are:

- *Civil Protection and Fire Service Department*: aims to protect populations from several risks and mainly acts in the active fire extinction process;
- *Forestry and Agriculture Department*: represents the competence on forest management, thus acting at a passive prevention scale; and
- *Urban and Spatial Planning Department*: which should integrate multi-sectoral land-use planning to actively prevent wildfires.

Fire in Europe: different structures, analogous functions: When considering wildfire prevention and extinction, two big typologies of institutional organization systems arise:

- **Civil Protection Perspective**: *Civil Protection and Fire Service Departments* usually has the competences for wildfire extinction; this kind of institutional structure highly integrates all wildfire respond services for fires affecting WUI, and it works with an integrated emergency perspective. It usually presents difficulties to influence in wildfire prevention policies, since these prevention measures are usually dispersed among several forest management programs. Then, suppression efficiency pressures are not translated into forest planning, which is where prevention infrastructures are designed. Examples of countries applying this model are: France, United Kingdom, Portugal, and Catalonia and Navarra in Spain (where fire service competences are regionally transferred).
- **Forest Perspective**: *Forestry and Agriculture Department* can have both the competences on wildfire suppression and wildfire prevention, and it is structurally different to Civil Protection and other emergency agencies (Firefighters, Medical staff, etc.). This kind of institutional structure highly integrates design of prevention infrastructures with their future use by the extinction system bodies, and it usually has integrative policies including wildfires in forest planning structures. However, this results in having two different fire extinction systems (urban areas and forest fires) which potentially generate biases when working on an emergency in a WUI in which both houses and forests need to be defended. Examples of countries applying this model are: Italy, and Aragón and Castilla la Mancha in Spain.

Multi scale forest Planning: crucial Integration

Wildfire management is also characterized by multi-scale elements. Similar to other issues which need to be tackled by planning, wildfire risk can be addressed at different scales - from operational planning at stand level, to a regional-scale planning. The integration of this multi-scale integrative context is crucial in successful reduction of landscape vulnerability to large wildfires.

In Catalonia (NE Spain), different levels of planning have been nested to integrate wildfire risk in forest planning instruments. The following scheme (Figure 15), from PLANA, (2011a), presents the proposed model for integration of wildfire risk in forest planning at a multi-scale level.

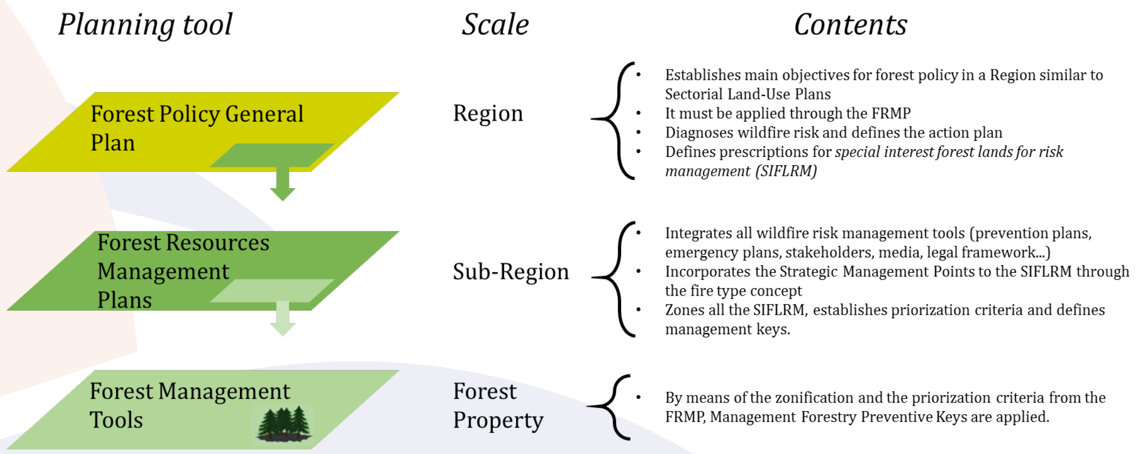


Figure 15. Model of integrated levels of forest planning in a European region (Catalonia) Source: PLANA, 2011a.

Climate change in Europe: past, present and future

Historically, wildfires have been present in all forests around Europe. However, catastrophic wildfires are more related to Southern European Countries, the ones with a Mediterranean climate, since the fire intensity achieved and urban configuration have threatened more people than in Northern countries (JRC, 2015). Therefore, fire suppression and prevention policies have received more investment in Southern European countries.

However, there has been an increasing concern about wildfire threats in Northern European countries in recent years. There has been an increase in the number, intensity and size of fires in many countries and regions (Sweden 2014, Bulgaria 2013, Ireland 2011) not used to these events. Wildfires are showing changes in their behavior. Specifically, there has been an increase in the proportion of crown fires reaching high intensities and triggering larger fires. This has provoked an ad hoc reaction from European institutions. In the context of anticipated changes in climate, wildfires should be a major concern in different regions of Europe.

Weather conditions which favor fire are predicted to increase under climate change predictions in European countries (MORIONDO et al., 2006; FLANNIGAN et al., 2009; BATLLORI et al., 2013). However, the potential evolution of fire regimes is still uncertain and under discussion (Box 7). Here we present some of the main ideas that are predicted for Europe, separating broadly among Mediterranean and non-Mediterranean regions:

- **Mediterranean regions:** An increase in rainfall variability is expected, which may increase the occurrence of intense rainfall events but also more frequent and severe droughts (DE LUIS et al., 2010). These could point to a desertification of current Mediterranean ecosystems, leading to profound changes in vegetation patterns and species composition. It is not so clear how the interactions between changes in vegetation and more fire-prone weather conditions will evolve. High intensity fires are predicted to be less common if vegetation becomes more arid, as there will be less vegetation and lower fuel loads (Figure 16). However, the transition to more arid vegetation landscapes will take a long time (LINDNER et al., 2010). The transition time between the present high-load vegetation forests that have developed under more humid conditions, to drier conditions may represent the highest risk period for high intensity fires, since weather conditions will be more prone to fires, but the fuel loads will have built up and will be more characteristic of a more humid climate. Given an uncertain situation, adapting management actions should be implemented to mitigate the possible effects of climate change.

- **Other non-Mediterranean regions:** In northern parts of Europe, the fire risk is likely to increase (KHABAROV et al., 2014). Global simulations of future fire regimes indicate that the probability of fires will increase in Central and Northern Europe. In combination with social and economic changes affecting forest and landscape dynamics, the result may be greater exposure to devastating fire.

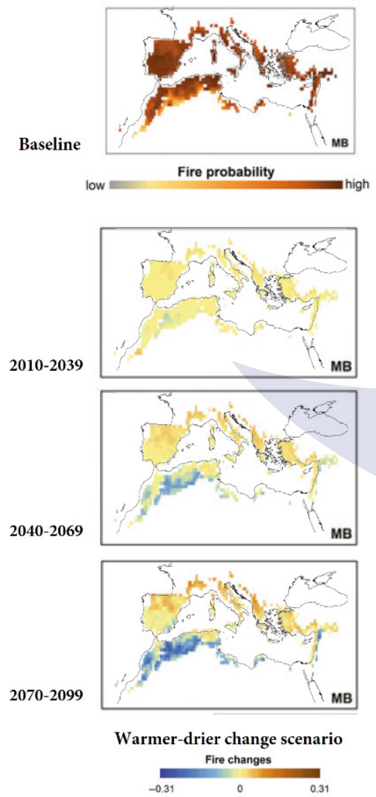


Figure 16. Forecasted fire activity scenario for the Mediterranean Basin. The top map shows the mean fire probability occurrence for baselines conditions (1971-2000). The three maps below show the predicted probability changes relative to the baseline for three time periods. For this case, weather effects of future climate consists of the ensemble of six Global Climate Models depicting warmer-drier conditions over the 21st century under IPCC (2007) AR4 A2 emission scenario.

Box 7**. Scenarios for fire-policies decision-making.**
Scenario analysis is a valuable and frequently applied technique to help to decide fire budgets and wildfire risk reduction policies under conditions of complex uncertainties associated with future changes. Scenarios have been characterized as the *"… plausible and often simplified descriptions of how the future may develop based on a coherent and internally consistent set of assumption about key driving forces and relationships"* (ROUNSEVELL et al. 2006). Forest and landscape evolution, and consequently fire regime evolution, can also benefit from the use of scenarios to help policy makers make decisions based on plausible futures and reducing the associated uncertainty (Figure 17). Even more, the use of scenarios may be used under a modeling framework to better understand consequences of current decisions made at large temporal and spatial scales. A narrative description of a scenario highlighting the main scenario characteristics and dynamics, and the relationships between key driving forces and main features defines a conceptual framework for the scenario-making process. The elaboration of conceptual frameworks to generate global change scenarios for the different regions is crucial for a long term assessment to capture all the variability that the future may exhibit. Climate simulations produced by the United Nations Intergovernmental Panel on Climate Change (IPCC) and regional downscaled data have been a primary source for climate projection and policy decision making in terms of energy and climate. Several European countries have already benefitted from the use of climate scenario generation to develop regional policies in the mitigation of climate change effects. The IPCC reports are the seed from which different governments apply climate policies. In fact, as a product from the IPCC reports, an *Executive Summary for Policymakers*[7], including main guides for policy makers in complex technical topics, is available to help in the regional policy development. Furthermore, other agents are also using the scenarios definition for decision making. The World Economic Forum, an organization that aims to engage the foremost political, business and other leaders of society to shape global, regional and industry agendas, provides the conceptual scenarios for the mainstreaming of economic policies in regional contexts[8]. Scenarios may integrate socioeconomic storylines using a structured framework and should identify their associated drivers of environmental change with specially impact on landscape dynamics. Special attention might be devoted to climate changes, changes in forest management and social impacts to help wildfire decisions.

[7] http://www.climatechange2013.org/images/report/WG1AR5_SPM_FINAL.pdf
[8] http://www3.weforum.org/docs/WEF_Scenario_MediterraneanRegion_Report_2011.pdf

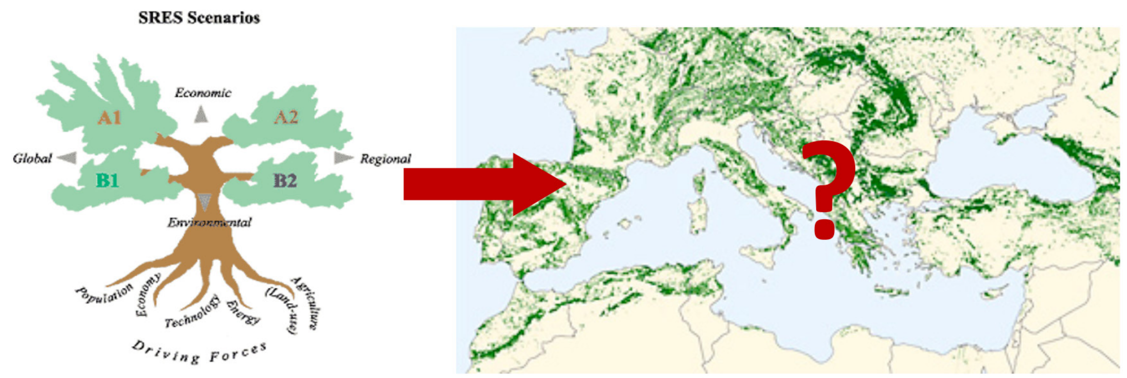


Figure 17. Socio-economic scenarios that may affect European forests with uncertain future. Source: Own prepared for this report. The tree on the left is from the IPCC Special Report on Emissions Scenarios (SRES) (capitol3.docIPCC, 2000).

3.2.2 Methodology of Fire Types, Critical Points and Strategic Management Points identification: towards incorporating large wildfire risk into landscape decision making

Need on the Fire Type approach

The relative role of weather, topography and vegetation on fire regimes is not fully understood, but their contributions are known to vary in time and space. For the last decades, the increase in incidence and impact of wildfires in Europe has created a need to better understand fires and the processes behind them, to help understand how the pattern of fire occurrence may change. Furthermore, from an operational point of view, an anticipated need for decision-making during fire events has contributed to the development of a fire classification into fire spread patterns and corresponding fire types (COSTA et al., 2011). It has been through this classification that suppression brigades have improved their capability to make decisions during a fire event, based on previously studied fires, and thus gaining valuable time to extinguish fires and enhancing fire suppression strategies.

One way to capture the spatial variability of fire regimes is to focus on the conditions ultimately leading to specific fire spread patterns in a given area. Dominant fire spread patterns are usually linked to specific synoptic weather conditions, topography, and vegetation patterns, determining fire behavior and thus fire suppression opportunities.

The challenge is to transform the Fire Types knowledge into landscape management actions aiming at providing new opportunities for a more efficient suppression and ultimately reducing landscape vulnerability to large wildfires. Publications on fire types have been produced in many countries. For instance, the publication of the Fire Types Classification in Catalonia (CASTELLNOU et al., 2009; DUANE et al., 2015) has served to improve planning of extinction strategies by firefighters. It has also become a useful tool for infrastructure planning and minimizing the impact of wildfire. Furthermore, this classification has allowed public bodies to better define the capabilities of extinction systems, identifying weaknesses and mismatches between fire regime realities and fire-fighting strategies. This knowledge and the anticipatory nature of the planning based on Fire Types has allowed the identification of critical points (i.e. areas where changes in fire behavior are likely to be significant and lead to opportunities for fire-fighters to stop a fire). Hence, fire extinction limits have been more clearly identified and fire-fighting is starting to change its nature to be progressively shifting to a carefully planned activity based on forest and land planning (Figure 18).

The characterization and classification of wildfires has brought together operational firefighting systems, forest planners and land planners, since this classification provides valuable information for land planners to integrate the prediction of future wildfires in defining strategies for landscape use (PLANA, 2011a).

Figure 18. New challenges in the prevention infrastructures design. Source: COSTA et al., 2011.

Fire spread patterns and Synoptic meteorological situation: Diagnosis

The proposed concept starts from the premise that assuming similar topography and meteorology, fire spreads in a similar way (Figure 19) (CASTELLNOU et al., 2009; COSTA et al., 2011). Fire changes its intensity depending on fuel availability, which depends mainly on accumulated hydric stress, fuel amount, structure and distribution. To identify Fire Types based on predetermined fire spread patterns affecting a particular area, one must analyze the historical records of wildfires in the region using available information from field works and fire statistics. Then, one can classify and forecast where the different Fire Types will occur and what frequency they are likely to have. According to the identified Fire Types in a region, a map regarding fire type frequency in different zones can be described and Homogenous Zone Fire Regimes can be identified (see PIQUE et al., 2011 for further information). Different zones can be identified which have particular combinations of Fire Types often associated with particular landscape structures, specific topography and wind regimes. With this map, the spatial location of fire-fighting facilities and infrastructures (fuel breaks, forest management to reduce canopy cover…) can be strategically located to match the requirements of potential fire occurrences.

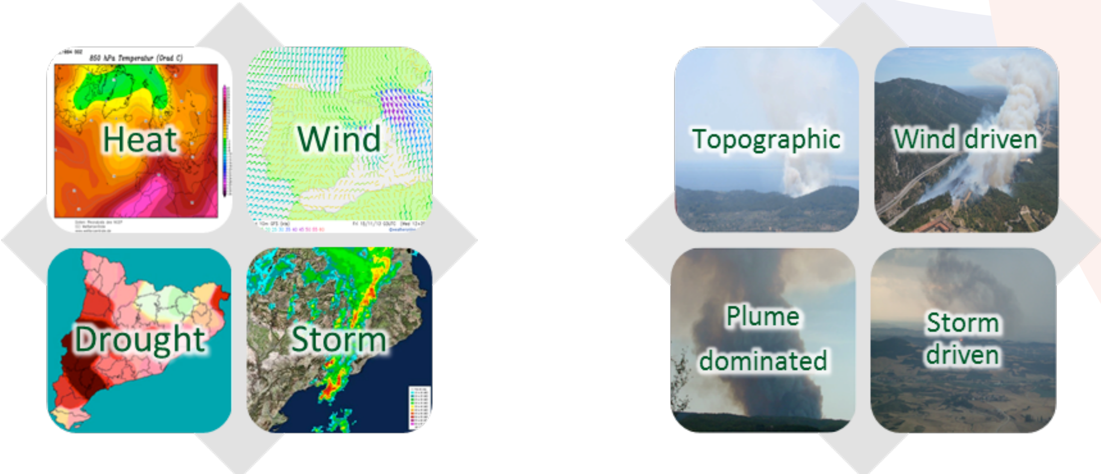


Figure 19. Factors affecting the synoptic weather situations (left) and main fire spread patterns (right).

Critical Points identification

Once the Fire Type regime in a region has been mapped, the results allow identification of locations where fire may accelerate or decelerate, and also change its intensity. Fire Services can identify these Critical Points, and therefore optimize cost-efficiency in terms of effort of suppression against unburnt protected area. Critical Points are usually found where there are abrupt changes in topography; they can be identified by making a geomorphology analysis of the relief, looking for ravine junctions, crest line junctions, and mountain passes (Figures 20 and 21).

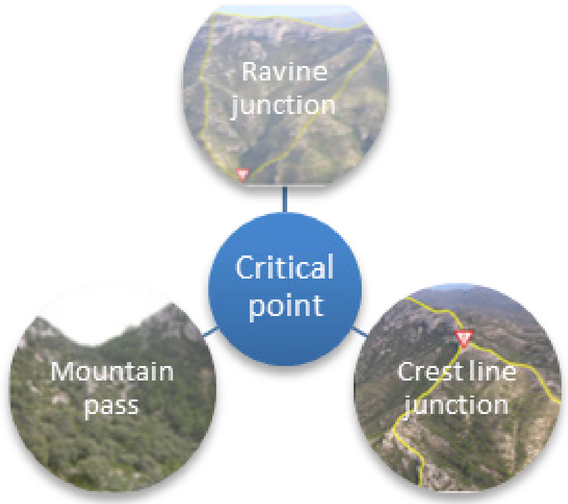


Figure 20. Critical Points Types.

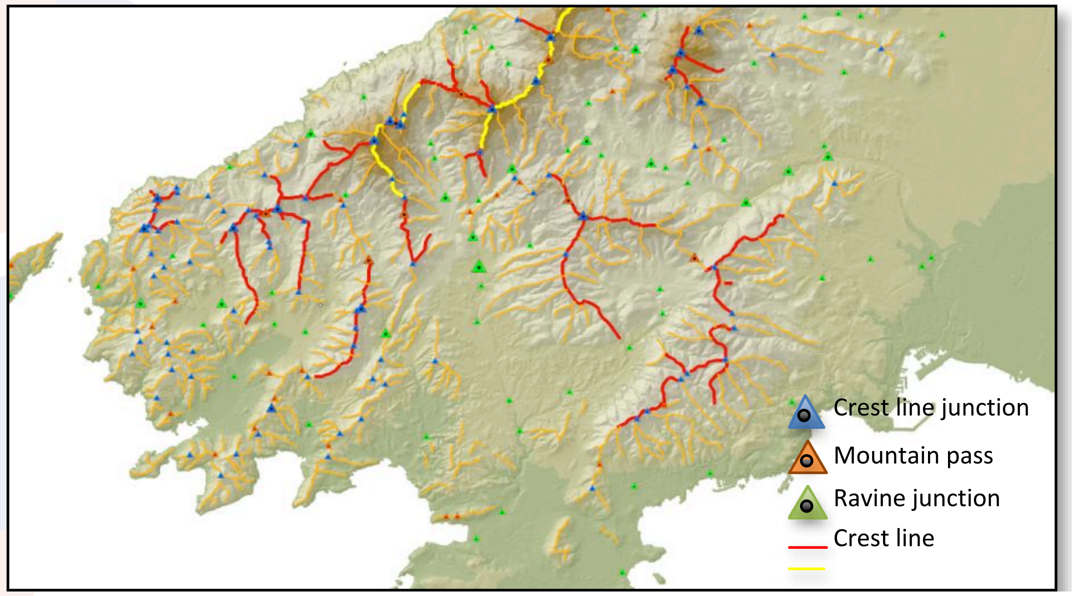
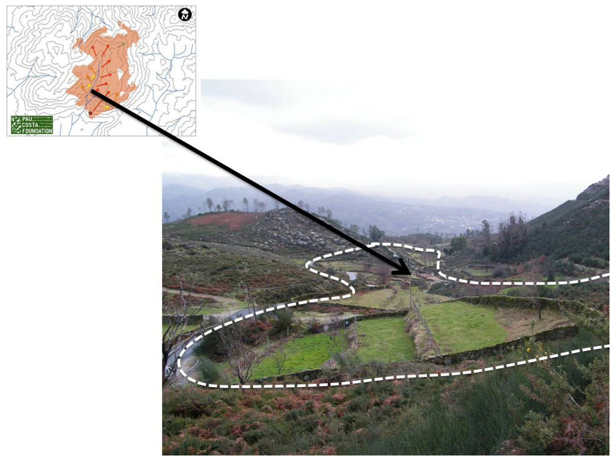


Figure 21. Critical Points identification in Mallorca, Balearic Islands, Spain. Source: Tecnosylva S.L.; Pau Costa Foundation.

Strategic Management Points design

Strategic Management Points (SMPs) are planned infrastructure features at a Critical Point that allow extinction of fires within the margins of safety and extinction capacity rates. It has been shown that the suppression efforts when applied on predetermined and carefully selected small areas based on anticipatory fire behavior knowledge are more effective than spreading resources along the fire perimeter. So far, SMPs have mainly been mostly implemented in Mediterranean Spain. However, they could be implemented all over Europe. Their identification is mostly related to the Critical Points where fires may overcome fire suppression capabilities. The objectives are to reduce fire spread speed and intensity, to ensure a secure point for firefighters, and to provide suppression resources such as anchor points or water tanks.



Strategic Management Point identification. Author: Pau Costa Foundation

The main suppression operations planned to be performed in a SMP are the ones summarized in Table 2, as well as the needs of the infrastructure.

Table 2. Main suppression operations planned in a Strategic Management Point

OPERATION	PICTURE	INFRASTRUCTURE NEEDS
Water hose		• Low fuel load to generate surface fire • Access route for a large truck • cul-de-sac area by turn around trucks Water supply point
Heavy machinery		• Shrublands vegetation type (not trees) • Road access for heavy vehicles (bulldozer)
Back fire		• Low fuel load, but with fine fuel to ignite quickly • Anchor line • Security zone nearby
Direct attack with manual tools		• Low fuel load area • Surface/understory fire with low intensity • Security zone nearby

Strategic Management Points: A "Self-Regulate System" model

The successful implementation of the SMPs over large areas is a challenge. The high number of stakeholders involved in identification, building, maintenance and use of SMPs involves many agencies and administrative bodies (from private forest owners to forestry services and fire extinction services) that must interact at different levels

Therefore, a self-regulating system is proposed as an appropriate approach to develop SMPs (Figure 22). The system aims to adopt a flexible structure that ensures the implementation of the SMPs at different levels. These kinds of systems have been properly applied to other complex protocols in emergency planning (structural fire prevention).

Preventing fires in the territorial and urbanization planning can be an example:
- The administration has set regulations, instructions and recommendations;
- The technicians and architects use these instructions in their planning;
- Builders and installation engineers constructed following widely adopted standards;
- The supervisory authorities control the application of the rule at all levels;
- Schools qualify professionals at each level;
- Administration inspects compliance at all levels.

The structure defines:
- **the what** – the type of SMP to be implemented;
- **the who** - the ones that will use and maintain the SMP;
- **the how** – who defines the whole implementation;
- **the transfer of knowledge** – ensuring the maintenance of the same structure over time.

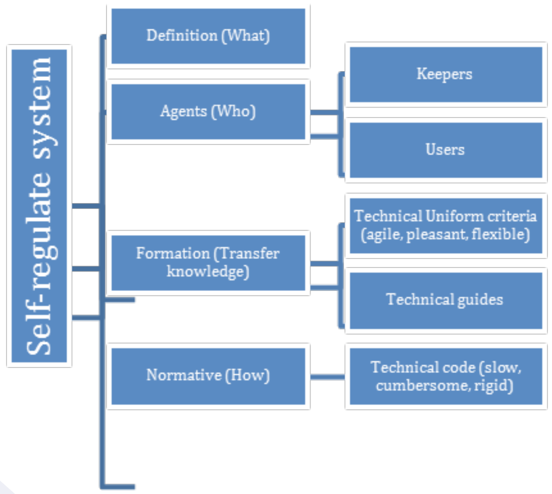


Figure 22. Diagram of the structure of the self-regulate system for the Strategic Management Points.

To find out more see:
Report on Methodology for incorporating large fire risk landscape management decision making. FIREfficient Project. Deliverable 16.
http://firefficient.ctfc.cat/, http://www.lessonsonfire.eu

3.3 Fire ignition assessment and integration in planning prevention and forestry measures

By José Ramón González

3.3.1 Usefulness of ignition modelling for fire prevention

The occurrence of wildfires requires the presence of a heat source and specific fuel conditions to trigger an ignition or starting point. The heat source will enable the combustion of nearby fuel and the subsequent spread of the fire. Regarding the study of the factors behind the occurrence of fire ignitions, it has to be mentioned that those ones related with human activities attract most attention when studying fire ignitions across densely populated regions, as for example those in the EU. This attention can be easily supported by the relative importance of human-caused fires in the EU. Of the fires occurring in the EU during the 2006-2010 periods, those caused by humans, either deliberately, due to negligence, or accidentally, are far more common than those of natural origin (Table 3).

Table 3. Relative importance of fire causes across EU, from GANTEAUME et al. (2013).

	Fires of known cause %	Fire Causes %			
		Natural	Human related		
			Accident	*Negligence*	*Deliberate*
Europe North	80	7.3	14.1	64.7	13.9
Europe Centre	87	0.5	3.8	39.3	56.4
Europe South	71	4.7	6.0	33.5	55.8

Fire ignition modeling focuses on the occurrence of fires, being an important part of the analysis of fire regimes. Ignition modeling does not take into account the amount of area burned or the impact of the fires. Ignition modeling includes the study of the spatial and temporal aggregation patterns of fire ignitions and usually includes identifying and weighting the factors (socio-economic, climatic, fuel related) behind the occurrence of fire ignitions.

Knowing where fire ignitions are more lilkely to occur according to their specific cause can be used for implementing more efficient policies and regulations for limiting dangerous human activities that are known to trigger fires. Additionally, in a very limited number of cases, the study and identification of “ignition hotspots” has resulted in tools for identifying the activities of arsonists (GONZALEZ-OLABARRIA et al., 2012). Such is the case in Catalonia, where there is an early alert system in place, and a specific vigilance protocol in the defined hotspot areas.

Otherwise, ignition modeling alone has limited use in fire prevention, but increases the capacity of other tools, such as Fire Danger Rating Systems (FDRS) and fire spread models, when they are linked. There is a high degree of uncertainty in predicting where and when the ignitions take place , as both natural events and human activities leading to their occurrence are often difficult to predict or even to measure. Still, fire ignition modeling can be used in strategic prevention if used to modify regulation on hazardous activities (allocate time and space restrictions on forest works, pasture burning, recreational activities, etc.).

Although a limited number of ignitions evolve into fires of significant size, the knowledge about their spatial and temporal distribution provides information for assessing potential risk of fire that can be used to allocate resources for early attack fires in higher risk areas. Combining the results of models for predicting ignition occurrence with FDRS helps to include the socio-economic factors behind human-caused ignitions to the weather and fuel moisture components that basically define FDRS, as the FDRS focus on evaluation of the seriousness of the burning conditions if a fire starts. The number and spatial distribution of ignitions can also be integrated into fire spread models to generate spatially continuous information on probability of fire occurrence for landscape planning purposes when reducing the negative impact of fires is a goal.

Lighting marks in trees show the presence of natural ignitions in the ecosystems. Author: Eduard Plana Bach

Aspects to consider when studying fire ignitions

Ignition modeling is a heterogenous field of science, with a variety of approaches that defines both the expected results and their potential usefulness when using them in planning fire prevention measures. This heterogeneity brings richness to the field of study, but also raises certain concerns that should be addressed when designing a study or interpreting results. The most important issues that should be considered are: the importance of the minimum fire size used as input data; the level of ignition cause aggregation; and the methodology used for implementing the study.

Importance of the minimum fire size used as input data: Regarding this aspect it has to be mentioned that the so called ignitions used as input data for modeling purposes are in fact fires affecting a certain surface area, rather than ignitions. The process of recording those fires is associated to a minimum fire size, which depends on the requirements of regional or national administrations. Despite the known fact that only a few ignitions evolve into large fires, neglecting those “non-important” fires may be a loss of important pieces for completing the fire regime puzzle.

The minimum size of the recorded fires influences the importance of the factors defining their occurrence:

1) As the size of recorded fires increase, the influence of factors related to the fire spread potential also increases. Such factors include: amount, fuel type and spatial arrangement of fuel types; previous and prevailing weather conditions; topography; and in some cases the difficulty to implement an early detection and suppression due to the remoteness of the fire initiation point.
2) As the size of the recorded fires decreases, the importance of the ignition sources and the possibility of identifying the factors behind their occurrence increase.

Importance of aggregating ignition causes: Traditionally, modeling the occurrence of ignitions has relied on broad causality groups, as for example natural versus human caused ignitions or on the segregation of human cases into pooled groups of ignition causes (e.g. intentional, accidental, negligence, restarted, etc.). Ignitions of human origin can hardly be considered as a uniform group as their etiology can be quite different. Nevertheless, it is known that causal groups such as negligence or accidents are the result of merging ignitions from more specific causes such as pasture burning or other types of agriculture related burnings, forest works, cigarette smokers, electric lines, railroads or campfires, each one of them deriving from specific human behavior and related activities.

The spatial-temporal aggregation of the ignitions is expected to vary depending on the specific ignition cause. The indicators used to explain those socio-economic and environmental factors behind the occurrence of fire ignitions should follow similar spatial and temporal aggregation patterns (Figure 22). Therefore, by combining ignitions from pooled causes, when analyzing the influence of socio-economic factors of fire ignition occurrence, we will obtain results that depend on the ignitions that came from the more frequent cause or are more aggregated spatially. This aspect will translate in diluting the influence of the not so common ignition causes, limiting the possibility accurately discerning relations between the occurrence of ignitions and human behavior, and hampering future studies about the influence of ignition causes on the fire characteristics other than temporal and spatial distribution.

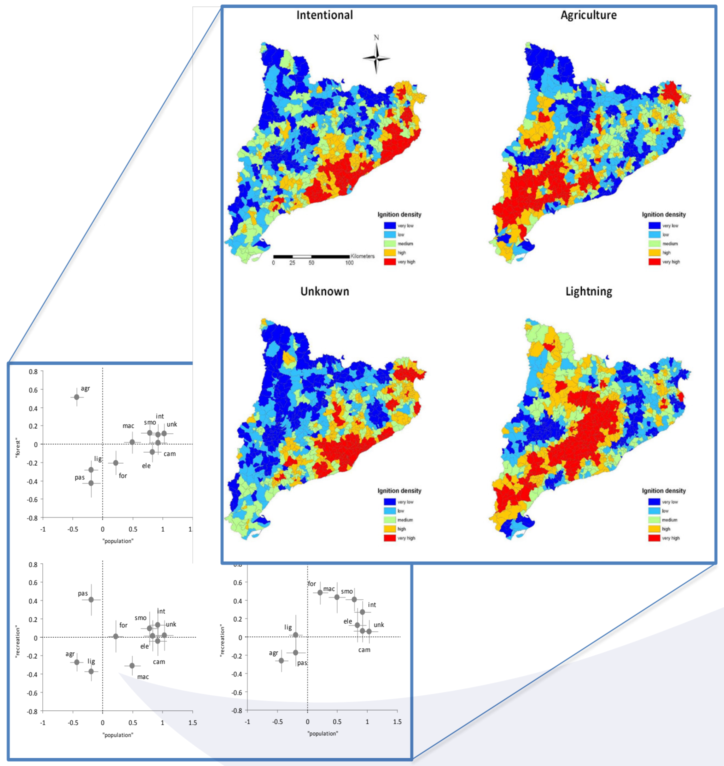


Figure23. Example of fire ignition danger rating for Catalonia, based on segregated ignition causes (from GONZALEZ-OLABARRIA et al., 2015). The study clearly showed that both the spatial distribution of ignitions and the factors related to their aggregation varied with the specific ignition cause.

Importance of the methodology used for the analysis: The statistical method and the spatial scale at which the data is aggregated have an impact not only on the results but especially on their interpretation. This influence on the potential results becomes even more obvious when selecting the spatial scale to aggregate ignition data, as the selected aggregation scale will define both the type and availability of variables to be used as ignition precursors, and the spatial resolution of the outputs to be used for making decisions (Figure 23). The spatial scale of the data and results can be defined based on: the specific ignition locations; the location of ignitions versus a set of random non-ignited points; a spatially continuous grid where the occurrence or the frequency of ignitions is accounted; on administrative or ecological borders; or on a combination of multiple scales.

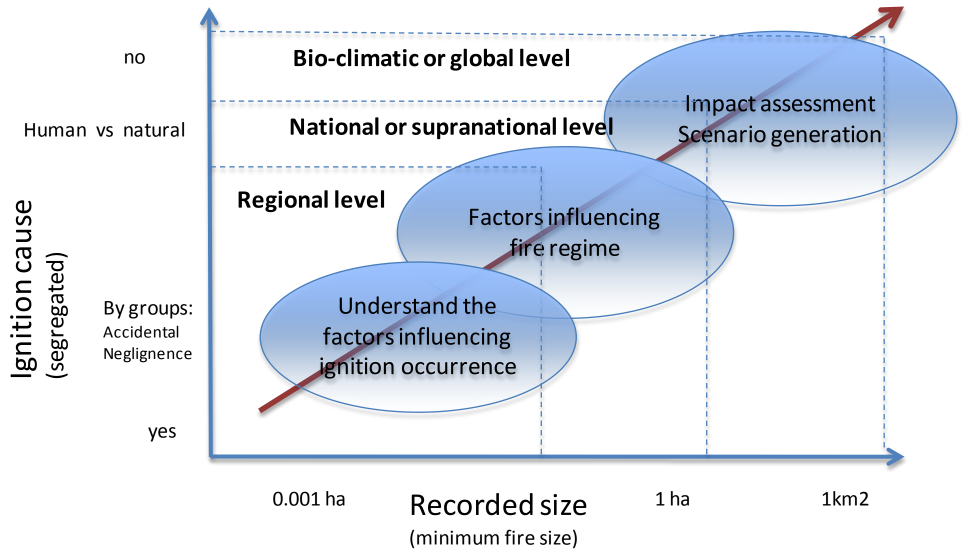


Figure 24. Ignition models frames: The size of the recorded fires, the spatial framework of the study, and the level of aggregation of the ignition causes defines the results to be obtained and their usefulness. Defining a clear objective for the study should be the first question before any analysis.

3.3.2 Integration of ignition knowledge in planning prevention measures

Most studies on modeling fire ignitions aim to identify the factors influencing fire occurrence. However, the utility of ignition modeling goes far beyond identifying hazardous activities triggering ignitions. Using “not so small fires (>0.1 ha)” which were aggregated into broad groups according to causes, the spatial and temporal variability of fire occurrence is also relevant. This type of analysis, limits the acquisition of information about the causes of ignition and influencing factors, and this limits its potential use for planning preventive measures. However, the impact of fires does not depend on their cause but on their size, intensity and the elements (human, natural, infrastructures) that they endanger. Therefore, such analysis provides information about where fires of significant size are more likely to occur, when they are likely to occur, and their expected size, being a crucial piece of the risk assessment puzzle, as it defines most of the elements required to understand the fire regime at a regional level.

The knowledge about the occurrence of fire ignitions gains relevance for planning prevention measure once linked to other tools, such as FDRS or fire spread simulators (Figure 24).

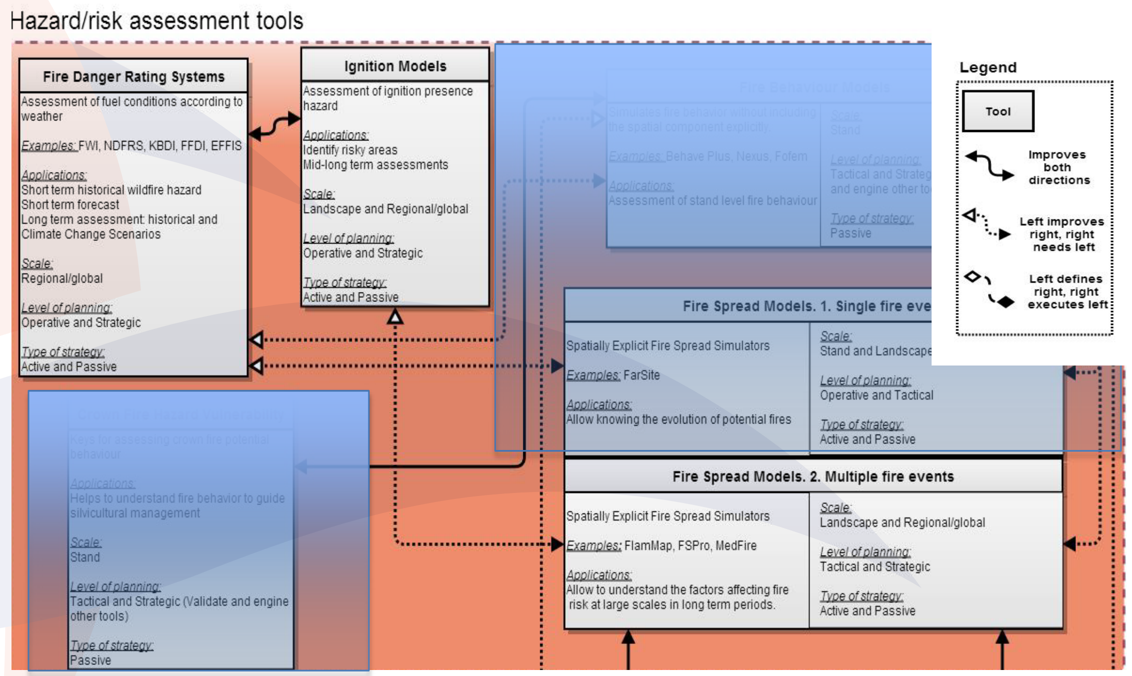


Figure 25. Potential linkage between fire ignition models and other tools for assessing the risk of fire.

Linkage to Fire Danger Rating Systems

Although a limited number of ignitions evolve into fires of significant size, the knowledge about their spatial and temporal distribution provides information for assessing potential risk of fire that can be used to allocate resources for early attack fires on the more risky areas. For example, it is possible to combine the spatial-temporal distribution of fires with the basically weather driven FDRSs. This combination of the ignition modeling results can be used to validate the results from the FDRSs; to use the outputs of different FDRSs as explanatory variables when modeling fire occurrence, or to improve danger ratings by adding the contribution of socio-economic variables related to the occurrence of fires to the fire danger indexes generated by FDRSs.

FDRSs predict the potential fire behavior of fires, often on a daily basis and are based on the weather and fuel moisture conditions, providing information about the potential fire intensity and danger in relation to the required suppression capability. The main of use FDRSs is to generate daily danger maps to set alerts and mobilize extinction resources across a region or country. Among the FDRSs, the Canadian Fire Weather Index (CFWI) is the most commonly used, and the one available at EU level through the EFFIS system. The CFWI is also used by the UK Met Office and has recently been calibrated for improved use in northern European settings (DE JONG et al., 2015).

Linkage to Fire Spread Simulators

Another important use of the spatial and temporal distribution of ignitions is the simulation of fires, for evaluating the probability of fire occurrence across a landscape. The probability of fire occurrence is a key aspect to be considered when planning the management of forest under risk of fire, which may include allocating prevention measures (Figure 25). By linking the probability of fire occurrence to the damage that is expected on a fire affected area, we will obtain a prediction of the expected losses over a period of time. In this regard it should be mentioned that the expected damage will depend on those goods and services that we are willing to protect, and the protection of which is included in the objectives of a management plan.

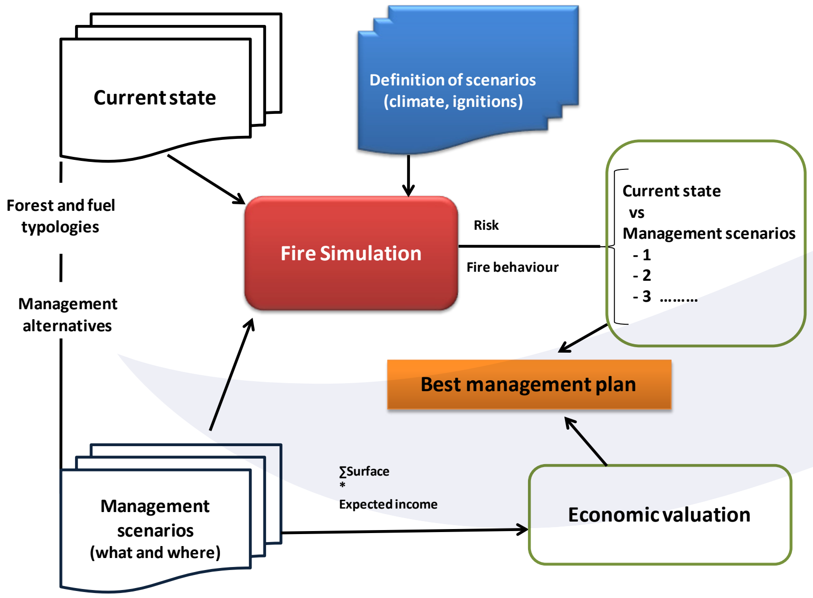


Figure 26. Example of integrated methodology for the selection of a forest prevention plan where ignitions are included.

Estimating the probability of fire occurrence is implemented by including a GIS based shape-file of fire ignitions on fire spread models (Figure 26). Spatially explicit fire spread models are simulation systems that provide information about how the fire will behave across a landscape in terms of directional vectors of fire spread, fire intensity, fire spread speed, fire spread areal contours, etc. FSPro (Fire Spread Probability), and FlamMap (Fire mapping and analysis system) are examples of fire spread models that allow the inclusion of multiple fire ignitions, and for evaluation of fire occurrence. Both have been developed by the Missoula Fire Sciences Laboratory and the Rocky Mountain Research Station of the USDA Forest Service, for prevention planning.

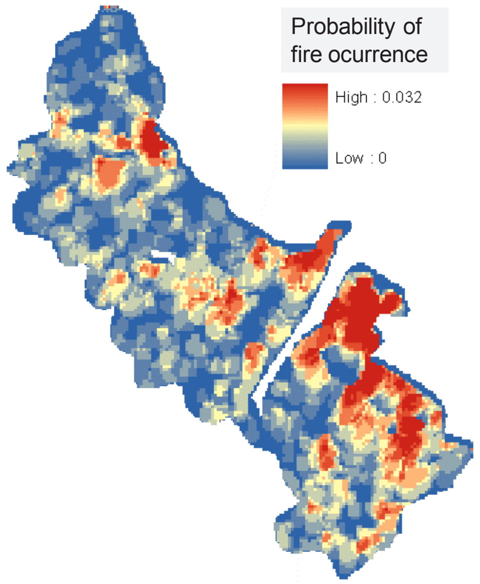


Figure 27. Example of output to be obtained from FlamMap once multiple fires simulated (GONZALEZ-OLABARRIA et al., 2012).

FSPro is a system that calculates the probability of a fire reaching any point in a studied landscape (raster maps of slope, elevation, aspect, fuel type, tree height, canopy base height, canopy bulk density, canopy cover), given an existing fire ignition or fire perimeter. FSPro performs hundreds or thousands of separate fire growth simulations using a minimum travel time fire spread method, by applying multiple weather scenarios. The amount of time a fire reaches each point, combined with the total number of fire simulations, will show a fire probability surface. FlamMap is a fire mapping and analysis system which estimates potential fire behavior across a landscape. By introducing similar landscape information as in the case of FSPro, but applying constant values on fuel moisture and weather, the system produces fire behavior calculations – such as spread rate, flame length, fire line intensity, fire crowning – for each point in the study area. FlamMap provides the possibility to calculate minimum travel times for fire spread, and fire occurrence probability, which is useful in determining effective fuel treatment locations. A difference between these systems is that FlamMap is mainly designed for tactical planning of fuel management operations, whereas FSPro is designed for larger areas and a more strategic planning frame, and considers a temporal dimension that FlamMap lacks.

To find out more see:
Report on Protocol for ignition risk assessment. FIREfficient Project. Deliverable 12.
http://firefficient.ctfc.cat/, http://www.lessonsonfire.eu

4.

EMPOWERING LAND AND FIRE MANAGERS IN WILDFIRE RISK

Author: Eduard Plana Bach

4. Empowering land and fire managers in wildfire risk

4.1 Training standards in wildfire risk planning for fire and land planners

By Oriol Vilalta, Mariona Borràs, Jordi Vendrell, Helena Ballart, Juan Camaño, Alexander Held and Daniel Kraus

Definition and background

Knowledge and experience in vegetation fire management is something that takes many years for people to attain. Fire behavior is complex and the theory needs to be understood but also observed and tested in real burning and fire suppression situations to allow a person to learn and gain confidence. Transferring this experience to the planning level is key for future fire management. Competency standards are often used as a fundamental part of a competency based training system. Competency standards are a description of the performance required in a work situation, describing the knowledge needed to support that activity, in a context or range of situations. In the European Qualifications Framework (EQF)[9] context competency standards are used to define learning outcomes and to capture experience. This means that competency standards can be used to support work based training and qualifications at a particular level of activity. This applies equally to land use and spatial planners, assisting better fire management.
The main benefits of competency standards are to:

- support a better match between the needs of the labor market and education and training provision;
- facilitate the validation of practical experience and informal learning as well as formal training and;
- help the transparency and comparison of qualifications across training systems from different countries.

Author: Fernando Abad

The emphasis is on the outcomes of learning, which is a major change from the traditional approach to training that emphasized inputs, for example the number of training hours. Competency standards are normally defined by general statements sufficient to describe the activity. Detail is provided in other documents such as training manuals, assessment guidance and other reference material.

Training standards in wildfire risk planning for fire and land planners: General Idea

Fire resilience and mitigation to reduce the impact of unwanted fires need more consideration in land-use and spatial planning. This starts with the inclusion of fire management aspects in the planning process in landscape and land-use planning. With the development of generic competency standards this project aims to support this development for more resilience based fire planning. Experience and competency levels have to be defined and described in the format of a EQF compatible standard.

Adapting prevention structures to the fire type in each territory is based on identifying the critical points for every fire type and the existing management opportunities in the landscape. The knowledge of fire patterns and historical fire data, complemented by the fire services experience, must be included in this training standard.

Scope: This standard sets out good practice for integrating wildfire resilience into land management planning at three levels: regional planning, landscape planning, and forest planning. Training standards aims to help reduce the likelihood and severity of wildfires in forests, woodlands and other vegetated land in Europe and promote appropriate fire mitigation regimes. It is primarily focused on the planning measures that can be used and only covers operational issues, such as fire suppression activities, where they benefit from some element of land management planning.

[9] http://ec.europa.eu/ploteus/

Target: The main professional profiles suitable to obtain this competency are: land-use planners, fire planners, forest managers, emergency planners, and urban planners. In addition, it is recommended to forest and woodland owners, forestry practitioners, planning teams and all those involved in adaptive management to build resilient forests and landscapes. It aims, especially to foster cooperation and the understanding among all the stakeholders.

Specific training standards: The adoption of this training standard will allow professionals to identify opportunities in the landscape in order to:

- Reduce wildfire spread and support suppression actions (reducing fire intensity).
- Deciding the best place to create preventive infrastructures for mitigating wildfires depending on the expected fire behaviour.
- Designing these preventive infrastructures detailing some specifications such as size, shape, secure accesses and/or vegetation distribution inside and surrounding the infrastructure to improve landscape resilience.

4.1.1 Acquisition and maintenance of training standards in wildfire risk planning

Previous skills required

As described in *Training Standard Achievement*, one of the most important steps in acquiring this competency is to be capable to determine the fire types in the respective environment and fire regime. Previous skills required for the process of acquisition of this training standard are:

- **Local and regional meteorology and its interaction with the territory:** The occurrence of adverse weather episodes (drought and high temperatures) is relevant for the development of large wildfire events. Understanding the interactions between meteorology and territory allow the landscape managers to understand the fire interactions at the local level. For example, the same synoptic weather situation may result in different weather conditions in different areas. Apart from that, a very good knowledge of wind interactions is essential to predict the fire behavior at a local level and to prevent accidents.

- **Ability to read cartographic maps, focusing on ravine bottoms, crests and mountain pass:** The ability to read and understand cartography is essential for anybody who needs to identify the Strategic Management and Critical Points (ravines, steep slopes, crests, etc.). As shown in previous sections of this report, fire behavior is determined in part by topography. Therefore, it is essential to be able to identify these points as a landscape manager. These changes in topography are at the same time, the best operational places to create the opportunities for the fire services through the Strategic Management Points.

- **Development of management plans:** Building wildfire resilience can be undertaken during each one of the seven stages of the forest management planning process: *Scoping, Survey, Analysis, Synthesis, Implementation, Monitoring and Review* (FC, 2014). Knowing the basic requirements of management plans is a required skill for this competency.

Training standards achievement

In order to acquire this competency in planning, the previous skills defined above must be proved. Then, students must attend a complete training to understand concepts and methodologies used to integrate wildfire risk into landscape, or prove previous competencies acquired for this purpose. In order to address specific gaps in the students' knowledge and experience, some specific actions must be addressed:

- **Lack of experience with real fire** (wildfires or prescribed burning) → A field visit will be mandatory to gain practical understanding of wildfire dynamics, fire effects on vegetation and effects of fire behavior on the landscape. If possible, students will attend to a prescribed burn to understand fire behavior. In northern European environments, where conducive weather for prescribed burning is less predictable, it may be necessary to use wildfire simulations (using wildfire spread models) to assist students when experiencing real fires is not possible (SMITH, 2015).
- **Lack of knowledge on planning tools** → Maps will be constantly used during the training, and cartographic analysis will be constantly carried out to ensure students understand and apply planning concepts.

It is recommended to use a 'real scenario' during the training on which students must apply the theoretical concepts. This 'real scenario' must be visited in the field after theoretical sessions. At the end of the training, students must demonstrate the acquired knowledge by means of an exam, and the capability to be able to integrate wildfire risk into the landscape through planning exercises.

Training standards maintenance

Once students have obtained the competency, they must continue integrating the methodology in forest management and contingency plans for those areas with high risk of wildfires in their territories. It is recommended that students accumulate experience in real fire situations (prescribed fire), and keep abreast of news related to wildfires in their areas. It is also required to be continuously in communication with wildfire collaborative networks in the territory (such as Wildfire Groups).

4.1.2 Training standard knowledge

Knowledge required for acquiring this training standard is based on experienced-methodology developed and tested during recent decades by Fire Services across Europe. These can be exported to other areas such as forest management, land planning or spatial planning.

General knowledge

- **Basic concepts of fire behavior:** Fire behavior can be described as the reaction of a fire to the influence of fuel, topography and weather conditions (fire triangle). Understanding and being capable to detect when this fire behavior will change during a wildfire is crucial to obtain this competency (see Box 8). More specifications related to fire behavior, like spot fires, rate of speed of the front of fire and intensity of fire must be clarified and previewed for designing Strategic Management Points: (detailed below).

- **Fire spread patterns:** The concept of spread patterns refers to the key concept outlining the way in which the fire spreads over the terrain. Depending on the spread pattern, three main spread types of fire can be distinguished: topographic, wind-driven and plume fires.

- **Critical Points:** After determining spread patterns for a territory, Critical Points must also be defined. It is necessary to understand the Critical Points concept as it is the first step for identifying Strategic Management Points.

- **Fire Types:** When analysing historical fires, it becomes obvious that under the same topography and weather (synoptic weather situation) conditions, fire spreads following similar spread schemes.

- **Strategic Management Points (SMPs) concept and objectives:** These areas identified as potential management opportunities, adapted to the requirements of the suppression service, reduce fire behavior – during a wildfire - . The main objectives of the SMPs are:
  a) **Reduce Rate of Spread**, which is the rate of advance of a wildfire (km/h or miles/h).
  Which is the expected rate of spread of a potential wildfire in this territory?
  b) **Reduce distance of spot fires**. Spot fires are fire outside the main fire perimeter caused by sparks and embers transported by the wind or convective smoke column.
  Does the wildfire have the capability to generate spot fires? What is the maximum distance of spot fires during a wildfire?
  c) **Reduce fire intensity and its behavior**. When talking about wildfires, 'intensity' can be described in terms of flame length. Intensity is closely related to forest structure and fuel availability.
  d) **Build anchor points**. An anchor point is an area with no fuel where the fire service can start activities to extinguish the fire, such as implementing fire control lines.
  e) **Build Safety Zones**. SMPs must be safety zones for staff of suppression forces. A safe zone is an identified area of safety where people will find refuge. This is one of the five basic concepts of the LACES (Lookout, Awareness or Anchor point, Communications, Escape routes, Safety zones) protocol [10] needed to ensure safety in wildfire suppression practices.

- **Fire ecology:** Fire plays an important role in forest ecosystems. Severe fires that burn all vegetation in an area lead to replacement of all vegetation by new growth. This can be an opportunity to **restore** ecosystems. Low to medium severity fires, may lead to partial or complete replacement of herbaceous and shrub vegetation, and also affect trees. They play an important role in **maintaining** or perpetuating certain ecosystems.

Specific knowledge

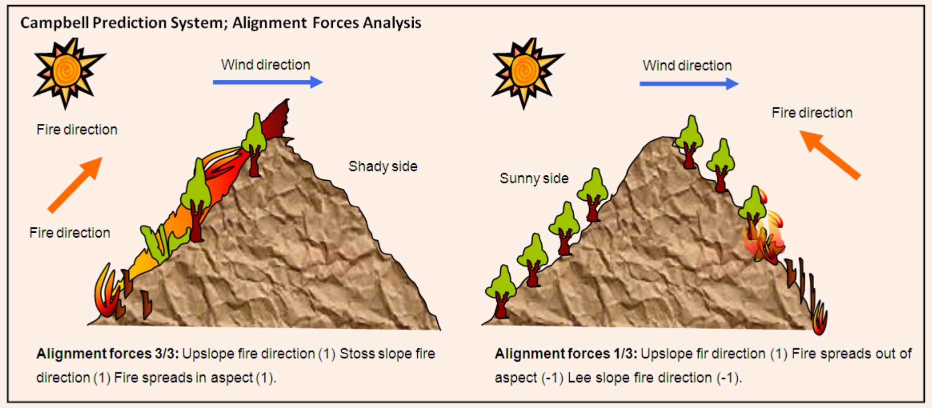
- **Historical fires data of the local area**: In a particular territory, the same weather situation, over the same topography, results in the same fire spread pattern, which means similar fire behaviors

[10] https://en.wikipedia.org/wiki/Glossary_of_wildfire_terms#L

and spread patterns that were seen in past fires. This is the essential ingredient, together with the weather information and also the understanding of cartography to begin the understanding of the Fire Types concept.

- **Identify most relevant spread patterns in the local area:** The identification of different fire behaviors, fire movements, etc. allow the land managers to compile methodologies for the SMP identification for each Fire Type.
- **Design of Strategic Management Points**: SMPs must be designed to protect population and environment through fire hazard reduction.
  - **a) Location and type of SMPs**. Once spread patterns and Fire Types have been defined for a territory, then it is possible to determine the best location for SMPs. Each spread pattern and Fire Type have some SMPs associated, but they must be adapted to the needs of each territory. Understanding and recognizing all specific needs for integrating wildfire risk into a territory is one of the keys of this competency.
  - **b) Prevention infrastructures typology** depending on fire behavior expected.
    - **Safety zone** (described above)
    - **Water supply**: Is a facility that provides water for the fire services in isolated places with a specific time.
    - **Low-fuel-load strip**: Is an area where fuel treatments have been applied with the aim to reduce the fire spread.
    - **Anchor point** (described above).
  - **c) Distribution and structure of vegetation inside and surrounding prevention infrastructure**. The final density and distribution of vegetation inside and surrounding the prevention infrastructure must be defined. As described in *Large forest fire risk assessment and fuel management: operational tools and integrated approach* (PIQUÉ and GONZÁLEZ-OLABARRIA, 2014 - Task 2.1, FIREfficient project), a set of Fuel Management Tools for Fire Hazard Reduction can be applied to break fuel continuity and reduce fuel load.

Box 8. **The Campbell Prediction System (CPS) for fire behavior prediction.**
The Campbell Prediction System (CPS) is a practical way to use on-scene fire behavior observations to determine fire behavior strategies and tactics. CPS allows to predict where the potential fire behavior will likely exceed a suppression resources' threshold of control. The CPS analysis is based on the alignment of forces; **a simple way to view the fire ground and to explain how the fire will change in intensity** (CAMPBELL, D. 2003). There are three primary causative forces present which influence the variations in intensity and rate of spread of a wildfire. As the fire burns over the topography, the forces change independently. Each force can aid or retard the spread. The forces can work together or cancel each others effects out. The three forces usually associated with fire behavior are Weather, Topography and Fuel. The primary forces that cause wildfires to change are wind, slope, and fuel temperature variations (aspect). Observations of how these forces vary in the path of the fire are the first step in predicting changes in the fire behavior potential. A segment of a wildfire will gain intensity and speed where it finds a time or place of more favorable alignment. To communicate this change it's said; "The fire is going into better alignment with ---" (naming the force of change.) A good and safety extinction strategy is to fight fire where it is out of alignment or where will be.



SOURCE: PLANA and BARRIGÓN, 2007.

- **Validation and Evaluation of Strategic Management Point and Infrastructures:**
  - **a) Simulators for validation**. As described in (PIQUÉ and GONZÁLEZ-OLABARRIA, 2014), some Empirical Models can simulate *the spread of wildfires across landscape in real time, or ideally faster than real-time […]to help manage landscape for fire risk*. These models can be used, for example, to validate the prevention infrastructures designed previously, and to test the resilience of the landscape. During the training in the Spanish pilot site, the simulator Wildfire Analyst™ was used to validate the Fire Type determined and the *planned infrastructures*. Results of this validation were verified on a field visit.

    Also, colleagues from Northern Ireland explained, during a visit to a pilot site in the Mourne Mountains, the use of these empirical models to assess fire behavior over the Eastern Mournes under two different weather patterns (*The Eastern Mournes Wildfire Report, 2012,* Annex in PAGÉS et al., 2015).
  - **b) Field validation**. It is necessary to validate the effectiveness of SMPs in the field. The location and vegetation structure of SMPs must be analysed *in situ* to verify that the spread rate speed of fire would decrease in these areas.

- **Collaborative Network**: The Eastern Mournes Wildfire Report (PAGÉS et al., 2015) *recognized the importance of establishing a collaborative problem solving approach between land managers, the fire service, relevant agencies and other stakeholders […]* (see Chapter 2.1)

4.1.3 Evaluation of skills

Knowledge: What must be known and understood?

- Knowledge and understanding of fire behavior, fire weather and fire danger;
- Weather conditions, topography and fuel;
- Changes on fire behavior and spread. Campbell Prediction System CPS[11];
- Wildfires Generation concept[12];
- Knowledge and understanding of characteristically spread patterns;
- Topographical, Wind-driven and Smoke-Plume driven fires;
- Knowledge of Strategic Management Points concept and objectives;
- Knowledge of all tools available in the territory to reduce fuel load;
- Knowledge of the methods and techniques of prescribed fire and fuels management;
- Expert knowledge of the ecological response to the presence or absence of fire;
- Knowledge of fire effects as it relates to fuel manipulation and prescribed fire;
- Expert knowledge of environmental laws, regulations, and policies;
- Knowledge of empirical models to simulate spread of wildfires across landscape, including Geographic Information Systems.

Skills and abilities: What the trainee must be able to do? (checklist)

- Ability to implement mitigation measures to reduce risks identified in an approved fire prevention plan;
- Ability to conduct an analysis of historical fire records and determine specific areas where mitigation measures can be developed and implemented;
- Compile historical information of: wildfires, weather conditions and landscape management;
- Define Strategic Management Points and determine vegetation treatments inside and surround them
- Define spread patterns in the terrain;
- Define Critical Points in the terrain;
- Validate pre-suppression infrastructures defined in the territory;
- Ability to cooperate with local wildfire networks;
- Knowledge and ability to participate in the interdisciplinary planning process;
- Ability to develop and implement forest management and contingency plans;
- Ability to develop mitigation measures designed to reduce hazards and risks;
- Ability to monitor and evaluate Fire Hazard Reduction programs and determine their effectiveness in meeting management goals and objectives.

To find out more see:
Report on Specific tools for training fire and landscape planners in the use of fire-spread simulation models. FIREfficient Project. Deliverable 13.
Report on Training standards in wildfire risk planning for land and fire planners. FIREfficient Project. Deliverable 17.
http://firefficient.ctfc.cat/, http://www.lessonsonfire.eu

[11] http://www.emxsys.com/cps/default.html
[12] https://www.ucm.es/data/cont/docs/530-2013-10-15-GALIANA_MONTIEL_IUFRO_Braganza2010.pdf

4.2 Developing knowledge management transfer tool: LESSONS ON FIRE platform

By Oriol Vilalta, Mariona Borràs, Jordi Vendrell and Helena Ballart

Knowledge Management (KM) is one of the hottest topics today in both the industry world and information research world. In our daily life, we deal with huge amount of data and information. Data and information is not knowledge until we know how to dig the value out of it. This is the reason we need knowledge management. Unfortunately, there is no universal definition of knowledge management, just as there is no agreement as to what constitutes knowledge in the first place (UNC, 2014). DAVENPORT (1994) defines KM as *the process of capturing, developing, sharing, and effectively using organizational knowledge*.

Many recent authors suggest that the use of Virtual Communties of Practice (VCoP) based on Web 2.0 tools is a new paradigm for the Knowledge Management (KM) of organizations (KABBAS AL-GHAMDI et al., 2015). As described in Wenger at al. (1998), a *Community of Practice* is defined as groups of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis. If a community was created under Web technologies and works through the Web, it is called *Virtual Community of Practice*. Virtual communities of practice can be defined as 'Groups of professionals brought together by shared goals and common concerns regarding participation, exchange, trading, organizing and management of their tacit and explicit in order to improve their professional performance, as well as the performance of their organizations as a whole. These communities are characterized by self-regulation (KABBAS AL-GHAMDI et al., 2015).

According to KABBAS AL-GHAMDI et al. (2015), the most important challenges for virtual communities facing the traditional KM systems are: (1) capturing tacit knowledge, (2) Knowledge sharing and communication and (3) Facilitating Innovation.

LESSONS ON FIRE platform

Following GIMENEZ et al. (2015) guidelines to create a successful VCoP, the LESSONS ON FIRE platform has been design in order to capitalize the maximum of the expert knowledge on wildfire risk reduction in EU landscapes. The objectives of the platform are:

1. **Create a site of reference for land and fire planners**, administrated most of the time by the community, and coordinated by FIREfficient partners.
2. **Integrate a database of experts**, organized by categories (see Deliverable 20) and capacity to show some professional skills for each participant. This database will be automatically updated, as experts have to register in the site.
3. **Stimulate discussion and exchange of knowledge between European experts**. Create a participatory platform in order to start a discussion, reply, share documents and invite other experts to participate.
4. **Exchange of documents between European experts**. Create a library organized by categories and defined by keywords. Search option to find easily documents (by categories and keywords). File formats accepted: PDF, Images, and Videos.
5. **Filter participation**. Only logged participants will be able to generate discussions, participate and upload documents, in order to 'control' the participation.
6. **Foster participation of targeted experts**: create *communities* to make experts feel in the *appropriate* group.

The platform LESSONS ON FIRE allows creating **communities** to generate **debates** among experts on specific issues, with certain confidentiality. A user registration system has been searched to allow knowing the participants' professional profile in the debates.

Besides being able to generate a huge number of discussions, documentation can be added and filed in an organised way to ensure its search in the website. In this way, LESSONS ON FIRE will end up being a searching **library** about the integration matter of forest fires risk in the landscape.

Within LESSONS ON FIRE you will also find a data base in a **directory**, which will allow you knowing, locating and contacting professionals from different disciplines in an international level. The experts search can be done depending on their work field or the area where their work is developed.

LESSONS ON FIRE is available at: **www.lessonsonfire.eu, www.lessonsonfire.com, www.lessonsonfire.org**

To find out more see:
LESSONS ON FIRE: A Participatory and Knowledge-based platform. FIREfficient Project. Deliverable 21.
http://firefficient.ctfc.cat/, http://www.lessonsonfire.eu


Prescribed burning training. Author: MASTER Fuego

5.

GLOSSARY OF TERMS AND ACRONYMS

Author: Eduard Plana Bach

5. Glossary of terms and acronyms

Glossary of terms

The following terms and definitions are extracted from the European Glossary for Wildfires and Forest Fires (EUFOFINET project; STACEY, 2012).

Aerial fuels: Any fuel found at a height of more than 3.5 metres above the ground surface.

Advancing fire: This is fire progression associated with the head (front) of the fire. Fire behavior in this area is usually characterized by more intense burning, increased flame height and length and more rapid rates of spread. It will usually occur when a fire burns with the support of one or more forces of alignment (for instance, wind or slope).

Anchor point: An advantageous location, usually a barrier to fire spread, from which to begin constructing a control line. An anchor point is essential when constructing a control line because it will ensure that the control line is completely closed and that the fire cannot breakout of the area of containment. The creation of an anchor point is sometimes a key element included within the LACES safety protocol.

Available fuels: The proportion of the total fuel that would burn under specified burning and fuel conditions.

Average wind direction: The most frequent direction from which a wind blows at a particular location over a specified period of time, usually 10 minutes as specified by the World Meteorological Organization.

Average wind speed: The mean average wind speed at a particular location over a specified period of time, usually 10 minutes as specified by the World Meteorological Organization.

Backing fire: A lower intensity fire or part of a fire which burns against the wind and/or down slope.

Barrier: Any natural or artificial obstruction to fire spread. This is normally an area devoid of fuel which is large enough in size to prevent a fire passing through or over it.

Burn:
a) To be on fire.
b) An area of fuel consumed or partly consumed by a fire.
c) An injury to flesh caused by a cauterizing agent, heat from a fire, or a heated object.
d) A managed fire (i.e. an operational burn or prescribed burn)

Burning conditions: The state of the combined components of the fire environment that influence fire behavior within available fuels. Burning conditions are usually specified according to the factors of aspect, weather, slope/topography, and fuel type and load.

Burn severity: A qualitative assessment of the heat pulse directed toward the ground during a fire. Burn severity relates to soil heating, large fuel and duff consumption, consumption of the litter and organic layer beneath trees and isolated shrubs, and mortality of buried plant parts.

Cause of fire: The sequence of events and actions that brings an ignition source into contact with materials first ignited which leads to sustained combustion. For statistical purposes, causes of fire are usually grouped within a standard classification.

Convection column: A rising column of pre-heated smoke, ash, particles and other debris produced by a fire.

Convection-driven fire: A fire that is spread predominantly by the intensity of the convection column.

Containment: An area of a fire where control has been established and no breakout is anticipated.

Control line: An inclusive term for all constructed or natural barriers and treated fire edges used to control a fire.

Controlled fire: A fire with a secure perimeter, where no breakouts are anticipated.

Critical Point: This is a point in time or space when/where there will be a significant influence on fire spread, rate of spread and/or fire intensity.

Crown fire/Crowning: When a fire burns freely in the upper foliage of trees and shrubs. There are three different types of crown fires:

- **Active Crown Fire** – A fire that advances as a wall of flame engulfing all surface and aerial fuels.
- **Independent Crown Fire** - A fire that advances through aerial fuels only.
- **Intermittent Crown Fire** - A surface= fire involving torching behavior but without sustained crowning activity. Rate of spread is controlled by the surface fire.

Escape route: A pre-planned route to be taken in the event of unforeseen hazardous circumstances (for instance, an unexpected change in fire behavior). An escape route is an important part of an escape plan and is a key element of the LACES Safety Protocol.

Evacuation: The removal of people from dangerous or potentially dangerous areas and their subsequent relocation to safe areas.

Extinction: The ceasing of the combustion process, either naturally or as a result of suppression activities.

Extreme fire behavior: Fire behavior that becomes erratic or difficult to predict due to its rate of spread and/or flame length. This type of fire behavior often influences its environment.

Fire: Fire is the product of the chemical reaction of combustion. The three factors of fuel, oxygen and heat must all be present in the correct proportions for combustion to occur. When the combustion process is initiated, heat and light are emitted and a fire occurs.

Fire activity: Description of a fire based on an assessment of visible evidence, including the speed of the fire, flame length, flame height, fire severity, and fire behavior.

Fire analysis: The process of reviewing the behavior and effects of a specific fire or group of fires and/or the actions that have been taken or which might be needed to suppress it/them.

Fire behavior: The reaction of a fire to the influences of fuel, weather, and topography. Different types of fire behavior include:
- **Smouldering fire** - A fire burning without flame and with minimal rate of spread.
- **Creeping fire** - A fire with a low rate of spread and generally with a low flame length.
- **Running fire** - A fire with a high rate of spread.
- **Torching** - A fire that burns from the ground through the surface and aerial fuels and into the crown of a single tree or small parcel of trees.
- **Spotting** - fire behavior where sparks and hot burning embers are transported by the wind or convection column to land beyond the fire perimeter resulting in spot fires.
- **Crowning** – When a fire burns freely in the upper foliage of trees and shrubs.

Firebreak: An area on the landscape where there is a discontinuity in fuel which will reduce the likelihood of combustion or reduce the likely rate of fire spread. Firebreaks may be naturally occurring or may be deliberately created as part of a wildfire mitigation or prevention activities.

Fire damage: The loss that is caused by the fire. This loss will normally include financial costs, but will also include other direct and indirect costs to the environment and society.

Fire danger: A general term used to express an assessment of both fixed and variable factors of the fire environment that determine the ease of ignition, rate of spread, difficulty of control, and impact. Fire danger is often expressed as an index.

Fire dependent ecosystem: An ecosystem which requires periodic fires in order to maintain the character, diversity and vigor of its intrinsic plant and animal communities. A fire dependent ecosystem will often be composed of pyrophile species.

Fire dependent species: Plant and animal species which require regular fires in order to trigger or facilitate regeneration mechanisms, or to regulate competition from other species. Without fires, these species would become extinct.

Fire ecology: The study of the relationships and interactions between fire, living organisms and the environment.

Fire edge: Any section of the fire perimeter.

Fire effects: The physical, biological, and ecological impacts of fire on the environment.

Fire environment: The surrounding conditions, influences, and modifying forces of topography, fuel, and weather that determine fire behavior, fire effects and impact.

Fire footprint: The outer shape of the fire perimeter at a given point in time. In the context of restoration, the fire footprint will be the final extent of the perimeter.

Fire growth: The evolution of a fire from ignition to self-sustaining propagation and its movement through available fuels.

Fire hazard: Any situation, process, material or condition that can cause a wildfire or that can provide a ready fuel supply to augment the spread or intensity of a wildfire, all of which pose a threat to life, property or the environment.

Fire history: The reconstruction and interpretation of the chronology of wildfire occurrence and the causes and impacts of wildfires within a specified area.

Fire intensity: The rate at which a fire releases energy in the form of heat at a given location and at a specific point in time, expressed as kilowatts per meter (kW/m) or kilojoules per meter per second (kJ/m/s).

Fire model: A computer program which will predict or reconstruct fire behavior and rate of spread of a fire from a point of ignition or area of origin.

Fire regime The pattern of fire occurrence, fire frequency, fire seasons, fire size, fire intensity, and fire type that is characteristic of a particular geographical area and/or vegetation type.

Fire resistant plant: A plant species which has morphological or seasonal growth characteristics that give it a high probability of surviving a wildfire. Heat-insulating bark, seasonal dormancy, and the ability to regenerate through stump sprouts or aerial re-growth (broadleaved) are specific examples of fire resistant characteristics.

Fire risk: The probability of a wildfire occurring and its potential impact on a particular location at a particular time. Wildfire risk is calculated using the following equation: Fire risk = probability of occurrence x potential impact.

Fire season: The period or periods within a year when wildfires are likely or most likely to occur.

Fire sensitive ecosystem: An ecosystem with a low resilience to fire. Fire sensitive ecosystems will struggle to recover from the passage of a wildfire.

Fire sensitive species: Species with a relatively high probability of being killed or scarred if a wildfire occurs. Specific examples include trees with thin bark or highly flammable foliage, or animal species that are unable to evade the heat of a wildfire.

Fire severity: Fire severity can be defined in two ways:
- The degree to which a site has been altered or disrupted by fire.
- The capacity of a fire to cause damage.

Fire intensity and the amount of time a fire burned within a particular area, among other possible factors, will influence fire severity.

Fire spread: The movement of a fire through available fuels arranged across the landscape.

Fire triangle: Diagram which presents the three factors that are necessary for combustion and flame production: FUEL-HEAT-OXYGEN.

Fire Types: There are three different schemes for classifying fire type:
1. Classification of a fire or section of fire according to the fuel level within which it occurs. For example, aerial, crown, understory, surface and ground fires.
2. Classification of a section of fire according to its position along the fire perimeter. For example, head, tail and flank fires.
3. Classification of a fire or section of fire according to the visual characteristics it displays. For example, smouldering, creeping, backing, running…

Flame height: The vertical extension of a flame. Measurement of flame height is calculated perpendicular from ground level to the tip of the flame. Flame height will be less than flame length if flames are tilted due to wind or slope.

Flame length: The total length of a flame measured from its base at ground level to the flame tip. Flame length will be greater than flame height if flames are titled due to wind or slope.

Flammability: Relative ease with which a fuel will ignite and burn with a flame.

Flank fire: A fire spreading or predicted to spread parallel (approximately at a right angle) to the prevailing wind direction or a slope.

Flanks: The parts of a fire's perimeter that are roughly parallel to the main direction of fire spread. The flanks usually have less fire intensity than the head fire because they have a weaker alignment with wind or slope.

Forces of alignment: A collective term for the forces that have a significant impact on wildfire behavior. These forces can support or hinder fire development and can be used to predict likely fire behavior, including fire spread and fire intensity. Wind, slope and aspect are considered to be key forces of alignment.

Fragmentation: The process of transforming large continuous areas of vegetation and fuel into smaller discontinuous areas. Fragmentation leads to a change in fire regimes through the alteration and discontinuity of fuels.

Fuel: Any material that can support combustion within a wildfire environment. Fuel is usually measured in tons per hectare.

Fuel arrangement: The horizontal and vertical distribution of all combustible materials within a particular fuel type.
- **Horizontal fuel arrangement** - A description of the distribution of fuels on the horizontal plane. The horizontal arrangement of fuels will influence the relative ease with which fire can spread horizontally across an area of land.
- **Vertical fuel arrangement** – A description of the distribution of fuels on the vertical plane, from the ground up to the canopy levels of vegetation. The vertical arrangement of fuels will influence the relative ease with which fire can spread vertically through the fuel layers.

Fuel assessment: The estimation or calculation of total and available fuel that is present within a specific area.

Fuel continuity: The extent to which fuel arrangement will support fire spread.

Fuel consumption: The amount of a fuel that is removed by a fire, often expressed as a percentage of the fuel load.

Fuel-driven fire: A fire or part of a fire that is spread predominantly by the arrangement, condition, and/or other characteristics of the fuel within which it is burning. This situation occurs in the absence of a significant effect from the forces of alignment, such as wind, slope and aspect. Fuel-driven fires can produce erratic fire behavior.

Fuel layers: The classification of fuels according to their height relative to the ground surface.
There are five general fuel layers: **Aerial fuels, Elevated fuels, Near surface fuels, Surface fuels, Ground fuels**

Fuel load: The amount of fuel present within a particular area. Fuel load is measured in weight per area measured (usually in kilograms per square meter). Fuel loading is expressed in relative terms as either "heavy fuel loading" or "light fuel loading".

Fuel management: The process of managing fuel or fuel arrangement. The aim of fuel management is usually to create a discontinuity in fuels to achieve fragmentation.

Fuel model: A mathematical representation of fuel properties within a specified location, often used to predict and plot likely fire spread and intensity.

Fuel treatment: The deliberate manipulation or removal of fuels using one or more of a variety of different means to:
- reduce the likelihood of ignition; and/or,
- reduce potential fire intensity; and/or,
- reduce potential damage; and/or,
- assist suppression activities.

Heat transfer: The process by which heat is imparted from one body or object to another. In wildfires and forest fires, heat energy is transmitted from burning to unburnt fuels by:
- **Convection** – Transfer of heat by the movement of masses of hot air; the natural direction is upwards in the absence of any appreciable wind speed and/or slope. Convection can include spotting behavior.
- **Radiation** – Transfer of heat in straight lines from warm surfaces to cooler surroundings.
- **Conduction** – Transfer of heat through solid matter.

Hot spot: A small burning area within a fire perimeter which requires suppression action as part of the mop-up phase of suppression.

Ignition: The initiation of combustion.

Ignition method: The means by which a fire is ignited.

Ignition patterns: A generic term for the three key techniques for igniting a managed burn:
• **Line ignition** - igniting a burn in strips along a control line and the adjacent fuel.
• **Points of fire ignition** - igniting a number of fires within an area of fuel. The aim of this technique is for the individual fires to burn into one another.
• **Fingers of fire ignition** - a low intensity back burn which is achieved by igniting lines of fire at right angles to a control line and parallel to the wind.

LACES: An essential safety protocol which should be implemented at wildfire incidents to address risks and hazards. The correct implementation of LACES helps to ensure that suppression personnel are appropriately supervised, informed and warned of risks and potential hazards and that they are aware of how and where to escape should a high risk situation occur.
LACES is an acronym for:
- L = Lookouts
- A = Awareness or Anchor Point
- C = Communication
- E = Escape route and plan
- S = Safe area

Ladder fuel: Fuels that provide vertical continuity which allow fire to move through the vertical fuel arrangement.

Land management: The process of managing the use and development of an area of land for: wildfire prevention; conservation, restoration or protection of the environment; commerce; and/or for other reasons.

Land use planning: A decision-making process involving the allocation of areas of land to different uses and/or vegetation types.

LIDAR (Light Detection And Ranging): An optical remote sensing technology that can measure the distance to or other properties of a target by illuminating the target with light, often using pulses from a laser. LIDAR technology has applications in geomatics, geography, geology, geomorphology, forestry, remote sensing as well as in airborne laser swath mapping (ALSM), laser altimetry and contour mapping. LIDAR data is usually used to produce Digital Elevation Models (DEMs).

Managed burn: A planned and supervised burn carried out for the purpose of removing fuel either as part of a Fire Suppression Plan (an operational burn) or a land management exercise (a prescribed burn).

Mega fire: A wildfire demonstrating abnormally extreme fire behavior. Mega fires will usually represent a significant challenge to suppression agencies because they are very resource intensive to suppress and can pose a significant risk to the safety of suppression personnel.

Mitigation: A collective term used for those activities implemented prior to, during, or after a wildfire which are designed to reduce the actual or potential consequences of the wildfire. Mitigation measures can include efforts to educate governments, businesses and the general public on appropriate actions to take to reduce loss of life and property during wildfire incidents. The development of mitigation measures is often informed by lessons learned from prior incidents.

Modeling: The process of creating a representation of part of the real world and subjecting it to some form of parameters and variables for the purpose of predicting, simulating or describing the real world.

Point of ignition: The precise physical location where the source of ignition came into contact with materials first ignited.

Post-fire succession: All of the different stages involving the growth of different species of plants within an area that has been affected by the passage of a wildfire. A number of different post-fire succession stages (series) can occur, dependent upon the environment. The first and last stages of post-fire succession are always referred to as the growth of "pioneer species" and the "fire climax":
1. **Pioneer species:** Species of plant that quickly grow and settle after the passage of a fire. The growth of pioneer species represents the first stage of post-fire succession.
2. **Fire climax:** The final stage of post-fire succession. The fire climax will often be a plant community at a stage of succession which is maintained by periodic fires.

Preparedness plan: A pre-determined strategic scheme or program of activities which is formulated in order to satisfactorily prepare an organization or a geographic area to respond effectively to wildfire incidents.

Prescribed burn: A planned and supervised burn carried out under specified environmental conditions to remove fuel from a predetermined area of land and at the time, intensity and rate of spread required to meet land management objectives. There are three specific types of prescribed burn which are used for restoration activities:
- **Conversion burn:** The use of fire to eliminate unwanted species that have appeared through natural regeneration. The ultimate purpose of conversion burning is usually to prepare an area for planting or to introduce different species.
- **Regeneration burn:** The use of fire to promote the natural regeneration of species which need heat/fire to release their seeds or to break a period of dormancy.
- **Site preparation burn:** The use of fire to remove slash left after the logging of burned timber. The purpose of a site preparation.

Prevention: The act or process of reducing the occurrence and/or impact of wildfires.

Pyrophile species (phyrophyte): Species that are able to survive wildfires and/or to regenerate after wildfires through germination stimulated by fire, stumps sprouts or aerial re-growth (i.e. broadleaved trees).

Rate of spread: A measurement of the speed at which a fire moves across a landscape. Rate of spread is usually expressed in meters per hour.

Risk: The probability of a hazardous event occurring and the potential outcome/consequences of that hazardous event. Risk is calculated using the following equation: Risk = probability of occurrence x potential impact

Risk assessment: The process of establishing information regarding acceptable levels of risk and actual levels of risk posed to an individual, group, society or the environment. The process involves the identification of risk, an assessment of probability and an assessment of potential impact.

Risk management: A process involving the systematic application of policies, procedures and practices to identify, analyse, evaluate, manage, control, communicate and monitor risks.

Safe area: An identified area of safety where people can find refuge.

Slash: Debris left lying on the ground after logging, pruning or thinning operations within woodland. Slash may consist of both course and fine fuels and sometimes forms a significant surface fuel.

Spotting: Fire behavior characterized by sparks and embers that are transported through the air by the wind or convection column. Spotting can be classified as short range or long range.

Strategic Management Point: Planned infrastructures that allow extinction of fires within the margins of safety and extinction capacity rates. The objectives are to reduce fire spread speed and intensity, to ensure a secure point for firefighters, and to provide suppression resources such as anchor points or water tanks.

Surface fire: A fire that burns within the surface fuel layer.

Tactics: The deployment of resources at a wildfire incident to achieve the aims of a fire suppression plan.

Topographical wind: When the direction and/or speed of a meteorological wind is altered by the topography of the landscape. Importantly, topographical winds are a general wind adaptation and they occur on a larger scale than more localized slope winds.

Topographically driven fire: A fire that is spread predominantly by the shape of the landscape, such as the steepness of slopes and gullies.

Torching: A fire that burns from the ground through the surface and aerial fuels and into the crown of a single tree or small parcel of trees.

Transition zone: An area where the spread of a fire changes direction. Transition zones can be identified by changes in the appearance of indicators.

Understory fire: A fire that burns beneath a canopy of trees. It can occur during the course of a wildfire or may be a tactic for a prescribed burn.

Wildfire: Any uncontrolled vegetation fire which requires a decision or action regarding suppression. Wildfires are commonly classified according to size and/or impact upon suppression resources.

Wind-driven fire: A fire or part of a fire that is spread predominantly by the speed and direction of the wind.

Window of opportunity: A period of time or location on the landscape when/where it will be particularly advantageous to adopt particular suppression tactics or actions.

Wildland: An area in which development is essentially non-existent, except for the presence of basic infrastructure such as roads, railroads and power lines. Any buildings and structures will be widely scattered.

Wildland Urban Interface (WUI) environment: The zone of transition between wildland and human settlements and/or development.

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List of Acronyms

A.G.S.-C.T.F.C. – Sustainable Management Area fo the Forest Sciences Centre of Catalonia
C.B.A. – Cost-Benefit Analysis
C.F.W.I – Canadian Fire Weather Index
C.P.S. – Campbell Prediction System
C.T.F.C. – Forest Sciences Centre of Catalonia
C.V.Fo.C. – Crown Fire Hazard Charts
De-a – Distance between Surface and Ladder fuels
Ds-a – Distance between Surface and Ferial fuels
E.F.F.I.S.- European Forest Fire Information System
E.F.I. – European Forest Institute
E.G.F. – European Qualifications Framework
E.R.C.C.- Emergency Response Coordination Centre
E.U. – European Union
F.C.C. – Percentage of Aerial Cover
F.D.R.S. – Fire Danger Rating System
F.O.G. – Fire Operation Groups
F.R.S. – Fire Rescue Services
F.S.Pro. – Fires Spread Probability
G.F.M.C. – Global Fire Monitoring Centre
G.I.S. – Geographic Information System
H.R.O. – High Reliability Organization
Ha – hectare
I.P.C.C. – Intergovernmental Panel on Climate Change
K.M. – Knowledge Management
L.A.C.E.S. – Lookout, Anchor point, Communications, Escape routes, Safety zones protocol
L.F.F. – Large Forest Fires
La.F.H.A. – Ladder Fuel Hazard Assessment
m. – Meters
M.I.C. – Monitoring and Information Centre
P.C.F. – Pau Costa Foundation
R.C.E. – Percentage of Ladder Cover
R.C.S. – Percentage of Surface Cover
S.M.P. – Strategic Management Points
S.R.E.S. – Special Report on Emissions Scenarios
S.R.E.X. – Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation
U.N.I.S.D.R. – the United Nations Office for Disaster Risk Reduction
U.S.D.A. – United States Department of Agriculture
U.T. - G.R.A.F-D.G.P.E.I.S. – Technical Unit of the Forest Actuations Reinforcement Group – General Directorate of Fire Prevention and Extinction, and Rescue of Catalonia
V.Co.P. – Virtual Communities of Practice
W.U.I. - Wildland Urban Interface

6.

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FIREfficient

Operational tools for improving efficiency in wildfire risk reduction in EU landscapes

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