FIREfficient

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

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Methodology for incorporating large fire risk into landscape management decision making

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1. INTRODUCTION

Goals

Landscape evolution in Europe has been closely linked to anthropic factors for centuries. These factors have been of different nature and have been changing along history. However, from the second half of XX century, transformations are more intense and changes are accelerating. Land abandonment and agriculture intensification (Moreira *et al.* 2001), urban economic concentration, Wildland-urban-interface sprawl, forest expansion (Améztegui *et al.* 2010), and lack of forest management, are the main drivers of change in Europe in the last decades, and all them are increasing wildfire occurrence risk, fire intensity and population exposure. During last years, wildfire extreme events have been recorded in several areas from Europe: Portugal (2003 and 2005), South-East France (2003), Spain (2006, 2009 and 2012) and Greece (2000, 2007 and 2009), and even in more unusual regions as Sweden in 2014.

The response from governments and public administrations to this challenge has been focused on the reinforcement to suppression policies. Nevertheless, large forest fires events from these last years have shown the control capacity limitations from the suppression systems. Low and medium fire suppressions can lead paradoxically to the existence of high intensity fires under adverse weather conditions due to continue fuel availability in the landscape (Minnich 1983; Piñol *et al.* 2007; Costa *et al.* 2011). Expecting that wildfire extinction policies will be the ones able to reduce are burnt would be an error. This has been shown to be untruth; modifying fire regime by reducing fire intensity and increasing its frequency seems to be more feasible (Piñol *et al.* 2007). Then, LWF could be reduce by increasing prescribed burning or replacing extinction policies leading to wildfire management policies.

Landscape planning seems to be one of the potential solutions to the large wildfires problem (Loepfe *et al.* 2012). Given an extreme fire weather event, firefighters brigades are usually unable to stop fires. Only by the profit of the opportunities provided by the landscape, fire can decrease its intensity and firefighters can act to content the fire. Landscape planning can both help wildfires to not reach such intensities both by a prevention forest management, and helping firefighters' actions during suppression strategies. Thus, wildfires become a multi-sectorial issue relating forest managers, civil protection bodies and urban and land-use planners, which should interrelate and collaborate aiming at reducing European landscape vulnerability to large wildfires.

Mediterranean ecosystems are particularly affected by global change, and tipping-points might be reached during this century with the predicted increase of both the frequency and the intensity of disturbances associated to climate change, land-use change and lifestyle (FAO 2013). Similar challenges may also appear in peripheral areas, specifically in Europe in northernmost limits. Given fire intrinsic presence in the ecosystems, the challenge does not consist in its final eradication of the systems, but consists in anticipate and reduce spread fires capacity, and thus reduce goods and people damage. The solution has been manifested to not depend on the direct investment on suppression efforts, but considering an integrative landscape planning that incorporated potential wildfire occurrence and spread into landscape socioeconomic dynamics.

The purpose of the present guide is to develop a methodology for incorporating wildfires risk in decision-making landscape management, aiming at facilitating easier choices between alternative management actions and fuel treatment, and thus reduce landscape vulnerability to large wildfires from a cost-effectiveness perspective.

Approach

The first part of the guide presents the background and state of the art in terms of fire and landscape planning, as well as a brief explanation of some of the methodology used to achieve the present guide: interviews to fire experts and meetings with fire groups have helped to identify challenges, weaknesses and limitations to the ideas presented in this document.

Given the wide-possibility potential user of this guide, the character adopted by the same is quite general. Firstly it aims to help decision-makers at the landscape planning and forest management level to situate and adapt their potential management actions, aiming to reduce the spread of possible fires in the different regions. Finally, it aims to help the discussion of the potential policy measures that agencies can adopt to reduce fuel load in the landscape, and at the same time, reduce large wildfires vulnerability.

By this guide the aim is to reduce landscape vulnerability to large wildfires by:

- Reduce intensity and impact of LWF
- Increase security, efficiency and effectiveness of suppression bodies
- Reduce risk on goods, people and economy
- Increase cost-effectiveness ratio in investments for fire risk reduction.

We propose that forest management is translated into landscape ordination, through the knowledge of the spread and behavior of fires. Usually this potential fire spread has been assessed by fire analyst in the firefighters' brigades. Firefighters are able to stop small wildfires, and control damage to people. In front of a large wildfire, landscape and forest planners are the ones that could reduce the negative impact of the fire, by technical decisions conducted to facilitate firefighter's operations and reduce fire potentials. Hence, bringing up together the different agencies of the public administration is a challenging goal presented in the guide.

During the guide, a European context is considered for the proposed methodology. However, some examples of specific regions of different parts of Europe will be used as case studies for illustrate the management actions proposed or the limitations on the implementation. More specifically, Catalonia will be the most redundant region used as case study, since it is one of the most advance regions in terms of fire prevention, management and extinction at the European level.

2. BACKGROUND, STATE OF THE ART IN EUROPE AND METHODOLOGY FOR THE PRESENT PROPOSAL

Land planning and fire regulation: historical perspective

In contrast with flood risk, wildfire risk has not been yet translated into land planning. Commonly in Europe, wildfire risk planning has been seen as urban planning and territorial planning identifying certain risk zones where edification is forbidden. In any case, this planning is mostly centered in wildfire-urban-interfaces. Urbanism usually doesn't contemplate wildfire risks. Many other risk have been incorporated, as earthquakes or floods, but wildfires have historically not been considered, both for its low risk perception in many regions, and for the difficulty associated to its more stochastic behavior.

Nowadays, most part of investments dedicated to prevention are bound to build extinction support infrastructures.

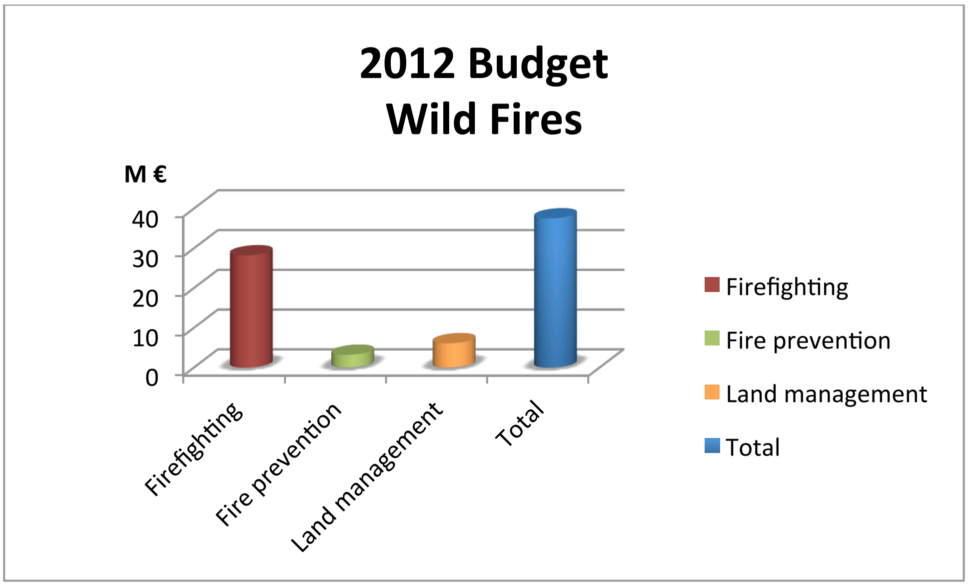


FIGURE 1: BUDGET FOR PREVENTION AND FIREFIGTHING WILDFIRES IN CATALONIA IN 2012 (FORESTRY AND INTERIOR DEPARTMENT).

Public investment in forest management, prevention and fire-fighting, are closely linked. Today the trend is to focus investment in wildfire prevention and extinction. This is a policy that tends to perpetuate the large wildfires in high fire recurrence areas. However forest management investment (and therefore reduction of fuel) is the one capable to reduce large wildfires incidence disadvantages wildfires.

Stakeholders involved

Wildfires and the problematic with Wildland-Urban interface (Wui) is a problem of territorial scale tackled from sectorial logics. Without a transverse scale perspective, approach the solution ins very difficult. Land planning strategy have to overcome a double paradox: the inadequacy of the institutional structure and the territorial dynamics.

In Europe we find examples of organizations (Wildfire Groups in UK and Coordination Group for wildfire prevention in Girona) that are leaders in integrating all stakeholders in land management (public and private) and to develop action plans prevention of wildfires. These can be an example of implementation.

The three departments involved in land planning related emergencies are: Civil Protection Department, Environmental Department and Land-use Department:

Fire types as a landscape management tool and Strategic Management Points: context

For the last decades, an increment on the incidence an impact of wildfires in Europe has created an inherent need to better understand fires and the processes behind them, to help predict both the occurrence and the spread of new fires. Furthermore, from an operational point of view, an anticipation need of the decision-making during fires has contributed to create a fire classification into different fire spread patterns and fire types. It has been through this classification that suppression brigades have become capable to make decisions during the same fire event, based on previously studied fires, and thus winning extinction-time and enhancing fire suppression strategies.

The characterization and classification of wildfires has bring 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. Hence, by the increment of knowledge on the potential spread of fires, the uncertainty can becomes risk, which enables the transfer of emergency management into landscape and forest planning.

As a result of the analysis of hundreds of fires, firefighters are currently able to know which spatial points are the ones where fires run away and exceed extinction capacity rates. Therefore, the challenge is to transform this knowledge into landscape management actions aiming at produce new opportunities, and finally reduce landscape vulnerability to large wildfires.

Fire types as planning tools:

The publication of fires types (M.Castellnou, 2011), which has served to be able to plan extinction strategies by firefighters and improve its efficiency. It has also become a great tool for planning of infrastructure to prevent wildfires.

It allowed us to define the capabilities of their own extinction extinguishing systems. It was from this moment that forest fire prevention has focused on large fires.

it has passed of:

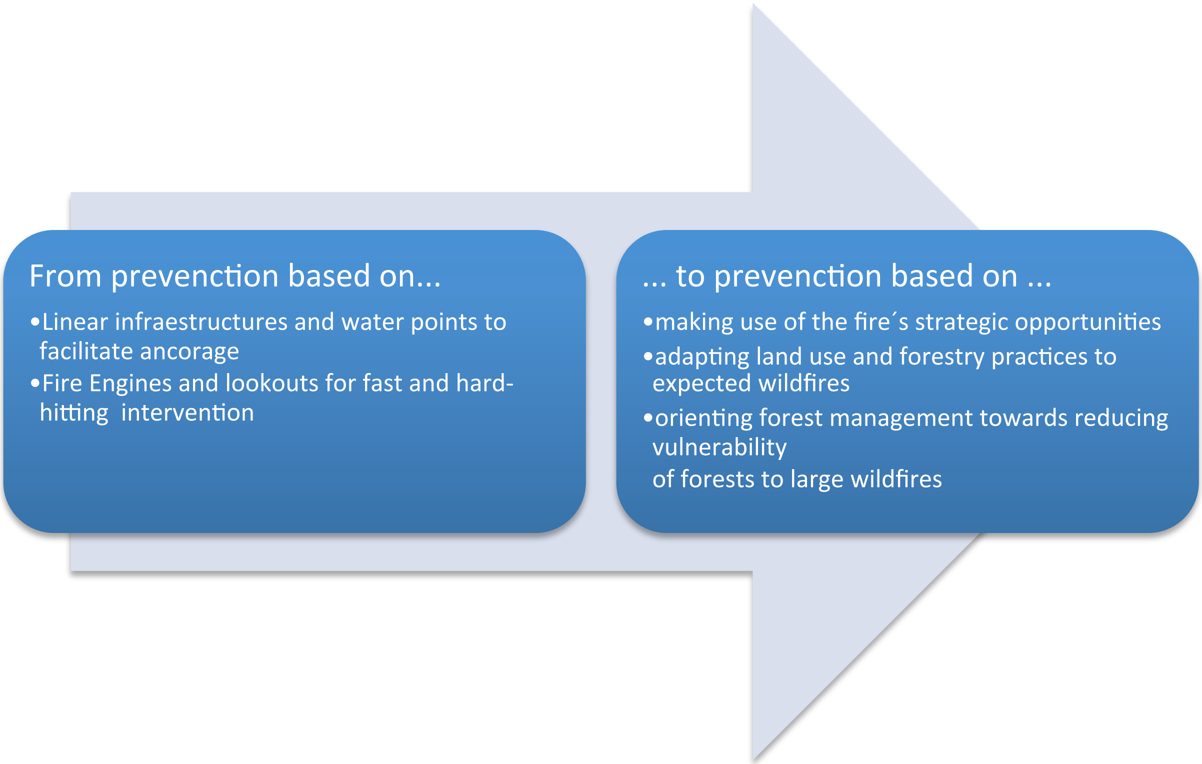


FIGURE 2: SOURCE: (P.COSTA, 2011) EVOLUTION OF THE WILDFIRE PRENVENTION

The wildfire definition in fire types allow to design type and size each infrastructure specifically for that wildfire will have to be used. So be very adjust in its design and sizing.

Each of these fires can be described common characteristics. And it is from these specific characteristics that can begin to define exactly how the infrastructure could be by to cope.

Strategic Management Points:

Strategic Management points have shown to be one of the optimal tools for this kind of cost-effectiveness problems joining prevention, extinction and management. Furthermore, Strategic Management points are feasible in all regions in Europe, although its development has been mostly in accomplished Mediterranean Spanish areas.

Europe situation

In Europe, wildfires impact more than half a million hectares of forest every year (Khabarov *et al.* 2014). Nonetheless, Europe has shown to have different fire regimes characterizing the regions (Joint Research Centre 2014). The spatial wildfire situation in Europe diverges in the different regions and countries, and should be tackled distinctly at the regional and national levels, taking into account wildfire incidence and fire processes, as well as past, present and future socio-economic conditions.

The approach given to wildfire issue around the different countries in Europe has taken different formulations. Depending on the risk severity of wildfires in the national contexts and the different political and administrative systems existing in each country, wildfires receive distinct consideration within the national policy instruments. For instance, in northern countries, wildfires are a subject of growing concern while in Mediterranean countries the concern has already been treated as a major natural risk. Policy measures in each country are influenced by the perceived level of threat, which varies with the intensity and scale of fire-related problems. The Mediterranean Basin countries have more and more significant policies contemplating different levels of wildfires as a threat, as well as an extended implementation of regulations about fire prevention. In the rest of Europe (especially in Northern countries) forest production goals are more important than forest fire prevention in forestry management, thus in national prevention policies.

Furthermore, and as a general rule around the continent, fire policies affronting wildfires have been usually characterized by the adoption of new political measures based on fast post-reaction to a past catastrophic situation, rather than proactive mitigation before an emergency arises.

Fire issue in Europe: different structures, analogous functions

Structural department in Europe is specific from each region. Nonetheless, competences are identical in all regions even they are located in different departments. Aiming at contributing to a specific regional view, the following conceptual schemes should be transposed to each region institutional structure.

Usually, at a European level, there are two large institutional organization systems when considering wildfire prevention and extinction:

- **Civil Protection Department**: It usually has the competences for wildfire extinction, while wildfire prevention usually falls in forest department. This kind of institutional structures highly integrate all wildfire respond services for fires affecting WUI, and they use to work with a integral emergency perspective. But in contrast, they use to present difficulties to influence in wildfire prevention policies, since these prevention measures use to be dissolved among several forest management programs. Then, suppression efficiency pressures are not translated to forest planning, the ones designing prevention infrastructures.

FIGURE 3

- **Forest Department**: it can have both the competences on wildfire extinction and prevention, and they are structurally different to Civil Protection and the rest of emergency agencies (Firefighters, Health personal, etc.). This kind of institutional structures highly integrate prevention infrastructures with it use from extinction system bodies, and it use to have integrative policies including wildfires in forest planning structures. However, having two wildfire extinction systems (Structural and Forestry), generates biases when working on an emergency in a WUI including both target defensing items (houses and forests).

Figure 4

In fact, institutional structures architecture tend to approach between them aiming at providing a better response to a complex problem, which requires a transversal contribution between the different departments.

Climate change in Europe: past, present and future

A wide set of global changes are affecting currently the European environment at landscape levels. Specifically, socio-economic changes and climate change are driving fire regimes changes at the European level (Amatulli *et al.* 2013; Raftoyannis *et al.* 2014). Data over recent decades points to sharp changes in fire recurrence, intensity and severity (Díaz-Delgado *et al.* 2004; González-Olabarria *et al.* 2007) associated with widespread land abandonment and fuel accumulation (Moreira *et al.* 2001; Pausas and Fernández-Muñoz 2011), global warming (Terradas *et al.* 1998; Pausas 2004) and fire suppression activity (Brotons *et al.* 2013; Moreno *et al.* 2014). Land-use changes have also shown a high incidence on fire dynamics: land-

Figure 5

Figure 6

use changes have aggravated fire hazards in terms of fire intensity reached (land abandonment processes leading to higher build up fuel accumulation rates (Ursino and Romano 2014) and people exposition (Wildland-urban-interfaces increment during last decades (Lampin-Maillet *et al.* 2011; Syphard *et al.* 2013)).

Climate change reported during last decades has shown to have effects on the occurrence, spread and size of fires in several regions of the world (Moritz *et al.* 2012). These effects have been documented to range from minor changes on fire distribution (Terrier *et al.* 2014) to potential changes on fire sizes and frequencies (Terradas *et al.* 1998; Pausas 2004; Batllori *et al.* 2013).

Historically, fire has been present all around Europe (Costa *et al.* 2011). However, wildfire's devastating associated events are more related to Southern European Countries, the ones with Mediterranean climate, since the intensity achieved and urban configuration have threaten more people than in Northern countries. Therefore, suppression and prevention policies have received more investments in Southern European countries.

During last years, an increasing concern has been arising in Northern European countries. An increment of the number, intensity and size of fires in many regions (Sweden 2014, etc.), has shown a progressive colonization of devastating LWF phenomena in countries not used to these events. Wildfires are showing changes in their behavior (crown fires, high intensity fires, large wildfires, etc.), which has provoked an ad hoc reaction from European institutions. Even further, in front a climate change situation, wildfires imply a major concern in the European countries.

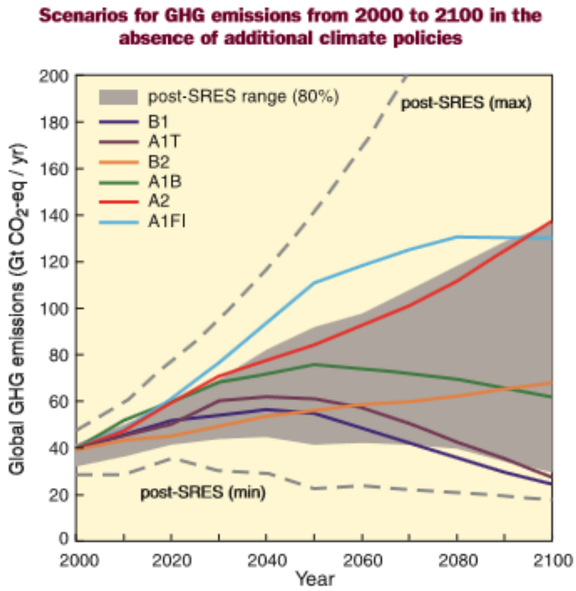


Figure 3.1. *Global GHG emissions (in $GtCO_2$-eq per year) in the absence of additional climate policies: six illustrative SRES marker scenarios (coloured lines) and 80th percentile range of recent scenarios published since SRES (post-SRES) (gray shaded area). Dashed lines show the full range of post-SRES scenarios. The emissions include CO_2, CH_4, N_2O and F-gases. {WGIII 1.3, 3.2, Figure SPM.4}*

FIGURE 7

Fire weather conditions are predict 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. Here we present some of the main ideas that are projected to happen in Europe, separating broadly among Mediterranean and non-Mediterranean regions:

- *Mediterranean EU-regions*

  Mediterranean ecosystems occupy a sensitive portion of global fire occurrence, and show a high fire-climate relationship, in particular for precipitation-related variables (Batllori *et al.* 2013). Precisely, precipitation trends predictions to the future are more uncertain compared to temperature changes. Despite there is no clear, an increase in rainfall variability is expected

(Servei Meteorològic de Catalunya 2012), which may prolong and intensify summer drought, and also enhance the occurrence of intense rainfall events (de Luis *et al.* 2010; Servei Meteorològic de Catalunya 2012), which would lead to more often and severe droughts. These could point to a desertification of current Mediterranean ecosystems, which could directly lead to profound changes in vegetation patterns. Thus, two main vegetation changes are predicted to happen under a climate change situation: one the one hand, changes in species composition, rolling over a more drought adapted vegetation. And on the other hand, less build up capacity from forests and shrublands due to low humidity rates. This could lead to less biomass available to burn in these ecosystems.

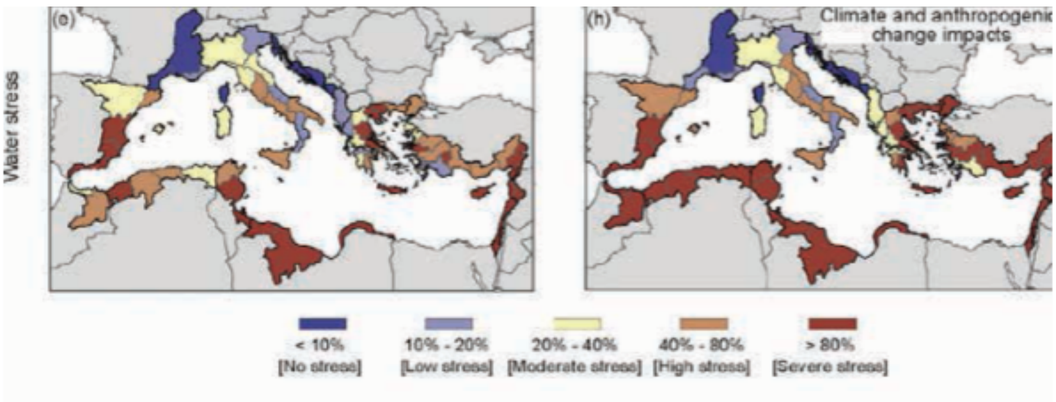


FIGURE 8

Fire weather danger is expected to increase in Mediterranean Europe (Mouillot *et al.* 2002; Moriondo *et al.* 2006). A substantial decrease in summer precipitation (up to 70 %) is projected for 2070–2099 in some areas of southern Europe, increasing the frequency and severity of forest fires (Alcamo *et al.* 2007). More often droughts, worst and more frequent extreme conditions, as well as a temperature increase and a moisture decrease are all factors that are related to an increase of fire events and catastrophic fire events.

The trade-offs between these two phenomena (vegetation desertification and more prone fire weather conditions) is not well known how they would evolve. To this, many social and human factors have to be taken into account. An increase of fire suppression efforts could lead to a homogenization of vegetation masses at landscape level (Minnich and Chou 1997; Brotons *et al.* 2013). Agricultural abandonment is also increasing fuel biomass in these areas (Moreira *et al.* 2001). And finally urban planning is changing both how vegetation is located in the space and how humans are in front fire risk (Syphard *et al.* 2014).

High intensity fire are predicted to be less common if vegetation gets more arid, with less fuel load on the landscapes. Even though, the transition between current forests to deserted vegetation landscapes is going to be long. The time of bypass could represent a deterioration of high intensity fires, since weather conditions will be more prone to fires and vegetation will still being the one characterized in a more humid climate. Even more fire and landscape management should be implemented in a worsen wildfire scenario.

- *Other non-Mediterranean regions in Europe*

  At a European level, several changes are affecting current forest situation (Fares *et al.* 2015). Most of them are related to social and economic pressures with an uncertain future for fire regime evolution, and even further when mixed with the climate change threat. Forest evolution at a European level has two sides: new forests are gaining ground and pushing up overall forest area, but existing stands are becoming less productive with age and damage. To this, an increase of fire weather situation in northern latitudes has to be summed to the situation, leading to novel fire situations faced by northern European countries.

  In northern parts of Europe, the fire risk is likely to increase (Khabarov *et al.* 2014). Global simulations of future fire regimes point to an increase of the probability of fires in the future in Central and Northern Europe, which mixed with social and economic changes affecting forest and landscape dynamics, could worse wildfire population exposure in front more devastating fire scenario.

3. PROPOSED METHODOLOGY

First: Fire regime diagnosis

We start from the premise, that with the same topography and meteorology (Castellnou, 2000; Expòsito i Cordero, 2004), fire spreads following scheme similar propagation. And change the intensity depending on availability of fuel, which depends mainly on accumulated hydric stress and the amount and structure fuel.

To know the fire types and the fire regime affecting a particular area is key to effectively plan actions to prevent wildfires and forest management. For get this information, we need to analyze the historical track of wildfires in the region.

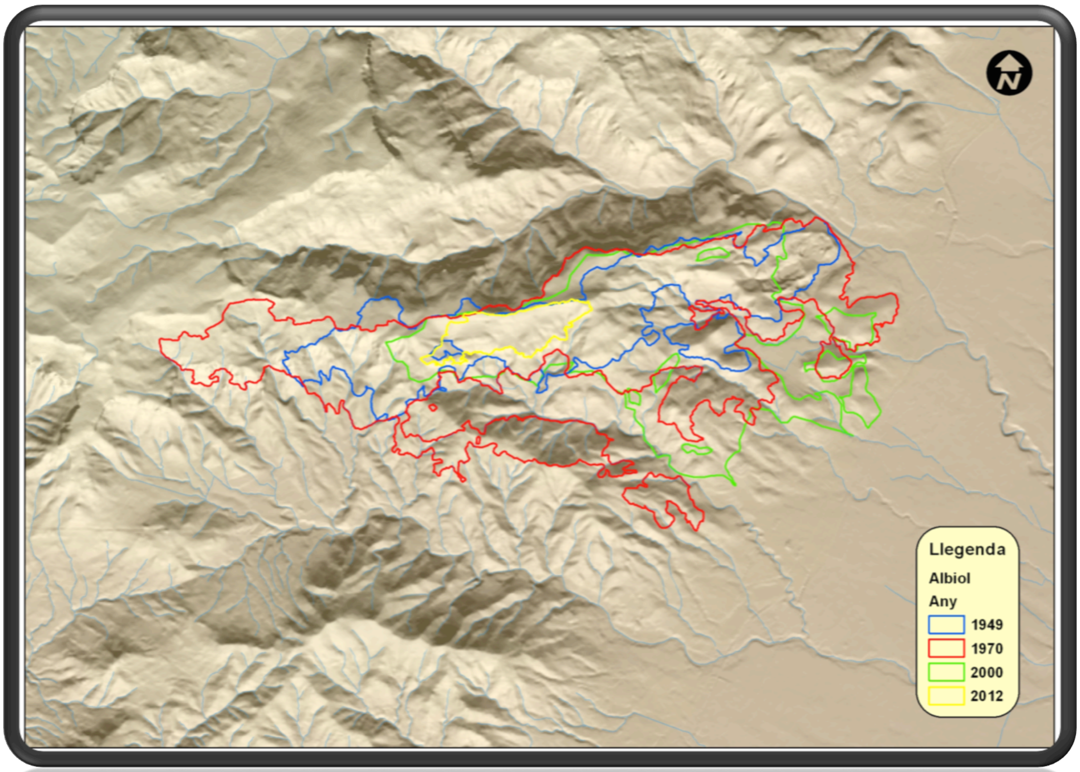


Figure 9: Historical sequence of the same fire spread pattern and the same meteorological synoptic situation in different years to Albiol (Catalonia)

In (Figure 13) we can observe three similar wildfires that have burned in different years in the same area in the same synoptic meteorological situations. The results of three perimeters are very similar and indicate that they are governed by the same pattern. The keys to this pattern are found in the interaction between topography and meteorology similar.

Fire typology identification in the regions:

In general, identifying fire types is done by analyzing the patterns of spread and synoptic situations by observing the relevant and repeated aspects that allow the classification of forest fires. (Pique, M. 2011)

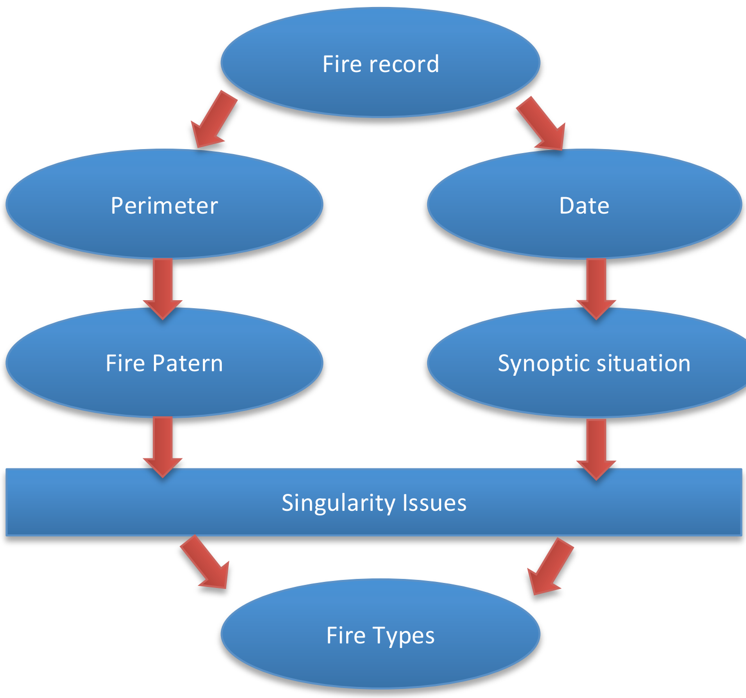


FIGURE 10: CATEGORIZATION PROCESS OF HISTORICAL WILDFIRES (PIQUE, 2011).

Fire spread patterns and Synoptic meteorological situation

Related with physical phenomena that occur in a forest fire, the fire spread is marked by the interaction between the fuel, weather and topography. You can see in the fire spread triangle.

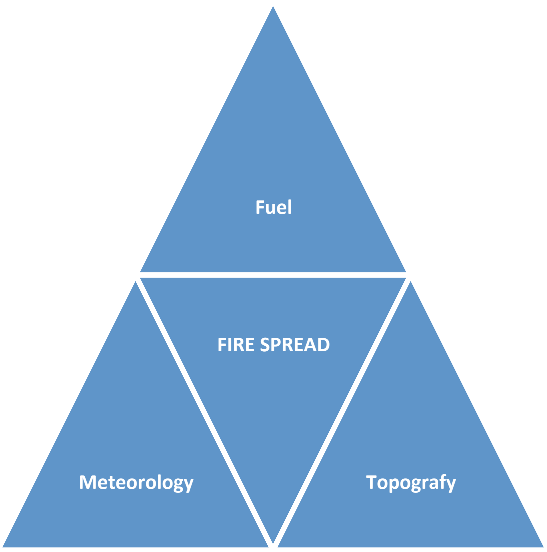


FIGURE 11: FIRE SPREAD TRIANGLE

Depends on the driving force that dominates this system, forest fires are classified into four groups (Rothermel, 1972):

- Topographic fire
- Wind driven fire
- Plume dominated fire
- Storm driven fire

And the weather will be responsible for establishing which is the pattern spread more relevant in every fire depending on the meteorological aspects most prominent and what influence they have had on the fuel:

- Heat
- Wind
- Drought
- Storm

FIGURE 12 FIRE SPREAD PATTERNS

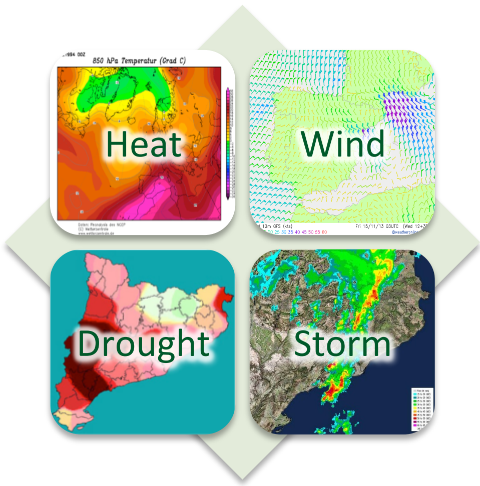


FIGURE 13: SINOPTIC METEOLOGICAL SITUATION

Fire types

To specify the Fire Types, we specify local aspects repeated. These aspects are associated with the interaction between the meteorological synoptic situation and relief. These aspects include:

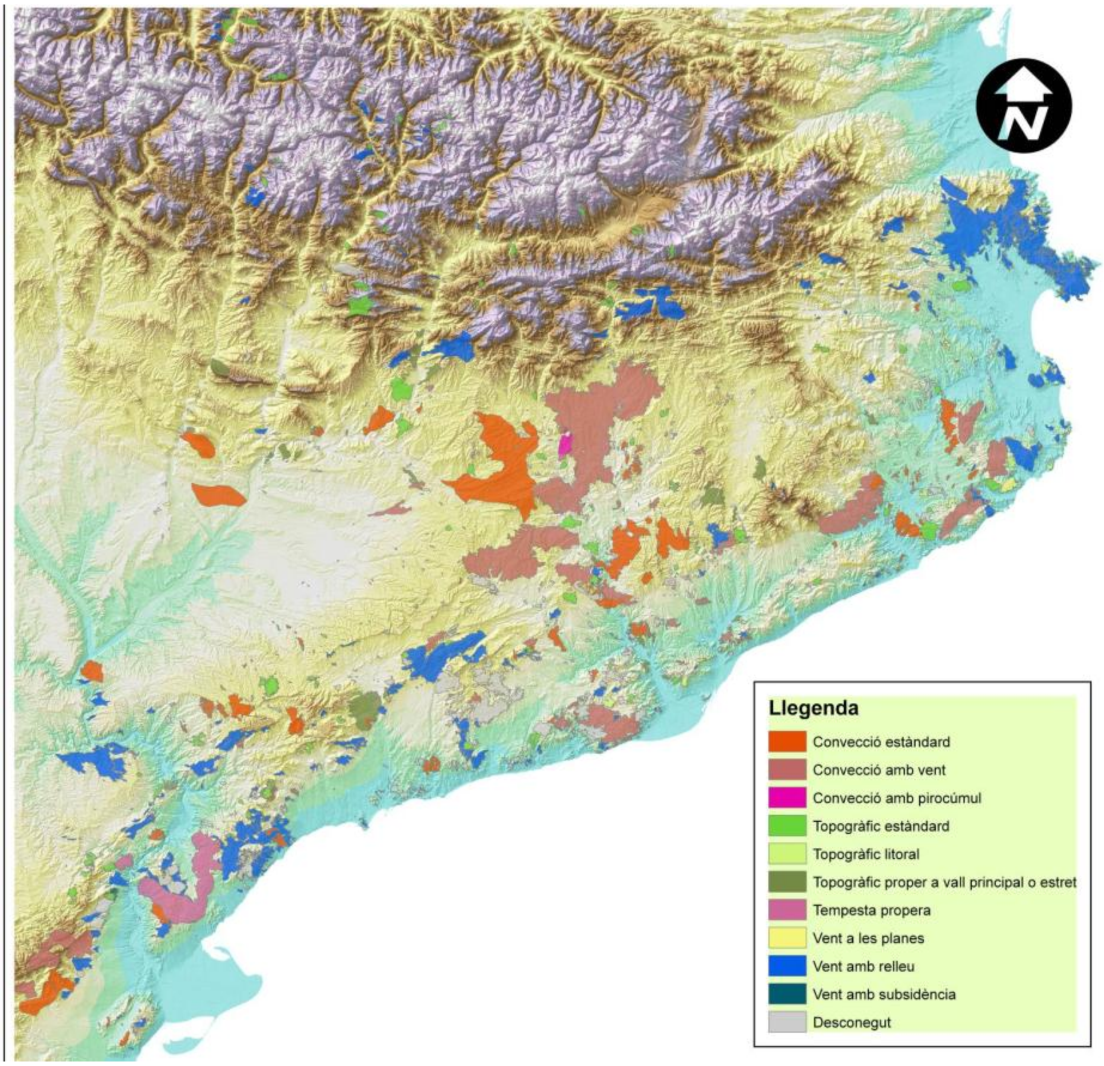
- Sea breeze: Regime rotating winds associated with the interaction land-sea
- Venturi Effect: Channeling and speeding winds in some narrow gorges
- Turbulence: Counterwinds generated by the interaction between strong winds and abrupt relief
- Subsidence: in subcidence zones with descending winds. With general winds along the surface at night and rising up during daytime.

- Pyrocumulus: With the collapse of a pyrocumulus cloud
- (...)

In Catalonia have identified 10 different fire types according to this classification. Although these type fires can occur anywhere in the world (Costa, P. 2011)

TABLE 1 FIRE TYPES IN CATALONIA.

Topographic	Standard topographic fires
	Coastal topographic fires
	Topographic fires in main valleys and canyons
Wind driven	Wind-driven fires in flat land
	Wind-driven fires in mountainous terrain
	Wind-drinven with subsidence
Plume dominated	Standard convection dominated fires
	Convection dominated fires with wind
	Convection dominated fires producing pyrocumulus clouds
Storm driven	Storm-driven fires



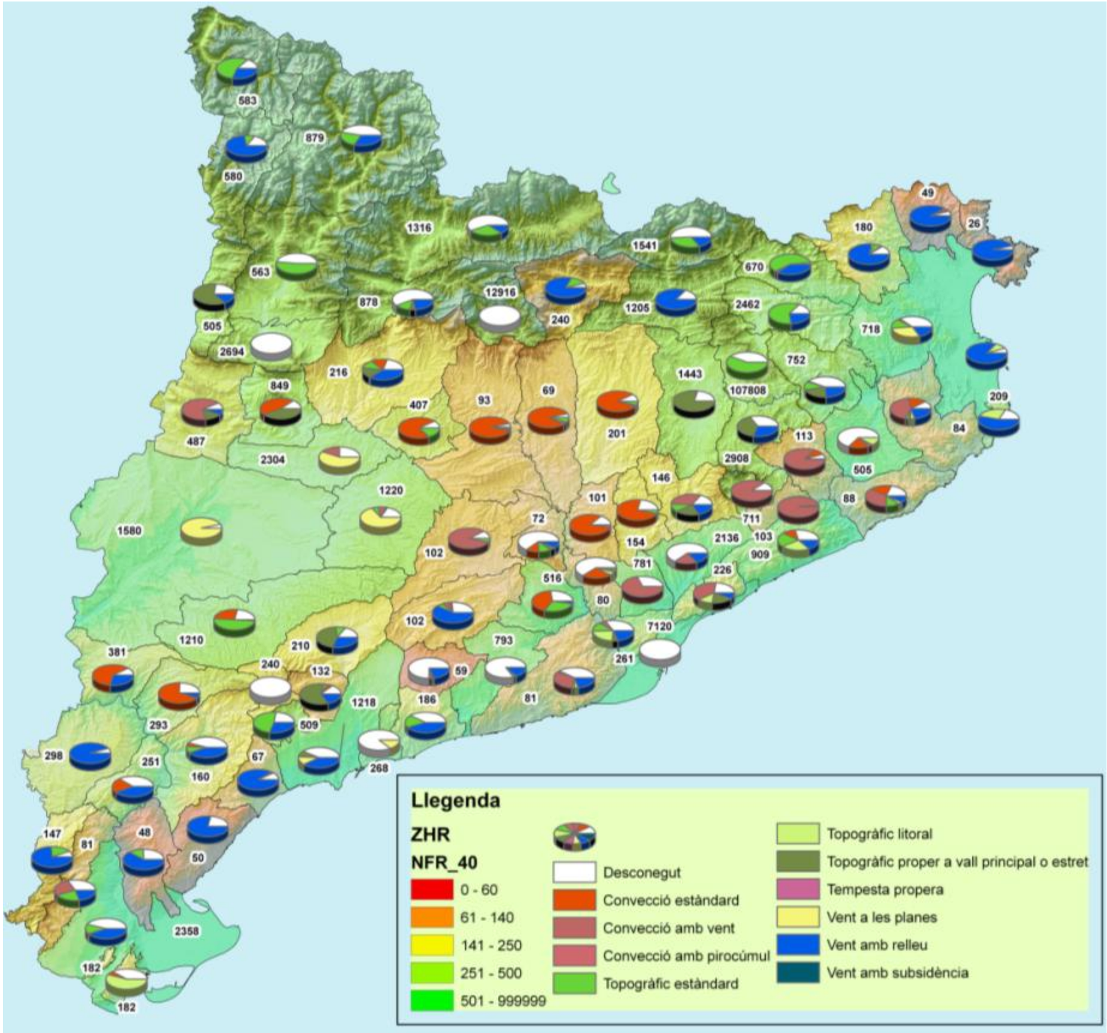
MAP 1: MAP OF WILDFIRES CLASSIFIED UNDER FIRE TYPES IN CATALONIA CONTRY

This classification (fire types) has gone in depth knowledge how wildfires moving above the land and how they interact with the weather. From this we can deduce how wildfires exceed our ability to extinction and where we could find extinction opportunities.

This is the basis for planning the landscape to reduce vulnerability to each fire types of large fires.

To make the leap in landscape planning we need to know where the different fire types of wildfires and what their freqüènica.

Homogeneous zones



MAP 2: MAP OF HOMOGENEOUS ZONES REGIME AND DISTRIBUTION OF WILDFIRE TYPES IN CATALONIA COUNTRY

With this map we have a distribution of high fire danger and wildfire risk and we can to plan infrastructures for each fire types.

Critical points identification

Once studied the different fire types we observed that there are certain points where the ground that generate accelerations and decelerations in the fire spread and intensity of fires. As the fire grows these points act as gateways to new potentials. These points will say "Critical Points".

This knowledge appears to collecting operational experiences of fire department. We are looking to points where behavior is lower (for speed and/or intensity) and therefore is within the ranges to ability to extinction. The work is very effective when we acted in a small area that is the gateway to a great potential.

FIGURE 14: ANDRATX 2014 FIRE; PLA DE S'AVANGÈLICA (SOURCE: GOVERN DE LES ILLES BALEARS)

Into the sequence of images you can see as the Andratx fire can have access to one of the critical points (Pla de S'Avangèlica), and it does slowly and at low intensity. Once you reach in these point, the fire grows quickly and burns all potential to high intensity related to the critical point.

The critical point is located in the abrupt relief; Therefore, we can locate all critical points making an geomorphology analysis of the relief, seeking:

- Ravine junction
- Crest line Junction
- Mountanin pass

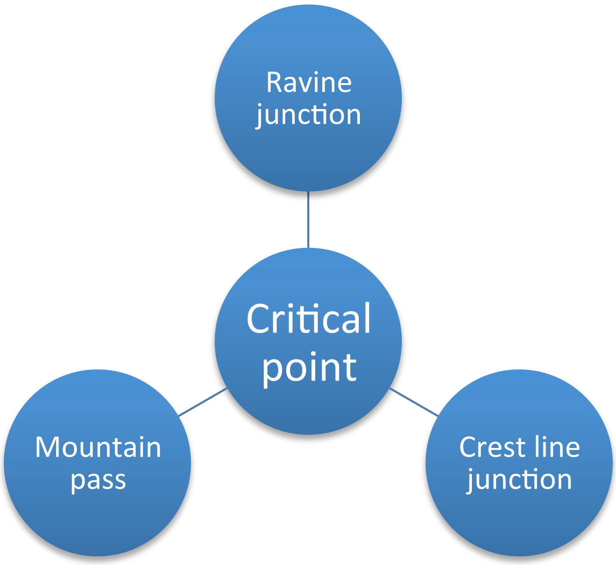
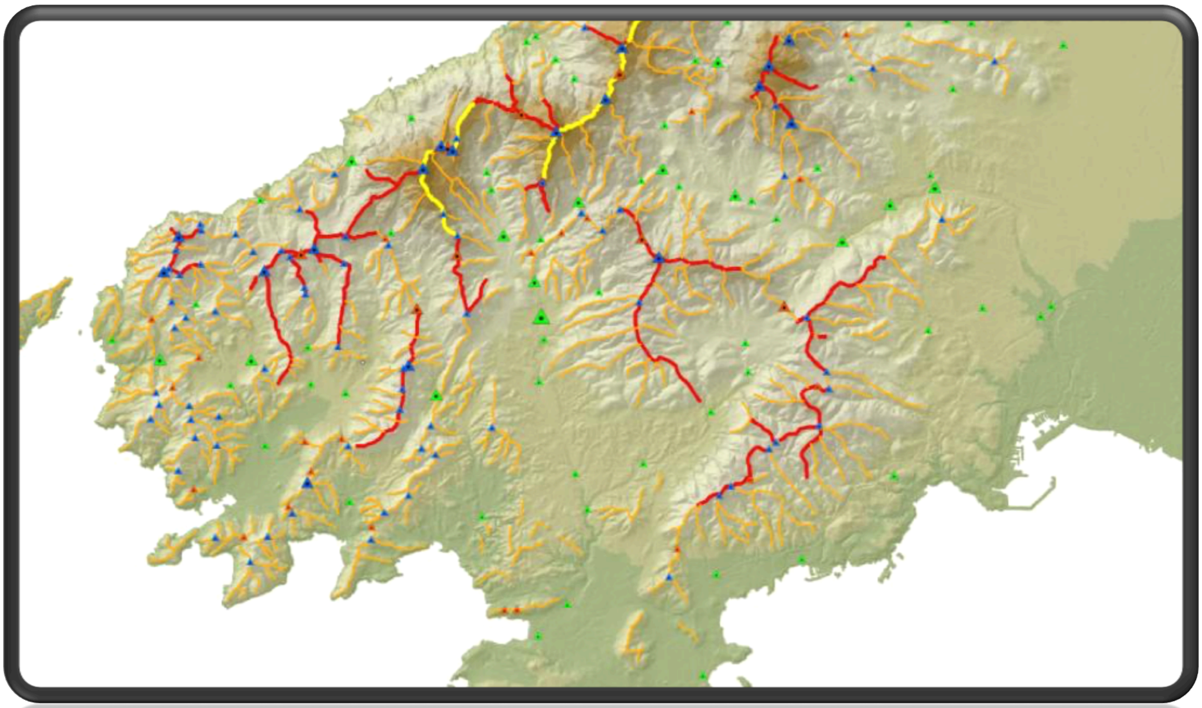


FIGURE 15: CRITICAL POINTS TYPES

FIGURE 16: CRITICAL POINTS TYPES



MAP 3: CRITICAL POINTS (SOURCE: GOVERN DE LES ILLES BALEARS)

The critical points can be associated with a specific surface according to each of the potential fire types. So act as gateways using the fire to increase new potenctials. The prevention and extinguishing system should work to prevent the easy acces of wildfire to the gateways.

Second: Prevention

Strategic Management Points

We know where is the gateway to fire types run so quickly and that exceed extinction capacity rates. We want to transform this knowledge into opportunities and reduce landscape vulnerability .

The main idea is to confirm that the Strategic Management Points technique is useful for this purpose. I want to show that the SMP are viable outside Spain through your example.

Sistema d'extinció d'incendis forestals

When raise any wildfire prevention action work should know very well which extinction operation it is that you have to do of this infrastructure.

You must know the needs and impediments for that their work is successful.

Each fire department and every maneuver they have specific requirements in terms of reliability and safety. Compliance with these requirements should be given to the infrastructure because it can be used successfully.

Third: Long-term planning:

Fire policies at long term under different scenarios

Forecasting fire regimes changes, related to area burnt, fire event allocation, fire spread, and fire frequency, is one of the challenges facing current decisions when considering climate change at the European level, in order to help policy making in fire management, prevention and extinction. European policies dealing with fire issues have usually been proposed after catastrophic events, proposing solutions after new fire catastrophic events, not before, and usually being ineffective under new situations. Moreover, the evolution of future fire regimes, under a climate change situation, can entail cause 'novel' or 'no analogue' environmental conditions, which presents new challenges for management, policy and planning. The use of model projections under different scenarios is a key step for understanding system's evolution and reduce uncertainty.

Scenarios for decision making

A valuable and frequently applied technique to help to decide under the complex uncertainties associated with future changes and their impacts is scenario analysis. 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). 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.

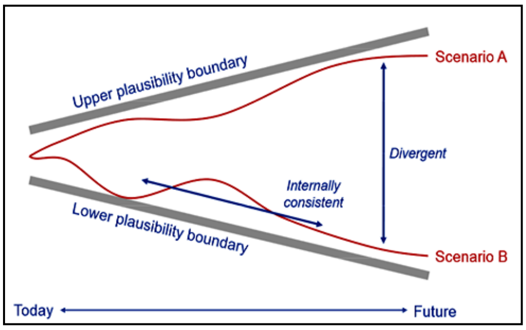


FIGURE 17

Forest and landscape evolution, and consequently fire regime evolution, can also benefit from the use of scenarios to help policy makers to build decisions based on plausible futures and reducing a part of the uncertainty associated. Even more, the use of scenarios may be used under a modelling framework to better understand consequences of current decisions made at large temporal and spatial scales.

Thus, it is important to consider different scenarios of change for landscape management and planning. Thus, the elaboration of conceptual frameworks to generate global change scenarios for the different regions is crucial for a long term assessment. 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.

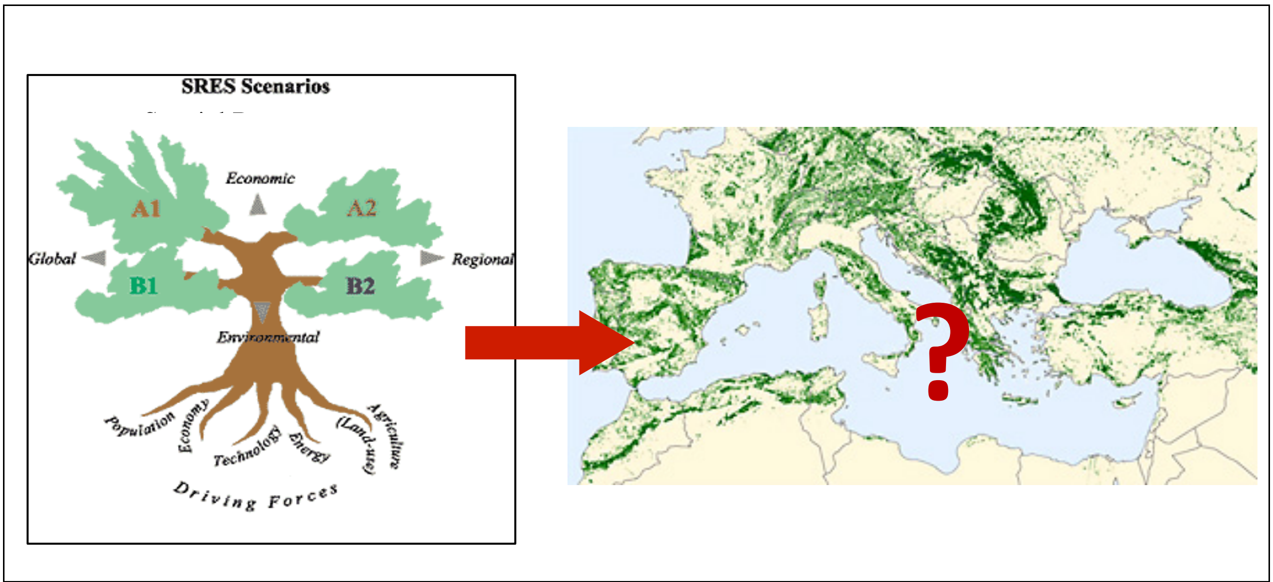


FIGURE 18

Once under a conceptual framework of how systems will evolve, it is then recommended to adopt and define adaptive management strategies according to the goals set for each of the different EU regions. Not a unique recommendation is done, but the important is to set the goals, understand the system, deal with possible futures to reduce uncertainties and decide under quantitative criteria.

Modelling framework for decision making:

Forest management has benefited from recent research effort on methodologies and decision tools, towards a more science-based approach. The use of models in the assessment of fire regime changes can be used as a basic tool to quantify potential changes and to evaluate the complex interaction between factors affecting the different components of fire regimes (Miller and Ager 2013). With many ecological processes that still unknown (ie. fire spread stills in the frontier of research; (Keeley *et al.* 2012)), and many unknown evolution socio-ecological factors affecting large scale phenomena (land abandonment, outsourcing economic sectors, etc.), the complexity of fire regimes entails a very difficult assessment of the consequences of current policies on the evolution of landscape systems. Complex systems as the ones characterizing the fire process usually require from mathematic models to better understand potential ecosystem evolutions under different pressures of change. Thereby, uncertain evolutions can become more accurate, helping the process of decision making.

Furthermore, quantifying the implications of a set of different suppression policies is crucial in the long-term assessment of current decisions with usually uncertain consequences. For instance, a greater investment on fire suppression for the last decades has not been shown to stop the intensity and devastating effects of fires nowadays (Tedim *et al.* 2013). Some experiments have shown important and significant effects of different fire suppression strategies on area burnt in Catalonia at a landscape scale and for long-term periods. The work done by Regos et al. 2014 actually showed how letting fires burn in mild weather conditions could increase suppression opportunities for suppression in large fires during adverse weather conditions. This is just one optional strategy that can be adopted at large scales and that can be implemented by policy measures at a European level when quantifying appropriately its effects at a long term period.

Climate Change and fire suppression: scenarios and projections in EU landscapes examples

For the present guide, some examples of climate projections have been built aiming at presenting a range of possibilities to assess future scenarios of change in European landscapes. We display the projection and reproduce some of the most important changes on fire regimes in different parts of Europe according to climate change scenarios and different fire suppression scenarios. We have applied the MedFire model (Brotons *et al.* 2013) to the Iberian Peninsula, and we have compared two regions with different fire regimes in terms of total annual area burnt and fire sizes distribution. The two studied regions are Andalusia (South Spain), and Galicia (North-west Spain). The greater difference between the fire regimes in the two regions is the amount of total area burnt that is burnt in large fires. While in Andalusia total area burnt is smaller, the percentage of area burnt in large fires is bigger than in Galicia.

We defined landscape scenarios according to climate variations and firefighting treatments to assess fire regime evolution of the two regions. We proposed two simple climate treatments: (C0) the percentage of severe years in the 50-year period is equal to the percentage of the observed period (from 1968 to 1999), and (C1) this percentage is double. We established two firefighting treatments: the first one did not involve any fire suppression strategy, whereas the second involved active fire suppression extinguishing any fire that burn agriculture covers, or fires burning sclerophyllous forest in not ascending conditions, or wind-back fires in pine and shrub forests (70% of efficiency). These scenarios start in 2000 year with the same initial conditions, and project the fire regime and the effects on landscape composition over a 50-year period. We ran 50 replicas of each scenario.

TABLE 2: THE FOUR SCENARIOS CONSIDERED.

Scenarios	**Climate Scenarios**	
	Same climate	**Double Severe Climate**

			Years
Fire suppression strategies		**C0**	**C1**
No firefighting	**0**	0-C0	0-C1
Active fire suppression at 70%	**70**	70-C0	70-C1

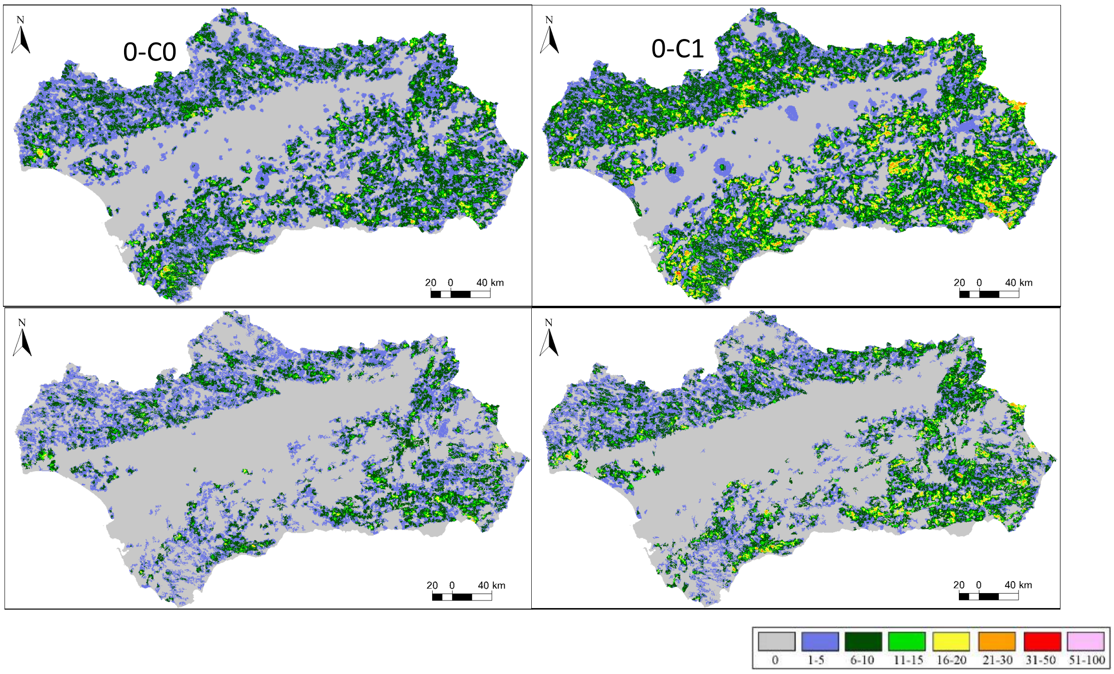


FIGURE 19: FREQUENCY OF BURNING IN LARGE FIRES (EXTENSION GREATER THAN 500 HA) AT LEAST ONE TIME OVER A 50-YEAR PERIOD UNDER THE (0-C0), (70-C0), (0-C1), AND (70-C1) SCENARIOS IN ANDALUSIA.

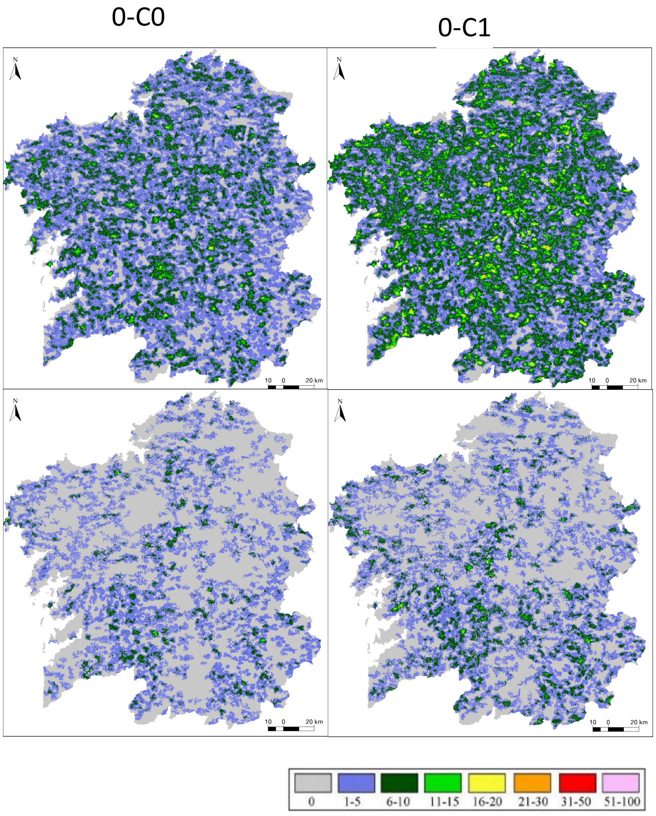


FIGURE 20: : *FREQUENCY OF BURNING IN LARGE FIRES (EXTENSION GREATER THAN 500 HA) AT LEAST ONE TIME OVER A 50-YEAR PERIOD UNDER THE (0-C0), (70-C1), (0-C1), AND (70-C1) SCENARIOS IN GALICIA.*

The greater difference between the two fire regimes described is the amount of total area burnt that is burnt in large fires. While in Andalusia total area burnt annually is smaller, the percentage of area burnt in large fires is much bigger than in Galicia. In contrast, Galicia has a very low number of large fires. Galicia has a particular fire regime governed largely by social constrains related to a traditional use of fire (Catry *et al.* 2010). A very traditional rural population stills using fire as a management tool, which combined with a more flammable landscape because changes in species composition product of forests plantations are the main causes of a high fire incidence. However, the landscape spatial pattern present in the region, characterized by very small patches of the different land covers, may influence in the low capacity of fires to spread and become large fires. Consequently, and similarly to other regions as northern Portugal, fires are not very large. In contrast, in Andalusia, fire events are less common, but as a consequence of traditional forest management abandonment and land abandonment, fuel build up accumulation has induced a fire prone landscape. Fire spread is more devastating than decades before, and wildfires are usually very large.

These differences have different implications for the run scenarios. In Galicia the landscape structure does not allow fires to get big, even increasing fire suppression efficiency. Fire suppression policy decisions can lie on this kind of evidences: an increment on fire suppression efforts in Galicia will not be translated in a decrement of large fires. Thus, efforts should be focused on understanding the main problematic of each region, and on preforming the appropriate experiments aiming at decreasing negative fire impacts under climate change scenarios.

Thus, using the same data source, a different range of fire regimes (in terms of area burnt, severe years and fire size distribution) can have direct consequences on the evolution of the system under the same drivers of change. Consequently, when regarding landscape planning aiming at reduce predicted fire impacts at a landscape scale under a climate change scenario, an exhaustive work on understanding the processes governing fire regime in the different areas should be done before making decisions. Fire suppression changes aiming at minimize fire effects at a landscape effects cannot be the same in Galicia or in Andalusia. The same can be applied to other regions of Europe. Hence, the regionalization of the fire phenomena, bound to more local processes (both socio economic processes and climatic local changes), is a crucial step towards a better policy adaptation in a European context.

4. DISCUSSIONS

Weaknesses:

Weaknesses on the proposed methodology

A usual demand from different agencies working on landscape planning has been the creation of a wildfire risk cartography as a starting element from which work on more landscape developments. However this has not been always direct to achieve, being still nowadays not clear what really mean a wildfire risk (in terms of frequency, recurrence, intensity, etc.)

5. ANNEXES

Wildfire Case Study

The Mourne Mountains, Co. Down, Northern Ireland

Background

The Mourne Mountains are subject to wildfires and are one of the worst affected sites in Northern Ireland, for example, wildfire damaged between 8–10 square kilometres of upland heath in the Mournes in April/May 2011.

FIGURE 21: WILDFIRE ON SLIEVE LAMAGAN, MOURNE MOUNTAINS, MAY 2011.

The *Mournes* consist of a compact range of granite mountains forming the highest ground in Northern Ireland and are situated in the southeast of the Province in County Down (see Map 4).

Within the Mountain range, 12 peaks extend to over 600m, with Slieve Donard rising to 852m. It is characterised by thin peat soils and areas of blanket bog and is designated as a Special Area of Conservation (SAC) and Area of Special Scientific Interest (ASSI) due to its unique combination of upland habitats and associated vegetation communities including the largest extent of European dry heaths in Northern Ireland. The area provides a range of ecosystem services including agriculture, biodiversity, carbon sequestration, forestry, health and well-being, mineral extraction, recreation, tourism and water catchment.

MAP 4: LOCATION OF THE MOURNE MOUNTAIN RANGE INDICATED BY THE RED ARROW.

MAP 5: 1: VIEW OF THE EASTERN MOURNES MOUNTAINS SHOWING THE HEATHLAND AND RESERVOIRS

Previous efforts by a broad stakeholder group called the Safer Mournes Partnership to reduce the incident of wildfire following increased wildfire activity in the 2000s had stalled, and following the 2011 fires interested parties realised an insurmountable problem would develop if mitigation methods continued in the same way.

The situation was deadlocked with government departments acknowledging the issue but unable to identify a lead department to establish a strategic cross departmental plan and NI Wildfire Forum. A solution needed to be found that was innovative and presented a workable, cost effective option to break the deadlock.

This happened when Mourne Heritage Trust facilitated an initiative where Northern Ireland Environment Agency, Northern Ireland Fire and Rescue Services (NIFRS) and Northern Ireland Water jointly commissioned Wildfire Advisory Services (WAS) to produce the Eastern Mournes Wildfire Report (2012).

The Eastern Mournes Wildfire Report 2012 – Main Findings

Wildfire Advisory Services was commissioned to deliver advice on how to reduce the impact of wildfire in the Eastern Mourne Mountains (EMM). The study area was approximately 7000 hectares and included a water catchment of 3000ha within the ring of high peaks in the Eastern Mournes owned by NI Water, and 4000ha on the outer slopes owned by NI Water, Private Mountain Trustees, private landowners, Forest Service and the National Trust (all within the SAC/ASSI).

The focus of the proposal submitted by Wildfire Advisory Services was aimed at limiting as far as possible the vulnerability of the landscape and water resources to disturbance caused by wildfire, either as a direct result of fire or by the damage caused to the soil layer within the water catchment area.

The threat of wildfire cannot be eradicated, therefore the realistic approach adopted within the project was to provide recommendations on how the number, likelihood and size of wildfire incidents could be

reduced. This included an appraisal of how effective intervention response was by both the Fire and Rescue Service and the rural land management sector.
The project recognised the importance of establishing a collaborative problem solving approach between land managers, the fire service, relevant agencies and other stakeholders, and to this end a cross section of local stakeholders and government bodies were interviewed in the development of its recommendations.
The Report analysed weather, terrain, fuel availability and fire history and identified two critical weather patterns that featured in the largest wildfire incidents in the Eastern Mournes:

- Type A; High pressure building from the European continent causing a strong drying environment with high easterly winds.
- Type B; High pressure causing a drying environment but with lower easterly winds.

Type A scenarios would create conditions that threatened the whole Eastern Mourne area, while Type B conditions would generally spread fires along the valleys, especially the main ones.
Computer simulations using *NEXUS* and *Wildfire Analyst* were run to ascertain fire behaviour over the Eastern Mournes (under Type A and B scenarios), which identified the links between the various parts of the terrain and disclosed the routes or fire paths that were available for a fire to move across the landscape.

The main vegetation types present across most of the EMM consisted of heathers and grasses, which provided substantial quantities of 'fine fuel`. The fuel was arranged with connectivity and continuity over the landscape, providing some fires with the potential to spread across what was a 'flammable landscape` for considerable distances causing significant damage (see Photos 1 and 2).

Therefore, the reduction in the size, scale and impact of wildfire primarily depended on how well the above vegetation was managed. In particular, it was important to put in place a plan that broke fuel continuity and reduced fuel loading. The report identified the critical locations (Strategic Management Points - SMP) where fuel/vegetation should be managed to have the maximum effect on limiting the potential of a fire to spread. This totalled approximately 143ha or 2% of the study area.

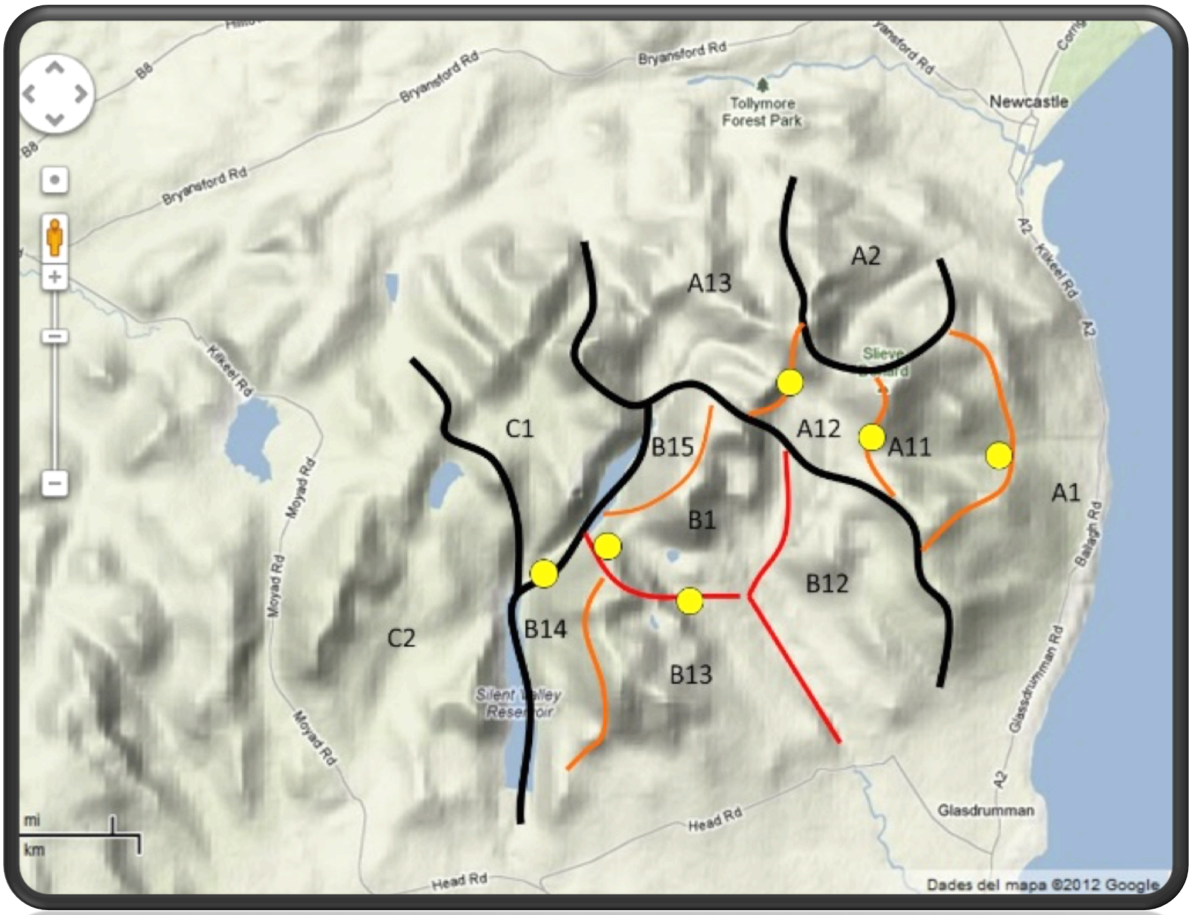


FIGURE 22: SHOWING THE LINKAGE POINTS BETWEEN DIFFERENT LANDSCAPE AREAS IN THE EASTERN MOURNES AND THE CRITICAL LOCATIONS WHERE FUEL LOADING SHOULD BE REDUCED (SMPS).

The report also assessed the capacity for emergency response and concluded that NIFRS was largely unsupported by the rural sector and arrangements were not in place to enable it to effectively cooperate/communicate with land managers, which had a significant impact on the effectiveness of fire-fighting operations but also impinged on FRS preparedness and planning. Moreover, although well trained the FRS lacked the tactical ability to suppress or contain parts of a fire that demonstrated high intensity, and lacked specific weather and wildfire knowledge and equipment. The lack of management of the fuel/vegetation by land managers resulted in a situation where there were few opportunities to prevent the spread of high intensity fires.

The results of the research demonstrated that the land sector and NIFRS were involved in a form of crisis management that at times overwhelmed their resources. The number, size and intensity of historical fires provided evidence that the current approach was failing and the EMM remained under severe threat from landscape sized wildfire incidents. To reduce the risk it was essential that action was

taken that limited a fire's potential to spread across the EMM, which could only be achieved by managing the fuel/vegetation that was available to burn. The actions outlined would significantly reduce the risk of fire spreading over large areas, and from one part of the landscape to another, reduce the size and impact of all fires that occur, and also provide the means to establish a long term and sustainable fuel management plan that could eventually be extended into other parts of the EMM.
It was of the utmost importance that a greater understanding of wildfire, and its environment, be developed both within NIFRS and the rural/land sectors. Only then could partners work together effectively and make informed decisions. There was a great deal of evidence to suggest that the threat posed by wildfire in the UK would increase in the future. By addressing the issues now, members of any fire group and the organisations that they represented could build up knowledge of the phenomena; this would permit an improved response in future years.

Actions Following the Report

As a result of the report the **Mourne Wildfire Group** was established in October 2014 and has three sub-groups tasked with developing actions on Land Management (including the recommended SMP), a Strategic Wildfire Plan, and Emergency Response.
Initial actions under the Mourne Wildfire Group focused on carrying out a 5ha prescribed burn at one of the report's recommended SMP between the Ben Crom and Silent Valley Reservoirs, and was regarded by government departments as a pilot exercise to inform further similar work on ASSIs, and also wildfire policy. MHT prepared the prescribed burn plan, commissioned a habitat survey and achieved Government assent for carrying out the work on an SAC/ASSI. N.B. currently controlled burning is not permitted on an ASSI, and in particular on peat bogs, so NIEA were very cautious about this proposal. NI Water monitored impact on water quality.
The burn was carried out by MHT and NIFRS personnel in March and April 2015 (Photo 3). MHT led the burn, which had a joint aim of establishing the required fuel reduction and also enabling recovery of the heathland to a good habitat condition. Of important note is that the resources needed to carry out the burn were made available through a working partnership between NIFRS and MHT (with consents from NIW and NIEA), where specialist equipment was shared and staffing numbers achieved to ensure the burn was managed in a controlled way and to a specific prescription. Moreover, the exercise was also regarded as a training opportunity for NIFRS and MHTs wider staff.

FIGURE 23: PRESCRIBED BURN AT SILENT VALLEY, MOURNE MOUNTAINS MARCH 2015

As it is a pilot exercise, recovery management of the heathland following the burn will be critical to demonstrate whether it provides an adequate SMP and does not reduce the habitat quality. MHT is managing the site recovery including liaising with the farmer who grazes the mountain with sheep to ensure the appropriate stocking density is achieved to supress the *graminoids* and allow the heather and broader biodiversity to recover.

The burn has illustrated the need for land managers and emergency services to work together to learn about their local environment, their capabilities, to increase knowledge and skills, and to maintain momentum (where a lack of practical management may risk the initiative becoming stalled as a paper exercise).

Challenges

There is still no designated lead government department in Northern Ireland and no National Wildfire Forum or resourced Strategic NI Wildfire Plan.

MHT & NIFRS have much broader remits and lack the resources to properly commit personnel to drive the initiative and carry out the practical work as required. (For example the pilot prescribed burn took 8 days, which equated to 83 staff days at a staff cost of approximately £9300, which does not include the broader planning, management and equipment costs that were involved).

Austerity policies in the United Kingdom have impacted significantly on the resources available to the Northern Ireland Executive. This in turn has badly affected MHT, which is at risk of losing a significant proportion of its core funding from July 2015. The various government departments and agencies, including NIFRS, have also suffered cuts, which raises the question of how to sustain this new initiative. However, it also provides an opportunity to demonstrate the value in the proposed approach including SMPs, which require relatively small resources to ultimately avoid the greater costs of treating fire damaged catchment water, the loss in tourism and agricultural land and timber value etc., particularly as disturbances to upland areas are predicted to increase (FRISK Go – see below).

Broader Aspects

The EMWR aligns well with other initiatives including an earlier study on the heathland in the Eastern Mournes that identified the increasing threat of wildfire and the need to consider actions that were not currently routinely carried out on heathland in the UK. In particular, it recommended managing fire breaks and establishing diverse micro habitats (e.g. re-wooding river valleys and raising the water table in certain locations), **as part of building resilience into the landscape.**

MHT and NIFRS are working hard to network with wider practitioners to profile the Mournes initiative and to develop understanding of the international wildfire context & opportunities. This has involved:

- NIFRS and MHT personnel attending tactical burning training in Catalonia.
- NIFRS and MHT personnel carrying out demonstrations on controlled burning to wide stakeholder groups including farmers and NGOs, under an NIEA led series of events to raise wildfire awareness.
- Participation in the European Forest Risk initiative (FRISK Go) including a workshop in Catalonia, and a study visit to Norway to establish understanding and networking across northern European countries.
- NIFRS Commander attending a knowledge exchange visit to South Africa (via FRISK Go)
- Participation in the European POFISmart initiative aiming to establish post fire recovery modelling tools, and the European FIREfficent initiative.
- Close working with representatives of the Dept of Agriculture in the Republic of Ireland aiming towards a coordinated broader island of Ireland wildfire initiative.
- Exploring partnerships with academic institutions including Kings College London and Edinburgh University to develop modelling and stakeholder value assessment profiles.

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