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Cristina Montiel
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(editors)

EUROPEAN FOREST INSTITUTE

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EUROPEAN FOREST INSTITUTE

SIXTH FRAMEWORK PROGRAMME

FIRE PARADOX

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Executive summary

Prescribed burning is increasingly being recognized and incorporated as a management practice in forest and other land management policies, especially in those countries which were pioneering its introduction in Europe. In this context, prescribed fire appears to be a potential management technique to attain different objectives such as silvicultural improvement, control of insects and diseases, habitat management and biodiversity conservation. Further, it has been demonstrated in the field of fire management that the use of fire is an efficient tool for the reduction of hazardous fuels and as an indirect attack during wildfire suppression (suppression fire). In most European countries, however, there are still important constrains and negative attitudes towards the use of fire that need to be overcome.

In the frame of the Fire Paradox project "An innovative approach for integrated wildland fire management. Regulating the wildfire problem by the wise use of fire: solving the fire paradox" (2006–2010), which aims to create the scientific and technological bases for new practices and policies for integrated wildland fire management, the assessment of prescribed burning and suppression fire practices has been undertaken by both the research and development domains, in order to identify opportunities as well as promote the future development of strategies for its implementation in Europe.

Within this context, this publication aims to provide policy makers, policy implementers and the general public with background information and analysis for the successful implementation of prescribed burning and suppression fire practices in European countries. By analysing successful case studies, it seeks to understand the factors that influence the success of prescribed burning and suppression fire and to facilitate application in other countries.

For this purpose the book is structured in three sections. The first section provides background information for those not familiar with the practice of fire use for management objectives. It includes general and basic notions on prescribed burning and suppression fire, as well as an overview of the spatial and temporal development of both practices in Europe. It also provides the main criteria considered for the identification of good examples.

The second section constitutes the core of the book, which consists of a selection of good practices and best programmes that present, in some cases, long-term examples for the most representative objectives for fire use as a management practice in Europe, namely nature conservation in protected areas, the management of habitats for hunting, landscape management, fire use in fuel reduction and during fire fighting (suppression fire). The authors of the case studies are managers responsible for the creation and implementation of the practice or programme of the Fire Paradox consortium as well as external professionals. The reason for this choice is related to the character of the book, which serves to disseminate good practices, and therefore needs the adoption of a more practical approach to be better understood by end-users.

The book concludes with an analysis of potential barriers and factors for success for the development of prescribed burning and suppression fire, as well as a discussion on the lessons learned and the way ahead.

1. Background Information on Prescribed Burning and Suppression Fire

1.1 Prescribed Burning and Suppression Fire Techniques: from Fuel to Landscape Management

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1.1.1 Have we forgotten how to use fire?

Throughout Europe, ancestral fire use techniques evolved under conditions that well suited the needs of each land management system. Accordingly, the technical capacity of fire use varied significantly due to different intents, geographical and climatic variations as well as the ecosystems. For this reason, a very local knowledge on fire conditions was necessary to ensure sustainable land use over the centuries. Whether it be Norwegian farmers burning their coastal heathlands; workers in the slash-and-burn agricultures in Sweden, Finland and the mountain ranges of central Europe; shepherds maintaining the productivity of their grazing grounds in Mediterranean countries or gamekeepers maintaining habitats and hunting grounds in Scotland, common to them all was the deep understanding of the weather conditions and wind patterns that created the required fire behaviour to achieve the desired fire effects in order to reach their management and resource objectives.

In most European countries, the significant socioeconomic changes that were experienced throughout the 20th century were characterised by an increase in population and land abandonment triggered by a rural exodus (Castellnou and Miralles 2009). This created a more urban society to whom traditional land use techniques became only a fading recollection of an archaic life. A profound restructuring of landscape features with much less discontinuity due to land abandonment and undergrazing was the result (Castellnou et al. 2009). Former agricultural land reverted to semi-natural vegetation like shrublands and woodlands; and reforestation programmes, fundamentally based on conifers, were extensively implemented in post-war Europe. The underuse of the productivity of former extensively used land had similar effects in almost all European countries but with very different consequences. In the more fire-prone regions, vegetation recovery, the increasing costs of fire suppression as well as reforestation programmes caused a significant fuel build-up. Meanwhile, in more productive regions, reforestations and the natural process of vegetation recovery were driving the loss of habitats and open landscapes.

As quickly as these profound changes in the landscape progressed, the knowledge of fire use had vanished and with it disappeared the understanding of fire's role in our landscapes. There was no place anymore for ancestral and traditional fire

Figure 1. Traditional burning techniques in coastal heathlands of Norway (photo by P.E. Kaland).

use, and the techniques that had developed in largely fire-resistant landscapes over centuries were soon forgotten as urban societies grew. However, under the influence of new large wildfires, megafires and prolonged fire seasons, European societies are slowly but increasingly accepting the need to use fire, both as prescribed fire as well as a suppression tool. The question remains: Can we retrieve ancient knowledge on fire use and the techniques that were developed and adapted to landscapes that have disappeared? We will always lag behind this dynamic process if we do not learn both from our own and our neighbours' history on how we can adapt our fire use techniques to today's local conditions while a broad perspective on fire use in management systems is still lacking.

1.1.2 The technical aspects of fire use

Prescribed and suppression Fire: definitions and concepts

Apart from traditional and ancestral fire use techniques, prescribed burning and suppression fire use are playing an ever increasing role in Europe as technically advanced instruments. However, fire use is increasingly restricted to trained and specialised personnel of state organisations, with few exceptions. Interestingly, the

loss of a fire culture throughout European rural societies has lead to the perception of prescribed burning as a 'novum' among the available land management tools and techniques. Indeed, prescribed burning can be described as the careful application of fire under specified fuel and weather conditions to meet specific resource management objectives and long-term management goals, and this adds a planning aspect to traditional ways of fire use. Prescribed fire is mainly used as a tool in active and passive fire prevention where prescribed burning operations are based on the use of low-intensity fires that aim at reducing fuel loads and thus reducing the risks of high-intensity fires.

Any fire directly used as a suppression technique during uncontrolled fires is considered as suppression fire. There are several ways in which fire is used to fight fire – collectively these are termed suppression fire. Burnout or burning-out is defined as removing fuel between a constructed fireline and the edge of a fire. This is often done at the rear or on flanks of the fire continuously with fireline construction. Backfire is similar to a burnout except it is ignited to take advantage of the convective indraft ahead of an oncoming fire. Backfiring is relatively uncommon because it is typically performed directly ahead of the advancing head of an intense fire. Timing is critical to allow for the reversal of wind direction associated with the blocking of ambient wind by the main front and indrafts to the headfire. Backburn is defined as an ignition intended to spread in a backing direction into the wind or down a slope. Backburning may be used in a prescribed fire or during wildfires.

The main objectives and tactical options for suppression fire use can be summarised as directing or slowing down fire spread, mitigating re-ignition risks and limiting suppression actions to an anchor point. Sometimes the most effective fire tool that will strengthen the suppression of a large fire is to reduce the fire intensity of the fire front, so that an anchor point can be established. This can be the most successful tactic to mitigate re-ignition risks by avoiding an increase of fire intensity through a firing operation near a critical point.

Fire use techniques: a typology based on operators skills

From a technical perspective, the use of fire is multifaceted as many factors contribute to the variation in fire use techniques. First, there are the different ecosystems or fire regimes in Europe which relate to different fire management objectives; second, there are the skills and knowledge that provide the basis for achieving the fire effects that meet management objectives. However, the hierarchical diversification of fire use capabilities is more critical than the geographical differences of fire use techniques. An attempt to classify fire specialist groups by their capabilities to use fire can be made as following:

Group A: Control ignition progress to prevent fire from escaping control. This is the most common level of knowledge regarding fire use in management systems; however, it is a huge step forward to reach even this basic level. The competence to apply fire to a piece of land requires at least some knowledge on how to use different ignition patterns to influence fire behaviour and to achieve the objectives of a firing plan. The burning techniques that are applied in this group are aimed at controlling fire spread rather than fire intensity. Thus they are mainly used in ecosystems where differences in fire effects are either less pronounced or are of a uniform fuel type that is conducive to controlling fire spread. Safety and security are the main factors in applied burning techniques, and the control of fire effects

is typically rather poor with only random variations in fire behaviour. At this level of knowledge suppression fire operations include simple burnouts for perimeter definitions in fuel types with low complexity.

Group B: Control ignition pattern to achieve a desired intensity and residence time. A higher level of knowledge and accumulated experience is required to apply ignition techniques that create the desired effects through the maintenance of a certain intensity and burning rate that is controlled meter by meter. Since the responses of both fuel types and ecosystems vary significantly leading to variations in fire intensity and residence time, it is crucial that people performing firing operations have good control over the factors that cause the variation. The combination of different ignition patterns and topographical and weather conditions produce very specific effects both in prescribed burning as well as in fire suppression operations. However, this level of knowledge cannot be achieved by only theoretical training since it requires recurring experience over a longer time period, different seasons, fuel types and terrain. Anyone who makes a decision on the ignition pattern at the fire front should be able to observe and extract information to identify significant changing factors, i.e. factors that are affecting the fire's behaviour such as relevant aspects of the smoke column, terrain, fuel availability, crew and organisational capabilities, and the alignment of these factors. Additionally, changing factors should be related to opportunities for fire suppression, i.e. extrapolating observed fire behaviour that is affected by a current set of factors to similar conditions; understanding how small changes in the ignition pattern will change the fire's behaviour; and adapting ignition patterns to achieve the preferred fire behaviour. Consequently, much information needs to be processed continuously by any individual firing operator; further, an ignition pattern needs to be constantly adapted to maintain the desired fire behaviour: starting, anchor point and direction of the ignition, the spacing of the ignition points and between the ignition lines.

Group C: Control fire effects on the ecosystem through fire intensity and residence time. This third level of knowledge is a significant step forward since it comprises a profound understanding of fire effects and their causes. Different fire intensities and residence times can have a wide range of impacts on soil, soil organic layers, vegetation and animals, which can change on a scale of meters. Understanding the complexities of these impacts is necessary to meet many management objectives. In contrast, focusing on average properties of a fire regime may lead to too narrow prescriptions. Understanding and considering adaptations and life histories of the dominant species that control a fire regime, rare species, responses of exotic or invasive species, or other targets of management are further key issues for planning the use of fire at this level. The application of this level of knowledge of fire use, however, is limited since it requires a higher level of knowledge to create a fire behaviour that produces the desired effects, and the capability to monitor these effects both on short and long term. On this level, it is also essential to understand the difference between the use of fire during a restoration and a maintenance phase of a fire regime. Restoration measures involve focused burning with specific objectives for each burn, whereas maintenance calls for variable fire applications within the normal ranges for a given fire regime or ecosystem.

Group D: Apply fire to slow down or re-direct a crown fire with extreme fire behaviour. Active crown fires with long distance spotting during extreme heat waves

offer only very few opportunities for fire control and containment. Any new ignition set in front of the fire can act the same way as any spot fire and can help speed up the fire spread. Consequently, a profound understanding of fire behaviour based on intensive training, many hours' experience of wildfires with extreme fire behaviour, high skills in controlling fire behaviour, and the capacity to anticipate and analyse are required to use fire at this advanced level. The aim of this type of fire use is to anticipate the travel paths of the fire runs and to slow them down in direct or parallel attacks. If the rate of spread can be decreased with targeted fire use below the pace of progression of the suppression systems, fire can be controlled.

From a landscape point of view, suppression fire is a tool that should be used with scientific knowledge since it is a live element and can evolve according to our plan, or totally in another way. The underlining issue is not just to use fire but when, where and how to use it.

1.1.3 Where do we want to go? Shifting from fire suppression to fire management

Since each ecosystem has a different capacity or need of fire, and each fire management system also has a distinct window, fire ecology and fire suppression systems have to be taken into account equally when promoting fire use broadly over Europe. Fire use in Europe is often regulated not only nationally but also regionally/locally (Seijo 2009). For this reason, there are a diversity of adaptations and responses for multiple landscapes, multiple socio-economic realities, different purposes to use fire, different fire regimes and the factors that make large fires escape control (Castellnou and Miralles 2009; Castellnou et al. 2009). As landscapes evolve, societies are facing formerly unknown fire problems that need to be approached locally. This diversity of concepts of responses to fire by different agencies and organisations, however, are offering a key opportunity to adapt European societies to changing environments if experience accumulated by others is shared and taken into account. Any new response concept cannot only be based on one reality – it must include shared knowledge from other fire management systems. Consequently, looking at fire regimes from a European perspective immediately offers some lessons to be learned on the use of fire, something that would otherwise take a much longer when only studying one fire region. In the past, this has lead to fire policies that are based on fast and forceful fire suppression, which can be deceptively encouraging in the short-term. However, they did not lead to sustained decreases in the areas burned; rather, to the increasing relative significance of large fires – even megafires – as experienced in Catalonia 1986/1993, Galicia 1994/2005 and Greece 2001/2006. Changes in the importance of large fires with extreme behaviour are related to changes in the landscape (Castellnou et al. 2009; Piñol et al. 2005), especially when the fuel types at the landscape level are continuous dense tree stands. Large fires occur all over Europe, in northern countries as well as in the Mediterranean region, but with different frequencies. When observing the fire history of a single region over the last century, a large fire may be seen as an anomaly; however, by broadening the view over similar regions, a consistent pattern may be revealed.

Figure 2. Prescribed understory burning in a *Pinus canariensis*-stand in Gran Canaria (photo by D. Kraus).

The most important step towards the wise use of fire is to identify exactly where we are in the evolution of the fire problem and adapt responses locally by taking into account the lessons learned from other regions that have had a previous similar experience. Table 1 summarises the evolution of respective generations of large fires in Euro-Mediterranean landscapes (Castellnou and Miralles 2009) and the type of fire use possible to prevent or response to these fires. It becomes clear from this that with the evolution of the fire problem, the knowledge and skills requirements for fire use, be it prescribed burning or suppression firing, have changed and are still changing in Europe. However, the fires that Europe faces today are increasingly fires of the 4th and 5th generation where even the highest levels of fire use competencies (Groups C and D) will not make a difference in the firefighting approach. Here, the pure technical approach of fire use comes to an end and new fire management concepts need to be sought by moving away from a the firefighting response to the strategic placing of prevention measures (Finney et al. 2005). In order to cope with a worsening wildfire situation, there is a need to change the strategy towards changing the landscape by managing the fire regime itself to solve the problem, i.e. a change from suppressing all fires that lead to high fire intensity regimes, towards a new approach based on tolerating fire regimes with low intensity fires. Further, fire-fighting organisations must adapt to cope with low frequency, high-impact large fire situations through gaining knowledge and experience.

Table 1. Generations of large fires in Euro-Mediterranean landscapes, and the management and fire use options by decade from the 1950s.

Generation	Explanation	Types of fires	Landscape management and fire use operations
1st 1950s and 1960s	*Continuity* of fuels over the landscape allows large perimeters. Few farmlands left as fuel breaks, few anchor points.	Fires, that burn 1000 ha to 5000 ha. Surface fires and mainly wind-driven.	*Control the spread of the ignition (Group A):* Backburning and burnout operations, especially perimeter definition with burnout operations. Prescribed burning in uniform rangelands and heathlands.
2nd 1970s and 1980s	*Rate of Spread.* Fuel buildup is allowing faster fires and spotting. The speed of fires overruns the holding lines.	Fires from 5000 ha to 10 000 ha. Wind- and topography- driven.	*Control fire intensity (Group B):* Identifying opportunities associated with windows of opportunities. Greater ability of combined operations. A broader range of objectives and techniques to manage wildland fires and prescribed burning.
3rd 1990s	*Fire Intensity.* Fuel buildup is allowing crown continuity, resulting in active crown fires and convective plumes, beyond control capacity. Each fire offers very few opportunities to control. Fire changes behaviour faster than the information moves in the chain of command.	Crown fires and long spotting distances. Fires from 10 000 to 20 000 ha. Extreme heat waves are supporting high-intensity fires.	*Slowing down fires (Group D) and controlling fire effects (Group C):* Directing or delaying fire spread to reach specific resource management objectives. Understory prescribed burning. Prioritise opportunities associated to windows of opportunities. A greater ability to manage ignition lines combined with other techniques, with a broader range of objectives.
4th since 2000	*The Wildland-Urban Interface (WUI)* becomes involved in the forest fire environment. Residential and industrial areas are increasingly affected by wildland fires.	Fires that can start and be stopped inside WUI and burn more that 1000 ha.	New landscape conditions are forcing a change from attacking the fires to defending houses and people in a new defensive situation. Application of fire analysis grows. Simulators, GPS and mapping technologies to follow resources on time appear.
5th since 2000	*Megafires.* Zones under risk are faced with simultaneous large, fast and extremely intense wildfires.	Simultaneous crown fires involving WUI zones, mainly during heat waves.	The current situation: new skills are needed to respond to simultaneous large fires. The answer is sharing resources, but a new form of knowledge exchange and sharing information and experience is needed.

1.1.4 How do we get there?

The shift from fire suppression to fire management has clear ecological and economic benefits and not only in landscapes with a high proportion of large fires and with prescribed burning and suppression fire programmes in place. However, this shift will be a very slow process due to perceived risks, social acceptance and the need of different organisations to cooperate: emergency, forest, fire as well as landscape planning services. In addition, it is time consuming to build an organisation with the necessary skills and capabilities since a good programme for prescribed burning requires a broad basis of fire specialists who can perform prescribed burns at least at Group C level; and for a good programme for suppression fire use a basis of Group B operators and Group C managers at least is essential. In order to achieve the required changes for the shift towards managing fires, most organisations will have to start with basic prescribed burning programmes to acquire a basis that is sufficiently broad to gain experience in the use of fire. The following describes the process towards fire management in different phases each marked by a specific fire use capability:

Phase 1. Prescribed burning programmes in homogeneous fuel types. The number of European countries performing prescribed burning is increasing, both for fire prevention purposes (Portugal, France, and northern Spain) and other land management objectives (Sweden, Scotland, Germany, and parts of Spain) (Lázaro et al. 2008). Most of these prescribed burns are performed in rather homogeneous fuel types such as rangelands, heathlands or forest stands with little understory. Under these conditions, the operators conducting the prescribed burns must have a good control of fire spread and at least some basic knowledge of fire behaviour in their particular landscape. Fire specialists who are necessary for this phase thus belong to Group A, with a few experts in fire ecology and in fire behaviour at least of one particular landscape. Drip torch operators in these types of prescribed burns do not only need the training and experience to apply different ignition patterns specified in a firing plan, they also need basic training to interpret the landscape and read maps to reduce the risk during the prescribed burns. They must also participate in the briefings and be able to apply techniques and tactics to suppress any potential fire escape with light portable pumps, engines and hoses or with power and hand tools.

Phase 2. Suppression fire use in landscapes dominated by homogeneous fine fuel types. When large fires overcome the suppression capacity of a fire fighting organisation, they run out of control with significant impact on the economy and sense of risk of the general public. In such situations, fire use can be used as a technique to support fire control. In Portugal, Spain and Cyprus, suppression fire was introduced during the latter half of the last century as a tool where burnout and backfire operations were used on continuous large fire perimeters (see Table 1, Fire Generations). The required abilities to perform fire operations, apart from general fire fighting operations, ranged from controlling the fire spread of an ignition line in landscapes dominated by fine fuel types to controlling the intensity of ignitions set to stop wildfires in landscapes dominated by continuous dense shrublands. This rather broad range of abilities has been evolving in different ecosystems and fire regimes in Europe; however, as an ancestral fire culture was being increasingly lost, some of these abilities had to be acquired locally by observation and experience as well as by training that incorporated fire use concepts applied by other countries. In

Figure 3. Burning out operation during the Pals Fire in 2009 (photo by Bombers, GRAF).

order to face complex large fires in Wildland Urban Interface (WUI) areas, a strong control of the ignition pattern is necessary. This can only be achieved by gaining sufficient experience in a well-thought prescribed burning programme that includes foremost understory burning and other burns where the ignition must be adapted on a scale of meters.

Phase 3. Prescribed burning programme for understory burning. The prescribed underburning of forest stands requires a higher control on fire intensity and residence time on a scale of meters. Practically every drip torch operator in a prescribed burn must thus constantly adapt the ignition progress to achieve a given fire behaviour objective; at the same time, the prescribed burn boss adapts the general ignition pattern to larger changes in topography and meteorology, especially adapting the fire behaviour to its desired effects. This constant adaptation of every ignition line can be achieved, e.g. by a specialist in charge who is followed by someone in training. The required skills for these burning units are at the Group C level; further, a significant number of the personnel in these units should have the capacity to control the:

- spread of the ignition
- fire intensity and residence time to minimise tree mortality
- fire effects on the ecosystem by regulating the fire's intensity and heat release

Once people are well trained in controlling the fire spread of an ignition line, they can then participate in understory burning under the supervision of someone who is

Figure 4. The 2006 Montmel Fire in Catalonia – an example of a fire that was not suppressed as it was seen that its effects could be used to benefit the vegetation structure (photo by Bombers, GRAF).

controlling the fire's intensity. Experience in prescribed burning of open rangelands and heathlands leads to gaining experience in controlling the spread of the ignition, whereas experience in understory burning leads to acquiring control over fire intensity and heat release. However, to control the effects of fire on the ecosystem, training in both fire ecology and in interpreting the burn plan correctly is needed. Experience in controlling fire behaviour as a drip torch operator is also required as this helps igniters gain experience in relating fire behaviour to fire effects.

Phase 4. Use of suppression fire techniques to slow down wildfires. The megafires of the last decade have shown the need to use suppression firing techniques in some countries but restricted to highly trained fire specialists, e.g. in Catalonia (2000), France (2005), Sardinia (2006) and Portugal (2004) (Lázaro et al. 2008; Rifa and Castellnou 2007). High intensity crown fires in the vicinity of Wildland Urban Interfaces (WUI) were beyond the capacity of control for any fire suppression approach and are a major threat to life and property – the only solution was an indirect attack approach far from the fire. In wildfires with such extreme behaviour, even backfiring and burning out could not stop the fires. As a consequence, the next step was to enlarge the objectives of the suppression operation and anticipate when and where the fire's behaviour would change in favour of the intervention units and

thus offer an opportunity for suppression. In this context, fire is used to slow down the rate of spread of a wildfire and thus lower its pace of progression, and in this way gain precious time for others to stop and control the fire. This complex strategy requires that the fire behaviour analyst is able to anticipate the fire behaviour with a fire specialist in order to apply the exact ignition intensity.

Phase 5. Managing ignitions. Tolerating or even introducing medium-sized fires in a significant proportion to a landscape regularly hit by large wildfires reduces the proportion of such large fires (Piñol et al. 2007). While the extent of surface to be burned is widely recognised as a need, it is a very difficult and expensive goal to achieve (Nasiatka 2003). The overall objective of fire suppression is no longer to minimise the area burnt, it must also reduce the negative impacts of wildfires by considering land use objectives and ecosystem sustainability. The opportunity to manage unplanned fires for positive purposes, where each part of a wildfire is managed according to its resource objectives regardless of whatever caused the fire, appears a logic step. However, there are socio-political constraints since wildland fire use policies are mainly associated to natural ignitions in large natural landscapes where the fire suppression cost is perceived as higher than the perceived risk associated to managing unplanned ignitions (Van Wagtendonk 2007). Nevertheless, first experiences in Catalonia have shown the efficiency of this approach even in a densely populated landscape when monitored carefully and when the overall burning window for such fire use is taken into account and observed. This was seen, for example, during the Montmel Fire in 2006 when the fire was not suppressed but confined to a specific area and allowed to burn where fire behaviour was benign and rated as a beneficial treatment for the affected forest stands. The final judgement to let this fire burn and achieve the desired effects was based on the large database of Catalan wildfires, which has a high temporal and spatial resolution that facilitates the cross-referencing of burning conditions and fire effects of other fire events.

1.1.5 What do we need? From more resources to more knowledge

The required shift from focusing on fire exclusion towards fire management implies a shift in investment from ‘more resources’ to ‘knowledge’. While resources are still needed in today’s ‘large wildfire era’, knowledge and understanding of fire use in fire management systems is the key. Identifying the main factors that allow fires to escape control in each region, and the lessons to be learned through each experience allow fire management organisations to become efficient and progress towards appropriate fire management policies, strategies and tactics.

The ability of an organisation to change its strategy and include new types of tools, techniques and tactics depends on its capacity to manage this change through good leadership on the politics of fire. Changes are more likely to be made after an event that society has deemed catastrophic, but not severe enough to render the organisation unrecoverable so they can use and build on existing structures. This is only possible, however, if a society’s key civil and social actors, such as the forest and land based sector, the civil protection services and NGOs as representatives of the general public, are involved.

In this sense, we need to be prepared for changes by knowing and understanding the complex interactions between fire and ecosystems; and by understanding what management systems we already have in place. The era of local experts is coming to an end; and as exchanges of people and information are becoming a must, it implies that in order to adapt to the coming changes we need fire managers – not managers of specific ecosystems or types of burns.

This is important for both individuals and organisations. In complex systems that operate in chaotic environments where the need to manage the unexpected arises, an organisation needs more than a command structure and control, it needs a learning culture to enhance and sustain safe and effective work practices (Nasiatka 2008; Saveland 2008). Experience must flow into the system and any operation carried out is part of the new database of common knowledge, something that will be shared among the community of future fire managers.

1.1.6 Conclusions

After extreme fires affected Portugal, France and Spain in 2003, Spain in 2005, Portugal and Spain in 2006, and Greece in 2007, the importance of building experience and cooperation was emphasised. However, as megafires are rare occurrences in each country, it means that a professional fire fighter might only be faced with such an event two or three times at most separated by several years. This has basically three important implications:

- People based in state fire services (both structural and forest service based) cannot accumulate enough experience to be prepared for such a big event; further, it will always mean confrontation with a new situation that needs a different response (more anticipation and working in advance) than the usual direct attack approach.
- Resources of a single fire service will not be enough for a 'megafire' event.
- Fire service leaders are often replaced after extreme events because they are blamed for the large areas burned rather than understanding the evolution of landscapes and its implications on new types of fire scenarios. Consequently, fire services - state fire departments, structural and forest service fire fighters – are not acquiring cumulative experience and may thus be repeating failed strategies by attacking fires with all resources available.

Reinforcement should be made in accumulating experience through extensive, continuous training that incorporates lessons learned from well-documented past fires. We have to ensure that everybody knows and well understands the conditions and operations of each fire, so we can create a 'common experience'. Also, the use of fire as a suppression technique unavoidably requires that we gain experience through extensive prescribed burning programmes. Additionally, sending fire specialists outside their comfort zones ensures they can gather more and new experiences to be adapted back home in unexpected situations.

The transmission of experience is much more difficult to achieve. The exchange of information and experts as promoted in learning organisations are insufficient

as they now stand. However, this will be the most important issue in this coming century as we face severe ecosystem changes and a changing socio-economy that will bring us new fire regimes with different effects as well as new problems through more large wildfires as landscapes evolve. Furthermore, training all personnel using fire as a technique must be based on in-depth knowledge, since in fast wildfires and in complex prescribed burns most of the tactical decisions are taken by lower levels in the hierarchy.

In both wildfires and prescribed burning, we need good leadership in all fire operations. This can be achieved through incorporating a fire analyst to help in detecting and prioritising windows of opportunities, and through creating fire specialist groups to perform suppression fires and who can take the lead during operations. This requires extensive training and exchange programmes for individuals as well as for those who form part of teams that can pass on their knowledge to a wider audience. We need to use an analytical approach to determine where and when to attack a fire, so that resources can be used to their maximum capacity.

Finally, promoting a wise use of fire requires public awareness strategies that stop selling fires as punctual fire emergencies to the public, but attempt to explain fires as an integral part of landscape dynamics.

While fire as an operational technique is certainly a first and important step, fire management must keep evolving from being a technique that manages fuels to becoming a technique that manages the landscape.

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1.2 Development of Prescribed Burning and Suppression Fire in Europe

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1.2.1 Introduction

Fire can be a destructive force and, conversely, a natural and vital component in ecology as well as a useful tool for improving people lives. Often it is also both at the same time (Myers 2006). These are the two faces of fire, an issue which is receiving recent and growing interest due to changing paradigms in ecology and nature conservation (Goldammer et al. 2007). Moreover, the critical role of fire has acquired an international dimension after being contemplated within the overreaching framework of the Strategy to Enhance International Cooperation in Fire Management and the Fire Management Voluntary Guidelines (FAO 2007).

Nonetheless, the recognition of the role of fire as a management tool has not achieved the same development in all parts of the world nor does it have the same meaning. Long-term changes in vegetation caused by successful fire exclusion as well as escalating suppression costs has led to the use of prescribed fire use for fuel management and ecological purposes in the USA, Australia and Canada. Scientists, managers, and policy makers in these countries have recognised the need to focus on the role of fire in land management rather than strictly the suppression of wildfire. Thus the introduction of prescribed burning practices is largely derived from the functional role that natural fire has played in ecosystems through historical and contemporary fire regimes (Pausas and Keeley 2009; Pyne 1997). This panorama is quite different from Europe, where fire is presented as a substitution tool for historical mechanical or natural fuel treatments, and hence is to be applied in cultural landscapes rather than natural fire ecosystems. In this context, the objectives for its implementation are focused on counteracting the negative consequences that the abandonment of old land uses have had for the maintenance of traditional landscape structures, or transferring principles from fire ecosystems to those ecosystems in which fire under prescribed conditions has positive effects on stabilisation.

More than two decades after its introduction, the use of fire for management purposes (prescribed burning and suppression fire) is more developed in those countries that were pioneers in its introduction (Portugal, France and Spain) and mainly in the field of fire management. In the rest of the European countries, the use of fire for management is still applied sporadically and most countries continue to develop this practice at the experimental level mainly due to different type of constraints, such as over-restrictive legal frameworks, complex territorial structures, lack of experience among professionals or negative perceptions from the public (Xanthoupoulos et al. 2006).

Additionally, in Europe there are rural areas where a fire culture is alive and traditional fire use is still an effective and economic tool for the burning of agro-forestry remnants, stubble and grazing improvement. Thus, the maintenance of these types of practices is not only beneficial for the communities' wealth, but also constitute an important management scheme which contributes to fuel reduction. However, the changing spatial and socioeconomic contexts where these practices are developed, as well as restrictive and un-adapted approaches adopted by responsible administrations, have contributed to turn this traditional use into the most important cause for wildfires in many European, especially Mediterranean, countries, (DG JRC/IES 2008).

For both the traditional and planned use of fire, new opportunities and challenges are underway for the development of the use of fire for management purposes in Europe. Regarding fire management, particularly in Mediterranean countries, the increasing risk of high-severity wildfires and the impossibility to continue increasing suppression efforts at high economic costs, requires new approaches in order to improve their prevention and suppression strategies. On the other hand, the loss of open landscapes associated to rapid socioeconomic changing conditions has lead fire-exclusion policies in certain sectors of nature conservation, forestry and landscape management being reconsidered (Goldammer et al. 2007).

In this context, this chapter aims to contribute in filling the gap of knowledge on the current use of fire practices in Europe, its distribution and its importance since previous studies have been rather scattered and only focused on some European regions (Pyne 1997; Botelho and Fernandes 1997; Goldammer and Bruce 2004). It also aims to identify future scenarios for the introduction and development of prescribed burning and suppression fire practices in Europe. Although the review of modern fire use techniques is the main objective of this chapter, the inclusion of traditional fire use practices has also been considered relevant since they are an important factor for the development of future prescribed burning and suppression fire policies. Here, traditional fire use is the use of fire by rural communities for land and resource management purposes based on traditional know-how. In this regard, the main characteristic that clearly distinguishes prescribed burning form traditional fire use is adequate planning (Pyne et al. 1996) and post- evaluation, which determines whether the pre-determined management objectives have been reached and allow for future improvements (Fernandes 2002). Both traditional and modern fire use techniques are described here separately.

1.2.2 A long standing tradition of fire use in Europe

In Europe, as in other continents around the world, anthropogenic fire has been recognised as one of the most significant alterations to fire regimes (Conedera et al. 2008; Scott et al. 2000). Especially since Neolithic times, with the explosion of agricultural civilisations, fire became an essential tool to expand agricultural lands. From the very first moment, each environment – ager (field), saltus (grassland) and silva (forest) – had its own type of fire (Pyne 1997); also, the type of burning practices were also influenced by the geographic conditions in each region.

In the Mediterranean region, the pastoral use of fire has continued throughout history until the present, and has become an integral component – together with

grazing and other traditional cultivation systems – of the anthropogenic factors which have shaped the ecological and genetic diversity of Mediterranean landscapes as we know them today (Di Pasquale et al. 2004; Naveh 1975). The interaction of fire and grazing is present along the entire Mediterranean Basin. In France for instance, and in particular in the Pyrenees, pastoral fires set in rangelands (écobuages) constituted for millennia an irreplaceable tool to clear abandoned agricultural lands invaded by woody vegetation and increase its productivity (Métailié 2006; Lambert 2008). Throughout the Mediterranean basin, many vegetation formations are the result of the continuous use of fire by shepherds such as the phrygana communities in Greece (Papanastasis 1976, 1980).

In countries from temperate and boreal Europe, fire became an essential tool for the expansion and occupation of new lands (landnam), being the most representative techniques in swidden agriculture and shifting cultivation systems (Pyne 1997; Goldammer 1998; Bradshaw and Hannon 2006). Along temperate Europe, from Ireland to Poland and from the Balkans to the Baltic countries, methods and goals were common and similar to those used nowadays in the tropics, Southeast Asia and arid and sub-humid areas in Africa (Montag 1990; Pyne 1997). The burning of grasslands for pasture was also common on lands that were too poor for agriculture and poor in resources. In particular, the heather and moor landscapes characteristic in Atlantic countries such as Belgium, Germany, France, Norway and the United Kingdom are the product of more than 5,000 years of burning by rural communities (Haaland 2003; Dodgshon and Olsson 2006).

Therefore, almost no place in the continent has escaped from the recurrent use of anthropogenic fire which has shaped many landscapes of high value in Europe (Pyne 1997, Goldammer 1998, 2000). This dependence between humans and fire remained imperturbable for thousands of years until the arrival of the industrial revolution and the coming of fossil fuels (Pyne 1997). However, this transition in land use did not have the same triggers or take place at the same moment in different countries and regions in Europe.

In central European and Atlantic countries, traditional burning practices continued into the first half of the 20th century. The post World War II changes in agricultural policies to maximise outputs as well as new economic and quality of life issues led to the imposition of fire bans and complete fire suppression policies, which translated into the elimination of the traditional fire use practices in the region (Goldammer 1998; Goldammer and Bruce 2004). This tendency was similar for northern European countries, although the use of fire in silviculture enjoyed a come-back in Sweden and Finland after World War II (Lovén and Aänismaa 2004; Niklasson and Granström 2004). Today, the use of fire as a traditional tool for land management in these two regions has practically vanished as the socioeconomic context of the region has changed.

The cessation of traditional burning practices has, however, some exceptions, especially in the United Kingdom, where the traditional burning of heathlands (muirburn) is still a widespread practice, although the proportion of use varies significantly in the local and regional context (Davies et al. 2008). Heathlands dominated by *Calluna vulgaris* species are frequently burned by gamekeepers, shepherds, farmers and other traditional land-managers to develop a mosaic habitat favourable for species such as the red grouse (*Lagopus lagopus scoticus*), sheep and deer, and for the improvement of grasses (SEERAD 2001, DEFRA 2007). Recently,

Figure 1. Ribera d'Ebre, Municipality of Rasquera, Tarragona. Spain.

the reestablishment of traditional burning methods has taken place in some areas like in the Black Forest (Germany), the Koli National Park (Finland) (Loven and Äänismaa 2004), and in the Atlantic heathlands of Western Norway (Haaland 2003).

For southern European countries, the progressive abandonment of traditional burning practices were initiated later, since economic and demographic crisis in rural areas did not reach the maximum until the 1960s, especially for more remote and less favoured areas (Metailié 2006; Vélez 2005). However, traditional fire uses are still maintained today in rural regions where fire is an important cultural practice and an effective and economic tool for the burning of agro-forestry remnants and stubble as well as for grazing improvement. This is the same situation for eastern European countries, where the use of fire is an economic and irreplaceable tool in rural activities (Merou and Papanastasis 2002; Konstantinov 2003). Moreover, in many rural regions, the use of fire to protect rural assets from wildfires has also been a long-standing traditional practice used by rural communities. Nowadays, it is very often used clandestinely by the local inhabitants due to the absence of appropriate participatory and governance mechanisms to regulate the use of tactical fire.

For those areas where traditional burning practices are maintained, the complexity lies in the fact that the degree of loss of cultural knowledge has not been uniform. The maintenance of traditional practices vary considerably depending on the socio-ecological context where they take place; even differences can be found according to the valleys and agropastoral systems (Metailié 2006). Moreover, changing socioeconomic and spatial conditions in rural areas (e.g. the encroachment of

Figure 2. Pasture burning in Sardinia, Italy (photo by N. Ribet, 2006).

vegetation, and the decrease and aging of the rural population) have contributed to modify the practice over time from a cultural practice used by rural society to a clandestine and uncontrolled burning usually performed individually (Faerber 1995). Also, responsible administrations have contributed to the depreciation of the practice due to un-adapted approaches and the condemnation of this practice – mostly pastoral fires – as dangerous activities (Ribet 2009).

In this context, traditional fire use practices have evolved to become the main cause for wildland fires as shown in national databases, especially in Mediterranean countries. In Spain, for instance, around two thirds of the total number of fires (60%) is directly related to rural activities which involve the use of fire (Vélez 2005). Similar percentages have been recorded in Portugal (50%) and Italy (65%) (DG JRC/IES 2008).

1.2.3 Overview of prescribed burning and suppression fire practices: development and management objectives

In Europe, the use of fire as a modern management technique, and in particular prescribed burning, was introduced in the early 1980s in southern European countries, 40 years after its official endorsement by the United States Forest Service in forests in the south of the country (Wright and Bailey 1982). Since the very beginning, first

experimental initiatives were started to adapt this technique to European conditions. In southern European countries, mainly Portugal, France and Spain, research was developed in the field of fire risk reduction (Botelho and Fernandes 1997; Rigolot 1995; Vélez 1988) while in central Europe, first prescribed burning initiatives were motivated by new ideas and principles for the restoration of traditional landscapes and the emulation of natural disturbances (Goldammer 1978, 1983).

The use of fire as a technique for wildfire suppression has, however, a long tradition in Europe. Suppression fire has been used by the local population as a wildfire fighting tool before the Fire Fighting Services were established in many European countries prone to fire hazard. Recently, fire fighting administrations have approached the use of fire as a complementary tool to other conventional fire fighting techniques. Suppression fire techniques had an earlier development between the 1970s and the 1980s in Portugal and Spain, and more recently in southern France and other southern European countries. However, in some cases, suppression fire monitoring has been hindered by the confusion between traditional use by rural populations and its implementation by forest and civil protection services, as well as due to the clandestine character associated with this technique in many European countries.

Today, prescribed burning and suppression fire practices are more developed in those countries that were pioneers in its introduction and mainly in the field of fire management. Portugal and France have succeeded in developing the first fire use policies in Europe with specific legal frameworks, specialised teams as well as national systems for the professional accreditation in the use of these techniques. Spain has also progressed in this direction, but mainly at the regional level. In the rest of the European countries, with exceptions such as Sweden and the United Kingdom, fire use for management purposes is still applied at the experimental level within the context of research projects for nature conservation or the maintenance of open landscapes (Goldammer and Bruce 2004).

Reduction of wildfire incidence and severity

The reduction of wildfire incidence and severity is the predominant management objective in the southern countries of Europe where prescribed burning is presented as an economic and efficient tool for the reduction of fuel accumulation and thus difficult fire propagation (Fernandes and Botelho 2004); for the creation and maintenance of fuelbreaks (Molina et al. 2006); to decrease the initiation of fires due to uncontrolled rural burnings (Vélez 2005); for the creation of strategic areas for fire suppression; and for the training of suppression teams in the use of fire (Castellnou et al. 2007). Although tactical fire is one of the most ancient techniques for wildfire suppression, today suppression fire use is a social, political and technical challenge. It requires highly qualified people with technical skills, well established communications with the local population and insight into traditional socio-spatial structures.

France currently represents the country where prescribed burning has acquired greater development with around 4000 to 5000 ha burnt every year mainly on rangelands (Lambert 2008). This degree of development has been possible mainly due to the 'French National Network of Prescribed Burning Teams' created in 1990 (Rigolot 2000), which today includes 28 PB teams distributed within the French Mediterranean region, the Pyrenees and the Alps. The principal objective for the use

Figure 3. Prescribed burning for the protection of a coastal *pinus* stand in Bages forest,Vaude, France (photo by E. Rigolot)

of prescribed burning is the prevention of wildfires either for fuel build-up control objectives or to avoid the escape of rural burnings; however, as the burning teams are becoming more skilful, the use of prescribed burning is progressively being more and more used for environmental purposes (Rigolot 2005). One of the results obtained by the network has been a certification for Prescribed Burning Bosses organised by the L'École d'Application de la Securité Civile (ECASC).

In Portugal, despite the fact that in the early 1980s around 74 280 ha were managed extensively in *Pinus pinaster* stands of northwest Portugal in the frame of the first prescribed burning programme for fire risk reduction in Europe (Fernandes and Botelho 2004), its use was drastically reduced at the end of the decade; further, from 1994 onwards it was used rather locally and primarily in the experimental field. However, progress at the management level has been accelerated over the past ten years with the development of a legal framework and the creation of specialised teams in the use of prescribed burning and suppression fire. The implementation of prescribed burning in Portugal is supported on accredited technicians in fogo controlado, who are responsible for planning and executing the burning with the support of wildfire prevention teams (sapadores florestais). Moreover, in the last few years, new teams have been developed by the National Forest Service to promote the extensive implementation of prescribed burning and suppression fire techniques at the national level: the Group of Prescribed Burning Specialist (GEFoCo) and the Group for the Analysis and Use of Fire (GAUF).

In Spain, the prescribed burning technique has been developed locally and, in some cases, even sporadically. The decentralised political character of the country means that the development of prescribed fire is very different from region to region. At state level, the central government has developed a national programme with a strong focus

Figure 4. Prescribed burning at the landscape level, S. João do Deserto, Portugal (photo by P. Palheiro, 2007).

on social prevention – the Integral Wildland Fire Prevention Teams (EPRIF) – in order to promote controlled burnings, among other duties. Statistics from 2003–2008 show that 6910 ha were managed in shrubland type vegetation during this period. At the regional level, similar initiatives to avoid uncontrolled burnings from rural populations have been developed in Galicia, Castilla y León, Asturias and Cantabria. In other regions, another approach has been adopted with the development of professional teams trained in the use of fire for prevention and suppression purposes within forest or civil protection services. This is the case in Cataluña (GRAF teams, since 1999) and Canarias (U.O.F.F-PRESA teams, since 2002).

Until recently, fire use for management purposes was not used or even allowed in many regions of Italy and in Greece, in particular. In Greece, the situation has not changed – the use of prescribed burning has only been used experimentally in the past in forest plots, shrublands and mountain pastures (Liacos 1977, Papanastassis 1976, 1980). However, important progress has been achieved in Italy recently, facilitated by the exchange among prescribed burning professionals from other European countries (e.g. Portugal and Catalonia in Spain) in the frame of the Fire Paradox project. Results from this exchange have been the development of the first prescribed burning programme in the Cilento National Park (Campania region). This is included in the Forest Fire Defense Plan 2008 with the objective to manage fuel accumulation under pinewoods (*Pinus halepensis* and *Pinus pinaster*) and the development in Sardinia (in 2008) of the first institutional team licensed to use fire for fire suppression as well as for prevention actions (Mastros do Fogu).

Nature conservation, silviculture and landscape management

In the 1970s, new ideas for the restoration of traditional land use methods or disturbance processes began to arise in order to maintain old cultural landscapes. Due to the increasing interest in heritage issues, both ecological and cultural, there has been a gradual re-evaluation of the role of fire over the last 30 years (Goldammer and Bruce 2004).

Figure 5. Prescribed burning for nature conservation in continental *Calluna* heathlands in the Nature Reserve Drover Heide, Düren, Germany (photo by D. Kraus, 2007).

In central European and Atlantic countries, the use of PB is focused on the management of endangered habitats and the conservation of open landscapes (Goldammer et al. 2007). Most of the initiatives identified are developed at the experimental level within the framework of research projects for nature conservation, where prescribed burning is considered, among other alternatives, as tools to attain specific conservation objectives. Therefore, the use of fire for management purposes developed within countries in this region does not constitute a real management tool in practice, due to restrictive legal frameworks (e.g. Germany, Netherlands) and since special permits are required to be able to implement it.

In Germany, the first experimental burn took place in 1977 in the Forest District Breisach, in the Federal State of Baden-Würtemberg, followed up by several burns and workshops until 1983. Since then, many initiatives have been developed with various objectives including the management of viticulture landscapes, restoration projects for Atlantic heathlands, the management of *Calluna vulgaris* on former military camps, fuel management and forest biodiversity of *Pinus sylvestris*, as well as the management of pasture and grouse habitats (Goldammer and Bruce 2004).

To a much lesser extent, the Netherlands and Denmark have both developed experimental programmes aimed at the restoration of heathland ecosystems. In the Netherlands, the use of prescribed burning is used in military areas to maintain open heathlands, since in some areas unexploded ammunition prevents the use of sod-cutting and mowing (e.g. Oldebroek and Harskamp shooting areas). The main

Figure 6. Prescribed Burning in Scottish moorlands, United Kingdom (photo by D. Kraus, 2007).

objectives are to conserve particular heathland plant species (*Arnica montana*), black grouse and certain insects (van der Zee 2004). In Denmark, prescribed burning has been used as a tool to restore vulnerable coastal dunes and dune heathlands within the EU LIFE NATURE project 'Restoration of Dune Habitats along the Danish West Coast' (2001–2005). Mosaic burning was one of the sustainable management methods used to re-establish natural dynamic processes (Jensen 2004).

In the United Kingdom, in addition to the widespread traditional practice of burning heathland as already mentioned, the implementation of prescribed fire has been developed in *Pinus sylvestris* stands to improve the habitats of woodland grouse (Capercaillie, *Tetrao urogallis*) in Inverness-shire within the frame of a LIFE Project (2003–2006), and through experimental burning on pine stands of Glen Tanar State in Aberdeenshire (Bruce and Servant 2004).

In northern European countries – Norway, Sweden, and Finland, which largely belong to the boreal and hemiboreal vegetation zones – the technique of prescribed burning is used as a sustainable forest management practice within the framework of forest certification (FSC Sweden 2006; and FSC Finland, 2006) and for the management of biodiversity in natural protected areas. In Sweden, around 50–200 ha are burned annually for biodiversity management. The county of Västernorrland is a referent in the implementation of this technique with 485 ha having been burned since 1993 (e.g Jämtgaveln and Stormyran-Lommyran nature reserves).

The implementation of prescribed burning has been developed by burning teams consisting of Burn Bosses and Ignition Specialists from the County Administrative Boards.

Most of these projects are part of the 'Eurasian Fire in Nature Conservation Network Network (EFNCN)', coordinated by the Fire Ecology Research Group/ Global Fire Monitoring Center (GFMC) which, since 2000, has constituted a key platform for the development of prescribed fire for the temperate boreal zone in Europe and adjacent countries in southeast Europe, the Caucasus, central and northwest Asia.

1.2.4 New perspectives for fire use practices

Although in southern European countries the technique of prescribed burning had initially been used for wildfire risk reduction, recognising the importance of fire for the Mediterranean ecosystems, as well as the experience accumulated by researchers and professionals in the implementation of this technique, has contributed to the diversification of management objectives towards more environmental concerns. In France, for example, where the use of prescribed burning is increasingly important in the field of environmental planning (e.g., Natura 2000 documents, LIFE programmes etc.) (Rigolot 2005), prescribed burning has begun to be used to improve protected species habitats such as the Bonelli's eagle (*Aquila fasciata*) in the Petit Luberon Natural Park (Vaucluse) (Kmiec 2005) and mouflon (*Ovis aries*) in the massif of Caroux (Hérault) (Babski et al. 2005). In Italy, prescribed burning has been used experimentally in the Natural Reserve of Vauda (Piemonte) within the frame of a research project developed by the Department Agro-forestry of the University of Turin to evaluate the ecological effects of prescribed burning and grazing for the conservation of *Calluna vulgaris* heathlands (Ascoli et al. 2009).

In Mediterranean countries, the increasing risk of high-severity wildfires and escalating suppression costs require new approaches to improve prevention and suppression strategies. In this context, exchange among fire professionals has contributed to the development of operational teams specialised in both the use of prescribed burning and suppression fire, even in countries that have traditionally had a negative attitude towards the re-introduction of fire use as a management technique (e.g. Italy).

In other European countries, altered fire regimes due to changing socioeconomic and climatic conditions have resulted in more severe periods and an increase in the number of fires and burned areas in countries which were not affected by this problem in the past (DG JRC/IES 2008). In this context, some countries have promoted the use of prescribed burning as an effective tool with which to reduce fuel accumulation. In Germany, after the extreme droughts in summer 2003, prescribed burning was reintroduced experimentally for fuel reduction along railway lines in Bavaria State (Hetzel and Goldammer 2004). In eastern countries, the SEE-ERANET Southeast-European European Research Area has initiated the research and development of prescribed burning practices in Hungary and Macedonia in collaboration with Germany. Further, with regard to non-European countries,

Figure 7. Dialogue between professionals and livestock farmers in Salamanca, Spain (photo by I. Juárez, 2006).

opportunities for prescribed burning have started in North Africa. For example, in 2008 in Morocco, a highways agency began prescribed burning on shrub fuels located along the highways to clear the external and central lanes as a substitute to mechanical clearing.

The recognition of the important role that traditional burning practices had for the maintenance of many European landscapes and ecosystems (Pyne 1997; Goldammer 1998; Goldammer et al. 2007), as well as its contribution as a management scheme to reduce forest fuel accumulation (Xanthoupoulos et al. 2006), has contributed to the development of programmes aimed at supporting these practices in recent years.

In those areas where traditional burning practices have been lost, mostly in northern and central European countries, the reestablishment of traditional burning systems relates not only to its cultural heritage value, but also to the role that these management practices had in the conservation and maintenance of valuable ecosystems and cultural landscapes. Some examples of these types of initiatives are found in the Black Forest (Germany) and in the Koli National Park (Finland) (Loven and Äänismaa 2004). In the Heathland Centre (Lygra, Bergen) in Norway, traditional management has been continued in cooperation with local farmers in order to preserve the open heathlands and its associated culture (Haaland 2003).

In those places where traditional burning practices have been maintained, pasture burnings have been subject to support schemes and, in some cases, have converged in a modern management technique used for fire risk reduction or the management of natural areas, prescribed burning. In these cases, traditional practice is restored through institutional practice (Ribet 2009), which finds its referent in pastoral burning (Lambert 2008). In practice, however, the development of prescribed burning programmes can be carried out with greater or lesser integration

of traditional know-how ranging from complete substitution by professionals, execution by professionals with the support of shepherds, to training and execution by shepherds.

As new opportunities for both traditional and planned fire use practices increase in Europe, it is crucial to identify and exchange best practices in order to assist countries and regions in identifying the steps to be followed in order to sustainably integrate fire as a tool in managing the environment. Therefore, participatory mechanisms, lesson-drawing, know-how transfer and training schemes are required in order to move from a one-dimensional perception of the negative impacts of fire to that which considers the positive effects of fire within an integrated fire management strategy. Further, learning processes on fire use should be enhanced within the existing national and international fire management networks.

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2. Identifying Good Practices and Programme Examples for Prescribed Burning and Suppression Fire

2. Identifying Good Practices and Programme Examples for Prescribed Burning and Suppression Fire

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2.1 Reasons and opportunities for the use of fire in Europe

Pollen and charcoal records in Western Europe reveal the advent of slash-and-burn agriculture in the late Neolithic between 4300 and 2300 B.C. (Rösch et al. 2004). Since then, the historical use of fire has been manifested in the development and shaping of a variety of land-use systems in the region (Goldammer et al. 1997; Pyne 1997). Mechanical treatment, the intensive utilization of biomass for domestic purposes, the impact of livestock grazing and the application of fire modified formerly forested lands to open lands and shaped distinct landscape mosaics. These open land ecosystems provided habitat requirements for a flora and fauna that otherwise would not occur in forest ecosystems.

Modern agricultural practices and the reduction of fire use due to legal restrictions or prohibitions in most European countries on one side and the rural exodus associated with the abandonment of traditional land management practices, including fire use, on the other, are dramatically altering these ecosystems. The rural depopulation and the rapid increase of fallow lands are resulting in a loss of open land ecosystems and habitats, even resulting in the alteration of whole landscape patterns. At the same time, the increasing availability of phytomass – a consequence of the decrease of its use – has resulted in an increase in fuel loads at the landscape level and hence an increase in wildfire hazards.

There are thus a number of reasons and approaches in Europe to maintain, restore or introduce the use of fire in some ecosystems or land-use systems.

First, as fire use is part of the cultural heritage of European rural communities, preserving fire culture in those regions and places where it has remained can be justified, despite the recent territorial trends. Furthermore, the lessons to be learnt from the traditional wise use of fire could lead to innovative and efficient fire policies in Europe, which give response to the demands of those European rural communities with a fire culture that depend on the use of fire for their welfare. Not only is this beneficial for them, it also constitutes a fuel management scheme which reduces fire risk in the community (Lázaro and Montiel 2010: 148).

Second, there is the need to understand fire behaviour in order to deal with the current fire problem in Europe. Although the problem differs from one region to another, a general summary could be made from the appearance of new fire-prone

areas and by the proliferation of megafires. It would also be interesting to capitalize the remaining knowledge of fire use and the experiences accumulated by others through the demonstrative function of the existing good examples of fire use for different management purposes.

Critical knowledge and understanding of good fire-use practices and programmes in different regional contexts and land-management systems are undoubtedly needed to acquire a realistic, strategic vision of fire management that is adapted to the current challenges and new demands in the context of global change.

2.2 Management purposes for fire use

In Europe's landscapes, the prevailing fire regimes have been shaped by human-ignited fires. Direct fire application in land-use systems and human-caused wildfires – ignited accidentally by negligence or by design – have influenced both cultural and natural landscapes since the beginning of land cultivation. Thus, the targeted use of fire in ecosystem management in Europe is predominantly in those vegetation types that have either been shaped by human-ignited fires over historical time scales or where the application of prescribed fire reduces the vulnerability to and damages from uncontrolled fires. Fire is also used as a tool to substitute abandoned cultivation practices and control wildfires.

2.2.1 Maintenance of grazing lands

The use of fire to maintain grazing lands' openness and species composition is the most common practice that has survived its early application throughout Eurasia. Pastures that are threatened by succession are traditionally burned in a region stretching from the western Mediterranean via the Balkans to eastern Europe. Although banned by law in most countries, burnings are still practiced in many places (Lázaro and Montiel 2010). Together with the burning of agricultural residuals, pasture burnings are a major cause of wildfires, particularly in Mediterranean Europe.

Illegal burning is often carried out as 'hit-and-run' practices – pastoralists setting fires and fleeing the site to avoid prosecution. This often results in uncontrolled fires with a high likelihood of developing and spreading in the form of devastating wildfires to the bordering terrain. While many countries have not yet attempted to introduce a solution to this problem, Spain has made significant progress by developing a government-supported permit and support system for the use of prescribed fire for grazing improvement and fire social prevention (see Chapter 3.5). Similarly, prescribed burning for rangeland improvement is practised by the French Prescribed Burning Network in the Department Pyrenneés Orientales (see Chapter 3.4)

2.2.2 Wildfire prevention and control

The use of fire in the prevention and control of wildfires has a diverse history throughout Europe. While the application of prescribed fire to reduce fuels and

thus wildfire hazard within forests and in open lands surrounding forests has been practised only recently, fire used to suppress wildfires has a rather long tradition in some European countries.

Wildfire hazard reduction burning in forest stands and surrounding vegetation
In Europe, the concept of using prescribed fire (PB) as a management tool to reduce combustible materials on the surface of forest stands, and thus the energy potential and the risk of high-intensity and severe wildfires has a relatively short history. Prescribed burning for fuel reduction in forests was first practised in Portugal in the 1980s (Rego et al. 1983; Fernandes and Botelho 2004). The use of fire to reduce wildfire hazards in forests and brushlands by means of reducing fuel load or creating and maintaining fuel-breaks then extended through France and Spain. Professional networks were thus created to develop these fire use practices in southern regions (see Chapter 3.4)

The introduction of prescribed fire for wildfire hazard reduction can be considered as an innovative tool, applicable in forests and other wooded lands with target species resilient or tolerant to low-intensity surface fires. In some cases, prescribed fire can be regarded as a substitution tool to replace historic fuel reduction methods, e.g. the intensive use of biomass for domestic or silvopastoral forest use.

Suppression firing
Fire has been used by local inhabitants as a firefighting tool long before the Fire Suppression Services were established in the many European countries prone to fire hazards. Recently, firefighting administrations have closely examined the use of fire being used as a complementary tool with other firefighting techniques. In fact, suppression fire is a potentially powerful and very efficient technique, especially in the event of large wildfires (Montiel et al. 2010)

The use of fire to fight wildfires may involve a number of techniques such as backfiring, counter firing and burning out. The development of these techniques may have an impact on European wildfire policies and entail the substitution of the fire exclusion approach by the professional and technical use of fire. Nevertheless, suppression firing techniques are not yet sufficiently used in Europe – being first developed in Portugal and Spain (in the 1970s and 1980s), and more recently in southern France and a number of other European countries. Two European institutional programmes for the development of suppression fire techniques are considered in this book: the example of the Portuguese National Programme on Suppression Fire (Chapter 3.6) and that of the Catalonian Regional Programme on Fire Management (Chapter 3.7).

2.2.3 Conservation of biodiversity

One of the main objectives in the use of prescribed fire in western Europe is for the conservation and restoration of the biodiversity heritage of former cultivated lands or lands otherwise affected by human-ignited fires (habitat and biodiversity management). The range of application is rather wide; for instance, Chapter 3.2 provides an example of prescribed burning practices for habitat and wildlife management in Atlantic heathlands (mainly dominated by *Calluna vulgaris*) in

Scotland, while Chapter 3.3 depicts an example of the fire management of protected heathlands in Germany.

The use of prescribed fire in the restoration and maintenance of habitats of species dwelling in forests is pioneered by management in Finland and Sweden. Traditionally, fire has been used in the boreal forests of the Nordic countries in order to improve the growth and productivity of tree stands by removing the temperature-insulating raw humus layers or to facilitate natural forest regeneration (Viro 1974; Mälkönen and Levula 1996). Since the 1990s, first experiments and currently extended applications have been underway to use fire to re-create forest stands as they were under pre-industrial conditions – more open stand structures – and to create habitats for endangered insect species (e.g. *Stephanopachys linearis* and *S. substratus; Aradus spp.*), wood-decaying fungi and vascular plants. Chapter 3.1 provides the history and objectives of the use of prescribed fire for nature conservation in protected areas in Västernorrland, Sweden.

2.2.4 Substitutional fire use for landscape management

The use of fire as a tool to substitute or replace another form of vegetation treatment is referred to as substitutional fire use. In central Europe, there are abundant open vegetation types that were shaped by agriculture, grazing or other land use (the extraction of biomass for harvesting domestic fuels, stable litter, thatching material, etc.). Some of these open land habitats have a high biodiversity or landscape conservation value. In the late 20th century, many sites threatened by succession have been maintained by mechanical (mowing, mulching, etc.) or prescribed grazing measures that were financed by public subsidies. However, increasing costs and the financial constraints of public budgets and a rapid increase of fallow over the last three decades have prompted scientists and conservationists to replace costly mechanical and grazing measures by prescribed fire.

The Middle Rhine Valley (Germany) represents a typical example of the widespread conflict between the high nature conservation value of the cultural landscape and the abandonment of traditional land use. The Valley constitutes one of the largest coherent xerothermic areas of Germany with habitats and vegetation types that are classified as endangered at the European level. The necessity to develop management concepts to protect this landscape was emphasized by listing the Upper Middle Rhine Valley in the UNESCO World Heritage List as a protected cultural landscape in 2002 (Bonn 2004). In order to prevent further loss of the characteristic open habitats as a consequence of dramatic reduction of vine cultivation and other land use, a research and development project investigated the essentially uncontrolled ('semi-wild'), extensive grazing by horses and goats on the steep slopes, clearing the shrub-dominated shallow slopes with tank-tracks and prescribed burning (Bonn et al. 2009). Although prescribed burning was applied successfully during the experimental phase of the project, especially in the grass stage and earlier succession dominated by *Rubus spp.*, it turned out to be limited as a tool for restoring overgrown xerothermic habitats on sites of progressed development stages dominated by *Prunus mahaleb* and *Cornus sanguinea* (Driessen et al. 2006).

2.2.5 Restoration of traditional practices of swidden agriculture

Until the middle of the 20th century, slash-and-burn agriculture with a spatio-temporal land-use pattern similar to the 'shifting cultivation' system was widely practised in Europe and has left landscape features that are still visible, for example the small-sized burning plots with their distinct successional patterns (Goldammer et al. 1997). There are two regions where this kind of fire treatment is practised for demonstration purpose:

- Historic slash-and-burn practice in the Black Forest of Germany: two sites near Freiburg (Yach, Vorderlehengericht) demonstrate the procedure of rotational cutting and use of coppice trees, the burning of residuals followed by the seeding and harvesting of wheat with the subsequent fallow and forest regrowth period (Lutz 2008).
- Koli National Park in Finland is the only national park in the world that has a fire symbol in its logo. The traditional slash-and-burn practice in Koli is demonstrated regularly and reveals the importance of this traditional land use on the composition of Finland's boreal coniferous forest that has been shaped by this cultivation over centuries (Lovén and Äänismaa 2004).

There is also a scientific interest to reconstruct earlier slash-and-burn practices, e.g. those that evolved in the late Neolithic. The most recent experiment to reconstruct Neolithic fire cultivation was conducted in 1999 in Forchtenberg, Germany (Rösch et al. 2002).

2.3 Management and training networks for the use of fire in Europe

During the last several years, a number of informal networks have been created in Europe to promote the exchange of knowledge and skills for the use of fire as a management tool. These collaboration initiatives on the matter of fire training have provided significant effects and practical results on different scales. It is worth mentioning the following bi-lateral or international cooperation programmes:

- *Prescribed Fires Exchanges:* Visiting specialists participate in suppression fire exercises and burning for fuel management (prescribed burning). This is the case of the exchanges between the Northumberland Fire and Rescue Service (UK) and the GRAF-DGPEIS team (Catalonia, Spain), or the SUAMME Service (France) and the GRAF-DGPEIS team (Catalonia, Spain).
- *Knowledge Exchanges:* Exchanges aiming at learning from the experience acquired by the host (past fires visits, prescribed fires results visits, organizational issues, etc) (e.g. Lo Forestalillo and the Fire Paradox Journal).
- *Practices Exchanges:* The main objective is to carry out some exercises, practices and competences evaluation (analysis, exercises, digging firelines, etc). This is the aim of the Fire Paradox Summer Bases.
- *Planned Fire Management Exchanges:* Collaborations in fire situations or at times of high fire risk, with the aim of the visitors participating in fire

suppression or suppression firing exercises. These are usually planned during the period of elevated risk, e.g. exchanges between the GRAF-DGPEIS team (Catalonia, Spain) and the CFVA (Sardinia, Italy); and the Bombers de la Generalitat de Catalunya (Spain) and the Sapeur Pompiers de l'Aude (France).

Eurasian Fire in Nature Conservation Network[1] is one of the early initiatives that provides a platform and networking mechanism for those who conduct research and/or actively apply prescribed burning for the purpose of nature conservation (biodiversity management, habitat management), landscape management and forestry. This network, facilitated by the Fire Ecology Research Group / Global Fire Monitoring Center, followed the tradition of the 'International Symposia on Fire Ecology' held in Freiburg (Germany) between 1977 and 1989, becoming operational in 2001. The region of interest is temperate-boreal Eurasia and the adjoining countries of southeast Europe, Caucasus as well as central and northeast Asia. The network aims to develop and gradually expand communication and networking mechanisms, in which European partners present their views and projects on research and development in the cultural, natural history and prehistory of fire; the application of prescribed fire in nature conservation and landscape management; and fire ecology.

Within the Mediterranean region, the Fire Paradox project has also launched a recent initiative to gather prescribed burning professionals from different countries. Since 2009, two annual meetings in Lousa (Portugal, 2009) and Bosa (Italy, 2010) have held the 'Euro-Mediterranean Prescribed Burning Forum'. The aim is to promote experience and knowledge exchange between experienced practitioners and professionals who are not yet familiar with the use of this technique.

Since 1990, France has also established an active PB network with a total of 28 prescribed burning teams, distributed in the Mediterranean Departments as well as in the Pyrenees and the Alps. Together, they constitute the National Network of Prescribed Burning Teams currently coordinated by the SUAMME (Service d'Utilité Agricole Interchambres Montagne Mediterranéenne Élevage). The objectives of the network are knowledge transfer, experience exchange, training and stimulating the dialogue between the different stakeholders involved (Rigolot 2000). One of the main results obtained by the French PB network has been a certification for PB Bosses organised by the École d'Application de la Securité Civile (ESASC).

Fire training exchanges and networks are thus badly needed to empower potential users to experience different fire environments in order to develop the confidence and competence to use fire in their home regions. This is particularly important in the case of suppression fire, as to acquire enough experience in one's home area alone can take many years. Furthermore, experiencing fire use in various environments and organizational structures broadens an individual's competence and provides for a more flexible use of fire. Fire training networks also help by providing a sufficient number of experienced personnel in cases where mutual assistance is required and for work exchanges.

1 http://www.fire.uni-freiburg.de/programmes/natcon/natcon.htm.

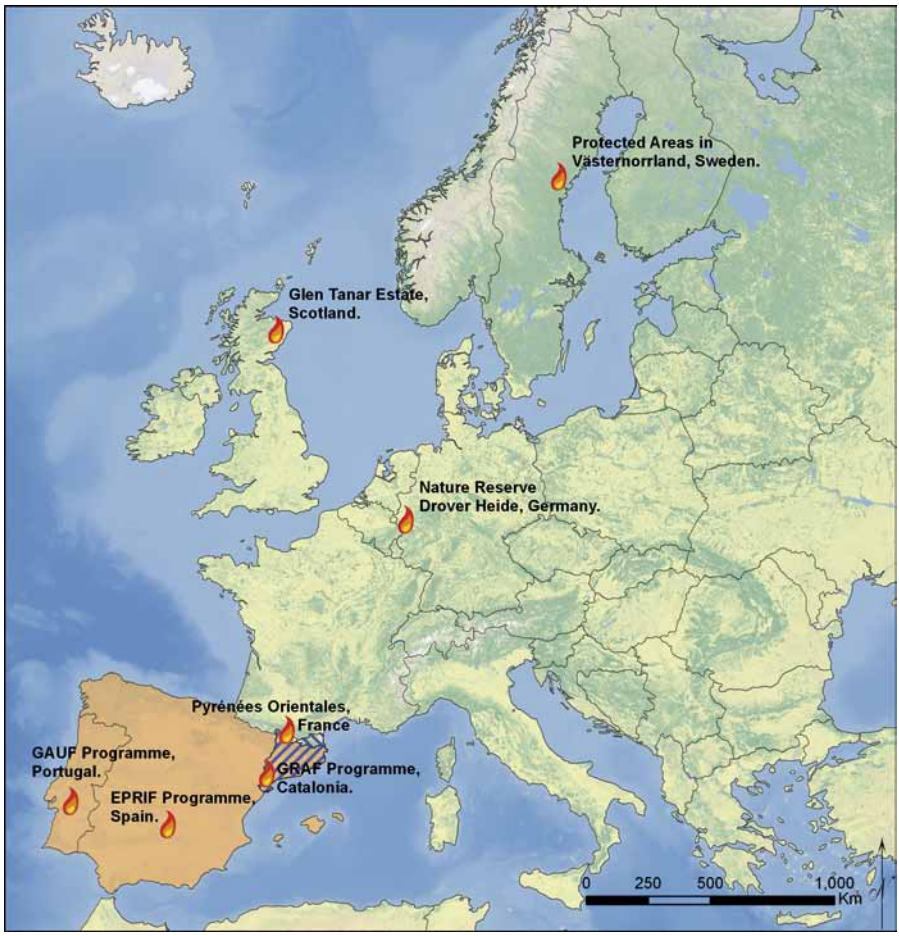

Figure 1. Distribution of selected good practices examples and national and regional programmes for fire use in Europe.

2.4 Selection of case studies

Beginning from the utility and interest of fire use with different management objectives, a selection of good practices and best programmes is presented in the following chapters. The aims of this selection are to (i) provide sound examples of how fire use is applied in Europe for land and fire risk management; (ii) present different aspects of this management tool from particular cases; and (iii) determine the supporting and impeding factors for fire use in Europe's regions.

The selected case studies are representative of the different management objectives for the use of prescribed burning and suppression fire in Europe. They also show diverse implementation procedures, adapted to different countries and socio-spatial contexts (see Figure 1).

The first example of good practices is the case of prescribed burning for nature conservation in protected areas in Västernorrland (Sweden). Chapter 3.1 presents the bases, the implementation process, and the assessment of a recent prescribed burning programme developed in a nature reserve and framed in a boreal forest context.

The German case study also concerns a nature reserve related to landscape management objectives. The use of fire in the Drover Heide nature reserve, over an open heathland and poor grasslands ecosystem, has overcome different legal and ecological constraints and, as a consequence of the successful results obtained every year since 2007, has raised interest in the neighbouring areas.

Unlike the two prescribed burning programmes recently carried out in Sweden and Germany, the practices of fire use for habitat and wildlife management at the Glen Tanar Estate (Scotland) are the best example of a deeply-rooted traditional use of fire in Europe. The maintenance of fire use as a land management practice (called 'muirburn' in Scotland) is a good expression of the strong cultural component of these techniques. Further, the Muirburn Code and the Heather and Grass Burning Code are also good references for future 'best practice' management guidelines.

Another representative case of fire use in Europe is the French Prescribed Burning Network, presented through the experiences of the professional team in Pyrenneés Orientales. This national network is established in Mediterranean regions, covering diverse management objectives from wildfire prevention to pastoral and biodiversity purposes. The experience of the Pyrénées Orientales unit is exemplary given its long period in service as well as the importance of the surface area that has been treated for the last 20 years (600 to 1400 ha each year or a total of 17 000 ha on some 1900 plots).

Finally, three nationwide programmes of fire use with different objectives are also included. The Spanish EPRIF Programme is a strategy for the conciliation of interests between rural people and forest administration, comprising the wise use of fire for grazing improvement and social fire prevention. This programme deals with the negative aspects of traditional fire use – the origin of many forest fires – and at the same time it attempts to promote best practices.

The Portuguese National Programme of Fire Use and Analysis Group (GAUF) focuses on tactical fire use for fire fighting. This Programme has a strong strategic component and its implementation is carried out by professional teams. The Catalonian Programme of Fire management, implemented by the Forest Action Support Group (Grup de Recolzament d'Actuacions Forestals, GRAF) is a similar one. Its objective is also to manage forest fire risks. The philosophy of this Regional Programme, established in 1999, is to base fire fighting on fire analysis, in order to adopt dynamic strategies of attack, containment, confinement or management by using hand tools, heavy machinery as well as suppression fire tactics.

All the examples presented below follow a similar structure. The situation before the fire use practices or programme began is first described, including major issues, trends and conditions in the area (e.g. the ecological role and impact of fire, and the economic and social contexts). Second, a summary of the main objectives and strategies of the programme or action is provided with a description of the problems faced in its implementation. The results achieved are then presented – how inhabitants' living conditions and the sustainability of ecosystems have improved, the identification of specific opportunities and constraints as well as addressing people's

changing attitude towards fire use. Finally, the most important lessons learned are summarized together with a reflexion on how the initiative benefited from other experiences and how the programme could be replicated or adapted elsewhere.

The examples of good practices and programmes presented below provide critical knowledge and understanding of fire use in different regional contexts and land management systems, aiming to disseminate the social and ecological opportunities for these techniques.

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3. Good Practices and Programme Examples

3.1 Prescribed Burning for Nature Conservation in Västernorrland, Sweden

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3.1.1 Introduction

Fire in boreal forest ecosystems

Before the beginning of modern forestry in Sweden, fire was the dominant disturbance agent in boreal forests. Fire´s most important role is the creation of a diversity of stand structures and successional stages. Several studies have provided us with an understanding of the natural and historical fire regime (Zackrisson 1977; Engelmark 1987; Niklasson and Granström 2000; Carcaillet et al. 2007). We know from these studies that the first attempts of fire suppression started at the end of 1800. At the beginning of the 20th century, both fire frequency and annual burned area had declined dramatically, since the focus of modern forestry was the production of high value timber. There was no place for fire any longer and the formerly fire prone pine (*Pinus sylvestris*) dominated forests were transforming into dense and productive spruce (*Picea abies*) dominated stands with little to no fire influence. At present, the annual burned area is only a fragment of what it used to be and, as a consequence, the fire return interval has increased significantly (Niklasson and Granström 2000; Granström 2001).

As a result, Sweden's boreal forests do not look like they used to since both fire suppression (Esseen et al. 1997; Linder et al. 1997, Kouki et al. 2001; Uotila et al. 2002) and intensive forestry (Linder and Östlund 1998; Axelsson and Östlund 2001; Kouki et al. 2001) have changed both their structure and their dynamics, especially over the past 50 years. A pine dominated forest before the beginning of dimension cutting could be described as a multi-layered forest (Linder and Östlund 1992) with a relatively open stand texture as a consequence of the effects of a natural fire return interval of 40–50 years. At present, however, most stands have not experienced any fire for more than 120 years. A study from a nature reserve in Västernorrland shows that a stand logged in the middle of 1800 had an average of less than 200 dominant trees per hectare, with a mean basal area of 23.6 m^2 per hectare (Pahlén 2000). Just before transforming the same area into a nature reserve, the same stand was again logged and had an average 850 trees per hectare, and a mean basal area of 35.3 m^2 per hectare (Pahlén 2000).

Figure 1. Low intensity surface fire is the prevalent type of forest fire in the boreal forest in Sweden (photo byTomas Rydkvist).

In general, it is widely recognized that missing disturbance events and a change of their historical pattern are factors of major importance when it comes to loss of biological diversity in many parts of the world (Gill and Bradstock 1995), especially in boreal ecosystems (Granström 1996). The dramatic changes in forest landscapes have led to more favourable conditions for shade tolerant species – both among fauna and flora – since the forests have become a lot denser. There is a great need, therefore, to restore protected areas in boreal forests with the reintroduction of fire.

In order to recreate fire prone forests and promote fire dependent species, prescribed fire has been increasingly used in Sweden to meet specific management objectives. According to the Swedish Forest Stewardship Council (FSC) standard, all certified forest owners must burn an area corresponding to 5% of their annually logged area (Swedish Forest Stewardship Council 2000). Further, the local County Administration of Västernorrland performs prescribed burning in nature reserves with the main objective of restoring the stand structure and composition in forests where fires have been suppressed for a long time, as well as to provide habitats for species that benefit from forest fire.

Prescribed burning in Västernorrland

The first prescribed fire in a nature reserve in the county of Västernorrland was set in 1993 in the Jämtgaveln Nature Reserve. Fire history in the area indicated that there

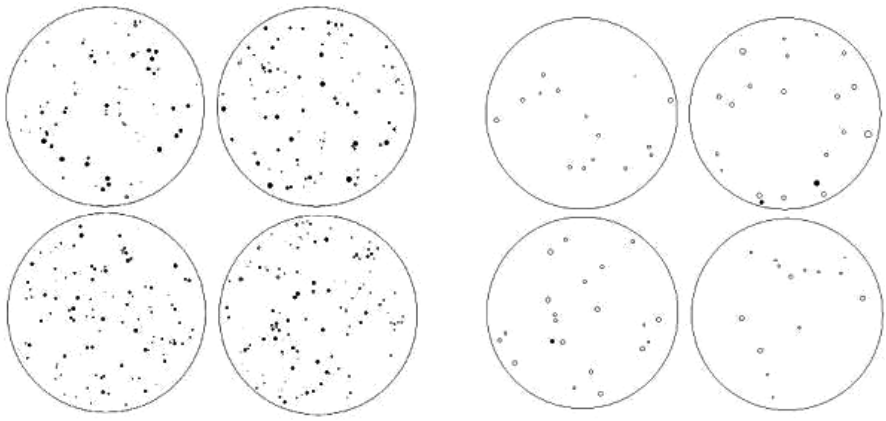

Figure 2. Different tree density between today's forest (left) and the same stand between the latest fire and dimension logging that started around 1850–1870 (right). Black dots are living trees (Pahlén 2000).

had been at least 64 fire events between 1364 and 1894 (Linder 1988). This first prescribed burn was planned in a seed-tree stand in a heavily logged area under an agreement between the government and the landowner before transforming it into a nature reserve. There were neither objectives nor prescriptions set for the burning other than the use of fire itself. The fire had a very low effect on biological diversity – the fire burned with high-intensity and caused high mortality among the retention trees. There were two more burns in 1995 and 1996, both in logged stands, but with more seed trees left per hectare and a less intense fire compared to 1993. Some pines received fire scars - a desired and very positive effect for biodiversity. In some fire scars, the red-listed beetle *Stephanopachys linearis* – a fire-dependent species which lives in the rough bark adjacent to fire-scars – was found. However, this was put down to good fortune since these two fires lacked objectives and prescriptions. Had there been objectives and prescriptions, the area might not have been burnt with the same ignition pattern or technique or under those conditions. The fires did not have any beneficial impacts on the biological diversity in the stands and were merely thought as a trial phase. However, these burns did not change the generally negative view of fire among nature conservationists. There were no plans on allowing prescribed fires to become a natural ingredient in the management of nature reserves.

In 1999, the county administration conducted what is the still largest prescribed fire in the county in the Helvetesbrännans Nature Reserve, which totals 120 hectares dominated by a fire shaped forest. A study of fire history found traces of at least 28 fire events between 1165 and 1891 (Jonsson 1999) and an average return interval of 84 years before 1650 and 58 years after 1650 respectively, and was thus considered fire prone. This burn also lacked specific objectives and written prescriptions, with the use of the fire itself being considered sufficient. This burn differed from those in Jämtgaveln in that it was conducted in an unlogged stand. Generally, the fire had only very little impact on the tree layer and no impact on the duff- and raw

humus layers since the conditions were somewhat moist compared to the current prescription windows. In some smaller patches, however, it was able to cause both high mortality and a change in the stand structure where the habitat for some pyrophilous insects, such as the red-listed beetle *Nothorhina muricata syn. punctata*, has improved. The fire was also intense enough to kill off almost the entire spruce dominated understory. However, there were no intentions on using fire on a broader scale in order to manage nature reserves.

The situation did not change until the Restoration Programme started in the Stormyran-Lommyran Nature Reserve in 2002. The fire in Helvetesbrännan, however, served as a learning object, with the burning objectives set beyond what was achieved there. The Restoration Programme had a desire to mark a shift in paradigm from free development towards a management that is based on natural disturbances – something that could be applied to almost every nature reserve in the county.

3.1.2 The Restoration Programme in the Stormyran-Lommyran Nature Reserve

The need for restoration in Stormyran-Lommyran

The first step in the plan of the Nature Conservation Office of the County Administration of Västernorrland to try and turn the management of protected areas into a disturbance-based management started with the restoration of the Stormyran-Lommyran Nature Reserve (SLNR) where fire would play an important role for many years to come. The Reserve is an area with both mires (400 hectares) and forest area (600 hectares). In the Swedish Mire Protection Plan, mires are classified in the highest protection class and within this context, the idea evolved to include more than 600 hectares of fire prone forests surrounding a large mire complex in the protection plan to restore these stands to a pre-industrial stage since they had been little affected by modern forestry. They had, however, been exposed to dimension cutting from 1861 (Jonsson 1999) and some minor logging operations. This was an opportunity to restore a large area of forest into more favourable habitats for fire dependent species as by opening up the stand, lighter conditions and a warmer stand climate could be created to favour pyrophilous species. A great many of these species are favoured by disturbances such as fire; however, their populations have declined rapidly due to fire suppression and the lack of disturbances for more than 100 years. A full-scale restoration also aimed to develop methods to increase the amount of dead wood – both snags and downed logs.

Four major goals for the restoration were set up:

- *Recreate a fire prone stand structure*
  A fire prone stand structure is a forest with great heterogeneity regarding tree age, diameter, height and species composition; it also includes a large proportion of deadwood in different stages of decay – both downed logs and snags. An important feature is the variety of both species and the numbers of deciduous trees in the boreal forest.

- *Create the possibilities for the regeneration of pine and deciduous trees and create options for pine to grow big*
  We lack the regeneration of both pines and deciduous trees – chiefly aspen (*Populus tremula*) and willow (*Salix caprea*) – which are very important to biodiversity. We also lack big and very old pines. One solution would be to promote the annual growth rate by reducing the amount of stems per hectare and thus increase the nutrient and sunlight available for individual trees.
- *Increase the amount of deadwood, chiefly snags – both instantly and delayed*
  Since there has been no large disturbance in the area since 1876, there has been no major production of deadwood. The snags that should be present have either been logged for firewood, tar production, forest hygiene or as prevention against forest fires. Although this might be the most important goal for biodiversity, it will take the longest time to fulfil if production is not boosted by deliberately injuring pines to shorten the time to produce wood of other qualities, e.g. resin impregnated wood. The long-term goal is that pine snags should be some 15% of the total volume.
- *Strengthen populations of fire favoured species at the landscape level*
  By starting our work by fulfilling the other goals, we believe that we will create habitats, structure and substrates important to fire-dependent and fire-favoured species.

Restoration measures prior to the prescribed fire

The restoration measures included the selective logging of some 38,000 m^3 of surplus trees, mainly spruce, to be followed by the planned prescribed burning of 575 hectares. It was also necessary to reduce the number of trees from the average 900 stems per hectare to 400.

There were two main reasons why selective logging was used. First, a dense stand, such as in the reserve, is risky to burn due to the abundance of ladder fuels; second, it can take a very long time before it dries out sufficiently to reach the desired effects. Dense spruce stands are susceptible to torching and bear a high risk of spotting, which needs to be minimized during a prescribed fire. Another risk is that they often grow into the crowns of large pines; for this reason, in order to save and restore a forest dominated by 400-year old pines, the risk of losing them through torching spruce takes high priority. This means that as many of them as possible must be removed and the branches are cut close to the ground to prevent the flames being carried up into the canopy.

After burning selectively logged stands in SLNR it was envisaged to transfer the knowledge acquired in this area into other reserves that are lacking fire influence. The initial idea was to test the large-scale removal of timber and logging slash to reduce the available fine fuel; following the trial phase of the prescribed fires in SLNR, stands would then be burned in other protected areas without any removal of timber with fire as the sole management method. It was decided to start the prescribed burning programme by conducting a couple of prescribed fires in fairly open stands with defined and safe perimeters. The opportunity for a trial phase was thus given in SLNR since the perimeters of all burn plots had been cleared of trees

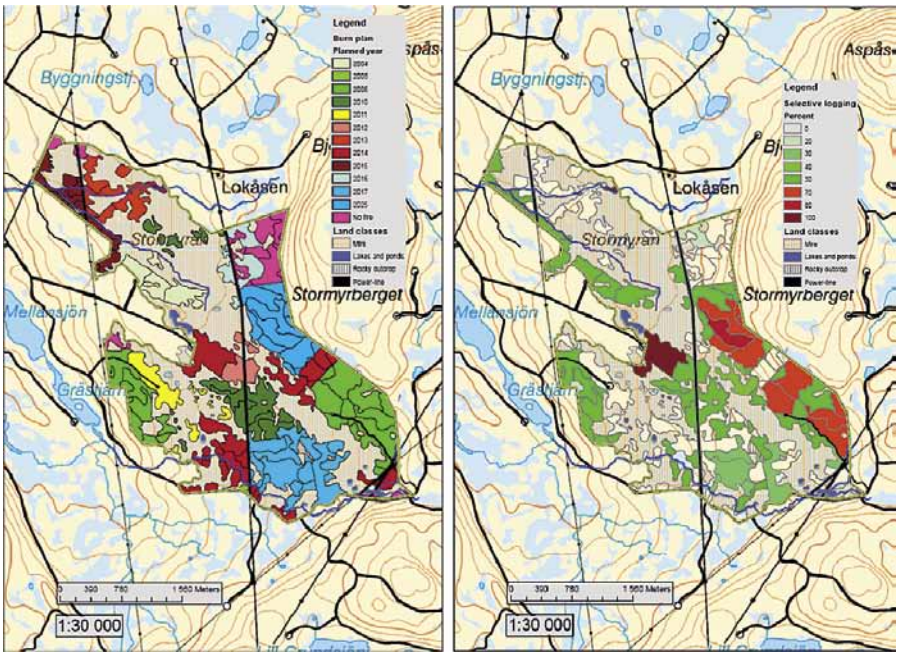

Figure 3. Map of the Stormyran-Lommyran Nature Reserve showing the area planned for prescribed burning (left) and for selective logging (right).

and slash within a 20–metre border. It was thus possible to start with well-planned areas before the fire programme was expanded.

3.1.3 Implementation of the prescribed burning programme

Conflicting perceptions on management concepts

Most nature reserves do not accurately represent the history of boreal forests in Sweden, since there is a lack of fire-affected reserves; for this reason, it was (and still is) recommended not to leave any more fire-prone boreal forest for free development. The concept of restoration in a boreal forest, however, was not easy to launch since it was innovative in Swedish conservation practice. Many conservationists, NGOs and government officials consider that Sweden's boreal forests do not require any management regardless of their size. Many deem forests as being 'romantic', leaning towards the idea of 'free development' where an unmanaged and untouched forest resembles a state of 'Shangri-La'. The predominant attitude among Swedish society was that man should not intervene and that disturbances such as fires, storms, and insect outbreaks were exceptional and exogenous events that do not belong to the normal state of forests. Consequently,

Figure 4. A fire shaped forest in the nature reserve of Hede urskog in the county of Jämtland. This is what we hope to achieve by our restoration (photo by Göran Eriksson).

the need to protect forests against such disturbances in both managed forests and reserves (Kuuluvainen 2002) is widely proclaimed by nature conservationists. While these perceptions might be applicable to very large areas, in Sweden nature reserves cannot be isolated from the surrounding landscapes in which they exist. If this is taken into consideration, it means that these areas must be actively managed in some way or another to mimic the effects of natural disturbances.

In this context, it is interesting to see that fire management in Canada's National Parks also has to deal with similar problems. In Canada, society previously viewed national parks as places where natural processes could operate free of human intervention. However, there was a gradual realisation that parks were not self-regulating systems but remnant islands impacted by human stress. The lack of disturbances is evident even in Canada's much larger national parks compared to Sweden's more affected forests.

One important aim, however, was to define fire as a natural ingredient in managing protected areas with the idea to start using prescribed fires in SLNR as a 'kick-off' to a genuine fire programme for the whole county. To this aim, many excursions to the area for conservationists, NGOs, decision makers and the general public had to be organised. It was necessary to identify the problems that exist in boreal forests in Sweden and it was important to realize the role of natural disturbances such as fire and to improve the knowledge and know-how of prescribed fire. As a result of these

first awareness campaigns, new courses and training on fire as a restoration tool, fire behaviour and fire effects on habitats and species were developed. It was felt time to launch a package of education materials on boreal forest history and natural disturbances and how to use fire so that managers could feel comfortable about what to do in nature reserves.

Further, many people, including persons working with conservation, are afraid of fire and the fact that it can destroy or consume everything in its path – even whole forests. Two seldom asked questions are why forests look like they do and what processes and events (disturbance history) have led to this. As the answer would be that forest fires were a regular occurrence prior to modern forest management, it was crucial to get this message across to decision makers, since without a large fire programme there would be little point in including the forest as a part of the nature reserve.

The convincing phase

The next step was to convince local NGOs that Sweden's boreal forests need active management such as prescribed burning as well as to convince the general public that a large fire programme is not a waste of taxpayer´s money, but an investment in biological diversity. It was difficult, however, to reach out to NGOs with the message of prescribed fire and other management activities in boreal forests since the majority involved in conservation organisations still favour free development. Another important step was to present and discuss the fire programme with the local fire department. The reaction was positive and after some fruitful discussions with the fire chief and other staff agreements were made.

Finally, a very supportive argument for restoration was financial. Since the total volume of timber that was planned to be removed had a market value of some SEK 6.5 million (EUR 650,000), the costs of purchasing the land could be reduced by this amount. The next step was to come to an agreement with the previous landowner Svenska Cellullosa AB (SCA), a major Swedish forest company, where and how to carry out the selective loggings. After an agreement was reached, the County Administrative Board decided where, when and how to carry out the logging with SCA responsible for the actual operation. The logging was planned very thoroughly because we did not want it to be an ordinary harvesting operation – we wanted to use the harvester in different ways, e.g. injuring pines by scraping pieces off the bark so as to make them produce more resin and thus impregnate the wood. This was done because there was a shortage of resin-impregnated wood due to a lack of disturbances – the pines that grew after the last fire had not been exposed to any disturbance since the late 1800s. By targeting spruce, we also could reduce ladder fuels – sometimes a major problem when burning forest stands similar to these.

3.1.4 Results

The first prescribed fire in the area did not start until August 2004 due to a lack of experienced personnel and available contractors to conduct the burn. Once started,

Figure 5. Prescribed burning was introduced into Stormyran-Lommyran Nature Reserve in 2004 as a restoration tool (photo by Mathias Rönnqvist).

it appeared to be meeting all the biological objectives and was thus considered as a good burn. An overlying layer of warmer air at the height of the canopy and a steady wind at 2.5 m/s prevented most of the convective heat from reaching the canopy directly; further, the smoke column with the convective heat was bent off and thus did not have lethal temperatures when it reached the lower canopy. Consequently, the desired tree mortality of maximum 50% set in the prescriptions was not reached satisfyingly, although some 24 hectares were burnt in only 4.5 hours. The fire was conducted as a strip ignition against the wind with spacing of five-metre wide strips to become ten-metre spacing because of the low fire intensities. Only where intense updrafts of hot gases were able to break the thermal layer was a patchy mortality observed; the resulting heterogeneity was a very positive effect. In some smaller patches, a smouldering fire was allowed to burn for nine weeks, which had a major impact on the tree-layer since many trees fell due to almost complete root consumption. Smouldering fires have been a vital ingredient in the natural fire regime since the highest frequency typically occurs at the end of July (Engström 2000) when the humus layer often is dried out thus sustaining smouldering combustion. It created good seedbeds in patches of bare mineral soil for the regeneration of both pine and deciduous trees, and thus can be regarded more positive than negative despite the root consumption. The regeneration of *Populus tremula* suckers and *Salix caprea* shoots within the burn site was abundant

Figure 6. Fire scars on old pine trees are the preferred habitat of some pyrophilous insect species (photo by Tomas Rydkvist).

– even the germination of aspen seeds was found. Another positive effect is that the seedlings inside an area with a 'jackstraw' structure of fallen trees have more chances of escaping browsing since elk and deer avoid such areas and the difference in tree height associated with reduced browsing is substantial (Ripple and Larsen 2001; de Chantal and Granström 2007).

After the success of this first prescribed burn, subsequent fires in the area aimed at a gradual improvement – both of the biological results and overall burning procedures. In 2006, 126 hectares were burnt on four occasions in areas that had been logged in 2003 when 9,111 m³ of solid wood had been removed. During the logging operations, the harvester cleared a ten-metre wide strip of trees, brushes and slash to secure the perimeter around the burn site. In some parts of the perimeter, a mineral guard was constructed with an excavator with the remaining parts secured either by mires or by a small brook that beavers had dammed to a considerable width. The excavator also dug water holes around the perimeter to secure a good supply of water and reduce the length of the hose lines. A wet-line along the border between the burn sites and an unlogged stand was constructed with a helicopter that was on stand-by during the burning operations. Since there were no more security concerns, the opportunity in such a large burn plot to alter ignition patterns and fire intensities could be intensively used to create heterogeneity. Consequently, the fire produced very patchy tree mortality and a diverse impact on the ground layer.

In July 2006, a contractor was assigned to conduct a burn in an approximately 40-hectare area in the western part of the nature reserve. The FWI index values were well within the prescriptions, and the objectives for the burn had been set as a maximum mortality of 50% over the whole area with no older pines being destroyed. It was vital to burn with low intensity in this stand since there were many pines from an older generation, many of which had multiple fire scars where traces of the fire-dependent red-listed beetle *Nothorhina muricata* had been found – an insect that populates the same tree for decades (Ehnström and Holmer 2007). These stands were logged in a similar way as the rest of the stands in the reserve; however, it had also been cleared of logging slash to keep the fire intensity at a low level to save the old pines and the substrate for *Nothorhina muricata*. This burn was the worst burn in a protected area so far – the contractors did not meet any of the objectives, nor did they keep it within the range of the stipulated mortality since it was a total kill. The contractors tried to complete the burn before some incoming rain in the evening and advanced too quickly, letting large parts of the area burn with the wind. This resulted in too high intensities and too fast rates of spread killing all the old pines – a great loss since such old pines are very rare in today's boreal forests. The flame length was estimated by measuring the charred height - as high as 9.2 m on the leeward sides and 2.5 m on the windward side. Van Wagner's crown scorch height model (Van Wagner 1973) predicts that for a wind speed of 2.2 m/s, with an air temperature of 21°C and a flame length of 3 m, there will be a scorch height of just below 20 m. Very few pines can survive a fire with such intensity. It will take some time before a new forest is established since the nearest seed source is a good distance away.

This planned prescribed fire was completed with a second burn in August 2006 when the remaining 17 hectares were burned under supervision of the county administration. It was a completely different fire with low intensities and low and patchy mortality as a result of altering the firing technique and the ignition pattern. The average flame length in this second burn was 0.5 m. Most of the fire was a backing fire and consequently it took some time to complete the burn. In a partially logged stand like this, it takes a backing fire just under one hour to complete one hectare. The burning operation continued without any problems and there was a potential for smouldering fires that probably would keep on burning for some time. During a late season prescribed fire in August, one must be prepared for lengthy smouldering, and a simple mop-up with only water has to be accompanied by hard work with hand tools.

The experience with the fires of 2006 saw the need to start with some serious education and it was clear that an Ignition Specialist (IS) or Ignition Boss (IB) must be in charge of the ignition pattern and firing techniques. Although most of the prescribed burns in the nature reserve had met the plan's overall and specific biological objectives and can be seen as successful burns, they would not have passed as 'good burns' under today's prescriptions and procedures. Several escapes occurred during and after conducting the burns although without any major consequences. This was mainly due to careless patrolling along the fire perimeters and poor mop-up operations as a consequence of poor communications – instructions had not been passed on adequately to the burn crews resulting in many minor mistakes and failures. However, the occurrence of several minor incidents is a good indicator

that there is potential for major failures within the organisational structure. Today, the regulations and prescriptions regarding prescribed burning have been altered with security and information exchange defined as top priority. Even the slightest mistake and a small fire burning outside the fire perimeter are seen as failures. No black area is tolerated outside the prescribed fire perimeter and every incident, good or bad, must be considered during the after action review (AAR). Currently, the judgment of whether or not a fire is good or bad is solely based on security reasons and not biological objectives. A really bad escape can be very beneficial to biological diversity, but it must be handled as a wild fire and managed accordingly.

3.1.5 Lessons learned

One important lesson learned was that it takes much convincing before a fire programme can be started – and once started it demands constant arguing for its continuation, something the Nature Conservation Office was not prepared for. It was not enough to provide some successful examples and prove that prescribed fire improves biological diversity. Decision makers and authorities had to be reached in another way. This was mainly done by increasing the cooperation with neighbouring counties and with the Mid Sweden University, who were able to support the programme with convincing and scientific arguments on the beneficial aspects of fire.

Information exchange is an essential element in prescribed fire – something that needs to be improved in many ways. One way is to seek help from professional fire information specialists, chiefly from North America. Disseminating information to the general public must also be improved by using channels such as the Internet, brochures and newsletters.

Experience has shown that there is a need for more personnel being involved with special assignments during a fire. As a consequence, the organisational structure of the burn teams has been changed to include an Ignition Specialist/Boss instead of just using a Burn Boss. This has substantially improved the quality of the burning and helped to reach the desired objectives more easily since this is a main responsibility of the Ignition Specialist/Boss. Furthermore, the Ignition Specialist is also responsible for collecting weather data and has the mandate to refuse ignition due to bad conditions or other reasons.

It is also apparent that developing the structural hierarchy based on the concept of High Reliability Organising (HRO) is not an easy but an essential task. At present, as there is only one burn crew with high-enough competence, there is an urgent need to educate new crew members in all positions of the organisation, particularly Ignitions Specialist as they are responsible for reaching the overall objectives. The need for education and training must be met through more demanding objectives and more technically demanding burnings. At the same time, there is also the need to quickly create several new prescribed fire teams in order to be able to burn several stands or nature reserves in different parts of the county. Since the burning window is typically short, full advantage of good weather conditions must be taken and more burns must be conducted on the same day. This can only be achieved when more people are trained and more equipment is acquired.

3.1.6 Transferability

The prescribed fire programme in Västernorrland has always closely cooperated with fire scientists from the Swedish University of Agricultural Sciences (SLU) who run University courses on Fire Management and play a major role in training crew members in both theory and practice. The courses conclude with an excursion to the burn sites in Stormyran-Lommyran – something that has been appreciated by the students as they get to discuss with fire managers on-site. A close relationship with scientists is also essential in building a responsible organisation based on the latest knowledge.

A joint programme with the neighbouring counties and with the Swedish Forest Service has not only stimulated education and training but also put more focus on the issue. This cooperation, still under development, aims to create mobile prescribed fire teams that operate outside their own county and that can use each other's equipment.

How we have restored our boreal forests in Sweden is a new and unique approach – one that can be adapted in other counties with similar problems. The fact that we have already burned key-habitats is something that other counties in Sweden can learn from. In most cases, it is a matter of attitude and the courage to start a fire in such a stand – as only by doing can we learn and develop.

This fire programme has also attracted some international interest, recently establishing close cooperation with Finland, Canada, the US and Germany. Our aim is to increase these international contacts and cooperation in several ways since we cannot remain in our 'duck pond' for ever. We need to seek contacts with people and organisations with more competence, skill and experience than we have in order to increase our own competencies, regardless of their origin.

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3.2 Fire Use Practices for Habitat and Wildlife Management in Scotland and the UK with a Case Study from Glen Tanar Estate

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3.2.1 The context of fire use in British uplands

Natural fire in Scotland

Scotland has an oceanic or hyper-oceanic climate; however, despite the wet western side and an east that is drier but with rain falling evenly throughout the year, fire is a significant natural force. It is likely that fire has been a significant natural disturbance mechanism in the native pinewoods of Scotland (Peterken 1996), particularly in the eastern highlands. Historical evidence indicates a significant risk of landscape-scale fire in conifer woodlands (e.g. Caledonian Mercury 1826) and heather moorlands (Simmons 2003) started by dry lightning. This is an area with a more continental (hemi-oceanic) climate where short-term droughts are common. At one site in the eastern highlands, Glen Tanar Estate, the natural fire return interval has been estimated to be in the region of 80–100 years, based on the historical evidence of the past four centuries (Marren 1986, Miller and Ross 1990). While fire is regularly used as a management tool in the uplands, fire use has been suppressed in UK forests. By ignoring, rather than studying the role of fire in forest ecology in Scotland, there is a danger of exposing areas to damaging wildfires and failing to recognise an important ecological process.

Traditional fire use

Fire has been associated with land management in the UK back to the Neolithic period and beyond. While initially used to drive or attract animals for hunting, fire has been used for many centuries to improve grazing land for cattle and sheep. This has continued to the present day (Fig. 1) and provides a cultural link back to the swidden practices used when land was originally brought into production thousands of years ago (e.g. Robinson and Dickson 1988, Tallis and Switsur 1990,

Figure 1. A management burn on heather-dominated grouse-moor on Glen Tanar Estate (photo by C. Legg).

Simmons 2003). However, the use of fire as a land management practice (called 'muirburn' in Scotland) developed significantly in the 19th century on the back of the incredible wealth created during the Industrial Revolution in Britain. Some of this wealth was moved back into the countryside by individuals buying estates and then managing these estates primarily as hunting reserves. The techniques of muirburn were adapted for habitat management for red grouse (*Lagopus lagopus scoticus*), an upland game bird that lives in heather (*Calluna vulgaris*). Muirburn is also used extensively to manage red deer (*Cervus elaphus*) in upland areas. There are therefore considerable differences between the traditional techniques used for burning in the UK and prescribed burning operations found in other countries.

The burning of ground vegetation in forests has effectively been suppressed in forests for several centuries. However, fire is sometimes used to clear branches or heather from sites as a ground preparation tool prior to forest establishment by planting or natural regeneration (Hancock et al. 2005). Firebreaks are also sometimes created alongside forests by burning. Fire is used occasionally on farmland in Scotland to burn straw – a practice that has been stopped in England and Wales – and to clear gorse (*Ulex europaeus*). Prescribed burning is used more frequently on private than on publicly owned land.

There is also occasional burning of reed beds where fire is used to 'clean' old stems to improve the quality and commercial value of reed subsequently cut for thatch.

Traditionally, burning was often a shared activity between neighbours or it drew on other manpower resources within the land management unit. However, with increases in labour costs, there are now fewer people with appropriate fire

knowledge to share the task (Hudson 1992). Those left are generally older and less prepared to take the risks of wildfires occurring due to escapes. Insurance is becoming more expensive to obtain and so the use of fire is being constrained in many areas due to the significant resource requirements and financial costs. There is a need to increase the productivity of practitioners by implementing training initiatives and developing a professional prescribed burning skill base. Technical developments and research are also expanding the window of opportunity for burning and helping fire suppression efforts.

3.2.2 The practice of Muirburn

The 'best practice' management guidelines are laid out in the Muirburn Code and its supplement (SEERAD 2001a, 2001b) for Scotland and the Heather and Grass Burning Code (DEFRA 2007) for England. The Muirburn Code and the Heather and Grass Burning Code are concise documents that summarise the legal requirements and provide little more than bullet points on best practice. The Supplement to the Muirburn Code, however, provides a much more detailed discussion and explanation of the recommendations and the logic behind them.

The current guidelines, based on the Muirburn Code and more recent research, can be arranged into four main areas:

- Legislation and legal obligations
- Planning where to burn (and where not to burn)
- Planning how to burn
- Burning safely and responsibly

Legislation

The principal legislation governing muirburn in Scotland is the Hill Farming Act 1946 (OPSI undated b) though this has been superseded in England by The Heather and Grass etc. Burning (England) Regulations 2007 (OPSI undated b) and is likely to be revised for Scotland in the near future. These regulations specify the minimum conditions that must be met by the burning of vegetation. They specify a legal burning season (from October or November to the end of March or mid May, exact dates depending on location and circumstances) and although a permit may be issued for burning outside this period in England this is not currently possible in Scotland. The law also requires the person who makes muirburn to inform neighbours and to take the necessary precautions to ensure that the fire can be controlled without causing damage. Burning at night is forbidden.

The Heather and Grass Burning (England) Regulations 2007 also restrict the area of burning to individual fires of less than 10 ha with other measures to protect soil and water courses. Provision is made for Natural England (the body advising the UK Government on the natural environment in England) to issue permits for burning outside the regulations where this is necessary for safety reasons or it is "expedient for the conservation, enhancement or management of the natural environment for the benefit of present and future generations".

Planning where to burn and where not to burn

A large part of the skill of muirburn lies in understanding where it is appropriate to burn and where burning would be inappropriate. Vegetation burning may have several different objectives, but most often it is to improve the habitat quality for a target animal species. Red grouse, cattle, sheep and deer all have quite different requirements in terms of the age and quality of vegetation that is their preferred food, accessibility of the habitat and the optimal size and spatial distribution of burnt patches. Burning increases the accessibility of young green shoots to herbivores and the young shoots have a higher nutritional value. The new growth of grass in burned areas may also be available several weeks earlier in spring, the time of year where food quality is most critical to animals. Burning is also valuable for maintaining certain types of vegetation, notably habitats dominated by heather (*Calluna vulgaris*). Conversely, fire can be used to promote the establishment of Scots pine (*Pinus sylvestris*) or birch (*Betula spp*) seedlings on heather-dominated moorland adjacent to woodland.

However, the best-practice guidelines focus more on the environmental damage that can be caused by burning in some situations where fire should not be used or should only be used with extreme caution. These include sites with known high biodiversity interests (e.g. land with protected species or sites designated as Sites of Special Scientific Interest where burning may be restricted in a management agreement), woodland, woodland edge and scrub where young establishing trees will be killed. Burning is also restricted where the regeneration of the vegetation is likely to be slow (e.g. at high altitude or on exposed ridges), where erosion may result (steep hillsides and gullies) or where there may be a significant change in the species composition following fire (e.g. where bracken, *Pteridium aquilinum*, is present in small quantities, but may expand rapidly after a fire). There are particular risks of burning on blanket peat and other deep organic soils where the fire may penetrate the ground as a smouldering ground fire that is extremely difficult to extinguish.

Planning how to burn

Much of the practice of burning has been developed by tradition over the last 200 years. The vast majority of burning is done by gamekeepers, crofters, shepherds, farmers and other traditional land-managers. Many learned the skills from older colleagues and have little or no formal training though professional standards and training courses do now exist (Lantra 2002a and 2002b).

Planning for burning largely depends on knowing in advance what your land management objectives are and what type of fire behaviour will achieve this objective. Then more detailed plans can be made on where, when and how you intend to burn. This means understanding the topography and fuel, and how these will interact with different weather conditions, especially the direction and strength of the wind, to create appropriate fire behaviour. Fires are also planned so that they will remain within the threshold of control or reach a point where they will go out themselves without significant effort.

Figure 2. A well-burned grouse moor providing high quality habitat for red grouse with a mosaic of different ages of heather (photo by M. Bruce).

As most burning is carried out by land managers who live and work in the areas they intend to burn, they have a deep understanding of the layout of the ground and how different weather conditions affect fire behaviour on different parts of their ground. On some days when it is too dangerous to burn in some situations it may be perfectly safe in others that are sheltered from the wind or sun. Plans also take into account the distribution of effective natural firebreaks or previously burnt areas that can be relied upon to stop a fire.

Resources and equipment, usually hand tools and some form of water pump mounted on an All Terrain Vehicle (ATV), are chosen that will be appropriate to the ground conditions. Fire plans are written and mutual assistance arrangements between land management units are made through local fire groups, working in partnership with the fire services to provide back up if an escape occurs.

Burning safely and responsibly

With relatively high average fuel moisture, most fires are lit as low intensity head fires, burning with the wind. Burning often occurs over deep organic soils so it is not practical to dig fire lines and a form of ‘unbounded burning’ is practised. With unbounded burning practices, where fires lit with the wind are the norm, careful thought is needed to make sure that the fires can be extinguished.

Figure 3. Traditional burning techniques enhanced by modern prescribed burning knowledge for safe and responsible burning (photo by M. Bruce).

Specialised fire suppression hand tools and pumps have been developed over the years. Control of the fires is usually achieved using hand tools, fire beaters, to control the flanks of the fires or the shoulders of the headfire to pinch the fire out or by allowing the fire to burn out against natural fire breaks.

Work study tests of the fire suppression equipment have been carried out for heather and grass fires (Murgatroid and Bruce 2009). These tests have given an indication of the productivity of different types of fire suppression equipment. The tests compared hand tools, very high pressure fogging pumps and water drops from helicopters. The tests have given an indication of the type and quantity of resources needed to control fires in the uplands of Britain.

In drier conditions, more reliance is placed on fire-fogging units and cut or burnt firebreaks. The very high pressure fogging units are very effective at extinguishing most fires. With the high average fuel moisture, firebreaks are cut with a tractor mounted chain swipe. The firebreaks are not dug down to mineral soil due to the deep organic soil layers, which are usually wet in the spring burning season. Instead, they should be cut immediately before the burning so that the remaining moss and litter does not dry out and let a creeping fire cross the firebreak. The weather conditions should be monitored throughout and burning should be stopped if it becomes either too dry or too windy (over 15 miles per hour, 6.7 m s-1, 24 km hr-1, Beaufort Force 4) when fires become more difficult to control.

Critical to safe burning is to have the knowledge to understand fire behaviour in different circumstances and the skills to be able to apply fire safely. To know in advance how the fire is likely to behave when moving upslope, if the speed or direction of the wind changes, or if the fire moves into a different vegetation type. Some of this knowledge can be taught, but a full understanding of all the complexities involved requires a considerable amount of practical experience and knowledge of the ground.

Implementation of the Codes

Extensive vegetation management by burning in the UK takes two forms. On the drier heather-dominated moorlands of the east of Britain, the management is primarily for sporting interests in red grouse. In order to maintain sufficiently high population densities of grouse to support economically viable shooting, each bird's territory (2–5 ha) should contain a range of different ages of heather. The birds also avoid the centres of large burned areas where there is little cover from predators. The burning is therefore mostly of small patches of less than 0.5 ha and no more than 20–30 m wide. Heather is normally burned when it is between 20 and 30 cm tall (equivalent to a burn rotation of about 10–15 years, depending on growing conditions). At this age, the heather regenerates rapidly and a near monoculture of heather can be maintained. The burning is done mainly by experienced gamekeepers in line with the muirburn code; however, there are some exceptions and management fires do occasionally escape control.

In the wetter west of Scotland, however, the majority of fires are grass fires where the dominant species is *Molinia caerulea*. The burns are conducted primarily by shepherds or for deer management. Because both sheep and deer range over much larger areas than red grouse there are fewer reasons to burn small patches. Fires, therefore, tend to be much larger and less care is taken to ensure that appropriate firebreaks or other precautions are in place. There is still a culture in some areas that 'if it will burn then it should be burnt' with fires are frequently lit and then left to burn out unattended. While fires in Molinia-dominated grasslands rarely burn into the wet organic soils beneath and the grass grows back rapidly, frequent fires in this type of vegetation can greatly reduce the biodiversity interests; further, uncontrolled fires that burn into other habitat types can cause considerable damage.

Fire hazards are increasing in some areas where fuel loads are increasing due to changes in management. For example, where new native pinewoods are being created to fulfil biodiversity objectives, heather is growing along with the regenerating trees. Heather and grass fuel loads are increasing due to a reduction in grazing pressures caused by the rationalisation of upland farms, changes in farm subsidy payments (SAC 2009) and pressure from both environmental interests and the government to reduce wild deer populations (Deer Commission 2001). The cull of animals during the outbreak of foot and mouth disease in 2002 also contributed to fuel-driven fires during spring. Heather has also returned to some pine and larch forests after thinning. Countering the reduction in available labour resources has been a continuing investment by landowners in fire suppression equipment used for burning operations in the form of all-terrain vehicles with small tanks and very high-pressure, low-volume fire fogging systems attached.

3.2.3 Prescribed burning initiatives

Prescribed fire and habitat management in pine forests

Despite the long tradition of vegetation management by burning on open moorlands as described above, fire has not been used for the management of ground vegetation within forests in the UK for centuries and the tradition, once probably associated with cattle grazing, has long been lost. Similarly, fire suppression and the fragmentation of natural pine forests have virtually excluded natural wildfire from the native pinewoods. However, prescribed burning to improve the habitat for conservation of the woodland grouse (*Tetrao urogallis*) has been started recently at an experimental level. The distinctive wildlife of the native pinewoods has been affected by the gradual changes to habitat structure that occur over time. In some long-established native pinewoods such as Glen Tanar and Abernethy, where grazing has been restricted over a long period, blaeberry (or bilberry, *Vaccinium myrtillus*) areas are becoming dominated by long rank heather to the detriment of woodland grouse species (Summers et al. 2004). The dense ground vegetation (often including a deep layer of mosses) also inhibits tree seedling regeneration. Burning has been shown to help blaeberry regenerate and compete with heather (Welch et al. 1994). Consequently, areas of pinewoods where heather growth is suppressing blaeberry under the pine tree canopy have been burnt. Initial results indicate both the successful regeneration of blaeberry (Bruce and Servant 2004) (Fig. 4) and an increase in the establishment of tree seedlings, particularly of Scots pine (Hancock et al. 2005, 2009). No pine trees were killed by initial crown scorch. A fire prescription for this work was gradually developed using a mixture of American, Australian and European material (Reinhart and Ryan 1988, Wade 1986, AFAC 1996a, b, Uggla 1973, Sirén 1973) as a basis that will be interpreted along with the results of the ongoing monitoring work.

Prescribed burning trials at Glen Tanar

The management team at Glen Tanar Estate recognised that there were significant gaps in their knowledge of fire. The team has been actively involved in wildfire training, research and the development of improved fire suppression systems from 1997 (SGFFPG 1999, Bruce 2002, Murgatroid 2002, Murgatroid and Bruce 2009, Lantra 2002a, b).There have been three long-term aims: to understand how to suppress fires successfully, to develop skills in wildfire and prescribed fire management and to develop an understanding of fire ecology in the Scottish context. A key part of this work has been a series of test fires conducted between 1997 -1998 on fire suppression systems and in 2002 on suppression, fire behaviour and fire ecology. The latter project is covered as a case study.

In the spring of 2002, the conservation agency Scottish Natural Heritage commissioned Glen Tanar Estate to carry out applied research into prescribed burning in the form of a series of burning trials (Bruce and Servant, 2003) in and around the forest. Similar trials were also undertaken by the Royal Society for the Protection of Birds (RSPB) at Abernethy Forest Reserve in 2001–2003. This work challenged the assumption that fire should be banned from the forest environment.

Figure 4. Site of an experimental fire in pine forest in Glen Tanar showing the rapid regeneration of blaeberry (*Vaccinium myrtillus*), the preferred habitat for Capercaillie. (*Tetrao urogallus*). There is scorch of the lower foliage on some trees (photo by C. Legg).

Objectives:
The objectives of 2002 project conducted at Glen Tanar were to:

- investigate the relationships between fire behaviour and fire effects in a pinewood context;
- increase the proportion of blaeberry in the shrub-layer of the pinewood by burning a number of strips of heather without damaging other parts of the pinewood ecosystem; and
- inform on the development of fire prescriptions appropriate for the Scottish pinewood context.

The prescription:
The lack of information on prescribed burning techniques appropriate to pinewoods in Scotland led the team towards adapting prescribed burning concepts and experience from other countries with similar ecosystems. One of the key concepts emerging from this review was that conifers similar to Scots pine suffered from fire-induced mortality as a result of three main processes (Reinhardt and Ryan 1988):

a) crown scorch
b) damage to the cambium layer at the bole of the tree
c) damage to the roots

A fire prescription was therefore prepared with these factors in mind and with the knowledge of some key fire behaviour variables. First, that there is an established relationship between flame length, fireline intensity and height of lethal crown scorch for conifers. As a rule-of-thumb, fire is lethal to foliage at a height of six times the flame height (AFAC 1996 a) and mortality was considered likely when the scorch is greater than 30–50% of the live crown (Alexander M, personal comment, but also see Fernandes et al 2008). Second, damage to the cambium layer diminishes in proportion to the thickness of bark protecting the tree and, furthermore, bark thickness generally increases with tree age and stem diameter (Wade 1986). Third, as it is accepted that water creates an effective thermal barrier, roots in saturated soil are therefore reasonably well protected from the heat pulse generated by a passing fire front (Chandler et al. 1983). As has been mentioned, a key objective was to kill the heather and blaeberry bushes but not damage the blaeberry rhizomes and roots underground. Work in Swedish pinewoods by Schimmel and Granström (1996) indicated that this would be possible by controlling fire severity (which is defined as the direct effects of heat on the vegetation, soil and litter layers). Again, the method that can be used to achieve this is to use the protective qualities of a damp moss and litter layer.

The design of fire prescriptions thus incorporated the need for trees tall enough to avoid excessive crown scorch; trees large enough to have sufficient protective bark; and soils that were sufficiently damp to avoid excessive root damage. Sites were chosen with these features and prescribed burn unit plans and operational plans were developed for each site.

Assessment of results achieved

The fire intensities were on average within prescription; however, some damage has nonetheless been inflicted on the trees, largely caused by headfires. To minimise damage to the overstorey it is necessary to restrict flame lengths. This could be achieved in future by:

- changing the ignition pattern to include more backfires, flank fires and narrow spot line ignition;
- burning when fuel moisture contents are higher; or
- burning downhill.

Alternatively, burning could simply be concentrated at the forest edge and in canopy gaps.

The very high fire intensities produced by these fires have highlighted the potential dangers of a wildfire occurring in rank heather, where flame lengths and fireline intensities can reach the top end of the spectrum for surface fires There is a need to give careful consideration to the hazards and risks created by such fires and the need to put in place effective control measures. These may include fire planning, training, sourcing of appropriate equipment, and the use of prescribed burning to reduce fuel loads and to create firebreaks.

3.2.4 Lessons learned

The Glen Tanar and Abernethy projects have shown that it is possible both in operational and ecological terms to use prescribed burning successfully, even with relatively high fire intensities, also to modify the shrub layer structure and composition to improve Capercaillie habitat within pinewood areas. The fires have achieved the primary objective in the forest of improving the environment for blaeberry by removing the competition from heather without damaging blaeberry rhizomes. Research (Hancock et al, 2009) has also been carried out that indicates significant benefits in pine seedling establishment following the application of prescribed fire. This research should stimulate a process of re-evaluating the range of potential benefits of prescribed fire in Scottish pinewoods, and should call into question fire policies that completely exclude the use of fire.

These experimental fires in a native forest environment have built upon the experience of extensive prescribed burning in open moorland environments where fire has been used successfully in wildlife management for 150–200 years. They demonstrate that fire can be used in woodland management for manipulating the species composition of ground vegetation, for promoting regeneration of trees and for controlling fuel loads. Fire should be included as an additional tool in the forester's armoury.

However, the use of prescribed burning for vegetation management is controversial. The economic, social and ecological environment in which land management takes place is changing. Most of the research into moorland management was done in the 1960s (reviewed in Hobbs and Gimingham 1987) when the priority for land management was to maximise the economic returns of the land either from sheep production or from grouse shooting (hunting). While these remain priorities for many of those who manage private land, the rising costs of labour make it increasingly difficult to make an economic return. Consequently, relatively few of the remaining grouse moors are run as profit-making businesses (Hudson 1995) and sheep production only survives through heavy subsidies; further, sheep numbers are declining rapidly since changes to the subsidy payments were made by reform of the Common Agricultural Policy (SAC 2009). A consequence of the reduction in labour is that the burning rotation tends to be lengthened with an increase in fuel loads compounded by the reduced grazing pressure. There is, therefore, an increased risk of more severe fires that may bite into the peat and older heather that regenerates much less well than heather burnt when its most vigorous growth phase at about 10–15 years of age. Poor regeneration of heather in a moorland habitat can leave soil exposed to erosion, open the community to expansion of less desirable plant species and reduce habitat quality for the red grouse.

Meanwhile, other demands are increasingly being made on upland areas. These include the conservation of biodiversity, ecosystem services and landscape benefits.

Globally, heathlands are a rare and threatened habitat type, declining in many areas of Europe, and the UK moorlands are of international conservation importance (Thompson et al. 1995). Prescribed burning has been shown to have a number of potential biodiversity benefits such as providing habitat for upland wading birds (Tharme et al. 2001) and increasing the diversity of lichen communities (Davies and Legg 2008). Elsewhere in Europe, fire is seen as a mechanism to prevent their

loss and increase landscape diversity (e.g. Sedláková and Chytrý 1999; Calvo et al. 2002; Vandvik et al. 2005; Ascoli et al. 2009).

However, as with any land use management system, some species will benefit from the particular habitat conditions created and others will be disadvantaged. There has therefore been a strong call from some quarters for burning management to be reduced or even banned from some habitats where burning has traditionally been used. This is particularly the case on blanket bog where *Sphagnum* mosses are seen as 'foundation species' that would play a dominant role in the natural system, having significant effects on both the physical and chemical properties of the rooting medium for other species and also as important peat formers. Regular burning, however, encourages the dominance of heather or grasses and sedges (*Molinia* and *Eriophorum spp*) which rapidly shade out the *Sphagnum* mosses.

There is also growing debate about the role of fire in the context of the carbon balance. While vegetation burning globally plays a major role in climate warming in raising the carbon dioxide concentrations of the atmosphere, it has been argued that heather burning may be carbon neutral, or even beneficial in some situations. The carbon present in above ground vegetation is mostly lost to the atmosphere on burning, but the lost carbon is reclaimed as the vegetation recovers. However, it has been argued that burning may increase the productivity of heather, which increases the rate of the accumulation of roots below ground as they are left behind by the fire. Thus the net input of carbon to the soil on regularly burned vegetation that is growing vigorously may exceed that of unburned heather that is relatively moribund (Clay and Worrall 2008; Farage et al. 2009). However, the evidence for this so far is limited and controversial (Legg et al. 2010). There are other processes involved as well, including the progressive desiccation of peat that may result from changes to the hydrology caused by regular burning. The long-term consequences of management burning on vegetation type and peat structure and stability may be more significant than any short-term gains measured over single fire cycles (Legg and Davies 2009).

Significant quantities of carbon are lost by smouldering fires where peat deposits or other organic material in the soil is ignited (Fig. 5). These wildfires can continue to smoulder for days or weeks. Both the environmental damage and the costs of habitat restoration are immense. Research into the ignition point of peat fuels has been conducted (Rein 2009). If peat deposits are considered as important carbon sinks, then fire management practices will need to adapt in order to be able to protect them. Prescribed burning can potentially play an important role in creating fuel breaks and managing fuel loads that reduces the risk or extent of these damaging wildfires.

Associated with changes to the structure and hydrology of peat are growing concerns about the relationship between regular management burning and water quality (Mitchell and McDonald 1995; Clay et al. 2009). A high proportion of the drinking water in the UK comes from catchments dominated by fire-prone vegetation on organic soils. Along with changes to the speed of decomposition of peat, an association has been established between the area under intensive management burning and water coloration due to dissolved organic carbon (Yallop and Clutterbuck 2009). Moorland peats near the main industrial centres in England are also highly contaminated with pollutants accumulated over the centuries that can be released into the river systems by fire (Rothwell et al. 2007).

Figure 5. Consequences of a smouldering peat fire following a summer wildfire in a pine plantation. The peat continued to smouldering for six weeks after the initial surface fire and all of the peat was consumed in many places exposing the roots and killing the trees (photo by M. Bruce).

3.2.5 Transferability

Vegetation management using fire in the UK has provided a good example of a traditional land use system that, while having its origins in prehistory, has been practised in a well-established form for the last 200 years. Standards of competence coupled with training, experience, and the published best-practice guides show how this can be done both safely and with minimal damage to the environment. Experimental fires have also demonstrated how the traditional burning of open moorlands could be extended to the conservation management of the ground vegetation and the regeneration of pine woodlands.

It is clear, however, that there is a continual need for review of these practices as the economic, social and ecological environment changes. A changing climate is also expected to have direct effects on wildfire frequency and intensity, as warmer and drier summers increase the fire hazard. In particular, the increased frequency and length of summer droughts will increase the probability of surface wildfires becoming damaging peat fires. Climate change will interact with changes in land use and the composition and structure of vegetation to change both the patterns of wildfire and the distribution and frequency of prescribed burning. Only with new research and a regular review of procedures will prescribed burning retain a role in the sustainable management of upland vegetation in a changing world.

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3.3 The Use of Prescribed Fire for Maintaining Open *Calluna* Heathlands in North Rhine-Westphalia, Germany

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3.3.1 Introducing the landscape

The Drover Heide nature reserve is located only a few kilometres south of the town of Düren (Nordrhein-Westfalen, Germany) in the transition zone from the Eifel range to the Lower Rhine Plain. The reserve, comprising 680 hectares of which 150 hectares are open heathland (Mirsch 1997) and 150 hectares poor grassland (Jirjahn et al. 2004), contains valuable habitats for several highly endangered plants and animals that depend on open landscapes (Anders et al. 2004). Because of the importance of its habitats, the reserve is embedded into the European network Natura 2000 and is further classified as a bird sanctuary. The area is famous for rare species such as the Nightjar (*Caprimulgus europaeus*) with 35 breeding areas and the Woodlark (*Lullula arborea*) with six breeding areas – both of which are highly restricted to open habitats.

The reserve has been extensively used as a military training area for more than a hundred years. To date, the area is still Federal property and is administered by the Institute for Federal Real Estate (BIMA) under the Federal Forest District 'Wahner Heide'. During the last ten years, all management activities have been coordinated and conducted by the Biological Station Düren, a local incorporated association. All issues related to nature conservation are administered by Düren County's Landscape Board. As a result of the military activities, the reserve's vegetative structure has been kept open for a long time. However, the military activities gradually declined in the 1980s to cease completely in 2005. It was during this period of decreased military activity that the vast heathlands developed.

The area has a predominantly Atlantic climate with a mean annual temperature of 9.5 C and characterised by mild winters with low snowfall and warm summers but with no extreme heat events. The average precipitation is 605 mm and mainly falls between May and August. Soils originate from the 2.5 to 3-metre thick Holocene loess that covers the tertiary depositions of sands, grit and clay. In contrast to the sandy soils of most other heathlands, such as the famous Lüneburg Heath (Jirjahn et al. 2004; Mirsch 1997), Drover Heide is growing on a highly productive clay-loam where the heather (*Calluna vulgaris*) can reach a height of up to 1.5 m on these nutrient-rich soils with a mean fuel load of 18.61 t/ha. In order to maintain the characteristics of this open landscape, management activities have been intensified significantly over the past 20 years. As in other similar heathlands in central Europe, over-aged heather

Figure 1. The Drover Heide nature reserve comprises 680 ha of open heathland and poor grasslands surrounded by a wooded belt (photo by R. Mause).

and the invasion of woody species are identified as the main problems.

3.3.2 Management activities in open habitats

During the course of intensive military activities, especially tank manoeuvres, the area was kept open without any active management; however, it was often necessary to plant woody species to protect the soil and avoid dust clouds during the summer. Today, almost the entire area is densely vegetated and the patches of denuded soil that were special habitats have vanished. A local herd of around 300 sheep graze seasonally on most of the poor grassland habitats.

Several methods to maintain the heathland are used in the reserve:

- Mowing: the possibility to mow and dispose of the swath is limited as the terrain must be relatively flat and free of woody vegetation to allow access of heavy machinery.
- Grazing: since 2005, a fenced area of almost 150 hectares is regularly grazed by herds of Scottish Highland Cattle and goats, which resulted in a significant reduction of woody vegetation (mainly *Populus spp.* and *Betula spp.*).
- Mulching: in the case of strongly over-aged heather (more than 15 years) and

Figure 2. Map and orthophoto of the Drover Heide nature reserve with large tracts of open heathland in the centre (source: Biological Station Düren).

a high proportion of woody vegetation, the only possible management method up to 2007 was mulching, which can be carried out at relatively low costs as all plant material is shredded and remains on the site. However, if the layer of the mulched material is too thick, natural regeneration of the heather is hampered.

- Prescribed Burning: since early 2007, prescribed burning has been one of the reserve's management activities. Between January and March, approximately ten hectares of over-aged and bush encroached heathland are burnt annually by a contractor.

3.3.3 Supporting and impeding factors for prescribed burning in North Rhine-Westfalia

All legal preconditions regarding the use of fire in Nordrhein-Westfalen (NRW) have been tightened both for the private sector as well as for communal areas. During the 1970s and 1980s, it was very common in rural areas and forests to burn agricultural residue, slopes, brushwood and stubble fields. Since the 1990s, however, it is now widely forbidden with special permission required to burn lopping residue from orchards and hedges. This also limited forestry activities since burning brushwood on piles was only allowed under strict requirements during bark beetle epidemics and

Figure 3. The main management activities to maintain open heathlands are mulching, cutting, grazing and fire (photos by R. Mause).

wind throw. The legal framework for burning is given by the Landscape Law and the Immission Protection Law of Nordrhein-Westfalen. Special permission can only be granted by the municipal public order offices and the county's Landscape Board.

Before the first prescribed burn in March 2007, fire as a management tool for the maintenance of open landscape was completely excluded by law in NRW. The only exceptions were in actively used military training sites such as Sennelager near Paderborn.

The general public perceives fire as a destructive element and a hazard to humans and nature, as can be observed every summer when the media report on large fires and environmental destruction in southern Europe. The role of fire in ecosystems and its positive effects are often not recognised, and although wildfire problems such as in the Mediterranean are non-existent in NRW, public opinion on fire is biased. Another factor limiting the use of fire is its impact on recreation as burnt areas are generally perceived as unattractive.

It was, however, noted that visitors regularly suggested that fire be used on

heathlands since this was the traditional way of improving pasture land as it was something they could relate to.

Steps towards the use of fire in the Drover Heide nature reserve

Although the first discussions on the possible use of controlled fire to maintain the *Calluna* heathlands in the reserve were initiated already in 2002 by the Biological Station Düren, it took almost five years for the first burn to be implemented. The first step was to reach a consensus among the experts of the Landscape Board of Düren and the land owners who were represented by the Federal Forest Office Wahner Heide, which is also responsible for the management of several other major properties in Germany, including some actively used military training areas. Occasionally, accidental fires break out in these areas as a result of military manoeuvres and some are intentionally set for training purposes. The main purpose for fire use in these areas is to keep the terrain open and reduce combustible material for safety reasons and not for nature conservation. This was the main reason why the land owner showed only little concern towards the use of controlled fire. However, the legal administration of all nature reserves, including Drover Heide, is under the responsibility of the County Landscape Board. According to the Landscape Law and the General Rules for Conservation Areas, it is generally forbidden to light fires in nature reserves and it is mandatory, in all cases, to apply for special permission from the local authorities.

Prior to the first application of fire, the Biological Station Düren and the County Landscape Board decided to extend their knowledge on the effects and the ecology of fire by visiting an actively used military training site in Belgium (Elsenborn) to inspect several areas that were regularly burned to keep the site open. As the site is still used as a shooting range, there is a great likelihood of accidental fires that are contained by control lines. Because of the high load of ammunition in the impact area, there are no activities for fire suppression; rather, to keep uncontrolled fires from getting too intense and to keep the range open, vast areas are burnt in a controlled way annually by the responsible forest office and the military. A positive consequence is the maintenance of huge areas of *Nardus* grasslands, *Meum* pastures and *Calluna* heathlands that are unique in their vast extent (Mirsch 1997; Müller et al. 1997). Experiencing such breathtaking landscapes certainly helped the endeavour of introducing prescribed fire to the nature reserve.

Selection of burn sites

The experts agreed that it is reasonable to apply controlled fire to maintain open *Calluna* heathlands and to restore over-aged and bush-encroached heathlands and that it leads to the desired results (Anders et al. 2004; Mirsch 1997; Müller et al. 1997; Niemeyer and Fottner 2004). Prescribed fire thus became the third alternative to manage heathlands after mowing and mulching.

The selection of burning sites was conducted by the following criteria based on an agreement between the land owner and the County Landscape Board:

- Over-aged heathland with a strong encroachment of woody vegetation

Figure 4. The first attempt to get the prescribed burning programme underway in 2006 was delayed by ammunition from WWII (photo by R. Mause).

(restoration measure urgently required) (Anders et al. 2004); terrain (partially) is not appropriate for heavy machinery due to its relief or age of the vegetation; the heather is growing on loamy-clay with strong woody stems, which limits the use of a rotary mower or cutter bar – the only viable options thus being mulching and prescribed fire.

- Burning plots should not be close to public hiking trails for both safety and aesthetic reasons. During the first year of the trial, it was decided not to expose the black areas to the general public.
- Plots should be situated along old tank tracks which can serve as control lines

In addition to these basic criteria, more specific burning objectives require additional conditions. It is important to note here that it was decided to use a prescribed fire regime for a maintenance burn rather than for a restoration burn even though the treatments were rated as restoration measures. Both prescriptions for central Europe differ significantly from each other; however, since the burning permits were issued only until March 15, the prescriptions for maintenance burning were more appropriate. The burning objectives were to promote the regeneration of *C. vulgaris*; kill off small diameter trees and bush; and to create a patch mosaic. The main limitations to reach these objectives were a tight burning window due to the weather and the short days in early winter (insufficient solar pre-heating of

fuels). Burning conditions need at least three to four consecutive days with relative humidities below 60% in February/March, or a Fine Fuel Moisture Code (FFMC) of over 80, but a Duff Moisture Code (DMC) below 20 from March 21.

It was also necessary to obtain another permit from the neighbouring community of Vettweiß according to §7 of the Federal Immission Protection Law. In addition, the police authorities and local fire brigades had to be involved in the planning process. Since the nature reserve is a former actively used military training site and in addition contains heavy loads of ammunition and explosives from WWII, it was also necessary to include an explosive ordnance disposal unit.

The general public was informed of the first trial via the media and an information leaflet on the positive effects of controlled fire.

Further, a cost estimate was required. As a practical approach was desired, it was preferred to have payments for a contractor based on a daily rate. There is an annual budget available for maintenance measures in open landscapes, which allowed easy access to funds for the trial.

The local fire brigade was informed and a fire engine was present during the first burn as required by the authorities. The firefighters found it a very interesting experience and a good exercise since they would have to respond in case of an accidental fire. Further, the police were informed but were not present as no adverse effects on traffic were expected. It was also necessary to inform Nörvenich – a nearby military air base – about the burning operations as the open heathland is a training area for Tornado flight manoeuvres and serves as a bail out area in emergency situations.

3.3.4 Results

Since 2007, some 6–10 hectares of heathland have been burnt annually accompanied by the ecological assessments of permanent plots for floristic studies, different animal groups, such as *Arachnidae* and *Carabidae*, as well as birds. The desired effects on the vegetation structure were reached by a mix of flanking and fast spreading head fires to remove over-aged Calluna plants. It was not desired to have any thermal effects on the soil to allow small fauna to survive the fire. This can be achieved when the days are sufficiently long (from early February) and after frosty nights (below 0°C) but sunny days with a typically high FFMC and medium DMC. These conditions assure fast spread rates and ease of ignition but only superficial consumption of fine fuels – intensities can be high but with a short residence time and can be typically met during wintery highs between February and mid April.

Vegetation

The results of the floristic assessment far exceeded all expectations. Vegetative as well as the generative (seed) regeneration of *Calluna* was abundant all over the area by the summer following the burning operations. Of major importance is the fact that the burn plots showed a significant increase in biodiversity as Atlantic

Figure 5. The desired effects are reached by fast spreading head fires to remove over-aged Calluna plants. No thermal effects on the soil are wanted to allow small fauna to survive the fire (photo by D. Kraus).

heathlands, in general, are rather poor in species composition (Jirjahn et al. 2004; Mirsch 1997; Müller et al. 1997; Niemeyer and Fottner 2004). Prior to the burn, the heathland comprised over-aged monocultural stands of *Calluna vulgaris*; however, after the fire various species of the initial phase of a heathland (Müller et al. 1997) and species of mat grass swards (Jirjahn et al. 2004) such as *Nardus stricta, Molinia caerulea, Danthonia decumbens, Polygala vulgaris, Carex pilulifera*, and *Agrostis vinealis*, were germinating on the burn plots. The burn plots are located within the fenced paddock, which leads to a revival of the traditional management method of fire and animal grazing.

The results for the reduction and repression of woody vegetation was another important aspect. The mortality among young *Betula spp.* trees was almost 100% after the burns, especially after the optimal burn conditions in March 2007 where the temperature remained relatively warm (6°C) for several days and the relative humidity, which allowed for the excellent drying of the fuels. Consequently, the resulting temperatures of the backing and flanking fires exceeded the lethal point for almost all young trees and bushes. While some trees were resprouting relatively quickly after the fire, they did not survive the summer period and the browsing pressure of cattle and goats. Rabbits who feed on young shoots also have a certain influence on the post-fire mortality although this is difficult to quantify.

Figure 6. Abundant vegetative and generative regeneration of Calluna plants can be found on the exposed soil after burning (photo by R. Mause).

Arachnids and Carabid beetles

Both groups have been monitored in five ground traps (inspected every two weeks) since June 2006, which fortunately includes one vegetation period prior to the first burn. There is already the tendency that several species, especially the rare thermophilous, are benefiting from the prescribed burning. For example, several thermophilous Arachnid species typical to heathlands (Schmidt and Melber 2004) were counted on site after the burn and included: *Agroeca proxima, Callilepis nocturna, Xerolycosa nemoralis* and *Micaria silesiaca*. The burnt area can thus be considered a substitute habitat for the patches of denuded soil created by intensive tank driving (Anders et al. 2004).

Birds

It is particularly remarkable that both nightjar and woodlark established breeding territories immediately after the burning operations as this helped to confirm the preferences of these ground breeding species as described in the literature. Both species deserve particular attention in the reserve as they are very rare breeding birds in NRW and need a special management concept.

3.3.5 Lessons learned from the use of prescribed fire in the nature reserve

The success of a prescribed burning operation is totally dependent on the local weather conditions, with wind direction being the most critical variable. As the terrain in the reserve resembles a long stretched hill, it means that with varying wind directions the leeside effects of the burn plots are more pronounced. The situation is further complicated by a forest belt that surrounds the open core area which contains patches of woody vegetation. This is where the leeside effects play the most crucial role in determining if a plot can be burnt or not, as the drying mechanisms for the heather fuels are unfavourable during the winter burn season. It takes much more time to overcome the effects of rime, especially after frosty nights, due to shading effects in these highly productive heather stands that can reach 1.5 m in height. Consequently, it is advisable to prepare more burn plots than can actually be burnt on the day to be able to react to the prevailing wind situation. This means it is of major importance to prepare burn plots on both western and eastern windward sides.

Generally, the window during the winter burn period is very narrow – operations do not usually start before midday after the relative humidity has dropped below 50%, and after 16.00 it becomes very difficult to light a new fire because the humidity is too high. This means that as there are only four hours per day available for the actual burning, it makes sense to prepare as much as possible in advance so as not to shorten the burning window even more. Experience also showed that it is very efficient to create control lines of four to six metres wide around the burn plots with a mulcher.

The main success, however, was the reduction of upcoming woody vegetation. Almost 100% of young *Betula spp* trees did not survive the burning because the high flame temperatures exceeded the lethal point of the trees by damaging the xylem in a way that caused the total desiccation of the plants. At a later stage, fungi and other infections became established in the fire scars and caused further damage to surviving trees, leading to the final kill-off. This, in addition to the natural regeneration of *Calluna*, is seen as pivotal for the permanent preservation of open landscapes since mechanical treatment does not have such resounding success. Young *Betula spp* and *Populus spp* trees, for example, react with strong resprouting after being cut back with chain saws and thus make second treatment necessary within a short time. Further, the remaining stumps of thin trees can destroy tractor tires – a problem during subsequent heathland maintenance. It must be considered, however, that dense patches of young trees do not allow the development of a substorey or layer of herbal vegetation and thus carry only very low fuel loads; it is critical, therefore, that the treatments are started timely. Also from a bird protection point of view, total removal of the woody vegetation is not desired.

During the winter burn season (October–March), only a few days are suitable for efficient burning operations. Since the heather reaches a maximum height of 1.5 m, it takes some time until the fuels are dry enough after precipitation. This requires a relatively low organisational preparation phase prior to the burning operations – experience shows that one day is usually enough to have everything in place.

Figure 7. The limitations for the use of prescribed fire are a tight burning window due to the weather and short days in early winter (insufficient solar pre-heating of fuels). Burning is only possible if relative humidities are below 60% for three to four consecutive days in February-March (photo by D. Kraus).

3.3.6 Transferability of results from the prescribed burning in the nature reserve

The main overall success of the prescribed burning treatments in the Drover Heide nature reserve generated a certain interest in the technique from neighbouring nature reserves as well as military training sites. Since the problems that occur in the nature reserve are common to other heathlands that have abandoned active management, the Drover Heide model with the combined grazing and burning approach will certainly play a key role in the development of management plans for similar areas. With an area of around 700 000 hectares, active and former military training areas contain many habitats with some of the highest biodiversity in Germany; and since they are littered with Unexploded Ordnances (UXOs), mechanical treatment is severely limited. For this reason, prescribed fire is both a plausible and effective technique which can be used to preserve these unique landscapes.

The reaction of the local inhabitants to the use of prescribed fire was astonishingly indifferent. Although smoke development was significant during the burning operations, nobody called the fire service or police – which was most likely due to the comprehensive information campaigns prior to the burns.

During the second burn, a group of 30 hikers watched the operation from safe distance; unfortunately, however, it was not possible interview them to get their views on the treatment. On subsequent guided excursions to the reserve, the burn plots were generally perceived as 'unusual' by the visitors. Once the ecological processes and context were explained, most people showed understanding; however, some advocates of 'free development' disagreed with both this and any approach in which humans interfere with nature, i.e. all forms of management. From a nature conservation point of view, however, the management concept in the reserve is undisputed with clear rules from the FFH directive. Further, as the political representatives of the county and its communities consider the heathland and the open landscape of the reserve an important recreation area, free development is not an option.

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3.4 The French Prescribed Burning Network and its Professional Team in Pyrénées Orientales: Lessons Drawn from 20 Years of Experience

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3.4.1 From a Prescribed Burning technique to the emergence of a National Prescribed burning Network in France.

The concept of 'brûlage dirigé', the French term for prescribed burning, was introduced in France in the 1980s by the French Institute for Agricultural Research (INRA) in Avignon and the Agricultural and Environmental Engineering Research Centre (CEMAGREF) in Aix en Provence, as a follow up of a field trip to the USA by Mediterranean forest managers (Alexandrian et al. 1980). The INRA 'Forest Fire Prevention' research unit in Avignon was in charge of testing its feasibility and effectiveness as a clearing technique for Mediterranean ecosystems. This assessment was carried out by comparing it with classic clearing techniques, i.e. manual and mechanical clearing.

On their release, the research results were received with much interest by managers, albeit without them ever leading to any real integration into their selection of management tools for these ecosystems. As opposed to other countries, such as Portugal, where forest managers quickly adopted this technique (Moreira da Silva 1988), prescribed burning was only used in a few specific cases in the French Mediterranean region between 1980 and 1987.

However, at the end of this period, faced with major summer fires in the Pyrénées Orientales (PO) region and with extensive experience in the Lozère region, the Prefect took the initiative of requesting the intervention of the national civil protection services to create fuelbreak areas at the forest massif level . The Sociéte d'Elevage des Pyrénées-Orientales (Lambert 1988), which had begun to implement some initial experiments in prescribed burning with the help of the CEMAGREF (Alexandrian 1985), was chosen to run the operation alongside the supervising public services for the areas. In this way, the first real official prescribed burning programme for the 'defence of forests against fires' (DFCI) started in the winter of 1986/87 in the Pyrénées Orientales.

Highly interested in these initial prescribed burning results, foresters from Generalitat de Catalunya and the Forestier Sapeurs (Forest Fire-fighters) in the Alpes-Maritimes (Robion, 1990) followed this programme during the winter of 1989. In turn, the forest fire-fighters in the Lodève, with the support of the INRA-Avignon, attempted to develop the technique to become a form of fire prevention that would be more precisely managed near forest areas.

In 1990, the effect spread by establishing prescribed burning teams in 10 of the 15 Mediterranean regions of the Entente pour la Forêt Méditerranéenne (Mediterranean Forest Agreement), diversifying its objectives and considering new environments for treatment. In the desire to exchange knowledge and be recognised, the teams merged with the INRA Avignon forest fire prevention team in the winter of 1989–1990 to form the Réseau de Brûlage Dirigé (RBD – Prescribed Burning Network) whose aims were to:

- spread knowledge on the impacts and operational methods
- exchange experiences in logistics, incidents and accidents
- draft project monitoring methods (project files, geo reference databases)
- be involved in joint awareness activities with government officials and the general public
- implement prescribed burning and suppression fire (feux tactiques) courses
- acquire and improve operational and safety equipment
- increase dialogue between research and practitioners for technique application
- develop legislation and regulatory adaptation to prescribed burning

At present, this network is supported by the Service d'Utilité Agricole Montagne Méditerranéenne et d'Elevage (Mediterranean Mountain and Farming Agricultural Utility Service) of the Chambres d'Agricultrure (Chambers of Agriculture) in the Languedoc-Rousillon (OIER-SUAMME) with state financial support (Mediterranean Forest Conservatory, CFM). It brings together all practitioners and research teams in France interested in prescribed burning and implements its operations in the south of France from its centre in Provence-Alpes-Côte d'Azur.

To date, there are 28 teams covering diverse management objectives in large geographical areas: the DFCI (fire prevention) objective for coastal areas and a marked pasture demand inland (piedmont, summer or high mountain pastures) – all able to ultimately be combined with environmental or hunting requirements. All teams carry out the prescribed burning of some 4000–5000 ha for all purposes annually.

As an example of this harmony between research and local demand, and between the network and the teams, we will now introduce one of the oldest teams in France: the prescribed burning team in the Pyrénées Orientales region.

3.4.2 Territorial context in Pyrénées-Orientales

From rural exodus to extensive livestock farming

The Pyrénées-Orientales (PO) region is home to vast wildland areas influenced by both mountain and Mediterranean climates where rural abandonment, beginning at the end of the 19th century, led to an inadequacy in practices and know-how with regards to renewing forestry and pasture resources. The abandonment of these areas allowed them to be recolonised by forests and shrublands, leading to a huge accumulation of fuel for large fires. However, alongside the invasion by woods, the social functions of these vast areas have also diversified as wild game management, nature tourism activities and, most recently, the incorporation of environmental and heritage concerns are overtaking pasture, farming and ancestral forest uses.

Figure 1. At the mountain level, overgrazing of grassland in the foreground invaded by Provence broom and mountain pine (photo by Bernard Lambert).

At this crossroads of uses and expectations, farmers, shepherds, foresters, the fire service and environmentalists have united to develop cooperation on fire use, meeting the new social demands in these areas.

If crop production (viticulture, horticulture and arboriculture) is economically dominant in the Pyrénées Orientales, livestock farming has nevertheless managed to develop an original organisation and develop large areas despite its low economic turnover (<5% of farming economic return). After a long decline, livestock has been on the increase since the beginning of the 1990s (+25% from 1989 to 2000) and presently accounts for 21 000 cattle units (UGB Unité de Gros Bétail, equivalent to an adult cow). With over 150 000 ha (around 1/3 of the area's 400 000 ha), it is mainly extensive and 'nomadic' since more than 2/3 of the herds move to summer pastures (the highest percentage in the Languedoc-Roussillon region). The best low-altitude pastures (terraced pastures and woody areas from 300 to 1000 m high) accommodate the herds at the end of autumn and in winter; the mountain and subalpine terraces in the spring and at the end of summer; and the higher subalpine level (>2000 m) in summer. The cattle are thus almost always outdoors throughout the year and production is quasi-organic.

However, the long agricultural abandonment and closure of areas caused by rural abandonment throughout the 19th century and beginning of the 20th century has negatively influenced the current pastoral activity in the medium term. At

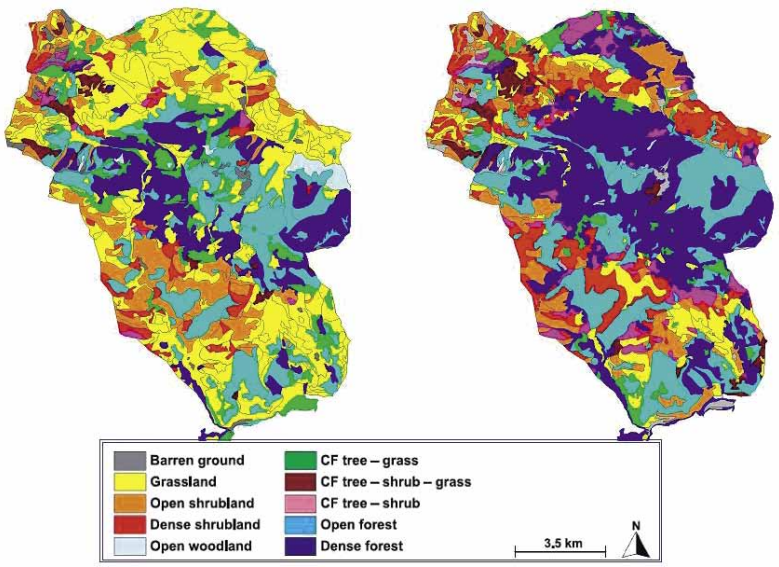

Figure 2. Vegetation maps from 1953 to 2000 showing the evolution of pastoral areas in Madres Coronat (from Roura et al. 2005).

Mediterranean and mountain levels, the disappearance of wood demand from mines or charcoal for the local steel industry, as well as farming activity on thousands of small plots, has led to a slow re-conquest of land first by forbs (e.g. *Cytisus purgans, Rosa canina, Prunus spinosa, Cistus laurifolius* and *Cistus monspeliensis*) and then trees (*Pinus uncinata* in high altitude areas and *Quercus pubescens* and *Quercus ilex* in lower areas). This natural process of reforestation opens up a pernicious imbalance in the 'pastoral chain': the overgrazing of ancient crop fields and grass pastures at mountain and subalpine levels coupled with the under-grazing of pastures in lower or adjacent levels.

Furthermore, closing areas and reducing pastoral activity are a threat to the biological diversity of natural environments and increase the risk of fire. The agro-silvo-pastoral activities have always been the mould for the biological diversity of open spaces and landscape variety. This is why in this region, which covers a broad altitudinal range (0 to 2921 m) and hosts a richness of major heritage interest areas, most of the pastoral areas belong to Natura 2000 sites. They manage 12 natural habitats of community interest: three priority areas, one quarter of the heritage flora and heritage vertebrate fauna in the Catalan Pyrenees, with 40% of nesting birds using the open and semi-open spaces for reproduction. Thus, an historical analysis of plant physiognomy from 1953 to 2000 at the Natura 2000 site of the Massif des Madres Coronat (Roura et al. 2005) showed that the pastures and prairies had regressed over 70% in 50 years in favour of forests and shrublands (Figure 2). This has also led to an increased fire hazard.

Today, we are seeing a development in multi-functional livestock farming where the livestock farmer is no longer simply a breeder, but takes part in managing and maintaining the environment. In this way, the necessary conservation of biodiversity, wildlife management and offering support for tourist activities are added to the aims of animal production and renewing plant resources.

Pastoral burning in the Pyrenees

If most intentional fires in past centuries had essentially agricultural, pastoral and industrial aims (Trabaud 1989), their methods of use were often strongly designed (Sigaut 1975) and integrated into a coherent cultivation system. It is precisely these systems or technical sequences as a whole that should be taken into account in order to explain the interest and use of fire:

(i) One of the most widespread practices in old European agriculture was the écobuage, referring to 'slash and burn' practices of cutting and then burning the grasses. Its aim was to mineralise humus, eliminate obstacles for the germination of cereals and, above all, reduce soil acidity levels.

(ii) Another widespread technique employed to improve hunting, clean terrain under trees to collect fruit or to favour grass growth for herds was the brûlage à feu courant (pastoral burning) of shrublands and grasslands. In the Languedoc-Rousillon (Ladurie 1966), pastoral burning is still an irreplaceable tool with which to eliminate grazing land scrub spots or cullage on abandoned farmland invaded by woody plant life.

(iii) Across the Pyrenees, the man-environment relationship has co-evolved over millennia with fire. The scope of the phenomena is described in the records of the Pic du Midi Observatory from 1906, where it states that the smoke from pastoral fires sometimes left the air so thick that is was impossible to perform astronomic observations for several days (Métailié 1981).

However, the socio-economic decline in the mountain region and the resulting increased overgrowth has led to a significant modification of practices and activities linked to fire. In this way, the forest administration, which at its foundation in the 17th century had implemented control procedures for écobuage in order to protect the woods and forests under State property (Ribet 1999), thus returned to this administrative framework dedicated to agriculture against the practice of pastoral burning.

Consequently, the Chamber of Agriculture in the Pyrénées Orientales was confronted by a double dilemma: first, with the disappearance of shepherds and therefore the cultural practices that entailed small interventions in the environment, livestock farmers needed to re-open their pastoral area menaced by reforestation; and second, the need to find a solution to the acute problems from wild pastoral burnings which regularly led to uncontrolled damaging fires.

Thus, unable to suppress fire and so as to limit the ecological, economic and social consequences, the agricultural profession wanted to reintegrate burning into the techniques available to farmers and shepherds. This meant putting an institutional structure into place so as to help livestock farmers manage fire and control the ecological and social effects.

Figure 3. An écobuage site in Mosset in the Pyrénées Orientales – to the left, a uniformed guard (Source: GEODE Faculté Le Mirail, Université de Toulouse).

3.4.3 The introduction of prescribed burning as a tool for pastoralism, biodiversity and fire fighting in the Pyrénées Orientales: unit purpose and operation

After the catastrophic fires in 1976 and 1986, which ravaged 17 000 and 8000 ha respectively, both public services (ONF State Forest Service, Regional Agriculture and Forest Office, etc.) and elected officials wanted to protect the forest massif and reduce the cost of fire suppression by restructuring the area based on support from local bodies, especially regional livestock farmers. In this context, it was proposed to create vast agro-forestry corridors known as 'fuel breaks' that would be managed by livestock farmers. However, as a dense overgrowth of trees and shrubs, steep slopes, the presence of rocks and even low walls inhibited mechanised equipment, classical clearing techniques proved inoperative or too difficult for most areas.

In February 1984, an unexpected event provided a response: a fire, lit by a local livestock farmer after a cold snowy period, ran across one of the demonstration sites. A few months later, the burnt *Cistus* had turned into a carpet of perennial grass (*Brachypodium ramosum, Festuca ovina, Koeleria*). This naturally led the organisations involved to rethink their vision of fire and rediscover its use through the prescribed burning technique.

As a result, and within the framework of the operation 'improving sylvo-pastoral

management in the dry mountains of the Pyrénées Orientales' financed by the State and with the support of the forestry services (DDAF Regional Agriculture and Forestry Office and the ONF State Forest Service), research institutes (CEMAGREF and INRA) and the farming profession (Inter-Chamber of Agriculture Service and the Livestock Farmers Society of the Pyrénées Orientales), experiments on five- to ten-hectare plots were carried out from 1984 to 1987. This was carried out to ensure the awareness of conditions for good fire control and better outline the impact in areas subject to fire techniques and pastoral management.

Creation and purposes of the 'prescribed burning team'

Given the results of the first trials and the increased demand for pastoral burning from shepherds which openly increased, the partners came to an agreement to try to integrate the use of fire in managing fuel breaks and pastures. The convergence of these two problems, i.e. pastoral burning and 'wise' fire use from institutional managers, created ipso facto the need to put forward an organisation that would be able to satisfy the demand of several thousand hectares per year.

The major involvement of the Regional Fire Emergency Services, the County Council, the ONF and the Chamber of Agriculture led the Prefecture services to create the first prescribed burning team in France in autumn 1986 – with the agricultural profession as the contracting authority – with a view to an experimental pastoral burning campaign. In this way, in the winter of 1986/87, ten plots (150 ha) comprising the diversity of the shrublands and heaths of the area sensitive to fires were burnt.

Thanks to the success of this first campaign, and in light of the advanced reversion process, the flammability of oro-Mediterranean vegetation, the climate context combining dryness and strong winds, and finally the loss of livestock farmer know-how, the profession and prefecture services decided to continue with an official specialised structure in the use of fire. The 'PO prescribed burning team' was thus created to:

- train and make livestock farmers aware of the use of fire; however, as prescribed burning involves diagnostics, dialogue and consensus (see Section 3.4.5), the acquisition of know-how is essential;
- take over from farmers, if possible, when carrying out difficult projects;
- prioritise the practice of prescribed burning on fuel breaks to reduce the occurrence of large fires;
- organise 'training operations' for Regional Fire Emergency Services (SDIS) and National Civil Security Units which intervene in cases of large fires; and
- propose training workshops for candidates taking the 'Prescribed Burning Chief Certificate' developed by the Ecole d'Application de la Sécurité Civile in Marseille.

During the second stage in 1995, the agricultural profession launched the systematic elaboration of management plans for high mountain pasture areas within the framework of the European Agri-environment Measures to avoid the closure of mountain summer pastures (estives). In intense collaboration with other managers or site uses, these plans – covering over 40 summer pastures (around 70 000 ha or 60% of the mountain pasture area in the Region) – each summer pasture was subject

Figure 4. Prescribed burning site for the training of livestock farmers (photo by Bernard Lambert).

Figure 5. Prescribed burning on a fuel break before opening grazing. (photo by Bernard Lambert).

Figure 6. Prescribed burning for training purposes (photo by Bernard Lambert).

to an inventory and diagnostic. It was in this framework where new techniques for intervention upon pastoral areas were proposed. Amongst the existing clearing methods, the use of fire, now admitted, was considered a formidable tool available for shepherds and managers. Prescribed burning was thus systematically included in every summer pasture management plan.

Finally, from 2000, new objectives were assigned to the unit:

- Integrating prescribed burning into the selection of management tools for species areas (grey partridge, Pyrenean chamois, etc.) and habitats in Natura 2000 sites.
- Ensuring know-how exchange with the specialised unit on forest fires from the Fire Services of Catalonia (Grups de Recolzament d'Actuació Forestal, GRAF teams) within the framework of the European INTERREG-BDSUDOE programme , associating the teams of neighbouring areas in the Region and the University of Tras-Os-Montes e Alto Douro in Vila Réal, Portugal.
- Since 2006, offering an introduction to prescribed burning to regional fire fighters and the use of 'backfire'.

The Legal Structure of the Unit

The PO Prescribed Burning Unit is supervised by the Société d'Elevage des Pyrénées Orientales, an old farming union association founded in 1918. It mobilises

the national security units (50 professionals and 8 to 10 fire engines) every year through the Prefecture Civil Protection Services. Joint agreements are in place between the Military Service Command for Civil Security and the Société d'Elevage with compliance being under the control of the Pyrénées Orientales Prefect. Since 2006, the Regional Fire and Rescue Service in the Pyrénées Orientales, governed by the County Council, also offers support within the framework of a separate agreement (5 to 25 professionals and 1 to 3 fire engines).

Responsibility is divided as follows:

- The Sociéte d'Elevage is the single body legally responsible for prescribed burning in the Region.
- Only the 'eight prescribed burning team chiefs', required by the PO prescribed burning team and certified by the École d'Application de la Securité Civile, are authorised to lead operations.

Logistics

a) Campaign preparation:

- An inventory of support requests or for the execution of burning operations: individual requests from farmers or groups (towns, pastoral groups); in the case of summer pastures demands, these are collected by the Farming Service at the Chamber of Agriculture.
- The production of the corresponding technical specifications (prescribed burning plan) and estimates are most often based on group or individual pasture diagnostics and/or pasture development plans, produced beforehand and which have an application period of over five years. These diagnostics are performed by the Pastoral Service at the Chamber of Agriculture.
- Local consultation: the prescribed burning project is sent to all local stakeholders involved in the project file, setting out the location, outline and propositions in terms of recommendations, estimates and grant rates.
- Regional consultation, comprising the production of an intervention calendar and the financial and institutional framework for the campaign, emerges from both the validation of the technical specifications for each project (prescribed burning plan) and the units to be mobilised. This consultation is supervised by the Regional Project Consultation and Analysis Committee, and called by the Regional Office for Equipment and Agriculture (DDEA) at the start of November bringing together all involved services.
- Campaign planning (logistics and administrative and financial management) is then carried out.

b) Prescribed Burning operations (November-March):

- Reconnaissance, with the help of the prescribed burning file validated by the Regional Committee: reconnaissance of every burn is carried out on the eve or a few days before in order to assess the conditions in situ.
- The performance of the work with small teams (November to March): these are operations carried out on foot, without engines, by members of the

National Civil Security service, the Catalan fire service, the local fire services and the livestock farmers or shepherds. Spot burning tasks are performed in complete security on plots limited beforehand by prescribed burning or by snow in small or low combustible formations.

The aims are to learn to: follow current regulations; control the fire front based on weather conditions and the level of plant dryness; ensure the limits of the fire are extinguished; and assess the environmental impact.

- Work with heavy equipment (January to mid-March): these are forest fire training exercises with national and local fire services. These projects involve the necessary mobilisation of heavy equipment due to the major accumulation of fuel and the need to protect sensitive areas (forests, housing and facilities).
- Each ongoing project is subject to supervision and includes: recording data (on paper) according to the grid produced by the National Prescribed Burning network (environmental description, weather, fire behaviour methods, incidents and the impact of plant life), producing a photographic record of the burn, as well as updating the geo-referenced digital databases.
- Finally, administrative and financial management: including telephone discussions on the eve or same morning, accounting for the supervision, producing estimates and invoicing, and the final appraisal of the campaign.

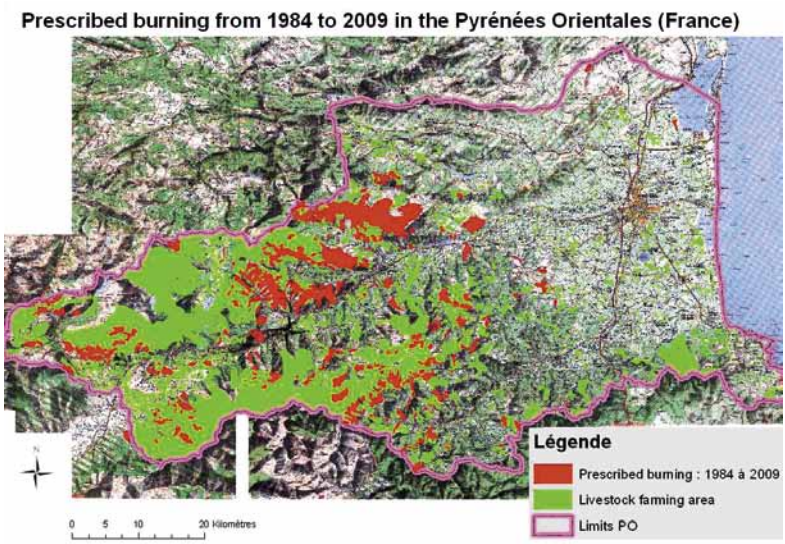

Figure 7. Prescribed Burning operations in Pyrenees Orientales from 1984–2009 (Bernard Lambert, SUAMME).

3.4.4 Assessment and Limits

A success to be continued in the future

a) The unit has treated 14% of the surface area given over to farming over a 20-year period:
Prescribed burning was performed between 1987 and 2009 on 17 000 ha of the 118 000 ha dedicated to livestock farming, i.e. 14% of the total area. The size of the treated plots varies from 0.5 ha to 179 ha, with the average standing at 9 ha. Figure 3 shows livestock farming areas in green (including main forage areas declared by livestock farmers in 2004 on the Land Parcel Identification System) and the prescribed burnings in red, which are mainly concentrated at mountain level, either in shrubland areas close to farms or in low summer pasture areas. The work is equally divided between the Mediterranean area prone to fire and the mountain and subalpine levels.

b) Prescribed burning – a tool for biodiversity:
The difference in opinion between American researchers, in favour of a change in policy to restore fire as a means to protect biodiversity, and French administrations, supporters of a systematic fight against all types of fire, is today less marked. Further, fire is perceived by scientists and managers of nature areas as an integral part of the evolutionary cycle of certain ecosystems (Mangeot and Lambert 1995).

Figure 8. Patchwork burning in broom shrubs in the Massif des Madres in February 2008 (photo by Bernard Lambert).

However, the adjustment of the prescribed burning technique could favour a patchwork of areas optimising biodiversity based on the differentiated implementation between plots or within a single plot. Managers may plan technical sequences – completely or partially integrating fire, the ranges within which to treat it and the return time period. Such 'spot' burnings (from 100 m² to 10 000 m²) are now systematic in the high heathlands in the Pyrénées Orientales (Rigolot and Lambert 1998).

c) Success in terms of the fight against pastoral fires:
The effectiveness and validity of this policy can be shown by the results in the Massif du Madres-Coronat, where pastoral burning was substituted by prescribed burning in the 1990s.

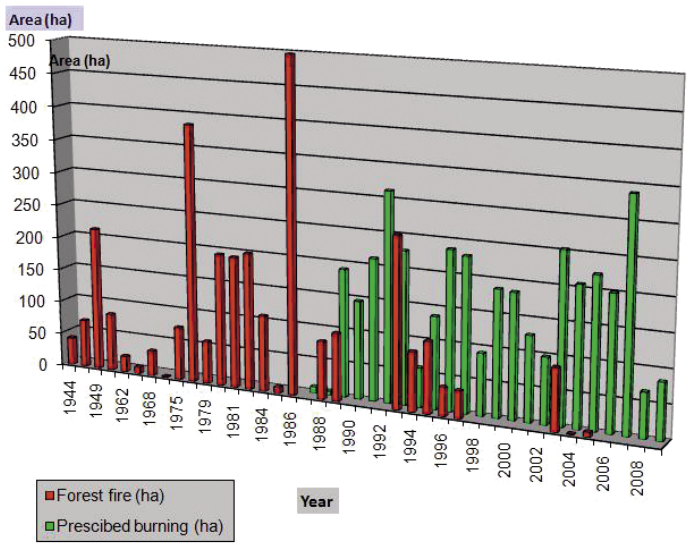

Figure 9. The evolution of forest fires and prescribed burning in the Massif des Madres (Bernard Lambert).

d) Acceptable Costs:
Prescribed burning is put forward for its low operational costs. This fact masks differences according to the nature of the work.

- The least expensive work is that carried out in supporting livestock farmers in the pre-mountain areas – in non-wooded areas – where estimated costs are EUR 50 to EUR 100/ha.
- Work in wooded areas and with strict forest fire prevention objectives is generally more costly from EUR 100/ha to EUR 600/ha (as compared to mechanical clearing at EUR 800 to EUR 2400/ha and manual clearing from EUR 2000 to EUR 4000/ha).

- By frequently using natural limits as safety strips, work preparation only represents 12% of the total costs.

As an example, the average price in the 2008–2009 campaign was EUR 136/ha for a total area of 620 ha.

e) Prescribed burning is being increasingly incorporated with other techniques:
The local project for pasture recovery in the municipality of Eyne demonstrates the potential for complementarily in the space and time of techniques, much more than their contrast. This project combined a set of techniques on 22 ha (mechanical clearing, burning, overseeding, etc.) where over 50% of the total cost was met by a collective livestock farmers association.

Limits

a) The ever more changeable weather conditions dictate a variation of the level of prescribed burning activity from year to year:
After the logistical set-up (1987–1989) and long consolidation periods (1990–2002), recent developments show a clear contrast between very good and very bad years.

Faced with increasingly unstable and uncertain weather conditions, increasing professionalism and resourcefulness need to be exercised in order to take advantage of narrow windows of opportunity. This is done by adopting a strategy that combines great implementation flexibility with the capacity to simultaneously plan several operational groups in short favourable prescription windows.

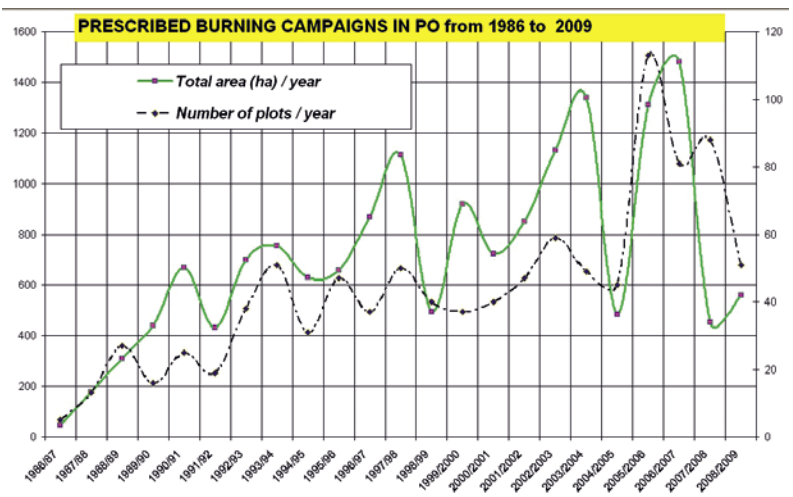

Figure 10. Annual assessment of the number of plots and total area treated by the PB team in Pyrenees Orientales (Bernard Lambert).

b) More complex consultation has led to a reduction in project size:
Prescribed Burning prescriptions are put together in an increasingly complex scenario where the old forest/livestock farmer relationship has given way to a larger number of stakeholders. This leads to increasingly heavy technical specifications and increasingly smaller 'burning plots', which are now a general trend throughout all regions.

c) The burden of administrative management:
In less than ten years, we have gone from six hours of management per plot to over 18, comprising: diagnostics, consultation, burning, impact control and administrative and financial management.

d) The strong decline in burnt surface areas in recent years has resulted in government officials lacking motivation:
If the risk of fire objectively remains, government officials, faced with annual improvements in assessment, are tempted to reduce public finance, which currently accounts for over 75% of the cost of unit operation at around EUR 100 000/year for 1000 ha.

f) Stronger public opposition to the practice:
The excellent assessments in terms of fire fighting have, unfortunately, encountered a loss of awareness of the risk amongst 'new locals' coming from the city with urban backgrounds. This group is increasingly dominating local committees and municipal councils and set government officials against a practice they consider dangerous, ineffective, and responsible for erosion, deforestation and atmospheric pollution.

After convincing environmentalists through their involvement in impact assessments for burning in the areas, we now have to identify information channels for these 'new stakeholders'.

3.4.5 Lessons learned and transferability of the experiences of the professional prescribed burning team in Pyrennées Orientales

The experience of the Pyrénées Orientales unit is exemplary at both regional and national levels thanks to its long service period and the importance of the surface areas that have been treated each year (600 to 1400 ha on 40 to 80 plots) for the last 20 years (17 000 ha on 1900 plots) and for other features such as:

- Supervision performed by a professional organisation (the Société d'Elevage des Pyrénées Orientales) guaranteeing the control of the service by the farming profession.
- The number of regional partners involved when consulting and producing prescriptions.
- The importance of public funds mobilised for the operation.
- The cross-border nature of knowledge exchange during the campaigns.
- Its involvement in the National Prescribed Burning Network (RBD) and the working group for pastoral burnings at the Pyrenean Chambers of Agriculture.

These conditions mean that useful lessons can be learnt for the correct development of prescribed burning:

a) Diagnostics and consultation are the basis for a good 'prescribed burning plan'
Prescribed burning is a well-planned and orderly operation. In this way, and without taking into account compliance with current regulations (see below), prescription should be formulated so as to respond to clearly defined targets comprising the physical and biological features of the area, ecological constraints and social expectations – the prescribed burning plan.

The first stage of the plan is to identify the primary demand, which might be for livestock farming, fire hazard reduction, silviculture or cinegetic purposes. Later, the ecological constraints will then limit this first demand level. Following this, social expectations should be integrated - in outstanding landscapes or at the edge of very busy roads, for example, burning may be limited to only those areas without any visual impact, the rest being cleared manually. Subsequently, this information, combined with the physical features, will set the size and distribution of the burn plots and the desired operational method: micro-climate conditions (wind, air humidity and temperature), plant physiology, dryness level of the fuel, litter and soil, and finally, the methods required to guide and control the fire, and carry out any preliminary work needed.

b) Strict compliance with regulations
In all regions susceptible to fire in the south of France, the use of fire by land owners and those holding land use rights is strictly regulated by order of the Prefects. However, in reality, most present or potential fire users are totally unaware of the content of the often complex orders. This lack of awareness is thus the source of misunderstandings and conflicts between shepherds and farmers and the Fire Service – whose role is more fire suppression than promotion – and with mayors and the police, in particular, who are responsible for compliance with the legislation and controlling safety. Users, therefore, generally learn little from the orders except the notion of a ban.

In order to avoid any conflict, reports, complaints and, above all, to impede the 'clandestine' use of fire, which often leads to uncontrolled fires, a return to good practices should be encouraged, going beyond compliance with current regulations:

- Information prior to and on the same day as the fire for nearby or the most involved partners – town council and neighbouring councils, local fire brigades, police forces, forest rangers, hunting associations, reserve commissioners and ski resort managers.
- Remain in constant contact with the media about the fire (mobile phone).
- Proper supervision of the area's surroundings and points of entry (signs notifying of the burning, the presence of personnel, flashing lights, etc.).

c) Livestock farmer support for rediscovering know-how
After years of abandoning the use of fire, many shepherds and farmers have lost their traditional know-how and their knowledge on controlling fire is often non-existent. Farmers should be encouraged to take training in basic techniques. In this way, in the areas where all traditional practice had disappeared, controlling fire

could eventually lead to the implementation of a type of sponsorship in the form of mixed teams comprising experienced supervisors and livestock farmers to conduct good practice rediscovery workshops.

By this, livestock farmers could sign a document (charte) to respect good practice in pastoral burning, which would be produced by every micro-region and validated by the professionals responsible as well as competent state and regional services.

d) The creation of an 'observatory' for practices and effects on the environment

Compiling data relating to each burning project comprising, for example, the geo-reference, filling out performance files, photographs, etc. could be systematically put into place so as to allow both the control of the impacts of fire and their combinations with their pasture or agricultural assessments.

Supplying these data to an 'observatory for burning practices' would allow their effects to be analysed and any adjustments made.

e) The qualified use of fire fighters

The experience in the Pyrénées Orientales shows that the demand for using fire amongst farmers to manage their territory could never be met by the fire fighting services alone. In order to cover the demand of 400 livestock farmers (using 100 000 ha of summer pastures and 80 000 ha of arable land and trails), around 50 to 80 projects covering 700 to 1400 ha/year, the Pyrénées Orientales unit needs to mobilise fire brigade services for over eight weeks between January and March. Extrapolating these figures to other regions in the mountain range, where surface areas to be burnt per year are 5 to 20 times higher, shows that it would be impossible to replicate such an organisation in highly rural sectors as there would be a lack of fire fighters.

In addition, as the favourable conditions for using fire are very short (a few hours on short winter days), any prior planning for projects would be a waste of resources. In good conditions, just a few people are needed; in dry conditions, however, over four forest fire vehicles and around 30 individuals would be needed to provide less-than-satisfactory results.

In this way, experience has taught us that fire is a typical rural tool as its use takes into account environmental conditions which only local farmers are able to grasp and use to good advantage. Before attempting to substitute rural know-how for specialised units ill-equipped to satisfy demand in terms of both quantity and quality, we prefer to reserve the use of fire fighters solely to 'seal in' strategic areas' bordering points designated for protection (forests, houses, etc.). Most surfaces would thus be returned into the hands of the farming profession.

f) Network usefulness

To conclude, given the vast differences in the physical and social settings, the need to rediscover know-how, and the complexity of fire effects on different ecosystems' features, only network exchanges coupled with research will be able to meet the challenge of achieving the successful use of prescribed burning. From its creation, the PB National Network has been in place to share experiences with practitioners, researchers, government officials and administrations. This network is currently a source of important outcomes for the development of the practice: the guidelines for

good practices, prescribed burning files, decision support tools, training courses and qualifications, adaptations to regulations, bringing together research knowledge on burning effects, pollution and smoke toxicity to name a few.

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3.5 Prescribed Burning for Improved Grazing and Social Fire Prevention: the Spanish EPRIF Programme

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3.5.1 The rural people at the origin of forest fires

For millennia, fire as a tool for vegetation management has been the basis of agriculture and livestock-raising. Today, fire is still an essential component of the rural technologies in many places of the world and the Mediterranean Basin is no exception. However, the use of fire in a context of changing socio-economic conditions can also be a component of several conflicts that can cause wildfires. Some are especially present in countries like Spain as discussed here.

Persistence against 'slash and burn' for agricultural purposes

This conflict arises out of the use of fire to eliminate forest vegetation and its subsequent replacement by agricultural crops.

However, the current tendency is for the conflict to die out because land can only be reclaimed in areas where irrigation is possible and are thus highly limited due to their dependency on the availability of water. In addition, European Union (EU) policy for preventing surpluses (CAP) is deterring further settlements on forest lands, which are usually low productivity areas due to their quality or slope. This conflict, however, is tending to disappear.

Land abandonment

The conflict arises as a result of rural activities ceasing on marginal agricultural lands, either spontaneously or encouraged by the EU's policy against surpluses. Leaving the land unattended gives rise to an invasion of wildland species in a process that leads to the future regeneration of the forest. This invasion very quickly generates the most dangerous types of light fuel accumulations, in which fires breaking out for whatever reason take on high speeds and intensities and are extremely difficult to fight.

The tendency in this conflict is to regulate the change in land use from farm to forest, with funds to make it viable and prevent fuel accumulations. However, the process of giving up the land is outpacing current policies. In addition, this process makes owners who might request subsidies disappear. However, even with subsidies

it is difficult these days to find people who would be interested in investing money to protect something that does not directly produce anything for them. This is a conflict that is also tending to worsen in the entire Mediterranean Basin.

Burning grasses and bushes to renew pastureland

Legislation in Spain forbids the use of fire in forest areas and in a belt of 400 m surrounding the forest. Outside this area, authorisation to use fire must be applied for from Forest Services; however, issuing a burning permit depends on the fire danger index. Generally, there are rules related to the fire season during which authorisation cannot be given (Vélez 2000a).

Nevertheless, this preventive legislation is indirectly defied by regulations protecting people living in the mountains. The current situation is characterised by the continuous reduction in the number of shepherds as a result of rural depopulation. While one possible fire management policy would be to encourage grazing in depopulated areas, there are two problems which prevent this policy from working:

- First, the average age of the population remaining in the forest land is very high. The human ageing process reduces physical strength and increases resistance to change in personal behaviour. This is why they carry on burning 'to regenerate pastureland' as they did in their youth, but without taking adequate precautions against the changed fuel conditions. Due to the large fuel accumulations, their burning technique proves uncontrollable with fatalities recorded each year as they burn pastureland - in 2003, for example, nine persons of 67 years and older were killed by forest fires in Spain and 83 in Portugal (Viegas 2004).
- Second, the EU's incentive policy allocates subsidies based on the number of sheep and goats without any relation to the area of land on which these animals graze. This policy allows the owners to take them to seasonal pastures.

Those who utilise these subsidies know how to apply for them and are more often than not from the urban environment. The apparent lack of relationship between landowner and land users leads to the hiring of shepherds who many times set fire in an uncontrolled way thus causing wildfires.

This problem could be minimised by greater internal coordination of EU regulations as well as promoting the use of controlled burning.

Burning agricultural remains

Fires spreading into forest areas arise from the use of fire to remove agricultural harvest remains (stubble burning) and prepare the land for further sowing – a tradition on cereal growing lands. It is also carried out to remove underbrush and weeds or any other vegetation interfering with farming.

In Spain, as in all Mediterranean countries, legislation runs parallel to that which governs pasture burning (Vélez 1992). Likewise, this conflict arises through the failure to comply with preventive measures laid down by legislation and which are

specified in burning permissions. To avoid any burning costs, it is cheaper not to take any precautions. In addition, if an illegal burn runs wild, the Administration must prove who carried out the burn in order to hand out a penalty (burden of proof) to the offender.

The current tendency is that this type of burning will increase. In fact, farmland is becoming a mere support for the crop since the farmland's organic matter is destroyed every year by burning and thus has to be fertilised to compensate for these losses. In other words, this is a completely non-ecological method of agriculture.

The negative ecological effects of these burnings resulted in it being prohibited by the European Commission in 2005 related to agricultural lands benefiting from subsidies under the Common Agricultural Policy (CAP). To enforce the prohibition, the subsidy would be withdrawn if the land owner initiates stubble burning.

Declaration of specially protected areas

Conflicts arise from the imposed limitations of land use that these declarations bring to local communities. When a region is declared a National Park, Natural Park or some other protection area, certain restrictions are established aimed at conserving or restoring natural resources. This has an immediate influence on the livelihood of the area's inhabitants and may clash with their established land uses and traditions. Confrontations can occur and one of the causes of these conflicts is forest fire.

The aim in environmental policies is to recognise these potential conflicts and take compensatory measures, which should be extended to the entire population in the protected regions' area of influence.

The conclusion is that these types of conflicts will tend to widen, even though these protected regions are controlled by good management.

Many of the above conflicts are reflected in the Spanish Forest Fires Data Base (EGIF), which registers the cause of each fire in the fire reports. There are two main 'origin' categories of rural of forest fires:

- Carelessness: divided into the sub-categories of 'agricultural burning' and 'grass burning'.
- Arson: intentions to burn are categorised to explain arson. As rural burning without permission is included here, both agricultural and grass burning come under this category.
- Another sub-category is 'burning due to animal damage', i.e. to scare away wild animals from the crops.

The average figures for 1991–2005 are given in Table 1.

This means that nearly two thirds of the total number of fires has a verified rural origin, i.e. they are related to the traditional use of fire. These fires account for more than half of the total land burned each year in Spain.

Many fires are also caused by people living in rural areas, although their intentions are related more to human nature (like revenge) than to agricultural technologies.

The magnitude of these figures makes it a priority to establish a systematic prevention policy aimed at the rural population (Vélez 2002).

Table 1. Fire causes 1991–2005.

Fire cause	Percent of total number of fires	Percent of total burned surface
Carelessness (legal burnings)		
Agricultural burning	4	5
Grass burning	3	2
Deliberate (illegal burnings)		
Agricultural burning	33	16
Grass burning	17	30
Animal damages	3	3
Total	60	56

3.5.2 The EPRIF Programme as a strategy for the conciliation of interests

The traditional use of fire as a tool in rural (agricultural) technologies has been classified as a dangerous activity by all Forest Administrations in Europe. Occasionally, it has been totally forbidden, but without success. This is why many legal systems have opted to continue to allow fire use under regulations that, for example, set zones and periods of prohibition, and require burning licences (Vélez 2000b). In addition, adopting sets of preventive measures against fire escapes must also be followed. However, there are always some who do not concern themselves with licences and precautions, and continue burn regardless causing forest fires.

These conflicts of interests are easy to identify: on one hand, rural inhabitants burn to manage their vegetation; the Administration, on the other, tries to limit open burning to prevent fires from spreading to forests.

Conflicts can also come about indirectly. For instance, in North-western Spain, it has been observed that most illegal burnings are now set after sunset, since a growing number of fire detection and firefighting flights only take place during the day.

Now that stubble burning has been forbidden in Spain, farmers can get rid of the straw by:

- burning illegally in an uncontrolled way
- ripping up the spikes as near as possible to the ground by the crop harvester lowering the harvesting tool. This can also result in fires due to sparks being generated from the metal tool striking stones.

The conclusion is that the prohibition of stubble burning can, in fact, exacerbate forest fires. A conciliation of interests, therefore, seems to be the right way to prevent the practice of arson.

Table 2. Annual averages 1996–2005

Provinces	Total no of fires	Fires of rural origin		Total % rural
		carelessness	deliberate	
A Coruña	2.568	79	837	35.7
Lugo	1.401	21	117	9.9
Ourense	3.842	42	1.661	44.3
Pontevedra	3.275	78	1.158	37.7
Asturias	1.605	43	294	21.0
Cantabria	346	64	154	63.0
La Rioja	106	42	24	62.3
Huesca	107	30	5	29.0
Canarias	78	7	2	11.5
Navarra	327	30	13	13.1
Cáceres	783	49	65	14.6
Avila	174	23	20	24.7
León	653	147	94	36.9
Zamora	542	41	116	29.0

The definition of the Programme

Conciliation of interests between farmers and Administration is being promoted by a programme of controlled burnings during winters. This programme was first started in three high-risk districts in the north-western and northern regions of Spain in 1999.

During the 2008–2009 winter fire season, the programme was carried in seventeen districts listed in Table 2 with the fire occurrence and the cause of rural origin.

A team of four worked in each district – specialists who work in the fire helicrews in summer, and who are trained in controlled burning and in arousing public awareness in rural areas.

The EPRIF or 'Integral Prevention Teams' (EPRIF is the Spanish acronym) works in close coordination with local foresters, although the organisation and budget comes from the Ministry of Environment. The terms of reference for this activity are shown in Annex 1.

EPRIF's tasks

The EPRIF teams work from November until April of the following year. Their tasks are the following:

a) Diagnose fire danger:
   - analyse the information on fire causes stored in the Data base;
   - identify local needs for burning (number of livestock heads);
   - identify local uses of fire (methods of burning, times, etc.); and
   - identify relationships between the Forest Administration and the local people (conflict assessment).

b) Public relations:
   - present the controlled burning programme to the local authorities (mayors) and to the local foresters;
   - attend meetings with local farmers' associations, visit to livestock markets, etc.; and
   - demonstrate the programme.
c) Prepare joint of plans for bush and grass burnings with farmers' associations and local foresters.
d) Execute and evaluate burnings with the help of the administration's firefighting resources to prevent escapes.
e) Conduct mobile patrols with small slip-on ground tankers.
f) Engage in firefighting when necessary.
g) Investigate fire causes in the district.

Profile of EPRIF's specialists

In order to perform the above tasks efficiently, the specialists are selected according to the following criteria:

- Aged between 25 and 35 with a university degree in Forestry;
- Minimum five years experience in the Special Forest Fire Brigades (BRIF), similar to the American 'hot-shots' like Fire Boss;
- Have had practical training in controlled burning during their jobs in the brigades;
- Possess good communication skills - identified after their records in the brigades and verified in a selection interview; and
- Have good physical fitness according to the standard test for suppression personnel (step test).

The EPRIF's programme Field Coordinators have the same profile plus a diploma from the Advanced Course on Prevention organised by the Ministry of Environment.

These preconditions aim at programme efficiency; further, the personnel are guaranteed employment for six-months in the programme, plus another four months in the summer brigades (BRIF). This is minimum ten months' employment each year – creating a good incentive to remain in forest fire activities and not to look for other less-demanding work.

General working procedures of the EPRIF programme

Step 1: Based on an agreement between the Ministry of Environment (DGB) and each Region, the decision on which districts the EPRIFs will be sent is based on the information on fire causes in the National Data Base (EGIF). Once the decision is made, the DGB contracts a company (working unit) and provides the necessary staff with the described profile for each EPRIF.

The fee paid by the DGB to each company covers salaries and per diems as well as other costs (vehicles, materials, etc).

Figure 1. Previous visit to an area in order to prepare the burning (photo by ADCIF, MARM).

Step 2: The EPRIF arrives in their assigned district and establishes its headquarters in the office provided by the local Forest Service – frequently the town hall or fire station (if there is one). The first meeting with representatives of the local forest service and the local administration is held to clarify (or remind) the objectives of the EPRIF and discuss the difficulties encountered in preventing and finding the causes of fire. During this and follow-up meetings, the EPRIF attempts to identify the existing conflicts between the rural people and the administration. Conflicts can arise, for example, from the differences in interests between the main village and other villages in the district.

Identifying conflicts can only be completed after first listening to the farmers.

Diplomacy is a must during this phase since the EPRIF has to work on good terms with all sides.

How the EPRIF objectives are explained to the local foresters is critical because due to their attitudes and beliefs, they often perceive 'fire prevention' and 'fire exclusion' to be synonymous. At this stage, it is also necessary to get them to appreciate that the use of controlled burning – according to Forest Law – is the best practice that will stop illegal burnings and thus prevent run-off wildfires.

Further, local foresters must be made to understand that the main objective of the EPRIF is fire prevention.

Locals authorities and foresters often see the EPRIF as a well qualified group of fire suppression experts (as they rightly are), and would thus prefer to have them available mainly for suppression instead for carrying out controlled burning.

Step 3: Information obtained during these preliminary meetings with officers from the forest service and municipal governments is verified by analysing the data base and by interviewing other groups such as local farmers' associations, country workers' unions and the main cattle breeders (if they use grazing extensively). Both agronomic and livestock services are also good sources of information as they are often responsible for distributing subsidies from the Common Agricultural Policy (EU/CAP) and they can thus provide information on which types of subsidies farmers receive (e.g. livestock farms).

Critical information required concerning livestock is that of the relationship or connection between land ownership and shepherds. Where no connection exists, illegal burning (to regenerate the grass) without putting into place any preventive measures to avoid fire escapes is more likely.

Other good information sources can be local tool, machine and fertilizer suppliers.

Step 4: After identifying as far as possible the situation in the district, it is necessary to contact the risk groups. They can be met at local or regional livestock markets, pubs, or wherever people go in the evenings, they can even be met at church on Sundays.

The locals need to be made aware that the EPRIF team is living in their community, and that their duty is not to penalise farmers, rather to help them use fire in a responsible way.

At this stage in the process, an open meeting to a wider audience can be organised in the town hall, where the EPRIF makes it known that it is available to assist in preparing burning plans with the land owners, and train people to carry out burning in the correct way.

These kinds of meetings can be coordinated with environment education activities to get over the message that rural people are causing forest fires by their burns and that they can be harmed by the fires. It can also offer to prepare burning plans supported by forest brigades and ground tankers if necessary. The contact details of the EPRIF team (address and cell phone number) should be given at these meetings so they can be contacted when a burning is envisaged.

Step 5: A first demonstration of the programme has to be prepared in coordination with the local forester.

It would be interesting to select two different places, one owned by the municipality and the other by a farmer. It is important to agree with the collaborating parties that they disseminate their burning experience with farmers living in the locality. The pilot farmers or stakeholders will later help the programme by spreading information to their neighbours.

These burnings always consist of grass or shrub burnings (fuel models 1, 2, 3, 4, 5, 6) (ICONA 1997) - never conducted under a tree canopy.

In this 'demo', the phases of a controlled burning to be followed are:

a) Requesting a burning permission from the Forest Service; setting alternative dates and the low risk conditions to start burning.
b) Spreading information on the burning date to neighbours, the local Forest Guard and to the Civil Guard (rural police).
c) Fixing the needs of the personnel and equipment to secure safe control of the burning. If necessary, requesting help from the Forest Service and the Fire Service (if available in the area) or from neighbours.

Figure 2. Reunion with local stakeholders in order to organize a burning plan and explain the fire prevention aims (photo by ADCIF, MARM).

d) Cleaning a fire-break around the area or, at least, creating a fuelless barrier between that area and the woodland to be protected; and if necessary, requesting assistance, for example, from a Forest Service's dozer working in the locality.
e) Obtaining the weather forecast to calculate the parameters of the fire's behaviour. This issue can be developed in a short seminar with the farmers. Most times, they know very well what can happen if they burn under certain conditions; however, at other times they do not have a clear concept of fire behaviour, and this lack of knowledge can lead to the wrong decisions being made.
f) Safety issues: how to prevent accidents.
g) Taking the decision to burn and the burning plan (by strips, spots or piles; time of the day, etc.)
h) Evaluating the results:
   - Costs
   - Vegetation consumption
   - Further grass regeneration or shrub resprouting
   - Possible damage

Table 3. EPRIF Activities, November 2007 – April 2008

Activities	Number	Time (h)	Surface (ha)
Meetings with farmers and the administration	570	1290:03	–
Sensibilization talks	83	257:44	–
Fuel management without fire	3	20:31	10.50
Controlled burning	218	1069:30	1559.43
Fire suppression	129	223:47	–
Causes investigation	32	122:41	–
Logistic activities	–	1455:00	–

Step 6: Although this preparation is time consuming, it contributes to creating a positive attitude in the district regarding this activity, and promotes good relations between the rural people and local officers.

This means that there must be a continuous flow of information to maintain the requests for preparing burning plans.

For instance, pictures and descriptions of the 'demo' burning can be sent to the local media such as newspaper offices. Radio, however, is probably the most effective channel since many rural people listen to the radio when they are in the fields. This may help prevent opposition from urban population, whose minds are often fixed at the 'fire exclusion' approach.

Step 7: Once the activity is introduced, the EPRIF has to continue to systematically offer its services in the same way as described in Step 4.

Appraising EPRIF's work

The control of EPRIF's work is made through detailed reporting after every activity – a standard form filled by the team. These reports provide information for monitoring the activities as well as seeing if the objectives were met.

During the campaign 'November 2007 – April 2008' the following activities were carried out in fourteen districts: (Table 3):

a) Meetings: promotion meetings were held with farmers; others with the Forest Administration or with the municipal authorities. In order to promote controlled burning, it is necessary to first agree with the administration to get permission and prepare plans, etc.
b) Sensibilisation: talks were addressed to the local people to review the best techniques to control the burnings.

Figure 3. Controlled burning execution (photo by ADCIF, MARM).

c) Fuel management (mitigation) without fire: this was sometimes necessary to protect houses or other facilities by showing an alternative approach to the use of fire.
d) Controlled burning: most burnings had the objective of managing grazing lands - in most cases municipal or communal land rented to farmers. In 90% of the burnings, the results were satisfactory for the land owners (public or private).
e) Fire suppression: although this is not the main objective, the EPRIF team had to help in a number of fires, because when it is possible to disseminate burning experience, it is also possible to burn illegally.
f) Investigation of fire causes: as there are only investigation brigades in some provinces, EPRIF offers this service necessary also for prevention.

The EPRIFs have had very encouraging results after ten years of this programme: in all districts where they operate, a drastic change in attitudes on the use of fire both among the farmers and local foresters can be observed. They now realise that they can control burnings just by working together; and in doing so, they can prevent fires from spreading into the forests.

In the summer 2004, just after the last EPRIF campaign, a remarkable reduction in the number of fires was registered in all six districts. This result motivated the Central Administration to increase the number of EPRIFs to seventeen during the November 2008–April 2009 campaign, supplemented by a further six financed by the Regional Government of Galicia.

Although controlled burning is in all cases the main activity, other actions are necessary to reach conciliation between people and administrations.

Figure 4. Controlled burning execution (photo by ADCIF, MARM).

3.5.3 Lessons learned: the importance of environmental education when living with fire

The magnitude of the conflicts related with the rural origin of fires makes the establishment of a systematic prevention policy aimed at the rural population a priority. To design this policy, it is necessary to consider that:

- rural people use fire for a number of utilitarian purposes
- fire prohibition has never succeeded
- fire effects can be controlled with the appropriate techniques

In an urbanised society like Europe, the concept of fire management is little understood because the historical memory of rural burnings has long since been lost and substituted by the concept of total 'fire exclusion'. The traditional use of fire has been lost, and the rural people who still burn become relics of ancient times.

At the same time, land abandonment produces more and more fuel accumulations and escaping wildfires from agricultural burning or weekend camping/hunting becomes a major agent of disturbance in the remaining forest ecosystems.

Therefore, it is necessary for people and the administration to become aware of and understand the role of fire in the environment, as well as to integrate it in present silvicultural practices – in other words, why rural people use fire. Only by

doing this can there be correct and responsible burnings instead of wildfires. This is the essence of the EPRIF programme.

Moreover, to effectively deal with the negative aspects of traditional fire use, there is a need to complement these types of programmes with persuasive activities that teach the rural people that both they themselves and their neighbourhoods can be badly affected by uncontrolled fires. This message faces a major barrier – their distrust for the Forest Administration (FA) since permission must be requested for all activities, even on private land, and its varying levels of levies and fines.

The sensibilization campaign of the rural population, started in Spain in the 1980s, found an innovative way to educate the public at the beginning of the 1990s. The approach included community theatre plays as means to approach the population in fire-prone communities. These plays, performed by professional theatre groups not identified as Administration agents, were able to present, in a dramatic way, how rural attitudes were causing fires and the tragic consequences of these fires to the country people, sometimes even resulting in loss of their lives (Vélez 1987).

During the last ten years, seven plays were written by famous Spanish authors, which were played in the rural areas during the fire seasons – both in summer and in winter (grass fires mainly occur in the winter months). Tens of thousands of rural people came to watch these plays in the main squares of their villages in summer, and in schools and sport facilities – even in churches in winter. This has allowed them to think and ponder on the dangers of fire created by grass and bush burnings in their own fields and surroundings.

The systematic monitoring of opinions has shown that receptivity among the rural people is consistent. Results of large scale surveys indicate a general approval of the fire message (rural people cause forest fires by their burnings and can also be harmed) and the way of getting the message across, i.e. theatre plays.

Although the local people are becoming more and more urbanised, they are, at the same time, becoming increasingly aware of the negative effects wildfires have, and are thus asking for and seeking ways in which to cooperate. However, primarily because of the dangers to human lives in fire suppression activities, the administration has agreed to facilitate cooperation through the various volunteers organisations aimed at preventive activities and, only in well-defined conditions, help in fire suppression. These organisations are always linked to a municipal authority in order to get good cooperation from all kinds of people and stakeholders(Garriga 2000; Suarez 2000).

These programmes are best explained by two slogans in Spain's sensibilisation campaigns:

- Let us live with fire and endure it
- Everybody against wildfire

3.5.4 Transferability

This preventive approach has been developed only after deep and extensive work into investigating the causes of fires. The Spanish Forest Fire Data Base is 40 years old, updated every year with the information collected by the provincial services

following a set of standardised rules. By the beginning of the 1990s, investigations into the causes of fires were improved by a wide training programme for the Forest Guards (Agentes forestales) and Rural Police (Guardia Civil).

The figures given in Table 2 are thus a solid base on which to take decisions for real prevention addressed to the real causes.

This means that the EPRIF programme could be adopted by other countries if a previous work of fire causes investigation is organised and its conclusions are the same as those found in Spain.

Under these conditions, it would be necessary to make a political decision if existing legislation does not accept that controlled burnings in woodlands are a management tool. Support from with the public and environmental groups must also be secured before the legislation can be amended. As fire is forbidden in many places in Europe, to re-introduce it would require much promotion and information.

Further, the farmers' associations should be contacted, as in many cases they do not like to or want to recognise that some traditional practices can be the cause of a fire. Their support will help in spreading the information among other farmers and interest groups.

Obviously, resources other to those described here must work in close connection with the administration charged with prevention policies as well as the local authorities

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Annex 1. EPRIF Terms of Reference

Specific missions

These missions are to be developed in the district previously chosen with the Regional Authority and in coordination with its services, which will provide an office in the district.

- Education on Forest fire prevention techniques for the rural population: farmers, livestock breeders, shepherds, forest owners and hunters.
- Advising the public in preventive silviculture work: fuel breaks, slash elimination, roads cleaning, wells, reservoirs, etc.
- Planning and implementing controlled burning with farmers
- Patrolling the district during high risk days
- Investigating fire causes
- Environmental education for children in schools

Complementary mission

Assistance to the district services in the first attack to those fires starting in its area of operations. The EPRIF team will work under guidance (command) of the district fire chief.

EPRIF equipment

- Standard Individual Protection Equipment, according to the 'Catalogue of Equipment and Tools', CLIF Recommendation, MMA 2000 (nomex overall, hard hat, fire boots, gloves, etc.).
- Standard tools for burning (drip torch) and suppression (pulaski, shovel, macleod, etc.) according to the CLIF Recommendation.
- Investigation box containing the following:
  - Camera
  - Thermometer, psychrometer and anemometer
  - Compass, metric tape and lantern
  - Sampling tools
  - Elements to mark the origin of the fire
- Two cell phones
- A 4 x 4 vehicle able to carry seven people plus equipment
- Educational documents (videos, pamphlets, handouts, etc.)

Labor term

- Week hours
  37.5 hours a week, on usual work days.
  When some tasks cannot be performed during weekdays, overtime will be compensated with vacation time. Some examples of these tasks are: burnings during good weather conditions that fall on Sunday; meetings with farmers in livestock markets on Sundays; fire suppression at weekends, etc.
- Daily hours
  7.5 hours a day usually from Monday to Friday.
  When it is necessary to extend this shift (e.g. because of fire suppression) the maximum limit will be twelve hours from the arrival at the job place.
  After this limit, the personnel will have a minimum rest of eight hours.

Control of activity

The EPRIF team will prepare a report of each activity by filling the standard EGIF form. These forms are sent every 15 days to the 'Area de Defensa contra Incendios Forestales'. (The National Forest Fire Service, Ministry of Environment).

3.6 The Portuguese National Programme on Suppression Fire: GAUF Team Actions

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3.6.1 Introduction

The use of fire to fight forest fires, one of the techniques promoted and used by the Fire Use and Analysis Group (GAUF), is probably as old as the deliberate use of fire by humans with a history that probably dates back several hundred thousand years. Until recently, however, this practice was, and still is, banned by law or at least ignored in most European countries. This led to a clandestine and unsupervised use of this technique and therefore it is not easy to find written records of its use. However, we can piece together part of this history through interviews, accounts and some knowledge.

In Portugal, in the history of forest fire fighting of the last few decades, we can identify different ways in which fire was used to fight forest fires:

For a period that probably ended in 1982 (although it is impossible to date accurately), fire was basically used by the Forest Services personnel who were responsible for fighting fires. Fire–fighting work was generally carried out by forest and senior forest rangers with help from rural workers and any locals who were available. These people had experience and profound knowledge of the forest and forest areas, yet the only means to fight fires were locals equipped with manual tools. Their most powerful fire fighting tool, however, was fire - a tool used as the last resource with the utmost discretion and only with the approval of the expert in charge of managing and protecting the threatened area.

In 1982, the National Fire-fighter Service (volunteer fire fighters) took overall responsibility for fighting fires; however, there was no cooperation between the two organisations aimed at sharing and applying the knowledge gained. Most likely, fire continued to be used as a tool to fight fires, but with an ever increasing level of secrecy and unaccountability by those with little knowledge of the forest, the forest areas and of fire itself. These factors probably led to bad experiences which, in turn, gave rise to negative reactions on the use of this practice in some areas of the country and resulted in it being categorically excluded as an option in some areas.

We will now expand on the events related to the use of prescribed burning (fogo controlado) in Portugal since it was the use and development of this technique that generated the necessary conditions for the creation of the GAUF in Portugal.

In Portugal, the use of fire as a means to manage the ecosystems has been used for thousands of years. The decrease in its rational use is most likely due to the prohibitions enforced in the mid 20th century (most recently) and the rural exodus. Fire is an element of the Mediterranean landscape and was used for various

purposes, such as agriculture, pasture renewal or, in more recent times and to a lesser extent, as a means to protect forest populations against forest fires.

The first references to the use of fire in Portugal as a means to protect forest populations against forest fires date back to 1836 in 'Manual de Instrucçoes Praticas' [Practical Instructions Handbook] by Frederico Vernhagen (Monteiro Alves et al. 2006).

Some 140 years after this first written evidence, the fuel management technique was once again tested in Portugal thanks to the visit of a North-American specialist, Edwin Komarec, and to the interest, enthusiasm, and entrepreneurial ability of Moreira da Silva (BEng), forest manager in northern Portugal (Silva 1997). The first controlled fire trials were carried out in the Peneda-Gerês National Park and in the Entre Douro e Minho public forest. From the outset, Moreira da Silva invited the universities and the National Forest Station to follow and investigate the use of prescribed burning. In this phase of the use of fire as a preventive measure, the operatives were forest rangers and senior forest rangers who were familiar with using fire to fight forest fires. The use of fire as a preventive measure by the same people who fought forest fires and were responsible for implementing forest management soon led to a rapid increase in its use, as they believed in the effectiveness of this technique to reduce fire hazards.

The integrated functions of these operatives allowed for a better strategic selection of the areas to treat. Also, as they had the additional benefit of using fire in prevention and in fire fighting, they were also better equipped to gain experience and knowledge in terms of the planning and execution of the techniques.

Between 1976 and the mid 1990s, the use of prescribed burning evolved and was used either to a lesser or greater extent by using different methods based on the experience gained and the research results (Fernandes and Botelho 2004). From 1993, however, the use of this technique shows a steep decline mainly because the responsibility for using the technique was concentrated in the hands of very few people (basically two experts who both left the forest service at almost the same time).

In 2002, thanks to the determination of several people representing various organisations – Forestis (Federation of Forest Producers' Associations); UTAD (University of Trás os Montes and Alto Douro); and DGRF (Directorate-General of Forest Services) – the general guidelines for a more generalised and sustained use of prescribed burning in Portugal were defined and implemented.

Between 2002 and 2006, the strengths of this initiative were the following:

- Definition of the certification process for prescribed burning technicians.
- The implementation by Forestis of several training courses for the certification of specialised prescribed burning technicians.
- Training for the support operational teams who will use prescribed burning (Sapadores Florestais).
- Implementation of actions aimed at reinforcing training and execution, and at promoting this technique in a variety of ecosystems and land tenures throughout the country.
- International exchange of information, with workshops and training sessions on how to apply this technique.
- The existence of about 50 technicians who were certified in prescribed burning

and 120 trained operatives by the end of 2006.
- Elaboration and publishing of the specific regulation on the use of prescribed burning (Decree-Law 156/2004 and implementing order no. 1061/2004 that sets forth the regulation on prescribed burning).

The planning and execution phase of prescribed burning at the landscape level began in 2005. Its main goals were to decrease the forest fire potential in strategic areas and to increase the possibilities of fighting big forest fires in forested areas.

The knowledge and experience gained by using prescribed burning led a group of experts to achieve an important level of knowledge and maturity in terms of fire behaviour. It would have been an enormous loss not to capitalise on this knowledge to fight forest fires in a country where they pose such a serious problem, as is the case in Portugal.

There were a series of other factors that together significantly influenced the conditions necessary to create the opportunity to implement this initiative, namely:

- The catastrophic years of 2003 and 2005, during which large areas of Portugal were devastated by forest fires (about 425,000 ha and 340,000 ha, respectively) despite the increasing investment (especially from 2000) in fire prevention and fire fighting.
- In 2006, the publication of the National Defence Plan for Protection of the Forest Against Wildfires outlining actions to be implemented over a ten-year period aiming at a progressive decrease in forest fires.
- The existence of a group of people in influential positions who understood the need for new strategies.
- Professionalisation of the service responsible for coordinating civil protection in Portugal and its openness to using new strategies and the use of new approaches.
- The openness that led to a closer cooperation between fire-fighters (responsible for fire fighting) and forest managers (responsible for fire prevention).
- The creation of the Fire Paradox project with access to other approaches and strategies, the opportunity of cooperating with professionals from different countries, and the greater international recognition of fire-related activities.

3.6.2 The Fire Use and Analysis (GAUF) teams

The idea of putting together teams which include technical knowledge of fire analysis and the use of fire was brought about by a group of technicians with connections to the forest services and the Fire Paradox project. The initiative deals with the knowledge available to an ever increasing group of prescribed burning specialists (as stated above). It also saw the need to incorporate large strategic and professional components into the fire fighting system. Further, it deals with the possibility and the need to bring about a turning point in the use of fire to fight forest fires, and the knowledge gained from the incorporation of these factors into the fire fighting systems in other countries.

The creation and institutionalisation of GAUF

Following a training initiative which took place in April 2006 (described in section 3.6.3) and various contacts, a group of technicians (at the time without any specific designation) was put together under the umbrella of an agreement between the DRGF and ANPC (the Portuguese National Authority for Civil Protection) and reporting to the DGRF. Its main goals were to help ANPC fight major forest fires (or fires with the potential to become major forest fires), during the extended attack phase (over two hours in duration) by resorting to fire analysis and the use of suppression fire components. These teams intervene nationwide and can be distributed throughout the country depending on meteorological and structural fire risk and the importance of the forest or environmental considerations.

During the critical period of 2006, the team comprised 11 experts (five Portuguese nationals and six from: Spain (two – GRAF Grups de Recolzament d'Actuacions Forestals), France (one – EM Espaces Méditerranéens) and Argentina (three – Plano Nacional de Manejo del Fuego).

In 2007, as a result of the performance and potential shown in 2006, the Fire Use and Analysis Group (GAUF) was officially created. Its existence and functions were set out in ANPC's National Operative Standard and its main goals were to:

(i) help the Operations and Relief Commander (COS) identify critical points, intervention opportunities, and the development of suppression strategies for forest fires;
(ii) plan and carry out fire suppression operations (backfire and tactical fire);
(iii) help develop, coordinate and carry out other suppression techniques; and
(iv) make decision in terms of fire management.

Figure 1 shows the organic structure of the GAUF group within the National Forest Authority (current name of DGRF).

In 2007, the number of members on the team increased from 11 (in 2006) to 19. While the decision-makers wanted to increase this number even further, it was not possible because of the specific pre-requirements demanded for team members. Eligibility criteria for admittance to the team include: prescribed burning certification, ample experience, expertise in prescribed burning demonstrated in practical sessions, experience in fighting fires, training in fire analysis, commitment, and physical and psychological abilities. In 2007, the team could, once again, count on the collaboration of colleagues from other countries, namely those countries that collaborated in 2006.

The number of team members increased again in 2008 and 2009, but this time there was very little participation from members from other countries. There was no participation from other countries in 2008 and 2009 (although the critical 2009 period is still underway) since the number of Portuguese members increased and because in terms of forest fires, it was not necessary to reinforce the teams. However, we keep the contacts of the members from other countries readily available should they be needed.

As far as the Portuguese GAUF teams are concerned, they are made up of a restricted number of permanent core members (five in 2008 and eight in 2009) who, outside the critical periods, handle the planning and the execution of prescribed

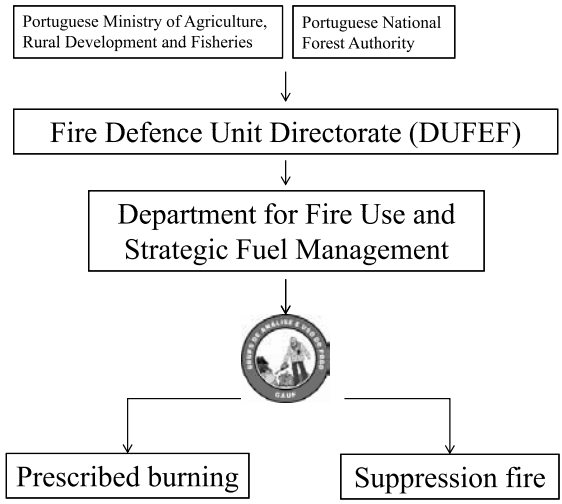

Figure 1. Structure of the Fire Use and Analysis Group.

Table 1. Annual variation of GAUF members.

Countries of origin of the participants and GAUF members	Year			
	2006	2007	2008	2009
Portugal	5	10	22	26
France	1	1	1	1
Argentina	3	5	0	0
Spain	2	3	0	0
Total of members	11	19	23	27

burning, organise training sessions, and deal with other aspects related to fire prevention. The other members are hired on a seasonal basis when needed. These temporary members are technicians that come mainly from Forest Producers Organisations who assign them to GAUF. This system of adjusting the number of team members according to needs leads to cost savings and allows us to count on the participation of technicians who concentrate on other forest management tasks, outside the critical periods, in particular on preventive actions. These members bring their knowledge of the areas they usually work in to the team. One other advantage is the fact that GAUF's knowledge and philosophy can be transmitted to and incorporated by a larger number of partners.

Figure 2. GAUF vehicle and fire suppression equipment (photo by Manuel Rainha).

Composition and functioning of the GAUF teams

The teams are composed of three members with specialised training in prescribed burning, fire analysis, and the use of fire to suppress forest fires. Intervention by the GAUF teams is requested to the National Command for Relief Operations (CNOS) of ANPC, that requests the activation of the teams to one of the two GAUF national coordinators. Assessment of the need to the GAUF teams may be carried out by the CNOS, the District Commanders of Operations and Relief (CODIS), the Relief Operations commanders (CNOS), by AFN liaison technicians or by GAUF members. Any operations which require the use of fire must be authorised by Commanders of Rescue Operations (COS) or CODIS.

GAUF equipment

Each GAUF team has fire analysis equipment (a laptop computer with geographic information software and fire behaviour simulation software, mobile internet, a portable meteorological station, and a printer), fire suppression equipment (a vehicle equipped with tools for sapadores florestais, drip torches and fuel). The vehicles are equipped with automatic detection and localisation units (URLA) which allow real-time transmission of the GPS coordinates to the teams and pre-configured automatic messages for operational use according to the position and operational situation.

Since 2008, the teams have access to a small aircraft equipped with URLA, cameras, and visual and infrared video cameras enabling flyovers to rapidly assess the perimeter of the fire, its behaviour, and to identify critical points and fire fighting opportunities.

Figure 3. Suppression fire training. Lousã 2007 (photo by Adriano Germano).

Figure 4. Backfire manoeuvre operation (photo by Pedro Palheiro).

When mobilised to a fire, the teams have back office support. The coordinator and/or other technicians provide them with information on fire behaviour – analysis of current situation and predicted development, current and expected weather conditions, topography, fuel, fire records – as well as establishing and maintaining contacts. The back office team is also responsible for liaising with the institutions.

Training and selecting the operatives
Apart from the analysis and classroom training sessions held several times a year, operations with real fire are carried out for training purposes and as a way to select those operatives who will become part of the GAUF teams (initial selection is carried out by permanent members of GAUF). These exercises follow a specific sequence for igniting prescribed burning, using the upper limit on the prescribed burn scale for wildland fires. The aim is to ignite fires which have similar characteristics to actual forest fires.

3.6.3 Implementation of GAUF teams

It was always going to be controversial to create a group to help fight forest fires, external to the institution responsible for civil coordination, whose main goals and contribution would be to help make decisions in terms of operations by defining strategies to fight fires based on fire analysis and the use of suppression fire.

First, because there are professional command structures in Portugal, both centralised and local, under the umbrella of ANPC that might not accept input from members of other structures when making operational decisions; second, the aim to make public and official the use of a technique that had previously been used but ignored from a legal standpoint; and third, the bad examples set by the incorrect use of this technique led it be banned in some areas.

The initial action that somehow managed to overcome resistance to these two factors was the organisation of a training course on fire analysis and the use of suppression fire in a training exercise that took place in April 2006 in Lousã. The partners from the Fire Paradox project, the Espaces Mediterraneens NGO (EM – France), GRAF (Catalonia, Spain) as well as the French professional fire-fighters participated in the organisation and execution of this training course. It proved to be the turning point and created a more open climate which led to the participation of forest technicians in fighting forest fires resorting to fire analysis and the use of suppression fire (at this stage it was still called backfire). It was a course organised by the Directorate-General for Forest Resources (former DGRF, current National Forest Authority – AFN), with the participation of members from the National Authority for Civil Protection (ANPC), volunteer fire-fighters (humanitarian associations), the National Fire-fighters School, certified experts in prescribed burning from Forest Producers' Organisations (OPF), and the Institute for Nature Conservation and Biodiversity (ICNB). The main results achieved were the openness and the link established between the present members and the organisations which were represented there, and the advantage presented by the appropriate use of fire analysis and suppression fire evidenced during the exercise.

Relationship with other fire fighting organisations on the operational stage

GAUF teams do not have a defined hierarchy in the operational stage, which sometimes leads to operational problems when coordinating the fire-fighting teams during the extinguishing operations. This problem becomes more evident the

higher the diversity of situations in which the teams operate. This diversity has been increasing gradually with interventions in terms of positioning of resources and coordination of fire-extinguishing operations which only have access to water (direct attack) or manual tools.

While executing fire operations, GAUF was helped by several support teams. It was difficult to coordinate these support teams as they would either not acknowledge the chain of command or they would be unable to perform their assigned tasks – frequently due to the lack of knowledge or experience in these types of operations.

For the GAUF teams to be able to coordinate members of other organisations, the commanders of COS needed to be given the power to coordinate the information passed on to the teams, so that the orders given by the members of the GAUF teams would be respected and implemented even though established chains of command had been bypassed.

The use of fire to fight forest fires and the influence of GAUF

When using fire to fight fire, GAUF intends to contribute to both its legalisation and accountability. The goal is not to increase its use but rather to stop it from being a clandestine practice - a method that it is used appropriately. Its use must be visible and conscientious and it should be based on specific training and the experience of the technicians who use it, on their identification and accountability. Suppression fire should be regulated instead of secret thus transforming a tool into a technique with all that it implies. The clandestine use of this technique leads to unregulated use thus protecting the people who use it. It is news when the results are positive and it becomes a secret when they are negative.

It is a paradox that is easily explained, but usually difficult to put into practice in the operational stage. GAUF teams frequently find themselves in a position where they have to require that clandestine and inappropriate use of fire in the operational stage is abandoned when, under other circumstances, they may need that same team to participate in interventions that need suppression fire. On one hand, the use of this technique is being promoted, on the other however, the use of this technique should be limited to those experts who possess the required training and skills. In Portugal, the recently passed law on the use of technical fire should significantly contribute to the clarification of this situation.

GAUF's dimension

The reduced number of team members gives rise to frequent mobility and requires that they be available when there are a number of actions taking place simultaneously. As far as the forest fires that occurred in Portugal in 2006 and 2008 are concerned, this limited number of teams was sufficient to respond to the civil protection requests and to provide added-value in terms of strategy and results in terms of fighting forest fires. However, should the catastrophic events of 2003 or 2005 ever be repeated, this limited number of teams will certainly be insufficient to make a difference and to contribute significantly to reducing the problem.

3.6.4 Balance of the results achieved

In 2006, the team actively participated in the analysis of fire behaviour, in the making of decisions, and in support with hand tools in the suppression of six forest fires. In 2007, the team intervened in 70 forest fires with an active participation in fire analysis (36), the use of fire (30), the use of hand tools (24) and decision making (6) (Table 2).

Table 2. GAUF intervention in forest fires in 2006 and 2009.

Year	Interventions in fires	Analysis	Use of fire	Manual tools	Decision making support
2006	6	-	6	6	-
2007	70	36	30	24	6
2008	22	20	4	11	13
2009*	27	24	21	20	24

* values prior to 2 June, 2009

In 2007, there were two different periods of forest fires. The first period took place during July to September; the second during October/November. Thanks to the weather conditions during the first period, which limited the number of days with extreme fire propagation potential, most initial attack operations were successful. The intervention of the GAUF teams was not necessary because of the number of resources available and their quick deployment coupled with the fact that there were fewer occurrences than usual in Portugal (which had planned for major incidents). In most cases, these fires were controlled with traditional means. The second period covered October and November, during which the absence of prolonged rainy periods associated with dry wind provided enough fuel to burn even during the night. This, together with the lack of available suppression teams and the use of traditional fire at this time of the year to renew pastures or other purposes led to the ignition of several fires with their subsequent suppression. The GAUF team participated in 29 incidents from 7 to 18 November 2007. In many of these incidents, which developed under favourable conditions and in strategic places, the GAUF team prioritised fire management over immediate attempts to extinguish the fires. This only happened when the fire was beneficial in defending the forest against forest fires (elimination of fuel materials, landscape partitioning, etc.) due to its location, the type of vegetation and its behaviour, which was also beneficial to the local users of the land and the ecosystems.

In 2008, as was the case during the critical period of July to September of 2007, weather conditions were unfavourable to the incidence of forest fires with extreme propagation characteristics. This factor, together with the availability of resources, led to virtually no situations that required the intervention of the GAUF teams – 22 fires in all.

Figure 5. Backfire manoeuvre operation. Forest fire in Meda, Guarda (07/2008) (photo by João Tomé).

From 11 March to 2 June 2009, the GAUF teams intervened in 27 forest fires – mainly in March, a period where there was no rain and there were numerous ignitions in the woods and forest villages. Ignitions in forest villages were considered top priority because of the perceived value of the ecosystem. GAUF focused on protecting the public areas on forest perimeters.

3.6.5 Lessons learned

Incidents outside critical periods

Intervention in fires outside critical periods was important, especially in autumn 2007, because it presented an excellent opportunity to train the teams in both the use of suppression fire and fire management. Since milder weather conditions (especially in terms of temperatures) than those usually registered during critical periods lead to less intense fires, intervention is less urgent and with a greater number of opportunities for training than with summer fires. Some of these incidents are caused by land users for land management purposes. The fires are usually ignited in situations with low fire potential that are suitable for managing combustible materials; they also defend the forests against fires through mixed interventions that combine fire fighting and the use of fire to fight fires. At this time of the year, there are fewer resources available to fight forest fires which gives teams more freedom to intervene (without having to call in the civil protection authorities) in very frequent and diverse incidents.

The importance of forest management and prescribed burning in training and forest fire fighting

As mentioned, training, knowledge and the experience gained by those responsible for the planning, execution and coordination of prescribed burning is the basis of the required training for all GAUF members. Planning and the extended use of this technique require knowledge of all elements that influence fire behaviour – either

for controlled or for territory management purposes. These combustible materials management sessions or ecosystems management sessions provide the best training opportunities for all participants in fire fighting and contribute to better personal performances, to better team work, and to better understanding between teams with different characteristics in the operational stage.

The analysis carried out during fire fighting operations provides an excellent framework for learning to identify strategic places and the conditions in which to implement specific actions to manage combustible materials. The knowledge of forest ecosystem management and the work in the areas of fire prevention and fire fighting contribute to a better understanding of the potential of fire (depending on its location), the behaviour of fire and its expected impact on management purposes.

Traditional use of fire

The need some users of forest areas have to use fire and the knowledge that some of them still have regarding the correct use of this practice has been progressively compiled and transmitted by GAUF. Where fire is used during preventive training sessions coordinated by GAUF, an attempt has been made to recognise and incorporate these needs whenever possible, thus promoting a relationship with local people and contributing to the satisfaction of their needs.

One of the goals of the group is to contribute to a legal and operational framework adapted to the specific circumstances and practices of these users. In both the medium- and long-term future, we hope to be able to contribute to the promotion of traditional and appropriate use of fire in the management of natural terrains. This can be seen as a management tool, to create the necessary conditions for independent use for all those who master the technique and who, in turn, will be able to aid those who need help in using the technique. In this way, we may be able to turn a serious problem (the unlawful use of fire in extreme situations) into a management opportunity relevant to the management of combustible materials and landscape partitioning, thus contributing significantly to defending the forest against fire.

3.6.6 Transferability

The GAUF initiative was a pioneer in the European Union context bringing together in one single organisation the integration of the use of fire, prevention (prescribed fire), management, and fire fighting (suppression fire).

The regulation on the use of fire recently published in Portugal may become a model at the European level due to the detailed way in which the subject has been approached and handled. In most countries, there is very little legislation regarding this technique and when there is relevant legislation, it has been banned.

In 2009, Decree-Law 124/04 was updated in Decree-Law 17/09 which, under the term technical fire, defines the use of fire by certified technicians in terms of prevention (prescribed fire), and fire-fighting (suppression fire). Suppression fire was divided into two categories: backfire and tactical fire. Technical and functional

standards would be established later through the publication of Decree 14031/09 of May 2009, which "defines the technical and functional standards for the use of technical fire, requirements for professional training, and certification criteria for people certified to plan and execute controlled and suppression fire".

Knowledge of other contexts and the connection to professionals from other countries promoted by the Fire Paradox project drove the GAUF initiative forward. The presence of these professionals in training sessions and fire-fighting teams in Portugal increased the status of the Portuguese members and greatly contributed to the acceptance and consolidation of the group. It is worth mentioning the strong influence the participation of members from Fire Paradox had on the composition and functioning of the teams during the first years, specifically 2006 and 2007. We could almost say they were 'Fire Paradox teams' composed of Portuguese, Spanish (GRAF-Catalonia), French (Espaces Mediterraneens) and Argentinean (Plano Nacional de Manejo del Fuego) members.

The awareness of other circumstances where serious problems exist, despite the availability of huge resources and manpower deployment but where strategy and knowledge are not prioritised, also contributed considerably to the philosophy of the group. This knowledge also helped to convey the idea that one does not often need many resources to make a difference. The major problem of the number and frequency of catastrophic forest fires in Europe and particularly in Portugal will probably not be solved by a matter of resources.

Further, the cooperation between specialists from different countries gave Portugal the possibility to integrate members from other countries if necessary. Under the auspices of this international cooperation, Portuguese specialists from the GAUF teams will also be able to participate in fire-fighting operations abroad. The future possibility of having specialised teams on the ground in Europe which are prepared, and which have the mobility and ability to intervene in any country should be promoted by sharing training and operational experiences.

Despite the influence of other projects in the creation and development of GAUF, the specific circumstances in Portugal demanded the imposition of various rules for the creation and functioning of the group, which would be difficult to apply in other countries. Even if the principles and philosophies are usually applicable, the same is not true of the procedures. The complexity of organising forest fire prevention and combat in different European countries require that each country establishes its own procedures. However, knowledge and mastery of the factors that influence fire behaviour, the role that fire may play in the management of ecosystems, namely Mediterranean ecosystems, the risk of fire, and the potential of the use of fire as a prevention and suppression technique are applicable or could be applicable in all European countries.

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3.7 The Catalonian Programme on Fire Management: GRAF Team Actions

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3.7.1 Wildfires situation in Catalonia until 1999, and the establishment of the GRAF Programme

Wildfires started to be a problem in Catalonia in the 1960s. In particular, 1967 was the year when fire services started operating in Spain and Catalonia (Vélez 2000). Before that, fire suppression was a local issue and there was still active burning to improve grazing, which was forbidden by law in the 1960s. This fact, together with the major migration from rural spaces towards urban areas, contributed to changes in the forest landscapes turning them from an agricultural-forest mosaic into large areas of continuous forest with an unbroken mass of available fuel for wildfires (Plana 2006).

The development of wildfires experienced an 'in crescendo' trend up to the 1980s, when winters like that of 1983 and mostly summers like that of 1986 raised significant social alarm. The problem of wildfires became one of the main concerns of a more and more urban society (Arola 1996; Seijo 2009). In 1986, following the worst wildfire season ever recorded where some 100 000 hectares were burnt, Catalonia finally established fire brigades (already initiated in 1981) that would be specialised to operate in rural spaces and forest areas. The 'Foc Verd' programme (based on a fast and forceful response to suppress any new ignition) and the Associations for Forest Defence (ADF) (associations of local owners to help in this fast and powerful response) were also introduced (Peix 1999).

At the time, Catalonia was entering the '3rd Generation of Wildfires', characterised by fires of great intensity and spread rates which advanced through tree crowns (Castellnou et al. 2005); its response was and still is a programme based on: (i) rapid detection to avoid the prompt spread of the perimeter; (ii) a first severe attack to contain the flames as soon as possible; and (iii) zero tolerance in the use of fire in order to avoid ignitions.

Thus, a suppression system based on a direct attack approach by fire brigades was established. Direct attacks were based on the use of water delivered through 25 mm hose lines at high pressure (Consellería de Governació 1980). The use of bulldozers was also banned due to issues with landowners, and hand tools was replaced due to their slowness compared to water. Likewise, aerial means were introduced to increase the capacity of dropping water. Such was the value of the forest to a more

Figure 1. Landscape changes due to the abandonment of rural areas and traditional land-use practices.

and more urban society (Seijo 2009), the authorities refused to sacrifice even a single square meter, and thus parallel and indirect attacks were also abandoned.

While this policy resulted in a decrease in the number of large wildfires, those still occurring became larger and larger and thus the extinction paradox arose (Minnich 1983; Piñol et al. 2007; Rifa and Castellnou 2007). The disappearance of medium-sized wildfires, which contributed to create and maintain a landscape mosaic, coincides with the first 25 years of general abandonment of rural areas. Most of the farmland abandoned in the late 1960s became covered with regenerated woodland, which resulted in the explosive situation experienced in the 1990s.

The 1990s, especially 1994 and 1995, experienced an increase in the virulence of wildfires - the 1994 fire season far exceeding that of 1986; however, the real turning point in fire policies was the Solsona Fire of 1998, when over 12,000 hectares burnt within 12 hours and crown fires engulfed rural villages (Plana 2006). The Fire Department realised that the suppression of small wildfires and 'zero tolerance' was creating a country devoid of a heterogeneous landscape mosaic. It was this unprecedentedly continuous landscape with exceptional high fuel accumulation that was causing the increase in wildfire intensity; it also prompted a trend towards convection rather than radiation dominated fires. After analysing the 1998 fire season, it was clear that the continuous fuel loads at the landscape level demonstrated that large wildfires (LWF) were no longer a result of bad fire suppression duties or exceptional drought. Weather conditions of just low relative humidity (RH) or windy situations were enough to favour a fire behaviour that overwhelmed the capacities of the suppression systems all across the country.

Faced with the scenario in which fire suppression becomes a more and more complex emergency situation in an urban environment, one that always affects people and property, it was necessary to return to forest and fuel management practices to reduce the occurrence of LWF. Likewise, the aim of increasing the suppression capacity of fire brigades was also pursued by improving and increasing suppression opportunities through the use of a wider range of tools and manoeuvres, including parallel and indirect attacks. Improving both operational capacities and

Figure 2. Massive crown fires during the fires of Solsona in 1998.

knowledge was also pursued (Rifa and Castellnou 2007). The Forest Action Support Group (Grup de Recolzament d'Actuacions Forestals, GRAF) was created to pursue these aims by introducing these requirements to the Fire Department, while restoring the use of fire both as a suppression tool and for management purposes. As shepherds had done by conducting traditional burning to improve grazing, GRAF's objective was to emulate these practices by using small fires to create a landscape mosaic that would help in keeping fires small and more manageable.

However, the situation back then was quite different. There was a continuous landscape overloaded with fuel, much different to the traditional, discontinuous mosaic with very low fuel loads. The use of fire required acting with greater caution and more tools were required; however, deeper knowledge of fire, in particular, was essential. The Fire Department needed to understand the complexities of wildfires and to translate this knowledge by increasing the number of opportunities of suppression. In response to these new social needs, GRAF was thus created as a programme committed to advancing in fire knowledge and to implementing this science as a fire management tool (Rifa and Castellnou 2007).

It was finally recognised in 1998 that the suppression system that operated between 1981 to 1986 to provide a faster and stronger response to the increase of large wildfires by investing 100% of the budget in early detection, became obsolete as a consequence of the 'extinction paradox'. In answer, the introduction of the GRAF units and their technical unit was seen as a key. These specialists in wildland fires are integrated into the Fire Department and their objectives are to (i) increase knowledge within the organisation in order to improve fire suppression in the short term; and (ii) work to improve the prevention of each specific type of wildfire (Castellnou and Nebot 2007).

Figure 3. Burning pasture land.

Figure 4. Burning out operation from a forest road.

3.7.2 Definition of the GRAF Programme

The philosophy of wildfire suppression after the Solsona wildfire in 1988.

The GRAF programme started with the following premises, to:

1. provide the Fire Department with capacity to manoeuvre hand tools, heavy machinery and the use of fire;
2. capitalise accumulated experience in wildland fires;
3. implement fire analysis as an operational tool; and

4. implement fire management (incl. prescribed burning) as a service provided by the Fire Department

In essence, it was intended to transform a fire task force whose only strategy was based on direct, static attacks into a new one. It was to be based on its resources and capacity to analyse the situation – to adopt dynamic strategies of attack, containment, confinement or management, depending on the analysis performed (Castellnou 2002).

The aim was to avoid the collapse which occurs when the wildfire suppression strategy fails, e.g. when more and more resources are deployed and where and when they are not effective. The formula to avoid this collapse consists of being ahead of the events through analysis – by identifying when and where the suppression system will be efficient to concentrate the means here instead of wasting resources. At the same time, opportunities for suppression increased significantly after shifting from direct attack approaches – with water as the only suppression possibility – to a multiple-option approach that included indirect or parallel attacks with fire, hand tools and machinery.

Capitalising on the experience acquired by the Fire Department in each fire event was seen as essential. In order to achieve this, fire reports on fire development and response activities are published on the Internet and the Intranet, as well as in weekly magazines (Castellnou et al. 2007), so that all parties can share their experiences.

Key positions and functions of the GRAF Programme

In accordance with the programme's philosophy, it is necessary to identify the key positions and functions of the system to be able to organise a hierarchic structure. The development of GRAF was designed to fit into a Fire Department structure with an (i) an Extinction Director, responsible for emergency situations; (ii) a structure of intermediate command or Sergeants, who coordinate the resources, and (iii) intervention units consisting of fire engines manned with five fire-fighters, led and coordinated by a Corporal or a Firefighter Type I.

Based on this structure, the GRAF Programme has the following functions:

Chief Fire Analyst

The Chief Fire Analyst is completely committed to wildland fires. He/she must have sound knowledge and understanding of wildland fires to identify their key parameters for suppression opportunities and risky situations, and to track and monitor the season of fire risk. He/she is in charge of directing operations involving the use of fire, and is responsible for building and training the GRAF units, as well as for the Fire Department's forest policy. He/she is always reachable and on-call for duty.

Technical Unit

The Technical Unit is a team of technicians responsible for coordinating both the GRAF units and the duties involving forest issues of the different regions of the Fire Department. They have territorial assignments in forest management; however,

Figure 5. Operational centre of the Fire Service in Bellaterra.

regarding the monitoring of training fires, GRAF logistics and operations in wildland fires, their field of action is the whole of Catalonia. They work weekly in winter, but during the fire risk season they work on four-day shifts. They are the technical staff of GRAF's daily guard.

GRAF Units

The units comprise firefighters who join GRAF during a period of their career. They receive specialised training on related forest ecology and management topics, and gain much experience in wildland firefighting since they move throughout Catalonia providing assistance in all kinds of forest fires. In addition, these units can be sent abroad for international assistance.

The units start work at the beginning of the fire season when they are grouped at their base from which they are sent to any fire location to analyse, track and act. The aim is for them to gain the widest and most diverse experience possible. Out of season, the units' members work as regular firefighters but remain reachable.

These units are responsible for directing manoeuvres involving hand tools and the use of fire as well as coordinating other groups in fire suppression (Forest Defence Groups, volunteers, etc.). They are constantly tracking and validating opportunities, and are a basic component which gives advice and information to the intermediate command. They are also responsible for directing all the actions included in the programme of winter burning.

Figure 6. GRAF units deploying to their assigned suppression tasks.

Fire Department
The Fire Department provides the command structure of Firefighters Type I, regular firefighters as well as seasonal workers. They are responsible for the intervention during any kind of accident or disaster, including wildland fires. When the latter occurs, they basically carry out a direct attack with high-pressure water hose lines. They also have hand tools to access areas beyond the reach of water hoses or duff dominated places.

Geographical distribution and specialisation

The locations of the GRAF units are determined according to the differing fire management requirements in Catalonia and are:

- GRAF Lleida: Base in Tremp. Specialised in high mountain fires and pasture burning in the Pyrenees, as well as in lightning-caused fires in inaccessible spots.
- GRAF Girona: Base in Cassà de la Selva. Specialised in wind-driven wildfires and burning in the Pyrenees, and in evergreen forests of holly and cork oak.

- GRAF Barcelona: Base in Rubí. Specialised in Wildland-Urban-Interface fires (WUI), as well as in wildfires and burning in areas covered by *Pinus nigra* and *Pinus halepensis*
- GRAF Tarragona: Base in Reus. Specialised in winter fires, and in fires and burning in areas covered by *Pinus halepensis*

Training as the basis of all operations

Training can be seen as the basis of GRAF's operations. Firefighters join the units because they are offered more experience and training. Training in different units is structured in a string of courses which are designed as follows:

CIEG: Introductory Course to GRAF Special Skills, 68 training hours, with the focus on:

- reducing risk to themselves and others in operations involving the use of fire
- being able to apply manoeuvres combined with hand tools, chainsaws, aerial means, water and fire lines
- being able to apply ignition devices, following specified firing plans for ignition rate, pattern, and spacing
- acquiring a basic fire analysis language

CAIF: Course of Forest Fire Analysis, 132 training hours plus a minimum of two fire seasons and two prescribed burning seasons. During this course, the objectives are:

- In addition to applying and following firing plans, the need to adapt ignition to achieve fire management objectives and plans at an appropriate scale. This is achieved by changing the spacing between ignition lines, the ignition rate, the position or the starting point and direction of an ignition. When performing a burnout, backfire or a prescribed burning operation, a CAIF certified firefighter can assign the ignition procedure to a GRAF firefighter with a CIEG certificate.
- Understanding fire analysis language, plus identifying and interpreting the main factors which dominate fire behaviour in real time as well as being able to anticipate it at the fire line. This provides decision criteria on whether to adapt an ignition, adapt the shape of a defence line and to communicate critical, useful information on what they are observing.

CAOFT: Advanced Course of Fire Analysis, 150 training hours plus one to two additional fire and prescribed burning seasons. This training course aims at providing qualifications for:

- Identifying, interpreting and anticipating fire behaviour at the fire line, a sector or the whole fire. This enables to track opportunities, set priorities amongst them and communicate this as critical and useful information.
- Directing the performance of operations involving the use of technical fire, both prescribed burning and suppression fire, including the coordination of surveillance and safety duties.

- Knowing the basic context of fire ecology and the different sensitivity of species to different types of fires in order to understand burning plans and to carry them out, and to gather and analyse relevant information.

Part of this training is a minimum of 50 hours of yearly prescribed burning as well as pre- and post-season training to integrate the lessons learned from the most significant fires.

3.7.3 Process of implementation of the GRAF Programme

The implementation or introduction of the GRAF philosophy within the Fire Department has undergone several stages to date and is summarised below:

1999–2001: Growing phase
The first units were formed by 36 members. The first prescribed burnings were performed in pastures, scrubland and low woodland, always framed in an experimental show-programme for the forestry sector, and as a required part of the GRAF training programme. General training was organised for the whole Fire Department.

The suppression capacity of fire use was proven in wildfires in Cap de Creus in 2000, where over three kilometres of burnout were performed. Another example is the burnout of more than one kilometre used in the wildfire in Xert in 2001, which enabled the suppression of the fire that had been burning for three days.

2002–2005: The stabilisation phase
The units reached 74 members (approx. 17 per unit). The prescribed burning programme was enhanced with management experience in accordance with the prevention plans and general planning of the Department for Environment. The first exchanges for prescribed burning with France and Portugal were also initiated.

During this period, in particular during the 2003 and 2005 fire seasons, the first simultaneous large wildfires occurred – similar to those in the 1990s. GRAF's work was already bearing fruits – the programme was approved and thus fully integrated into the Department.

Fire management in wildfires like those of St Llorenç-Savall or Maçanet de la Selva were amongst the best examples of GRAF incorporating fire analysis and anticipating opportunities to contain the wildfire, as well as the possibilities to engage in joint actions with units performing direct attack with water (UT GRAF 2003; Castellnou et al. 2010a). In these two seasons, 34% of the perimeter was initially controlled without water, including 21% through means of suppression fire, mainly at the fire fronts. In these seasons' large wildfires, GRAF units were assigned to parts of the fire that were growing beyond the capacity of control to look for new suppression opportunities, after which they applied the chosen approach and then called on other resources to support, complement or continue the operation. When they are no longer needed, they move on to look for the next opportunity. In case

a fire was fast or intense enough, a special GRAF unit (the 'trackers') was only identifying suppression fire opportunities ahead of the fire, that can be useful for other units in case the fire reaches that areas.

2006: Vandellòs

The 2006 fire season was good for GRAF and its philosophy as it was recognised as the centre of the firefighting strategy regarding wildland fires. GRAF also gained new standing as wildland fire specialists – especially after actions at the fire in Vandellòs, simultaneous fire events in Empordà County as a result of a persistent north wind, and after providing assistance during the intense wildfires in Galicia and Aragon (Castellnou et al. 2007).

The Vandellòs fire was a north-west wind-driven wildfire which started in spring and affected 1200 hectares (UT GRAF 2006). It occurred four days after a burning of slash piles performed by EPAF staff (Teams of Active Fire Prevention of the Fire Department). Environmentalists, following the pressure from ecologist groups, maintain that the burning was the ignition source and the media blamed GRAF's fire management and its prescribed burning programme for the fire outbreak. This involved a court trial and the burning programme came to a halt. The case was closed, however, when it was eventually proven that the slash-pile burning was not the ignition source. Even after the trial, the first decree on fire management regulating the use of fire in prevention and extinction duties was approved.

2007–2009: Waiting

Finally, GRAF had come to fruition and the Fire Department no longer took it as an experimental programme but integrated it in the Department's structure. Negotiations with syndicates started to define how GRAF units will be integrated and kept operational. The difficulties lay on gathering two different working hours and dedication within the same collective – GRAF members work more days per year than regular fire-fighters and carry additional tasks (executing prescribed burnings, control lines, manoeuvres with aerial means, etc.) but share the same premises, holidays, vehicles, etc.

During suppression operations, GRAF, despite still being a tactical unit, is increasingly taking on the role of leading and concentrating resources to priority areas due to their high analytical capacity and their ability to quickly track other suppression opportunities for the following operational units.

2010: The future

The new model positions the GRAF units as part of the structure of the Fire Department, clearly establishing that:

- GRAF firefighters are available all year round, i.e. there is also a winter shift.
- There are two headquarters and the number of bases will increase from four to eight.
- The numbers of fire fighters per team are reduced, but the intensity and level of training increases. The minimum operational number is six firefighters, able to track and identify opportunities for fire suppression. This requires an increase in the size of the standard task force through merging several teams or introducing extra personnel of the Fire Department.

Figure 7. Prescribed burn conducted by GRAF for training purpose.

3.7.4 Results achieved

Prescribed Burning

Prescribed burning has been performed pursuing clear training, experimental and educational objectives. There are four work lines:

Ensuring experience in fire of GRAF personnel
Every GRAF fire-fighter must complete at least 50 hours of prescribed burning annually to ensure the capacity to observe and understand fire, and make decisions. This capacity is essential for the safe use of fire. This aims to teach the personnel to observe the flames in order to gather useful information so as to manage them rather than just considering the flames as the problem to attack.

Carrying out training in the use of fire and ignition patterns
Working with fire requires mastering ignition patterns and knowing how to control them. This is achieved through burning as a controlled training scenario. The acquired knowledge can then be applied in suppression duties. This system is easier and more fruitful than learning from errors in wildfires.

Figure 8. Pattern of ignition lines that burn as flanking fires.

R&D Platform: Experimental programme involving different university research groups.

The various research work related to the fire's effects on soil, vegetation, and fauna enables to differentiate the effects of low intensity fires from those of high intensity ones. The purpose is clearly to communicate the effects involved in the use of fire to the general public. This is a main sticking point since society, particularly the urban and metropolitan one, does not understand the role of fire, and is thus reluctant to supporting a serious prescribed burning programme, especially in sensitive areas like the metropolitan areas of coastal Catalonia.

The involved universities in this R&D Platform are the University of Lleida; the University of Barcelona; the Autonomous University of Barcelona; the University of Girona; the Technical University of Catalonia as well as some research centres (CREAF, CERTEC and CRAM).

Experimental platform to show the effects of the use of fire to land owners and to forest managers

Every prescribed burn can be considered a land management activity. In this sense, prescribed burning is of interest for forest training centres, owners' associations and technical workshops through the organisation of open days, where the burning can be observed and used to disseminate knowledge.

Fire Management

The analysis of past large wildfires enabled us to gather knowledge about spread patterns and develop the fire types concept (Castellnou 2000; Castellnou et al. 2009), i.e. the expected fire development in a certain landscape unit, based on the study of historical large wildfires. Fire types are linked to a specific synoptic and macro-topographical scenario and related to a spread pattern, which enables the identification of critical points where fire spread will be reinforced, e.g. junctions of crest lines in wind-driven fires, or the daily shift of the sea breeze. This facilitates the understanding of the dynamics of a given fire regime in a specific territory, including the specific pattern of fire spread that potentially might overwhelm suppression capacity. It also includes understanding the spread of fires under various weather conditions and terrain, which is used to prioritise areas for fire management where locations and weather conditions most likely result in problem fires are identified through analysis prior to fire occurrence.

This fact allows:

- Moving suppression resources to improve efficiency: the whole community gets involved when any part is at risk. In addition, there is an increase of collective knowledge and experience, which was one of the aims pursued with the change of the approach after 1998.
- Preparing the strategy in advance: since we know in advance the spread pattern of the wildfire we can plan ahead.
- Establishing the reference of historical wildfires: review of the problems involved, the manoeuvres performed, etc. allows us to use reference fires as a training tool for considering defined risk episodes.
- Identifying prevention needs regarding standard wildfires: prevention is linked to a specific suppression necessity – we are observing the principle of a real coordinated and integrated fire management policy in order to avoid large wildfires.

Suppression of wildland fires

The suppression methods have evolved in the ten years since the implementation of GRAF. Whereas the large wildfires of the 1990s burnt from 8000 to 10 000 hectares a day, at present, and in similar conditions, only 1500 to 2000 hectares are burning.

This is possible due to:

- Better integration of diverse manoeuvres, which allows us to take advantage of a higher number of opportunities.
- The use of fire suppression during parallel or indirect attacks, which enables firefighters to stop the advance of a large wildfire, e.g. 34% of the actions or manoeuvres performed in 2009 involved parallel or indirect attacks.
- The introduction of ‘trackers’ who identify new suppression opportunities for the GRAF teams to manoeuvre and keep the initiative.
- Capitalising on experience resulting in a well trained task force and a higher capacity of manoeuvres.
- A more patchy landscape, due to the large fires of the 1980s and 1990s.

Legislation

The Decree of the Generalitat de Catalunya (Catalonian Regional Government) nº 3120/2006 of 25 July on the regulation of technical fire management by members of the fire prevention and extinction services of the Regional Government, is a great advance in making this new philosophy official. It was passed in 2006 and its current application, now in 2009, enables GRAF to consider eventual modifications to broaden its brief.

3.7.5 Lessons learned

Objective integration: 2-Phase Suppression Concept

The concept of the 2-Phase suppression operations enabled GRAF to integrate several suppression and containment strategies into the same task force (Rifa and Castellnou 2007). As there is an urgent need for speedy operations, reducing the initial uncertainty about what to do is the organisation's main objective.

The ability to implement the strategy of perimeter suppression from the rear, while at the same time tracking opportunities to attack at the head, enables simultaneous and fast operations at the fire. In Mediterranean landscapes like Catalonia, this means that wildfires can be controlled in just one evening or night.

As a basic strategy, containing the fire takes place when the priority involves limiting the fire's capacity to expand the flaming front. If this happens before the units working on the perimeter can react, the fire escapes. The 2-phase suppression and the containment strategy pursue the aim of hindering and stopping a fire's capacity of growth. All this enables fire-fighters to gain time to perform classic perimeter suppression.

However, deep knowledge of the spread pattern as well as a fire evolution prediction tool are needed. Deeper knowledge and the prediction tool were the major differences between the situation in 1998 and 2009, even more important than the increase in available tools or the use of fire. The lesson learnt is that timely response requires experience, and it is difficult to acquire experience in only small territories. As maintaining and up-dating this knowledge involves frequent practise, international exchanges are becoming more and more necessary.

Fuel management: society involvement

Fuel management requires large-scale social acceptance to be feasible. Prescribed burning programmes or strategic fuel treatments at critical points are only rather specific activities at present. In contrast, the problem of large wildfires can be seen as a major problem of fuel continuity at the landscape level and of wildfires with massive spotting. This implies that an extensive large-scale management programme is needed to manage the problem of large wildfires, since the intensity is the limiting

factor to suppression capacity, and we only have carried out intensive prevention and management programmes to a limited extent so far.

It is essential to get society involved and committed to understanding that a landscape mosaic will enable us to limit the effects of large wildfires. The landscape is not a static but a dynamic reality – and sometimes one must give up part in the interests of the whole.

Society education: the big challenge

Helping society understand that it is necessary to live with the problem of low intensity fires rather than constantly fighting high intensity wildfires is a great challenge. It is difficult to demonstrate that high intensity fires harm the environment and that low intensity is the lesser of two evils as it helps to avoid the big problem; however, we must be able to communicate the fact that this is the direction we must go if we want to gain the upper hand against large wildfires.

This is a long-term undertaking – one that has already started and, given the pace at which society is accepting the changes introduced by the Fire Department through GRAF, we can be optimistic about.

3.7.6 Knowledge exchange

GRAF has taken part in wildland fires abroad, giving assistance and support to other countries by collaborating and participating in suppression operations, and giving advice for planning a strategy to suppress a fire based on fire analysis. GRAF has not only taken part in suppressing wildfires abroad, but also in training courses with other Fire Departments, passing on their knowledge on fire use, the analysis of wildfires and the use of hand tools.

Another channel where GRAF was involved in training and passing on knowledge is through the University. GRAF members have lectured at the University of Lleida, on the wildland fires course as well as on modules of the Master in Wildland Fire Management. In addition, they also took part on the National Course of Fire Management at the National School of Civil Protection; at the University of Girona where they dealt with issues involving forest management; and at the University Jaume I where they dealt with issues involving forest policies.

GRAF units, within the task force of the Fire Department of the Catalonian Regional Government, track opportunities to stop the advance of a wildfire's flames, while other members of the Fire Department secure the back and flanks of the fire so it will not expand. This method features a 2-phase operations approach, which has been exported to other countries as a model for an operational structure for forest fire suppression. Thus, GAUF in Portugal, GRAFF in France, and the Wildfire Team in the UK, have asked GRAF for advice on how to create and train their specialist units. Also nationwide, GRAF has been a reference in fire suppression, laying the foundations for the creation of units specialised in the analysis of wildland fires in regions such as Aragon, Castilla-La Mancha and Andalusia.

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4. Potential Barriers and Factors for Success

4. Potential Barriers and Factors for Success

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4.1 The scientific and technical process of legitimacy

4.1.1 The recognition of the role of fire in ecosystems: linking science and management

In all the reviewed examples, the (re)introduction of fire as a modern management tool has entailed the need to adapt the technique to local conditions. From its outset, the first experiments were initiated to determine the effects of fire in ecosystems, analyse fire behaviour and to adapt concepts and planning schemes to their specific conditions. In most cases, these first trials clearly took on the character of a demonstration.

Experiments have demonstrated that prescribed burning can be successfully used in both operational and ecological terms. However, there still is a different level of recognition of the role that fire can play in ecosystems. The French case study (see 3.4) is a successful example of how scientist and managers have formally come together and recognised the role of fire in maintaining and enhancing biodiversity. In Sweden, although fire has been recognised as a dominant disturbance agent in boreal forests, restoring fire use in protected areas has required a long convincing phase due to the widely shared principle of free development (see 3.1). Other examples, such as the in case of the United Kingdom (see 3.2), illustrate how the lack of fire studies and the tendency to ignore fire ecology is hampering the application of fire in forest management.

Successful case studies suggest that a key factor for success, especially at the initial stages, is to establish intense dialogue between managers and scientists. This enables both the development of initial experimental trials and demonstrates the need to increase fire knowledge. Likewise, results obtained from research in the experimental field give managers both solid arguments to convince decision makers and authorities; contribute to changing the common negative perception of fire; and add to the legitimacy of the use of fire as a tool, as shown in the Portuguese example (see 3.6).

In this regard, research projects (e.g. Fire Paradox), networks (e.g. French National Prescribed Burning Network) and demonstration programmes (e.g. LIFE programme) have shown to provide important scenarios for dialogue and exchange between professionals and researchers. This cooperation has also resulted in training in both theoretical and practical modules (see 3.1.). Further, arranging field visits to experimental burn sites with the involved agencies, conservationists and landowners has been decisive in improving the understanding of the effects of fire and its role in ecosystems (see 3.7).

However, the use of fire is still controversial and there is a constant need for new research to respond to new social and environmental demands and concerns. The UK case, for instance, highlights the growing debate about the role of fire in the context of carbon balance (see 3.2). Another example is the Catalan case (see 3.7), which highlights the need to differentiate between the effects of low intensity and high intensity fires as a means to justify intervention in sensitive areas for society (e.g. metropolitan areas).

4.1.2 The incorporation of fire as an efficient technique for land management

At present, the use of fire for management purposes constitutes an alternative to counteract some of the problems derived from the abandonment of traditional land use organisation (e.g. increase in fire hazard, loss of biodiversity, etc.). This has been exemplified in the best practice studies with different management objectives.

Prescribed burning has been shown to be an efficient and economic technique for fuel management reduction in areas that cannot be accessed by mechanical means. Thus, fire has been incorporated in the technical sequence together with other management techniques (see 3.3 and 3.4). Also, in those ecosystems where fire formerly played an important role either due to its natural role or due to its longstanding use by local communities, the re-introduction of fire has notably improved biodiversity and contributes to the maintenance of traditional landscape structures (see 3.1. and 3.2). Moreover, the Portuguese and Catalan examples show how both suppression fire and prescribed burning provide excellent opportunities to increase the options available for suppression strategies as well as to train teams in the use of fire (see 3.6 and 3.7).

With regard to traditional fire use practices, the Spanish example shows how prescribed burning can result in an important reduction in the number of fire ignitions caused by uncontrolled burning due to the satisfaction of traditional users' demands (see 3.5). Moreover, in the United Kingdom, traditional fire use practices have not only been accepted and promoted through best practices codes, but the know-how derived from these traditional uses has also constituted the starting point for the experimentation on the use of prescribed burning (see 3.2).

From different fields of expertise, the case studies analysed in this publication highlight a series of common needs for the integration of prescribed burning and suppression fire techniques in management schemes and to overcome potential obstacles:

- There is a need for a continuous exchange of experiences and acquired knowledge between professionals as a means to promote learning processes and solve common problems. This transfer should not be restricted to professionals but should also include researchers. Professional network structures and exchanges between professionals framed within R&D projects should be promoted.

  For the development and implementation of suppression fire techniques, experience acquired in the use of prescribed burning in the field of prevention is essential, since it provides the skills and the knowledge needed to exercise fire techniques safely and efficiently in suppression. Moreover, given the

reduced number of opportunities to accumulate experience in fire suppression operations, exchanges between professionals are essential.

- There is a need to increase the number of specialised professionals in prescribed burning and suppression fire. In some of the presented case studies, the initiatives depended on a small group of people and thus the continuity of the programme was put at risk when they were no longer able to carry it out (see 3.6). In other cases, the lack of trained professionals or operational structures hindered the implementation of the programmes (see. 3.1).

  Further, the increasingly frequent bad meteorological conditions for the implementation of prescribed burning requires that a relatively high number of trained professionals are available for burning in very narrow prescription windows (see. 3.4).
- For prescribed burning in particular, in order to attain effective results in the fight against fires, there is a need to overcome cultural biases at the local level and develop real extensive programmes to reduce the intensity and propagation of large fires. This involves not only a an important effort in increasing the number of prescribed burning professionals, but also a wider acceptance of fire use by the general public, local stakeholders and the agencies involved .

Moreover, as pointed out in the case of the French Pyrenees (see 3.4), in areas where fire culture is well preserved and there is a need to use fire for the communities' welfare, prescribed burning might be insufficient to absorb the demand of farmers. In these situations, the only solution is for both practices to co-exist and to orient prescribed burning to execute those burnings which require the professional use of fire due to either safety reasons or refine prescription objectives.

4.2 The necessary adaptation to a changing territorial and cultural context

4.2.1 The abandonment of traditional land use systems: new scenarios for fire use practices

The main opportunities for using fire for management purposes are derived from the need to solve new problems emerging from the crisis of traditional land-use systems. This process is affecting a large number of mountain areas in Europe. The example of the French Pyrenees (see 3.4.) illustrates how the abandonment of traditional land use systems resulted in indirect negative consequences: an increase in fire hazard and the number of large fires; the degradation of forage value of rangelands; the loss of biodiversity value; and the increase in the homogeneity of forest areas due to agricultural abandonment.

These new problems thus entail the need to search for new alternatives better adapted to the current territorial situation. The German example (see 3.3) illustrates how fire might constitute one of the management alternatives to counteract the negative consequences (e.g. invasion of ligneous formations, loss of biodiversity, etc.) of the abandonment of a land use scheme, in this case military use, which kept an open landscape of high biodiversity value and specific richness.

However, the change in the spatial and socioeconomic conditions derived from the abandonment of traditional land-use schemes may also imply unexpected negative consequences for fire use. For instance, changes in spatial conditions mean a major complexity for the traditional use of fire. The Catalan example (see 3.7) is very illustrative in this sense, where the situation changed: from a compartmented landscape with low fuel accumulation maintained by different agroforestry uses (here fire was present in a controlled and positive way) to an homogeneous landscape of vast forest areas with great fuel accumulation, where traditional uses could hardly be maintained (here fire easily escaped from an increasingly aging and reduced population density). Additionally, the increasing multiple uses of natural areas entails the apparition of new activities which co-exist in space and time in the same territory with traditional activities; together with traditional pastoral, agricultural and forest uses, leisure activities such as hunting as well as new environmental and patrimonial interests are emerging (see 3.4.). This might result in conflicts due to opposing interests leading to an increase in restrictions for fire use.

There is an imperative need, therefore, to continuously revise and adapt fire use techniques to changing spatial and socioeconomic conditions, and to respond to emerging demands derived from these (e.g. conservation of biodiversity values, ecosystem services and landscape services). With regard to traditional fire use, this is an essential need since changing socio-economic and spatial conditions have resulted in traditional fire use practices not being adapted to the present context. This has resulted in an increase in fire risk associated to the practice further influenced by the loss of know-how. The Spanish case study is representative of the northern Mediterranean basin with more than two thirds of the total number of fires and more than half of the total burned area related to the use of fire in rural activities. However, far from adopting restrictive approaches, traditional fire practices should be encouraged through best practices and traditional fire users should be trained to rediscover fire (see 3.2 and 3.4).

As for prescribed burning practices, the French case study (see 3.4) as an example of a long programme well illustrates how, during the last few years, the multiple uses of natural areas have incorporated additional limits to meteorological constrains derived from new social and environmental demands. In this context, the different experiences have highlighted the need to adopt participatory approaches in planning to reach consensus – not only with the agencies involved but also with diverse local stakeholders.

4.2.2 The adaptation of fire use techniques to the new cultural context

The re-introduction of fire use techniques as an alternative to management not only faces firmly established principles such as the free development principle in boreal forests or the fire exclusion policy in the Mediterranean, but also strong public opposition. Fire is perceived as a destructive element and a major threat to communities. The image of the brute force and rapid devastation of large summer fires is translated to all fires regardless of their intensity and the spatial and temporal scale for the evaluation of its effects on ecosystems. This is valid not only for Mediterranean countries, most affected by wildland fires, but also in other countries

which have incorporated the negative perception of fire as a destructive element for natural areas (e.g. Germany) (see 3.3).

This strong public opposition is even more evident at the local level. For instance, in some rural areas the arrival of neo-rural inhabitants, who are no longer familiar with traditional fire use, decreases the legitimacy of rural communities to use fire to manage lands. Therefore, the historical memory of fire use is substituted by an attitude of rejection and fire exclusion (see 3.4 and 3.5).This attitude is also transferred to using fire techniques in suppression, which often results in a clandestine and unlawful use of these techniques (see 3.7).

However, changing paradigms in different management fields are contributing to overcome this generally accepted negative attitude towards fire:

- Changing paradigms in landscape management and nature conservation policies have started to recognise the role that both natural and anthropogenic fires have had in shaping landscapes and ecosystems of high biodiversity and scenic value (see 3.2 and 3.3). In the frame of the increasing value acquired by cultural landscapes in Europe, these tendencies have a positive influence on the process of the legitimacy and social acceptance of fire use.
- Also, in the field of fire management, the numerous large fire episodes experienced in Europe during the last two decades, mainly in southern countries, demonstrated that it is impossible to suppress all fires and that there is the need for some regions to learn to live with fire. This entails moving from an exclusively suppression-oriented fire policy to a mitigation/adaptation policy. The Catalonia case illustrates a new management scenario, where managing low intensity fires constitutes a better situation than fighting high intensity fires (see 3.7).

The different experiences reviewed in this publication show how the introduction of new techniques must be supported by a series of common elements in order to guarantee the process of the social acceptance and legitimacy of fire use in management:

- There is a need to recognise that there are rural communities which depend on the use of fire for their welfare. This is not only an important cultural value, but also constitutes a fuel management scheme which favours fire hazard reduction as well as being an important source of information for the development of professional fire use policies. This recognition is fundamental to achieve its acceptance. In this sense, prescribed burning and suppression fire might constitute tools to legitimise a demand which was kept veiled from the general public as well as to improve relations between traditional fire users and agencies (see 3.4 and 3.6).
- There is a need for educational programmes and participatory approaches for both the general public and the main stakeholders involved in the development of prescribed burning and suppression fire programmes.

The general public needs to accept that there are some regions which need to learn to live with wildfires. In this context they need to understand that under controlled conditions, fire can constitute an efficient tool to avoid a bigger loss due to future uncontrolled wildfires as well as being beneficial for the maintenance of some

ecosystems and landscapes. This acceptance is fundamental for the development of extensive fire use programmes in order to reduce the probability of the propagation and intensity of large fires. The challenge is to be able to reach the general public with the right message; this entails not only adapting the message transmitted by the mass media to the general public, but developing educational campaigns adapted to the different interest groups (e.g. schools, managers, politicians etc.). Moreover, in order to adapt the messages transmitted by the media, it is necessary to organise, for example, training sessions and field trips with them in order to pass on the right message to the public.

In particular, with regard to stakeholders and agencies, these different experiences have demonstrated how participatory approaches and educational programmes throughout their development are needed in order to guarantee its acceptance and continuity.

4.3 The development of an adapted policy framework for fire use

4.3.1 Barriers to institutional change

For decades, over-restrictive laws and policy frameworks for fire use have been adopted as a means of reducing the high percentage of wildfires caused by the negligent or intentional use of fire in forest areas. Other sectoral policies (e.g. landscape, nature conservation etc.) have also incorporated the same approach eradicating the use of fire in other types of open landscapes. However, the Mediterranean examples (see 3.4 and 3.5) demonstrate how, in those areas where fire is still an important part of rural activities, the results of this prohibitive policy approach have met with limited success. On the contrary, such policies often result in a clandestine use of fire and thus an increase in uncontrolled fires.

Although some countries have legislation that authorise fire use under set conditions, this often does not entail losing the unusual character of these types of practices. Thus, the development of specific legal frameworks for prescribed burning and suppression fire needs to overcome firmly established restrictive legal frameworks or the total absence of legal provisions for its use at best.

The changes in policy needed to overcome these impediments to prescribed burning and suppression fire have, in most cases, been adopted ‘ad-hoc’ after major fire events. This entails bringing positions closer and finding solutions to common problems. Countries affected by this problem have realised that even in spite of high suppression efforts, there will always be situations in extreme conditions which will exceed the suppression capacity of fire-fighters. There is the need for policies to focus once again on fire prevention actions in order to reduce the intensity of future fires as well as to increase the available resources for fire suppression through indirect attacks. Both prescribed burning and suppression fire are among the alternatives to solve these problems. The Portuguese case study (see 3.6) demonstrates how the decisive policy changes adopted in 2006 (after 2003 and 2005 fires) meant the restructuring of their national fire defence system. This reform set the stage for a new

legal framework for the use of prescribed burning and its inclusion in the National Fire Plan at the same level as other conventional techniques.

However, some examples also illustrate that the opposite is also true. The French case study shows how good fire campaigns might discourage politicians from supporting these new approaches (see 3.4). Additionally, a negative response by the general public might also be expected. When prescribed burning and suppression fire practices are highly effective, fires become less frequent and damaging. Typically, the general public becomes less tolerant of a fire's negative aspects (e.g., smoke, charred landscapes, and increased risk of escaped fires) and less supportive of fire management funding when they perceive less risk. In a sense, success breeds ambivalence, if not resistance (see 3.7).

4.3.2 The implementation process

One of the first steps needed to achieve an institutional framework favourable for the use of fire is to clarify the legal and normative consideration of its use. In this way, it will result in the reduction of clandestine and unsupervised practices and will contribute to their legalisation and consolidation. In this sense, both the Catalans and Portuguese have developed legal frameworks for prescribed burning and suppression fire practices which constitute European referents due to their pioneering nature and their detailed defining of basic concepts and procedures. This clarification is fundamental for fire use techniques to become a regular alternative for intervention.

Second, different examples have highlighted the importance of adopting new governance approaches into the implementation process of prescribed burning and suppression fire programmes. The Spanish case study is an example of a prescribed burning programme which has adopted a conflict resolution approach. In this example, prescribed burning is part of a wider social fire prevention programme where interventions are planned by the EPRIF team in collaboration with local stakeholders and agencies (see 3.5). Similarly, the French case study describes the local and regional meetings held at the beginning of each burning campaign to discuss the interventions in detail (see 3.4). In both cases, these participatory approaches are considered key factors to avoid potential conflicts and incomprehension, which might threaten the future acceptance of these programmes. However, progress achieved by these means is usually palpable in the medium-long term and needs an intense effort of coordination and encouragement. The Catalan example points out how in some cases conflicts are overcome through legal processes. In this case, the regulation of fire use by forest and fire services, questioned by different interest groups, was legitimated by the justice system (see 3.7).

Finally, a third key element to enable the implementation of prescribed burning and suppression fire practices is the consolidation of both operational and administrative procedures, which is the best guarantee of achieving the definitive implementation and continuity of these techniques.

In most cases, the loss of traditional know-how and the complexity of using fire under current conditions result in the restricted use of prescribed burning and suppression fire techniques by professionals. This often implies developing

competence standards and training programmes for professional users, and defining a professional structure that should be integrated into existing institutions (see 3.6 and 3.7).

The majority of these examples illustrate the complexity of administrative tasks, which are both time and resources consuming. However, the consolidation of administrative structures and procedures is fundamental for the development of prescribed burning and suppression fire policies. The example of the French Pyrenees describes in detail how a diverse demand (fire defence, grazing improvement, environment etc.) has been canalised by a pastoral institution. In this case, the consolidation of the administrative procedure in an agricultural organisation has enabled the incorporation of other types of demands that benefit from different sources of funding from different sectors (e.g. fire policies, environmental, etc.) and the development of the programme at different management levels (e.g. local, regional, etc.).

5. Lessons Learned and the Way Ahead

5. Lessons Learned and the Way Ahead

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5.1 Lessons learned

From the identification of examples of good programmes of prescribed burning and suppression fire, their explanations and the assessment of potential barriers and factors of success, some major lessons were learned:

- In spite of the noticeable differences in objectives for the use of fire, all programmes have very identifiable and clear objectives.
- In spite of the very different social contexts of the different situations, all programmes are socially accepted or socially promoted.
- All programmes found different but sustainable funding schemes allowing for long-term perspectives.
- In all key situations, fire professionals play a very significant role due to their knowledge, training and experience.

The diversity of situations of fire use in Europe is very striking in terms of objectives, social contexts and funding schemes. In the selected case studies, the use of prescribed burning is shown to change in objectives in a geographical gradient from north to south – from conservation to habitat and wildlife management, from landscape management to grazing improvement and to wildfire prevention and suppression. The same geographical differences apply for the social contexts, the public acceptance and the funding schemes, with a diversity of combinations of non-governmental and governmental entities.

Even so, while the diversity of situations seems so variable, at the same time there are remarkable similarities in the characteristics of the key agents involved. All these fire professionals share an academic background in forestry or natural sciences, followed by extensive training and practical experience.

The same combination of training, education and experience as a fundamental triangle for success in fire management agents was reported in a recent paper addressing the challenges to educating the next generation of wildland fire professionals in the US (Kobziar et al. 2009).

Also, it seems that in all the fire use programmes reviewed in this book, there was an apparent evolution from a simple first-phase application of the techniques to the integration of much more comprehensive activities including intensive planning and monitoring. This indicates that integration of activities is also a key element for the successful implementation of these programmes.

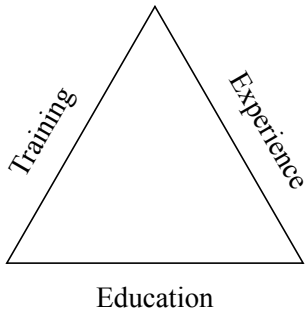

Figure 1. The fire professional development triangle depends on integrating training, education and experience to provide the background for achieving effective fire science and management (Kobziar et al. 2009).

Fire management as a tool of land management appears in each and every country and region of the European Union, setting the challenge and need of a proper regulation on the matter (Lázaro and Montiel 2010). Further, those countries with territories at medium or high fire risk, where fire is a traditional land use and resource management tool, should promote Social Fire Prevention Programmes (similar to the Spanish EPRIF Programme) that could also be integrated in the Rural Development Programmes. The main aims of these programmes should be:

a) Analysis of the causes and motivations for uncontrolled burning.
b) Population awareness campaigns on fire risk and compliance with regulations.
c) Promotion of programmes for controlled burning, where appropriate.
d) Promotion of alternatives to fire use for fuel management, such as clearings, use of forest biomass or controlled grazing, where appropriate.

Considering the great heterogeneity of political measures and regulations on fire management, their insufficiency or inadequacy in many cases, and the wide diversity of situations in fire use that is present in Europe, it appears a necessary step to define a normative framework able to update and harmonise the different existing legislations and policies on the matter. The aforementioned framework must start from the knowledge of the current demands and necessities as well as from the acknowledgement of diversity. It must therefore be flexible enough to improve and favour the effectiveness of the adopted measures by the competent political-administrative authorities.

Consequently, a positive approach to fire management is possible. It requires being aware of the regulation of fire as a tool for wildland fire risk management (prescribed burning and suppression fire) and land management (crop and livestock uses, landscape management and nature preservation). But it also demands a new policy and legislation approach to promote a responsible, useful fire use, adapted to the different contexts and socioeconomic and spatial demands, in accordance with technical requirements and social interests.

5.2 The way ahead

The lessons learned about good practices and best programmes of prescribed burning and suppression fire are a fundamental basis to show the way ahead for the development and regulation of fire use in Europe.

The diversity of situations found in the professional use of fire in European countries and regions can be turned into an excellent richness which can be exploited to explore advancements in science as well as training professionals rather than being a problem. In fact, many of the fire use professionals can only accumulate limited experience in their own operations and lack possibilities to broaden their abilities by taking part in activities carried out in different scenarios.

The way ahead would therefore include considering the creation of a permanent exchange forum for fire practitioners to share knowledge and information, based on the very successful experiences identified and promoted in Fire Paradox. This exchange forum could have a European dimension but it could easily reach beyond Europe as indicated by the great success of the First South-American Symposium on Fire Ecology and Management, organised in Puerto Madryn (Argentina) on 7–13 June 2009.

Although professional training is also a fundamental component of fire management, research carried out in Fire Paradox shows that progress still has to be made in order to achieve accepted and stabilised European standards[1]. Only after this step will it be possible to have better mobility of fire professionals between countries since these European specialists are especially important in the suppression of very large fires.

The way ahead must also pursue the acceptance of European standards for training fire professionals by countries, based on the proposals started in Fire Paradox, and also the cooperation between European entities for adequate training.

Academic education is another necessary element for successful programmes. However, a critical mass is required to carry out a successful international academic programme. The way ahead would therefore be to prepare an International Graduate Programme in Integrated Fire Management, collecting the aforementioned critical mass from the various initiatives already existing and the available competences, but allowing for specialisation and for a more comprehensive understanding of the diverse situations for fire use. Again, this would be a European initiative that could take advantage of the established links between some European Universities and others in North America, South America or Australia.

The competent authorities may also define Best Practice Guidelines for Fire Use, appropriate for different national and regional circumstances and aiming to guarantee the environmental and economic benefit of fire use practices. The Best Practices Guidelines should address issues related to:

a) The experience and qualification needed for each task.
b) How the burn plan is verified.
c) Whether or not public consultation is required.
d) Obtaining environmental and economic benefits.

1 Deliverables obtained in the frame of Module 10 – Academic and professional training, are available at Fire Intuition Platform: http://fireintuition.efi.int/

Finally, all these European initiatives for education, training, regulations and sharing of experiences proposed by Fire Paradox should be within the scope of the concept of Integrated Fire Management (Rego et al. 2010). This concept is new as it explicitly includes the use of fire (namely prescribed burning and suppression fire) for different purposes and also community fire use by integrating the activities and capacities of the rural population to develop different objectives of land management.

The promotion of good practices and best programmes is a way of pursuing the wise use of fire as a management tool in Europe. However, it is also necessary to define the basis for new political and juridical measures in order to develop integrated fire management systems adapted to the European context. In this regard, the first steps have been given in the frame of Fire Paradox, with the proposal of a new European Framework Directive on Fire (Rego et al. 2010), that have been discussed in different fora as the Conference on the Protection of forests in Europe (Madrid, Spain 6–7 April 2010), the meeting of the EC Expert Group on forest Fires (Rhodes, Greece, 6–7 May 2010) and the 114th meeting of the Standing Forestry Committee (Brussels, 20 May 2010).

The proposed Framework Directive starts from the knowledge of the current demands and necessities as well as from the acknowledgement of diversity concerning fire problems and fire use in Europe. The objective of the Directive is to establish a framework for wildland fire management, fire use regulation as well as wildfire suppression in order to limit the negative consequences of wildfires on the safeguarding of property and humans, the environment, cultural landscapes and economic activities. Then, it means an opportunity to harmonise and update the national regulations on the matter, defining a common reference, which guarantees effectiveness and adaptation to the specificity and diversity of the European context. It is set out as a proper way to avoid uniformism in the juridical treatment of the matter in the whole territory of the European Union and, at the same time, establish a harmonising, basic and minimal arrangement, flexible enough to avoid an undesired homogenisation.

After all, the fundamental concept of Fire Paradox – fire can be seen as a positive tool or a negative force – is illustrated all over Europe starting in Finland, where fire is seen in the traditional proverb as 'a bad master or a good servant'. But an even more clear illustration of an agent capable of simultaneously putting out bad fires and creating good fires is the Salamander, chosen by François I of France as his personal symbol with the motto 'Nutrisco et extinguo', meaning 'I nourish [the good] and extinguish [the bad]'. The Salamander would be continuously present in all the buildings of the French king, for example in the Palace of Chambord where several hundreds of salamanders are displayed and where Leonardo da Vinci took part in its design.

The roots of Integrated Fire Management have been therefore present in the European culture for a long time as fire has been both used and fought for millennia. From proverbs and symbols to current examples, as those presented in this book, there is a long history of illustrating the importance, utility, opportunity and progression of this concept.

This book aims at contributing to build up the concept and the practices related to professional fire use. The examples presented herein illustrate cases of advances in European fire use in recent history. These good examples are still scarce at

Figure 2. The Salamander, Emblem of François I of France. As the symbol of fire and cold, the Salamander could live in the fire without being consumed, but it could also extinguish the fire due to the exceptional coldness of its body (Image from http://tudorswiki.sho.com/page/Francis+I+Historical+Profile).

the European level but they prove that progress is being made and that further developments are possible. Lessons have to be learned from these examples to inform us of the way ahead. This is the continuous learning process required to move towards fully Integrated Fire Management.

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Fire has traditionally been a management tool for rural societies and is still a part of European culture in many regions. Fire use also plays an increasing role in forest and other land management practices and policies in Europe. In the form of prescribed burning, it appears to be a potential management technique to attain different objectives such as silvicultural improvement, control of insects and diseases, habitat management and biodiversity conservation. Moreover, in the field of fire management, the use of fire has demonstrated that it is an efficient tool for the reduction of hazardous fuels and in indirect attack during wildfire suppression (suppression fire). However, in most European countries there are still many constraints and negative attitudes towards the use of fire that need to be overcome.

In the frame of the EU Fire Paradox project, this research report aims to provide policy makers, policy implementers as well as the general public with background information and analysis in order to successfully regulate traditional fire use practices as well as to implement prescribed burning and suppression fire practices in European countries. Within this context, it seeks to understand the factors that influence the success of prescribed burning and suppression fire programmes, and to facilitate their application in other countries through analysing successful case studies. It also provides the main criteria with which to identify good examples.

A collection of good practices and best programmes are presented for the fields of nature conservation in protected areas; the management of habitats for hunting; landscape management; and fire use in fuel reduction and during fire fighting operations (suppression fire use). The authors of the case studies are managers responsible for the creation and implementation of the practices or programmes. The book concludes with an analysis of potential barriers and factors for the successful development of prescribed burning and suppression fire in Europe, as well as a discussion on the lessons learned and the way ahead.

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