FIRE-RES

Innovative technologies & socio-ecological-economic solutions for fire resilient territories in Europe

D1.9 IA 1.4. brief 1: Integrated fire management model: demonstration, training and piloting activities, including new-fire prone areas

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Abstract: This report is the first of two deliverables aiming to implement an integrated fire management model (IFM) to enhance the resilience of forest territories in Europe. It aims to provide a portfolio of well-documented fire management experiences for the scientific assessment of the medium- and long-term effects of IFM on ecosystem services, and demonstration and training of appropriate IFM techniques and strategies. The information provided is structured in appendices.

Key words: Demonstration activities; fire use experiences; low-intensity wildfire; New-fire areas; Prescribed burning; Wildfire management.

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Table of contents

1. Introduction: report aim and structure

Recent extreme wildfire events (EWE) have offered valuable insights, pointing the necessity to modify current fire management strategies that exclusively focus on suppressing all types of fire. These approaches often lead to the buildup and accessibility of fuels, which would directly translate to energy in the landscape. When, as a result of a fire this energy is released, it could trigger an EWE subject to favourable atmospheric conditions (Castellnou et al. 2022). Among all the different factors that combined would prompt an EWE, energy in the landscape is the only one that could be managed in advance and integrated fire management (IFM) is identified as a commendable approach to achieve this objective.

This report represents the first of two deliverables that seek to delineate fire management models to shift the focus from territorial risk management to a desired strategy of sustainable and integrated fire management (IFM) to improve the resilience of landscapes to EWE in Europe by integrating the role of fire on the ecosystems.

The main goal of this deliverable is to provide a well-documented portfolio of fire management practices that will facilitate the implementation of an integrated IFM model centred on the use of fire. This information will provide support for demonstration and training activities that facilitate progress in defining and implementing IFM models utilizing fire, adapted to different regions in Europe. The information gathered, combined with literature review and expert knowledge, will serve as the scientific basis for the Deliverable 1.10. The main objectives of the last deliverable are to develop technical recommendations, contribute to social awareness, and support the development of legal framework of the use of fire. Deliverable 1.10 will also incorporate the Technology readiness levels (TRLs), according to the Gran Agreement Innovation Action 1.4.

Drawing on the workshop dialogue on IFM, a literature review, and the shared perspective of the IFM strategy with some FireEuRisk project partners and founded in the Fire Paradox Project (Costa, P. 2011), the present document commences by presenting the definition of IFM strategy and specifically accentuating the chosen approach in this deliverable, which revolves around the use of fire. It then advances to structure the collected experiences related to the use of fire, which scientifically validate the recommendations of the subsequent Deliverable (D1.10).

2. Integrated fire management (IFM) model: adding fire use to the strategy

2.1. IFM definition

The IFM strategy is characterised as an approach that addresses the challenges and considerations offered by both harmful and beneficial fires. It addresses the natural environments and socio-economic systems in which these fires occur. It provides a conceptual framework for planning and operational systems that encompass social, economic, cultural and ecological assessments with the purpose of minimizing fire damage and maximizing its benefits (Rego et al. 2010; Faivre et al. 2018). The strategy entails evaluating and balancing the risks connected with fire, while also recognizing its potential ecological and economic benefits that it may play in specific areas, landscapes or regions (Myers 2006).

2.2. Challenges

Based on modelling tools, such as those developed by FirEUrisk (Chuvieco et al., 2023) for wildfire risk, crucial areas for current or future fire scenarios can be identified and integrated in a Fire management strategy (Alcasena et al. 2019). FIRE-RES, with a more comprehensive and broader perspective that integrates ecological and landscape management, identifies primary challenges in achieving resilient landscapes in the context of EWEs. These challenges are associated with the necessity of managing fuel at landscape scale, focusing in minimizing damage rather than merely avoiding EWE, which is also influenced by atmospheric casuistic (Deliverable 1.1). This document specifically emphasizes integrating the use of fire, whether through planned ignitions via prescribed burns or unplanned ignitions via managed fire, as an innovative approach to fostering resilient landscapes and communities.

To significantly impact at the level of Extreme Wildfire Events, the presence of fire —rather than substitutes like mechanical forest treatments or grazing— must be extensively implemented across the territory. Fire is the most effective means of reducing the occurrence of EWE, as they effectively remove available fuel load compared to other treatments (Fernandes 2015). Fire not only reduces tree density and fuel quantity, but also transforms or eliminates available fuel over a broader extension, with ecological effects that modify, actually restore, both species interrelationship processes and viability or successional exit that will ultimately modify how the ecosystem receives the impact of the fire disturbance.

At the landscape level, management should aim for annual treatment rates >5 % of the landscapes to effectively control wildfire extents in forests, with 3–4 units of prescribed burning needed to reduce wildfire by one unit (Fernandes 2015). For instance, in Catalonia, studies indicate that management of approximately 15,000 hectares per year through prescribed fires or managed wildfires (Bearn et al 2023) with a treatment frequency of 8-10 years could serve as a basis (Duane et al. 2019; Alcasena et al. 2018; Casals et al. 2016).

Expanding the use of fire is imperative despite various various social, legal, environmental and practical constraints (Fernandes et al. 2013). In terms of practical constraints, climate change is expected to significantly shorten the prescribed burning season, complicating implementation and having unknown effects on ecosystem recovery from fires, whether prescribed or unplanned (Kupfen et al. 2020). Prescribed fires have numerous positive or neutral effects on soil, understory, and trees (Fernandes et al. 2018) but can also have negative effects, especially when compared to mechanical treatments, such us increasing runoff and erosion rates (Fernandez et al. 2017), or affecting wildlife mortality (Lyet et al. 2009), among others. Despite these challenges, expanding fire use remains critical to enhancing landscape resilience to EWEs, necessitating a landscape-specific approach that collaborates with related initiatives like Holisoils (www.Holisoils.eu) and Pyrolife (www.pyrolife.lessonsonfire.eu) projects.

Finally, given the necessity of scaling fire effects to the landscape level, the only method to dramatically affect fuel availability to a degree that could be determinant for EWE, demands a much deeper integration of fire management than what prescribed burning alone implies. Managed wildfires must therefore play an essential role in accomplishing this objective. A major aspect in enabling widespread application of managed wildfires is the preparation of landscapes. Landscape use appears as a vital instrument in this regard, providing as an effective approach to prepare landscapes for easing fire restoration.

More specifically, the challenges identified in D1.1 and that will be addressed in this document are as follows:

FIRE AS A MANAGEMENT TOOL:

a. Minimizing inappropriate use of fire and maximizing its appropriate use to increase landscape resilience to wildfire. By promoting the figure of Fire Manager (2.4.1) to improve the capacity of the use of fire, by presenting a portfolio of examples of good practices in the IFM implementation (2.3) and a database of well-documented studies where the effect of prescribed burning on different ecosystems components can be consulted (2.5).

b. Understanding how to restore ecologically appropriate fire regimes, taking advantage of appropriate fire use and incorporating new advances in fire ecology. By gathering the knowledge gained through research and experience on the different forms of fire, including prescribed burning, traditional burning, managed wildfire and technical fires (2.5), implementing the role of Fire Manager it could make a difference on this objective (2.4). This restoration should have an upscaling effect and reach a landscape scale (e.g. California's strategic Plan for Expanding the use of Beneficial Fire. March 2022)

c. Skills needed for the use of fire in specific ecosystems (e.g., subalpine forests) and regions of Europe are poorly developed. So, it is important to improve knowledge on the effects of fire on these regions that allows improving the use of fire in these areas (2.5).

d. Establish a common monitoring protocol to evaluate fire impacts and the effectiveness of integrated fire management actions to inform future management decisions, including incorporating new knowledge (e.g., fire use in non-fire prone areas). Implementing a platform that aims to collect well-documented prescribed burns experiences supported by various research areas to create a database that will be publicly available in the Fire-Res website (2.5) can contribute to this challenge.

GOVERNANCE AND RISK AWARNESS:

a. Rapid risk awareness assessment - explore the role of human behaviour in shaping individual and collective livelihood resilience to collective shocks. Designing and implementing a serious game 'Play with Fire', as a tool to evaluate societal wildfire risk awareness at the same time as increasing awareness through experiential learning. The implementation of the game on the one hand let us explore what citizens believe are the factors and conditions that interact to create a wildfire risk and on the other hand offer to learn and reflect about the role of humans in shaping risk. More information will be found in deliverable 1.10.

b. Integrate traditional burnings and/or prescribing burnings (cultural knowledge and giving local communities a role). To improve multidisciplinary participation in the processes required for achieving integrated wildfire governance, increased awareness across disciplines and stakeholders is needed. With this objective, the Living Lab Germany-Netherlands (Wageningen University and Waldbrandteam), along with the Catalan Fire and Rescue Service, organized the 'Living with Integrated Fire Management' training. This program aimed to enhance resilience to wildfires in the context of climate change and targeted diverse professionals from various fields and countries. It included topics such as fire ecology, EU legal framework, and adaptive management, among others. The design principles of the training will be replicated in the LL Portugal. For more details, see the report in the appendix section [4.2.1].

2.3. IFM implementation

An IFM model entails the implementation of an IFM strategy to achieve specific objectives (e.g., resilience to EWEs; Biodiversity enhancement…) within a designated area through planned, adapted and implemented actions by various stakeholders. The FIRE-RES model aims to manage fuel at both stand and landscape scales to reduce EWE occurrences and enhance the resistance and resilience of landscapes to fire, leveraging its ecological benefits.

This model involves the integration of the three technical components of fire management: prevention, suppression and use, while considering the key attributes of fire:

- Ecologically appropriate fire regime,
- socio-economic and cultural necessities of using fire, as well as
- the potential damage and benefits that fire can have on society.

Specifically, to develop and implement an IFM model based on fire use, several steps are necessary:

- Assessing the ecological, social, cultural and economic roles of fire within a specific area.
- Evaluating socially acceptance and sustainable solutions using fire.
- Understanding the influence of fuel characteristics on fire behaviour and severity.
- Identifying other threats that interact with fire such as land use changes, invasive species, climate change and other perturbations (e.g., drought and insect outbreaks)

- Analyzing the underlying causes of fire-related threats, and the extent of ecosystem degradation.

2.3.1. Planning the territory

Landscape planning is essential for implementing an IFM model aimed at enhancing landscape resilience to wildfires. While under extreme conditions, landscape configuration and composition may have minimal impact on fire spread and size (Cruz et al., 2022), strategic spatial allocation of low-fuel discontinuities can decrease fire growth rate, enhance potential for fire suppression, and mitigate fire damage (Moreira et al., 2020; See D1.11). The plan should define the typology and schedule of fuel management actions for each strategic area, considering the benefits or constraints in the provision of other ecosystem services. Planning should cover actions to be executed before, during, or after a fire, taking into account their interactions. The provision of other ecosystem services, such as water or biodiversity, must be integrated into the design and selection of actions to be implemented.

Appendix A1 provides an example of strategic planning aimed at enhancing long-term resilience and ensuring the provision of ecosystem services. It is important to acknowledge that, while this example serves as a valuable starting point, it can be further refined by introducing and planning various fire uses forms.

2.3.2. Implementing planned actions through fire use

There is a wide spectrum of management types that can potentially be used to increase the resilience of a territory. Fire, along with forestry and silvopastoralism, has been used as instruments to open and maintain areas with different objectives. The model that encompasses fire use as an important component facilitates implementing cost-effective approaches that incorporates a diverse range of fire management options to be implemented before, during and after a wildfire event.

These approaches involve a combination of strategies and techniques for prevention and suppression, that incorporate the deliberate use of controlled fires, whether prescribed burns, managed wildfire as well as traditional burning practices. Appendix A2 provides a portfolio of various experiences in fire use, which are summarized in the following sections.

Wildfire management

Within an EWE scenario, once the emergency has been activated, suppression strategies must transition to management strategies, and the emergency system strategy should focus on which scenario should be avoided (D1.3). At this stage, fire services should implement tools that facilitate these management objectives.

Technical fire

Technical fire can be defined as a tool that not only allows to confine fire within certain boundaries but also regulate the amount of energy released. Technical fires can be carried out by qualified personnel during an emergency under specific environmental conditions and based on an analysis of fire behaviour (Rego et al. 2010). Since the area affected by a wildfire can be very large, and it is difficult to know the location of all the responders and residents, the use of fire during an emergency can lead to dangerous situations. For this reason, it is very important that the team responsible for the use of fire are qualified, and regulations and laws are needed to protect this tool and the team in charge of the execution (e.g., DECRET 312/2006, de 25 de juliol, *pel qual es regula la gestió del foc tècnic per part del personal dels serveis de prevenció i extinció d'incendis de la Generalitat de Catalunya*).

In appendix A3.1.2 different technical fire use experiences are detailed.

Wildfire suppression planning

During the prevention phase, the identification and adaptation of fire regimes, through fire types and opportunities in the landscape, critical points (Costa, P 2011), in accordance with the requirements of the wildfire management is a crucial stage. This involves the creation of structures within the territory that can help manage fires during the emergency phase (D1.3). This entails executing measures from planning to the implementation of the forest and landscape's structure modification.

It is vital to carry out an upscaling in relation to wildfire suppression planning, since the EWE scale is at landscape level, and former infrastructures, created for topographic and wind driven fires, would not yield sufficient impacts on EWE's fire behaviour. This must be accomplished with the agreement of the community, as outlined in the Fire Forums methodology (IA 4.1) . It will also bring about the necessity to adapt messages and advice to the community (IA 5.9).

There are different tools for the creation of structures within the territory that can help managing wildfires. In this sense, silvopastoralism is an essential tool for the sustainable management of Mediterranean forest ecosystems from a biological, social and economic perspective (Casals et al. 2009). The effectiveness of herbivore grazing as a means of maintaining fuel break biomass under a critical threshold for fire prevention purposes has been widely demonstrated in different experiences throughout the Mediterranean basin (Etienne et al. 1990; Pardini et al. 1993).

In appendix A 3.3.2 silvopastoral experiences combined mechanical clearing or fire to maintain fuel loads under a threshold together with the objectives of provision of agropastoral products and biodiversity conservation are detailed.

Fire as ecological process

Fire plays a crucial role in shaping ecosystems and exerts a strong ecological and evolutionary influence on various aspects of ecosystem function (Bradstock, 2010). Fire regimes are the spatial and temporal characterization of wildfires in specific regions and time periods. To characterize fire regimes, wildfires are usually described in terms of their intensity, frequency, severity, seasonality and size (Bradstock, 2010). In areas with minimal human intervention, such as wilderness areas in the United States, the concept of natural fire regimes applies. In contrast, the term historical fire regimes refer to the characteristics of wildfires during specific historical periods. While characterizing past fire regimes, natural or historical, is challenging, assessing current fire regimes and their recent changes due to factors related to human activities and climate change is comparatively easier (McLauchlan et al., 2020). For example, human activities have a significant impact on current fire regimes, whether through changes in land use or the implementation of specific fire management measures. Climate change is also altering the current fire regime by, among other mechanisms, increasing atmospheric instability and the number of days that favour forest fires.

In wilderness areas of the United States land managers often use estimates of fire regimes and forest conditions prior to European settlement to develop forest restoration goals (Miller & Safford, 2017). In European regions, the challenge of IFM therefore lies in the introduction of socio-ecologically desirable fire regimes to increase the benefits of fire while minimizing its negative impacts. Therefore, the socio-ecological objectives of ecosystems should guide the introduction of fire regimes that are compatible with desired future states. For example, if conservation of *Pinus halepensis* is the desired forest type state, a low-frequency, high-severity fire regime would be favoured to promote regeneration while minimizing the risk of cone immaturity. Conversely, if the aim is to maintain P. nigra (Domenech et al, 2018) the desired fire regime might require low severity and high frequency fires. These examples only consider the dominant tree species as the goal but when establishing fire regimes, all ecosystem components, including, for instance fauna and soil, should be considered.

The integration of fire into IFM systems can take various forms, as detailed in the following sections.

Traditional fire use

Traditional socio-cultural burning serves as a key tool for management in various regions. In Europe, human use of fire has been acknowledged as one of the most significant causes for the alteration of natural fire regimes and it persists in several regions as a management tool for different resource management purposes such as grazing, burning agro-forestry remains and game management (Rego et al. 2010). Traditional burning must be conducted under legal regulations and good practices based on historical know-how. Though traditional fire management remains common in some regions (e.g. northern Britain, Nordic countries, Western Pyrenees) in many areas its use has reduced due to regulation and land-use change.

The integration of traditional fire use within the Integrated Fire Management (IFM) strategy is imperative. Excluding it from the strategy would overlook the significant impacts of such fires on the ecosystem. Moreover, incorporating traditional fire practices is essential for achieving substantial surface impact, especially considering their promotion by local entities and landowners, often supported by synergies with local and traditional practices.

Hence, the implementation of any new model's implementation should not impede the continuation of established fire practices. Instead, it should facilitate their integration into the new framework.

Prescribed burnings for ecosystems management purposes

Prescribed burning (PB) is the planned use of fire to achieve precise and clearly defined management objectives and makes a vital contribution to the delivery of ecosystem goods and services. Reducing fire hazard was the initial motivation for PB across many areas of southern Europe, but PB now includes an array of objectives, from biodiversity conservation to carbon management (Fernandes et al 2013). In temperate-boreal Europe and neighbouring Eastern Eurasian regions PB has been used primarily in conservation (biodiversity management) but also in fuel reduction and pest management (Goldammer 2013). However, a variety of factors constrain consolidation of PB as a management tool (Lazaro and Montiel 2010). These include risk-related concerns; a lack of evidence-based policy making; a shortage of experienced professionals; limited use of existing decision support tools; negative public perceptions; and limited legal frameworks and professional accreditation schemes. Previous EU research projects (FIRETORCH and FIREPARADOX) have collated information on the efficacy of PB for fuel reduction and ecosystem service delivery.

Managed wildfire

Managed wildfires can be incorporated into the integrated fire management model to establish a comprehensive framework for fire decision-making. This integration offers a series of technical decisions and actions aimed at monitoring an unplanned ignition and to conduct a fire to a predetermined limit of contention to achieve planned resource management objectives (Rego et al. 2010).

The addition of wildfire management into an IFM requires to the following requirements:

- evaluate whether the effects of a wildfire in a given area results in a desired or undesired future condition,
- weighing relative benefits and risks and
- responding appropriately and effectively based on stated objectives for the area in question.
- According FIRE-RES D1.1 the management of wildland fires to accomplish specific pre-stated resource management objectives in predefined geographic areas outlined in Fire Management Plans. The current debate over managed wildfire is political rather than technical or scientific.
- In the U.S., there is controversy over simultaneous "let it burn" fires with other large wildfires as resources are limited, as well as constrains linked with its social impacts and air quality.
- At the European level, in Portugal, a new law was recently passed that allows some fires to burn. It will not be translated into action on the ground but will be used to regulate the legal consequences in those cases where the authorities are not able to control the fires because of a lack of resources or uncontrollable fire behaviour.
- In Catalonia, la Vall d'Aran region is a good example of how to incorporate the use of wildland fire. A strategic plan has been adopted as requested by the stakeholders and general public of the territory (Conselh Generau d'Aran 2022). Within this program, there are management objectives that can be achieved with conventional prescribed burning, but in some specific locations the option of wildland fire use, that is a "let it burn" strategy, can also be considered. This strategic plan consists of a reference document (strategic design), a dynamic environment GIS for managers, an assessment of landscape dynamics through modelling, and a monitoring program.

2.4. Actors

To ensure successful implementation of IFM, it is crucial to have the necessary actors in place to facilitate implementation. While it is not mandatory to assign specific individuals to these roles, professionals already working in the relevant territories can assume these responsibilities. However, it is desirable that those involved in the process have a minimum profile or the necessary knowledge to contribute effectively to implementation.

The IFM strategy requires a new way of training our future experts, either through the introduction of a dedicated role like the Fire Manager or by leveraging existing roles in the territory, aa broader way of defining scientific excellence, and stimulation of opportunities for people from various disciplines and sectors to meet and learn (Stoof and Kettridge, 2021). Engaging in knowledge exchange regarding fire ecology and fire management principles with stakeholders and end-users is crucial. This exchange helps improve decision-making capacities and enhances the acceptance of fire as a driving component of forest ecosystems. In this deliverable we detail the training experiences carried out to exchange the knowledge gathered with stakeholders involved in the fire management process.

2.4.1. Fire manager's profiles

The Fire Manager role is aimed at facilitating the implementation of the IFM strategy. Although not essential, the appointment a designated Fire Manager clarifies the minimum qualifications needed by professionals in order to effectively contribute effectively to the implementation of the IFM strategy.

A Fire Manager must have a diverse range of skills, derived from various fields, including ecology, forestry, fire science, social science, and legal frameworks. This expertise ensures a comprehensive understanding and effective implementation of IFM strategies. A competence expertise chart could be used to compare the expertise of Fire Managers expertise as proposed in the AFAN project (Figure 1).

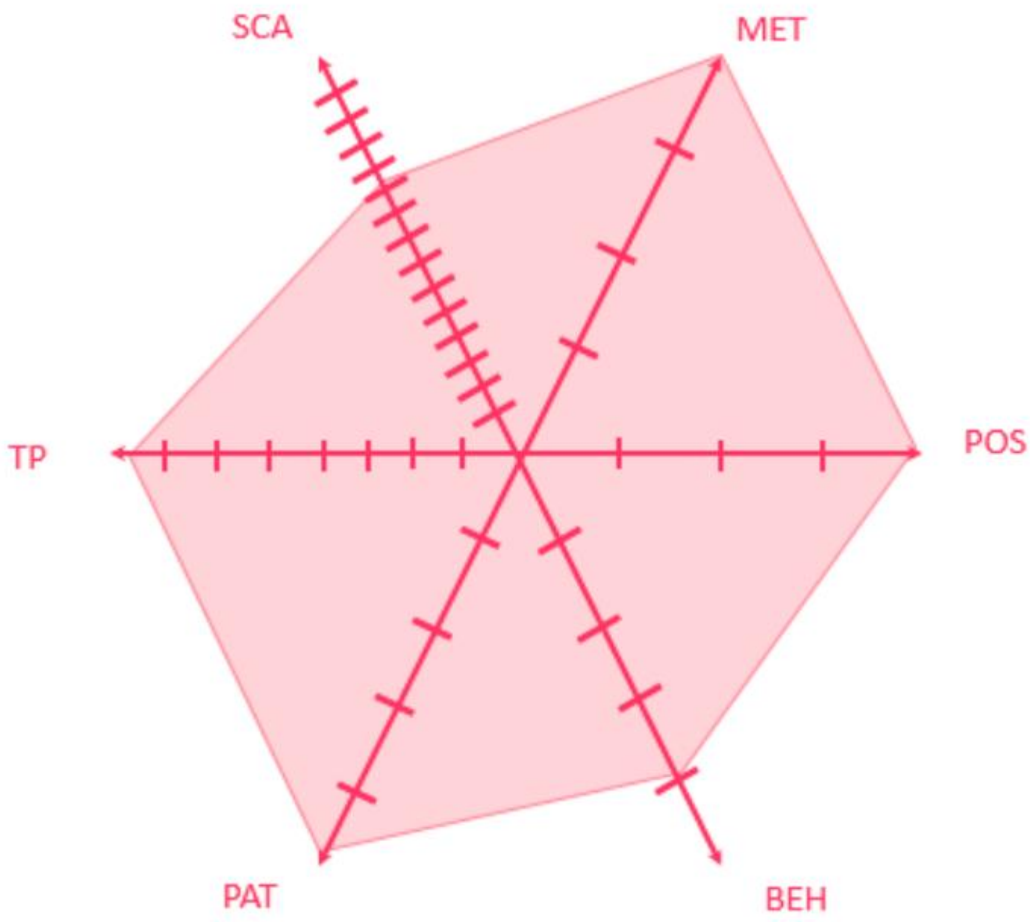

Figure 1. FA expertise chart proposed in the AFAN project. Each FA or organization can create a self-description using this spider chart. Each axis describes a thematic (MET- Impact of meteorology on fire behaviour, POS- Fire position, BEH- Fire behaviour, PAT- Fire spread patterns, TP- Tactical Planning, SCA- Strategy and Scenario awareness) and it is graded considering the total number of points regarding the expertise of each topic.

The outlined skills for a Fire Manager outline the essential competencies required to effectively implement IFM strategies. These skills would be:

1. Resilience and innovation: Fostering resilient landscapes and employing innovative solutions to manage fire-related challenges.
2. Fire regime knowledge: Ability to explain the fire regime and its biophysical and social drivers and impacts, and future developments of fire and landscapes.
3. Fire behavior understanding: Understand what the fire wants to do, what the fire can do, what you want to do and what you can do. Understand what the ecosystem wants to and can do.

4. Interdisciplinary understanding: Understand interrelationships between climate change, nitrogen, social and environmental migration, biodiversity, and other big topics, and fire.

5. Landscape analysis: Analyse the relationship between landscape planning and management and fire behaviour and risk.

6. Legal foundations: Knowledge of fire prevention and safety regulations, regulations for the protection of protected areas, and regulations for the technical use of fire.

7. Perception and culture of fire: Understanding of the technical and societal barriers to fire management, the loss of fire culture, and the new reality of emerging risk.

8. Personal interest connection: Connect what happens with the fire with their own interest.

9. Practical considerations: Understanding of the practical implications of fire-related regulations, including derived responsibilities and potential contradictions between organizations.

10. Prevention and suppression systems: Knowledge of the basic operation of forest fire suppression, communications, and safety.

11. Use of fire: Experience with prescribed burns, including planning, operation, safety, communication aspects, and different typologies of prescribed burns along different desired objectives.

2.4.2. Fire manager's profiles specific for EWE

Moreover, in FIRE-RES D1.1, specific competencies essential for a Fire Manager to proficiently address challenges associated with EWE have been identified. These skills are:

1. Communication skills: Ability to effectively communicate and manage information flow during emergencies.

2. Interoperability knowledge: Understanding of how different systems and organizations work together during fire events.

3. Training and capacity: Continuous learning and development to monitor and predict Extreme Wildfire Events (EWEs).

This profile encompasses a wide range of skills and knowledge areas, making a fire manager well-equipped to handle the complexities and challenges of fire management in various contexts. It's important to note that the specifics of this role can vary depending on the region, the specific ecosystem, and the local laws and regulations. Therefore, continuous learning and adaptation are key aspects of this role specially in EWE context.

Usually, the possibility of official training and even the possibility of exigence of a specific qualification, is connected to the existence of a specific law that will demand specific requirements to the people participating in the use of fire. In any case, regulations regarding the use of fire, whether for suppression or fire management, should be seen as a means to ensure best practices. Promoting such regulations at the European level could be an effective way to achieve this objective.

In the framework of the FIRE-RES project in task 1.3 two pilot training, for Fire Managers, have been considered the first in the Living Lab Netherlands- Germany and a second in Living Lab Portugal.

2.5. Knowledge, research and experience

The primary goal of the IFM model is to incorporate the presence of fire and its effects on ecosystems. In order to accomplish this, it is imperative to accumulate the knowledge acquired through research and experience about various types of fire, including prescribed burning, traditional burning, managed wildfires and technical fires. As a first step, a platform has been created to gather comprehensive data on well-documented prescribed fire locations across Europe. This information could prove valuable to fire managers and fire researchers.

2.5.1. Database on well-documented prescribed burning sites

Although there has been significant advancement in the research on prescribed burning since the 1980s, the scientific foundation for this practice remains fragmented and incomplete, making it difficult to define burning regimes for different targets (Fernandes, 2018). The established platform intends to combine all fragmented research by gathering general information on well-documented prescribed burning sites, thereby providing as a valuable resource for both fire managers and researchers. Fire managers will have access to various publications that examine the effects of prescribed burning on different ecosystem components, which will be helpful in developing burning regimes to achieve specific objectives. Fire researchers can use the database to select studies for conducting meta-analyses on different aspects of prescribed burning that could help define burning regimes, i.e. consider the spatial and temporal dimensions of prescribed burning to achieve a specific goal, as research currently focuses on single events that do not allow the definition of regimes. The database might, for example, make it possible to analyse the dynamics of fine fuels after burning in diverse conditions. In addition, the database improves communication between fire researchers and managers and site managers and enables informed decision making regarding prescribed burning regimes.

Attempts have been made to develop a database on prescribed burning, such as the Fire Paradox project (Molina et al., 2009). However, access to the relevant publications and documentation that were originally available on the Fire Paradox information portal — Fire Intuition (fireintuition.efi.int/) — is no longer available. A database built by the Eurasian Fire in Nature Conservation Network (EFNCN), which served the Fire Paradox database, continues to systematically gather and archive demonstration plots for prescribed burning, although without current updates as stated on the website. While this database is valuable, it also has downsides in terms of the time-consuming process associated with the specific information neededand the data collecting is done via a Word document.

The criterion for inclusion of prescribed burning sites in the platform is that previous or ongoing research has been carried out at the site. The platform is designed to facilitate data entry and collection and recognize scenarios where users have multiple burns at one site or multiple sites with similar information fields. For example, after completing the questionnaire for one site, users can copy the values to another and make the necessary adjustments, significantly speeding up data entry. To access the questionnaire and participate in the survey, users must create a unique username and password that allows them to securely access the system and save the information entered. In the appendix A 4, a description of the platform and a summary of the information gathered by 11/04/2024 can be found.

2.6. Governance and legal framework

The acceptance and use of fire is a fundamental component of a landscape that is resilient to fire, alongside landscape management, community engagement, loss avoidance and recovery (Newman Thacker et al., 2023). Fire use manifests in various methods and manifestations, from traditional burning for a multitude of reasons (de Oliveira, et. Al. 2023), and prescribed burning for landscape management or fuel reduction (Fernandes et al., 2013), to tactical fire used in uncontrolled wildfire events. The use of fire is facing challenges in numerous nations due to public perception, smoke concerns, and limited resources to burn sufficient area during typically small windows of opportunity in terms of weather conditions. Nevertheless, the benefits of this age-old practice can range from maintaining cultural practices and livelihoods, to biodiversity, social coherence, training and networking.

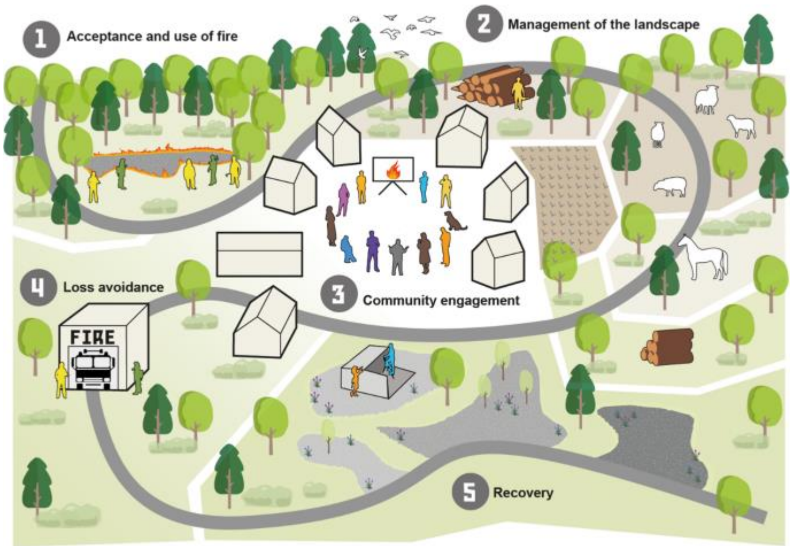

Figure 2. Core components of a fire resilient landscape: acceptance and use of fire, management of the landscape, community engagement, loss avoidance and recovery (Newman Thacker et al., 2023)

Within Europe, the governance of fire use varies significantly, and has not been systematically analysed (Silva et al, 2010). The most recent inclusive evaluation of fire use governance was conducted within the Fire Paradox project, by Montiel-Molina (2013). In a country like Spain the responsibility of regulating fire use is tackled by autonomous regions like Catalonia or Castile-La Mancha. Both Spain and Italy have only implemented regulations at a regional level (D'Amelio, 2022). Within the Mediterranean region, Montiel-Molina (2013), emphasizes that Portugal is the sole European country that has implemented legislation to regulate fire use on a national level, introduced in 2004. In similar endeavours, France introduced prescribed burning practices through the Forest Act of 9 July 2011. Outside of the Mediterranean region, the author reports ambiguous regulations in Sweden and Poland, while Lithuania, Italy, and Germany, which had previously prohibited fire utilization, were starting to reintroduce fire use experimentally for protected area management (Montiel-Molina, 2013). In Northern Europe (Estonia, Finland, Latvia, Lithuania, Sweden), despite the recognition of the natural role of fire in boreal and hemi-boreal ecosystems, a negative public perception of the use of fire and a lack of a legal framework persisted (Montiel-Molina, 2013). Yet it is crucial to note that fire governance is considerably in flux in emerging fire regions, which implies that rules and regulations may likely have evolved since 2013. A global review of fire policy conducted more recently highlighted that fire use regulation remains vague, or poorly implemented across several European countries, including the United Kingdom and Italy, where it is a matter managed at local rather than national levels (Pandey et al., 2023).

To produce a current comprehensive overview at pan-European level, we examined data collected through the Global Fire Use Survey conducted by Smith et al. (2023, 2024). This analysis demonstrates that fire use exists in all 25 European countries represented in the survey (Error! Reference source not found.a). This fire use ranges from burning practices to support small-scale livelihoods and/or for cultural reasons, to fire used by companies or large landowners, protected area managers or state agencies (Error! Reference source not found.b). Survey respondents indicate that the governance of fire use widely varies within Europe (Error! Reference source not found.c)), ranging from state regulations prohibiting fire for any reason or for certain reasons; regulations limiting or banning fire within protected areas, making some or all fire conditional upon certain criteria; economic incentives or educational campaigns being in place to limit fire use, or local governance based on traditional knowledge being in place to ensure fire use is controlled (Figure 3c) . These diverse types of governance approaches also vary within countries.

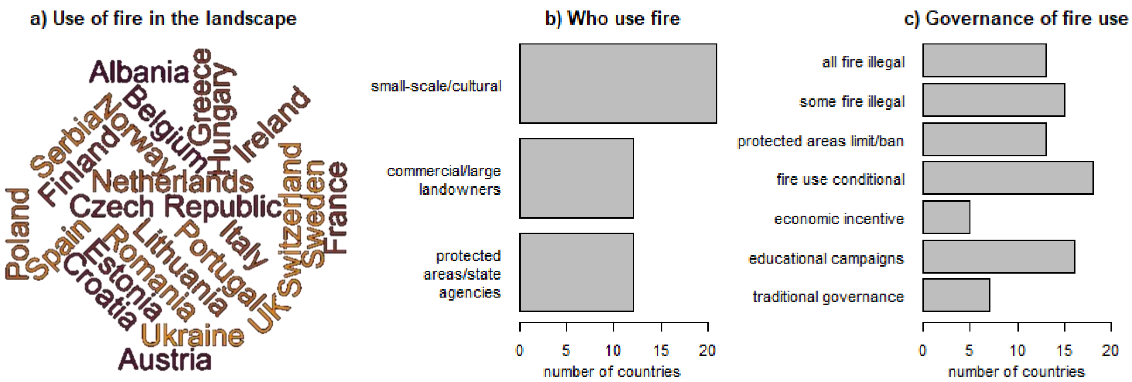

Figure 3. Pan-European analysis of the Global Fire Use Survey dataset. a) European countries represented in the survey for which respondents indicated the existence of landscape fire use (two responses for Belgium were contradictory but given the decades long history of fire use in the Mechelse heide (Gorissen et al. 2021 we included Belgium here as well. b) which groups use fire in this country; c) governance of the fire use practice. The Global Fire Use Survey (Smith

et al) was conducted from December 2022 to June 2023 and contains 55 responses that consider European countries and regions, out of a total of 313 responses.

Despite the numerous obstacles that the governance of fire utilization faces, fire is employed throughout Europe, from the Northern regions to the Southern regions. In Norway, informal civic groups among farmers have surfaced to implement prescribed burning for heathland management since 2009, notwithstanding the lack of a legal framework that regulates the practice or liability in case of negligence (Metallinou, 2020). In 2007, during a mega-fire in Greece, villagers autonomously resorted to using fire to eliminate the fuel surrounding their villages, thereby protecting them, as the firefighting organization had practically collapsed (Tedim, 2016). These instances demonstrate that there are scenarios where decisions to use fire were taken based on specific circumstances rather than as part of a broader legal strategy.

The aforementioned examination illustrates a broad range of methodologies to the governance of fire use, and a necessity for adaptable, comprehensive legal frameworks and community engagement strategies that harness fire's benefits while alleviating its hazards.

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4. Annexes

4.1. Landscape planning (A1)

4.1.1. Landscape planning for resilient landscapes: The Soriguera example (A 1.1)

Aquilué, Núria (CTFC)

The purpose of this landscape-level planning is to promote resilient agroforestry landscapes to the factors of climate change and the sustainable provision of multiple ecosystem services in the context of promoting circular bioeconomy, which allows adding value to local natural resources, as well as advocating for a rural development model that integrates the needs of the territory. Jointly and consensually between the scientific-technical team and the team of managers representing the different thematic areas related to the territory, a series of objectives that should be promoted have been established. These are:

- Reduction of the risk of large forest fires
- Conservation of biodiversity
- Provision of agro-silvo-pastoral products
- Blue water provision

Territory

Soriguera is a municipality located in the Pyrenees, at an altitude between 596 – 2438 m a.s.l.; with an area of 106.4 km^2 and a population density of 4 inhabitants per km^2 (Figure 1). Forests cover the predominant land (72%), followed by shrublands (15%). The fuel load in agricultural areas, grasslands or pastures, shrublands, and wooded areas is *ca*. 2.48 t/ha, 3.64 t/ha, 19.7 t/ha, and 12.1 t/ha, respectively (Figure 4).

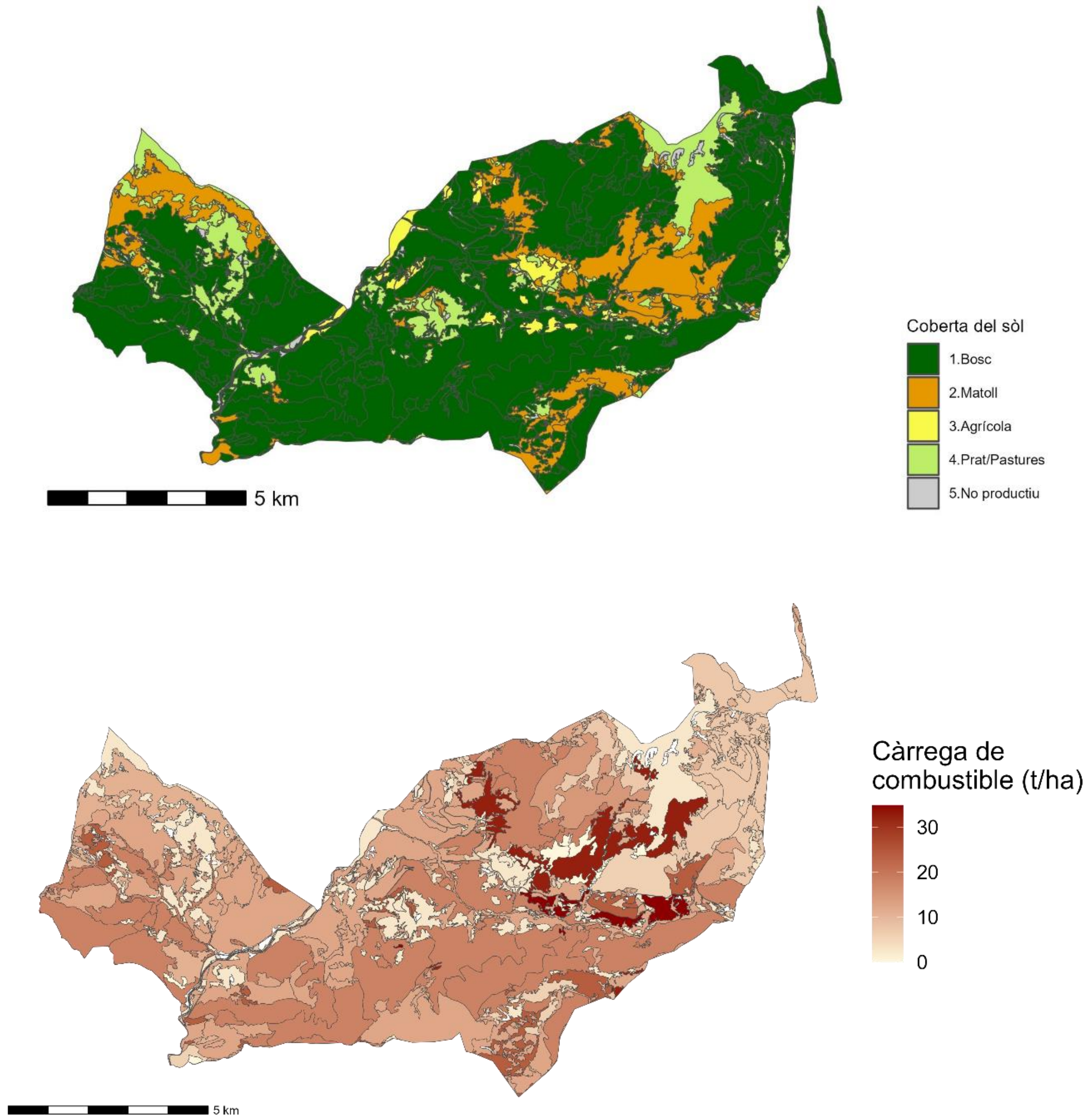


Figure 4. Land covers (above) and superficial fuel-load (below)

Planning

To develop a proposal for creating a resilient agroforest landscape in this territory, we defined the main changes in land cover to promote the agro-silvo-pastoral activites, and a series of alternative forest management options, which could potentially contribute favorably to achieving the premises of overall resilience. The planning of actions to achieve a resilient agroforest landscape has been carried out through a process of spatial optimization and assessment using expert criteria. We created a data matrix, where for each landscape unit of Soriguera, all possible change alternatives are listed. Each alternative is accompanied by a future estimation of all ecosystem services considered. The spatial optimization tool is based on this matrix and a series of weights associated with each ecosystem service to find an optimal solution that maximizes all ecosystem services while respecting the prioritization order established by the weights. Thus, a generic proposal for a resilient agroforestry landscape for Soriguera is obtained, in which equal priority is given to the four main objectives considered. The optimization tool results in an optimal solution that maximizes the ecosystem services associated to these four objectives. To simulate different forest management treatments and estimate the evolution of forest masses according to each alternative model, the FORMES forest dynamics and management model has been utilized (Trasobares et al. 2022).

Based on this solution, experts in the territory from different action areas were consulted to characterize and identify specific areas for prioritizing certain activities, requiring special management measures, or presenting restrictions regarding the proposed changes. In this way, an action plan is designed to lead to a resilient agroforestry landscape, respecting, in a consensus manner, the prioritizations of each expert area. Specific areas according to expert criteria include, on one hand, areas with agro-livestock vocation, on the other hand, priority areas for biodiversity conservation, and finally, strategic areas for the prevention of large forest fires. For the inclusion of this latter criterion, members of the GRAF unit (CFRS) provided strategic zones for preventing large forest fires (Figure 5). In these areas, the actions to be carried out are closely related to breaking the continuity of large fuel masses, to minimize the potential for large forest fires and prevent them from spreading from one slope to another of the different massifs.

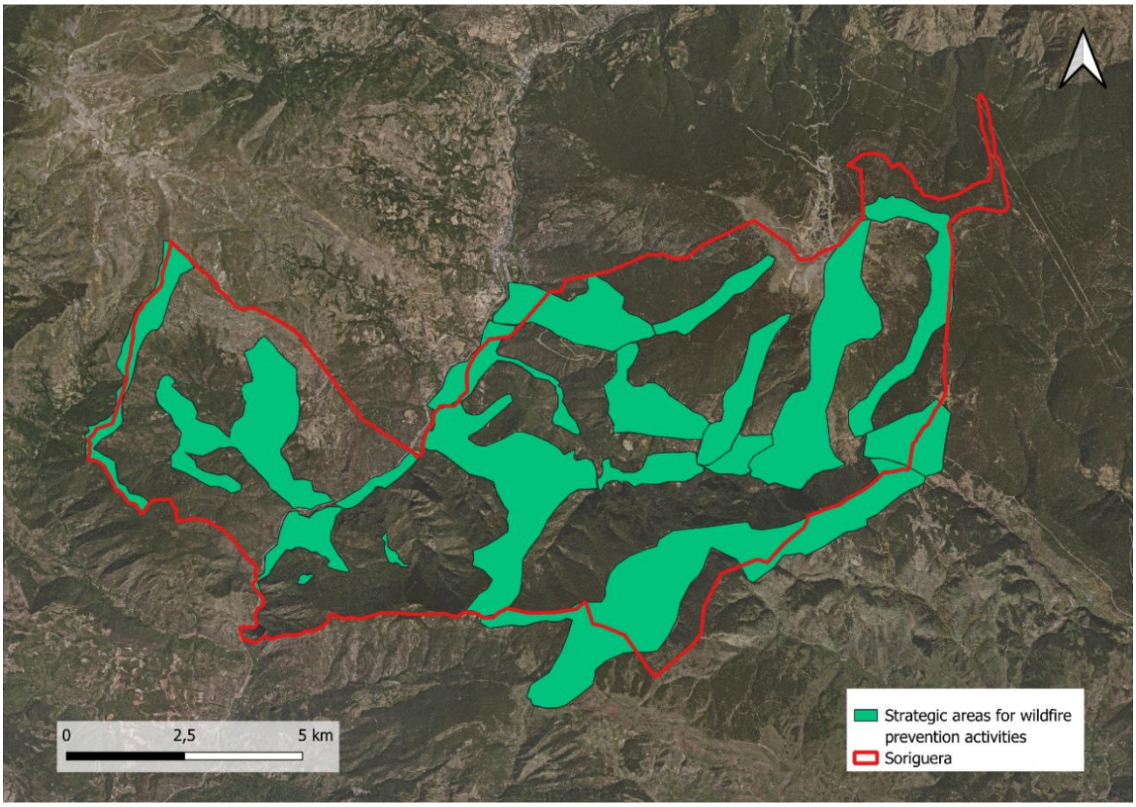


Figure 5. Strategic zones to promote forest activities for wildfire prevention

4.2. Training experiences and capacity building in fire use (A2)

4.2.1. Fire Managers training (A 2.1)

In the FIRE-RES project a 1$^{st\ pilot}$ training has been implemented in 25th September (online session) and 9-13th of October 2023 in Walsrode, Germany.

The training was designed and organized through the collaboration of the Living Lab Germany-Netherlands [Wageningen University and Waldbrandteam], and the Catalan Fire and Rescue Service team, as part of the WP1, from the FIRE-RES project. The goal of this course was to bring together people from a range of different fields and countries to become leaders in creating a change to make landscapes more resilient to wildfires in the context of climate change.

Aim

The Integrated Living with Wildfires Training sought to provide participants with a comprehensive understanding and skill set in fire management while fostering interdisciplinary collaboration and networking. Specifically, the training aimed to:

- Equip participants with the knowledge and skills necessary for integrated fire management, moving beyond the focus on fire suppression alone.
- Encourage informal connections and networking among participants.
- Facilitate regional and institutional knowledge exchange, fostering intra- and inter-group learning and collaboration.

Therefore, the main aim of the training was to exchange knowledge on integrated wildfire management, strengthen networking, and increase cooperation opportunities.

Target group

People who are willing and able to make changes in their regions/countries to move to live with fire. Participants can work in fields like policy-making, land management, and emergency services, as well as other fields.

Location and dates

The training event took place in two parts. The first part consisted of a 3.5-hour online session, and the second part consisted of a 3.5-day in-person training.

The online session took place on Monday, 25th September 2023, from 09:00 to 12:35 hours, through a Microsoft Teams platform. The In-person training took place from the 9th (dinner) to the 13th of October 2023 (afternoon), at the ANDERS Hotel in Walsrode, northern Germany.

Curriculum, methods, and strategies

When planning the "Living with Integrated Fire Management" training, the organizers worked together to choose the topics. They thought about the training's goals and who would be attending. Since the people coming to the training had different levels of knowledge about Integrated Wildfire Management, the organizers started with a short online course. This course covered the basic ideas, making sure everyone had the same starting knowledge.

After the online course, there was more detailed training in person. This part of the training went deeper into the topics. The main subjects of the training were carefully picked to suit the different backgrounds and knowledge levels of the people attending. This way of doing the training, starting online and then moving to in-person sessions, made sure everyone could learn and participate effectively. The key topics included:

- Integrated wildfire management
- Changes in wildfire risk awareness
- Practical use of fire
- Fire ecology
- EU legal framework
- Adaptive management
- Cross-cutting topics in interactive sessions
- Fire behavior

The methods used in the training were diverse. They included inviting expert speakers, allowing time for plenary discussions on the main topics, interactive sessions for case study analysis and discussion, using tools like a sand table for visualizing case studies, and field visits to observe fire behavior experiments and discuss forest management on-site. The training's strategy was to provide various opportunities for learning, socializing, and networking, both in formal sessions and informal settings, indoors and outdoors. For more details on the topics and methods, please refer to the appendix, where the full agenda is provided.

4.3. Portfolio of fire use experiences (A3)

4.3.1. Experiences in wildfire management (A 3.1)

Experiences in technical fire use during wildfire emergency (A 3.2)

Following the challenges and gaps identified and collected in Fire-RES D1.1, technical fire on EWE allows:

a) Less resources used during suppressing operations and those committed to the mop-up phase as technical fire operations involve fewer personnel, and since the fire perimeter can be strategically chosen, the result is simpler mop-up with fewer resources.

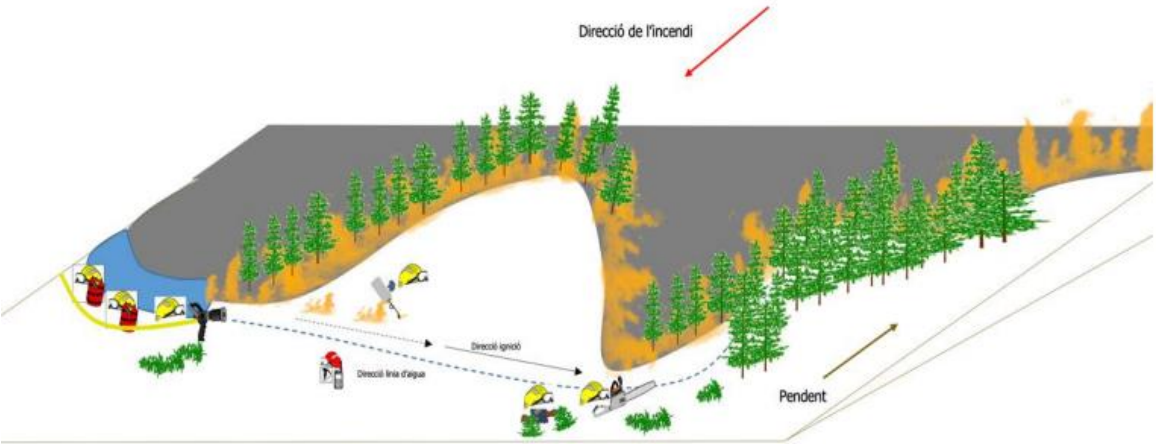


Figure 6. Scheme of defining the perimeter between a water line, a box opening team, and a burning team in order to trace a shorter and faster extinguishing and finishing perimeter. (translation: Direcció del vent: wind direction, Pendent: slope, Direcció d'ignició: ignition direction). Source: Bombers (CFRS) 2020 Guia operativa: Maniobres amb Foc tècnic 1 https://interior.gencat.cat/web/.content/home/030_arees_dactuacio/bombers/foc_forestal/publicacions_tecniques_i_normativa/guies_tecniques/operacions_i_maniobres/2020_maniobres-foc-tecnic_GUI.INVE.002_v1.pdf

b) New tactical objectives, related to the idea of management of the wildfire, could be implemented such as:

a. Creating wide burnt buffers that will ensure the confinement strategies to achieve specific resolution scenario.

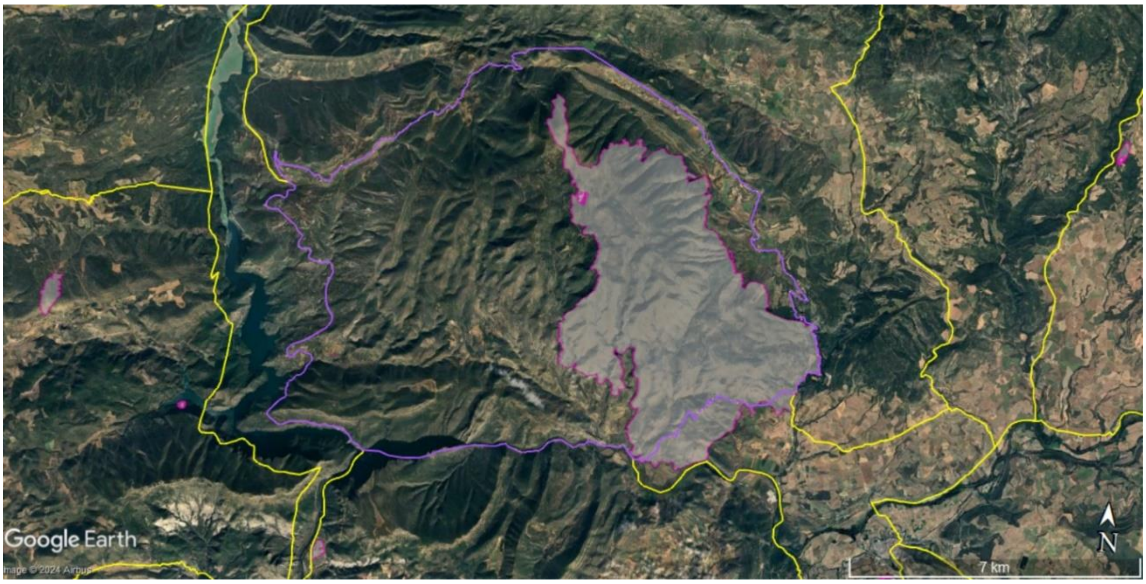


Figure 7. Preplanned confinement polygons (5.000 ha approx.) at Catalonia level, detailed area of Baldomar. Source: CFRS

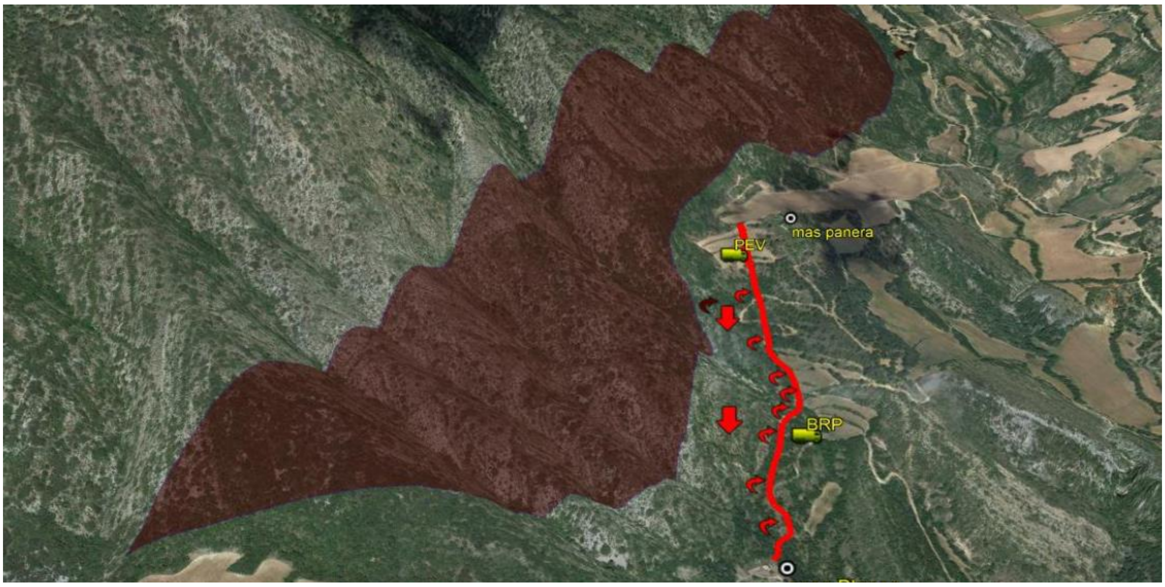


Figure 8. Proposal Sketch for an implementation of the use of technical fire to ensure the confinement of the fire line within the limits of the scenario resolution. On the stablished contention line formed by road, fields, and trails fire is used to improve the effectiveness in the weakest points. Source: Manoeuvre diagram used in 2022 Baldomar fire, Bombers (CFRS) internal use (unpublished).

Figure 9. Use of technical fire to achieve confinement objectives in Baldomar fire 2022. Source: CFRS.

b. Implement energy released lamination strategies, to prevent critical amounts of energy released, burning some areas in advance within the resolution scenario desiderated.

Figure 10. Technical fire implemented in Odena 2015 fire with the objective to widen the confinement effect of the existent road. Source: Odena Fire information report. Bombers (CFRS) 2015, available at: https://interior.gencat.cat/web/.content/home/030_arees_dactuacio/bombers/foc_forestal/consulta_incendis_forestals/informes_incendis_forestals/2010-2019/2015/20150726_I_REMS_Odena_ENGLISH.pdf

c. Diverting the fire's trajectory to keep it away from specific areas. This technique, achievable only through technical fire usage, alters the fire's behavior. An example is the 2021 Santa Coloma de Queralt case, where a backburn was conducted to divert the fire's head. (Sources: Video on the Firefighters' YouTube channel (https://www.youtube.com/watch?v=ycNARCi6sUw at 3:53 min).

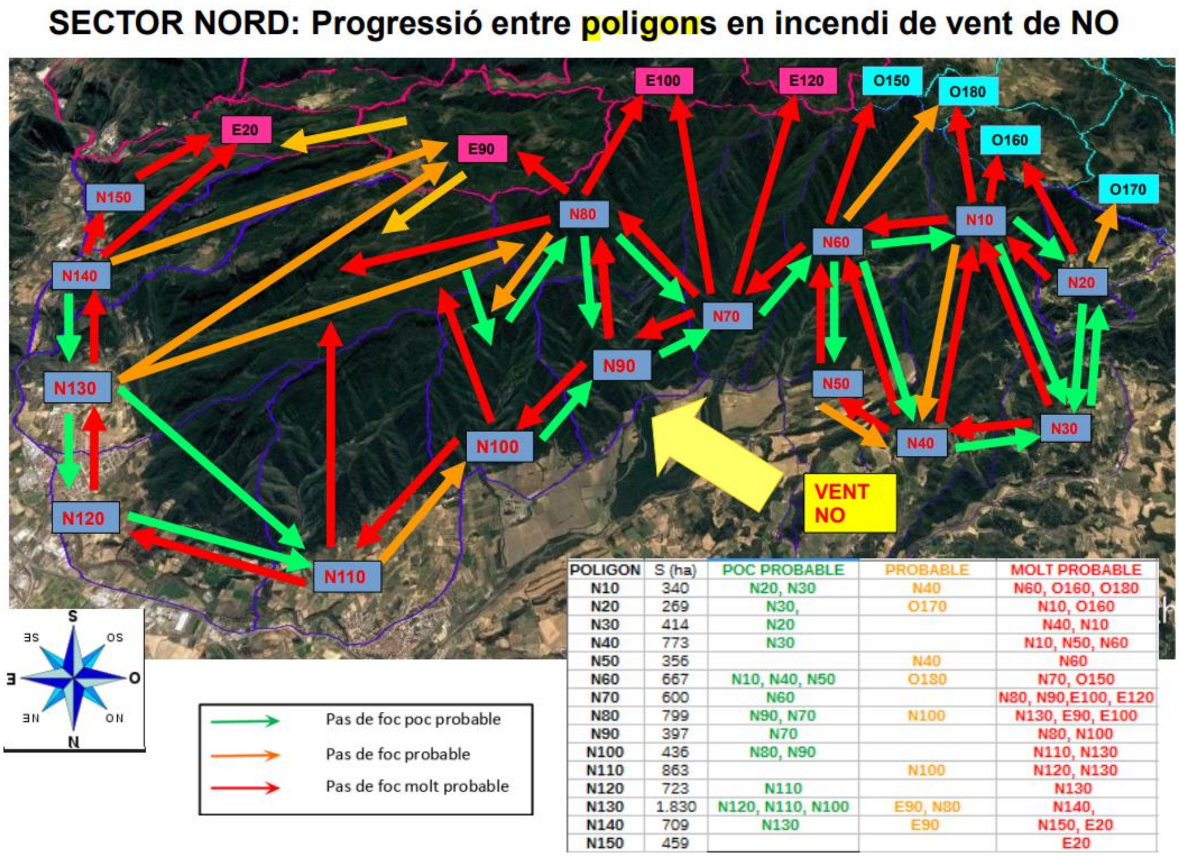
Figure 11. Technical use of fire to modify fire spread direction. Source: Bombers (CFRS) 2020. Sta Coloma de Queralt 2020 Fire report in English: https://interior.gencat.cat/web/.content/home/030_arees_dactuacio/bombers/foc_forestal/consulta_incendis_forestals/informes_incendis_forestals/2020-2029/2021/20210724_I_RET_Santa_Coloma_de_Queralt_ENGLISH.pdf

Experiences in wildfire suppression planning (A 3.3)

Fire suppression opportunities identification (A 3.3.1)

Wildfire suppression planning is a process of developing strategies, actions, and resources to effectively prevent, mitigate, respond to, and recover from wildfires. It involves the coordination of various stakeholders, such as fire agencies, land managers, communities, and government authorities, to create comprehensive plans that address the complexities of wildfire management in a specific area.

During the planning process there are different aspects regarding uncertainties and hypothesis of work (Arilla, E. 2023). Some of these uncertainties could be managed in advance, on a prevention phase. Specifically, the suppression opportunities identified during the prevention planning, could be managed to reduce uncertainties regarding their use on a future wildfire, and make them safer, efficient, and more useful.



POLIGON	S (ha)	POC PROBABLE	PROBABLE	MOLT PROBABLE
N10	340	N20, N30	N40	N60, O160, O180
N20	269	N30,	O170	N10, O160
N30	414	N20		N40, N10
N40	773	N30		N10, N50, N60
N50	356		N40	N60
N60	667	N10, N40, N50	O180	N70, O150
N70	600	N60		N80, N90,E100, E120
N80	799	N90, N70	N100	N130, E90, E100
N90	397	N70		N80, N100
N100	436	N80, N90		N110, N130
N110	863		N100	N120, N130
N120	723	N110		N130
N130	1.830	N120, N110, N100	E90, N80	N140,
N140	709	N130	E90	N150, E20
N150	459			E20

Figure 12. Polygons analysis, for the north-west wind's situation in Pandols I Cavalls Fire Prevention Plan. Example of fire suppression planning opportunities process, where once the opportunities are identified through the Potential polygons analysis (Arilla et al 2023), some measures could be implemented to improve the effectiveness of the tactics planned on the opportunity identified. Source: Project of strategic and basic infrastructures for the prevention of forest fires of the Priority Protection Perimeter (PPP) T3 Massif of the Mountains of Prades-Poblet Forest. Agresta- DAAC 2017. https://gencat.cat/agricultura/normativa/informacio_publica/pla-projecte-infraestructures-estrategiques-prevencio-incendis-massis-muntanyes-prades/projecte-infraestructures-estrategiques-basiques-prevencio-incendis-forestals-ppp-t3-massis-muntanyes-prades-bosc-poblet.pdf

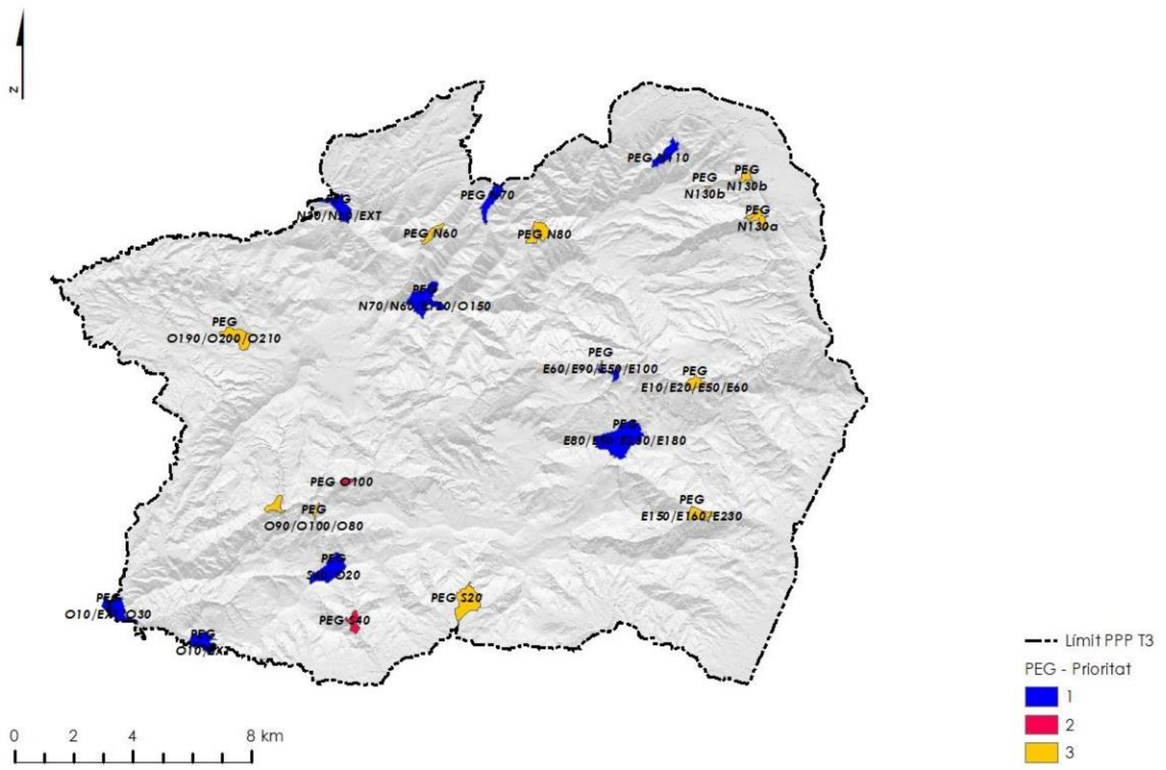


Figure 13. Strategic Management Points (PEG). Example of fire suppression planning opportunities process, where once the opportunities are identified through the Potential polygons analysis (Arilla et al 2023), some measures could be implemented to improve the effectiveness of the tactics planned on the opportunity identified. Source: Project of strategic and basic infrastructures for the prevention of forest fires of the Priority Protection Perimeter (PPP) T3 Massif of the Mountains of Prades-Poblet Forest. Agresta- DAAC 2017.

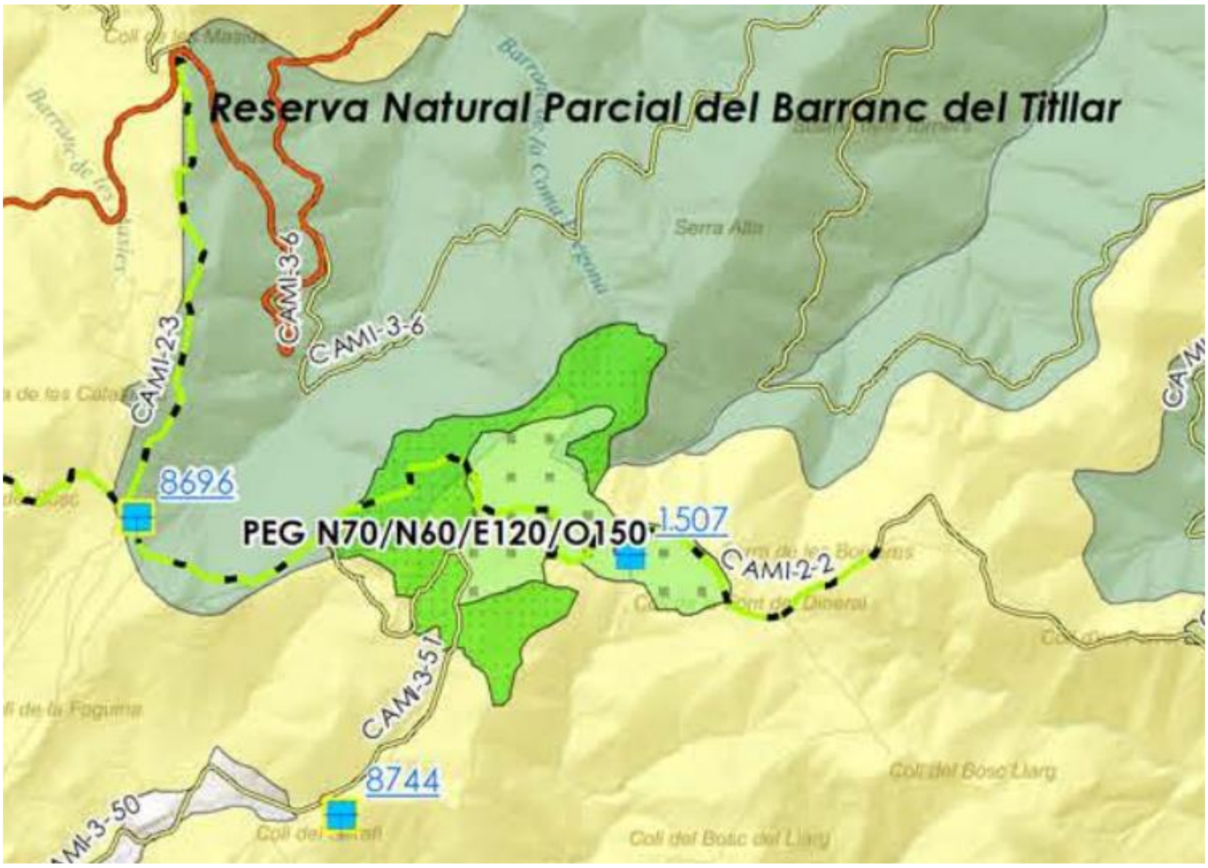


Figure 14. Example of different infrastructures implementation of a strategic management point (PEG) In Pandols and Cavalls Fire Prevention Plan. Source: Project of strategic and basic infrastructures for the prevention of forest fires of the Priority Protection Perimeter (PPP) T3 Massif of the Mountains of Prades-Poblet Forest. Agresta- DAAC 2017.

Silvopastoralism as a sustainable tool to reduce fuel load (A 3.3.2)

Experiences in Sardinia

Franca, Antonello; Monagheddu, Arianna

In the framework of WP1 IA1.4 of the FIRE-RES project, the CNR begun two demonstration fields in spring 2023, in two different silvopastoral contexts; one is a firebreak with goat grazing field and the other is prevention grazing field; both fields are located into the forest area of Mount Grighine, located in the province of Oristano between territories of Ruinas, Villaurbana and Siamanna in Sardinia, Italy (Figure 1 and 2).

Figure 15. Geographical references of Mount Grighine

1) Firebreak managed with goat grazing

The main objective of this demonstration field is to study the effect of goat grazing on fire prevention. On detail, the effect of goat grazing on the reduction of fuel biomass will be evaluated, comparing grazed vs ungrazed plots. Also, a different agronomic management of the understorey permanent grasslands (silvopasture) will be tested: the productivity of natural grassland vs. a semi-natural grassland, the latter characterized by the oversowing of an adapted pasture mixture, will be evaluated, both on wooded areas subjected to shrub clearing and at different intensity of clearing and shading, and on an open firebreak, cleared mechanically with the complete removal of the plant coverage. Furthermore, the effect of mineral fertilization on silvopasture productivity (natural or sown) will be tested in different sub-areas.

Figure 16. Geographical references of firebreak managed with goat grazing

Experimental test description

We divided the experimental field (about 4 ha of total surface) in two macro-areas: i) a wooded area, approximately a strip 30 m wide and 1200 m long and ii) an open firebreak (adjacent to the wooded area), approximately 20 m wide and 1200 m long. The wooded strip, different forestry and agronomic interventions were carried out on 12 experimental plots, each 30 m wide and 100 m long, in order to define 4 experimental treatments at different tree densities due to the application of different techniques of shrub clearing and/or tree thinning. Within each plot in the wooded strip and subjected to brush clearing and deforestation practices, a central strip 20 m wide was sown for the entire length of the plot itself (50 mt), while the two 5 m strips on the sides of the central strip sown, will be used for natural grassing. Similarly, in the open firebreak area deprived of vegetation, a 10 m strip adjacent to the wooded area was sown along the entire length of 1200 mt, while the remaining 10 m wide strip was used as natural grass. We will study the effect of goat grazing managing the grazing by using electrical fences for performing controlled rotational grazing, in order to compare ungrazed areas with grazed areas. The flock is made up of around 80 Sardinian goats. The stocking rate and the grazing will be conducted in conjunction with the shepherd. Inside the ungrazed plot we will identify two or three virtual sample areas for vegetation analysis (Casals et al., 2021). The method that will be used for the vegetation analysis will be implemented by a “L” shape transect of 10 m x 10 m into a field area of 20 m x 20 m. The main goal of this method is to describe the type of vegetation, by first visual analysis, and then characterize the plants’ details by analyzing physical characteristic like crown diameter, height, etc. At the end, we can improve the results by carrying out the floristic analysis to determinate both quantity and quality of biomass among grazed biomass and ungrazed biomass.

Treatments

Experimental plots are divided in 4 treatments, concerning different vegetation densities:

- Low density, "F-", (Figure 4) sparse trees, with tree thinning and shrub clearing carried out exclusively by mechanical vehicle (backhoe loader), and tree removal carried out mechanically (plots 2 and 3)
- Medium density, "F+", medium dense area with mechanical bush clearing using an excavator (and manual trimming by operators with chainsaws), manual deforestation by operators using chainsaws, and mechanical deforestation (plots P10 and P11).
- Greater density, "F++", thicker areas, with tree thinning and shrub clearing carried out through exclusive manual intervention by operators on the ground (with chainsaws), and tree removal carried out mechanically (plots P9 and P12);
- Control "F100" (Figure 5) treatment with maximum density, fully wooded areas (with not agronomic practices). Among the 6 parcels present (P1, P4, P5, P6, P7 and P8), having double dimensions compared to the previous ones (100x30 m each), only 4 parcels will be considered in the experimentation: P5, P6, P7 and P8.

Agronomic interventions

The main treatments are fertilization and sowing, in 4 different treatments (F-, F+, F++, F100) of the wooded strip and open firebreak. Both interventions were carried out on 1st February 2024.

Broadcast fertilization (by fertilizer spreader trolley) was carried out with simple superphosphate (19% P2O5) with a dose of 200kg /ha:

- 5 m wide strip along the sown firebreak, adjacent to the wooded area (Figure 19)
- 5 m wide strip into the cleared wooded area, adjacent to the open firebreak
- 10 m strip in the sown area of the plots subject to brush clearing and deforestation.

Figure 17. Clearing density in F- plot

Figure 18. Access point in F100 plot

Figure 19. Fertilization into open firebreak 5 m wide strip

Different soil treatments were made before sowing in the wooded plots and in the open firebreak. In the wooded plots, manual raking was carried out, necessary for the removal of branches and litter left on the ground after the shrub clearing operations. Subsequently, manual broadcast sowing of the seed mix was carried out (dose 50 kg/ha) (Figure 20).

Along the open firebreak, tillering was carried out before the sowing (seed mix) using tractor + fertilizer spreader (dose 35 Kg/ha) (Figure 21).

Figure 20. Manual sowing into the wooded plots.

Figure 21. Mechanical sowing into open firebreak

The seed mix was composed by:

- 27.5% *Medicago polymorpha* L. var Pratobello
- 12.5% *Trifolium resupinatum* L. var Nitroplus
- 15% *Trifolium subterraneum* L. var Campeda
- 20% *Cichorium intybus* L. var Spadona
- 7% *Lolium rigidum* Gaudin var Nurra
- 18% *Lolium multiflorum* Lam.

The seed mix (Figure 22) was identified following the outcomes of the Eranet Med Project LIVINGAGRO, which tested a similar mix for grazed woody areas with sub-acid soils.

Figure 22. Seed mix.

2) Prevention grazing field

Not far away from the first one mentioned, between the western side of Grighine Mount and the village of Villaurbana (Figure 23), there is another demonstration field, approximately 16 ha (). The field is a buffer area around the protected forest, where the fuel biomass is conventionally controlled by sheep and cattle grazing. The main objective is to study the effect of cattle and sheep grazing on the fuel biomass control, by observing the vegetation composition and, specifically, the shrub encroachment on grazed and ungrazed conditions. Vegetation's composition will be analyzed through transects, following Casals et al. (2021) in grazing area and ungrazed area, thanks to positioning of exclusion cages.

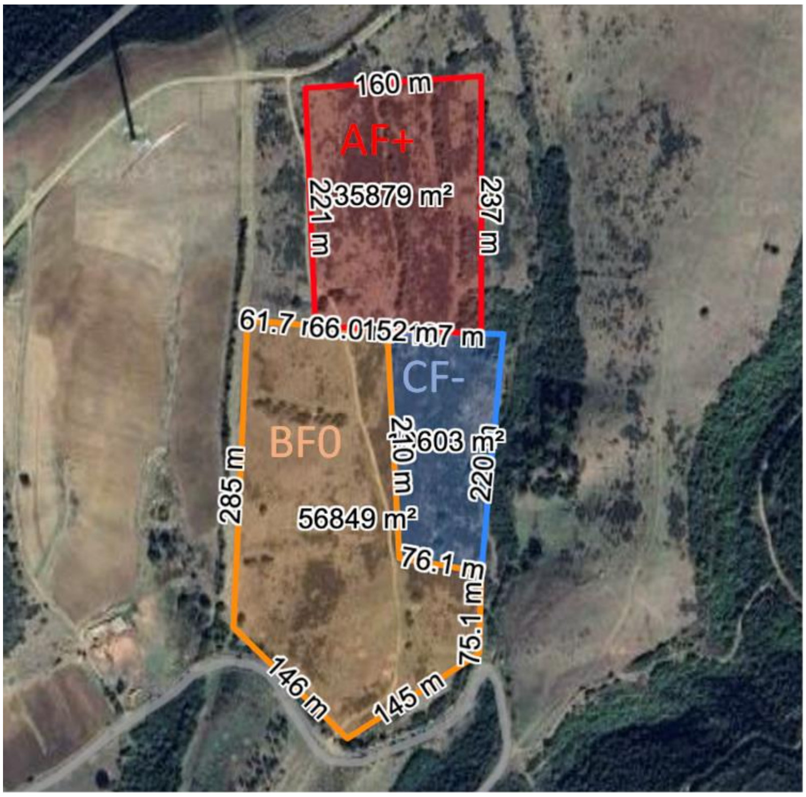


Figure 23. Geographical references of prevention grazing field and the subdivisions in the three plots.

Experimental test description

The entire demonstration field will be divided into 3 large plots (Figure 12), each one with a different level of shrub clearing. In each single plot exclusion cages will be placed of 6 m x 6 m dimension. The 3 plots are named A, B and C, and they have different types of vegetation. We can divide them in relation to the level of vegetation clearing that has been carried out on them. We can indicate with:

- Plot AF+ (red): not vegetation clearing (high shrub density)
- Plot CF- (blu): mechanical shrub clearing (low shrub density)
- Plot BF0 (orange): not shrub clearing, plot with a natural low shrub density

REFERENCES

Casals, Pere; Tarragó, Albert; Taull, Marc. 2021. Guía técnica para la caracterización en campo de formaciones arbustivas. Proyecto MatoSeg. Centre de Ciència i Tecnologia Forestal de Catalunya. Solsona.

Experiences in Catalonia

Taüll Marc; Gallego Mar; Casals Pere (CTFC)

*Nebot Edgar, *** (CFRS)*

The purpose of this experience is to demonstrate the contribution of grazing combined with the use of fire in the maintenance of open areas with low fuel load and high value for the conservation of biodiversity. As an innovative experience, the use of virtual fence collars stands out, allowing animals to be kept within an area without the need to install physical wire fences. This is especially relevant in areas with shallow soil depth or where fencing can harm wildlife.

The experience is in the Montgrí massif, located in the NE of the Iberian Peninsula. The area corresponds to a strategic area for fire prevention. It is a flat area, with thin and clay soils, largely the result of a fire that occurred in 2001 and currently dominated by a Mediterranean garrigue with scattered pine trees. The area has a high value for diversity, being the habitat of very rare moss species and a hunting area for threatened raptor species.

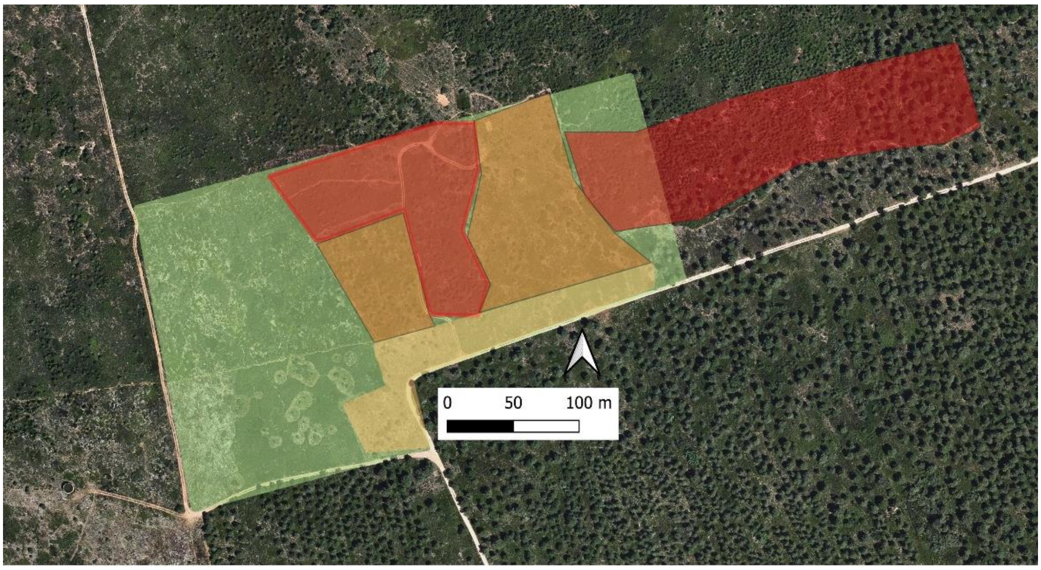


Figure 24. Planned grazing in mechanical or prescribed burning managed stands in Montgrí. The areas burned in 2022 and 2024 are shown in orange and red respectively. In green, the ca 7.5 ha grazed by Albera cows.

The experience consists in implementing prescribed grazing for one month and a half in 7.5 ha. The area has been partially treated by prescribed fires at the end of winter in 2022 or 2024 (Figure A3.2). To reduce implementation cost and ease the movement of animals from one stand to other, we defined a virtual fence in the area to be grazed. The animals have a GPS on their collars that notifies them when they are reaching to the edge of the grazing area (Figure 25). The warning consists of 4 beeps of increasing intensity before carrying out an electric discharge at the edge of the fence.

Figure 25. Albera cow with a virtual fence collar grazing in the recently burned area in Montgrí.

4.3.2. Experiences in fire as ecological process (A 3.4)

Prescribed burnings (A 3.4.1)

Experiences in Portugal

In Portugal, on 19/03/2024, in the Trevim area (Cume do Trevim), on the ridge and border between the districts of Coimbra and Leiria, more specifically in Baldios Penedos de Góis, adjacent to the area of Câmara de Góis (Mata da Oitava), 20 hectares of the Natura 2000 network were managed with prescribed burning (Figure 26).

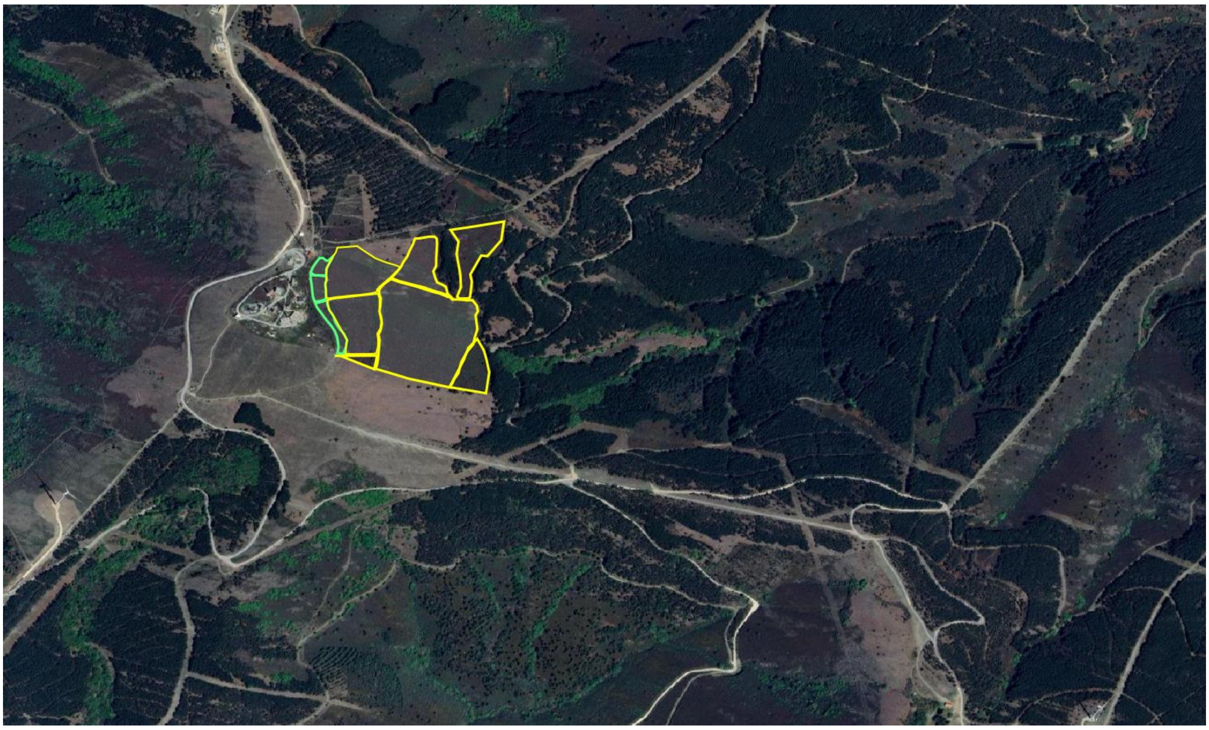


Figure 26. Location of the prescribed burns carried out in Portugal.

The burns carried out had several objectives:

- Protect the strategic points of communication antennas and buildings located on the ridge at the highest points of the Serra da Lousã, covering an area on the border between the districts of Leiria and Coimbra.
- Protect the forest areas included in the Natura 2000 network, by protecting the areas managed by Baldios de Vilarinho (Coimbra - Lousã), taking into account the priority areas included in the Natura 2000 network.
- Contribution to forestry management in a strategic area, with a reduction in the fuel load, i.e. a reduction in the shrub load available for burning, thereby reducing the intensity of a possible wildfire, minimizing/reducing extreme wildfire events and increasing the protection of the areas that include Casal da Silveira and Baldios do Candal, with the associated increased protection of the village of Candal and the increased resilience of the population
- Benefits for hunting, especially for the *Cervus elaphus* deer grazing area.
- Creation of the necessary conditions with firefighters and controlled fire scenarios on the ground to test sensors with inherent data collection in the " Wearable System for controlled fire testing " - IA 5.7, with the aim of improving the monitoring system of firefighters with the development of body-worn devices (data of physiological and environmental factors) and vehicles (data of environmental aspects) in real time in a digital interface (INESCTEC).
- Knowledge and training of firefighters from different fire brigades in the region, volunteer firefighters, municipal firefighters, Special Civil Protection Force, improving

knowledge of the territory used for prevention, which will facilitate action in the event of a wildfire.

Managed wildfire (A 3.4.3)

The Strategic Plan for the Sustainable Management of the Fire Regime in Val d'Aran (Conselh Generau d'Aran (2022)), and the experience of the Canejan 2023 fire are examples of an approach that as a main characteristic integrates the concept of Environmental Fire Flow which serves to establish where, when, and how, we can manage fires and perform prescribed burns to maximize the benefits of prescribed fire and minimize the impacts of fires at the level of the entire Aran community.

The fire in Canejan on March 16th, 2023, occurred in an area compatible with multifunctional landscape management with prescribed fire as part of the Strategic Plan for the Sustainable Management of the Fire Regime in Val d'Aran (Plan Estrategic de Gestion Sostenibla deth Regim de Huec ena Val d'Aran, https://tauler.seu.cat/pagDetall.do?idEdicte=354679&idens=8103980001).

The Strategic Plan for the Sustainable Management of the Fire Regime in Val d'Aran is not just a controlled burning program. It's a proactive framework that integrates fire management (or fire use) as a tool for multifunctional forest management at a landscape scale. This approach allows emergency management organizations to handle low- to medium-intensity fires in pre-identified, pre-designed, and formally approved areas. It's crucial to understand that the decision to allow the fire to reach clear containment lines, also known as 'fire grazing,' is not spontaneous but the result of strategic planning and consensus; it's emergency pre-planning in action.

The fire was managed according to the strategic plan and finally affected 327 ha. For more information the official report could be consulted: https://interior.gencat.cat/web/.content/home/030_arees_dactuacio/bombers/foc_forestal/consulta_incendis_forestals/informes_incendis_forestals/2020-2029/2023/20230316_VA_Canejan_informe.pdf .

4.4. Database of well documented prescribed fire studies (A4)

4.4.1. Information collected until 11/04/2024 (A 4.1)

After two weeks of disseminating the platform link among the researchers, the data collected up to 11/04/2024 includes information from a total of 21 sites located exclusively in Spain, most of them in Catalonia (Figure 27). A total of 46 prescribed burns were carried out at all sites, most of them in spring. *P. nigra* is the predominant tree species, occurring at 10 of the 21 sites, followed by 6 sites with *P. halepensis.*

Figure 27. Geographic position of well-documented prescribed burning sites gathered by 11/04/2024.

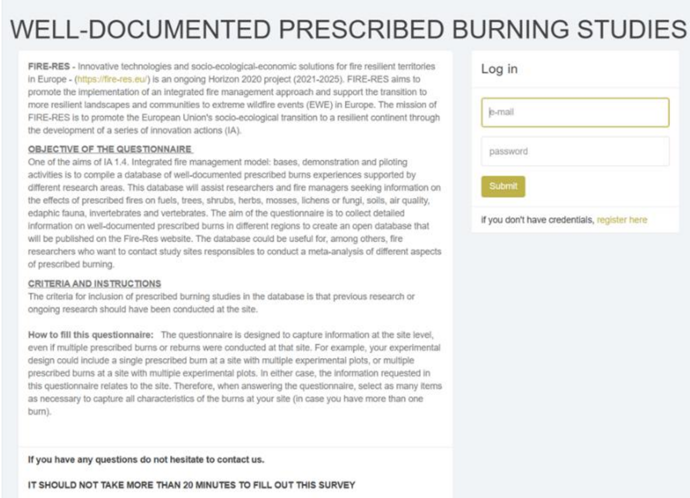
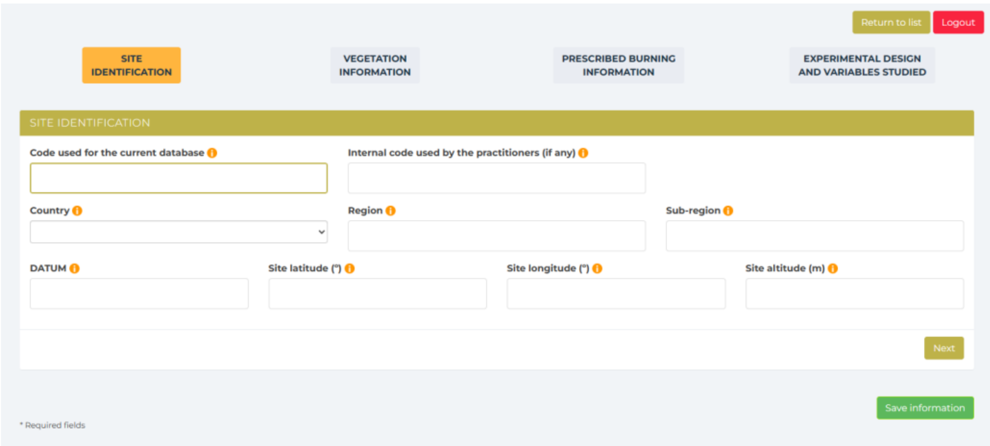
Variables analyzed at tree level include mortality, growth, defenses, interaction with drought, physiological processes and, at shrub level, resprouting ability, resprouting vigor, growth, composition, cover/height and, at herb level, forage quality and weed dynamics. At the soil level: organic matter content/dynamics, microbial biomass, functional diversity.

Fire behavior variables have been measured in most studies, including residence time, combustion time (flame and smoldering fire duration), flame angle, flame height, rate of spread and fuel depth. Fire severity variables assessed include crown scorch height, crown volume scorched, bark char code, visual assessment of soil organic matter, remaining twig diameter of shrub individuals, ash deposition and color, fuel consumption, fuel depth, crown scorch height, crown volume scorched, bole height scorched and tree mortality.

4.4.2. Description of the platform (A. 4.2)

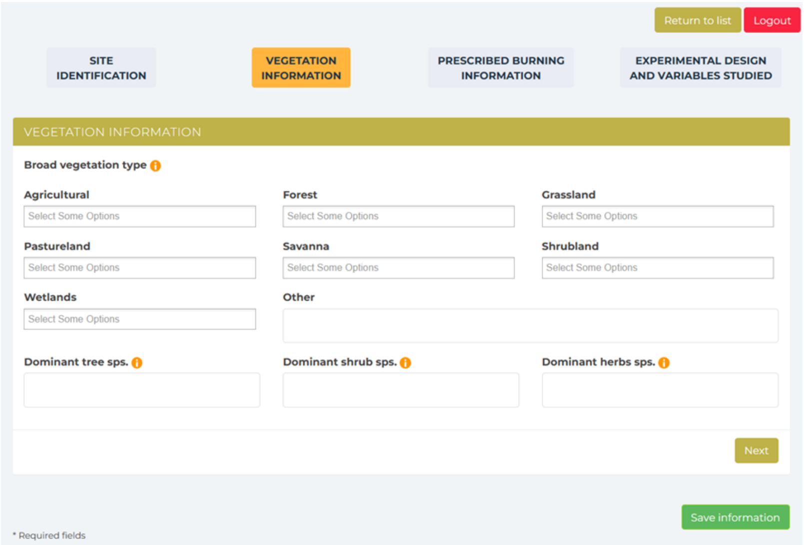
The platform aims to collect well-documented prescribed burns experiences supported by various research areas to create a database that will be publicly available in the Fire-Res website. The different sections of the platform are described below.

Section 1: Contact information

Description: users must create a unique username and password that allows them to securely access the system and save the information entered.

Section 2: Site identification
Description: Here, specific codes used to identify the site within the current database, along with any internal codes utilized by practitioners for reference. Geographic details such as country, region, sub-region, and specific coordinates (latitude, longitude, altitude) of the site are captured in this section.


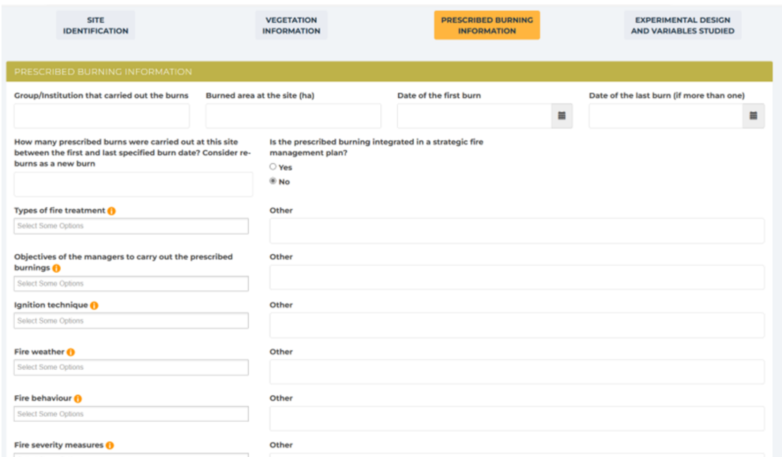
Section 3: Vegetation information

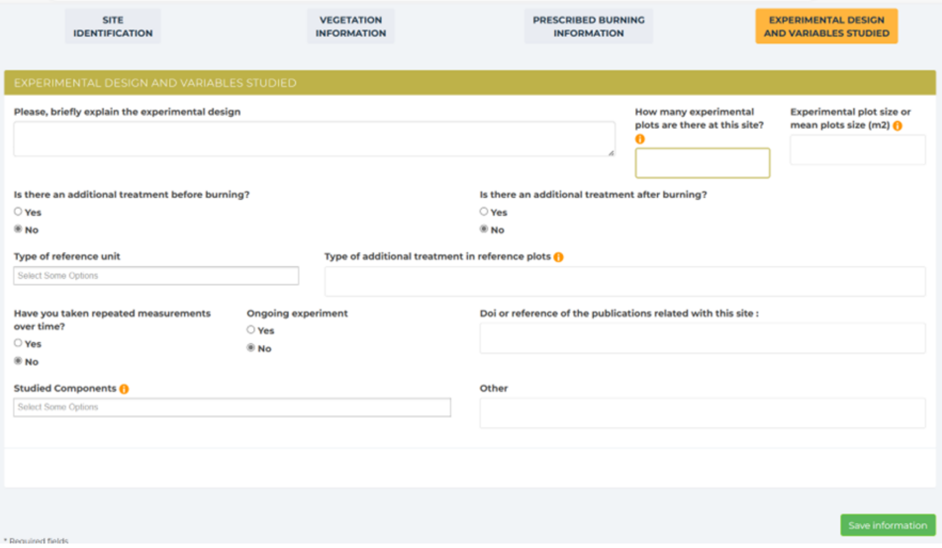
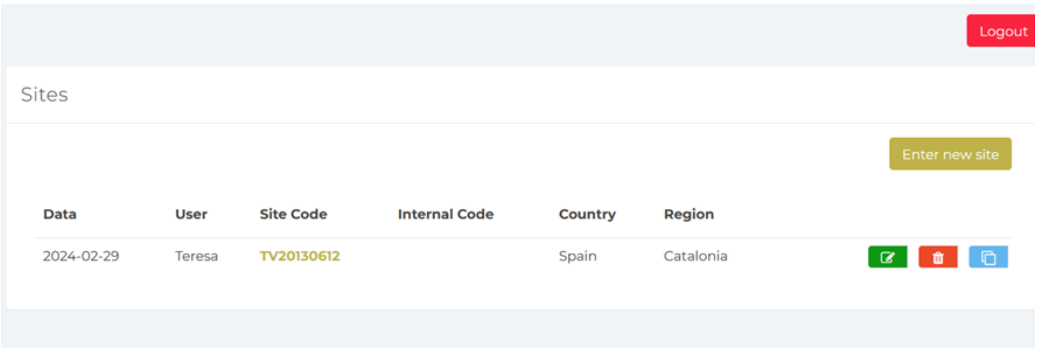
Description: This part requires information about the vegetation type present at the site, including dominant tree species, shrub species, and herbaceous species



Section 4: Prescribed burning information

Description: Details related to prescribed burning activities are recorded here, including the institution conducting the burns, burned area, dates of burn events, integration of burning in fire management plans, types of fire treatments, objectives of the burns, ignition techniques, fire weather conditions, fire behavior, and measures of fire severity.



Section 5: Experimental design and variables studied
Description: This section addresses the experimental design used at the site, including the number and size of experimental plots, any additional treatments applied before or after burning, the type of reference unit used, and whether repeated measurements were made over time. In addition, information on ongoing experiments and references to relevant publications are sought. Finally, the different components and variables studied are catalogued, ranging from fuels and vegetation to soil properties, microbiology, fauna, air quality and other relevant factors.

NOTE: After completing the questionnaire for one site, users can copy the values to another and make the necessary adjustments, significantly speeding up data entry.


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