FIREURISK - DEVELOPING A HOLISTIC, RISK-WISE STRATEGY FOR EUROPEAN WILDFIRE MANAGEMENT

Grant Agreement Number: 101003890 **Call identifier:** H2020-LC-CLA-2018-2019-2020	
Topic:	LC-CLA-15-2020 Forest Fires risk reduction: towards an integrated fire management approach in the E.U.
Instrument:	RIA

D2.2 – Report on training sessions for agricultural uses of prescribed burnings

Deliverable Identifier:	D2.2
Deliverable Due Date:	31/03/2024
Deliverable Submission Date:	10/04/2024
Deliverable Version:	v.1.0
Lead partner:	CNR
Authors:	Bachisio Arca, Michele Salis, Grazia Pellizzaro, Valentina Bacciu, Liliana Del Giudice, Carla Scarpa, Andrea Ventura, Pierpaolo Duce, Romain Matile, Sebastien Lahaye
Work Package:	WP2 - Risk reduction to improve protection
Task:	Task 2.1 - Reduce probability and potential of ignitions
Dissemination Level:	☒PU: Public ☐ CO: Confidential, only for members of the Consortium (including the Commission Services)

Revision History

Version	Date	Edited by	Description
v.0.1	25/11/2023	CNR	Document content outline
v.0.2	13/11/2023	CNR	First Draft Version
v.0.3	26/01/2024	CNR & SAFE	First Version of D22
v.0.4	27/03/2024	CNR & SAFE	Revised Version of D22
v.1.0	10/04/2024	CNR & SAFE	Final version submitted

Quality Control

Type	Date	Reviewed by	Approved/Comment
Internal/Peer/External	02/02/2024	Luis Mario Ribeiro	Comments
Internal/Peer/External	12/02/2024	Juan Ramon Molina	Comments
Internal/Peer/External	12/02/2024	Juli G. Pausas	Comments
Internal/Peer/External	05/04/2024	Vasileios Kazoukas	Approved
Internal/Peer/External	05/04/2024	Juli G. Pausas	Approved

Executive Summary

This Deliverable describes the experiences conducted in two FirEUrisk Project Demonstration Areas, namely Sardinia (Italy) and the French Alps, related to the design, management and evaluation of training sessions on the use of prescribed burning; the document derives from the activities carried out under Task 2.1 of FirEUrisk Project (A2.1.1, Reducing citizen-driven fire ignitions).

Prescribed fire interventions have a potential impact on agro-pastoral activities, as they promote better management of the grazing lands, but they have also a direct impact on the prevention of severe and extreme wildfires, which would be limited by conducting prescribed burning under moderate conditions. Training interventions are aimed at farmers themselves (French Alps), or as in Sardinia, allow to improve the training of personnel in various roles involved in wildfire prevention and management (Forest service, Volunteers, Forestry agencies).

Overall, prescribed burning in fire-prone areas can contribute to manage flammable vegetation types, to reduce wildfire hazard, and to maintain cultural landscapes. A number of studies evidenced that prescribed fires have limited effects on soils and biodiversity, while wildfires are in several cases very damaging. However, the adoption of prescribed burning in the Euro-Mediterranean region is mostly confined to limited areas and extent. In the light of promoting the spectrum of wildfire management practices, the expansion of manager and farmer ability and awareness on the use of prescribed burning is crucial for the whole Southern Europe.

The paper is structured into four main chapters. A general introduction summarizes the state of the art of prescribed fires and the current legislation in France and Italy, with the aim to identify the regulatory frameworks for a wider adoption of this practice. Next, the experimental training carried out in both Demonstration Areas are presented, listing the main rules for their organization as well as the assessment of the landscape and environmental conditions required to identify the implementation windows.

Finally, some considerations are made, with an assessment of the impact of these activities and the potential benefits that could be obtained from a more regular adoption of prescribed burnings, both in terms of increased autonomy of farmers in conducting interventions, and better preparation of the agencies in charge of wildfire prevention, but also of fire-fighting and mop-up activities; further advantages of training activities consist in the adoption of a single standard for the execution of interventions, and thus of a better cooperation among the agencies in charge of land management.

Disclaimer

The content of the publication herein is the sole responsibility of the publishers and it does not necessarily represent the views expressed by the European Commission or its services.

While the information contained in the documents is believed to be accurate, the authors(s) or any other participant in the FirEUrisk consortium make no warranty of any kind with regard to this material including, but not limited to the implied warranties of merchantability and fitness for a particular purpose.

Neither the FirEUrisk Consortium nor any of its members, their officers, employees or agents shall be responsible or liable in negligence or otherwise howsoever in respect of any inaccuracy or omission herein.

Without derogating from the generality of the foregoing neither the FirEUrisk Consortium nor any of its members, their officers, employees or agents shall be liable for any direct or indirect or consequential loss or damage caused by or arising from any information advice or inaccuracy or omission herein.

Copyright message

© FirEUrisk Consortium, 2021-2025. This deliverable contains original unpublished work except where clearly indicated otherwise. Acknowledgement of previously published material and of the work of others has been made through appropriate citation, quotation or both. Reproduction is authorised provided the source is acknowledged.

Table of Contents

Revision History 2
Quality Control 2
1 Introduction 11
1.1 State of the art 11
1.2 The use of fire as tool for wildfire prevention and links to agro-pastoral activities 12
1.3 The use of prescribed burnings for fire prevention in southern Europe 13
1.4 Current legislation in Italy and France regarding the use of prescribed fires for preventive purposes 15
1.4.1 Italy 15
1.4.2 France 17
1.4.2.1 A legal framework for any use of fire: pastoral burning and prescribed burning 17
1.4.2.2 Burning methods regulated at departmental level 18
1.4.2.3 Training courses for institutional staff and team organization 19
1.4.2.4 Organization of departmental prescribed burning units 20
1.4.2.5 New perspectives to come 21
2 Experimental Trainings in Italy 22
2.1 Local Context 22
2.2 Course Description and Purposes 23
2.2.1 Municipality of Suni 23
2.2.1.1 The prescribed burning plan 23
2.2.1.2 Field activities 27
2.2.1.3 Classroom training 30
2.2.2 Municipality of Alghero 31
2.2.2.1 The prescribed burning plan 31
2.2.2.2 Field activities 32
2.2.3 Prescribed burning activities in other sites 34
2.3 Final Considerations 35
3 Experimental Trainings in France 37
3.1 Local Context 37
3.2 Course description and purposes 38
3.2.1 Explanation of the training process: 38
3.2.1.1 Description of the course 39
3.2.2 Instructions and checklists to help farmers manage pastoral burnings 44
3.2.2.1 Site planning 44
3.2.2.2 Site preparation 45
3.2.2.3 Organization of controlled burning 45
3.3 Final Considerations 46

4 Conclusions 49
5 References 51

List of Figures

Figure 1: Localization of the prescribed burning units in France. 21
Figure 2: Localization of the prescribed burning units in Sardinia. 23
Figure 3: Pastures and wooded pastures. 25
Figure 4: Pastures with a prevalent shrub component. 25
Figure 5: Map of the areas treated by prescribed fires in 2023, near the Municipality of Suni (100 ha treated, September-October 2023)....28
Figure 6: Preliminary meeting before the 28
Figure 7: Discussion of the examples and case studies. 28
Figure 8: Methods to charge and use the drip torches. 29
Figure 9: Training on the use of blowers-sprayers. 29
Figure 10: Description of the tools installed in a pick-up vehicle. 29
Figure 11: Medium and heavy tanker modules. 29
Figure 12: Use of fire in pastures infested by Carlina spp. 30
Figure 13: Use of fire in pastures with presence of Rubus. 30
Figure 14: Setup of an anchor line using fire. 30
Figure 15: First phases of the prescribed burning (linear ignitions). 30
Figure 16: Parallel fire lines intervention. 30
Figure 17: Controlling flames using blowers-sprayers. 30
Figure 18: Classroom training activities: safety rules. 31
Figure 19: Classroom training activities. 31
Figure 20: Map of the parcels treated in Surigheddu. Each square plot has 1 ha size. 32
Figure 21: Illustration of the plan. 33
Figure 22: Explanation of the main rules to implement the interventions. 33
Figure 23: Composition of the intervention team. 33
Figure 24: Use of the sprayer to control the anchor line. 33
Figure 25: Visible image by drone during a backfire training. 33
Figure 26: Infrared image by drone during the training. 33
Figure 27: Samples for estimating dead and live fuel load and moisture. 34
Figure 28: Weather data monitoring. 34
Figure 29: Fire behavior analysis by visible images. 34
Figure 30: Fire behavior analysis by infrared images. 34
Figure 31: The wildland-urban interface area of Nuoro. 35
Figure 32: The recreational urban pine forest of Nuoro. 35
Figure 33: Prescribed burnings in areas with shrubs and oaks. 35
Figure 34: Prescribed burnings in open deciduous forests. 35
Figure 35: Briefing before the burnings. 38
Figure 36: Proceeding to the test fire. 38
Figure 37: Locations of the sites where the prescribed fires were carried out. 39
Figure 38: Exercise of extinction. 41
Figure 39: Phase of burning. 41
Figure 40: Preparation of the unit with the farmers. 41
Figure 41: Burning of Genista cinerea. 42
Figure 42: Result of a burning of Genista cinerea. 42

Figure 43: A farmer leading the firing operation. 43
Figure 44: Closing a unit. 44

List of Tables

Table 1: Regional Laws specific to fire management, Forest Laws/Plans/Regulations and AIB plans dealing with prescribed burning in the 20 Italian Regions. 16
Table 2: Fuel model parameters used as reference in the Suni plan (expressed in metric units) (Scott & Burgan, 2005). 25
Table 3: Main parameters for the evaluation of the prescribed burning implementation window. 26

List of Acronyms

Table: List of Acronyms

List of Acronyms	
IP	Ignition probability
FMS	Fuel moisture content
FMD	Fuel model
BP	Burn probability
FL	Flame length
CFA	Crown fire activity
WUI	Wildland-urban interface
SDI	Suppression difficulty index
IFM	Integrated Fire Management
PF	Prescribed Fire
PB	Prescribed Burning
ICNF	Instituto da Conservação da Natureza e das Florestas
PFAR	Regional Environmental Forestry Plan
CFVA	Sardinia Forest Service
Forestas	Sardinia Forest Agency
PM10	Particulate Matter 10 micrometers or less in diameter
PRAI	Sardinia Region Wildfire Management Plan
PAI	Sardinia Region Hydrogeological Survey Plan
SIC	Site of Community Importance
LACES	Lookouts, Awareness, Communication, and Escape route and plan, Safe areas
IPE	Individual Protective Equipment
GAUF	Fire Analysis and Use Group
ONF	Office National des Forêts

1 Introduction

As part of the FirEUrisk project, the Work Package 2 specifically investigates how the different factors of wildfire risk can be lowered, considering both danger and exposure-vulnerability conditions. In particular, Task 2.1, which focuses on the reduction of both probability and potential of ignitions, includes Activity A2.1.1, in which strategies and methods devoted to limit citizen-driven fire ignitions are taken into account. Among these strategies, a significant attention was given to the design, test, and evaluation of a program of controlled fires, carried out in two Demonstration Areas (Sardinia, Italy, and French Alps, France) in agreement with the needs of local communities, and to the organization of training sessions for the application of prescribed burnings for agro-pastoral purposes in rural areas.
This Deliverable, after a brief overview about the links between the use of fire and agro-pastoral activities, and on current southern Europe legislation (with a focus on Italy and France cases in a specific section) on the use of fire as tool of fire prevention, describes the experiences carried out in both Sardinia and French Alps on the use of prescribed fires for supporting agro-pastoral activities.

1.1 State of the art

Fire is an integral part of many ecosystems around the world. For millennia, fire has played an important ecological role contributing, together with other anthropic and/or natural factors, to landscape biodiversity and characteristics (He et al 2019, McLauchlan et al 2020). Humans began to control and utilize fire over two million years ago, so that separating the human influence from the natural occurrence of fires on the landscape is difficult. For instance, Native Americans used frequent, low-intensity fires for agricultural purposes and for managing wildlife habitats and hunting areas (Pyne 1996).
Fire represented, and still represents, an intrinsic ecological process also in the Mediterranean Basin ecosystems that are often constituted by fire-prone vegetation (Pausas et al., 2008, Fernandes et al, 2013). In Euro-Mediterranean countries, fire has been used by humans as a management tool since early times. Pre-industrial fire regimes were generally characterized by low severity burning in shrublands and open woodland landscapes and were commonly associated with widespread agropastoral land uses (Seijo and Gray 2012, Fernandes et al, 2013). In that context, fire performed a significant ecological function by reducing undergrowth vegetation, allowing sunlight to reach the ground, and enriching the soil of nutrients (He et al., 2019, McLauchlan et al., 2020). However, when a fire evolves into a large wildfire and becomes uncontrollable and destructive, it can be a major disruptive agent that can cause significant losses to ecosystems, farms, human values and sometimes human lives (Chuvieco et al., 2023).
In recent decades the general trend in number of fires and surface burnt in the Euro-Mediterranean areas (Italy, France, Spain, Portugal, and Greece) has increased despite the increasing fire suppression efforts (Pausas and Vallejo, 1999; San-Miguel-Ayanz et al. 2023). From 2011 to 2020, southern Europe experienced an average of about 38,000 fire ignitions per year with an annual burned area close to 320,000 hectares (San-Miguel-Ayanz et al., 2023), even if with significant interannual variations in terms of area burned and incidence of large and destructive events (e.g.: Viegas et al. 2017; Almeida et al. 2023). The observed recent changes in fire regimes are the result of complex interrelationships between the increasing frequency and length of adverse weather conditions, agricultural decline, land abandonment processes, afforestation and poor forest management, with accumulation of flammable materials at the landscape scale (Barbati et al., 2015; Mancini et al., 2018; Salis et al.,2022; Miezïte et al., 2022). The combined effects of these factors determined a more frequent occurrence of wildfires with dimensions and behaviors that make their control extremely complicated. In addition, the growth of urban settlements and Wildland-Urban Interfaces have resulted in a further increase in wildfire risk. This fire regime alteration also entails an increasing cost related to wildfire suppression (Molina et al. 2019). It is therefore necessary for the EU society to address the challenge of adapting to altered fire

regimes that threaten ecosystem services, human well-being and properties by reviewing policy choices related to fire management in order to rebalance public expenditure for wildfire suppression and prevention activities (Moreira et al, 2011, 2020; Colonico et al. 2022)

The concept of Integrated Fire Management (IFM), or sustainable fire management, has been arising in the last decade as a management approach for adapting to and mitigating the impacts of extreme wildfires and altered fire regimes. IFM is defined as the set of actions aimed at reducing the extent and severity of extreme wildfires and mitigating the impacts of large catastrophic fire events while maintaining biodiversity, ecosystem services and human wellbeing (Fernandes, 2020). Some of these actions include different types of fuel treatments such as controlled and prescribed burning, silviculture treatments, understory reduction, and grazing. To achieve these goals, IFM needs the support of fire science, fire policy and local communities through a strong cross-sectoral and interdisciplinary collaboration between experts from different sectors and disciplines that can address ecological, economic, and social aspects of fires.

1.2 The use of fire as tool for wildfire prevention and links to agro-pastoral activities

The use of fire into agro-silvo-pastoral systems was a continuous practice that endured in Southern European countries until the mechanization of agriculture and the introduction of inorganic fertilization in the latter part of the 19th century (Oliveira and Fernandes, 2023; Meira Castro et al, 2020). In fact, the areas intended for extensive farming production in these countries were, and are often, the result of a combination of grazing, cutting of shrubs and fires (Honrado et al., 2017).

Prescribed fire differs from pastoral fire in that it represents, as better explained below, an authorized and controlled application of fire by a team of fire experts on planned surfaces. Prescribed fires are therefore applied by adopting precise prescriptions and operational procedures, to achieve specific objectives integrated into territorial planning (Bovio and Ascoli, 2012; Hiers et al., 2020).

Traditional pastoral burning involves the partial removal of standing vegetation by fire and is still practiced today with the aim of cleaning and promoting the renewal of meadows and pastures. The main beneficial effects of this practice are to control weeds and herbaceous species unpalatable to livestock, to remove woody shrubs and small trees and make way for forage plant species, and to facilitate animal access in inaccessible areas.

Controlled fires are planned in the most convenient periods when vegetation is characterized by relatively low flammability and both risk of forest fires and impacts on the soil are low. Furthermore, controlled fires are often used in almost inaccessible and non-arable areas (e.g.: steep slopes; presence of superficial rocks and stones), where the use of fire can offer advantageous cost-benefit ratios compared to other agronomic practices.

In addition to the positive effects mentioned above and mainly related to livestock breeding, the use of fire has other beneficial effects on the environment in terms of soil protection and prevention of uncontrolled and devastating wildfires. Regarding the first aspect, for instance, in Alpine ecosystems low intensity fires can reduce the risk of avalanches by burning dry grasses to create a 'slippery carpet' in winter, and can help lowering the likelihood of bank flooding by burning woody elements that can cause obstructions in watercourses. Referring to the second aspects, pastoral fires avoid accumulation of potentially flammable biomass and help create and maintain mosaic-structured landscapes that can reduce wildfire spread and intensity.

Agro-pastoral farming represents, especially in hilly and mountainous areas, an important economic activity closely linked to tourism as it contributes to defining the identity of these regions; these small farms and the surrounding mosaic landscapes are, in fact, considered picturesque places by the large number of tourists who walk the mountain or hilly paths during the summer season. Moreover, they contribute to the maintenance of a mosaic of landscapes and

biodiversity which are destined to be lost with the abandonment of the land. The abandonment of small-scale farming can dissolve the traditional landscape mosaic and can intensify the connectivity between homogeneous and extensive patches with high fuel loads caused by contemporary afforestation and rewilding and by the lack of management of shrublands and forest areas (Oliveira and Fernandes 2023; Ganteaume et al, 2013). The abandonment of pastoralism and the decline in grazed areas have also contributed to the disappearance of pastoral practices typical of marginal areas, including pastoral burning.

Although pastoral fires are fundamental in the management of the territory and for economic activities, there are however risks associated with them (possibility of escaping fires, increase in local pollution, effects on soil properties, etc.). Some studies reported a relationship between the use of fire as a tool for pasture maintenance by extensive livestock production and the frequency of wildfires (Parente et al., 2018; Casau et al., 2022). This type of use of fire, especially if conducted by inexperienced people, can constitute a negligent cause of fires. More recently, other authors suggested that the common perception of pastoral burnings as the main cause for the increase in severe summer wildfires is not supported by data (Oliveira and Fernandes, 2023): they observed that pastoral fires typically occur in winter or precede the rainy season in early autumn. Moreover, banning the use of pastoral burnings by the community does not prevent the occurrence of unauthorized fires (Coughlan, 2016): pastoral fires applied in clandestine conditions and uncontrolled can result in the spread of large wildfires under fire-prone weather.

In any case, potential negative impacts must therefore be minimized through a territorial organization that plans and supervises controlled burning, in order to maximize their positive effects. If conducted within a regulated framework and carried out by professionals and/or appropriately trained shepherds, pastoral fires can be included among the integrated fire management practices capable of responding not only to the need to reduce wildfire risk but also to a series of requirements related to the maintenance of ecosystem services.

The concept of prescribed fire or prescribed burning, as an action included within integrated fire management, fits into this scenario.

The term Prescribed Fire (PF) or Prescribed Burning (PB) refers to the planned use of fire, adopting specific prescriptions and operating procedures, to achieve precise and clearly defined objectives. This technique is characterized by the presence of legislative prescriptions, i.e. precise indications regarding season and frequency of burnings, environmental conditions in which performing the activities, and techniques to be adopted to control fire characteristics and potential behavior. These indications allow to avoid unwanted effects and can vary based on management objectives and environmental limits and conditions of a given territory. Prescribed fires are planned, designed, and applied in many geographical areas with several purposes such as prevention of forest fires in WUIs and in forested areas, management of pastoral resources, conservation of ecosystems and biodiversity, or training of firefighting personnel (Fernandes et al, 2013).

1.3 The use of prescribed burnings for fire prevention in southern Europe

The first prescribed fire experiments in southern Europe were conducted in the Mediterranean pine forests of Greece in the late 1960s (Liacos 1986). This experience remained an isolated episode until the late 1970s when a series of studies on the impacts of prescribed fires on ecosystem components began in collaboration with US researchers (Alexandrian et al., 1980; Fernandes et al., 2013). After these first common experiences in southern Europe, the use of prescribed fires followed different paths depending on the country (Fernandes et al, 2022).

Prescribed burnings appeared in France in the 1992 forestry law (Law n° 92-613 of 6 July 1992). The law allowed land management agencies to conduct prescribed burnings for wildfire prevention purposes. In 1996 and 1998, the French legislation considered prescribed fires as a formal training process, and in 2001 considered prescribed fire in its full

extent (Forest Orientation Law 2001). The law specifies that in areas where protection against wildfires is necessary, the activities to prevent wildfires (which should be carried out by the State, local Authorities and their groups or their agents such as the National Forestry Office and Departmental Fire and Rescue Services as well as authorized trade union associations) may include prescribed burnings.

In Italy, the National Forest Service, in collaboration with the Experimental Institute of Silviculture, conducted several experiments in Tuscany and Sardinia in the 1980s aimed at evaluating the potential of prescribed fires in reducing the fuel load and for maintaining the firebreaks (Calabri 1981, Buresti and Sulli 1983). Although the National Forest Service recognized the benefits of prescribed burnings and the results were promising (Calabri 1988), this activity was suspended for many years.

The interest and attention towards this technique returned at the beginning of the 21st century when several scientific, operational and training experiences, also including prescribed fires, were carried out at a regional level (Basilicata, Campania, Friuli Venezia Giulia, Piedmont, Sardinia, Tuscany). Examples of this activity are represented by the experimentations on the use of prescribed fires conducted in Sardinia in 1999 (Massaiu, 1999), and by the survey conducted on a national scale, as part of the Fire Torch project (Botelho et al., 2002), on the knowledge and perception of prescribed fires among forestry operators (Leone et al., 1999).

After 2010, there has been a renewed interest on prescribed burnings (Ascoli et al., 2012). Prescribed fire legislation is a regional responsibility (Bovio and Ascoli 2012), and the legal framework is provided in the wildfire national law (No. 353/2000). Based on that, several Regions updated their legislations by means of either fire management plans or regional laws, providing for the possibility of authorizing experiments or applications of prescribed fires also in National Parks, State and Regional Reserves (Bovio and Ascoli, 2012). To date, 70% of Italian regions regulate prescribed burnings in either a fire management plan or in a regional law (Fernandes et al., 2022), and various scientific and operational experiences have been carried out at a regional level with the collaboration of multiple entities (e.g., Universities, Research Centers, Regional Services, Park Authorities, etc.).

In Spain, the first burning plan was applied at the beginning of the 1990s, but the “prescribed burning” concept came later and became popular only at the beginning of the 21st century. Prescribed burning legislation and regulation are regional. Similarly to Italy, each region has generated a plethora of legal frameworks. Some regions (Galicia, Asturias, Castilla y León, Valencia, Andalucía) have forest laws in which the use of fire follows specific annual regulations. Other regions base their regulations on specific ordinances or decrees, for example, the Proposal Note of Law (Andalucía, 2017) declared that prescribed burning should be implemented and promoted. According to this political agreement, a technical team specialized in burning was created to train forest fire agency. Fernandes et al. (2022) highlighted that, in any case, most of these regulations are oriented to control the use of fire and rarely to promote prescribed burning programs.

The use of prescribed burning in Portugal has been regulated by dedicated legislation since 2006. Today, the Technical Fire Regulation, annexed to Order no. 7511/2014, of June 9, attributes to Instituto da Conservação da Natureza e das Florestas (ICNF) the powers to recognize prescribed fire training, accredit prescribed fire technicians, manage the national prescribed fire database and accredit operational burners. According to the same Regulation, the management of the standards governing suppression fire, as well as the accreditation of suppression fire technicians, are the responsibility of the ANEPC - National Emergency and Civil Protection Authority (https://www.icnf.pt/florestas/gfr/fogotecnico/planosfogocontrolado). Recently, in southern Europe, interesting initiatives are taking shape, such as the Prescribed Fire Training Exchanges (TREXs) (https://cilifo.eu/trex) or the Fire-Adapt project (https://www.fireadapt.eu/en/). These initiatives can provide experiential training and knowledge that builds robust local capacity for fire management and offers professional fire practitioners a more holistic perspective while implementing treatments that support community and landscape objectives.

1.4 Current legislation in Italy and France regarding the use of prescribed fires for preventive purposes

1.4.1 Italy

As reported in the previous paragraph, the application of the prescribed fire technique in Italy spread through experiences diversified by geographical areas and purposes. However, the regulatory framework that regulates the application of this technique lacks clear guidelines today, constituting in fact one of the main limitations for the development of its use (Leone et al., 1999; Lazaro and Montiel, 2010; Ascoli et al., 2012). The Italian legislation regulating prescribed fire is characterized by considerable variability with national and regional laws on forestry and forest fire prevention, regulations, prescriptions and forestry planning documents, dealing with the topic with different approaches generating marked differences among Regions.

Italy's comprehensive approach to wildfire management is mainly framed by Law 353/2000 ("Legge-quadro in materia di incendi boschivi") (updated by Law 155/2021), which also mandated Regions for planning the forecasting, prevention and firefighting activities (AIB plans). In this Law, the concept of fire is precisely defined and unequivocally distinguished from prescribed fire. This distinction is an important aspect to be regulated, to also clarify the issue from a terminological point of view (Bovio and Ascoli, 2012). However, the Law 353/2000 does not regulate prescribed fires, which instead appeared in its bill (6303/2000, July 1999). This highlights how the topic was known and considered by the legislator, even if not transposed into the final version of the law. A reference to prescribed fires in Law 353/2000 can be appreciated in Art. 8, which indicates that the Minister of the Environment, in agreement with the Regions involved and based on the proposal of the managing bodies, can prepare a specific plan for National Parks and State Nature Reserves (Bovio and Ascoli, 2012). For the drafting of this planning instrument, specific guidelines have been published in 2002 and in 2009.

In 2021, the Italian Government issued new regulations, specifically the Legislative Decree 120/2021 and the Law 155/2021, to enhance coordination, forecasting and response capabilities. In the new Law 155/2021, the Regions must include in the AIB plans the areas treated with prescribed fire (Art. 3, comma 3c-bis). Prescribed burning is recognized as a tool for fuel reduction, and it is defined as "an expert application of fire on planned areas, through the use of specific personnel trained in the use of fire and adopting prescriptions and operating procedures previously defined with specific guidelines by a Technical Committee" (Art. 4, comma 2-bis). The issuing of these specific guidelines envisaged by Legislative Decree 120/21 is still expected. Until the date of entry into force of these guidelines, the relevant provisions already defined by the AIB regional plans and regulations remain in force.

According to Bovio and Ascoli (2012), in 2012 only two Regional Laws (Piedmont and Basilicata) dedicated to forest fires also regulated prescribed fires. Other regions, such as Calabria, Campania, Lazio, Liguria and Lombardy treated the same topic in the context of regional forestry laws, forestry regulations, general forestry police provisions (PMPF), and forestry plans.

In 2016, the number of regions regulating prescribed burning through Regional Laws increased to 13. Nowadays, almost all regions but Trentino Alto Adige and Umbria, regulate prescribed burnings through different tools, as per Table 1.

Table 1: Regional Laws specific to fire management, Forest Laws/Plans/Regulations and AIB plans dealing with prescribed burning in the 20 Italian Regions.

Regions	**Regional Law**	**AIB plans**	**Forest Laws / Plans / Regulations**
Abruzzo		AIB plan 2023-2025	RL n. 3/2014, Art. 52, comma 2
Basilicata	RL n. 13/2015, Art. 7, comma 2	AIB annual plan 2023	
Calabria		AIB annual plan 2023	PMPF 14.07.2011, Art. 12, Art 16
Campania	RL n. 20/2016 ALL ART	AIB plan 2023-2025	General Forestry Plan 2009-2013
Emilia Romagna		AIB plan 2022-2026	Regional forestry regulations n. 3/2018, Art. 59
Friuli Venezia Giulia	RL n. 17/2019		
Lazio		AIB plan 2023-2025	RL n. 39/2002, Art. 68
Liguria		AIB plan 2022	RL n. 4/1999, Art. 43
Lombardy		AIB plan 2023	Regional forestry regulations n. 5/2007
Marche		AIB plan 2022	
Molise		AIB plan 2018	
Piedmont	RL n. 21/2013, Art. 1 and Art. 6	AIB plan 2021-2025	
Apulia		AIB plan 2023-2025	RL n. 1/2023, Art. 24 RL n. 24/2021
Sardinia		AIB plan 2023-2025	RL n. 8/2016
Sicily		AIB plan 2023-2025	
Tuscany		AIB plan 2023-2025	Tuscany Forestry Regulations, DGR n. 48/2003 Regulation n. 11/2019
Trentino Alto Adige		-	
Umbria		-	
Valle d'Aosta		AIB plan 2023-2025	
Veneto			

In Sardinia, prescribed burning was introduced into the AIB planning in 2010. In 2014, the experiences carried out suggested that the planning, scheduling and execution processes of prescribed fires could be carried out on an experimental basis, especially on limited zones in pastures, eucalyptus and pine forests also to create firebreaks, and in preventive actions to create protection bands for larger areas. However, the application of prescribed burning on Mediterranean maquis was excluded, at least until the consolidation of a strong experience and operational routine of the fire specialists. In 2016, Sardinia's forestry sector underwent a major reorganization with the introduction of the Regional Law n. 8/2016, commonly known as the "Forest Law of Sardinia". The new law aimed to address the lack of comprehensive legislation in the forestry sector in Sardinia, where the only available regional instrument was the Regional Environmental Forestry Plan (PFAR), adopted in 2007, given the growing importance of the forestry sector's environmental, social, economic, and cultural significance, locally and internationally. The LR n. 8/2016 set out forest management objectives, including forest protection, sustainable resource management, biodiversity conservation, prevention of forest fires, and promotion of economic development related to the forestry sector.

The law presents references to prescribed burnings in article 22 paragraph 1 letter. c) since it "promotes, also through the Regional School of the Sardinia Forest Service, the research and experimentation of innovative operational techniques and organizational models for the improvement of fire extinguishing techniques, to be disseminated

through the constant training of firefighting operators". Through this article, the Sardinia Forest Service (CFVA) can apply prescribed burnings for research, management and training functions (including active firefighting through backfires). Furthermore, prescribed fires can be also applied by the Sardinia Forest Agency (Forestas), in coordination with the CFVA for research, training and management functions, as defined in the LR n. 8/2016, articles 36 and 37. In fact, prescribed fire represents a fundamental tool for the operational training of forestry personnel responsible for using fires to put out wildfires (AIB plan, 2023).

The application of prescribed fires is authorized by the territorial services of the CFVA in order to identify the most appropriate moment for its execution through a project document, drawn up according to the guidelines prepared by the General Directorate of the CFVA, according to the following parameters:

a) Relative air humidity;
b) Air temperature;
c) Terrain slope;
d) Fine fuel moisture content;
e) Number of days since the last rain;
f) Percentage of surface fuel load to be eliminated;
g) Quality and quantity of plant cover to be safeguarded;
h) Ignition technique to be applied;
i) Evaluation and control of possible spot fires.

The prescribed fire projects, drawn up according to the guidelines approved by the General Directorate of the CFVA, must identify the most appropriate period for the use of fire. Designed prescribed fire operations should consider local weather forecasts and can only be conducted in favorable environmental conditions and within safety windows of weather parameters (optimal implementation window).

Prescribed fires activities can be carried out by CFVA with the collaboration of the Forestas Agency, as well as the University, the National Research Council of Italy and other research bodies, in order to promote scientific and technological knowledge. Where necessary, the projects will be accompanied by communication plans to explain to local communities and citizens the aims of the application of prescribed fires.

The areas treatable with prescribed fires include the existing or newly created firebreaks in the forest areas managed by Forestas, as well as other areas, identified by the CFVA, where fuel reduction represents a priority. Furthermore, even in the periods characterized by high wildfire danger conditions, the application of prescribed fire interventions by CFVA is permitted.

1.4.2 France

1.4.2.1 A legal framework for any use of fire: pastoral burning and prescribed burning

Since the 1990s, in some departments of southern France, prescribed burnings for pastoral and wildfire prevention purposes have been carried out by institutional bodies. This transfer of "burning" responsibilities from farmers to specialized services was mainly due to the decline in the number of farmers in these regions. There were no longer enough competent livestock farmers (and local people capable of carrying out burnings in collaboration with breeders) to ensure that burnings could be carried out in good conditions. The French Forestry Law defines the concept of prescribed burning and specifies who is authorized to use it: The decree of April 9, 2002, reproduced in article R131-7 of the French Forestry Code, for the application of article L. 131-9 prescribed burning is understood to mean *"the destruction by fire of grasses, undergrowth, litter, slash, branches, dead wood, forest trees or other types of vegetation, when they have a long-lasting dominant and decaying character, the maintenance of which is likely to encourage the*

spread of fires; it specifies that this operation is carried out in a planned and controlled manner within a predefined perimeter, with the obligation to ensure the safety of people, property, forest stands and adjacent land, in accordance with the specifications approved by each departmental prefect". (Decree of April 9, 2002, reproduced in article R131-7 of the French Forestry Code, for the application of article L. 131-9 about prescribed burning)

The Forestry Code defines the persons authorized to use fire:

- Pastoral and agricultural burning: only owners and assignees (e.g. livestock farmers) are authorized: article L131-1: *"It is forbidden for anyone other than the owner of land, whether wooded or not, or other than the occupants of such land on behalf of their owner, to carry or light fires on such land and up to a distance of 200 meters from woods and forests and similar land subject to the provisions of article L. 131-4"*.

- Prescribed burning for fire prevention. Only authorized burning teams are allowed, and they must obtain the prior agreement of the owners, as defined in article R131-10:
    - *"The State, local authorities and their groupings, authorized syndicate associations and their agents, who plan to carry out the incinerations and prescribed burnings mentioned in article L. 131-9, must first obtain the agreement of the owners of the land concerned or the occupants on their behalf.*
    - *To this end, they send them notification by any means capable of establishing a definite date, specifying a one-month deadline for response. In the absence of a response within this period, their agreement is deemed to have been reached. (…)"*
- Fires and backfires: in the event of a wildfire, the firefighting services (fire department) do not require the prior agreement of owners: article L131-3: "*The emergency operations commander may, even in the absence of authorization from the owner or occupants of the land concerned, use tactical fires for firefighting purposes*".

1.4.2.2 Burning methods regulated at departmental level

Prefectural decrees adapt to local contexts (droughts, wind, periods of atmospheric pollution), and the rules for using fire can still be specified at the municipal level by municipal decree (mayor level).
Within the departments, the burnings are subjects to prefectural decrees which set out the forest code and regulate this practice. They define in particular:

- a period prohibiting pastoral burning which corresponds to the summer period with the most pronounced fire risks, an authorized period of pastoral burning and an intermediate period.
- according to the defined periods, the procedures to be carried out:
    - prior declaration to the municipality or,
    - prior authorization from municipality relayed to the prefecture for agreement.
    - exceptional exemption in certain cases with agreement from the prefecture.
- all the means necessary for the safe conduct of the burning:
    - authorized burning hours associated with these periods.
    - the number of people needed.
    - the surface area authorized to burn in one piece.
- the necessary precautions around the perimeter of the area to be burned.
- notify the fire department before and after ignition.

Pastoral burning remains prohibited:

- in the event of too strong wind, the limit of which is defined for each department.

- in the event of an episode of air pollution, observed or anticipated, when the levels of air pollutants (PM10 particles, ozone, nitrogen dioxide) are higher than the information and recommendation or alert threshold.
- in the event of an exceptional fire risk outside the ban period defined in the prefectural decree.

Within the regulatory framework described above, authorizations for pastoral burning involve:

- Municipality and prefectures, during periods when burning is subject to prior declaration or authorization.
- In some departments, burning is subject to authorization by the "Commission Départementale de Brûlage Dirigé" (Departmental Commission for Prescribed Burning), which remains under the aegis of the prefecture, which may or may not approve projects with additional requirements. In this way, burning projects are brought to the attention of the local players concerned (foresters, administration, elected representatives, firefighters, environmental associations, etc.) for advice and recommendations.
- Local Ecobuage (=pastoral burning) Commissions have been set up in some departments to provide better advice for breeders. These are multi-disciplinary consultation committees bringing together breeders, hunters, local associations, environmental partners, administrations, mayor, fire departments, etc.

1.4.2.3 Training courses for institutional staff and team organization

In France, prescribed burnings for wildfire prevention and attack are made by a pool of around 200 technicians (mainly firefighters and State foresters). They all benefit from the same training with a national label created in 2004. This training does not concern agricultural burning, which is either taught sporadically in a few departments, or is already well known to farmers themselves. The terms of this training are defined in an inter-ministerial circular (Ministry of the Interior and Ministry of Agriculture and Forestry). Circular DGFAR / SDFB / C2004-5033 and DGER / SDFP / C2004-2009 of August 31, 2004, on the training and validation of the achievements of those responsible for the prescribed burning and / or incineration (http://agriculture.gouv.fr/sites/minagri/files/documents//dgfarc20045033z.pdf). The purpose of this circular is to specify the procedures for implementing the training and validation of assets acquired by those responsible for the prescribed burnings, carried out to prevent forest fires.
This training gives the possibility of carrying out controlled burnings on land that the people do not own. The objectives of these prescribed burnings are mainly fuel reduction and wildfire prevention, even if burning has often multiple interests (prevention, pastoralism, etc.).
The training provided by the authorized institutions is done in 18 days and organized in 3 modules which aim at the following educational objectives:

- Module 1 (5 days): Being able, under the authority of a site manager, to carry out prescribed burning at a defined sector and in compliance with the regulations in force (crew level).
- Module 2 (10 days): Being able to carry out the preparation and monitoring of the prescribed burning sites regarding the specifications and in compliance with the regulations in force.
- Module 3 (3 days): Being able to supervise burning sites directed against the specifications and in compliance with safety rules for staff and third parties.

This training is complemented by a period of application in the form of a fellowship and continuous professional practice, as well as exchanges during annual national prescribed burning meetings. Companionship involves participating in the management of a prescribed burning site, under the authority of a senior official.
To enter training, the candidate must:

- Submit proof of an ability to supervise a team issued by his employer.

- Present a medical certificate of fitness to carry out the activity of responsible for the controlled burns.

These conditions are verified by the director of the authorized training establishment.

At the end of the candidate's training, the provisional training certificate is issued for a probationary period of 2 years. During this 2-year application period, the holder must participate, and be able to prove by attestations from his employer of his participation in:

- 3 days of companionship in different regions, teams and contexts.
- 4 days of professional practice as Burn boss with his own team or with other teams.
- 1 day of participation in annual national prescribed burns, as far as their organization is concerned.

Participation in these activities validates the training certificate for a period of 5 years.

The validity of the training certificate is then extended for 5-year periods, provided that the holder warrants at least 10 supervised controlled burnings and participates at least once in the national meeting of prescribed burns during the 5 years period. In general, a person following the training takes around 5 years to complete all the steps and be qualified.

1.4.2.4 Organization of departmental prescribed burning units.

Today, prescribed burning units have been set up in thirty departments. These multi-disciplinary units bring together players with an interest in using fire as a tool.
Each year, a team organizes a three-day meeting to share and exchange experiences.

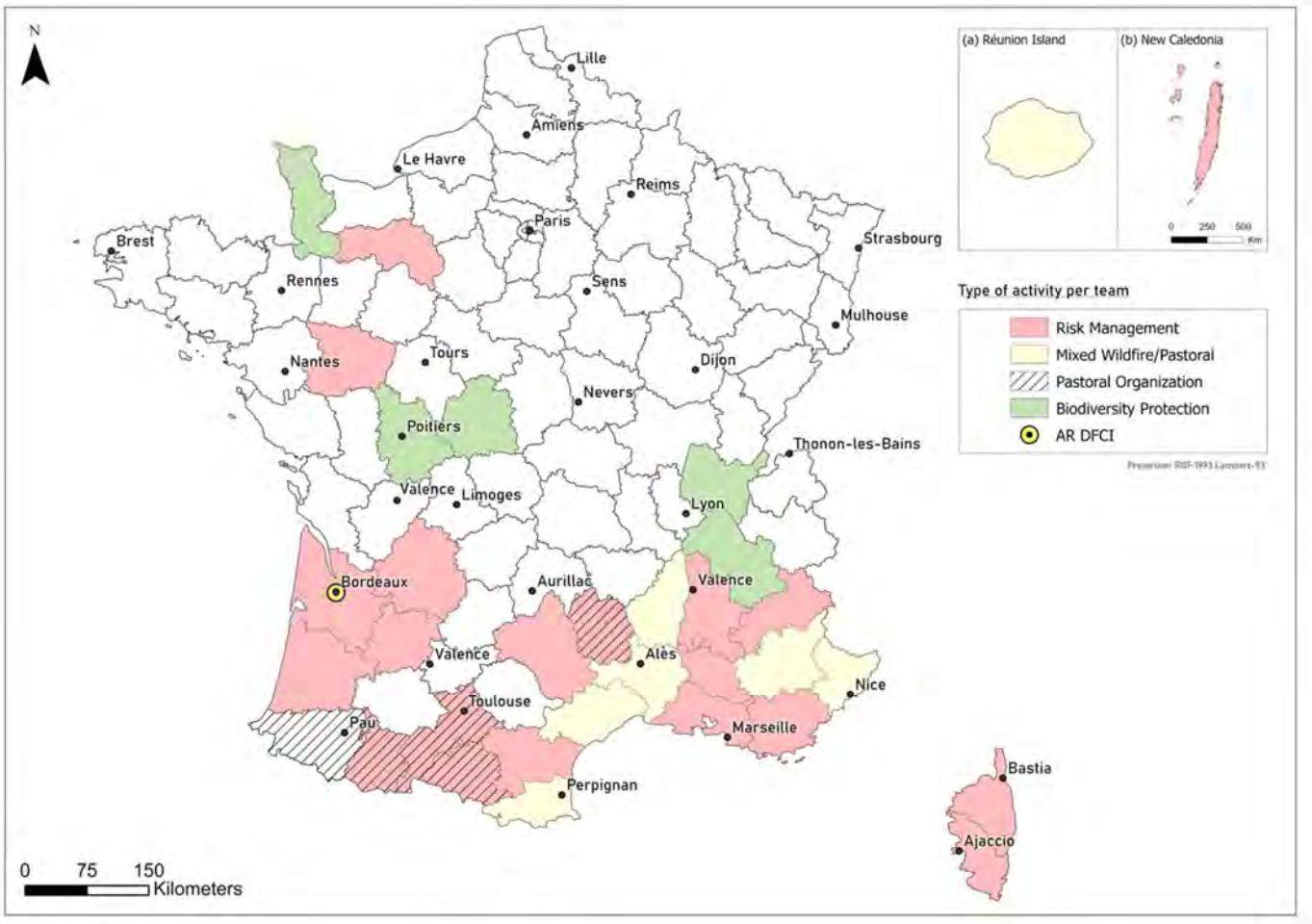


Figure 1: Localization of the prescribed burning units in France.

1.4.2.5 New perspectives to come

Despite the most severe fires have generally occurred in the Mediterranean area during the last decades, devastating ones happened in Bordeaux region in 2022.

As a result, the French parliament issued the National Law 2023-580 of 10 July 2023 to reinforce prevention and response in the light of the increasing and the extending risk of wildfires. Resulting from a parliamentary proposal, the 62-article law, divided into eight titles, aims to strengthen the prevention, protection and fight against the intensification and extension of fire risk: by providing for the development of a national and regional strategy (Title I); by better regulating the areas bordering forests, urban areas and infrastructures, in order to reduce fire outbreaks and the vulnerability of people and property (Title II); by managing forests and promoting silviculture in the face of fire risk (Title III); by improving forest management and development, by understanding forest fire protection on a massif scale (Title IV); by mobilizing the farming community to strengthen synergies between agricultural practices and forest fire prevention (Title V); by raising public awareness of the fire risk (Title VI); by equipping fire-fighting systems to deal with the risk (Title VII); and by financing the reconstitution of more resilient forests after a fire (Title VIII).

2 Experimental Trainings in Italy

2.1 Local Context

Large areas of central and northern Sardinia are characterized by agroforestry management, with extensive livestock farming: in these areas, fire has been largely used as pasture management tool in the past. Today, such agro-silvo-pastoral zones are increasingly affected by abandonment, resulting in an increasing risk of severe and extreme wildfire spread, due to the presence of heavy fuel load, the horizontal and vertical continuity of fuels, and a hilly orography. The use of fire could enable better management of these areas and thus could become a tool for preventing wildfires with severe and extreme behavior, as well as to support grazing management and weed control. Unfortunately, the window for the implementation and application of prescribed burning interventions (usually in September in areas mostly covered by herbaceous fuels), especially with dry fuels and relatively risky weather patterns, could conflict with the laws and regulations of the Sardinian Region.

The idea of a collaboration among the Sardinia Forest Service (CFVA), the local communities and the stakeholders who at the local level have an interest in a better management of agro-pastoral territories was first developed in the municipality of Suni, where a pilot activity was established in 2010 to respond to these needs, to allow for a reduction of uncontrolled burnings or even wildfires, and to organize a plan of controlled burnings in areas proposed by local agro-pastoral workers or defined as strategic zones by CFVA. The positive results of this collaboration led CFVA to invest in training on techniques for conducting controlled burnings and in general on the use of fire for prevention activities. Therefore, in the context of this renewed interest on the use of fire, the Surigheddu training programs (in the municipality of Alghero, Northwestern Sardinia) and other training initiatives conducted mainly in the field and associated with the execution of prescribed burning interventions (Isili, Nuoro, Bonorva, etc.) were realized (Figure 3). It should be noted that institutional bodies, and in particular CFVA, also engaged research institutions, and specifically CNR-IBE, to obtain data, simulations, and information to support the design, execution and monitoring of interventions.

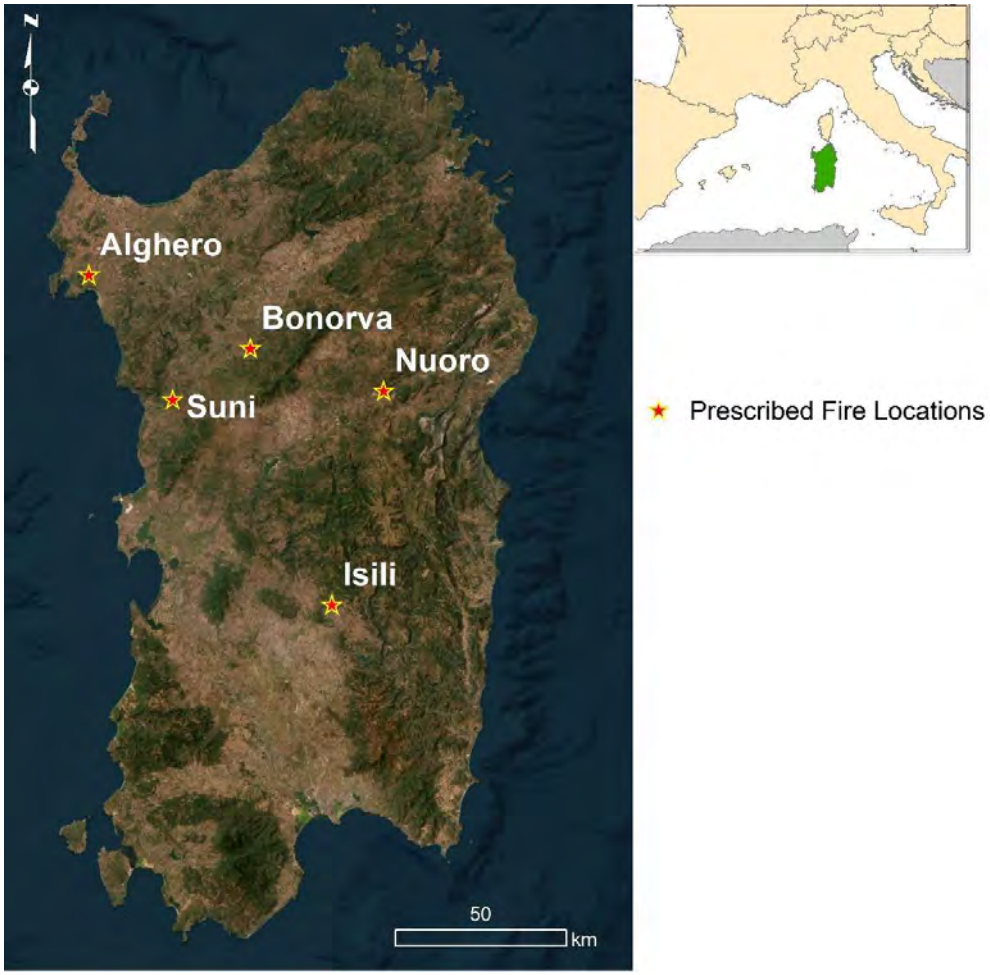


Figure 2: Localization of the prescribed burning units in Sardinia.

2.2 Course Description and Purposes

2.2.1 Municipality of Suni

2.2.1.1 The prescribed burning plan

The plan of prescribed burnings to be conducted in the municipality of Suni was carried out by the CFVA - Territorial Inspectorate of Oristano, which was assisted by personnel from the other Sardinian Inspectorates as well as from other Institutions (e.g.: Forestas). The plan was preceded by a phase of consultation with the main stakeholders of the Suni territory, and with the municipal administration, several livestock farmers and landowners, and the volunteer associations involved in environmental monitoring and protection of the territory. This consultation was essential to define the needs of the local community and the priority of interventions, also taking into consideration that most of the areas to be treated have private owners. The first applications in the use of fire in the municipality of Suni started in 2009-2010, precisely after a specific request to CFVA coming from the municipal administration and the breeders, and the subsequent meetings to assess a standard authorization procedure and administrative protocols, to evaluate the feasibility of the interventions and to develop the prescribed fire program.

The breeders of this area have always expressed a strong interest in “clearing” the land with fire, with the primary purpose of renewing pastures prior to the first autumn rains, a well-established practice in the culture of the inhabitants of these areas. It is also relevant to highlight that several land parcels in the municipality of Suni are characterized by

superficial rocks and stones, with large portions of non-arable lands. The practice of the use of fire in private lands by the owners is allowed by regional regulations only after September 15, when weather conditions are milder than in the summer (lower temperatures, higher atmospheric humidity, and higher fuel moisture, including more relevant fuel moisture recovery during nighttime hours) and do not allow the uncontrolled spread of a fire. In order to have a larger temporal window to use the fire for agro-pastoral purposes, and to have the possibility of treating larger surfaces, the farmers and the municipal administration of Suni requested an anticipation (September 1) of the starting date for the application of controlled fires in private lands. However, at the beginning of September, the presence of weather conditions that could lead to severe fire behavior fires is still possible. Therefore, the CFVA proposed a detailed planning of interventions, carried out by the CFVA forces, while respecting the safety conditions of operators, and minimizing environmental damages related to the use of fire. The use of controlled fire interventions after September 15 can be conducted both by CFVA and the farmers, after presenting an official request to CFVA and in compliance with the regional regulations.

The prescribed fire plan defined by CFVA with the cooperation of stakeholders aligns with the Sardinian wildfire prescriptions (PRAI), in which the use of fire in agro-silvo-pastoral contexts (such as burning grasslands, crops and silvicultural residues, pastures with limited presence of trees or shrubs, and temporarily unproductive farmlands) is allowed for areas greater than 15 ha and in the period between September 1 and October 31, to individual or associated parties who, through their municipal administration, submit specific applications to CFVA to carry out interventions of controlled burnings. PRAI also defines that the Territorial Inspectorates of CFVA must receive these applications at least 20 days before the period of interest. The prescribed fire plans are instructed by the Territorial Inspectorates of CFVA, which verify suitability and sustainability of interventions, including the evaluation of weather and climate conditions, and authorize their execution, carried out by CFVA and with the cooperation and logistical support of the farmers.

The objectives of the project carried out for the municipal administration of Suni can be schematically summarized by the following points:

1. to reduce fire risk through the reduction of fuel load and continuity, as well as the number of wildfires or uncontrolled events;
2. to improve the quality and palatability of grass species for livestock;
3. to organize and execute training activities for personnel engaged in forest fire prevention and fighting;
4. to reduce social conflicts related to the use of fire and to land management;

The prescribed burning plan of the municipality of Suni included an accurate territorial framework, with an analysis of the environmental constraints that need to be taken into account for the design of the interventions: for instance, in the area of Suni, hydrogeological constraints (such as those defined in the “Piano stralcio di bacino per l’assetto idrogeologico” (PAI) (Hydrogeological Master Plan of the Basin) and the important restrictions on land management (presence of “Siti di Interesse Comunitario” (SIC) (Sites of EU Community Interest) were carefully considered. Pre-existing planning, such as Municipal Interface Risk Plans, were considered to identify urbanized areas characterized by the greatest vulnerability or exposure to wildfires.

Socio-economic conditions were also considered. The natural areas of the municipality of Suni, located in the context of a large basaltic plateau in the Planargia macro area, are characterized by a predominantly agro-pastoral development, while in the neighboring municipality of Bosa, along the coast, prevails a development related more to beach tourism and other activities that aim at a touristic and eco-sustainable exploitation of the territory. There are no roads with major traffic flows, major residential areas, hospitals, or other infrastructures that require supplementary management precautions, such as smoke management during the implementation of works to avoid air visibility and air quality problems. However, the project provides for the adoption of basic management interventions to limit the impact of smoke on communities.

Finally, a fire regime analysis was carried out with the Plan, which equally provided important information for the identification of areas with higher hazard and risk conditions. Maps of the wildfires that occurred in past years were used to assess the potential for fire spread and intensity. In particular, the behavior of particularly severe fires that occurred in the area was assessed, such as the fire that occurred in July 2009, which burned an area of about 7,000 ha and threatened the urban-rural interfaces of the municipality of Suni.

The areas where the prescribed burnings are carried out are generally represented by herbaceous pastures and woody pastures mainly grazed (Figure 3). To a lesser extent, treatments were also conducted in abandoned farmlands characterized by a predominant shrub component that restrict livestock transit (Figure 4). The forest component is largely represented by open agroforestry areas with *Quecus pubescens*, *Quercus suber*, and, in limited areas, *Quercus ilex*; among the most represented shrub species, *Rubus ulmifolius*, *Pistacia lentiscus*, and *Pteridium aquilinum*.

The plan comprised a detailed analysis of the fuel characteristics and an estimate of potential fire behavior, by both conducting field surveys and determination of fuel loads and using previous data collected in Sardinia, related to similar agroforestry conditions; these fuel estimation activities were conducted in collaboration with CNR-IBE. This phase also conducted to the adoption of a set of standard fuel models in the prescribed burning plan ((Scott and Burgan, 2005) (Table 2).



Figure 3: Pastures and wooded pastures.



Figure 4: Pastures with a prevalent shrub component.

Table 2: Fuel model parameters used as reference in the Suni plan (expressed in metric units) (Scott & Burgan, 2005).

Fuel Model Code	Fuel load (ton/ha)					SAV ratio (1/m)					Fuel bed depth (cm)	Dead fuel moisture of extinction (%)	Heat content (J/g)
	1 hr	10 hr	100 hr	live herb	live woody	1 hr	10 hr	100 hr	live herb	live woody			
GR1	0.22	0	0	0.67	0	6562							
GR4	0.62	0	0	4.69	0	6562	0	0			60	15	18622
GR7	2.24	0	0	12.11		6562							
SH7	7.85	11.88	4.93	0	7.62	2461	358	98		5249	183	15	18622

The prescribed burning plan defines an implementation window which is based on a set of weather, fuel moisture and orographic conditions, along with minimum, maximum and optimal ranges (Table 3).

Table 3: Main parameters for the evaluation of the prescribed burning implementation window.

Parameter	Minimum	Optimal	Maximum
Air temperature (°C)	12	16-25	30
Air relative humidity (%)	12	20-35	55
Wind speed (km/h)	2	3-8	12
Fuel moisture (%)	7	10-12	15
Days from the last precipitation > 10 mm	1	2-3	5
Slope (°)	0	10-20	100
Crown base height (m)	2	3	
Spot fire		absent	limited
Rate of spread (m/min)	1	2-4	8
Fireline Intensity (km/m)	150	200-250	400
Flame length (m)	0.30	0.60-0.70	1.20
Fuel load reduction objective (%)	85	95	100

Moreover, the plan defines the ways to implement the interventions in relation to the ignition technique, the fire management rules, the individual protective equipment to use. The reference ignition technique is the linear one, with predetermined anchorage depending on the slope and wind, and the feasibility to use blowers or other equipment. The plan also outlines the use of controlled ignitions for isolated shrub patches and the procedures to avoid smoke emissions to inhabited areas; adequate communication to local communities should be guaranteed in exposed areas and on days with high dispersion of smoke. Regarding the management of interventions, the plan defines to use the LACES (Lookouts, Awareness, Communication, and Escape route) protocol (Gleason 1991). Finally, the treated areas cannot be left uncontrolled before the declaration of operation closure.

2.2.1.2 Field activities

During the 2020-2023 period, different field activities were carried out for implementation of the interventions described in the plan (

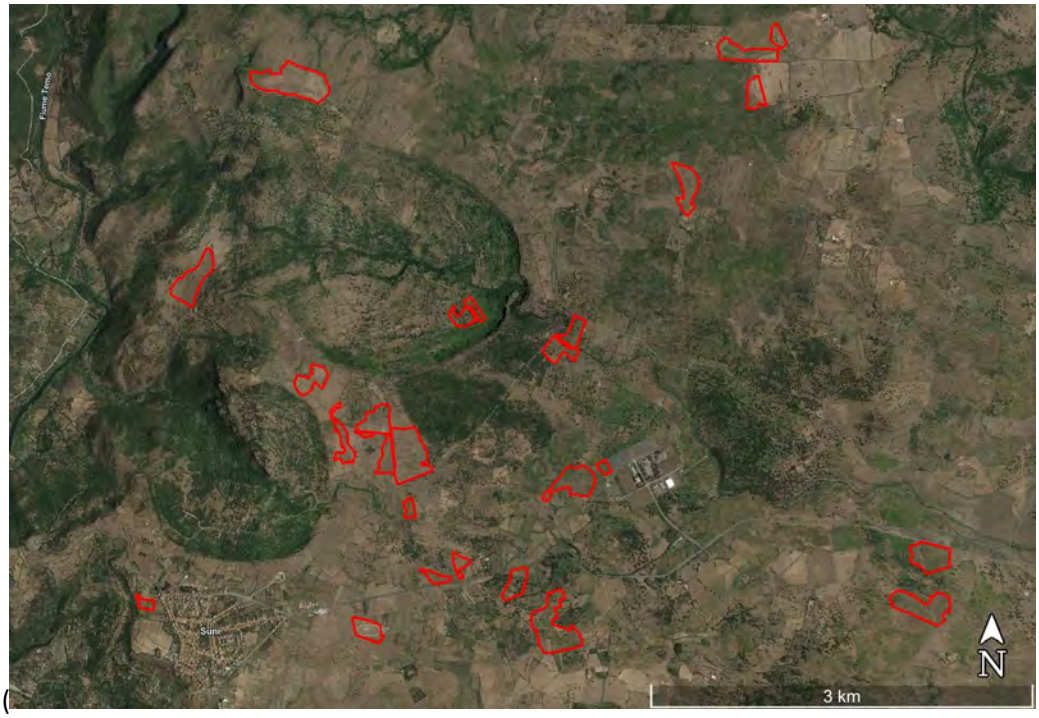


Figure 5). The field activities began with a meeting in which both farmers interested in the prescribed fire plan and municipal administrators participated. During the meeting, the CFVA briefly explained the objectives of the program and highlighted the importance of an effective collaborative relationship to make the interventions more successful. Farmers were asked to prepare the basic infrastructures necessary for the access to farms and the transit within the farms of the CFVA vehicles needed for the safe conduction of the interventions, while also optimizing implementation time and areas covered.

The prescribed burnings were preceded by a training session carried out in the field: the main goal was to describe the burning methodologies, to perform the interventions in safety conditions, and to optimize the temporal efforts of the teams. Information on the implementation windows and preferred weather conditions were also discussed (Figure 6 and Figure 7). In addition, the operational mode of carrying out the prescribed burning was explained. Optimal ignition points and lines were preliminarily identified considering orography and weather factors, and the availability of anchor lines that would allow proceeding while minimizing the risk of escaped fires. The techniques for constructing an anchor line were explained, either using blowers and sprayers, or water pumps able to deliver adequate volumes of water and to mix foaming products and water.

Next, the first phases of the prescribed burning operations were presented: they usually consist of proceeding in parallel fire lines (strip-heading fires), so that the lines influence each other and make the fire more controllable with low fire intensities.

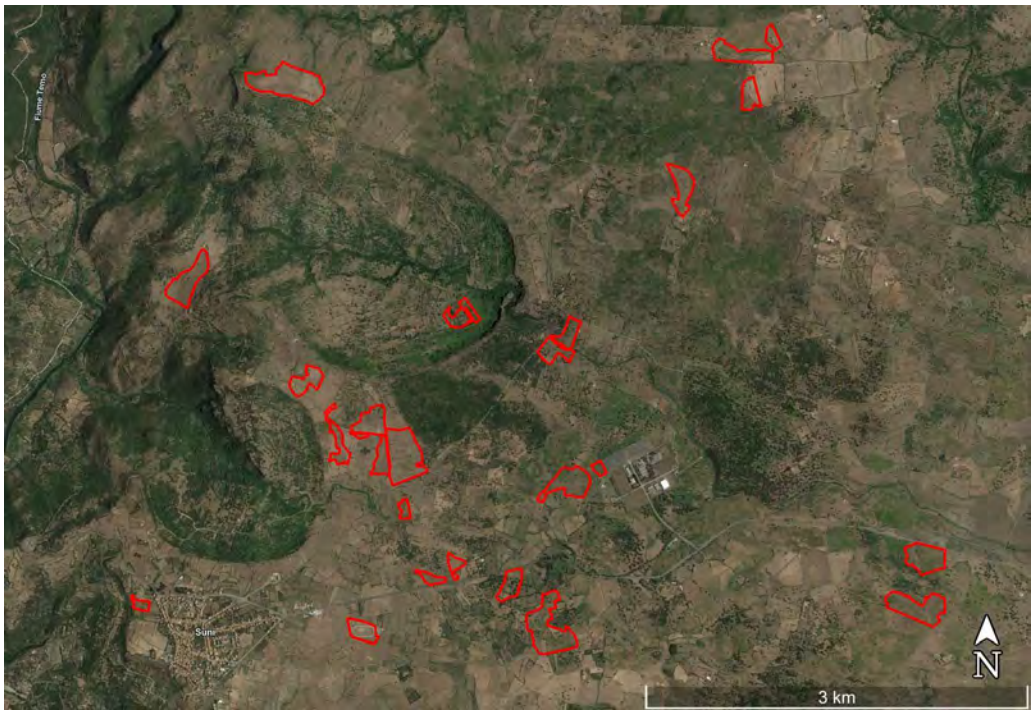


Figure 5: Map of the areas treated by prescribed fires in 2023, near the Municipality of Suni (100 ha treated, September-October 2023).

Finally, the advantages that can be obtained from controlled burning operations were described, and in particular the possibility of limiting fuel load and continuity with moderate flame intensities in the treated areas, to avoid damages to the soil organic component and to prevent soil erosion. The benefits in terms of reduction of severe wildfires and ignition likelihood during the following fire seasons were also presented, together with the reduction in the expenses of terrestrial and aerial fire suppression interventions. In operational contexts, the application of fire can be an effective way to create safe areas and "close" active fire perimeters by creating burned strips, thus limiting the rekindling potential, the duration of suppression and mop up, and suppression efforts, especially in complex terrains.



Figure 6: Preliminary meeting before the training activities.



Figure 7: Discussion of the examples and case studies.

CFVA also discussed how to proceed regarding the communications during the prescribed fire interventions, the use of different radio frequencies and the possible use of a dedicated radio frequency in order to prevent interferences with the communications of the other CFVA teams involved in ordinary activities. The DPI equipment and the importance of its full functionality was emphasized, indicating the factors to be taken into consideration for its full efficiency.

Finally, a demonstration was given on how to proceed with the different manual and mechanical means used during the interventions: the drip torches, the blowers-sprayers, the Gorgui, the pick-up firefighting modules equipped with water tanks, pumps and hose reel, the medium and heavy tanker modules (more than 3000 liters) (Figure 8 - Figure 11).

The optimal use of the various tools and vehicles was described. The optimal composition of the teams for CFVA is the following: two men take care of the line ignitions and are supported by one or two units devoted to control the flames through the use of the blower-sprayer; if needed, the personnel equipped with medium and heavy fire fighting modules can lower fire spread or intensity in the downwind and flanks portions. The selection of mechanical means for the interventions is strongly influenced by the accessibility conditions of the area and by the slope.



Figure 8: Methods to charge and use the drip torches.



Figure 9: Training on the use of blowers-sprayers.



Figure 10: Description of the tools installed in a pick-up vehicle.



Figure 11: Medium and heavy tanker modules.

During this training phase, to facilitate the learning of concepts, practitioners and staff were asked to illustrate what they thought was the best possibility of intervention on several hypothetical conditions, differing in orographic and meteorological conditions. For each case study, the trainee staff gave opinions on how to intervene. To conclude this phase, to assess the fuel moisture conditions and the potential behavior of fire, an ignition test was carried out.

This briefing phase was then followed by the field execution of the prescribed burnings (Figure 12 - Figure 17). The daily area treated varied according to the width of the implementation windows. In general, when weather conditions were favorable, areas of up to 30 hectares per day were treated. The intervention implementation windows were about 15-20 days. The most appropriate time of the day was chosen to facilitate a rapid implementation of the intervention, following the safety and environmental rules reported in the prescribed burning plan: in several cases, the interventions started in the early afternoon and lasted until sunset.



Figure 12: Use of fire in pastures infested by Carlina spp.



Figure 13: Use of fire in pastures with presence of Rubus.



Figure 14: Setup of an anchor line using fire.



Figure 15: First phases of the prescribed burning (linear ignitions).



Figure 16: Parallel fire lines intervention.



Figure 17: Controlling flames using blowers-sprayers.

2.2.1.3 Classroom training

In Spring 2023, a classroom training session was held during a focus group organized as part of the FirEUrisk project (Figure 18 and Figure 19). The training session was mainly targeted to farmers. The activity aimed at addressing safety issues in cases of controlled fire interventions directly carried out by farmers, during the period when the use of fire is allowed. The importance of the use of basic individual protective equipment (IPE) was emphasized, as well as the use of proper clothing to avoid risky situations. In addition, it was explained to the farmers the importance of conducting the fire interventions in safe conditions and the importance of identifying an escape route to be used in case the fire becomes difficult to control; in addition, it would be necessary to have a vehicle located in a safe area that can be easily reached and used in case of an escaped fire. Individuals should also use fire in groups and not alone, so that in case of difficulties a support and help would be available. Attention was given to problems due to the presence of smoke, which can limit breathing and can limit visibility, direction and spread of fire, or identification of safe areas. Considering

all these factors, a recommended mode of use of fire was also discussed and recommended: the Sardinia Forest Service (CFVA) would establish the anchor lines and secure the parcels to be treated, and then the farmers would apply the fire independently and safely.



Figure 18: Classroom training activities: safety rules.



Figure 19: Classroom training activities.

2.2.2 Municipality of Alghero

2.2.2.1 The prescribed burning plan

The prescribed burning plan to be carried out in the municipality of Alghero (location of Surigheddu), prepared by the Territorial Inspectorate of Sassari, was characterized by two main objectives: (1) to conduct several training sessions aimed at training personnel engaged in wildfire prevention and fighting; (2) to carry out fuel management interventions, through controlled burnings, in a public area potentially subjected to severe and extreme wildfires, owned by the Regional Administration of Sardinia.

The training activity was guided by the Fire Analysis and Use Group (GAUF) of CFVA and involved CFVA staff as well as the staff of other agencies that cooperate in the Sardinian fire management campaigns (FORESTAS Agency, volunteers, etc.), as defined in the POA 2020 Operational Management Objective Program (Code SAP 20210600). These training and field activities also represented a further deepening of some of the topics covered during the Wildfire Analyst Course organized by CFVA in 2021, in the framework of a transboundary project (Italia-Francia Marittimo Program, MED-Star project). In 2023, CFVA recruited new agents, and the planned prescribed burnings in Surigheddu represented the first training opportunity for these agents.

The area on which the interventions were planned is predominantly characterized by herbaceous vegetation, with high fuel loads due to absence of grazing, quality of the soil and forage exploitation. Although predominantly flat, the area poses a potential threat for severe and extreme wildfire behavior due to the exposure to strong north-western winds and the proximity to hilly areas covered by forests and shrubs and to residential areas with dispersed and clustered WUIs. For these reasons, the plan also provided preventive measures for limiting smoke emission hazards. A simplified methodology for estimating smoke column characteristics and behavior during the operations was used, and was based on visual estimations of fuel load, prevailing types, and smoke color.

The prescribed burning plan was developed by involving stakeholders, represented by the Provincial Administration of Sassari, the Agency in charge of road network (and neighboring areas) management (ANAS), and the Regional Administration of Sardinia that owns the Surigheddu area. Also in this case, CNR-IBE collaborated in the drafting of the plan by providing useful data for characterizing fuels and for predicting controlled fire spread and behavior under different weather and moisture scenarios.



Figure 20: Map of the parcels treated in Surigheddu. Each square plot has 1 ha size.

2.2.2.2 Field activities

The field activity took place either at the beginning of the summer season (2021, 2022) or at the end of the season (2023), under the weather conditions established in the prescribed burning plan, which defined an implementation window and specific prescriptions regulating the execution of interventions. The interventions were preceded by a field training session, in which the plan of interventions was described with the help of maps and documents (Figure 20, Figure 21 and Figure 22). The total area to be treated, about 35 ha, was divided into plots of about 1 ha, on which anchor areas were planned to be used before conducting the training and using the fire.

Depending on the weather scenario, and particularly on the wind direction, the preferential procedures to create the anchor lines were described, and were based on the use of mechanical means equipped with hoses and able to mix the water with foaming products and distribute it by specific nozzles used by CFVA. It was explained how to minimize the smoke emissions, particularly in case of emissions directed by the wind towards rural-urban interface areas. As far as the management of the area during the prescribed burnings is concerned, the LACES protocol was explained, in addition to the importance of radio communications, the frequencies to be used, and the importance of monitoring the treated area while waiting for the active fire extinction and the conclusion of the activities.

The scalable organization of the intervention team was described, with no less than two teams involved, each one consisting of 4 units and lead by a responsible (Figure 23). All operations were coordinated and directed by a prescribed fire manager. The prescribed fire lines were associated to at least two anchor areas and were constantly supported by AIB vehicles equipped with mechanical means ready to operate in case of need (Figure 24).

The prescribed fire activity was carried out with the use of all personnel on a rotational basis. The prescribed fires were performed on large plots (1 ha size) and burning single plots, so that one of the two-sided anchor zones to be adopted before new linear ignitions was the treated plot. Upon completion of this training phase, a simulated backfire was conducted in an adjacent zone of about 5 ha. Considering weather and spread direction, a fire was ignited with the purpose of simulating a real wildfire, and then a backfire (Figure 25 and Figure 26) was implemented to stop the fire spread. The backfire was ignited alongside a secondary road that served as an anchor line.



Figure 21: Illustration of the plan.



Figure 22: Explanation of the main rules to implement the interventions.



Figure 23: Composition of the intervention team.



Figure 24: Use of the sprayer to control the anchor line.



Figure 25: Visible image by drone during a backfire training.

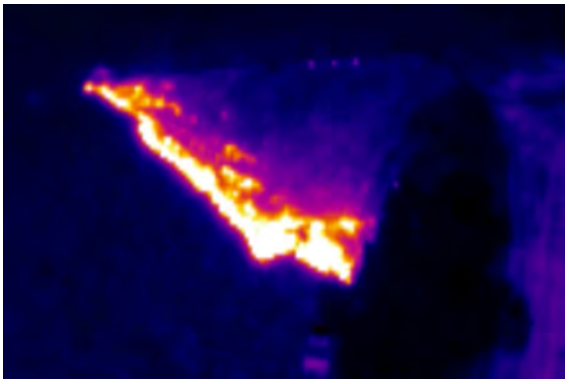


Figure 26: Infrared image by drone during the training.

The CNR-IBE was involved in the evaluation of fuel load, moisture and general characteristics in the areas to be treated, as well as in the monitoring of the basic parameters of fire propagation and behavior (flame depth and length, and spread rate) and of weather conditions (Figure 27 and Figure 28) (before and during the prescribed burnings). The collected data were made available to CFVA to complete the training activities with the description of the actual field conditions regarding fuel load, height, and fuel moisture. To characterize fire behavior, the video materials recorded by drones, both in the visible and infrared fields (Figure 29 and Figure 30), were also of considerable importance; these images also allowed the localization of the operators during the prescribed burnings. The multimedia materials were used to make a video description of the initiative that was disseminated within the FirEUrisk project, as well as in other projects and initiatives.



Figure 27: Samples for estimating dead and live fuel load and moisture.

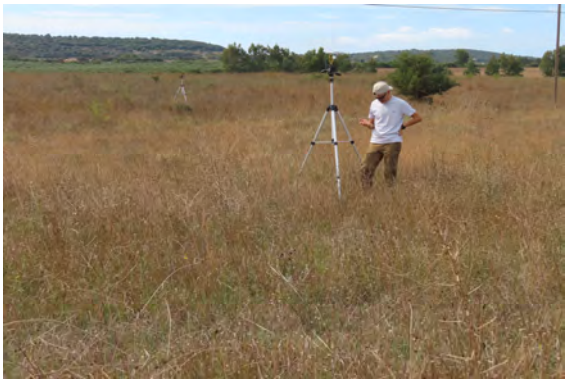


Figure 28: Weather data monitoring.



Figure 29: Fire behavior analysis by visible images.

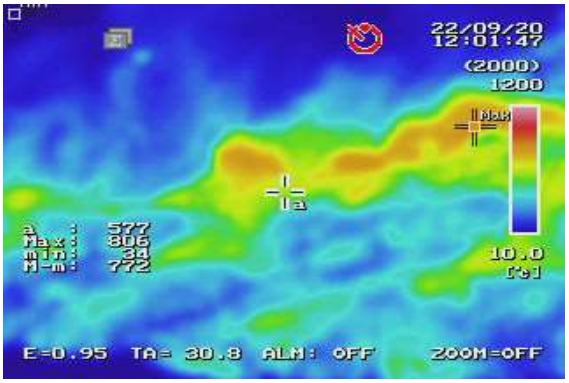


Figure 30: Fire behavior analysis by infrared images.

2.2.3 Prescribed burning activities in other sites

The positive results obtained in Suni and Alghero, and the renewed interest in the use of fire in Sardinia, together with the objective structural weakness of some areas (presence of rural-urban or wildland-urban interfaces, presence of roads, firebreak management requirements, historical fire regimes, etc.), led CFVA to expand the use of prescribed fire in other areas of the island.

In the Isili municipality (central Sardinia), prescribed burnings carried out in 2021 and 2022 involved an agro-silvo-pastoral area, with variable canopy cover, but in some cases with closed vegetation trees. The use of fire aimed at reducing the shrub biomass and necromass and the vertical continuity of vegetation. The area treated is located within a penitentiary colony with a large forest area that requires preventive interventions, particularly nearby a provincial road that could be a source of ignitions.

Another interesting application of prescribed burnings in a wildland-urban interface area was carried out in the municipality of Nuoro (Figure 31 - Figure 34), where fire was applied after silvicultural interventions aimed at increasing canopy base height, safeguarding the tree component (deciduous forest) and reducing the shrub component.

In the municipality of Bonorva (Central Sardinia), prescribed burnings have been conducted to protect WUI areas, as well as areas of significant naturalistic interest and a wind farm that requires specific preventive interventions, as the use of aerial means during wildfires is restricted in these zones.



Figure 31: The wildland-urban interface area of Nuoro.



Figure 32: The recreational urban pine forest of Nuoro.



Figure 33: Prescribed burnings in areas with shrubs and oaks.



Figure 34: Prescribed burnings in open deciduous forests.

2.3 Final Considerations

The initiatives described have generated a positive impact at the regional level, and probably could promote a further expansion of fire-based interventions to address differentiated and multiple prevention and vegetation management needs. The current impact can also be measured through the numbers of these experiences. The Surigheddu interventions provided a specific training for about 70 operators per year, belonging both to CFVA but also to other regional agencies involved in fire prevention and firefighting. A significant number of units was also involved in the Suni, Isili and Nuoro prescribed burnings, with at least 25 operators for each day of activity. In terms of areas treated, interesting results were observed. For instance, in the municipality of Suni large portions of land were treated in the last years, and in 2023 at least 120 hectares of land were managed with controlled fires. In general, the prescribed burning teams, and specifically the most trained units, are able to treat up to 30 hectares per day in safe conditions; in this municipality we also observed the benefit of the farmer involvement, which can also independently carry out the interventions with the fire, in safe conditions, thanks to the support and assistance of the regional authorities.

The training carried out in Sardinia has also become an opportunity for collaboration with other national bodies institutionally in charge of wildfire management (e.g.: Vigili del Fuoco, Civil Protection, Carabinieri, other Regional Administrations) or research institutions engaged in the development of new technological tools (e.g.: CNR, CIMA, CMCC, University of Sassari). In some cases, as for example in the Surigheddu activities, experts from the Office National des Forêts (ONF) (National Forest Office) of France and other experts from Corsican Agencies (France) were also involved in these training and education activities. The training conducted has certainly increased the knowledge of CFVA and other regional agencies (Forestas, Civil Protection), a background that can be useful for different types of wildfire management based on the unconventional use of fire (i.e.: backfires, tactical fires, or interventions aimed at

clearing vegetation to avoid rekindling). In addition, the training helped improving the procedures of internal communication and team spirit during the execution of all interventions.

The use of fire has been confirmed as a useful and economical land management tool, as it allows the control of areas characterized by high fuel load and continuity, and often by increasingly relevant land abandonment processes. This management could have positive effects on a multi-year basis, for example, for the control of the shrub components as well as of *Rubus ulmifolius*, ladder fuels, or highly flammable vegetation, with the main goal of maintaining a mosaic of lands and fuels that can facilitate wildfire suppression and management in case of wildfires. Of course, it is crucial to guarantee and support the maintenance of biodiversity in forests and agroforestry areas.

A key positive effect of this management strategy was the reduction in the number of fires and in burned areas during the fire season. This is very important, as uncontrolled and severe wildfires would have much more serious impacts on the landscapes, particularly in forest areas, and on agro-silvo-pastoral and anthropic values.

Reducing wildfire risk thus allows for better structuring the multi-functional potential and role of agro-pastoral areas, even in the context of protecting local communities from wildfires and other natural risks, and can help strengthening the image of authenticity of the agri-food products, which are highly appreciated by tourists and could generate an increasing flow of exports.

3 Experimental Trainings in France

3.1 Local Context

Farmers, including livestock farmershave been using fire for a very long time, if not "forever". (Dumez 2010). In France, there are many different names for this practice: “essartage”, when fire was used to clear forests and turn them into pastureland; “écobuage” in poor meadows, where the grass was lifted to dry the roots before burning them, and so on. Today, agricultural fire is mainly used for pastoralism. Combined with the passage of animals, it helps to maintain forage surfaces in areas that are inaccessible to mechanical equipment, such as steep slopes and marshy areas. Fire frequency can vary greatly. In the Pyrenees-Atlantique and Cevennes departments, woody plants are burned every year or two, even though they are less than 15 centimeters high. This low intensity burning of low vegetation maintains the root system of the resource.

Except in these areas, pastoral burning is generally carried out at intervals of 8 to 12 years, or even more. In the Alpes de Haute-Provence region, pastoral burning is carried out to reduce the growth of vegetation not consumed or controlled by the herds. These are mainly shrubs (broom, *Genista cinerea*; boxwood, *Buxus sempervirens*) but also coarse grasses (brachypods, *Brachypodium pinnatum*; perennial oats, *Helictotrichon sempervirens*). In this way, the areas are kept open and attractive to the herds.

However, because of natural reforestation, heathland areas dedicated to grazing are now adjacent to coniferous forests. In this context, the practice of burning by the farmers themselves often results in overflow into forested areas, necessitating considerable fire-fighting resources in areas that are very difficult to access.

In 1994, in the Alpes de Haute-Provence region, following a record winter in terms of forest fires caused by the overflow of pastoral burns, a departmental prescribed burning unit was set up. Its existence was then formalized by Prefectural Order in 1997. This unit is made up of people from the prefecture, the firefighters, the foresters, the departmental conseil and CERPAM the breeding syndicate at the service of farmers.

Its primary objective is to implement burning in natural environments, under the supervision of duly authorized professionals and with adequate technical and human resources. This practice has considerably reduced the area burnt by wildfires caused by pastoral burns that have escaped. Its effectiveness has been confirmed by its inclusion among the priority measures of the Plan Départemental de Protection de la Forêt Contre l'Incendie (Departmental Forest Fire Protection Plan), approved by the Prefect in 2007, as an action aimed at reducing the fuel biomass for wildfire prevention.

Since its inception, the departmental prescribed burning unit has been collectively planning the implementation of burning sites. Requests for burning sites are submitted by CERPAM to local livestock farmers and local authorities. After CERPAM has examined the request, a site survey is carried out to assess feasibility and the resources required.

The work is carried out primarily by the Brignoles UIISC7, a military firefighting unit, either in light, reactive teams to adapt to weather conditions, for sites that allow it, or in larger teams reinforced with heavy equipment during a specific period (winter vacations), for sites that require it.

In addition to these burnings carried out by military firefighters, others are carried out by local teams of departmental firefighters and foresters.

However, over the years, the activity of the department's prescribed burning unit has declined, and firefighter-military reinforcements have been less active for several years.

Pastoral demand remains active, however, while the pastures are gradually colonized with shrubs and trees, the practice of pastoral burning is in decline. Indeed, pastoral management of this type of environments, driven solely by mastication, ends with a complete recolonization of the woody shrub components in a few years. Periodic “clearing” of the land every 5 to 10 years by mulching or burning the plot must supplement the grazing to maintain a sufficient

forage resource. However, in steep mountainous areas, rocky zones, wetlands or in places where mechanical equipment cannot be used, clearing vegetation is only technically possible through controlled fire.
The use of fire then appears to be a technical necessity to reduce the biomass on mountain pastures and participate in parallel issues such as landscape management and reducing fuel for wildfire prevention. However, the use of fire is decreasing for many reasons: loss of knowledge, reduction of personnel on farms, increase in societal issues, impact of the smoke, impact on the soil and the environment, etc.



Figure 35: Briefing before the burnings.



Figure 36: Proceeding to the test fire.

3.2 Course description and purposes

The official training intended for institutional staff does not apply to farmers who carry out pastoral burning, because it is long and focused on supervising formed burning teams, which is of no interest to them. Training for herders is carried out sporadically in some regions without, however, having been standardized.
The objective of the training program, carried out by FirEUrisk in 2023, was to enable breeders to meet the safety requirements necessary for conducting a pastoral burning project. The training program covered a wide range of aspects: regulatory, meteorological, pastoral, and specific technical subjects to carry out pastoral burning in the best conditions.
The theoretical part of the course incorporated many of the elements and materials used in professional training, adapted to the needs of pastoral burnings: fire management methods, fire breaks, regulations, air pollution, burning report sheets, health and safety principles.
More specific elements have been added concerning the planning of burning sites, agronomic and pastoral objectives, the policy of joint purchasing of equipment and mutual aid.

3.2.1 Explanation of the training process:

The training program took place over one year in three phases:
1/ Two days of training in February 2022, focusing on theoretical skills and the practical application of prescribed burning. Two 2000 m2 units of 30-40 cm high *genista cinerea* heath were burned.
2/ Planning and preparation for pastoral burning. During the following summer, farmers were invited to plan one or more burns on their agricultural plots and analyze the complexity and feasibility of this burns. Each farmer's plot was then prepared (firebreaks) under the guidance of the trainers.
3/ Three days of burn practice in February and March 2023



Figure 37: Locations of the sites where the prescribed fires were carried out.

3.2.1.1 Description of the course

First Session

Day one

In the morning, kick off and theoretical part.

Presentations, survey of trainees' expectations: tour de table; administrative documents to be completed; update on the timetables and agenda.

Context of the training

Regulations on prescribed burning.

- Planning a burn:
  - Risk assessment, areas to protect.

- Weather conditions to bear in mind, consideration of atmospheric pollution.

The agronomic objectives (impact on flora and fodder production) of pastoral burning.

- Preparing a burn: securing edges with firebreaks.
- Carrying out a burn: technical methods for carrying out a prescribed burn.

Specialized equipment and common equipment purchasing policy for the team.

In the afternoon, professional setting in the field, before ignition:

- Presentation of the stages of a prescribed burning operation:

  Stage I – The action plan:

  - Recognition of the site by the members of the team and the resulting action plan.
  - The team (number, definition of each person's role, safety instructions, links with the site manager).
  - Means of communication within the team and with the SDIS (Dispatch) and information procedure at the start and end of the work.

  Stage II – burning:

  - fire control techniques according to the burning objectives to be achieved, the means required and the necessary weather and fuel moisture conditions (with their effects on fuel moisture).

  Stage III - The end of the work:

  - extinguishing, monitoring, informing the authorities, evaluating, and following up.



Figure 38: Exercise of extinction.



Figure 39: Phase of burning.



Figure 40: Preparation of the unit with the farmers.

Day two

Putting a pastoral burning into practice: 2 plots of 2000 square meters had been burned during the training.

- Reconnaissance of the unit, description of the burning plan: objectives to be achieved, safety measures for personnel and in case of escape, distribution of roles between ignition and containment, method of setting fire to the plot, logistic for the fuel and water, etc. Presentation of the case to be treated in the field with elements of description, definition of an intervention strategy (preparation of the site, human resources with roles of each and equipment needs, fire techniques, etc.)
- Implement site preparation measures, notify firefighters, install equipment and water supplies and carry out the test ignition.
- Conduct the burning, stop the fire and monitor to avoid possible rekindles.
- Take stock of the burning by drawing up the worksite report sheet: analysis of the planned/realized balance and responsiveness of the professional. Analyze the lived experience, the situations encountered and the contributions of such an operation.



Figure 41: Burning of Genista cinerea.



Figure 42: Result of a burning of Genista cinerea.

Interseason: Planning and preparation of the plots

Planning: Planning is very important and can be easy when you know your terrain well, but it's essential for assessing the feasibility of a project. It should be noted that planning is not taught in training courses for professionals; it is learned "on the job" within departmental teams after training. However, for our training project for farmers, it was important to add this part of management, as breeders need to be familiar with all aspects of burning, from planning to preparation and execution.

Two aspects of planning needed to be addressed:

- **Assess the possibility of burning at a given location.**

  Based on the skills acquired during the first session and their experience of prescribed burning, while using the checklist criteria provided (see Section 3.2.2), trainees were asked to:

  - Choose an area to burn on their farm.
  - Find a plot of land with existing boundaries such as tracks or paths, preferably in a type of scrubland commonly found in the pastures of the Southern Alps, such as boxwood, broom, etc. to prioritize safe burnings in areas where vegetation could be cleared. In terms of complexity of work, constraints and surface area, farmers were free to choose, as long as it was consistent with the means and personnel available.

- **Formalize planning.**

  As it is essential to be able to communicate and coordinate a burning action, they were asked to formalize the planning using the burning sheets provided. Two sheets were available, a "simple" one and an "exhaustive" one. In addition to these sheets, the planning had to be completed by providing:

  - A plan, map or drawing of their agricultural plots.
  - A few photos, if possible.
  - As an option, an explanation of the complexity of the work and a link with their pastoral activity.

- **Validation of planning and choice of plots to be prepared.**

Once the plans had been received, the training team went out into the field to assess the feasibility of the burnings and select the plots that would be prepared for the second training session. Four plots were selected for which recommendations were drawn up for preparation. The site planning file has been then drawn up to apply for administrative authorization. A sheet of the site analysis was made available to farmers.

Preparation: The preparation instructions were based on existing regulations, which require firebreaks to be at least twice the height of the vegetation to be burned and at least 2 meters wide.

Second session

During the month of February 2023, the second session took place with three days of burning.



Figure 43: A farmer leading the firing operation.

3.2.2 Instructions and checklists to help farmers manage pastoral burnings.

A checklist was provided to farmers during the training. Inspired by North American literature (USA[1] and Canada[2]) and adapted to the regional and public contexts, this checklist helps to choose a burning site and plan its implementation. It details the characteristics that define the complexity of a burning operation, and then summarizes the main points for preparing the plot, the human, material, and regulatory resources required. Then, it details the elements to consider before, during and after burning.

3.2.2.1 Site planning

The planning phase begins with a study of the characteristics of the area where prescribed burning is to be carried out. This stage is essential for drawing up the burning prescription and evaluating the results of the operation. It is carried out to (1) analyze the factors in the field, broken down by points, which make it possible, and (2) assess the complexity of a burning on the site. This initial diagnosis determines the burning team's ability to carry out the operation, and to formulate prescriptions for doing so in the safest possible conditions and within the regulatory framework set by the region.

Site selection, factors that influence the probability of success:

- Size.
- Shape.
- Type of fuel.
- Access.
- Values, issues.
- Operation costs.
- Burning limits.

Assessment of the complexity of the burning:

- Duration of the burning.
- Objectives of the burning.
- Size of the project.
- Resource requirements.
- Type of ignition.
- Potential for social disruption.
- Negative environmental values.
- Potential for fire escape.



Figure 44: Closing a unit.

Analysis of these factors leads to a diagnosis of the feasibility of the operation and the formulation of the safety measures to be implemented.
Formulation of prescriptions (area to be secured).

[1] NWCG Prescribed Fire Plan Template: https://www.nwcg.gov/publications/484, Prescribed Fire Complexity Rating System Guide: https://www.nwcg.gov/publications/424.

[2] CCME Guide sur le brûlage à ciel ouvert : https://ccme.ca/fr/res/guide_brulage_a_cielopenair_fr.pdf

3.2.2.2 Site preparation

Once the burning site has been chosen, the checklist recalls the elements to be prepared in the field, the size of the team and equipment required for the operation, and the preparation of administrative, regulatory, and technical aspects.

Preparation of the edges (fire break, lines) and response to the formulated prescriptions

The fire break must be at least 2 times the height of the vegetation to be burned. The vegetation in this area must be crushed to separate the plot from the surrounding vegetation. (Ex: grass of 1 m high, fire break at least 2 m wide).

Planning the resource requirements

- Personnel: Number of people at the ignition, holding, etc.
- Equipment: number of drip-torches, water resources and field positioning, etc.

Scheduling of the work

- Limits set by the regulations.
- Periods of prohibition.
- Weather conditions (wind, humidity...) desired on the day of the burning.
- Derogation request file.
- Integration in the pastoral management.
- If in Natura 2000 area, inform the sector coordinator.

3.2.2.3 Organization of controlled burning

Once planning and preparation have been completed, the burning area has been described, the burning objectives defined, the unit prepared and the requirements met, the checklist then details the important considerations for prescribed burning, before, during and after the operation.

The day before the prescribed burning

- Taking the weather forecast (of the day and after).
- Consult local website to find out about air pollution.
- Check before departure, people, equipment, consumables.
- Verification of authorized burning time slots.

The day of the prescribed burning

Before ignition

- Taking weather forecast.
- One hour before ignition, inform the dispatch (18 or 112), police (17), mayor.
- Reconnaissance of the site perimeter.
- Assessment of the wind in different sectors.

Team organization

- Reminder of individual and collective safety rules.
- Explanation of the plan in the event of a fire problem and personal injury.

- Explanation of the action plan.
- Distribution of positions between lighting, holding and logistics.
- Setting up the team, equipment and machines

Ignition

- Test ignition.
- Controlled burning of the plot.
- Respecting the boundaries of the plot.
- Balancing the ignition lines.
- Strategic position of the prescribed burning boss.
- Logistics coordination (fuel, water, food).
- Holding of possible fire escape.
- Reorganization of burning in the event of an incident.

End of burning

- Extinction before the end of the authorized burning time.
- Complete extinction of the edges.
- Reconnaissance of the site perimeter.
- Extension of holding (if necessary).
- Information to dispatch (18 or 112).
- Equipment reconditioning.

3.3 Final Considerations

During these two sessions of prescribed burning in the field, interspersed with an off-season during which the planning of burning operations was practiced, the trainees were able to acquire many skills necessary for the overall objective of "Technical and regulatory control of the integrated fire management". Seven sheep farmers and one cattle farmer took part in this training course in the Southern Alps. During the two training sessions, 4 days of practical work were carried out on units ranging in size from 0.2 to 1.3 ha. Inside these units, several ignitions and “little” prescribed burns were carried out, in order to acquire a good understanding of the different phases of a prescribed burn: from test ignition to the "closure" of a burn unit.

The skills covered and acquired also included: regulatory aspects, personnel safety, joint purchasing of equipment and mutual assistance between farmers, securing edges during burnings, site preparation, starting the fire, conducting the fire, ending the burning, monitoring and…practice.

Trainees' feedback on the course was very positive. Several comments stand out:

- A request for more detailed documentation on how to behave when setting fire and on fire management techniques (securing edges, determining the starting point of the burning, etc.).
    - There is a lot of documentation available, often in English, which is a problem for people who don't speak the language. The French documentation used for this training comes from training courses for professionals and institutional communication brochures, which can easily be found on the Internet. The theoretical material provided covers all the techniques to be acquired, with diagrams and videos, in as concise a manner as possible. To perfect the skills required for fire management, we have opted for a hands-on approach (rather than a theoretical one) by having students carry out five prescribed burnings. The documents provided, however, enable them to cover all the aspects involved in carrying

out a burning independently (2 report sheets, a planning-preparation-operations checklist sheet, regulatory documents from the authorities, etc.).

- Farmers consider the training to be short. In fact, compared with the 3-session training course for professionals, the training offered to breeders is short (5 days over 2 years).
    - This time constraint was decided upon, due to the difficulty of mobilizing breeders for longer than two consecutive days in France as elsewhere, because of the time constraints linked to a livestock farming activity. It was decided to spread the training over 2 seasons, with a first session of burning to get to know the technique and see how the fire behaves in the field. Farmers were then given time during the summer to think about their pastoral burning needs and plan one or more burning plots on their land. And finally, to give them time to prepare their plots before the burning (securing the edges of the plots, etc.).
- The need for technical support for future burnings: mastering the use of fire takes years and practice, so in the future, if they want to continue the activity on their own, breeders are advised to carry out technically simple burnings over small areas, in line with their technical capabilities, using good safety zones, such as tracks or agricultural meadows that have been grazed short, and above all to remain humble…

All participants agreed on the additional benefits of pastoral burning.
Pastoral burning offers parallel benefits, with multiple effects on ecosystems. In particular, in the French Alps they contribute to:

- Fire prevention by promoting a mosaic of landscapes with barrier areas and less potential fuel mass.
- Reduce the risk of avalanches by burning dry grasses that create a "slippery carpet" in winter.
- Reduce the risk of ice jams in the watercourses of the watersheds concerned (thereby reducing the associated risk of weakening bridges or flooding banks) by burning woody elements.
- Maintain an open environment.

In order to meet its primary objectives and parallel services, the maintenance of pastoral burning remains a major challenge. The gradual closure of environments through the abandonment of pastoral burning in turn favors the disappearance of livestock farming practices, characteristic of mountain areas. This practice is therefore one of the levers for sustaining pastoralism, which represents an important economic activity in the mountains.
Mountain tourism is also indirectly linked to pastoral practices. Pastoral activity is an asset for mountain tourism, since on the one hand it contributes to the attractive identity of mountain areas, and on the other it helps maintain a mosaic of landscapes and biodiversity. Tourism in the mountains plays a pivotal economic role for many working people, and the sector is perceived as having great potential (4-season tourism, etc.).
Although pastoral burning is fundamental to the management of mountain environments and economic activity, there are associated risks (fire propagation, increased local pollution, etc.). These risks are minimized by a regional organization that plans and supervises burnings, the key to their success.
Following these two sessions initiated by the FirEUrisk project, the CERPAM breeding syndicate is keen to make this type of training permanent. A request for financial support has been made to the departmental council for the following years, distinguishing between two types of training: initial training such as that carried out as part of this project, and consolidation training for trainees who have already completed the first training course or who have already carried out burnings.
This willingness to continue training in the years to come alone demonstrates the interest and need in the field to master the fire tool for pastoral management of mountain environments. A replication of this training course is already possible in France, but for better dissemination, this training would require formalization and validation to French standards known as Qualiopi. Replication in other countries will depend largely on the interest of farmers, the

regulatory possibility of using fire, and the availability of local expertise to bridge the gap between international expertise and local knowledge.

4 Conclusions

In Mediterranean areas, fire has been a key element for land management for agricultural, forest, pastoral and hunting purposes, and has shaped landscapes, agricultural and forest ecosystems. After the second half of the XX century, the rapid socio-economic changes, with significant variations in land uses and landscape patterns, and the role played by fire-exclusion policies, led to progressive increases in fuel continuity and load, afforestation of areas previously devoted to agro-silvo-pastoral productions, and loss of the traditional burning practices. The growing abandonment of agro-silvo-pastoral activities and the lack of management in Mediterranean wildlands, in conjunction with climate change, is leading to a rise in the occurrence of large and severe wildfires, as those happened in the most recent fire seasons in Europe (e.g.: 2017; 2021; 2022) (Wunder et al. 2021; Fernandes 2022; Salis et al. 2022; Pulido et al. 2023). In recent years, changing paradigms in wildfire and land management and in nature conservation are reconsidering the important and functional role played by controlled low-intensity fires in the management of ecosystems and landscapes and in the reduction of wildfire hazard and risk. In this context, the prescribed burning experiences carried out in Sardinia and French Alps within the FirEUrisk project highlighted the potential and usefulness of the use of fire as a tool in agro-pastoral and rural areas. Apart from the differences in legislation and operational organization among EU Countries, the definition and execution of training sessions of controlled fires in the study areas allowed to improve dialogue and communication between stakeholders and land/wildfire managers and local communities and goes in the direction of creating more sustainable landscapes and policy frameworks. In the study areas, as well as in the whole Mediterranean context, there is a growing interest in the potential of the use of fire as a management tool: this Deliverable summarizes the main aspects of the prescribed burning experiences and training courses carried out and serves as basis for the replication of similar experiences in other areas.

In Sardinia, the training covered prescribed fire applications by the Sardinia Forest Service personnel in a variety of conditions, from agro-pastoral and agroforestry environments to WUIs, with operational trainings conducted in the field. This field activity is carried out after specific courses, organized periodically by the Sardinia Forest Service, that cover wildfire spread and behavior analysis, firefighting, and the use of fire as a tool (prescribed fires, backfires, etc.). The implementation windows of the application of prescribed fires are variable depending on a number of factors, which mainly relate to the objective of the prescribed fires, the bioclimatic conditions of the area, and the specific weather conditions of a given year. Generally speaking, for the cases presented in this Deliverable, interventions have been conducted and are generally conducted in the spring or fall in the contexts of WUIs (Nuoro, Bonorva), just before the fire season to reduce herbaceous fuel loads under Quercus forests (Isili), and just before autumn rains, around early September (Suni). The key point is to comply with the regulations defined in the specific prescribed fire plans regarding weather conditions, so that the prescribed fire is carried out under moderate weather and low-fire intensity conditions. Farmers have been educated to facilitate the Sardinia Forest Service interventions and to conduct preventive measures and controlled fires on their own, under fully safe conditions and within the allowed windows. The training presented in this report has involved about 200 Forest Service workers; dozens of farmers have been involved in Suni's activities.

In France, following on from this training project, the CERPAM livestock syndicate intends to promote a series of training courses for livestock farmers. A project proposal has been made to seek funding from the departmental council and the Chamber of Agriculture.
This project would comprise two levels of training.

- Initial training based on the organization developed during the FirEUrisk project. This training would comprise 5 days divided into two sessions. The first session would cover the theory and regulations required for practical use and will include a prescribed burn session. The second session would be dedicated by carrying out several

burns. Between these two sessions, a period would be devoted to planning a burn on one's own land and preparing a unit for burning (land and administrative documents).

- Consolidation training for stock farmers who have taken the initial training course. This training would consist of five days of prescribed burning, preceded by a phase of planning and preparation of the units to be burned, carried out in consultation between the farmers and the trainers.

In France, a training course of this type is possible because the legislative framework authorizes the practice of prescribed burning for landowners. It can be replicated in the same configuration with farmers in other regions, adapting the regulatory part to the departmental context. For replication in other countries, adaptation to the regulatory context have to be done, and the agronomic objectives would have to be adjusted to the local context. The application and management of prescribed burning in the field would remain the same whatever the context is.

5 References

Alexandrian, D., Chautrand, L., & Delabraze, P. (1980). Prescribed fire study tour. Forêt Méditerranéenne, 2(2), 229-236.

Almeida, M., Ribeiro, L.M., Alves, D., Viegas, D.X., …, Suarez-Moreno, M. (2023). Analysis of 2021 critical wildfire events in the Mediterranean region, Publications Office of the European Union, Luxembourg. doi:10.2760/562495, JRC133972.

Ascoli, D., Catalanotti, A., Valese, E., Cabiddu, S., Delogu, G., Driussi, M., Esposito A, Leone V, Lovreglio R, Marchi E, Mazzoleni S, Rutigliano FA, Strumia S, Bovio, G. (2012). Esperienze di fuoco prescritto in Italia: un approccio integrato per la prevenzione degli incendi boschivi. Forest@-Journal of Silviculture and Forest Ecology, 9(1), 20.

Barbati, A., Corona, P., D'Amato, E., & Cartisano, R. (2015). Is landscape a driver of short-term wildfire recurrence? Landscape Research, 40(1), 99-108.

Bill 6303/2000 (https://leg13.camera.it/docesta/313/15804/documentotesto.asp?PDL=6303&leg=13&tab=2)

Botelho, H., Fernandes, P., Rigolot, E., Rego, F., Guarnieri, F., Bingelli, F., Vega, J.A., Prodon, R., Molina, D., Gouma, V., Leone, V. (2002). Main outcomes of the Fire Torch project: a management approach to prescribed burning in Mediterranean Europe. In Forest fire research and wildland fire safety: Proceedings of IV International Conference on Forest Fire Research 2002 Wildland Fire Safety Summit, Luso, Coimbra, Portugal, 18-23 November 2002. Millpress Science Publishers.

Bovio, G., & Ascoli, D. (2012). Fuoco prescritto: stato dell'arte della normativa italiana. L'Italia Forestale e Montana, 67(4), 347-358.

Buresti, E., & Sulli, M. (1983). Is the fire a cultural tool? Annali dell'Istituto Sperimentale per la Selvicoltura, Arezzo (Italy).

Calabri, G. (1981). Il fuoco prescritto, una discussa tecnica per la gestione dei boschi. Montanaro d'Italia Monti e Boschi, 32.

Calabri, G. (1988). L'introduction du brûlage contrôlé en Italie. In: Proceedings of the Atelier sur le brûlage contrôlé. Avignon, 14-18 Mars. INRA-FAO-IUFRO.

Casau, M., Dias, M. F., Teixeira, L., Matias, J. C., & Nunes, L. J. (2022). Reducing rural fire risk through the development of a sustainable supply chain model for residual agroforestry biomass supported in a web platform: a case study in Portugal Central Region with the Project BioAgroFloRes. Fire, 5(3), 61.

CCME Guide sur le brûlage à ciel ouvert: https://ccme.ca/fr/res/guide_brulage_a_cielopenair_fr.pdf

Chuvieco, E., Yebra, M., Martino, S., Thonicke, K., Gómez-Giménez, M., San-Miguel, J., Oom, D., Velea, R.,…, Viegas, D. (2023) Towards an Integrated Approach to Wildfire Risk Assessment: When, Where, What and How May the Landscapes Burn. Fire, 6(5), 215. https://doi.org/10.3390/fire6050215

Circular DGFAR / SDFB / C2004-5033 and DGER / SDFP / C2004-2009 of August 31, 2004, on the training and validation of the achievements of those responsible for the prescribed burning and / or incineration (http://agriculture.gouv.fr/sites/minagri/files/documents//dgfarc20045033z.pdf).

Colonico, M., Tomao, A., Ascoli, D., Corona, P., Giannino, F., Moris, J. V., Salvati, L., Barbati, A. (2022). Rural development funding and wildfire prevention: Evidences of spatial mismatches with fire activity. Land Use Policy, 117, 106079.

Coughlan, M.R. (2016). Wildland Arson as Clandestine Resource Management: A Space–Time Permutation Analysis and Classification of Informal Fire Management Regimes in Georgia, USA. Environmental Management. 57 (5), 1077-1087.

Dumez, R. (2010). Le feu, savoirs et pratiques en Cévennes. Le feu, savoirs et pratiques en Cévennes, 1-248.

Fernandes, P.M. (2019). Variation in the Canadian fire weather index thresholds for increasingly larger fires in Portugal. Forests, 10(10), 838.

Fernandes, P.M. (2022). Make Europe's forests climate-smart and fire-smart. Nature, 609(7925), 32.

Fernandes, P.M., Davies, G.M., Ascoli, D., Fernandez, C., Moreira, F., Rigolot, E., Stoof, C. R., Vega, J.A., Molina, D., (2013) Prescribed burning in southern Europe: developing fire management in a dynamic landscape. Frontiers in Ecology and the Environment 11, e4–e14. https:// doi. org/ 10.1890/ 120298

Fernandes, P.M., Rossa, C.G., Madrigal, J., Rigolot, E., Ascoli, D., Hernando, C., Guiomar N.G., Guijarro, M. (2022). Prescribed burning in the European Mediterranean Basin. Global Application of Prescribed Fire, 1st ed.; CRC Press: Boca Raton, FL, USA, 230-248.

Ganteaume, A., Camia, A., Jappiot, M., San-Miguel-Ayanz, J., Long-Fournel, M., Lampin, C. (2013). A Review of the Main Driving Factors of Forest Fire Ignition Over Europe. Environmental Management 51, 651–662.

Gleason, P. (2005). Pollution response during national special security events: striking a balance between security and response. In International Oil Spill Conference (Vol. 2005, No. 1, pp. 943-948). American Petroleum Institute. GLEASON, P. LCES - a key to safety in the wildland fire environment. Fire Management Notes, v. 54, p. 9, 1991

He, T., Lamont, B.B., & Pausas, J.G. (2019). Fire as a key driver of Earth's biodiversity. Biological Reviews, 94, 1983–2010. https://doi.org/10.1111/brv.12544

Hiers, J.K., O'Brien, J.J., Varner, J.M. et al. (2020). Prescribed fire science: the case for a refined research agenda. fire ecol 16, 11. https://doi.org/10.1186/s42408-020-0070-8

Honrado, J.P., Lomba, A., Alves, P., Aguiar, C., Monteiro-Henriques, T., Cerqueira, Y., Monteiro, P., Barreto Caldas, F. (2017). Conservation management of EU priority habitats after collapse of traditional pastoralism: navigating socioecological transitions in mountain rangeland. Rural Sociology, 82(1), 101-128.

Italia-Francia Marittimo Program, MED-Star project (https://interreg-maritime.eu/it/web/pc-marittimo/home)

Lazaro, A., & Montiel, C. (2010). Overview of prescribed fire policies and practices in Europe and other countries. In: Silva, J.D., Rego, F., Fernandes, P., Rigolot, E. (Eds.) Towards integrated Fire Management - Outcomes of the European Project Fire Paradox, European Forest Institute, Joensuu, pp. 137-149.

Legislative Decree 120/2021 "Disposizioni per il contrasto degli incendi boschivi e altre misure urgenti di protezione civile. (21G00130)" (https://www.normattiva.it/uri-res/N2Ls?urn:nir:stato:decreto.legge:2021-09-08;120)

Leone, V., Signorile, A., Gouma, V., Pangas, N., Chronopoulous-Sereli, A. (1999). Obstacles in prescribed fire use in Mediterranean countries: early remarks and results of the Firetorch project. In: Proc. Int. Symp. on Forest Fires: Needs and Innovations, Cinar S.A., Athens, pp. 132–136.

Liacos, L.G. (1973). Present studies and history of burning in Greece. In Proceedings of the 13th annual tall timbers fire ecology conference, Tallahassee.

Loi 2023-580 "Loi n° 2023-580 du 10 juillet 2023 visant à renforcer la prévention et la lutte contre l'intensification et l'extension du risque incendie" (https://www.legifrance.gouv.fr/dossierlegislatif/JORFDOLE000047409881/)

Loi d'Orientation Forestière (2001) LOI n° 2001-602 du 9 juillet 2001 d'orientation sur la forêt (https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000000223691/)

Mancini, L.D., Corona, P., Salvati, L. (2018). Ranking the importance of wildfires' human drivers through a multi-model regression approach. Environmental Impact Assessment Review, 72, 177-186.

Massaiu, A. (1999). Il fuoco come tecnica di gestione territoriale. Applicazione di fuoco prescritto in Sardegna. MSc Degree Thesis, Università di Firenze.

McLauchlan, K.K., Higuera, P.E., Miesel, J., Rogers, B.M., Schweitzer, J., Shuman, J.K., Tepley, A.J., Varner, J.M., Veblen, T.T., et al. (2020). Fire as a fundamental ecological process: Research advances and frontiers. The Journal of Ecology, 108(5), 2047–2069. https://doi.org/10.1111/1365-2745.13403

Meira Castro, A.C., Nunes, A., Sousa, A., Lourenço, L. (2020). Mapping the causes of forest fires in Portugal by clustering analysis. Geosciences, 10(2), 53.

Miezïte, L. E., Ameztegui, A., De Cáceres, M., Coll, L., Morán-Ordóñez, A., Vega-García, C., Rodrigues, M. (2022) Trajectories of wildfire behavior under climate change. Can forest management mitigate the increasing hazard? Journal of Environmental Management 322, 116134

Molina, J.R., González-Cabán, A., Rodríguez y Silva, F. (2019). Potential Effects of Climate Change on Fire Behavior, Economic Susceptibility and Suppression Costs in Mediterranean Ecosystems: Córdoba Province, Spain. Forests, 10(8), 679; https://doi.org/10.3390/f10080679

Moreira, F., Ascoli, D., Safford, H., Adams, M.A., Moreno, J. M., Pereira, J.M., Catry, F.X., Armesto, J., Bond, W., Gonzaléz, M.E., Curt, T., Koutsias, N., McCaw, L., Price, O., Pausas J., Rigolot, E., Stephens, S., Tavsanoglu, C., Vallejo, V. R., Van Wilgen, B.W., Xanthopoulos, G., Fernandes, P.M. (2020). Wildfire management in Mediterranean-type regions: paradigm change needed. Environmental Research Letters, 15(1), 011001.

Moreira, F., Viedma, O., Arianoutsou, M., Curt, T., Koutsias, N., Rigolot, E., et al. (2011). Landscape – wildfire interactions in southern Europe: implications for landscape management. Journal of Environmental Management 92, 2389–2402. doi: 10.1016/j.jenvman.2011.06.028

National Law No. 155/2021 (https://www.normattiva.it/uri-res/N2Ls?urn:nir:stato:legge:2021-11-08;155)

National Law No. 353/2000 "Legge-quadro in materia di incendi boschivi" (https://www.parlamento.it/parlam/leggi/00353l.htm)

NWCG Prescribed Fire Plan Template: https://www.nwcg.gov/publications/484, Prescribed Fire Complexity Rating System Guide: https://www.nwcg.gov/publications/424.

Oliveira, E., Fernandes, P.M., Barros, D., & Guiomar, N. (2023). Unraveling the Effect of Fire Seasonality on Fire-Preferred Fuel Types and Dynamics in Alto Minho, Portugal (2000–2018). Fire, 6(7), 267.

Parente, J., Pereira, M. G., Amraoui, M., & Tedim, F. (2018). Negligent and intentional fires in Portugal: Spatial distribution characterization. Science of the Total Environment, 624, 424-437

Pausas, J.G., Llovet, J., Rodrigo, A., Vallejo, R. (2008) Are wildfires a disaster in the Mediterranean basin? – A review. International Journal of Wildland Fire 17, 713-723. https://doi.org/10.1071/WF0715

Pausas, J.G., Vallejo, V.R. (1999). The role of fire in European Mediterranean ecosystems. In: Chuvieco, E. (eds) Remote Sensing of Large Wildfires. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-60164-4_2. https://doi.org/10.1007/978-3-642-60164-4_2

POA 2020 Operational Management Objective Program (https://www.mase.gov.it/pagina/piano-operativo-lambiente)

Pulido, F., Corbacho, J., Bertomeu, M., Gómez, Á., Guiomar, N., Juárez, E., Lucas, B., Moreno, G., Navalpotro, J., Palomo, G. (2023). Fire-Smart Territories: a proof of concept based on Mosaico approach. Landscape Ecology, 1-18.

Pyne, S.J., Andrew, P.L., Laven, R.D. (1996). Introduction to wildland fire (2nd ed.). New York: John Wiley & Sons, Inc.

Regional Environmental Forestry Plan (PFAR) 2007 (https://www.sardegnaforeste.it/article/piano-forestale-ambientale-regionale)

Regional Law Basilicata No. 13/2005 "Norme per la protezione dei boschi dagli incendi" (https://www.ambientediritto.it/Antincendio/incendi%20lex/basilicata_lr2005_n.13.htm)

Regional Law Piedmont No. 16/1994 "Interventi per la protezione dei boschi dagli incendi" (http://arianna.consiglioregionale.piemonte.it/ariaint/TESTO?LAYOUT=PRESENTAZIONE&TIPODOC=LEGGI&LEGGE=16&LEGGEANNO=1994)

Regional Law Sardinia No. 8/2016 "Legge forestale della Sardegna". (https://buras.regione.sardegna.it/custom/frontend/viewInsertion.xhtml?insertionId=7d36f04a-e552-48fd-adc6-4bd912e574d1)

Salis, M., Del Giudice, L., Jahdi, R., Alcasena-Urdiroz, F., Scarpa, C., Pellizzaro, G., Bacciu, V., Schirru, M., Ventura, A., Casula, M., Pedes, F., Canu, A., Duce, P., Arca, B. (2022). Spatial patterns and intensity of land abandonment drive wildfire hazard and likelihood in Mediterranean agropastoral areas. Land, 11(11), 1942.

San-Miguel-Ayanz, J., Durrant, T., Boca, R., Maianti, P., Liberta`, G., Jacome Felix Oom, D., Branco, A., De Rigo, D., Suarez-Moreno, M., Ferrari, D., Roglia, E., Scionti, N., Broglia, M., Onida, M., Tistan, A. and Loffler, P. (2023). Forest Fires in Europe, Middle East and North Africa 2022, Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/871593, JRC135226.

Scott, J.H., & Burgan, R.E. (2005). Standard fire behavior fuel models: a comprehensive set for use with Rothermel's surface fire spread model. Gen. Tech. Rep. RMRS-GTR-153. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 72 p.

Seijo, F., Gray, R. (2012). Pre-industrial anthropogenic fire regimes in transition: the case of Spain and its implications for fire governance in Mediterranean type biomes. Human Ecology Review, 58-69.

Technical Fire Regulation, annexed to Order no. 7511/2014 "Despacho 7511/2014, de 9 de Junho" https://dre.tretas.org/dre/317418/despacho-7511-2014-de-9-de-junho)

Viegas, D.X., Almeida, M.F., Ribeiro, L.M., Raposo, J., Viegas, M.T., Oliveira, R., Alves, D., Pinto, C., Jorge, H., Rodrigues, A., Lucas, D., Lopes, S., Silva, L.F. (2017). O complexo de incêndios de Pedrógão Grande e concelhos limítrofes, iniciado a 17 de junho de 2017. Technical Report. Forest Fire Research Center, Association for the Development of Industrial Aerodynamics, University of Coimbra. [The complex of fires of Pedrógão Grande and bordering counties, begun on June 17, 2017 - written in Portuguese]

Wunder, S., Calkin, D.E., Charlton, V., Feder, S., de Arano, I.M., Moore, P., Rodríguez Y Silva F, Tacconi L, Vega-García, C. (2021). Resilient landscapes to prevent catastrophic forest fires: Socioeconomic insights towards a new paradigm. Forest Policy and Economics, 128, 102458.

https://firenetworks.org/trex/?fbclid=IwAR0aO_rN5OnWt2muf-5CAlsu5zyc6rVH16M8tpRPIke-WiIr3qdxmZfSDpE