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Handbook to Plan and Use Prescribed Burning in Europe





Handbook to Plan and Use Prescribed Burning in Europe



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Abbreviations

M – dead fine (1hr) fuel moisture content (%)

Codes of the Canadian Forest Fire Weather Index System

FFMC – Fine Fuel Moisture Code

DMC – Duff Moisture Code

DC – Drought Code

FWI – Fire Weather Index

Introduction

Prescribed burning is the planned application of fire to achieve forest and wildland management goals. The practice of prescribed burning demands skills and experience and is always under public scrutiny. The wise use of fire should maximize the benefits of burning while avoiding or minimizing its negative impacts. Consequently, prescribed burning is framed by land management goals and site-specific treatment objectives and is conditioned by both environmental and social restrictions. The decision-making and planning process can thus benefit from decision-support tools that are expected to expand and strengthen the technical proficiency of the practitioners.

The inception and adoption of prescribed burning by managers and management organizations is relatively new in Europe and dates back to the early 1980s. The use of prescribed burning is geographically restricted and its potential to manage wildlands is still largely unfulfilled, especially in forested areas. The political and socio-economic environment is decisive, but there is a need for more basic knowledge and operational guidelines to assist prescribed burning programs. The FIRE PARADOX project directed most of its effort to technological development, training and dissemination. As one of the outcomes, this handbook compiles, organizes and synthesizes the information — both qualitative and quantitative — relevant to burning prescriptions in European ecosystems, i.e. the conditions desired for the burn and that will fulfil the pre-defined treatment objectives.

The conceptual framework to plan, carry out and evaluate a burn operation in Figure 1 is implicit in the handbook. Knowledge that was dispersed or needed to be formalized is aggregated and digested. The handbook has been developed by:

1. Examining the available technical information, i.e. burning guides and best practices (e.g. Vega et al. 2001, Fernandes et al. 2002, Scottish Executive Environment and Rural Affairs Department 2008).
2. Collecting prescriptions from the agencies and individuals involved in prescribed burning management or research in Europe.

- 3. Collecting information from the FIRE PARADOX prescribed burning demonstration sites.
- 4. Using models of fire behaviour and effects to generate burn prescriptions to achieve more generic or more specific treatment goals.

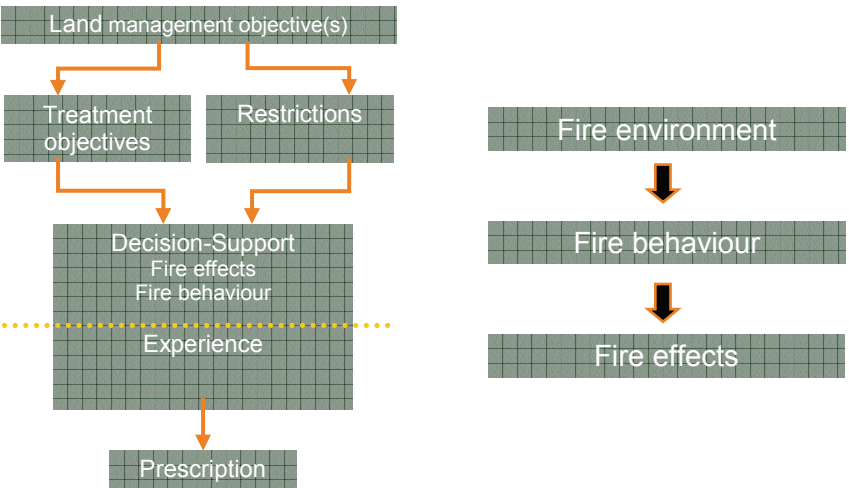


Figure 1. Framework to plan prescribed fire, or towards a more exact use of fire.

The handbook gathers prescriptions from all around Europe, from sub-tropical (Canary Islands) to boreal (Sweden) environments. The information is organized and presented in a hierarchy that considers vegetation type, country or region, and management objective. Most data respects to the application of fire to decrease fuel hazard or to manage habitats for pastoral or nature conservation purposes in diverse types of shrubland and pine woodland. Included in the handbook are ranges for the desired weather and moisture conditions and fire behaviour and effects, as well as ignition patterns and the return interval

for the treatments. Two types of prescriptions are presented, respectively:

- to achieve a broad goal, e.g. renew pastures;
- or to attain a specific treatment objective, usually defined in quantitative terms, e.g. reduce fuel load by 70%.

The technological solutions to plan prescribed fire operations vary across Europe. General burning windows consisting of ranges in weather conditions or in fire danger rating indexes (like in Sweden, Germany and Portugal) are commonplace. In Catalonia, Spain, six standard prescriptions are individualized based on fuel availability and wind speed. USDA Forest Service fire simulation tools are used in Spain and Portugal to prepare site-specific prescriptions, which include sets of values (minimum, preferred, maximum) for weather conditions, fuel moisture contents, fire behaviour characteristics and selected fire effects. In Portugal, the PiroPinus tool (Fernandes 2003) was developed to assist in planning and evaluating the results of prescribed underburning in maritime pine (*Pinus pinaster*) stands.

Prescribed burning practitioners are the main target of the 'Handbook to Plan and Use Prescribed Burning in Europe' and can benchmark their practice against the recommendations, familiarize with and try prescriptions developed elsewhere for the same objective and provide input towards improvement and refinement. In the course of exchanges between regions and countries, this handbook is expected to constitute a rapid reference guide for the 'outsiders'. Educational organizations and environmental consultants will also benefit. The handbook will naturally find application in prescribed burning training and outreach, and can provide a framework to plan research on fire ecology topics. We expect that this handbook will contribute both to disseminate and to improve the wise use of fire across Europe.



Generic types of prescribed burning windows

Generic types of prescribed burning windows		
Country / Region	Spain / Catalonia	
Type of burning	Pile burning	
Fuel availability	Wind	Relative humidity
Coarse (10hr) fuels only. The availability of both the finer (1hr) and thicker (100hr) fuels is nil or very low.	Moderate (5-25 km hr ⁻¹)	40-80%
Remarks	After very small amounts of rainfall in the previous day, fog or dew. Phenology: in the dormant or near-dormant season.	
Type of burning	Underburning of forest stands with a well-developed shrub layer	
Fuel availability	Wind	Relative humidity
Fine (1hr) fuels only. The availability of thicker dead fuels and live fuels is low.	Moderate (5-25 km hr ⁻¹)	30-65%
Remarks	A sequence of some wet days followed by a few dry days is required. The window will be closed with very small amounts of rainfall in the previous day, fog or dew. Phenology: in the dormant or near-dormant season.	

Type of burning		Underburning of forest stands with low or scattered shrubs	
Fuel availability	Wind	Relative humidity	
Fine (1hr) and coarse (10hr) fuels.	Calm ($< 5 \text{ km hr}^{-1}$)	30-90% when the litter is deep	
	Moderate ($5\text{-}15 \text{ km hr}^{-1}$)	25-55% when main fine fuel are herbs	
Remarks		A sequence of rainless days allows the forest floor to dry. Not in spring if herbs are abundant. Preferably in early summer.	
Type of burning		Stubble, grassland, shrubland	
Fuel availability	Wind	Relative humidity	
Fine (1hr) fuels	Indifferent ($< 20 \text{ km hr}^{-1}$)	35-90% when fine fuels are mainly tall herbs	
		30-70% in other cases	
Remarks		The window is defined by the absence of recent rain and the existence of cured herbs. Depending on phenology, in late spring and summer and in some winters (in coastal Mediterranean areas), and in winter and early spring, depending on snow (in more continental or higher areas).	

Vegetation type
<i>Pinus pinaster</i>
Management objective
Hazard reduction
Country
Portugal

Prescription elements	Range	Optimum
Burn season ^a	Oct. - April	Mid Nov. - mid Feb.
Fire return interval (yrs.)		2 - 4
Weather-related variables		
▪ Wind speed (km hr ⁻¹)	1 - 12	3 - 6
▪ Air temperature (°C)	≤ 20	< 13
▪ Relative humidity (%)	≥ 24	31 - 78
▪ No. days since rain	2 - 28	4 - 12
Dead fuel moisture (%)		
▪ Surface litter/elevated fine	12 - 45 ^b	15 - 21
▪ Lower (decomposing) litter	≥ 100	≥ 150
▪ FFMC	≥ 70	≥ 83 ^c
▪ DMC	< 30	≥ 10 ^d
FWI	< 17	≥ 3 ^c
Ignition pattern	Backing ^b , Strip-head ^e , Point ignition.	

Fire behaviour	Range	Optimum
Rate of spread (m hr ⁻¹)	5 - 160	10 - 50
Flame length (m)	0.2 - 1.3	0.5 - 1.1
Byram's fire intensity (kW m ⁻¹)	10 - 500	50 - 150

Observations and supplementary information

^a Extending the burn season into Spring is thought to increase the likelihood of infestation by bark beetles and the susceptibility to crown scorch.

^b The likelihood of unsustainable, marginal backfire spread increases for values >22%, subject to variation in the surface fuel complex.

^c Threshold for optimum (non-marginal) fire spread.

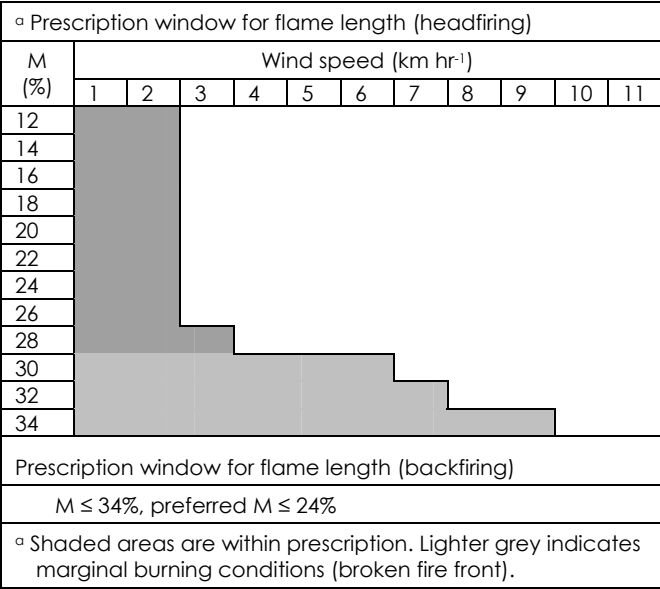
^d Threshold for optimum fuel consumption.

^e Should not be used when the moisture content of surface litter/elevated fine fuels is <21%.

The prescription is valid for litter-, grass/fern- or shrub-dominated (*Erica* spp., *Pterospartium tridentatum*, *Ulex* spp.) understorey.

Vegetation type
Pinus pinaster
Management objective
Hazard reduction
Treatment restrictions
crown scorch ratio < 0.30; lower litter consumption <50%
Country / Region / Site
Portugal/ Trás-os-Montes/ Padrela

Maximum allowed flame length (m)			
		Wind speed (km hr ⁻¹)	
		0	12
Temperature (°C)	0	1.5	2.2
	20	0.6	1.3



Lower litter moisture content (%)	≥ 105
^a DMC	≤ 26

Ignition pattern	Back, strip-head
------------------	------------------

Observations and supplementary information

Second fire treatment. Stand age = 25 yrs.; stand height = 10 m; crown base height = 3.7 m; mean dbh = 13.0 cm; stand density = 2458 trees ha⁻¹. Fuel complex dominated by litter and a shrub layer of *Pterospartium tridentatum* and *Erica umbellatta*. Surface fine fuel load = 24.4 t ha⁻¹.

^a Corresponds to the value of lower litter moisture content assuming a slow drying rate after rainfall.



Vegetation type
Pinus pinaster
Management objective
Hazard reduction, thinning from below
Treatment restrictions
crown scorch ratio < 0.60 (dominant trees); minimize mortality in the (co)dominant tree strata; lower litter consumption <25%
Country / Region / Site
Portugal/ Trás-os-Montes/ Alvão

Maximum allowed flame length (m)			
		Wind speed (km hr ⁻¹)	
		0	12
Temperature (°C)	0	1.4	2.1
	20	0.5	1.2

Prescription window for flame length (headfiring)												
M (%)	Wind speed (km hr ⁻¹)											
	1	2	3	4	5	6	7	8	9	10	11	12
12												
14												
16												
18												
20												
22												
24												
26												
28												
30												
32												
34												
36												
38												

Prescription window for flame length (backfiring)
$M \leq 24\%$
^a Shaded areas are within prescription. Lighter grey indicates marginal burning conditions (conducive to broken fire front).

Lower litter moisture content (%)	≥ 178
^a DMC	≤ 12

Ignition pattern	Back, strip-head
------------------	------------------

Observations and supplementary information
Naturally regenerated stand, age = 14 yrs.; stand height = 7.8 m; crown base height = 1.7 m; mean dbh = 11.0 cm; stand density = 1520 trees ha ⁻¹ . Fuel complex dominated by litter and ferns, with scattered shrubs (<i>Pterospartium tridentatum</i> , <i>Erica umbellata</i> , <i>Ulex minor</i>). Surface fine fuel load = 12.1 t ha ⁻¹ .
^a Corresponds to the value of lower litter moisture content assuming a slow drying rate after rainfall.

Vegetation type
<i>Pinus pinaster</i>
Management objective
Hazard reduction
Treatment objective
Surface fuel reduction $\approx$ 80%
Country / Region / Site
Spain / Galicia / Val de Nacedo

Prescription elements	Range	Optimum
Weather-related variables		
▪ Wind speed (km hr ⁻¹)	0 - 10	3 - 5
▪ Air temperature (°C)	6 - 18	10 - 12
▪ Dew point temperature (°C)		5 - 10
▪ Relative humidity (%)	> 30	45 - 60
Dead fuel moisture (%)		
▪ Surface litter/elevated fine	$\geq$ 5	10 - 25
▪ Lower (decomposing) litter	$\geq$ 25	40 - 75
▪ Humus	$\geq$ 60	85 - 100

Ignition pattern	Strip-head, lines 1-5 m apart
-------------------------	-------------------------------

Fire behaviour	Range	Optimum
Rate of spread (m hr ⁻¹)	$\leq$ 300	90 - 180
Flame length (m)	< 2	1 - 2

Observations and supplementary information
4th fire treatment. Stand height = 13 m; stand density = 516-635 trees.ha ⁻¹ . Fuel complex dominated by litter with scattered Mediterranean shrubs (<i>Quercus suber</i> , <i>Cistus populifolius</i> , <i>C. ladanifer</i> , <i>Arbutus unedo</i> , <i>Lavandula stoechas</i> , <i>Daphne gnidium</i>).

Vegetation type
<i>Pinus pinaster</i>
Management objective
Hazard reduction
Treatment objective:
To eliminate 75% of fine (1hr) fuels and 50% of 10hr fuels
Country / Region / Site
Spain / Castilla-la-Mancha / MUP n.º 10 Sierra Alta, Collado Brezal

Prescription elements	Range	Optimum
Weather-related variables		
▪ Wind speed (km hr ⁻¹)	0 - 30	10
▪ Air temperature (°C)	18 - 26	20
▪ Relative humidity (%)	30 - 70	40
▪ Cloud cover	0 - 100	60
Fuel moisture (%)		
▪ 1hr	7 - 14	10
▪ 10hr	10 - 20	14
▪ 100hr	70 - 150	100

Ignition pattern	Point, strip-head
------------------	-------------------

Fire behaviour	Range	Optimum
Rate of spread (m hr ⁻¹)	6 - 60	30
Flame length (m)	0.2 - 0.8	0.4

Observations and supplementary information
30-year old stand, with pruning and shrub (<i>Erica arborea</i>) slash.

Vegetation type
<i>Pinus nigra</i>
Management objective
Hazard reduction, range management
Country / Region / Site
Spain / Catalonia/ Tremp, La Vileta

Prescription elements	Range	Optimum
Weather-related variables		
▪ Wind speed (km hr ⁻¹)	2 - 5	4
▪ Air temperature (°C)	12 - 20	16
▪ Relative humidity (%)	32 - 55	40
Fuel moisture (%)		
▪ 1hr	6 - 10	8
▪ 10hr	8 - 12	10
▪ 100hr	10 - 14	12
▪ Live herbs	80 - 125	90
▪ Live shrubs	90 - 140	115

Ignition pattern	Strip-head
-------------------------	------------

Fire behaviour	Range	Optimum
Rate of spread (m hr ⁻¹)	60 - 180	90
Flame length (m)	0.3 - 1.0	0.6

Observations and supplementary information
30-year old stand with scattered shrubs and an important herb layer.

Vegetation type
<i>Pinus canariensis</i>
Management objective
Hazard reduction, biodiversity
Country / Region / Site
Spain / Canary Islands / Pico de la Gorra, San Mateo

Prescription elements	Range	Optimum
Weather-related variables		
▪ Wind speed (km hr ⁻¹)	2 - 25	15
▪ Air temperature (°C)	5 - 26	15
▪ Relative humidity (%)	35 - 65	45
Fuel moisture (%)		
▪ 1hr	5 - 10	7
▪ 10hr, 100hr	7 - 15	10

Ignition pattern	Back, flank
------------------	-------------

Fire behaviour	Range	Optimum
Rate of spread (m hr ⁻¹)	6 - 120	30
Flame length (m)	0.3 - 1.5	0.5

Observations and supplementary information
Stand with pruning and shrub (<i>Tellina microphylla</i> , <i>Adenocarpus foliolosus</i>) slash.

Vegetation type		
<i>Pinus sylvestris</i>		
Management objective		
Conservation, restoration		
Specific Management objective		
Change forest structure to a more open condition; change forest composition towards pine-dominated or broadleaved-dominated		
Country / Region		
Sweden / Vasternorrland		

Prescription elements	Range	Optimum
Burn season	June-August	Variable ^a
Fire return interval (yrs.)	40 - 60	
Weather-related variables		
▪ Wind speed (km hr ⁻¹)	2 - 35	7 - 18
▪ Air temperature (°C)	18 - 30	<25
▪ Relative humidity (%)	≥ T	> 35
▪ FFMC	80 - 90	
▪ DMC	20 - 65	^a

Fire behaviour	Range	Optimum
Rate of spread (m hr ⁻¹)	10 - 500	50
Flame height (m)	0.3 - 4	0.7
Byram's fire intensity (kW m ⁻¹)	10 - 20 000	300

Ignition pattern	Point ignition, strip-headfire
------------------	--------------------------------

Observations and supplementary information
^a Late season burns, i.e. drier conditions are preferred when achieving <i>Picea abies</i> mortality is a priority.

Vegetation type		
<i>Eucalyptus globulus</i>		
Management objective		
Hazard reduction		
Country / Region		
Spain / Galicia		
Prescription elements	Optimum	
Weather-related variables		
▪ Wind speed (km hr ⁻¹)	3 - 10	
▪ Air temperature (°C)	≈10	
▪ Relative humidity (%)	≈50	
▪ No. days since rain	4 – 12 ^a	
Ignition pattern	Backing, strip-head	
Fire behaviour	Range	Optimum
Flame length (m)	< 1.0	
Byram's fire intensity (kW m ⁻¹)	< 200 ^b	< 150 ^c
Observations and supplementary information		
^a Number of days required for sustained fire spread.		
^b Sprouting from the stem expected in up to 25% of the trees with dbh < 5 cm.		
^c Sprouting from the stem restricted to trees of dbh < 5 cm.		
Prescription based in experimentation carried during the Spring in 11-19 year-old stands, generally with heavy understorey fuel loads and a tall shrub layer. Cambium kill (wounds) in the lower stem seldom occurs for dbh > 10 cm.		

Vegetation type
Shrubland ^a
Management objective
Hazard reduction, maintenance or improvement for range
Country / Region
Portugal

Prescription elements	Range	Optimum
Burn season ^b	Sept. - May ^b	Oct.-Febr.
Weather-related variables ^c		
▪ Wind speed (km hr ⁻¹)		5 - 15
▪ Air temperature (°C)		8 - 20
▪ Relative humidity (%)		20 - 70
▪ No. days since rain		3 - 7
Dead fuel moisture (%)		
▪ Elevated fine fuel	12 - 40	12 - 20

Ignition pattern	Backing, flanking, heading, point or ring ignition.
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Fire behaviour	Range	Optimum
Rate of spread (m hr ⁻¹)		90 - 270
Flame length (m)		1 - 4

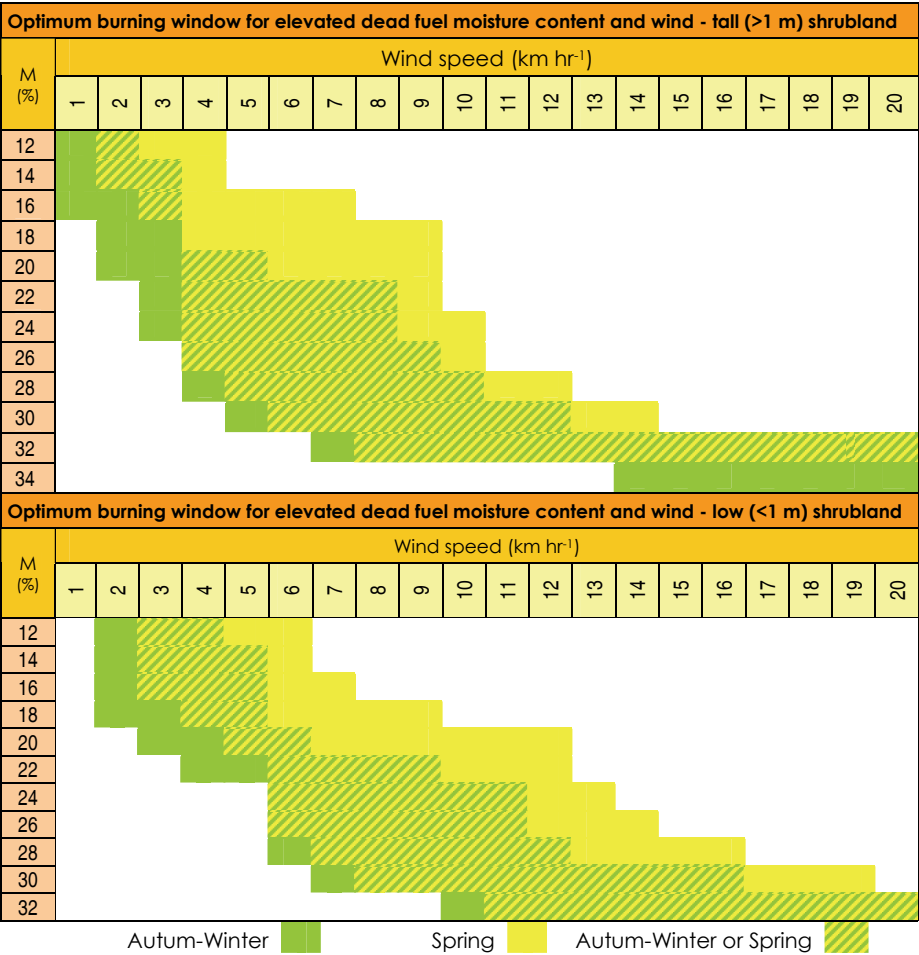
Observations and supplementary information
^a Generic prescription for a broad range of atlantic, sub-atlantic and Mediterranean shrubland types, including dominance or co-dominance by <i>Erica</i> spp., <i>Pterospartium tridentatum</i> , <i>Ulex</i> spp., <i>Cytisus</i> spp., <i>Quercus coccifera</i> and <i>Cistus ladanifer</i> .

^b Good burning conditions in *Q. coccifera* stands might not occur before February or March. The best opportunities to burn *Cytisus* and *Cistus ladanifer* stands can happen in early Autumn. Because of coarser and greener fuels, sustainable fire spread will require higher wind speed and lower dead fuel moisture content in these types, especially when live herbs are present. *C. ladanifer* is difficult to burn unless mixed with other species (*Erica*, *Pterospartum*, *Ulex*) and/or in the presence of a dead grass layer.

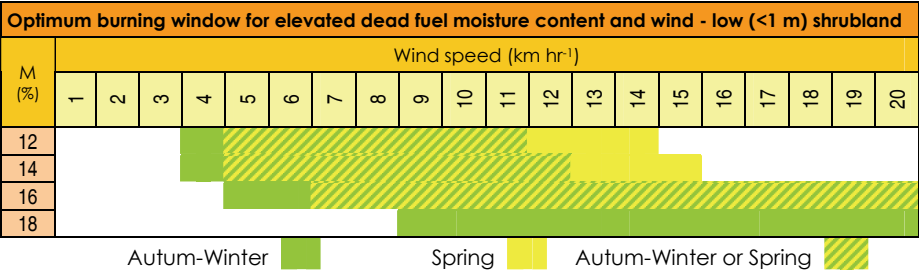
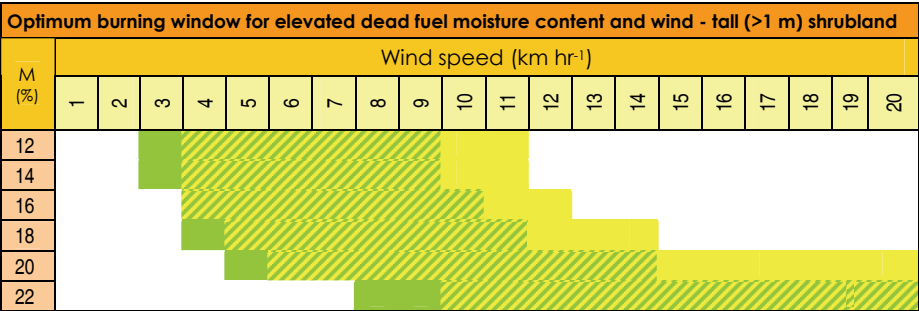
^c Sustained fire spread is unlikely when the ISI < 5 (*Cytisus*, *Q. coccifera*, *C. ladanifer*) or < 2 (remaining types).



Vegetation type	Shrubland dominated by <i>Erica</i> , <i>Ulex</i> , <i>Pterospartium</i>
Manag. objective	Hazard reduction, range management
Country:	Portugal



Vegetation type	Coarser/greener shrubland types (<i>Quercus coccifera</i> , <i>Cytisus</i> spp.)
Manag. objective	Hazard reduction, range management
Country:	Portugal



Vegetation typeAtlantic and sub-Atlantic shrubland ^a**Management objective**

Hazard reduction, maintenance or improvement for range

Country / Region

Spain / Galicia

Prescription elements	Range	Optimum
Burn season	Dec.-April ^b	Jan.-March
Weather-related variables ^c		
▪ Wind speed (km hr ⁻¹)	2 - 15	2 - 12
▪ Air temperature (°C)		5 - 15
▪ Relative humidity (%)	20 - 70	35 - 65
▪ No. days since rain	3 - 12	3 - 7
Dead fuel moisture (%)		
▪ Litter/duff	> 110	
▪ Elevated fine fuel	< 35	

Ignition pattern

Backing, flanking, heading or point ignition

Fire behaviour	Range	Optimum
Rate of spread (m hr ⁻¹)	600 - 720	

Observations and supplementary information

^a Mixed heathland (*Erica* spp., *Calluna vulgaris*, *Pterospartium tridentatum*, *Ulex* spp.). Stands dominated by either *Pterospartium tridentatum* or gorse species (*Ulex minor*, *U. europaeus*, *U. gallii*).

^b Autumn burning is restricted by the lack of sufficiently dry days and hunting activities. Spring burning is constrained by weak or unstable winds, high live fuel moisture content (especially in *Ulex*) and live grass underneath the shrub canopy.

^c The preferred weather conditions are associated to dry and cool winds from the N or E, after moderate rainfall.



Vegetation type
Calluna heathland
Management objective
Habitat maintenance/improvement for game and range
Country / Region
Scotland / uplands

Prescription elements	Range	Optimum
Burn season	<450 m elevation	
	1/10 – 30/4	1/10 – 15/4
	>450 m elevation	
	1/10 – 15/5	1/10 – 30/4
Fire return interval (yrs.)	8 - 25 ^a	≈ 15
Weather-related variables ^b		
▪ Wind speed (km hr ⁻¹)	10 - 25	15 - 20
▪ FFMC	< 80	

Ignition pattern	Headfiring, backfiring ^c <50-m wide strips, preferably <30-m wide
------------------	--

Fire behaviour	Range	Optimum
Rate of spread (m hr ⁻¹)	30 - 480	60 - 300
Flame length (m)	0.5 - 3.0	0.5 - 1.5

Observations and supplementary information
^a Dependent on site productivity. Fire should be applied within a stand height range of 20 - 30 cm. When <i>Calluna</i> is mixed with grass, burning can be delayed until vegetation is a bit taller.

^b Moss and litter should not be completely dried out. The duff layer should be exposed but not consumed by fire.

^c Backfiring should be avoided in the presence of peat. Ignition patterns including uphill fire spread should be cautious or avoided, respectively when terrain slope is higher than 18° and 26°.

Vegetation type

Calluna heathland (dry continental) ^a

Management objective

Conservation, maintenance

Specific Management objective

Calluna regeneration, top-kill small-diameter shrubs and trees, creation of a patch mosaic

Country / Region

Germany / Eastern and Central

Prescription elements	Range	Optimum
Burn season	February – mid April	
Fire return interval (yrs.)	10 - 12	
Weather-related variables		
▪ FFMC	> 80 ^b	
▪ DMC	< 20	

Ignition pattern

Backfire, flanking, strip-headfire

Observations and supplementary information

^a Established on sandy soils with *Pinus sylvestris* as the dominant tree.

^b In February burn after frosty nights ($T < 0^{\circ}\text{C}$) and after relative humidity is below 60% for 3-4 consecutive days.

Easily ignited and relatively fast fires are required, assuring partial consumption of fine fuel and no effects on soil. Intensity can be high as long as residence time is low.

Vegetation type

Calluna heathland (coastal)

Management objective

Conservation, restoration

Specific Management objective

Top-kill encroached shrubs and trees, *Calluna* regeneration, creation of a patch mosaic

Country / Region

Germany / North, NW islands

Prescription elements	Range	Optimum
Burn season	June-September	June-July
Fire return interval (yrs.)	8 - 12	
Weather-related variables		
▪ Wind speed (km hr ⁻¹)	< 25	
▪ Air temperature (°C)	< 30	
▪ Relative humidity (%)	> 35	
▪ FFMC	< 70	
▪ DMC	≈ 25	
▪ DC	≈ 150	
▪ FWI	< 17	

Ignition pattern

Back fire, flank fire, strip-head fire

Observations and supplementary information

Relatively intense and fast fires are required, assuring consumption of most fine fuel and some humus consumption, but without smouldering.

Vegetation type

Calluna heathland (dry continental)

Management objective

Removal of unexploded ordinance (UXO); conservation, maintenance

Country / Region

Germany / Eastern and Central

Prescription elements	Facilitate UXO removal	Hot removal of UXO
Burn season	Febr. - April	June - Septe.
Weather-related variables		
▪ Wind speed (km hr ⁻¹)	< 25	
▪ Air temperature (°C)	< 30	
▪ Relative humidity (%)	> 35	
▪ FFMC	< 70	
▪ DMC	Low	≈ 25
▪ DC	Low	≈ 150
▪ FWI	< 17	

Ignition pattern	Point ignition (preferably aerial)	Back fire, flank fire
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Observations and supplementary information

In areas contaminated by UXO, burning can be done throughout the year, i.e. using prescriptions that either approach restoration or maintenance of *Calluna* heathland.

Vegetation type
Calluna heathland
Management objective
Conservation
Specific Management objective
Regenerate <i>Calluna</i> and top-kill encroaching trees (<i>Populus</i> , <i>Betula</i>)
Country / Region
Italy / Piemonte

Prescription elements	Range	Optimum
Burn season	15.12 - 15.3	15.1 - 15.2
Fire return interval (yrs.)	8 - 15 ^a	
Weather-related variables		
▪ Wind speed (km hr ⁻¹)	1 - 15	6 - 7
▪ Air temperature (°C)	-2 - 10	5 - 8
▪ Relative humidity (%)	30 - 70	40 - 50
▪ No. days since rain	2 - 20 ^b	6 - 10
Dead fuel moisture (%)		
▪ Litter	20 - 80	35
▪ Elevated fine fuel	10 - 35	15

Fire behaviour	Range	Optimum
Rate of spread (m hr ⁻¹)	120 - 480	
Flame height (m)	0.5 - 2.0	
Byram's fire intensity (kW m ⁻¹)	500 - 2000	

Ignition pattern	Strip headfiring 20 - 30 m length, 5 m apart
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Observations and supplementary information

^a Dependent on the success of *Calluna* regeneration. Fire should be applied when canopy cover and height reach 50-60% and 30 cm.

^b *Calluna* heathland in NW Italy grows on fragipan soils, water logged and frozen in early winter. Litter is wet even in the driest prescribed condition. Hence, heat transfer to soil, which could affect *Calluna* resprouting, is minimum.

Prescribed fire should be followed by grazing and/or mowing



Daide Ascoli

Vegetation type*Cytisus oromediterraneus* - grass ^a**Management objective**Rangeland management ^b**Country / Region**

France / Eastern Pyrenees

Prescription elements	Range	Optimum
Burn season	Autumn - Winter	
Fire return interval (yrs.)	6	
Weather-related variables		
▪ Wind speed (km hr ⁻¹)	5 - 25	10 - 15
▪ Air temperature (°C)		10 - 15
▪ Relative humidity (%)		30 - 60
▪ No. days since rain		5
Phenology	Curing (grass)	

Ignition patternStrip headfiring
Lines 10-m apart**Observations and supplementary information**

^a Encroaching pines (*Pinus uncinata*): cover = 5%, height = 4 m. Shrubs: cover = 40%, height = 0.5 m. Grass (*Festuca rubra*, *Agrostis vulgaris*): cover = 80%, height = 0.50 m.

^b Intensively grazed by cattle, mostly in summer.

Vegetation typeCytisus - ferns ^a**Management objective**Rangeland management ^b**Country / Region**

France / Eastern Pyrenees

Prescription elements ^c	Range	Optimum
Burn season	Autumn - Winter	
Fire return interval (yrs.)	5	
Weather-related variables		
▪ Wind speed (km hr ⁻¹)		20 - 30
▪ Air temperature (°C)		8 - 15
▪ Relative humidity (%)		50 - 75
▪ No. days since rain		5
Phenology	Curing (ferns)	

Ignition pattern

Strip headfiring

Observations and supplementary information

^a Shrubs (*Cytisus scoparius*, *C. oromediterraneus*, *Rubus*): cover = 60%, height = 1 m. Ferns (*Pteridium aquilinum*): cover = 90%, height = 0.40 m.

^b Spring and autumn grazing with cattle and horses.

^c In the southern Massif Central of France, broom-dominated shrubland (*Cytisus scoparius* and/or *Genista cinerea*, sometimes with *Spartium junceum*) is burned within a relative humidity range of 10 - 85%. Wind speeds > 10 km hr⁻¹ are optimum.

Vegetation type*Cytisus oromediterraneus***Management objective**

Hazard reduction, biodiversity, range management

Country / Region / Site

Spain / Catalonia / Tabascan, la Pleta del Prat

Prescription elements	Range	Optimum
Burn season	Mid Oct.-Mid April	
Weather-related variables		
▪ Wind speed (km hr ⁻¹)	0.5 - 15	5
▪ Air temperature (°C)	5 - 20	10
▪ Relative humidity (%)	≥ 30	50 - 60
▪ No. days since rain		5
Fuel moisture (%)		
▪ 1hr	12 - 16	14
▪ 10hr	14 - 18	16
▪ 100hr	16 - 20	18
▪ Live herbs	140 - 200	170
▪ Live shrubs	120 - 180	150

Ignition pattern

Point, Strip-head

Fire behaviour	Range	Optimum
Rate of spread (m hr ⁻¹)	900 - 2100	1500
Flame length (m)	2 - 12.5	4 - 5.5

Observations and supplementary information

Scattered patches of *Betula pendula*, *Quercus petraea* and *Pinus sylvestris* within the shrubland. Burn restrictions include avoidance of rocky areas and burning by patches to disrupt the continuity of *Cytisus*.

Vegetation typeMediterranean-type shrubland ^a**Management objective**

Hazard reduction

Country / Region / Site

Spain / Catalonia / Coll de Canyelles – Montperdut, Cap de Creus

Prescription elements	Range	Optimum
Weather-related variables		
▪ Wind speed (km hr ⁻¹)	0 - 20	5
▪ Air temperature (°C)	5 - 20	10
▪ Relative humidity (%)	25 - 65	45
Fuel moisture (%)		
▪ 1hr	8 - 12	10

Ignition pattern

Back, flank

Fire behaviour	Range	Optimum
Rate of spread (m hr ⁻¹)	< 120	
Flame length (m)	< 2.5	1

Observations and supplementary information

^a (Co-)dominated by *Quercus coccifera*, *Erica arborea*, *Calicotome spinosa*, *Cistus* spp., *Lavandula stoechas*, *Rosmarinus officinalis*, *Brachypodium* spp. Scattered *Quercus suber* and *Q. ilex* trees should not be damaged. Burning should be avoided from March to May because of bird nesting.

Vegetation type
<i>Cistus monspeliensis</i> / <i>Ulex europaeus</i> - grass ^a
Management objective
Rangeland management ^b
Country / Region
France / Eastern Pyrenees

Prescription elements ^c	Range	Optimum
Burn season	Autumn - Winter	
Fire return interval (yrs.)	6 ^c	
Weather-related variables		
Wind speed (km hr ⁻¹)	5 - 15	10
Air temperature (°C)	8 - 12	10
Relative humidity (%)	35 - 70	50
No. days since rain		5
Phenology	Curing (grass)	

Ignition pattern	Strip headfiring. Lines 20-m apart
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Observations and supplementary information
^a Shrubs: cover = 40%, height = 0.5 m. Grass (<i>Brachypodium ramosum</i>): cover = 40%, height = 0.10 - 0.15 m.
^b Extensively grazed by cattle in November-January and April-May.
^c When <i>Cistus</i> cover <30%. Reduced grazing pressure in the previous season is required to assure fine fuel continuity.

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