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LARGE FIRE RESPONSE PREPAREDNESS

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This publication is the final technical report summarizing main results of PREVAIL (Prevention Action Increases Large Fire Response Preparedness) project, co-funded by European Union Humanitarian Aid and Civil Protection (call DG ECHO 2018 Call for projects on prevention and preparedness in civil protection and marine pollution - (***826400-PREVAIL-UCPM-2018-PP-AG***).

Project description: PREVAIL

Fire management organizations are confronting with evolving wildfire regimes. The combination of extreme climate events and fuel accumulation is leading to increasingly large wildfires that often overwhelm the suppression capacity of single countries. There is a need to shift fire management strategies towards changes in the spatial pattern and amount of fuels at the landscape scale to reduce large wildfire probability. At the same time, new models to make landscape-based fire prevention sustainable under an economical, societal and environmental perspective is needed. In this regard, PREVAIL is a cooperative project among 5 research organizations of fire prone European countries (Italy, Spain, Portugal, Greece) that aims at demonstrating how wildfire landscape-based fire prevention can make large fire suppression more effective and less costly.

Project target activities are:

- statistical and econometric analysis of prevention, preparedness and suppression measures to counteract large fires;

- simulation of past large fire events, to reconstruct fire behaviour and predict effects of alternative fuel management scenarios on the reduction of fire suppression effort;

- developing a DSS to plan and optimize smart solutions at the water catchment scale to increase the leverage and cost-effectiveness of fuel management treatments and promote development of local economy ensuring their maintenance in a climate change context;

- determining best strategies to integrate prevention and preparedness to large-fire events, sharing and spreading “smart” solutions, implemented locally in partners’ countries, by trans-national training and producing material to raise awareness of citizens, land managers and fire operators.

PREVAIL will provide empirical knowledge, practical tools and analytical techniques to improve UCPM effectiveness in the fire disaster management cycle (prevention-preparedness-response), in terms of cost optimization and large fire risk reduction.

On the website there is free access to all project results(https://www.prevailforestfires.eu/dissemination/).

Partnership:

University of Tuscia - UNITUS (Lead partner)

Università degli Studi di Napoli Federico II – UNINA

Centre de Ciència i Tecnologia Forestal de Catalunya Foundation - CTFC,

Hellenic Agricultural Organization, Institute of Mediterranean Forest Ecosystems - DEMETER,

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1. Introduction

Extreme wildfires are an emerging major natural hazard in Mediterranean regions[1] [2] [3]. In Southern Europe, these events are the resultant of complex socio-ecological processes and interacting climate and land use changes[4] [5]. Increases in extreme fire seasons[6] will lead to a dangerous self-feeding circle that hardly allows a sufficient recovery of ecosystem services and of rural land development[7] [8] [9] [10] .

Policies focused on fire suppression are no longer able to reduce impacts of changing fire regimes and alternative paradigms have been advocated[11]. There is a general consensus in the scientific community on the need for a fire management change towards cause-oriented policies, with a holistic perspective on fire prevention and smart land planning[2] [12]. In the last years, land-based fire prevention as strategy to prevent and reduce fire hazard exposure and vulnerability has been gaining momentum also at political level[4]. One of its major goals to foster **fire resistant and resilient landscapes and communities (fire-RR landscapes)**, i.e. territories subject to fire risk in which socio-economic activities aim to minimize fire related risks, limit fire impacts while obtaining benefits for ecosystem services and natural resources.

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European policies reveal great potential for the transition process towards fire-RR landscapes. Anyway, there are many difficulties to implement EU policies at regional/local level **considering that due to subsidiarity principle land management is often a regional responsibility** in European Mediterranean countries. Constraints and limitations include the complexity of landscape governance in rural areas based on ownership (i.e. different land tenure rights in private and public lands, ownership fragmentation, unknown land owners...) and on interventions purpose, often torn between static conservationism and pro-active land management. Fuel availability is also a thorny issue, sharply increasing with the growing land abandonment and often difficult to manage given to land marginality[13] In addition, the lack of economies of scale for the economic sustainability of landscape-scale fuel management makes it extremely difficult to invest at the local scale.

However, **there are several grassroot local fuel management programs, especially in southern European countries, with the ability to intelligently plan and build fire-RR landscapes**. These strategies involve many actors from different sectors, supported by many complementary activities useful to the social and economic context. In many southern EU countries, for example, prescribed burning is carried out not only to reduce fuel load, but also for habitats and biodiversity management. Multiple benefits can also be provided by goat or sheep grazing activities, through which biomass on the ground is reduced and, at the same time, grazing products are marketed. To create fire-RR landscapes is imperative the convergence of multiple shared goals, and these examples illustrate the importance of adopting (smart) solutions in fuel management that include various local components.

In its two years of work, the PREVAIL project has produced a solid knowledge base to promote effective action in this direction. The overarching project idea is to **find out and document cost-efficient and circular ways for transforming fuelled landscapes into fire-RR landscapes**, by planning and implementing **active and passive prevention activities** in woodlands, rural lands and wildland urban interfaces. Shaping up **fire-RR landscapes is instrumental to resize the severity of many future wildfires and to protect citizens, infrastructures and values** (Figure 1). **Fire-RR landscapes make active prevention less costly and Civil Protection and response more efficient and safer.**

[13] Azevedo, J.C., Moreira, C., Castro, J.P., Loureiro, C., 2011. Agriculture Abandonment, Land-use Change and Fire Hazard in Mountain Landscapes in Northeastern Portugal, in: Landscape Ecology in Forest Management and Conservation. doi:10.1007/978-3-642-12754-0

Figure 1 - PREVAIL logo, in a nutshell: shaping up fire resilient landscapes (the green hemicycle) can help resizing the dimension and severity of future fires in Europe (the orange strip).

This Report draws from project key exploitable results to present lessons learned and innovative approaches for the creation of a shared governance for building-up fire-RR landscapes.

Contents are organized in the four Chapters.

Analysis of large fires in Southern Europe: data information gaps on fire suppression and insights to build fire-RR landscapes: findings from various analysis conducted on fire statistics currently available in project partner countries are presented to highlight: i) optimal data collection format to come up to a reliable estimate of the suppression costs incurred during large wildfire events; ii) likelihood of a fire to become large; iii) contribution of different vegetation/land cover types in stopping large fires; iv) the contribution of fuel treatments on the reduction of fire spread and firefighting demand.

Socio-ecological Decision Support System for fuel management: an easy-to-apply methodology for planning fuel management activities in a particular territory is outlined, incorporating stakeholders perspective in the assessment of wildfire risk.

Role of EU public funding in fire prevention: a comparison of the public expenditure on fire prevention across PREVAIL partner countries is offered and of its spatial distribution in connection with fire risk at territorial level; possible paths to improve the future efficiency of public spending are also identified.

Innovative approaches to building fire-RR landscapes: the fire smart solutions, sustainable, cost-efficient, circular and adaptive processes to reduce landscape flammability, integrating active and passive prevention goals and approaches, via fire-smart marketing of related products and services, are brought to the fore as model to set in motion a stronger territorial governance framework (cross-sectoral, multi-level, multi-actor).

Final remarks: considerations to accelerate the transition process towards fire-RR landscapes and a set of key messages by target groups are provided.

2. Analysis of large fires in Southern Europe: data information gaps on fire suppression and insights to build fire-RR landscapes

Our capacity to resize the severity of future wildfires largely depends on our knowledge and understanding of the conditions that allow wildfires to spin out of control and increase in size. The analysis of large fires events occurred in the past in Southern European countries can potentially shed light on the interplay of fire weather and fuel-rich landscapes from which intense fires originated, thus resulting in very large areas burned and, in many cases, significant impacts on human lives and assets. However, this opportunity is largely constrained by the availability of statistical and geodatabases with harmonised information on single wildfire events: e.g. fire perimeters, meteorological data and fire weather indices, fire-fighting resources deployed during the event. **The lack of data, or poor data quality, on these variables also hinders the possibility to reckon the fire suppression costs associated to large wildfire events**. This represents an **obstacle** also in the perspective of **demonstrating to what extent the implementation of land-based fire prevention activities a reduction of the suppression costs**.

Little attention has been paid so far on whether fire statistics, currently provided by different National and Regional authorities[14], are useful to address wildfire management information issues raised above. In the PREVAIL project wildfires databases were assembled, compared and processed in various ways, in order to highlight knowledge and guidance on how to:

- Estimate the costs of large wildfire suppression.
- Predict the likelihood of a starting fire to become large.
- Understand the contribution of different vegetation/land cover types in stopping large fires.
- Simulating the contribution of fuel treatments on fire spread and firefighting demand.

Detailed explanation of the data, methods and findings of these activities is provided by specific project deliverables[15]. In this section main lessons learned, and current knowledge gaps are highlighted.

Fire suppression cost estimation

When wildfires occur, the Authorities responsible for assessing suppression costs are subject to various operational and administrative tasks, which usually lead to a partial recording of the information necessary for an analytical estimate of the costs of suppressing large fires. Where the deployment of aerial resources to suppress wildfires was significant and there is a need for a high level of precision in the economic estimate

[14] Greece: XXX; Italy: Carabinieri Corps (Comando Unità per la tutela Forestale, Agroambientale e Agroalimentare-CUFAA), Italian National Civil Protection (only for specific large fire events); Portugal: Portuguese forest fires database (SGIF), National Civil Protection database; Catalonia: Wildfire Prevention Service - Ministry of Agriculture, Livestock, Fishing and Food - Government of Catalonia General; Directorate of Wildfire Prevention, Extinction and Rescue – Ministry of Home Affairs – Government of Catalonia

[15] https://www.prevailforestfires.eu/wp-content/uploads/2021/03/2.3.pdf
https://www.prevailforestfires.eu/wp-content/uploads/2021/03/3.1.pdf

of the suppression cost incurred, it is necessary to reconstruct the constituent parts of the costs accounted for, during ground and aerial fire suppression (i.e. teams and equipment involved in ground operations; number and type of aircrafts) based on a precise accounting of the time/duration of fire-fighting operations. However, the reconstruction of cost can be somewhat laborious when fire suppression operations have involved several autonomous accounting organizations (e.g. Forestry Corps, Civil Protection, Fire Brigade, Local Police, Voluntary Associations, etc.). In fact, we realized that **data recorded on fire registers of the fire-fighting activity**, provided by the competent authorities in the different countries, **do not follow a quality standard in data collection**, nor a uniformity of contents, **for both the characteristics of the fires and the means used**, or at least, the **time of use of individual means**.

Consequently, the PREVAIL project identified an **optimal data collection format to allow subsequent estimation of fire suppression costs**, based on the record structure listed in Table 1.

Errore. L'origine riferimento non è stata trovata.

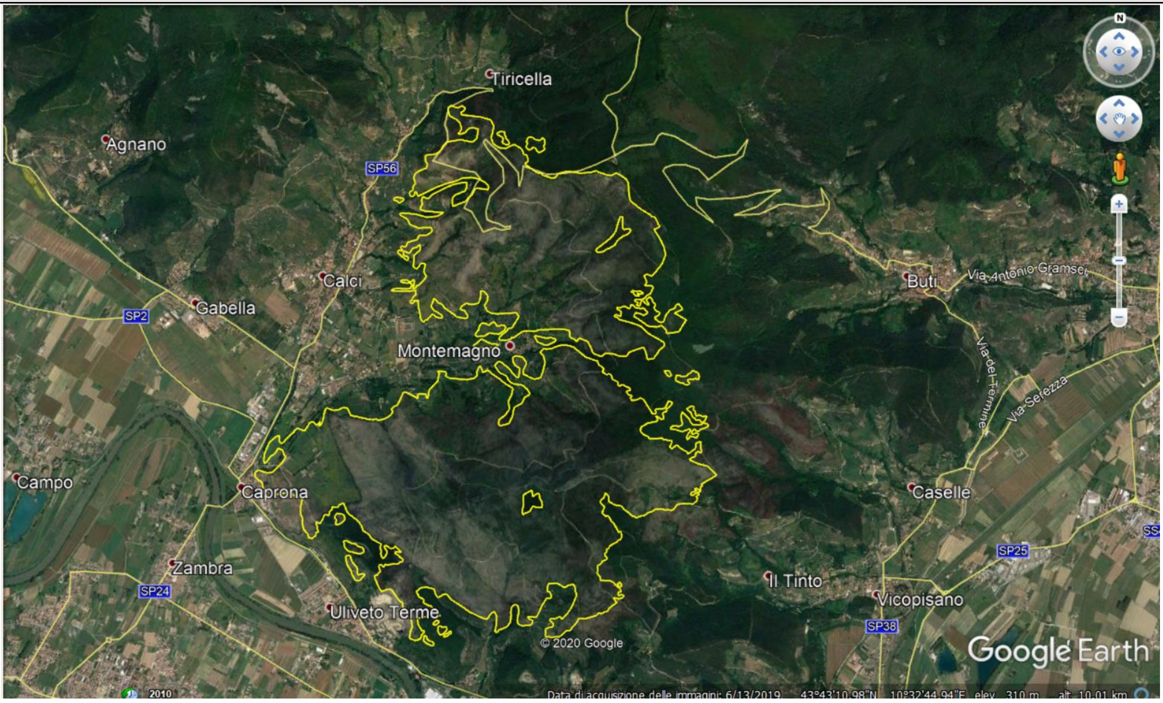
Table 1 – (left) The optimal data structure for analytical estimation of suppression costs in Southern Europe (ground suppression operations). (right) The optimal data structure for analytical estimation of suppression costs in Southern Europe (aerial means).

Name crew	ID
ID radio	Air vehicle
Function	Starting operation
No. Persons	date and hour
Activation date	ending operation
Deactivation date	date and hour
Starting mission date	Operation time (hours and min)
Arrival on the field date	Operation type (e.g. extinction, surveillance,
Coming back date	helitransport of brigades)
Number and type of equipment and vehicles for suppression	
Operation time (hours, min)	
Operation type (e.g. regular suppression, mop-up)	

This data collection format should be ideally compiled by an agency operating at a national level for each European country, using a common template that covers, e.g., all fires that have required aerial intervention. This solution would allow for an analytical, low-error estimate of the suppression costs to be devised on a national scale, and be disaggregated over time and space, according to policy requirements.

An example of the application of this approach is provided in the box below, for a large wildfire (1,069 hectares) that affected on Monte Serra in the Calci area (province of Pisa, central Italy), from 24th September to 30th September2018. The Union Civil Protection Mechanism was also activated (Activation code EMSR 316). Based on the data provided by the operating room of the Tuscany region and by the Italian National Civil Protection it was possible to estimate the entire cost of suppression of the event (UCPM intervention excluded).

Box 1 | Estimation of fire suppression cost, Calci wildfire (2018)



Fire perimeter (in yellow) of the Calci wildfire (Pisa, Tuscany).

The aircrafts involved, both helicopters and Canadair, were active for most of the day on September 25th and, more marginally, on the following three days, from September 26th to September 28th, 2018.

A total of **6 helicopters from the Tuscany region** (80 flight hours) and **11 aircrafts** deployed by the Italian National Civil Protection (156 flight hours) intervened on the event. A total of 1,249 operators, organized in 530 field actions, were deployed to face the fire front, for a total of 6 working days (25th September to 30th September).

The operating room of the Tuscany region coordinated ground suppression operations and those of regional air vehicles (helicopters), while the Italian civil protection emergency room, coordinated the interventions of air vehicles (mainly Canadair), which contributed significantly to the extinguishing of the fire, classified as being particularly dangerous due to its proximity to the town of Calci and other peri-urban settlements in the Pisa metropolitan area.

The total cost of the personnel involved in all the extinguishing activities amounted to **324,652 euros**. The cost of the operation room activities, including the activities of both the regional operation room and the national civil protection emergency operation room, was estimated at **1,868 euros**. The total cost of air vehicles was estimated at **1,166,956.76 euros**, of which the cost of the air means made available by the national civil protection was equal to ***896,494.09 euros***. The remaining cost was incurred by the regional civil protection of the Tuscany region. Based on this analytical approach, the total cost of extinguishing the Calci fire was quantified in **1,493,476.44 euros**, equivalent to **1,397 euros per hectare**.

Likelihood of a starting fire to become large

The PREVAIL project consortium assembled database of 360 large (>500 ha) fires and 495 small fires (< 500 ha) selected in a systematic way, that occurred in Greece, Italy, Portugal and Spain (Catalonia) in the 2000-2019 period. The full database includes an extensive list of variables (Table 2) but, as previously explained, not all the variables were available in all countries. Therefore, analyses had to be carried on subsets, depending on the missing variables. The analysis offered interesting insights about where and when large fires are most likely and the factors affecting them. The following key findings were obtained:

- although large fires (>500 ha) are relatively uncommon, in general a fire to become large seems to be influenced by the simultaneous existence of large fires and relative humidity;
- the probability is also affected by wind velocity; however, the poor data quality regarding wind velocity, did not allow this variable to be included the prediction models
- despite all the limitations of the complete database, based on a large sample size of (N=499 large and small fires from Greece Portugal and Italy), it is possible to devise a relatively strong model (Nagelkerke R^2 =0.51) of the **probability of a fire to become large**, based on binary logistic regression, with **relative humidity, number of parallel fires and water distance** as independent variables[16].

In conclusion, it is confirmed the **importance of good quality data regarding the conditions and the response capacity at the initial stage of the fire**. Whereas the time of first intervention was one of the available variables, it was not matched with any information about the **composition and strength of the firefighting resources dispatched for initial attack**. The large number of resources reported for each large fire, refer to its final stage and do not allow a meaningful analysis about the interplay between conditions, size of resources and first intervention, as contributors for the probability of fire to escape initial attack.

[16] The equation of the model is: PLARGE = 1/[1+EXP(-(1.238 – 0.030 RH – 0.028 WATERDISTANCE+ 1.034 PAR_LFIRES))]

Table 2 - Variables that were desirable for inclusion in the Fire Statistics Database assembled for PREVAIL.

Short name	Description	Justification
COUNTRY	Country in which the fire occurred	Allows for shorting and examination of differences. The strength of fire suppression organization may be different between countries. Vegetation and climate may also be different.
LATITUDE	Latitude (WGS 84)	In the Mediterranean, it is likely that fires are more intense in the south. There may be differences in vegetation. In addition, timing of fires in the year may be different.
LONGITUDE	Longitude (WGS 84)	Probably less important. However, the proximity to the coasts that are generally oriented north - south may be influential.
DATE	Date of fire start	It identifies the period in the year. May help assess the peak of the fire season in each country and in the Mediterranean.
TIME	Time of fire start	It is related to the burning conditions, the available time for intense fire behavior and the available time for firefighting under daylight.
ELEVATION	Elevation above mean sea level of the point where the fire started (m)	Elevation influences the fire environment (vegetation, fuels and their condition, weather). Higher elevation is usually associated with rough topography and fewer roads.
TEMP	Air temperature (^{O} C)	Air temperature influences the ease of ignition of fuels and the likelihood of spot fires.
RH	Air relative humidity (%)	Relative humidity influences the moisture content (MC %) of dead fuels. Lower MC makes their ignition faster.
WIND	Wind speed (km h^{-1})	Wind influences the rate of spread of the fire.
SLOPE	Slope (%) of the area where the fire started	The steeper the slope the higher the rate of spread and the more difficult to fight the fire.
AIRDISTANCE	Distance of closest air resources base (km)	It is likely that the closest the air resources are located to the fire area the more effective the air support can be (timely, quick arrival of reinforcements).
WATERDISTANCE	Distance from water (sea or lake or reservoir) (km)	This distance may affect the effectiveness of amphibian waterbombers and helicopters that can pick-up water from the sea or a lake.
FIRSTINT	Time of first intervention of firefighting resources (min)	The longer this time, the fire has a better opportunity to grow and become large.
BURNEDFOREST	Burned forest area (ha)	Burned area of forests, large and small shrubs and forest grasslands. Fires in these vegetation types are generally more difficult to fight.
BURNEDAREA	Total burned area (ha)	Burned area of all types of vegetation including agricultural land (ha).
VEGETATION[1]	Weighted fire hazard estimate for the vegetation types that burned (rating 1-5)	Various types of vegetation have different fire intensity and rate of spread potential, as well as “difficulty of control”. Weighing is based on the fire hazard rating for each type and its contribution to the total burned area (ha).
PAR_FIRES	Number of small and large fires that were burning or started on that day (not including this fire)	This is an indication of the firefighting load that existed and may be related to the availability of inadequate resources.
PAR_LFIRES	Number of large fires (>500 ha) that were burning or started on that day (not including this fire)	This is an indication of the difficulties the firefighting organization had to face. It is likely that there were inadequate resources and the fire weather conditions were very adverse.
FIREFIGHTERS	Number of firefighters including official volunteer firefighters	They carry out ground firefighting.
OTHER_CONTR	Other contributing personnel not specialized in firefighting (Army personnel, Local authorities, etc.)	They contribute to the firefighting capacity, especially of large fires.
FIRETRUCKS	Number of firetrucks (all types)	They contribute to the firefighting capacity on the ground.
HEAVYMACHINES	Number of heavy machinery such as dozers	They contribute to the firefighting capacity on the ground, especially in large fires.
AIRPLANES	Number of airplanes (all types)	They contribute to the firefighting capacity from the air.
AMPHIBIAN	Number of amphibian airplanes (subset of AIRPLANES)	They contribute to the firefighting capacity from the air.
HELICOPTERS	Number of Helicopters	They contribute to the firefighting capacity from the air.

Assessing the contribution of different vegetation/land cover types in stopping VLF

The PREVAIL project consortium collected also more in-depth geospatial data for 30 large fires (burned area> 500 ha) occurred in the project countries (Figure 2). The external perimeter, as well as the perimeter of the unburned islands within the burned area of each of these wildfires were digitized, so to classify the length of the final perimeter by vegetation or land use (Table 3). Furthermore, the perimeters of unburned islands within the burn area were digitized providing further evidence of fuel situations that hinder the spread of the fire or favor fire suppression (Figure 3).

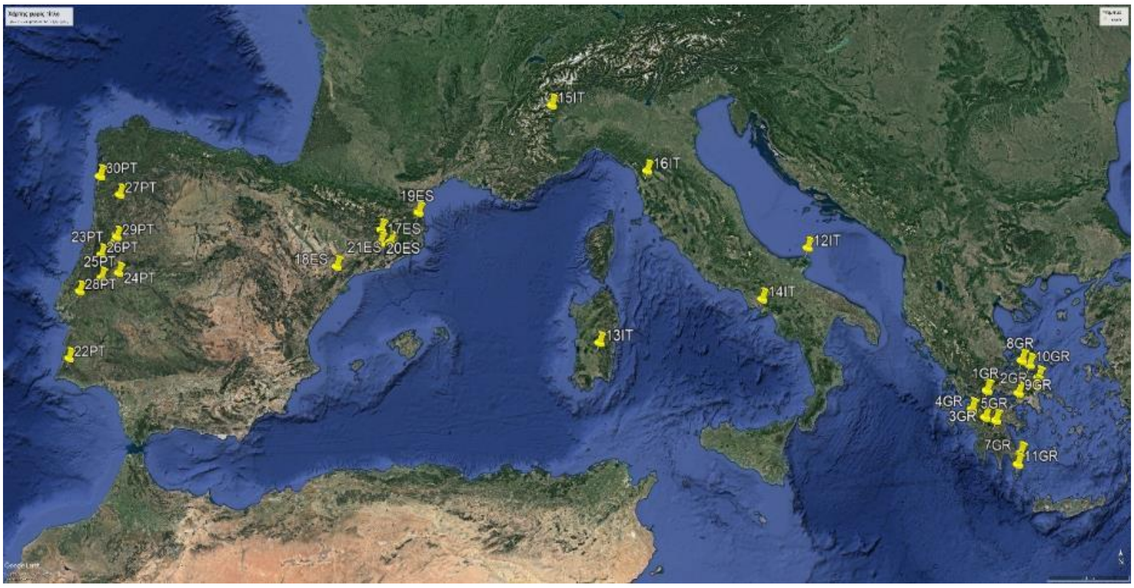


Figure 2 - The locations of the 30 very large fires included in the PREVAIL database.

Table 3 - Vegetation/land use types used to classify the external fire perimeter and the perimeter of unburned islands.

Code	Vegetation/land use type	Code	Vegetation/land use type
1	Sea	18	Phrygana/Scrub
2	Lake / pond	19	Low shrubs (<70 cm)
3	River	20	Medium shrubs (<150 cm)
4	Unpaved narrow Road	21	Tall shrubs (150 cm< h <400 cm)
5	Paved road (two lane)	22	Pine forest
6	Wide road (more than two lanes)	23	Tall conifer forest (other than pine)
7	Railway lines	24	Oak forest
8	Bare ground	25	Eucalypt forest
9	Firebreak (linear)	26	Other broadleaved tall forest
10	Fuelbreak or managed fuels (incl. prescribed burning)	27	WUI area (interspersed)
11	Green belt (football field, golf course, etc.)	28	Settlement/Village
12	Tree orchard (other than olive)	29	Town/City
13	Olive grove	30	Industrial area
14	Vineyard	31	Quarry
15	Annual agricultural cultivation (wheat etc)	32	Recently burned area (3 years or less)
16	Greenhouse	33	Mixed broadleaved & coniferous forest
17	Grassland		

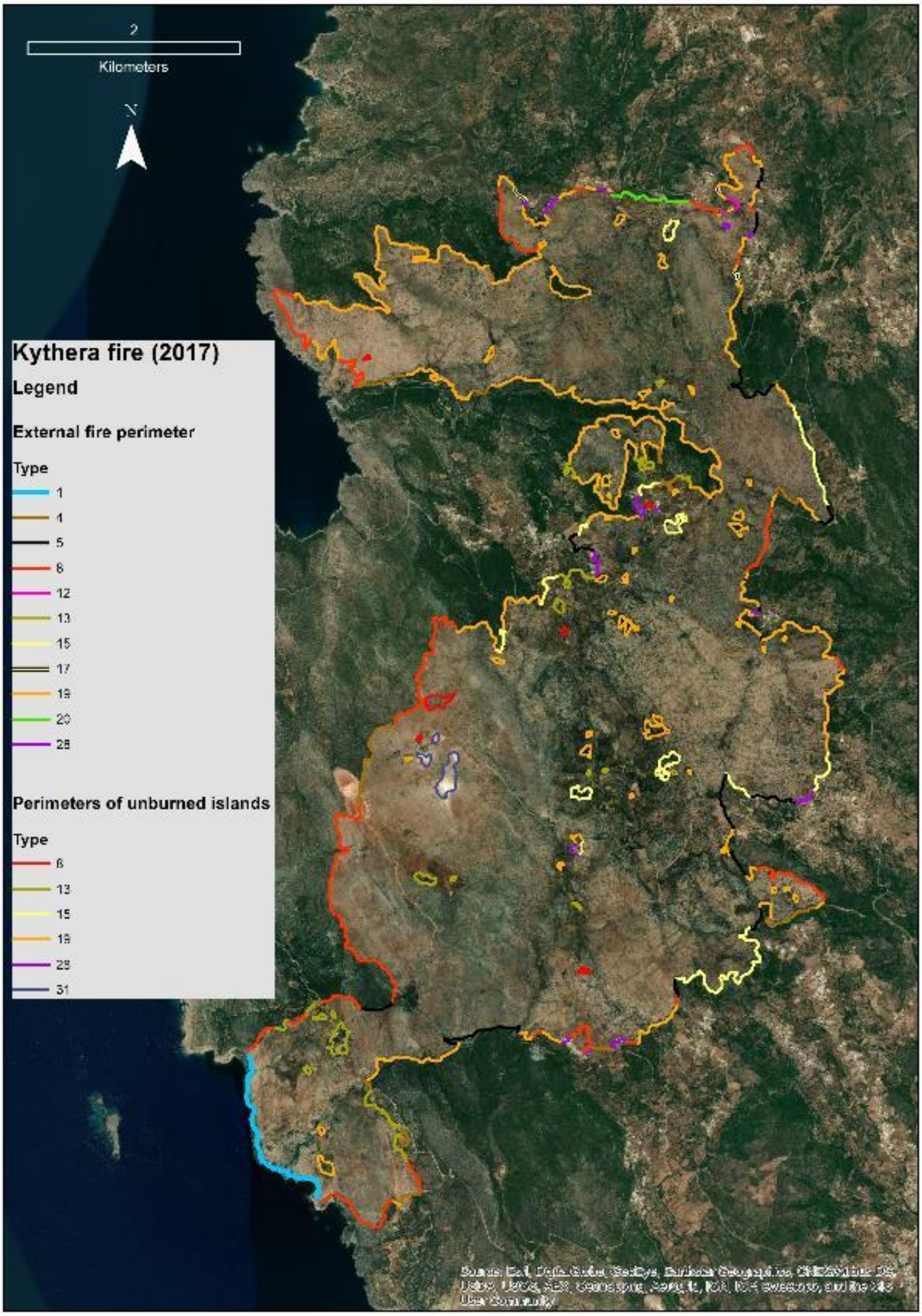


Figure 3 - External perimeter and unburned islands perimeter lengths estimation for the fire of August 4, 2017 on Kythera island, Greece (see Table 3 for the legend codes).

The **analysis of the large fire perimeters offered interesting insights to understand where large fires stopped spreading or were controlled**. Most of the final perimeter length (90%) consist of areal features. By standardizing the length of the fire perimeter (external and unburned island) of each vegetation/land use type, by the area of that type included in the final perimeter, it is possible to rank the vegetation/land cover types that hindered the spread of the fire and favoured fire suppression (Table 4). Classes ranked on the top, have longer extinction perimeter for the area they occupy. The very small area occupied by certain classes may have inflated their ratio (e. g. greenhouses, linear features at the bottom of the table) and the value could only be considered as indicative.

At the top of the list are urban areas where there is no fuel to burn; skipping greenhouses, for the reasons already explained, other areas without vegetation are also good contributors to stopping a fire, namely lakes and ponds, industrial areas, villages or other settlements, and linear firebreaks.

Vineyards and tree orchards, other than olive groves, are also very effective, competing with obvious area types without available fuel: quarries, green belts, and bare ground. Wildland-urban interface areas, probably because of the special attention they receive in fire-fighting operations, are also areas where wildfires are controlled. **Annual agricultural cultivations** are ranked next, followed by other broadleaved tall forests and by fuel-breaks with managed understory fuels. On the other end, olive groves, tall and medium shrubs, pine forests and mixed broadleaved and coniferous forests offer the least opportunities for fire control.

These findings offer good insights to recognize the relative contribution of the various vegetation/land use types in the creation of fire-RR landscapes. **A diversified patchwork of vegetation/land use types offers more possibilities to stop wildfires** as well **as more options for rural populations to develop economic activities that can contribute to its maintenance**. In the following Section, EU public funding opportunities to maintain and to restore the “power” of this patchwork by supporting active and passive prevention activities are discussed.

Table 4 - External perimeter length, unburned island perimeter length and their sum (m) by vegetation/ land cover type, the area of that type contributing to the burned area (ha), and the total perimeter to area ratio (km/ha).

Code	Land use/vegetation type	External perimeter length (m)	Unburned island perimeter	Total perimeter length (m)	Area (ha)	Ratio (km/ha)
29	Town/City	111160	42949	154109	51	3.02
16	Greenhouse	410	0	410	0	2.16
2	Lake/pond	37272	563	37835	26	1.46
30	Industrial area	7834	304	8138	43	0.19
28	Settlement/Village	106894	85546	192440	1089	0.18
9	Firebreak (linear)	7570	111	7681	48	0.16
14	Vineyard	23145	9248	32393	230	0.14
12	Tree orchard (other than olive)	214885	168529	383414	2749	0.14
31	Quarry	15810	11879	27689	219	0.13
11	Green belt (football field, golf course, etc.)	1250	2046	3296	29	0.11
8	Bare ground	89590	36123	125713	1781	0.07
27	WUI area (interspersed)	87097	19584	106682	1542	0.07
15	Annual agricultural cultivation (wheat etc.)	796531	471115	1267646	25065	0.05
26	Other broadleaved tall forest	67246	1254	68499	1850	0.04
10	Fuelbreak/managed understory fuels	4405	1826	6232	191	0.03
19	Low shrubs (h<70 cm)	564575	476673	1041247	33761	0.03
17	Grassland	105580	26917	132497	5832	0.02
23	Tall conifer forest (other than pine)	27106	3059	30165	1360	0.02
24	Oak forest	294160	89975	384135	17732	0.02
25	Eucalypt forest	165174	81803	246977	11631	0.02
32	Recent burn	11662	0	11662	626	0.02
18	Phrygana/Scrub	180212	44045	224257	13467	0.02
13	Olive grove	307424	276578	584002	35921	0.02
21	Tall shrubs (150 cm< h < 400 cm)	107050	15262	122312	8126	0.02
22	Pine forest	484872	88229	573100	53815	0.01
20	Medium shrubs (70<h<150 cm)	35723	13460	49182	7892	0.01
33	Mixed broadleaved & coniferous forest	17303	0	17303	2986	0.01
1	Sea	43379	0	43379	0	0.00
3	River	99882	92125	192007	0	0.00
4	Unpaved narrow road	78442	11104	89545	0	0.00
5	Paved road (two lane)	245292	28845	274138	0	0.00
6	Wide road (more than two lanes)	28145	0	28145	0	0.00
7	Railway lines	21309	2973	24282	0	0.00
	Total	4388390	2102123	6490513	228062	

Simulating the contribution of fuel treatments on fire spread and firefighting demand

Decision-making regarding the fuel management options most suitable for reducing fire risk in a given territory, requires an evaluation of the characteristics of alternative fuel management scenarios. In this regard, one crucial aspect is to understand the implications that alternative fuel treatments may produce on fire spread, but also on the related firefighting demand. This is particularly relevant where locally available fire-fighting resources are limited. The large fire in 2017 on the island of Kythera in the south of Peloponnese of Greece (Figure 3) epitomizes such a common situation. Its location, away from a base of aerial firefighting resources, and ground reinforcements needing many hours to reach the island, make it a prime candidate for examining the value of fuel treatments for averting the probability of a large fire.

The real wildfire started on 4th August 2017 and was not attacked effectively at its first stages, burned vigorously for three days, threatening homes and a monastery (Moni Mirtidion, Figure 4) and finally reached a size of 2,621 ha. Parts of its perimeter stopped at the sea (Figure 3).

Figure 4 - Wildfire of Kythera island at August 6, 2017, at 17:27 (Photo: Valerios Kalokairinos).

The fire spread of the real wildfire was realistically simulated, in the framework of PREVAIL project activities with the support of the G.FMIS fire simulator, based on good spatial data on fuels, weather and topography. The simulated fire spread at each step (1 hour) is shown in Figure 5, highlighting with different colours the flame length along the perimeter. The classes correspond to the broadly accepted limits for firefighting. It is noted that at no point across the perimeter a flame length over 10 m is predicted.

The G.FMIS was also used for the simulation of four fuel management scenarios, in order to discover what would be the result on fire spread if they had been applied to the area that burned prior to the fire event. The four scenarios were:

- Scenario 1: Mechanical treatment (tractor) only in agricultural areas
- Scenario 2: Mechanical treatment (hand tools) only in agricultural areas
- Scenario 3: Grazing everywhere (in all types of vegetation)
- Scenario 4: Intense grazing everywhere (in all types of vegetation)

These alternative fuel treatments alter in different ways fuel conditions: grazing reduces the amount of herbaceous fine fuels, the shrub component, the fuel depth (height) and the fine fuels, while mechanical treatment breaks the horizontal continuity and changes the fuel depth (height) of the vegetation.

The simulation based on existing fuels (Figure 5) was compared with the fuel treatment scenarios in terms of perimeter growth and flame length (Figure 6, Figure 7). The significant effect of grazing (treatments 3 and 4) is obvious. On the other hand, treatments 1 and 2 seemingly have little effect. However, this is also the result of the relatively small percentage that agricultural areas occupy within the burned area. It is reminded that only agricultural areas receive fuel treatment under scenarios 1 and 2.

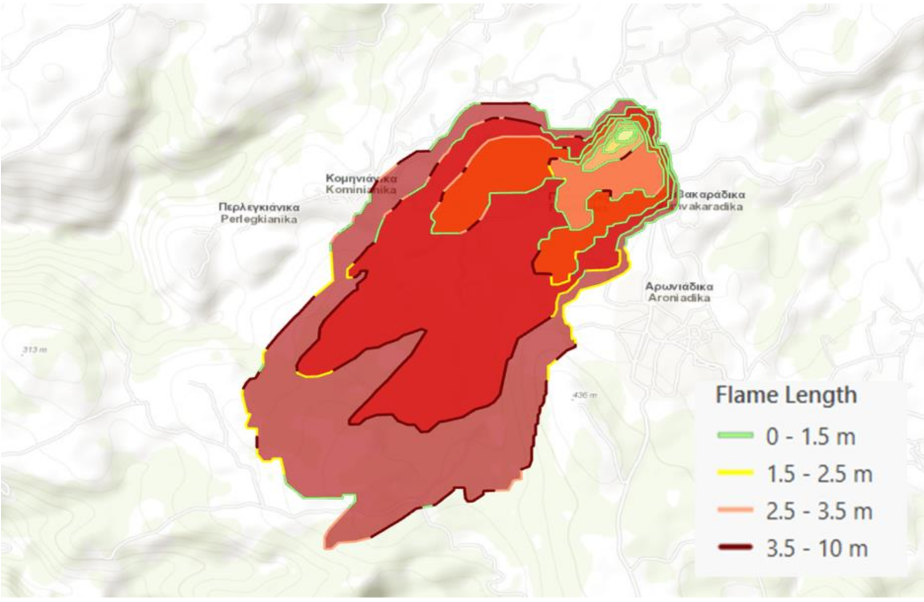


Figure 5 - Simulation of Kythera fire based on existing fuels, showing the flame length classes along the perimeter at each (hourly) simulation step.

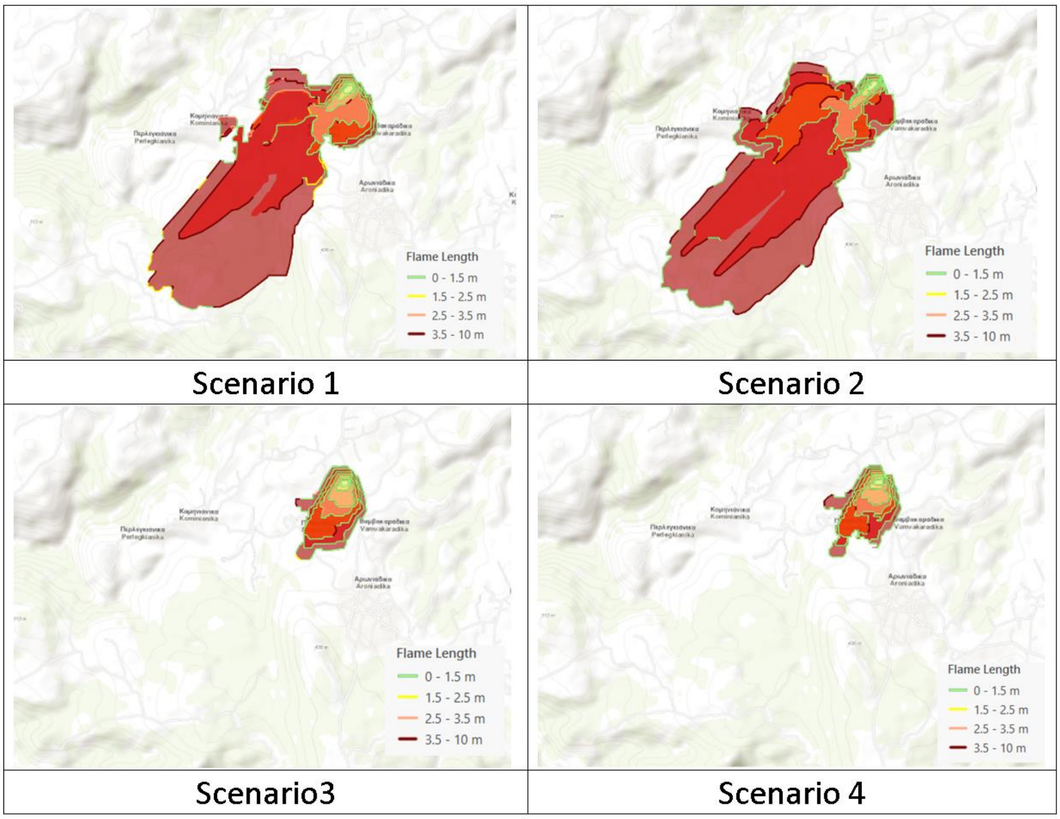


Figure 6 - Influence of the four fuel treatment scenarios on burned area (simulation of 6 hours).

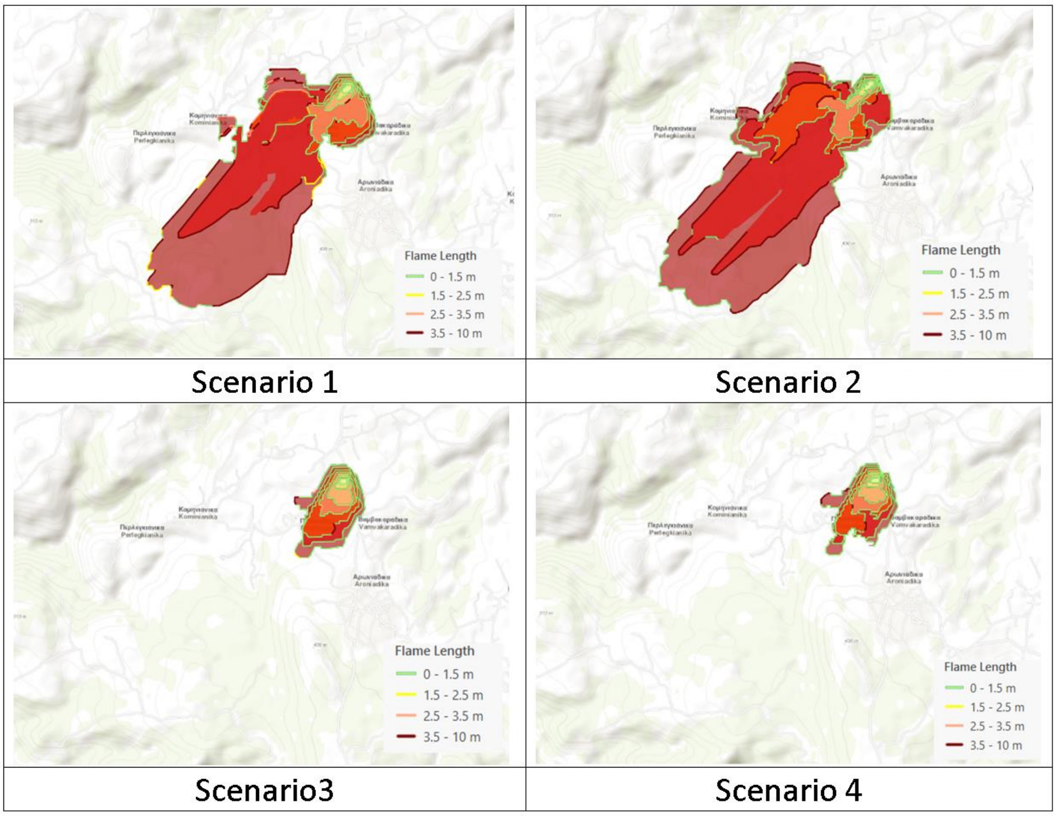


Figure 7 - Influence of the four fuel treatment scenarios on flame length along the perimeter (simulation of 6 hours)

Finally, in order to assess the **effect of the fuel treatments on the required firefighting effort**, the length of the flank of a fire that can be extinguished by a firetruck with a capacity of 2500 l, was calculated as a function of flame length[17]. For a more realistic estimation of firefighting requirement, a reduction in the effectiveness of the firetrucks has been calculated, taking into account the time spent for water refilling and the average time for emptying the load of a firetruck to the fire. As a result, it was possible to relate the estimated perimeter growth, simulated under different scenarios, with firefighting demand (Figure 8).

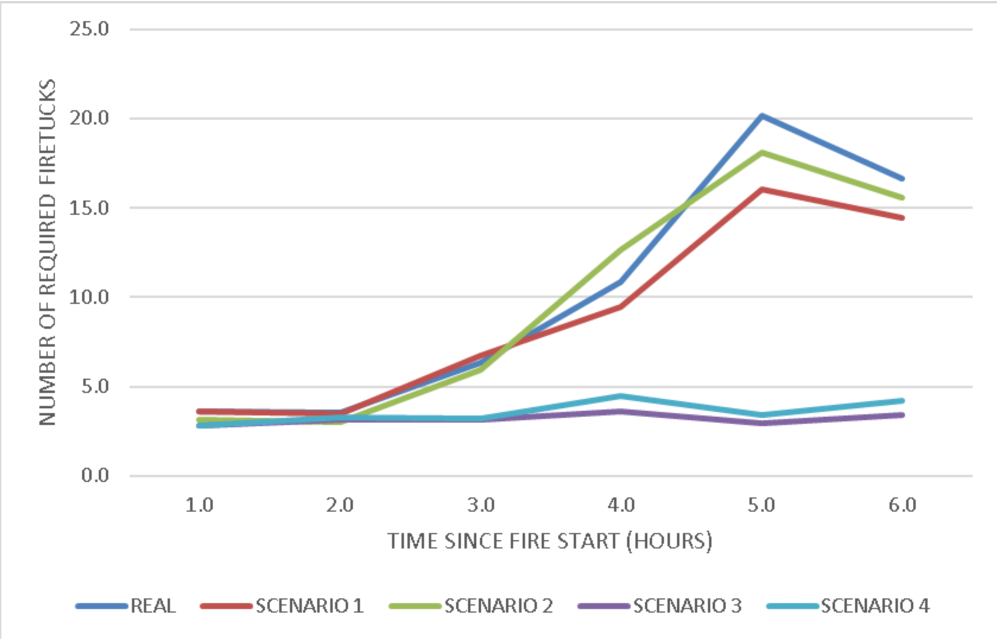


Figure 8 - Evolution of the required number of firetrucks for controlling the perimeter of the fire as a function of time, for the five simulations.

Our findings show that scenarios 1 and 2 (treatments in agricultural areas only) do not affect the length of fire perimeter, but reduce the required firefighting effort, through the reduction of flame length along many parts of the perimeter. The capacity of the available firetrucks on the island (13) is exceeded after roughly 4 hours. It is unlikely that reinforcements will arrive by boat by that time (as it happened in 2017).

Scenarios 3 and 4 reduce both perimeter growth rate and flame length, thus reducing the needed firefighting effort. The number of firetrucks on the island is not exceeded. Broadcast fuel treatment through grazing over all of the land is much more effective (and cost free, actually producing income) than scenarios 1 and 2.

[17] Simos, M., and G. Xanthopoulos. 2014. Assessment of the effectiveness of the forest fire fighting ground forces in Greece. pp. 665-672. In proceedings of the 7th International Conference on Forest Fire Research on "Advances in Forest Fire Research", November 17-20, 2014. Coimbra, Portugal. Viegas D. X., (editor). ADAI/CEIF, University of Coimbra, Portugal. 1919 p.

3. Socio-ecological Decision Support System for fuel management

Wildland fuel management is a key element of land-based fire prevention because forest fuel is the element of the fire triangle that can be modified by human action and mitigate the potential occurrence of unwanted and severe wildfires. Wildland fuels are composed of all kinds of plant material, including grasses, shrubs, trees, and dead leaves. Hazardous fuel accumulation and continuity will result in larger and faster wildfires, and hence, more difficult to manage.

Strategic fuel management (i.e., cost-efficient change in landscape flammability planning optimal interventions at the right place and time) is a very complex matter, which includes identification of the key drivers of landscape flammability, territorial needs, objectives and priorities, limitations to be observed, and real-world application. The Fuel Management Decision Support System proposed by the PREVAIL consortium is intended to be a road map to guide land fire managers in these tasks. It aims to provide a clear and easy-to-apply methodology for planning strategic fuel management activities in a particular area of interest.

PREVAIL DSS-FM aims to **minimize complexity** by being direct and accurate, and by firstly **addressing the fundamental locations for fuel treatment in a certain area of interest**, and thereafter, by applying fire behavior simulators and expanding those locations according to stakeholder objectives and decisions. Hence, the **target territory** is analyzed as a **holistic system where existing planning, management and stakeholders' perspectives are considered and integrated with landscape needs**.

PREVAIL DSS-FM is intended to be general methodology defined for all territories and conditions, based on a set of rules and dependent on stakeholder engagement.

It is structured into three fundamental sections and inherent questions, as follows:

1. **The NEED for fuel management: Is there a need for fuel management?**
2. **The DIAGNOSTIC for fuel management: Where to treat?**
3. **The ACTIONS for fuel management: How and when to treat?**

The three sections are sequential, as each section depends on the previous one. The conceptual model of PREVAIL DSS for Fuel Management is shown in Figure 9. The methodology to implement the three sections of this model, or roadmap, is described in detail in the project deliverable # 5.1[18]. Here we provide an overview of the cornerstones of each section of PREVAIL DSS-FM.

[18] https://www.prevailforestfires.eu/wp-content/uploads/2021/04/PREVAIL_-D5.1.pdf

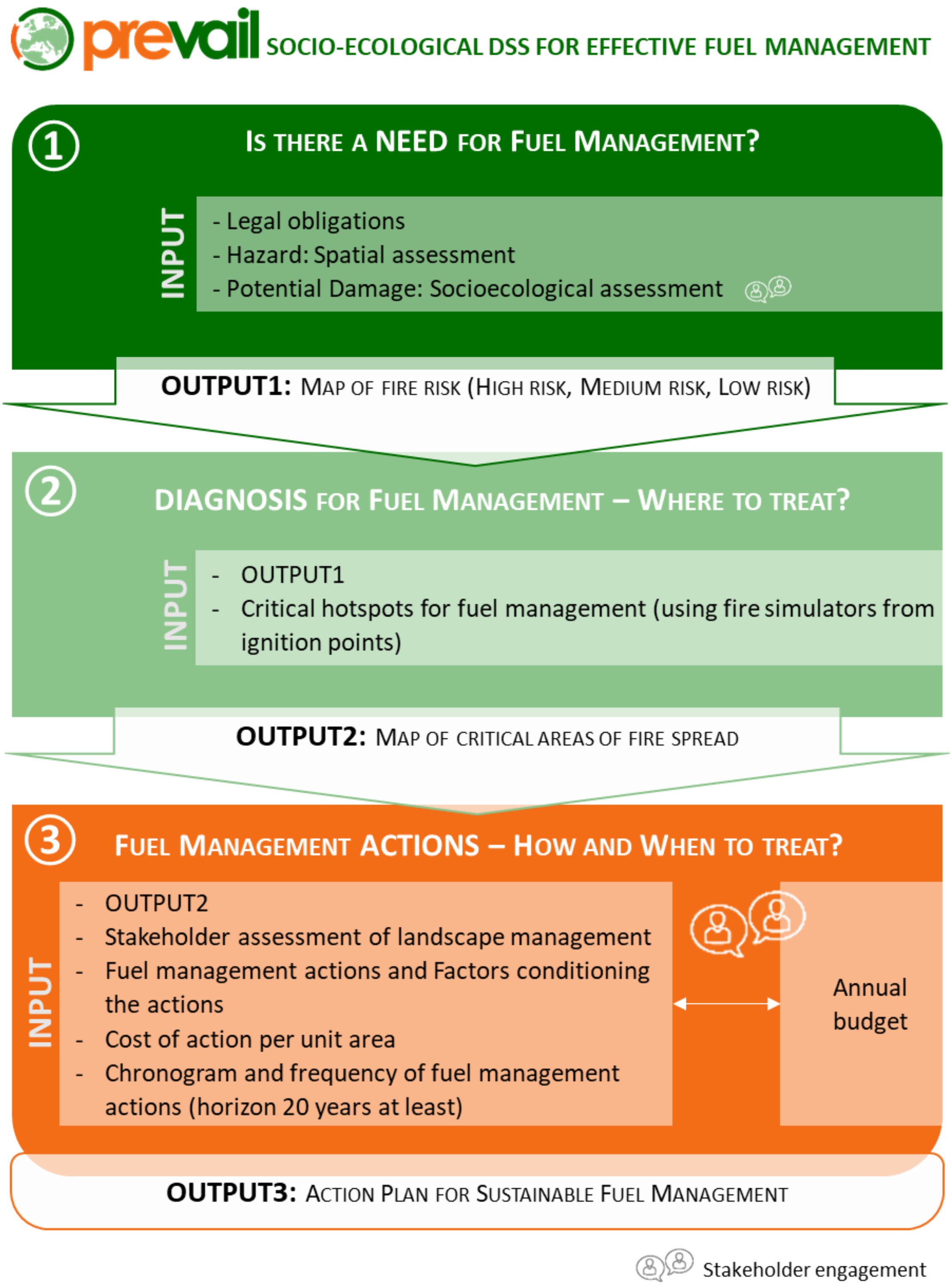


Figure 9 - Roadmap of PREVAIL Decision Support System for Fuel Management.

The need for fuel management (Section 1) is based on the spatial assessment of fire risk for a given territory or Area of Interest (AoI), as shown in Figure 11. We used the following definition of risk and potential damage[19]:

Risk = Hazard x Potential damage

Potential damage = Element at risk (exposure) x Recovery time

In many European countries fire hazard assessment is generally provided by responsible Agencies for wildfire protection, in the form of cartographic information (e.g. maps of Regional Wildfire Prevention Plans). Fire hazard maps classify the territory into distinct areas (spatial polygons) with an ordinal scale of wildfire hazard. On the other hand, potential damage assessment calls for an in-depth understanding of the influence of socioeconomic aspects on fire risk. This is achieved by stakeholder engagement. The conceptual model for the quantification of the potential damage, applied in PREVAIL DSS-FM, is shown in Figure 10.

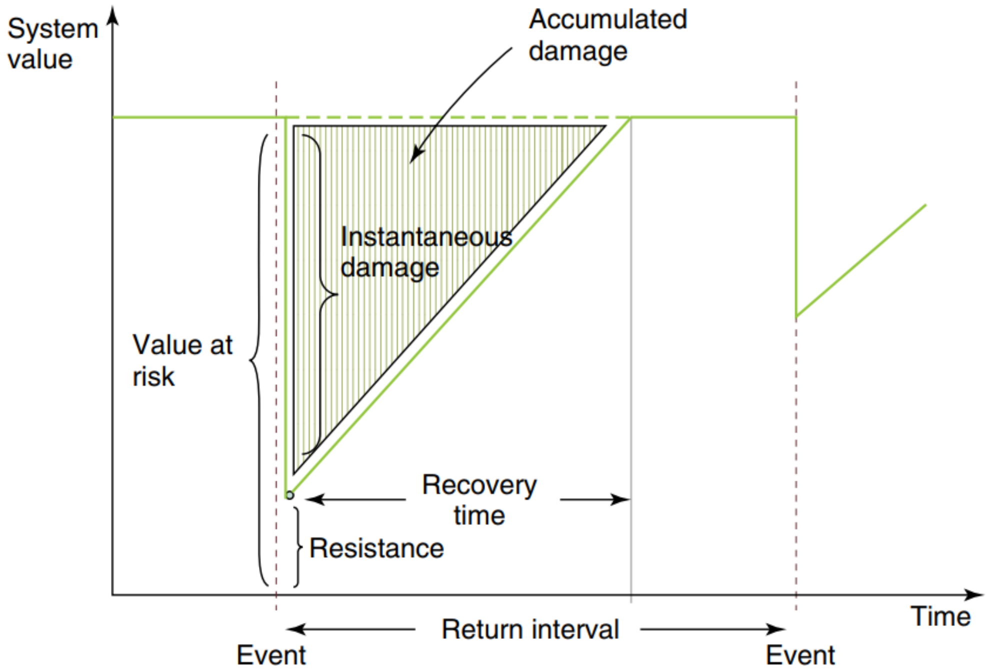


Figure 10 - Potential damage and values at risk[20].

[19] Other risk definitions and formulas may be used, such as the one by UN Office for Disaster Risk Reduction (UNDRR), 2017, available at https://www.preventionweb.net/disaster-risk/risk/disaster-risk/, in which risk is a function of hazard, exposure and vulnerability.

20 Retrieved from: Rego, F. C., & Colaço, M. C. (2013). Wilfire Risk Analysis. In A. H. ElShaarawi & W. P. Piegorsch (Eds.), Encyclopedia of Environmetrics (Second Edi). John Wiley & Sons, Ltd. https://doi.org/https://doi.org/10.1002/9780470057339.vnn023

The potential damage is calculated as a multiplicative function of values attributed to single elements at risk based on four criteria: vulnerability, socio-ecological value and recovery time (Table 5).

Table 5 - Final ranking of values at risk according to stakeholders. Examples are given, according to the stakeholder's assessment carried out in the Portuguese focus group.

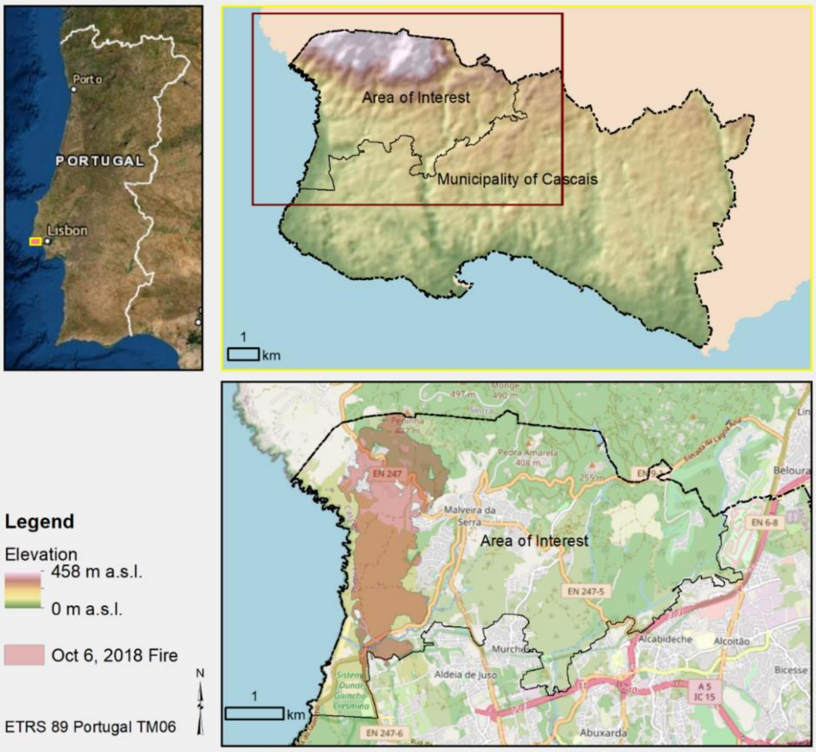
Steps	**1st: list the name of the values at risk**	**2nd: classify their vulnerability**	**3rd: classify their socio-ecological value** (classify separately and sum the two values)		**5th: classify their recovery time**	**6th: calculate final value**
	Element at risk	**Vulnerability**	**Ecological value**	**Socio economic value**	**Recovery time**	**Final value**
Scale	**N/A**	**0: No damage; 1: 25% damaged; 2: 50% damaged; 3: 75% damaged; 4: Value destroyed**	**1 (Low value) to 4 (Very high value)**	**1 (Low value) to 4 (Very high value) or Euros (tangible)**	**1 (less than 1 year to recover) to 4 (long time or hardly to recover completely)**	Multiply all previous classifications
	Priority habitat 5210	1	4	4	4	32
	Native species	1	4	4	4	32
	Riparian vegetation	1	4	4	2	16
	Mediterranean scrubland	1	3	2	1	5
	Quercus pyrenaica stands	0,5	4	2	4	12
	Natural grasslands	0	3	2	1	0
	Agriculture mosaic	0	2	4	2	0
	Temporary ponds	0	4	2	2	0
	Dune system habitats	0,5	4	3	2	7
	Nature tourism	1	1	4	2	10
	Nature tourism infrastructures	1	2	3	2	10

Accordingly, elements at risk can be localized in the AoI as spatial data layers (areas, lines, or points) with different classes of potential damage, depending on the target area, scale of analysis and stakeholders involved. The Map of Fire Risk (Figure 11) derives from the intersection of the Hazard Map and the Map of Potential Damage and it is organized in three classes (low, medium, high). The level of risk is derived from a two-way contingency matrix (Table 6).

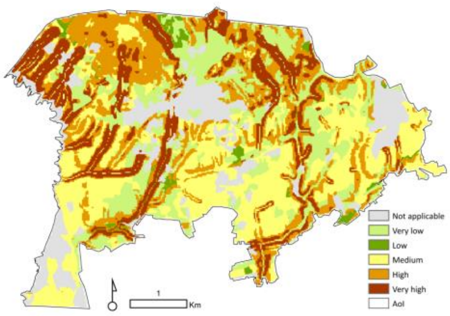
Table 6 - Spatial matrix with "High risk", "Medium risk", and "Low risk" classes. The number of classes shown for the spatial assessment is based on the Portuguese hazard map. However, it may be adapted to a specific territory, independently of the scale of analysis.

		HAZARD: Spatial assessment					
		0: Null	**1: Very low**	**2: Low**	**3: Medium**	**4: High**	**5: Very high**
POTENTIAL DAMAGE: Socioecological assessment	**0: Null**	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
	1: Very low	Low risk	Low risk	Low risk	Low risk	Medium risk	Medium risk
	2: Low	Low risk	Low risk	Medium risk	Medium risk	Medium risk	Medium risk
	3: Medium	Low risk	Low risk	Medium risk	Medium risk	High risk	High risk
	4: High	Low risk	Low risk	Medium risk	High risk	High risk	High risk
	5: Very high	Low risk	Medium risk	Medium risk	High risk	High risk	High risk
							Medium risk is Cost-dependent

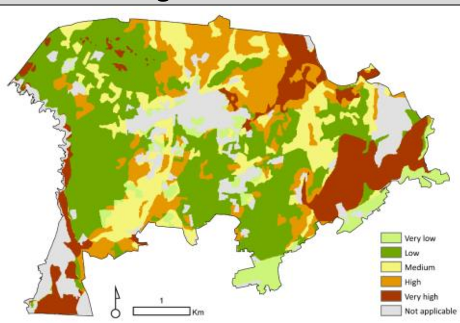
Area of interest (AoI)



Fire hazard



Potential damage



Fire risk

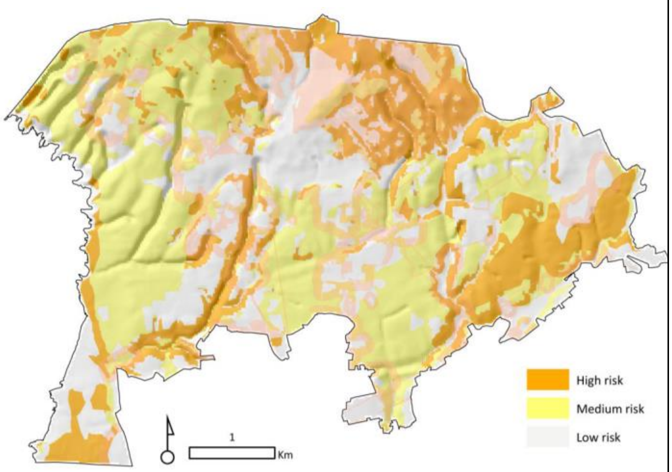


Figure 11 - Components of fire risk in the territory of an Area of Interest (AoI) located in the Municipality of Cascais.

The **spatial locations where fuel management should be carried out** are not only **areas at high** (or medium) fire risk, but also the **spots that may increase fire spread rate, intensity, severity**, and/or create new fire fronts, i.e. ***critical areas for fuel management***. These areas are drawn using fire simulators from ignition points (Section 2). If there are no historical ignition points available, ignition points distributed according to an ignition probability criteria (e.g., in a buffer of the road network) may be used. Legal Obligations for performing fuel management in the (AoI) must be also considered. For instance, the Forest Fire Defense network in Portugal, which is a set of Mandatory Areas for Fuel Management in areas surrounding settlements and infrastructures, conceived to protect people and key infrastructures. An example of critical areas for fuel management and mandatory areas for the AoI is illustrated in Figure 12.

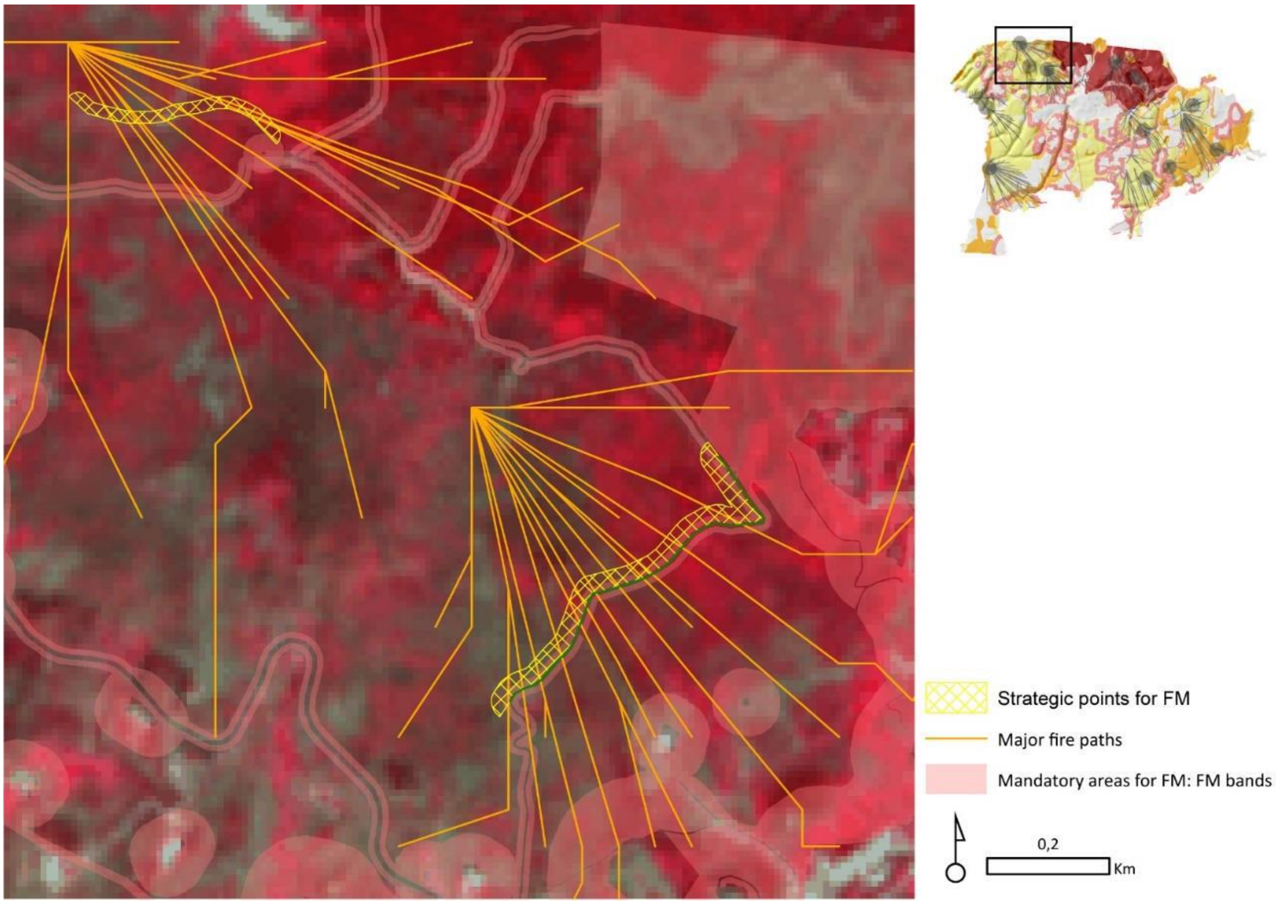


Figure 12 - Example of 2 Strategic points for fuel management. The northern strategic point is based on a tiny lane where a corridor of 20 meters was applied; for the southern strategic point, an enlargement of the mandatory corridor was performed adding a length of 20 meters in the direction from which the fire will likely arrive, considering past fire events. Scale 1:10.000.

The last step of the PREVAIL Decision Support System for Fuel Management concerns the formulation of an Action plan for the sustainable fuel management of the target area (Section 3). It comprehends the fuel management actions to be carried out at the priority areas for fuel management identified in the previous steps, as well as their frequency, the management goals of the different stakeholders and their synergies.

Every **action to manage fuel has its own demands, constraints, and characteristics**. For instance, when using heavy machinery, it is necessary to have a good logistic to transport the dozer to the area of intervention, have a certified driver, the slope cannot be too steep, etc. Prescribed burning also has its own demands and constraints, such as a PB plan, certified technicians, the meteorological window of opportunity, type of fuel, etc. Some constraints may also occur when the fuel management is next to a highway or hospitals due to the smoke it produces. For a sound decision about the most appropriate actions to implement, it is important that **the manager is aware of the different techniques and their pros and cons** (Table 7).

There is also a need to consider that the beneficial outcomes of all these practices have only a temporary effect since vegetation continues growing afterwards.

Despite most of these activities can found financial support in rural development programmes (see Section 4), it is crucial to find smart solutions to systematically reduce fuel and keep them reduced over time, where it's appropriate to do so, and capture some commercial value from this process (see Section 5).

Table 7 - Example of a Matrix of solutions for Fuel Management actions. Conditioning factors and their characteristics must be adapted to each AoI. Examples are given in some cells.

<table>
<tr><td colspan="5" rowspan="2"></td><th colspan="5">Factors conditioning the actions</th></tr>
<tr><th>Smoke</th><th>Slope</th><th>Meteorology</th><th>Land cover</th><th>Etc.</th></tr>
<tr><th rowspan="10">FM Actions</th><th rowspan="3">Business as usual</th><th colspan="3">Machinery</th><td></td><td></td><td></td><td></td><td></td></tr>
<tr><th colspan="3">Heavy machinery</th><td></td><td>E.g.: >20%</td><td></td><td></td><td></td></tr>
<tr><th colspan="3">Prescribed burning</th><td>Ex: highways, WUI</td><td></td><td>Window of opportunity</td><td></td><td></td></tr>
<tr><th rowspan="7">Landscape integrated management for fire prevention</th><td rowspan="7">Agroforestry Management</td><td rowspan="3">Livestock husbandry</td><td>Sheep</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Goats</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Cows</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Conservation</td><td>Wild animals</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Wood forest products</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Non-wood forest products</td><td>Resin extraction</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Mushrooms</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

4. Role of EU public funding in fire prevention

The shift towards more severe and expensive fire seasons, in terms of fire suppression, calls for a paradigm change in wildfire management policy, in order to rebalance public expenditures between suppression and those wildfire prevention activities able to mitigate the negative impacts of fire.

In this framework, the PREVAIL project has highlighted how several funding programs at European level can help to support fire prevention. The most important are three out of the five programs within European Structural and Investments Funds (ESIF): the **European Regional Development Fund** (ERDF), the **Cohesion Fund** (CF) and the **European Agricultural Fund for Rural Development** (EARDF). Besides these structural funds, specific pilot projects can be funded by specific programs including LIFE or INTERREG. An extensive analysis is presented in a specific project deliverable[21]. In this section we focus on the main findings.

The Rural development program

Among the EU funding schemes for wildfire prevention, the most relevant is EARDF, since its financial support corresponds to about 74% of the total EU programmed expenditure related to the thematic objective 5 “Climate Change Adaptation, risk prevention and management”. The prevention against wildfires has been funded using different measures during the different RDP programs. In the RDP 2007-13, there was no measure with a one-to-one relation with direct wildfire prevention. The RDP measure more closely related with direct wildfire prevention (or post-fire restoration) is the **“2.2.6: Restoring forestry potential and introducing prevention actions”**. In fact, depending on the priorities of geographic area covered by the RDP, the 226 funding can be allocated to prevention of forest hazards other than wildfires (e.g. storms, avalanches). However, funds spent under this measure well reflect the relative importance allocated to prevention of (and restoration after) forest hazards out of all activated RDP measures, wildfire being one of the most important ones in the examined Countries. In the **RDP 2014-2020**, **prevention against risks has been included in measure 8.3 (prevention of damage from forest fires, natural disasters) and 8.4 (restoration from forest fires, natural disasters).**

The full dataset collected during the PREVAIL project about programmed funding and total expenditure under the framework of RDP 2007-2013 allowed us to derive some key facts about the level of investments in direct forest risk prevention, across the PREVAIL project Countries. In this regard, in Figure 13 the percentage of the programmed expenditure for the measure 226 over the total programmed expenditure is compared, showing how Spain has given a higher relative weight to prevention against natural disasters if compared to the other three countries.

[21] https://www.prevailforestfires.eu/wp-content/uploads/2021/03/2.2.pdf.

The data collected allowed us also to evaluate the efficiency of the use of RDP resources, quantified by the rate realisation of programmed expenditure. In the case of RDP 2007-2013, this rate is rather high in the case of Italy, Portugal and Spain, where around 80% of the programmed expenditure in the measure 226 has been realised. On the other hand, Greece has spent just 15% of the programmed budget (Figure 14).

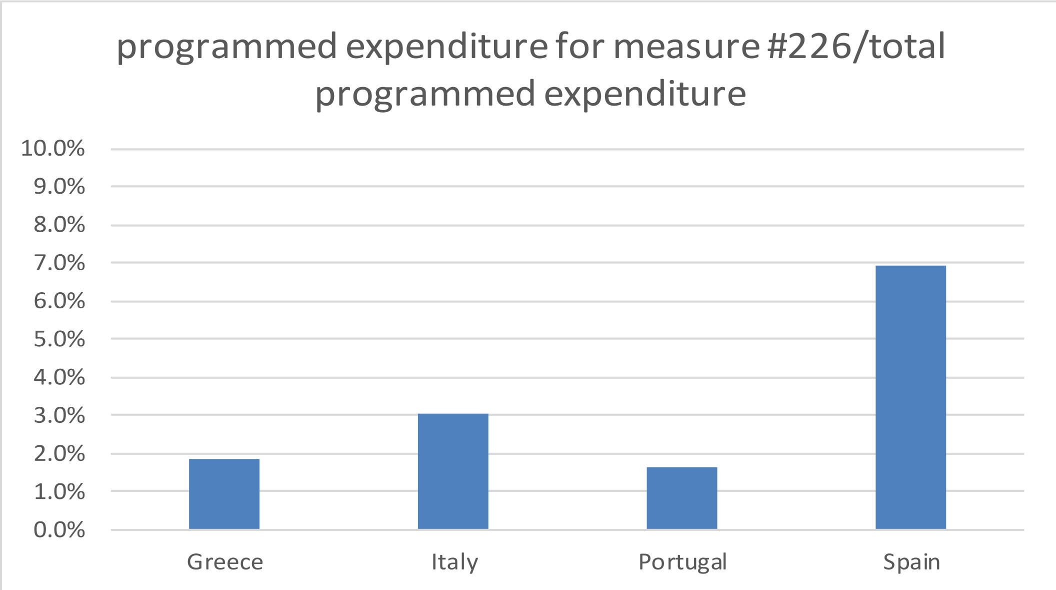


Figure 13 - Percentage of the programmed expenditure for the measure 226 (RDP 2007-2013) over the total programmed budget of the national RDP (Source: https://enrd.ec.europa.eu/ updated to June 2015).

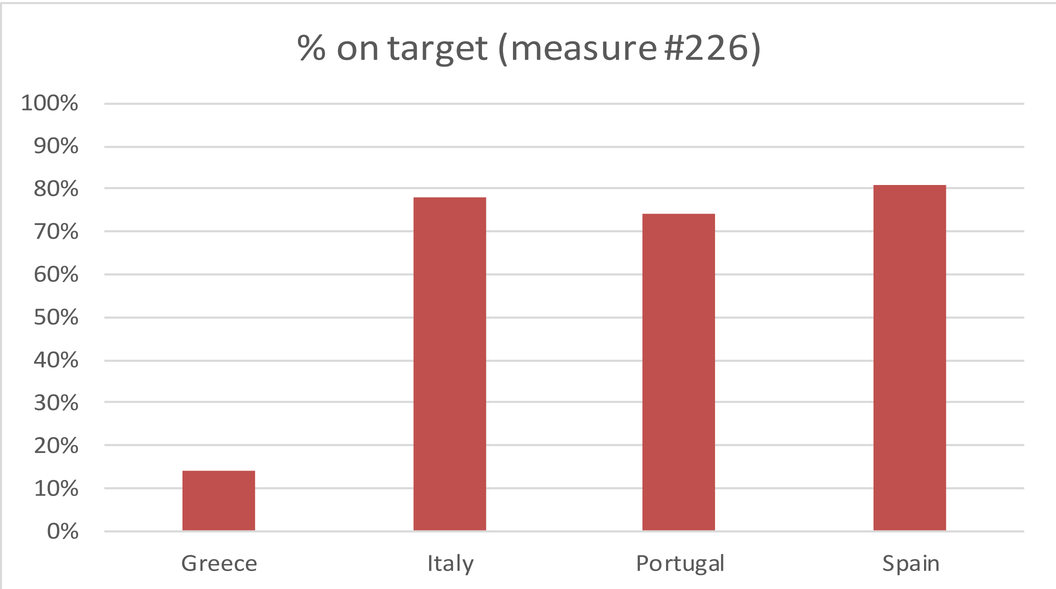


Figure 14 - Percentage of measure #226 (RDP 2007-2013) on target across the partner Countries (Source: https://enrd.ec.europa.eu/ updated to June 2015).

A rate of realization lower than 100% has been also found in many regions across project Countries for most of the measures linked to forest activities. This partial expenditure has brought to a reduction of fund allocation in the subsequent RDP program for measures devoted to support the forest sector. For instance, Italy has programmed for the RDP 2014-2020 a total expenditure for measure 8.3 reduced by 30%[22] if compared to programmed expenditure for measure 226 (RDP 2007-2013). If we consider 8.3 and 8.4 together, in any case the programmed funds decreased from the 539 mln of euros of the measure 226 (RDP 2007-2013) to 501 mln of euros.

For a better understanding of the spatial allocation of public expenditure for forest fire prevention, we have produced a map for each partner country which shows the value of the measure 226 expenditure per hectare of forest[23]. Although there is no way to devise from expenditure data the actual intensity of investments on the ground, as publicly available data do not report the total forest area benefiting from RDP 226 subsidies, the public expenditure on measure 226 per hectare of forest is intended just as a proxy of the intensity of the investment, to allow for comparison between different Regions. This analysis allowed us to figure out some differences across countries (Figure 15 to Figure 18). Our findings show that the unitary volume of expenditure in Spain and Italy is between 32 and 36 € per hectare, while in Portugal and Greece is just 12 € and 1.7 €, respectively.

[22]Source Italian ministry for agriculture, updated at 2018.

[23]The public expenditure on measure 226 per hectare of forest has been calculated as the ratio between the total public expenditure at regional (Italy, Spain) or subnational (Greece, Portugal) level and the total amount of forests and other wooded areas (i.e. classes 3.1 and 3.2 of Corine Land Cover 2006).

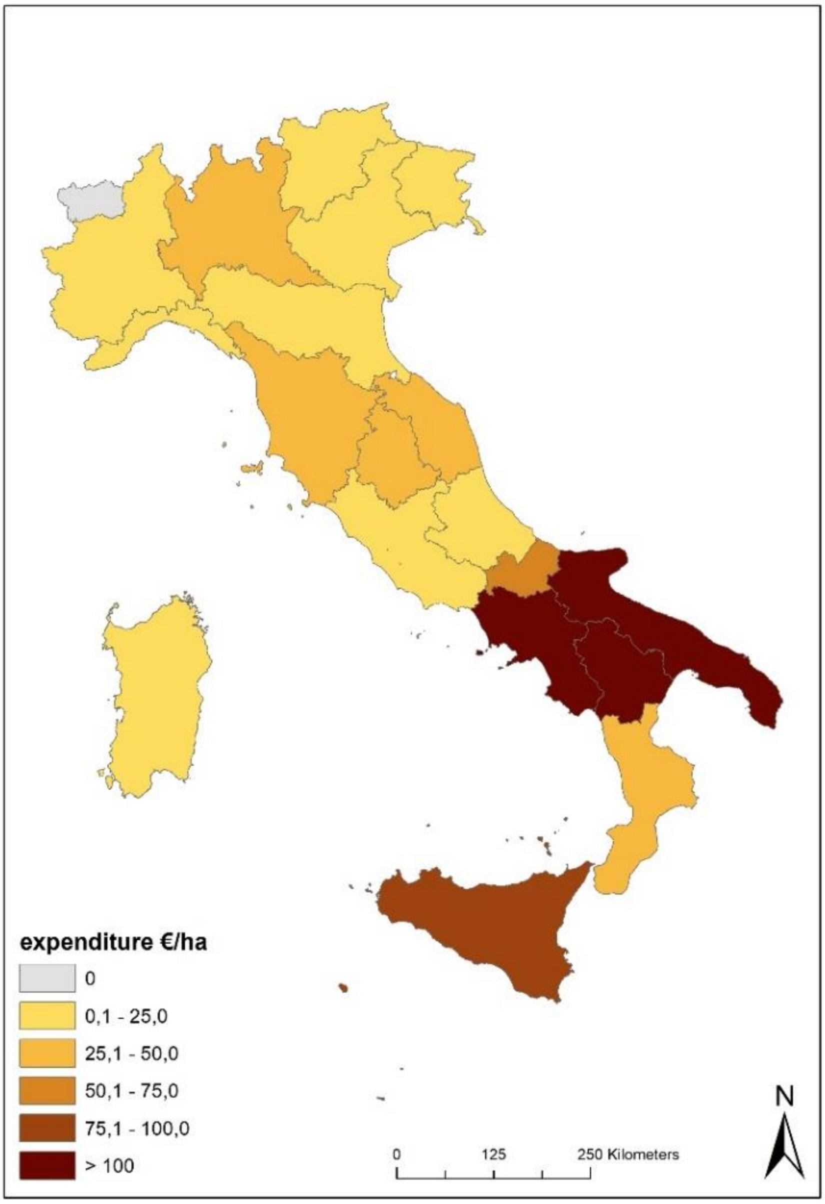


Figure 15 - Public expenditure for the measure 226 of the RDP 2007/2013 (expressed in € per hectare of forest) at regional level in Italy.

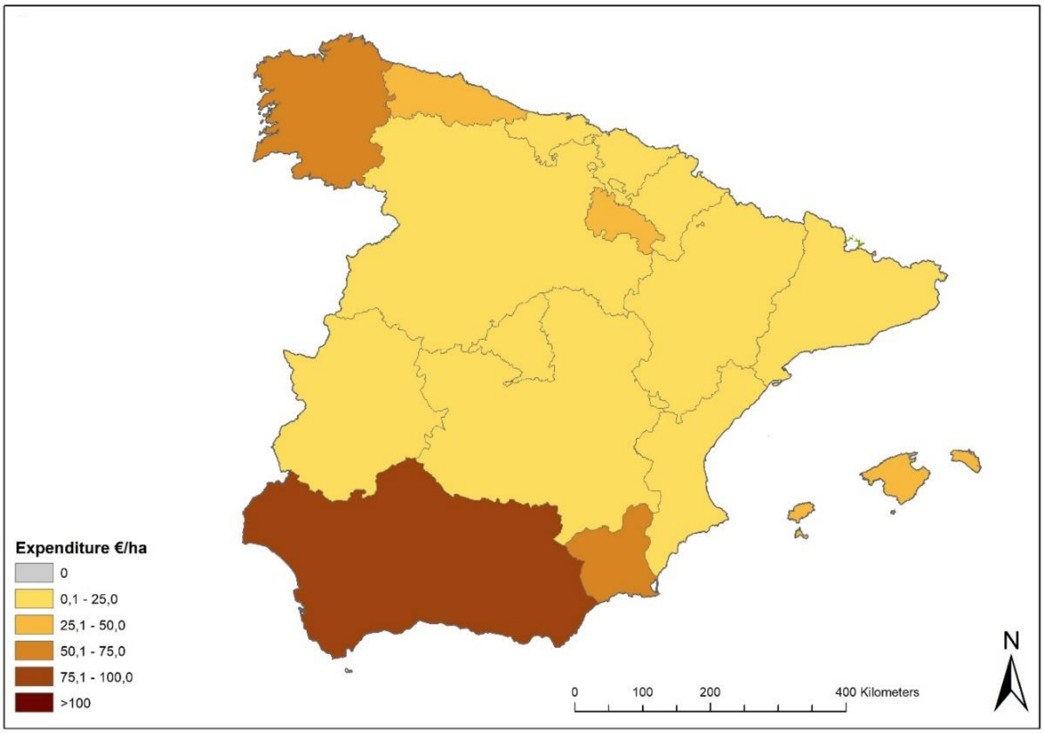


Figure 16 -. Public expenditure for the measure 226 of the RDP 2007/2013 (expressed in € per hectare of forest) at regional level in Spain.

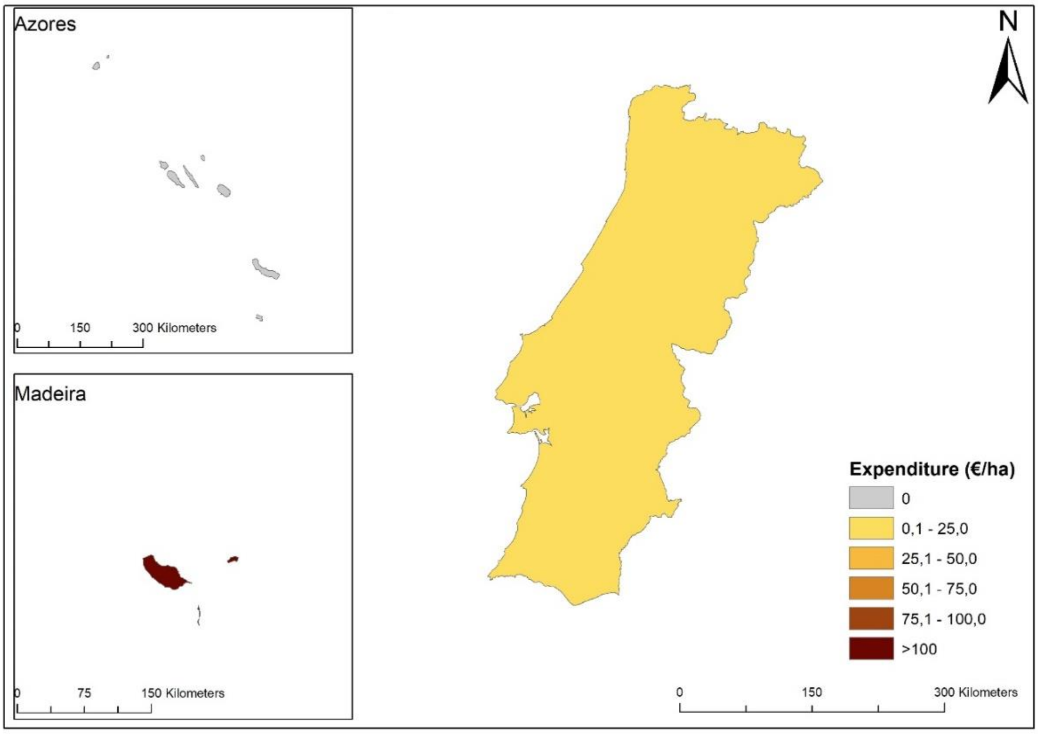


Figure 17 -. Public expenditure for the measure 226 of the RDP 2007/2013 (expressed in € per hectare of forest) at NUTS1 level in Portugal.

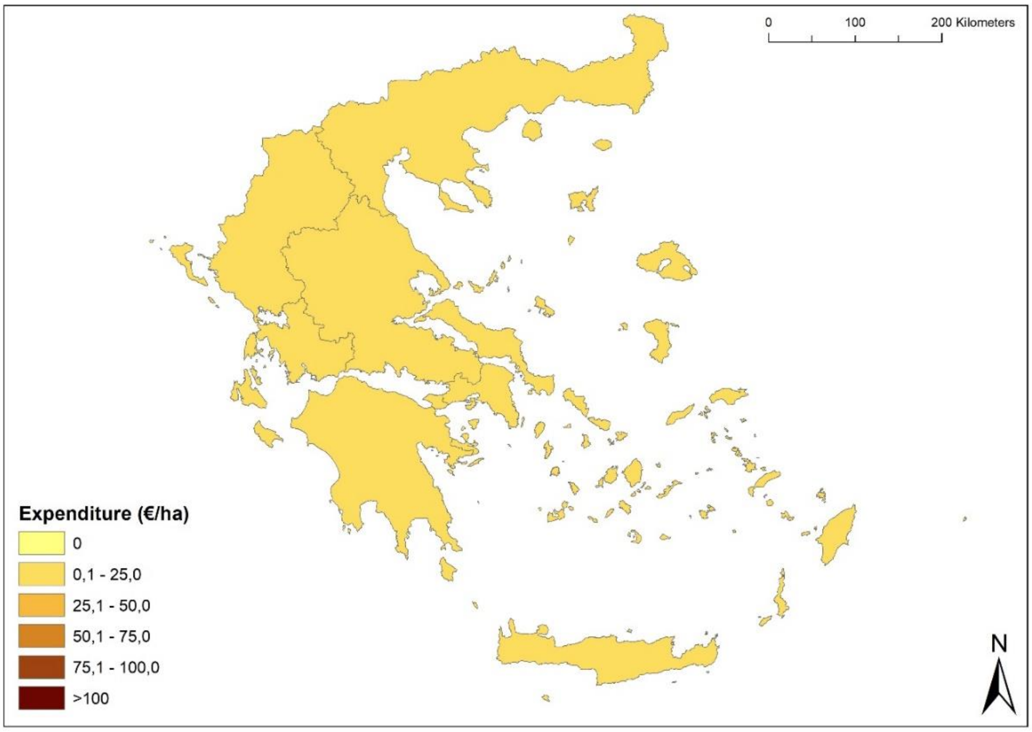


Figure 18 - Public expenditure for the measure 226 of the RDP 2007/2013 (expressed in € per hectare of forest) at "decentralized administration level" in Greece.

"Active" vs "Passive" prevention

PREVAIL's project vision of fire prevention goes beyond the forest sector and aims to promote an integrated cross-sectorial approach to build-up fire-RR landscapes. Any decrease or increase in forestry, farming and grazing activities in rural areas produce effects on the amount and spatial distribution of vegetation and associated fuels and, accordingly, affects the vulnerability and exposure of territories to fire. This situation leads to recognize as wildfire prevention, not only **measures to reduce fuel loads or change the spatial arrangement of fuels in forest areas (active prevention)**, but actions capable to support a well-managed landscape mosaic, through the **maintenance of forestry, farming and grazing activities therein (passive prevention)**. In this "patchwork" of land uses, as explained before, fire spreads more slowly, burns with less intensity and severity, and is less costly to suppress.

According to this view, the PREVAIL's project has proposed a reclassification of RDP measures according to their direct or indirect role in fire prevention and proposed the terms "active" and "passive" prevention to identify this set of measures (Table 8). In the case of "passive" fire prevention we have distinguished activities influencing forest fuel (B1), landscape mosaic (B2) and social structure (B3).

Table 8 - Proposal of classification of RDP measures according to their direct (code A) and indirect (Codes from B1 to B3) effect on fire hazard reduction. Codes C (measures supporting fire suppression) and D (no effect) were also added in order to be sure a code is given to all of the RDP measures.

Types of measures can have a direct effect in the short period (+++), an indirect effect in the medium period (++) or in the long period (+).

	Classes and sub-classes	Code	Definition and examples	Relevance for fire prevention
DIRECT MEASURES OF FIRE PREVENTION	**ACTIVE PREVENTION**	**A**	Action directly related with fire prevention as: firebreaks, water points, fuel management in strategic points, etc. *Example of measure in the 2007-2013 RDP:* 226 - Restoring forestry potential and introducing prevention actions	+++
INDIRECT MEASURES OF FIRE PREVENTION	**PASSIVE PREVENTION**	**B**	Actions involving fuel removal, through the maintenance of forestry and agriculture activities on the territory, which indirectly affects fuel loads distribution at landscape level.	
	Forestry production	**B1**	Actions related with forest management and forest products mobilisation (wood and non-wood forest products – except grasslands, see below): selective and commercial thinning, clear cuttings, cork exploitation, roads constructions for wood mobilisation, etc. *Example of measure in the 2007-2013 RDP:* 122 - Improvement of the economic value of forests, 123 - Adding value to agricultural and forestry products, 226 too.	++
	Maintaining mosaic landscape and grazing	**B2**	Actions related with the crop lands and mosaic landscape maintenance, and the related farming and grazing activities (including both: grasslands and complementary grazing in the forest understory). *Example of measure in the 2007-2013 RDP:* 126 - Restoring agricultural production potential, 222 - First establishment of agroforestry systems on agricultural land	++
	Other societal and structural support to rural development	**B3**	Actions of support to rural development: training, extension services, support for business, basic services for the economy and rural population, etc. *Example of measure in the 2007-2013 RDP:* 112 - Setting up of young farmers, 341 - Skills-acquisition and animation measure with a view to preparing and implementing a local development strategy	+
	SUPPRESSION	**C**	Actions related with fire suppression and emergency management. *Example of measure in the 2007-2013 RDP: Normally, they are not included into RDP*	Na
	NO EFFECT	**D**	Actions no related with fire prevention, preparedness, response and recovery of burnt areas. Actions not funded .	Na

Such classification has been applied at regional level in Italy, where public expenditure on different RDP 2007-2013 measures was available also at municipality level. An in-depth analysis conducted on expenditure data available at such disaggregated spatial level, allowed a more accurate assessment of the expenditure spatial structure. The findings from the analysis show that the 226 measure was financed (and presumably implemented) in an extremely fragmented way across the examined territories and many areas at high fire risk were not treated at all using this measure (Figure 19). Furthermore, the measures not specifically aimed at supporting fire prevention but with an indirect positive effect on fire hazard reduction are not associated to specific fire risk categories (Figure 20).

On one side, this fragmentation may be influenced by the local context and the efficiency of certain local administration to handle RDP calls. On the other side, however, this fragmentation may reflect an unclear design in the allocation of the measures themselves and, thus, difficulties in the use of RDP funding for fire prevention in rural areas. Knowledge gained from stakeholders involved in PREVAIL Workshop#1[24] also suggested as possible areas of improvement to reduce the fragmentation of funding to make a clear link between the spatial allocation of RDP measures and territorial areas most exposed to the forest fire hazard in the geographical area covered by each single RDP. In this direction, there is a need **to rethink the criteria for the territorial allocation of active and passive fire prevention measures under the RDP**, so that **territories most exposed to the forest fire risk**, are to receive **greater concentration of resources**. In this perspective, the Fuel Management Decision Support System presented in Section 2 is an easy-to-use tool to support the decision-making of RDP Management Authorities.

Another possibility is to open **multi-measures calls** for integrated territorial projects finalized to fire prevention. These integrated projects can include both active prevention (e.g. fuel management, firebreaks) and passive measures with positive effect on fire prevention (e.g. active forest management and forest products mobilization, mosaic landscape maintenance, grasslands and complementary grazing in the forest understory).

But all of this requires greater capacity of political and cross-sectoral dialogue and coordination between public Administrations, in order to establish synergies between public Institutions, in charge of the wildfire prevention planning, and RDP Management Authorities. Otherwise, the potential to leverage the impact of public policies on wildfire risk management in rural territories will remain untapped, to some extent.

[24] https://www.prevailforestfires.eu/wp-content/uploads/2021/03/2.1.pdf

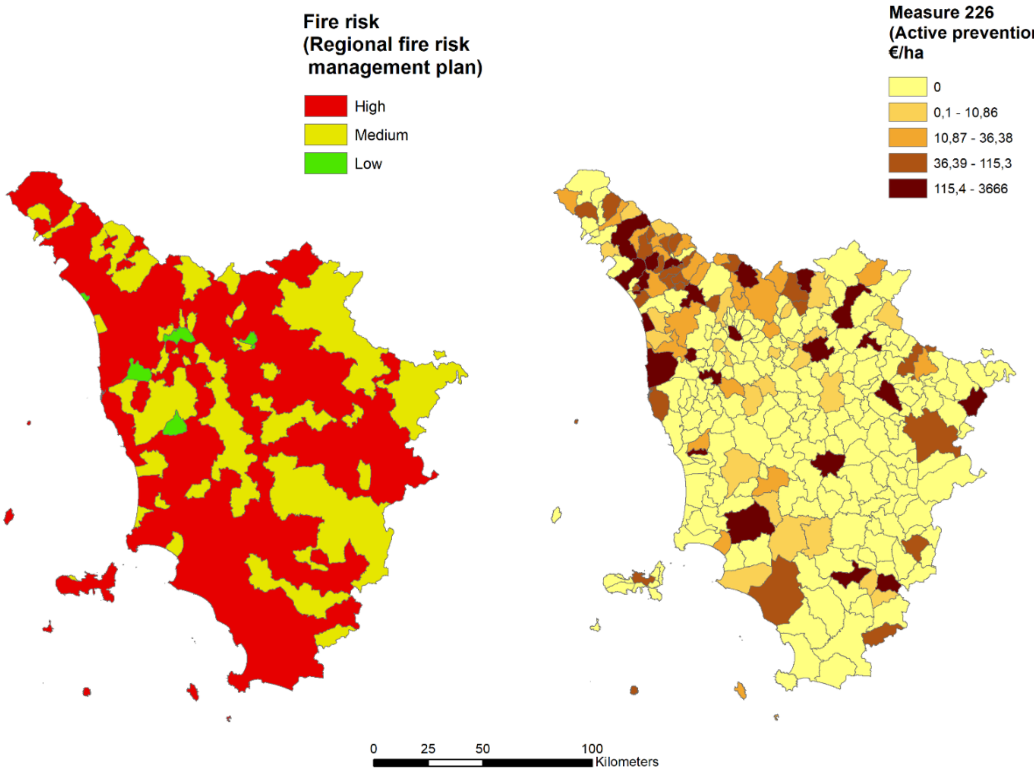


Figure 19 - Spatial distribution at municipality level of fire risk and public expenditure on active prevention (measure 226 of the RDP 2007/2013, expressed in € per hectare) in Tuscany Region (Italy).

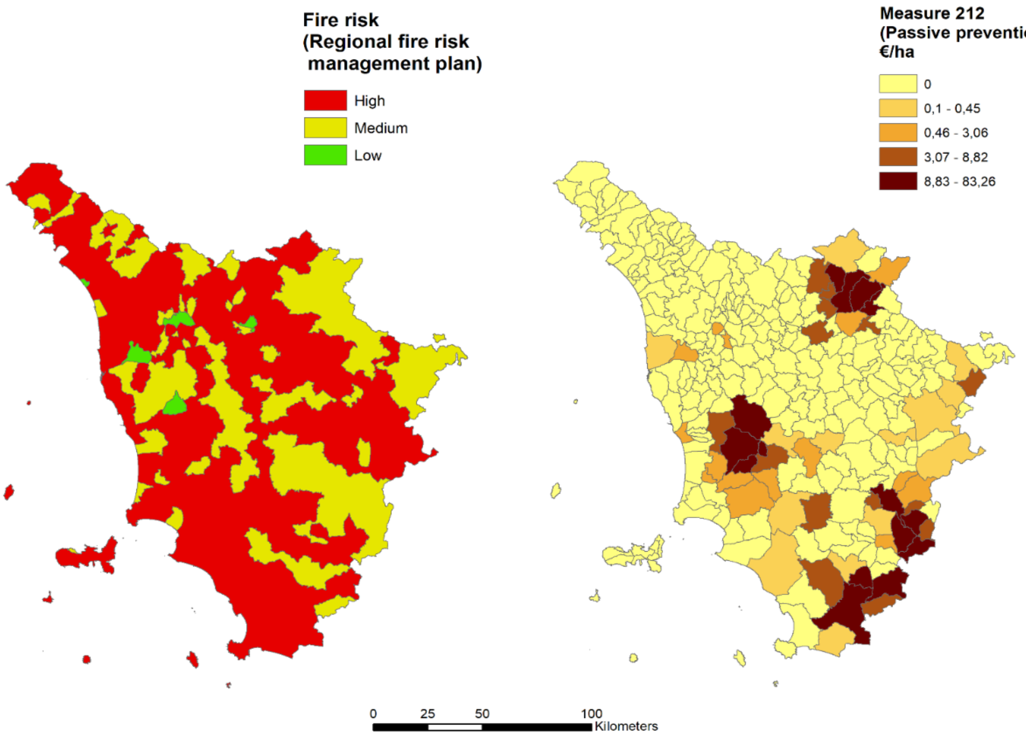


Figure 20 - Spatial distribution at municipality level of fire risk and public expenditure for a passive prevention measure (measure 212[25] of the RDP 2007/2013, expressed in € per hectare) in Tuscany Region (Italy).

[25] Payments to farmers in areas with handicaps, other than mountain areas.

5. Innovative approaches to building fire-RR landscapes: the fire smart solution

Landscape based fire prevention is one of the major strategies we have in southern Europe to mitigate large-wildfire risk[26]. To build such fire-resistant and resilient landscapes we need multiple synergies among sectors responsible for strategic fuel management planning (i.e. active prevention[27]) and sectors responsible for passive fire prevention[28] such as forestry, agricultural and grazing management, but also the energy sector, urban planning, and nature conservation. However, to make this happen, to plan and build such landscapes, we need to address the complexity of land governance processes, the complexity of cultural, political and organizational legacies that each European territory has, the complexity of multiple and conflicting interests, the fragmented land property issue, and in particular, we need to achieve a sustainable process.

Achieving economic, social and environmental sustainability is a major challenge and we need models to achieve such sustainability. In the PREVAIL project we searched initiatives where bottom-up needs, ideas and solutions have been meeting top-down European policies, funds and incentives to mitigate wildfire risk, while achieving cross sectoral links, public-private partnerships, and multiple land management, social and economic goals. We documented success cases that managed to trigger multiple synergies to build a sustainable process.

The PREVAIL consortium identified agencies, in project partner countries, directly or indirectly involved in fuel management programs. In total, we contacted 67 agencies involved in fire prevention and, through a refined consultation process[29], we identified and analyzed a set of 32 relevant fuel management initiatives at the local level. In order to harmonize the data collection, we designed a common template to interview responsible agencies. The template included several sections, covering a wide spectrum of information: name of the initiative and its promoter, contacts, location, funds supporting fuel management (EU projects, RDPs, Local/Regional funds), phases of the Disaster Risk Management (DRM) cycle implemented (Prevention - active or passive, Preparedness, Response and Recovery). Finally, a section with a set of open-ended questions, dealing with different topics useful for a subsequent Gap analysis, describes the initiative and opinions from actors/agency implementing it: the type of fuel management activities and their contribution to fire prevention, their limitations and the needs to improve their efficiency in fire risk management, the

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[26] Moreira, F., Ascoli, D., Safford, H., Adams, M.A., Moreno, J.M., Pereira, J.M.C., Catry, F.X., Armesto, J., Bond, W., González, M.E., Curt, T., Koutsias, N., McCaw, L., Price, O., Pausas, J.G., 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, 1–6. doi:10.1088/1748-9326/ab541e

[27] Actions directly related to wildfire prevention as firebreaks and fuelbreaks, water points, fuel management in strategic points, silvicultural intervention to increase resistance and resilience to fire disturbance, etc. (Deliverable 4.1 - Working paper on cases, agencies and actors identified).

[28] Actions involving fuel removal, through the maintenance of forestry and agriculture activities on the territory, which indirectly affects fuel loads distribution at landscape level (Deliverable 4.1).

[29] Deliverable 4.1 - Working paper on cases, agencies and actors identified.

indicators to assess and monitor the work results, and additional details. The full list of contacted agencies, the format of the survey, and all compiled forms are available online[30].

To analyse landscape-based fire prevention initiatives and extract best strategies, we defined six key criteria (Table 9): sustainability, cost-efficiency in Disaster Risk Management, synergies, cooperation, best existing knowledge, adaptive management. These criteria were considered essential as they consider multiple needs addressed in the European strategies (e.g., bioeconomy, biodiversity, forestry) while meeting wildfire prevention requirements. Survey interviews were analyzed to assess to what extent they fulfilled the criteria in Table 9. Data and information from the survey were used to perform descriptive analysis of some identified initiatives and institutions, to select model solutions for landscape based fire prevention, and to analyze strengths and weaknesses of the selected initiatives through qualitative analysis (Gap analysis).

[30] https://www.prevailforestfires.eu/project/dissemination/

Table 9 - Criteria to assess fuel management initiatives.

Criteria	Sub-criteria	Description
Sustainability	**Circularity**	Resource-efficient valorisation of biomass resulting from fuel management in integrated, multi-output production chains, sustaining fire hazard reduction while benefiting the local economy, involving multiple sectors under a fire management vision, and producing positive self-feeding cycles.
	Short supply chain	Local supply chains of primary and secondary products resulting from fuel management programs, including a marketing strategy that valorises the ecosystem service delivered by the fire hazard reduction.
	Nature based	Coherence with environmental conservation and sustainable management under EU biodiversity strategies (e.g. SCI in Natura 2000 sites, Biosphere Reserves, etc.), enhancing the delivery and maintenance of ecosystem services. Fuel management techniques and their spatio-temporal planning is based on the ecological understanding of ecosystem and landscape dynamics in a given fire regime.
	Social sustainability	Fuel management programs considering a strong social component, involving local communities in landscape management and valuing community choices in pursuit of shared goals. Management activities derives from local needs and the results are useful to the community, providing mutual benefit.
Cost-Efficiency in Disaster Risk Management		Initiatives showing cost-benefit or cost-efficiency criteria both in terms of market price and/or environmental and social services. Funding not directly related to fire management converge on it, optimizing cost-effectiveness. Similarly, land management activities not directly related to fuel management can be planned to maximize fire prevention.
Synergies	**Source of funding**	Integration of multiple funding sources (both local and European) in fuel management programs allowing for a wide range of fire management actions. Multiple funding denoting high continuity in local land management, allowing for constancy in the management of fire-prone landscapes.
Synergies / Cooperation	**Integration and Convergence of multiple land management goals**	Multidisciplinary approach and presence of shared land management goals involving different actors in the fire management program, maximizing efforts and diversifying solutions in risk management.
Cooperation	**Participation**	High level of cooperation at the local level considering the community as a central node. Local community information and training in risk management and participatory processes involving multiple social components.
Best existing knowledge	**Strategic fire prevention planning**	Spatio-temporal planning of fuel management in strategic areas that prioritize the protection of key territorial assets (e.g. wildland-urban interface, ecosystem services), integrated with fire-fighting strategies based on landscape opportunities.
	Innovative fire hazard reduction techniques	Implementation of advanced fuel management techniques, traditional practices and nature-based solutions (e.g. variable retention harvest, prescribed burning, prescribed grazing, etc.).
Adaptive management	**Impact assessment**	Use of indicators and monitoring programs to evaluate the effectiveness of fire prevention activities in the short and long term. Evaluations of fuel management programs efficiency considering both the environmental (fire regime change, ecosystem maintenance) and the socio-economic component (local production, security), assessing the impacts at the landscape scale.
	Lesson learnt approach	Implementation of a lessons learned approach incorporating best results and failures of action implementation, making them robust, transferable, and, at the same time, sensitive to local conditions and regional contexts that benefit from other similar experiences.

The survey identified 32 fuel management initiatives (Figure 21) covering a wide range of southern European landscapes and fire regimes. These include 18 strategic fire prevention initiatives at regional/local level, 6 programs managed at national level, and 8 international projects. All initiatives fulfilled at least one or more key evaluation criteria (Table 9). Among agencies involved in fuel management initiatives, 60% belong to public agencies and 40% to private ones (Figure 22). Public actors are largely involved in Italian and Spanish initiatives, diversely in Portugal where private agencies prevail. Analysing fuel management programs characteristics, the overall data show that the initiatives have been financed by both regional, national, and European funds, particularly related to the Rural Development Program (RDP), and other forms of funding related to private investments (Figure 23- left). Among the Disaster Risk Management phases, Active Prevention (85%), Passive Prevention (80% overall) and Preparedness activities (50%) prevail (Figure 23- right). Among passive prevention activities, those dedicated to maintaining the landscape mosaic are the most represented, including agriculture, grazing and forestry production.

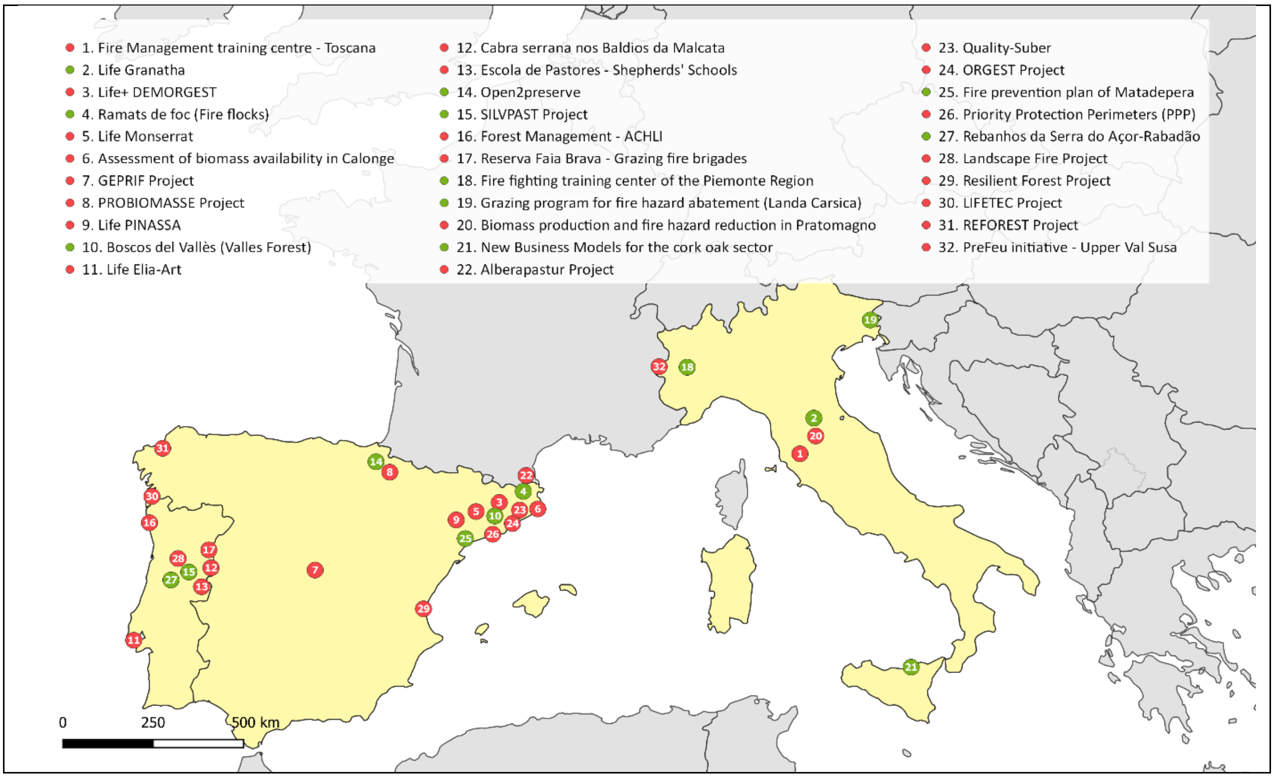

Figure 21 - Selected fuel management initiatives in southern European countries fulfilling one or more key criteria (Table 9). In 'green' the initiatives presented in Table 10.

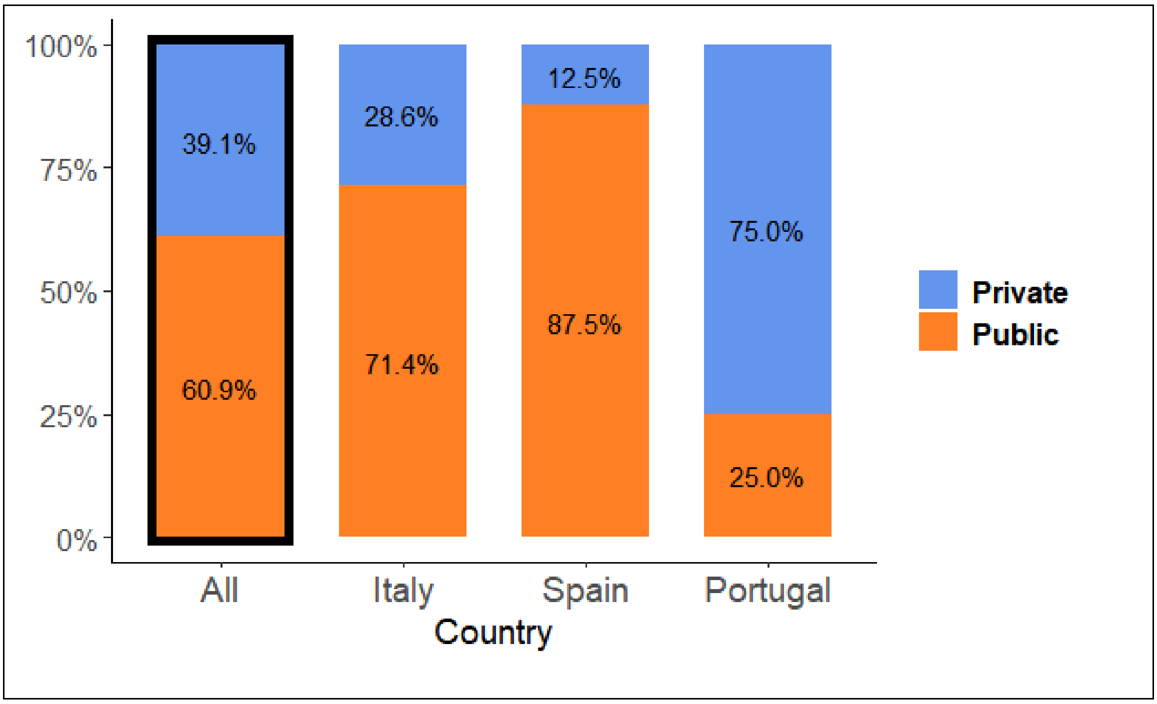

Figure 22 - Distribution of fuel management initiatives between public/private agencies.

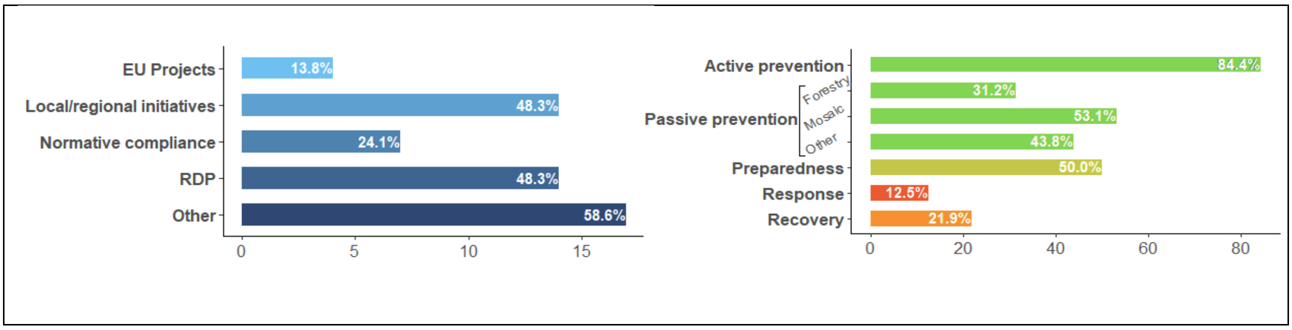

Figure 23 -Initiative source of funding (left); DRM cycle phase covered (right).

Table 10 reports information of a selection of initiatives in relation to the fuel management activity for fire hazard reduction in woodland, shrub and herbaceous vegetation using several silvicultural techniques (e.g., selective thinning, variable retention harvest, prescribed burning), mechanical clearing and prescribed grazing[31] using bovine, goat and sheep. In most cases, interventions are carried out in strategic areas defined by specific fire prevention plans (from the municipal to the regional scale) such as: (i) fuelbreak networks (linear infrastructures to support firefighting) in strategic areas in relation to expected large-fire occurrence; (ii) forest blocks considered priority for the ecosystem services delivered (e.g. general protection from soil erosion, direct protection of infrastructures exposed to rocks falls, tourist use) in order to increase their

[31] Lovreglio, R., Meddour-Sahar, O., Leone, V., 2014. Goat grazing as a wildfire prevention tool: A basic review. IForest 7, 260–268. doi:10.3832/ifor1112-007

resistance and resilience to fire disturbance; (iii) wildland-urban interface areas to protect sensitive residential, service or production areas.

Table 10 - Sub-set of fuel management initiatives assessed.

Map number	Initiative name	Contribution to fire hazard reduction	Activated chain and social/environmental services	Cooperation actors
2	LIFE Granatha	Biomass and shrub cover reduction in scrubland through mechanical cutting, prescribed burning and grazing in shaded fuelbreaks and blocks.	Production and marketing of organic brooms made of *Ericaceae* (the "granatha"). Bird species and habitats (4030) conservation. Training of fire-fighting operators (AIB).	Fire-fighting operators of Toscana region (AIB), local farmers and producer.
4	Ramats de foc (Fire flocks)	Reduction of herbaceous and shrub biomass by grazing (horses, goats, sheep) in strategic areas for wildfire prevention.	Dairy products and beef, goat and sheep meat under the 'Ramats de Foc' label, which unites local farmers, butchers and restaurateurs.	Municipalities, private landowners, local farmers.
10	Boscos del Vallès (Valles Forest)	Fuel control through biomass reduction, good forest management, wildfire prevention infrastructures	Biomass buying-selling market for small and big biomass consumers (privates, hospital, university, etc.), generation of proximity energy.	Municipalities, Government, Forest Defence Association (ADF), forest owners, forest research centres.
14	LIFE Montserrat	Fuel control in strategic areas through grazing and prescribed burning. Eosystem-based measures to increase resilience and stability of forests against fires.	Supply chain of dairy, beef, goat and sheep meat products under the 'Can Mimó' label. Biodiversity and habitat conservation and improvement. Creation of a mosaic landscape to increase connectivity.	Regional administrations, Forest Owners association, a Private foundation, Natura 2000 sites.
15	SILVPAST Project	Fuel management through grazing (cows and horses), remote sensing monitoring (drone and gps collars), biodiversity monitoring and conservation, support decision-making.	Increase *Quercus pyrenaica* forage for animals, helping landowners save money on animal feed.	Forest owners and managers, landowners, policy makers (from local to the national level).
18	Firefighting training centre of the Piemonte Region	Training programs in firefighting and prescribed burning techniques, fuel management along fuel breaks in strategic areas through prescribed burning, tactical fire and grazing management, grass and shrub cover reduction assessment.	Fuelbreak cleaning for cows' transit and touristic activities (trekking and ski).	Regional authorities, a private enterprise, Fire brigades volunteers and operators, local farmers and community.
19	Grazing program for fire hazard abatement (Landa Carsica)	Fuel control in strategic areas through prescribed burning and grazing (sheep), Restore pastures productivity.	Land assignment to local farmers, value chain of products from grazing (meat), sheep breeding for didactic ends.	Private landowners, "Landa Carsica" business network of local farmers.
21	New Business Models for the cork oak sector	Biomass and shrub cover reduction with mechanical cutting in *Quercus suber* woods.	Production of semi-processed products for bio-building, cork-based panels and granulates. Use of the resulting biomass for factory heat. Cork forest restoration (habitat 9330).	Private agencies, universities, local cork producers.
25	Fire prevention plan of Matadepera	Fuel management through grazing (goats and sheep), sustainable forest management, biodiversity conservation.	Employment and agricultural management to feed livestock, proximity market line for cattle products (meet).	Natura 2000 site, farmers, shepherds and local producers.
28	Rebanhos da Serra do Açor-Rabadão	Maintenance of the primary firebreaks network and fuel management around local town through goat grazing.	Dairy goat products. Eucalyptus and conifers forest plantations preservation. community interaction in a pedagogical perspective through visits.	Local farmers, forestry producers, Municipality, local community.

The selected initiatives here analyzed are a useful pool from which to extract key elements for sustainable landscape based fire prevention programs in Southern Europe and provide insight and concrete fire-smart solutions to build a general model. Figure 24 summarizes the main components extracted from the selected initiatives, while Table 11 presents a Strength Weakness Opportunities Threats (SWOT) analysis assessment. Key elements of a fire-smart solution include **Sustainability**, both at environmental and socio-economic levels. Several initiatives aimed at reducing fire risk by fuel management while acting at the same time on various components of natural systems by stimulating different ecosystem services such as provisioning services (e.g. livestock products, wood), regulation services (e.g. carbon sequestration, erosion prevention, pollination, etc.), supporting services (local habitats and biodiversity conservation) and cultural ones (eco-tourism, landscape mosaic). For example, in the LIFE Montserrat[32] and LIFE Granatha[33] initiatives, fuel management is complemented by high environmental awareness, fostering habitat and biodiversity conservation and connectivity between landscape patches, including links to Natura 2000 sites. Moreover, several fire-smart solutions implemented a short supply chain under a circular bio-economy perspective, valuing fire-marketing products like wood as a raw material and agricultural and pasture products. In some initiatives fire hazard reduction was recognized as an ecosystem service. An example is the "Ramats de foc" (Fire flocks) project[34], in which value is added to the sale of grazing products through a label that certifies the herds' fire risk management tasks (Figure 25, top). Similarly, another initiative promotes wine production through the 'Vi fumat' label (Figure 25, bottom right). Vi Fumat is a clear example of how the mosaic landscape can help containing wildfires. The wineyards served as a fuelbreak to stop a specific wildfire occurred in 2012, thus enhancing all the positive externalities resulting from fire prevention in a circular and sustainable economy.

[32] Miñambres, L., 2018. Life Montserrat: ramaderia, prevenció d'incendis i gestió d'hàbitats. Agro-Cultura 71, 11–13.

[33] Ascoli, D., Berretti, R., Campedelli, T., Londi, G., Miozzo, M., Tellini, G. (2017). Il Progetto LIFE Granatha: Coltivazione delle eriche e fuoco prescritto per la conservazione dell'habitat degli uccelli delle brughiere. Sherwood 230: 28-32.

[34] Domènech, R., Soy, E., 2020. Girona – Fire Flocks, grazing systems to reduce wildfire severity. C 25 Girona, Spain Aims 499–507.

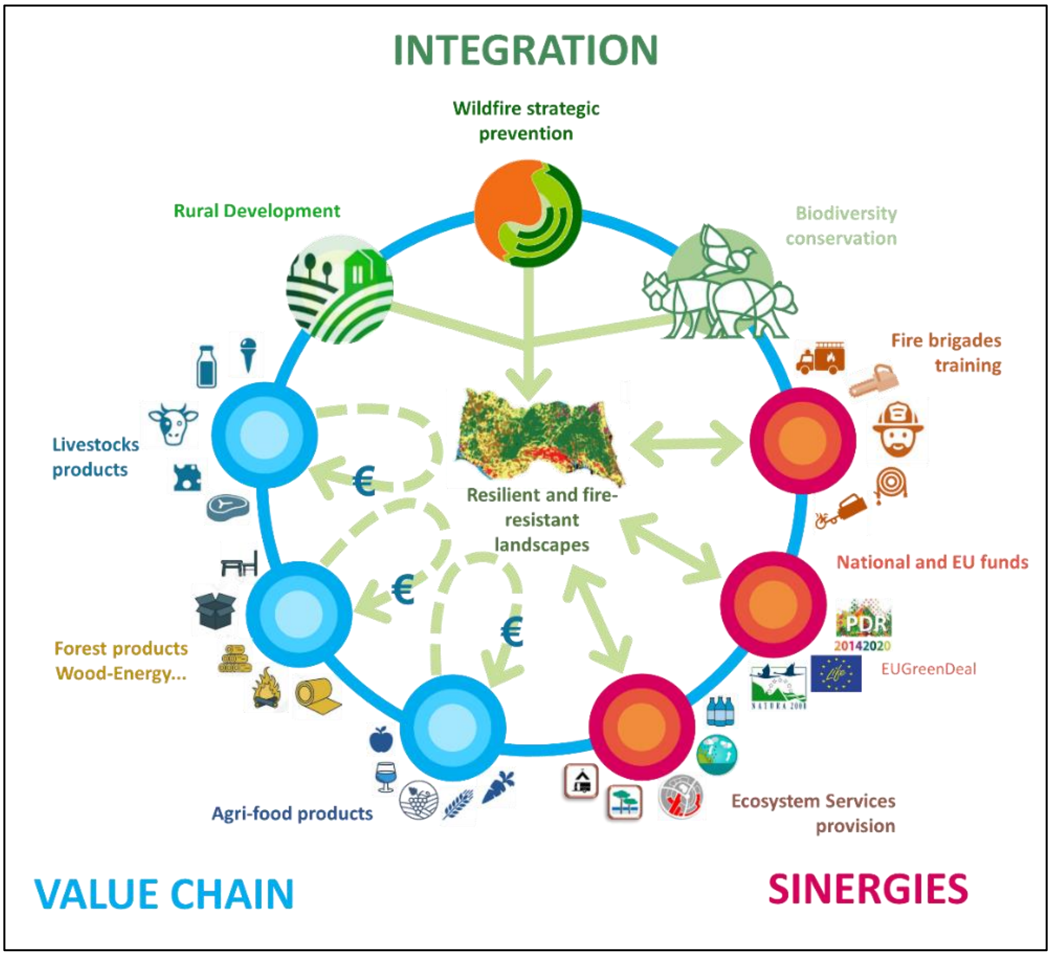

Figure 24 - Key components of a fire smart solution for creating fire-RR landscapes.

Table 11 - SWOT matrix for fire smart solutions implementation to achieve fire-RR landscapes.

Strengths	**Weakness**
Wildfire risk reduction through different activities of the territory contributing to maintain and promote a mosaic landscape less vulnerable to wildfire spread. Multiple techniques linked to fuel reduction (prescribed burning, silviculture actions, pre-planned wildfire prevention infrastructures, reduction of fuel loads, grazing, etc.). Fuel management as civil protection tool, protecting strategic buildings and Wildland Urban Interface areas. Convergence towards multiple land management goals maximising cost-benefits. Special attention to Prevention and Preparedness enables timely and professional action. Variety of initiatives indicates complexity, cross-sectoral, spatial and temporal extension of wildfire risk management. Non-wood and wood production in public and private forests. Combine wildfire management actions with nature conservation.	Different distribution of competences in wildfire management increases the challenges of harmonizing a common strategy. Insufficient available budget to implement the actions needed. Lack of human resources to cover all actions to be done. Too bureaucracy processes (legal processes related to some instruments, plans or actions to be developed). Non-economic viability of some local activities (e.g., low market value of products).
Opportunities	**Threats**
Cooperation between international partners and local actors, and within communities. Increase of capabilities, training and knowledge of Fire Service professionals. Contribution of several EU projects provide innovation and transferability among regions under common challenges. Increased risk awareness (communication actions to society, environmental education, etc.). Contribution to decrease the land abandonment. Promotion of local economies and development of marginal territories, through either ecotourism, recreational activities or new business models. Foster the use of forest, agricultural and grazing products. Development and certification of the local short supply chain. Development and maintenance of wildfire prevention infrastructure. Experimental areas for reforestation after fire. Preparation and implementation of annual Fire Protection Plans.	Low involvement of private forest owners to contribute with their land to extend fuel management actions. Shifting the focus to Prevention, institutions should not devalue the role of Fire Suppression (Response) and post-disaster Recovery. Not updated forest management plans and obsolete RDP models.

Figure 25 - Fire-marketing products: Dairy products from the "Ramats de foc" project, Catalunya, Spain (top), the "Mompantable" produced with pine forests affected by high fire severity in Val Susa, Italy (bottom left); and 'Vi Fumat' wine which served as a fuelbreak in a 2012 la Junquera wildfire, Catalunya, Spain.

Another key element of fire-smart solution implemented in the analysed initiatives is **Cooperation** and **Integration**, converging fire prevention goals, environmental well-being, local development and optimizing **Cost-efficiency**. Examples are the initiatives carried out by the "Fire Management Training Centre" of the Tuscany region, and the Firefighting training Centre of the Piemonte region, where prescribed burning activities are accompanied by the training of fire-fighting operators[35]. In the SILVPAST project[36], landscape planning for fire prevention is combined and favoured by the productive agricultural, pastoral and forestry territorial realities and the political actors involved in local and national land management. In fact, in several initiatives we documented **Synergistic** approaches, relying on local cooperation and international support.

[35] Ascoli, D., & Bovio, G. (2013). Prescribed burning in Italy: issues, advances and challenges. iForest-Biogeosciences and Forestry, 6(2), 79.

[36] https://www.terraprima.pt/en/projecto/23

Initiatives such as the Open2preserve project[37] (Tresserras et al., 2018) or the Landscape fire Project[38] (and other selected Interreg Sudoe and LIFE projects) perfectly embody this vision, being promoted and financed by European funds, regional administrations, research institutes, local associations, and private foundations, laying the framework for long-term management programs of fire-prone landscape. To be considered a new alternative, fire-smart solutions must make the best use of the **Best existing knowledge** resulting in innovative projects with a clear social and territorial scope. The Boscos del Vallès project[39] stands out as a major innovation in Catalonia, working in fire prevention through the valorisation of biomass and exploiting its products to energetically power several local public facilities, such as the hospital and sports facilities of the Autonomous University of Barcelona. In addition, the project contributes to local forest landscape management and engages in environmental education though risk awareness and communication actions in schools. Finally, smart solutions must have an **Adaptive Management approach**, monitoring prevention efforts and learning from past experiences. Among the criteria analysed, this is the least represented due to the young age of many initiatives, however a long-term example is the GEPRIF Project[40], in which the efficiency of corrective measures for post-fire forest hydrological restoration, new biodegradable materials for post-fire erosion risk reduction and the cost-effectiveness of prevention, extinction and rehabilitation activities are evaluated.

The surveys and individual forms describing each initiative are available in deliverable 4.1 and 4.2 on the PREVAIL project website. Further information on the documented initiatives can be found on the Lessons on Fire[41] platform and GoProFor database[42] and one YouTube channel of the PREVAIL project[43].

[37] Tresserras, R.M.C., Azpilicueta, L.M., Garciandia, L.S.E., Martínez, M.V.S., Istilart, J.L.S., Echavarren, L.E., Durruty, J.L., Unzue, O.U., Aróstegui, A.Y., Ortigosa, A.P. de M., 2018. Open2Preserve: preservación de espacios abiertos de montaña. Navarra Agraria 231, 30–32.

[38] https://life.cimvdl.pt/

[39] Renom, I.G., 2018. Boscos del Vallès - Prevenció d'incendis a partir de la dinamització del mercat de la biomassa forestal. Consell Comarcal Del Vallès Occidental 2, 20.

[40] Silva, J.S., Rego, F.C., Fernandes, P., Rigolot, E., Silva, J.S., Rego, F.C., Fernandes, P., Rigolot, E., Integrated, T., Fernandes, P., 2020. Towards Integrated Fire Management . Outcomes of the European Project Fire Paradox To cite this version : HAL Id : hal-02823740 Towards Integrated Fire Management – Outcomes of the European Project Fire Paradox.

[41] https://lessonsonfire.eu/en

[42] https://www.lifegoprofor-gp.eu/advanced-search

[43] https://www.youtube.com/channel/UCvMhqvCwbxyx3XGIPuIzRtQ

6. Final remarks

The PREVAIL project provides analyses and results useful to increase awareness of the benefits of landscape-based fire prevention founded on a sustainable economic, social and environmental management for the community. It demonstrates the key importance of synergies between sustainable forest fire management, rural development, nature conservation and adaptation to climate change. It also contributes to reduce tensions between public opinion and management activities based on sustainable fuel management. PREVAIL key messages by target groups are summarized in Table 12.

The development of fire-smart initiatives as those here documented, based on a full understanding of large-fire drivers, integrating strategic fuel management and land governance processes, must be a great stimulus in structuring shared policies that take into account local realities. The European Green Deal[44] by recognizing forest preservation and restoration in Europe as one of its key objectives, offers political backing to the implementation of the innovative active and passive prevention solutions, here presented, to reduce the incidence and extent of wildfires. In the implementation of the Green Deal it is crucial to recognize the role of Fire Smart Management, implementing Integrated Fire Management with additional elements. In order to accelerate the transition process towards fire-RR landscapes across Europe through Fire Smart Management it is also important to build a strong network between the different smart solutions applied locally, thus integrating local innovative solutions into international sustainable development policies. For this purpose, we decided to showcase examples of fire smart solutions on both the Lesson on Fire and GoProFor platforms.

New policies supporting land management, such as RDPs and national regulations, must broadly include fire prevention directly and be built on common premises. An analysis of the smart solutions identified by PREVAIL shows how the lack of adequate funding, the difficulty of accessing it and the lack of economic viability of prevention actions are at the root of the difficulties of local fire prevention projects. The development of common policies for land management must consider local needs and start from them to build common and community-friendly strategies of action. Finally, fire prevention must be politically and economically recognized as an ecosystem service useful for a new European Bioeconomy, enhancing all the positive externalities resulting from fire prevention in a circular and sustainable economy.

Fire-RR landscape can be achieved by aware communities on a shared governance model, able to decide objectives and practices to prevent, control and use fire. Extreme fire events increasingly involve the wildland-urban interface, severely affecting infrastructures and citizenship. In this context, analysing the cost-efficiency of fire suppression, implementing strategic fuel management with the support of DSS and building fire-smart solutions is a real civil protection process, reaching multiple shared objectives through

[44] COM (2019) 640 of 11.12.2019.

smart and transdisciplinary actions, which include both local cooperation and international involvement in risk management. To reach conscious fire risk management, single solutions are not sufficient and only the multiple and widespread application of smart solutions at local/regional level would allow the creation of large territories with a high capacity to resist, react and be resilient to fire impacts. In order to make local examples useful for international governance, a strong network between the various initiatives and institutions involved in fire hazard management is necessary, creating a mutually beneficial synergy at an international level.

Table 12 - Summary of key messages organized by target groups.

Target	**Key messages**
Journalists	Prevention of forest fires requires active management of forest areas. Sustainable fire prevention is different from logging and is necessary to increase the resistance and resilience of our forests to extreme fires. Fire disturbances are part of the natural dynamics of ecosystems, if their frequency and intensity remain within the historical range of variability. Flammability is an intrinsic property of natural landscapes.
Environmental associations	Sustainable forest management for fire prevention is compatible with the protection of forest ecosystems and may be necessary to ensure the safety of territories and protect over time the regulation, mitigation and adaptation services to climate change provided by forests. Forest planning is a useful tool to ensure the mitigation of the negative impacts of fires and at the same time obtain sustainable benefits from forests, including the conservation of the biodiversity that characterizes forest ecosystems. Forest fire prevention planning is open to the participation of different stakeholders and can harmonize different needs and create synergies on the same territory. Active management is useful in situations where the priority is to reduce natural hazards and the danger of forest fires. The use of wood for energy purposes from prevention forestry activities can be compatible with the conservation of natural habitats and allows for climatic benefits compared to the use of fossil fuels.
Private forest owners	Wildfire (Forest Fires) prevention requires active management of forest areas. Active management in forest properties mitigates forest fires risk at the landscape scale. It provides benefits to society that should be remunerated. Property aggregation allows an economy of scale that makes preventive fuel management sustainable. Associated management allows small owners to participate in forest planning and enjoy its economic and image benefits. Fire prevention plans are needed to reduce fire risk, increase forests sustainable benefits and access rural development funding. Forestry engineers are professionals trained in the most advanced and sustainable management and planning techniques for forest fire prevention. The sustainable intensification of local wood harvesting for fire prevention can help reducing long-distance environmental impacts and meet the needs of primary processing companies.
Urban and peri-urban area administrators	Green areas and agricultural areas within the wildland-urban interface, when managed correctly with regard to the risk of forest fire, offer great benefits to society: mitigate heat island effect, decrease hydrogeological risk; increase psycho-physical well-being.
Large companies, investors, industrials	The prevention of forest fires is one of the safeguards against climate change and can compensate for the negative impacts associated with production, but it requires investments to strengthen the supply chains that support fire-resistant and resilient landscapes.

	Public interest in forests and agro-forestry-pastoral territories managed correctly for the prevention of forest fires is growing sharply.
Science communicators	Forest fires are a complex phenomenon that emerges from the interaction between biological, physical and socio-economic processes of a territory. Sustainable preventive forestry is different from deforestation and is necessary to continue to guarantee ecosystem services over time and to promote mitigation and adaptation to climate change. A properly managed forest landscape for fire prevention is aesthetically pleasing. A well-developed local agro-forestry-pastoral chain that supports forest fire prevention can be useful for quality agro-food production. Properly managed forests in mountain basins decrease the risk of forest fires and hydrogeological disasters for cities and communities downstream.
Local and regional councils	The use of local and certified wood obtained from fire preventive forestry interventions avoids short and long-distance environmental and social impacts and attracts consumers who are attentive to short supply chains and sustainability.
Furniture companies, wood supply chains	Wood and its high-tech by-products obtained from local supply chains aiming at preventing forest fires have excellent structural and aesthetic characteristics and have lower environmental impacts than concrete and steel, while ensuring the economic sustainability of fire prevention.
Construction industry companies	The use of local and certified wood that derives from fire preventive forestry interventions avoids short and long-distance environmental and social impacts and supports the fight against climate change.
Protected areas management bodies	Prevention of forest fires requires active management of forest areas. A properly managed forest landscape for fire prevention is aesthetically pleasing. A local forestry chain that derives the raw material from preventive forestry activities is useful for territorial development and employment, and reduces the hydrogeological risk for cities and communities downstream. Fire prevention planning is open to the participation of different stakeholders and can harmonize different needs on the same territory.
Citizens of "forest" municipalities	A well-developed local agro-forestry-pastoral chain, starting from the raw material produced by fire prevention activities (forestry, pastoralism, agriculture), is useful for quality, certified and eco-friendly agri-food production.
Producers and consumers of quality food products, small distribution business	Forest fires are a complex phenomenon that emerges from the interaction between biological, physical and socio-economic processes of a territory. Planning must integrate an assessment of the vulnerability of forest services and society to forest fires and anticipate any response and recovery strategies. Forest research has useful solutions to facilitate the drafting of forest plans and to integrate aspects that are difficult to assess such as the future evolution of forests in scenarios of climate change and extreme events.