Building

FIRE-SMART LANDSCAPES

in the Mediterranean Region

OIKOS

Abridged version

Imprint

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List of abbreviations

Abbreviations	Definitions
ACS	Al-Shouf Cedar Society
AEC	Agri-environmental and climate measures
AGIF	Integrated fire agency
AGSBR	Alliance for the Green Shouf Biosphere Reserve
ANC	Areas facing natural constraints
AOI	Area of interest
AW	Awareness raising
AWI	Additional workdays index
BD	Biodiversity
BII	Biodiversity improvement index
CAP	Common agricultural policy
CC	Climate change
CIHEAM	International Centre for Advanced Mediterranean Agronomic Studies
CINA	Constructive innovation assessment
CO2eI	Carbon Equivalent Index
CONTAG	Contagion index
CREAF	Centre for Research on Ecology and Forestry Applications
CSIC	Spanish High Council of Scientific Research
CSR	Corporate social responsibility
CTA	Constructive technology assessment
CTFC	Forest Science and Technology Centre of Catalonia
DSS	Decision-support system
EAFRD	European Agricultural Fund for Rural Development
EC	European Commission
EFFIS	European Forest Fire Information System
ENRD	European Network for Rural Development
ES	Ecosystem services
ESF+	European Social Fund Plus
ETS	European trading system
EU	European Union
EWA	Environment and Water Agency
FAO	Food and Agriculture Organization
FES	Forest ecosystem services
FLR	Forest Landscape Restoration
FM	Fuel management
FMC	Municipal Forest Management Committees
FRRL	Fire Resistant and Resilient Landscape
GDEM	General Directorate of Environmental Management
GDP	Gross Domestic Product
GFAS	Global Fire Assimilation System
GFMIS	Global fire management information system
GHG	Green House Gas
GIS	Geographic Information System
GPFLR	Global Partnership on Forest Landscape Restoration
GRAF	Group for forest action
HD	Habitats Directive
INFOCA	Forest Fires Emergency Plan of the Andalusia Regional Government

Abbreviations	Definitions
IR	Innovation regions
IRR	Internal rate of return
IT	Innovative technologies
IUCN	International Union for the Conservation of Nature
JTF	Just Transition Fund
KM	Knowledge management
LBI	Landscape biodiversity index
LC	Land cover
LDN	Land Degradation Neutrality
LGI	Landscape governance index
LII	Livelihood improvement index
LPI	Largst patch indexLargst patch index
LTD	Landscape treatment designer
LU	Land use
LULUCF	Land Use, Land Use Change and Forestry
LWF	Large scale wildfires
M	Million
MIT	Massachusetts Institute of Technology
MM	Mediterranean Mosaics
MoU	Memorandum of Understanding
MSI	Multi-stakeholder institutions
MSP	Multi-stakeholder platform
NGO	Non-governmental organization
NP	Number of patches
NPV	Net Present Value
NRM	Natural resources management
NTFP	Non-timber forest products
OA	Organic agriculture
PAFRAC	Perimeter-Area Fractal Dimension
PB	Prescribed burning
PES	Payment for ecosystem services
PIA	Priority intervention area
PIP	Policy influencing plan
PLAN	Percentage of landscape
PMU	Pastoral management unit
PO	Producer organization
PPP	Priority Protection Perimeter
R	Research
RA	Regional agency
RAPCA	Network of Grazed Fuel-break Areas of Andalusia
RD	Rural development
RIA	Research and innovation action
RLPI	Resilient landscape pattern index
ROE	Return on equity
ROI	Return on investment
SEA	Strategic Environmental Assessment
SILR	Sustainability Index for Landscape Restoration
SMP	Strategic management points
SQI	Soil quality index

Abbreviations	Definitions
SWBL	Shouf-West Beqaa Landscape
UN	United Nations
UNCCD	UN Convention to Combat Desertification
US	United States of America
USAID	U.S. Agency for International Development
USD	US dollar
VRI	Vulnerability reduction index
WFI	Water flow index
WFP	World Food Program
WG	Working group
WP	Work package
WQI	Water quality index
WRI	World Resources Institute
WFRM	Wildfire risk management
WSI	Water stress index
WUI	Wildland Urban Interface
WWF	World wildlife fund

Executive Summary

The very high frequency and intensity of extreme weather events – intense heat waves and drought - resulting from the acceleration of climate change in recent years have triggered a dramatic increase of wildfire activity and intensity with devastating environmental and socio-economic impacts that will become more accentuated in the coming decades. This is especially true in Mediterranean Europe, where recent research found out that forest areas in central-south France, Spain, Portugal, Greece, and central-southern Italy have low resilience to prevailing disturbance regimes. Moreover, the increase in fuel availability and continuity caused by poor management, rural abandonment, and forest simplification have led to a significant reduction of post-fire recovery capacity in many forest areas of the Euro-Mediterranean countries. Under such scenario, the main approach to prevent sixth generation fires and keep them within manageable limits is the restoration of the social, economic, and ecological resilience of mosaic-like forest landscapes, in which incentives to fix and increase the rural population support innovative green business models around ecosystem' goods and services linked to fire-smart landscape practices.

Throughout the last decades there has been a great debate on policies, strategies, and mechanisms for managing forest fires, with growing criticism of the ineffectiveness of concentrating resources on fire extinction and the need to develop integrated strategies around five axes: risk reduction/prevention; readiness; response/fire suppression; post-fire restoration; and research. Most of the wildfire management public policies and funding in the Euro-Mediterranean countries still focus on sophisticated extinguishing equipment for fire suppression, undervaluing the need of major preventive landscape planning and implementation measures. However, there are still significant barriers that prevent the large-scale planning and dissemination of integrated fire prevention plans and measures that allow landscapes to swift from fire-prone to fire-smart ones.

The approach outlined proposed by this publication revolves around the planning of fire-smart land uses and natural resources management practices, as well as their extension and distribution pattern in the landscape, so that the quantity, quality, and distribution of the plant biomass help minimize the risk of fire ignition linked to large devasting wildfires and increase post-fire recovery capacity. The guideless for the planning of fire-smart landscapes are based on the conceptual framework and principles of Forest Landscape Restoration (FLR) **[1]** - "a large-scale and long-term process leading to the recovery of the ecological functionality and the improvement of human livelihoods in degraded landscapes, in a way that increases the ecological and socio-economic resilience against environmental risks – such as large wildfires - and the ecosystem services upon which we all depend".

Participatory landscape planning involves performing the following steps: (i) Defining the landscape boundaries; (ii) Establishing multi-stakeholder and multi-disciplinary landscape planning teams and governance mechanisms; (iii) Performing a root-cause analysis of wildfire impacts in the landscape, (iv) Carrying out a landscape fire-risk analysis & modelling. The document analyses the process, guiding the reader through the formulation of the necessary baseline assessment, the mapping and selection of the priority intervention areas where risk is "high to very high", and the formulation of a desired scenario with alternative fuel models for the prioritized areas. This process leads to the development of a vision and a fire-smart Landscape Action Plan, together with a prioritization of locally adapted, cross-sectoral, and innovative fire-smart land uses and management measures and an analysis of the fire-smart landscape interventions, including different sustainable biomass management actions linked to the protection, management and/or restoration of forests, pastures, and farmland. Abandoned agricultural and pastoral lands in numerous landscapes of the Euro-Mediterranean region, has given rise to secondary successional stages with a very high accumulation of dry biomass, whose slow natural evolution towards mature stages presents a very high risk of fire without human intervention. The document reviews and analyses a set of active interventions in degraded landscape areas with high fire risk, to enhance and restore the species diversity, functionality, fire resilience and ecosystem services of the natural and seminatural habitats.

[1] The Global Partnership on Forest Landscape Restoration. https://www.forestlandscaperestoration.org/

Besides ecological restoration, fire-smart landscape interventions aim to enhance the social, and economic resilience of the landscape to wildfires, and generate a range of ecosystem goods and services that benefit multiple stakeholder groups linked to rural development and biodiversity conservation. The guidelines therefore address the need to identify economic, social, and ecological returns to ensure the sustainability of the investment made, the development of business plans for the economic activities linked to the management measures, the analysis of potential sources of financing to cover part of the costs of their implementation, and the strategies and practices for mapping, engagement and empowerment of stakeholders and beneficiaries. The design of long-term, adaptive monitoring systems that allow, in a simple way, to evaluate and qualify the impacts of fire-smart interventions in an integrated way is addressed by the guidelines together with financing mechanisms for fire-smart landscapes and the need to address cross-sectoral policy barriers and build an enabling policy framework, at local, national, and international levels.

The last section of the document includes a set of recommendations for the design of a fire-smart landscape planning process and the description of case Studies with best practices in building landscape resilience to wildfires from different Euro-Mediterranean countries, together with a review of relevant EU-funding regional projects for fire-smart landscape planning.

[1] The Global Partnership on Forest Landscape Restoration. https://www.forestlandscaperestoration.org/

1. The problem

1.1. Wildfires in Southern Europe

The extremely high frequency of intense heat waves and drought that affected Europe – mainly western Europe - in July and August 2022 resulted in a dramatic increase of wildfire activity and intensity with devastating environmental and socio-economic impacts. According to data from the European Forest Fire Information System (EFFIS), the total cumulative burnt area in the EU from the start of the year to early September amounts to over 750,000 hectares (68% of which during the summer season), compared to an average of just around 260,000 hectares in the period 2006-2021 **[2]**. This has also caused a significant increase in smoke emissions (including carbon gases, particulate matter and volatile organic compounds) from wildfires, which only in the period of July and August were estimated at 6.4 megatons of carbon **[3]**, the highest level since 2007 **[4]**.

The very high frequency and intensity of extreme weather events – intense heat waves and drought - resulting from the acceleration of climate change in recent years have already triggered a dramatic increase of wildfire activity and intensity with devastating environmental and socio-economic impacts that will become more accentuated in the coming decades. Despite the fact that the number of wildfires has been decreasing on average in recent years, mainly thanks to an increase in suppression investments, a small number of large-scale wildfires, known as sixth generation fires **[5]**, which are practically impossible to be controlled, acquire catastrophic dimensions with an increase in the total area burned, smoke and gas emissions, and major ecological, socio-economic and human lives losses (1).

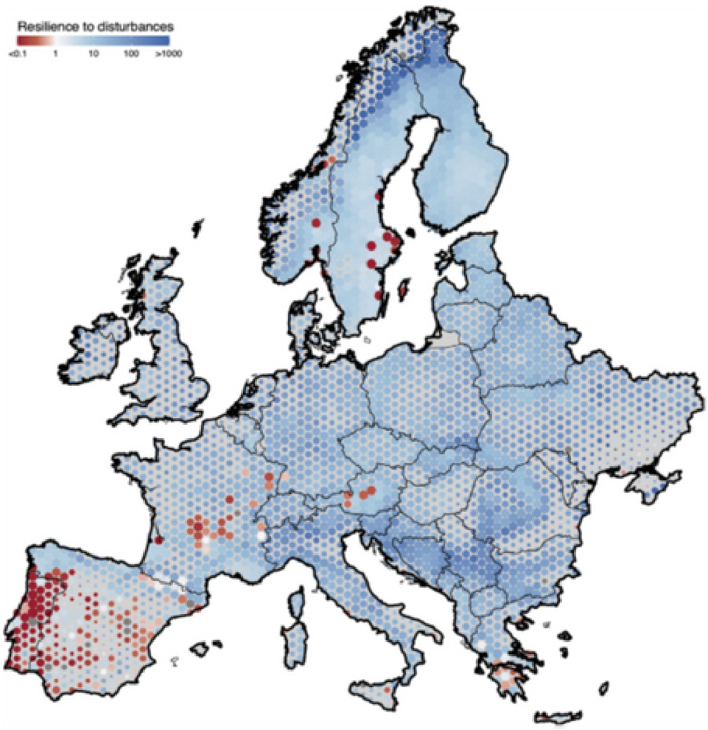

Figure 1. The Resilience of Europe's Forest Ecosystems to Disturbance (3)

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[2] https://atmosphere.copernicus.eu/europes-summer-wildfire-emissions-highest-15-years
[3] Data from the CAMS Global Fire Assimilation System (GFAS).
[4] https://atmosphere.copernicus.eu/europes-summer-wildfire-emissions-highest-15-years
[5] Large-scale fires in which climate change has become the main engine of devastating fires in territories with a very high accumulation of biomass, that feed on themselves and expand thanks to the generation of their own climatic conditions, forming clouds known as pyro-cumulo-nimbus above the smoke column from the wildfire, that produce electric storms with very damaging torrential rains and lightning (known as fire storms) that generate new fire foci.

The combined effect of very high fuel load accumulation in the landscape fire-prone weather conditions exacerbated by climate change is giving rise to a "perfect storm" in which wildfires become completely uncontrollable. Moreover, high-severity fires could significantly reduce the post-fire recovery capacity of Mediterranean forests, causing the replacement of forestland by shrubland hosting flammable vegetation that regrows quickly after fire (2). This trend may be strengthened in the future by predicted increased aridity, with changes in the climate envelopes of natural forest habitats towards more xeric forest ecosystems or woody formations of a shrubby nature. Recent research (3) found out that forest areas in central France, Spain, Portugal, Greece and southern Italy - approx. 14% of Europe's forests - have low to very low resilience to prevailing disturbance regimes - windthrow, bark beetle outbreaks or wildfire - in which the average disturbance recurrence interval occur faster than forest recovery and tree mortality could push forests into a critical state, such as shifting to shrubland ecosystems. The climate change exacerbation of the frequency and intensity of wildfires, together with the increase in fuel availability and continuity caused by poor management, rural abandonment, and forest simplification - reduction of compositional and structural diversity from forest stands and landscapes -, have led to a significant reduction of post-fire recovery capacity in many forest areas of the Euro-Mediterranean countries.

With this scenario, the main approach to prevent sixth generation fires and keep them within manageable limits is the restoration of the social, economic and ecological resilience of mosaic-like forest landscapes, in which incentives to fix and increase the rural population support innovative green business models around ecosystem' goods and services linked to fire-smart landscape practices. This will make it possible to sustainably plan and manage the distribution, accumulation and quality of biomass in critical areas of the landscape and the adoption of fire-risk reduction land uses and practices, all this drastically reducing the spread capacity of the fire and facilitating the fire management works.

1.2. The landscape fuel load: land use / land cover (LU/LC) changes in the past decades

For about 6 decades there have been important changes in terms of rural development, population dynamics, land tenure and policies, in the rural areas of the European Mediterranean countries, which have contributed to exacerbate fire risk. The following issues should be mentioned:

A **migratory boom** to the big cities since the 60s of the 20th Century has given rise to a strong depopulation of large rural areas that led to abandoned coppiced forests with high density of tree stems suffering growth stagnation and dieback, the accumulation of biomass in unmanaged coniferous plantations, and the colonization of the unused cropland and pastureland by secondary forests and shrub communities with a very high fuel load. From an agropastoral matrix with low plant biomass and scattered woody vegetation patches, the landscape changed to a matrix of too dense woody vegetation cover with highly dense continuous biomass, and scattered patches of farmland plots.

A **prevalence of maladaptive practices with high fire risk in depopulated rural areas**. The scarce remaining rural population in depopulated rural areas is aged, which makes it difficult to quickly spot and respond to extinguish fires before they become uncontrollable. In addition, the remaining rural population tends to unproperly use the ancestral practices of using fire to burn stubble and grass in a context of enormous increase in dry biomass in the landscape matrix and absence of human population, generating a very high risk of fire ignition and further spread. Rural depopulation, along with changes in land tenure and policies, have also favored overexploitation of pastoral resources in areas previously regulated by shared communal rules, generating an increase of non-palatable species and a perverse use of fire to control its expansion.

Medium- to large-scale public (and private) forestation plans between 1960s and 1990s for fast-growing tree plantations were implemented in numerous territories affected by rural depopulation, giving rise to a high homogenization of the previous mosaic landscape, with a very high fuel load. The predominant use of fire-prone pine and eucalyptus species together with the absence of a business plan for many of the plantations and lack of public funds for their management contributed to the accumulation of dry biomass and to a deficient sanitary state that favoured the rapid spread and intensification of fire events, with an increase in post-fire regeneration and erosion problems.

New development trends in densily vegetated rural areas have greatly increased the wildland-urban interface fires, with the construction of secondary houses, industries, roads, electric power lines, wind and solar power facilities, and the increase in activities with a high fire ignition risk (e.g. smoking, making campfires and barbecues, using power lines/panels, machinery and vehicles that generate sparks, dumping waste such as glass that can start fires, burning to create gaps that facilitate hunting or the increase of mushrooms and other forest products).The temporary presence of a population from outside the territory, with little or no knowledge of ecosystem dynamics, natural resources management and the environmental risks derived from their presence and hobbies in this new environment, significantly increases the risk of fire ignition and spread.

Lack of integration and conflictive relationship among the different land uses of the territory, and between the few remaining traditional uses and their surrounded natural environment highly modified by its abandonment. The multifunctionality of the rural landscape, in which the population made a combined use of forest, pasture, agricultural, water and mineral resources, often favoured by a communal governance regime, has been largely lost, giving rise to unconnected sectors with high competition between different stakeholders' interests. Rural depopulation, together with changes in the governance of the territory (e.g. disappearance of common property institutions), tenure conflicts, and the appearance of new private and/or public objectives (e.g. creation of protected areas, private or public forest plantations, hunting reserves, etc.) not directly linked and integrated into the development objectives of the existing rural populations, have given rise to territorial conflicts, often making use of fire to harm some of the interested parties (e.g. destruction of the habitat and of the populations of protected species, such as the wolf, which is seen as a threaten to the livestock interests) or to favour some economic interests (e.g. opening of clearings to favour hunting activity; burning of forests to force the commercialization of their timber; burning of natural vegetation to promote urban development).

The reasons behind the chronification of LU conflicts and maladaptive practices that make landscapes extremely vulnerable to wildfires are:

- **Lack of participatory integrated landscape planning and governance** processes agreed upon by the different actors in the territory for the effective management of fire-resilient land uses (LU types and distribution within the landscape), together with the absence of harmonized trans-sectoral policy measures integrating fire-risk reduction in all rural development sectors.
- **Limited incentives** for land users to stay in rural areas, help mainstream fire risk reduction into natural resources management and adopt new economic models for ecologically sound and economically viable fire-resilient businesses that revitalize rural population.
- **Limited public and private funding** for innovation research.
- **Lack of willingness and know-how** to transfer innovation to practitioners and ensure its effective, long-term adoption.

1.3. Climate change trends and fire dynamics

Human-induced global changes – emissions of green-house gases (GHG) and land use/land cover changes largely responsible for these emissions - have skyrocketed since the second half of the 20th century, accelerating climate change and its impacts. Climate change trends have already reduced European forests' resilience to natural disturbances, namely wildfires, windthrows and insect outbreaks (4). Climate change has also brought to light previously hidden vulnerabilities linked to LU/LC changes and maladaptive practices, leading to conditions under which the extent and intensity of forest fires in the EU will increase in the next years (4).

Most climate models predict for the Euro-Mediterranean region substantial increase in temperature and decline in precipitation - which has already caused heat stress and largely reduce water availability in the southern European countries - and sharp increase in climate variability, with more frequent and intense weather events, such as heatwaves, droughts, strong winds, and intense rains that concentrate the annual precipitation in few and very brief torrential events (5).

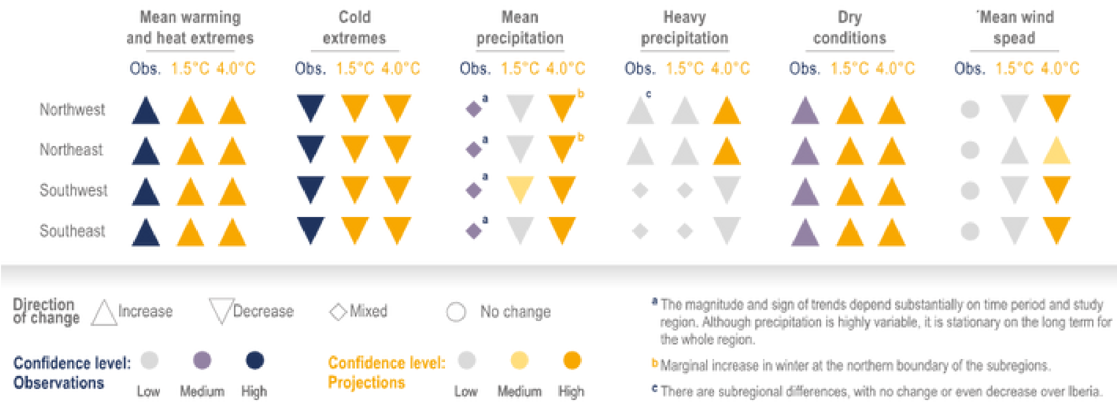

Figure 2. Observed and projected (at global warming levels of 1.5°C and 3°C) direction of change of climate drivers and confidence levels for Mediterranean land sub-regions (5)

Heatwaves, droughts and strong winds are the fire-prone weather conditions characterizing years with massive wildfire outbreaks, like the one in 2022. This, together with the accumulation and continued presence of fuel load, the strong desiccation of the abundant plant biomass of the landscape (high evapotranspiration and minimal input to roots in dry soils)n the Mediterranean rural landscapes, and the inability of soils to retain rainwater, (which tends to be scarce and occur in the form of intense torrential rainfall that in a very short time provides the expected precipitation for several months), generate the necessary conditions to increase the likelihood of occurrence of uncontrollable sixth generation wildfires. For instance, in Spain the record for days of heatwaves has been broken in summer 2022 with 42 days, practically half of the summer days, resulting in several sixth-generation fires and a burned area of more than 300,000 ha, the largest area burned in the summer season so far in the 21st century.

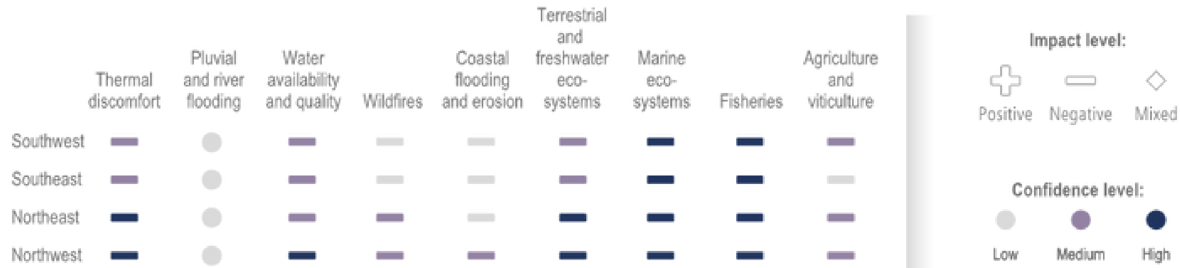

Figure 3. Attribution of observed impacts of climate change in the Mediterranean region (5)

Species distribution models predict a wholesale redistribution of forest habitats and species in the next decades due to climate change, yet current speed of changes in the temperature and precipitation ranges of current bioclimates may far exceed the capacity of many species to cope with their migratory needs (6). The extent to which species populations will adapt will depend upon phenotypic plasticity, strength of selection, fecundity, interspecific competition, and biotic interactions. In the case of widespread species with large populations and high fecundity are likely to persist and adapt but will likely suffer adaptational lag for a few generations (7). Species with small populations, fragmented ranges, low fecundity, or suffering declines due to introduced insects or diseases should be candidates for facilitated migration (7). In all cases, the planning of resilient landscapes must consider management, restoration and protection measures that facilitate the adaptation of habitats and forest species to the changing climate and increase their resilience in the face of increasing climatic disturbances, and specifically to the risk of fire (6). The best adaptation strategy should support the increase of diversity at all levels (genus, species, communities, and landscape), including measures such as (6):

- *In situ* and *ex situ* conservation of genetic reserves, with special focus to the protection of well-preserved forest stands and relic tree populations, as well as the potential use of better adapted plant provenances and genotypes in forest management and restoration interventions.

- Species diversification, especially in ecotonal zones, including both potential species and species best adapted to the predicted climate envelop.
- Emulate long-distance dispersal by establishing small populations of different tree species to enhance their ability to track moving climate envelops throughout landscapes.
- Conservation and restoration of biotic dispersal vectors with an important role in the long-distance dispersal of plant species.
- Changes in silvicultural practices (e.g. longer rotation periods; adaptation of tree densities to water availability; close-to-nature forestry improving the structure, age classes and species diversity in forest stands).
- Changes in soil management practices to improve soil water infiltration and storage.

2. The challenge

Throughout the last 4 decades there has been a great debate on policies, strategies and mechanisms for managing forest fires, with growing criticism of the ineffectiveness of concentrating resources on fire extinction and the need to develop integrated strategies around five axes: risk reduction/prevention; readiness; response/fire suppression; post-fire restoration; and research.

Most of the wildfire management public policies and funding in the Euro-Mediterranean countries still focus on sophisticated extinguishing equipment for fire suppression, undervaluing the need of major preventive landscape planning and implementation measures to overcome the combined effect of the extreme fire-prone weather conditions - exacerbated by climate change - and the growing accumulation of plant biomass or fuel in depopulated rural landscapes that preclude effective suppression. Experts on sixth generation fires stress that the best way to deal with them is to invest most efforts on prevention measures, focusing on the integrated landscape planning of fire-smart LU/LC types and land management practices which helps to maintain the fuel load of the landscape within acceptable levels (8,9,10). This helps reduce the size of potential fires and facilitates an effective response.

However, there are still significant barriers that prevent the large-scale planning and dissemination of integrated fire prevention plans and measures that allow landscapes to swift from fire-prone to fire-smart ones. Specifically, the following barriers can be summarized:

2.1. Landscape fire management barriers

2.1.1. Little capacity and/or willingness for cross-sectoral integration that help mainstream harmonized fire-risk reduction measures in the policies and development plans regulating the different rural development sectors and infrastructures

Risk of fire is linked to different policy sectors - agricultural, pastoral, infrastructure development, urban planning, waste management, industry, tourism - both in terms of maladaptive management practices, and in terms of LU/LC distribution pattern and interfaces with forestland in the landscape. In the case of rural abandonment, enabling conditions would be needed to support the municipalities in the arduous task of quantifying and planning the fire-smart distribution of plant biomass in their territories, carrying out cadastres on abandoned properties, and organizing participatory planning processes with land owners (or in the case of unknown owners, identify alternatives for municipalities to assume their tasks) to identify fire-resilient LUs with high socio-economic potential, help them develop business models that demonstrate the economic return of investments, and subsidize their start-ups.

It will be difficult to swift from fire-prone to fire-smart landscapes without an integrated fire management strategy common to the different development sectors in the landscape, which:

- plans and defines the type of fire-resilient uses and management practices that are suitable for the different parts of the landscape.
- account for factors that may produce trade-offs between different development and nature conservation interests with an understanding of why (and what) trade-offs result, discuss about the variety of positive and negative effects associated with different development and biodiversity conservation needs, and agree on common wildfire resilience goals and outcomes that help create synergies between stakeholders acting at different scales (e.g. local communities within the immediate vicinity to fire-risk areas; users of the ES of interest living outside the landscape) and ensure sustainable return (the ecological, social and economic multiple-benefits) on investments.
- establishes harmonized cross-sectoral regulations and effective cooperation mechanism among all concerned sectors of the public administration.
- develops the capacity of policy-makers and decentralized public administration staff to formulate cross-sectoral fire-smart regulations, inform land users and practitioners about them, and give technical support for their effective implementation.

2.2. Economic barriers

2.2.1. Limited attention and budget allocation to fire-risk reduction or prevention needs in the national and sub-national fire management policies and strategies

The experience of recent years (e.g. sixth-generation fires in 2017 in Portugal, in 2021 in Greece, and in 2022 in Spain) demonstrates that the availability and use of large extinction means, in a context of high fuel load landscapes and fires-prone weather conditions exacerbated by climate change, is very insufficient to deal effectively with sixth generation fires if fire-smart landscape planning and management measures are not incorporated. It is especially urgent to:

- significantly increase the fire management budget and the percentage devoted to prevention measures, and distribute it to all the concerned sectoral budgets.
- The budget increase must be accompanied by an increase in prevention personnel with annual contracts (and not only for the summer period), since prevention is necessary throughout the different seasons of the year, and, in addition, climate change is generating conditions of high fire risk in all seasons, including winter.

2.2.2. The absence of comprehensive cost-benefit analyses as a powerful tool to convince fire-smart landscape advocates – policy makers, landowners and users, potential investors – on the diverse set of benefits generated by fire-smart LUs and management practices, and on the interest to invest in sustainable biomass management innovative business models

Assessing the costs and benefits of investments on fire-smart land uses and management practices will allow decision-makers to demonstrate that investments in fire-smart options are worth and result in better economic, social and environmental outcomes. The modelling of fire-smart interventions and their benefits furthermore allow for prioritizing investments based on different sustainability criteria: which ecosystem services are prioritized (ecological return), who should benefit (social return), and when will benefits be realized (economic return on investment costs). Policy makers need to understand the costs of fire-smart interventions as well as the multiple benefits: employment effects, tax and Gross Domestic Product (GDP) contribution, and indirect economic values – for example, the value of carbon sequestration and non-marketable ecosystem services as avoided erosion and hydrological services.

The promotion of public-private partnerships should help create incentives favouring green businesses linked to fire risk reduction interventions that also help absorb the costs of sustainable biomass management interventions in the landscape. Innovative green development opportunities help increase the presence of active population in depopulated landscapes, monetize the management of huge amounts of biomass the short- to mid-term, and generate economic return. Currently, there are several financing options to support fire-smart interventions in the landscape involving public and private cooperation, such as:

- The EU Green Deal policies and budgets, as well as the national, regional and local public incentives supporting green infrastructures, green business, sustainable land and biomass management practices, nature protection and ecological restoration interventions.
- Private-public sustainable certification schemes and payments for ecosystem services such as carbon credit, water, tourism, and biodiversity.
- Corporate social and environmental responsible programs supporting green value chains.
- Business accelerator platforms supported by partnerships between the corporate sector, international NGOs, IUCN, the EU, UN organizations and governmental aid agencies.

Considering the volume of biomass to be managed in the landscape to be effective in reducing the risk of large-scale fires, it is important to focus on a multiple financing strategy, including different public-private options.

The PREVAIL EU-funded Project has analysed and identified lessons learned on “smart-solutions” (11) for wildfire prevention that make a synergistic use of private, public and EU resources to activate value chains and marketing strategies that valorise biomass-management products, and take advantage of by-products and services generated by fuel management activities and their positive externalities on ecosystem services. These mechanisms catalyse the interest of multiple stakeholders (economic actors, private consortium, land and fire management agencies) for improving the cost-efficiency of landscape fuel management. The initiatives were assessed according to the following criteria and sub-criteria: (i) sustainability (circularity, short supply chain, ecological return, social return), (ii) cost-efficiency in risk reduction, (iii) synergies and cooperation (source of funding, multiple-management goals, participation and good governance), (iv) knowledge exchange and transfer, and (v) adaptive management (impact assessment, lesson learnt approach).

2.3. Governance barriers

2.3.1. The socio-economic drivers of wildfires should be tackled from a multi-stakeholder and multi-disciplinary perspective so that innovative governance mechanisms for cooperation on fire-risk reduction and prevention can be established

Partnerships between public administrations and civil society aim at lowering the risk of forest fires at landscape level, but also at increasing auto-protection of communities in rural areas, fostering co-responsibility (12). Examples of multi-stakeholder cooperation mechanisms on fire-risk reduction are:

- Forest defence groups in Catalonia and Andalusia (Spain) are coordinated associations of local volunteers (chiefly farmers and forest owners) and town councils that participate in planning and execution of municipal fire prevention activities. Moreover, they collaborate with firemen for fire extinction.
- Forest Intervention Zones (Portugal) gather small forest owners to jointly manage their land, preventing land abandonment and upscaling interventions, with the final aim of maintaining fire resilient landscapes.
- Grazing agreements in Catalonia and Andalusia (Spain) establish formal collaboration frameworks between forest owners and shepherds, and contracts between extensive breeding shepherds and public administrations to develop biomass reduction activities with livestock, both in the forest and in the WUI.

These initiatives complement existing wildfire management measures and constitute good examples of social innovation, involving society in tackling the fire problem, bringing together social and technical concerns, and encouraging citizens’ fire related knowledge.

2.4. Know-how transfer barriers

2.4.1. Although wildfire growing impacts have prompted a paradigm shift toward proactive wildfire management that prioritizes prevention and preparedness instead of response, the landscape stakeholders remain unprepared to mainstream collaborative fire-risk reduction objectives and prevention measures into the day-to-day work

Local stakeholders, regardless of type, age, gender, education, income or level of engagement in natural resources management, recognized more and more the high urgency of wildfire risk management. This is important because awareness of risk is a key enabling factor for engagement with proactive wildfire management (13). However, land users often feel excluded from decision-making on how to build a more resilient landscape to fire. They also lack the necessary knowledge to understand how to incorporate fire prevention measures into their day-to-day work, and there is a lack of understanding and trust between the different users and managers of the territory on the potential positive synergies that exist between management practices that offer a prevention value when they are applied jointly and following fire-risk reduction protocols – e.g. contracts between forest owners and shepherds to apply controlled grazing after thinning operations - but that are traditionally seen as harmful (e.g. grazing in the forest; burning of bushes and pastures; etc.).

Likewise, the option of changing the use of the property – e.g. replacing a fire-prone pine plantation with a more resilient agroforestry land plot of chestnut and oak trees - or recovery the use of an abandoned property – e.g. the clearing of a too dense secondary forest to support a multiple production of firewood and mushrooms - requires the creation of capacities to manage the change with a multiple perspective of fire-risk reduction and sustainable production, paying special attention to the training of local user groups on the development of a green business model that ensures the three pillars of sustainability (economic, social and ecological return).

A fire-risk reduction or prevention strategy for the landscape usually includes a combination of:

- direct measures, such as the establishment and management of firebreak areas, biomass growth control in strips of different widths along infrastructures and around urban areas, the establishment of water points in critical sites of the landscape, legal regulation and penalization of risky activities, awareness campaigns during the summer season, etc.
- indirect measures, such as supporting grazing activities in critical fire-risk areas of the landscape, or supporting the recuperation of fire resilient land uses that help reduce fuel load in the landscape, such as agroforestry systems and practices, the use of forest and agriculture biomass for bioenergy, etc.

More and more, direct and indirect measures must be integrated, and fire managers and users of the territory must collaborate so that fire-risk reduction is effectively implemented within the landscape.

According to researchers (13), several factors influence social preference, support, and active involvement in fire prevention, including:

- citizen involvement in decision-making, with special attention to fire-smart landscape planning of LUs and management practices, and trade-offs among land uses/users and between development and conservation objectives.
- understanding of the added value or perceived effectiveness that the proposed practices have in terms of fire prevention.
- familiarity with the prevention practices and techniques.
- perceived responsibility and individual/community capacity (expertise, time, financial means and tools) to implement or incorporate them into day-to-day work.
- trust or confidence in those implementing a practice or who should collaborate in a multiple-practice prevention measure.
- landownership and location of prevention treatment (e.g. preference for use of prescribed fire in remote areas and thinning in the urban-wildland interface).
- cultural context and beliefs about or attitudes towards proposed treatments (e.g. effect on wildlife, potential for escape, aesthetics).
- clear demonstration of the multiple ecological, social and economic benefits provided the proposed practices, with the special focus on the economic return on investments.

3. The Solution: Integrated fire-smart landscape planning and implementati principles

Increasing the resilience of the landscape against wildfires and their exacerbation by climate change (sixth generation wildfires) is based on the planning of fire-smart land uses and natural resources management practices, as well as their extension and distribution patter in the landscape, so that the quantity, quality and distribution of the plant biomass help minimize the risk of fire ignition (avoidance of maladaptive practices and social conflicts) and fire spread (LU/LC fuel load reduction) linked to large devasting wildfires, and increase post-fire recovery capacity. The project approach to guide the planning of fire-smart landscapes of the project is based on the conceptual framework and principles of **Forest Landscape Restoration (FLR) [6]** - "a large-scale and long-term process leading to the recovery of the ecological functionality and the improvement of human livelihoods in degraded landscapes, in a way that increases the ecological and socio-economic resilience against environmental risks – such as large wildfires - and the ecosystem services upon which we all depend".

The following table introduce the FLR principles and their correspondence with the proposed fire-smart landscape planning principles:

FLR Principles	Proposed Fire-smart Landscape Planning Principles
Focus on the entire landscape: FLR takes place within and across entire landscapes, not individual sites, representing mosaics of interacting land uses and management practices under various tenure and governance systems. It is at this scale that ecological, social and economic priorities can be balanced.	**3.1.** Participatory landscape planning of fire-smart LU/LC types, management practices and their landscape distribution pattern.
Tailor to the local context using a variety of approaches: FLR uses a variety of approaches that are adapted to the local social, cultural, economic and ecological values, needs, and landscape history. It draws on latest science and best practice, and traditional and indigenous knowledge, and applies that information in the context of local capacities and existing or new governance structures.	**3.2.** Prioritization of locally adapted cross-sectoral and innovative intervention measures.
Maintain and enhance natural ecosystems within landscapes: FLR does not lead to the conversion or destruction of natural forests or other ecosystems. It enhances the conservation, recovery, and sustainable management of forests and other ecosystems.	**3.3.** Enhance and restore the diversity functionality, fire resilience and ecosystem services of the natural and seminatural habitats in the landscape.
Restore multiple functions for multiple benefits: FLR interventions aim to restore multiple ecological, social and economic functions across a landscape and generate a range of ecosystem goods and services that benefit multiple stakeholder groups.	**3.4.** Sustainable return on fire-risk reduction investments, ensuring the provision of ecological, social and economic benefits.
Engage all stakeholders and support participatory governance: FLR actively engages stakeholders at different scales, including vulnerable groups, in planning and decision-making regarding land use, restoration goals and strategies, implementation methods, benefit sharing, monitoring and review processes.	**3.5.** Enabling multi-stakeholders to be actively involved in the implementation of fire-smart landscape plans through 360º capacity development interventions and innovative governance mechanisms.

[6] The Global Partnership on Forest Landscape Restoration. https://www.forestlandscaperestoration.org/

FLR Principles	Proposed Fire-smart Landscape Planning Principles
Manage adaptively for the long-term landscape resilience: FLR seeks to enhance the resilience of the landscape and its stakeholders over the medium and long-term. Restoration approaches should enhance species and genetic diversity and be adjusted over time to reflect changes in climate and other environmental conditions, knowledge, capacities, stakeholder needs, and societal values.	**3.6.** Long-term adaptive monitoring and financing mechanisms for fire-smart landscapes.

The following subchapters describe each principle and its implications for fire-smart landscape planning.

3.1. Participatory landscape planning of fire-smart LU/LC types, management practices and their landscape distribution pattern

Participatory landscape planning involves performing the following steps:

3.1.1. Defining the landscape boundaries

Fire-smart landscape planning takes place within and across entire landscapes, not individual sites, representing mosaics of interacting land uses and management practices under various tenure and governance systems. It is at this scale that ecological, social and economic priorities can be balanced. The landscape boundaries often do not correspond to the existing political and administrative limits, therefore, a new governance layer (embedded in the existing ones) for the fire-resilient landscape planning and management process priorities may be needed.

3.1.2. Establishing multi-stakeholder and multi-disciplinary landscape planning teams and governance mechanisms

Fire-smart landscape planning needs to be given an 'institutional hub' around which the multi-sector and multi-stakeholder collaborative approach can be built, and thus ensure credibility in the process, appropriation of the results, and a framework for its implementation.

The lead institution should appoint a team leader, and convene a core team of experts with good knowledge of the targeted landscapes and skills on various themes (e.g. landscape ecology, biodiversity, climate change, fire management, rural development, social science, economy, GIS modelling). The core team should be in charge of carrying out baseline assessments and analysis (e.g. fire-risk modeling, fire-smart prioritization, cost-benefit analysis), which will serve as a basis for discussion with the rest of the participants in the landscape planning process. The other participants that the assessment team should actively engage are representatives of key stakeholder groups (e.g. decentralized governmental institutions; technical staff from the local administration; land user organizations; private companies active in the landscape; local NGOs; academia including secondary schools and universities; research organizations).

3.1.3. Root-cause analysis of wildfire impacts in the landscape

A root-causes analysis highlights the need to understand and remove the underlying socio-economic and political causes that truly drive large-scale wildfire impacts in the landscape, which means "scaling up" the fire-smart landscape objectives and actions and strengthening the sustainable return of the prioritized fire-resilient interventions through macro-level measures such as policy reforms, market incentives and regulations and socio-economic dynamics. The primary objective is to address these fundamental questions about the pervasive trend toward high fire risk in the target landscapes:

- What are the underlying socioeconomic forces and circumstances driving high fire risk?
- How are these root causes interlinked?
- What are possible responses to these forces and circumstances that could reduce the pressure on biodiversity?

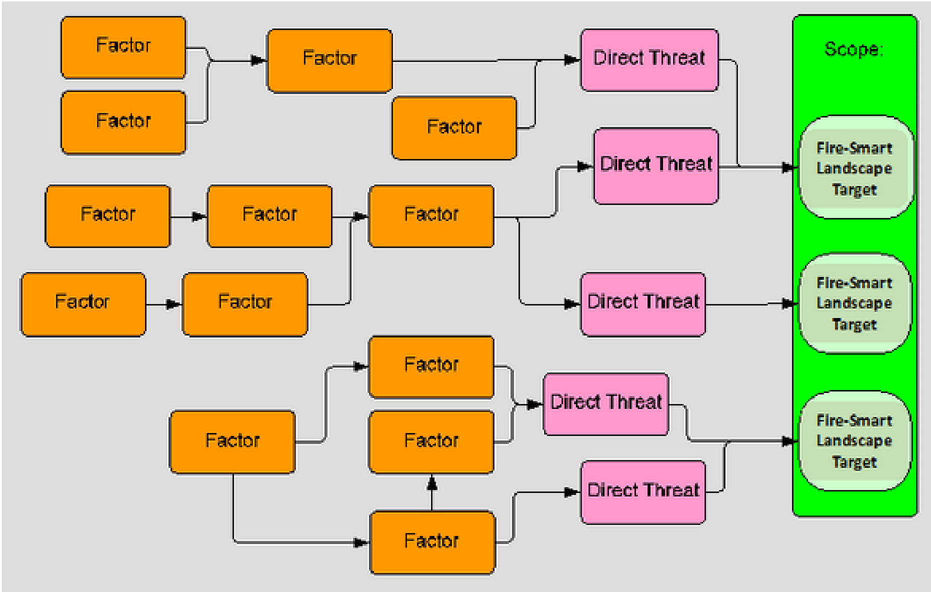

Figure 4. Generic conceptual model for the root-causes' analysis (14) [7]

Conceptual modelling is a participatory information recording and analysis method that involves using boxes and arrows to represent factors and the links between them. Participants should (14):

- Define fire-smart landscape (FSL) targets on cards and, if relevant, show relationships between them.
- Identify and rate the most critical direct threats to the FSL targets, using criteria (e.g. scope, severity, irreversibility). Put them on cards and use arrows to connect them to the FSL targets.
- For each direct threat brainstorm the different factors (indirect threats and/or opportunities as well as enabling conditions) that lie behind the direct threat. Indirect threats are often related to demographic change; social change; inequality and poverty; loss of governance; public policies, markets, and politics; macroeconomic policies; and development biases. These factors can often be favorable and, therefore, present themselves as opportunities. Opportunities may also include conditions, attitudes, and values that will support conservation action. As an iterative process, you should discuss with your group your confidence level in the different portions of your analysis and which stakeholders or other experts you might need to consult to deepen the research.
- For each factor, you may also want to list the relevant actor/stakeholder who is responsible for the factor and/or the motivation for their action.
- Ensure that some participants are assigned to take each direct threat and associated factors and write a brief text describing the relationship among the factors, threats, and FSL targets.

The conceptual model will help to identify the critical factors that the planning process should focus on, and the different types of interventions needed in terms of direct LU/LC modification actions, biomass management and landscape resilience restoration, and landscape resiliency restoration actions. Indirect improvements in policies, economic opportunities, governance mechanisms, generation and transfer of knowledge through training and technical advice, etc.

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[7] Fire-smart Landscape Target: an element of fire-risk reduction and/or social-ecological resilience to wildfires at the landscape level that has been chosen to focus by the planning team; **Direct threat**: A human action that immediately impact the fire-smart landscape targets; degrades one or more biodiversity targets; **Factor**: A generic term for targets, direct and indirect threats, and opportunities. It is often advantageous to use this generic term since many factors – for example livestock grazing – could be both a threat (overgrazing linked to fire to prevent the growth of non-palatable plant species) and an opportunity (sustainable grazing to control fuel load after mechanical cutting or prescribed burning).

3.1.4. Landscape fire-risk analysis & modelling

Identification, mapping and prioritization of both landscape areas with high wildfire ignition and spread risk and low post-fire recovery capacity (focusing on the interface between high fire ignition risk and high fire spread risk) and fire-smart interventions, in relation to fire behaviour, fire-prone LU/LC types and management practices, their extension and distribution pattern in the landscape.

Wildfire Decision Support Systems (DSS) are integrated information systems that collect, manage, and analyze input data - up-to-date geospatial and satellite data on meteorology, landform, LU/LC, spatial information on fuels and fire history - for deriving predictions of fire behavior and propagation through simulation mathematical/economic models supporting wildfire risk management decision making and carry out the landscape planning of preventive fuel treatments. The PREVAIL project (15) has developed a decision support system for fuel management (PREVAIL DSS-FM) that incorporates economic, social and ecological goals into landscape management planning and includes the different cross-scale stakeholders' perspectives along the DSS development and as end-users to test its efficiency and validity. In line with the DSS proposed by PREVAIL, we have defined the following steps:

STEP 1 - The NEED for fuel management within the landscape

The objective is to evaluate which fuel models present a high risk against wildfires and which changes, in terms of accumulation and distribution of dry biomass in the landscape, are necessary to increase its resilience. This will feed the process of prioritization of landscape areas with high risk of fire, and identification and selection of alternative uses and management practices that constitute acceptable and locally adapted fuel models.

The first activity of this step is to **describe the existing LU/LC types/sub-types and related management practices as fuel models** in quantitative (fuel load) and qualitative (type of biomass) terms, as well as the associated fire risk category (very low, low, moderate, high, very high fire spread and fire ignition risks) and post-fire recovery capacity. An evaluation of how the climate change projections for the target landscape can modify the level of fire risk (positively or negatively) of each fuel model is desirable, even if it is only done qualitatively.

Table 1. LU/LC types/sub-types, fuel models, fire risk, and post-fire recovery capacity [8]

LU/LC Type/Sub-type		Fuel Model (FM)		Fire Spread Risk (FSR)			Fire Ignition Risk (FIR)			PRC
Nº	**Description (management, stakeholders, tenure…)**	**Nº**	**Description (fuel load and type…)**	**QLV**	**QNV**	**CCM**	**QLV**	**QNV**	**CCM**	

[8] LU: Land Use; LC: Land Cover; FM: Fuel Model; QLV: Qualitative Value; QNV: Quantitative Value; CCM: Climate Change Modification; FSR: Fire Spread Risk; FIR: Fire Ignition Risk; PRC: Post-fire Recovery Capacity.

The next activity consists in the production of a **GIS map showing areas with different fire risk categories** (LU/LC patches translated as fuel models with very low, low, medium, high or very high fire risk) for the target landscape, based on the intersection of:

- the hazard map (based on terrain features such as slope, aspect, and relief; LU/LC fuel models with different fire risk categories; historical data of fire events; and fire management experts' opinion)
- the potential damage map (the landscape elements at risk, their vulnerability, their socio-economic value and their recovery time to achieve the state prior to the event).

STEP 2 - The WHERE to intervene in the landscape

This is based on the **selection of strategic "high to very high fire risk areas"** on the map produced in the previous step **where to prioritize fuel management interventions**.

Acting in all areas with a high risk of fire to convert fire-prone into fire-smart landscapes is the most desirable, although this entails some fundamental limitations, which greatly condition their viability:

- The very high economic cost of managing excessive fuel load in vast areas of the landscape that require a reduction and control of dry biomass. The abandonment of the territory in the last decades has led to a huge accumulation of biomass whose management is difficult in terms of economic cost and time needed to carry out the necessary operations.
- The human desertification of abandoned rural landscapes, which largely prevents the implementation of fire-resilient management measures.
- Problems of tenure rights and landowner allocation of single use objectives (or absence of management objectives), which make it difficult to coordinate and apply complementary fire-smart management practices (e.g. forest owners and shepherds agreements to apply controlled grazing after forest thinning).
- Difficulty in analysing the ecological impact of the proposed fire-smart changes in land uses and management measures and addressing the trade-offs that ensure sustainable return (the ecological, social and economic multiple-benefits) on investments.

In order to overcome these limitations, multivariate models together with the opinion of fire management experts (e.g. experts from decentralized fire services with deep knowledge of fire dynamics in the targeted landscape) help to prioritize critical areas of the landscape where to concentrate risk reduction interventions, with the aim of making the most effective use of economic resources available over time (8,9,16,17,18,19,20,21,22,23).

The methodology for prioritizing high fire risk areas where to concentrate the available resources may include the following actions (18):

- Highlight the interface between LU/LC fuel models with high/very high (H/VH) fire spread risk (FSR) and high/very high fire ignition risk (FIR) in the produced GIS maps. In this way, we will make a selection of landscape areas with elements at risk in which both H/VH FIR and FSR coincide spatially, the combination of which implies a high probability of occurrence of large-scale fires.
- Fire ignition models, based on historical data of past fires and geospatial variable (e.g. land use, distance to roads, urban sites and power lines, population density) and the opinion of forest fire experts with knowledge of the target landscape, to simulate landscape sites with likelihood of future fire occurrence (map of ignition probability) making use of fire ignition models (based on historical data of past fires and the previously identified geospatial interface areas between H/VH FSR and FIR).
- Generate burn probability, fire intensity levels, flame length probability and perimeter of burned area, making use of fire simulations based on landform data (slope, altitude, aspect), meteorological data, and the produced/mapped LU/LC fuel models and H/VH FIR and FSR interfaces.
- Quantification of impacts (losses and benefits) caused by the different levels of fire intensity, based on expert/model assignation of susceptibility for the different forest species and different types of infrastructures, to quantify the risk as the expectation of economic loss.

These actions will lead to a spatial optimization with the identification of the landscape polygons or areas where fire-smart interventions maximise their contribution with respect to large-scale fire risk reduction, with a multi-objective focus to satisfy the needs of the different landscape actors (that is, burned area reduction in urban centres, in productive forests, pastures and farmland, in biodiversity value areas, etc.). The resulting spatial arrangement of fire-smart interventions may contemplate two different complementary strategies:

- Fire-risk reduction interventions in areas with assets with high expectations of social and economic losses (e.g. urban areas, infrastructures and highly productive forestland).
- Multifunctional interventions at the landscape scale to increase the overall ecological and social resilience to wildfires.

Fuel treatment optimization determines "where" in the landscape, the size, shape and aggregation of the landscape areas to be treated, the amount and type of biomass to be removed, so that making rational use of the limited budget available is maximized, and the investments made minimize the losses associated with forest fires. The analysis must consider the legal regulations for performing fuel management in the selected areas that may conditioned final decisions regarding interventions in a case-by-case basis (e.g. the existence of *Mandatory* Areas for Fuel Management surrounding settlements and infrastructure, conceived to protect people and key infrastructures, restrictive regulations in protected natural land, and land tenure limitations, etc.).

STEP 3 - The DESIRED SCENARIO: alternative fuel models for the prioritized high fire risk areas

Once the critical areas of the landscape are known and mapped, in terms of fire risk and the fuel models and interfaces that generate them, the planning team must propose a preliminary list of alternative fire-smart fuel models (LU/LC types and associated practices) that when replacing the current fire-prone ones, would contribute to reduce the risk of occurrence of large-scale fires.

The proposals for alternative models may consist of:

- Alternative management or restoration practices aimed at modifying the fuel load of critical areas and elements at risk, in terms of landscape distribution, quantity and quality of treated biomass.
- Alternative LU/LC types in critical areas, which can range from the recovery of agricultural or pastoral uses in abandoned areas covered by dense woody vegetation, to the substitution of uses with a high risk of fire (e.g. fire-prone tree plantations species) to low or medium risk uses (e.g. agroforestry systems with low densities of less flammable and regrowth tree species).
- Establishment of more or less wide strips, with very little vegetation cover, along infrastructures or around houses and urban centers.

The identification of alternative fire-smart land uses and management practices (desired fuel models) should pay special attention to the catalytic effect of the integration between resilient sectoral uses (e.g. combined use of thinned and pruned biomass from forest and woody crops together with controlled grazing), ensuring the adaption to the local context and needs (ecological, social, cultural, and economic). This integrated approach is primarily based on sustainable biomass management interventions lowering fire ignition and fire spread likelihood and enhancing post-fire recovery.

The preliminary list of alternative fuel models may consist of factsheets for each fuel model, with the description of the proposed interventions, their effect in terms of fire risk reduction (e.g. expected changes in terms of distribution, quantity and quality of biomass; predictions in terms of reduction of burned area and socio-economic losses; improvement of post-fire recovery capacity; reduction of ignition risks), the expected multiple benefits (ecological, social and economic), the requirements for their implementation, the existing opportunities to facilitate practitioners in their adoption (e.g. the availability of best practices and guidelines; the existence of supportive policies and economic incentives), and examples of successful implementation in a similar context within the country and elsewhere in the Mediterranean region.

A preliminary list of alternative fuel models for the prioritized H/VH fire risk areas should be introduced, described and justified (in terms of the multiple ecological, social and economic benefits they provide) in a workshop with the participation of all the concerned landscape stakeholders. The multi-stakeholder prioritization and validation process consists in:

- The revision of the preliminary list of alternative fire-smart LU/LC and management practices (desired fuel models) to replace fire-prone ones, which may entail modifications to the proposals of the experts of the planning team, based on stakeholders' views and needs.
- The evaluation of the proposed fuel models, addressing conflicts, tradeoffs and synergies concerning different stakeholders' goals, tactics and decisions, as well as the implications in terms of costs, resources needed, governance, tenure and legal constraints and obligations, etc. This allows visualizing and quantifying what changes, to what extent and where in the landscape are necessary to reduce the risk of wildfires to a socio-ecologically acceptable level, and to what extent the changes respond to the different needs of the stakeholders concerned.
- The selection of fuel models and management practices that show viability, that is, whose costs are affordable, whose implementation is feasible considering the socio-economic reality of the territory, and which provide complementary and sustainable ecological, social and economic benefits. This also requires the identification of existing/ legal obligations for fuel management in the prioritized H/VH fire risk areas, and if they do not exist, discussion about needed obligations.
- Discussion with participants about their knowledge of the selected fuel models, feasibility of each fuel model interventions in the prioritized H/VH fire risk areas, and quantification of their costs, in order to build a Matrix of budgeted solutions for the fuel models, based on the list of agreed set of interventions.

Table 2. Possible fuel management actions selected for each priority intervention site

Site	Description of the fire-smart target (fuel model)	Actors involved																Fire-smart intervention type [9] (indicate the different types that should be combined in each site).	Total estimated cost
		A		B		C		D		E		F		G		H			
		1 [10]	2 [11]	1	2	1	2	1	2	1	2	1	2	1	2	1	2		

- **Stakeholder assessment of the chronogram and frequency of the different fire-smart intervention types linked to each fuel model**: in order to be effective, fuel management (FM) interventions need to be performed in phases, in a scalar way, seasonally (meteorological factors), according to ecological dynamics (e.g. avoiding disturbing fauna), periodically (e.g. according to growth dynamics of different vegetation types), and over long-term periods. As part of the workshop discussions, a table with a chronogram for each FM action within the priority landscape sites will be presented and discussed so that stakeholders may give their input and improve the table.

[9] As an example of intervention types: A: forest thinning with specific description of type of forest, thinning density, etc; B: productive firebreak area with fruit tree crop planting, with specific description of type of crop, planting density, etc; C: controlled grazing, with specific description of livestock type and numbers, duration, yearly season, etc; D: biomass clearing in strips along roads, with specific description of type of road, strip width, etc; E: biomass clearing around settlements and houses, with specific of type of settlement, ring width, etc; F: other; G: other; H: other…
[10] Cost (Euros) per hectare.
[11] Percentage of the site where this type of intervention is applied.

Table 2. Possible fuel management actions selected for each priority intervention site

Priority Landscape Site	Fuel model type description	Fire-smart management practice (FSMP)	Technique to be used	1st action (date)	2nd action (date)	3th action (date)	4th action (date)	Etc.
Site 1		**FSMP1:**						
		FSMP2:						
		FSMP3:						
		Etc.						
Site 2		**FSMP1:**						
		FSMP2:						
		FSMP3:						
		Etc						
Etc.								

STEP 4 - The VISION: Fire-smart Landscape Action Plan

A vision statement and mapping exercise becomes the starting point for discussion about developing the fire-smart landscape long-term goals and turning them into more specific and tangible outcomes that can drive activities and result in accomplishments. Defining a common vision enables the landscape stakeholders to share their experiences, concerns and needs in relation to forest fires, visualize different planning scenarios for territorial uses and fire risk modification (e.g. burned area reduction, prevention of devastating fires due to their intensity and/or spatial dimension with a high impact on ecological systems, infrastructures, goods and human lives), account for factors that may produce trade-offs between different interests with an understanding of why (and what) trade-offs result, discuss about the variety of positive and negative effects associated with different development and biodiversity conservation needs, and agree on common wildfire resilience goals and outcomes that help create synergies between stakeholders acting at different scales (e.g. local communities within the immediate vicinity to the prioritized H/VH fire-risk areas; ecosystem services' beneficiaries living outside the landscape).

The FSL planning team should complete the collection and analysis of data on the fire-smart interventions that characterized the selected fuel models (e.g. management plan, technical data, actors involved, necessary resources, costs) and their enabling conditions (policies, training, governance, sustainability) to be included in a draft fire-smart landscape plan to be presented to the participants of the visioning workshop.

The Fire-smart Landscape Action Plan should include:

- The analysis of the root-causes of large-scale wildfires in the target landscape.
- The GIS mapping, analysis, and description of the critical areas for fire-risk reduction, current fuel models and concerned stakeholders.

- The alternative fuel models, validated by all concerned stakeholders, describing their impacts on fuel load and burned area reduction, ecological, social and economic resilience.
- A detailed management plan of each proposed fuel model, with the technical description, requirements, constraints, and features facilitating or conditioning their implementation.
- The resources needed (human, animal and material), tasks and responsibilities.
- A gender- and youth disaggregated capacity development plan for all concerned public and private stakeholders, to ensure that practitioners understand the value, acquire the knowledge and skills needed to apply the proposed fire-smart measures, and to establish green business based on goods and services linked to fire-smart interventions.
- A policy influencing plan (PIP) analysing the strengths, weaknesses, gaps and opportunities of existing policies and governance mechanisms to support the fire-smart landscape plan implementation and defining targets and practical recommendations for the creation of a more conducive cross-compliant policy framework and the transfer of knowledge to practitioners about the existing supporting regulations and EU/national incentives that are available for fire-smart interventions.
- A result framework describing the objectives, outcomes, outputs, activities, timeframe and budget to cover the costs (cost per unit of each proposed fuel model type) of the fire-smart landscape plan. Information on when to treat or implement the proposed management actions in each fuel model must be explicit in the action plan, defined for a horizon of at least 20 years (timeframe needed to guarantee success) in a chronogram and frequency of fuel management actions (20 years period). 20 years is considered a comprehensive period that is needed for a continuous and re-evaluation assessment of fuel actions, and in this way guarantee its success (15).
- A cost-benefit analysis and a multiple financing strategy (e.g. combination of private and public financing opportunities for direct/indirect fire prevention issues linked to rural development, green businesses, bioenergy, nature protection, ecological restoration, among other issues) to cover the necessary costs to implement over time all the alternative fuel models proposed in the target landscape. This is needed to support fundraising efforts and incorporate fire prevention interventions in the annual rural development and fire management budgets for the target landscape.
- A participatory and adaptive monitoring plan for the set of fire-smart landscape interventions, which helps to improve the implementation and decision-making on innovative actions with little previous experience over time, and to produce and disseminate the knowledge developed at the national level. landscape, national and international.

The Fire-smart landscape plan should be embedded into existing pluriannual strategic planning and investment plans of the different subnational administrative levels that correspond to the limits of the landscape to better guarantee its proper implementation and financing to better guarantee its proper implementation and financing. Likewise, this makes it possible to improve the existing sectoral policies at the landscape level through the mainstreaming of fire-smart objectives in the existing municipal and regional strategies and plans.

As already mentioned, a fundamental barrier when it comes to restoring fire-smart landscapes is the depopulation of territories with a high risk of large-scale fires. That is why the implementation of fire-smart landscape plans must be coupled with the adoption of policies and incentives to fix and increase the rural population in depopulated rural areas, through innovation and development actions (e.g. development of skills for both service providers and land users; multi-actors' innovative governance mechanisms; new marketing strategies for goods and services linked to fire risk reduction) for the creation of professions and viable green businesses that integrate fire-risk reduction, and whose activities should be coordinated with fire-smart interventions from other sectors, such as small livestock businesses providing controlled grazing services in firebreak areas, thinned forest patches and cropland supplying biomass to local bioenergy companies, or biomass growth control around buildings and infrastructures. In addition, the impossibility of finding a single source of financing that allows the management of the excess of dry biomass in high fire-risk areas of the landscape, makes it necessary to develop a combined strategy that integrates the use of public funds and incentives **[12]**, the development of private businesses and green value chains linked to fire-risk reduction goods and services, and the development of public-private partnerships for the payment of the ecosystem services provided by fire prevention, such as its link to the voluntary carbon market.

[12] For instance, the increase and allocation of part of the budget of regional and local fire management plans, rural development plans, climate change adaptation and mitigation plans, ecosystem restoration plans, and biodiversity conservation plans, for boosting the adoption of complementary cross-sectoral fire prevention measures.

3.2. Prioritization of locally adapted, cross-sectoral and innovative fire-smart land uses and management measures

The shift from fire-prone LU/LC types (current fuel models) and landscape distribution pattern to a landscape with a distribution pattern and typology of LU/LC that are fire-smart entails the integrated adoption of several complementary sustainable biomass management practices or fire-smart interventions.

Fire-smart landscape interventions include different sustainable biomass management actions linked to the protection, management and/or restoration of forests, pastures and farmland. In most cases, it is necessary to integrate two or more types of sustainable biomass management intervention, which are intersectoral and require the establishment of collaboration frameworks between different actors in the territory (e.g. forest owners, pastoralists and farmers) and harmonized management plans (e.g. a management plan for controlled grazing based on fire-smart objectives, aligned and compatible with a forestry, agroforestry or agricultural fuel management plan in the same intervention area).

3.2.1. Fuel-break areas

The lack of effectiveness of traditional firebreaks (lines of limited width with bare soil that break forest continuity in critical areas of the landscape) in the face of large-scale forest fires has led to a reconsideration of the design of landscape areas that help to reduce or stop the advance of the fire and facilitate the access and interventions of the extinguishing agents. The most innovative trend that is followed in different Euro-Mediterranean countries is to create wider fuel-break areas a few hundred meters wide, with the possibility to maintain a low tree cover, and the mandatory use of controlled grazing with locally adapted species compatible with the established tree and herbaceous cover. The objective is to increase efficiency in slowing down the spread of fire, improve access for fire-fighting personnel, and absorb management and maintenance costs with the economic return provided by established crops and livestock.

Fuel-break areas may consist of:

- A low-density tree layer of natural or planted forest tree species dispersed over a natural herbaceous cover.
- A low-density agroforestry tree plantation (e.g. chestnuts, cherries, plums, almonds, figs, carobs, olives, among others) over a living mulch cover (wild or cover crop interplanted);
- A plantation of vines over a living mulch cover (wild or cover crop interplanted).
- An herbal cover of farmland or pastureland.

Tree architecture, density and composition:

- Pruning of the lower tree branches may be needed to break vertical fuel continuity.
- Tree density may be defined according to different complementary goals (reduction of fire severity, economic production, landscaping, creation of habitats for vulnerable species), and possibly justified by its proven effectiveness in terms of fire severity reduction in other areas.
- It is desirable to have a mixture of tree species with different life forms and resistance to fire (e.g. resprouting, fruit-producing that attract seed dispersal fauna, nitrogen-fixing, symbiotic with fungi) to increase their effectiveness and rapid post-fire recovery.

Location:

- They are usually set up in critical areas of the landscape that allow the fire front to be broken (e.g. mountain headlands that separate different valleys) and where it is necessary to facilitate the access of extinguishing agents.

Complementary fire-smart interventions:

- Initial **mechanical clearing and/or prescribed burning** of excess woody biomass (shrubs and trees). This is a necessary first step that entails a high economic cost, and, in the case of prescribed burning, a large number of highly specialized personnel and expensive equipment. If it is possible to ensure the complementarity of the other fire-smart actions, especially controlled grazing, it would not be necessary to repeat it in the future. In any case, without the guarantee of having long-term collaboration agreements between landowners and herders, and a sufficient number of herders and cattle, it is advisable not to undertake the initial thinning, as this would entail a double cost of having to return to cut after a few years.

- **Tree thinning**. In the case of critical areas with high tree density, often the result of unmanaged plantations or secondary ecological succession after the abandonment of agro-pastoral land or post-fires, it will be necessary to do more or less intense thinning to reduce the tree density to desired levels.
- **Tree planting**. In the case of establishing productive and/or diversified fuel-breaks, it would be necessary to carry out plantations of agroforestry and/or forestry species/varieties well adapted to the agro-ecological conditions of the intervention area, possibly having been evaluated for their adaptability to projected climatic conditions (9).
- **Controlled grazing**. Shepherds that take part in wildfire prevention programs make their livestock graze intensively in priority fuel-break areas designated by forest services and, thus, vegetation (herbal and woody species) fuel loads are reduced to volumes of dry matter per hectare compatible with mild wildfires with reduced flame length and slow rate of spread. The livestock species and the stocking rate applied needs to be adapted to the annual biomass production rates in the targeted fuel-break area (24). Moreover, controlled grazing management should include measures (e.g. grazing seasonality, suitable livestock species and breeds, the use of protectors) that avoid destroying the existing saplings and seedlings of tree species, especially oaks.
- **Sustainable management of agriculture biomass residues**. In many landscapes, the burning of stubble and pruning remains not only contributes to carbon emissions, but also poses a high risk of fire, especially between late summer and winter. Biomass from crop stubble and olive/fruit tree pruning is a relevant energy feedstock that does not generate additional demand for land, nor negative impact on the environment and biodiversity. On the other hand, crop stubble and pruning lefts may sustain both fodder needs and agricultural processes that provide beneficial ecological services (e.g. soil organic carbon, soil water conservation). Farmers, with the support of agricultural technicians and researchers, can integrate into their management plans, reconciling or combining these three contrasting agriculture residues' management operations is possible, thus obtaining renewable energy and fodder while preserving soil quality, its health status and fertility.

Economic sustainability: biomass management is very costly, especially in forest landscapes, where the abandonment of the territory has generated a continuum of very extensive woody shrub and tree cover. That is why, for its implementation to be feasible, it is essential to make use of different sources of financing, from public funds assigned to fire prevention to the establishment of new and innovative businesses based on the production and commercialization of direct or indirect products of the management of a biomass that often has a marginal value (difficult extraction and processing, coupled with low market value).

- **Agroforestry**: The FSL planning teams should support landowners in fuel-break areas to select tree species/varieties with high productive value, help them develop business plans that demonstrate an economic return over time, and provide them with information and access to incentives from the national and EU policy schemes that support this type of green initiatives. Likewise, researchers active in the target landscapes can help define densities that simultaneously maximize production and reduce fire risk.
- **Controlled grazing**: in exchange for this service, livestock farmers may receive money and/or in-kind remuneration, which can consist of animal housing, fences or water troughs. The amount of payment per hectare may vary depending on the grazing difficulty (steepness, type of vegetation and distance to animal housing) associated to the assigned fuel-break areas. However, the work of each shepherd should be evaluated every year, and the amount of money they finally receive may be adjusted depending on results (24). One of the main economic constraints that limit the interest of herders in taking part in controlled grazing programs is the fact that pastures in areas with high fire risk tend to be unproductive and limit the economic sustainability of the activity. The FSL management teams should support online marketing initiatives for high-quality local fire-fighting products to generate a market niche that attracts consumers sensitive to the environmental value of the products, promote complementary tourist activities (e.g. visits and stalls to the livestock companies of the program), and facilitate connections between livestock producers and other actors in the "fire-fighting livestock products" value chain, such as butcher and dairy shops, restaurants, hotels, interested in the added value of the fire-fighting environmental role that it gives to the products. This, together with training programs on “fire-prevention grazing to control biomass load” of the various pastoral schools that have currently been created in different regions, will help to get a sufficient number of professional shepherds (landscape network of controlled grazing shepherds) to be able to manage the excess biomass in critical areas of the landscape.

- **Mechanical clearing, thinning and pruning**: These are necessary interventions to start the processes of shifting from fire-prone to fire-smart LU/LC in critical areas of the landscape, which have a high cost per hectare, difficult to be covered by the existing funds for fire prevention at the national or regional level (especially when considering the vast areas of fire-prone landscapes with high fuel load). That is why it is necessary to innovate in the creation of sustainable businesses linked to a biomass of low market value (e.g. shrubs and tree stems with diameters, shapes and mechanical properties of little interest for the traditional wood market). The project LifeGranatha **[13]** in Tuscany (Italy) has restored the ecological functionality of heathlands (*Erica spp.* shrub communities), that provide habitat requirements for the reproduction of many bird species of special conservation concern, through the clearing of excessive fuel load whose cost is absorbed through the revitalization of a local green value chain linked to the production and marketing of brooms and other tool made by the *Erica scoparia*, as could guarantee a continuous and lasting management of heathlands. The forest landscape restoration initiative of the Shouf Biosphere Reserve (Lebanon) has developed actions to manage, process and marketing the remains of thinning and pruning both in the olive groves of the region, as well as in the very dense unmanaged secondary pine forests and abandoned coppice oak woodlands located in critical areas of the landscape with a high fire risk. Biomass residues are used to produced briquettes to feed the heating and cooking stoves in the local villages, with the multiple objective of avoiding the burning of agricultural residues in autumn, which is the main cause of fires in the region, reducing the risk of fire spread in excessively dense secondary forests, improving a more mature forest structure and biodiversity, substituting an expensive and polluting type of energy (diesel) diffused in the homes for a more economical and carbon-neutral one, and create green job opportunities and small businesses that help absorb the costs derived from biomass management.

3.2.2. Climate adaptive forest management

Many Mediterranean forests have had as management objectives mainly the protection of watersheds and the extraction of wood (e.g. firewood, cellulose, construction furniture). Currently, the costs of forest management have made the periodic cuttings necessary for a sustainable management of these forests unfeasible. The increase in water stress derived from climate change (heatwaves, droughts and changes in the seasonal distribution and decrease in rainfall) and the consequent accumulation of dry biomass entails a high risk of forest dieback and high fire spread. One way to face the necessary costs for an adaptive management of the biomass of these forests is the adoption of multipurpose objectives and diversification of productive and cultural ecosystem services.

Multipurpose objectives may consist of:

- The economic valuation and promotion of a set of non-timber forest products (NTFPs), such as mushrooms, resins, fruits, honey, wild herbs, tree fodder and pastures, that are complementary to a limited production of wood.
- The development of forest biomass management plans (forest thinning and pruning) with the dual objective of reducing fire spread risk and improving the production of NTFP products. In numerous cases (e.g. production of mushrooms in beech forests in Italy; production of resins in pine forests in Extremadura, Spain) researchers have verified that the reduction of tree densities necessary to reduce the risk of fire also favours an increase in the production of NTFPs, with an added economic value for forest owners and for the creation of associated local companies and jobs. The adoption of thinning plans can prevent irrational forest burning actions to open clearings, used in some countries of the region to promote the growth of edible mushrooms (e.g. the target landscape complex of Komovi and Prokletije in Montenegro).

Location:

- Dense forest stands **[14]** with low to medium conservation value, with high fire spread risk located in landscape areas where they interface with high/very high fire ignition areas (e.g. roads, urban land, power lines and stations).

[14] Secondary conifer and broadleaf forest that come from the post-fire regeneration of burnt areas and the colonization of abandoned farmlands; productive forest and tree plantations with the predominant objective of wood production; unmanaged plantations and degraded forests with watershed protection objective.

Complementary fire-smart interventions:

- **Tree thinning**: Forest technicians and researchers should support forest owners in the development of thinning plan to reach optimal densities linked to fire spread risk reduction, to develop a more mature and climate-resilient forest structure, and to the growth of highly commercial NTFPs (e.g. the management of thinning operation in the beech forests of Parma region by the Borgotaro Mushroom Consortium, Italy **[15]**; the establishment of suitable tree densities - 200 trees per hectare of *Pinus pinaster* - in the Sierra de Gata landscape by the Extremadura Mosaic Project Team, that are the most favourable ones for achieving both optimum resin production per hectare, with the additional function to significantly reduce fire spread risk). A selective thinning and pruning plan must be defined, maintaining an adequate distribution of the best developed individuals and the regeneration of the different species of existing trees, cutting trees with the worst growth and that are close to each other, and pruning the lower part of the remaining trees to break both vertical and horizontal fuel continuity. The planning of thinning operations must integrate an environmental impact study of the technologies used and the access roads to avoid problems of soil degradation, hydro-geological instability and impact on sensitive fauna and flora.
- **Tree planting**: In the case of fire-prone monospecific forest stands dominated by obligate seeders such as conifers, and with the added objective of diversifying ecosystem services, it is advisable to identify several native tree species that are well adapted the target landscape according to climate change projection and plan a gradual seed collection, nursery production and planting program to make forest stands more resilient and suitable for multipurpose objectives.
- **NTFP inventory, valuation and management**: With the participation of local stakeholders and researchers, it will be important to inventory and evaluate the productive and economic potential of different NTFPs, as well as define the most suitable forest densities for their production, and the management protocols for sustainable NTFP harvesting.
- **Controlled grazing**: In this case, it is important to assess the compatibility of livestock with multipurpose production objectives to avoid possible negative impacts on tree regeneration and NTFP species populations. Timber extraction through thinning can be linked to an economically viable production plan for firewood or other wood products - especially if there is economic diversification from various wood and NTFP products - which would reduce the need for livestock use.
- **Biodiversity monitoring**: The reduction of excessive tree densities and increase of tree species diversity usually has a positive effect in terms of biodiversity (e.g. increase in species of birds, mammals, insects, fungi and plants), although it is necessary to select indicators and establish a monitoring system that allows understanding the impact of thinning operations in the indicator species.

Economic sustainability: In this case, forest economists need to help forest owners to assess the economic value per hectare of the different wood and NTFP products with the greatest potential in the target area. It is important to define the profitability that the owners can obtain based on the extension of their property and if it is limited (small properties) analyse the economic sustainability derived from the creation of producer groups through collaboration agreements such as forest associations and cooperatives to standardize management practices in line with the fire-smart objectives, reduce thinning and pruning management costs, and enhance the capacity and cost-effectiveness of individual owners in production, processing and marketing (e.g. reduction of overall expenses; the sharing of production/processing equipment; joint marketing opportunities with greater bargaining power).

- **Thinning and pruning**: Forest technicians and researchers should support forest owners to evaluate the potential use (especially energy) of the wood to be extracted to carry out a sustainable production and commercialization plan if it is profitable, and/or the establishment of agreements with the local population for its possible distribution as payment for the clearing work.

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[15] https://www.fungodiborgotaro.com.

- **NTFP harvesting**: Forest economists should support forest owners in the development of business plans for the target NTFP products, taking advantage of the opportunity to add economic value through the labelling as high-quality fire risk reduction products, and territorial marketing strategies, which help consumers recognize the additional ecological and sociocultural value of these products, and promote ecocultural tourism (with the creation of local companies and jobs) associated with them. Moreover, the FSL team and experts should identify funding opportunities (e.g. annual rural development funds available for landscape and type of intervention) to help forest owners subsidize part of the costs of management costs.

3.2.3. Sustainable management of biomass in secondary shrublands

One of the main problems in terms of high fire risk is the large extension of secondary shrub areas that have colonized abandoned pastures and farmlands in numerous Mediterranean landscapes. The reduction of biomass in these vast shrubby areas is one of the greatest challenges in terms of fire risk reduction due to the size and high cost of the necessary shrub clearing operations, and the difficulty of obtaining an economic return that can help to absorb part of its costs. Likewise, the public funds available for preventive actions are highly insufficient to be able to face this task.

Location:

- Dense shrubland stands with low to medium conservation value, with high fire spread risk located in landscape areas where they interface with high/very high fire ignition (e.g. roads, urban land) and fire spread (e.g. dense forest stands) areas.

Complementary fire-smart interventions:

- **Initial mechanical clearing and/or prescribed burning of excess shrub biomass**. The different scrub habitats have an ecological and sociocultural value that must be preserved, so the objective should be to create a mosaic of cleared patches, for the establishment of pastures (possibly with scattered trees) and cultivated patches, defining the cleared areas. in the most critical areas in terms of fire spread and in interface areas with high fire ignition risk areas. As previously mentioned, clearing is a necessary first step that entails a high economic cost, and, in the case of prescribed burning, a large number of highly specialized personnel and expensive equipment. If it is possible to ensure the complementarity of the other fire-smart actions, especially controlled grazing, it would not be necessary to repeat it in the future. In any case, without the guarantee of having long-term collaboration agreements between landowners and herders, and a sufficient number of herders and cattle, it is advisable not to undertake the initial thinning, as this would entail a double cost of having to return to cut after a few years.
- **Tree planting**. The planting of sparse trees with low densities, focusing on multipurpose resprouting species with greater resilience to fire and with high economic potential (e.g. oak, chestnut, hazel nut species symbiotic with truffles and other economically valuable mushrooms), is recommended in cleared scrub areas. with agroforestry vocation, with the multiple objective of reducing fire spread risk, reduction of climatic risks (increased microclimate and shading for domestic and wild animals), creation of companies and jobs with very high economic profitability that also help to absorb the costs of biomass management, and biodiversity enhancement.
- **Controlled grazing**. Shepherds that take part in wildfire prevention programs make their livestock graze intensively in priority fuel-break areas designated by forest services and, thus, vegetation (herbal and woody species) fuel loads are reduced to volumes of dry matter per hectare compatible with mild wildfires with reduced flame length and slow rate of spread. The livestock species and the stocking rate applied needs to be adapted to the annual biomass production rates in the targeted area [16]. Moreover, controlled grazing management should include measures (e.g. grazing seasonality, livestock species used, use of protectors) that avoid destroying saplings and seedlings of regrowth species, especially oaks.
- **Biodiversity monitoring**: The reduction of excessive shrub biomass with the establishment of a mosaic of patches - shrubs, pasture with/without scattered trees and farmland - has positive effects in terms of biodiversity (e.g. increase in species of birds, mammals, insects, fungi and plants), although it is necessary to select indicators and establish a monitoring system that allows understanding the impact of the designed operations in the habitat requirements of the targeted species.

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[16] Ruiz-Mirazo, J. & A.B. Robles. 2012. Impact of targeted sheep grazing on herbage and holm oak saplings in a silvopastoral wildfire prevention system in south-eastern Spain. Agroforest Syst (2012) 86:477–491 DOI 10.1007/s10457-012-9510-z.

BOX 1. Mechanical clearing versus prescribed burning

The reduction of dry biomass in dense shrubby areas, with or without a tree layer, always requires mechanical clearing using different brush-cutting techniques or prescribed burning. The choice between mechanical cutting or prescribed-burning depends on numerous factors, including the costs, the existing of qualified personnel and technological resources, the environmental risks, the impact on the amount and speed of biomass regrowth, and the resulting ecological conditions and species composition of the LU/LC targeted by the fire-smart intervention (25).

Prescribed burning	Mechanical clearing
• Soils nutrients may decline in prescribed burning plots few years after treatment causing deeper soil degradation than mechanical clearing. • It may cause faster regrowth of pyrophytic shrub species with a negative effect in terms of fire resilience and management costs. • It requires large crews of qualified professionals and technicians, and substantial resources for planning and implementation. There is always the fear of the probability of losing control of the burned areas. • Without a planned and agreed collaboration for controlled grazing, prescribed burning may be economically unfeasible. • Negative public opinion, especially in the proximity of residential developments or urbaN areas, environmental laws regulating air quality and smoke, and risk-averse forestry agencies and policies are also major impediments to the widespread use of prescribed burning. • Centuries of detrimental fire use, especially by shepherds and farmers, have contributed to exacerbate the negative public perception of the use of fire (often ban by law). The adoption of prescribed burning can contribute to create confusion and stimulate an increase in the illegal use of fire by farmers and herders and the risk of control loss under unfavorable weather conditions.	• Can be more effective to control shrub regrowth than prescribed burning. • It maintains the regrowth of the natural shrub community and facilitates to a higher extent the recovery of the original grassland vegetation. • It has let requests in terms of professionalization and staff. • Without a planned and agreed collaboration for controlled grazing, mechanical clearing may be economically unfeasible.

Prescribed burning (PB) has been used worldwide since the first half of the 20th century for fire hazard reduction, forest and range management and biodiversity conservation (26). However, in the domesticated forest landscapes of Europe, with their small-sized forests finely intermixed with small-scale agricultural systems, heritage landscapes, protected areas, and numerous rural and urban forest users with different demands, values and perceptions, the use of fire as a land management tool may be undesirable, and its benefits may not be fully appreciated (9). Legislation has set the scene for prescribed burning experiments in some Mediterranean countries and regions, encouraged by international research projects on integrated fire management, such as FIRE PARADOX (27) and ALPFFIRS [17]. However, the absence of clear guidelines in prescribed burning regulations, especially concerning the attribution of responsibilities in the use of fire, has de facto prevented its implementation in many cases.

[17] https://www.wsl.ch/en/projects/alpffirs.html

Economic sustainability: biomass clearing in vast shrubland areas is very costly, reason why, for its implementation to be feasible, it is essential to make use of different sources of financing, from public funds assigned to fire prevention to the establishment of new and innovative businesses based on the production and commercialization of direct or indirect products of the management of a biomass that often has a marginal value (difficult extraction and processing, coupled with low market value).

- **Agroforestry:** The FSL planning teams should support landowners in cleared shrubland areas to select tree species/varieties with high productive value, such as oaks and other broadleaf trees linked to truffle and other edible mushrooms production, help them develop business plans that demonstrate an economic return over time, and provide them with information and access to existing best practices and incentives from the national and EU policy schemes that support this type of green initiatives. Likewise, researchers active in the target landscapes can help define planting densities and management plans that simultaneously maximize NTFP production and reduce fire risk.
- **Controlled grazing**: The economic opportunities linked to controlled grazing were already introduced in the description of the fuel-break areas.
- **Shrub biomass clearing**: The economic opportunities linked to mechanical clearing were already introduced in the description of the fuel-break areas. In the case of prescribed burning, not having a product resulting from the action, prevents raising the possibility of an economic activity that generates benefits, and must be financed through public and/or private incentives.

3.2.4. Active ecological restoration interventions in degraded landscape areas with high fire risk

The EU Biodiversity Strategy for 2030 commits to planting at least 3 billion additional trees in the EU by 2030 with the aim to "increase the EU forest area and resilience, enhance biodiversity, and help with climate change mitigation and adaptation" **[18]**.

Landscape degradation can be caused by intense modification of the potential natural vegetation cover that increases the risk of fire in the landscape. Overexploited wooded, shrubby and herbaceous areas, although they may present a lower accumulation of biomass than in well-conserved situations, are characterized by a greater amount of dry biomass (e.g. overgrazed plants with many dry branches; mortality of trees and shrubs due to the less water retention of compacted and eroded soils) which increases the risk of spreading fire. Abandoned agricultural and pastoral lands in numerous landscapes of the Euro-Mediterranean region, has given rise to secondary successional stages with a very high accumulation of dry biomass, whose slow natural evolution towards mature stages presents a very high risk of fire without human intervention that accelerates the process (thinning to get stands of forests). structurally more mature with horizontal and vertical fuel discontinuity) or that supports a change of use in patches that break the fuel continuity of the landscape (e.g. clearing shrubland to restore past agriculture or pastoral LU/LC). Likewise, overexploited areas with extensive, very dense plantations of pines and eucalyptus trees that homogenize the landscape, breaking its mosaic structure, also generate an intense accumulation of dry and pyrophilic biomass and a high risk of spreading fire. In both cases, it is necessary to intervene in the landscape to recover its ecological functionality and its resilience against climatic risks and large fires, through protection actions (e.g. temporary enclosures to reduce grazing pressures), management (changes of uses in landscape patches to break the fuel continuity of large plantations), or active ecological restoration (e.g. plantations with a diversity of species with different life forms to recover the ecosystem and its ability to respond and recover from fires.

[18] https://environment.ec.europa.eu/strategy/biodiversity-strategy-2030_en

The active ecological restoration of degraded areas of the landscape comprises a series of possible actions:

- Selection of autochthonous woody and herbaceous species with a multipurpose value (e.g. re-sprouting fruit species that attract seed-dispersal fauna, regrow after fires and have an economic value), based on models of bioclimatic envelope changes, for direct planting from seeds of genetically diversified populations, or their production in nurseries.
- Development of production techniques for autochthonous multipurpose species to produce hardened seedlings resistant to lack of water and soil nutrients.
- Realization of diversified planting techniques (e.g. locally- and climate-adapted planting densities, water-conservation soil preparation and soil mulching measures, planting season, planting material selection and field distribution, maintenance and use of existing vegetation with nursery-effect) with a mixture of seeds, cuttings and/or seedlings of dominant multipurpose species and woody and herbaceous companions, so that the ecosystem can be rebuilt more quickly.
- Enrichment planting in stands of woody and herbaceous formations to diversify the composition of multipurpose trees with a forest approach or mixed agroforestry system.
- Temporary enclosures of degraded pastures to regenerate their specific composition and diversify the stand with dispersed woody species that increase their climate and fire resilience.

3.2.5. Sustainable management of pastures

In the case of pastures, beyond the consequences of abandonment on the accumulation of woody tree and/or shrub biomass already mentioned in the previous cases, one must also consider the negative effect that overgrazing can cause in terms of fire risk. ignition and spread. Overgrazing causes a loss of palatable species and an increase in unpalatable species that limit pasture productivity. On certain occasions, in which there has been intense human depopulation, loss of traditional governance systems of the pastoral commons, and maintenance of subsistence livestock with maladaptive practices (permanent excessive pressure from pastures, without rotation and resting system), farmers tend to burn the pastures, to improve their specific composition. The lack of grazing planning, loss of knowledge, will and ability to maintain or recover communal governance systems mean that fires can break out without any control mechanism and escape to neighbouring uses that may represent interfaces with high fire risk areas (e.g. dense forest stands, urban areas).

In this case, fire-smart practices are basically practices of sustainable management and recovery of pastures, which require an evaluation of the carrying capacity, rotational management systems of the pastures adapted to the area of intervention, the establishment of infrastructures and points of necessary water for livestock, and pasture restoration actions not linked to fire, such as the establishment of temporary enclosures to protect livestock from access, by sectors and in a gradual and organized manner, the recovery of vegetation cover. The enclosures can include actions of seed sowing and seedling planting of herbaceous and woody species of high palatable value to more rapidly enrich degraded pastures.

An effective restoration of the sustainable uses of pastures entails restoring a viable and responsible communal governance system, with formal agreements between users and landowners on the rights of uses, how they are distributed among users spatially and temporally; definition of management plans of the rotation and resting type (including enrichment planting) with calculation of cattle carrying capacities and residence time by pasture sections (pasture mapping and cattle movement system) based on multiple objectives of productivity, biodiversity conservation and fire risk reduction; training courses on sustainable management and fire-smart livestock; budgeting for equipment and infrastructures (e.g. water points, stables, etc.), as well as a business and marketing plan for the economic sustainability of productive farms.

3.2.6. Sustainable management of agricultural biomass

Maladaptive farmland practices (e.g. burning pruning residues and stubble) are a major cause of fire ignition and spread in many forest landscapes. Modern agricultural biomass management approaches and techniques, such as the conservation agriculture principles for both herbaceous and woody systems, involve a multiple use of this biomass that is partly integrated into the soil (e.g. previously shredded pruning residues and stubble), partly used to produce bioenergy and compost, and partly used as fodder for livestock.

In this way, its burning and consequent risk of fire spread are avoided, in addition to improving other ecosystem services such as soil fertility, the conservation of its water resources, especially during the summer drought period, with a positive effect on the hydration of the plants, the microclimate and relative humidity of the territories that in a certain way reduces the risk of fires.

Although it is not an action directly translatable into fire-smart, the promotion of conservation agriculture and the multiple use of agricultural biomass (sometimes integrated with forest biomass, as is the case of briquettes for energy in the landscape of the Shouf biosphere reserve in Lebanon) in landscapes with a high risk of fire is a measure that provides important direct and indirect effects in terms of risk reduction, improvement of ecosystem services, and improvement of productivity and agricultural benefits for the locals. farms, especially in conditions of increased droughts and loss of soil and environmental water resources derived from climate change.

3.2.7. Biomass clearing around houses, settlements, and infrastructures

During the last decades, the generalized tendency to build isolated houses and entire neighborhoods nearby forested areas has supposed an increase of the large-scale interaction between the forest risks and human settlements (28). Furthermore, the natural reforestation of many croplands after their abandonment has led to forests getting close to many towns and population hubs. In this context and with the increase in forest fire severity, it is more likely that high-intensity fires impact houses and the population, becoming a risk for people and infrastructures.

Three different types of interfaces are identified between wildland and human built areas (wildland-human interface) (29):

- Wildland-Urban Interface: an area where homes, public buildings and commercial structures meet with or are dispersed within wildland vegetation.
- Wildland-Infrastructure Interface: an area where infrastructures (e.g. roads, railways, or powerlines) meet with or are dispersed within wildland vegetation.
- Wildland-Industrial Interface: an area where industrial facilities (e.g. chemical plants, oil depots, warehouses) meet with or are dispersed within wildland vegetation.

Wildfire prevention measures in Wildland-Urban-Infrastructure-Industrial interfaces are based on the assumption that fire-risk is a function of variables related:

- Classes of infrastructures (type, grouping or isolation level).
- Human activities.
- Presence/absence of fuel load according to vegetation types and structure.

Infrastructure configuration and aggregation of vegetation is then spatially integrated and mapped using a geographical information system (GIS) and then statistically treated to classify WUI entities according to settlement and vegetation types and aggregation. The aim of the GIS analysis is to identify which urban and vegetation configurations have a higher fire incidence. Information on past fires is extremely valuable data, to be combined and processed with other variables, such as land use, human infrastructure, topography or type of vegetation, for different purposes. Several studies in Spain, France and the US demonstrated that fire risk is higher at intermediate levels of urbanization due to the spatial arrangement of ignition sources and fuels (30,31,32).

The morphology of scattered settlements maximizes the perimetric area in contact with wildlands and thus the probability of being affected by wildfires. Regarding forest structure, more hectares have burned at medium levels of aggregation than at high continuity of vegetation, as might be expected, and, in some cases, agricultural and grazing lands may increase fire frequency and burned area (30). However, it is important to collect additional information about the territorial context, as different structural and circumstantial factors, such as physical characteristics (e.g. topography, fuels), dynamic factors (e.g. weather) or even causes of ignition, detection systems and the extinction strategy implemented can influence wildfire incidence.

After identifying and mapping the most critical areas, the best method for reducing risk is to alter the fuel in terms of loadings and stand structure through fuel treatments in a certain width of strips or perimeters surrounding buildings. In addition, the establishment of effective evacuation plans (e.g. ensuring an efficient road network to evacuate people) and availability of water to intervene around the houses is necessary.

Responsibilities for preventing the occurrence of forest fires and/or limiting their damages should be attributed to (28):

- **owners and managers of the houses and infrastructures**: they must be aware of the exposure to a fire-risk and they act consequently, by: reducing the vegetation load in gardens that are directly touching the house constructions; separating the most flammable items from the house walls (wood piles, miscellaneous items...); being aware of the safety measures and protocols for evacuation of the area in case of a fire; having water supplies and clean access areas; clearing of a trip of land between the urban limit and the surrounding vegetation, creating a buffer without available fuel; following the official recommendations on fire bans and road access requirements (which seek above all to ensure people's safety in the case of a fire event); avoiding the use of tools that could produce sparks on the days with a greatest risk; employing barbecue covers and other safety items around barbecues, having water supplies available; avoid lighting off fireworks near areas with forest vegetation; notifying the emergency line if there is a fire; reporting or warning negligent behaviors of irresponsible use of fire or situations that could generate a risk of fire.
- **public administration and land planners and managers**: they must prioritize the integration of fire prevention and suppression measures into urban and infrastructural planning and define policy regulations on fire prevention intervention in wildland-urban-infrastructural-industrial interfaces.

In Europe, a common legal framework to define and harmonize WUI areas for practical fire risk management and spatial planning does not yet exist.

Table 4. National Legal frameworks with reference the spatial definition of WUI (28)

Countries	WUI distances adopted	Reference law
France	100 m urban settlement; 200 m around vegetation areas.	- French Forest Law 9/July/2002
Italy	50–200 m urban areas; 200 m–400 m around vegetation areas, depend to local region.	- Framework Law on forest fire 2000/353 and regional planes.
Portugal	100 m urban areas; 200 m around vegetation areas, Intervention Priority zone.	- National forest law against forest fire 30 June 156/2004.
Spain	50–100 m around urban areas; 100 m–400 m around vegetation areas, depend to local region.	- Ley de Montes 43/2003 and regional planes.

The European Union influences wild-fire legislation through EC regulations, but every nation and region produces their own forest protection policies, generating a very heterogeneous legislative landscape. This is especially evident in decentralized countries where local governments develop their own forest fire plan. In Portugal and France, the centralized administrative system provides a unique definition of the WUI (33). In these countries the WUI areas are identified as the overlay of a buffer zone of 100 m around urban areas and 200 m around vegetation land cover. In Italy and Spain, where the decentralized governance structures have delegated authority over forest management to the regions, there are diverse WUI definitions. The buffer distances around urban settlements vary from 50 to 200 m and 100 to 400 m around woody vegetation covered areas.

3.3. Enhance and restore the species diversity, functionality, fire resilience and ecosystem services of the natural and seminatural habitats in the landscape

Although fire is part of the dynamics of Mediterranean ecosystems, today it is difficult to define the natural regime of national disturbances linked to fire and its influence on the ecological processes of the different ecosystems that characterize the bioclimatic floors of the Mediterranean region throughout its wide latitude and longitude. In addition, as we have already mentioned, the ancient anthropic transformation of the ecosystems in the region, the profound rural abandonment processes of the last decades, and the intensification of environmental risks due to climate change, make fires more of a social issue than a natural one, becoming extremely difficult to analyze wildfires as a natural disturbance.

The response to fire of some species whose regeneration is activated after fires is known, such as the coastal xerophytic pine forests (e.g. *Pinus halepensis, P. brutia, P. pinaster*), although the frequency and seasonality of anthropic fires can be incompatible with the ecology of these species, resulting in regeneration problems. The proposal of prescribed burning as part of the fire risk management sometimes has among its objectives that of mimicking the natural disturbances that support the successional processes of some natural ecosystems. However, the lack of knowledge about the functioning of this type of natural disturbance in highly anthropized landscapes makes it difficult to understand if the result corresponds to this objective and has the risk of promoting fire-prone natural systems, hindering their evolution towards fire-resilient advance successional mature stages (e.g. perpetuating pyrophytic scrubland and pine forests).

The most widely proposed and/adopted fire-smart interventions linked to increasing the resilience of natural ecosystems are (6):

3.3.1. Conservation and connectivity restoration among old-growth forest stands

The conservation of mature forest stands in the landscape, whose microclimate, structure and specific diversity and trophic relationships favour a more resilient response to fire. However, as in many Mediterranean landscapes, old-growth forests tend to be relic small stands scattered in the landscape, whose small size makes them highly vulnerable to fire. In this case, it is very important to support ecological restoration actions to increase connectivity between unconnected relic stands, and to manage the biomass in a strip around these nuclei to reduce the risk of fire spread towards them.

3.3.2. Diversification of species in forest stands

Anthropized forests are usually monospecific, with a high dominance of a single species that has been favoured based on the selected use (e.g. wood, resin, silvo-pastoral, etc.). Restoring species diversity in forest stands, with special focus on post-fire re-sprouting species that attract seed-dispersal fauna and help improve soil fertility, increases the ability of the landscape to recover more quickly after wildfires. In the Mediterranean context, the diversification of conifer forests with the numerous native *Quercus* species from different parts of the region, and other species that produce fruits (e.g. *Sorbus* spp*; Prunus* spp*.; Pyrus* spp*.; Malus* spp*.; Arbutus* spp.; etc.) that attract dispersing fauna, is a measure supported by numerous forest landscape restoration projects, which also contributes to the sustainable social and economic return on investment, since they are species that can generate significant benefits for the local population.

3.3.3. Changes in the vegetation structure and species composition to speed up natural succession towards mature stages

Abandoned agriculture and pastureland, as well as landscape areas that suffered fires in past decades, may be dominated by dense scrublands and secondary pine forests of high-flammable species that generate fuel load continuity with a higher fire risk. Pilot experimental measures in Valencia (Spain) with a combination of selective clearing of high-flammable *Ulex parviflorus* scrubs and the planting of re-sprouting species seedlings have transformed the scrubland into a landscape dominated by grasslands with scattered re-sprouting scrubs that provided fuel load discontinuity in just 3 years (34). Moreover, the mulching of the soil surface with brush-chipping has greatly reduced the germination rates of fire-prone seeders.

3.3.4. Habitat diversification

Breaking fuel continuity in the landscape through mechanical cutting or prescribed burning (forest thinning, forest gap opening, and shrub clearing in non-forest areas) followed by controlled grazing helps create new habitats and favours the diversification of species linked to forests with more mature structure and grasslands.

3.3.5. Management of post-fire snags and woody debris

The burned forest stands present a bleak aspect which conditions the social demand to improve their aesthetic appearance. In addition, much of the burned wood is economically usable, and needs rapid harvesting before it becomes useless. However, the post-fire snags and woody debris can play a fundamental role in the natural regeneration of burned areas and in their stability against risks of erosion by water runoff.

Adequate, locally adapted management protocols for burnt logs and branches spread on the ground can provide a physical barrier that protected the seedlings against ungulate herbivores (37), and help reduce soil erosion. Burnt logs and branches left on site after the fire act as nurse objects that can improve pine seedling establishment and growth by both reducing water stress and increasing nutrient availability (38). Burnt logs and woody debris represent a potential source of nutrients that are progressively released to the soil during decomposition. Standing dead trees attract seed-dispersal birds and enhance post-fire natural regeneration (39).

Management decisions may not only be based on the ecological effects on forest regeneration and soil stabilization, but also on socio-economic factors, such as the social opposition to standing post-fire snags due to aesthetical problems, the social demand for the economic use of snags and woody debris, security reasons, etc. It is recommended to test several options (i.e. whether to keep all standing dead trees; to keep part of the standing dead trees and cut the rest, which may be left on the ground; cut all standing dead trees and leave them on the ground and remove part, or all the standing dead trees). In the case of pine trees with serotinous cones, the harvesting of standing dead trees should be postponed for at least three/four years, so as to allow the seed dispersal of this type of cones, which are known for the delayed opening. Pilot experimental measures in Sierra Nevada (Southern Spain) demonstrated that the best option for the area was to keep part of the standing dead trees and cut the rest, leaving them on the ground (39). This technique offered a number of benefits, such as: lower runoff erosion and higher soil nutrient incorporation, higher seed dispersal and regeneration, high protection of seeds against herbivores, microclimatic improvement, and lower management costs. The harvesting should be carried out with minimum mechanical activity, before the rainy season (39). The combination of species with different life strategies (i.e. re-sprouting species like *Quercus* spp, *Arbutus* spp, that regenerate well after fire; fruit trees which will attract seed dispersal fauna; nitrogen fixing shrubs; etc.) in post-fire restoration work helps increase the resilience of forest stands and forest landscapes (40). A number of projects supported by WWF in Morocco and Tunisia and by IUCN in Lebanon have built the capacity of NGOs, local communities and the forest administration to diversify plant production in tree-nurseries, and grow a wider range of native tree, scrub and herbal species with different life strategies, for their use in post-fire restoration actions.

3.4. Sustainable return on fire-risk reduction investments, ensuring the provision of ecological, social and economic benefits

Fire-smart landscape interventions aim to enhance the ecological, social and economic resilience of the landscape to wildfires, and generate a range of ecosystem goods and services that benefit multiple stakeholder groups linked to rural development and biodiversity conservation.

Participatory processes through consultations and workshops with interest groups (e.g. landowners and users, forest and protected area managers, local administration, private entrepreneurs) to identify, propose and select suitable fire-smart LU/LC and management measures, must include the identification of economic, social and ecological returns to ensure the sustainability of the investment made. This also helps to make visible the potential compatibilities that exist between the benefits expected by stakeholders with different interests and facilitate the negotiation processes between them. Likewise, the quantitative information is used to develop a business plan for the economic activities linked to the management measures, and to analyze potential sources of financing that cover part of the costs of their implementation.

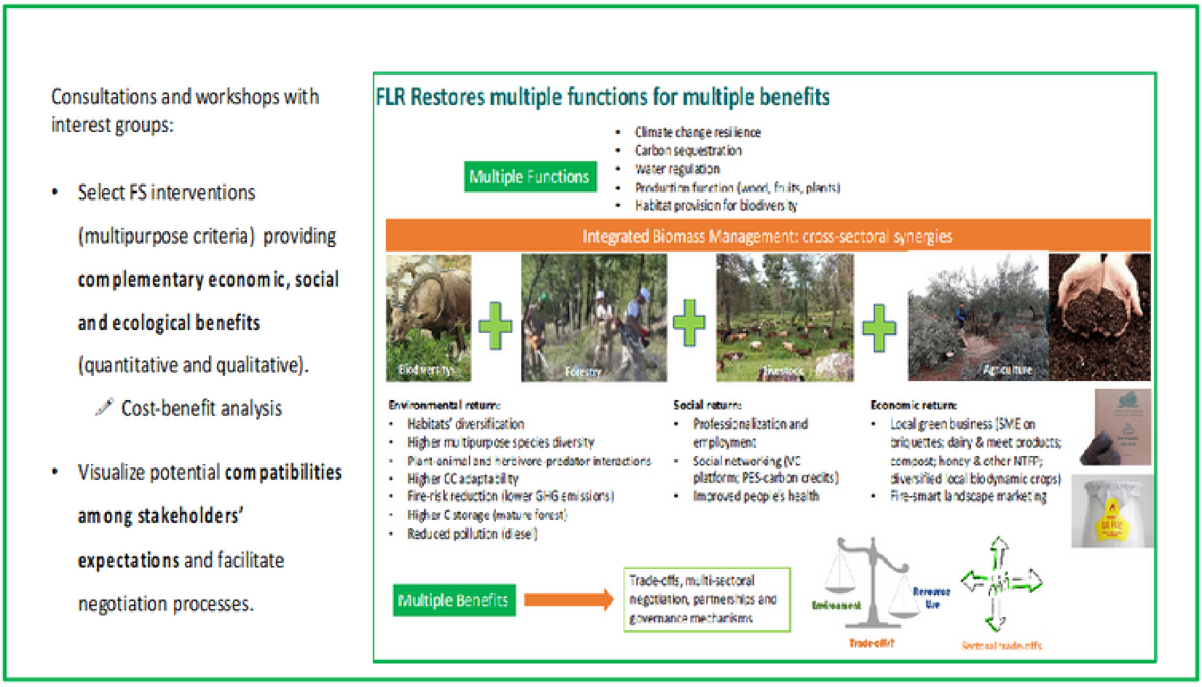

Figure 5. The multiple functions and benefits of integrated biomass management interventions from forestry, livestock grazing, agriculture and biodiversity

Assessing the costs and benefits of land use investments will allow decision-makers to demonstrate that investments in fire-smart interventions are worth and result in better socio-economic and environmental outcomes. The different public and private stakeholders in the landscape can make use of customized decision-making tools on impacts, cost and environmental, social and economic benefits provided by different alternative scenarios with or without a set of fire-smart landscape interventions, to help resolve trade-offs between different stakeholders' needs and interests. Several authors and institutions have developed methodologies for the analysis of costs and benefits of forest landscape restoration to support decision-making on the options that provide the highest sustainable return in ecological, social and economic terms (41, 42, 43, 44, 45). Based on referred papers, a cost-benefit analysis may include the following steps:

Step 1 - Setting the scene: users should establish the purpose and parameters of the analysis, what activities are relevant, who should be involved, and what should be measured. Key questions for the analysis should be established at this time in order to ensure that the outputs of the analysis are helpful.

Table 5. Examples of questions (42)

- What are the costs of inaction? What will happen if we continue under business as usual?
- What investments or policies produce the greatest benefits? What are the costs?
- Which considerations cannot be quantified or monetized, and thus are not included in a cost-benefit analysis?
- What resources are available to conduct an analysis and what level of confidence is needed at this point?
- What are the total environmental / social / financial benefits of different investment scenarios?
- Which investment scenarios are most profitable? Which are most cost-effective?
- By how much do different groups / individuals benefit under different scenarios? How much do different groups / individuals lose under different scenarios?
- Which scenarios are most effective in leveraging public investment?
- What are key risks / threats to a potential fire-smart landscape investment?
- What are the total costs of different scenarios?

Step 1 should also define which fire-prone LU/LC and management practices (fire-prone scenario) are targeted and the proposed fire-smart scenario(s) (LU/LC type and set of fire-smart interventions that will be used). also requires the **identification of potential fire-smart landscape interventions** (e.g. productive firebreak areas with agroforestry systems; thinning and pruning of very dense secondary conifer forests and abandoned broadleaf coppice stands; clearing gap areas to break fuel continuity in vast extensions of pine plantations or secondary natural forests to re-establish formerly abandoned agricultural dry-stone wall terraces and pastures; protection of natural relic old-growth forest stands and restoration of connectivity; etc.).

Step 2 - Define the stakeholders who will be impacted by the shift to the proposed fire-smart fuel model. Beneficiaries and other stakeholders should be mapped with the specific purpose in determining the costs and benefits of an FLR investment: it is critical to define stakeholders by the costs that they assume and the benefits that accrue to them.

Table 6. Example of analysis of the stakeholders' costs and benefits

Stakeholder type	Potential costs	Potential benefits
Public administration	• Directly purchase, lease, or subsidize land, materials, equipment, and labor. • Fiscal incentives for improved land use or commodity produced.	• Increased tax collection. • Political support. • Public-private partnership supporting payment schemes, value chain innovation platforms or inclusive agribusiness models.
Protected area managers	• Inputs and labor for biodiversity restoration interventions.	• Higher ecosystem resilience to fire risks • Higher species biodiversity (e.g. re-sprouting and soil improving plant species, seed-dispersal fauna, pollinators and pest control fauna, etc.) • Higher connectivity between relic old-growth forest stands.

Stakeholder type	Potential costs	Potential benefits
Landowners, users and entrepreneurs	• Purchase or lease land, materials, equipment, and labor. • Opportunity cost of current land use.	• Increased production and/or income margins. • Improved local ecosystem services unrelated to production • Social and environmental corporate responsibility benefits.
Local community members	• Opportunity cost of current land use. • Labor.	• Employment opportunities. • Higher supply of forest, pastoral and/or agricultural products. • Lower exposition of their lives and assets to fire risks. • Improved local ecosystem services supporting their land uses (e.g. pollination and pest control for crops; climate resilience; water regulation, nutrient cycling).
Commodity off-taker	• Price premium for high-value commodities produced under fire-smart management systems. • Purchase of carbon credits or payments for services (carbon sequestration, watershed protection, biodiversity conservation) provided by fire-smart LU/LC managers in the landscape.	• Long-term insurance of access to sufficient quality supply. • Price premium from own customers. • Reputational benefits (environmental and social corporate responsibility).
Global/regional community	• Taxes contributing to fire-smart investments.	• Global targets on climate change mitigation, Land Degradation Neutrality, Bonn Challenge on Forest Landscape Restoration, UN Decade on Ecosystem Restoration. • Global biodiversity benefits.

From the perspective of the concerned landscape actors, the analysis should decide about the benefits or ecosystem services to be analyzed and measure in monetary and non-monetary terms (e.g. green value chains around provisioning services such as wood, NTFP, livestock and farming products, or cultural services such as eco-tourism; employment opportunities; carbon sequestration, watershed protection; biodiversity conservation; soil health).

Step 3 - Catalogue the positive and negative impacts and define how they will be measured: which impacts matter most to the stakeholders who will be impacted by restoration and what units of measurement are most useful for measuring them. Impacts are broadly defined to include both inputs – the costs of conversion to a fire-smart scenario – and the outputs – the ecosystem services that will represent the benefits.

Cost categories:

- Implementation costs: investments in land, labor, and materials and include any expense directly related to the establishment and operation of a restoration project, which could include hiring, training, and managing employees or buying materials.
- Transaction costs: the cost for landowners and implementing agencies to identify viable land to restore and negotiate over terms that ensure restoration meets both local and national priorities.
- Opportunity costs: the tangible goods and services that were foregone to make restoration possible.

Benefit categories:

- Supporting (e.g. habitat for species; species and genetic diversity), regulating (e.g. carbon sequestration, erosion control), provisioning (e.g. wood and NTFP products, crop yields) and cultural (e.g. recreational, aesthetic, educational) services.

Step 4 - Model costs and benefits. Based upon the above steps, the analysis would generate alternative scenarios to the business-as-usual one, defining the desired climate-smart LU/LC and management practices for each priority high-fire risk area in the landscape, including: stakeholders involved, proposed interventions, time horizon, the spatially explicit area of intervention, interface with other LU/LC types, etc. An important scenario will be the baseline scenario, or the expected land use given no intervention. Establishing a baseline creates a reference point to which to compare the alternative investment scenarios; the difference between the baseline scenario and alternative scenario can be seen as the costs and benefits of inaction

Scenarios would be generated as a one-hectare model for each proposed climate-smart LU/LC type with one a combination of fire-smart interventions defining their costs and benefit to be scaled up to the entire landscape. These one-hectare models are then scaled-up across each priority area for fire-risk reduction and/or the entire landscape. Scenarios should elaborate the sustainable return on investment (time horizon for the costs to generate benefits). Fire-smart investments generate benefits over a long period and extending the time horizon of the analysis will enable to capture all benefits of the investment. Long time horizons are especially appropriate for economic analysis that consider the public benefits of global public goods that take a long time to materialize (e.g. carbon sequestration).

Modeling and its results furthermore allow for prioritizing restoration investments based on different criteria: which ecosystem services are prioritized, who should benefit, and when will benefits be realized? Does the landowner and/or user choose to improve land productivity, to protect water resources, to avoid erosion, to increase pollination and pest control services, to reduce fire risk, to improve climate change adaptability, or some combination? Policy makers need to understand the costs of the fire-smart landscape planed priority interventions, as well as the multiple benefits they provide - employment effects, tax and Gross Domestic Product (GDP) contribution, and indirect economic values (e.g. the value of carbon sequestration and non-marketable ecosystem services as avoided erosion and hydrological services).

The cost-benefit model should estimate costs and benefits individually for each group of stakeholders involved in the analysis, and will be critical for the analysis of distribution of costs and benefits.

Table 7. Example of costs and benefits by beneficiary type (EUR/ha)

Stakeholder	Investment costs	Revenues from goods and services	Tax-revenues	CC – GHG emissions reduction	LDN	Watershed protection	Fire-risk reduction	BD
Fire-smart implementor landowner and/or user			n.a.	n.a.				
Protected Area Authority								

Stakeholder	Investment costs	Revenues from goods and services	Tax-revenues	CC – GHG emissions reduction	LDN	Watershed protection	Fire-risk reduction	BD
Downstream communities or land users		n.a.	n.a.	n.a.	n.a.		n.a.	n.a.
End-buyer companies			n.a.					
Local administration	n.a.			n.a.				
National government		n.a.						
Global community		n.a.	n.a.					

Each cost will be calculated by estimating the amount of an input that is needed for 1 hectare production, and the price of one input. Conversely, benefits will be estimated by determining the quantity of outputs that are produced per hectare and the value of each output. Broadly speaking, costs can be split into capital expenditures (e.g. the purchase of land, perennial seed- lings, equipment, or infrastructure), operational expenditures (e.g. hiring labor for thinning and pruning, controlled grazing, producing and planting seedlings), and working capital (e.g. short-term expenses for the purchase and sale of goods). In kind contributions, particularly labor and land, should also be incorporated into the cost benefit analysis even if they do not result in direct expenses. Benefits can be determined by estimating the quantity of the set of products produced under fire-smart intervention scenario, and multiplying by the expected prices, even if all or part of the products are used for subsistence and not sold at markets.

While the value of provisioning services is usually calculated through the "price * quantity" equation, the methodologies used to determine price for regulating and cultural ecosystem services can be more complicated. Gromko et al (2019) provide an overview of valuation methodologies for different ecosystem services.

Step 5 – Analysis of costs and benefits: Having determined costs and benefits over time, the user should construct a model, estimating the flow of economic and/or financial value over time. In simple terms, this will look similar to the Table below. Models can be constructed for the project as a whole – the total economic value of the project – and for individuals or groups of stakeholders – the financial value of investments. It may be desirable to understand the costs and benefits for a specific stakeholder, for example, a private investor.

Once a model is constructed, the user can conduct a variety of calculations for different types of analysis and indicators:

- the **net present value (NPV)** of similar investments discounted to present terms, can be compared to determine which is more profitable;
- the **internal rate of return (IRR)** describes the effectiveness of each euro spent and allows the user to compare profitability of investments of different sizes;
- the **benefit/cost ratio** for analyzing the effectiveness of invested resources;
- the **return on investment (ROI)** or profitability return for every euro invested, **and return on equity (ROE)**, measure the efficiency of resources invested. A cost-benefit analysis should account for uncertainty by conducting a sensitivity analysis. Sensitivity analyses test how the calculations of the model change if key input data changes. This allows the user to understand under which conditions their investment is feasible or not and the variables that have the greatest impact on a project's success.

Monetizing environmental and social benefits is a difficult and, at times, controversial topic. Stakeholders may value environmental benefits differently and therefore dispute the findings of the analysis. However, although some services, such as biodiversity, may not be valued in a cost benefit analysis, it can still be included in decision-making. Moreover, there may be political or social considerations that are difficult to monetize and include in the analysis. Benefits to one group may be valued more than benefits to another group because of political reasons or market pressures, although this may not be included in the cost benefit analysis.

3.5. Enabling multi-stakeholders to be actively involved in the implementation of fire-smart landscape plans through 360° capacity development interventions and innovative governance mechanisms

Since the vast majority of wildfires are caused by humans, fire-risk reduction is closely tied to understanding and modifying people's perceptions and attitudes that favour the ignition and spread of wildfires, activate their willingness to participate in the planning and management of fire prevention and build their capacities so that they can effectively and long-term apply the fire-smart priorities for the target landscape.

3.5.1. Multi-stakeholder involvement

Multi-stakeholder participation presents a number of potential advantages in addressing the challenges posed by large-scale wildfire prevention at the landscape level (9):

- Helps to develop a comprehensive understanding of the relationship between the risk of fire and certain land uses and management practices, incorporating the multiple perspectives of the target groups, and facilitating higher-quality shared decisions about the need/possibility of including fire risk reduction objectives as part of improved management practices and uses.
- Promotes social learning through an improved knowledge about each other's roles and actions towards fire risk reduction, and the development of trust that facilitates the agreement of collaboration frameworks between land users whose risk reduction activities are necessarily complementary.
- Enables the proposed fire-smart interventions and technologies to be better adapted to local sociocultural and environmental conditions, facilitates participatory co-generation of knowledge and action, and enhances their rate of adoption and diffusion among target groups.
- Reduces the likelihood of marginalizing those groups on the periphery of the decision-making context (e.g. elderly, unemployed and low-income users from depopulated rural areas), who, properly involved and trained, can play a fundamental role in reducing risks, although their exclusion may lead to an increase in the risk of fires due to conflicts between land users, bad management practices and isolation.

Table 8: Type of actor directly or indirectly related to fire landscape management

Category	Actor
Local level	Public and private forest and farmland owners; shepherds and harvesters of forest products with formal and informal access to land; agricultural, livestock and forestry workers; municipalities; fire brigades; communal land user organizations; primary/secondary schools; local enterprises.
Landscape/ regional level	Local NGOs, producer organizations, users' associations and unions, local development associations, intermunicipal commissions, regional public delegations, extension services, fire brigades, universities and research organizations.

Category	Actor
National level	Central administration in charge of forestry, agriculture, livestock, water, civil protection, nature conservation, tourism, civil works, energy, technology and information, transportation sector, education, communication; national NGOs; value chain actors linked to forest, agriculture, livestock and water commodities (plant reproductive material and animal breed suppliers, traders, processors, transporters, wholesalers, retailers and final consumers); tourism sector private actors.
National government	International organizations dealing with forest landscape restoration and fire management issues (e.g. EFFIS, GPFLR, UNEP/FAO lead organizations for the UN Decade on Ecosystem Restoration; FAO Collaborative Partnership for the Mediterranean Forests); International buyer companies and tour operators linked to fire-smart value chains; international NGOs and IUCN; Business accelerator programs; EU agencies.

The FSL planning team must include social science experts to better incorporate the human dimension in the analysis of the root causes of increasing wildfire risk; understand the multi-actors' perceptions and attitudes towards wildfires; and identify the actions that help increase their willingness and empower them to incorporate fire prevention into their day-to-day work and to actively participate in local governance structures to coordinate fire prevention measures. The stakeholders' identification and analysis should include:

- Understand the **type of actor/social network/institution, how they operate, interact with each other and the quality of this interaction** (good, bad, neutral, non-existent), what they value and how they make use of natural resources, whether they perceive fire as a risk to their lives, property and the quality of their environment, as a culturally rooted land management tool or as a response to socio-economic conflicts.
- Identify **knowledge, skills and capacities** on fire-resilient landscape planning and implementation tools (e.g. policies, planning processes, fire-smart interventions, etc.). It is important to identify **lead actors and organizations** with demonstrated experience on fire-smart LU and management practices and define the strategy to involve them.
- Realize the existence of **conflicts and problems** among them (and within networks and institutions) that may be related to governance problems, land use conflicts, unsustainable management and fire-prone landscape degradation. It is important to identify **veto agents** that could compromise the fire-resilient landscape objectives and define the strategy to face them.
- Realize the potential and/or existence of **positive interactions** around collaborative fire-smart LU interventions, and the opportunities they provide for effective shifting to fire-resilient landscape scenarios.

Table 9. Stakeholder analysis

Actor	Type	Linkage with fire management	Knowledge/ interest on FRR	Level of support/ opposition/ veto	Positive interactions with other actors	Negative interactions with other actors	Strategy to get their support/overcome barriers

The analysis of the human dimension of wildfires help better design: (i) awareness raising and educational actions, tools and materials on the growing threat to society posed by uncontrollable forest fires in a context of climate change and rural abandonment, (ii) multi-stakeholder, gender and age sensitive, capacity development (both for future trainer and practitioners) and coaching support programs supporting land users and managers to effectively test and adopt prevention measures and fire-smart LU management practices with a sustainable return on investments (economic, social and ecological), and to actively participate in landscape planning, policy development, monitoring for adaptive management, knowledge generation and upscaling.

3.5.2. Innovative governance arrangements

Governance, as a basic social function through which actors interact to influence decisions, processes, and outcomes, is central to the design, implementation and monitoring of fire-smart forest landscape planning (46). The many "**governance**" definitions have in common that they **refer to people** (e.g. stakeholders, actors, groups, individuals), **decision-making actions**, and **tools that enable people to make those decisions** (e.g. policies, rules, regulations, incentives, institutions, know-how) (47). In a fire-prone landscape context, governance refers to the rules and decision-making processes involving actors with stakes in the landscape that work together to shape the future of their shared landscape (46) in terms of climate and wildfire resilience.

Governance arrangements are necessary for:

3.5.2.1. Multi-stakeholder platforms for the FSL planning process.

It is important that the institutional responsibility for leading the landscape planning process be clearly identified and recognized/accepted by the different actors involved in the process. It should be assumed by an in-country institution or as a partnership between several institutions in charge of guiding and facilitating the planning process, and providing the institutional 'hub' around which the multi-sector and multi-stakeholder collaborative process can be built. The initiators of the planning process will need to convene a team, including two to three members providing coordination and facilitation to the planning process, and a larger number of multi-stakeholder and multi-disciplinary specialists providing advice and insight on their particular areas of expertise (GIS, ecology, NRM, social/gender, economic, policy, etc.), skills, and affiliations (e.g. civil servants from public administrations at different decentralized levels, conservation and development NGOs, rural development agencies, rural community groups, land user associations, tourism enterprises, extension service providers, business and trade organizations, private organizations and enterprises, research and academy).

3.5.2.2. Long-term governance structures for the implementation of the FSL plan

A fundamental objective of the planning process is to establish a long-term **governance structures or multi-stakeholder platforms (MSP)** for the implementation and monitoring of the fire-resilient landscape plans. It can be the same platform in charge of the planning process. MSP should not add complexity to the existing governance structures, which would lead to inaction, but rather catalyse coordinated action, and facilitate the permeability of information and knowhow and collaboration between existing institutions. Multi-stakeholder Platforms (MSP) should:

- Be a refence space for all fire-resilient interventions in the landscape with a mandate around the fire-smart landscape plan implementation, and a portfolio of products and services for its members.
- Ensure representativeness: develop a database of potential members, an active membership campaign, several factsheets with benefits for key landscape actor (e.g. public administration, landowner and/or user) to become MSP members.
- Become a vector to aggregate its members through the identification of the main members' needs, and identification and assignation of the leading roles and responsibilities that the different members can play.
- Have a transparent strategy for participation and exchange of knowledge (e.g. periodical meetings; social networks).
- Be active and transparent with its members about the different projects underway and the periodical financing opportunities that can benefit the platform and enhance landowners and users' involvement in periodical fundraising opportunities.
- Monitor members' actions (visits to the projects, monthly bulletin highlighting members' achievements), and certify members' projects and deliverables based on the agreed fire-resilient landscape objectives, tools and methodologies.

3.5.2.3. Formal collaboration frameworks among landscape practitioners for the joint implementation of complementary fire-smart management practices.

- **Forest owners' associations** (representing both private owners and public administration interests) are strategic cooperative responses to large wildfires for achieving fire risk reduction objectives (48). Associationism among forest owners for a collaborative and consensual management of small forest properties is identified as an effective governance mechanism to increase socio-ecological resilience to large wildfires with additional benefits:
  - Planning can be implemented at a scale larger than of just one single small property, better addressing landscape-level risk reduction needs.
  - Costs can be lowered, and owners can be more competitive in the marketing of their products.
  - Bureaucratic procedures are less demanding.
  - Strength position when dealing with political bodies and negotiating policy improvements.
  - Sense of union, sharing experiences and identity and building a common narrative and discourse that help strengthen ties to that territory.

- **Formal contracts between forest owners or public administration and shepherds** for long-term land stewardship through the complementary implementation of forest thinning and controlled grazing.

- **Innovative commodity platforms connecting producers and end buyers and consumers** in green value chains of agricultural, forest, livestock and eco-tourism products and services derived from fire-smart interventions.

- **Public-private partnerships under Payment for Ecosystem Services (PES) schemes** for the purchase and sale of ecosystem services such as carbon storage, watershed protection or biodiversity conservation, linked to the fire-smart landscape plans.

- **Landscape wildfire operation groups**, as for instance in Portugal **[19]**, coordinating unified action of local community members, local associations, police, fire and rescue services, forest and rangeland services, the army, and private forestry firms to streamline both prevention and firefighting efforts. In Portugal, these agencies support communities to clear land around settlements, create evacuation plans for high-risk villages, issue permits for controlled burning of debris, guide forest engineers and firefighters on how to create fire breaks, provide subsidies for shepherds to implement controlled grazing, among other fire prevention issues.

- **Local volunteer groups** to: inform locals, including students, and secondary house owners and visitors on how to prevent forest fires and prepare their homes and themselves for such an event, and on mobilizing them to carry out fuel management along roads and forest restoration works; ; distribute risk assessment forms (risk due to the vegetation and the vulnerability of the buildings) to the owners of settlements offering recommendations on what needs to be changed to improve safety and warning information in case the owner would decide to stay and defend, recommending early evacuation in case of high-risk, hard-to-defend structures; produce and distribute awareness materials (informative videos, brochures, articles, interviews with local radio stations). in Kythira Island (Greece) after the devastating fire in 2017, a small yearly investment supporting volunteer groups on fire prevention, assigning/employing highly motivated specialized individuals, with a small budget to organize fire prevention activities, can made a substantial long-term contribution to reducing fire loads and damage with a cost/year less than 3–4 h of flight time of aerial resources (49).

[19] https://www.context.news/climate-risks/portugal-fights-wildfires-with-new-tactics-as-heatwaves-raise-risk

3.5.3. Capacity development

The incorporation of fire risk reduction in land management practices requires both a change of mentality to add this objective to the development or conservation objectives that guide the interventions of landscape managers and users, as well as knowhow to adopt innovating solutions that allow the modification of management practices to respond effectively to wildfire risk reduction objectives.

This entails understanding the costs and benefits (sustainable economic, social and ecological return on investments) derived from the proposed solutions (e.g. LU changes, limitations on certain production activities, production diversification), and the training of the actors involved for their effective application, and for the development of business plans that allow a rapid economic return of the required investment. The training of local actors in fire-prone landscapes encounters a main barrier, which is the depopulation of the territory and, therefore, the absence of a sufficient number of users of the territory to be trained in risk reduction. For instance, although controlled grazing is considered a fundamental post-mechanical (prescribed burning) clearing practice to control vegetation growth in firebreak areas, the number of grazers remaining in fire-prone landscapes is vastly insufficient to be able to perform that task effectively.

The implementation of fire-smart landscape plans needs major investments to professionalize practitioners on fire risk management practices (e.g. new curricula for farmers, shepherds and forest managers schools) and to create attractive employment opportunities that help fix rural population and attract new settlers.

The training must be continuous (monitoring of all phases of the practice to be learned and repetition over several years), on-the-field, with a research-oriented approach to be tested and fine-tuned for each local context, and participatory so that there are exchanges between peers, and a mechanism of collaboration and exchanges between the different users of the landscape that perform the same function or whose functions must be complemented is encouraged. The inclusion of training modules in sustainable business models linked to the fire-smart practices proposed in each landscape, and the accompaniment of the people trained by the teams that lead fire-smart landscape planning projects, is essential to ensure a minimum percentage of success in the implementation of fire-smart initiatives in the landscape. Moreover, the capacity of fire-smart landscape managers should be strengthened through regional networking: the Landscape practitioners can benefit from training opportunities and learning visits linked to regional networking initiatives and EU projects.

3.6. Long-term adaptive monitoring and financing mechanisms for fire-smart landscapes

3.6.1. Long-term financing

The specific financing opportunities for the long-term implementation of fire-smart landscape plans differ depending on a given landscape's agro-ecological, social, economic, legal and political features, together with the prioritized fire-risk reduction interventions. We can differentiate between [20]:

- **Asset investments**, which are direct investments in physical components of the landscape or activities that contribute to restoring landscape fire-resilience, such as forest thinning, controlled grazing, the ecological restoration of resilient forest and grassland habitats, the creation of productive firebreaks with agroforestry planting, improved management of crops, and water infrastructure and management, etc.; and
- **Enabling investments** that lay the institutional and policy foundation for asset investments by generating incentives for asset investments and supporting landscape coordination (e.g. stakeholder engagement and cooperation, appropriate legal and regulatory frameworks, knowledge and capacity to plan and manage fire-smart landscapes, and the development of incentive mechanisms).

[20] Besacier, C., Garrett, L., Iweins, M. and Shames, S. 2021. Local financing mechanisms for forest and landscape restoration – A review of local level investment mechanisms. Forestry Working Paper No. 21. Rome, FAO. https://doi.org/10.4060/cb3760en.

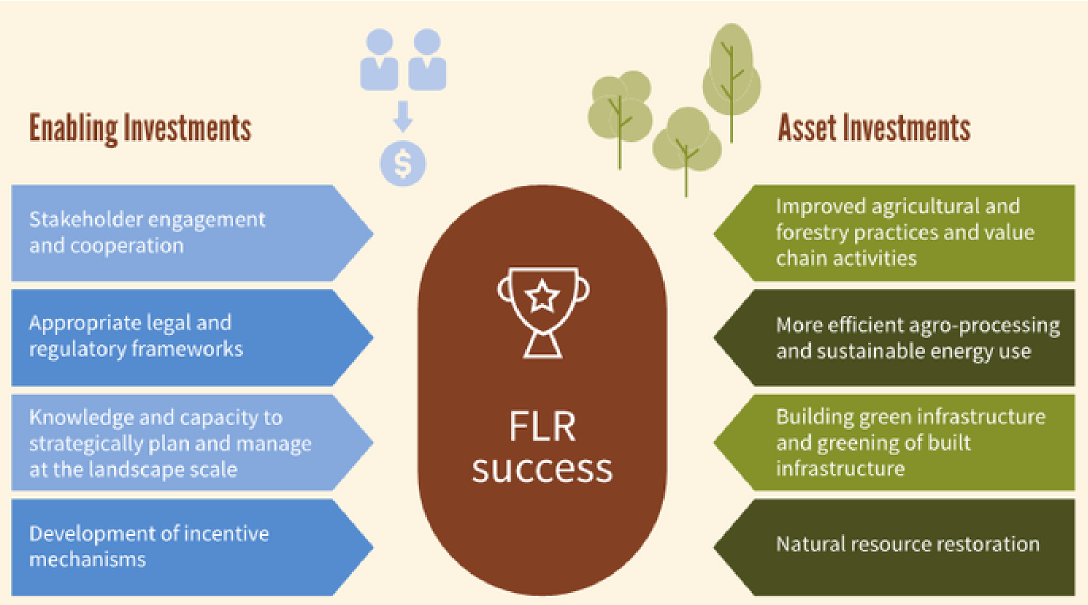

Figure 6. Asset and enabling investments for FLR success **[21]**

Enabling investmentsare therefore needed to lay the institutional and policy foundation to facilitate and attract asset investments and support fire-smart landscape coordination. In the context of fire-smart landscape planning, enabling investments include investments in stakeholder engagement and cooperation (e.g. multi-stakeholder platforms, development of forest, livestock and agriculture users' associations and cooperatives), appropriate legal and regulatory frameworks (e.g. secured tenure and commercial rights), knowledge and capacity to strategically plan and manage at the landscape scale (e.g. technical extension and training) and the development of incentive mechanisms (e.g. fair market access and conditional rewards such as tax-reduction or other public incentives for fire-smart interventions). Enabling investors typically include public-sector funds, governmental development assistance and philanthropic sources.

If associated with proper market mechanisms, asset investments can present an opportunity to generate financial returns for local stakeholders, resource managers and investors. Market mechanisms for fire-smart interventions such as the establishment of productive fire-breaks with agroforestry plantations, sustainable agriculture and forestry production resulting from combined biomass management interventions (bioenergy, compost, diversified crops and non-timber forest products, ecotourism services) can provide an economic return, making them profitable and desirable in the long term (e.g. livelihood and value chain development for landscape and forest products and services, including the establishment of payment mechanisms for ecosystem services such as carbon sequestration, watershed protection and biodiversity conservation, certification schemes, ecotourism and the participation in green value chains for forest, agricultural and livestock commodities). Some asset investments critical to landscape restoration under current scenario of landscape depopulation are, however, unable to generate (sufficient) financial returns to attract sufficient commercial sources of finance, and other sources are therefore required. This is the case, for example, of controlled grazing, a fundamental activity to control the development of biomass after clearing and thinning in high-risk areas of the landscape, which, due to the scarcity of shepherds and the low productivity of the high-risk areas (e.g. steep slopes with limited growth of pastures), cannot generate enough economic resources from the marketing of their products and requires the establishment of payments to shepherds to perform the function of biomass growth control.

Asset investments may also include corporate social responsibility (CSR) commitments (made by companies seeking to mitigate reputational or operational risks or compensate carbon emissions with landscape restoration interventions), investments from domestic banks willing to offer below-market capital, or even from allocations by government budget line items to implement the EU Green Deal policies.

[21] Ibid.

3.6.2. Enabling policy framework

3.6.2.1. National and sub-national level

Fire-smart landscape planning and implementation can be hampered by unaligned sectorial policies, tangible and intangible barriers between different agencies' working procedures, mandates and agendas, lack of transfer of knowledge about policies at the decentralized levels, and inability of civil servants to inform land users about policies and regulations. The implementation of priority fire-smart interventions is often hindered or prevented by conflicting regulations from different sectoral polices or by regulations that have conflicting objectives with those of fire risk reduction.

Fire-smart landscape planning should address and amend cross-sectoral policy barriers to fire-risk reduction to create an enabling legal environment supporting the implementation of the prioritized risk reduction interventions. As a follow up to the planning exercise, the project teams should develop a policy influencing plan (PIP), including:

- Several policy briefs with new/revised cross-compliant policy proposals with regulations for the implementation of integrated fire-smart interventions at national and sub-national levels and describing the accompanying implementation frameworks that detail the "what", "when" and "who", including monitoring, and recommended incentives to contribute to the implementation costs.
- The collection of best practices demonstrating the positive environmental, social and economic impacts provided by the prioritized fire-smart interventions, to help justify the proposed policy changes. Information events should be organized targeting policy makers, civil servants and public officials, land practitioners, NGOs, research/academia, to raise awareness about the positive return of policy improvements.
- The design and implementation of an advocacy plan to put forward for consultation and acceptance of policy makers the proposed policy briefs, with the support of the landscape partners. The plan should include public surveys for developing advocacy messages, public events to help make an advocacy case of the revised/new policies and regulations to be approved, inclusion of advocacy-related information in websites, enroll high-profile individuals to publicly advocate for the proposed changes, etc.

3.6.2.2. International Level

The **European Green Deal** aims to boost the efficient use of resources by moving to a clean, circular economy and stop climate change, revert biodiversity loss and cut pollution. It outlines investments needed and available financing tools to ensure a just and inclusive transition. The European Green Deal covers all sectors of the economy, notably transport, energy, agriculture, forestry, buildings, and industries.

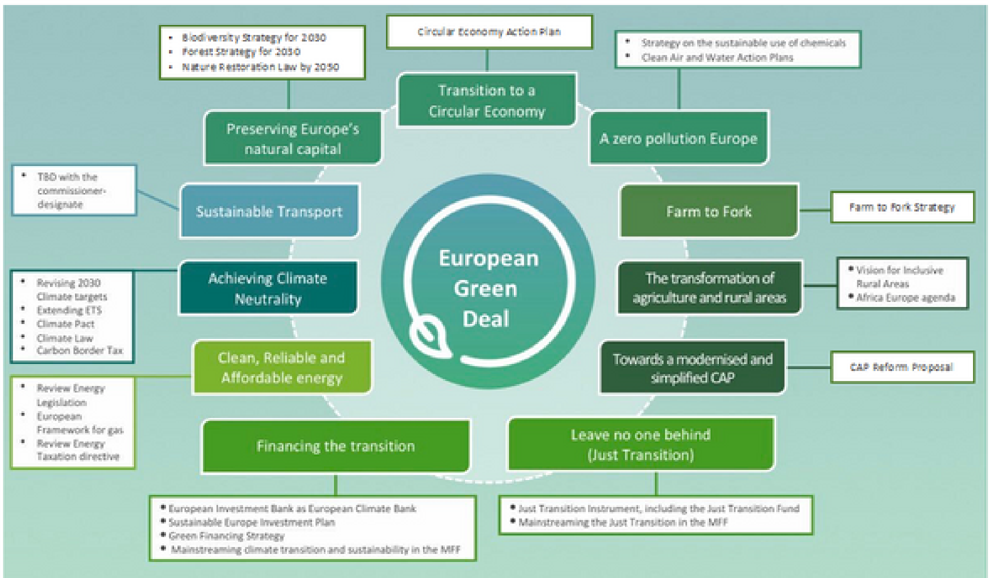

Figure 7. The European Green Deal transformative policies

The European Green Deal provides an action plan to boost the efficient use of resources by moving to a clean, circular economy, restore and protect nature, build climate resilience and cut pollution and GHG emissions. It states that the Commission will identify measures, including legal ones, to help Member States improve and restore damaged and carbon-rich ecosystems to good ecological status. The Green Deal also emphasised that all EU actions, policies, and resources should pull together to help the EU achieve a successful and just transition towards a sustainable future.

The European Green Deal is built around the following components:

- **Designing a set of deeply transformative policies** with major implications on the shift from fire-prone to fire-smart landscapes, namely the **EU Biodiversity Strategy for 2030, the Nature Restoration Law by 2050, the NEW EU Forest Strategy for 2030, the Common Agricultural Policy, the Farm to Fork Strategy, the Carbon Funding Strategy, the new Bio-economy Strategy, and the 2021 Climate Law**. Annex 2 provides further description of these policy frameworks.
- **Mainstreaming sustainability in all EU policies**: A Sustainable Europe Investment Plan will dedicate financing to support sustainable investments.
- ***Mobilising research and fostering innovation***.
- ***Activating education and training***.

3.6.3. Long-term adaptive monitoring

Given the complexity of social, environmental, and economic factors linked to the fire-smart landscape plans, it is necessary to design monitoring systems that allow, in a simple way, to evaluate and qualify the impacts of fire-smart interventions in an integrated way – at the landscape level. The World Resources Institute (WRI) has developed a Sustainability Index for Landscape Restoration (SILR), which constitutes a tool for monitoring the biophysical and socioeconomic impacts of landscape restoration and provide information for decision-making processes (50). Fire-smart landscape plans may adapt the SILR methodology to monitor the biophysical and socioeconomic impacts of fire-smart implementation.

A Sustainable Index for restoring Fire-smart landscapes (SIFSL) may combine several objectives and sub-indexes, such as for instance:

Table 10. Objectives and elements of SIFSL

Objectives	Sub-indexes
To achieve a resilient mosaic-like pattern of LU/LC within the landscape	**Resilient landscape pattern index (RLPI), composed of several sub-indexes**, such as: • Perimeter-Area Fractal Dimension (PAFRAC): complexity in the shape of LU/LC patches, from very simple ones –squares or rectangles (e.g. crops) – to more complex ones (e.g. forests). • Percentage of Landscape (PLAND) occupied by each LU/LC. • Number of Patches (NP) that expresses the fragmentation of LU/LC types. • Largest Patch Index (LPI) showing the area of the largest fragment for each LU/LC classes. • Contagion Index (CONTAG) showing the potential for connectivity in the landscape. • LU/LC interface risk index.
To increase carbon stocks by implementing sustainable biomass management interventions in critical areas of the landscape according to the fire-smart landscape plan	Carbon equivalent index (CeI): multiplying the number of potential hectares to be prioritized for fire-smart interventions by the values of the carbon equivalent balance per hectare, according to the amount of carbon equivalent stored for each of the proposed fire-smart practices in the landscape.

Objectives	Sub-indexes
To reduce water stress affecting LU/LC systems in the landscape	**Water stress index (WSI), composed of several sub-indexes:** • Remote sensing estimation of vegetation water content can be utilized to real-timely monitor vegetation water stress. • Low-cost tree trunk relative water content sensors for monitoring of the tree water status. • Simple field soil water content sensors to measure an ideal vegetation and soil water content value.
To increase the resilience of natural and seminatural ecosystems to wildfires	Biodiversity improvement index (BII) that measures the impact of fire-smart practices on habitats/species resilience to fire. It may combine a set of sub-indexes: • Resilient habitat conditions: (i) diversification with climate-adaptive and fire-resilient species/genotypes; (ii) habitat structure improvement of age classes, forest layers and tree densities; (iii) vertical discontinuity of fuel. • Resilient landscape conditions: (i) fuel load reduction through mosaic-like structure improvement; (ii) improvement of species migration needs to reduce climate-risks through landscape enrichment of woodland islets.
To improve governance in the landscape to a level that allows coordination, equity and the development of positive leadership that contributes to the implementation of a fire-smart landscape plan	Landscape governance index (LGI) that measures the governance situation for the management of a given landscape. Tool structured in 3 components: (a) governance capacities, (b) governance process and (c) governance outcomes. Each component contains a number of indicators representing different dimensions of governance: (i) Coordination, (ii) Resources, (iii) Deliberation, (iv) Leadership, (v) Shared vision, (vi) Access, use and generation of information, (vii) Adjusting decisions to the context, (viii) Management and regulatory instruments, (ix) Equity, (x) Promotion and capacity to learn from past experiences, (xi) Accountability. LGI is calculated through focus group sessions ensuring the participation of multiple stakeholders. The tool/questionnaire presents 5 response options for each indicator, through which the corresponding component of governance is rated. The average score for the eleven questions (indicators) for the 3 LGI components may take values between 0 and 5. An LGI of 0 (zero) will indicate a completely disjointed and dysfunctional state of governance. An LGI of 5 will indicate that the maximum has been reached in each of the governance dimensions.
To increase the number of jobs and local enterprises involved in production, processing and marketing of goods and services that come from fire-smart LU and management practices	Livelihood improvement index (LII): it is a proxy of the improvement in the living standards of the landowners and users (disaggregated by gender and age) involved in the fire-smart landscape implementation measures. To calculate this index, we could use several proxies: (i) number of hectares under fire-smart LU/LC; (ii) productivity improvement (in tones and/or in expected economic return, and/or in expected employment generated) for each of the proposed fire-smart practices in the landscape; (iii) number of sustainable green business and employs created, disaggregated by gender.

SIFSL Aggregation: Once each of the components of the Sustainability Index for Fire-smart Landscapes has been obtained, the index can be calculated by averaging all the values:

$$\text{SIFSL} = \frac{\text{RLPI} + \text{CeI} + \text{WSI} + \text{BII} + \text{LGI} + \text{LII}}{6}$$

4. Recommendations for the Fire-smart Landscape Planning Process

4.1. Assess the landscape boundaries

The boundaries of the project's target landscapes coincide with the boundaries of designated protected areas. It is important that the team leading the planning processes analyse to what extent these limits allow addressing the fire risks that affect the protected areas and decide whether it is necessary to expand the landscape boundaries to include neighbouring areas where most of the ignitions occur and where the interfaces with the highest fire risk occur (e.g. wildland-urban interface, managed forests and pastures/infrastructures interfaces with high fire spread risk towards the interior of the protected area.

4.2. Establish multi-stakeholder and multi-disciplinary landscape planning teams and governance mechanisms

The lead institution in each target landscape should appoint a team leader and convene a core team of experts with good knowledge on relevant issues for integrated fire-smart management planning (i) wildfire management; (ii) biodiversity conservation and ecology; (iii) rural development (land uses, land tenure, sectoral policies); (iv) rural economy and sustainable business models and value chains; (v) national/sub-national policies and incentives linked to the EU Green Deal, as well as land tenure, and spatial planning; GIS expertise, (vi) social science (e.g. the human dimension of fires, rural population dynamics, gender issues); (vii) GIS modelling expert. Taking into account the enormous importance of the social dimension in the causes of fires and their prevention, it is very important to ensure good social expertise that analyzes the human dimension of wildfires, population dynamics linked to rural abandonment, gender and age issues, etc. Moreover, considering that landscape biomass management entails high costs, which often prevent its implementation, it is also important to ensure expertise in rural financing mechanisms, such as incentive systems or payments for ecosystem services, and innovative and diversified business models. Considering the limited resources of the project, it would be desirable if the missing experts could be assigned as in-kind contribution from partner organizations that adhere to the planning process.

It should be established a multi-stakeholder platform (MSP) at the landscape scale that creates an enabling environment for vertical and horizontal participation, coordination, and decision-making. It is important to establish a governance mechanism for the planning process, which can be maintained for the implementation phase, beyond the scope of the project. A Fire-smart Landscape Planning and Management Platform could be established, led by the organization best placed in front of landscape stakeholders. Due to the difficulty of establishing new governance mechanisms, it would be useful to analyse if any existing platform could play such a role. Otherwise, it would be recommendable to propose an informal platform open to a longer representation and post-planning formalization. Likewise, and as a result of the planning process, the creation of multi-stakeholder platforms at different levels can be identified and/or promoted, from practitioner platforms whose fire-smart activities are complementary (e.g. multi-stakeholder associations or collaboration agreements between landscape forest, livestock and agriculture users) and that have an economic outlet (innovative value chain platforms for forestry, agricultural and/or pastoral products, that connect producers with end-market plays and consumers through fire-smart quality brands and certifications).

The platform membership should be based on an in-depth analysis of landscape stakeholders, their interactions, and their differentiated interests and collaborative roles in managing landscape plan fire-smart interventions. The platform must be inclusive (with sensitivity to gender issues, vulnerable groups and direct users of landscape resources) and must provide services to its members in terms of:

- coordinating meetings, consultations and discussion events (e.g. workshops, meetings with land practitioners, etc.);
- raise awareness and train its members in key approaches, themes, methodologies and tools for good planning;
- share relevant information for its members regarding the planning process and other relevant national and international processes;
- identify post-planning process funding opportunities and facilitate a joint fundraising initiative for its members and the platform itself. A representative number of participants from the different stakeholder groups should be contacted and invited to attend the planning workshops and meetings.

4.3. Root-cause analysis of wildfire impacts in the landscape

Considering that in most of the cases of the target landscapes the real causes of the fires are unknown, it is important to carry out a first analysis with the participants of the Fire-smart Landscape Planning Platform of the direct causes and drivers that have led to a situation high risk of fires in landscapes. This will make it possible to establish a chain of connections between direct causes and root causes and make a first identification of the type of actions necessary at different levels (human dimension of the landscape, policy drivers, economic drivers, etc). Root-causes analysis results will help formulate the problems that the fire-smart landscape planning process wants to answer.

4.4. GIS fire risk analysis in relation to the distribution pattern and interface between LU/LC, anthropic actions and biomass accumulation (fire-prone LU/LC fuel load models), prioritization of landscape areas with high fire risk, and prioritization of the type of fire-smart interventions (fire-smart LU/LC fuel models)

The leading team of each landscape, with the support of Istituto Oikos and NOA, has already carried out an exercise of analysis and identification of high fire risk areas, the existing LU/LC with low to high risk of ignition and spread of fire, and an initial proposal of fire-smart fuel model to replace fire-prone practices in interface areas and high-risk LU/LC types that help reduce the burned area in the target landscapes. It is important that the leading team of each landscape refine these preliminary results prior to the first planning workshop with the stakeholders, and that they identify as quantified as possible the environmental, social and economic benefits that can result from the models of fuel fire-smart (LU/LC types and management practices in high fire risk areas), and the complementarity of fire-smart interventions at the same intervention site or at the landscape level.

The lead team should:

- prepare an information dossier prior to the participation process (and to be used during the workshops) to introduce the project, the planning process, the rules of the game, and the baseline information collected by the project team;
- establish the role of the project team in the process of elaboration of the fire-smart landscape plan, including leading person, facilitator, rapporteur, support team (experts, etc.), explain objectives of the process, roles and responsibilities expected of each one;
- prepare a road map of the process and agenda for each workshop.

During the first workshop, the project team should introduce the project objectives, the rationale followed, the key concepts, the proposed methodology and the preliminary results of identification and prioritization of fire-risk areas and fire-smart interventions. The presentation should open a debate with the members of the workshop, who can be organized into work focus groups as they see fit, to gather opinions on the above and collect ideas from the stakeholders that complement and/or modify the above.

The working groups should revise the preliminary proposals and propose new ones on fire-smart LU/LC types and management practices. In a table listing and describing the new proposals, they should include the environmental, social and economic benefits that according to them are derived from them, as well as the complementarity among the proposed fire-smart practices and land users. They should also fill in other columns with barriers and opportunities that they think exist for its implementation, including issues related to technologies, political issues, financial issues, capacities, governance, etc.

In plenary discussion, the lead team should organize a process to select a list of previous and new proposals that demonstrate their fire-smart impact and the provision of complementary multiple benefits (indicators and criteria can be previously defined to guide the selection exercise).

The landscape lead team will collect the results of the workshop and assign tasks to its members to complete information that demonstrates the feasibility of the validated proposals: technical aspects, complementarity between practices, identification of landscape user groups linked to each practice, cost-benefit analysis of each fire-smart fuel model type (complementary set of fire-smart interventions), identification of applicable innovative business models, policies and economic incentives that can be applied to support the practitioners of each practice, definition of indicators and monitoring methods of impacts on multiple benefits, etc. Assess the coherence and effectiveness of the existing multi-sectoral governance arrangements to learn about how actors from different sectors and levels interact and influence each other, understand potential barriers (e.g. limited authority, lack of coordination and harmonization of mandates of different sectoral institutions that can lead to conflicting outcomes and inadequate actions) and opportunities for the landscape planning process. In this process, the team will conduct interviews with a selection of users of each fire-smart practice to understand what is needed for it to be effectively incorporated into their daily work (e.g. training, technical support, inputs and equipment, governance mechanisms, etc.).

The outputs to be introduced in the second workshop would be:

- Detail cost-benefit analysis and description of the prioritized fuel models (alternative scenarios) with complementary fire-smart practices. It is recommended that integration between all rural sectors (agriculture. Livestock, forest, urban, infrastructures, tourism) and insurance of multiple benefits guide the development of the prioritized fuel models. Classify them according to:
    - targeted LU/LC type;
    - fire risk reduction objectives;
    - linkage and/or complementarity of fire-smart interventions;
    - expected results in terms of fire risk reduction (biomass management practices that help reduce fuel load (dry matter) content and expected burned area);
    - stakeholders involved (direct implementors, indirect supporters);
    - sustainable return on investment (identifying and quantifying environmental, social and economic impacts of investment);
    - costs and financing opportunities **[22]**.
- Capacity development plan for all concerned actors to enable them to implement fire-smart interventions.
- Multiple financing strategy for the implementation of the fire-smart landscape plan, including public financing opportunities (e.g. the EU Green Deal policies and budgeted national priorities applicable to the landscape; national/sub-national tax system); public-private partnerships such as payment mechanisms for ecosystem services (carbon sequestration, watershed protection and biodiversity conservation) or innovation value chain platforms for inclusive agribusiness; corporate social and environmental responsibility; crowdfunding; innovative business models for producer groups.
- Policy analysis, with identification of opportunities and barriers, and introducing a policy influencing plan to guide lobby and advocacy actions.
- A proposal for the long-term governance (multiple-stakeholder governance mechanisms at various levels) for the implementation of the fire-smart landscape plan. The criteria for assessing processes within landscape-level platforms include three principles of good governance (representation, participation and equity, and accountability and transparency) and eight conditions for effective operation (capacities, resources, adaptive management, leadership, theory of change, facilitation and communication, trust, and commitment).

In a second workshop, the lead team will present the results of its analysis of elements that make the implementation of the selected fire-smart practices feasible or not. In this workshop, participants will create a roadmap to schedule fire-smart practices based on their priority and applicability until the enabling conditions are met.

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[22] It is important to calculate: (i) how much biomass must be managed in each proposed practice, in what extension of the territory, where it is located in the landscape, and to whom it belongs (tenure); (ii) how many human resources are necessary to manage that biomass (e.g. number of shepherds needed to carry out controlled grazing in all the defined areas), how many of these human resources are already found in the landscape and where, how many are missing and where, how to get the missing ones, what training must be given to everyone in terms of fire prevention management and business development of economic activity, and what resources are necessary to be able to run viable activities; (iii) what negotiations and agreements are necessary between owners and managers of biomass and mechanisms to implement them; (iv) what synergies should occur between different uses in the same place for an effective management of biomass; (v) what environmental indicators must be defined and monitored to ensure a positive or neutral impact on biodiversity and ecosystems.

Likewise, the participants will discuss and agree on coordination and collaboration mechanisms between practitioners in charge of practices that are complementary. The incorporation of the fire-smart landscape plan priorities into existing governance mechanisms (e.g. multi-annual plans for protected areas; municipal plans; etc.) will also be discussed, identifying necessary actions and a timeframe. The workshop will end up by:

- Agreeing on a common fire-smart vision for the analysed landscape, which integrates the multiple needs and benefits of the different actors involved (including biodiversity).
- A road map for the next steps:
  - financing strategy;
  - formalization of the fire-smart landscape plan governance mechanism;
  - mainstreaming of fire-smart priority interventions into existing development and financing plans in the landscape.
- Set of activities to enhance linkage with partner landscapes and actors under EUKI, MedForVal, and other regional networks.

ANNEX 1

Case Studies with Best Practices in Building Landscape Resilience to Wildfires

Case Study 1

Integrated landscape planning of cross-sectoral climate- and fire-resilient interventions: Mosaico Extremadura Project (9, 51, 52, 53, 54)

In the semi-domesticated forest landscapes in southern Europe, with their small-sized forests intermixed with small-scale agriculture plots and pastures, including a relevant cultural and natural heritage, and a mix of rural and urban users with contrasting demands, values and perceptions, it is much more complex and challenging to identify the specific drivers causing large scale wildfires and the best solutions. Approaches for addressing complex problems include adaptive management, multisector decision-making, institutions that enable management to span administrative boundaries, markets that incorporate natural capital, and collaborative processes to engage diverse stakeholders and address inequalities.

Project description

The Sierra de Gata landscape (15,100 ha) in the north-western part of Extremadura (Spain) is a mountainous area prone to anthropogenic fires. Past pine and eucalyptus plantations **[23]** and the conversion of numerous agricultural lands and abandoned pastures into very dense shrubby woody formations have significantly increased the risk of wildfires, nowadays exacerbated by climate change induced extreme weather events. The Mosaico project is a response to an 8,000 hectares wildfire that occurred in summer 2015 and forced the evacuation of three villages in the upper catchment of the Gata river basin. The project aims to restore, through a collaborative land management approach, a mosaic-like landscape consisting of a mix of different fire-resilient LU/LC types (i.e., tree-crop plantations, livestock grazing, forest product harvesting) that, strategically distributed in critical high-fire risk areas of the landscape, will function as productive firebreaks that will effectively reduce fire risk.

The project rests on two assumptions:

- the maintenance of interspersed patches of forests, crops, pastures, and grazed shrubs is key to fire prevention due to its function of breaking up the continuity of hazardous fuels across the landscape;
- the economic opportunities generated by fire-smart farming and forestry in mosaic landscapes make the planned fire-smart interventions economically sustainable, while reducing arson ignition causes as a form of protest against restrictive and punitive policies.

[23] Between 1940 and 1984 in Spain, 3,678,522 ha of land (nearly 14% of the current forest land) were afforested, most of it with flammable pine and eucalypt species.

Fire-Risk Reduction objective

- Reduce wildfire risk thanks to the development of productive firebreak areas control of the growth and breakage of biomass continuity in fire break areas.
- Rapid alert of new fires by increasing the presence of shepherds with an active fire management role in the territory.

Climate Change mitigation and adaptation value

- Avoidance of fire spread resulting in GHG emissions reduction.
- The initiative does not address the quantification of GHG emissions' reduction resulting from the fuel load control through grazing.

Participatory landscape planning of wildfire-risks and prioritization of climate-smart interventions

- Fire-smart landscape planning aimed to determine the potential of the fire-resilient interventions responding to the following questions:
  - do Mosaico-promoted interventions function as effective firebreaks? if so, to what extent do interventions influence fire behavior and fire extinction methods?
  - are the interventions implemented in the landscape high fire-risk areas?
- Planning methodology was based on the development of a **relative fire risk index** and **simulations of the fire behavior** in the landscape under two scenarios: before (2010 selected as the reference year) and after the 2015 large wildfire. Simulations of surface fire behavior with and without interventions were performed using **FlamMap software** to calculate under 2 climate scenarios: the **flame length** and **rate of spread**, being both variables directly related to fire extinction capacity, and fuel moisture conditions. Simulations were performed with a 5 m cell size, using the following datasets:
  - the **digital terrain model** for altitude, slope, and aspect;
  - the **fuel model and tree canopy cover** maps for 2010 provided by the regional government of Extremadura, and for 2016 based on projections of fuel models and tree canopy cover for each of the interventions considered. The impact of the proposed interventions on the fire extinction capacity was assessed through the definition of four "extinction classes" based on the thresholds of flame length and rate of spread, evaluating in each landscape unit whether the implementation of interventions was able to improve the "**extinction class**", and if so, by how many degrees.

The location of interventions in relation to fire risk at the landscape was analyzed through the definition of a relative "**risk index**", (considering the "sub-catchment" as the spatial unit of analysis), based on the calculation of:

  - **Hazard**, disaggregated in **Fire Behavior** (flame length and rate of spread for each climate scenario) and **Ignition Probability** (historical occurrence and LU/LC interfaces); and
  - **Vulnerability**, disaggregated in **Value** (Economic value of ecosystem services, and nature protection designation) and **Fragility** (Human population density, and Biophysical environment including regeneration capacity and potential erosion).

- A participatory database (data on proponents, location, type, area, management plan, implementation status, etc.) including potential fire-smart agro-silvo-pastoral interventions was developed in consultation with local stakeholders. A total of 23 interventions were selected for the planning process, covering a total of 732 ha, of which almost 76% corresponded to forestry, 18% to livestock, and only 7% to agricultural interventions.
- The implementation of the proposed interventions resulted in improved extinction capacity (efficacy level 1 to 6) in 84% and 76% of the simulated area for the climate scenarios L10 and VL35, respectively. Most interventions were located in areas with medium and high relative risk indexes (classes 3 and 4). The landscape planning exercise proposed changes in fuel model type in nearly 90% of the 732 hectares covered by the project interventions. So far, the implementation of part of the proposed fire-smart interventions has modified the risk of fire from very-high risk to low or moderate risk in 101% of the mapped high fire-risk areas. The interventions were implemented by private and public landowners, and included:
  - forestry interventions (i.e., tree thinning and shrub clearing in areas devoted to resin tapping): 300 ha (41.1% of total area) from fuel model type 7 (trees with understory shrubs) to type 9 (forest with a thin litter layer) had a positive impact, reducing both flame length and rate of spread.

Resin tapping has recently become an attractive forest-based livelihood option due to the eco-climatic suitability of the area (average production of 2.4 to 3.1 kg of resin/tree/year), high market demand and stable price of resin. Around 30 resin tappers have been established in Sierra de Gata since its promotion began in 2015, and the potential for further expansion is high.

  - **agricultural interventions**: 18.9 ha of fuel model type 2 (unmanaged tree-crop plantations), 15.3 ha of type 5 (dense, young shrubs) and almost 10 ha of type 7 (forest trees with understory shrubs) converted into fuel model type 1 (managed perennial woody crops with pasture underneath). However, the efficacy of fuel model 1 has a low flame length, but a high rate of spread. Agricultural interventions (i.e., commercial tree-crop plantations) will be most effective as productive firebreak areas when established on abandoned agricultural land currently covered with flammable dense woody vegetation.
  - **livestock grazing interventions**: 37.5 ha of highly hazardous vegetation with fuel model type 6 (shrubs older, taller, or drier than in type 5) and 25.2 ha with fuel model type 4 (dense shrubs or young trees with a height greater than 2 m) converted into fuel model type 1, in this case corresponding to grazed pasture. Targeted controlled grazing in designated productive fuel break areas can be a cost-effective management option to reduce biomass fuel and the costs of mechanical clearing, while producing meat and milk as by-products and giving shepherds due recognition as land stewards.
- Most fire-smart interventions that were analyzed were found in landscape areas with medium to high relative fire risk index. The produced landscape planning maps with high-fire risk areas should guide the future location of fire-mart fuel model types in these areas to be considered “strategic management points” (SMPs) where fuel load reduction or the establishment of green infrastructure will allow for maximum risk mitigation at the landscape level. Further studies to identify SMPs are essential to help prioritize areas for the strategic location of fire prevention interventions, and will help forest managers and other stakeholders to make better, more informed decisions about desired changes on LU and management practices in SMPs.

Governance arrangements and multi-stakeholder participation

- Stakeholders’ participation requires time, long-term political commitment and institutional support, sufficient resources, and fundamental changes in public institutions including a new working culture moving away from “the expert knows best” culture and a new perspective on the role of rural people as land managers. The Mosaico project demonstrated that the participation of landowners and users in decision-making planning and collaborative strategies can effectively mobilize rural people and other stakeholders for the co-creation, in partnership with forest administrators, of agroforestry landscapes more resilient to fire.
- The Mosaico project has produced highly relevant social benefits and outcomes that show the important advantages of collaborative approaches for fire risk management: (1) During the fire-smart landscape planning phase, the project launched an online open call for fire-smart land management proposals to increase resilience in fire-risk areas. Many landowners responded, providing good ideas on forest, agriculture and livestock grazing uses, combined or not, that helped increase resilience to wildfires. The project demonstrated that when given the chance and the voice, rural stakeholders take a proactive rather than reactive responsibility and positively influence key decisions on fire-smart actions in public and private forests.
- Shepherds active in the landscape were recognized as fire-fighters and their work of controlled grazing in high-fire risk areas were economically remunerated, with part of the public funding annually allocated to the mechanical clearing of fire breaks.

Capacity development, participatory action research and innovation

- The project has supported practitioners with capacity development interventions around fire-smart management practices, including controlled grazing management, prescribed burning, agroforestry, green business development and marketing, invasive species.

Enabling policy framework

- Policy revision will be needed to facilitate landowners' procedures to convert back into agroforestry systems and pastures some areas of secondary forests with a high accumulation of biomass from the abandonment of old crops and pastures. There is an interesting precedent from the regional government of Galicia in northwestern Spain with large fire-prone areas, that enacted a pioneering law in 2021 for the restoration of wooded areas from the abandoned agriculture land with the explicit recognition of agroforestry as a permitted and promoted restoration practice that acts as a productive land-use system with a high fuel break value.
- The Mosaico Extremadura experience is being used as an example to lobby policy-makes at the regional and national level for policy improvement to facilitate and upscale fire-smart interventions at a broader scale.

Ecosystems' resilience restoration (diversity, functionality, post-fire recovery capacity)

- Conversion of burned forest stands into pastures and fruit tree crops, and restoration of former woody crop plots and pastures within forestland, with complementary controlled grazing, contributed to regain the landscape mosaic-like structure, with a potential positive impact in terms of increasing habitats' diversity and resilience to wildfires.
- The initiative supports the restoration of tree species diversity in forest and agroforestry stands, and species diversity and quality of pastures.

Financing and cost-effectiveness

- **Source of funding**: The long-term commitment from the regional government and the university of Extremadura was fundamental for securing funding (1 million euros from the regional government with the capacity to leverage 2 million more from projects lead by the university).
- **Cost-effectiveness**: It is estimated that the implemented interventions have reduced fire-risk from very high to low or moderate in 11 % of the High-fire risk areas mapped.

Sustainable return on investment (multiple benefits)

- **Economic return**: multistakeholder collaboration has helped to increase the capacity of stakeholders to accomplish work and leverage other funding in support of the approach. The University team supported landowners in accessing EU funds to convert fire-prone fuel models into fire-smart ones (e.g. forest clearing, controlled grazing, fruit tree planting, forest diversification with re-sprouting species such as oaks, chestnuts, hazel nuts, pistachio, and strawberry-trees), to organize themselves as user associations and cooperatives, and to develop new business models around fire-smart production systems (e.g. diversification of chestnut processed products; innovative production of spirits and fresh fruits from wild forest species such as strawberry tree, new climate-adapted products, such as pistachio and hazel nut).
- **Social return**:
  - social recognition of the important role played by extensive livestock combined with forest clearing operations, and agroforestry farming as fire-risk reduction land uses and management practices, and thanks to awareness raising actions, field events and workshops organized by the Mosaico Project team;
  - the project helped with additional employment to match shepherds income, increase number of shepherds, and reduce outmigration of young unemployed;
  - promotion of local breeds and marketing their products with a fire-risk reduction label to enhance product value and attract consumers;
  - higher collaboration of shepherds with foresters, and among small forest owners;
  - general revitalization of rural development opportunities, attracting new settlers.
- **Environmental return**:
  - fire-risk reduction;
  - habitat and species diversification;
  - soil erosion control in firebreaks.

Case Study 2

The Mediterranean Mosaics Initiative: Regaining landscape resilience to climate risks through Forest Landscape Restoration planning and implementation in the Shouf-West Beqaa Landscape (Lebanon) (55,56,57,58,59,60,61,62,63)

Forest landscape restoration (FLR) is the planned process of regaining ecological integrity and enhancing human well-being across deforested or degraded large territories, with the goal to restore the resilience of high biodiversity- and cultural-value landscapes to the feedback loop between climate change and anthropogenic disturbances. It implies the participatory planning, prioritization and implementation of a set of cross-sectoral integrated interventions around protection, adaptive management and active restoration of the landscape ecosystem services supporting both sustainable development and biodiversity conservation.

Forest and landscape restoration is recognized by the United Nations as a means to reach Sustainable Development Goals, the National Determined Contribution of countries to the Paris Climate Agreement, The New York Declaration on Forests, the UNCCD Land Degradation Neutrality objectives, and the Bonn Challenge to bring 350 million ha of deforested and degraded land into restoration by 2030.

Project description

In 2012, ACS **[24]** - the organization managing the Shouf-West Beqaa Landscape (SWBL) that corresponds to the 50,000 ha of the Shouf Biosphere Reserve- joined the international project "Mediterranean Mosaics" (MM), whose goal was to build the resilience of Mediterranean biodiversity and culturally outstanding mosaic-like forest landscapes to global change.

The SWBL is divided into a core zone (115.5 km^2) for the strict protection and restoration of biodiversity; a buffer zone (64.5 km^2) where development activities should be compatible with the conservation objectives; and a transition zone (359 km^2) that includes all the villages surrounding the buffer zone where sustainable natural resource management practices are promoted. The mosaic-like mountainous landscape supports a wide range of natural and semi-domesticated habitats with high diversity of flora and fauna species, including 32% of the remaining cedar forests in Lebanon. The historical over-exploitation of cedar forests, the irrational exploitation of quarries and pastures, the abusive construction of houses in forested areas, and the massif abandonment of agriculture terraces have given rise to a vulnerable landscape to climatic risks, including the growing occurrence of wildfires.

The project adopted an integrated and cross-sectoral landscape-level approach, including:

- participatory spatial planning,
- responsible governance of tenure and natural resources management,
- ecological restoration of ecosystem services of natural and semi-natural ecosystems that make up the landscape,
- and recovery and promotion of sustainable multipurpose forest, agricultural, pastoral and eco-tourism uses adapted to climate risks.

The project has applied an innovative for a gender and youth unemployed inclusiveness approach to the involvement of the different actors (landowners and users; Syrian refugees; private companies and producer associations/cooperatives; public extension agents; public administration at the municipal, district and national level; environmental and social NGOs; researchers; primary, secondary and university education centers) in awareness-raising actions, in the creation of employment and green businesses targeting new markets on ecological certification and fairtrade, and in the long-term policy and financing sustainability of the climate-resilient landscape plan.

The Mediterranean Mosaics project was shaped along the set of guiding principles of forest landscape restoration, proposed and adopted by the founders and members of the Global Partnership on Forest Landscape Restoration (GPFLR).

The implementation team included the ACS team, several international experts, national experts, local NGOs, forest committees at the municipality level, local private entrepreneurs, and in partnership with international NGOs, the ministries of Agriculture, of the Environment, and Spatial Planning, FAO, the WFP, Italian Aid, USAID, the EU, and private companies.

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[24] Al-Shouf Cedar Society.

Fire-Risk Reduction objective

- Reduce of fire risk thanks to integrated forest and agriculture biomass management and water harvesting in high fire risk areas:
  - biomass reduction along roads and in high fire-risk areas covered with very dense secondary Brutia pine forests;
  - reopening of secondary forest areas that occupied abandoned agricultural areas, to restore productive terraces systems;
  - collection of agriculture waste (olive and fruit tree pruning remains and olive pomace) to prevent them from being burned and to be used together with forest biomass for bioenergy and compost;
  - controlled grazing in cleared areas and thinned forest stands to control biomass growth;
  - construction of water harvesting green infrastructures in key areas of the landscape with the multipurpose objective to support firefighting operations, wildlife and livestock troughs, and agriculture irrigation.

Climate Change mitigation value

- Avoidance of wildfires resulting in GHG emissions reduction.
- Replacement of GHG emissions from polluting diesel heating systems in the rural houses with green bioenergy products.
- The initiative does not address the quantification of GHG emissions' reduction resulting from the fuel load control through grazing.

Participatory landscape planning of wildfire-risks and prioritization of climate-smart interventions

- The project has undertaken participatory landscape planning exercises at the municipality level, following the FLR planning tools to analyse root-causes of landscape degradation, prioritize high-risk intervention areas, and prioritize climate-adaptive intervention measures providing multiple ecological, social and economic benefits.
- The project has mapped and ranked LU/LC types according to their conservation status at the municipality level. At the landscape level the project has mapped and quantified the availability of extractable forest and agriculture biomass – thinning of abandoned too dense forest stands and collection of pruning residues and olive pomace from fruit tree and olive crops - to plan bioenergy and compost production and make viable business plans for small enterprises.
- The project has not made use of any multifactorial GIS model to identify and map priority areas for FLR interventions help prioritize where to intervene throughout the phases of the project and determine the type of intervention to be carried out. Given the increased risk of fires derived from climate change and the high accumulation of dry forest biomass where most of the dense secondary pine forests and urban settlements are closely intermingled, and the pressure of building construction is very high, it is advisable to apply a multivariable model for the planning of environmental risks for the entire landscape, with special focus on fires.

Governance arrangements and multi-stakeholder participation

- The project actively engaged stakeholders at different scales, including vulnerable groups such as Syrian refugees, young unemployed and women, in planning, decision making, and in the implementation of restoration actions. The stakeholders' assessment and mapping stage involved the identification of people, groups, and institutions that have interest in FLR or will be affected by FLR interventions. A stakeholder table was produced to:
  - visualize the influence and level of interest of each stakeholders group;
  - understand which stakeholders share similar goals or have similar interests;
  - identify potential alliances between groups that may join efforts to advocate for actions supporting FLR.

- **Stakeholders' participation** was fostered through the following steps:
  - **Team building**, including ACS staff;
  - **Information and consultation** to introduce the FLR rationale, objectives, and methodologies to all the identified stakeholders, targeting men, women, young unemployed, and refugees.
  - **Engagement**, through open calls for tender to benefit from development grants and local/international training opportunities and learning visits around different FLR type of interventions;
  - **Empowerment**, with major investments in training of both practitioners and future trainers, professionalization of young unemployed women and men in new jobs linked to FLR, and continuous coaching assistance to guide practitioners in the complex process of testing and adopting new management practices, which usually do not bring visible improvements until after several years of change.
  - **Partnerships and networking**, establishing partnerships with international organisations and donors.
- **Participatory governance mechanisms for FLR planning, implementation and monitoring** included the creation of the following, new bodies:
  - **Alliance for the Green Shouf Biosphere Reserve (AGSBR)**, an informal network aimed at gathering all the main partners and stakeholders of all the landscape municipalities around a common FLR vision, with the multiple objective of empowering on FLR planning and implementation, reducing trade-offs to maximize environmental and socio-economic benefits, and leveraging resources for the long-term FLR goals.
  - **Municipal Forest Management Committees (FMCs)** with up to 15-20 members representing the municipal council, community organizations, extension agents, women groups, NGOs and local schools, were established in sixteen municipalities with the aim to have credible grass-root structures with legitimacy and recognition from local stakeholders and respect from the communities.
- **Multi-actors agriculture innovation platforms for green value chains**, supporting the organization of formal (associations and cooperatives) and informal producer groups using biodynamic organic farming practices for multiple crop production in the restored agricultural terraces (productive firebreak areas) and the already existing ones, and the development of marketing platforms:
  - national and international organic fair-trade certification, involving direct contacts between local producer organizations and fair-trade buyer companies from Italy and Beirut;
  - promotion of short marketing circuits through direct sales from the producers to the consumers on the same farm or in local weekly markets, adding commercial value to the products by linking the products with ecotourism activities.

Capacity development, participatory action research and innovation

- Through continuous training and coaching by international peers, the project has invested significant resources to **build the capacity of forest, agriculture and livestock producers** on ecologically-sound and risk reduction production systems.
- Creation of **employment opportunities**. Farmers, unemployed young and Syrian refugees – both women and men – were professionally trained on integrated biomass management, ecological restoration with native plants and on-the-field planting techniques, dry stone wall reconstruction, sustainable NTFP harvesting, and the construction and conditioning of nature trails and other ecotourism-related infrastructures.
- Strengthening the capacity of the landscape stakeholders through **regional networking**: ACS staff and different type of landscape practitioners benefited from training opportunities linked to several regional networking initiatives. Two-ways training courses and learning visits were organized in the Shouf-West Beqaa landscape and abroad - mainly in Italy and Spain. with a very practical hands-on approach, following a peer-to-peer approach, putting in

Enabling policy framework

- Pilot interventions were used to influence national policies on forest management and fire risk reduction, including: the National Forestation Plan, the National Fire Management Strategy, the National Green Plan and ppatial planning regulations.

Ecosystems' resilience restoration (diversity, functionality, post-fire recovery capacity)

- Restoration of abandoned agriculture terraces colonized by dense secondary pine forests into multi-crop productive farming systems and controlled grazing after forest thinning contributes to regain a fire-smart landscape mosaic-like structure of forest, agriculture and pasture patches with a positive impact in terms of increasing habitats' diversity and reducing fire risks.
- Thinning of secondary pine forests contributes to the growth of the existing oak, strawberry tree and other broadleaf tree species, as well as the growth of herbal plants and fungi species in the forest understory with a positive impact on the forest biodiversity and resilience to fire. However, biodiversity improvements require the definition and monitoring of specific indicators to verify positive impacts and adjust biomass harvesting and controlled grazing. This is an issue that still needs to be integrated in the FLR initiative.
- The reintroduction of a key stone wild herbivore – the Nubian ibex – will help manage the biomass of forests and pastures in the core zone of the biosphere reserve, with a positive effect on natural habitats and plant species diversity.

Financing and cost-effectiveness

- **Source of funding**: The FLR initiative in the Shouf-West Beqaa landscape has been financed with financial support from several sources: MAVA Foundation; EU ENPI; FAO; AICS (Italian Aid), World Food Program "cash for food e-cards". Two more projects funded by the Italian Cooperation and the EU have just started to keep supporting the FLR plan implementation.
- **Measure cost**: Restoring 1 hectare of dry-stone wall terraces with diversified production of aromatic plants, fruit trees, vegetables and/or vines has a cost of USD 10,000; Restoring 1 hectare of degraded forest with a diverse set of native species has an average cost of USD 2,000; Thinning 1 hectare of dense secondary pine forest, has an average cost of USD 8,000.
- **Payment system**: The project has supported landowners and users' organization through matching grants and soft loans to implement fire-smart interventions with a business development approach.
- **Cost-effectiveness**: Several fire-smart project interventions focused on the development of economically viable local businesses. For instance, the programme has supported the establishment of a bioenergy plant in the village of Kfarfakoud to produce briquettes for cooking and heating from local waste materials. The factory produces about 6,000 briquettes per day with the plan to increase production from 1 million briquettes in 2013 up to 5.6 million in 2021. The net profit is 25% of sales (USD 50/t of briquettes, with a sale price of USD 200/t), part of which reverts to the improvement of the management of the landscape and FLR implementation. The project managed to decrease the cost from the average national cost of USD10 per each planted seedling to USD 2, thanks to:
  - an accurate plant production protocol avoiding the excessive consumption of water and other inputs;
  - the equipment used for soil preparation;
  - the professionalization of the staff involved in plant production and field planting;
  - the exclusion of watering in the maintenance of the restored sites.

Sustainable return on investment (multiple benefits)

- **Economic return**: The focus of the project is to generate economic sustainability linked to the supported fire-mart practices, such as the management of forest and agricultural biomass for the production of bioenergy and compost, the creation of native forest and agricultural plant nurseries, the creation of green value chains for agro-forestry-pastoral products produced on terraces and restored forests and from controlled grazing.
- **Social return**:
  - The professionalization of unemployed youth generates jobs in a territory with depopulation problems; poverty alleviation and gender balance have been major criteria for the selection of candidates;
  - The generation of green business opportunities in a period of intense economic crisis in the country has promoted the return of residents who had migrated to Beirut.
  - The use of biomass for bioenergy to replace the use of diesel for house heating has contributed to reduce pollution and health problems;

- The implementation of a sustainable biomass management plan avoided the problem of wild and uncontrolled felling in many parts of Lebanon, as a response of the population to the serious economic and energy crisis. ACS is coordinating the implementation of thinning and pruning plans in dense secondary forests and coppiced oak woodlands, and part of the harvested wood is being distributed free of charge to economically vulnerable local population, thereby avoiding destructive actions.

- **Environmental return:**
  - fire-ignition reduction through the use of agriculture waste for bioenergy and compost and the clearing of biomass along roads;
  - habitat diversification through biomass management that helped restored agriculture land and grassland stands that break fuel continuity in forestland;
  - plant species diversification in managed and restored forest and agriculture land;
  - higher ecosystem resilience to climate change;
  - lower GHG emissions through the use replacement of diesel with bioenergy, and burned area reduction.

Monitoring for adaptive management and knowhow dissemination

- ACS team with support from international experts have monitored socio-economic and environmental impacts of sustainable biomass management, forest, agriculture and pasture restoration, and productive agricultural systems.
- Knowhow transfer through research papers and outreach materials and activities (education and training activities, media, online, information events and workshops).

Case Study 3: RAPCA [25] Project

Controlled livestock management in firebreak areas, complementary to forestry prevention measures (24,64,65,66)

Silvo-pastoralism is a traditional practice in the Mediterranean forest landscapes, having as a main characteristic the movement of livestock following the latitudinal and altitudinal seasonal availability of grazing resources. Rural abandonment, little economic viability and tenure constraints have resulted in a limited presence and movements of livestock, together with an excessive accumulation of dry fuel load in unmanaged forests, and abandoned pastures and agricultural lands.

Sectoral public European policy reforms such as the Common Agricultural Policy, are aware of the degree of decline that extensive livestock farming is suffering in southern Europe. Silvo-pastoralism is claimed as a strategic system to be promoted, due to its multifunctionality:

- production of food and other goods such as wool, leather and rural tourism;
- contribution to the conservation of biodiversity and cultural landscapes; and
- its fundamental role in preventing the risk of forest fires.

In the Euro-Mediterranean countries there are more and more public administrations implementing extensive livestock plans for the control of fuel load in several urban, peri-urban and rural areas. It is seen as a much cheaper substitute for the periodical mechanical works (e.g. mechanical cleaning operations of woody vegetation in firebreaks), which may also be used as a complementary biomass control intervention to be implemented after thinning operations in high and coppice forests, or as a complementary measure to prescribed burning interventions. However, successful experiences with a certain temporal and territorial scope are scarce.

Description

RAPCA involves local shepherds who, with their guided flocks, maintain low biomass levels in almost 6,000 ha [26] of fuel break areas in public forests, with a direct fire prevention goal. RAPCA program is part of the Forest Fires Emergency Plan of the Andalusia Regional Government (INFOCA), managed by the regional General Directorate of Environmental Management (GDEM) and executed through the Environment and Water Agency (EWA), with the scientific advice of the CSIC [27] experts' group of *Pastures and Mediterranean Silvo-pastoral Systems* of the (CSIC).

A technical team of the EWA annually determines, under strict technical criteria, the most appropriate fire break areas to control biomass growth and select the shepherds, to take advantage of an existing traditional activity and livestock management infrastructure in the area. On average, 38 ha of fuel breaks are assigned to each engaged shepherd, and these are invited to participate in the program, through open calls (electronic bidding portal of the Regional Government). Most of the invited shepherds (94% in 2015) have small-ruminant herds of traditional sheep and goat breeds adapted to local conditions. Shepherds undertake their activity every year through annual contracts, with higher grazing intensity in spring/early summer to ensure optimal biomass reduction during the high fire risk season. EWA staff monitors compliance. Targeted grazing does not completely substitute the mechanical clearance of biomass in fuel breaks, but it does reduce the frequency of mechanical interventions.

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[25] RAPCA: Red de Áreas Pasto-Cortafuegos de Andalucía.
[26] Number of hectares in 2016.
[27] CSIC: Spanish High Council of Scientific Research.

Fire-Risk Reduction objective

- Reduce fire spread risk thanks to the control of the growth and breakage of biomass continuity in fire break areas.
- Rapid alert of new fires by increasing the presence of shepherds with an active fire management role in the territory.

Climate Change mitigation value

- Avoidance of fire spread resulting in GHG emissions reduction.
- The initiative does not address the quantification of GHG emissions' reduction resulting from the fuel load control through grazing.

Participatory landscape planning of wildfire-risks and prioritization of climate-smart interventions

- The information available does not allow to conclude that multi-stakeholder participatory planning processes occurred in the planning of the RAPCA network interventions. However, RAPCA network is embedded in the Forest Fires Emergency Plan of the Andalusia Regional Government (INFOCA [28]) carried out by emergency and civil protection and forestry departments of the Regional Government, and subject to public information and consultation. The RAPCA fire-prevention grazing interventions mainly complements the mechanical works in areas of difficult access and high slope. Only researchers from the Higher Council for Scientific Research in Spain (CSIC) have participated in the planning of preventive grazing activities based on the objectives of plant biomass control.
- Calculation of the amount and type of biomass to be controlled in the landscape is mainly linked to the periodical regrowth of fuel load – both herbal and woody vegetation - to be periodically cut and/or controlled through grazing.
- There is no integrated landscape vision in terms of multi-sectoral fire-resilient objectives and integrated priority interventions addressing the sustainable management of biomass from the different development sectors and infrastructures of the landscape.

Governance arrangements and multi-stakeholder participation

- The initiative has not established any governance structure or multi-stakeholder platform (MSP) for the long-term implementation of the yearly fire-risk reduction grazing interventions.
- Staff from the public forestry service, shepherds and researchers from CSIC, are the main stakeholders participating in the implementation of the RAPCA network, being shepherds absent from the planning of RAPCA network operations.
- Controlled grazing is applied on both public and private forestland that have applied to the public call for tender on financial aid for fire prevention under the modality "maintenance of firebreaks by livestock grazing".
- The role of CSIC: research on carrying capacity, biomass control effectiveness of livestock grazing in fire break areas, and impacts on species population and diversity, vegetation and soil; design of the controlled grazing management system; technical advice to governmental staff and shepherds on the implementation of grazing interventions; monitoring, knowledge generation and dissemination.

Capacity development, participatory action research and innovation

- The Regional Agency (RA) of Agriculture, Fisheries and Rural Development and the RA of Environment and Territory Planning, have launched the "Andalusian School of Shepherds", to increase the professionalism of shepherds in their role as fire controllers and making shepherding work attractive to young people in rural areas. Livestock associations and unions, Breed Associations, Universities, Entities of the Ministries, City Councils and Provincial Councils, among others, are collaborators in this training initiative.
- At a national level, the "Association of Shepherds for the Mediterranean Forests", is an NGO for the promotion of the environmental, social and economic benefits provided by extensive livestock in agro-forestry landscapes.

Enabling policy framework

- The RAPCA network of areas for fire-risk reduction through controlled grazing interventions is embedded in the policy document "Forest Fires Emergency Plan of the Andalusia Regional Government" (INFOCA).

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[28] INFOCA: Plan de Emergencia por Incendios Forestales de Andalucía (Forest Fires Emergency Plan of the Andalusia Regional Government).

Ecosystems' resilience restoration (diversity, functionality, post-fire recovery capacity)

- Controlled grazing contributes to regain the landscape mosaic-like structure of forest and pasture patches with a potential positive impact in terms of increasing habitats' diversity. However, this requires field verifications with specific indicators, which may not be part of the initiative itself.
- The initiative supports the restoration of species diversity and quality of pastures.

Cross-sectoral integration and complementarity of climate-smart biomass management interventions providing multiple benefits

- Controlled grazing for herbal and woody biomass growth control in high fire-risk areas and firebreaks is proposed as a complementary measure to mechanical biomass clearing works.
- The information analysed does not provide details on the mechanical biomass clearing in firebreaks, neither on biomass management in forest stands beyond firebreak areas. This makes it difficult to understand if the management of firebreak areas with controlled grazing forms part of a comprehensive cross-sectoral landscape management plan for fire prevention.

Financing and cost-effectiveness

- **Source of funding**: RAPCA annual cost is covered by the Forest Fires Emergency Plan of the Andalusia Regional Government (INFOCA [29]). It represents approx. 1% of the total INFOCA budget for fire prevention activities in the region.
- **Measure cost**: RAPCA unit costs in 2017 were 137 €/ha (from which 80 €/ha are running costs or payments to shepherds, and 57 €/ha are transaction cost corresponding to the hiring of RAPCA staff and setting up infrastructures in the forest areas for shepherds to develop their activities).
- **Payment system**: Maximum payments are established, consisting of a fixed initial bonus of 300 € for participating in the scheme and a variable share ranging from 42 €/ha to 90 €/ha considering the grazing difficulty. Levels of compliance with the defined biomass consumption target modulate the maximum payment: 100%, 75% or 50% compliance. Compliance levels below 50% do not receive remuneration. According to the contracts signed with the regional government, shepherds are requested to achieve an annual consumption of 90% of the herbaceous layer and 75% of the shrub layer.
- **Cost-effectiveness**: It is estimated that the scheme saves up to 75% (63% on average) of the fuel breaks management costs by mechanical clearance with handheld brush cutters: mechanical biomass removal tariffs may vary between 364.70 €/ha and 2,412.14 €/ha for manual clearing and between 209.67 €/ha and 2,339.50 €/ha for light machinery, depending on plant coverage, stem diameter and slope.

Sustainable return on investment (multiple benefits)

- **Economic return**: The intervention is subsidized through the annual budget of INFOCA public funds. However, there are shortcomings in terms of economic sustainability, which should depend largely on the sustainability of the livestock business and the added value that the role of firefighter can give it in the production of quality goods. According to the information analysed, the initiative has not supported farmers to improve their businesses to become economically viable, neither promote the develop of certification schemes and the marketing of the additional value of high-quality local products in terms of fire-risk reduction.

[29] INFOCA: Plan de Emergencia por Incendios Forestales de Andalucía (Forest Fires Emergency Plan of the Andalusia Regional Government).

- **Social return:**
    - social recognition of the important role played by extensive livestock farming, thanks to awareness raising actions on media, field events and workshops, and the role of shepherds in creating awareness and respect for the rural environment;
    - additional employment to match shepherds income, increase number of shepherds, and reduce outmigration;
    - improvement of structures, improvement and construction of water points and tanks, protection fences for species of botanical interest, , use of removable sheepfolds and fenced areas to confine livestock, use electric shepherd, etc.;
    - promotion of local breeds and their products;
    - increased collaboration of shepherds with foresters; (vi) general revitalization of rural development opportunities.

- **Environmental return:**
    - fire-risk reduction;
    - habitat diversification;
    - soil erosion control in firebreaks.

Monitoring for adaptive management and knowhow dissemination

- Experts from the forestry service and CSIC provide a permanent follow-up to the shepherds' work through periodical visits.
- Evaluation of results during summer when shepherds stop grazing activities and compared with control sites (fenced areas with no grazing). This leads to methodology improvements.
- Knowhow transfer through research papers and outreach materials and activities (media, online, information events and workshops).

Case Study 4

Biomass management for fire-risk reduction through integrated forestry and livestock grazing interventions: LIFE Montserrat (67,68,69,70,71,72,73)

Rural abandonment and post-fire natural regeneration has led to highly dense secondary pine forests in the coastal mountains of the Mediterranean countries, such as Spain, France, Croatia, Greece, Turkey and Lebanon. The recovery of the traditional mosaic structure of the landscape entails an integrated management of biomass with the aim of breaking the continuity derived from the homogenization of secondary pine forests and reopening spaces for extensive grazing and agriculture.

Project description

LIFE Montserrat had three specific objectives:

- The **creation of strategic fire prevention areas and their maintenance through silvo-pastoral practices** that prevent the spread, facilitate extinction, reduce the intensity, extension and risk of large forest fires -GIF-.
- The **conservation and improvement of biodiversity** in the area through the maintenance and restoration of priority habitats and the habitats of threatened and protected species.
- **Increased ecological connectivity of the landscape** and the areas of the Natura 2000 network "Montserrat-Roques Blanques-Riu Llobregat and Sant Llorenç del Munt i l'Obac", through the creation of a continuous mosaic of grasslands, thickets and natural forests.

The project has established a network of green infrastructures in the mountain of Montserrat, within the Metropolitan Region of Barcelona, to help prevent large-scale wildfires, while conserving the natural heritage in 14 municipalities around the mountain landscape. Interventions consisted in:

- The reduction of tree density (from 50,000 to 1,000 individuals per ha) and fuel load in 1,300 ha of approx. 38 years old highly dense pine forests (350 ha/yr) that resulted from post-fire natural regeneration after a devasting fire in 1986, and improvement of the forest structure. After clearing operations, livestock grazing helps control fuel load and keeps biomass within desired volumes.
- The opening of cleared areas in forestland to recover past farmland and pastures. The opening of gaps took place through:
  - mechanical clearing in 45 hectares; and
  - prescribed burning in 65 hectares, with low intensity flames undertaken by professional specialists, according to technical guidelines, subject to strict safety standards, and with reduced environmental impacts on soil, flora and fauna. In open areas with tree cover maintained a density of 50-100 stems was maintained; in open areas with just high dense shrub layer, all woody vegetation was cut.
- The establishment of 10 structured livestock management plans in strategic fire-risk areas in the landscape covering 1,400 hectares, through agreements between shepherds and forest owners.
- Awareness raising to enhance the sense of responsibility and involvement of the local population in reducing fire risks took place through educational activities in 20 primary and secondary schools in the landscape, including field visits, and involving 1,300 pupils.

Fire-Risk Reduction objective

- Reduce fire spread risk thanks to tree thinning, fuel load control in managed forest stands and opened areas, and breakage of biomass continuity within the landscape.

Climate Change mitigation value

- Avoidance of fire spread resulting in GHG emissions reduction.
- The initiative does not address the quantification of GHG emissions' reduction resulting from the fuel load control through grazing.

Participatory landscape planning of wildfire-risks and prioritization of climate-smart interventions

- The information analysed (web pages and papers) shows no evidence that multi-stakeholder participatory planning processes occurred in the planning of the LIFE Montserrat interventions.
- It seems that the LIFE Montserrat prioritization of high fire-risk areas is based on the areas already designated by the Fire Service of the Regional Government of Catalonia.
- The Support Group for Forest Actions (firemen GRAF) carried out a landscape analysis based on historical data on the type of fires occurring in the landscape and developed scenarios for large-scale wildfires (LWF) identifying Priority Intervention Areas (PIAs) where to invest to limit the spread of LWFs. Pastoral management units (PMUs) were defined by overlapping PIAs with land tenure and prioritized land uses. The set of all the PMUs form the project management area or PMA, where the LIFE Montserrat actions were implemented.

Governance arrangements and multi-stakeholder participation

- According to the information analysed, the initiative has not established any governance structure or multi-stakeholder platform (MSP) for the long-term implementation of the yearly fire-risk reduction grazing interventions. However, it is embedded in the already existing governance structures of the Montserrat Mountain Natural Park and Montserrat Rural Park.
- The main stakeholders participating in the implementation of the LIFE Montserrat project are: the public administration, the private foundation Catalunya La Pedrera, the Forest Science and Technology Centre of Catalonia (CTFC), local shepherds, farmers, and forest owners, the Montserrat Association of Forest Owners, and the Montserrat Association of Shepherds.
- The project team organized awareness raising events and individual meetings with forest owners to increase membership of the Forest Association and participation to the project interventions. A new Association of Shepherds was established with 14 members, and grazing agreements and permits were signed between members (forest owners and shepherds) of the two associations.

Capacity development, participatory action research and innovation

- Livestock management was considered as a key intervention to secure long-term fire-resilient success, but the number of shepherds in the landscape was too limited. In order to overcome this problem, the project established a collaboration agreement with the Catalonian School of Shepherds, an entity with extensive experience in building capacity of individuals interested in the livestock sector in a professional manner. This agreement allowed the development of 8 viable livestock business plans to be developed within the time horizon of the LIFE Montserrat.
- The public Centre for Research on Ecology and Forestry Applications (CREAF) and the Forest Science and Technology Centre of Catalonia (CTFC) have provided scientific support to design biomass management experiences, plan field activities and monitor results.

Enabling policy framework

- In 2003, the Regional Government of Catalonia approved Law 5/2003 on the prevention of forest fires in urbanizations, which assigns subsidiary responsibility to the mayors for the application of the law. Life Montserrat hold meetings with mayors and provided the necessary information to help tackle the problem of finding economically viable solutions for the maintenance of the fire prevention strips of these urbanizations, proposing to carry out these maintenance tasks through the livestock farms linked to the project.

- Life Montserrat has worked together with the different areas of the Department of Agriculture, Livestock and Food of the Regional Government to facilitate that the aid programs for prevention of fires and for extensive livestock are accessible to livestock farms in the territory. The project defined the Priority Protection Perimeter (PPP) of Montserrat, With the completion of LIFE Montserrat, the PPP allows opening avenues for economic compensation to ranchers for grazing in strategic areas. On the other hand, thorough work has been done on reviewing the grazing coefficients of the areas with grazing cattle after the end of the project, since the aid of the first pillar of the CAP is another essential factor for the sustainability of the farms.
- The technical team of the project has sought solutions to ensure the economic sustainability of the project in the long term, but numerous contradictions were found between the environmental and rural development policies coming from the European legislation that has been brought to the attention of the Commission, to try to find effective solutions.

Ecosystems' resilience restoration (diversity, functionality, post-fire recovery capacity)

- Reopening gaps in dense pine forest stands has contributed to restore grassland and forest habitats and flora and fauna species populations; controlled grazing contributes to regain the landscape mosaic-like structure of forest and pasture patches with a potential positive impact in terms of increasing habitats' diversity and landscape resilience.

Cross-sectoral integration and complementarity of climate-smart biomass management interventions providing multiple benefits

- Controlled grazing for biomass management in high fire-risk areas is proposed as a complementary measure to mechanical biomass clearing and prescribed burning works.
- The woody biomass cut through mechanic clearing in dense forest stands and shrublands was crushed or piled on the same forestland for its degradation and further integration into the soil.
- Low-intensity, prescribed burns of biomass do beneficial things to secure carbon storage: burn less above and below ground biomass than wildfires and consequently emit less carbon, reduce the risk of high intensity wildfires by removing fuel, and is a selective intervention that avoids the killing of large trees that store carbon in their biomass.
- Biomass mechanical clearing has contributed to reduce tree density, improve structure of forest stands and reopen abandoned agriculture and pastures.

Financing and cost-effectiveness

- **Source of funding**: Total budget of 3,561,825, from which LIFE funding covered 1,763,000 € and project partners covered 1,798,825 €.
- **Cost-effectiveness**: The revised documentation mentioned a cost-benefit study prepared by the CTFC that has made it possible to verify that the work carried out has benefited the stability and vitality of the forests, and has reduced their vulnerability to forest fires, with a return Cost/ Benefit has been positive. However, the study is not available in the project web page.

Sustainable return on investment (multiple benefits)

- **Economic return:** The long-term viability of fire-smart landscape management plans fully depends on the local socioeconomic fabric, so that framework policies, such as the CAP, need to be modified and adapted to support and favour small and medium-sized enterprises and value chains around climate-smart biomass management interventions and related businesses (e.g. bioenergy, livestock products, NTFPs, tourism) in high fire-risk rural landscapes, and balance their weight within the industrial agriculture and forestry. The project has supported the establishment of direct sales circuits for local organic products, including producer-consumer proximity tourist activities, with a circular economy approach and with the aim of raising awareness of the society about the fire-smart role of pastoral activities in the landscape.

- **Social return**:
    - social recognition of the important role played by biomass management through joint forestry and extensive livestock farming, thanks to educational activities in primary and secondary schools and awareness raising actions on media, field events and workshops;
    - additional employment opportunities has increased number of shepherds, and reduce outmigration of young unemployed;
    - collaboration agreements between forest owners and shepherds for long-term land stewardship through silvo-pastoral interventions, involving the respective associations, and contracts between owner and shepherd;
    - improvement of structures available to shepherds;
    - promotion of local breeds and their products, although little was mentioned about concrete steps in this sense;
    - higher collaboration of shepherds with foresters, with the special tasks of fire detection surveillance and fire prevention;
    - general revitalization of rural development opportunities.

- **Environmental return**:
    - fire risk reduction;
    - enrichment of rodent and coleopter species in managed forests with 1,000 stems/ha and forest structure similar to mature forest stand;
    - fire-risk reduction;
    - habitat diversification with higher extension of priority pasture habitats under HD, and higher diversification of butterflies in opened areas compared to dense pine forest stands;
    - conversion of livestock farming into organic production systems, including organic agriculture for fodder production;
    - soil erosion control in firebreaks;
    - managed Aleppo pine forests (Habitat 9045) better adapted to climate change and with higher biodiversity

Monitoring for adaptive management and knowhow dissemination

- The lack of landscape analysis and mapping [30] in the initial phase of the project have limited a cost-effective use of the available economic resources for biomass management in such a large landscape area.
- The project has defined and measured the following impact indicators:
    - Efficiency and implementation of biomass management plans:
        - progress according to planed interventions;
        - impact on biodiversity (targeted habitats and species);
        - effect of the different management practices on the structure, composition, productivity of the managed and restored plant communities.
    - Biodiversity conservation indicators:
        - evolution of species populations from targeted birds, butterflies, rabbit, and flora;
        - conservation status of restored and managed priority forest (e.g. *Pinus nigra; P. halepensis; Taxus baccata*) and grassland habitats under the HD;
        - connectivity among restored/managed stands of priority habitats.
- Monitoring plots were affected by new fire events (required changes in re-stablishing new monitoring plots), delays in the implementation of grazing activities in several grazing management units, and difficulties in the assumption of monitoring responsibilities by the different stakeholders.
- The limited timeframe of the project implementation prevents the obtaining of significant and conclusive monitoring results, being necessary at least 5 years after the end of the project to carry out a sufficient analysis.

[30] e.g. identification of the most suitable mosaic-like structure with the number and landscape distribution of dense forest/shrub areas to be cleared; the required connectivity between areas from similar habitat types to maximize biodiversity; the mapping and zonation of the different conservation values, in terms of habitats, fauna and flora species, to fine-tune the “where” and the “what” in terms of biomass management interventions.

ANNEX 2

The EU Green Deal Policy Areas

The EU Green Deal policy areas include relevant sections directly or indirectly addressing wildfire prevention needs.

EU Biodiversity Strategy for 2030

The Commission will strengthen the **European Business for Biodiversity movement**, creating incentives for the take-up of **nature-based solutions and innovation on nature restoration with business and employment opportunities** in various sectors. Under **Invest EU**, a dedicated natural-capital and circular-economy initiative will be established to **mobilise at least €10 billion over the next 10 years, based on public/private blended finance**. The Commission has developed an EU Taxonomy with a list of environmentally and climatically sustainable economic activities that contribute to protecting and restoring biodiversity and ecosystems. This will be further supported by a **Renewed Sustainable Finance Strategy** which will help ensure that the financial system contributes to mitigating existing and future risks to biodiversity, and better reflect how biodiversity loss affects companies' profitability and long-term prospects. The Commission will further promote **tax systems and pricing that reflect environmental costs**, including biodiversity loss to help shift the tax burden from labour to pollution, resource use and other environmental externalities.

Nature Restoration Law

The **Nature Restoration Law** aims to improve good conditions and **restore degraded European habitats by 2050** (intermediate milestones of 30% by 2030, and 60% by 2040), from agriculture land and seas to forests and urban environments. As part of the Nature Restoration Law, the EU Biodiversity Strategy sets outs a **pledge to plant at least 3 billion additional trees by 2030**, in full respect of ecological principles, with the aim to increasing the EU forest cover and, with that, the EU land carbon sink and stock.

Legally binding instruments for ecosystem restoration are proposed, covering in particular those ecosystems **with the most potential to capture and store carbon and to prevent and reduce the impact of natural disasters, such as wildfires**. The Law includes an Annex with examples of restoration measures addressing fire-risk reduction needs, such as:

- Enhance forest diversity by creating mosaics of non-forest habitats such as open patches of grassland or heathland, ponds or rocky areas.
- Introduce high-diversity landscape features (green infrastructures) in arable land and intensively used grassland, such as buffer strips, field margins with native flowers, hedgerows, trees, small forests, terrace walls, ponds, habitat corridors and stepping-stones, etc.
- Increase the agricultural area subject to agro-ecological management approaches such as organic agriculture or agro-forestry, multi-cropping and crop rotation, integrated pest and nutrient management.
- Reduce grazing intensity or mowing regimes on grasslands where relevant and re-establish extensive grazing with domestic livestock and extensive mowing regimes where they were abandoned.

New EU Forest Strategy for 2030

It recognises the central role of forests, and the contribution of foresters and the entire forest-based value chain for achieving **by 2030 at least 55% of EU's GHG emissions reduction by 2030, and a sustainable and climate-neutral forest bioeconomy by 2050**, while **ensuring that all ecosystems are restored, resilient, adequately protected, and sustainably managed** considering the multifunctionality, the variety of forests and the three inter-dependent pillars of sustainability.

Under its Component 1, the Strategy supports:

- the **sustainable use of wood-based resources for bioenergy** if biomass is produced sustainably and used efficiently, taking into account the Union's carbon sink and biodiversity objectives as well as the overall availability of wood within sustainability boundaries in 2030 perspective;

- the **empowerment of public and private people for sustainable forest-based bioeconomy, through Pact for Skills** (adapting education and training for a sustainable forest bioeconomy), and the European Social Fund Plus (ESF+) to enhance employment and entrepreneurship valorising the sustainable use of forest products and services.

Under its Component 2, the Strategy supports:

- Forest restoration and sustainable forest management for climate adaptation and **forest resilience against** climate change impacts, **wildfires**, pests, diseases and create other positive spill over effects to environmental risks, (e.g. **integrated landscape fire management systems**; the creation or maintenance at stand and landscape level of genetically and functionally diverse, mixed-species forests; the use of well-adapted genetic resources and ecosystem-based approaches to forest restoration and management).
- **Financial incentives for forest owners and managers** for improving the quantity and quality of EU forests. Options and knowhow on **public and private markets** for the provision of **forest ecosystem services** are being **explored with EU research support** and a **LIFE preparatory action [31]**. The Forest Strategy provides the following **examples of public and private payment schemes** for ecosystem services:

    - The **Croatian tax** for all requires natural and legal persons conducting economic activities and an income over 400.000 euro to pay 0.0265% of their total revenue for benefiting from forest ecosystem services and through a special national fund this is distributed to forest owners according to the forest area in accordance to the forest management plans.
    - The **French Label Bas Carbon scheme** allows private and public actions to voluntary offset their greenhouse gas emissions by financially supporting environmental services (low-carbon actions) in forest management in France.
    - In 2019 **Portugal** launched a **pilot program to pay forest ecosystem services in two natural parks** covering the re-naturalisation of eucalyptus plantations, planting autochthonous species and the development of non-wood products.
    - As part of the **green heart of cork initiative** developed by WWF Mediterranean, a private drinks company paid forest landowners to protect a water aquifer that was used for their production process.
    - The **Finnish Metso Programme** pays private forest owners to set aside their land for biodiversity; the amounts provided depend on the value of the land and for how long the forest will be set aside.

Member States are specifically **encouraged to set up a payment scheme** for ecosystem services for forest owners and managers to cover for costs and income foregone similarly to exemplary national schemes such as the Finnish METSO programme. Member States are also **encouraged to accelerate the roll out of carbon farming practices**, for instance via eco-schemes on agroforestry or rural development interventions to cover biodiversity-friendly re- and afforestation investments, agroforestry and other non-productive investments for environment- and climate-related objectives.

Common Agricultural Policy (CAP)

It provides financial support for forests and forest management, namely for adaptation and resilience to climate-related risks, through the national Rural Development Programs. In 2014-2020, the CAP forestry measures committed EUR 6,7 billion in support of EU policy targets, mostly for afforestation (27%), prevention of forests fires and disasters (24%) and investments on resilience, ecological and social functions (19%). The new CAP (for 2023-2027) offers increased flexibility to design forest-related interventions ensuring a synergetic approach between the European Green Deal, the national forest policies, and the EU environment and climate acquis, in particular the set-up of **ecosystem services' payment schemes in an action plan for both carbon farming and carbon removal certification, to be adopted by the end of 2021**.

[31] https://innoforest.eu/; https://sincereforests.eu/

The EU's Rural Development policy (2nd CAP pillar). It aims to achieve the following strategic objectives:

- fostering the competitiveness of agriculture;
- ensuring the sustainable management of natural resources, and climate action;
- achieving a **balanced territorial development of rural economies and communities**, including the creation and maintenance of employment. Its financing instrument (**EU Agriculture Fund for Rural Development - EAFRD**) has a budget of €95.5 billion for 2021-27 to assist farmers and inhabitants to increase sustainability and competitiveness, through actions to improve the attractiveness of rural areas both for living and for job creation; support for innovation and diversification of on-farm activities; actions aimed at restoring, preserving and enhancing ecosystems related to agriculture and forestry, with a positive impact on biodiversity, soil, water and air; among others.

Farm to Fork Strategy

It addresses comprehensively the challenges of sustainable food systems. In the framework of the Farm to Fork Strategy, the EC is committed to implement the **EU Carbon Farming Initiative under the Climate Pact** aimed at the «generation of tradable carbon certificates» to be sold in the European Trading System (ETS). The initiative will promote a **new green business model around carbon sequestration by farmers and foresters** which provides them with a new source of income to decarbonize commodity chains, **contributing to the EU climate neutrality objective.** This should be rewarded, either via the common agricultural policy (CAP) or other public or private initiatives (carbon markets). The New EU Forestry Strategy, approved in July 2021, clarified that forest investments will be included in the Carbon Farming Initiative.

The Commission also offers financial support for **pilot initiatives on carbon farming through the LIFE Program and the European Rural Development Fund [32]**. Private initiatives can finance carbon farming schemes through the generation of **carbon certificates** that can be traded in the markets. Beneficiaries would receive payments linked to the results delivered, ensuring a more targeted use of the relevant funds towards the intended climate or environmental objective, such as the provision of ecosystem services. The Commission is furthermore developing a **regulatory framework for certifying carbon removals**, as announced in the **Circular Economy Action Plan.**

The new '**eco-schemes**' will offer a major stream of funding to boost sustainable practices, such as precision agriculture, agro-ecology (including organic farming), carbon farming and agro-forestry. Member States and the Commission will have to ensure that they are appropriately resourced and implemented in the CAP Strategic Plans.

In the framework of the **circular bio-based economy**, the Commission will speed-up market adoption of **environmentally-sound energy efficient solutions** in the agriculture and food sectors, such as anaerobic digesters for biogas production from agriculture and livestock waste and residues; combined use of forest and agriculture biomass waste for bioenergy; placing solar panels in farmhouses and barns. To further support **sustainable forest-based bioeconomy** for a climate neutral future, the strategy proposes measures for **innovation and promotion of new materials and products to replace fossil-based counterparts** as well as for **boosting the non-wood forest economy, including ecotourism.**

European Climate Law

It writes into law the goal set out in the European Green Deal for Europe's economy and society to become climate-neutral by 2050: a legally binding target of **net zero greenhouse gas emissions by 2050.** The road to a climate neutral economy includes the strategic priority of "Reaping the full benefits of bioeconomy and creating essential natural carbon sinks by developing more sustainable land-use and agriculture". Forests and forest products will play a crucial role in reaching the ambitious net removal target for the Union of -310 million tonnes of CO2-eq as set out in the proposal for a **revised Regulation on Land Use, Land Use Change and Forestry (LULUCF).**

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[32] More details on funding opportunities for carbon farming can be found in the Communication "Sustainable Carbon Cycles" and the accompanying Staff Working Document "Carbon Farming".

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MED ITER RE3

Restoring the Resilience of Mediterranean Landscapes to Reduce GHG Emissions from Wildfires

A project aiming to reduce fire-related GHG emissions in three target landscapes in Greece, Montenegro and France, through the application of Forest Landscape Restoration (FLR) principles for fire-smart restoration of landscapes.

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