Building Fire-smart Landscapes in the Mediterranean Region: Problem Analysis and Selected Best Practices

MED ITER RE3

Supported by:

Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag

European Climate Initiative EUKI

OIKOS

Imprint

Authors

Pedro Regato (independent consultant, Spain)
Lilian Car (Parc Naturel Régional du Luberon, France)
Enes Drešković (independent consultant, Montenegro)
Christina Georgatou (Manag. Unit of Samaria NP and the Protected Areas of Western Crete - NECCA, Greece)
Dany Ghosn (CIHEAM - Mediterranean Agronomic Institute of Chania, Greece)
Ranko Kankaraš (Ministry of Agriculture, Forestry and Water Management, Montenegro)
Alessio Martinoli (Istituto Oikos ETS, Italy)
Aleksandar Mijović (Protection of Natural and Cultural Heritage and Sustainable Development, Montenegro)
Ilektra Remoundou (CIHEAM - Mediterranean Agronomic Institute of Chania, Greece)
Aline Salvaudon (Parc Naturel Régional du Luberon, France)
Rémi Savazzi (Office national des forêts - ONF, France)
Azra Vuković (Green Home, Montenegro)

Layout

Erika Stellini (Istituto Oikos ETS)

Cover photo

Pedro Regato

Recommended citation

Pedro Regato, Lilian Car, Enes Drešković, Christina Georgatou, Dany Ghosn, Ranko Kankaraš, Alessio Martinoli, Aleksander Mijović, Ilektra Remoundou, Aline Salvaudon, Azra Vuković (2023). Building fire-smart landscapes in the Mediterranean region: problem analysis and selected best practices. Project "MediterRE3 (REstoring REsilience of Mediterranean landscapes to REduce GHG emissions from wildfires)". Istituto Oikos ETS (Milan, Italy), Parc naturel régional du Luberon (Apt, France), Green Home (Podgorica, Montenegro), CIHEAM-MAICh (Chanià, Greece). Technical Report.

Supported by:

Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag

European Climate Initiative EUKI

This project is part of the European Climate Initiative (EUKI). EUKI is a project financing instrument by the German Federal Ministry for Economic Affairs and Climate Action (BMWK). The EUKI call for project ideas is implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. It is the overarching goal of the EUKI to foster climate cooperation within the European Union (EU) in order to mitigate greenhouse gas emissions.

OIKOS

Parc naturel régional du Luberon

unesco Réserve de biosphère Luberon-Lure

CIHEAM MAI CHANIA

GREEN HOME act green

Table of content

1. **The problem** 5
   1.1. Wildfires in Southern Europe 5
   1.2. The landscape fuel load: land use / land cover (LU/LC) changes in the past decades 7
   1.3. Climate change trends and fire dynamics 8

2. **The Challenge** 10
   2.1. Wildfire management barriers 11
   2.2. Landscape planning barriers 11
   2.3. Economic barriers 12
   2.4. Know-how transfer barriers 13
   2.5. Governance barriers 14

3. **The Solution: Integrated fire-smart landscape planning and implementation principles** 15
   3.1. Participatory landscape planning of fire-smart LU/LC types, management practices and their landscape distribution pattern 17
      3.1.1. Some exaples of fire-smart landscape planning methodologies in the Mediterranean countries 20
   3.2. Enabling multi-stakeholders to be actively involved in the implementation of fire-smart landscape plans through 360º capacity development interventions and innovative governance mechanisms 24
      3.2.1. Multi stakeholders involvement 25
      3.2.2. Innovative governance arrangements 30
      3.2.3. Capacity development 32
   3.3. Sustainable return on fire-risk reduction investments, ensuring the provision of ecological, social and economic benefits 33
   3.4. Prioritization of locally adapted, cross-sectoral and innovative fire-risk reduction intervention measures 39
      3.4.1. Prodictive firebrack areas throught agroforestry 39
      3.4.2. Forest thinning favorive multipourpouse interactivity 40
      3.4.3. Selective biomass harvesting through thinning in abandoned coppice forests and secondary dense forest stands, favouring tree species diversification 40
      3.4.4. Mechanical clearing or prescribed burning of shrubland patches and shrubby understorey layer in open forest stands, combined with controlled grazing 41
      3.4.5. Multipurpose biomass processing and marketing for bioenergy and compost 42
      3.4.6. Controlled grazing in firebreak areas 44
      3.4.7. Biomass clearing around houses, settlements, and infrastructures 44
      3.4.8. Sustainable agroecological production systems 47
      3.4.9. Active ecological restoration interventions in degraded landscape areas with high fire risk 47
      3.4.10. Incentives to repopulate and reuse abandoned rural territories with fire-smart business models 48
   3.5. Enhance and restore the species diversity, functionality, fire resilience and ecosystem services of the natural and seminatural habitats in the landscape 49
      3.5.1. Conservation and connectivity restoration among old-growth forest stands 49
      3.5.2. Diversification of species in forest stands 50
      3.5.3. Changes in the vegetation structure and species composition to speed up natural succession towards mature stages 50
      3.5.4. Habitat diversification 50
      3.5.5. Management of post-fire snags and woody debris 50
   3.6. Long-term adaptive monitoring and financing mechanisms for fire-smart landscapes 51
      3.6.1. Long-term financing 51
      3.6.2. Enabling policy framework 53
         3.6.2.1. National and sub-national level 53
         3.6.2.2. International Level 54
         3.6.2.3. Long-term adaptive monitoring 60

4. **Case Studies with Best Practices in Building Landscape Resilience to Wildfires** **65**

4.1. Integrated landscape planning of cross-sectoral climate- and fire-resilient interventions: Mosaico Extremadura Project **65**

4.1.1. Project description **66**

4.1.2. Fire-Risk Reduction objective **66**

4.1.3. Climate Change mitigation and adaptation value **66**

4.1.4. Participatory landscape planning of wildfire-risks and prioritization of climate-smart interventions **66**

4.1.5. Governance arrangements and multi-stakeholder participation **69**

4.1.6. Capacity development, participatory action research and innovation **70**

4.1.7. Enabling policy framework **70**

4.1.8. Ecosystems' resilience restoration (diversity, functionality, post-fire recovery capacity) **70**

4.1.9. Cross-sectoral integration and complementarity of climate-smart biomass management interventions providing multiple benefits **70**

4.1.10. Financing and cost-effectiveness **71**

4.1.11. Sustainable return on investment (multiple benefits) **71**

4.1.11.1. Economic return **71**

4.1.11.2. Social return **71**

4.1.11.3. Environmental return **71**

4.1.12. Monitoring for adaptive management and knowhow dissemination **71**

4.1.13. References **72**

4.2. The Mediterranean Mosaics Initiative: Regaining landscape resilience to climate risks through Forest Landscape Restoration planning and implementation in the Shouf-West Beqaa Landscape (Lebanon) **72**

4.2.1. Project description **72**

4.2.2. Fire-Risk Reduction objective **73**

4.2.3. Climate Change mitigation value **74**

4.2.4. Participatory landscape planning of wildfire-risks and prioritization of climate-smart interventions **74**

4.2.5. Governance arrangements and multi-stakeholder participation **75**

4.2.6. Capacity development, participatory action research and innovation **76**

4.2.7. Enabling policy framework **77**

4.2.8. Ecosystems' resilience restoration (diversity, functionality, post-fire recovery capacity) **77**

4.2.9. Cross-sectoral integration and complementarity of climate-smart biomass management interventions providing multiple benefits **77**

4.2.10. Financing and cost-effectiveness **77**

4.2.11. Sustainable return on investment (multiple benefits) **79**

4.2.11.1. Economic return. **79**

4.2.11.2. Social return. **79**

4.2.11.3. Environmental return **79**

4.2.12. Monitoring for adaptive management and knowhow dissemination **79**

4.2.13. References **80**

4.3. RAPCA: Controlled livestock management in firebreak areas, complementary to forestry prevention measures in the Region of Andalusia (Spain) **81**

4.3.1. Scheme description **81**

4.3.2. Fire-Risk Reduction objective **82**

4.3.3. Climate Change mitigation value **82**

4.3.4. Participatory landscape planning of wildfire-risks and prioritization of climate-smart interventions **82**

4.3.5. Governance arrangements and multi-stakeholder participation **82**

4.3.6. Capacity development, participatory action research and innovation **83**

4.3.7. Enabling policy framework **84**

4.3.8. Ecosystems' resilience restoration (diversity, functionality, post-fire recovery capacity) **84**

4.3.9. Cross-sectoral integration and complementarity of climate-smart biomass management interventions providing multiple benefits **84**

4.3.10. Financing and cost-effectiveness 84
4.3.11. Sustainable return on investment (multiple benefits) 85
4.3.11.1. Economic return 85
4.3.11.2. Social return 85
4.3.11.3. Environmental return 85
4.3.12. Monitoring for adaptive management and knowhow dissemination 85
4.3.13. References 85
4.4. Biomass management for fire-risk reduction through integrated forestry and livestock grazing interventions: LIFE Montserrat 86
4.4.1. Project description 86
4.4.2. Fire-Risk Reduction objective 87
4.4.3. Climate Change mitigation value 87
4.4.4. Participatory landscape planning of wildfire-risks and prioritization of climate-smart interventions 87
4.4.5. Governance arrangements and multi-stakeholder participation 87
4.4.6. Capacity development, participatory action research and innovation 88
4.4.7. Enabling policy framework 88
4.4.8. Ecosystems' resilience restoration (diversity, functionality, post-fire recovery capacity) 89
4.4.9. Cross-sectoral integration and complementarity of climate-smart biomass management interventions providing multiple benefits 89
4.4.10. Financing and cost-effectiveness 89
4.4.11. Sustainable return on investment (multiple benefits) 89
4.4.11.1. Economic return 89
4.4.11.2. Social return 89
4.4.11.3. Environmental return 91
4.4.12. Monitoring for adaptive management and knowhow dissemination 91
4.4.13. References 92
4.5. EU Funded Regional Projects relevant for fire-smart landscape planning 93
4.5.1. Firelogue (2021-2025) 93
4.5.2. FIRE-RES (2021-2025) 93
4.5.3. FirEUrisk (2021-2025) 94
4.5.4. InnoForESt Project (2017-2020) 94
4.5.5. PREVAIL - Prevention action increases large fire response preparedness (2019-2021) 96
4.5.6. RESONATE – Resilient Forests for Society (2021-2024) 96
4.5.7. SILVANUS (2021-2025) 97
4.5.8. TREEADS – A Holistic Fire Management Ecosystem for Prevention, Detection and Restoration of Environmental Disasters (2021-2025) 97

5. Recommendations for the Fire-smart Landscape Planning Process **98**
5.1. Assess the landscape boundaries 98
5.2. Establish multi-stakeholder and multi-disciplinary landscape planning teams and governance mechanisms 98
5.3. Root-cause analysis of wildfire impacts in the landscape 99
5.4. 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) 99

Bibliography **102**

List of abbreviation **107**

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 [1]. 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 [2], the highest level since 2007 [3].

The very high frequency and intensity of extreme weather events resulting from the acceleration of climate change in recent years have caused important changes in the behaviour of wildfires. During the 2022 fire season in southern Europe, fire experts described some large scale wildfires as "sixth generation fires [4]", in which the energy they release is such that they have the ability to change the weather around them, forming clouds known as *pyrocumulonimbus* 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 (i) very high fuel load accumulation in the landscape (extensive, very uninhabited territories with a continuum of highly dense and dry plant biomass with high levels of desiccation and defoliation due to substantial increases in temperatures and declines in precipitation causing intense evapotranspiration and soil water shortage) and (ii) fire-prone weather conditions exacerbated by climate change (the intensification of extreme weather events with long and repetitive periods of drought, heatwaves, and strong winds), is giving rise to a "perfect storm" in which wildfires become completely uncontrollable. Moreover, repeated 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 [5]. This feedback supposedly favours shrubland persistence preventing evolution towards mature successional stages, which may be strengthened in the future by predicted increased aridity, with changes in the climate envelopes of natural forest habitats towards more xeric potential forest ecosystems or woody formations of a shrubby nature.

---

[1] https://atmosphere.copernicus.eu/europes-summer-wildfire-emissions-highest-15-years

[2] Data from the CAMS Global Fire Assimilation System (GFAS).

[3] https://atmosphere.copernicus.eu/europes-summer-wildfire-emissions-highest-15-years

[4] Since a rural exodus occurred in many parts of the world in the mid-20th century and agricultural uses were abandoned, fires have been evolving:

First generation: Fires gain speed in farming areas that were no longer being used.

Second generation: The vegetation recolonizes abandoned farmlands, with a continuous cover of unmanaged, very dense vegetation through which the fire can spread rapidly. As a result, the first measures against fires – creating firebreaks – are applied.

Third generation: A landscape dichotomy arises. The population is concentrated in the metropolitan areas while rural areas empty. This causes the fires to gain intensity and consume the entire vegetation mass in which they start. Fire-fighting devices increase.

Fourth generation: In the 90s there was a boom in second homes in rural areas in countries like those in the Mediterranean region. Wildland-urban interface increases in areas where the rural environment is abandoned and increases the frequency of people who carry out risky activities (e.g. barbecues, smoking, lighting campfires, use of machinery that generates sparks), and the presence of infrastructures (e.g. electric lines, roads) that represent a fire ignition cause. They are very voracious and dangerous fires.

Fifth generation: They occur when there is also simultaneity: several fires break out at the same time, causing the collapse of services. And from there we get to the **sixth generation**, in which climate change has become the main engine of devastating fires that feed on themselves and expand thanks to the generation of their own climatic conditions conducive to fires, in territories with a very high accumulation of biomass. You can only carry out a defensive strategy, that is, establish priorities and decide what you want to save. The only way to combat it, experts say, is prevention.

[5] Baudena, M. et al. 2019. Increased aridity drives post-fire recovery of Mediterranean forests towards open shrublands. New Phytologist (2020) 225: 1500–1515.

Recent research analyzed the resilience of Europe's forests to disturbances (e.g. windthrow, bark beetle outbreaks or wildfire) using satellite-based disturbance and recovery indicators, founding 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 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 [6]. The climate change exacerbation of the frequency and intensity of wildfires, together with the increase in fuel availability and continuity caused by poor management and rural abandonment, and the simplification of many forest areas with little species diversity and major absence of re-sprouting woody species, have led to a significant reduction of post-fire recovery capacity in many forest areas of the Euro-Mediterranean countries.

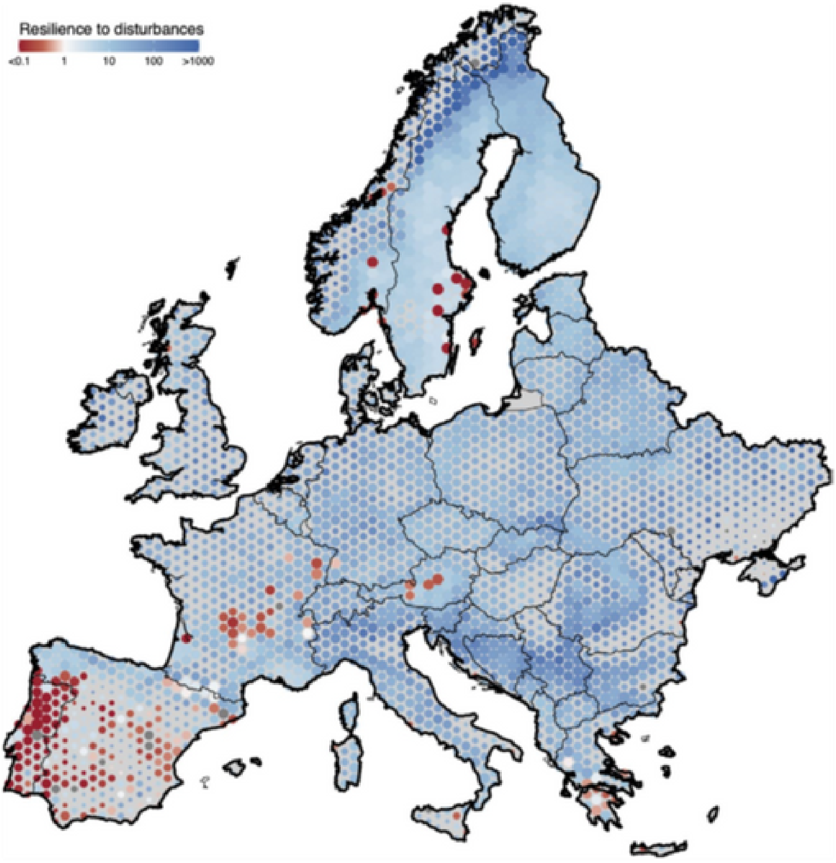


Figure 1. The Resilience of Europe's Forest Ecosystems to Disturbance [7]

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 business models around goods and services linked to fire-smart landscape practices. This will make it possible to face major changes in terms of fire-prone LU/LC types with absence or poor management and in terms of their distribution pattern in the landscape, so that the high fuel load of the landscape - accumulated in the form of extensive fire-prone scrublands and secondary forests resulting from the abandonment of agricultural and pastures and in the form of extensive fire-prone pine and eucalyptus plantations - can be managed sustainably.

[6] Senf, C. 2021. Post-disturbance canopy recovery and the resilience of Europe's forests. Global Ecol Biogeogr. 2022;31:25–36.
[7] Ibid.

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 LU/LC changes in the rural areas of the European Mediterranean countries:

A **migratory boom** to the big cities since the 1960s has given rise to a strong depopulation of large rural areas in which climatic, soil and landform constraints resulted in subsistence agricultural systems incompatible with an acceptable socioeconomic development for a growing population. The abandonment of these territories led to the stagnation of abandoned coppiced forests and the colonization of the unused cropland and pastureland by natural vegetation - different types of secondary forests with the predominance of Aleppo, Brutia and Maritime pine species and maquis in the coastal regions, and several conifer and broadleaf tree species and shrubs in inland areas. These abandoned and secondary woody ecosystems are currently in intermediary development stages with a very high accumulation of dry biomass that continuously occupy large areas of the landscape. From an agropastoral matrix with low plant biomass and scattered woody vegetation patches, the landscape changed to a matrix of dense woody vegetation cover with a high density of continuous biomass, and scattered patches of farmland plots.

The scarce remaining rural population 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 maintain 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.

Medium- to large-scale public (and private) forestation plans, with a major soil and watershed protection objective (but also commercial), were launched in numerous territories affected by rural depopulation (e.g. inland areas of Spain, Turkey, and the Maghreb countries; southern France), mainly between the 60s and the 90s of the 20th century. Plantations focused on fast growing species – mainly pine species but also eucalyptus – and further increased the extent of the landscape matrix with dense woody vegetation cover. The absence of a business plan for many of the plantations and lack of public funds for their management (e.g. to cover the costs of periodic thinning) contributed to the accumulation of dry biomass and to a deficient sanitary state that favoured by the increase of drought and high temperatures due to climate change, has led to dieback events in different areas of the Mediterranean region. Likewise, the use of resinous and non-sprouting species (obligate seeders), such as pines, has favoured the rapid spread and intensification of fire events, with an increase in post-fire regeneration and erosion problems. In the specific case of Portugal (and some regions of Spain), large-scale industrial eucalyptus and pine plantations for pulp production contributed to sharply modify mosaic-like agro-silvo-pastoral landscapes into homogeneous woody landscapes, which have turned out to be extremely sensitive to the devastating latest generation fires, with enormous socio-economic and ecological impacts.

Development of the recreational potential of rural areas with high landscape, cultural, and biodiversity value, with the construction of new buildings, roads and power lines in densely vegetated areas, and the introduction of new businesses (e.g. touristic houses, eco-tourism enterprises, nature trails) and human activities (e.g. hiking, camping, quad and 4-wheel driving, mountain biking, hunting, wildlife observation tours, mushrooms' harvesting) in densely vegetated natural areas. This has greatly increased the wildland-urban interface and the seasonal presence of population from outside the territory and new fire-risk activities causing great socio-economic and ecological losses. 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 (e.g. smoking, making campfires and barbecues, using machinery and vehicles that generate sparks, dumping waste such as glass that can start fires), 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 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 the new dynamics of sixth-generation wildfires are: (i) the 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; (ii) the limited economic incentives for land users to help mainstream fire risk reduction into natural resources management and to support the adoption of new economic models for ecologically sound and economically viable fire-resilient businesses that revitalize rural population; (iii) the limited public and private funding for innovation research; and (iv) the 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 continues to negatively affect European forests, particularly but not only in landscapes dominated by mono-specific and even-aged forest plantations, as well as by secondary pine forests, stagnated coppiced forests and dense shrublands that have resulted from the abandonment of past agropastoral uses and fire events. Climate change has also brought to light previously hidden vulnerabilities aggravating other destructive pressures such as pests, pollution and diseases, and it affects forest fire regimes, leading to conditions under which the extent and intensity of forest fires in the EU will increase in the next years [8].

Most climate models predict for the Euro-Mediterranean region (i) 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 (ii) 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.

[8] Costa, H., de Rigo, D., Liberta, G., Houston Durrant, T., San-Miguel-Ayanz, J. (2020) European wildfire danger and vulnerability in a changing climate: towards integrating risk dimensions. JRC PESETA IV project – Task 19. Luxembourg: Publication Office of the European Union.

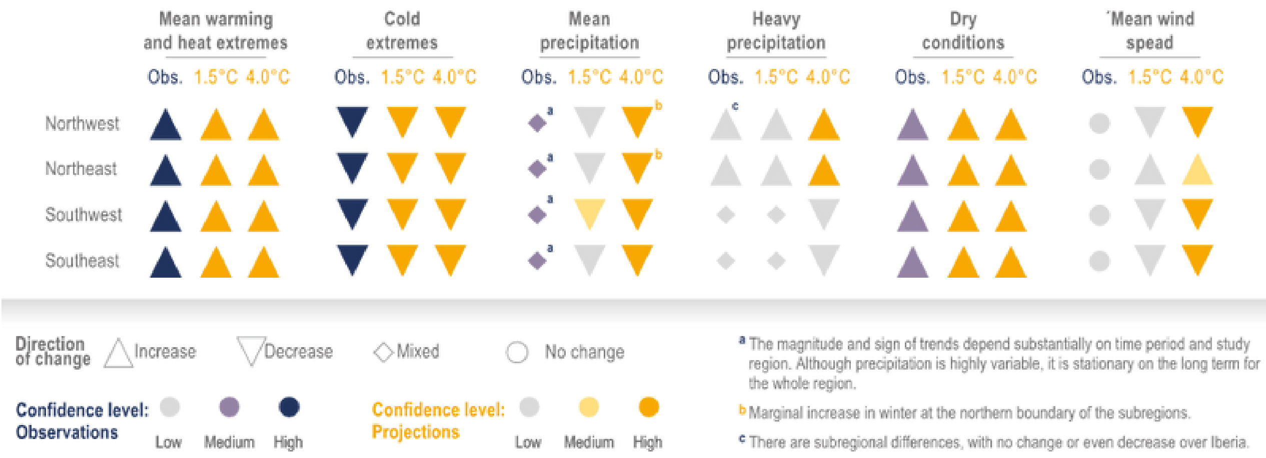


Figure 2. Observed and projected (at global warming levels of 1.5°C and 3°C) direction of change of climate drivers and confidence levels for Mediterranean land sub-regions [9]

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 biomass as a result of the abandonment and secondary colonization of pastures and agricultural fields by dense natural vegetation, the stagnation of abandoned coppiced land with high density of water-stressed stems, 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), and the strong desiccation of the abundant plant biomass of the landscape (high evapotranspiration and minimal input to roots in dry soils), generates 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, under a heatwave situation 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.

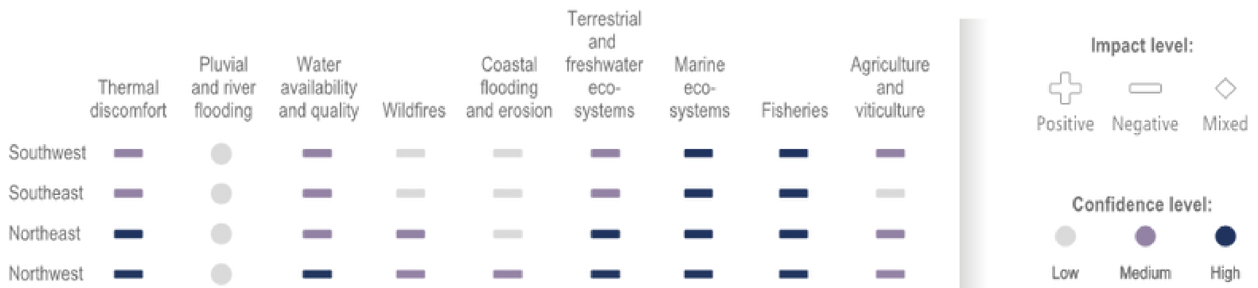


Figure 3. Attribution of observed impacts of climate change in the Mediterranean region [10]

[9] Ali, E., W. Cramer, J. Carnicer, E. Georgopoulou, N.J.M. Hilmi, G. Le Cozannet, and P. Lionello, 2022: Cross-Chapter Paper 4: Mediterranean Region. In: *Climate Change 2022: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C.Roberts, M.Tignor, E.S.Poloczanska, K.Mintenbeck, A.Alegría, M.Craig, S.Langsdorf, S.Löschke, V.Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 2233–2272, doi:10.1017/9781009325844.021.
[10] Ibid.

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 or prevention; readiness; response or 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 - hard to extinguish even with the most sophisticated equipment - stress that the best way to deal with them is to invest most efforts on prevention or risk reduction, focusing on integrated landscape planning, identifying land use types and a landscape distribution pattern that reduces fire risk, and proposing/applying fire-smart forest, pastoral and agriculture management and restoration interventions around the sustainable and integrated use of the landscape biomass for fuel load accumulation within acceptable levels. This helps reduce the size of potential fires and facilitate an effective response.

Researchers from the region have modelled the effect of fire-resilient LU/LC planning and fuel load management in forest landscapes - with special attention to the wildland-urban interface - on the reduction of the area burned by wildfires [11], [12], [13]. Likewise, based on experimental research results, prevention measures have already been tested and introduced in the different countries of the region, with special attention to the use of grazing as a complementary fire management measure to control the growth of plant biomass in firebreak areas, the cutting of plant biomass around infrastructures (houses, roads and power lines), and the prescribed burning of herbs and shrubs in hotspot areas of the landscape with high fire risk. Only in a few cases has the planning of fire-smart landscapes been applied to specific landscapes - either based on modelling and/or participatory landscape mapping processes with the selection of priority high-fire risk areas and priority fire-smart LUs and management measures -, as is the case of the project “LIFE Montserrat” in Catalonia (Spain) [14], the project "Mediterranean Mosaics" in the Shouf-West Beqaa landscape of Mount Lebanon [15], and the "Mosaico Extremadura" project in the Sierra de Gata landscape of the extreme central-western part of Spain [16].

---

[11] Bertomeu, M.; Pineda, J.; Pulido, F. Managing Wildfire Risk in Mosaic Landscapes: A Case Study of the Upper Gata River Catchment in Sierra de Gata, Spain. *Land* **2022**, 11, 465. https://doi.org/10.3390/ land11040465.
[12] Alcasena, F.J. 2019. Wildfire risk management in southern European landscapes: Towards a long-term comprehensive strategy. PhD, several papers.
[13] F. Moreira, O. Viedma, M. Arianoutsou, T. Curt, N. Koutsias, et al. 2011. Landscape - wildfire interactions in southern Europe: Implications for landscape management. Journal of Environmental Management, Elsevier, 2011, 92, p. 2389 - p. 2402. hal-00653523.
[14] https://lifemontserrat.eu/
[15] Hani, N., Pagliani, M. & Regato, P. Eds. 2020. Forest and Landscape Restoration Guidelines. Regaining Landscape Resilience, Ecological Functionality and Human Well-being in the Shouf-West Beqaa Landscape, Lebanon.
[16] Bertomeu, M.; Pineda, J.; Pulido, F. Managing Wildfire Risk in Mosaic Landscapes: A Case Study of the Upper Gata River Catchment in Sierra de Gata, Spain. *Land* **2022**, 11, 465. https://doi.org/10.3390/ land11040465.

2.1. Wildfire management barriers

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

Despite knowing that the accumulation and continuous distribution of plant biomass in the landscape is one of the determining factors of devastating fires, the strategies and budgets for fire management in the countries of the region are still focusing on wildfire extinction. 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.

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

Wildfire management strategies and operational mechanisms are part of the forest policies, legislation, and budget. However, the risk of fire is in many cases linked to other sectors - agricultural, pastoral, infrastructure development, urban planning, waste management, industrial uses, tourism - both in terms of maladaptive management practices, and in terms of LU/LC distribution pattern and interfaces with forestland in the landscape.

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 (i) forces local actors to plan and define the type of fire-resilient uses and management practices that are suitable for the different parts of the landscape, (ii) increases the percentage of the fire management budget allocated to prevention measures and distributes it to all the concerned sectoral budgets, and (iii) establishes harmonized cross-sectoral regulations (and effective cooperation mechanism among all concerned sectors of the public administration), that establish fire resilient land uses and management measures, and economic incentives that favour green businesses linked to fire risk reduction interventions and help absorb the costs of sustainable biomass management interventions in the landscape; (iv) 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 guide their effective implementation.

2.2. Landscape planning barriers

- Landscapes highly transformed by public and private afforestation plans and/or by the expansion of secondary dense woody vegetation as a result of rural abandonment, in which the accumulation of biomass is very high, widespread and continuous, lack comprehensive and financially supported fuel load reduction interventions, at large-scale and in the long-term, to reduce fire risk below a threshold that prevents devastating fires.

There are extensive landscapes in the countries of the Euro-Mediterranean region in which drastic changes would be necessary (i.e. cutting down most of the existing pine and/or eucalyptus plantations in few years and restoring the mosaic structure of the landscape with smaller patches of resilient LU/LC) to avoid the risk of sixth-generation fires in the forthcoming years. These imply difficult political decisions due to:

- the need to undertake policy reforms banning or limiting the extension of large-scale fire-prone tree plantations and regulating their distribution in the landscape, against the immediate economic interest for enterprises and small private owners, and promoting landscape multifunctionality with subsidies to support the conversion towards alternative resilient agroforestry uses and cover the economic losses generated to local owners and enterprises until the new uses bring benefits.

- the need to solve trade-offs and reach agreements in a very short time among a large number of landowners with different interests and capacities.
- the enormous public-private incentives (e.g. green value chains, payment schemes for environmental services such as carbon credits and water, Green Deal public incentives, corporate responsible programs) necessary to promote innovative socio-economic development to increase active population in abandoned rural landscapes, and to monetize the management of huge amounts of biomass in a short time and generate economic return.

In the case of the "*Mosaico Extremadura*" initiative, launched as a response to the 2015 devastating 8,000 ha fire event in Sierra de Gata (central-western Spain) that occurred in few days with an economic loss of 52 million €, a participatory fire-smart landscape planning exercise was carried out with the identification and landscape distribution of fire-resilient LU/LC types and management practices, to convert a highly flammable landscape dominated by pine plantations and dense shrublands into a mosaic-like fire-resilient one. However, the size of the required interventions, the difficult negotiations and establishment of governance mechanisms with the different land users and owners, and the high cost of biomass management and LU conversion, are too high to be able to act quickly enough to prevent further devastating fire events, like the one affecting the area in summer 2022.

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 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.

2.3. Economic barriers

- 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 LU investments 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)? Does the forest owner, in collaboration with shepherds, choose to improve forest health conditions, diversify productivity (e.g. wood, mushrooms and livestock), reduce fire risk, store carbon, avoid erosion, or some combination? 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 PREVAIL Project, funded by the EU Civil Protection Mechanism Programme, has analysed and identified lessons learned on "smart-solutions" **[17]** 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.

---

[17] Ascoli, D.; S. Oggioni; A. Barbati, A, Tomao; M. Colonico; P. Corona; F. Giannino; M. Moreno; G. Xanthopoulos; K. Kaoukis; M. Athanasiou; C. Colaço; F. Rego; A.C. Sequeira; V. Acácio; M. Serra; E. Plana. Deliverable 4.2. PREVENTION ACTION INCREASES LARGE FIRE RESPONSE PREPAREDNESS, *Grant Agreement No. 826400-PREVAIL-UCPM-2018-PP-AG*

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).

2.4. Know-how transfer barriers

- 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 [18]. 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 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:

i) 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.
ii) 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.

[18] McCaffrey, S.; E. Toman; M. Stidham; B. Shindler. 2013. Social science research related to wildfire management: an overview of recent findings and future research needs. *Int. J. Wildland Fire 22,* 15–24.

According to researchers [19], several factors influence social preference, support, and active involvement in fire prevention: (i) 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; (ii) understanding of the added value or perceived effectiveness that the proposed practices have in terms of fire prevention; (iii) familiarity with the prevention practices and techniques; (iv) perceived responsibility and individual/community capacity (expertise, time, financial means and tools) to implement or incorporate them into day-to-day work; (v) trust or confidence in those implementing a practice or who should collaborate in a multiple-practice prevention measure; (vi) landownership and location of prevention treatment (e.g. preference for use of prescribed fire in remote areas and thinning in the urban-wildland interface); (vii) cultural context and beliefs about or attitudes towards proposed treatments (e.g. effect on wildlife, potential for escape, aesthetics); (viii) clear demonstration of the multiple ecological, social and economic benefits provided the proposed practices, with the special focus on the economic return on investments.

2.5. Governance barriers

- The socio-economic drivers of wildfires should be tackled from a multi-stakeholder and multi-disciplinary perspective so that innovative governance mechanisms for fire-risk reduction or 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 [20]. Some examples are reported below:

- 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.
- Plan 42 in Castilla-Leon (Spain) has promoted a cultural change in pasture management systems in common forest land, reducing fire incidence. Mechanical clearance was introduced for scrub control instead of the traditional fire use.

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.

[19] Ibid.

[20] Varela, E. & Górriz, E. 2014. Enhancing Forest Fire Prevention: Governance. EFI news, Nº 1, Vol. 22.

3. The Solution: Integrated fire-smart landscape planning and implementation 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 shift of fire-prone maladaptive land uses and practices by others that are sustainable and resilient to fire, has a high economic and social cost. It is conditioned to the identification, social acceptance, effective adoption and consolidation of innovative cross-sectoral fire-smart solutions that demonstrate sustainable return on investments (environmental, social and economic return) and are jointly implemented by all concerned stakeholders that are empowered with the necessary knowledge, governance mechanism and resources.

The proposed case studies with best practices in building fire-smart landscapes are assessed based on a series of principles, which can be fully or partially met, the ideal situation being to meet all of them. The **proposed principles** come from the conceptual framework of **Forest Landscape Restoration (FLR)** - "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 (e.g. large wildfires and droughts), and the ecosystem services upon which we all depend".

Willemen et al. (2014) **[21]** designed a methodology to spatial planning and monitoring at the landscape scale to guide diverse stakeholders in locating, designing and monitoring integrated cross-sectoral production, biodiversity conservation and livelihood security interventions to improve benefits for people living in rural landscapes. Stakeholders undergo an eight-step process, conducted in five phases. In the fire-smart landscape planning process, the first phase would be devoted to: (i) stocktaking, and understanding the problem – fire impacts and high fire risk areas linked to LU/LC types, management practices and their landscape pattern distribution -, and (ii) identifying and locating benefits within the landscape – fire-resilient fuel models for the different LU/LC and landscape distribution patter; priority high-fire risk areas for implementing priority climate-resilient and fire-smart interventions. Stakeholders develop a GIS platform composed of landscape-scale maps, to identify and visualize priority high-fire risk areas for priority fire-smart interventions that correspond to the supply of large wildfires risk reduction benefits in the landscape and to inform the planning of place-based interventions. Areas are identified where changes would lead to improvement of landscape benefit flows. A monitoring element is included to guide stakeholders to quantify and describe landscape benefits, so that change can be detected and measured.

[21] Willemen L, Kozar R, Desalegn A and Buck LE. 2014. *Spatial planning and monitoring of landscape interventions: Maps to link people with their landscapes*. A User's Guide. Washington, DC: EcoAgriculture Partners. In: Cazdon, R.L. & M.R. Guariguata. 2018. *Decision support tools for forest landscape restoration: Current status and future outlook*. Occasional Paper 183. Bogor, Indonesia: CIFOR.

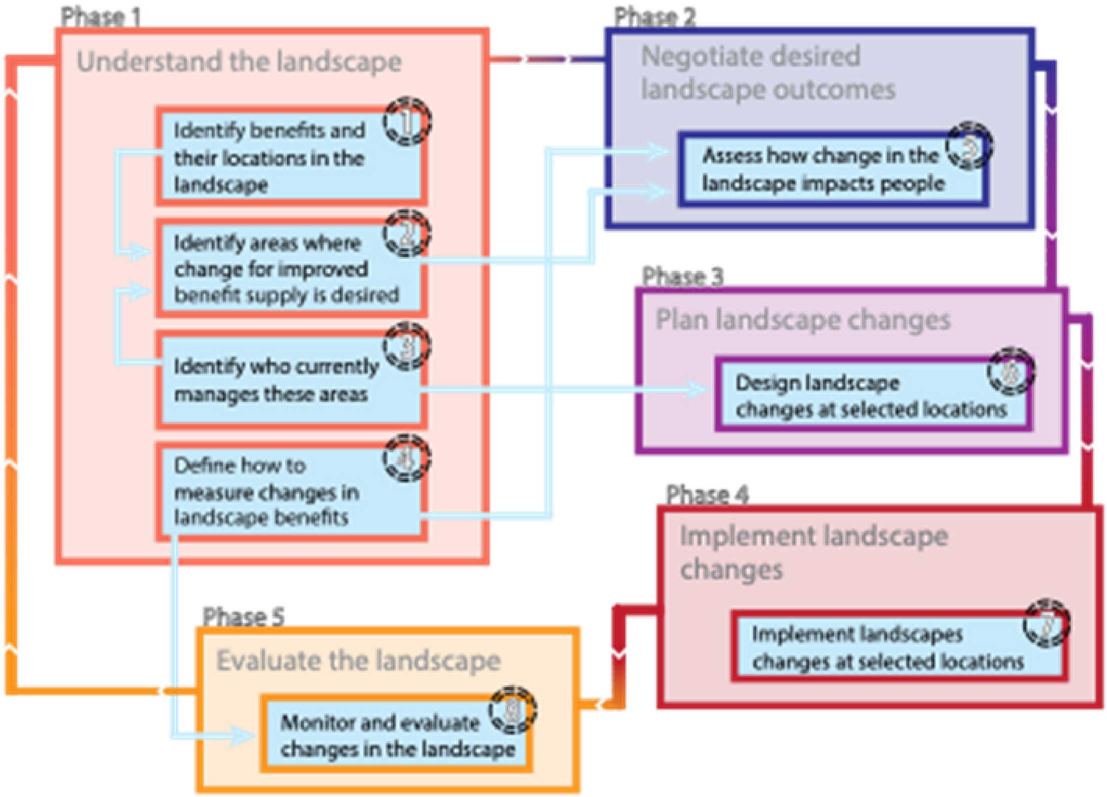


Figure 4. The eight steps of planning and monitoring landscape interventions, in which maps are used within the five-phase adaptive collaborative management process [22]

Desired landscapes changes are then negotiated, planned, and implemented in phases 2–4. Phase 5 involves development of a spatial strategy for monitoring and evaluation of landscape changes that also incorporates adaptive management and long-term financing opportunities of landscape interventions.

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

FLR Principles [23]	Proposed 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
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.	**3.2.** Enabling multi-stakeholders to be actively involved in the implementation of fire-smart landscape plans through 360° capacity development interventions and innovative governance mechanisms.

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

FLR Principles	Proposed Principles
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.	**3.3.** Sustainable return on fire-risk reduction investments, ensuring the provision of ecological, social and economic benefits.
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.	**3.4.** 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.	**3.5.** Enhance and restore the diversity functionality, fire resilience and ecosystem services of the natural and seminatural habitats in the landscape.
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:

a) **Defining the landscape boundaries**, based on ecological and socio-economic and cultural criteria. A landscape is defined by a set of natural and semi-natural systems that give it a differentiated natural identity that is inextricably interwoven with a culture of traditional uses of natural resources that give cohesion to the population, a specific local identity and a sense of belonging. 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.

b) **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. In our case, the institutional responsibility for leading the fire-smart planning process falls on a public institution (e.g. the managing authority of the Luberon Regional Nature Park), a non-profit organization (e.g. Green Home for the Prokletije-Komovi landscape complex) and on an academic/research technical institution (e.g. CIHEAM-Chania for Samaria National Park).

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: (i) ecology (e.g. ecosystem functioning, biodiversity), (ii) fire management, (iii) rural development (land uses, land tenure, sectoral policies), (iv) social science (e.g. the human dimension of wildfires, rural population dynamics, gender issues), (v) economy (e.g. sustainable rural business models); (vi) GIS modelling expert. The core team will be in charge of carrying out baseline assessments and analysis (modeling) of the landscape fire risk, 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: (i) decentralized governmental institutions; (ii) technical staff from the local administration; (iii) land user organizations; (iv) private companies active in the landscape; (v) local NGOs; (vi) academia (e.g. secondary schools, universities); (vii) research organizations.

c) **Root-cause analysis of wildfire impacts in the landscape.** It 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 root-causes analysis should determine: (i) the underlying policies, institutional dynamics, market forces and human actions driving the direct causes which lead to wildfire impacts in the landscape; (ii) the interlink between direct and root causes; and (iii) the priority interventions at various levels to address them. Only by exploring, understanding and addressing the root causes of large-scale wildfire impacts at the various levels - local, regional, national and international – the project can create conditions for success and sustainability.

   Although the national statistics of the Euro-Mediterranean countries identify negligence or arson as the cause of around 90% of forest fires, in many cases the specific causes and the actors responsible for the ignition of wildfires are not known. Considering the limited number of fires started by natural events, the risk of ignition is a human issue, which requires a deep analysis of the social dimension.

d) **Landscape fire-risk analysis & modelling.** Identification, mapping and prioritization of 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), in relation to fire behaviour, fire-prone LU/LC types and management practices, their extension and distribution pattern in the landscape.

e) **Biomass characterization in the Landscape (existing fuel models).** Classification of the existing LU/LC types and related management practices as fuel models, according to its effect on the abundance, quality and distribution of plant biomass, carbon stock, and fuel load value. 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 identification and selection of alternative uses and management practices that constitute acceptable and locally adapted fuel models.

f) **A shared vision for a fire-smart landscape: stakeholders' prioritization of fire-resilient interventions (desired fuel models).** The vision statement and mapping exercise becomes the starting point for discussion about developing fire-smart landscape 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 fire-risk areas; users of the ES of interest living outside the landscape).

The multi-stakeholder prioritization process consists in: (i) the identification of alternative fire-smart land uses and management practices (desired fuel models) to replace fire-prone ones; (ii) the evaluation of different scenarios that allow 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 (iii) the selection of viable change options throughout a transition process towards a desired fire-smart landscape, that is, whose costs are affordable, whose implementation is feasible considering the social reality of the territory, and which provide complementary and sustainable ecological, social and economic benefits.

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.

Fire-smart landscape plans are important tools to guide decisions on landscape resilience to environmental-risks, such as forest fires, in the pluriannual strategic planning and investment plans of the different subnational administrative levels that correspond to the limits of the landscape. The participatory fire-smart landscape planning process implies data collection and GIS analysis with the participation of multi-disciplinary technical teams, including fire management experts, and in consultation with all concerned local stakeholders.

The process can be supported by GIS multi-variable models that allow the development of past, current and future scenarios to analyse and visualize the hypothetical effects of changes (past and/or proposed) in the landscape in terms of fire risk reduction. These are tools that aim to facilitate the analysis and visualization of complex multifactorial problems and support decision-making and negotiations between actors with different visions, concerns and interests. In recent years, various models have been developed to support the management of fire-smart landscapes in different Euro-Mediterranean countries affected by large fires (Alcasena *et al*., 2016; Alcasena *et al*., 2018; Aquilué *et al*., 2019; Bertomeu *et al*., 2022; Canibé Iglesias *et al*., 2022; Cervelli *et al*., 2022; Magalhães *et a*l., 2021, Xanthopoulos *et al*., 2021).

Possibly the proposals to convert fire-prone into fire-smart landscapes come up against some fundamental limitations, which greatly condition their viability:

- **The very high economic cost of managing the 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 identify and 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.

This must be coupled with policies and incentives to fix and increase the rural population in depopulated rural areas, through the transfer of innovation (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 are 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 [24], 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.

3.1.1 Some examples of fire-smart landscape planning methodologies in the Mediterranean countries

Coupling fire landscape dynamic models (MEDFIRE [25]) and land use change models (MEDLUC [26]) helped evaluate the effect of past, current and proposed landscape management scenarios (based on the substitution of landscape patches mostly covered by young forests and scrublands for agriculture land, and on changes in their size, aggregation and distribution pattern in the landscape) on fire behaviour (ignition probability and fire spread) in the Spanish region of Catalonia [27]. Results suggested that increasing discontinuity through the conversion of natural and semi-natural land cover to agricultural land on fire-prone landscapes appears to be a potential management alternative for reducing total burnt area, preventing fires from burning out of control and diminishing fire recurrence. According to the model, when new agricultural land patches are sparsely allocated in the landscape, the strategies that interrupt forest continuity largely contribute to reducing total burnt area. This also reinforce fire-fighting capacity by facilitating access to the fire perimeter, reducing overall fuel-load and fire intensity, and creating firebreaks that will slow down or even stop the advancing front. However, the fragmentation of forestland, especially in landscape areas with mature forests, must avoid the possible negative impact on the biodiversity linked to mature ecosystems, incorporating this criterion in the planning and selection of intervention areas. Authors also conclude that the strategy of using agriculture patches in forest landscapes to control the fire regime may be limited under future climate conditions, and other strategies such as prescribed burning, mechanical biomass harvesting, and controlled grazing may need to be implemented.

In the framework of the EU-funded PREVAIL project [28], authors tested four fuel treatment scenarios – (1) mechanical treatment of biomass with tractor in agriculture areas; (2) the same with hand tools; (3) moderate grazing in all vegetation types; (4) intensive grazing in all vegetation types - using the GFMIS [29] simulation system (detailed landscape fuel map and data on the meteorological conditions to simulate the spread of the 2017 large-scale fire), in order to discover what would have been the result on fire spread (fire perimeter growth and flame length) if they had been applied to the area that burned prior to the fire event. Grazing reduces the amount of herbaceous fine fuels, the shrub component, the fuel depth (height) and the fine fuels while mechanical treatment breaks the horizontal continuity and changes the fuel depth (height) of the vegetation.

[24] e.g. 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.

[25] Landscape dynamic model that integrates vegetation dynamics and fire regimes to investigate the interactions among ecological processes shaping Mediterranean landscapes (Aquilué, N et al. 2019. *The Potential of Agricultural Conversion to Shape Forest Fire Regimes in Mediterranean Landscapes*. Ecosystems https://doi.org/10.1007/s10021-019-00385-7).

[26] Spatially explicit land-use/land-cover change model designed to reproduce any LULC transition (Aquilué, N et al. 2019).

[27] Aquilue´, N.; Fortin, M-J.; Messier, C.; Brotons, L. 2019. The Potential of Agricultural Conversion to Shape Forest Fire Regimes in Mediterranean Landscapes. Ecosystems https://doi.org/10.1007/s10021-019-00385-7

[28] Xanthopoulos, G., Athanasiou, M., Varela, V., Kaoukis, K. 2021. Work Package 3. Large fires case studies analysis Deliverable 3.3. – Fuel management scenarios. PREVention Action Increases Large fire response preparedness. Grant Agreement No. 826400-PREVAIL-UCPM-2018-PP-AG. Funded by European Union Humanitarian Aid and Civil Protection.

[29] Global fire management information system.

Results concluded that scenarios 1 and 2 (treatments only in agricultural areas) did not affected the length of fire perimeter but reduce the required firefighting effort through the reduction of flame length along many parts of the perimeter, although the capacity of the available firetrucks on the island could be exceeded after roughly 4 hours. Scenarios 3 and 4 reduce both perimeter growth rate and flame length, thus significantly reducing the needed firefighting effort. It seems that broadcast fuel treatment through grazing over all of the land is much more cost-effective (and cost free, actually producing income) than scenarios 1 & 2, assuming that the number of shepherds and herds is sufficient to cover the entire area, that they are trained to incorporate fire-risk reduction objectives in grazing management, that there are agreements between landowners and herders to incorporate controlled grazing in the management of each land property, and that grazing interventions are compatible with ensuring multiple ecological, social and economic benefits.

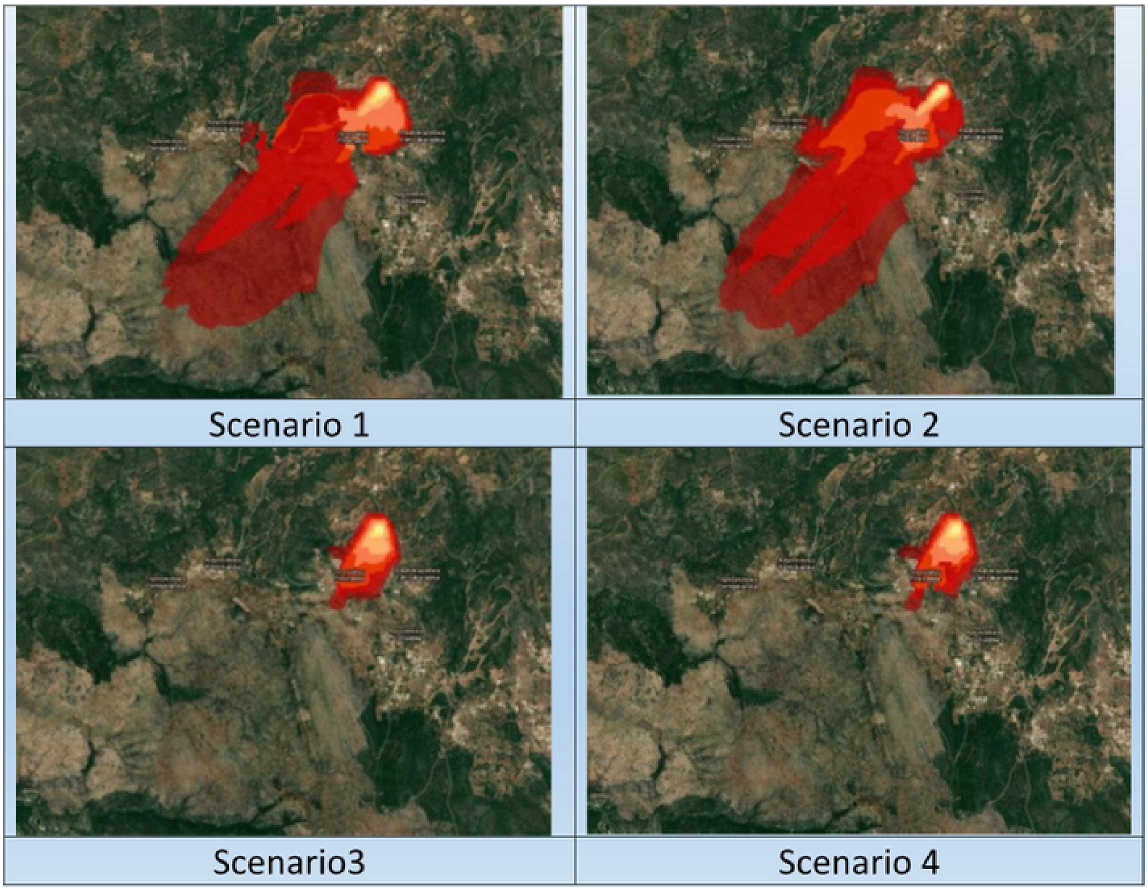


Figure 5 . Influence of the 4 scenarios of fuel treatment on fire rate of spread (simulation of 6 hours) in the 2017 wildfire in Kythera Island [30]

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 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 the DSS efficiency and validity **[31]**.

[30] Xanthopoulos, G., Athanasiou, M., Varela, V., Kaoukis, K. 2021. Work Package 3. Large fires case studies analysis Deliverable 3.3. – Fuel management scenarios. PREVention Action Increases Large fire response preparedness. Grant Agreement No. 826400-PREVAIL-UCPM-2018-PP-AG. Funded by European Union Humanitarian Aid and Civil Protection.

[31] Sequeira A. C., Colaço M. C., Acácio V., Rego, F., Xanthopoulos, G. 2021. Deliverable 5.1 – Decision support system for effective fuel management: application to Cascais Case Study (Portugal). PREVENTION ACTION INCREASES LARGE FIRE RESPONSE PREPAREDNESS. Grant Agreement No. 826400-PREVAIL-UCPM-2018-PP-AG.

PREVAIL DSS-FM is structured into three fundamental sections and inherent questions:

- The NEED for fuel management: is there a need for fuel management? **A map of low, medium and high fire risk areas** is produced, based on the intersection of (i) the hazard map (quantification of null, very low, low, medium, high and very high hazard based on terrain slope and LU/LC fuel models) and (ii) 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).
- The DIAGNOSTIC for fuel management: where to treat? This is based on the **intersection of the map of low, to high fire risk areas** (previous section output), **with the identification of strategic landscape points for fuel management** (drawing landscape spots that may increase fire spread rate, intensity, severity and/or create new fire fronts, making use of fire simulators from historical ignition points or random points in high fire ignition locations, such as road infrastructures, and including information on historical fires, their typology and behavior). The analysis must consider the ***Legal Obligations for performing fuel management in the area of interest*** (AoI), such as the existence of *Mandatory* Areas for Fuel Management surrounding settlements and infrastructure, conceived to protect people and key infrastructures.

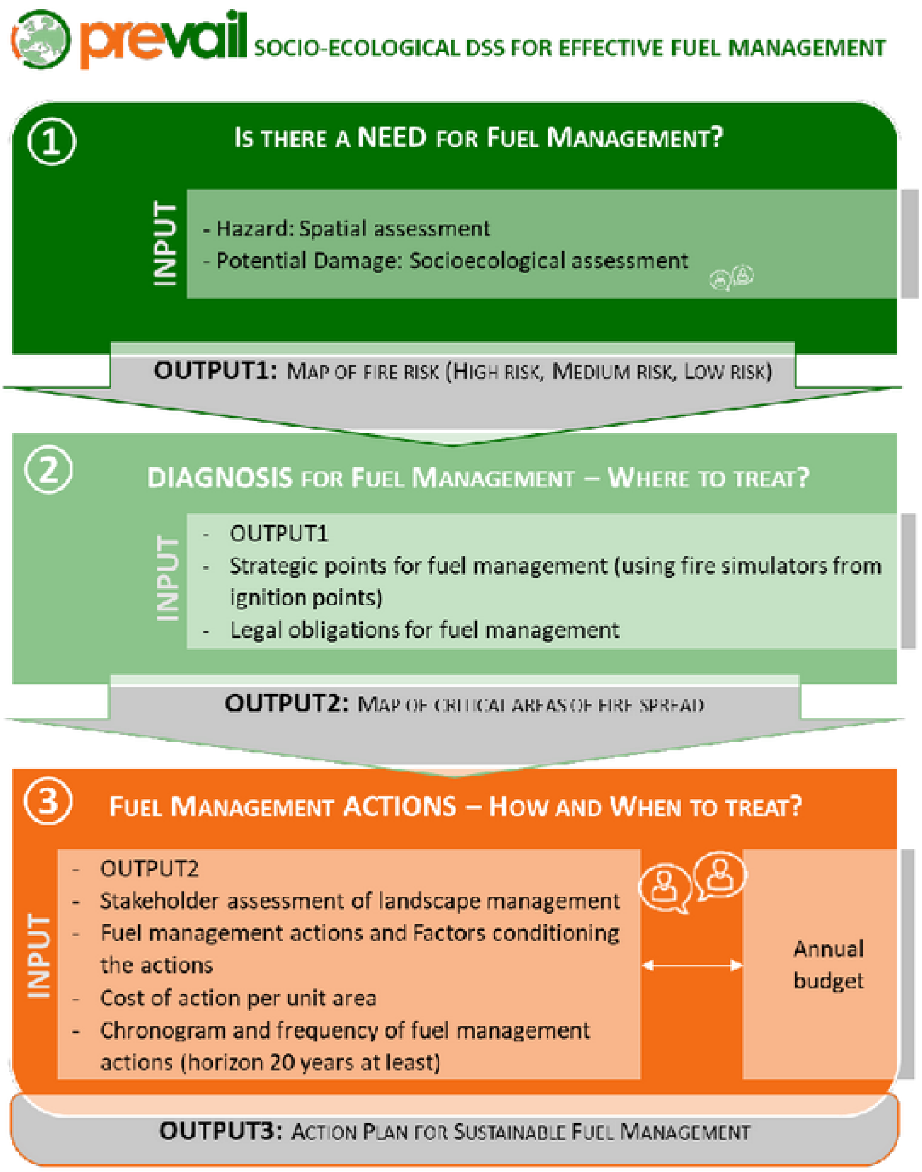


Figure 6. Roadmap of PREVAIL Decision Support System for Fuel Management [32]

[32] Ibid.

- The ACTIONS for fuel management: How and when to treat? How to treat is the action plan for sustainable fuel management of the target landscape, which is defined through the combination of: (i) map of critical areas of fire spread (previous section output), (ii) stakeholder assessment and proposition of fuel management options, addressing conflicts, tradeoffs and synergies concerning different stakeholders' goals, tactics and decisions, and the existing legal obligations; (iii) requirements, constraints and features conditioning the proposed fuel management options; (iv) cost of each proposed management option per unit area.

  Information on When to treat or implement the proposed management actions must be explicit in the action plan for sustainable management, defined for a horizon of 20 years (adaptive-management monitoring timeframe needed to guarantee success) in a Chronogram and frequency of fuel management actions (20 years period). We considered 20 years as a comprehensive period that is needed for a continuous and re-evaluation assessment of fuel actions, in order to guarantee its success.

  A budget estimating annual costs will be needed to support fundraising efforts and incorporate fire prevention interventions in the annual rural development and fire management budgets for the target landscape.

According to Alcasena *et al*. (2019) [33], the main limitations of the experts' judgment to determine the location of strategic high-fire risk areas in the landscape and identify the most appropriate risk reduction measures in each case, are: (i) the difficulty of quantitatively evaluate the effect of the different alternatives in reducing the risk of fires (e.g. the delimitation of the shape and area of the treated plots, in addition to the type of measure used), and (ii) the difficulty of establishing priorities among the landscape areas to be treated in the case of extensive territories with a changing fire regime. The authors proposed a **methodology applied in a landscape of 36,000 ha with 14 settlements and 548 inhabitants (Navarra, Spain)**, that makes it possible to determine where potential highest losses are concentrated in the landscape, in addition to facilitating the strategic design of fire prevention interventions in multifunctional landscapes. The methodology includes the use of the following tools:

- 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), to simulate landscape sites with likelihood of future fire occurrence (map of ignition probability).
- Fire simulation based on landform data (slope, altitude, aspect), meteorological data, land use fuel models, and forest cover/structure data to generate burn probability, fire intensity levels, flame length probability and perimeter of burned area.
- 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.
- Spatial optimization of the treatments and the identification of the polygons or stands to be treated, with the Landscape Treatment Designer (LTD) program, which allows configuring the mosaic of treatments that maximizes the contribution of the treated area with respect to one or several objectives, with the aim of objective of satisfying the needs of different social agents (that is, multi-objective solutions). In this study, three objectives were established for the treatments: (1) reduction of fire risk in productive pine and oak forests, (2) reduction of fire risk in urban centres, and (3) collection of firewood and/or wood from fuel management.

The resulting spatial arrangement of interventions contemplates two different complementary strategies: (1) fire-risk reduction interventions in areas with assets with high expectations of economic loss (e.g. urban areas and highly productive forest stands), and (2) multifunctional interventions at the landscape scale to increase the overall 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. However, restrictive regulations in protected natural land, and land tenure conditioned final decisions regarding interventions in a case-by-case basis.

---

[33] Alcasena Urdíroz, Fermín J.; Vega García, Cristina; Ager, Alan A.; Salis, Michele; Nauslar, Nicholas J.; Mendizabal, F.J.; Castell, Rafael. (2019) . Metodología de evaluación del riesgo de incendios forestales y priorización de tratamientos multifuncionales en paisajes mediterráneos. Cuadernos de Investigación Geográfica, 2019, vol. 45, núm. 2, p. 571-600. https://doi.org/10.18172/cig.3716.

According to results, biomass management interventions in the vicinity of residential dwellings and productive forests significantly reduced fire-risk in the treated plot or stand, mainly due to the reduction in the intensity of the fire (that is, flame length). In the second case, the mosaic of strategic interventions at the landscape level aimed to reduce the transmission to urban centres (that is, the probability of burning) as well as the exposure in forest stands, in addition to maximizing the extraction of firewood or wood.

In urban settlements, private owners and the local administration must coordinate and get involved in the management of fuel in the urban-forest interface areas in order to generate communities adapted to forest fires. In the study area, the ploughing of cereal fields close to urban centres (up to 60 m) immediately after harvesting, as well as the maintenance of low fuel load vegetation strips and vegetable gardens in the urban perimeters, would significantly reduce the intensity of the fire front approaching inhabited settlements. The use of low-flammable species and the removal of all dead fuel (including piled firewood) in hedges and gardens close to houses and propane tanks (<30m) can be decisive in preventing the ignition of structures and stopping the transmission of fire between neighbouring houses. In addition, collaboration between neighbouring municipalities is also necessary as large fires originating outside the area study can cause serious damage to neighbouring settlements. The development and application of regional regulations and specific municipal ordinances can be very useful for this purpose, requiring compliance with preventive measures. The use of intumescent varnishes or paints in the structures and exterior carpentry, as well as the installation of fireproof blinds, would significantly increase the resistance of the structures to the direct impact of fire (the direct impact of the front at high intensities against the structure is unlikely, being flying sparks are the main causes of fires in urban areas). The construction of water points facilitate the operation and autonomy of the extinction means, the setting up safe meeting centres for the confinement of vulnerable people (children, the elderly and people with reduced mobility) can be a wise measure in rural areas with poor communication, and preferred evacuation routes in case of emergency to avoid accidents should be arranged.

The optimization model of this study is a very useful tool for incorporating the identification of strategic management points (SMP) and the techniques and prescriptions to be followed at each point into Technical Forest Management Plans. In the case of thinning in producing pine forests, it may be appropriate to treat the remains (crushing branches and tails) in stands with a high probability of burning or close to urban centres. Likewise, the execution of prescribed burning by qualified personnel is an appropriate technique for fuel reduction in the most mature pine forests and without excessive accumulations of remains. In oak forests with the use of firewood, clearing with subsequent stacking and chopping of the pruning remains is the most appropriate and widespread treatment. The management of communal pastures with extensive livestock is a complementary measure that helps prevent the growth of scrub and increases the durability of the treatments. Despite the fact that the length of the flame in herbaceous fuel models does not represent a great limitation during extinction, management with grazing can be decisive because the propagation speeds under extreme weather conditions (strong winds and low relative humidity) easily exceed the extinguishing capacity of the terrestrial extinction forces.

The identification of the most frequent causes of ignition allows the development of protocols with specific preventive measures that can be applied in places with a high probability of ignition. For example, ignitions caused by agricultural machinery are one of the most typical cases in summer (harvesters and balers). The application of preventive measures as well as the cleaning of vegetable remains in the ducts and motors, or the availability of fire extinguishing equipment or tanks that allow a rapid response in the event of ignition, can be decisive for extinguishing the fire in a first reaction.

3.2. Enabling multi-stakeholders to be actively involved in the implementation of fire-smart landscape plans through 360º 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, and thus activate their willingness to participate in the planning and management of fire prevention.

3.2.1 Multi-stakeholder involvement

Stakeholder participation presents a number of potential advantages in addressing the challenges posed by wildfires [34]: (i) helps to develop a comprehensive understanding of the problem and leads to higher-quality decisions due to the consideration of multiple perspectives; (ii) enables interventions and technologies to be better adapted to local sociocultural and environmental conditions, and enhances their rate of adoption and diffusion among target groups; (iii) increases the knowledge that stakeholders have about each other's actions, which may lead to the development of trust; (iv) greatly facilitates collaboration and monitoring of stakeholder behavior; (v) helps to increase public trust in decisions made by public administrations; (vi) may make research more robust by providing quality information, and it aids stakeholder empowerment through the co-generation of knowledge with researchers and by increasing participants' capacity to use this knowledge; (vii) promotes social learning through the development of new relationships, by building on existing ones and by helping participants to appreciate the legitimacy of each other's views; and (viii) reduces the likelihood of marginalizing those on the periphery of the decision-making context or society.

Stakeholders' identification and analysis should include the following aspects:

- Understanding 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.
- Identifying **knowledge, skills and capacities** on fire-resilient landscape planning and implementation tools (e.g. policies, planning processes, fire-smart interventions, etc.).
- Realizing 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.
- Realizing the existence of **positive interactions** around collaborative fire-smart LU interventions, and the opportunities they provide for effective shifting to fire-resilient landscape scenarios.
- Identifying the **veto agents** that could compromise the fire-resilient landscape objectives and define the strategy to face them.
- Identifying **potential leaders** on fire-resilient landscape planning and implementation, highly motivated and/or with demonstrated experience in fire-smart related activities and define the strategy to involve them.

The planning of fire-smart landscapes requires greater involvement of social science experts to better (i) incorporate the human dimension in the analysis of the root causes of increasing wildfire risk, (ii) understand the multi-actors' perceptions and attitudes towards wildfires, and (iii) 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 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.

[34] Bertomeu, M.; Pineda, J.; Pulido, F. Managing Wildfire Risk in Mosaic Landscapes: A Case Study of the Upper Gata River Catchment in Sierra de Gata, Spain. *Land* **2022**, 11, 465. https://doi.org/10.3390/ land11040465.

An example of innovation for **people's involvement** in fire prevention is provided by Xanthopoulos et al (2022) [35], who analyzed the project implemented by the Hellenic Society for the Protection of Nature and the Institute of Mediterranean and Forest Ecosystems in **Kythira Island (Greece) after the devastating fire in 2017** that burned 8.9% of the island. The project undertook an in-depth analysis of fire statistics for the island, develop a forest fuels map and a prevention plan for selected settlements based on fire modelling and on an assessment of the vulnerability of all the buildings, carried out with the contribution of groups of volunteers. The element of innovation was mostly in the way the technical work blended with the involvement of the people in order to achieve better fire prevention efficiently. Emphasis was placed on: (i) the contribution of volunteers through talks and workshops to inform locals, including students, 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; (ii) the distribution of a risk assessment form (risk due to the vegetation and the vulnerability of the buildings) to the building owners 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; (iii) the production of awareness materials (informative videos, brochures, articles, interviews with local radio stations). The lesson learnt is that a small yearly investment in fire prevention, assigning/employing highly motivated specialized individuals, with a small budget, to organize fire prevention activities, can make a substantial long-term contribution to reducing fire loads and damage. This cost could be less per year than 3–4 h of flight time of aerial resources and the results could be tremendous. Furthermore, if a fire prevention network is developed (e.g., across Greece) to link, guide and support these individuals, monitoring and assessing the results, any weaknesses would be quickly resolved, and the outcome would be impressive.

Stakeholder engagement in the PREVAIL DSS-FM [36] followed a focus group methodology (i) to create a list and respective ranking of priorities of the elements at risk for the area of interest (AoI) on the basis of stakeholders' views, and (ii) to select the most suitable fuel management actions and treatment timings, having in consideration the specificities of the AoI and concerned stakeholders. Relevant stakeholders for the AoI were identified and selected from entities in charge of fuel management and fire prevention interventions at different levels:

- Local level: public and private landowners, municipalities, local enterprises.
- Landscape/regional level: NGOs, producer organizations, users' associations, local development associations, unions, communal organizations, intermunicipal commissions, regional public delegations, research organizations.
- National level: central administration in charge of communication, energy, technology and information, transportation sector, nature conservation, agriculture, forestry, water, civil protection.
- Others: large-scale buyer companies, tour operators, consumers, or other organizations from outside the landscape with additional proposals for fuel management towards a more integrated landscape management.

With the support of a moderator, the PREVAIL team in the targeted Portuguese landscape (Cascais municipality) organized several workshops with representatives of the identified stakeholder groups, explaining the DSS roadmap, introducing participants, and undertaking the following steps.

---

[35] Xanthopoulos, G.; Athanasiou, M.; Nikiforaki, A.; Kaoukis, K.; Mantakas, G.; Xanthopoulos, P.; Papoutsakis, C.; Christopoulou, A.; Sofronas, S.; Gletsos, M.; et al. Innovative Action for Forest Fire Prevention in Kythira Island, Greece, through Mobilization and Cooperation of the Population: Methodology and Challenges. *Sustainability* ***2022***, 14, 594. https://doi.org/10.3390/su14020594.
[36] Sequeira A. C., Colaço M. C., Acácio V., Rego, F., Xanthopoulos, G. 2021. Deliverable 5.1 – Decision support system for effective fuel management: application to Cascais Case Study (Portugal). PREVention Action Increases Large fire response preparedness *Grant Agreement No. 826400-PREVAIL-UCPM-2018-PP-AG*.

- **Assessment of elements at risk by the stakeholders**, according to the following steps: (i) presentation of preliminary list of elements at risk in the AoI to the participants, that may be completed with new elements at risk proposed by the stakeholders; (ii) stakeholders' classification of each element at risk according to its vulnerability to fire [37]; (iii) stakeholders' assessment of the ecological and socioeconomic value of each element at risk [38]; (iv) stakeholders' classification of the likelihood of the recovery time [39].The final value will be given by the multiplication of all the previous classifications. The information is gathered by the management team and results are presented to be discussed among stakeholders, in order to reach a consensus on vulnerability, socioecological value, recovery time, and a final ranking for all elements at risk identified. This information will then be converted into the Map of Potential Damage.

Table 1. Final ranking of elements at risk according to stakeholders

Steps	1st: list the name of the elements at risk	2nd: classify their vulnerability	3rd: classify their socio-ecological value (classify separately and sum the two values)		4th: classify their recovery time	5th: calculate final value
	Element at risk	Vulnerability	Ecological value	Socio economic value	Recovery time	Final value
Scale	N/A	(0 - 4)	(1 - 4)	(tangible or intangible) EUR or (1 - 4)	(1 - 4)	Multiply all previous classifications

- **Stakeholder assessment of landscape management, looking for synergies and smart-solutions**: (i) explanation of the importance of the integrated landscape management approach, and presentation of best practices on wildfire risk management and fuel management smart solutions at the landscape level; (ii) introduction of the existing forest and fire management plans covering the target landscape and relevant stakeholders fuel management goals for the AoI, to identify missing elements, stakeholders' views and needs; (iii) identification, mapping and discussion of synergies, development and nature conservation tradeoffs (sustainable economic, social and ecological return on investments), and opposing management goals among landscape stakeholders; (iv) identification of existing/ legal obligations for fuel management in the AoI, and if they do not exist, discussion about needed obligations.

- **Stakeholders' assessment of fuel management actions, factors conditioning the actions and costs**: the PREVAIL team presented the list of business-as-usual techniques for fuel management and the smart solutions gathered during the previous step of the focus group discussions. Discussion with participants about their knowledge of these solutions, missing actions that are not included on the list, feasibility of these actions in the AoI, and quantification of the cost of each action, in order to build a Matrix of budgeted solutions for Fuel Management for the AoI like Table 2 based on the final list of actions previously defined.

[37] Previously defined as the percentage damaged in case of fire occurrence and classified in a scale from 0 to 4 (0: No damage; 1: 25% damaged; 2: 50% damaged; 3: 75% damaged; 4: Value destroyed).
[38] The value can be quantified in euros if it is a tangible value, or according to a scale (1: Low value to 4: Very high value) if intangible.
[39] Scale from 1 to 4 (1: less than 1 year to recover; and 4: a long time to recover completely, or very high difficulty to reach the prior state before the fire).

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

Site	Description of fire-smart target	Actors involved	Fire-smart intervention type* (indicate the different types that should be combined in each site).																Total cost
			A		B		C		D		E		F		G		H		
			1[40]	2[41]	1	2	1	2	1	2	1	2	1	2	1	2	1	2	

*: 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…

- **Stakeholder assessment of the chronogram and frequency of fuel management actions**: in order to be effective, fuel management (FM) needs 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. During the focus group, a table with a chronogram for each FM action and plot (single areas to be treated) within the AoI will be presented and discussed so that stakeholders may give their input and improve the table.

AoI	Technique to be used	1st intervention (date)	2nd intervention (date)	3rd intervention (date)	4th intervention (date)	5th intervention (date)	Etc.
Plot1							
Plot2							
Plot3							
Etc.							

- A final assessment of the presented DSS should be done for participants' validation and the project team should take on the task of presenting a financing plan, based on different existing opportunities (e.g. use of annual call for tender for EU funds, and for national funds allocated to fire management, rural development, etc., that are applicable to the target landscape), potential opportunities (e.g. establishing a payment system for ecosystem services; creating new policy incentives; developing public-private partnerships; crowdfunding; benefiting from environmental and social corporate responsible programs of business companies; etc.), and supporting landowners and users in developing business plans with economic return on investments, for the marketing of fire-smart LU goods and services (e.g. for the establishment of productive firebreak areas with fire-smart agroforestry systems).

After the great forest fires of the 1980s and 1990s, a process of **social learning** occurred among **forest owners in Central Catalonia (Spain)** [42]. Social learning is understood on its three main dimensions: (i) the depth of learning, that is, changes in understanding, attitudes and behaviour; (ii) the collective character of learning, facilitated by processes of social interaction, and (iii) the internalization of this learning by broad segments of society. According to researchers (Rodríguez-Carreras et al, 2020), a large number of forest owners believed that fires are much more destructive today

[40] Cost (Euros) per hectare.
[41] Percentage of the site where this type of intervention is applied.
[42] Rodríguez-Carreras, R.; Úbeda, X.; Francos, M.; Marco C. 2020. After the Wildfires: The Processes of Social Learning of Forest Owners' Associations in Central Catalonia, Spain. *Sustainability* 2020, 12, 6042.

and that without an organized action between the different landowners it is difficult to avoid the great economic, ecological, aesthetic, emotional, losses. Forest owners interviewed believe that management practices should be changed, not specifically in order to eliminate fire, but rather with the aim of creating forest structures that are resistant to its passage and which can reduce the risks presented by large wildfires. They proposed ideas very much in line with the more innovative proposals that have been made within the field of prevention management, which advocate the prevention of wildfires at the landscape scale: (i) prioritizing high-fire risk areas in the landscape; incorporating livestock to reduce forest fuel; (iii) fostering the production of biomass as a medium-term measure for the economic exploitation of forest fuel; (iv) favouring a forest management that guarantees mixed forests of conifers and broadleaf trees, and promoting the recovery/increase of areas for cultivation, even though they may be small; (v) implementing prescribed burning as a means to reduce biomass although this generated greater reservations among respondents.

Associationism for a collaborative and consensual management of forest properties was identified as the best governance mechanism to increase socio-ecological resilience to large wildfires with additional benefits: (i) planning can be implemented at a scale larger than of just one single property, better addressing landscape-level risk reduction needs; (ii) costs can be lowered, and owners can be more competitive in the marketing of their products; (iii) bureaucratic procedures are less demanding; (iv) strength position when dealing with political bodies and negotiating policy improvements; (v) sense of union, sharing experiences and identity and building a common narrative and discourse that help strengthen ties to that territory. Understanding forests as a dynamic landscape and the inevitability of fire as part of forest dynamics, require conscious social action to create socio-ecological structures that are less vulnerable to fire. Associationism is unusual in the context of private forest tenure in Catalonia, despite the great number of private forest properties. however, results demonstrate that the forest owners' associations (representing both private owners and public administration interests) in the analyzed forest landscape was a strategic cooperative response to large wildfires for achieving fire risk reduction objectives, a recognition of the need to link ecological and social structures in the territory, and one which we define as a form of 'socio-ecological resistance'. Our study highlights that the goals and actions of forest owners' associations have both an instrumental and emotional component, so that reason, emotion and action have come to form the three vertices of socio-ecological resistance to fire.

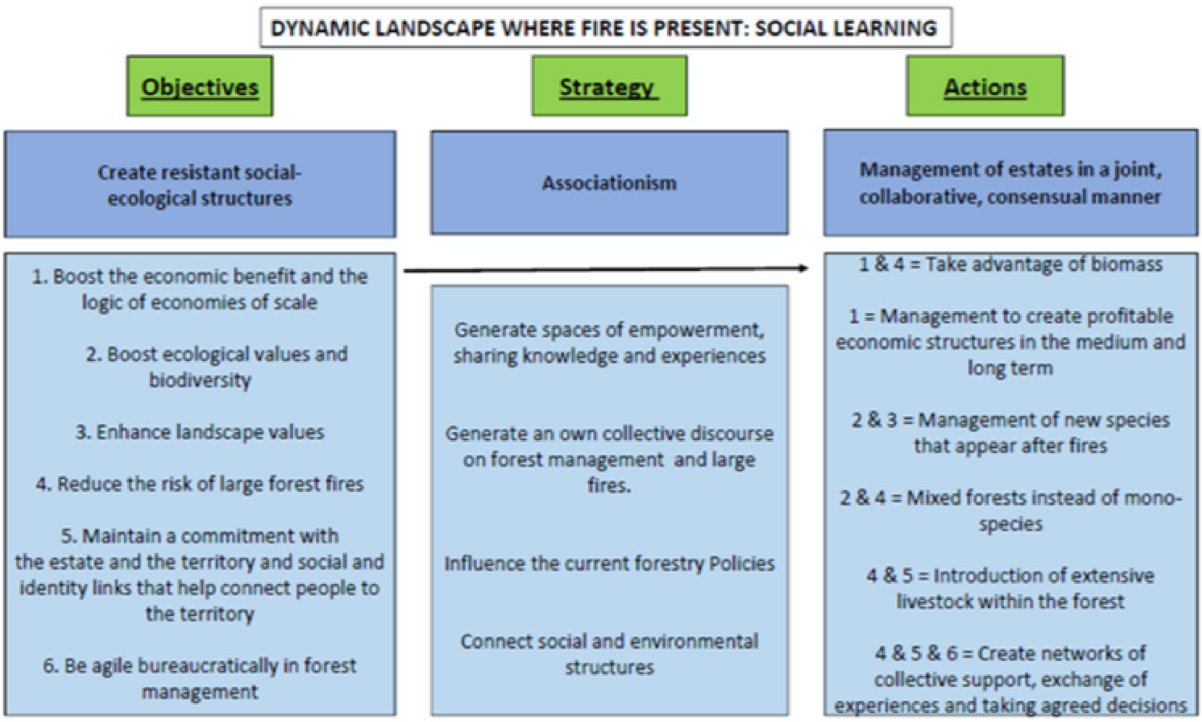


Figure 7. The social learning process of forest owners in Central Catalonia [43]

[43] Rodríguez-Carreras, R.; Úbeda, X.; Francos, M.; Marco C. 2020. After the Wildfires: The Processes of Social Learning of Forest Owners' Associations in Central Catalonia, Spain. *Sustainability* 2020, 12, 6042.

3.2.2. 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 [44]. 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) [45]. 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 directly influence decision-making processes and the degree to which different stakeholder groups are engaged in fire-smart landscape planning, implementation and monitoring, have access to fire-smart investment opportunities and share benefits from fire-smart landscape interventions.

The cross-sectoral and multi-stakeholder planning, coordination and implementation of fire-resilient LU/LC changes and management/restoration measures may require **imaginative formal or informal governance solutions embedded in existing polycentric governance structures** that facilitate the interlinkages among their represented institutions and individuals, and help to coordinate and monitor the implementation of integrated actions that effectively respond to the priorities established in the fire-resilient landscape plans.

Governance arrangements are necessary for:

- **the planning process**, which should help define a broad-based governance mechanism for the implementation of the objectives of the agreed fire-resilient landscape plan. It is important that the institutional responsibility for leading the landscape assessment and 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).

- **the long-term governance of fire-resilient landscape planning and implementation**: A fundamental objective of the planning process is to establish a long-term governance mechanism for the implementation and monitoring of the fire-resilient landscape plans. This requires imaginative solutions that do not add complexity to the existing governance structures, which would lead to inaction, but rather catalyze coordinated action, and facilitate the permeability of information and knowhow and collaboration between existing institutions. There are examples of **governance structures or multi-stakeholder platforms (MSP)** for the implementation of forest landscape restoration plans, such as the "Pact for the Restoration of the Atlantic Forest" in Brazil with the goal of restoring 15 million hectares of forest by 2050.

---

[44] Chazdon, RL et al. 2020. Key challenges for governing Forest and Landscape Restoration across different contexts. www.elesevier.com

[45] Mansourian, S. 2017. Governance and forest landscape restoration: A framework to support decision-making. Journal for Nature Conservation 37 (2017) 21–30.

[46] Chazdon, RL et al. 2020. Key challenges for governing Forest and Landscape Restoration across different contexts. www.elesevier.com

There are two key issues of success in MSP.

Legitimacy: quality of being accepted and perceived as a legitimate representative. Critical points are: (i) the representation – effective participation of all concerned stakeholders in the decision-making process; (ii) the inclusion of all concerned stakeholders in benefit-sharing from fire-smart landscape implementation; (iii) the transparency - clarity in the institution's goals, decision-making processes, and financing.

Effectiveness (ability to effectively deliver the MSP goals) / *Efficiency* (makes a timescale sufficient to maintain interest and support its members and sponsors).

Multi-stakeholder Platforms (MSP) for the implementation of integrated landscape plans often have operational problems:

Problems	Solutions
Lack of clarity on the added value of the MSP. Implementation measures not linked to the fire-smart landscape objectives and planned actions. Weak or absence of monitoring.	MSP mandate around the fire-smart landscape planning objectives and annual planned interventions: a refence space for all fire-resilient interventions in the landscape. A portfolio of products and services for its members should be developed.
Lack of a clear and active strategy to attract membership, and an imbalance representation of actors (e.g. land-bound actors are often the least represented).	Increase membership and representativeness through: (i) developing a database of potential new members from the different segments of the planned fire-smart priorities; (ii) an active membership campaign based on specific awareness raising materials; (iii) factsheets with benefits for a landscape actor (e.g. public administration, landowner and/or user) to become MSP member.
Passive communication and low knowledge transfer between MSP and its members. Participation seen as something that takes time (not something that saves time).	The platform should have a transparent participation strategy for participation and exchange of knowledge (e.g. periodical meetings; social networks). - Monitoring the members' actions (visits to the projects, monthly bulletin highlighting members' achievements).
Little consultation and/or involvement of members on key MSP issues, which makes them not feel part of it. Negative competition between MSP and its members, especially in terms of fundraising.	MSP should become a vector to aggregate its members through: (i) the identification of the main members' needs; (ii) identification and assignation of the leading roles and responsibilities that the different MSP members can play; (iii) MSP must 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; (iv) certification of projects and deliverables based on the agreed fire-resilient landscape tools and methodologies.

Establishing multiple stakeholder institutions is a necessary step to ensure effective, long-term implementation of fire-smart landscape plans. Interrelated multistakeholder institutions are established at different levels, from innovative commodity platforms connecting producers and end buyers and consumers in value chains of agricultural, forest, livestock and eco-tourism products and services derived from fire-smart interventions; to public-private partnerships for the purchase and sale of ecosystem services such as carbon storage, watershed protection or biodiversity conservation, linked to the fire-smart landscape plans; to the fire-smart landscape planning and management platform, with representation of the different public and private stakeholders with interests in the landscape and with responsibility for the implementation of the plans; to international partnerships on fire-smart landscape restoration and management, for the exchange of experiences and knowledge on innovation and fire-smart solutions applicable to landscapes.

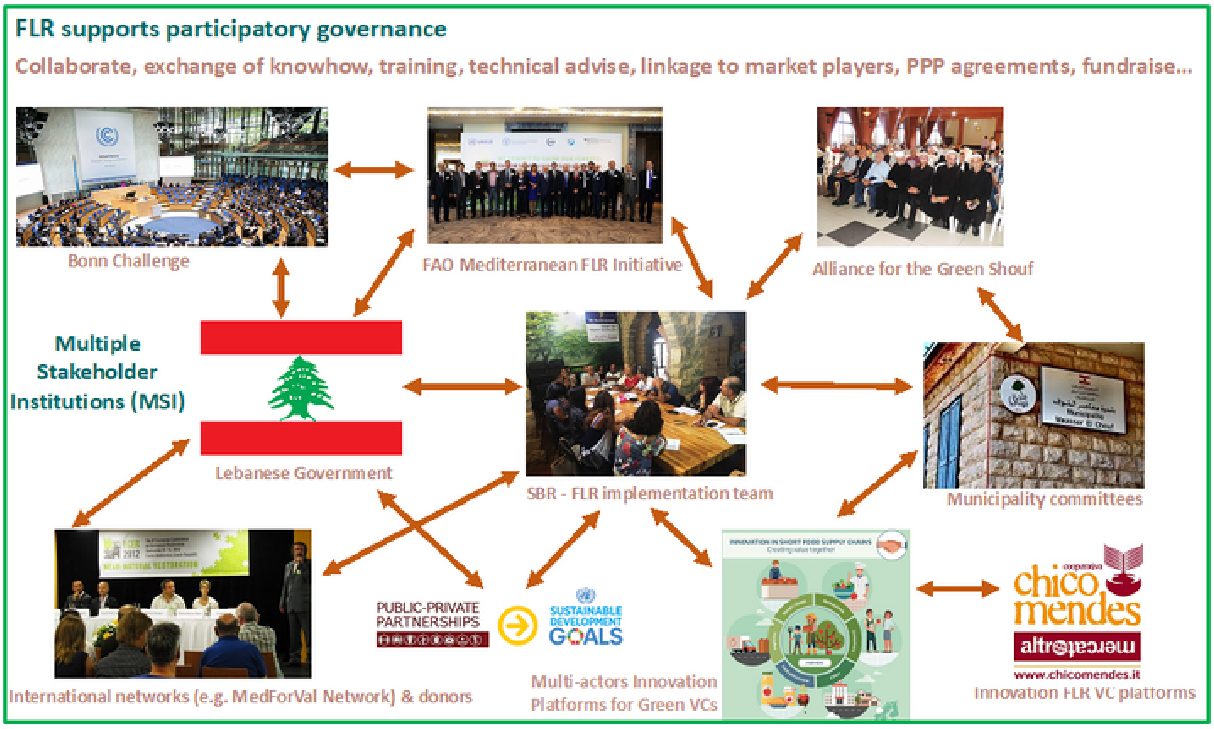


Figure 8. Multiple stakeholder institutions supporting the Shouf-West Beqaa FLR Landscape Planning

3.2.3. 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.

3.3 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.

The following figures include stakeholder consultations in the Shouf-West Beqaa Landscape in Lebanon about the multiple function and multiple benefits provided by fire-smart intervention priorities. In the case of tangible benefits, they should be quantified as much as possible, to understand the economic return on investments and generate interest among landowners and users of prioritized landscape areas for high fire risk reduction.

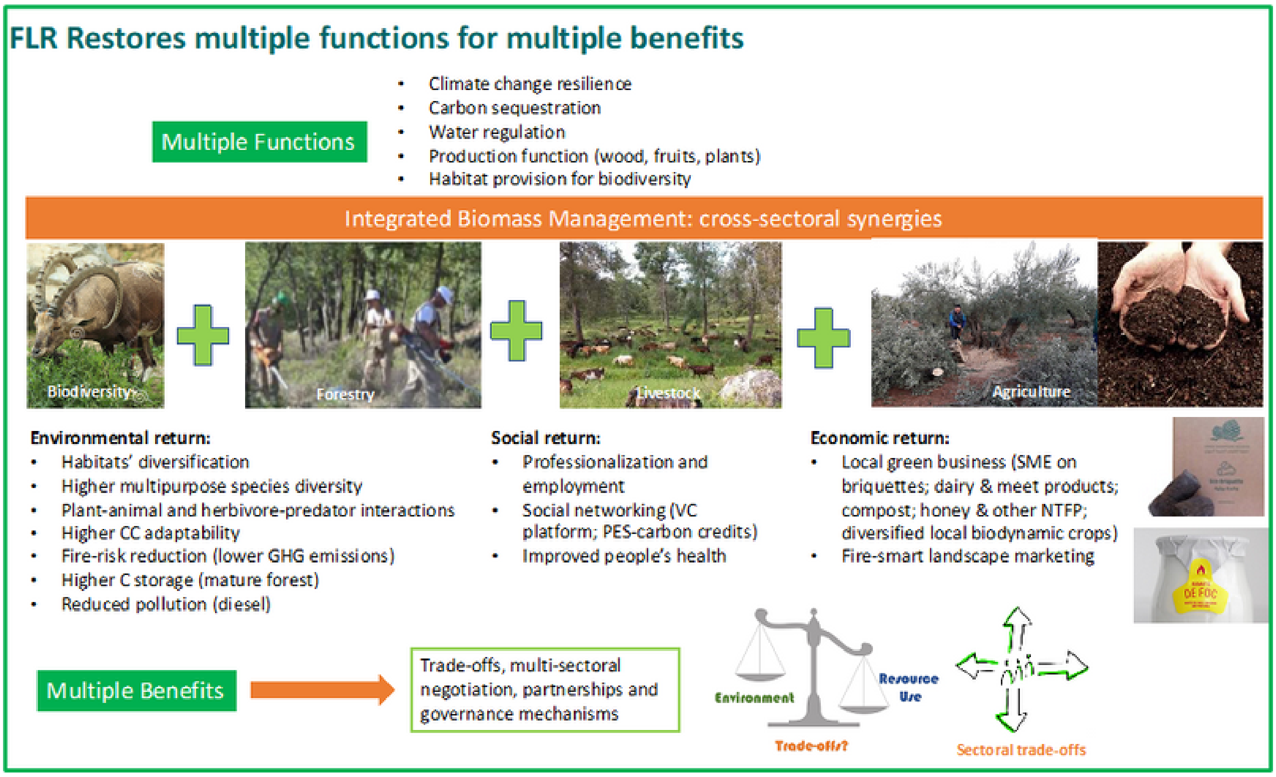


Figure 9. The multiple functions and benefits of integrated biomass management interventions in the Shouf-West Beqaa landscape

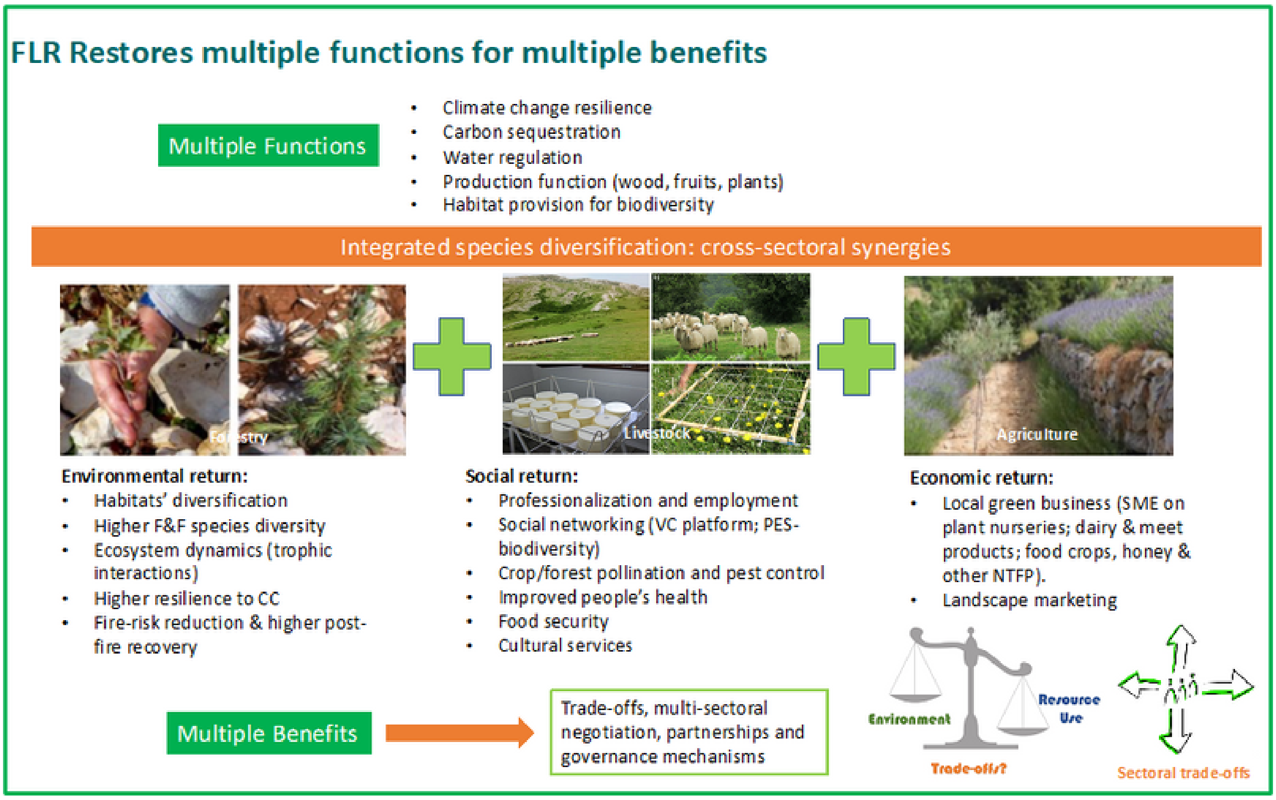


Figure 10. The multiple functions and benefits of integrated species diversification interventions in the Shouf-West Beqaa landscape

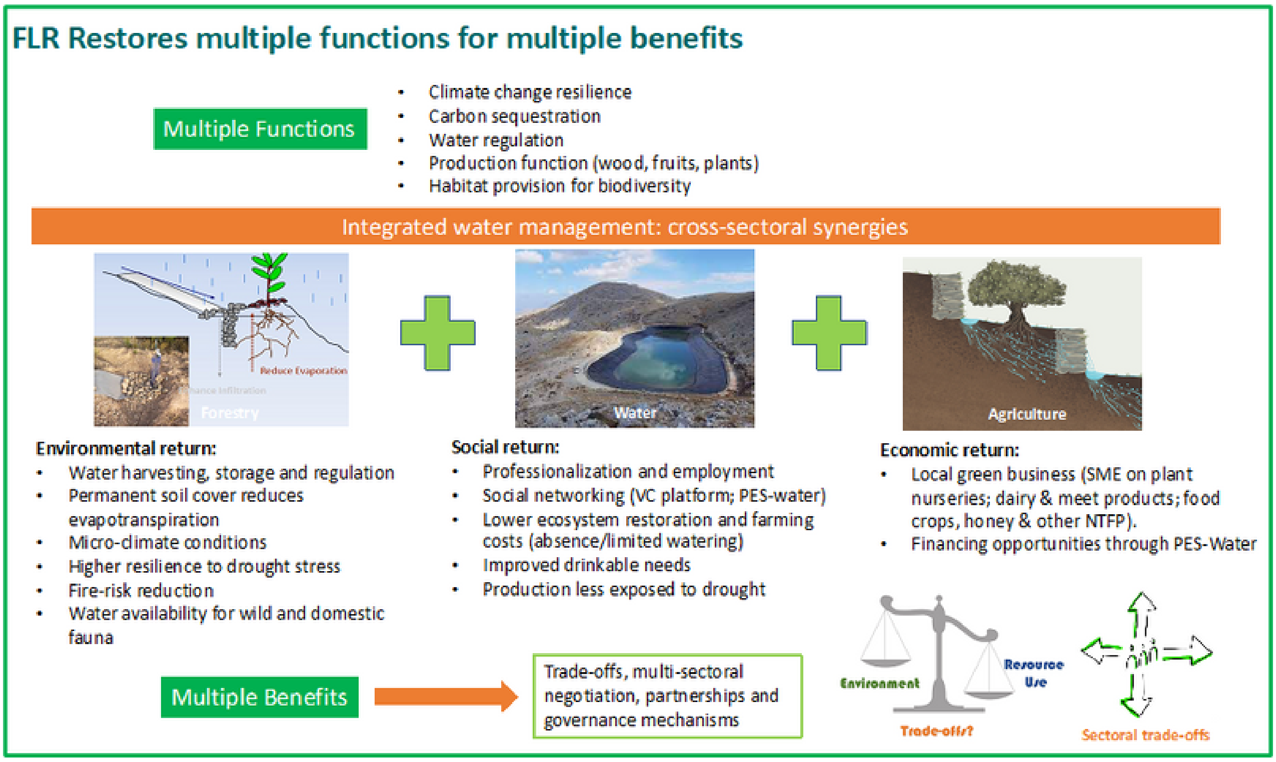


Figure 11. The multiple functions and benefits of integrated water management interventions in the Shouf-West Beqaa landscape

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. **Gromko *et al.* (2019)** [47] have developed an easily applicable economic framework, helping different public and private stakeholders in the landscape to develop a customized decision-making tool 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. The proposed methodology consists of a straightforward, four-step process:

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 being 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 4. Examples of questions

- 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?

One key question to highlight is the need to **determine the appropriate level of complexity**. On the one hand, a complex analysis that collects significant primary data will give the user a higher degree of confidence in the results. On the other hand, increasing complexity raises the costs of the analysis itself, and may not be necessary at an early stage of decision-making.

The cost-benefit analysis to address trade-offs between stakeholders related to different development and nature conservation sectors could follow a stepwise approach: a first step analysis would be based primarily on readily available reference data and would be less expensive. If the results are promising, the user may decide to proceed with a second stage analysis, investing more in primary sources of spatially explicit data to support investment planning decisions at landscape level.

Step 1 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.). They can be categorized in a table, with a first column on the current scenario of LU/LC fuel model type, a second column with the proposed scenario of LU/LC fuel model type, a third column with the priority set of combined climate-smart interventions to effectively achieve the desired change, and a fourth column with the mapping of actors to be involved, a fifth column with the potential costs, and a sixth column with the potential benefits, split into ecological, social and economic.

[47] Gromko, D; T. Pistorius; M. Seebauer; A. Braun; E. Meier. 2019. Economics of Forest Landscape Restoration: Estimating impacts, costs and benefits from ecosystem services. UNIQUE.

Beneficiaries and other stakeholders should be mapped. Stakeholder mapping is an important part of any decision-making process, but it has a 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 5. 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.
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.	• 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.
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 2 (Model costs and benefits), and Step 3 (Data collection): Step 2 and Step 3 are separate but will likely require an iterative process of moving back and forth to refine and improve results.

Based upon the above Step 1, the analysis would generate alternative scenarios to the business-and-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 6. 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	**X**	**X**	-	-	**X**	**X**	**X**	**X**
Protected Area Authority	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Downstream communities or land users	**X** (e.g. PES scheme)	-	-	-	-	**X**	-	-
End-buyer companies	**X** (e.g. PES scheme)	**X**	-	**X**	**X**	**X**	-	**X**
Local administration	-	**X**	**X**	-	**X**	**X**	**X**	**X**
National government	**X**	-	**X**	**X**	**X**	**X**	**X**	**X**
Global community	**X**	-	-	**X**	**X**	**X**	**X**	**X**

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 4 – 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. It may be desirable to understand the costs and benefits for a specific stakeholder, for example, a private investor.

Table 7. Analysis of cost and benefits over time

Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Costs	-900	-300	-300	-300	-300	-300	-300	-300	-300	-300	-300
Benefits	100	200	300	800	800	800	1000	1000	1000	1000	1000
Total accumulated return on investment	-800	-1000	-1000	-500	0	500	1200	1900	2600	3300	4000

Once a model is constructed, the user can conduct a variety of calculations for different types of analysis and indicators: (i) the **net present value (NPV)** of similar investments discounted to present terms, can be compared to determine which is more profitable; (ii) 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; (iii) the **benefit/cost ratio** for analyzing the effectiveness of invested resources; (iv) 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.

3.4. *Prioritization of locally adapted, cross-sectoral and innovative fire-risk reduction intervention measures*

The comprehensive fire-smart landscape plan analyses the fuel model of the different LU/LC types and the risk of ignition and fire spread in the landscape, with special attention to the interface between LU/LC types (areal; linear especially infrastructures and water banks; and specific, such as houses, water points, dumps, etc.) where there is a high probability of ignition due to accidents or bad practices in legal anthropic activities (e.g. sparks from the use of agricultural machinery or vehicles; sparks power lines; permitted agricultural burning that becomes uncontrollable), or to illegal or malicious activities (e.g. unauthorized burning to improve pastures, clearing stubble, opening clearings in the forest for hunting or mushroom gathering, mobilization of wood processing, conversion to developable land, pyromania, revenge or desire to harm other users of the territory).

The identification of areas of the landscape where to apply fire-smart LU/LC types and management practices can result in a very vast area of the landscape to be treated that can become unaffordable due to the costs, lack of human and technological resources, and governance barriers (land tenure and policies). For this reason, the planning exercise includes the prioritization of critical areas of the landscape where fire risk is very high or high (especially interfaces between LU/LC with high ignition risk and LU/LC with high spread risk). Numerous projects on fire prevention describe a list of fire-smart management practices (integrated or not) in the forestry, pastoral, agricultural, urban, and infrastructural fields. Below, there is a summary of the most accepted practices, addressing the pros and cons for their sustainable management.

3.4.1. *Productive firebreak areas through agroforestry*

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 forest fires has led to a reconsideration of the design of the firebreak area. The most innovative trend that is followed in different Euro-Mediterranean countries is to create wide areas instead of firebreak lines, with the maintenance of a very low tree cover (both native forest species and cultivated woody species such as locally adapted varieties and species of fruit trees and vines) and the 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.

The objective of the project team is to support the landowners and users in the selection of a production activity compatible with the firebreak objectives, such as chestnut and almond crops, or cleared groves of arbutus and oak trees, help them carry out the business plans, identify funding opportunities (e.g. annual rural development funds available for landscape and type of intervention) to subsidize part of the conversion and/or planting costs, and financially assist the owner in the years before the system becomes productive and an economic return. Likewise, the productive firebreak areas may involve several plots of different private and/or public owners, so the project team should identify the different owners, promote collaboration agreements between them, in the form of associations and cooperatives, to standardize management in line with the fire-smart objectives, reduce costs, and improve the production, processing and marketing capacity of all owners.

The support of control grazing to prevent the growth of shrubs and high herbs in the firebreak areas is necessary to reduce fire prevention costs, but also highly desired in terms of integrating the role of livestock in agroforestry production (e.g. integrated tree-crop-livestock system, supporting fodder production, shade, soil fertility, product diversification). The use of flail cutter for shrub clearing in the understorey of open woodlands and agroforestry plantations may be also recommended.

3.4.2. Forest thinning favouring multipurpose productivity

The thinning of dense forests can contribute to diversify complementary goods to wood, such as fungi, resin, fruits, etc. In fact, in some cases the forest is burned to open gaps and promote the production of some mushrooms, although a thinning plan could be developed to reach optimal densities linked to the growth of highly commercial mushrooms, as is already the case in some Italian forests (e.g. the Borgotaro Mushroom Consortium in the beech forests of Parma, Italy [48]). Another example is that of the Sierra de Gata landscape of the Extremadura Mosaic Project, where it has been determined that very low densities of 200 trees per hectare of maritime pine (*Pinus pinaster*) are the most favourable for achieving optimum resin production per hectare, with the additional function to significantly reduce fire spread risk.

The objective of the project team is to support the landowners and users in the identification of a diversified set of complementary goods and services linked to suitable tree densities for fire spread reduction, such as wood, mushrooms, resin, honey, fruits, among others, help them carry out the business plans, identify funding opportunities (e.g. annual rural development funds available for landscape and type of intervention) to subsidize part of the costs of management costs. Likewise, the multipurpose thinned forest areas may involve several plots of different private and/or public owners, so the project team should identify the different owners, promote collaboration agreements between them, in the form of associations and cooperatives, to standardize management in line with the fire-smart objectives, reduce costs, and improve the production, processing and marketing capacity of all owners.

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.

The reduction of excessive tree densities usually has a positive effect in terms of biodiversity (increase in species of birds, mammals, insects, fungi and plants), although it is necessary to select indicators and to establish a monitoring system that allows understanding the impact of thinning operations on the indicator species.

3.4.3. Selective biomass harvesting through thinning in abandoned coppice forests and secondary dense forest stands, favouring tree species diversification

Too dense forest stands, such as the abandoned stagnated broadleaf coppice and secondary forests that have colonized agricultural land and abandoned pastures or burned areas, suffer high water stress which causes a high accumulation of dry biomass and risk of dieback and fires. Selective thinning and pruning contribute to accelerate the ecological succession so that the treated stands reach a more mature forest structure, in terms of age classes and reduction of branches in lower parts of the trunks, and to favour specific diversification, maintaining small saplings of native tree species with slow growth due to the high density of the dominant species, and whose growth is activated after thinning.

The landscape team should define optimal tree densities in terms of fire spread reduction and biomass productivity, quantify multi-annual available biomass based on a thinning and pruning plan (e.g. annual surface for the removal of all trees up to x centimeters in diameter at breast height of the dominant pine species, while preserving all seedlings and saplings from the broadleaf tree species; annual surface for the removal of the worst stems of oak stocks, leaving two or three per stock, while preserving all seedlings and saplings from the broadleaf tree species), and help owners develop a business plan for an economic activity that provides economic return to the extraction of the biomass. A limitation when proposing a business activity may be the quality of the biomass of trees and shrubs in very dense and relatively young formations, and its potential use with profitable economic value. This requires an intense search for examples of innovation and development of the use of "marginal" biomass and the promotion of exchanges for the transfer of knowledge and technology.

---

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

For instance, in the Mediterranean Mosaics project in Lebanon, the project team has found an opportunity for innovation by promoting the combined use of thinning forest biomass in very dense secondary Brutia pine forests that have colonized abandoned terraces and stagnated *Quercus calliprinos* and Q. *infectoria* coppice woodlands with biomass from olive pruning and olive pomace, for the production of briquettes compatible with the heating stove system used in the houses of the local villages. This use is economically and technically viable and is locally adapted, although it may not be compatible with the systems of bioenergetic uses of other socio-economic realities of the Mediterranean region. A very positive aspect is the complementary use of forest and agricultural residues that, otherwise, would be burned in autumn, this being the main cause of fires in this landscape. In the case of the LIFE Granatha [49] project in Tuscany (Italy), the clearing of tree heather (*Erica arborea*) shrubs provided biomass for the production of traditional brooms.

As stated in the previous paragraph, 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.

Similarly , the reduction of excessive tree densities usually has a positive effect in terms of biodiversity (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 on the indicator species. Moreover, monitoring activities should also take care of the growth of the seedlings and saplings of broadleaf tree species to ensure an effective diversification with re-sprout species that are highly resilient to wildfires.

3.4.4. Mechanical clearing or prescribed burning of shrubland patches and shrubby understorey layer in open forest stands, combined with controlled grazing

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 human 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 land conversion intervention.

For instance, researchers have applied mechanical cutting and prescribed burning in experimental field plots of shrublands that have colonized abandoned subalpine grasslands in the Pyrenees to select the most appropriate management techniques that help prevent the expansion of highly encroaching shrubs, reduce fire risk and improve the conservation status of high-productive and species-rich grasslands ecosystems [50]. Undisturbed shrubland plots and productive grassland plots were used as a control to compare to compare them with the results obtained in the treated sites. In the analyzed case, the mechanical cutting of the shrub community was more effective to control its regrowth than prescribed burning and contributed to a higher extent to recover original grassland vegetation. The broom shrubs and smaller shrub species cover in prescribed burning plots increased faster than in the mechanical cleared plots during the 5 years following the treatment, although it did not reach the level of the controlled shrubland plot. Species richness and diversity increased in both types of treatments, although lower than in the controlled productive grassland plots. Soils nutrients declined in the prescribed burning plots 4 years after the fire treatment and no difference was observed between the mechanical clearing plots and the controlled shrubland plots, although soil fertility values were lower than in controlled productive grasslands plots. This study showed that grazing favours plant diversity and community complexity in subalpine grasslands, and demonstrated that, in the analyzed context, mechanical clearing is a better strategy than prescribed burning to restore grasslands after shrub encroachment because burning entails deeper soil degradation and faster regrowth of the pyrophytic shrub community.

[49] https://www.lifegranatha.eu/
[50] Alados C, Saiz H, Nuche P, Gartzia M, Komac B, de Frutos Á., Pueyo Y. Clearing vs. burning for restoring Pyrenean grasslands after shrub encroachment. CIG [Internet]. 2019 Sep. 4 [cited 2022 Dec. 7];45(2):441-68. Available from: https://publicaciones.unirioja.es/ojs/index.php/cig/article/view/3589

Prescribed burning has been used worldwide since the first half of the 20th century for fire hazard reduction, forest and range management and biodiversity conservation [51]. 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 [52]. Prescribed burning also present important ecological, technical, managerial, and logistical issues:

- Prescribed burning 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.
- Where fuel recovery is rapid, frequent burning at 2-year intervals may be necessary, which may make prescribed burning unfeasible for forestry agencies with limited budgets and staffing. Without a planned and agreed/budgeted complementation with the herdsmen who carry out 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 fire and fire use, which tends to be eliminated as a sustainable management practice and prohibited by law in numerous circumstances. 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 loss of fire control in increasingly unfavorable weather conditions.
- Prescribed burning can contribute to maintaining a pyrophytic landscape, by promoting and maintaining the predominance of fire-adapted species and avoiding succession to more mature and more fire-resilient stages.
- Despite some limitations, 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 [53] and ALPFFIRS [54]. 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.

Prescribed burning interventions must be coordinated with subsequent controlled grazing in the cleared land, otherwise, it is necessary to repeat the burning after a few years, with the consequent increase in intervention costs and carbon emissions.

3.4.5. Multipurpose biomass processing and marketing for bioenergy and compost

The management of biomass at the landscape scale entails high costs that are difficult to cover solely with public funds. For this reason, it is necessary to identify existing and innovative sustainable uses that help develop green business plans to support or create new local companies around the production of biomass from tree and shrub wood and forest and agricultural residues, and your local marketing: firewood, briquettes, pellets, carbon biochar, wooden utensils, compost.

[51] Pyne SJ (1997). Vestal fire: an environmental history told through fire, of Europe and Europe's encounter with the world. University of Washington Press, Seattle, WA, USA. In: Ascoli D, Bovio G, 2013. Prescribed burning in Italy: issues, advances and challenges. iForest 6: 79-89 [online 2013-02- 07] URL: http://www.sisef.it/iforest/ contents?id=ifor0803-005.

[52] Bertomeu, M.; Pineda, J.; Pulido, F. Managing Wildfire Risk in Mosaic Landscapes: A Case Study of the Upper Gata River Catchment in Sierra de Gata, Spain. Land 2022, 11, 465. https://doi.org/10.3390/ land11040465

[53] Joaquim Sande Silva, Francisco Rego, Paulo Fernandes and Eric Rigolot (editors). 2010. Towards Integrated Fire Management – Outcomes of the European Project Fire Paradox. Research Report 23. European Forest Institute.

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

Timber from thinning and pruning from coniferous and broad-leaved forests, as well as from olive trees of a certain thickness, has a more or less developed market in many landscapes for firewood and industrial wood products. However, it is the finer biomass from too dense formations of forests and shrubs that poses a high risk of fire, and that requires innovation in the development of economically viable, locally-adapted and socially demanded products. There are some examples developed in the fire-smart landscape plans of the Mediterranean region, as in the case of the Shouf-West Beqaa landscape where low-quality timber from thinning and pruning of secondary Brutia pine and abandoned Infectoria and Kermes oak coppice It is chipped and mixed with chipped olive pruned remains and olive pomace to produce briquettes for house heating stoves and to produce compost. In the EU funded Granatha LIFE project in Tuscany, biomass harvested from cleared *Erica arborea* maquis is used for the production of traditional brooms.

Box 1. Biochar production from forest and agricultural biomass waste [55]

Biochar is a porous, carbonaceous material that is produced by pyrolysis of biomass and is applied in such a way that the contained carbon remains stored as a long-term C sink or replaces fossil carbon in industrial manufacturing. It is not made to be burnt for energy generation **[56]**.

Fuel treatments (i.e., thinning and pruning) to mitigate forest fires will generate large volumes of forest residues together with available logging residues that can be used to produce biochar. Forest and agriculture management produce biomass wastes that may be used for biochar production. For instance, in the Portuguese region of Alentejo, both sectors generate 2 million tons of waste annually, (e.g. corn stalks, vine pruning, olive pruning, eucalyptus, pine, cork oak, and shrubs biomass waste) that could potentially produce 491,000 tons of biochar annually.

Although biochar is mostly recognized as a valuable resource for soil fertilization and conditioning, it also has significant potential to be used for water filtration and remediation processes, as an animal feed supplement, for GHG emission reduction (carbon sink), for insulation materials for the building sector, as an electrode material (for energy production and storage), cosmetic products, biogas production and improvement, and in catalytic processes. When applied as a soil amendment, biochar contributes to climate change mitigation by fixing carbon in stable aromatic bonds that are resistant to microbial degradation. This stability reduces immediate labile carbon release into the atmosphere. Moreover, other GHG emissions such as N_2O and CH_4 are significantly minimized, depending on soil type, with reductions that may achieve more than 50%, considering the introduction of biochar amounts equivalent to 10% of soil mass and 20t x ha. Conversion of animal or vegetable feedstocks into biochars also minimizes GHG emissions through the natural decomposition of such feedstocks.

Current regulations on biochar in Europe.

European Regulation	National Regulation		Voluntary Regulation
Not in force yet. Proposals are being developed and are expected to be implemented soon. It is anticipated that carbon and nutrient-rich biochars will be regulated by "end-of-waste criteria".	In force in Germany, Austria, Switzerland, and Italy. Biochar of vegetable origin only.	In other EU countries, free trade is only possible after obtaining registration or a permit.	Serves certification but does not have a legal basis. There are three main organizations: European Biochar Certificate (EBC); Biochar Quality Mandate (BQM); and International Biochar Initiative (IBI-BS).

[55] Garcia, B.; Alves, O.; Rijo, B.; Lourinho, G.; Nobre, C. Biochar: Production, Applications, and Market Prospects in Portugal. *Environments* **2022**,9,95. https://doi.org/10.3390/ environments9080095
[56] EBC (2012-2022) 'European Biochar Certificate - Guidelines for a Sustainable Production of Biochar.' European Biochar Foundation (EBC), Arbaz, Switzerland. (http://european-biochar.org). Version 10.1 from 10th Jan 2022.

Biochar applications are relatively new, justifying the existing gap in national and EU legislation regarding its production and use. Most EU countries do not have specific regulations for biochar, although all countries have regulatory procedures to use these materials for soil fertilization, meaning that one can apply for registration to use biochar as a fertilizer product. Voluntary biochar quality standards were designed to provide quality and safety indicators for the use of biochar in agricultural applications only, leaving other potential applications out of their scope. At the European level, until 2015, the industry was very small with about 20 biochar production plants in operation, but market dynamics increased significantly from 2016 onwards with more than 50 new plants installed, and a production of >20,000 t/y and growing, and a price of price of € 800 per ton.

The main economic obstacle to use forest residues spread across vast landscape areas is the high logistics cost of collection and machinery. Forest residues generated during commercial logging operations also present a fire risk that must be treated or removed. Some authors [57] have proposed the use of portable biochar systems using slow pyrolysis as an economically viable option to utilize forest residues, and as a more environmentally-sound option (2– 40 times lower net CO_2 eq. emissions) than slash burning.

3.4.6. Controlled grazing in firebreak areas

Several wildfire prevention programs in southern Europe are currently using livestock grazing for the maintenance of fuel-breaks. This silvo-pastoral management is valued for being sustainable and effective in reducing fuel loads as a complementary fire-smart intervention to be implemented after the mechanical clearing or prescribed burning of the shrubby vegetation cover. 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 [58]. 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.

In the event of wildfire, controlled grazing would facilitate that fire brigades gained control of the wildfire. In exchange for this service, livestock farmers 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 farmer should be evaluated every year, and the amount of money they finally receive can be adjusted depending on results [59].

3.4.7. 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 [60]. 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.

[57] Puettmann, M.; K. Sahoo; K. Wilson; E. Oneil. 2019. Life cycle assessment of biochar produced from forest residues using portable systems. Journal of Cleaner Production, Volume 250, 20 March 2020, 119564.

[58] 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.

[59] Ibid.

[60] Plana, E; Font, M; Serra, M., Borràs, M., Vilalta, O. 2016. Fire and forest fires in the Mediterranean; a relationship story between forest and society. Five myths and realities to learn more. eFIREcom project. CTFC editions. 36pp.

Three different types of interfaces are identified between wildland and human built areas (wildland-human interface) [61]:

- 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 [62] [63] [64]. 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 [65]. 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 two stakeholder types [66].

---

[61] Johnston, L.M., Flannigan, M.D., 2018. Mapping Canadian wildland fire interface areas. Int. J. of Wildland Fire 27, 1–14, http://dx.doi.org/10.1071/WF16221.

[62] Herrero-Corral, G; M. Jappiot; C. Bouillon; M. Long-Fournel. 2012. Application of a geographical assessment method for the characterization of wildlandeurban interfaces in the context of wildfire prevention: A case study in western Madrid. Applied Geography 35 (2012) 60e70.

[63] Lampin, C., Jappiot, M., Long, M., Morge, D., & Ferrier, J. P. (2008). Characterization and mapping of dwelling types for forest fire prevention. Computers, Environment and Urban Systems, 33(3), 224e232.

[64] Syphard, A. D., Radeloff, V. C., Keeley, J. E., Hawbaker, T. J., Clayton, M. K., Stewart, S. I., et al. (2007). Human influence on California fire regimes. Ecological Applications, 17(5), 1388e1402.

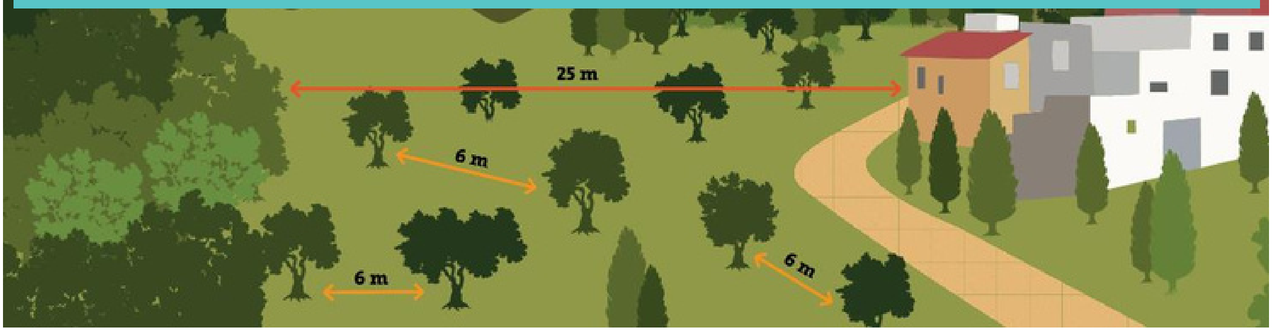
[65] Herrero-Corral, G; M. Jappiot; C. Bouillon; M. Long-Fournel. 2012. Application of a geographical assessment method for the characterization of wildlandeurban interfaces in the context of wildfire prevention: A case study in western Madrid. Applied Geography 35 (2012) 60e70.

[66] Plana, E; Font, M; Serra, M., Borràs, M., Vilalta, O. 2016. Fire and forest fires in the Mediterranean; a relationship story between forest and society. Five myths and realities to learn more. eFIREcom project. CTFC editions. 36pp.

- <u>Owners and managers of the houses and infrastructures</u>. 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 strip 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.

Housing developments, isolated houses and surroundings areas

- Perimeter protection strips are legally mandatory strips of land that must surround housing developments, isolated buildings and installation in contact with the forest.
- In these strips nearly all scrub must be removed and trees partly cut back to reduce the strength of fires and prevent them from reaching the houses.
- They must be at least 25 meters wide and free of dry vegetation and with any trees pruned and cleared.
- Vacant plots must comply with the same conditions as the perimeter protection strips.



With forest fires the safest thing is to be far away from the danger, but actually moving away from it may not be. In fact, in some cases ita can be very risky.

1. **In the home and garden**
    - Keep a strip of land free of vegetation and forest residue at least 2 meters wide around the building and meters wide around the plot.
    - In the garden, a minimum distance of 6 meters between the trees is recommended (increase the distance if the plot is on a slope). The branches must not touch each other.
    - Keep the roof clear of dry leaves, branches and other
    - organic matter
    - Store firewood away from the house
    - Be careful with the chimney! Protect it to prevent sparks
    - or embers falling down it into the house
    - Store fuel (gas bottles, gasoli containers, etc.) in ventilated and protected enclosures.
    - Have multipurpose ABC fire extinguishers for different classes of fire, especially in the kitchen, the attic and garage.

Figure 12. Example of recommendations for protecting building from wildfires in Catalonia (Spain) [67]

[67] <u>https://interior.gencat.cat/web/.content/home/030_arees_dactuacio/proteccio_civil/consells_autoproteccio_emergencies/incendi_del_bosc/documents/llibret_incendis_forestals_ang.pdf</u>

- The 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 8. National Legal frameworks with reference the spatial definition of WUI [68]

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 wildfire 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 [69]. 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.

3.4.8. Sustainable agroecological production systems

Sustainable agro-ecological farming systems include, biomass management measures to improve soil fertility and its water retention capacity, in addition to little/no soil mobilization, crop rotation and maintenance of a permanent vegetation cover. The management of stubble and pruning remains for soil mulching, compost and fodder, helps to reduce the risk of fires derived from agricultural burning. Moreover, the integration of livestock as part of the agro-ecological farming practices helps control fuel load in the farmed plot and neighbouring farmland habitats while also improving soil fertility. This type of farming practices also contributes to reducing carbon emissions derived from the use of agricultural machinery in conventional agriculture.

3.4.9. 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”.

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 and 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 have 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 (e.g. thinning interventions 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).

[68] Ibid.

[69] Modugno, S; H. Balzter; B. Cole; P. Borrelli. 2016. Mapping regional patterns of large forest fires in Wildland-Urban Interface areas in Europe. Journal of Environmental Management 172 (2016) 112e126.

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).

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

- Selection of native 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 native 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.

3.4.10. Incentives to repopulate and reuse abandoned rural territories with fire-smart business models

In some human depopulated landscapes with vast areas of continuous pine and/or eucalypt tree plantations adjoining vast land abandoned areas covered with dense shrub layer, drastic decisions about LU/LC changes and rural development incentives to increase population and re-manage the territory, should occur to avoid the risk of large devastating fires. For instance, as a response to the record 500,000 hectares burned in Portugal during the extreme wildfire season of 2017, the Portuguese Government approved a decree-law that prohibits replanting areas burned by forest fires with eucalyptus, with the objective of "promoting the existence of an adequate structure and native species composition in forestland", and announced sweeping land reforms and investments in a range of projects to protect local communities most at risk of wildfires in Portugal's central and northern districts [70]. However, the ban on new eucalyptus trees does nothing to cut risks from plantations already in place before 2017 to surrounding human settlements, and it does not comprehensively address the extremely high accumulation of fuel derived both from pine and eucalyptus plantations and from the vast expanses of scrub on abandoned land (this is one of the main claims of the timber industry that emphasizes the relatively high role of biomass accumulation due to rural abandonment in large devastating fires, rather than that resulting from plantations). This transitory regime, which applies to continental Portugal, aims to contribute to a greater balance between the different species in Portuguese forests, as well as "make forest industries compatible with the conservation of biodiversity and reduction of the risk of large devastating wildfires". As part of its new approach to tackling wildfires, Portugal has established an integrated fire agency (AGIF) unifying conservation officials, police, the army, and private forestry firms to streamline both prevention and firefighting efforts. The AGIF now urges communities to clear land of scrub, create evacuation plans for high-risk villages, and issue permits for controlled burning of debris. The agency also has taught forest engineers and firefighters how to create firebreaks through prescribed burns. Despite progress, **the long-term human desertification in rural areas remains a major challenge**. About 30% of rural properties in Portugal are now unclaimed, with disused property rapidly accumulating flammable undergrowth. As a result of such challenges, only 20% of AGIF's fire prevention goals have been achieved, despite growing knowledge and willpower to act. AGIF sees **reversing the rural exodus and revitalizing agriculture as key to cutting fire risks**.

---

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

Rural shepherds have received subsidies to run their herds, with funding expected through 2024, by which time the effort should be self-sufficient. Allowing local people to take charge of reducing fire risk on the land they manage is much more efficient than a top-down fire-fighting approach. After the 2017 disaster, for instance, some rural communities have taken the lead to cut a eucalyptus-free buffer zone around their settlements, without waiting for government help.

Some successful experiences in managing fire-smart landscapes focus on the development of green business models based on the management of traditional or innovative agroforestry systems and support for the rural population with technical support and the search for financing opportunities (e.g. European rural funds available for each territory) so that they see the opportunity to undertake agroforestry businesses with high market viability and repopulate rural areas. The demonstration of economic returns comparable to those of pine and eucalyptus plantations is necessary to achieve drastic changes in highly homogenized territories with high fire risk fuel models, without which it will be very difficult to avoid unmanageable large scale wildfires.

3.5 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 analyse 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 anthropised 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 the following.

3.5.1. 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 favours 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.

3.5.2. 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.

3.5.3. 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 [71]. Moreover, the mulching of the soil surface with brush-chipping has greatly reduced the germination rates of fire-prone seeders.

Early thinning in high dense Aleppo or Brutia pine saplings that have colonized abandoned or burned landscape areas is strongly advised to speed up tree growth, in order to create mature forest stands with high trees and wider crowns and favors the percentage of non-serotinous cones with larger numbers of viable seeds [72]. The increased production of viable seeds may create new economic opportunities to diversify pine production (i.e. the harvesting of pine seeds for tree nurseries and for edible uses, like the traditional pastry production in Tunisia and the *zaatar* mix in the Shouf region in Lebanon [73] (Regato, 2007). Lower tree densities will also decrease canopy closure and reduce surface fuel, with the consequent reduction of fire risk.

3.5.4. 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.

3.5.5. 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.

[71] Valdecantos A. (2008) Post-fire restoration strategies/interventions to increase forest resilience against large forest fires exacerbated by climate change: The case of Valencia (Spain). In: Regato, P. (2008) Adapting to global change, Mediterranean Forests. IUCN Centre for Mediterranean Cooperation.

[72] Verkaik, I, J.M. Espelta (2005) Effect of thinning and post-fire regeneration age on the reproductive characteristics of Pinus halepensis Mill. Forests. II International Conference on prevention strategies of fires in Southern Europe. CREAF.

[73] Regato, P. (2007) Management recommendations for Pinus halepensis seeds production in Gouria region (Tunisia). Unpublished report produced for the AECID Project: Programa Aumento de la sostenibilidad de los medios de vida de Poblaciones Rurales Vulnerables en Marruecos, Mauritania y Túnez. Spain.

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 [74] 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 [75]. 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 [76].

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 (Castro *et al.* 2010). 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 [77]. 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 [78]. A number of projects supported by WWF in Morocco 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.

3.6 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 different investment types [79]:

- **Asset investments** 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.

---

[74] Castro, J. 2013. Postfire Burnt-Wood Management Affects Plant Damage by Ungulate Herbivores. Hindawi Publishing Corporation International Journal of Forestry Research Volume 2013, Article ID 965461, 6 pages http://dx.doi.org/10.1155/2013/965461

[75] Marañón-Jiménez, S.; J. Castro; J.I. Querejeta, E. Fernández-Ordoño; C.D. Allen. 2013. Post-fire wood management alters water stress, growth, and performance of pine regeneration in a Mediterranean ecosystem. Forest Ecology and Management 308 (2013) 231–239.

[76] Castro J, Moreno-Rueda G, Hodar JA (2010b) Experimental test of postfire management in pine forests: impact of salvage logging versus partial cutting and nonintervention on bird-species assemblages. Conserv Biol 24(3):810–819. doi:10.1111/j.1523-1739.2009.01382.x

[77] Castro, J., G. Moreno-Rueda, J.A. Hódar (2010) Experimental Test of Postfire Management in Pine Forests: Impact of Salvage Logging versus Partial Cutting and Nonintervention on Bird– Species Assemblages. Conservation Biology, Volume 24, Issue 3, pages 810–819, June 2010

[78] Regato, P., R. Murti, M. Valderrabano, C. Danielutti(2010) Reducing Fire Disasters through Ecosystem Management in Lebanon (IUCN). In: Demonstrating the Role of Ecosystems-based Management for Disaster Risk Reduction. Prepared for the Partnership for Environment and Disaster Risk Reduction (PEDRR) Workshop, September 2010 UNU Campus in Bonn.

[79] 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.

- **Enabling investments** 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).

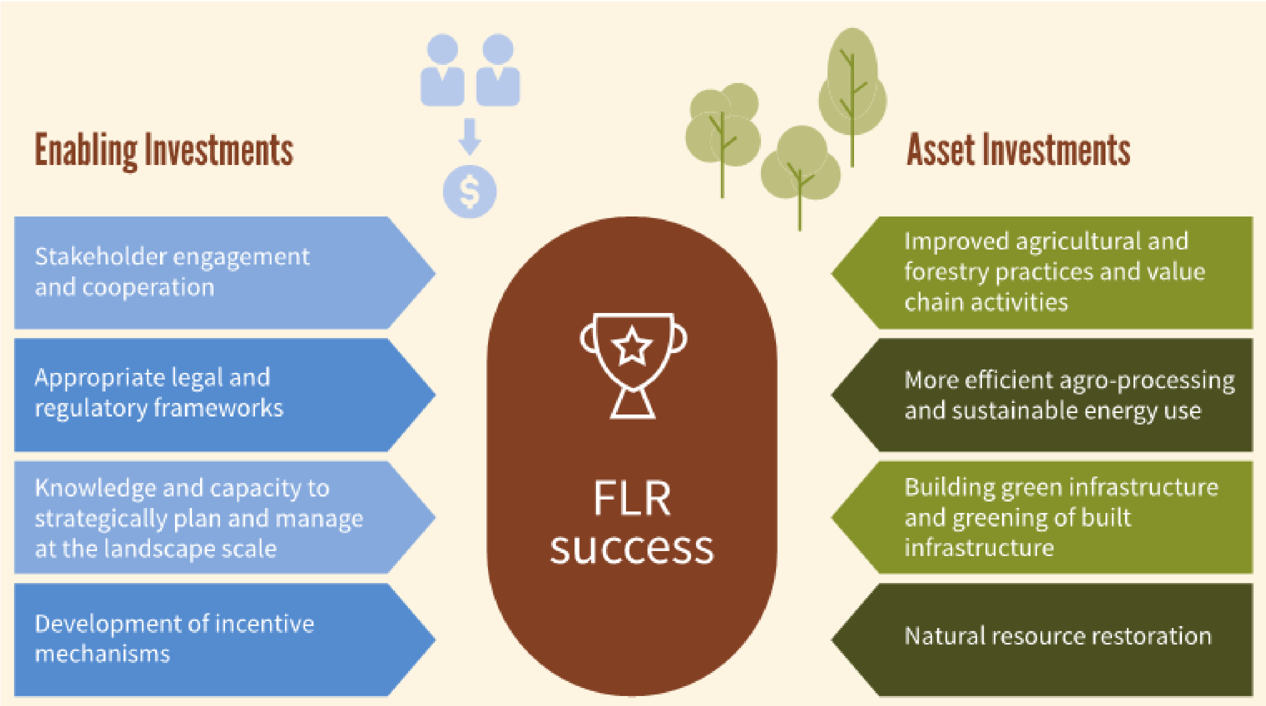


Figure 13. Asset and enabling investments for FLR success [80]

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)
- 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).

[80] Ibid.

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.

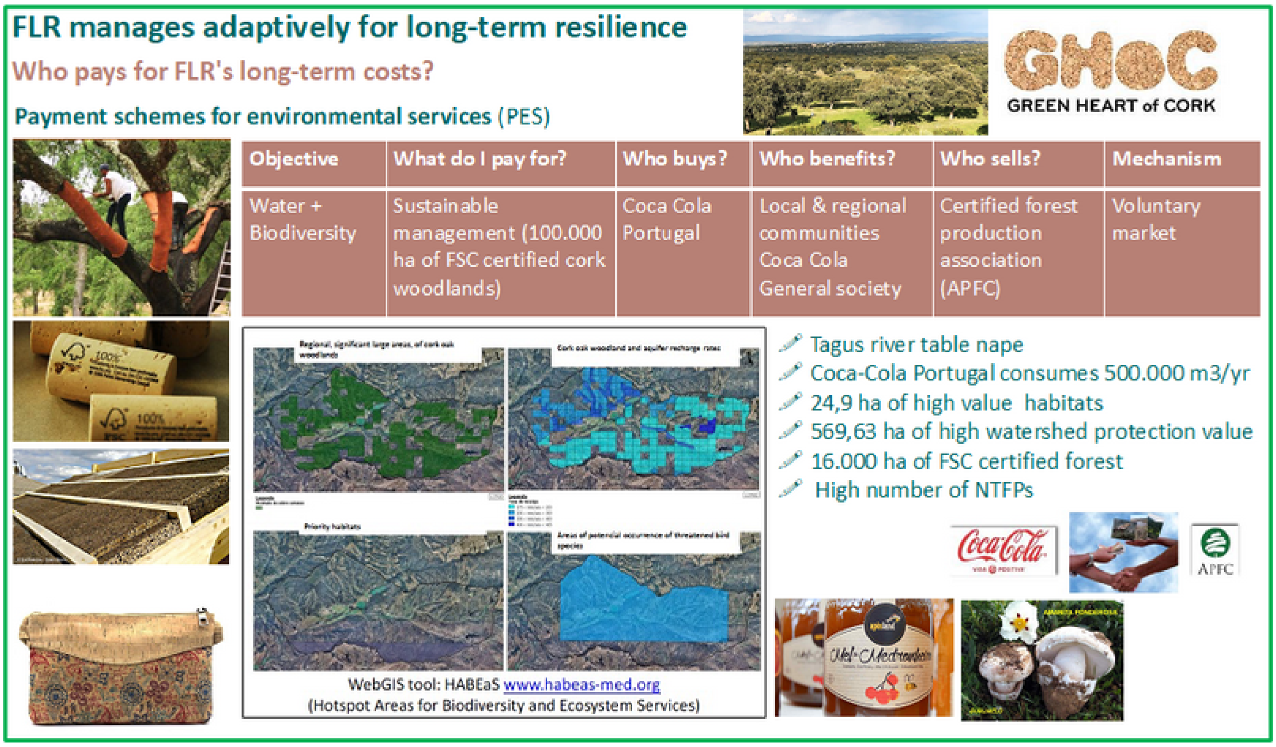


Figure 14. Payment scheme for watershed protection and biodiversity conservation services provided by sustainably managed cork oak woodlands in central Portugal [81]

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.

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.

[81] Bugalho, M., Silva, L. 2014. Promoting sustainable management of cork oak landscapes through payments for ecosystem services: The WWF Green Heart of Cork project. In Unasylva 242 (65), 29-33.

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 the following topics:

- 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.

3.6.6.2. 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.

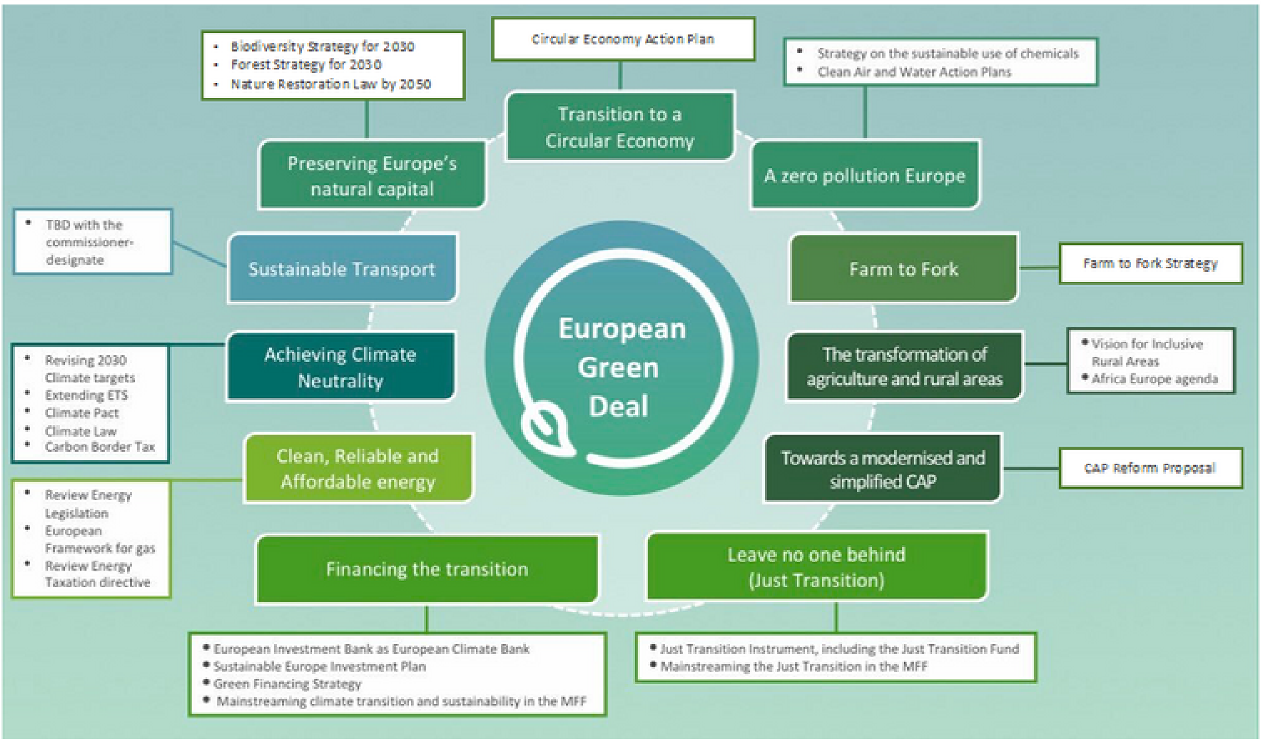


Figure 15. The European Green Deal transformative policies

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**, including: (i) ***increasing EU's climate ambition for 2030 and 2050*** (e.g. achieving climate neutrality by 2050; 2020 first EU Climate Law; ensure effective carbon pricing throughout the economy; more ambitious EU strategy on CC adaptation); (ii) ***'Farm to Fork' Strategy: designing a fair, healthy and environmentally-friendly food system*** (e.g. at least 40% of the common agricultural policy's overall budget would contribute to climate action; CAP national strategic plans reflect the use of sustainable farming practices, reduction of agro-chemicals, eco-scheme measures rewarding farmers' environmental and climate improvements, emissions reduction, water quality and low-carbon food; reduce the environmental impact of the food production, processing and retail sectors by taking action on sustainable farming practices, transport, storage, packaging and food waste; stimulate sustainable food consumption and promote affordable healthy food for all); (iii) ***Preserving and restoring ecosystems and biodiversity*** (e.g. Biodiversity Strategy 2030; new Forest Strategy 2030; Nature Restoration Law by 2050); (iv) Mobilizing industry for a clean and circular economy; (v) Building and renovating in an energy and resource efficient way; (vi) Accelerating the shift to sustainable and smart mobility; (vii) A zero pollution ambition for a toxic-free environment.
- **Mainstreaming sustainability in all EU policies**. The Commission has estimated that achieving the current 2030 climate and energy targets will require €260 billions of additional annual investment, about 1.5% of 2018 GDP. The Commission has proposed a 25% target for climate mainstreaming across all EU programs. A **Sustainable Europe Investment Plan** will dedicate financing to support sustainable investments, include proposals for an improved enabling framework that is conducive to green investment, and help prepare a pipeline of sustainable projects. **At least 30% of the InvestEU Fund will contribute to fighting climate change**. Moreover, projects will be subject to sustainability proofing to screen the contribution that they make to climate, environmental and social objectives. The European Union's **Just Transition Fund (EU JTF)** is a brand-new fund created under the 2021-2027 programming round, to support the regions and communities that are most negatively affected by the transition to climate neutrality, through low-carbon and climate-resilient activities, access to re-skilling programmes, jobs in new economic sectors, or energy-efficient housing.
- **Greening national budgets and sending the right price signals**. The review of the European economic governance framework will inform a debate on how to improve EU fiscal governance, including how to treat green investments within EU fiscal rules, while preserving safeguards against risks to debt sustainability. **Well-designed tax reforms** by Member States can make a more targeted use of VAT rates to reflect increased environmental ambitions, for example to support organic products.
- **Mobilising research and fostering innovation**. Horizon Europe, in synergy with other EU programmes, will play a pivotal role in leveraging national public and private investments. At least 35% of the budget of Horizon Europe will fund new solutions for climate, which are relevant for implementing the Green Deal. The **Horizon Europe** programme will also involve local communities in working towards a more sustainable future, in initiatives that seek to combine societal pull and technology push. The **European Innovation Council** will dedicate funding, equity investment and business acceleration services to high potential start-ups and SMEs for them to achieve breakthrough Green Deal innovation that can be scaled up rapidly on global markets. An immediate priority will be to boost the EU's ability to predict and manage environmental disasters. To do this, the Commission will bring together European scientific and industrial excellence to develop a very high precision digital model of the Earth.
- **Activating education and training**. The proposed **European Social Fund+** will play an important role in helping Europe's workforce to acquire the skills they need to transfer from declining sectors to growing sectors and to adapt to new processes. The **Skills Agenda and the Youth Guarantee** will be updated to enhance employability in the green economy.

The European Green Deal **embraces various policy areas with major implications on the shift from fire-prone to fire-smart landscapes**, namely the EU Biodiversity Strategy for 2030, the 2022 Nature Restoration Law, 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 1 provides further description of these policy frameworks.

These policy frameworks include relevant sections directly or indirectly addressing wildfire prevention needs.

As part of the implementation of the **EU Biodiversity Strategy for 2030**, the Commission proposed a **legally binding instrument for ecosystem restoration**, 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 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.

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**. To help unlock the investments needed providing certainty for investors and embedding sustainability in the financial system, 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.

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. Among the **legally binding targets for nature restoration in different ecosystems** that will apply to every Member State, there is "the **overall increase by 2030** of biodiversity and a positive trend for **forest connectivity, deadwood, share of uneven-aged forests, forest birds and stock of organic carbon**". 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.

The **New EU Forest Strategy for 2030** 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 people for sustainable forest-based bioeconomy**, encouraging all concerned public and private stakeholders to join the **Pact for Skills** to take concrete action to adapt education and training for a sustainable forest bioeconomy, and enhance employment and entrepreneurship through new enterprises valorising the sustainable use of products and services, making use of the European Social Fund Plus (ESF+).

Under its Component 2, the Strategy supports:

- forest restoration and reinforced 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'** development for the provision of **forest ecosystem services** are being **explored with EU research support** [82] and a **LIFE preparatory action** with the objective to be incorporated in EU funding programmes: ***InnoForESt*** aims to spark a transformation of the European forest sector by steering policies, governance mechanisms and businesses towards enhancing the provision of a wide range of forest ecosystem services (ES); six local level initiatives across Europe (including one Mediterranean country – Italy/Dolomites) were analysed in terms of innovative governance mechanisms for securing ES provision and financing. In addition, 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 native 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.

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

The **Common Agricultural Policy (CAP)** 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.**

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

i) fostering the competitiveness of agriculture;
ii) ensuring the sustainable management of natural resources, and climate action;
ii) 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.

In the context of the **Long-term Vision for Rural Areas**, a network of forest-dominant rural areas and municipalities will be promoted to give voice to forest rural areas, ensuring their representation in **key initiatives** (**rural observatory**, European Network for Rural Development - ENRD portal), and facilitating specific assessments of reality and needs of forest areas across the EU.

Box 2. Rural development priorities to be funded by the 2014-2022 Rural Development Program for Greece

RD Priority	Budget (million euros - M €)	Linkage with EUKI project
General remark		• WP 3 could include as part of the planning process an assessment of funding accessibility in the Chania Prefecture context, and mechanisms to support landowners and users to be aware of, be interested, and apply for funding.
(i) Knowledge transfer and innovation in agriculture, forestry and rural areas: 285 cooperation projects (including framework of EU Innovation Partnership); stimulating supply chain partnerships in agri-food sector; 28,600 training places made available to enhance knowledge transfer (AR, IT & R [83]) for practical implementation on farms and forests.	• No data	

[83] AW: Awareness raising; IT: Innovative technologies; R: Research.

RD Priority	Budget (million euros - M €)	Linkage with EUKI project
(ii) Competitiveness & viability of agriculture sector and sustainable forestry: business development & training for 36,900 young farmers' managed farms; restructuring and modernization of 8,978 farm businesses; COVID-19 related support to 143,648 olive sector farmers.	KM (22 M) Advisory Serv. (8.5 M) Investments (611 M) Young farmers (754 M) Farm & business Dev. (49.5 M)	• Young entrepreneurs on agriculture and livestock business involving biomass management (e.g. Fire-shepherds; Fire-woody crops).
(iii) Food chain organization (processing, marketing and risk management): support to participate to quality schemes, local markets and short supply chains for 29,250 holdings; investments in processing and marketing of 450 agri-food businesses.	Quality schemes (68.3 M) Investments (233 M) POs (27.8 M) Risk Manag. (80 M)	• Fire-fighting Label for dairy, meet, honey, grapes/wine, olive oil, etc. • Online marketing support to link producers and consumers (emphasis on tourism).
(iv) Restoring, preserving and enhancing ecosystems related to agriculture and forestry: 26.31% of farmland under BD conservation contracts; 26.09% of farmland under water management contracts; 25.30% of farmland under soil management contracts; small part of forestland under agroforestry and afforestation management contracts.	KM (15.5 M) Advisory s. (62.3 M) Investments (344 M) Forest (156.5 M) AEC [84] (593.7 M) ANC [85] (1,826.5 M) OA [86] (1,150.6 M)	• Conversion into fire-smart farmland and forest management in areas facing natural constraints (ANC), areas requiring env. and climate measures (AEC), and OA (linkage with Carbon balance)
(v) Resource efficiency and low C and CC-resilient economy in agriculture, food and forestry: efficient irrigation, but also renewable energy sources; prevention of damages in 45,000 ha forest.	Energy efficiency Investments (12.5 M) Renewable E. Invest (49.2 M) GHG reduction invest (1.2 M) Carbon Conserve. & Sequest Invest (5 M) Forest 112 M	• Combined use of forest and agriculture biomass waste into bioenergy. • Integrated agriculture, forest and livestock management promoting C conservation & sequestration.
(vi) Social inclusion and local development in rural areas: 50% rural population covered by a local development strategy; 10% rural population benefiting from improved services and ICT structure; 2,150 new jobs created by LEADER; 675 new jobs on non-agriculture activities.	LEADER & CLLD (512.5 M) Farm & Business Dev (38.5 M)	• Support the development of fire-smart local development strategies in Lefka Ori landscape.

The **Farm to Fork Strategy** addresses comprehensively the challenges of sustainable food systems. The Strategy' priority "**Ensuring sustainable food production**" aims to rapidly transform production methods, making the best use of nature-based, technological, digital, and space-based solutions to deliver better climate and environmental results, increase climate resilience and reduce and optimise the use of inputs.

[84] Agri-environmental and climatic measures.
[85] Areas facing natural or other specific constraints.
[86] Organic agriculture.

With the Farm-to-Fork Strategy approved in May 2020, 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** [87]. 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**.

The **European Climate Law** 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 CO_2-eq as set out in the proposal for a **revised Regulation on Land Use, Land Use Change and Forestry (LULUCF)**.

3.6.2.3. Long-term adaptive monitoring

The analysis of forest landscape restoration planning and implementation results worldwide suggest that success is linked with:

i) the existence of clear motivation;
ii) the enabling forces in place;
ii) the capacity developed and resources mobilized.

On this basis, the Global Partnership on FLR has defined a set of indicators to monitor the performance and impact of the implementation of forest restoration landscape plans.

---

[87] 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".

Theme	Indicator
Motivation	• Number of stakeholders aware of the multiple ecological, social and economic benefits provided by fire-smart interventions. • Existence of political will for fire-smart landscape planning and implementation. • Existence on champions supporting the implementation of fire-smart landscape plans.
Enabling conditions	• Fire-smart landscape plan is technically solid, identifies/ranks fire risks under a CC scenario and priority risk reduction interventions. • Number of aligned and integrated cross-sectoral policies. • Existence of responsible tenure governance mechanisms. • Existence of multiple stakeholder institutions supporting fire-smart planning and implementation, gender-inclusive and with clear allocation of functions and responsibilities. • Number of markets for products and services that come from fire-smart interventions identified and accessible to landowners and users.
Capacity developed and resources mobilized	• Existence of knowhow on locally adapted innovative fire-smart planning tools and implementation protocols for fire-smart interventions. • Number of stakeholders with knowhow on fire-smart landscape planning and implementation. • Number of land users and managers organized as associations or cooperatives supporting the implementation of fire-smart practices. • Incentives and funding for implementing fire-smart priority interventions exist and are easily accessible to land practitioners. • A user-friendly monitoring and evaluation system with ecological, social and economic indicators is developed and implemented with the participation of all concerned actors. • Results are analysed to improve planning and implementation, elaborate knowledge products adapted to the different social needs, and communicated.

Given the complexity of social, environmental, and economic factors linked to fire risks in Mediterranean landscapes, it is necessary to design monitoring systems that allow, in a simple way, to evaluate and qualify impacts of fire-smart interventions on the factors in an integrated way – at the landscape level - and, in turn, to provide individual information for each factor.

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 [88]. The SILR is composed of eight indexes that allow monitoring of the impacts of restoration in different dimensions of mitigation and adaptation to climate change:

- Water Quality Index (WQI)
- Water Flow Index (WFI)
- Soil Quality Index (SQI)
- Landscape Biodiversity Index (LBI)
- Carbon Equivalent Index (CO_2 eI)
- Additional Workday Index (AWI), which measures the improvement in the livelihoods of rural communities
- Vulnerability Reduction Index (VRI), which measures the reduction of vulnerability to environmental risk
- Landscape Governance Index (LGI), which measures the governance for landscape management

[88] Zamora Cristales, R. et al. 2017. Sustainability Index for Landscape Restoration: A tool for monitoring the biophysical and socioeconomic impacts of landscape restoration. WRI.

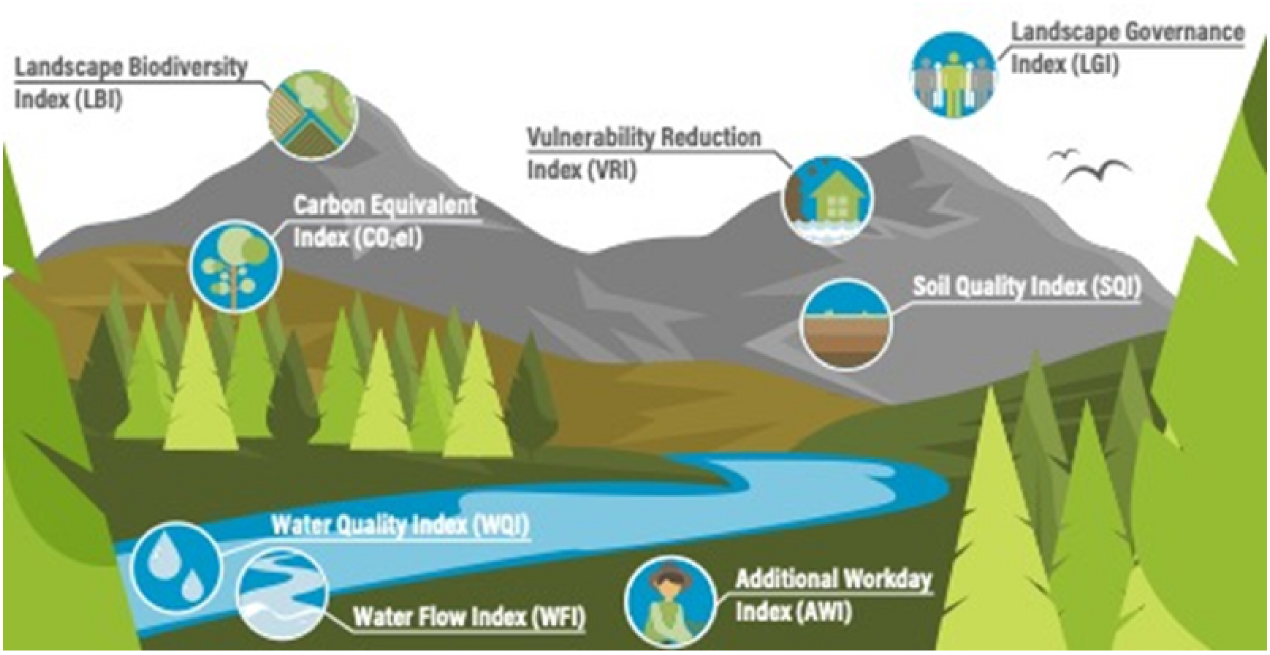


Figure 16. Components of the Sustainability Index for Landscape Restoration [89]

Once each of the components of the Sustainability Index for Landscape Restoration has been obtained, the index can be calculated by averaging all the values:

$$\mathbf{SIRL} = \frac{\mathbf{CO_2el + LBI + WQI + AWI + VRI + LGI}}{\mathbf{6}}$$

Fire-smart landscape may adapt the WRI Sustainable Index methodology for monitoring the biophysical and socioeconomic impacts of fire-smart planning and implementation to mitigate large wildfire risks. This requires reaching a consensus among the group of landscape stakeholders supporting the monitoring process on the focus of the impacts of fire-smart planning and implementation interventions to be monitored. Potential monitoring goals could be framed as follows:

- to achieve a resilient mosaic-like pattern of LU/LC within the landscape (Landscape pattern 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);
- to reduce water stress affecting LU/LC systems in the landscape (Water stress index);
- to increase the resilience of natural and seminatural ecosystems to wildfires;
- to reduce the vulnerability of people and their assets within the landscape to large wildfires (Vulnerability reduction index);
- 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);
- 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).

[89] Ibid.

Vulnerability Reduction Index (VRI). It is a proxy for the reduction of vulnerability to fire risk and is calculated from several indexes grouped into three major components: hazard and exposure; vulnerability, and lack of capacity.

Resilient landscape pattern index (RLPI). This is an index composed of several landscape indexes, which are numerical measures used in landscape ecology to report on the composition and configuration of landscapes, the proportion of each LU/LC, the morphology of landscape elements, the fragmentation of the landscape elements, and the interface that exists between its components. This index allows for the comparison between changes in the same landscape over time or have the potential to establish future scenarios in a given landscape. The WRI proposed five landscape indexes to form the RLPI:

- the Perimeter-Area Fractal Dimension (PAFRAC) that explains the complexity in the shape of each of the patches of the same type of land use (class), which can range from very simple ones –squares or rectangles (in the case of crops)– to more complex shapes, typical of a forest;
- the Percentage of Landscape (PLAND) that shows the percentage of the area that each class occupies in the landscape;
- the Number of Patches (NP) that expresses the fragmentation of a certain class or of the landscape in general;
- the Largest Patch Index (LPI) which is an index of dominance showing the area of the largest fragment for each of the classes;
- the Contagion Index (CONTAG) indicates the potential for connectivity in the landscape. A land use map is needed as a point of departure for their calculation.

Carbon equivalent index (CO_2eI). It refers to climate change mitigation. That is, the impact of restoration actions on the carbon equivalent balance that seeks to avoid losses and fix additional carbon to the existing stock. It can be obtained by 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. The sum of the values obtained would be the maximum expected value of carbon equivalent stored when implementing all fire-smart practices in the landscape. The minimum value represents the amount of carbon equivalent that would be stored if the fire-smart interventions were not carried out. This would theoretically give a value of 0 (zero), as the carbon that could be stored would not result from the fire-smart interventions. This implies that the CO_2 eI will range between 0 and 1. The index value will be closer to 1 as it approaches the expected target of maximum carbon equivalent stored as a result of fire-smart landscape implementation.

Water stress index (WSI). Water stress is defined as the water deficit in vegetation and soil for the LU/LC types of the landscape. It monitors changes in vegetation and soil water content resulting from fire-smart interventions. The importance of vegetation and soil water stress to fire risk reduction makes it relevant to include a water stress index in a sustainable index for fire-smart landscapes. A water stress value can be established making use of a combination of: (i) remote sensing estimation of vegetation water content can be utilized to real-timely monitor vegetation water stress; (ii) low-cost tree trunk relative water content sensors for monitoring of the tree water status; (iii) simple field soil water content sensors. An ideal vegetation and soil water content value can be established (determined according to biophysical limits) and a rating can be set, where the higher number represents the ideal water content.

Biodiversity improvement index (BII). It is used to define the optimal fire-smart management objective (e.g. changes in landscape pattern and distribution of LU/LC, vegetation stand shape, density, structure, composition resulting from different biomass management types and harvesting levels; type of ecological restoration planting densities and species composition) maintaining a favorable conservation status of natural habitats and landscape pattern on which multi-taxon indicators (e.g. birds, mammals, insects, plants) depend.

Livelihoods improvement index (LII).It is a proxy of the improvement in the living standards of the landowners and users involved in the fire-smart landscape implementation measures. To calculate this index, we could use several proxies, based on the landscape mapping of the sites prioritized for the different fire-smart productive interventions. The map reports the number of potential hectares of different LU/LC for each of the fire-smart practices proposed in the Landscape Plan. By multiplying the hectares by the expected production (tons/ha) that each combination of fire-smart measures (e.g. chestnut tree planting + controlled grazing) would generate in each LU/LC under management, the productivity (in tones and/or in expected economic return, and/or in expected employment generated) for each of the proposed practices in the landscape is obtained.

Landscape Governance Index (LGI). It measures the governance situation for the management of a given landscape. Governance refers to the process of interaction and integration between various organizations and individuals with different powers, authorities and responsibilities based on rules and traditions, which are oriented towards ensuring the provision of ecosystem services (food, water, biodiversity, tourism, etc.). WRI proposes a tool to be used in focus groups that is structured in three components:

- governance capacities,
- governance process,
- governance outcomes.

Each of these components contains a number of indicators representing different dimensions of governance:

- coordination,
- resources,
- deliberation,
- leadership,
- shared vision,
- access, use and generation of information,
- adjusting decisions to the context,
- management and regulatory instruments,
- equity,
- promotion and capacity to learn from past experiences,
- accountability.

The LGI is calculated from the application of a tool through focus group sessions ensuring the participation of multiple stakeholders in fire-smart landscape management. The tool/questionnaire presents five response options for each indicator, through which the corresponding dimension of governance is rated. The average score for the eleven questions –which correspond to each of the indicators and are analyzed and discussed in a participatory manner in the focus group – represents a LGI that takes values between 1 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.

4. Case Studies with Best Practices in Building Landscape Resilience to Wildfires

4.1. Integrated landscape planning of cross-sectoral climate- and fire-resilient interventions: Mosaico Extremadura Project [90]

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.

4.1.1. Project description

The Sierra de Gata landscape (15,100 ha) in the north-western part of Extremadura (Spain) is a mountainous area in southwestern Spain prone to anthropogenic fires. Past pine and eucalyptus plantations [91] and the conversion of numerous agricultural lands and abandoned pastures into very dense shrubby woody formations with a high accumulation of dry biomass, have significantly increased the risk of wildfires, nowadays exacerbated by climate change induced extreme weather events. Nearly 15,000 ha of very dense maritime pine (*Pinus pinaster*) forests are found in Sierra de Gata and in the neighboring landscape of Las Hurdes. The Mosaico project is a response to an 8,000 hectares large 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:

a) the involvement of rural people in agricultural, pastoral and forestry activities, that maintain 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 and facilitating the landscape location of safer zones from which fires can be suppressed; and

b) the economic opportunities generated from fire-smart farming and forestry activities in mosaic landscapes contribute to giving a positive economic return (covering and possibly exceeding biomass management costs) and make the planned fire-smart interventions economically sustainable, while reducing arson ignition causes as a form of protest against restrictive and punitive policies, which are common in centrally managed forest landscapes.

The project staff is composed of forestry, agriculture, and livestock technicians who have the following main responsibilities:

- provide advice and technical assistance to local stakeholders (farmers, shepherds, landowners, entrepreneurs, and NGOs) on the development of agricultural, livestock, or forestry projects (interventions) such as commercial tree-crop plantations, forest grazing, and resin tapping;
- facilitate dialog and collaboration between promoters of interventions and the regional Forest Service; and
- organize training, information and dissemination activities.

---

[90] Bertomeu, M.; Pineda, J.; Pulido, F. 2022. Managing Wildfire Risk in Mosaic Landscapes: A Case Study of the Upper Gata River Catchment in Sierra de Gata, Spain. *Land* ***2022***, 11, 465. https://doi.org/10.3390/ land11040465.

[91] 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.

4.1.2. 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 firebreak areas.
- Rapid alert of new fires by increasing the presence of shepherds with an active fire management role in the territory.

4.1.3. 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.
- The initiative simulated 2 climate change (CC) scenarios, to understand the effectiveness of the proposed fire-smart interventions. However, future studies should consider more CC scenarios, as more frequent and intense extreme weather conditions will increase the severity of fires.

4.1.4. 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 promoted by the Mosaico project responding to the following questions: (i) do Mosaico-promoted interventions function as effective firebreaks? if so, to what extent do interventions influence fire behavior and fire extinction methods? (ii) are the interventions implemented in the landscape high fire-risk areas?
- Planning methodology was based on the development of a r**elative 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 when the Mosaico project started (year 2016). 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: (a) the **digital terrain model** for altitude, slope, and aspect; (b) 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.

Group	Fuel Model	Description
Grass	1	Dried, short grass with complete ground cover. Scattered woody plants may be found on 1/3 of the area or less. Fuel load (dry matter): 1–2 t/ha.
	2	Dried, short grass with complete ground cover. Scattered woody plants convering from 1/3 to 2/3 of the area. Fire spread is still governed by herbaceous fuels. Fuel load (dry matter): 5–10 t/ha.
	3	Thick, dense, dried and tall grass (>1 m). Scattered woody plants may be present. Fuel load (dry matter): 4–6 t/ha.
Shrubs	4	Mature shrubs or dense plantations of young trees, with a height greater than 2 m. Fire spread through the canopy layer. Fuel load (dry matter): 25–35 t/ha.
	5	Dense, live, short shrubs (<1 m). Fire spread through leaf litter and grass layer. Fuel load (dry matter): 5–8 t/ha.
	6	Similar to model 5, but with more flammable species, or logging slash and taller plants. Fire spread in conditions of moderate to strong wind. Fuel load (dry matter): 10–15 t/ha.
	7	Highly flammable shrubs, 0.5 to 2 m high, as an understory layer in conifer forest. Fuel load (dry matter): 10–15 t/ha.

Timber litter	8	Dense forest, without shrub understory. Fire spread through thick leaf litter. Fuel load (dry matter): 10–12 t/ha.
	9	Similar to model 8, with less thick leaf litter of long needles or large leaves of broadleaves. Fuel load (dry matter): 7–9 t/ha.
	10	Forests with large quantities of dead biomass and fallen, dead trees due to perturbations (windstorm, pests, etc.). Fuel load (dry matter): 30–35 t/ha.
Logging slash	11	Open forest, intensively thinned. Pruning and thinning debris. Scattered debris from pruning and thinning, with resprouting herbaceous plants. Fuel load (dry matter): 25–30 t/ha.
	12	Biomass debris more abundant than trees. Ground completely covered by pruning and thinning debris. Fuel load (dry matter): 50–80 t/ha.
	13	Ground completely covered by large amounts of heavy and thick biomass debris. Fuel load (dry matter): 100–150 t/ha.

Table 1. Fuel models

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.

Extinction Class	Fire Behavior and Control Method	Thresholds	
		Flame Length (m)	Rate of Spread (m/min)
1	Low spread rate and flame length; hand tools	<1.2	<0.5
2	Moderate spread rate and flame length; heavy equipment	1.2–2.4	0.5–2
3	Crown fires (serious control problems)	2.4–3.4	2–33
4	Crown fires and spotting Control methods ineffective	>3.4	>33

Table 2. Extinction classes and thresholds for flame length and rate of spread.

The location of interventions promoted by Mosaico Project 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: (i) 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 (ii) **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. Interventions deemed unfeasible due to legal (e.g., requiring change from forest to agricultural land use), financial, or other important impediments were not considered. Thus, a total of 23 interventions were selected for the planning process, covering a total of 732 ha (i.e., 5% of the study area), of which almost 76% corresponded to forestry, 18% to livestock, and only 7% to agricultural interventions. Nearly 52% of the intervention areas are public land and 48% are private land.

Type of Intervention	Id Intervention	Ownership Status	Description	Area (Ha)
Agricultural	A-01	Private	Chestnut plantation	2.0
	A-02	Private	Almond and olive-tree plantation	8.4
	A-03	Private	Fruit plantation with apiculture	1.1
	A-04	Private	Olive-tree plantation	0.9
	A-05	Private	Red berries plantation	0.4
	A-06	Private	Mixed olive and chestnut plantation	0.8
	A-07	Private	Chestnut, almond, and pistachio plantation	26.3
	A-08	Private	Chestnut plantation	1.3
	A-09	Private	Almond and pistachio plantation	8.4
Forestry	F-01	Private	Thinning and mechanical clearing in chestnut forest	89.2
	F-02	Private	Thinning and mechanical clearing in forest farm	138.7
	F-03	Private	Mechanical clearing and tree planting	14.0
	F-04	Private	Thinning and mechanical clearing in chestnut forest	1.3
	F-05	Public	Thinning and mechanical clearing in resin tapping areas	172.7
	F-06	Public	Thinning and mechanical clearing in public forest	108.9
	F-07	Private	Thinning and mechanical clearing in chestnut forest	3.5
	F-08	Public	Mechanical clearing and tree planting in public forest	24.8
Livestock	L-01	Private	Sheep grazing in agroforestry farm	12.3
	L-02	Private	Sheep grazing in shrub lands	42.5
	L-03	Public	Targeted grazing in public forest land (BOCA)	28.0
	L-04	Public	Targeted grazing in public forest land (BOCA)	14.0
	L-05	Public	Targeted grazing in public forest land (BOCA)	31.2
	L-06	Private	Goat grazing in agroforestry farm	1.3

Table 3. Selected fire-smart intervention types

- 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); it had a positive impact, due to the type of targeted fuel model (forest with a thin litter layer), reducing both flame length and rate of spread and thus contributing to improving attack and suppression work. 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, stable price of resin, and its promotion by the Forest Service Office and local governments. 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. However, according to resin tappers involved in Mosaico, two important issues should be addressed to make it more attractive: undertake more intensive thinning to reach an optimum of 200-300 trees/ha should be conducted at tapping sites; the Forest Service Office to facilitate arrangements to involve resin tappers in silvicultural activities and other forest management works during the 4-month-long lean period in winter.
    - **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. However, an important policy constraint [92] is the need for political approval following a formal request for land-use reclassification from forest to agricultural land, to restore the former tree crop or vineyards or the establishment of new ones, a lengthy, bureaucratic process that is unlikely to succeed.

[92] The National Forest Law and The Agrarian Law of Extremadura consider as forest all agricultural land that has remained uncultivated for at least ten years and that contains forest trees or shrubs with a diameter at the base of 15 cm or larger.

- **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; livestock grazing would be more effective when implemented on the steep slopes with the most unfavorable fuel models. No change in fuel model was considered to occur when livestock interventions were proposed in areas that were already grazed or in existing fuel breaks (19.3 ha or 15% of the area under livestock interventions). 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. Based on experiences on controlled grazing for fire prevention in other Spanish and Mediterranean-wide regions, the Mosaico project team, together with a number of shepherds active in the landscape, proposed and implemented a targeted controlled grazing named BOCA on the fuel break network designated in the fire-smart landscape plan. The Regional Forest Service has started to upscale targeted controlled grazing to other forests areas of Extremadura region Targeted grazing however requires:
    - high-level, long-term political and institutional commitment,
    - appropriate, long-term financial incentives and infrastructure support, mainly troughs and folds,
    - adaptive management and continuous learning (e.g. to determine adequate stocking rates),
    - a sound monitoring plan to be strictly implemented, and –
    - commitment from forest managers, as conflicts will inevitably arise.
- The majority of the 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. Therefore, 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, innovative governance mechanisms to support collaboration between land users in charge of the application of complementary fire-smart practices, public and private economic incentives for landowners with their properties in SMPs to afford them, changes in policy regulations to facilitate changes.

4.1.5 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 a broad participation of landowners and users in decision-making planning processes to identify fire-resilient LUs and management practices can effectively mobilize rural people and other stakeholders for the co-creation, in partnership with forest administrators, of agroforestry landscapes more resilient to fire. This achievement can be further fostered by collaborative strategies that bring together and help organized landowners with neighboring small abandoned forestland plots as users' associations and cooperatives sharing management decisions and investments in a much larger landscape unit. More importantly, by promoting economic activity and restoring strong links between the rural population and its surroundings, collaborative approaches such as Mosaico have the potential for mitigating, or even reversing, the abandonment of rural areas and contributing to a more sustainable productive landscape.
- The Mosaico project has produced highly relevant social benefits and outcomes that show the important advantages of collaborative approaches for fire risk management. During the fire-smart landscape planning phase, the project team at the University of Extremadura launched an online open call for fire-smart land management proposals to increase resilience in fire-risk areas. Many landowners responded to the call, providing good ideas on forest, agriculture and livestock grazing uses, combined or not, that helped increase resilience to wildfires. The university supported proponents with technical and business-oriented advice to sustainably implement the selected proposed ideas. The project demonstrated that when given the chance and the voice, rural stakeholders take a proactive rather than reactive responsibility for reducing the vulnerability of the landscape and mitigating fire risk, 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. Moreover, the University team supported them with business-oriented training and marketing opportunities (e.g. a label was created and promoted on-line for livestock dairy and meat products recognizing the fire prevention role played by those shepherds which increases their market value and clientele).
- Major efforts occurred in supporting municipalities to develop 400 m wide strips in the wildland-urban interface, through the clearing of abandoned vegetation and its replacement with fire-smart pastureland, open woodlands and fruit tree crops with controlled grazing.

4.1.6. Capacity development, participatory action research and innovation

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

4.1.7. 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. The law explicitly recognises agroforestry as a permitted and promoted restoration practice that acts as a productive land-use system with a high fuel break value. Under a fire risk management perspective, the ancient "*enclavados*", traditional small-scale fruit tree planting spots frequently located within public forests throughout Spain, represented a very interesting fire-smart strategy, as the small-scale tree crops within a forest matrix are effective productive fuel breaks that, in the event of a fire, will help reduce fire spread and facilitate suppression works. Interestingly, enclavados were considered in the past as a problem by the forest administration as they complicated forest management operation, (often being exchanged for other land outside the forest and replaced by forest stands).
- 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.

4.1.8. 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 of forest, agriculture and pasture patches 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.

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

- Controlled grazing for herbal and woody biomass growth in productive firebreaks (agroforestry fruit tree crops and pastures), in thinned forest stands, and in the wildland-urban interface are proposed as complementary, cross-sectoral fire prevention measures.

4.1.10. 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 € from the regional government with the capacity to leverage 2 million more from projects lead by the university).
- Measure cost. The information could not be accessed
- Payment system. The information could not be accessed
- 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.

4.1.11. Sustainable return on investment (multiple benefits)

4.1.11.1 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 for the region, such as pistachio and hazel nut). By securing long-term commitment and funding from the regional government, stakeholders, including municipal governments, became more dedicated and committed to the project and more willing to invest their own financial resources in project interventions.

4.1.11.2. 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;
- improvement of structures available to shepherds, such as rehabilitation and establishment of small infrastructures, improvement and construction of water points and tanks, arrangement of sheepfolds;
- 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 (local associations and cooperatives) to be more cost-effective in fire prevention interventions;
- general revitalization of rural development opportunities, attracting new settlers.

4.1.11.3. Environmental return

- fire-risk reduction;
- habitat and species diversification;
- soil erosion control in firebreaks.

4.1.12. Monitoring for adaptive management and knowhow dissemination

- Experts from the university provide a permanent follow-up to the fire-smart interventions through periodical visits, interviews with landowners and users, and data collection. By being involved in participatory action research, stakeholders have provided valuable feedback to scientists, technicians, and local policymakers.
- No interventions about biodiversity monitoring to help understand the impact of fire-smart interventions and landscape reshaping on flora, fauna and fungi.
- Knowhow transfer through research papers and outreach materials and activities (media, online, information events and national and international workshops).
- The University team has participated in other EU-funded international projects (e.g. the transboundary *LIFE Landscape Fire* Project between Spain and Portugal), and is sharing knowhow with practitioners from other countries (Portugal, California, and Italy).

4.1.13. References

- Bertomeu, M.; Pineda, J.; Pulido, F. 2022. Managing Wildfire Risk in Mosaic Landscapes: A Case Study of the Upper Gata River Catchment in Sierra de Gata, Spain. Land 2022, 11, 465. https://doi.org/10.3390/ land11040465.
- LIFE Landscape Fire Project (2019-2021). https://life.cimvdl.pt
- Mosaico Extremadura Web Site. http://mosaicoextremadura.es
- Platform for the Design of Productive Firebreaks. http://cortafuegosproductivos.unex.es
- Presentation of the Mosaico Project in the "Training Course on Green Circular Economy". https://www.youtube.com/watch?v=Lu1Cz6mDNEs

4.2. The Mediterranean Mosaics Initiative: Regaining landscape resilience to climate risks through Forest Landscape Restoration *planning and implementation in the Shouf-West Beqaa Landscape (Lebanon)*

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 was recognized by the United Nations Convention on Biological Diversity's 2011-2020 Aichi Biodiversity Targets and is widely viewed as a means to reach the UN 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.

4.2.1. Project description

In 2012, ACS [93] - 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) surrounding the core zone 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, deciduous and evergreen oak forests, stone pine and Brutia pine forests, freshwater ecosystems, several shrubby and grassland habitats, and traditional dry-stone wall agricultural terraces and flatland crops. 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 in recent decades have given rise to a vulnerable landscape to climatic risks, including the growing occurrence of wildfires. The landscape vulnerability is exacerbated by the predominance of secondary woody formations with high accumulation of dry biomass and degraded slopes with high risk of erosion and limited water retention of the soil, together with a human reality of landscape depopulation with knowledge loss about sustainable cultural uses, which makes use of irrational practices with high fire-risk, water and air pollution, and loss of soil and water resources, land productivity, and biodiversity.

[93] Al-Shouf Cedar Society.

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 (ecological, social and economic return on investments) multipurpose forest, agricultural, pastoral and eco-tourism uses adapted to climate risks.

The project aimed to apply and to improve the national policies on biodiversity conservation, climate change, the national plan of forest restoration and land degradation neutrality, the national strategy of forest fire management, and the sustainable rural development program. Likewise, the initiative was a contribution to the national commitment to the Bonn Challenge of the restoration of forest landscapes.

The project applied an innovative 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 different project actions:

- awareness-raising actions,
- continuous and research-oriented training,
- field demonstrations of innovative viable solutions prior to their upscaling,
- development of a nature restoration model that solves trade-offs with development interests,
- creation of employment and green businesses targeting new markets on ecological certification and fairtrade,
- 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, experts from national research centres and environmental consultancy firms, local NGOs, members of forest committees at the municipality level, local private entrepreneurs, and in partnership with international NGOs (e.g. the Italian NGOs LIPU, Istituto Oikos Onlus and ILEX) and Private Foundations (e.g. MAVA Foundation), the Massachusetts Institute of Technology (MIT), the Ministries of Agriculture, of the Environment, and of Spatial planning, FAO, the WFP, the Italian Cooperation, USAID, the EU, and Private companies (e.g. Middle East Airlines; several national banks).

4.2.2. Fire-Risk Reduction objective

- Reducing 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.

- Rapid alert of new fires by increasing the presence of land users with an active wildfire prevention role in the territory.

4.2.3. 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 did not address the quantification of GHG emissions' reduction resulting from the fuel load control through grazing.

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

- The project undertook participatory landscape planning exercises at the municipality level, following the FLR planning tools to analyse root-causes of landscape degradation. In addition the project prioritised high-risk intervention areas and climate-adaptive intervention measures providing multiple ecological, social and economic benefits, such as
  - ecological restoration of degraded forests, pastures and agricultural terraces with the production and planting of native plant species and local crop species and varieties;
  - clearing of abandoned terraces already covered by very dense secondary Brutia pine forest to create productive firebreak areas for multi-crop production and reduce fire spread risk;
  - biomass management in abandoned oak coppiced and secondary dense Brutia pine forests – on this last case facilitating the growth of the existing seedlings of oaks, strawberry tree and other broadleaf species - together with the collection of agricultural pruning remains and olive pomace for bioenergy and compost; support to short-transhumance livestock management and dairy production, with agreements to carry out controlled grazing in biomass managed areas;
  - biodynamic multi-crop production in restored and existing terraces, including both local crop varieties and native aromatic and culinary shrubs, targeting both local markets, eco-tourism services, and international organic and fair-trade markets;
  - restoration of abandoned quarries;
  - support to the creation and/or improvement of small local businesses and value chain development around several FLR interventions, such as local tree nurseries, small bioenergy enterprises, local cooperatives for the production, processing and marketing of honey, aromatic/culinary plants, dairy products and vegetable/fruit tree crops, ecotourism service providers;
  - creation of nature trails and information panels on FLR practices implemented, crossing restored agro-forestry zones and accessing agro-tourism goods and services developed by landowners and managers; broad set of awareness raising and educational activities.

- The project mapped and ranked LU/LC types according to their conservation status at the municipality level. At the landscape level – only for the Shouf side of the mountain landscape - the project 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 activities in the landscape and make viable business plans for small local businesses.

- At the landscape level, the project addressed land tenure problems to improve spatial planning in the buffer zone of the Biosphere Reserve. In collaboration with the ministries on Spatial Planning and of Environment, the municipality administrations and the landowners, with the support of a consultancy firm, ACS undertook the following activities:
  - identification and demarcation of public and private land;
  - legal ascription of permitted uses in the buffer zone and compatible with the conservation of biodiversity and reduction of environmental risks;
  - contacts, negotiations and agreements with private owners whose plots of land are in sensitive areas, in terms of biodiversity values and climatic risks, to agree on the limitation of uses and/or carry out exchanges for other lands outside the buffer zone, in case the owner does not desist from making unauthorized uses, such as urbanization or intensive agricultural production.

4.2.5. 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 direct involvement in the implementation, monitoring and benefit sharing from 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; hired international assistance to provide advice, scientific guidance, training and technical support on FLR planning and implementation; expatriates and experts from the partner organization Istituto Oikos Onlus, supporting agriculture development and water management interventions; and several national organizations (e.g. environmental and architecture consultancy firms, research centers, private entrepreneurs).
  - **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, with special focus in the identification and involvement of lead practitioners especially prone to test and adopt innovation, and securing commitments for FLR implementation through informal agreements, MoUs and contracts.
  - **Empowerment**, with major investments in training of both practitioners and future trainers (e.g. ACS staff, municipal forest committee members, extension agents, NGO staff, school teachers, land users, private entrepreneurs, and researchers), 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 the Italian organizations Istituto Oikos Onlus, LIPUBirdLife Italy), Ilex (Italian Landscapes Exploration), FAO, and the partner organizations of MedForVal Network and the MAVA Mediterranean Conservation Program, to exchange know-how and experiences on FLR under a climate change scenario.

- 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. FMCs facilitated the development of FLR plans and the implementation of FLR interventions at the municipality level, catalysing the participation of the population of the municipality.

- **Multi-actors agriculture innovation platforms for green value** chains were established, 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. Different types of marketing platforms were developed:
    - 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 that promote the role of these products in reducing environmental risks and enhancing the ecocultural heritage of the landscape.

  An **innovation platform center** was established in Maaser Al Shouf, the town hosting the Biosphere Reserve headquarters, to promote platform members exchanges, collective action around production, processing and marketing, facilitate the organization of training, workshops and fairs, identify local, national and international opportunities such as public-private-partnerships for the targeted goods and services, facilitate contacts and meetings among producers and buyers, and facilitate the access to relevant information about value chain development opportunities.

4.2.6. 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 different topics:
    - ecologically-sound and risk reduction production systems,
    - helping organize themselves in producer associations and cooperatives,
    - ensuring sustainable production,
    - developing businesses that ensure the quality, hygiene and diversification of products,
    - improve their market value and the ability of individual and organized producers to access and negotiate in diversified markets.

- **Creation of employment opportunities**. Farmers, unemployed young and Syrian refugees – both women and men – were professionally trained on integrated biomass management (e.g. forest pruning and thinning, biomass processing for bioenergy, compost production, charcoal production, controlled livestock grazing), ecological restoration native plant production and on-the-field planting techniques, dry stone wall reconstruction, sustainable NTFP harvesting, rehabilitation of water reservoirs, and the construction and conditioning of nature trails and other ecotourism-related infrastructures. The FLR initiative has contributed to the successful results of the WFP "cash for food e-cards" program which for the first time formed skilled workers among vulnerable population groups – Syrian refugees and local families receiving food assistance – in areas of employment related to the FLR climate-resilient priorities. 376 trainees, of whom 67.5% Syrian refugees and 23.4% women, attended learning-by-doing training cycles with periodic sessions over several months, and got a certificate in the specified professions.

- **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 contact practitioners from the countries involved to exchange experiences and provide training on different topics:
    - sustainable agricultural production and marketing,
    - sustainable management and marketing of biomass and other forest products,
    - efficient water management,
    - management of protected areas,
    - biodiversity restoration –sustainable tourism.

4.2.7. Enabling policy framework

- Pilot interventions were used to **influence national policies on forest management and fire risk reduction**. These included:
  - National forestation plan: improved guidelines and criteria for innovative nursery techniques for the production of high-quality seedlings of a wide number of native species; improved guidelines and criteria for planting techniques without the need of irrigation, that increase the survival rate of the planted seedlings through the enhancement of soil water harvesting and storage in the planting sites to compensate the growing trend of summer water deficit and;
  - National Fire Management Strategy: revision of governmental regulations banning conifer forest thinning operations to allow sustainable biomass management interventions in high-fire risk areas and the conversion of secondary pine forest stands located in high fire risk areas into their former agricultural use (restoration of abandoned terraces) to break fuel continuity and reduce fire spread risk;
  - Green Plan: revision of guidelines about where and how dry-stone wall agriculture terraces should be restored;
  - Spatial planning regulations: revision of guidelines for the delineation of the boundaries and clarification of tenure rights and land use restrictions in protected landscapes (biosphere reserve zoning), improvements in the existing Detailed Urban Plans and development of Strategic Environmental Assessment (SEA) for the FLR interventions proposed for the buffer zone.

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

- Restoration of abandoned agriculture terraces colonized by too dense secondary pine forests into multi-crop productive farming systems and controlled grazing after forest thinning contributed 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 too dense secondary pine forests contributed 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 (higher percentage of post-fire re-sprouting species). However, biodiversity improvements require the definition and monitoring of specific indicators to verify positive impacts and adjust biomass harvesting and controlled grazing and the modification of the forest structure and species composition to the different needs in term of risk reduction, forest productivity and biodiversity conservation. 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, still ongoing – 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.

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

- The project integrated cross-sectoral biomass management interventions in forestry, agriculture and livestock grazing, with the multi-purpose objective to reduce water stress and accumulation of dry biomass in too dense forest ecosystems, prevent wildfires, and make an economic and social use of biomass through bioenergy and compost production and marketing.

4.2.10. Financing and cost-effectiveness

- Source of funding. The FLR initiative in the Shouf-West Beqaa landscape was financed with the support of several sources: two grants provided by the private MAVA Foundation; EU ENPI- project; FAO small-grant; Italian Cooperation project on agriculture terraces restoration and green value chain development; funding contribution from the World Food Program "cash for food e-cards".

Two more projects funded by the Italian Cooperation and the EU started in 2022 to keep supporting the FLR plan implementation. Moreover, the following initiatives of sustainable financing for FLR were tapped or are currently used:

- Corporate Social Responsibility. Private companies are willing to support environmental and social projects in the framework of their corporate social responsibility (CSR) strategies. Since the start of its FLR program, ACS has partnered with national and international private companies such as Middle East Airlines, Byblos Bank, Porches Club Lebanon, Khalil Fatal and Sons, Advanced cars, Lycee National Schools, Four Seasons Hotel, HSBC Bank and Patchi.
- Cedars Forever Program. It is a scheme launched by ACS to support the plantation of cedar seedlings in Lebanon, primarily in the Barouk cedar forest. Individuals and organizations may contribute to the program by adopting a Cedar: for USD 150 a cedar seedling will be planted bearing the name of the person who adopted it. So far, 5300 cedars have been adopted through this scheme.
- Cedar Loan Program. ACS set up the Cedar Loan Program to facilitate micro-loan access to local villagers and residents, for initiatives that are consistent with the vision of the SBR. Since 2013 ACS has awarded 172 loans worth USD 1000 - 3000 each, for a total value of USD 236,000. Approved applications include projects establishing or expanding plant nurseries, rehabilitating lands and stone terraces, and propagating aromatic/medicinal plants, as well as ecotourism services.

- 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, collecting and chipping the wood and transferring it to the bioenergy plan 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. Moreover, women and men young unemployed were trained to acquire a professional degree in work related to fire-mart interventions, which has generated paid employment. During the training sessions, the participants were paid through mechanisms of the "cash for food e-card" type of the WFP.

- 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 local bioenergy plant in the village of Kfarfakoud for the production of briquettes for cooking and heating from local waste materials – the olive pomace that result from olive oil pressing, and the wood waste from the pruning of olives and fruit trees, and from the thinning and pruning of oak and pine forests. Around 100 daily-paid workers are involved in the gathering of biomass from October to April. Five workers (2 permanent, 3 seasonal) manage the factory. 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.

  In the case of fire-smart field restoration interventions (e.g. establishing and/or enhancing species diversification in degraded forest and grassland ecosystems, through the production and planting of dominant and companions re-sprouting species, attracting seed-dispersal fauna and improving soil fertility) the project managed to decrease the cost from the average national cost of USD10 per each planted seedling to USD 2.5 (about USD 2,000 per hectare with an average of 800 seeds (acorns) and/or seedlings) thanks to:
  - an accurate plant production protocol avoiding the excessive consumption of water and other inputs;
  - the equipment used for soil preparation (auger machine);
  - the professionalization of the staff involved in plant production and field planting; the exclusion of watering in the maintenance of the restored sites.

4.2.11. Sustainable return on investment (multiple benefits)

4.2.11.1. Economic return.

The focus of the project was 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.

4.2.11.2. 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, so as to increase their chances to find jobs linked to the FLR program;
- 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 in the landscape has avoided the current problems of wild and uncontrolled felling in many parts of Lebanon, as a response of the local population to the serious economic and energy crisis that the country is suffering. ACS is coordinating the implementation of thinning and pruning plans in very 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. The example of the Shouf-West Beqaa landscape is being transferred to other areas of Lebanon to avoid alarming problems of forest degradation. Private and public land tenure clarification in the landscape buffer zone allowed to:
    - undertake negotiations and conflict resolution, supported by the establishment of suitable compensation and modalities for exchange of private land in buffer zone for public land in development zone;
    - identify economic valuation of opportunities for sustainable uses to convince land owners to adopt them;
    - propose incentives such as taxes reduction and other tactics, to push land owners towards sustainable uses in the buffer zone.

4.2.11.3. 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 intervention that helped restored agriculture land and grassland stands that break fuel continuity in forestland;
- plant species diversification in biomass 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.

4.2.12. Monitoring for adaptive management and knowhow dissemination

ACS team with support from international experts 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).

4.2.13. References

- Hani, N.; Regato, p.; Pagliani, M.; khaddazh, M.; Vernyuk, Y.I.; Sarkis, L.; Buhussein, R.; Buwadi, M.; & Dokukin, P. 2021. Old, abandoned terraces surveying and restoration as a contribution to the adaptive forest landscape restoration in Lebanon. *Acta Hortic*. 1324. ISHS 2021. DOI 10.17660/ActaHortic.2021.1324.34.
- Regato, P. 2020. Online lecture “Forest Landscape Restoration in the Shouf-West Beqaa Landscape (Lebanon): Regaining Landscape Resilience, Ecological Functionality and Human Well-being”. In Online Course “Training on Forest Landscape Restoration”, organized by ELTI-University of Yale and FAO.
- Regato, P. 2020. Forest and Landscape Restoration Guidelines: Regaining Landscape Resilience, Ecological Functionality and Human Well- being. The Shouf Biosphere Reserve. Hani, N., M. Pagliani & P. Regato Editors. Lebanon.
- Regato P., M. Pagliani & N. Hani. 2020. Woody Energy Value Chains: Briquette production within the adaptive Forest Landscape Restoration plan in the Shouf Biosphere Reserve, Lebanon. In: Global Bioenergy Partnership. Working Together for Sustainable Development
- Regato, P. 2019. Forest and Landscape Restoration Guidelines: The Shouf Biosphere Reserve. Hani, N., M. Pagliani & P. Regato Editors. Lebanon
- Hani, N., P. Regato, R. Colomer, M. Pagliani, M. Bouwadi, Z. Zeineddine. 2017. Adaptive forest landscape restoration as a contribution to more resilient ecosystems in the Shouf Biosphere Reserve (Lebanon) Plant Sociology, Vol. 54, Suppl. 1
- Enciso, E., R. Colomer, P. Regato, F. Martinez. 2015. Thermal Biomass for Lebanon. ACS.
- Colomer, R., P. Regato, E. Enciso. 2014. Forest Restoration Plan: Mediterranean Mosaics Project, Shouf Biosphere Reserve. ASC

4.3. RAPCA [94]: Controlled livestock management in firebreak areas, complementary to forestry prevention measures in the Region of Andalusia (Spain)

Silvo-pastoralism is a traditional practice in the Mediterranean forest landscapes, having as a main characteristic the movement of livestock throughout the mosaic of forest, pasture and agriculture patches of the landscapes 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 in the landscapes, together with an excessive accumulation of dry fuel load in unmanaged forests, and abandoned pastures and agricultural lands, and thus creating favourable conditions to the spread of uncontrolled fires under climate change trends.

The sectoral public European policy reforms that have an impact on rural areas, such as the Common Agricultural Policy, are aware of the degree of decline that extensive livestock farming is suffering in southern Europe. In this sense, 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;
- its fundamental role in preventing the risk of forest fires, through permanent and low-cost control of plant biomass, especially in high fire-risk areas of the landscape, such as fire-break areas preventing the spread of 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. It also plays a fundamental environmental education role for citizens. There are many ways to put it into practice, as well as financial compensation systems. Even so, successful experiences with a certain temporal and territorial scope are scarce.

4.3.1. Scheme description

RAPCA involves local shepherds who, with their guided flocks, maintain low biomass levels in almost 6,000 ha [95] 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 [96] experts' group of *Pastures and Mediterranean Silvo-pastoral Systems* of the CSIC.
In coordination with INFOCA [97], a technical team of the EWA annually determines, under strict technical criteria, the most appropriate firebreak areas to control biomass growth and select the team of shepherds located nearby, in such a way that it takes advantage (and enhances) of an existing traditional activity and the existing livestock management infrastructure in the area.
On average, 38 ha of fuel breaks are assigned to each engaged shepherd, which are located at an average distance of 3 km from their farms. Shepherds are directly 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 with the established biomass reduction objectives and determines whether the payment for the service performed is appropriate and in what amount, according to the results obtained. Targeted grazing does not completely substitute the mechanical clearance of biomass in fuel breaks, but it does reduce the frequency of mechanical interventions.

---

[94] RAPCA: Red de Áreas Pasto-Cortafuegos de Andalucía.

[95] Number of hectares in 2016.

[96] CSIC: Spanish High Council of Scientific Research.

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

4.3.2. Fire-Risk Reduction objective

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

4.3.3. 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.

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

- The information analysed (web pages and papers) 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 INFOCA carried out by emergency and civil protection and forestry departments of the Regional Government, and subject to public information and consultation of local corporations and social entities, and informed by the Andalusian Civil Protection Commission, the Andalusian Biodiversity Council and the Andalusian Council of local governments. It is understood that INFOCA define the fire risk areas in the regional municipalities and the green infrastructures (e.g. firebreak lines and broader firebreak areas that help break the horizontal and vertical continuity of the fuel load in the landscape), whose maintenance in terms of removal of woody biomass is carried out through mechanical extraction. The RAPCA fire-prevention grazing interventions mainly complements the mechanical works in areas of difficult access and high slope. Pastoralists and other land users do not seem to have participated in the elaboration of the RAPCA network plans. Only researchers from the 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 not an 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.

4.3.5. 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. The main implementers – shepherds – are hired through annual biding advertisements, defining payment amounts on the basis of the partial or total completion of the established biomass control targets.
- According to the information analysed, 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 public forestland, but also on private forestland, which 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.

4.3.6. 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", with the aim of increasing 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 involving shepherds, environmental agents, scientists, veterinaries, academic staff, and other individuals, active in the study, promotion and defence of the environmental, social and economic benefits provided by extensive livestock in agro-forestry landscapes. The Association supports the organization of meetings and workshops, training, awareness raising, the promotion of artisanal and organic livestock products, and undertakes policy and advocacy work for public administrations to facilitate the performance of this work and improve the working conditions of shepherds.

FireShepherds **[98]**

FIRE SHEPHERDS

The Project *Shepherds from the XXIst century: increasing professionalism in the management of extensive livestock, wildfires and landscape in the era of global change*, also known as *FireShepherds*, is an Erasmus+ project that started at the beginning of 2019 with the aim to prepare next generations of Shepherds in the management of extensive livestock with wildfire prevention purposes. It is led by a consortium of public and private organizations from southern France, Germany, Portugal and Spain (Catalonia, Extremadura and the Canary Islands), involved in training, technical support, research and governance/business support (e.g. cooperativism) for shepherds.

The project aims to create a cooperation network among European shepherds' schools, shepherds and public administrations to exchange good practices in the development of silvo-pastoralism and wildfire resilient landscapes. More specifically, it pretends to design and implement a learning module for shepherds' schools about silvo-pastoralism, in addition to the sharing of successful experiences from the different regions involved in the project. The consortium has a transnational perspective because of the increasing wildfires crisis and grazing regression that Europe is passing through.

FireShepherds project has two main actions:

- *Organization* of intern exchanges between the different partners of the consortium and involving shepherd school students, to visit and gain experience from successful experiences regarding grazing and landscape management like extensive livestock exploitations, prescribed burnings, slaughterhouses, etc.
- Development of 4 intellectual outputs (IO) to be used a training materials in the shepherd schools: (i) Document with the analysis of the competences that next generation of shepherds should learn to be economically competitive and ecologically/fire risk reduction sound.; (ii) Study module dealing with silvo-pastoralism and wildfire management, to be tested/fine-tuned during the last stage of the project and adopted by shepherd schools in the partner countries. factsheets for each successful best practice visited during exchanges, to be included in the study module. A pedagogic manual (PDF format) for free consultation in the website will explains in detail how to use the contents, how to evaluate student learning, proposals for practical and theoretical exercises, and a section will also be developed for professional breeders who are no longer studying in training centers but who want to learn some of the contents of the study module; (iii) An online platform to host the study module; (iv) Manual to implement silvo-pastoralism initiatives for fire management, targeting shepherds, technicians and policy makers.

[98] https://www.fireshepherds.eu

4.3.7. Enabling policy framework

- The RAPCA network of areas for fire-risk reduction through controlled grazing interventions is embedded in the policy document INFOCA.
- RAPCA responds to: (i) Law 45/2007 for the Sustainable Development of the Rural Areas, Article 24 ".... promoting the regeneration and cleaning of forests, as well as grazing activity, in those areas with a higher degree of abandonment or risk of fires"; (ii) Law 42/2007 on Natural Heritage and Biodiversity, Article 3 "Land custody: set of legal strategies or techniques through which land owners and users are involved in the conservation and use of the natural and cultural resources of the landscape; (iii) National Rural Development Framework, Measure on fire prevention; (iv) Andalusian Rural Development Plan, Measure on conservation and maintenance of fire lines and areas through grazing.

4.3.8. 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.

4.3.9 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 (e.g. how it works, impacts, destination of the collected biomass, etc.) in firebreaks, neither on biomass management in forest stands beyond firebreak areas. This makes it difficult to realize whether the complementary management of firebreak areas with controlled grazing forms part of a comprehensive cross-sectoral landscape management plan for fire prevention.

4.3.10. Financing and cost-effectiveness

- Source of funding. RAPCA annual cost is covered by the INFOCA. 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. This depends on the type and amount of vegetation, slope and proximity to animal shelter. 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. New payment systems (e.g. loan reduction costs for shepherds hiring public grasslands, including hotspot firebreak areas, instead of additional payment) may distort the effectiveness of the intervention, as shepherds with loans in these areas may feel to be punished if grazing is not done properly.

- 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.

4.3.11. Sustainable return on investment (multiple benefits)

4.3.11.1. Economic return

The intervention is subsidized through the annual budget of INFOCA public funds, which may undergo changes or cuts depending on the budgets approved each year. 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.

4.3.11.2. 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 (family, friends, neighbors);
- additional employment to match shepherds income, increase number of shepherds, and reduce outmigration of young unemployed;
- improvement of structures available to shepherds, such as rehabilitation and establishment of small infrastructures, improvement and construction of water points and tanks, protection fences for species of botanical interest, arrangement of sheepfolds, use of removable sheepfolds and fenced areas to confine livestock, arrange salt points on the firebreaks, use electric shepherd;
- 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.

4.3.11.3. Environmental return

- fire-risk reduction;
- habitat diversification;
- soil erosion control in firebreaks.

4.3.12. 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 (every 15 days). They assess the rate of consumption of the shrubby stratum and herbaceous stratum; vegetation damage; etc.
- Evaluation of results during summer, when shepherds stop grazing activities, and comparison 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).

4.3.13. References

- 2009 Pastoralism in Natural Parks of Andalusia (Spain): a tool for fire prevention and the naturalization of ecosystems. Ruiz-Mirazo J., Robles A. B. y González-Rebollar, J. L., in *Options Méditerranéennes*, Serie A (91) : 141-144, Ciheam/Zaragoza.
- 2011 Environmental benefits of extensive livestock farming: wildfire prevention and beyond. Ruiz-Mirazo, J. in *Options Méditerranéennes*, Serie A (100) : 75-82, Ciheam/Zaragoza.
- 2011 Two-year evaluation of fuelbreaks grazed by livestock in the wildfire prevention program in Andalusia (Spain) Ruiz-Mirazo, J., Robles A. B., y González Rebollar, J. L., in *Agriculture, Ecosystems and Environment* 141: 13-22, Elsevier .
- 2012 Impact of targeted sheep grazing on herbage and holm oak saplings in a silvopastoral wildfire prevention system in south-eastern Spain. Ruiz-Mirazo, J., Robles A.B. in *Agroforestry Systems* (en prensa), Springer.

4.4. Biomass management for fire-risk reduction through integrated forestry and livestock grazing interventions: LIFE Montserrat [99]

Rural abandonment and post-fire natural regeneration have led to highly dense secondary pine forests (e.g. over 50,000 pines/ha in the Montserrat mountain case) in the coastal mountains of the Mediterranean countries, such as Spain, France, Croatia, Greece, Turkey and Lebanon. This transitional phase towards mature forest stands evolves very slowly due to slow growth and poor regeneration and imposes serious environmental **[100]** and socio-economic **[101]** constraints that make the landscape highly vulnerable to large-scale wildfires. The recovery of the traditional mosaic structure of the landscape, which has demonstrated to be more resilient to wildfires, 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.

4.4.1. 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.
- 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 landscape 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 (Barcelona province, Spain). The project interventions focused on strategic areas of the landscape for fire-risk reduction, as delimited by the Fire Service of the Regional Government of Catalonia. 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 through a selection of the species (generally oaks remain and pines are cut), tree stems and shrubs to be cut so that the managed stands acquire a more mature-like structure, with a higher pinecone and acorn production that may facilitate post-fire recovery in the case of eventual future fires. 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 with the objective to restore a fire-smart mosaic landscape that breaks fuel load continuity, and with a greater diversity of habitats and species. The opening of gaps took place through: (i) mechanical clearing in 45 hectares; and (ii) 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.

---

[99] https://lifemontserrat.eu/es/
[100] e.g. landscape homogenization with a continuum of dry fuel load; poor biodiversity; water competition causing dehydration problems and forest dieback; limited ecosystem services such as soil fertility, water regulation, and the provision of non-wood forest products.
[101] e.g. limited value in economic and social terms of forest goods and cultural services; decline of traditional agriculture and livestock farming

- 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 to ensure accessibility for the extensive grazing activities of herds of cattle, goats and donkeys. LIFE Montserrat's supported investments in green infrastructure (pens, fences and water supplies), the purchase of livestock, and the development of business plans to reconcile the economic viability of each operation with the project's management goals.

- 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.

4.4.2. Fire-Risk Reduction objective

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

4.4.3. 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.

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

- The information analysed (web pages and papers) does not allow to conclude 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. Once PIAs were defined, key landscape actors/properties and possible alliances among them were identified. 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.

4.4.5. 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 project has supported formal and informal long-term partnerships between members of the Foresters Association and Shepherds Association as the best way to ensure collaboration among these sectors and the long-term implementation of the biomass management interventions.
- According to the information analysed, the main stakeholders participating in the implementation of the LIFE Montserrat project are: staff from the public administration from Barcelona province and the Regional Government of Catalonia, 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 (from 34 forest owners with 25 properties covering 3,00 ha at the project start up to 75 owners with 66 properties covering 6,000 ha at the project end) 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.

- The articulation on the ground of viable and integrated forestry and pastoral management units required an exhaustive knowledge of the complex social relationships and conditioning factors in which they must be applied, based on three aspects:
    - versatility to modify the existing planning as many times as necessary and adjust it to reality, taking advantage of the opportunities that have been generated in the territory;
    - adaptation to the rhythms, ways of doing things (e.g. signed or verbal agreements according to local ways of doing things) and needs of ranchers and owners, even if they were not those intended by the project and even if they involved longer execution times;
    - maximum involvement of the technical team to be close to the actors (forest owners and shepherds) on a regular and continuous basis over time, listening and understanding their needs, and generating the conditions of mutual trust.

- 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 to ensure accessibility for the extensive grazing activities of herds of cattle, goats and donkeys. LIFE Montserrat's supported investments in green infrastructure (pens, fences and water supplies), the purchase of livestock, and the development of business plans to reconcile the economic viability of each operation with the project's management goals.

- 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.

4.4.6. 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 Escola de Pastors de Catalunya (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.

4.4.7. 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 holds 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. In this way, both the economic viability of the farms and the municipal problem of maintaining the strips are addressed.

- To ensure continuity of the management model promoted by the project, and in particular the viability of livestock farms, 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, whether or not they are linked to the project. For this, the project technicians agreed on the need to define the Priority Protection Perimeter (PPP) of Montserrat, which are technical instruments defined by the Regional Government based on which fire prevention activity is prioritized in the different areas of Catalonia. 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. In order to face the environmental and climatic challenges of Europe, European environmental protection legislation and the guidelines from agricultural policy must be consistent and must guarantee an ecological, collaborative and efficient economy in the use of resources, which facilitates the incorporation and the maintenance of agroecological farms, especially in less productive areas such as the Mediterranean.

4.4.8. 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. Field verifications with specific environmental indicators, were undertaken although clear evidence of positive impacts will require a much longer timeframe than the project duration.

4.4.9. 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 and improve structure of forest stands. Mechanical clearing and prescribed burning have also contributed to reopen abandoned agriculture and pastures to help them become productive under ecologically-sound extensive management systems which also enhance the conservation of habitats listed in the HD and priority flora and fauna species depending on them.

4.4.10. 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 €.
- Measure cost. The information analysed (web pages and papers) does not allow to get cost estimation of most interventions (only information about prescribed burning was provided with a cost of 2,300 €/ha and average performance of 2.5 ha/day), neither to quantify the cost-effectiveness of the project.
- 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.

4.4.11. Sustainable return on investment (multiple benefits)

4.4.11.1. 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 favor 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.

However, the restoration of the landscape resilience and ecosystem services on which sustainable rural businesses depend, exceed the capacities of the Member States and EU budgets, and only with the incorporation of payment mechanisms for the fire-smart services provided by small and medium integrated agricultural, pastoral and forestry business initiatives, the great challenges of CC and its impacts, such as the exacerbation of large scales fires, can be tackled.

The project has supported the establishment of direct sales circuits for local organic products that come from the extensive pastoral business initiatives launched, 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.

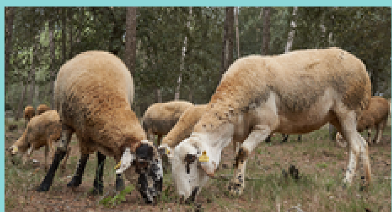
Developing green value chains for fire-smart high-quality livestock products

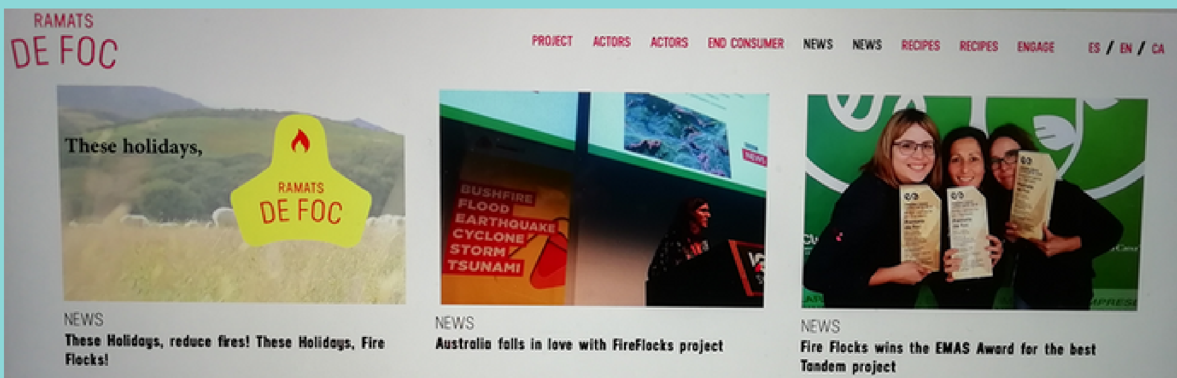
***The case of Ramats de Foc** [102]*

Ramats de Foc - "Fire Flocks" - is the marketing label displaying the added value of products from flocks fighting against wildfires, such as local meat and dairy products, with high quality and helping the conservation of forestland in the province of Girona (Catalonia, Spain). The value chain includes a network of foresters, shepherds involved in controlled grazing for fire prevention, butchers from the Artisan Butchers Guild of Girona counties, restaurants providing Ramats de Foc products, as well as end consumers buying from local producers:

- Wildfire management services map high fire-risk forest areas and define biomass control targets to be attained though controlled grazing.
- Extensive livestock farms undertake controlled grazing in mapped areas with sheep, goats, and/or cattle, following a grazing plan to meet defined targets.
- Butchers and restaurants sell meat and dairy products from flocks under the Ramats de Foc label, and explain the added value behind them.
- End customers become part of the fight against wildfires through the regular consumption of Ramats de Foc products, and support the continuity of extensive livestock farming in our forests.

Eating Ramats de Foc products and gastronomy is the flame that keeps grazing livestock alive in the Mediterranean forests, and the societal benefits it supplies. Ramats de Foc web page includes a map guiding consumers to the closest business where Ramats de Foc products can be found, depending on seasonality and stock.

[102] www.ramatsdefoc.org

4.4.11.2. 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 on livestock management has increased number of shepherds, and reduce utmigration 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, such as rehabilitation and establishment of small infrastructures, improvement and construction of water points and tanks, protection fences for species of botanical interest, arrangement of sheepfolds, use of removable sheepfolds and fenced areas to confine livestock, arrange salt points on the firebreaks, use electric shepherd;
- 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.

4.4.11.3. 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;
- opened areas provide habitat conditions for *Hieraetus* fasciatus (Bonelli’s eagle) with a new couple living in the area;
- 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.

LIFE Climark [103], among its actions, seeks to quantify ecosystem services in climate regulation (carbon) and water regulation of different types of managed and unmanaged forests. One of the typologies analysed are the dense pine forests of Aleppo pine (*Pinus halepensis*) in the post-fire regeneration phase with similar characteristics to the 1,300 hectares restored in the LIFE Montserrat project.

4.4.12. Monitoring for adaptive management and knowhow dissemination

- The lack of landscape analysis and mapping [104] 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 analysis, prior to field interventions, of the traditional extensive livestock management context and the pastoral potentiality in/outside the intervention areas where grazing has been reintroduced again, has been a major success in the project planning phase. However, limited consideration of the sociologic context has been a limitation that has required greatly increased efforts and resources to understand social relations that would allow the effective implementation of cross-tenure solutions (e.g. forest-owners and shepherds agreements and contracts) for fire-resilient integrated forestry and livestock management practices.
- The project has defined and measure the following impact indicators.
    - Efficiency and implementation of biomass management plans: (i) progress according to planed interventions (e.g. nº of ha opened through cutting, prescribed burning and maintained with livestock; nº of ha of forests with improved structure and density; nº ha grazed; nº of green infrastructures installed; biomass control impact;

[103] https://lifeclimark.eu/es

[104] 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.

adequate stocking rate for the managed plant communities; grazing pattern and intensity; livestock production and economic viability; effect on livestock production of the multipurpose fire-risk reduction and biodiversity conservation grazing objectives); (ii) 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: (i) evolution of species populations from targeted birds, butterflies, rabbit, and flora; (ii) conservation status of restored and managed priority forest (e.g. Pinus nigra; P. halepensis; Taxus baccata) and grassland habitats under the HD; (iii) 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. Post-project monitoring foresees data collection and analysis about the following indicators: nº of hectares grazed in the landscape; silvo-pastoral impact on biomass control; evolution of populations from selected keystone raptor species (*Hieraaetus fasciatus, Neophron percnopterus, Bubo bubo*); abundance of Rhopalocera butterflies; replicability by other projects based on the experience of LIFE Montserrat. Moreover, monitoring of biodiversity indicators will remain as part of the monitoring activities undertaken by the institutions in charge of managing the protected areas in the Montserrat mountain landscape.

4.4.13. References

- Technical report of the project (Spanish): https://lifemontserrat.eu/wp-content/uploads/2020/09/Informe-Final-LM_Resumen-Parte-Tecnica.pdf
- Silvopastoral management handbook (Spanish): https://lifemontserrat.eu/wp-content/uploads/2020/09/Manual-gestión-silvopastoral.pdf
- Report on prescribed burning (English): https://lifemontserrat.eu/wp-content/uploads/2020/09/Life-Montserrat_Prescribed_Burns_report.pdf
- Report on the benefits of prescribed burning (Catalan language): http://beteve.cat/clip/reportatge-els-beneficis-del-foc-prescrit-al-bosc/
- Project Document: https://lifemontserrat.eu/wp-content/uploads/2015/10/Presentació_LIFE_MONTSERRAT.pdf
- Layman awareness raising report: https://lifemontserrat.eu/wp-content/uploads/2019/07/00-Layman-Report-CAST-DIGITAL.pdf
- Project Video: https://www.youtube.com/watch?v=YEzpGrgUZWk

4.5. EU Funded Regional Projects relevant for fire-smart landscape planning

4.5.1. Firelogue (2021-2025).

The project is funded under the EU Horizon 2020 Research and Innovation Program. Firelogue has as a core objective the creation of a network for the discussion on the future of European Wildfire Risk Management (WFRM), identifying and engaging relevant stakeholders within the WFRM community. It thereby focuses mainly on the support of the Green Deal (LC-GD-1-1) Innovation Actions TREEADS, FIRE-RES, and SILVANUS (IAs henceforth) and the Research and Innovation Action (RIA) FirEUrisk (funded under the call LC-CLA-15), as well as other projects working on wildfire management. Thus, Firelogue will simultaneously coordinate the integration of stakeholders and findings into cross- sectoral WFRM recommendations as a roadmap towards meeting the 2030 impacts as expressed by the Green Deal call and beyond.

Firelogue established 5 sectorial Working Groups (WGs) to foster transdisciplinary dialogues so as to review and analyse existing WFRM approaches, and innovations suggested by their members and other activities in the broader WFRM community. The working groups are:

- WG1 on Ecology/environment
- WG2 on Societal aspects
- WG3 on Infrastructures
- WG4 on Insurance
- WG5 on Civil Protection aspects.

To ensure structured discussions and facilitate cross- working group exchange, all WGs worked along four horizontal thematic strands, reflecting the main policy aspects (Socioeconomic aspects, Climate Change Mitigation & Adaptation) and facilitators (Technology, Earth Observation) in WFRM. To properly manage the interaction with all the stakeholders, the project promotes the design and implementation of discussion and knowledge sharing formats including an Annual digital conference, Peer Review, Joint Impact Assessment, webinars, or networking events. More specifically, these activities intend to facilitate multi-stakeholder networking, exchange, and continuous engagement, as well as collect and synthesize their voices across the whole spectrum of politics, economics, civil protection, and civil society.

4.5.2. FIRE-RES (2021-2025) [105]

It was funded under the EU H2020 Research and Innovation Program and led by the Forest Science and Technology Centre of Catalonia in Spain. The project has 4 objectives:

i) to set the definition of extreme wildfire events and use it as the main axis to address the challenge ahead;
ii) to develop, demonstrate and deploy innovations at the technological, social, health/safety, administrative, ecological and economic levels;
iii) to integrate and upscale results from the niche-level innovations implemented locally in living labs across Europe and beyond;
iv) to raise societal awareness about extreme wildfires and transfer enabling knowledge to stakeholders.

The project will develop, deploy, demonstrate and upscale 34 innovative solutions addressing the challenges imposed by extreme wildfire events throughout 11 so-called living-labs from northern to southern Europe (including the Mediterranean countries of France, Greece, Italy, Portugal, and Spain), as well as Chile.

[105] https://fire-res.eu

4.5.3. FirEUrisk (2021-2025) [106]

This project is funded by the H2020 European Research and Innovation Program. It aims to improve wildfire risk assessment in Europe through a science-based strategy that includes:

- new tools for **assessing the danger and the vulnerabilities of communities and landscapes** through a combination of satellites and geospatial analysis with citizen participation;
- **wildfire risk reduction** through the analysis of the strengths and weaknesses of current fire guidelines and management strategies to offer improved alternatives to tackle the political, economic and social drivers behind extreme wildfires;
- **fire risk adaptation**, through the modelling of future climate and demographic scenarios to elucidate which changes should be considered for designing effective preparedness.

Demonstration Areas and Pilot Sites tested and validated the new methodologies together with local stakeholder groups. Pilot Sites covered a variety of wildfire risk conditions from north to southern Europe (including the Mediterranean countries of Croatia, France, Greece, Italy, Portugal, and Spain) to demonstrate the scalability of the solutions tested.

The project will develop a **public online platform** to boost exchange of data, codes and knowledge about wildfire risk management throughout Europe. This will facilitate the coordination among the different actors involved, from fire services and civil protection to policymakers and governments.

4.5.4. InnoForESt Project (2017-2020) [107]

It was funded by the Horizon 2020 European Innovation Action Program. The project had the aim to support enhanced coordination in policy making, and to facilitate the improvement, development and mainstreaming of policy and business innovations dealing with or affecting forest ecosystem services (FES). This fostered the sustainable and economically viable provision of a broad(er) range of FES across Europe, in particular those that lack market values but are of tremendous importance for societal wellbeing, (i.e. cultural and regulating FES). For this endeavour, an inter- and transdisciplinary consortium was formed by 16 institutional project partners from nine European countries to include about the same number of scientists from different universities and research institutes on the one hand as well as practitioners from different fields and organisational affiliations on the other.

InnoForESt consortium accompanied and analysed the experiences of six so-called 'Innovation Regions' (IRs) in European countries in their pursuit of developing innovative governance mechanisms that aim to secure the future provision and financing of FES through self-sustaining, economically viable business and/or cooperation models.

Figure 1. Innoforest six Innovation regions (IRs)

[106] https://fireurisk.eu/
[107] https://innoforest.eu/

Five overarching themes demaned consideration in the process of working towards innovative governance mechanisms for FES provision:

- **Maintaining direct link to FES provision.**
  - Collaborate with forest owners and managers when developing your product;
  - Include benefits of products from sustainable multi-functional forestry and marketing;
  - Come to an agreement with forest owners about the use of their forest and division of revenue.

  After the systematic stakeholder identification, the IRs, with the support of a team of scientists, went through a structured stakeholder network building process aimed at collaboratively developing (further) a governance mechanism suitable to spark innovations. They followed a particular method called 'Constructive Innovation Assessment' (CINA), engaging all relevant actors together through several workshops focusing on the analysis of alternative scenarios for different governance innovations around newly emerging technologies called (Constructive Technology Assessment - CTA).

- **Bringing diverse set of stakeholders together**
  - dentify, reach out and work together with potential clients, private customers, municipalities and other organizations relevant for public procurement and as cooperation partners;
  - Contact actors within the forest-based sector along the value chain, tourism and recreation service providers, producers of products, mediating agents, and network coordinators (e.g. NGOs, tourism agencies for forest-based recreational and health offers, forest owners and managers, and relevant research institutions in product and service development).
- **Structured, facilitated stakeholder network building**. Inform yourself about existing related networks and facilitators and actively engage with them.
- **Facilitated innovation development.**
  - assess current supply and demand for different FES;
  - follow a structured (product) innovation development process and networks;
  - actively engage in these networks to meet like-minded innovators, and potential partners from the landscape, country and abroad.
- **Payment mechanism for the provision of FES**. The IRs involved in InnoForESt showcased a number of different approaches to funding FES provision. All actively address private economy mechanisms that contribute to securing the provision and financing of provisioning, regulating and cultural FES. They range from crowdfunding (e.g. for biodiversity conservation) and sponsoring, to communal forests and private enterprises involved in regional biomass value chains, and compensation mechanisms (e.g. biodiversity, carbon emissions), or a combinations of them. The FES-related payment mechanisms and business models detected can be grouped into main three categories:
  - **Compensation payment mechanisms (PES) for forest management offsetting negative ES footprints**: Primarily direct payments for biodiversity conservation or carbon sequestration;
  - **Value added in value chains from multi-FES oriented forest management**: innovative governance mechanisms linking actors involved in production, processing and marketing of timber, NTFP, and innovative biomass products that contribute to refinancing forest management decisions beyond provisioning FES; widely established market-based instruments influencing the provision of FES include certification schemes for sustainable forest management;
  - **Business models for other sectors dependent on forests and their FES as a backdrop**; service innovations related largely to cultural FES (recreation and tourism) and are often developed by entrepreneurs outside the forestry sector. They generally rely on the availability and accessibility (or non-excludability) of regulating and cultural FES such as biodiversity, wildlife habitats, and attractive landscapes, which appear to be perceived as common property by the innovators and serve as the means to income generating entrepreneurial activity.

A number of on-going policy processes (e.g. Green Deal and associated strategies) offer windows of opportunity to proactively foster the provision of forest ecosystem services (FES) in particular regulating and cultural FES though innovative governance mechanisms. Several mention the need for creating incentives for forest management to achieve these objectives (e.g. the EU Farm to Fork strategy explicitly states the need for compensation payments and an associated system of robust certification rules for carbon sequestration). A prominent programme for supporting forest management for the provision of currently non-marketable FES is the Natura 2000 network payment, which provides lump-sum payments per hectare managed primarily for biodiversity conservation which is assumed to make up for "income forgone". Other EU policies also touch on forests' role in carbon sequestration, such as the EU emissions trading system, or the EU Taxonomy for sustainable activity.

InnoForESt findings suggest that in addition to payments related to carbon sequestration or biodiversity conservation, there is value in targeted support for local level initiatives that aim to secure provision of these and other FES through network-based approaches. The potential of these policy strategies to foster FES provision can only be realized if the goal of securing FES provision is integrated into existing and emerging governance and funding schemes. It should be addressed as an explicit objective that is pursued through targeted political steering and public support for private profit and non-profit business innovations.

4.5.5. PREVAIL - Prevention action increases large fire response preparedness (2019-2021) [108]

PREVAIL was funded by Funded by the European Union Humanitarian Aid and Civil Protection. PREVAIL was a cooperative project among 5 research organizations of fire prone European countries (Italy, Spain, Portugal, Greece) that aimed at demonstrating how wildfire landscape-based fire prevention can make large fire suppression more effective and less costly. The project targeted the following activities:

- Statistical and econometric analysis of prevention, preparedness and suppression measures to counteract large fires.
- Simulation of past large fire events, to reconstruct fire behaviour and predict effects of alternative fuel management scenarios on the reduction of fire suppression effort.
- Developing a DSS to plan and optimize smart solutions at the water catchment scale to increase the leverage and cost-effectiveness of fuel management treatments and promote development of local economy ensuring their maintenance in a climate change context.
- Determining best strategies to integrate prevention and preparedness to large-fire events, sharing and spreading "smart" solutions, implemented locally in partners' countries, by trans-national training and producing material to raise awareness of citizens, land managers and fire operators.

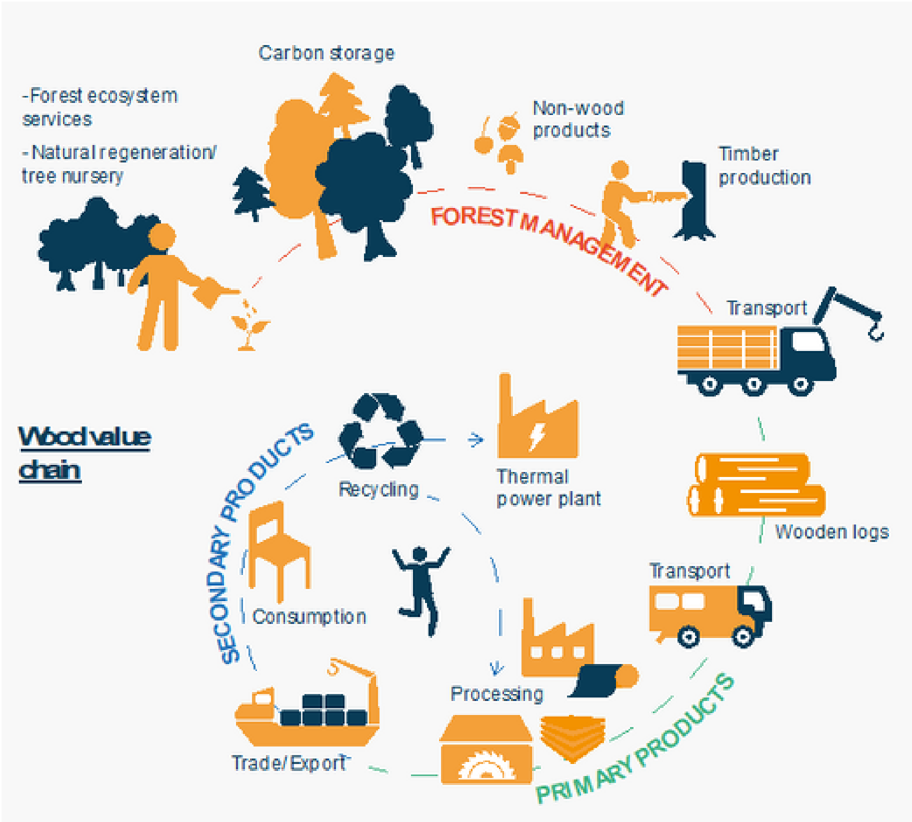
The overarching project idea is to find out and document cost-efficient and circular ways for transforming fueled landscapes into fire resistant and resilient landscapes (FRRL), by planning and implementing active and passive prevention activities in woodlands, rural lands and wildland urban interfaces. Shaping up FRRL is instrumental to resize the severity of many future wildfires and to protect citizens, infrastructures and values. FRRLs make active prevention less costly and Civil Protection and response more efficient and safer.

4.5.6. RESONATE – Resilient Forests for Society (2021-2024) [109]

It is a project funded by the EU Horizon 2020 Research and Innovation Program. It aims to generate the needed knowledge and practices for making European forests, the services they provide, and the related economic activities more resilient to future climate change, societal demands, and disturbances. The project includes 20 partner institutions from 12 different European countries and 9 regional case studies in north, central and Mediterranean Europe.

---

[108] Ascoli D., Giannino F. Moreno M., Plana E., Serra M., Xanthopolous G., Athanasiou M., Kaoukis K., Varela V., Rego F., Colaco C., Acacio V., Sequeira C., Tomao A., Ferrari B., Barbati A. (2021). PREVAIL (Prevention Action Increases Large Fire Response Preparedness) project | Final results. (DG ECHO 2018 Call *826400-PREVAIL-UCPM-2018-PP-AG*). 54 pp.
[109] https://resonateforest.org/



4.5.7. SILVANUS (2021-2025) [110]

It is funded by the EU Horizon 2020 Green Deal program and coordinated by Università Telematica Pegaso. The project objective is to implement and validate the SILVANUS sustainable forest management platform and methodologies for monitoring and protecting natural resources in the fight against extreme wildfire. Through technical and scientific innovation, the project will develop novel methodologies in monitoring and analysing ecological growth of natural resources to complement the analysis of biodiversity models. The environmental monitoring framework developed within the project will be supplemented with cutting- edge technologies for the early-stage detection and response coordination of wildfire. The project SILVANUS platform will offer support for the restoration and adaptation of natural forests.

The project includes 49 partners from the European Union, Brazil, Indonesia, and Australia, bringing together a large consortium of interdisciplinary experts to combat the threats of forest fires and improve forest resilience against climate change. The project will validate the innovation and applicability of its platform through the implementation of 12 pilots in 11 EU countries, (including the Mediterranean countries of Croatia, Greece, France, Italy and Portugal), Australia, Brazil, and Indonesia.

4.5.8. TREEADS – A Holistic Fire Management Ecosystem for Prevention, Detection and Restoration of Environmental Disasters (2021-2025) [111]

The project is funded by the EU Horizon 2020 Research and Innovation Program. It will adopt a holistic forest fire management and an adaptive, collaborative governance approach based on the deployment of a new systemic and technological framework covering all three interconnected fire management stages. Pilot use cases will be performed in seven European countries, (including the Mediterranean countries of Spain, Italy and Samaria NP in Crete, Greece), as well as Taiwan by a significant number of end users.

[110] www.silvanus-project.eu
[111] https://treeads-project.eu

5. Recommendations for the Fire-smart Landscape Planning Process

5.1. 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.

5.2 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 (wildfire management; biodiversity conservation and ecology);
    - social science (e.g. the human dimension of fires, rural population dynamics, gender issues)
    - rural economy and sustainable business models and value chains;
    - national/sub-national policies and incentives linked to the EU Green Deal, as well as land tenure, and spatial planning;
    - GIS modelling expert.
    - rural development (land uses, land tenure, sectoral policies)

  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.

- Build 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).

- 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.

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

5.3. 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.

5.4. 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 organised 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 a second workshop would be the following:
    - 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 [112].

[112] 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.

- 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 the 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. 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: (i) financing strategy; (ii) formalization of the fire-smart landscape plan governance mechanism; (iii) 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.

Bibliography

Alados C., Saiz H., Nuche P., Gartzia M., Komac B., De Frutos Á., & Pueyo Y. 2019. Clearing vs. burning for restoring Pyrenean grasslands after shrub encroachment. *Cuadernos de Investigación Geográfica 45* (2), 2019, pp. 441-468.

Alcasena, F.J. 2019. Wildfire risk management in southern European landscapes: Towards a long-term comprehensive strategy. PhD, several papers.
https://dialnet.unirioja.es/servlet/tesis?codigo=300028

Alcasena F.J., Salis M., and Vega-Garcia C. 2016. A fire modeling approach to assess wildfire exposure of valued resources in central Navarra, Spain. *European Journal of Forest Research, 135*, 87-107.

Alcasena F.J., Ager A.A., Bailey J.D., Pineda N., and Vega-Garcia C. 2018. Towards a comprehensive wildfire management strategy for Mediterranean areas: Framework development and implementation in Catalonia, Spain. *Journal of Environmental Management*, 231, 303-320. Doi:10.1016/j.jenvman.2018.10.027.

Alcasena F.J., Vega C., Ager A.A., Salis M., Nauslar N.J., Mendizabal F.J., and Castell R. 2019. Metodología de evaluación del riesgo de incendios forestales y priorización de tratamientos multifuncionales en paisajes mediterráneos. *Cuadernos de Investigación Geográfica*, 2019, vol. 45, núm. 2, p. 571-600. https://doi.org/10.18172/cig.3716.

Ali E., Cramer W., Carnicer J., Georgopoulou E., Hilmi N.J.M., Le Cozannet G., and Lionello P. 2022. Cross-Chapter Paper 4: Mediterranean Region. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C.Roberts, M.Tignor, E.S.Poloczanska, K.Mintenbeck, A.Alegría, M.Craig, S.Langsdorf, S.Löschke, V.Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 2233–2272, doi:10.1017/9781009325844.021.

Aquilue´ N., Fortin M-J., Messier C., and Brotons L. 2019. The Potential of Agricultural Conversion to Shape Forest Fire Regimes in Mediterranean Landscapes. *Ecosystems* https://doi.org/10.1007/s10021-019-00385-7

Ascoli D., Oggioni S., Barbati A., Tomao A., Colonico M., Corona P., Giannino F., Moreno M., Xanthopoulos G., Kaoukis K., Athanasiou M., Colaço C., Rego F., Sequeira A.C., Acácio V., Serra M., and Plana E. 2021. Deliverable 4.2. PREVENTION ACTION INCREASES LARGE FIRE RESPONSE PREPAREDNESS, *Grant Agreement No. 826400-PREVAIL-UCPM-2018-PP-AG*

Ascoli D., Giannino F., Moreno M., Plana E., Serra M., Xanthopolous G., Athanasiou M., Kaoukis K., Varela V., Rego F., Colaco C., Acacio V., Sequeira C., Tomao A., Ferrari B., and Barbati A. (2021). PREVAIL (Prevention Action Increases Large Fire Response Preparedness) project | Final results. (DG ECHO 2018 Call *826400-PREVAIL-UCPM-2018-PP-AG*). 54 pp.

Baudena M., Santana V.M., Baeza M.J., Bautista S., Eppinga M.B., Hemerik L., Garcia-Mayor A., Rodriguez F., Valdecantos A., Vallejo V.R, Vasques A., and Rietkerk M. 2019. Increased aridity drives post-fire recovery of Mediterranean forests towards open shrublands. *New Phytologist (2020)* 225: 1500–1515.

Bertomeu M., Pineda J., and Pulido F. 2022. Managing Wildfire Risk in Mosaic Landscapes: A Case Study of the Upper Gata River Catchment in Sierra de Gata, Spain. *Land* **2022**, 11, 465. https://doi.org/10.3390/ land11040465.

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.

Cánibe Iglesias M., Hermoso V., Campos J.C., Carvalho-Santos C., Fernandes P.M., Freitas T.R., Honrado J.P., Santos J.A., Sil A., Regos A., and Azevedo J.C. 2022. Climate- and fire-smart landscape scenarios call for redesigning protection regimes to achieve multiple management goals. *Journal of Environmental Management 322 (2022) 116045*.

Castro J. 2013. Postfire Burnt-Wood Management Affects Plant Damage by Ungulate Herbivores. *Hindawi Publishing Corporation International Journal of Forestry Research* Volume 2013, Article ID 965461, 6 pages http://dx.doi.org/10.1155/2013/965461

Castro J., Moreno-Rueda G., and Hodar J.A. 2010. Experimental test of postfire management in pine forests: impact of salvage logging *versus* partial cutting and nonintervention on bird-species assemblages. *Conserv Biol 24*(3):810–819. doi:10.1111/j.1523-1739.2009.01382.x

Cervelli E., Pindozzi S., Allevato E., Saulino L., Silvestro R., Scotto di Perta E., and Saracino A. 2022. Landscape Planning Integrated Approaches to Support Post-Wildfire Restoration in Natural Protected Areas: The Vesuvius National Park Case Study. *Land* **2022**, 11, 1024. https://doi.org/10.3390/land11071024

Chazdon R.L., Wilson S.J., Brondizio E., Guariguata M.R., and Herbohn J. 2021. Key challenges for governing Forest and Landscape Restoration across different contexts. *Land Use Policy, 104*. 104854. https://doi.org/10.1016/j.landusepol.2020.104854.

Colomer R., Regato P., and Enciso E. 2014. Forest Restoration Plan: Mediterranean Mosaics Project, Shouf Biosphere Reserve. *ACS*.

Costa H., De Rigo D., Liberta G., Houston Durrant T., and San-Miguel-Ayanz J. 2020. European wildfire danger and vulnerability in a changing climate: towards integrating risk dimensions. JRC PESETA IV project – Task 19. Luxembourg: *Publication Office of the European Union*.

EBC (2012-2022) 'European Biochar Certificate - Guidelines for a Sustainable Production of Biochar.' European Biochar Foundation (EBC), Arbaz, Switzerland. (*http://european-biochar.org*). Version 10.1 from 10th Jan 2022.

Enciso E., Colomer R., Regato P., and Martinez F. 2015. Thermal Biomass for Lebanon. *ACS*.

Garcia B., Alves O., Rijo B., Lourinho G., and Nobre C. 2022. Biochar: Production, Applications, and Market Prospects in Portugal. *Environments* **2022**,*9*,95. https://doi.org/10.3390/ environments9080095.

Gromko D., Pistorius T., Seebauer M., Braun A., and Meier E. 2019. Economics of Forest Landscape Restoration: Estimating impacts, costs and benefits from ecosystem services. *Initiative 20x20*.

Hani N., Regato P., Colomer R., Pagliani M., Bouwadi M., and Zeineddine Z. 2017. Adaptive forest landscape restoration as a contribution to more resilient ecosystems in the Shouf Biosphere Reserve (Lebanon). *Plant Sociology, Vol. 54*, Suppl. 1.

Hani N., Pagliani M., and Regato P. (editors). 2020. Forest and Landscape Restoration Guidelines. Regaining Landscape Resilience, Ecological Functionality and Human Well-being in the Shouf-West Beqaa Landscape, Lebanon. *ACS eds*.

Hani N., Regato P., Pagliani M., khaddazh M., Vernyuk Y.I., Sarkis L., Buhussein R., Buwadi M., and Dokukin P. 2021. Old, abandoned terraces surveying and restoration as a contribution to the adaptive forest landscape restoration in Lebanon. *Acta Hortic*. 1324. ISHS 2021. DOI 10.17660/ActaHortic.2021.1324.34.

Herrero-Corral G., Jappiot M., Bouillon C., and Long-Fournel M. 2012. Application of a geographical assessment method for the characterization of wildland urban interfaces in the context of wildfire prevention: A case study in western Madrid. *Applied Geography 35* (2012) 60e70.

Johnston L.M., and Flannigan M.D. 2018. Mapping Canadian wildland fire interface areas. *Int. J. Wildl. Fire* 27, 1–14, http://dx.doi.org/10.1071/WF16221.

Lampin C., Jappiot M., Long M., Morge D., and Ferrier J.P. 2008. Characterization and mapping of dwelling types for forest fire prevention. *Computers, Environment and Urban Systems, 33*(3), 224e232.

Magalhães M.R., Cunha N.S., Pena S.B., and Müller A. 2021. FIRELAN—An Ecologically Based Planning Model towards a Fire Resilient and Sustainable Landscape. A Case Study in Center Region of Portugal. *Sustainability* **2021**, 13, 7055. https://doi.org/10.3390/su13137055

Mansourian S. 2017. Governance and forest landscape restoration: A framework to support decision-making. *Journal for Nature Conservation 37* (2017) 21–30.

Marañón-Jiménez S., Castro J., Querejeta J.I., Fernández-Ordoño E., and Allen C.D. 2013. Post-fire wood management alters water stress, growth, and performance of pine regeneration in a Mediterranean ecosystem. *Forest Ecology and Management* 308 (2013) 231–239.

McCaffrey S., Toman E., Stidham M., and Shindler B. 2013. Social science research related to wildfire management: an overview of recent findings and future research needs. *Int. J. Wildland Fire* 22, 15–24.

Modugno S., Balzter H., Cole B., and Borrelli P. 2016. Mapping regional patterns of large forest fires in Wildland-Urban Interface areas in Europe. *Journal of Environmental Management 172* (2016) 112e126.

Moreira F., Viedma O., Arianoutsou M., Curt T., and Koutsias N. 2011. Landscape - wildfire interactions in southern Europe: Implications for landscape management. *Journal of Environmental Management, Elsevier, 2011*, 92, p. 2389 - p. 2402. hal-00653523.

Plana E., Font M., Serra M., Borràs M., and Vilalta O. 2016. Fire and forest fires in the Mediterranean; a relationship story between forest and society. Five myths and realities to learn more. eFIREcom project. *CTFC editions*. 36pp.

Puettmann M., Sahoo K., Wilson K., and Oneil E. 2019. Life cycle assessment of biochar produced from forest residues using portable systems. *Journal of Cleaner Production*, Volume 250, 20 March 2020, 119564.

Pyne S.J. 1997. Vestal fire: an environmental history told through fire, of Europe and Europe's encounter with the world. University of Washington Press, Seattle, WA, USA. In: Ascoli D, & Bovio G, 2013. Prescribed burning in Italy: issues, advances and challenges. *iForest* 6: 79-89 [online 2013-02- 07] URL: http://www.sisef.it/iforest/ contents?id=ifor0803-005.

Regato P. 2007. Management recommendations for Pinus halepensis seeds production in Gouria region (Tunisia). *Unpublished report produced for the AECID Project*: Programa Aumento de la sostenibilidad de los medios de vida de Poblaciones Rurales Vulnerables en Marruecos, Mauritania y Túnez. Spain.

Regato P. 2019. Forest and Landscape Restoration Guidelines: The Shouf Biosphere Reserve. Hani, N., M. Pagliani & P. Regato (editors). Lebanon. *ACS*.

Regato P. 2020. Online lecture "Forest Landscape Restoration in the Shouf-West Beqaa Landscape (Lebanon): Regaining Landscape Resilience, Ecological Functionality and Human Well-being". In *Online Course "Training on Forest Landscape Restoration", organized by ELTI-University of Yale and FAO*.

Regato P. 2020. Forest and Landscape Restoration Guidelines: Regaining Landscape Resilience, Ecological Functionality and Human Well- being. The Shouf Biosphere Reserve. Hani, N., M. Pagliani & P. Regato (editors). Lebanon. *ACS*.

Regato P., Murti R., Valderrabano M., and Danielutti C.2010. Reducing Fire Disasters through Ecosystem Management in Lebanon (IUCN). In: Demonstrating the Role of Ecosystems-based Management for Disaster Risk Reduction. *Prepared for the Partnership for Environment and Disaster Risk Reduction (PEDRR) Workshop, September 2010 UNU Campus in Bonn*.

Regato P., Pagliani M., and & Hani N. 2020. Woody Energy Value Chains: Briquette production within the adaptive Forest Landscape Restoration plan in the Shouf Biosphere Reserve, Lebanon. In: *Global Bioenergy Partnership*. Working Together for Sustainable Development

Rodríguez-Carreras R., Úbeda X., Francos M., and Marco C. 2020. After the Wildfires: The Processes of Social Learning of Forest Owners' Associations in Central Catalonia, Spain. *Sustainability* 2020, 12, 6042.

Ruiz-Mirazo J. 2011 Environmental benefits of extensive livestock farming: wildfire prevention and beyond. in *Options Méditerranéennes*, Serie A (100) : 75-82, Ciheam/Zaragoza.

Ruiz-Mirazo J., Robles A.B., and González-Rebollar J.L. 2009 Pastoralism in Natural Parks of Andalusia (Spain): a tool for fire prevention and the naturalization of ecosystems. in *Options Méditerranéennes*, Serie A (91) : 141-144, Ciheam/Zaragoza.

Ruiz-Mirazo J., Robles A.B., and González Rebollar J.L. 2011 Two-year evaluation of fuelbreaks grazed by livestock in the wildfire prevention program in Andalusia (Spain) . in *Agriculture, Ecosystems and Environment* 141: 13-22, Elsevier .

Ruiz-Mirazo, J. and Robles A.B. 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.

Sande Silva J., Rego F., Fernandes P., and Rigolot E. (editors). 2010. Towards Integrated Fire Management – Outcomes of the European Project Fire Paradox. *Research Report 23. European Forest Institute*.

Senf C. 2021. Post-disturbance canopy recovery and the resilience of Europe's forests. *Global Ecol Biogeogr.* 2022, 31:25–36.

Sequeira A.C., Colaço M.C., Acácio V., Rego, F., and Xanthopoulos G. 2021. Deliverable 5.1 – Decision support system for effective fuel management: application to Cascais Case Study (Portugal). PREVENTION ACTION INCREASES LARGE FIRE RESPONSE PREPAREDNESS. *Grant Agreement No. 826400-PREVAIL-UCPM-2018-PP-AG*.

Syphard A.D., Radeloff V.C., Keeley J.E., Hawbaker T.J., Clayton M.K., and Stewart S.I. 2007. Human influence on California fire regimes. *Ecological Applications, 17(5)*, 1388e1402.

Valdecantos A. 2008. Post-fire restoration strategies/interventions to increase forest resilience against large forest fires exacerbated by climate change: The case of Valencia (Spain). In: Regato P. 2008. Adapting to global change, Mediterranean Forests. *IUCN Centre for Mediterranean Cooperation*.

Varela E., and Górriz E. 2014. Enhancing Forest Fire Prevention: Governance. *EFI news*, Nº 1, Vol. 22.

Verkaik I., and Espelta J.M. 2005. Effect of thinning and post-fire regeneration age on the reproductive characteristics of *Pinus halepensis* Mill. forests. *II International Conference on prevention strategies of fires in Southern Europe*. CREAF.

Willemen L., Kozar R., Desalegn A., and Buck L.E. 2014. Spatial planning and monitoring of landscape interventions: Maps to link people with their landscapes. A User's Guide. Washington, DC: EcoAgriculture Partners. In: Cazdon, R.L. & M.R. Guariguata. 2018. *Decision support tools for forest landscape restoration: Current status and future outlook*. Occasional Paper 183. Bogor, Indonesia: CIFOR.

Xanthopoulos G., Athanasiou M., Varela V., and Kaoukis K. 2021. Work Package 3. Large fires case studies analysis Deliverable 3.3. – Fuel management scenarios. PREVention Action Increases Large fire response preparedness. *Grant Agreement No. 826400-PREVAIL-UCPM-2018-PP-AG*. Funded by European Union Humanitarian Aid and Civil Protection.

Xanthopoulos G., Athanasiou M., Nikiforaki A., Kaoukis K., Mantakas G., Xanthopoulos P., Papoutsakis C., Christopoulou A., Sofronas S., and Gletsos M. 2022. Innovative Action for Forest Fire Prevention in Kythira Island, Greece, through Mobilization and Cooperation of the Population: Methodology and Challenges. *Sustainability* **2022**, 14, 594. https://doi.org/10.3390/su14020594.

Zamora-Cristales R., Herrador D., Cuellar N., Díaz O., Kandel S., and Quezada J. 2020. Sustainability Index for Landscape Restoration. Washington, DC. *World Resources Institute*. 62 p.

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
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

Abbreviations	Definitions
SQI	Soil quality index
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