European Academies
easac
Science Advisory Council

Changing Wildfires: Policy Options for a Fire-literate and Fire-adapted Europe

EASAC policy report 48

May 2025

ISBN 978-3-7001-9739-3

This report can be found at
www.easac.eu

Science Advice for the Benefit of Europe

EASAC

EASAC – the European Academies Science Advisory Council – is formed by the national science academies of EU Member States, Norway, Switzerland, and the UK as well as by the Academia Europaea and by ALLEA. EASAC's 30 member institutions collaborate with each other in giving advice to European policy-makers. In its entirety, EASAC provides a strong means for the collective voice of European science to be heard.

EASAC's mission reflects the view that science is central to many aspects of modern life and that an appreciation of the scientific dimension is a pre-requisite to wise policy-making. This view underpins the work of many science academies at the national level. Given the importance of the European Union as an arena for policy-making, academies have recognised that the scope of their advisory functions needs to extend beyond the national domain and cover the European level. Therefore, European academies formed EASAC in 2001 so that they can speak in a strong voice at EU level.

Through EASAC, the academies provide collective, independent, strictly evidence-based advice about scientific aspects of policy issues to those who make or influence policy and legislation within the EU institutions and in EU Member States. EASAC aims to deliver advice that is comprehensible, relevant, and timely.

Drawing on its memberships and networks of academies, EASAC accesses the best of Europe's scientific expertise in carrying out its work. EASAC covers all scientific and technical disciplines, focusing on challenging questions in the fields of environment, energy, and biosciences including public health. Its activities include conducting substantive scientific studies, elaborating reviews and advice on specific policy documents, conducting workshops aimed at briefing policy-makers, and issuing statements on topical subjects. EASAC's work processes are open and transparent, and its results are independent of any commercial or political bias.

The EASAC Council has 30 individual members – highly experienced scientists nominated one each by the member academies, by the Academia Europaea and by ALLEA. The Council agrees the initiation of projects, appoints members of working groups, provides peer review for drafts and endorses reports for publication. EASAC is mostly funded by the member academies and has no commercial or business sponsors. EASAC's experts devote their time free of charge. EASAC is supported by a Secretariat hosted by the Austrian Academy of Sciences in Vienna. To find out more about EASAC, visit the website – www.easac.eu – or contact the EASAC Secretariat at secretariat@easac.eu.

EASAC Report No. 48
ISBN: 978-3-7001-9739-3
DOI: https://doi.org/10.1553/EASAC_Report_Changing-Wildfires_2025

Suggested citation:
EASAC (2025). Changing Wildfires: Policy Options for a Fire-literate and Fire-adapted Europe. Elmqvist, T, Valkó, O, Stoof, C, Akala, T, Arianoutsou, M, Arsava, K, Ascoli, D, Bengtsson, J, Castro, R, Engelbrecht, J, Fra Paleo, U, Granström, A, Ibisch, P, Kalabokidis, K, Kandárová, H, Marinšek, A, Knottnerus, A, Metallinou, M, Müller, M, Oliviera, T, Pereira, J, Plieninger, T, Palaiologou, P, Pulido Diaz, J, Saražin, J, Stoyanov, T, Thacker, FN, van der Werf, G, Zerefos, C. EASAC policy report 48 ISBN 978-3-7001-9739-3, www.easac.eu

EASAC Secretariat
c/o Austrian Academy of Sciences
Dr. Ignaz Seipel-Platz 2
1010 Vienna
Austria

Telephone: +43 1-51581-1208
E-mail: secretariat@easac.eu
Web: www.easac.eu

This report focuses on the following United Nations Sustainable Development Goals: goal 3 (health and wellbeing); goal 11 (sustainable cities and communities); goal 13 (climate action); goal 15 (life on land).

Cover image and infographic: Communication Works – Froning, Reise GmbH / Felix Sorau.
Text copy-edited and typeset in Frutiger by The Clyvedon Press Ltd, Cardiff, United Kingdom.

Contents

Cross-references in blue type to sections, tables, figures, boxes, or references contain hyperlinks.

Foreword

Across the globe, wildfires are increasing in intensity and scale. This report focuses on wildfires in Europe, which are also changing in frequency, timing, and intensity. For example, by the end of this century, Southern Europe will face more high-intensity wildfires than today; and on the regional scale, such events may occur as frequently as once every 2 years. Europe will increasingly have to learn to live with fire and adapt society to a new challenging reality. This report by the European Academies Science Advisory Council (EASAC) critically analyses, on the basis of the most recent scientific evidence of the effectiveness of suitable proactive approaches, the state of knowledge intended to reduce increasing wildfire impacts, framed in local and regional contexts.

The climate is changing, and in many parts of Europe there will be a large increase in multi-year droughts, leading to an increased probability of extreme fires. In addition to climate change, much of the increase in large wildfires is attributed to widespread land-use change in Europe, with the conversion of open landscapes to those of shrub and forest. Current fire-management policies focus mostly on suppression and are clearly inadequate for addressing the impacts of severe fire seasons associated with changes in the climate and land-use.

Europe is a diverse continent where the conditions and drivers of change differ substantially across regions, with the Mediterranean region having the highest probability of very severe wildfires in the future. However, continental, alpine, and boreal regions also need to be prepared for increased fire risk.

The combined effects of socio-economic, ecological, and climatic trends have led to a shift in regional fire regimes from being fuel-limited to weather-driven. Compared with historical patterns, the area burned today has fewer, larger fires, including extreme high-intensity wildfire events, which poses significant environmental and risk management challenges.

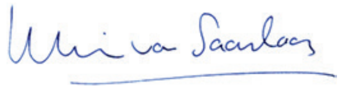
This report also highlights the fact that wildfires have more than just negative impacts. Many ecosystems are adapted to fire, and the use of fire by humans has a very long history, especially in Europe. The impacts of fires on ecosystems depend on when, where, how, and how often they burn, with some ecosystems even being dependent on fire. The positive impacts of wildfires in the environment never reach the news, whereas wildfire loss and damage do.

EASAC also emphasises the utmost need for strengthening institutional capabilities to address effective wildfire risk governance, cooperation, and coordination among stakeholders, as well as efforts to increase fire literacy. In addition to increasing budget expenditures for prevention and restoration, and adopting a system to allow effective sharing of sufficient suppression resources among the European Union's (EU's) member states, this report calls for European policies to recognise fire as an intrinsic process in European landscapes and to reinforce investments in land-use planning, agriculture, and environment policies.

The report links to several of the EU's policy areas, such as the Common Agricultural Policy, Climate Strategy, Biodiversity Strategy, Farm to Fork Strategy, the Forest Strategy, and the new Nature Restoration Law, and proposes policy options that are becoming increasingly urgent to be implemented at both the EU and member state levels. The report also explores design principles for the planned large-scale EU tree-planting programme to avoid inappropriately adding substantial amounts of flammable fuel in landscapes that are already vulnerable across Europe.

The report concludes by launching a toolbox of three urgent key messages and eight policy options to enable better management of fires today and to prepare and adapt society for fires in the future.

EASAC's work relies on the input and contributions of Europe's leading scientific experts. I thank all the members of the working group who generously gave their time to make this project a success and to write such a comprehensive report.



Wim van Saarloos
EASAC President

Summary

Wildfires in Europe are becoming more frequent and intense, even impacting regions that are historically less affected. This report, prepared by a working group of the European Academies Science Advisory Council (EASAC), examines the drivers behind these changes, explores the consequences, and reviews current wildfire management practices. It advocates for an integrated EU framework for fire adaptation and assesses current policies and strategies. Moving beyond fire suppression strategies alone, the report emphasises addressing root causes and strengthening institutional capacities. It advocates for enhanced cooperation and coordination between stakeholders, increased fire literacy, and improved funding for prevention, restoration, and land-use planning. It also supports a unified European integrated fire management system to enable the interoperability of qualified resource sharing among member states. The report culminates in a set of three urgent key messages and eight policy options designed to improve today's wildfire management and to prepare for future challenges. In the future, nearly one-fifth of Southern Europe may experience extreme fire danger as often as every 2 years. Europe must learn to coexist with fire and adapt to this evolving landscape.

Understanding wildfires

Defined as unplanned fires affecting various landscapes, wildfires are increasingly complex and driven by intertwined factors such as land-use changes, climate change, and social and economic dynamics. Policies must shift from predominantly suppression to integrated, adaptive strategies that manage fire as a natural element, recognising its ecological role in specific ecosystems. As such, local or regional definitions of acceptable risk would be beneficial, aimed at addressing only those situations that local policies consider to constitute an unacceptable risk to communities and the environment.

Drivers of change

With climate change intensifying droughts and reducing summer precipitation, wildfire risk is predicted to more than double by 2100. Urban expansion, urban sprawl, infrastructure development, and land-use changes, such as farmland abandonment and the spread of scrublands and forests, also significantly increase vulnerability to fire, necessitating investment in proactive measures to reduce risk.

Ecosystems and risk

Fire has both positive and negative effects, depending on the ecosystem type and the fire's timing, intensity, and frequency. Certain ecosystems depend on fires for biodiversity, while high-intensity or very frequent fires might have major impacts on ecosystem functioning and related services. Policy frameworks should account for this diversity, with a focus on risk reduction, post-fire restoration, and balanced fire use.

Regional differences

Fire risk varies across Europe. The Mediterranean, for example, faces more intense fires due to regional vegetation characteristics and seasonal weather patterns, whereas wildland–urban interface (WUI) areas across Europe require targeted risk management due to increasing exposure to fire.

Current EU policies

Current EU policies prioritise fire suppression; however, the increasing intensity of wildfires strongly emphasises the need for increased investment in proactive fire management along with climate change mitigation and adaptation, prioritising a reduction in damage over simply minimising the burned area.

Policy shifts and integrated frameworks

A proactive approach focusing on landscape management, restoration, and fire literacy is essential. Instead of a suppression-focused strategy, an integrated EU framework for landscape fire-risk governance should prioritise prevention based on stakeholder collaboration, rural development, risk awareness, behavioural change, and effective risk management underpinned by vertical and horizontal policy harmonisation.

Three urgent key messages

This report aims to embed fire resilience into European landscapes, ensuring that wildfires are managed not only as emergencies but also as part of a sustainable, proactive environmental strategy.

Urgent key messages

1 Prioritise the implementation of climate change mitigation and land-use policies

Swiftly implement existing EU climate change mitigation plans and land-use policies to address wildfire risk intensified by climate change, rural depopulation, farmland abandonment, and woody encroachment. The new Nature Restoration Law should also be swiftly implemented, with a particular focus on restoring peatlands and managing forests to reduce risk. Peatlands are critical for preventing significant carbon loss and mitigating climate feedback loops, because peatlands, the most carbon-dense ecosystems on Earth, store approximately 10 times more carbon per hectare than boreal forests.

2 Incorporate assessments of wildfire risk into biodiversity and tree planting initiatives

Ensure that scenarios of wildfire risk are thoroughly assessed and integrated before the Kunming–Montreal Global Biodiversity Framework's 30 × 30 strategy and the EU tree-planting programme are fully implemented. These initiatives must be aligned with firewise landscape management to avoid unintended consequences, such as increased fire vulnerability in afforested areas and exposure of large restoration investments to fire hazard.

3 'Living with fire': enhance public health interventions and education on wildfire risk

Address the severe health risks posed by wildfire smoke, particularly for vulnerable populations, by improving preparedness and public health interventions. Awareness should be increased through comprehensive education programmes for all ages, particularly young populations, fostering a fire-literate society equipped to adapt to the growing challenge of 'living with fire' in Europe.

Eight policy options

1 Invest in integrated wildfire risk reduction

Shift from dominant reactive fire suppression to a more balanced approach, combining proactive and reactive strategies.

- Actions: Focus on reducing fuel in high-risk areas, adopting multi-hazard planning, and aligning wildfire policies with broader disaster risk frameworks.
- Benefits: More effective wildfire management, reduced costs, and fewer gaps in cross-sector policies.

2 Implement nature-based solutions

The use of suitable nature-based solutions to reduce wildfire risk and support post-fire recovery.

- Actions: Implement prescribed grazing, prescribed burning, and native species reforestation.
- Benefits: Cost-effective biomass control, co-benefits such as water retention, erosion prevention and job creation in rural areas.

3 Embrace the role of fire

Recognising fire as part of many ecosystems and allowing planned burns to maintain ecological balance.

- Actions: Support prescribed burning and cultural fire practices to reduce fuel loads and benefit biodiversity.
- Benefits: Reduced wildfire intensity, improved ecosystem benefits, and preserved traditional practices.

4 Invest in education and communication for wildfire awareness

Increased fire literacy and preparedness through education for all ages.

- Actions: Integrate wildfire education in curricula and public awareness campaigns, which focus on fire literacy and management skills.
- Benefits: Greater public understanding and preparedness, more informed land-use decisions, and skilled professionals.

5 Invest in landscape management to reduce vulnerability

Design and maintain resilient landscapes that reduce wildfire risk.

- Actions: Promote mixed land use, agroforestry, and targeted conservation to create more fire-resilient environments.
- Benefits: Fire-resilient landscapes, diversified rural economies, and sustainable farming practices.

6 Harmonise sectoral policies

Align land-use and environmental policies to prevent unintended increased wildfire risk.

- Actions: Review sectoral policies with potential wildfire impacts, especially around afforested areas, ecological corridors, and urban planning and greening.
- Benefits: Fewer cross-policy conflicts, enhanced biodiversity protection, and reduced wildfire vulnerability.

7 Promote compact urban development

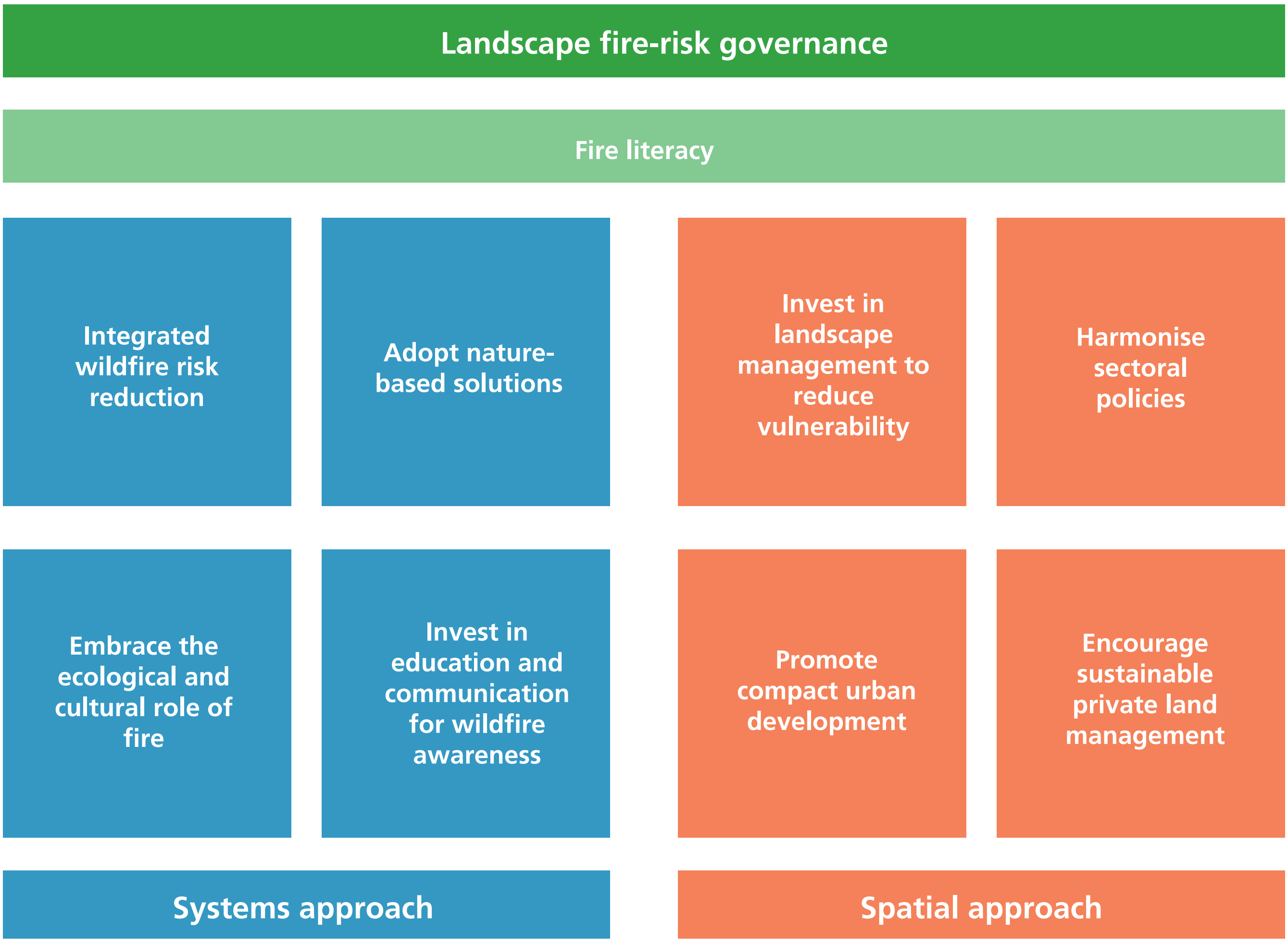
Reduce urban sprawl to limit the expansion of the wildland–urban interface and associated fire risk.

- Actions: Incentivise compact urban design, use farmland as a buffer, and integrate wildfire risk in urban planning.
- Benefits: Reduced exposure of urban areas to wildfires, lower carbon emissions, and safer peri-urban landscapes.

8 Encourage sustainable private land management

Support private landowners in adopting fire-resilient practices.

- Actions: Promotion of mixed-species forests, closer-to-nature sylviculture, extensive grazing, and climate-adapted farming practices.
- Benefits: Reduced fire fuel loads, biodiversity preservation, and stronger rural economies.




Changing Wildfires in Europe
>60,000
forest fires every year in the EU
€2 billion
economic losses annually
Climate change and land-use change lead to larger and more intense wildfires
More than twice as many urban areas are at risk of fire in Europe than in North America and Asia
2x
Wildfires in the EU burn, on average, half a million hectares yearly - nearly twice the size of Luxembourg
Vulnerable and marginalised populations are the most exposed
Reactive Fire Regime
High-impact wildfires
Proactive Fire Regime
Low-impact wildfires
Strengthening of reactive policies
Continuation of current policies
Strengthening of proactive policies
Integrating policies affecting wildfire risk
Climate Strategy
Forest Strategy
Common Agricultural Policy
Farm to Fork Strategy
Nature Restoration Law
Biodiversity Strategy

	Pathway 1 **Continuation of current policies**	Pathway 2 **Strengthening reactive policies**	Pathway 3 **Strengthening proactive policies**	Pathway 4 **Integrating policies affecting wildfire risk**
Wildfire regime	Reactive wildfire regime	Reactive wildfire regime	Proactive wildfire regime	Proactive wildfire regime
Wildfire risk reduction	Wildfire preparedness and response based on fire suppression Use of empirical based routines to assess risk and reduction measures	Strengthened wildfire preparedness and response based on fire suppression Use science to assess operational risks and promote more efficient use of resources	Combined wildfire preparedness and response, and ecosystem-based disaster risk reduction (ecoDRR) Reconciliation of cultural fire practices Integration of scientific and local ecological knowledge by involving multiple stakeholders in decision making	Combined wildfire preparedness, ecosystem-based disaster risk reduction (ecoDRR), and integrated landscape planning Reconciliation of cultural fire practices Integration of scientific and local ecological knowledge by involving multiple stakeholders in decision making Trade-off analysis supported by probabilistic scenarios
Wildfire policy integration	Not articulated	Not articulated	Strengthened sectoral actions and improved interaction	Better articulated, multisectoral, whole of government wildfire policies Wildfire risk business models for the insurance sector Adoption of a Landscape Fire Governance Framework
Ecosystem management	Wildfire excluded from ecosystems	Wildfire excluded from ecosystems	Recognition of the ecological role of fire in specific ecosystems Restoration of degraded ecosystems from wildfires	Recognition of the ecological role of fire in specific ecosystems Restoration of degraded ecosystems from wildfires
Management of biomass	Actions limited to some interfaces	Actions limited to very few interfaces	Actions extended to private and public property, and suburban areas Prescribed burning Prescribed grazing Diversified rural economies	Actions extended to private and public property, and suburban areas through integrated planning Prescribed burning Prescribed grazing Reduced biomass density and increased diversity in forest composition in non-protected areas Diversified rural economies
Soil management	Localised post-fire soil conservation	Localised post-fire soil conservation Slope stabilisation with hard-engineering solutions	Extended post-fire soil conservation Slope stabilisation with hard-engineering solutions combined with bioengineering	Extended post-fire soil conservation Slope stabilisation with hard-engineering solutions combined with bioengineering

	Pathway 1	Pathway 2	Pathway 3	Pathway 4
	Continuation of current policies	**Strengthening reactive policies**	**Strengthening proactive policies**	**Integrating policies affecting wildfire risk**
Landscape planning	Extensive monoculture in forests with fuel continuity without suitable management	Extensive monoculture, in forests with fuel continuity with improved management	Extensive monoculture in forests with fuel continuity Diverse and fire-resistant land use practices in forestry and farming	Integrated landscape planning and management Diverse and fire-resistant land use practices in forestry and farming Multifunctional and mosaic landscapes
Urban planning	Limited and non-articulated actions	Defensive space of individual buildings	Defensive space of individual buildings	Reduction of urban sprawl and fostering compact urban areas Integration of wildfire risk management into urban planning in peri-urban areas Fire-resistant construction in peri-urban areas Fire-resistant landscaping in peri-urban areas
Rural economy	Monoculture and industrialised, extractive economy, rural abandonment without countermeasures	Monoculture and industrialised, extractive economy, rural abandonment without countermeasures	Valuation of natural resources Diversified, unsustainable extractive and transformative economy	Valuation of natural resources Diversified, sustainable extractive and transformative economy
Public risk awareness	Limited and non-articulated actions	Campaigns to increase public awareness of emergency preparedness	Risk communication plans to increase public awareness of wildfire risk prevention and emergency preparedness	Risk communication plans to increase public awareness of wildfire risk prevention and emergency preparedness Risk communication plans to increase fire literacy across generations and sectors through education and training
Multihazard approach	Absent	Absent	Assessment of programmes and plans with impact on wildfire risk	Assessment of programmes and plans with impact on wildfire risk

Preamble

This report addresses the urgent need for updated policies to manage increasing wildfire risk in Europe. Wildfires are increasing in frequency, duration, and intensity, even in regions that are historically less affected. Society must adapt to the reality of living with fires. Yet current fire-management policies are insufficient for addressing high-severity fires and prolonged fire seasons exacerbated by climate change. Recognising this critical gap, the European Academies Sciences Advisory Council (EASAC) convened experts across Europe in 2023 and 2024 to analyse the evidence for proactive, holistic wildfire-management policies. On the basis of the latest scientific findings, this report presents an in-depth review of effective approaches to mitigate wildfire impacts across local and regional levels.

Wildfires affect various landscapes, including forests, shrublands, grasslands, peatlands, and urban areas. Wildfires have broad, often severe, impacts on natural ecosystems and socio-economic systems. The European Union's (EU's) climate adaptation strategy, adopted in 2021, aims to make Europe resilient by 2050, including addressing increased wildfire risk. Similarly, the EU's Forest Strategy for 2030 acknowledges climate-driven threats, including wildfire risk, facing European forests.

Despite these strategies, resources have been disproportionately allocated to fire suppression over prevention. The United Nations Environment Programme has called for a fundamental shift in funding, urging the EU and member states to reallocate spending toward prevention and improve monitoring and coordination. Currently, most resources are funnelled into emergency responses, with only a small fraction dedicated to planning and prevention, creating a significant imbalance (UNEP, 2022).

Scientific review of proactive approaches

This report provides a comprehensive review of the evidence for proactive approaches to wildfire risk management tailored to the EU. Effective strategies include fire regime management through land-use planning, fuel management, closer-to-nature forestry, grazing, and prescribed burning. Restoring burned areas and managing vegetation to reduce vulnerability to wildfire impacts are equally critical. The evidence base for the effectiveness of proactive measures is presented in sections A–C, and calls for actions are presented in sections D–F.

Policy linkages and recommendations

The report ties into several EU policy areas, including the Common Agricultural Policy, Climate Strategy, Biodiversity Strategy, Farm to Fork Strategy, Forest Strategy, and the new Nature Restoration Law.

Through key messages and recommendations, this report aims to embed fire resilience into European landscapes, ensuring that wildfires are managed not only as emergencies but also as part of a sustainable, proactive environmental strategy.

What are wildfires?

In this report, *wildfire* refers to all vegetation fires except for prescribed burns and traditional fires regulated by national and regional laws. The United Nations Office for Disaster Risk Reduction and International Science Council defines wildfires as any unplanned or uncontrolled fires affecting vegetation across natural, cultural, industrial, and residential areas (adapted from FAO, 2006) (see also Glossary on page 48). Wildfires can be ignited both naturally (e.g., by lightning or volcanic activity) and frequently by human activities.

While related terms exist, such as *wildland fire* – a broad term encompassing any fire occurring in wildland areas regardless of its cause, damage, or benefits (FAO, 2006, 2024) – this report primarily uses wildfire in line with international standards. *Landscape fire* is another term covering fires in natural and cultural landscapes, such as forests, peatlands, shrublands, grasslands, agricultural lands, and peri-urban areas, regardless of the ignition source or outcome.

Additionally, the term *fire regime* is occasionally used to describe the spatiotemporal patterns, frequency, and intensity of wildfires in a specific area over extended periods (Krebs *et al*., 2010).

Please refer to the Glossary on page 48 for more details about the terminology used.

A Wildfires, landscapes, and people

A landscape approach that views ecosystems as social–ecological systems that deliver vital services has become a central area of research (e.g. Millennium Ecosystem Assessment, 2005). It is where people and nature intersect, making landscapes a key arena for addressing sustainability challenges (Plieninger *et al.*, 2018). The landscape approach promotes integrative, transdisciplinary management, bridging divides between diverse land uses, such as forestry, agriculture, livestock, infrastructure, and urban settlements. This approach, if increasingly adopted in policy and practice, would support food production, watershed protection, biodiversity conservation and rural livelihoods as interlinked objectives within the landscape rather than in isolation (Scherr and McNeely, 2008).

Wildfires are increasingly recognised as a landscape issue (e.g. Moreira *et al.*, 2020; Cochrane and Bowman, 2021; Wunder *et al.*, 2021), similarly requiring a shift from isolated, single-focus management strategies to a holistic, adaptive approach that integrates land-use planning, agriculture, forestry, civil protection, and climate and energy policies (Stoof *et al.*, 2024). These interconnected sectors, each of which impacts fire management and broader disaster resilience, call for an integrated, multi-level, multi-actor, cross-sectoral governance strategy (Fra Paleo, 2015). This approach prioritises the reduction of loss and damage over simply minimising burned areas (Moreira *et al.*, 2020).

In Europe, wildfires are predominantly human-caused (Ganteaume *et al.*, 2013), with outcomes influenced by human-induced landscape alterations and settlement patterns (Moreira *et al.*, 2011; Bar-Massada *et al.*, 2023). These wildfire-prone landscapes function as social–ecological systems, where resilience is a critical focus (McWethy *et al.*, 2019; Thacker *et al.*, 2023).

Disasters often occur as interconnected hazard events, compounding impacts and creating polycrises that strain resources and intensify vulnerability. This also applies to the small number of global wildfire events that turn into wildfire disasters each year. When hazards occur simultaneously or sequentially, they interact, trigger other hazards, and amplify damage in a series of cascading effects. Through ‘spotting’, fires can spread over long distances, igniting new areas, accelerating the fires, and compounding the impact. Fires may be sparked by primary hazards such as lightning or infrastructure failure, and their severity is often fuelled by extreme conditions such as heatwaves or droughts—hazards in themselves that contribute to rapid wildfire spread.

Wildfires can also serve as primary hazards that trigger further hazards, impacting the environment and built infrastructure in two main ways: by altering environmental conditions or directly affecting structures. For example, a wildfire that destroys vegetation can lead to soil erosion and increased runoff during rainfall, resulting in gradual yet significant soil erosion and land degradation (Swain *et al.*, 2025). These types of cascading impact, often delayed, require continuous monitoring to be effectively managed.

Natural hazards, including wildfires, frequently set off technological hazards in so-called natech disasters. In wildland–urban interfaces (WUI), fires can cause structural damage to energy infrastructure, disrupt transportation networks, ignite urban and industrial facilities, and lead to further hazards.

Europe’s fragmented landscapes create an extensive WUI that is highly vulnerable to wildfires (see further in Chapter 8). The WUI is especially critical for Europe, where the population density around fire-prone areas is greater than in regions such as Australia or parts of the Americas (Bar-Massada *et al.*, 2023). It is therefore especially urgent to address the challenge of ‘living with fire’ in Europe.

Living with fire: cultivating cross-disciplinary and cross-border partnerships is key

Living with fire is an aspiration in many regions of Europe, as there is often a need for fire to be integrated into the landscape rather than excluded (Moritz *et al.*, 2014). The acceptance of fire is a key element of resilient fire-prone territories (Thacker *et al.*, 2023). However, for living with fire to become a reality, diversity is imperative (Stoof and Kettridge, 2022). The social–cultural context is important (Figure 1a), as is the diversity that crosses disciplines, risks, and borders, and so too are diverse partnerships, such as those linking academia with practitioners (see, for example, Barreiro *et al.*, 2021; Santos *et al.*, 2021) (Figure 1b).

Engaging inter- and transdisciplinary teams fosters a systems-thinking approach, emphasising wildfire as a social–ecological process rather than as the isolation of social and environmental aspects. Acknowledging the diversity of wildfire impacts is crucial, as vulnerable and marginalised populations often bear a disproportionate share of the negative effects (Paveglio *et al.*, 2015; Davies *et al.*, 2018; Palaiologou *et al.*, 2018; Ottolini *et al.*, 2023).

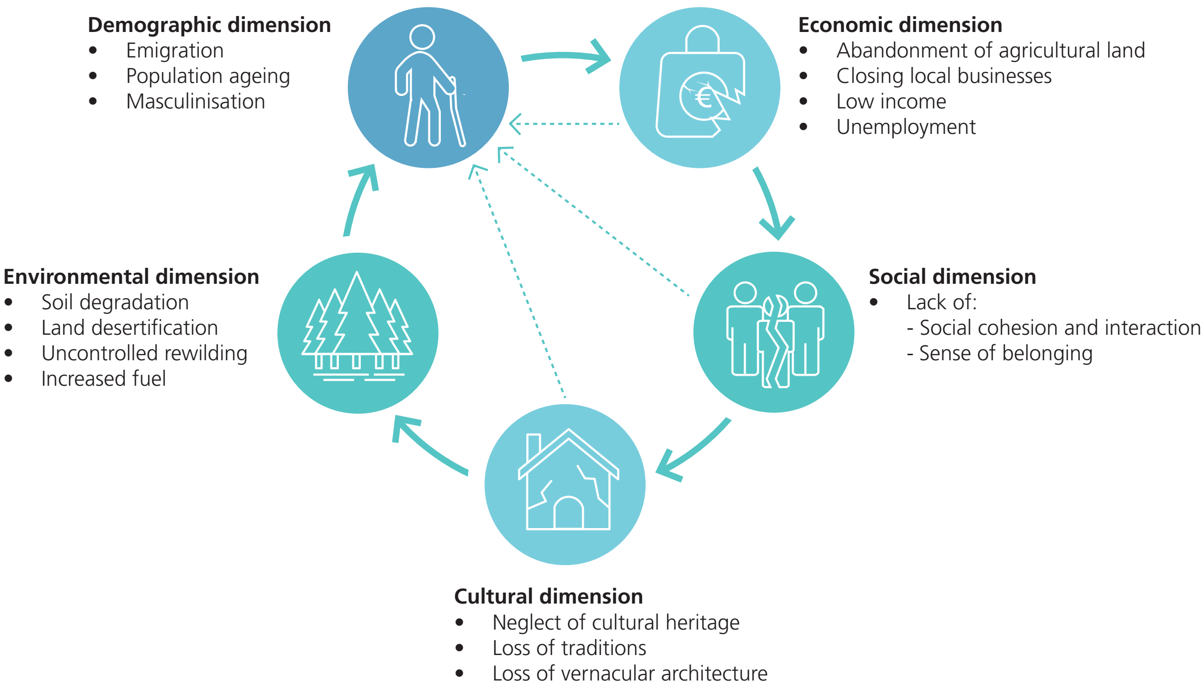


Figure 1a The social–cultural context of wildfires. Source: Graus et al. (2024).

Figure 1b An inter- and transdisciplinary perspective on living with fire.

Community preparedness depends on the capacity to integrate wildfire knowledge and actions into daily life, which varies widely across local contexts, highlighting the need for tailored solutions that incorporate traditional and local knowledge (Vigna *et al.*, 2024).

Policy frameworks aiming for coexistence with fire must recognise that response capacities differ across local, national, and international levels and should adapt accordingly. It is equally important to consider the broader disaster risk landscape, as communities at risk of wildfire, as emphasised above, are often exposed to multiple hazards. At the same time, wildfire is just one of many hazards and challenges that local communities face. Investing in general resilience is therefore key (Ottolini *et al.*, 2024).

Summary: wildfires, landscapes, and people

A landscape approach is crucial for addressing Europe's wildfire challenges, viewing wildfires as interconnected social–ecological phenomena requiring adaptive, cross-sectoral governance. Human-induced landscape changes and dense wildland–urban interfaces heighten vulnerability. Emphasising resilience, *living with fire* integrates fire into landscapes through diverse, interdisciplinary partnerships. Tailored, inclusive policies must address wildfire risk alongside broader cascading hazards to enhance broader disaster resilience and environmental justice.

Low-intensity prescribed fire in Sweden. Credit: Anders Granström.

B Why are wildfires changing?

1 Global wildfire regimes

Wildfires have been a key ecological process for hundreds of millions of years, shaping biomes and maintaining the structure and function of fire-prone ecosystems (Glasspool *et al*., 2004; Bond *et al*., 2005; Archibald *et al*., 2018) where the scale of both time and space are important (Figure 2). Over geological timescales, fire occurrence has varied markedly owing to changes in climate, atmospheric oxygen levels, and vegetation patterns. These fires have influenced evolutionary trajectories, with many plant and animal species adapting to specific fire regimes. For example, even high-intensity stand-replacing fires, while often viewed as destructive, might play a crucial role in fostering vegetation succession and creating mosaics of age classes that may increase long-term ecosystem resilience (Bond *et al*., 2005).

From a human perspective, some wildfires may offer critical ecosystem services, for example regulating biomass, controlling pests, and maintaining open landscapes for grazing and hunting (Pausas and Keeley, 2019). On the other hand, wildfires often result in the delivery of ecosystem disservices and have negative impacts on human well-being, health, and property (Sil *et al*., 2019). These benefits and harms emphasise the importance of understanding and managing fire regimes, particularly in fire-adapted landscapes (Bond and Keeley, 2005; Bond *et al*., 2005; Pereira *et al*., 2022).

Fire and herbivory as vegetation consumers

Bond and Keely (2005) considered fire and herbivory as global vegetation consumers, emphasising their role in maintaining ecosystems that have coexisted

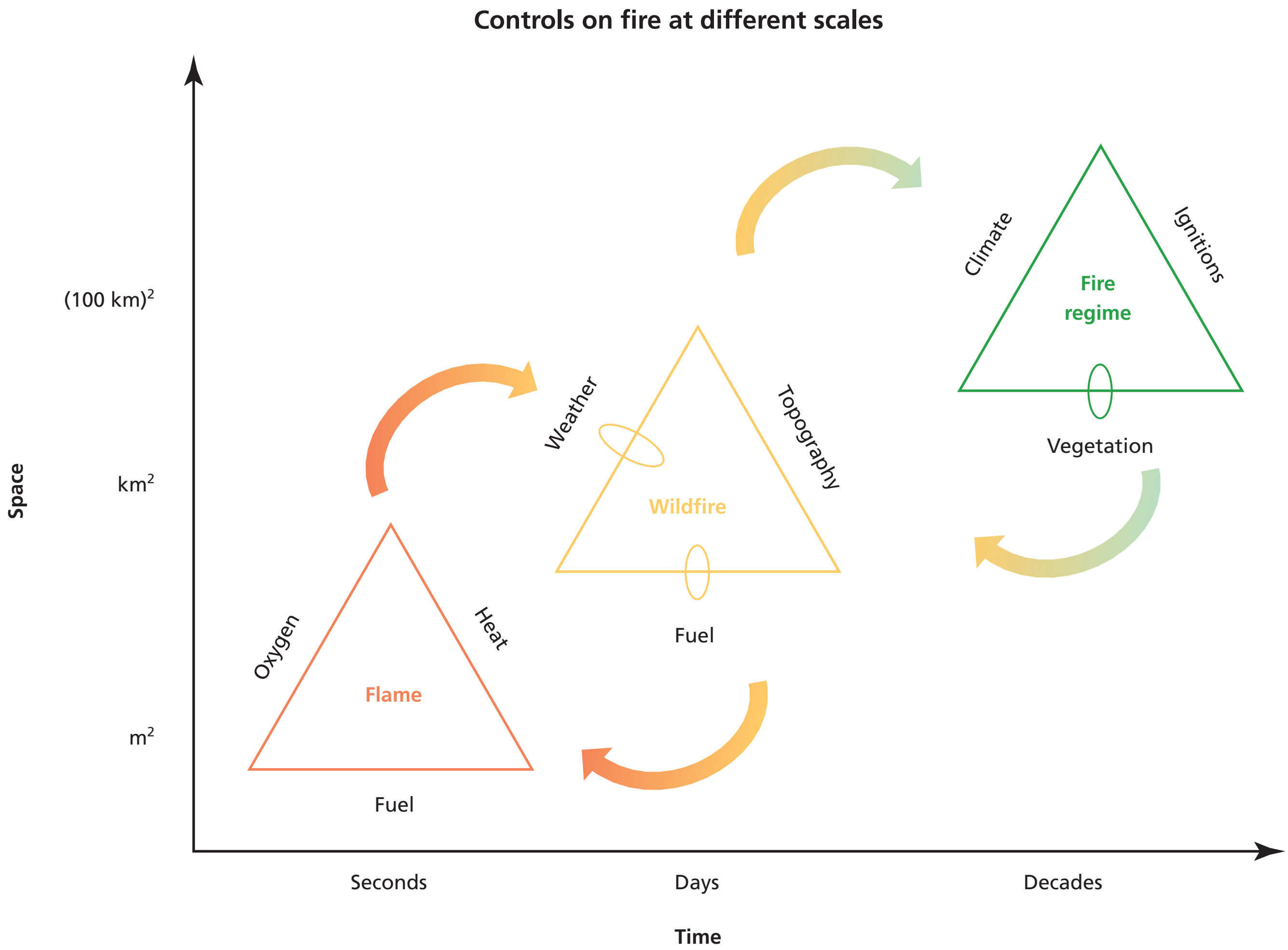


Figure 2 Dominant factors that influence fire at the scale of a flame, a single wildfire, and a fire regime (after Moritz et al., 2005).

with fire and grazing for millennia. Excluding fire from such systems can lead to fuel accumulation, creating a 'fire deficit' that results in devastating, uncontrollable fires. This highlights the importance of restoring and managing fire regimes, especially in sparsely populated regions with large continuous habitats, such as parts of Africa, Australia, and the Americas (Fernandes *et al.*, 2013).

Decline in low-intensity fires

Globally, approximately 780 million hectares burn annually—equivalent to the size of Australia (Chen *et al.*, 2023). Most of this burned area consists of low-intensity fires in tropical and subtropical savannas. However, these fires decline after agricultural conversion and landscape fragmentation (Andela *et al.*, 2017). In contrast, high-intensity wildfires, which are more destructive and have greater socio-economic impacts, are increasing (Cunningham *et al.*, 2024).

A historical example from Australia illustrates this trend. Indigenous Australians have practised fire-stick farming for thousands of years, creating frequent, low-intensity fires that shape the landscape (Steffensen, 2020; Bird *et al.*, 2024). The cessation of this practice following European colonisation has contributed to the resurgence of high-intensity wildfires (Bird *et al.*, 2024).

A more flammable landscape, driven by climate change, land abandonment, and afforestation, increases the frequency and intensity of wildfires (Cunningham *et al.*, 2024). There is an interplay between climate change and land-use changes that intensifies fire dynamics, reshaping fire regimes both globally and regionally (Varela *et al.*, 2020).

High-intensity fires and climate change

Climate change increases wildfire risk by increasing the frequency of extreme weather conditions that promote fuel drying and ignition (IPCC, 2021; Pausas and Keeley, 2021). Many regions are already experiencing larger burned areas and more intense fires. Projections indicate further escalation of fire weather conditions, even under moderate warming scenarios (Cunningham *et al.*, 2024).

While total global greenhouse gas emissions due to fires have remained relatively stable – owing to a decline in tropical fires offsetting increases in wildfires in extratropical regions (Zheng *et al.*, 2021) – the regional impacts are profound. Boreal and Arctic regions, for example, are witnessing rapid changes in fire regimes, as warming accelerates in these high-latitude areas (Kasischke *et al.*, 1995).

In Mediterranean and temperate regions of the world, human activities, such as changes in forest and grassland management, compound the effects of climate change. The result is longer fire seasons, more intense droughts, and sometimes increased occurrences of lightning, all of which contribute to greater fire activity (e.g. Hetzer *et al.*, 2024).

2 Changing wildfires in Europe

Wildfire trends in Europe mirror global patterns, with high-intensity fires increasing and overall burned areas declining (Hetzer *et al.*, 2024). The reduction in burned areas is partly due to the decline in pastoral and agricultural burning, particularly after 2013, because of stricter air-quality regulations (Marco and Bo, 2013).

European countries report fire data to databases such as the European Forest Fire Information System (EFFIS). Satellite data from the ESA FireCCI project using NASA's MODIS sensor reveal that Europe experiences more than 3 million hectares of burned area annually, with approximately 85% occurring in non-forest habitats. For example, crop residue burning in Ukraine accounts for more than 60% of the total burned area in Europe (note that since February 2022, war-related fires at a much larger scale have dominated in Ukraine (Matsala *et al.*, 2024; Sergiy Zibtsev, personal communication)).

In recent years, unprecedented fire events have occurred in Europe. In 2017 and 2018, high-intensity wildfires swept across Southern and Central Europe, claiming hundreds of lives. Even regions with historically fewer fires, such as Sweden, experienced severe fires driven by extreme droughts and heatwaves. A recent study projected that in Europe, many new areas, such as Central Europe and rapidly warming mountainous areas, will probably be exposed to severe fire weather. Fire-prone regions in Southern Europe are projected to experience even more extreme conditions (Hetzer *et al.*, 2024).

3 Wildfires and climate change in Europe

Europe's climate has already shifted beyond historical patterns, with 2023 marking the warmest summer in the Northern Hemisphere in more than 2,000 years (Esper *et al.*, 2024). The average global temperature anomaly for the first 10 months of 2024 (January–October) was 0.71 °C above the 1991–2020 average, representing the highest recorded temperature for this period and a 0.16 °C increase compared with the same period in 2023 (Copernicus, 2024). Projections under different warming scenarios (SSP1–2.6 to SSP5–8.5) indicate temperature increases of up to 8.5 °C by the end of the century, with the Mediterranean region expected to face the most severe impacts (IPCC, 2021).

Projected changes in fire weather

Precipitation patterns are also shifting. While Northern and Central Europe are projected to experience increased annual precipitation, the Mediterranean could experience decreases of up to 30%. These changes, coupled with rising vapour pressure deficit[1] and prolonged heatwaves, further increase fire risk across Europe (IPCC, 2021) (Figure 3). An increasing atmospheric vapour pressure deficit is a global phenomenon that has clear and usually deleterious impacts on a cascade of plant processes, including carbon sequestration, transpirational water loss, growth, productivity, and survival. These impacts are exacerbated by land–atmosphere interactions that link the dynamics of vapour pressure deficit and soil drought (Novick *et al.*, 2024).

Extreme weather events, such as multi-year droughts, are expected to double the probability of extreme fires in Europe by the end of the century (Grünig *et al.*, 2023). Central and Southern Europe are expected to experience prolonged fire seasons, with extreme fire danger occurring as frequently as once every 2 years in some areas (El Garrussi *et al.*, 2024).

Lightning as a cause of fire

Lightning is also an ignition source for wildfires. While global warming is expected to increase lightning-induced fires in many regions (Romps *et al.*, 2014), Europe's lightning patterns are projected to shift northwards, increasing risk at higher latitudes. Complex terrain and vegetation dynamics further influence the likelihood of lightning occurrences and ignition (Kotroni and Lagouvardos, 2008; Kahraman *et al.*, 2022).

4 Wildfires and land-use change

The increase in large wildfires and their severe impact across Europe over recent decades is intrinsically linked to land-use changes, in addition to the effects of climate change (Oliveira *et al.*, 2017; Cervera *et al.*, 2019; Mantero *et al.*, 2020; Ascoli *et al.*, 2021). These processes are driven by complex interactions in social–ecological systems, leading to landscape transformations that heighten wildfire risk.

Land-use change is shaped by an intricate interplay of socio-economic, cultural, biophysical, and ecological factors (Pinto-Correia and Kristensen, 2013; Plieninger *et al.*, 2016). These dynamics are influenced by agricultural and forestry market trends, urban expansion, rural depopulation, and evolving public policies at the local, national, and EU levels (Hearn and Álvarez-Mozos *et al.*, 2021).

Recurrent fires also drive land-use change by degrading vegetation, altering species composition, and favouring pyrophytic plants with fire-resistant traits, such as *Cistus* species in the Mediterranean (Acácio *et al.*, 2007). This creates fire-prone low scrubland areas and exacerbates erosion, leading to permanent shifts in land use (Acácio *et al.*, 2007).

Agricultural policy, land abandonment, and forest expansion

Agricultural intensification in the 20th century triggered significant rural-to-urban migration. Some reforms

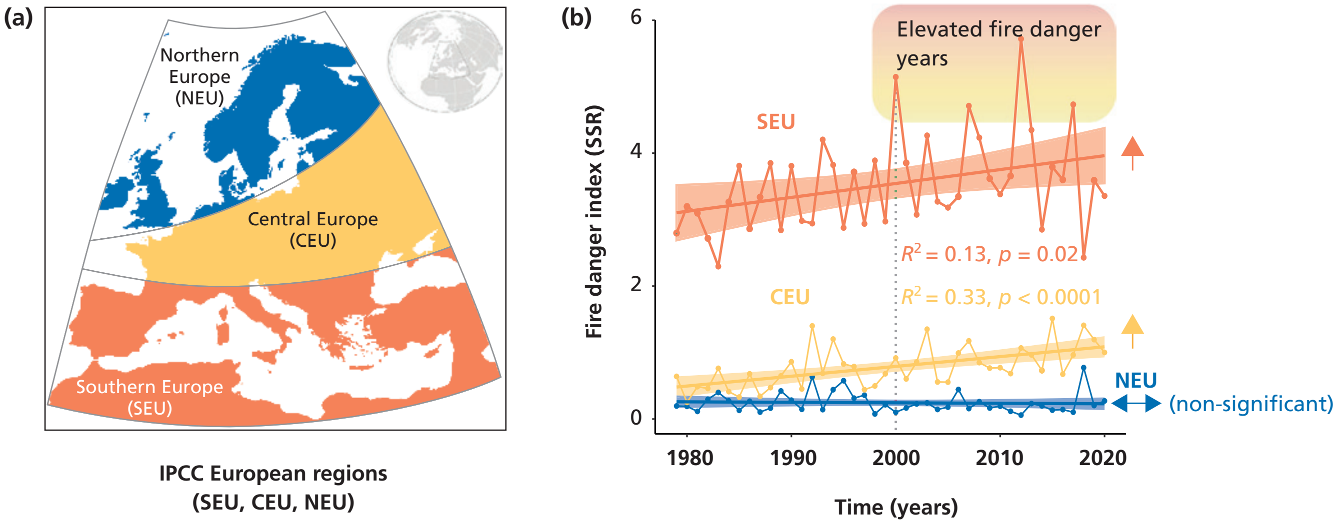


Figure 3 Observed and projected fire weather and risk trends. (a) IPCC regions in Europe. (b) Seasonal severity rating (SSR) trends (1980–2019), showing increasing fire severity in Southern and Central Europe. Source: Carnicer et al. (2022). Abbreviations: SEU, Southern Europe; CEU, Central Europe; NEU, Northern Europe.

[1] The vapour pressure deficit describes the drying capacity of the air, and its exponential rise is one of the most consequential impacts of climate change on terrestrial ecosystems (Novick *et al.*, 2024).

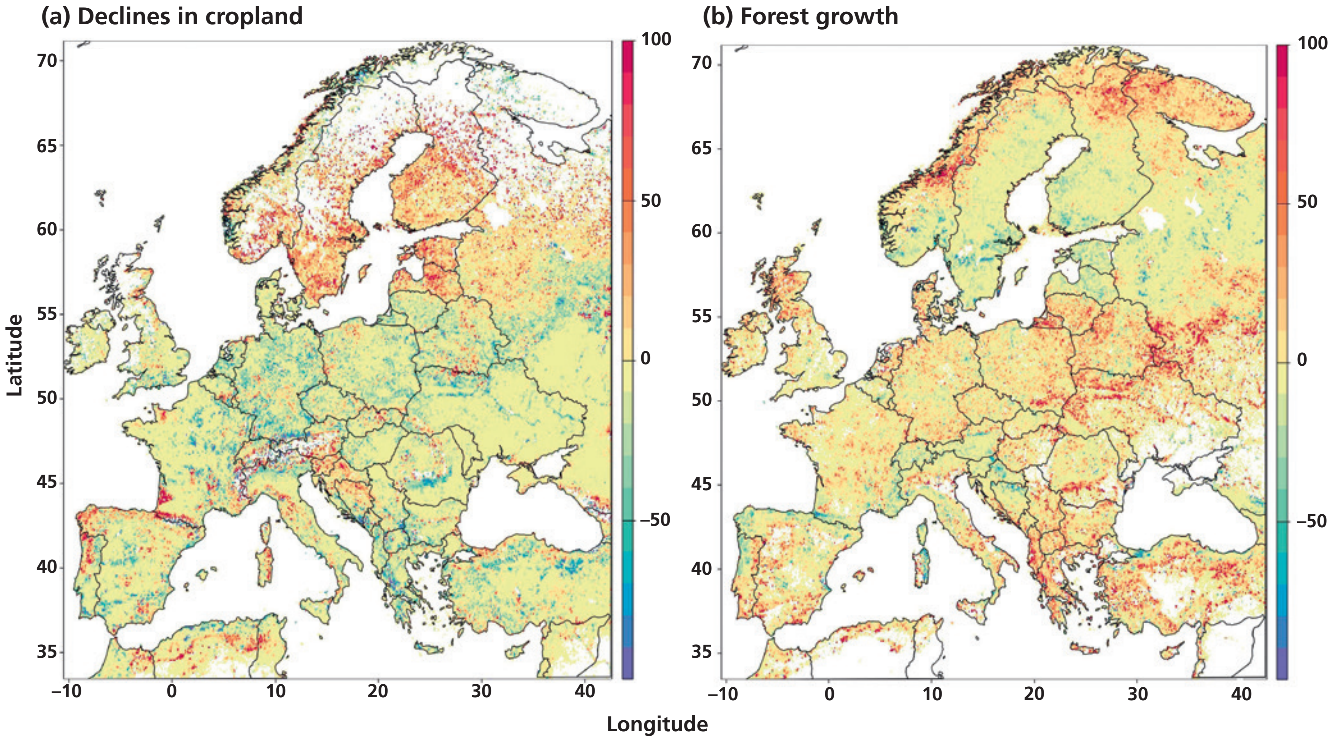


Figure 4 Percentage variation in land-use categories, 1992–2022. (a) Declines in cropland in Central Europe, Spain, Greece, and the Balkans. (b) Forest growth in Eastern Europe, Greece, and the Balkans. Source: adapted from ESA-CCI-LC data (B. Arca, unpublished data).

of the European Common Agricultural Policy since the 1990s have led to agricultural deintensification in marginal areas and, subsequently, forest expansion (Jepsen *et al*., 2015). While forest and shrubland cover increased and grassland area decreased, these trends also led to the homogenisation of landscapes and heightened fire risk through greater fuel continuity (MacDonald *et al*., 2000; Ascoli *et al*., 2021).

Studies reveal widespread land-use transformations across Europe. Kuemmerle *et al*. (2016) used CORINE and MODIS data to report declines in cropland and forest expansion, particularly in Eastern and Southern Europe. Similarly, ESA-CCI-LC data from 1992 to 2022 highlight significant reductions in cropland across Central Europe, Spain, Greece, and the Balkans, accompanied by forest growth in Eastern Europe and the Balkans (Figure 4). These processes also have mixed implications for biodiversity and ecosystem services, but in Southern Europe they are predominantly negative (Quintas-Soriano *et al*., 2022).

In Eastern and Central Europe, land abandonment has often led to unmanaged forest regrowth, with many areas dominated by coniferous plantations. These forests are particularly fire prone because of their high flammability (Blumröder and Ibisch, 2023). Conifers such as pines produce needle litter and resin-rich cones that are highly combustible (Shafisadeh *et al*., 1977; Ormeño *et al*., 2020). Poor forest management and regulatory constraints have further exacerbated fuel accumulation, even in temperate regions historically less affected by wildfires (Maringer *et al*., 2016).

Future projections indicate continued vulnerability in fire-prone regions such as Spain, Portugal, southern France, Italy, and Greece, where changing land-use patterns compound existing challenges (Pawlewicz and Pawlewicz, 2023). Despite all endogenous and exogenous force supporting forest expansion in the 20th century, Oliveira *et al*. (2017) argue that wildfire governance deficits may have been responsible for arresting forest transition and resulted in a loss of afforestation area since the 1990s.

Hydrological and climatic interactions in fire risk

Ecosystem productivity is closely tied to water availability, and greater biomass enhances soil water retention, which is crucial for mitigating fire risk (Lal, 2020). Forests and wetlands play a vital role in buffering temperature extremes, stabilising hydrological cycles, and reducing high levels of vapour pressure deficit, which drive fire risk (Miralles *et al*., 2019; Gohr *et al*., 2021).

In regions outside the Mediterranean, where there are no or only short dry seasons, dense uneven-aged forests with diverse understorey vegetation provide a cooler, more humid microclimate and reduce the flammability of combustibles (Pickering *et al*., 2021). In contrast, even-aged plantations and logged areas lack these buffering properties, leading to drier fuels and prolonged fire seasons (Blumröder *et al*., 2021; Brown *et al*., 2024). Soil moisture and temperature dynamics further increase the risk of fire, as drier soils are less resistant to heat and drought (Greiser *et al*., 2024).

The effects of forest management on fuel moisture often surpass those of climate warming (Brown *et al*., 2024). In some cases, logging and thinning, while intended to reduce fire risk, can inadvertently increase fire risk by altering structural complexity, desiccating fuels, and changing energy flows (Millikin *et al*., 2023). Promoting mixed-species forests with diverse age structures is therefore often seen as essential for mitigating these vulnerabilities (Ewald *et al*., 2023).

Severe wildfires can initiate feedback loops that may lead to ecosystem degradation, increased fire frequency, and shifts in vegetation composition (Landesmann *et al*., 2020). Recurrent burning may slow recovery, exacerbate erosion, and diminish water retention. Post-fire salvage logging may compound these issues by compacting soils, increasing runoff, and degrading the soil microbiome (Marcolin *et al*., 2019; Prats *et al*., 2021).

Summary: why are wildfires changing?

Wildfires are intensifying. Historically integral to many ecosystems, fire regimes are shifting globally and in Europe, with high-intensity fires rising as low-intensity fires decline. Drivers include warming, altered precipitation, inappropriate forest management, and farming decline. These changes heighten fire risk, challenge ecosystem resilience, and demand integrated management to address cascading social–ecological impacts.

5 Wildfires and carbon

Wildfires release greenhouse gases but may have minimal long-term impacts on carbon balances if vegetation recovers (Mack *et al*., 2021; Frelich *et al*., 2024). However, peatland fires typically have more severe impacts on carbon balances. Increased drought and severe fire weather are expected to increase burn rates and carbon losses in peatlands, potentially shifting them from carbon sinks to net sources by 2100, undermining global climate goals (Wilkinson *et al*., 2023) (see Figure 5 and further below). Forests and other ecosystems can store significant carbon when fire frequency and intensity remain moderate, with recalcitrant pyrogenic carbon from fires potentially buffering carbon dioxide (CO_2) emissions (Santin and Doerr, 2016; Jones *et al*., 2019), although the scale of this effect remains uncertain.

Forests as carbon reservoirs

Forests are critical carbon sinks, storing approximately 861 gigatonnes of carbon globally, with 44% soil organic carbon, 42% live biomass, and smaller portions of deadwood and litter (Pan *et al*., 2011, 2024). While tropical forests store the majority of the carbon in aboveground biomass, boreal forests hold most of the carbon in their soils, highlighting biome-specific carbon dynamics. Wildfires, especially intense fires, release large amounts of CO_2, methane (CH_4), and nitrous oxide (N_2O), directly impacting the global carbon cycle by reducing the capacity of forests to sequester carbon (Körner, 2003).

Severe fires convert soil carbon and nitrogen to greenhouse gases, altering the dynamics of soil organic carbon for years. Post-fire areas initially act as carbon sources, transitioning to carbon sinks as vegetation recovers. Recovery times vary, with estimates ranging from 2 to 14 years (Dore *et al*., 2008). Additionally, fires transform carbon into more stable forms, such as charcoal, which resist decomposition and contribute to long-term soil carbon storage (Pellegrini *et al*., 2022).

Fire behaviour influences carbon emissions, with ground, surface, and crown fires producing varying impacts. Ground fires, which burn organic material below the surface, can destroy root systems and deplete soil fauna, whereas surface fires primarily affect aboveground vegetation, allowing root-based regrowth. Crown fires, which reach treetops, emit the most carbon. Mixed crown and surface fires have the most severe carbon impacts because of their ability to reach the entire forest structure (Ribeiro-Kumara *et al*., 2022).

Long-term impacts and post-fire management

The long-term effects of wildfires on forest carbon balances are complex. Factors such as fire frequency, intensity, post-fire management – such as salvage logging, soil ploughing – and succession with deciduous trees may affect ecosystem recovery and carbon storage. Some studies even suggest that carbon storage can increase after fires, if a fire in a conifer-dominated forest results in a transition to a less fire-prone landscape dominated by deciduous trees (Mack *et al*., 2021). Poorly managed post-fire interventions can hinder regeneration and reduce carbon sequestration capacity (Blumröder *et al*., 2022). Shifts in vegetation composition, such as transitions to early successional or non-forest species, may, on the other hand, increase surface albedo (the fraction of sunlight that is reflected) but diminish overall carbon storage potential (Duveiller *et al*., 2018).

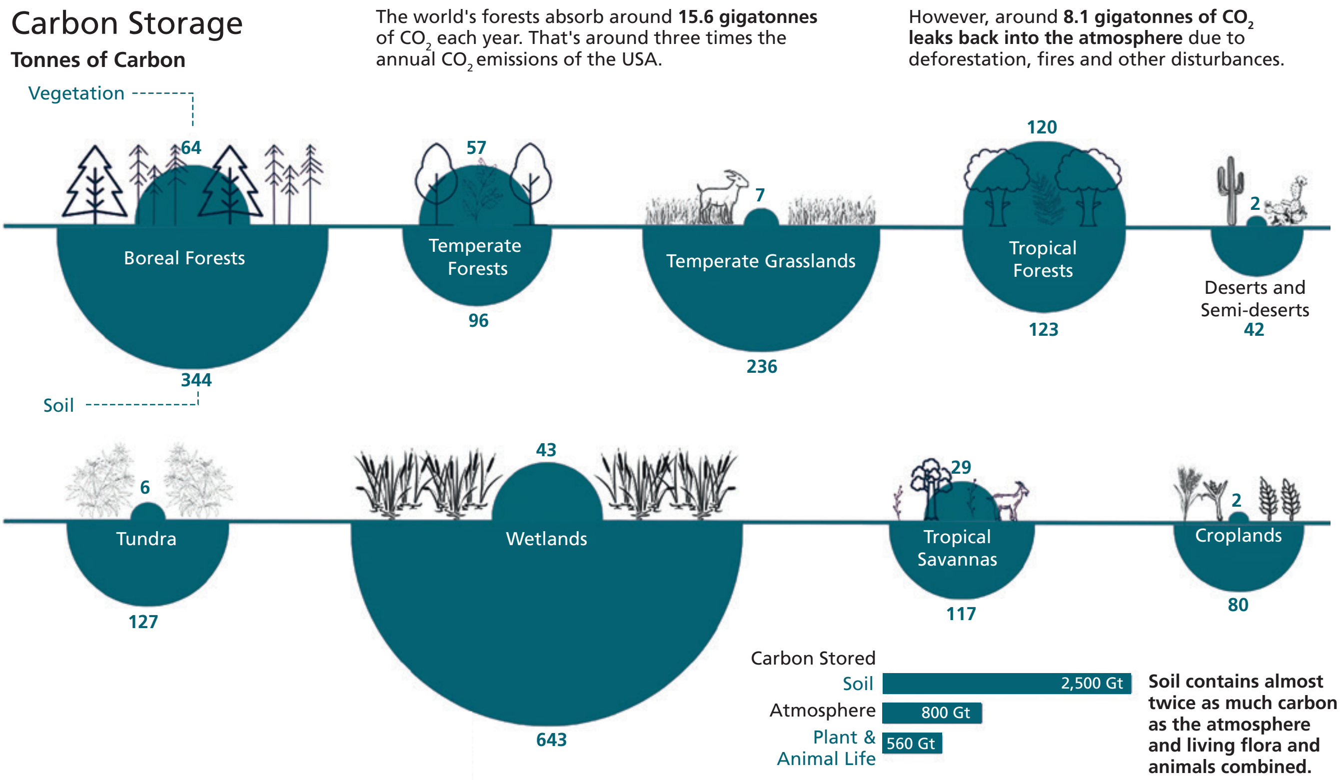


Figure 5 Distribution of carbon below and above ground in different types of ecosystem. Source: IPCC, NASA, https://www.visualcapitalist.com/sp/visualizing-carbon-storage-in-earths-ecosystems/, Miranda Smith.

Grasslands and carbon storage

Grasslands cover approximately 17.4% of the EU's land area, with most carbon stored in their soils (European Environment Agency, 2020; Schils *et al.*, 2022). Fires and grazing regulate carbon and nitrogen cycles in grassland ecosystems. While fires release CO_2 in the short term, they can stimulate regrowth and enhance carbon sequestration over time. Wildfire and post-fire recovery processes may result in more carbon being stored in the long term than initially released (Bowring *et al.*, 2022). Charcoal formation and other soil changes can stabilise soil organic matter, contributing to carbon retention and promoting the stabilisation of new organic carbon inputs (Leal *et al.*, 2019).

Integrating firewise management practices, such as controlled burning and grazing, can increase the role of grasslands as carbon sinks. These practices maintain ecosystem stability and resilience, helping offset carbon emissions. The inclusion of post-fire recovery processes in carbon cycle models is essential for accurately assessing the long-term impacts of wildfires on grassland ecosystems (Pellegrini *et al.*, 2022).

Peatlands: critical carbon reservoirs under threat

Peatlands, the most carbon-dense ecosystems on Earth, store approximately two times more carbon per hectare than boreal forests (Figure 5). Peatlands accumulate carbon over millennia through waterlogged conditions that slow plant decay. However, when peat burns, it releases ancient carbon stores, making these ecosystems a significant concern for climate feedback loops (Witze, 2020).

Peatlands are particularly vulnerable, as they dry out because of warming climates. Lowered water tables from drainage (often for agriculture or forestry) exacerbate this risk, increasing peat susceptibility to combustion. The Arctic wildfires of 2019 and 2020 highlighted the growing vulnerability of these carbon-rich systems, which burned millions of hectares and released significant carbon emissions (Hugelius *et al.*, 2020). Unlike forests, peatlands recover slowly after fires, with carbon losses often becoming permanent.

Rewetting and restoring degraded peatlands are crucial strategies for mitigating carbon loss. Restoration increases their resilience to wildfires and enhances their carbon sequestration capacity. Fewer human-impacted peatlands may continue to act as net carbon sinks despite fire events, emphasising the importance of minimising anthropogenic disturbances (Gray *et al.*, 2021). Restoring peatlands offers dual benefits for biodiversity conservation and climate change mitigation (Wilkinson *et al.*, 2023).

Summary: wildfires and carbon

Wildfires significantly affect carbon dynamics, releasing greenhouse gases, particularly in forests and peatlands. Forests can recover carbon storage post-fire, whereas peatlands, the most carbon-dense ecosystems, often face permanent carbon loss when burned. More research is needed to fully understand fire-related changes in forest carbon dynamics and to develop effective mitigation strategies that increase ecosystem recovery while balancing carbon emissions.

6 Wildfires and biodiversity

The effects of wildfires on biodiversity depend both on fire regime characteristics and on biotic factors, including habitat traits and species-specific responses (Pyke *et al.*, 2010; Valkó and Deák, 2021). The key fire regime variables include frequency, severity, intensity, timing, and extent. Biotic factors include species fire tolerance, regeneration capacity, interspecific interactions, and dispersal ability. Fire impacts are highly context dependent: immediate effects, such as organ injuries or mortality, are typically detrimental, but secondary effects can improve habitat conditions for recolonisation and reestablishment. As a result, fire impacts vary at the individual, population, and ecosystem levels.

Wildfires: positive and negative impacts on biodiversity

The 'pyrodiversity hypothesis' posits that variability in fire intensity and frequency fosters landscape-level biodiversity (Bond *et al.*, 2005; Steel *et al.*, 2024). Evidence supports this in fire-adapted ecosystems, where moderate fire regimes benefit species such as birds and pollinators (Kelly and Brotons, 2017). However, a meta-analysis by Jones and Tingley (2022) reported mixed results, suggesting that the hypothesis applies primarily to ecosystems with anthropogenic fire regimes. Wildfires are more likely to support biodiversity in fire-adapted systems, where moderate fires may increase habitat heterogeneity (Figure 6).

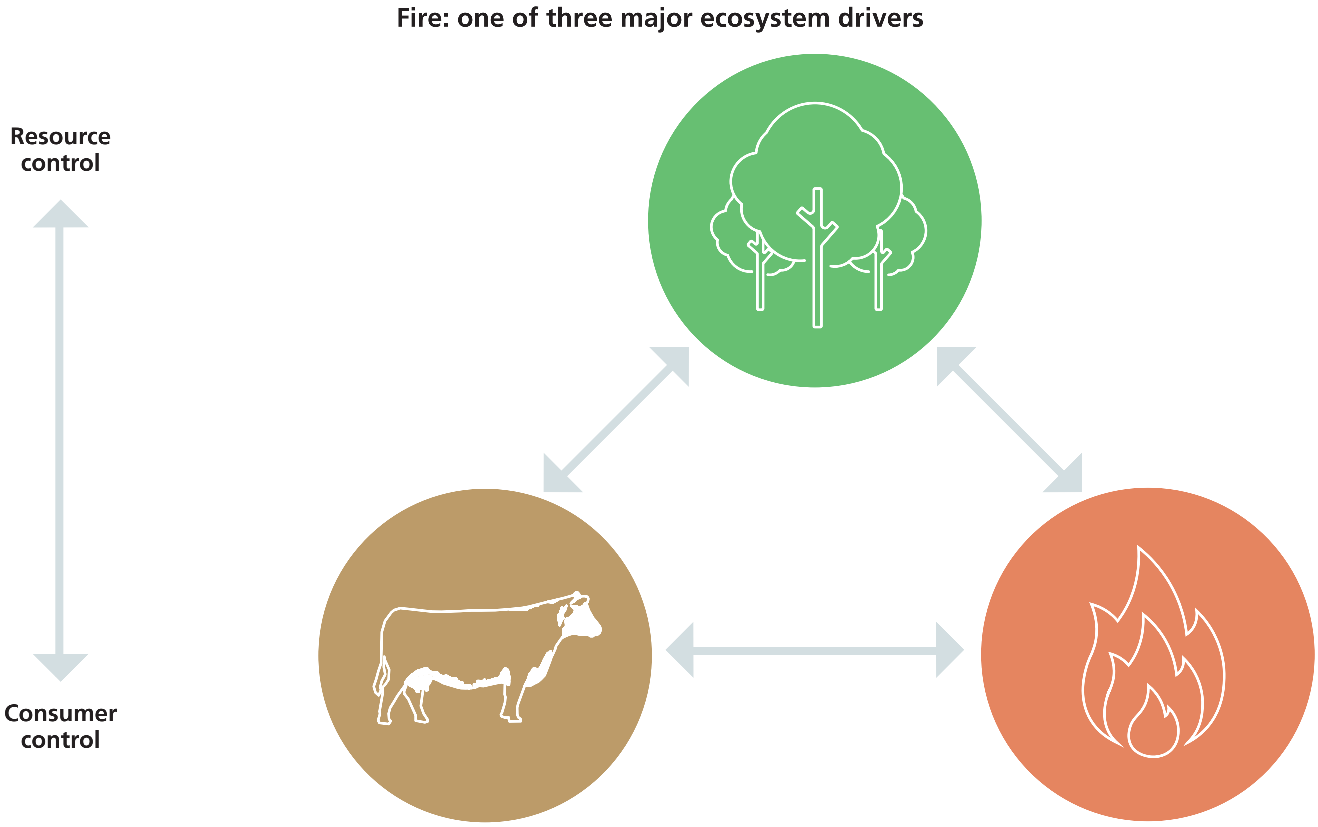


Figure 6 Fire, herbivory, and competition among plants are the three major factors controlling plant biomass globally. In fire-adapted 'blacker' worlds, where fire is a main biomass consumer, fire tends to benefit biodiversity, whereas in 'green' and 'brown' worlds, fire effects are more likely to be negative. Excessive fire intensity, similar to overgrazing, can harm biodiversity across all systems. Adapted from Bowman et al. (2016) and based on Bond et al. (2005).

Boreal forests: fire impacts and species adaptations

In boreal forests, the effects of fire on biodiversity vary widely depending on the species and fire regime. Low-intensity fires often benefit biodiversity by creating habitats for species that thrive in post-fire conditions, such as certain beetles (see Muona and Rutanen, 1994), fungi (see Tikkanen *et al*., 2006; Ramberg *et al*., 2023), and vascular plants, such as some *Geranium* species, which rely on heat for seed germination. Conversely, intense fires under extreme drought can harm soil biodiversity through excessive smouldering in the humus layer (see Malmström, 2010; Pérez-Izquierdo *et al*., 2023).

In Fennoscandia, *Pinus sylvestris* (Scots pine) has greater fire resistance than *Picea abies* (Norway spruce) because of its thicker bark and tolerance for dry soils (Spalt and Reifsnyder, 1962). Deciduous species such as birch and aspen, while poorly fire resistant, regenerate rapidly by sprouting or seed dispersal. In boreal forests, mixed-species forests often reduce fire risk, support biodiversity, and improve ecosystem resilience after fires (e.g. Jonsson *et al.*, 2019; Johnstone *et al.*, 2020; Mack *et al.*, 2021; Jaffe *et al.*, 2023).

Grasslands: fire as a disturbance and conservation tool

Globally, fire is a vital management tool in fire-prone ecosystems, such as savannas, grasslands, and shrublands in the Americas, Australia, and South Africa. In Europe, the potential for fire as a conservation tool remains underexplored. Grasslands in Europe, including seminatural grasslands, rely on disturbances such as fires to sustain biodiversity and prevent woody encroachment (Halada *et al*., 2011). Fire has played a pivotal role in shaping grassland ecosystems since the Neolithic period (Feurdean *et al*., 2020). However, traditional fire practices have declined because of socio-economic shifts (Valkó *et al*., 2014).

Low-intensity fires during dormant seasons benefit grassland specialists by reducing dominant species, creating open landscapes, and promoting thermophilic taxa such as early spring geophytes (see Valkó *et al*., 2014). However, high-intensity or frequent fires during growth or breeding seasons can harm plants and animals in vulnerable life stages. Prescribed burns offer a valuable tool for managing abandoned grasslands, controlling invasive species, and supporting threatened taxa, but further research is needed to optimise their application in Europe (Valkó and Deák, 2021).

Summary: wildfires and biodiversity

Globally, fire is a vital management tool for biodiversity conservation in fire-prone ecosystems, such as savannas, grasslands, and shrublands in the Americas, Australia, and South Africa. In Europe, the potential for fire as a conservation tool remains underexplored. Prescribed burning can play a key role in restoring grasslands, controlling invasive species, and enhancing habitats for fire-adapted species. Managing production forests to include diverse species is essential for enhancing post-fire recovery and maintaining biodiversity.

7 Wildfires in Europe: regional overview of trends

Europe is a diverse continent where the drivers and conditions influencing wildfire dynamics differ significantly across regions. Future projections indicate a near-doubling probability of very large fires in most regions by 2100, with the Mediterranean region having the highest risk (Figure 7). This chapter outlines regional characteristics that must be considered when developing strategies to manage wildfires effectively. We selected three contrasting regions for detailed analysis: Mediterranean Europe, continental and alpine Europe, and Northern Europe (Figure 7). These regions well exemplify the main fire regime characteristics and trends in Europe. However, it should be noted that not all parts of Europe are covered by these regions.

Mediterranean Europe

The Mediterranean region is particularly susceptible to wildfires because of its unique climate and social–ecological dynamics. The long, hot, and dry summers, coupled with short, mild winters, create ideal conditions for vegetation growth, fire ignition and spread. During the summer, specific synoptic weather patterns, including intrusions of Saharan air masses, exacerbate the situation and favour the occurrence of severe fire outbursts.

Historically, fires have been an integral component of Mediterranean ecosystems since at least the Miocene, with their influence intensifying during the Pliocene epoch as Mediterranean seasonality developed (Rundel *et al*., 2016). Fires have shaped the region's vegetation and ecosystems, contributing to its high biodiversity.

Since the middle of the 20th century, rural depopulation and agricultural land abandonment have profoundly altered Mediterranean landscapes (Newsham and Rowe, 2023). Vast areas of cropland have been replaced by shrubland or forest, increasing fuel loads and continuity at the landscape scale (San-Miguel-Ayanz *et al*., 2012; Oliveira *et al*., 2017).

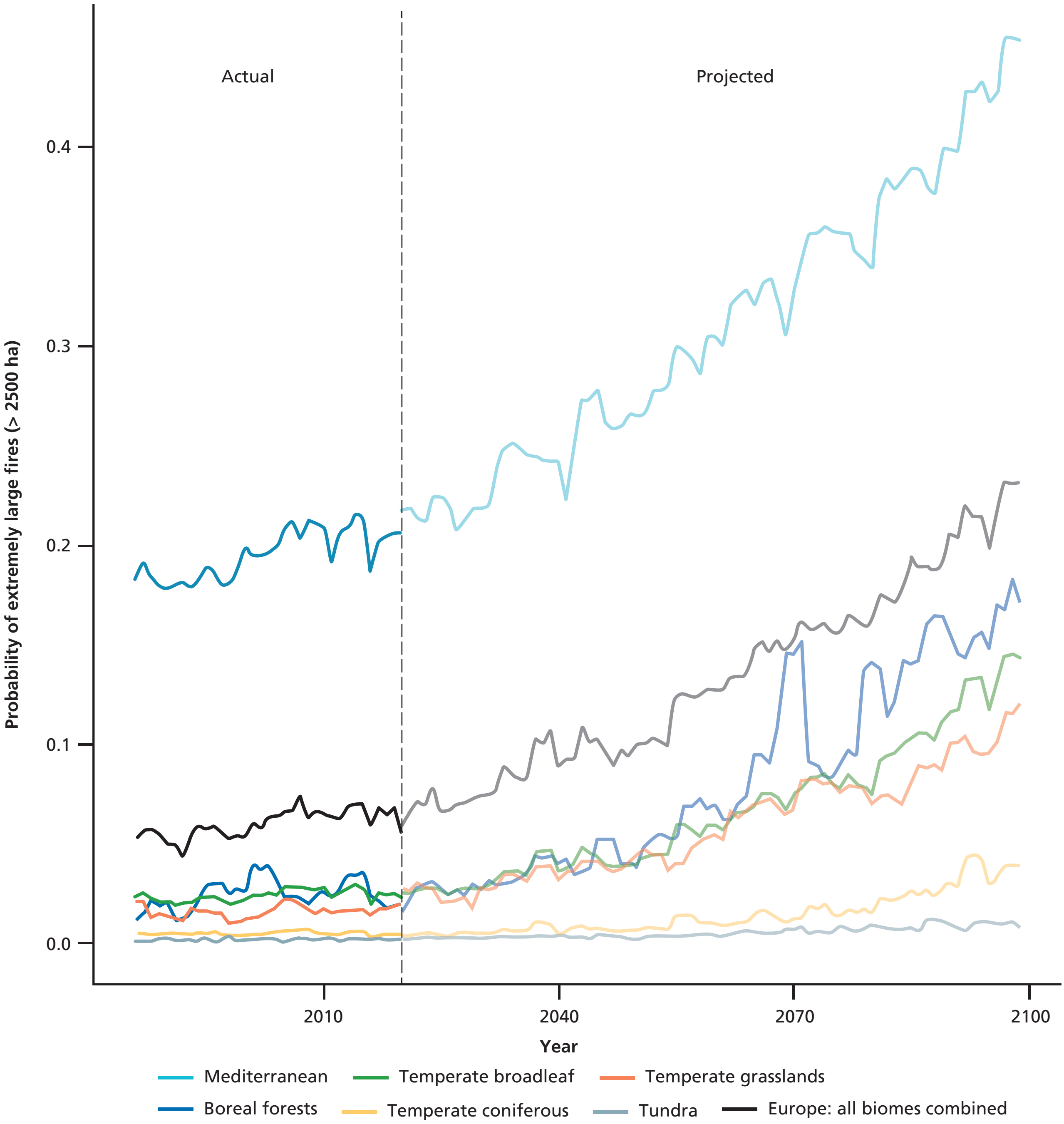


Figure 7 Probability of large fires (larger than 2500 hectares) in different European biomes from 1990 to 2100. Source: Grünig et al. (2023).

Recent climatic trends, including warming and drying, have intensified droughts and heatwaves (Vogel *et al.*, 2021; Bednar-Friedl *et al.*, 2022), contributing to more severe fire seasons (Ruffault *et al.*, 2020). These changes have shifted the region's fire regime from being fuel-limited to weather-driven (Pausas and Fernández-Muñoz, 2012) (see also Table 1).

Despite these challenges, in recent decades both the number of fires and the total area burned have decreased, which is attributed to reduced fire use in rural management and improved suppression capacity (Turco *et al.*, 2016; Rodrigues *et al.*, 2020) (Figure 8). However, burned areas are now concentrated in fewer but larger fires, including extreme high-intensity events (Royé *et al.*, 2020), which poses significant environmental and civil protection challenges.

While the decline in the burned area was notable but variable, peak years such as 1985 and 2017 demonstrated the region's vulnerability during severe fire seasons. In the 1980s and 1990s, Spain dominated the burned area statistics, but in the 21st century, Portugal took this position, with notable exceptions such as Greece's devastating fires in 2007.

Table 1 Summary of regional differences and similarities in some dominant regions of Europe in the distribution and drivers of wildfires (for details, see the text)

	Mediterranean Europe	Continental and alpine Europe	Northern Europe
Fire size distribution	• Most fires are small (up to 10 ha) • Fires larger than 100 hectares account for more than 80% of the total burned area	• Most fires are small (up to 10 ha) • Fires larger than 100 hectares account for 80% of the total burned area	• More than 80% of fires are small (up to 0.5 hectares) • Fires larger than 100 hectares account for 60% of the total burned area
Fire season conditions	• Peak fire season from July to September, but official fire season from May to October • Average number of high-danger days ranging between 50 and 60	• Fire season typically from May to September • Average number of high-danger days ranges between 20 and 35	• Fire season typically from May to September • Average number of high-danger days ranges between 20 and 35
Prevailing fire-prone vegetation types	• Sclerophyllous vegetation (>25%) • Deciduous forests (20%) • Coniferous forests (15%) • Agroforestry areas (10%) • Pastures (>15%)	• Dry conifer forests (50% in eastern alps, <30% western alps) • Conifer plantations • Temperate broadleaf forests with porous litter (e.g. chestnut and beech in western alps)	• Conifer forests (60%) • Peatlands • Heathlands
Societal conditions and major trends affecting the fire regimes	• Rural depopulation • Abandonment of agricultural land • Afforestation of farmland • Population ageing • Increase of absentee landowners • Urban sprawl, suburbanisation • Loss of cultural practices • Reduction and simplification of woodland uses	• Rural depopulation, • Abandonment of agricultural land • Suburbanisation, urban sprawl	• Rural depopulation, • Increase of absentee landowners

In Portugal, high-intensity fires have risen sharply (Parente and Pereira, 2016), and Greece has seen similarly notable increases in wildfire intensity, extent, and frequency, with projections suggesting up to 40 additional high-fire danger days annually in southern and eastern regions by the late 21st century (Rovithakis *et al*., 2022).

Continental and alpine Europe

Central and alpine Europe exhibit highly altered fire regimes. Fire has been integral to temperate and alpine ecosystems, shaping landscapes since the last glaciation (Tinner *et al*., 2005; Robin and Nelle, 2014). During the Bronze Age, human use of fire expanded agro-pastoral landscapes, further altering fire regimes (Feurdean *et al*., 2013; Morales-Molino *et al*., 2015).

In the plains of Central Europe, increased landscape fragmentation and less flammable vegetation have made fire a marginal disturbance. Fire suppression strategies have further reduced the occurrence of large fires, particularly in productive forests and near settlements (Müller *et al*., 2020). In contrast, mountainous regions face significant challenges due to population decline and the abandonment of agro-silvopastoral activities. These trends have increased landscape flammability and, combined with extreme fire weather events, have led to large fires with substantial impacts. In some alpine areas, fires now affect vegetation historically less exposed to fire, such as beech forests (Maringer *et al*., 2016) (see also Table 1).

Continental inner valleys are particularly vulnerable owing to their dry climates, flammable vegetation, and steep slopes. Lightning ignitions are more common in these areas, contributing to extensive fires that threaten ecosystem services such as protection against rockfalls and avalanches (Moser *et al*., 2010; Valese *et al*., 2014).

Northern Europe

Northern Europe, including the boreal regions of Fennoscandia, is characterised by vast conifer-dominated forests. Although these regions are similar to boreal North America and Asia, the annual area affected by high-intensity wildfires in Northern Europe remains relatively small. Fire intensity and severity are also typically lower than those elsewhere in the boreal zone (Wooster and Zhang, 2004; Rogers *et al*., 2015) (see also Table 1).

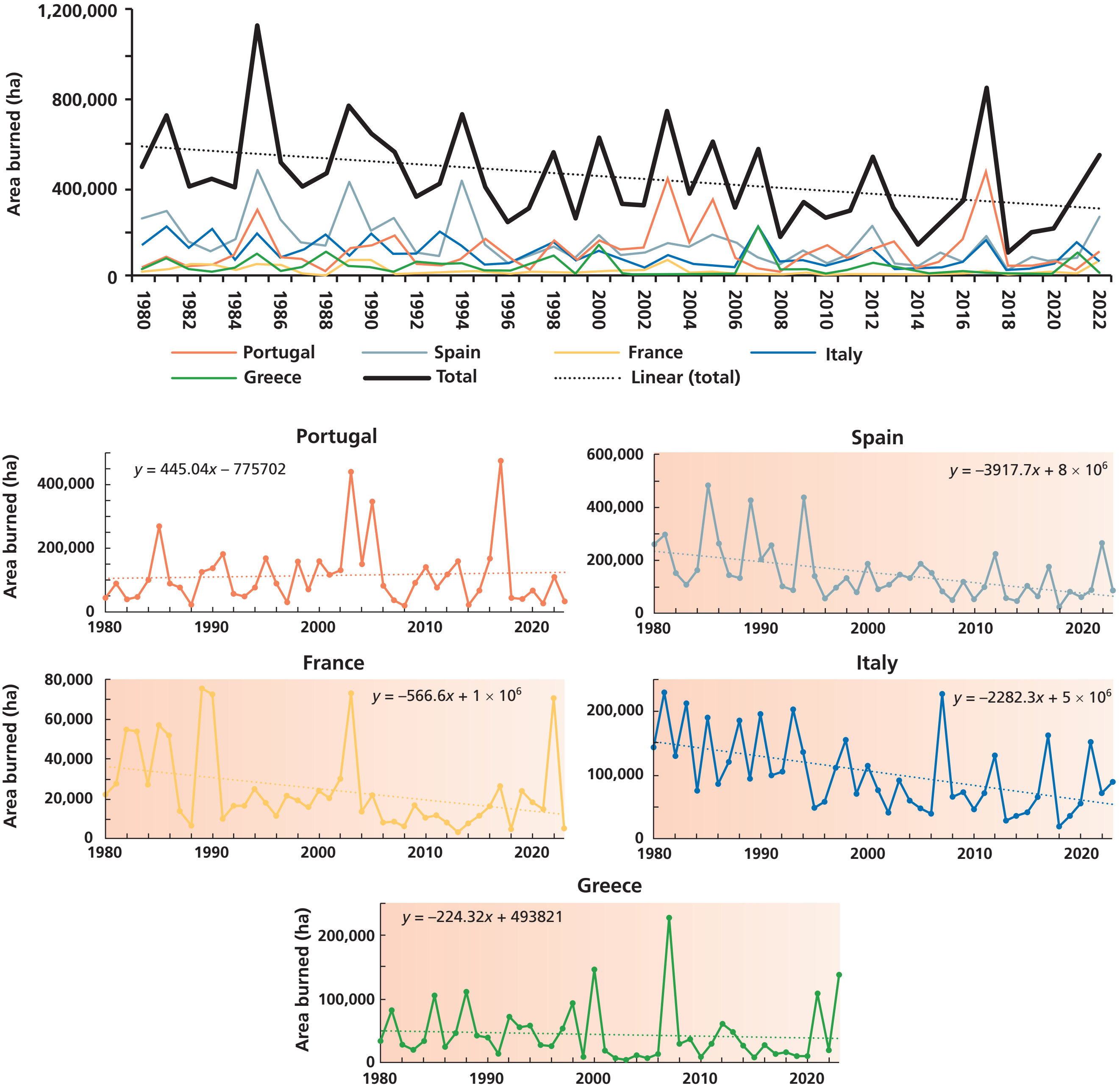


Figure 8 Areas burned in different parts of Mediterranean Europe. The area burned is decreasing but there are more large, high-intensity fires. Data source: San-Miguel-Ayanz et al. (2023).

Historically, Fennoscandia has experienced frequent fires due to cultural practices such as slash-and-burn agriculture and the use of fires to improve grazing lands. These practices maintained a balanced fire regime until the late 19th century, when industrial forestry and changes in land tenure reduced fire frequency (Niklasson and Granström, 2000; Wallenius, 2011).

Coastal heathlands, maintained for approximately 5,000 years through regular burning, exemplify how traditional practices shaped fire-safe landscapes (Kaland, 1986). However, the abandonment of these practices has led to fire-prone vegetation dominated by old heather deciduous species and young conifers (Gjedrem and Metallinou, 2023).

Today, the area burned annually in Fennoscandia is lower than historical levels, but the number of wildfires remains high. Owing to the dense network of forestry roads, initial fire responses are swift, and most fires are controlled at an early stage. For example, the average forest fire size in Finland in recent decades was only 0.4 hectares (Lindberg *et al.*, 2020).

However, severe fire events, such as those during the 2018 heatwave, revealed the region's vulnerability under extreme weather conditions. These events emphasise the need for strategies to address the increasing risk of large fires.

Summary: wildfires in Europe – regional overview of trends

Wildfires in Europe are increasingly influenced by regional dynamics, with the Mediterranean experiencing the highest risk due to hot, dry climates and land abandonment, leading to large, high-intensity fires. Continental and alpine regions are experiencing increasing wildfire threats from landscape changes and extreme weather, necessitating tailored strategies for diverse conditions. Northern Europe benefits from effective fire suppression but faces rising risk due to climate change.

8 Wildfires in the wildland–urban interface (WUI) in Europe

The WUI encompasses areas where human development meets wild land, including settlements, infrastructure, and cultivated land (Bénichou *et al*., 2021). These zones face various challenges such as wildfire hazards; habitat loss; landscape fragmentation; water, air, and soil pollution; and spread of zoonotic disease. The encroachment of residential areas and infrastructure into landscapes with high fuel density has increased the degree of fire risk to people and property (Figure 9). However, detailed analyses of the global extent and impacts of the WUI remain limited (Schug *et al*., 2023; Tang *et al*., 2024).

WUI expansion and fire risk

Bar-Massada *et al*. (2023) mapped Europe's WUI, revealing that it covers approximately 7% of the continent (363,000 km^2) (Figure 10).

In Europe, WUI expansion is driven by suburbanisation, urban sprawl, and private vehicle-dominant use. 'Pull factors', such as proximity to nature, and 'push factors', such as high housing costs in urban centres, accelerate this trend. Suburban abandoned agropastoral lands often transition into shrubland and forestland, creating vegetation corridors that facilitate fire spread (see Chapter 4). These dynamics increase wildfire risk, particularly in Mediterranean regions where summer pyro-meteorological conditions are severe.

Human activities in the WUI contribute to a high ignition frequency, compounding these risks. Efforts to assess WUI wildfire exposure are emerging. Ager *et al*. (2021) reported that the impacts of some wildfire events, such as the 2018 Paradise fire in California, are predictable on the basis of building-fuel density gradients, with maximum wildfire exposure at building densities of 1,400–1,500 structures per square kilometre.

However, although such research calculates the worst-case building density, the lowest safe limit has yet to be estimated, which is probably affected by a landscape's relative location, land use, and a community's level of awareness and preparedness for wildfires.

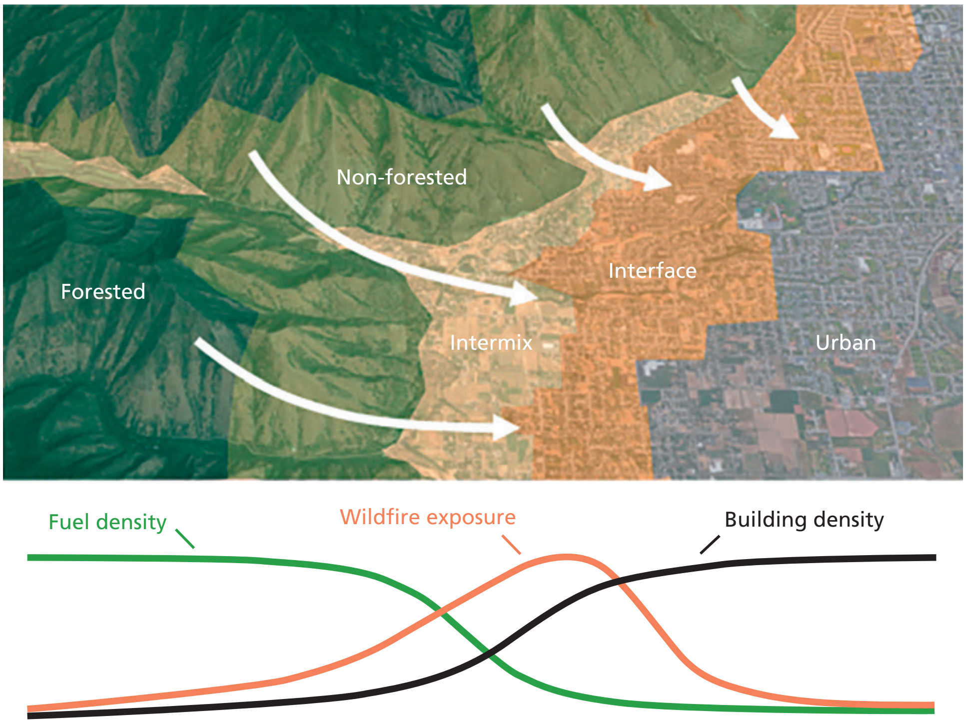


Figure 9 Simplified relationship between fuel density, wildfire exposure, and building density gradients in the WUI (after Ager et al., 2021).

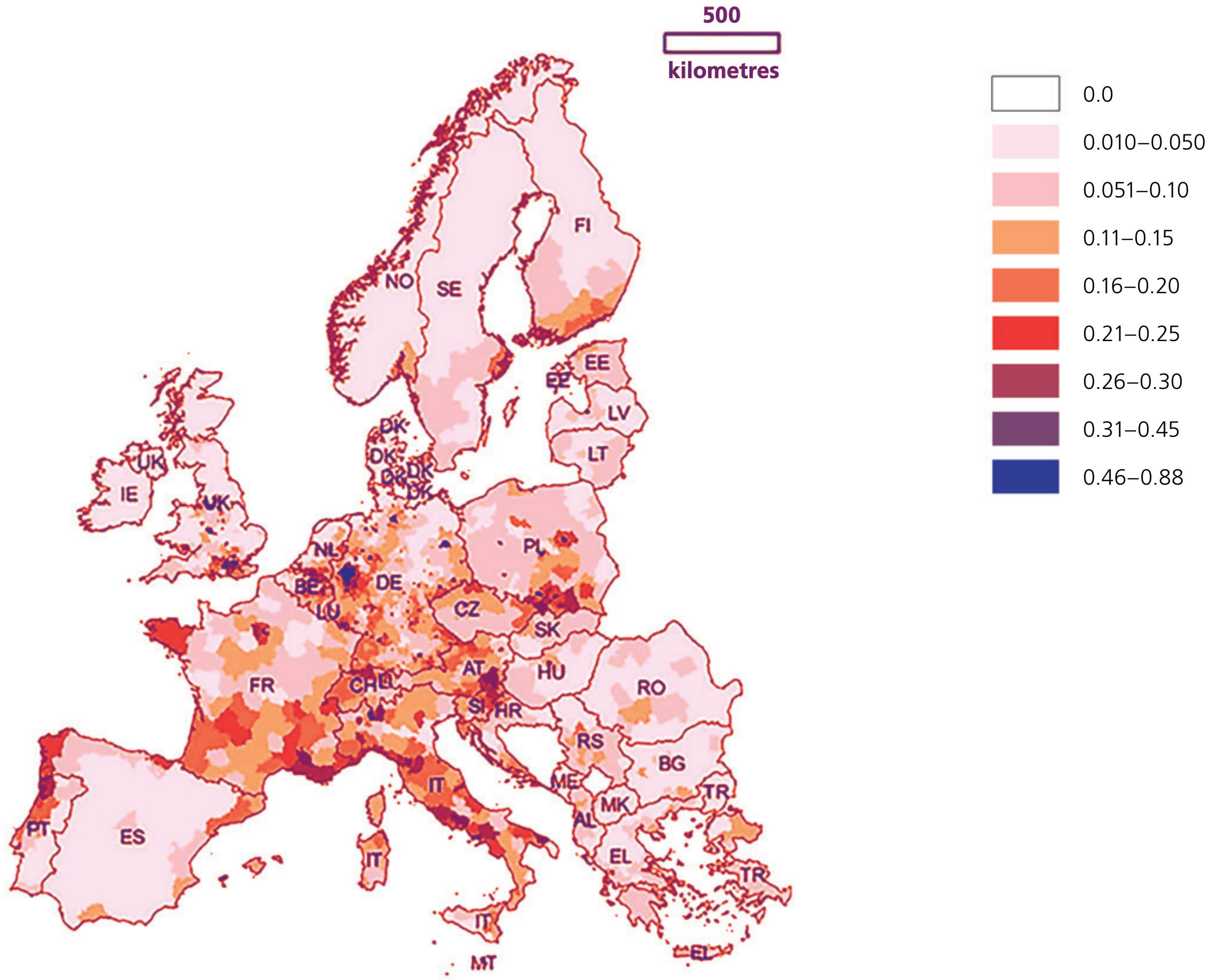


Figure 10 Percentage of total WUI per European region (NUTS-3), from Bar-Massada et al. (2023).

The 2025 Los Angeles wildfires: implications for Europe

As has become dramatically apparent recently, the Los Angeles area faces a growing wildfire threat due to climate change, land-use change, and extreme weather conditions. Although the fire-prone conditions in California may be rather specific, the events that played out in January 2025 can provide relevant lessons and warnings for urban areas in Europe also. The fires occurred in high-risk zones where regulation requires vegetation management, yet the fire severity was exacerbated by prolonged drought, and seasonal strong and dry Santa Ana winds, which created extremely fire-prone conditions. Studies show that human-induced climate change has significantly increased the risk of fire weather in the area, with extreme conditions now 35% more likely and fire seasons extending by more than 3 weeks (Barnes *et al.*, 2025). Vulnerable communities, particularly homeless and marginalised groups, faced disproportionate impacts, while infrastructure weaknesses exposed critical vulnerabilities.

Proposed policy responses and urban planning strategies

To build fire-resilient cities, experts in the region advocate strategic urban planning, including fire buffer zones, fire-resistant materials, and reduction of flammable exotic vegetation. Inspired by Kobe's earthquake recovery and Texas' flood management, Los Angeles is considering relocation incentives and urban densification in safer areas rather than rebuilding in high-risk zones. European cities should similarly integrate fire risk reduction into urban and wider land-use planning by limiting development in fire-prone areas, strengthen emergency preparedness, invest in resilient infrastructure, and support collaborative firewise governance of the wider urban–rural area.

9 Wildfires and tourism

Tourism in the WUI is particularly vulnerable to wildfires, as peak tourism coincides with the fire season. Tourists often lack awareness of fire risk and evacuation routes at visited sites, as seen in recent wildfires in Madeira (2016), Maui (2023), Rhodes (2023), and Montblanc, Spain (2024). Fires threaten local economies, disrupt livelihoods, and endanger tourists and residents, emphasising the need for preparedness.

Improving preparedness and evacuation strategies

Evacuation is the primary strategy for reducing wildfire risk to tourists. Tourists who lack property attachment generally accept early evacuation, whereas locals may prefer alternatives such as sheltering-in-place (Strahan *et al*., 2018; Ronchi *et al*., 2024). For example, in Cadiz (2016), tourists were evacuated while locals sheltered in place. In Rhodes (2023), thousands were evacuated by land and sea.

Effective tourist evacuation plans must address individuals with reduced mobility and include multilingual early warnings. Although disruptive, evacuations can improve preparedness and risk awareness for future local events.

Cross-border cooperation and heritage protection

In transboundary tourist regions, collaboration between countries is essential but often insufficient. It is clear that harmonised fire risk assessment, preparedness measures, and communication strategies are often lacking. Efforts to protect natural and cultural heritage sites from wildfires are particularly urgent, and hazard modelling can guide fuel management to prevent fires from threatening heritage sites and settlements (Bachantourian *et al*., 2023; Menemenlis *et al*., 2023).

Figures 11 and 12 illustrate examples from Tuscany, Italy, where landscape management integrates tourism, agriculture, and forestry. These coordinated efforts reduce fire risk while enhancing regional appeal. Mapping pyro-boundaries and fuel clusters can further delineate high-risk areas, supporting reforestation and protective measures in post-fire zones (Palaiologou *et al*., 2022; Tzamtzis *et al*., 2023).

Summary: wildfires in the wildland–urban interface (WUI) in Europe

The wildland–urban interface (WUI) in Europe poses significant wildfire risk because of expanding settlements near high-fuel landscapes, driven by suburbanisation and land abandonment. Tourism amplifies vulnerability, with peak seasons coinciding with fires. Effective evacuation plans, cross-border cooperation, and integrated landscape management are essential for reducing risk while preserving natural and cultural heritage.

10 Wildfires and health

Wildfires have significant health impacts, ranging from immediate injuries to long-term chronic conditions (EASAC, 2019). These include excess mortality, respiratory and cardiovascular diseases, mental health problems, and post-traumatic disorders, particularly in more vulnerable populations. While the short-term health effects caused by flames, heat, and smoke have been extensively studied, interest in longer-term

Figure 11 Examples of forestry work at the landscape scale in Tuscany, Italy. Source: Project WUITIPS (Ronchi et al., 2024).

Figure 12 The Tuscan landscape mosaic harmonises land uses, reducing wildfire risk (Agnoletti and Santoro, 2018).

consequences, including those from smoke exposure and psychological distress, is increasing. Research on wildfire-related health impacts has been conducted predominantly in the USA, Canada, Australia, and mainland Europe, with limited evidence available from the UK (Pashley *et al*., 2023).

Short-term health impacts: flames, heat, and smoke

The immediate health effects of wildfires primarily include burns, injuries, and deaths caused by direct exposure to flames and radiant heat. Fire response teams and residents in wildfire areas are at the highest risk (Stokes *et al*., 2021). Short-term respiratory effects are particularly concerning because of the large amounts of particulate matter and toxic gases released into the air. Wildfire smoke contains carbon dioxide, carbon monoxide, and fine particulate matter, which can also contaminate soil, water, crops, and food resources (Finlay *et al*., 2012).

Particulate matter (PM) is a primary pollutant of concern in wildfire smoke. PM_{10} particles (particulate matter with diameters less than 10 micrometres) can affect the upper respiratory system, whereas $PM_{2.5}$ particles (less than 2.5 micrometres in diameter) penetrate deeper into the lungs, where they reach the bronchioles and alveoli. These fine particles are associated with worsened respiratory symptoms, including asthma exacerbation, bronchitis, and chronic obstructive pulmonary disease, resulting in increased emergency visits, hospitalisations, and outpatient visits during wildfire events (Finlay *et al*., 2012; Reid *et al*., 2016).

Studies have also highlighted the potential for increased respiratory infections during wildfire seasons, and elevated emergency visits for upper respiratory infections have been reported in some studies (Reid *et al*., 2016). Immediate exposure to wildfire smoke has also been linked to an increased incidence of all-cause mortality, further emphasising the severity of these short-term impacts.

Premature mortality linked to smoke exposure

Wildfire smoke is a major contributor to premature deaths, largely because of $PM_{2.5}$ exposure. A study in California estimated that wildfire-related $PM_{2.5}$ caused between 52,480 and 55,710 premature deaths from 2008 to 2018 (Connolly *et al*., 2024). Across the USA, wildfire smoke now accounts for 25%–50% of $PM_{2.5}$ emissions. While overall air quality has improved in recent decades, regions affected by wildfires, particularly the western and northwestern USA, have experienced worsening summer $PM_{2.5}$ levels due to increased fire activity (Connolly *et al*., 2024).

Wildfire smoke also contains carcinogenic compounds, such as polycyclic aromatic hydrocarbons and volatile organic compounds. These substances adhere to particulate matter and persist in the environment, posing long-term health risks, and even low-level exposure to such toxins remains a concern, particularly for vulnerable populations (Finlay *et al*., 2012).

Cardiovascular and neurological health impacts

The impact of wildfire smoke on cardiovascular health is complex and less well understood than its respiratory effects. Some studies report significant increases in hospital admissions for circulatory diseases, including a 21% increase during wildfire waves in the North Region of Brazil (Requia *et al*., 2021). However, evidence of a clear association between wildfire smoke exposure and cardiovascular morbidity and mortality remains unclear, with conflicting findings across studies (Reid *et al*., 2016; Gould *et al*., 2024).

Emerging evidence suggests that wildfire smoke and heat stress may affect brain health. Fine and ultrafine particulate matter in wildfire smoke can enter the brain through the olfactory system and bloodstream, bypassing the blood–brain barrier. Once in the brain, these particles can induce neuroinflammatory and cerebrovascular effects, potentially contributing to cognitive impairment, accelerated cognitive decline, and dementia, including Alzheimer's disease (White, 2024).

Immune system impacts and chronic conditions

Exposure to wildfire smoke also affects immune system function, exacerbating asthma, allergic airway sensitisation, and chronic obstructive pulmonary disease (Skevaki *et al*., 2024). The immunoregulatory impacts of prolonged smoke exposure remain an active area of research. Understanding these effects, along with the broader interplay between climate change and immunology, is crucial for mitigating the health impacts of wildfire (Bowman *et al*., 2024; Skevaki *et al*., 2024).

Chronic health impacts, although less frequently studied, are significant. For example, long-term exposure to $PM_{2.5}$ from wildfires has been linked to increased mortality in Portugal, where between 31 and 189 deaths were attributed to wildfire smoke between 2015 and 2018 (Barbosa *et al*., 2024). Additionally, the psychological impact of wildfires is increasingly recognised. Post-traumatic stress disorder, depression, and anxiety have been documented in both adult and paediatric populations following wildfire events, with effects persisting for years (To *et al*., 2021).

Vulnerable populations and health inequalities

The health impacts of wildfires are not distributed evenly, with certain populations being more vulnerable to adverse effects. Pregnant women face heightened risks of preterm birth and low birthweight when exposed to wildfire smoke, similar to other forms of air pollution (Bansal *et al*., 2023). Children, elderly individuals, and individuals with pre-existing respiratory or cardiovascular conditions are also disproportionately affected (Reid *et al*., 2016; Pashley *et al*., 2023; Wilgus and Merchant, 2024).

The health impacts of wildfires also seem to be unequal in their geographical distribution and particularly affect some ethnic groups (Davies *et al*., 2018). Southern and Eastern European countries, where wildfire risk is more prevalent, bear a heavier burden of health impacts. The evidence suggests that individuals living in highly deprived areas (e.g. certain NUTS 2 regions) are more vulnerable to wildfires than those living in less deprived areas (van Daalen *et al*., 2024). However, gaps remain in understanding the sociodemographic factors that drive these inequalities (Grant and Runkle, 2022).

Adapting to and mitigating health impacts

Effective adaptation strategies are critical for mitigating the health impacts of wildfires. These include improved public health surveillance, targeted health management for vulnerable populations, and long-term research into the physiological and psychological effects of wildfires. Strengthening public awareness through tailored risk communication campaigns can also help communities better prepare for and respond to wildfire events (InterAcademy Partnership, 2022).

Community-level training programmes that educate individuals on wildfire risk and promote preparedness measures, such as maintaining home-ignition zones, are essential for building resilience. Such programmes should be complemented by policies that enhance multi-hazard early warning systems, emergency preparedness, civil protection infrastructure, and healthcare resources in high-risk areas.

Summary: wildfires and health

Wildfires pose a multifaceted threat to public health, with impacts ranging from acute injuries and respiratory distress to long-term cardiovascular, neurological, and mental health issues. Vulnerable populations and socially disadvantaged groups are disproportionately affected, highlighting the need for targeted interventions. Effective adaptation strategies are critical for mitigating the health impacts of wildfires. These include improved public health surveillance, targeted health management for vulnerable populations, and long-term research into the physiological and psychological effects of wildfires.

C How can we manage changing wildfires?

11 Challenges to today's wildfire management strategy

Traditional fire management strategies in Europe have focused predominantly on emergency response, aiming to minimise wildfire impacts during years with average fire weather conditions. While this approach has had some success, it falls short in addressing the impact of increasingly severe fire seasons driven by climate change. Two major issues have emerged from this narrow focus: (1) the accumulation of flammable vegetation and (2) disproportionate investment in suppression efforts at the expense of proactive landscape fuel management programmes.

Although the EU has taken substantial steps to enhance its coordination capacity for emergency response, more efforts are urgently needed to adopt a proactive approach that reduces the prevalence and severity of wildfires. Policies that focus solely or predominantly on mitigating short-term fire damage by emphasising suppression, inadvertently led to increased fuel loads, ultimately resulting in fewer but far more intense and destructive fires. This 'firefighting trap' has been extensively documented in Europe and the USA (Collins *et al.*, 2013; Fernandes *et al.*, 2020; Moreira *et al.*, 2020). Suppression-focused approaches reduce the role of fire as a natural biomass regulator, allowing unburned vegetation to accumulate and fuel subsequent extreme wildfires. This cycle intensifies risk to society, including loss of life, destruction of homes, and disruption of ecosystem services (Spadoni *et al.*, 2023).

Since wildfire risk often stems from multiple interacting factors, including continuous stretches of flammable vegetation and periodic extreme weather events, suppression is insufficient, as some fires exceed the response capacities of even well-equipped countries, particularly when events are synchronous across regions (Podschwit and Cullen, 2020).

12 Wildfire risk reduction: proactive approaches

Prescribed burning and its benefits and challenges

Prescribed burning, the application of fire under planned conditions by trained professionals, faces significant challenges in Europe, particularly in densely populated areas where air quality concerns, the risk of fire escape, and limited suitable weather conditions often restrict its use (Ascoli and Bovio, 2013). Meanwhile, there is a long history of the use of fire as a tool, which has proved effective in managing vegetation and mitigating fire risk (Weir and Scasta, 2022). Additionally, field experience across a range of countries shows the benefit of controlled burns for training purposes and bringing diverse stakeholders together, improving safety and efficacy of fire management during unplanned wildfires. Given the values and challenges of prescribed burning, trade-offs between the benefits and costs of prescribed burning must be carefully considered (Fernandes *et al.*, 2013).

Alternative fuel management techniques

Where prescribed burning is not feasible, alternative methods such as mechanical vegetation removal, prescribed grazing, and pyrosilviculture can help manage fuel loads (Fernandes, 2013). Strategic forest fuel management techniques, such as fuel breaks and strategic prevention points, have been shown to effectively disrupt fuel continuity, reduce fire intensity, and improve fire suppression personnel safety (Castellnou *et al.*, 2019; Aparício *et al.*, 2022).

Strategic prioritisation of forest management

Advanced technologies, including stochastic fire simulations and spatial planning tools, enable the prioritisation of fuel management in high-risk areas (Palaiologou *et al.*, 2021). Strategic planning focuses on multiple objectives, such as protecting residential zones, economic assets, and biodiversity hotspots.

Post-fire recovery and ecosystem restoration

In fire-sensitive ecosystems, fires are severe disturbances that can disrupt ecosystem processes and hinder recovery. Restoration efforts must focus on building resilience by promoting non-flammable vegetation, creating fire refuges, and supporting risk reducing recovery processes (He *et al.*, 2019). Conversely, fire-adapted ecosystems rely on periodic fires for their ecological functioning. Decades of fire suppression in such systems have created undesirable conditions, including fuel accumulation and altered fire behaviour (Bond *et al.*, 2005).

Forests play a vital role in regulating microclimates and hydrological cycles. Old-growth forests, in particular, are highly effective at cooling landscapes and mitigating extreme heat, emphasising the importance of preserving forest cover and connectivity (Gohr *et al.*, 2021). Conversely, practices such as salvage logging can increase fire risk by drying soils and altering microclimates (Blumröder *et al.*, 2021).

Fire refugia – areas that remain unburned during fires – are critical for conserving biodiversity and facilitating post-fire ecosystem recovery. These refugia often include wetlands, riparian zones, and shaded areas with high water-retention capacity, which act as sources for ecosystem recolonisation and resilience (Meddens *et al.*, 2018).

Restoration strategies must be tailored to specific ecosystems. For example, boreal forests benefit from promoting low-severity surface fires, whereas Mediterranean ecosystems require preserving biological legacies and encouraging natural regeneration (Castro, 2021; Salesa *et al.*, 2022). In grasslands, integrated fire-grazing models can reduce biomass and wildfire risk while supporting biodiversity (Bond and Keeley, 2005; Davies *et al.*, 2022).

Post-fire soil management is crucial for ecosystem recovery. High-intensity fires can irreversibly damage soils, whereas post-fire activities such as salvage logging or ploughing exacerbate erosion and hinder recovery. Effective soil restoration techniques include mulching, log erosion barriers, and non-intervention scenarios, which promote soil stability and vegetation recovery (Pereira *et al.*, 2018; Lucas-Borja *et al.*, 2024).

Although salvage logging can have several negative consequences, the removal of damaged trees after wildfires is a common practice, and in some cases, it can mitigate some social damage in the affected areas. It can (1) reduce the risk of blocking and damaging roads in the affected areas; (2) reduce the risk of clogging torrent channels, which could lead to erosion risks for infrastructure and settlements; (3) facilitate and make safer the implementation of erosion control measures and reforestation. For this reason, it is important that any post-fire logging operations are well planned and that nature-based solutions are preferred in order to maximise the positive impacts over the negative ones.

Summary: wildfire risk reduction: proactive approaches

Integrated fire management emphasises proactive approaches such as prescribed burning and fuel management to reduce wildfire risk. Restoration strategies focus on enhancing ecosystem resilience, preserving fire refugia, and promoting natural recovery processes. Tailored solutions address ecosystem-specific needs, from grasslands to forests, whereas investments in prevention and restoration complement suppression efforts to build sustainable, fire-adapted landscapes.

13 Synergies and trade-offs

Firewise[2] landscape management has the potential to create synergies while navigating trade-offs with other land-use approaches. This integration is crucial for fostering positive outcomes, minimising land-use conflicts, and promoting resilient ecosystems and communities. Understanding these dynamics is key to managing landscapes sustainably and balancing multiple objectives, such as wildfire risk reduction, biodiversity conservation, agricultural productivity, and social well-being (Sayer *et al.*, 2013; Moreira *et al.*, 2020).

Synergies between firewise practices and landscape management

1 Agriculture

Firewise practices align with various agricultural activities that reduce wildfire risk. For example, well-managed grasslands, annual crops, and irrigated croplands act as natural firebreaks by limiting the continuity of flammable vegetation. These agricultural systems reduce the risk of fire spread while maintaining productivity (Moreira and Pe'er, 2018). Introducing payments for ecosystem services can incentivise farmers to adopt firewise practices, such as rotational grazing or maintaining fire-resistant field margins, contributing to overall risk reduction (Lecina-Diaz *et al.*, 2023).

2 Urban and peri-urban planning

Integrating firewise principles into urban planning significantly enhances resilience at the wildland–urban interface (WUI). Zoning regulations, risk-informed infrastructure development, and the strategic placement of vegetation buffers reduce the exposure of settlements to wildfires (Gonzalez-Mathiesen and March, 2018; Intini *et al.*, 2020) (see Chapter 8). Additionally, by promoting land-use regulation, building standards and community preparedness programmes, urban areas can reduce vulnerability and improve adaptive capacity.

3 Tourism and outdoor recreation

Sustainable landscapes benefit tourism by preserving natural assets and reducing the disruption caused by wildfires. Fire-resilient landscapes protect vital tourism infrastructure and natural and cultural heritage, ensuring economic stability for rural areas

[2] An approach to managing landscapes and communities that reduces wildfire exposure and vulnerability while maintaining ecological, economic, and cultural value. This includes promoting fire-resilient vegetation, sustainable land use, and community preparedness. (see Glossary).

dependent on tourism revenues (Molina *et al.*, 2019). Efforts to mitigate fire risk through proactive land-use management can also increase the recreational value of landscapes, attracting more visitors and generating local income.

4 Biodiversity conservation

Firewise environmental management can support biodiversity by creating diverse habitat mosaics. Prescribed burning, for example, can maintain ecosystems that depend on periodic low-intensity fires, such as Mediterranean scrublands and some grasslands, fostering species that thrive in such conditions (Pereira *et al.*, 2021). By promoting structural diversity and ecological heterogeneity, fire practices can enhance the habitat quality of various species.

5 Public health

Reducing wildfire risk directly benefits public health by minimising exposure to hazardous air pollutants, particularly fine particulate matter ($PM_{2.5}$). These pollutants are linked to respiratory and cardiovascular diseases, which are exacerbated during wildfire events (Rappold *et al.*, 2019). Proactive fire management reduces the frequency and intensity of wildfires, mitigating their health impacts.

Trade-offs and conflicts between firewise practices and landscape management

1 Forestry practices

Monoculture plantations of flammable species, such as *Pinus* and *Eucalyptus*, conflict with firewise principles if poorly managed by increasing fuel loads and fire intensity (Hermoso *et al.*, 2021). Such plantations also compromise biodiversity and resilience (see the Box below). Transitioning to mixed-species forestry with more fire-resistant trees can reduce risks and enhance ecosystem services.

2 Residential and industrial development

Expanding settlements, infrastructure and industrial areas into fire-prone areas heightens wildfire risk.

Wildfires: managing risk in European tree planting programmes

Forests and trees in diverse settings provide crucial ecosystem services, notably carbon sequestration, which underpins tree planting as a key strategy for climate change mitigation (Bastin *et al.*, 2019). Global commitments such as the Bonn Challenge aim to restore millions of hectares of degraded land by 2030. In Europe, the EU Biodiversity Strategy and Forestry Strategy for 2030 envision the planting of 3 billion trees, which requires the conversion of 2 million hectares of treeless land into woodlands (Abeli and Di Giulio, 2023).

Challenges of overprioritising tree planting

Tree-planting efforts often overlook the ecological value of nonwoody habitats because of 'biome awareness disparity', which is rooted in 19th century European forestry traditions and postcolonial environmental governance (Davis and Robbins, 2018; Silveira *et al.*, 2022). This overemphasis on tree planting has drawn criticism for overestimating short- and medium-term carbon sequestration benefits compared with those of grasslands and for underestimating adverse effects, including habitat loss, exotic species invasions, and local livelihood disruptions (Temperton *et al.*, 2019; Terrer *et al.*, 2020; Silveira *et al.*, 2022). Planting flammable non-native species such as *Eucalyptus* and *Pinus* species is also criticised for its contribution to fuel accumulation leading to increased fire risk (Hermoso *et al.*, 2021).

Principles for firewise tree planting

To mitigate wildfire risk, tree planting in Europe must follow key principles related to site selection, stand management, spatial patterns, and species selection:

1 Site selection, stand management and spatial pattern

Strategic site selection and stand management are essential for minimising fire risk and afforestation should consider the following:

- Agroforestry should be supported, and open woodland vegetation should be protected in high-fire-risk regions (Moreira and Pe'er, 2018).
- Tree planting should be avoided in areas where native vegetation consists of open habitats, such as grasslands and (semi)arid zones (Veldman *et al.*, 2019).
- Alternative ecosystems such as grasslands in fire-prone areas should be restored to provide climate mitigation benefits without increasing wildfire hazards (Hermoso *et al.*, 2021).
- Manage existing exotic woody plantations to control their spread and reduce flammable fuel continuity (Brundu and Richardson, 2016; Mirra *et al.*, 2017).
- Manage stand structure and understorey vegetation to decrease flammability, i.e. reduce the vertical structure of the understorey fuel; reduce the use of ladder fuels to avoid crown fires; and prescribe burning, pruning, and forest management (Fernandes, 2009; Barros and Pereira, 2014).
- In continental and boreal regions, maintaining a dense understorey that supports a cool and moist microclimate reduces fuel flammability.

Tree planting should contribute to fire-resilient landscape mosaics, integrating firebreaks, buffer zones, and varied vegetation structures to minimise fire spread and intensity. Combining this approach with other land uses, such as agriculture and pasturelands, enhances ecosystem resilience and reduces fire risk (Moreira and Pe'er, 2018).

2 Species selection

Biodiversity conservation principles prioritise native species for afforestation, but this is often not considered by private landowners. The EU's Forestry Strategy 2030 allows the conditional use of non-native species, raising concerns due to their flammability and ecological risk (Pötzelsberger *et al*., 2020; Abeli and Di Giulio, 2023). Poorly designed afforestation campaigns often result in landscapes that are more prone to wildfires, which threatens both ecosystems and human safety (Fernandes *et al*., 2016; Veldman *et al*., 2019).

In general, transitioning from monoculture plantations to landscape mosaics and emphasising fire-resistant native species are critical measures to reduce these risks. Native species adapted to future climatic conditions can be identified through climate niche modelling (Barragán *et al*., 2023). Avoiding flammable forest structures and pyrophytic tree species such as *Eucalyptus* spp. and *Acacia dealbata* is important for reducing fuel loads and wildfire hazards (Brundu and Richardson, 2016; Guiomar *et al*., 2023). However, species selection alone cannot sufficiently reduce fire risk, especially in regions with a generally flammable native vegetation. This highlights the critical role of forest management in wildfire risk reduction (Fernandes *et al*., 2019; Guiomar *et al*., 2023).

Enhancing synergies while addressing trade-offs

A holistic, firewise approach can optimise the multifunctionality of landscapes. For example, combining agroforestry, sustainable forestry, and habitat conservation can deliver multiple ecosystem services while mitigating wildfire risk (Palaiologou *et al*., 2021). Tools such as stochastic fire simulations, multi-objective spatial planning and using faster-than-real-time models for enhancing fire management operations (Grasso and Innocente, 2020) can guide decision-making to achieve these synergies.

In addition, incorporating payments for ecosystem services, carbon credits, and agri-environmental schemes can incentivise firewise practices. Such mechanisms can generate funding streams from diverse sectors, supporting integrated fire management and rural development.

Finally, addressing wildfire risk requires participatory planning processes that incorporate local knowledge and community priorities and concerns. Inclusive governance ensures the equitable distribution of benefits and burdens, particularly for marginalised rural communities (Maezumi *et al*., 2024).

Residential areas in the WUI (see Chapter 8) often lack sufficient buffers or defensible spaces, making them highly vulnerable (Planas *et al*., 2023). Industrial facilities, especially those involving hazardous materials, exacerbate fire risk and might be the cause of wildfires in the case of accidents. Firewise land-use planning must prioritise safe development practices and establish protective measures for these zones (Sudmeier-Rieux *et al*., 2015).

3 Biodiversity conservation

Fuel management can conflict with conservation goals when it reduces habitat continuity. For example, maintaining firebreaks or fuel-reduced zones may fragment habitats critical for certain species. Balancing these needs requires careful planning to ensure that fire prevention measures do not disproportionately harm biodiversity (Pereira *et al*., 2021).

4 Agricultural activities

Some agricultural practices, such as the burning of crop residues, pastoral fires, and the use of heavy machinery during dry seasons, contribute to wildfire ignition (Moreira and Pe'er, 2018). Regulatory measures, including restrictions on these practices and incentives for safer alternatives, are essential to align agriculture with firewise strategies.

5 Prescribed burning

Although prescribed burning is an effective tool for reducing fuel loads, it can negatively impact air quality and increase resistance in nearby communities (Valkó and Deák, 2021). To address these challenges, governments must ensure planning and public awareness and establish clear protocols for safe implementation.

Summary: synergies and trade-offs

Firewise landscape management fosters synergies between wildfire risk reduction, biodiversity conservation, agriculture, urban planning, and public health. This approach minimises conflicts by integrating forestry, sustainable agriculture, and spatial planning. Challenges include balancing prescribed burning, habitat conservation, and afforestation risks.

14 Wildfire risk reduction: enablers and barriers

In previous chapters, we outlined a variety of proactive approaches for managing wildfires through diverse landscape interventions aimed at reducing fuel loads. These approaches involve distinct governance models. *Direct wildfire prevention* involves strategic landscape fuel treatments, such as mechanical thinning or prescribed burns, which are mostly funded by public agencies and maintained periodically. *Indirect wildfire prevention* leverages private, economy-driven land uses – such as livestock grazing, agriculture, or forestry practices – that simultaneously reduce fuel loads and create 'productive fuel breaks' (Pulido *et al*., 2023). These two approaches may be integrated into a smart prevention model, blending public and private governance to develop 'smart fire territories' (Tedim *et al*., 2016; Pulido *et al*., 2023).

Direct prevention: focused but costly

Direct prevention is typically planned and implemented by forestry or fire management departments, often in state-owned forests. Recently, pilot projects have extended these practices to private stakeholders, including forest owners, with public funding (Ascoli *et al.*, 2023). However, direct prevention is resource intensive and often short-lived, limiting its application across large regions. Statewide plans have been proposed to address concerns about extreme fires, but implementation remains challenging (Ager *et al.*, 2021; Aparicio *et al.*, 2022).

Fuel reduction efforts, when strategically placed, effectively reduce wildfire spread and severity, even under severe fire weather conditions (Kalies and Kent, 2016). For example, thinning and prescribed burning have been shown to significantly lower fire severity in treated areas (Cansler *et al.*, 2022). However, treatments may become less effective under extreme wind speeds or high fuel loads (Beverly *et al.*, 2020).

Prescribed burning is increasingly gaining attention in Europe. Long-term projects, such as pastoral burning in southern France, have resulted in a 35% reduction in average burned areas and have successfully prevented very large fires (Robios, 2012). Despite these benefits, challenges such as limited weather windows, regulatory barriers, and cost inefficiencies hinder widespread adoption. Cost optimisation strategies, such as combining prescribed burns with grazing or using non-timber forest products such as biomass, resin, or mushrooms, could increase the viability of these treatments (Varela *et al.*, 2018; Soliño *et al.*, 2018).

Southern Europe predominantly focuses on fire management efforts to protect populated areas and infrastructure. Firebreaks and fuel breaks, while effective, are concentrated in high-value forest areas and rarely extend to marginal regions (Xanthopoulos *et al.*, 2006). Modelling studies have highlighted their potential: for south Portugal, fuel breaks reduce burned areas up to 17% and burn probability between 4% and 31% (Oliveira *et al.*, 2016) while for central Portugal different fuel treatments reduce the burn are from 12% to 31% and decrease the probability of large wildfires by 10% to 40% (Benali *et al.*, 2021). In Sardinia and Greece, fuel treatments have demonstrated measurable reductions in wildfire intensity and extent (Salis *et al.*, 2016; Palagiologou *et al.*, 2020).

Indirect prevention: harnessing productive landscapes

Indirect prevention relies on creating productive fuel breaks, which integrate agroforestry, grazing, or other land uses that reduce fuel loads while providing economic benefits (Pulido *et al.*, 2023). These efforts have proved effective in reducing wildfire size and severity, particularly in heterogeneous landscapes that combine agriculture, shrublands, and forests (Damianidis *et al.*, 2020; Bertomeu *et al.*, 2022). Compared with direct prevention, indirect measures often cover larger areas at lower public costs, generate economic returns, and encourage stakeholder engagement (Table 2).

Successful examples abound. In Catalonia, Spain, the *Ramats de Foc* initiative employs livestock grazing to reduce fuel loads while marketing the meat produced as an ethical product (Soy-Massoni *et al.*, 2022). Similarly, the *LIFE Granatha* project in Italy reduced biomass and shrub cover while creating marketable organic brooms (Ascoli *et al.*, 2023). These initiatives demonstrate how indirect prevention can align wildfire risk reduction with rural economic development.

However, legal and administrative barriers often restrict indirect prevention efforts, particularly in fire-prone and depopulated areas. Regulatory reforms and certification programmes could incentivise private land managers to adopt fire-smart practices (Pulido *et al.*, 2023).

Smart prevention: integrated governance

Smart prevention combines the strengths of direct and indirect approaches through public–private partnerships. This integrated model has gained traction in recent years, driven by the alignment of wildfire risk reduction with broader land management goals (Tedim *et al.*, 2016; Pulido *et al.*, 2023). Recent modelling studies highlight the advantages of combining strategies, showing substantial reductions in suppression costs and improved outcomes (Sil *et al.*, 2019; Lecina-Diaz *et al.*, 2023) (Figure 13).

Case studies in smart prevention

Several innovative projects across Europe illustrate the potential of smart prevention. The RAPCA programme in southern Spain engages local shepherds to manage fuel breaks through guided livestock grazing, covering nearly 6,000 hectares under a payment for environmental services framework (Varela *et al.*, 2018). Similarly, the *Plan for Shrub Clearing* in La Rioja, Spain, has created landscape mosaics that significantly reduced burned areas over three decades (Lasanta *et al.*, 2022) (Figure 14).

The *MOSAICO* project in Extremadura (central–western Spain) takes a participatory approach, funding local land managers to implement fire-smart strategies. Despite administrative challenges, the project demonstrated moderate reductions in burned areas, which highlights the importance of integrating private and public actions to maximise impact (Pulido *et al.*, 2023) (Figures 15 and 16).

Table 2 Barriers and enablers of wildfire prevention approaches (see also Ascoli *et al*., 2023)

	Barriers	Enablers
Direct prevention	Limited public budget	Strategic application relative to fire spread
	Hard to implement in private land	Straightforward negotiation and implementation
	Interventions with short-term effects	Interventions may help fire suppression
	Excess of limitations for fuel management according to spatial planning	Increasing awareness of fuel management as a risk reduction measure
	Regulatory restrictions to implement prescribed burns in certain countries	Several fuel reduction options through multiple well-known techniques
Indirect prevention	Non-strategic location	Low/zero public implementation budget
	Lack of resources and skills to undertake participatory processes	Long lifespan of interventions
	Constrained regulatory framework	Associated co-benefits
	Non-economic viability of some local activities	Monitoring by landowners
	Lack of investment capacity in rural areas and low economic value of products	Convergence of multiple land management goals maximising cost–benefits
	Lack of regulatory mechanisms to involve beneficiaries of ecosystem services	Diversity of initiatives adaptable to the complexity of risk
Smart prevention	Complex private–public governance	Straightforward spatial planning and technical support provided
	Lack of enhancing policy	Funds potentially accessible from several missions of the EC Adaptation Strategy
	Limited budget and lack of human resources	Alignment among risk reduction measures through direct and indirect prevention
	Segmentation of competences in wildfire management	Policy request for integration in disaster risk management
	Excess of bureaucracy and administrative burdens before implementation	Acknowledgement in EC documents of the need of having resilient landscapes

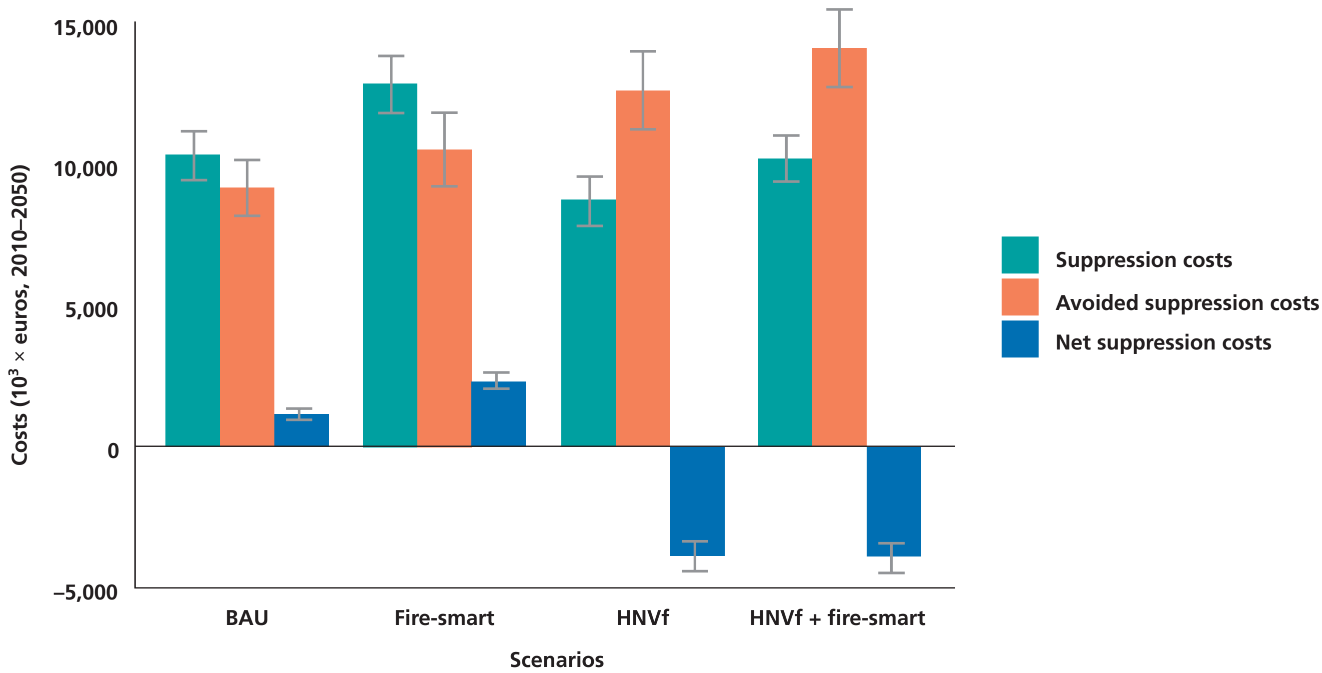


Figure 13 Cost–benefit analysis of land-use scenarios over 50 years. The present value of wildfire suppression costs, avoided suppression costs, and net suppression costs under various land-use management scenarios (Business-as-Usual (BAU), Fire-smart, High Nature Value Farmlands (HNVF), and HVNF + fire-smart) over a 50-year simulation period) (Lecina-Diaz et al., 2023).

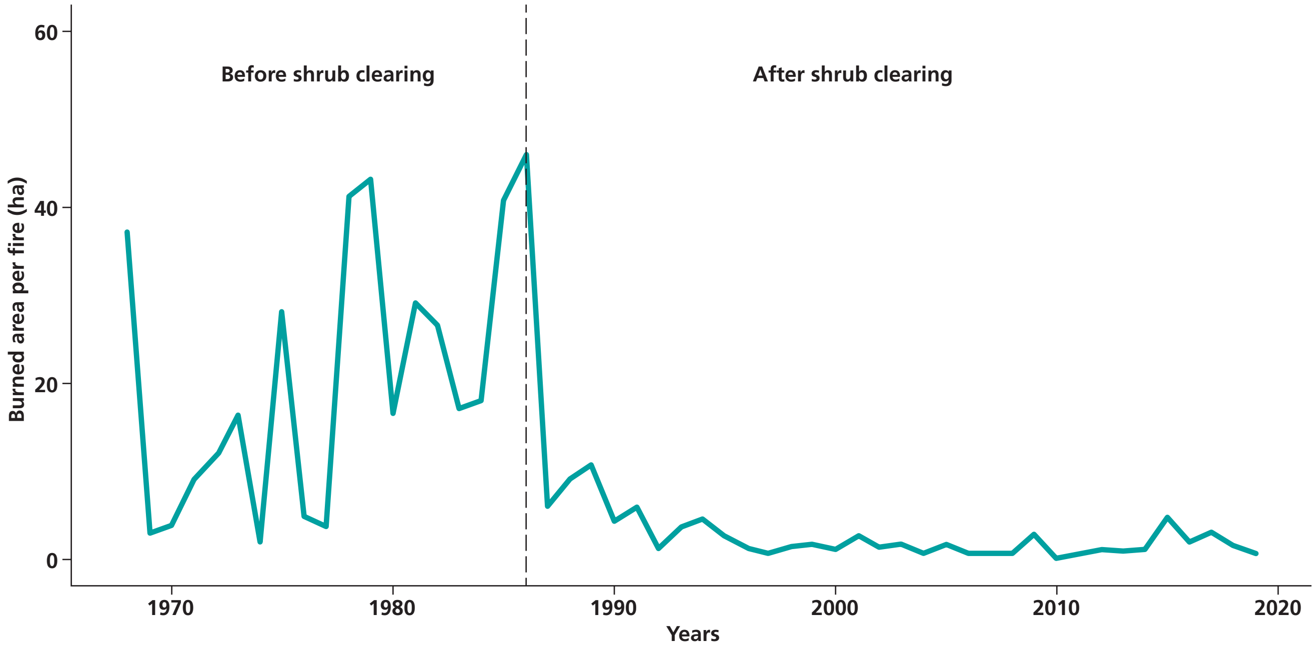


Figure 14 Burned area trends before and after landscape mosaic interventions in La Rioja, Spain. Average annual burned area per fire in the La Rioja community. The plot shows the temporal pattern before and after the adoption of fire control approaches based on landscape mosaics (Lasanta et al., 2022).

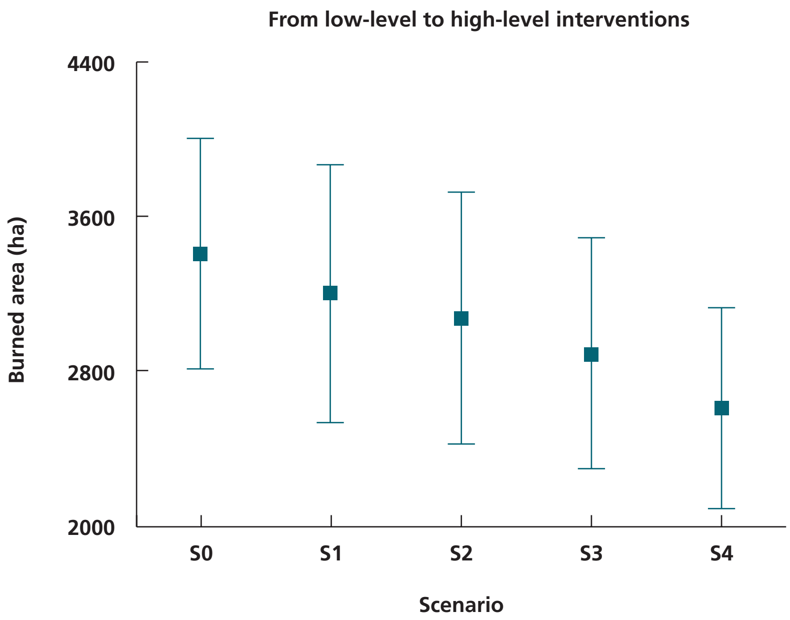


Figure 15 Impact of different intervention scenarios on burned areas in Extremadura. (a) Mean (±95% confidence interval) burned area in the S0–S4 scenarios from 20 random simulated ignition points. S0, control scenario (i.e. Business-as-Usual); S1, with private interventions of local land managers; S2, S1 plus public interventions; S3, S2 plus mixed interventions proposed; and S4, S3 plus interventions failed mainly because of administrative constraints (Pulido et al., 2023).

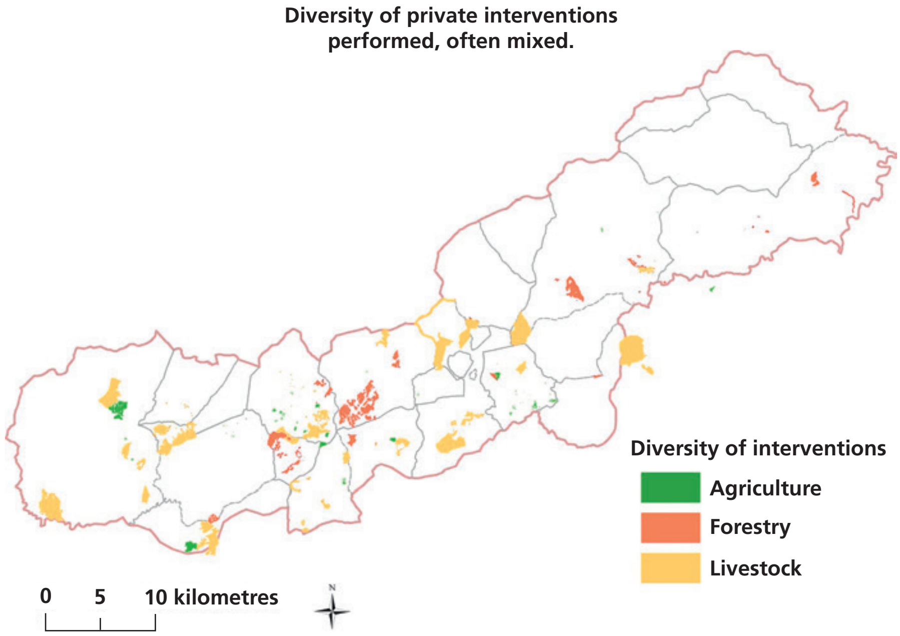


Figure 16 Map of private interventions performed by agriculturalists, shepherds, and forest dwellers (mainly resin tappers) in northern Extremadura (central Spain) (Pulido et al., 2023).

Barriers and opportunities for improvement

While promising, smart prevention faces significant challenges, including complex governance structures, limited budgets, and regulatory barriers. Long-term success depends on the alignment of fire-smart strategies with broader land-use and disaster risk reduction policies. Increasing awareness among decision-makers and integrating pilot projects into knowledge-sharing platforms such as FIRELOGUE will be critical for scaling up these efforts (https://firelogue.eu/).

Efforts to reduce wildfire risk must also address the causes and effects of underlying processes such as rural depopulation, land abandonment, and climate change through intersectoral policies. By fostering partnerships between the public sector, private landowners, and local communities, Europe can develop resilient landscapes that balance wildfire prevention with economic, ecological, and social objectives.

Summary: wildfire risk reduction—enablers and barriers

A multifaceted approach to reduce wildfire risk is essential for addressing the growing threat of wildfires in Europe. Direct prevention, indirect prevention, and smart prevention each play a role in creating fire-resilient landscapes. However, their success depends on overcoming regulatory, financial, and administrative barriers, as well as fostering collaboration among stakeholders. By integrating these approaches into cohesive strategies, Europe can mitigate wildfire risk while promoting sustainable land management.

D Towards an integrated wildfire policy framework

Disaster risk governance involves the interaction of social, political, and administrative actors to manage hazards, vulnerabilities, and exposures, aiming to reduce risk and mitigate the impacts of disasters. Building on Kooiman's (2003) concept of governance, this approach encompasses the actions of governments, the private sector, and civil society across multiple levels to address emerging challenges effectively (Fra Paleo, 2015). Collaborative, multi-level, and multi-actor systems – spanning local communities to national and multilateral entities – are key to their success.

In the context of wildfires, governance is often confined to forest departments, with a predominant focus on suppression rather than integrated, proactive strategies. This reactive approach overlooks the interconnected nature of hazards, failing to address the interplay between wildfire risk and other factors, such as land-use changes, climate change, and socio-economic vulnerabilities.

The need for integrated wildfire policies

Wildfires are not standalone events; they represent ecological processes, hazards, and cultural phenomena interconnected with broader risk. Current wildfire governance often neglects the multi-hazard perspective emphasised in the Sendai Framework for Disaster Risk Reduction (2015–2030). The midterm review of the framework (UNDRR, 2023) emphasises the urgency of systemic risk management, which considers interactions between multiple hazards.

Fragmented governance and sectoral policies exacerbate wildfire risk. For example, policies focused narrowly on forest preservation through suppression can inadvertently lead to fuel accumulation, intensifying future wildfire severity (Collins *et al.*, 2013; Moreira *et al.*, 2020). Breaking silos to develop integrated and proactive wildfire management approaches is critical.

As stated previously, adopting a landscape approach allows for the integration of ecological, economic, cultural, and social objectives, balancing synergies and trade-offs among competing land uses (Plieninger *et al.*, 2020). This perspective aligns with calls to view wildfires as complex risk problems, necessitating shifts from top-down management to participatory strategies (Moritz *et al.*, 2014; Tedim *et al.*, 2020; Essen *et al.*, 2023).

Collaborative knowledge coproduction and diverse stakeholder engagement are essential for fostering adaptive and inclusive fire governance (Stoof and Kettridge, 2022). Lessons from integrated water management in The Netherlands, which emphasise adaptive management and stakeholder participation, provide valuable insights for wildfire governance (Lambrechts *et al.*, 2023).

Sayer *et al.* (2013) identified principles for landscape approaches that are particularly relevant to wildfire management, including resilience, stakeholder capacity-building, and participatory monitoring. These principles form the foundation for integrated wildfire risk governance, highlighting the need for inclusive, multi-stakeholder processes.

Advancing fire governance: frameworks and initiatives

The recently proposed Landscape Fire Governance Framework, endorsed at the 8th International Wildland Fire Conference in 2023, marks a significant evolution from the FAO's 2006 voluntary guidelines for integrated fire management. The Landscape Fire Governance Framework emphasises multi-stakeholder engagement at the institutional level, fostering collaboration among governments, businesses, academia, and civil society. Its goals include improving rural area stewardship, changing fire-related behaviours, and enhancing risk management to safeguard lives, property, and environmental assets.

Other European initiatives complement the Landscape Fire Governance Framework. For example, the European Forest Institute and Spain's Ministry of Ecological Transition have proposed recommendations for Mediterranean ecosystems (Mauri *et al.*, 2023). These initiatives advocate integrating fire prevention into cross-sector policies, enhancing financial mechanisms, fostering wildfire education, harmonising information systems, and promoting international cooperation.

Despite these efforts, EU disaster risk management funding remains skewed toward response rather than prevention and preparedness (World Bank, 2021). Civil protection agencies across Europe report limited influence over other departments and insufficient resources for wildfire prevention. Addressing these barriers requires increased investment in prevention, improved institutional coordination, and capacity building to address systemic challenges.

Public policies and risk analysis

Public policies are foundational to wildfire risk governance, shaping planning, preparedness, and recovery efforts. Effective wildfire risk management must intersect with climate adaptation, agriculture, spatial planning, and water management policies. Comprehensive risk analysis, involving monitoring, inventories, and assessments, is crucial to understanding wildfire dynamics, identifying vulnerable elements, and informing decision-making processes.

Spatial planning plays a critical role in wildfire risk reduction. By incorporating wildfire risk assessment into urban, regional, and landscape planning, policy-makers can minimise exposure and vulnerability (Fra Paleo, 2009) of rural and wildland–urban interface (WUI) resident populations and assets while promoting sustainable development. Such approaches can reduce conflicts between social and environmental priorities, fostering resilience at multiple scales.

Community engagement and fire literacy

Public perceptions of wildfire risk significantly influence policy decisions. When risks are underestimated or misunderstood, essential wildfire management measures may face resistance. For example, prescribed burns or zoning regulations, while effective, can be politically challenging because of their potential unpopularity (Stedman, 2004). Community-based training programmes can bridge these gaps by raising awareness and fostering preparedness, equipping residents with practical knowledge about evacuation routes, procedures, and home ignition zone maintenance, which is eventually translated into behavioural change (Brenkert-Smith *et al*., 2012).

Fire literacy extends beyond professional expertise to encompass public understanding of fire behaviour, ecological roles, and socioecological dynamics (McGranahan and Wonkka, 2018). Building a fire-literate society involves integrating fire awareness into school curricula, community programmes, and risk communication campaigns. Reviving fire culture through education can reduce vulnerabilities, both for local residents and for those travelling as visitors to fire-prone regions.

Professional training should adopt interdisciplinary approaches, equipping practitioners in navigating the complexities of integrated fire management. This includes bridging disciplinary divides, engaging diverse stakeholders, and addressing knowledge gaps in emerging fire regimes (Stoof and Kettridge, 2022).

Risk communication and inclusive governance

Effective risk communication is critical for fostering public support and understanding of wildfire management strategies. Policy-makers should tailor messages to resonate with diverse audiences, emphasising shared values and actionable solutions. Inclusive planning processes that engage communities as active participants enhance the legitimacy and effectiveness of wildfire governance (Milner-Gulland *et al*., 2014).

Environmental justice considerations are equally vital. Integrating distributional, procedural, and restorative justice into wildfire governance ensures equity and inclusivity, reducing conflicts and promoting community buy-in (Fra Paleo, 2015). Justice-oriented frameworks can guide the development of strategies that balance risk reduction with social and ecological priorities.

Summary: towards an integrated wildfire policy framework

An integrated framework for fire adaptation and literacy in the EU must prioritise proactive approaches that align with broader disaster risk governance principles. By fostering fire literacy, engaging communities, and addressing systemic risks, policy-makers can create more resilient landscapes and societies. Coordinated efforts across sectors and levels of governance, supported by inclusive and justice-oriented frameworks, are essential for mitigating wildfire risk in the face of a changing climate.

E What is currently happening in the EU?

15 Emergency response approaches in the EU

Wildfire policies across Europe differ significantly owing to variations in fire risk, fire history, wildfire information and emergency response organisational structures. While the European Forest Fire Information System (EFFIS) provides a common platform for assessing fire danger, many countries also maintain their own fire risk systems to guide response strategies, personnel allocation, and infrastructure readiness (EFFIS, 2024).

During high-fire seasons, wildfire monitoring systems include preposition cameras with multi-sensor capabilities, ground teams, watchtowers, and aerial spotting teams equipped with airplanes or drones. Access infrastructure is a key component of the fire emergency response. Networks of forest and public roads, often originally built for forestry purposes, are critical for reaching fire locations. In fire-prone Mediterranean countries such as France, Greece, Italy, Portugal, Spain, and parts of Croatia and Slovenia, 'fire road networks' are well established (Pičman *et al*., 2011; Laschi *et al*., 2019; Saražin, 2025). In Central Europe, countries such as Poland also maintain fire-specific road networks (Bartosz-Sroka, 2019).

Additionally, fuel breaks – areas with a reduced amount of vegetation to slow wildfire spread – are increasingly adopted alongside road networks. These have been widely implemented in Portugal, Spain, and parts of France and Italy. Other essential infrastructure includes water resources for fire suppression, hydrant systems, and logistical hubs such as heliports for aerial suppression.

For the 2023 wildfire season, the rescEU – a reserve of personnel, equipment, and infrastructure, integrated into the EU Civil Protection Mechanism – wildfire suppression capabilities include 24 fire response planes, 4 helicopters, and more than 400 ground fire personnel deployed to Portugal, France, and Greece. These joint resources provide critical support for managing extreme wildfire events across the EU.

However, most initial emergency response resources for low-intensity wildfires remain organised at the national or regional level. Fire response teams vary significantly across member states, ranging from multi-purpose units to specialised wildfire response teams found in countries such as Portugal, Spain, and Italy. In several countries, additional units trained for remote areas, such as smokejumpers or hotshot crews or hand crews, can be deployed by helicopters or on the ground (Portugal, Spain, Switzerland, The Netherlands, Norway, Slovenia). Volunteer teams also play a critical role, particularly in Central Europe, where they constitute 95%–99% of all active fire response units (CTIF, 2024).

Aerial suppression capabilities vary widely across the EU. Southern European countries, which face greater wildfire risk, tend to maintain state-owned aircraft fleets, including medium- and large-capacity airplanes. In contrast, Central and Northern European countries rely primarily on helicopters, which are often operated by the military or the police for multi-purpose use. Private concessionaires or companies increasingly provide aerial suppression services in countries such as Austria, Italy, Norway, Portugal, and Spain.

16 Wildfire policies in the EU

Current EU wildfire policies and funding mechanisms primarily emphasise emergency responses to wildfire prevention, limiting their effectiveness in addressing the root causes of wildfire risk. Several key EU policies and financial instruments influence wildfire risk reduction, including the EU Regional Policy (cohesion policy), the Common Agricultural Policy, and specific programmes such as the European Regional Development Fund (ERDF) and the European Agricultural Fund for Rural Development (EAFRD). Approximately 90% of EU funding for forests comes from the European Agricultural Fund for Rural Development, with 27% allocated to afforestation, 18% to increasing forest resilience, and 18% to damage prevention during the 2014–2020 programming period (Miličević, 2023).

The EU also has other instruments, such as the LIFE programme, the Union Civil Protection Mechanism (UCPM), and the Solidarity and Emergency Aid Reserve (SEAR), which have direct and indirect impacts on wildfire policy. For example, the UCPM facilitates resource sharing among member states in disasters, coordinated through the Emergency Response Coordination Centre. The rescEU reserve, established in 2019, provides additional disaster response resources.

In terms of information systems, platforms such as the Civil Protection Knowledge Network (CPKN), EFFIS, and the Disaster Risk Management Knowledge Centre (DRMKC) operate as information hubs that promote risk analysis and better preparedness. EFFIS supports real-time wildfire monitoring and post-fire damage assessment, whereas DRMKC translates scientific data into actionable policies (see also Appendix 1).

Despite these efforts, EU wildfire risk management is hampered by the lack of a targeted, cohesive policy framework. Instead, wildfire risk is managed indirectly, disconnectedly, and fragmentarily through sectoral policies such as the EU Forest Strategy 2030, the Biodiversity Strategy, and the Climate Strategy. These strategies often mention wildfires as a secondary concern rather than addressing them directly. For example, the Biodiversity Strategy acknowledges fire as a threat to ecosystems but focuses primarily on nature-based solutions and forest health. Still, recent reports within the EU have given thought to governance issues, such as the wildfire peer-review reports on Greece and Italy (Arbinolo *et al*., 2024; Verde *et al*., 2024), with both reports calling for cross-sectoral approaches and governance revision, towards increased dialogue between all relevant stakeholders. While these calls are made for each reviewed country, the issuance of such recommendations on EU reports could signal acknowledgment of the need for policy changes on a broader scale.

Challenges to EU wildfire policy

The fragmented nature of EU wildfire policies stems partly from regulatory constraints. Article 196 of the Treaty on the Functioning of the European Union (TFEU) limits the EU's ability to harmonise civil protection laws across member states. This prevents the formulation of a comprehensive, integrated wildfire risk management policy. For example, Regulation (EC) No. 1485/2001, which amended earlier Council regulations on forest fire management, primarily addressed forest fire zoning but lacked the authority to enforce planning mandates.

In addition, the cohesion policy, which aims to promote territorial cohesion, has limited applicability for wildfire recovery efforts. As Pronto *et al*. (2023) noted, 'Cohesion Policy funding schemes are suitable mechanisms to finance wildfire prevention, preparedness, mitigation and adaptation, but less so for recovery'.

Some member states with frequent wildfires, such as Portugal, Spain, France, Italy, and Greece, have developed national wildfire policies. However, the lack of coordinated EU-level policies creates significant challenges for transboundary wildfires and for Central and Northern European countries, where wildfires have historically been less of a concern but are now increasing owing to climate change.

Opportunities for harmonisation and synergies

The EU's existing strategies, such as the Common Agricultural Policy, Climate Strategy, Biodiversity Strategy, and Farm-to-Fork Strategy, could be better harmonised with wildfire risk reduction principles. Such opportunities for harmonisation include the following:

- Ecological corridors: the biodiversity strategy's goal of increasing landscape connectivity could inadvertently facilitate fire spread. These corridors could be designed as firebreaks by avoiding flammable vegetation.
- Urban greening: increasing tree cover in cities and peri-urban areas requires the consideration of fire risk. Restoring grasslands and avoiding highly flammable vegetation can reduce vulnerability at the wildland–urban interface (WUI).
- Tree planting initiatives: the EU's goal of planting 3 billion trees by 2030 must prioritise fire-resistant, native species and diverse, multi-aged plantations. Afforestation should be avoided in regions where open habitats are ecologically critical, such as semiarid areas (Veldman *et al*., 2019) (see also the box on page 34–35).

There are also significant opportunities for reducing wildfire risk through synergies with measures related to the Common Agricultural Policy, including the following:

- Promoting extensive livestock grazing in abandoned areas to reduce fuel loads.
- Agricultural activities in the WUI should be supported to create fire-resistant buffers around settlements.
- Firewise forest management practices, such as maintaining open woodlands and agroforestry systems and using understorey biomass for bioenergy, should be encouraged (Moreira and Pe'er, 2018).

Summary: what is currently happening in the EU?

The EU wildfire response focuses mainly on reactive suppression, with various approaches across member states. Monitoring systems, road networks, and tools such as EFFIS support assessment preparedness. EU policies such as the Common Agricultural Policy and Biodiversity Strategy offer potential but lack integration for managing wildfire risk. Harmonising these strategies, prioritising fire-resistant vegetation, and scaling prevention funding can improve EU-wide risk management.

F What should the EU address in the future?

To prepare for the escalating challenges posed by wildfires, the EU must adopt an integrated approach that combines proactive and reactive strategies. Below, we list three urgent key messages from our review of the evidence and propose a toolbox of eight policy options that address both the social–ecological systems and spatial dimensions of wildfire risk management.

The interconnected policy options can be tailored to specific contexts, reflecting the diverse social–ecological landscapes across the EU. In Appendix 2, we provide successful examples across Europe about projects implementing each of the eight policy options to provide guidance and inspiration for their wide adoption.

Three urgent key messages

1 Prioritise the implementation of climate mitigation and land-use policies

Swiftly implement existing EU climate mitigation and adaptation plans and land-use policies to address wildfire risk intensified by climate change, rural depopulation, abandoned farmland, and changing landscapes. The new Nature Restoration Law should also be swiftly implemented with a particular focus on European peatland restoration. This is critical for preventing significant carbon loss and mitigating climate change feedback loops, because peatlands, the most carbon-dense ecosystems on Earth, store approximately 10 times more carbon per hectare than boreal forests.

2 Incorporating assessments of wildfire risk into biodiversity and tree planting initiatives

Ensure that scenarios of wildfire risk are thoroughly assessed and integrated before the Kunming–Montreal Global Biodiversity Framework's 30×30 strategy and the EU tree-planting programme are fully implemented by 2030. These initiatives must be aligned with firewise landscape management to avoid unintended consequences, such as increased fire vulnerability in afforested areas and exposure of large restoration investments to fire hazards.

3 'Living with fire': enhance public health interventions and education on wildfire risk

Address the severe health risks posed by wildfire smoke, particularly for vulnerable populations, by improving preparedness and public health interventions. Elevate awareness through comprehensive education programmes for all ages, fostering a fire-literate society equipped to adapt to the growing challenge of 'living with fire' in Europe.

Eight EU policy options for long-term proactive wildfire management

Wildfire risk reduction: a systems approach

Policy option 1. Adopt an integrated approach to wildfire risk reduction

Current wildfire policies emphasise fire suppression, a reactive approach that has led to biomass accumulation, increasing the severity of today's fires. While suppression can mitigate immediate losses, it is uneconomical in the long term and insufficient for addressing evolving fire regimes, which are influenced by climate change and increasing fuel loads.

Actions

- Shift from suppression-focused policies to a balanced framework of proactive and reactive actions.
- Wildfire risk policies should be integrated into broader disaster risk and climate change adaptation frameworks, adopting a multi-hazard approach.
- Investments in biomass management strategies should be increased, particularly near high-risk areas.
- Implement transitional models: prioritise proactive actions in the short term while gradually reducing reactive measures.

Benefits: Improved policy integration, reduced costs of suppression, and prevention of cascading hazards linked to wildfires.

Costs: Potential resistance from stakeholders in the fire suppression industry and local communities concerning perceived security risks.

Policy option 2. Adopt nature-based solutions for wildfire risk reduction

Nature-based solutions leverage natural processes to address societal challenges while providing environmental, social, and economic benefits. Ecosystem-based disaster risk reduction (ecoDRR) uses these principles to mitigate wildfire risk and restore ecosystems after fires.

Actions

- Understorey grazing in forests and woodlands, especially in high-risk areas near communities, should be promoted.
- Post-fire salvage logging should be avoided to minimise soil erosion and compaction.
- Implement bioengineering techniques for slope stabilisation and erosion control.
- Adhere to the IUCN global standards[3] on nature-based solutions for project implementation.

Benefits: Biomass reduction, erosion prevention, diversified rural economies, and job creation.

Costs: Resistance to proactive measures due to misconceptions about safety.

Policy option 3. Embrace the ecological and cultural role of fire

Fire suppression policies disregard the ecological and cultural significance of fire, which contributes to biomass accumulation and more severe wildfires. Fire is an integral component of certain ecosystems and has cultural significance in traditional land management practices.

Actions

- Recognising the ecological role of fire in specific ecosystems.
- Local communities should be supported in applying controlled burning for e.g. agriculture, forestry, and biodiversity conservation.
- Prescribed burns should be adopted under planned conditions to manage biomass and conserve biodiversity.
- Manage wildfires at acceptable levels to minimise harm to non fire-adapted ecosystems and human settlements.

Benefits: Reduced wildfire intensity, restored ecosystem services, and reconciliation of cultural fire practices with contemporary management.

Costs: Public concerns about prescribed burning, potential health effects, and resistance to 'let it burn' policies.

Policy option 4. Build educational and risk communication capacity

Integrated fire management requires interdisciplinary knowledge and skills that are often absent from traditional education and professional training. Increasing fire literacy across generations and sectors is essential for improving awareness, preparedness, and decision-making.

Actions

- Include fire management and landscape fire dynamics into primary, secondary, vocational, and higher education curricula.
- Foster interdisciplinary training programmes for professionals in fire management, combining engineering, natural sciences, and social sciences.

Benefits: Improved decision-making, greater fire literacy, fewer accidental ignitions, and better preparedness in emerging fire-prone regions.

Costs: Financial costs of developing and localising educational materials and adjustments to existing curricula.

Wildfire risk reduction: a spatial approach

Policy option 5. Adopt landscape management to reduce vulnerability

Extensive monocultures and poorly managed landscapes exacerbate wildfire risk. Transitioning to multifunctional landscapes with mixed land uses can improve fire resistance while supporting biodiversity, agriculture, and forestry.

Actions

- The use of mosaic landscape structures should be promoted to reduce fuel continuity.
- Foster agroforestry, extensive livestock farming, and rewilding initiatives with large herbivores.
- Manage biomass through prescribed burn, grazing, and mowing
- Restore degraded ecosystems using native species and create linear fuel breaks along roads and energy corridors.

Benefits: Fire-resilient landscapes, diversified rural economies, and ecosystem restoration.

Costs: Reduced short-term economic returns for landowners and potential habitat fragmentation.

Policy option 6. Harmonising sectoral policies to address wildfire risk

Current EU sectoral policies often have unintended consequences that exacerbate wildfire risk. For example, afforestation under the Common Agricultural Policy has led to forest encroachment near residential areas, increasing exposure to wildfire hazards.

[3] https://iucn.org/our-work/topic/iucn-global-standard-nature-based-solutions.

Actions

- Review sectoral policies at all governance levels to assess their wildfire risk implications.
- Promote synergies between policies while addressing trade-offs.
- Strategic environmental assessments are used to evaluate the wildfire risk of national plans and programmes.

Benefits: Avoidance of negative policy spillovers and progress toward integrated, multi-sectoral wildfire policies.

Costs: Increased complexity in policy design and coordination.

Policy option 7. Reducing urban sprawl and fostering compact urban areas

Urban sprawl amplifies wildfire risk by expanding the wildland–urban interface (WUI). Compact urban development can reduce exposure while offering co-benefits such as lower carbon emissions.

Actions

- Encourage compact urban planning and reduce urban sprawl into wildfire-prone areas.
- Wildfire risk management should be integrated into urban planning, particularly in suburban and peri-urban areas.
- Incentivise fire-resistant construction and vegetation in WUI zones.

Benefits: Reduced WUI vulnerability, safer urban environments, and co-benefits such as emissions reduction.

Costs: Potential resistance from developers and property price instability with increased social injustice. Loss of certain ecosystem services in suburban areas.

Policy option 8. Promotion of private sustainable land management practices

Private landowners play a critical role in managing landscapes. However, current practices often fail to adapt to changing wildfire risk and climate conditions, leaving landscapes vulnerable.

Actions

- Encourage diverse and fire-resistant land-use practices in forestry, shrubland, and grassland management that decrease fire risk.
- Provide incentives for silvicultural techniques that reduce biomass density and diversify forest composition.
- Foster extensive grazing and mowing to manage grasslands sustainably.
- The insurance sector should be incentivised for supporting firewise landscape management.

Benefits: Reduced fuel loads, biodiversity conservation, and economic opportunities for rural communities.

Costs: Higher costs may initially occur for sustainable farming and forestry practices, potentially reducing short-term profitability.

Contributors

Director of the EASAC Environment Programme
Thomas Elmqvist, EASAC, Sweden

Authors: Working Group Members
Cathelijne R. Stoof, The Netherlands (Co-Chair)
Orsolya Valkó, Hungary (Co-Chair)
Tuomas Aakala, Finland
Bachisio Arca, Italy
Kemal S. Arsava, Norway
Davide Ascoli, Italy*[4]
Jan Bengtsson, Sweden
Jüri Engelbrecht, Estonia
Urbano Fra Paleo, Spain
Anders Granström, Sweden
Pierre Ibisch, Germany
Kostas Kalabokidis, Greece
Aleksander Marinšek, Slovenia
Maria-Monika Metallinou Log, Norway
Mortimer Müller, Austria
Tiago Oliveira, Portugal
José M. C. Pereira, Portugal
Tobias Plieninger, Germany
Fernando Javier Pulido Díaz, Spain
Jaša Saražin, Slovenia
Todor Stoyanov, Bulgaria
Guido van der Werf, The Netherlands

Further contributions
Margarita Arianoutsou, Greece
Palaiologos Palaiologou, Greece
Fiona Newman Thacker, The Netherlands
Christos Zerefos, Greece (member of the EASAC Environment Steering Panel)

From the Bioscience and Public Health Programme (Chapter 12)
Rosa Castro, EASAC (Director of EASAC Biosciences and Public Health Programme)
Helena Kandárová, Slovakia (member of EASAC Biosciences and Public Health Steering Panel)
André Knottnerus, The Netherlands (Co-Chair of EASAC Biosciences and Public Health Steering Panel)

Peer reviewers
Jean-François Bastin, Belgium
Claire Belcher, UK
Marco Conedera, Switzerland
Helena Freitas, Portugal
Miklós Kertész, Hungary
Marija Kolšek, Slovenia
José Manuel Moreno, Spain
Cristina Santín Nuño, UK
Franziska Schmid, Switzerland
Harald Vacik, Austria

[4] The contribution of Davide Ascoli was within the Italian Agritech National Research Center and received funding from the European Union Next-Generation EU (PIANO NAZIONALE DI RIPRESA E RESILIENZA (PNRR) – MISSIONE 4 COMPONENTE 2, INVESTIMENTO 1.4 – D.D. 1032 June 17, 2022, CN00000022).

Glossary

Direct fire prevention

Proactive measures that directly reduce the likelihood of wildfire ignition or spread by addressing fuels in strategic locations. Examples include mechanical fuel treatments, prescribed burning, and the establishment of firebreaks and fuel breaks.

Ecosystem-based disaster risk reduction (ecoDRR)

Approaches that seek to reduce the adverse impacts of disasters on vulnerable communities and countries through nature-based solutions and ecosystem management.

Fire danger

The likelihood and potential intensity of wildfires in a specific area are influenced by factors such as weather conditions, fuel load, fuel moisture, and vegetation type. Fire danger is often measured by indices such as the fire weather index (FWI).

Fire deficit

The reduced frequency and intensity of wildfires resulting from the exclusion of fires from fire-adapted ecosystems lead to fuel load accumulation and an increased risk of high-intensity damaging fires.

Fire prevention

Actions are taken to reduce both the occurrence and negative impacts of wildfires, including public awareness campaigns, the regulation of fire-prone activities, fuel management, and the maintenance of infrastructure such as firebreaks.

Fire regime

The characteristic patterns of fire occurrence, frequency, intensity, seasonality, and type in a given landscape are shaped by natural and human factors that may change over time.

Fire risk

Fire risk: The probability of a wildfire occurring and its potential impact on ecosystems, human lives, and infrastructure. The potential loss of life, injury, or destroyed or damaged assets that could occur in a system, society, or community in a specific period of time are determined probabilistically as a function of wildfire, hazard exposure, vulnerability to wildfire, and coping capacity (adapted from the Sendai Framework for Disaster Risk Reduction).

Fire risk management

Fire risk management: strategies, plans, and actions to reduce fire risk through prevention, preparedness, response, and recovery measures, integrated across multiple sectors and scales.

Firewise

An approach to managing landscapes and communities that reduces wildfire exposure and vulnerability while maintaining ecological, economic, and cultural value. This includes promoting fire-resilient vegetation, sustainable land use, and community preparedness.

Fire suppression

Immediate emergency response to wildfire consists of control and extinguishment, involving fire response teams, water, equipment, and aerial resources. Fire suppression is a reactive measure focused on limiting wildfire loss and damage.

Fuel management

The modification of vegetation and organic matter – consisting of its reduction – may serve as potential fire fuel to reduce the intensity and spread of wildfires. Techniques include thinning, grazing, prescribed burning, and mechanical removal of biomass.

Indirect fire prevention

Land-use practices that indirectly reduce wildfire risk by promoting economic activities that limit fuel build-up. Examples include agroforestry, sustainable grazing, and the cultivation of fire-resistant crops.

Integrated landscape management

A framework for managing landscapes that balances multiple objectives, such as agriculture, forestry, biodiversity, development, and wildfire prevention. It emphasises collaboration among stakeholders to address interconnected challenges.

Integrated fire management

A holistic approach to wildfire governance that combines prevention, early warning, emergency response and suppression, and soil and vegetation recovery, considering ecological, social, and economic factors. It integrates wildfire policies with broader climate and disaster risk-management strategies.

Key vulnerable element

Critical components of a landscape or community that are particularly susceptible to wildfire impact. These include the human population, communities, infrastructure, industry and energy, biodiversity hotspots, and ecosystem services such as the water supply and air quality.

Landscape fires

Fires occurring in natural or seminatural landscapes, including wildfires and prescribed fires, that affect vegetation and ecosystems. These fires can be either beneficial or detrimental, depending on their context and management.

Landscape vulnerability

The susceptibility of a landscape to wildfire impacts is determined by factors such as fuel load, vegetation type, land use, ecosystem, topography, and climate. Vulnerable landscapes often have fuel continuity and limited coverage of firebreaks.

Natech

Natural hazards can trigger technological accidents.

Nature-based solution

Solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social, and economic benefits, and help build resilience. Such solutions bring increasingly diverse natural and natural features and processes into cities, landscapes, and seascapes through locally adapted, resource-efficient, and systemic interventions.

Prescribed burning

A fuel management technique consisting of the intentional use of fire under controlled conditions to reduce fuel loads, promote biodiversity, or achieve other land-management objectives. Prescribed burns are carefully planned and monitored to avoid unintended consequences.

Proactive approach

Fire management strategies and actions aimed at preventing the occurrence of fires and mitigating wildfire risk. These include fuel management, community awareness programmes, and the adoption of firewise land-use practices.

Salvage logging

Economically motivated practice of logging trees in forest areas that have been damaged by wildfire or other natural disturbances. The removal of damaged trees after a wildfire to mitigate ecological or social damage in the affected areas is not referred to as salvage logging in this report.

Vapour pressure deficit

The vapour pressure deficit is the difference between the amount of moisture present in the air and the potential amount of moisture the air can contain when it is saturated; also expressed as air relative humidity, presented in weather forecasts.

Wildfire

Unplanned or uncontrolled fires affect vegetation across natural, cultural, industrial, and residential areas (adapted from FAO, 2006). They are driven by weather conditions, fuel availability, and human activity. Wildfires can cause significant ecological, economic, and social impacts.

Wildland–urban interface (WUI)

The zone where natural landscapes meet urban and suburban areas, such as residential areas adjacent to forests or shrubland. The WUI is particularly vulnerable to wildfires because of the presence of flammable vegetation, population, assets, cultural and natural heritage, infrastructure, industry, and energy.

Abbreviations

EASAC	European Academies Science Advisory Council
EFFIS	European Forest Fire Information System
EU	European Union
PM	Particulate matter
WUI	Wildland–urban interface

References

Abeli, T. and Di Giulio, A. (2023). Risks of massive tree planting in Europe should be considered by the EU Forestry Strategy 2030. *Restoration Ecology* **31**, e13834. https://doi.org/10.1111/rec.13834.

Acácio, V., Holmgren, M., Jansen, P. A. and Schrotter, O. (2007). Multiple recruitment limitations cause arrested succession in Mediterranean cork oak systems. *Ecosystems* **10**, 1220–1230.

Ager, A. A., Day, M. A., Alcasena, F. J., Evers, C. R., Short, K. C. and Grenfell, I. (2021). Predicting paradise: modelling future wildfire disasters in the western US. *Science of the Total Environment* **784**, 147057.

Agnoletti, M. and Santoro, A. (2018). Rural landscape planning and forest management in Tuscany, Italy. *Forests* **9**, 473.

Andela, N. *et al.* (2017). A human-driven decline in global burned area. *Science* **356**, 1356–1362. doi:10.1126/science.aal4108.

Aparício, B. A., Alcasena, F., Ager, A., Chung, W., Pereira, J. M. and Sá, A. C. (2022). Evaluating priority locations and potential benefits for building a nation-wide fuel break network in Portugal. *Journal of Environmental Management* **320**, 115920.

Arbinolo, M., Patimo, G., Rey, E., Stokkeland, O., Verde, J. C., Casartelli, V., Marengo, A., Melinato, S., Mysiak, J., Salpina, D., Afentoulidis, S., Brăilescu, C. and Sørensen, J. (2024). UCPM Wildfire Peer review report: Greece 2024. https://doi.org/10.25424/CMCC-79TS-VV91.

Archibald, S., Lehmann, C. E., Belcher, C. M., Bond, W. J., Bradstock, R. A., Daniau, A. L. *et al.* (2018). Biological and geophysical feedbacks with fire in the Earth system. *Environmental Research Letters* **13**(3), 033003.

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

Ascoli, D., Moris, J. V., Marchetti, M. and Sallustio, L. (2021). Land use change towards forests and wooded land correlates with large and frequent wildfires in Italy. *Annals of Silvicultural Research*, **46**(2), 177–188. https://doi.org/10.12899/asr-2264.

Ascoli, D., Plana, E., Oggioni, S. D., Tomao, A., Colonico, M., Corona, P. *et al.* (2023). Fire-smart solutions for sustainable wildfire risk prevention: Bottom-up initiatives meet top-down policies under EU green deal. *International Journal of Disaster Risk Reduction* **92**, 103715.

Bachantourian, M., Kalabokidis, K., Palaiologou, P. and Chaleplis, K. (2023). Optimizing fuel treatments allocation to protect the wildland–urban Interface from large-scale wildfires in Greece. *Fire* **6**(2), 75.

Bansal, A., Cherbuin, N., Davis, D. L., Peek, M. J., Wingett, A., Christensen, B. K. *et al.* (2023). Heatwaves and wildfires suffocate our healthy start to life: Time to assess impact and take action. *Lancet Planetary Health* **7**(8), e718–e725.

Barbosa, J. V., Nunes, R. A., Alvim-Ferraz, M. C., Martins, F. G. and Sousa, S. I. (2024). Health and economic burden of wildland fires PM2. 5-related pollution in Portugal – a longitudinal study. *Environmental Research* **240**, 117490.

Bar-Massada, A., Alcasena, F., Schug, F. and Radeloff, V. C. (2023). The wildland–urban interface in Europe: spatial patterns and associations with socioeconomic and demographic variables. *Landscape and Urban Planning* **235**, 104759.

Barnes, C. *et al.* (2025). Climate change increased the likelihood of wildfire disaster in highly exposed Los Angeles area. World Weather Attribution. https://www.worldweatherattribution.org/climate-change-increased-the-likelihood-of-wildfire-disaster-in-highly-exposed-los-angeles-area/.

Barragán, G., Wang, T. and Rhemtulla, J. M. (2023). Trees planted under a global restoration pledge have mixed futures under climate change. *Restoration Ecology* **31**(3), e13764.

Barreiro S., Benali A., Rua J. C. P., Tomé M. and Pereira, J. M. C. (2021). Combining landscape fire simulations with stand-level growth simulations to assist landowners in building wildfire resilient landscapes. *Forests* **12**(11), 1498.

Barros, A. M. G. and Pereira, J. M. C. (2014). Wildfire selectivity for land cover type: does size matter? *PLoS ONE* **9**, e84760.

Bartosz-Sroka, A. (2019). Fire roads - Drogi pożarowe w lesie. Nadleśnictwo Cierpiszewo https://cierpiszewo.torun.lasy.gov.pl/aktualnosci/-/asset_publisher/1M8a/content/drogi-pozarowe-w-lesie.

Bastin, J. F., Finegold, Y., Garcia, C., Mollicone, D., Rezende, M., Routh, D. *et al.* (2019). The global tree restoration potential. *Science* **365**(6448), 76-79.

Bednar-Friedl, B., Biesbroek, R., Schmidt, D. N., Alexander, P., Børsheim, K. Y., Carnicer, J. *et al.* (2022). Europe (Chapter 13).

Benali, A., Sá, A. C. L., Pinho, J., Fernandes, P. M. and Pereira, J. M. C. (2021). Understanding the impact of different landscape-level fuel management strategies on wildfire hazard in central Portugal. *Forests* **12**(5), 522. https://doi.org/10.3390/f12050522.

Bénichou N., Adelzadeh, M., Singh, J., Gomaa, I., Elsagan, N., Kinateder, M., Ma, C., Gaur, A., Bwalya, A. and Sultan, M. (2021). National Guide for Wildland-Urban Interface Fires. National Research Council Canada. https://doi.org/10.4224/40002647.

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* **11**(4), 465.

Beverly, J. L., Leverkus, S. E., Cameron, H. and Schroeder, D. (2020). Stand-level fuel reduction treatments and fire behaviour in Canadian boreal conifer forests. *Fire* **3**(3), 35.

Bird, M. I. *et al.* (2024). Late Pleistocene emergence of an anthropogenic fire regime in Australia's tropical savannahs. *Nature Geoscience* **17**, 233–240.

Blumröder, J. S. and Ibisch, P. L. (2023). Wald- und Forstbrände im Klimawandel. *Geographische Rundschau* **11**, 32–36.

Blumröder, J. S., F. Schmidt, A., Grosse, G. S. and Ibisch, P. L. (2022). Ecosystemic resilience of a temperate postfire forest under extreme weather conditions. *Frontiers in Forests and Global Change* **5**. https://doi.org/10.3389/ffgc.2022.1070958.

Blumröder, J. S., May, F., Härdtle, W. and Ibisch, P. L. (2021). Forestry contributed to warming of forest ecosystems in northern Germany during the extreme summers of 2018 and 2019. *Ecological Solutions and Evidence* **2**(3), e12087.

Bond, W. J. and Keeley, J. E. (2005). Fire as a global 'herbivore': the ecology and evolution of flammable ecosystems. *Trends in Ecology & Evolution* **20**(7), 387–394.

Bond, W. J., Woodward, F. I. and Midgley, G. F. (2005). The global distribution of ecosystems in a world without fire. *New Phytologist* **165**(2), 525–538.

Bowman, D. M., Perry, G. L., Higgins, S. I., Johnson, C. N., Fuhlendorf, S. D. and Murphy, B. P. (2016). Pyrodiversity is the coupling of biodiversity and fire regimes in food webs. *Philosophical Transactions of the Royal Society B: Biological Sciences* **371**(1696), 20150169.

Bowman, W. S., Schmidt, R. J., Sanghar, G. K. *et al.* (2024). "Air That Once Was Breath" Part 1: Wildfire-smoke-induced mechanisms of airway inflammation. – "Climate Change, Allergy and Immunology" Special IAAI Article Collection: Collegium Internationale Allergologicum Update 2023. *International Archives of Allergy and Immunology* **185**(6), 600–616. https://doi.org/10.1159/000536578.

Bowring, S. P. K., Jones, M. W., Ciais, P., Guenet, B. and Abiven, S. (2022). Pyrogenic carbon decomposition critical to resolving fire's role in the Earth system. *Nature Geoscience* **15**(2), 135. doi: 10.1038/s41561-021-00892-0.

Brenkert-Smith, H., Champ, P. A. and Flores, N. (2012). Trying not to get burned: understanding homeowners' wildfire risk-mitigation behaviors. *Environmental Management* **50**, 1139–1151.

Brown, T. P., Duff, T. J., Inbar, A., Lane, P. N. and Sheridan, G. J. (2024). Forest reorganisation effects on fuel moisture content can exceed changes due to climate warming in wet temperate forests.

Global Change Biology **30**(1), e17023. https://doi.org/10.1111/gcb.17023.
Brundu, G. and Richardson, D. M. (2016). Planted forests and invasive alien trees in Europe: a code for managing existing and future plantings to mitigate the risk of negative impacts from invasions. *NeoBiota* **30**, 5–47. doi:10.3897/neobiota.30.7015. http://neobiota.pensoft.net.
Cansler, C. A., Kane, V. R., Hessburg, P. F., Kane, J. T., Jeronimo, S. M., Lutz, J. A. *et al.* (2022). Previous wildfires and management treatments moderate subsequent fire severity. *Forest Ecology and Management* **504**, 119764.
Carnicer, J., Alegria, A., Giannakopoulos, C., Di Giuseppe, F., Karali, A., Koutsias, N. *et al.* (2022). Global warming is shifting the relationships between fire weather and realized fire-induced CO_2 emissions in Europe. *Scientific Reports* **12**(1), 10365.
Castellnou, M., Prat-Guitart, N., Arilla, E., Larrañaga, A., Nebot, E., Castellarnau, X. *et al.* (2019). Empowering strategic decision-making for wildfire management: avoiding the fear trap and creating a resilient landscape. *Fire Ecology* **15**, 1–17.
Castro, J., Morales-Rueda, F., Navarro, F. B., Löf, M., Vacchiano, G. and Alcaraz-Segura, D. (2021). Precision restoration: a necessary approach to foster forest recovery in the 21st century. *Restoration Ecology* **29**(7), e13421.
Cervera, T., Pino, J., Marull, J., Padró, R. and Tello, E. (2019). Understanding the long-term dynamics of forest transition: From deforestation to afforestation in a Mediterranean landscape (Catalonia, 1868–2005). *Land Use Policy* **80**, 318–331. https://doi.org/10.1016/j.landusepol.2016.10.006.
Chen, Y., Hall, J., van Wees, D., Andela, N., Hantson, S., Giglio, L., van der Werf, G. R., Morton, D. C. and Randerson, J. T. (2023). Multidecadal trends and variability in burned area from the fifth version of the Global Fire Emissions Database (GFED5). *Earth System Science Data* **15**, 5227–5259. https://doi.org/10.5194/essd-15-5227-2023.
Cochrane, M. A. and Bowman, D. M. (2021). Manage fire regimes, not fires. *Nature Geoscience* **14**(7), 455–457.
Collins R. D., De Neufville R., Claro J., Oliveira T. and Pacheco A. P. (2013). Forest fire management to avoid unintended consequences: a case study of Portugal using system dynamics. *Journal of Environmental Management* **130**, 1–9.
Connolly, R., Marlier, M. E., Garcia-Gonzales, D. A., Wilkins, J., Su, J., Bekker, C. *et al.* (2024). Mortality attributable to $PM_{2.5}$ from wildland fires in California from 2008 to 2018. *Science Advances* **10**(23), eadl1252.
Copernicus (2024). Virtually certain to be the warmest year and first year above 1.5°C I Copernicus.
CTIF (2024). International Association of Fire and Rescue Services – member countries. https://ctif.org/member-countries.
Cunningham, C. X., Williamson, G. J. and Bowman, D. M. J. S. (2024). Increasing frequency and intensity of the most extreme wildfires on Earth. *Nature Ecology and Evolution* **8**, 1420–1425. https://doi.org/10.1038/s41559-024-02452-2.
Damianidis, C., Santiago-Freijanes, J. J., den Herder, M., Burgess, P., Mosquera-Losada, M. R., Graves, A., Papadopoulos, A., Pisanelli, A., Camilli, F., Rois-Díaz, M. and Kay, S. (2020). Agroforestry as a sustainable land use option to reduce wildfires risk in European Mediterranean areas. *Agroforestry Systems* **95**, 1–11.
Davies, B., Power, M. J., Braun, D. R., Douglass, M. J., Mosher, S. G., Quick, L. J. *et al.* (2022). Fire and human management of late Holocene ecosystems in southern Africa. *Quaternary Science Reviews*, **289**, 107600.
Davies, I. P., Haugo, R. D., Robertson, J. C. and Levin, P. S. (2018). The unequal vulnerability of communities of color to wildfire. *PloS ONE* **13**(11), e0205825.
Davim, D. A., Rossa, C. G., Pereira, J. M. and Fernandes, P. M. (2022). The effect of prescribed burning in decreasing wildfire extent in Portugal. *Environmental Sciences Proceedings* **17**(1), 36.
Davis, D. K. and Robbins, P. (2018). Ecologies of the colonial present: pathological forestry from the *taux de boisement* to civilized plantations. *Environment and Planning E: Nature and Space* **1**(4), 447–469. https://doi.org/10.1177/25148 48618 812029.
Dore, S., Kolb, T. E. and Montes-Helu, M. (2008). Long-term impact of stand-replacing fire on ecosystem CO_2 exchange of a ponderosa pine forest. *Global Change Biology* **14**, 1801–1820.
Duveiller, G., Hooker, J. and Cescatti, A. (2018). The mark of vegetation change on Earth's surface energy balance. *Nature Communications* **9**, 679. doi:10.1038/s41467-017-02810-8.
EASAC (2019). The imperative of climate action to protect human health in Europe, https://easac.eu/fileadmin/PDF_s/reports_statements/Climate_Change_and_Health/EASAC_CCH_Main_Report_WEB_2August.pdf.
EFFIS (2024). European Forest Fire Information System https://forest-fire.emergency.copernicus.eu/ (March, 2024).
El Garroussi, S., Di Giuseppe, F., Barnard, C. *et al.* (2024). Europe faces up to tenfold increase in extreme fires in a warming climate. *Climate and Atmospheric Science* **7**, 30. https://doi.org/10.1038/s41612-024-00575-8.
Esper, J., Torbenson, M. and Büntgen, U. (2024). 2023 summer warmth unparalleled over the past 2,000 years. *Nature* **631**(8019), 94–97. https://www.nature.com/articles/s41586-024-07512-y.
Essen, M., McCaffrey, S., Abrams, J. and Paveglio, T. (2023). Improving wildfire management outcomes: shifting the paradigm of wildfire from simple to complex risk. *Journal of Environmental Planning and Management* **66**(5), 909–927.
European Environment Agency (2020). The European Environment – state and outlook, knowledge for transition to a sustainable Europe. https://www.eea.europa.eu/en/topics/in-depth/land-use Eurostat, 2020. Share of main land types in utilized agricultural area (UAA) by NUTS 2.
Ewald, M., Labenski, P., Westphal, E., Metzsch-Zilligen, E., Großhauser, M. and Fassnacht, F. E. (2023). Leaf litter combustion properties of Central European tree species. *Forestry* **98**(1), cpad026.
FAO (2006). Fire management: voluntary guidelines: principles and strategic actions. FAO Fire Management Working Paper 17.
FAO (2024) Fire management: voluntary guidelines: principles and strategic actions. FAO Fire Management Working Paper 17. https://www.fao.org/forestry-fao/firemanagement/en/ https://openknowledge.fao.org/items/12eb1bc4-ce90-4901-a2f6-ba2f83fd9e38.
Fernandes, M. E. and Simões, P. (2024). Private forest owners' organizations adherence to policy tools. Insights from Portugal. *Forest Policy and Economics* **160**, 103147.
Fernandes, P. M. (2009). Combining forest structure data and fuel modelling to classify fire hazard in Portugal. *Annals of Forest Science* **66**, 415.
Fernandes, P. M. (2013). Fire-smart management of forest landscapes in the Mediterranean basin under global change. *Landscape and Urban Planning*, **110**, 175-182.
Fernandes, P. M., Davies, G. M., Ascoli, D., Fernández, C., Moreira, F., Rigolot, E. *et al.* (2013). Prescribed burning in southern Europe: developing fire management in a dynamic landscape. *Frontiers in Ecology and the Environment* **11**(s1), e4–e14.
Fernandes, P. M., Delogu, G. M., Leone, V. and Ascoli, D. (2020). Wildfire policies contribution to foster extreme wildfires. In Extreme wildfire events and disasters (pp. 187–200). Elsevier.
Fernandes, P. M., Guiomar, N. and Rossa, C. G. (2019). Analysing eucalypt expansion in Portugal as a fire-regime modifier. *Science of the Total Environment* **666**, 79–88.
Fernandes, P. M., Monteiro-Henriques, T., Guiomar, N., Loureiro, C. and Barros, A. M. (2016). Bottom-up variables govern large-fire size in Portugal. *Ecosystems* **19**, 1362–1375.
Feurdean, A., Liakka, J., Vannière, B., Marinova, E., Hutchinson, S. M., Mosburgger, V. and Hickler, T. (2013). 12,000-Years of fire regime drivers in the lowlands of Transylvania (Central-Eastern Europe): a data-model approach. *Quaternary Science Reviews* **81**, 48–61.
Feurdean, A., Vannière, B., Finsinger, W., Warren, D., Connor, S. C., Liakka, J. *et al.* (2020). Fire risk modulation by long-term dynamics in land cover and dominant forest type in Eastern and Central Europe. *Biogeosciences* **17**, 1213–1230.

Finlay, S. E., Moffat, A., Gazzard, R., Baker, D. and Murray, V. (2012). Health impacts of wildfires. *PLoS Currents* **4**. doi:10.1371/4f959951cce2c.

Fra Paleo, U. (editor) (2009). *Building Safer Communities. Risk Governance, Spatial Planning and Responses to Natural Hazards*. Amsterdam: IOS Press.

Fra Paleo, U. (editor) (2015). *Risk governance. The Articulation of Hazard, Politics and Ecology*. Dordrecht: Springer.

Frelich, L. E., Johnstone, J., Kuuluvainen, T. (2024). Boreal forests. In *Future Forests* (pp. 221–242). Elsevier.

Ganteaume, A., Camia, A., Jappiot, M. *et al.* (2013). A review of the main driving factors of forest fire ignition over Europe. *Environmental Management* **51**, 651–662. https://doi.org/10.1007/s00267-012-9961-z.

Gjedrem, A. M. and Metallinou, M. M. (2023). Wildland-urban interface fires in Norwegian coastal heathlands – identifying risk reducing measures. *Safety Science* **159**, 1–32, https://doi.org/10.1016/j.ssci.2022.106032.

Glasspool, I. J., Edwards, D. and Axe, L. (2004). Charcoal in the Silurian as evidence for the earliest wildfire. *Geology* **32**, 381–383. https://doi.org/10.1130/G20363.1.

Gohr, C., Blumröder, J. S., Sheil, D. and Ibisch, P. L. (2021). Quantifying the mitigation of temperature extremes by forests and wetlands in a temperate landscape. *Ecological Informatics* **66**, 101442.

Gonzalez-Mathiesen, C. and March, A. (2018). Establishing design principles for wildfire resilient urban planning. *Planning Practice & Research* **33**(2), 97–119.

Gould, C. F., Heft-Neal, S., Johnson, M., Aguilera, J., Burke, M. and Nadeau, K. (2024). Health effects of wildfire smoke exposure. *Annual Review of Medicine* **75**(1), 277–292.

Grant, E. and Runkle, J. D. (2022). Long-term health effects of wildfire exposure: a scoping review. *Journal of Climate Change and Health* **6**, 100110.

Grasso, P. and Innocente, M. S. (2020). Physics-based models of wildfire propagation towards faster-than-real-time simulation. *Computers & Mathematics with Applications* 80790–80808. https://doi.org/10.1016/j.camwa.2020.05.009.

Graus, S., Ferreira, T. M., Vasconcelos, G. and Ortega, J. (2024). Changing conditions: global warming-related hazards and vulnerable rural populations in Mediterranean Europe. *Urban Science* **8**, 42. https://doi.org/10.3390/urbansci8020042.

Gray, A., Davies, G. M., Doménech, R., Taylor, E. and Levy, P. E. (2021). Peatland wildfire severity and postfire gaseous carbon fluxes. *Ecosystems* **24**, 713–725. https://doi.org/10.1007/s10021-020-00545-0.

Greiser, C., Hederová, L., Vico, G., Wild, J., Macek, M. and Kopecký, M. (2024). Higher soil moisture increases microclimate temperature buffering in temperate broadleaf forests. *Agricultural and Forest Meteorology* **345**, 109828.

Grünig, M., Seidl, R. and Senf, C. (2023). Increasing aridity causes larger and more severe forest fires across Europe. *Global Change Biology* **29**(6), 1648–1659.

Guiomar, N. G., Pereira, J. M. and Fernandes, P. M. (2023). A planning model for fire-resilient landscapes in Portugal is riddled with fallacies: a critical review of "FIRELAN" by Magalhães *et al*., 2021. *Fire* **6**(10), 398.

Halada, L., Evans, D., Romão, C. and Petersen, J. E. (2011). Which habitats of European importance depend on agricultural practices? *Biodiversity and Conservation* **20**, 2365–2378.

He, T., Lamont, B. B. and Pausas, J. G. (2019). Fire as a key driver of Earth's biodiversity. *Biological Reviews* **94**(6), 1983–2010.

Hearn, K. P. and Álvarez-Mozos, J. (2021). A diachronic analysis of a changing landscape on the Duero river borderlands of Spain and Portugal combining remote sensing and ethnographic approaches. *Sustainability (Switzerland)*, **13**(24). https://doi.org/10.3390/su132413962.

Hermoso, V., Regos, A., Morán-Ordóñez, A., Duane, A. and Brotons, L. (2021). Tree planting: a double-edged sword to fight climate change in an era of megafires. *Global Change Biology* **27**(13), 3001–3003.

Hetzer, J. *et al.* (2024). The fire weather in Europe: large-scale trends towards higher danger. *Environmental Research Letters* **19**(8), 084017. https://doi.org/10.1088/1748-9326/ad5b09.

Hugelius, G. *et al.* (2020). Large stocks of peatland carbon and nitrogen are vulnerable to permafrost thaw. *Earth, Atmospheric and Planetary Sciences* **117**(34), 20438–20446. https://doi.org/10.1073/pnas.191638711.

InterAcademy Partnership (2022). Health in the climate emergency: a global perspective. https://www.interacademies.org/sites/default/files/2022-08/Health%20in%20the%20Climate%20Emergency_A%20global%20perspective_IAP%20report.pdf.

Intini, P., Ronchi, E., Gwynne, S. *et al.* (2020). Guidance on design and construction of the built environment against wildland urban interface fire hazard: a review. *Fire Technology* **56**, 1853–1883. https://doi.org/10.1007/s10694-019-00902-z.

IPCC (2021). Summary for policymakers. In: *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (Masson-Delmotte, V., Zhai, P., Pirani, A., Connors, S. L., Péan, C., Berger, S., Caud, N., Chen, Y., Goldfarb, L., Gomis, M. I., Huang, M., Leitzell, K., Lonnoy, E., Matthews, J. B. R., Maycock, T. K., Waterfield, T., Yelekçi, Ö., Yu, R. and Zhou, B., eds.).

Jaffe, M. R., Kreider, M. R., Affleck, D. L., Higuera, P. E., Seielstad, C. A., Parks, S. A. and Larson, A. J. (2023). Mesic mixed-conifer forests are resilient to both historical high-severity fire and contemporary reburns in the US Northern Rocky Mountains. *Forest Ecology and Management* **545**, 121283.

Jepsen, M. R., Kuemmerle, T., Müller, D., Erb, K., Verburg, P. H., Haberl, H. *et al.* (2015). Transitions in European land-management regimes between 1800 and (2010). *Land Use Policy* **49**, 53–64. https://doi.org/10.1016/j.landusepol.2015.07.003.

Johnstone, J. F., Celis, G., Chapin III, F. S., Hollingsworth, T. N., Jean, M. and Mack, M. C. (2020). Factors shaping alternate successional trajectories in burned black spruce forests of Alaska. *Ecosphere* **11**(5), e03129.

Jones, G. M. and Tingley, M. W. (2022). Pyrodiversity and biodiversity: a history, synthesis and outlook. *Diversity and Distributions* **28**(3), 386–403. https://doi.org/10.1111/ddi.13280.

Jones, M. W., Santín, C., van der Werf, G. R. and Doerr, S. H. (2019). Global fire emissions buffered by the production of pyrogenic carbon. *Nature Geoscience* **12**(9), 742–747.

Jonsson, M. J., Bengtsson, L., Gamfeldt, J., Moen, J. and Snäll, T. (2019). Levels of forest ecosystem services depend on specific mixtures of commercial tree species. *Nature Plants* **5**, 141–147.

Kahraman, A. *et al.* (2022). Contrasting future lightning stories across Europe. *Environmental Research Letters* **17**, 114023. DOI 10.1088/1748-9326/ac9b78.

Kaland, P. E. (1986). The origin and management of Norwegian coastal heaths as reflected by pollen analysis. *Anthropogenic Indicators in Pollen Diagrams* **19**, 36.

Kalies, E. L. and Kent, L. L. Y. (2016). Tamm review: are fuel treatments effective at achieving ecological and social objectives? A systematic review. *Forest Ecology and Management* **375**, 84–95.

Kasischke, E. S., Christensen Jr, N. L. and Stocks, B. J. (1995). Fire, global warming and the carbon balance of boreal forests. *Ecological Applications* **5**(2) 437–451.

Kelly, L. T. and Brotons, L. (2017). Using fire to promote biodiversity. *Science* **355**(6331), 1264–1265.

Kooiman, J. (2003). *Governing as Governance*. London: Sage.

Kotroni, V. and Lagouvardos, K. (2008). Lightning occurrence in relation with elevation, terrain slope and vegetation cover in the Mediterranean. *Journal of Geophysical Research: Atmospheres* **113**(D21).

Krebs, P., Pezzatti, G. B., Mazzoleni, S. *et al.* (2010). Fire regime: history and definition of a key concept in disturbance ecology. *Theory in Biosciences* **129**, 53–69. https://doi.org/10.1007/s12064-010-0082-z.

Kuemmerle, T., Levers, C., Erb K., Estel, S., Jepsen, M. R., Müller, D., Plutzar, C., Stürck, J., Verkerk, P.J., Verburg, P. H. and Reenberg,

A. (2016). Hotspots of land use change in Europe. *Environmental Research Letters* **11**(6), 064020.
Körner, C. (2003). Slow in, rapid out – carbon flux studies and Kyto targets. *Science* **300**, 1242–1243.
Lal, R. (2020). Soil organic matter and water retention. *Agronomy Journal* **112**(5), 3265–3277.
Lambrechts, H. A., Paparrizos, S., Brongersma, R., Kroeze, C., Ludwig, F. and Stoof, C. R. (2023). Governing wildfire in a global change context: lessons from water management in the Netherlands. *Fire Ecology* **19**(1), 6.
Landesmann, J. B., Tiribelli, F., Paritsis, J., Veblen, T. T. and Kitzberger, T. (2021). Increased fire severity triggers positive feedbacks of greater vegetation flammability and favours plant community-type conversions. *Journal of Vegetation Science* **32**(1), e12936.
Lasanta, T., Cortijos-López, M., Errea, M. P., Khorchani, M. and Nadal-Romero, E. (2022). An environmental management experience to control wildfires in the mid-mountain mediterranean area: shrub clearing to generate mosaic landscapes. *Land Use Policy* **118**, 106147.
Laschi, A., Foderi, C., Fabiano, F., Neri, F., Cambi, M., Mariotti, B. and Marchi, E. (2019). Forest road planning, construction and maintenance to improve forest fire fighting: a review. *Croatian Journal of Forest Engineering* **40**(1), 207–219.
Leal, O. A., Dick D. P., de la Rosa, J. M., Barbosa Leal, D. P., González-Pérez, J. A., Campos, G. S. and Knicker, H. (2019). Charcoal fine residues effects on soil organic matter humic substances, composition and biodegradability. *Agronomy* **9**, 384. doi:10.3390/agronomy9070384.
Lecina-Diaz, J., Chas-Amil, M. L., Aquilué, N., Sil, Â., Brotons, L., Regos, A. and Touza, J. (2023). Incorporating fire-smartness into agricultural policies reduces suppression costs and ecosystem services damages from wildfires. *Journal of Environmental Management* **337**, 117707. https://doi.org/10.1016/j.jenvman.2023.117707.
Lindberg, H., Punttila, P. and Vanha-Majamaa, I. (2020). The challenge of combining variable retention and prescribed burning in Finland. *Ecological Processes* **9**(1), 4.
Lizundia-Loiola, J., Otón, G., Ramo, R. and Chuvieco, E. (2020). A spatio-temporal active-fire clustering approach for global burned area mapping at 250 m from MODIS data. *Remote Sensing of Environment* **236**, 111493. https://doi.org/10.1016/j.rse.2019.111493.
Lucas-Borja, M. E., Plaza-Álvarez, P. A., Yáñez, M. D. C., Miralles, I., Ortega, R., Soria, R. *et al.* (2024). Long-term evaluation of soil functionality in Mediterranean forests after a wildfire and postfire hillslope stabilization. *Forest Ecology and Management* **555**, 121715.
MacDonald, D., Crabtree, J. R., Wiesinger, G., Dax, T., Stamou, N., Fleury, P., Gutierrez Lazpita, J. and Gibon, A. (2000). Agricultural abandonment in mountain areas of Europe: Environmental consequences and policy response. *Journal of Environmental Management* **59**(1), 47–69. https://doi.org/10.1006/jema.1999.0335.
Mack M. C., Walker, X. J., Johnstone, J. F., Alexander, H. D., Melvin, A. M., Jean, M. and Miller, S. N. (2021). Carbon loss from boreal forest wildfires offset by increased dominance of deciduous trees. *Science* **372**, 280–283.
Maezumi, S. Y., Fletcher, M. S., Safford, H. and Roberts, P. (2024). Fighting with fire: Historical ecology and community-based approaches to fire management, stewardship and ecosystem resilience. *One Earth* **7**(6), 936–941.
Malmström, A. (2010). The importance of measuring fire severity—evidence from microarthropod studies. *Forest Ecology and Management* **260**(1), 62–70.
Mantero, G., Morresi, D., Marzano, R., Motta, R., Mladenoff, D. J. and Garbarino, M. (2020). The influence of land abandonment on forest disturbance regimes: a global review. *Landscape Ecology* **35**(12), 2723–2744. https://doi.org/10.1007/s10980-020-01147-w.
Marco, G. and Bo, X. (2013). Air quality legislation and standards in the European union: background, status and public participation. *Advances in Climate Change Research* **4**(1), 50–59.
Marcolin, E., Marzano, R., Vitali, A., Garbarino, M. and Lingua, E. (2019). Postfire management impact on natural forest regeneration through altered microsite conditions. *Forests* **10**, 1014. doi:10.3390/f10111014.
Maringer, J., Ascoli, D., Dorren, L., Bebi, P. and Conedera, M. (2016). Temporal trends in the protective capacity of burnt beech forests (*Fagus sylvatica* L.) against rockfall. *European Journal of Forest Research* **135**, 657–673.
Matsala, M., Odruzhenko, A., Hinchuk, T. *et al.* (2024). War drives forest fire risks and highlights the need for more ecologically-sound forest management in post-war Ukraine. *Scientific Reports* **14**, 4131. https://doi.org/10.1038/s41598-024-54811-5.
Mauri, E., Hernández Paredes, E., Núñez Blanco, I. and Garcia Feced, C. (2023). Key recommendations on wildfire prevention in the Mediterranean. European Forest Institute.
McGranahan, D. A. and Wonkka, C. L. (2018). Wildland fire science literacy: education, creation and application. *Fire* **1**(3), 52.
McWethy, D. B. *et al.* (2019). Rethinking resilience to wildfire. *Nature Sustainability* **2**, 797–804. https://doi.org/10.1038/s41893-019-0353-8.
Meddens, A. J., Kolden, C. A., Lutz, J. A., Smith, A. M., Cansler, C. A., Abatzoglou, J. T. *et al.* (2018). Fire refugia: what are they and why do they matter for global change? *BioScience* **68**(12), 944–954.
Menemenlis D., Palaiologou P. and Kalabokidis K. (2023). Wildfire-residential risk analysis using building characteristics and simulations to enhance structural fire resistance in Greece. *Fire* **6**(10), 403.
Milicevic, V. (2023). The European Union and forests. Fact Sheets on the European Union. www.europarl.europa.eu/factsheets/en.
Millennium Ecosystem Assessment (2005). *Ecosystems and Human Well-being: Synthesis*. Washington, DC: Island Press.
Millikin, R. L., Braun, W. J., Alexander, M. E. and Fani, S. (2023). Unintended effects of fuel thinning on the microclimate in the coastal forests of southwestern British Columbia, Canada. *Preprints* 2023, 2023101426. https://doi.org/10.20944/preprints202310.1426.v1.
Milner-Gulland, E. J., McGregor, J. A., Agarwala, M., Atkinson, G., Bevan, P., Clements, T., Daw, T., Homewood, K., Kumpel, N., Lewis, J. and Mourato, S. (2014). Accounting for the impact of conservation on human well-being. *Conservation Biology* **28**(5), 1160–1166.
Miralles, D. G., Gentine, P., Seneviratne, S. I. and Teuling, A. J. (2019). Land–atmospheric feedbacks during droughts and heatwaves: state of the science and current challenges. *Annals of the New York Academy of Sciences* **1436**(1), 19–35.
Mirra, I. M., Oliveira, T. M., Barros, A. M. and Fernandes, P. M. (2017). Fuel dynamics following fire hazard reduction treatments in blue gum (*Eucalyptus globulus*) plantations in Portugal. *Forest Ecology and Management* **398**, 185–195.
Molina, J. R., González-Cabán, A. and y Silva, F. R. (2019). Wildfires impact on the economic susceptibility of recreation activities: application in a Mediterranean protected area. *Journal of Environmental Management* **245**, 454–463.
Morales-Molino, C., Vescovi, E., Krebs, P., Carlevaro, E., Kaltenrieder, P., Conedera, M. *et al.* (2015). The role of human-induced fire and sweet chestnut (Castanea sativa Mill.) cultivation on the long-term landscape dynamics of the southern Swiss Alps. *The Holocene* **25**(3), 482–494.
Moreira, F. and Pe'er, G. (2018). Agricultural policy can reduce wildfires. *Science* **359**(6379), 1001–1001.
Moreira, F., Ascoli, D., Safford, H., Adams, M. A., Moreno, J. M., Pereira, J. M., Catry, F. X., Armesto, J., Bond, W. and González, M. E. (2020). Wildfire management in Mediterranean-type regions: Paradigm change needed. *Environmental Research Letters* **15**(1), 011001.
Moreira, F., Viedma, O., Arianoutsou, M., Curt, T., Koutsias, N., Rigolot, E., Barbati, A., Corona, P., Vaz, P., Xanthopoulos, G., Mouillot, F. and Bilgili, E. (2011). Landscape - wildfire interactions in southern Europe: Implications for landscape management.

Journal of Environmental Management **92**(10), 2389–2402. https://doi.org/10.1016/j.jenvman.2011.06.028.
Moritz, M. A., Batllori, E., Bradstock, R. A., Gill, A. M., Handmer, J., Hessburg, P. F., Leonard, J., McCaffrey, S., Odion, D. C., Schoennagel, T. and Syphard, A. D. (2014). Learning to coexist with wildfire. *Nature* **515**, 58–66.
Moritz, M. A., Morais, M. E., Summerell, L. A., Carlson, J. M. and Doyle, J. (2005). Wildfires, complexity and highly optimized tolerance. *Proceedings of the National Academy of Sciences of the USA* **102**(50), 17912–17917.
Moser, B., Temperli, C., Schneiter, G. and Wohlgemuth, T. (2010). Potential shift in tree species composition after interaction of fire and drought in the Central Alps. *European Journal of Forest Research* **129**, 625–633.
Müller M. M., Vilà-Vilardell L. and Vacik H. (2020): Forest fires in the Alps – state of knowledge, future challenges and options for an integrated fire management. EUSALP Action Group 8.
Muona, J. and Rutanen, I. (1994). The short-term impact of fire on the beetle fauna in boreal coniferous forest. *Annales Zoologici Fennici* **31**(1): 109–121.
Newsham, N. and Rowe, F. (2023). Understanding trajectories of population decline across rural and urban Europe: a sequence analysis. *Population, Space and Place* **29**(3), e2630.
Niklasson, M. and Granström, A. (2000). Numbers and sizes of fires: long-term spatially explicit fire history in a Swedish boreal landscape. *Ecology* **81**(6), 1484–1499.
Novick, K. A., Ficklin, D. L., Grossiord, C., Konings, A. G., Martínez-Vilalta, J., Sadok, W. *et al.* (2024). The impacts of rising vapour pressure deficit in natural and managed ecosystems. *Plant, Cell & Environment* **47**, 3561–3589. https://doi.org/10.1111/pce.14846.
Oliveira, T. M., Barros, A. M., Ager, A. A. and Fernandes, P. M. (2016). Assessing the effect of a fuel break network to reduce burnt area and wildfire risk transmission. *International Journal of Wildland Fire* **25**(6), 619–632.
Oliveira, T. M., Guiomar, N., Baptista, F. O., Pereira, J. M. and Claro, J. (2017). Is Portugal's forest transition up in smoke? *Land Use Policy* **66**, 214–226.
Ormeño, E., Ruffault, J., Gutigny, C., Madrigal, J., Guijarro, M., Hernando, C. *et al.* (2020). Increasing cuticular wax concentrations in a drier climate promote litter flammability. *Forest Ecology and Management* **473**, 118242.
Ottolini, I., Arenas Conejo, M., Prat-Guitart, N., Uyttewaal, K., Pandey, P., Rodríguez-Giralt, I. and Cifre Sabater, M. (2023). A toolkit for fostering cocreation and participative community engagement with vulnerable communities at risk. PyroLife Project (deliverable D17). 35 pages.
Ottolini, I., Salesa, D., del Romero Renau, L. and Salvador Fernández, N. (2024). Kindling change: shaping a new fire culture in Mediterranean socioenvironmental systems from the roots. *Human Geographies: Journal of Studies and Research in Human Geography* **18**(1).
Palaiologou, P., Ager, A. A., Nielsen-Pincus, M., Evers, C. R. and Kalabokidis, K. (2018). Using transboundary wildfire exposure assessments to improve fire management programs: a case study in Greece. *International Journal of Wildland Fire* **27**(8), 501–513.
Palaiologou, P., Kalabokidis, K., Ager, A. A., Galatsidas, S., Papalampros, L. and Day, M. A. (2021). Spatial optimization and tradeoffs of alternative forest management scenarios in Macedonia, Greece. *Forests* **12**(6), 697.
Palaiologou, P., Kalabokidis, K., Day, M. A. and Kopsachilis, V. (2020). Evaluating socioecological wildfire effects in Greece with a novel numerical Index. *Fire* **3**(4), 63.
Palaiologou, P., Kalabokidis, K., Day, M. A., Ager, A. A., Galatsidas, S. and Papalampros, L. (2022). Modelling fire behavior to assess community exposure in Europe: combining open data and geospatial analysis. *ISPRS International Journal of Geo-Information* **11**(3), 198.
Pan, Y. *et al.* (2011). A large persistent carbon sink in the world's forests. *Science* **333**(6045), 988–993.
Pan, Y., Birdsey, R. A., Phillips, O. L., Houghton, R. A., Fang, J., Kauppi, P. E. *et al.* (2024). The enduring world forest carbon sink. *Nature* **631**(8021), 563–569.
Parente, J. and Pereira, M. G. (2016). Structural fire risk: the case of Portugal. *Science of the Total Environment* **573**, 883–893.
Pashley, C., Hemming, D., Adams-Groom, B., Borman, A., Johnson, E., Anees-Hill, S. *et al.* (2023). Health effects of climate change (HECC) in the UK: 2023 report. Chapter 10: Wildfires and health.
Pausas, J. G. and Fernández-Muñoz, S. (2012). Fire regime changes in the Western Mediterranean Basin: from fuel-limited to drought-driven fire regime. *Climatic Change* **110**(1), 215–226.
Pausas, J. G. and Keeley, J. E. (2019). Wildfires as ecosystem services. *Frontiers in Ecology and the Environment* **17**(5), 289–295. doi:10.1002/fee.2044.
Pausas, J. G. and Keeley, J. E. (2021). Wildfires and global change. *Frontiers in Ecology and the Environment* **19**(7), 387–395.
Paveglio, T. B., Moseley, C., Carroll, M. S., Williams, D. R., Fischer, A. P. and Davis, E. J. (2015). Categorizing the social context of the wildland urban interface: adaptive capacity for wildfire and community "archetypes". *Forest Science* **61**(2), 298–310.
Pawlewicz, A. and Pawlewicz, K. (2023). The risk of agricultural land abandonment as a socioeconomic challenge for the development of agriculture in the European Union. *Sustainability (Switzerland)* **15**(4). https://doi.org/10.3390/su15043233.
Pellegrini, A. F. A., Harden, J., Georgiou, K., Hemes, K. S., Malhotra, A., Nolan, C. J. and Jackson, R. B. (2022). Effects of fire on the persistence of soil organic matter and long-term carbon storage. *Nature Geoscience* **15**, 5–13. doi: 10.1038/s41561-021-00867-1.
Pereira, P., Bogunovic, I., Zhao, W. and Barcelo, D. (2021). Short-term effect of wildfires and prescribed fires on ecosystem services. *Current Opinion in Environmental Science & Health* **22**, 100266.
Pereira, J. M. C., Duarte Oom, Silva, P. C. and Benali, A. (2022). Wild, tamed and domesticated: three fire macroregimes for global pyrogeography in the Anthropocene. *Ecological Applications* e2588. https://doi.org/10.1002/eap.2588.
Pereira, P., Francos, M., Brevik, E. C., Ubeda, X. and Bogunovic, I. (2018). Postfire soil management. *Current Opinion in Environmental Science & Health* **5**, 26–32.
Pérez-Izquierdo, L., Bengtsson, J., Clemmensen, K. E., Granath, G., Gundale, M. J., Ibáñez, T. S. *et al.* (2023). Fire severity as a key determinant of aboveground and belowground biological community recovery in managed even-aged boreal forests. *Ecology and Evolution* **13**(5), e10086.
Pickering, B. J., Duff, T. J., Baillie, C. and Cawson, J. G. (2021). Darker, cooler, wetter: Forest understories influence surface fuel moisture. *Agricultural and Forest Meteorology*, **300**, 108311.
Pičman, D., Pentek, T., Nevecerel, H., Papa, I. and Lepoglavec, K. (2011). Possibilities of application of relative openness in secondary forest opening of slope forests in Croatia. *Croatian Journal of Forest Engineering* **32**(1), 417–431.
Pinto-Correia, T. and Kristensen, L. (2013). Linking research to practice: The landscape as the basis for integrating social and ecological perspectives of the rural. *Landscape and Urban Planning* **120**, 248–256. https://doi.org/10.1016/j.landurbplan.2013.07.005.
Planas, E., Paugam, R., Àgueda, A., Vacca, P. and Pastor, E. (2023). Fires at the wildland-industrial interface. Is there an emerging problem? *Fire Safety Journal* **141**, 103906.
Plieninger, T., Draux, H., Fagerholm, N., Bieling, C., Bürgi, M., Kizos, T., Kuemmerle, T., Primdahl, J. and Verburg, P. H. (2016). The driving forces of landscape change in Europe: a systematic review of the evidence. *Land Use Policy* **57**, 204–214. https://doi.org/10.1016/j.landusepol.2016.04.040.
Plieninger, T., Kohsaka, R., Bieling, C., Hashimoto, S., Kamiyama, C., Kizos, T., Penker, M., Kieninger, P., Shaw, B. J., Sioen, G. B., Yoshida, Y. and Saito, O. (2018). Fostering biocultural diversity in landscapes through place-based food networks: a "solution scan" of European and Japanese models. *Sustainability Science* **13**, 219–233.

Plieninger, T., Muñoz-Rojas, J., Buck, L. E. and Scherr, S. J. (2020). Agroforestry for sustainable landscape management. *Sustainability Science* **15**(5), 1255–1266.

Podschwit, H. and Cullen, A. (2020). Patterns and trends in simultaneous wildfire activity in the United States from 1984 to 2015. *International Journal of Wildland Fire* **29**(12), 1057–1071.

Pötzelsberger, E., Spiecker, H., Neophytou, C., Mohren, F., Gazda, A. and Hasenauer, H. (2020). Growing nonnative trees in European forests brings benefits and opportunities but also has its risks and limits. *International Journal of Wildland Fire* **6**, 339–353.

Prats, S. A., Malvar, M. C. and Wagenbrenner, J. W. (2021). Compaction and cover effects on runoff and erosion in post-fire salvage logged areas in the Valley Fire, California. *Hydrological Processes* **35**(1), e13997. https://doi.org/10.1002/hyp.13997.

Pronto, L. *et al.* (2023). Research for REGI Committee – Forest Fires of Summer 2022: Lessons to Draw from the Cohesion Policy Response. Brussels: European Parliament, Policy Department for Structural and Cohesion Policies. https://www.europarl.europa.eu/RegData/etudes/STUD/2023/747280/IPOL_STU(2023)747280_EN.pdf.

Pulido, F., Corbacho, J., Bertomeu, M., Gómez, Á., Guiomar, N., Juárez, E. *et al.* (2023). Fire-Smart Territories: a proof of concept based on Mosaico approach. *Landscape Ecology* **38**(12), 1–18.

Pyke, D. A., Brooks, M. L. and D'Antonio, C. (2010). Fire as a restoration tool: a decision framework for predicting the control or enhancement of plants using fire. *Restoration Ecology* **18**, 274–284. https://onlinelibrary.wiley.com/doi/epdf/10.1111/j.1526-100X.2010.00658.x.

Quintas-Soriano, C., Buerkert, A. and Plieninger, T. (2022). Effects of land abandonment on nature contributions to people and good quality of life components in the Mediterranean region: a review. *Land Use Policy* **116**, 106053.

Ramberg, E., Berglund, H., Penttilä, R., Strengbom, J. and Jönsson, M. (2023). Prescribed fire is an effective restoration measure for increasing boreal fungal diversity. *Ecological Applications* **33**(6), e2892.

Rappold, A. G., Hano, M. C., Prince, S., Wei, L., Huang, S. M., Baghdikian, C. *et al.* (2019). Smoke Sense initiative leverages citizen science to address the growing wildfire-related public health problem. *GeoHealth* **3**(12), 443–457.

Reid, C. E., Brauer, M., Johnston, F. H. *et al.* (2016). Critical review of health impacts of wildfire smoke exposure. *Environmental Health Perspectives* **124**, 1334–1343.

Requia, W. J., Amini, H., Mukherjee, R., Gold, D. R. and Schwartz, J. D. (2021). Health impacts of wildfire-related air pollution in Brazil: a nationwide study of more than 2 million hospital admissions between 2008 and 2018. *Nature Communications* **12**(1), 6555.

Ribeiro-Kumara, C., Santín, C., Doerr, S. H., Pumpanen, J., Baxter, G. and Köster, K. (2022). Short- to medium-term effects of crown and surface fires on soil respiration in a Canadian boreal forest. *Canadian Journal of Forest Research* **52**, 591–604. dx.doi.org/10.1139/cjfr-2021-0354.

Robin, V. and Nelle, O. (2014). Contribution to the reconstruction of central European fire history, based on the soil charcoal analysis of study sites in northern and central Germany. *Vegetation History and Archaeobotany* **23**, 51–65.

Robios, B. (2012). La cellule de brûlage dirigé des Alpes-Maritimes. XXIIles Rencontres Réseau des équipes de brûlage dirigé. Conseil Général des Alpes-Maritimes. Nice.

Ronchi, E., Vaiciulyte, S. and Labhiri, A. (2024). Wildland-Urban Interface Fire Touristic Infrastructure Protection Solutions: Guidelines for good practices for human protection. (TVBB; No. 3262). Lund University, Sweden: Department of Fire Safety Engineering. https://portal.research.lu.se/en/publications/wildland-urban-interface-fire-touristic-infrastructure-protection.

Rodrigues, M., Jiménez-Ruano, A. and de La Riva, J. (2020). Fire regime dynamics in mainland Spain. Part 1: Drivers of change. *Science of the Total Environment* **721**, 135841.

Rogers, B. M., Soja, A. J., Goulden, M. L. and Randerson, J. T. (2015). Influence of tree species on continental differences in boreal fires and climate feedbacks. *Nature Geoscience* **8**, 228–234.

Romps, D. M. *et al.* (2014). Projected increase in lightning strikes in the United States due to global warming. *Science* **346**, 851–854. doi:10.1126/science.1259100.

Rovithakis, A., Grillakis, M. G., Seiradakis, K. D., Giannakopoulos, C., Karali, A., Field, R. *et al.* (2022). Future climate change impact on wildfire danger over the Mediterranean: the case of Greece. *Environmental Research Letters* **17**(4), 045022.

Royé, D., Tedim, F., Martin-Vide, J., Salis, M., Vendrell, J., Lovreglio, R. *et al.* (2020). Wildfire burnt area patterns and trends in Western Mediterranean Europe via the application of a concentration index. *Land Degradation & Development* **31**(3), 311–324.

Ruffault, J., Curt, T., Moron, V., Trigo, R. M., Mouillot, F., Koutsias, N., Pimont, F., Martin-StPaul, N., Barbero, R., Dupuy, J. L. and Russo, A. (2020). Increased likelihood of heat-induced large wildfires in the Mediterranean Basin. *Scientific Reports* **10**(1), 13790.

Rundel, P. W., Arroyo, M. T., Cowling, R. M., Keeley, J. E., Lamont, B. B. and Vargas, P. (2016). Mediterranean biomes: evolution of their vegetation, floras and climate. *Annual Review of Ecology, Evolution and Systematics* **47**(1), 383–407.

Salesa, D., Baeza, M. J., Pérez-Ferrándiz, E. and Santana, V. M. (2022). Longer summer seasons after fire induce permanent drought legacy effects on Mediterranean plant communities dominated by obligate seeders. *Science of The Total Environment* **822**, 153655.

Salis, M., Laconi, M., Ager, A. A., Alcasena, F. J., Arca, B., Lozano, O. *et al.* (2016). Evaluating alternative fuel treatment strategies to reduce wildfire losses in a Mediterranean area. *Forest Ecology and Management* **368**, 207–221.

San-Miguel-Ayanz, J., Durrant, T., Boca, R., Maianti, P., Libertà, G., Jacome Felix Oom, D., Branco, A., De Rigo, D., Suarez-Moreno, M., Ferrari, D., Roglia, E., Scionti, N., Broglia, M., Onida, M., Tistan, A. and Loffler, P. (2023). Forest Fires in Europe, Middle East and North Africa 2022. Luxembourg: Publications Office of the European Union. https://data.europa.eu/doi/10.2760/348120.

San-Miguel-Ayanz, J., Rodrigues, M., de Oliveira, S. S., Pacheco, C. K., Moreira, F., Duguy, B. and Camia, A. (2012). Land cover change and fire regime in the European Mediterranean region. In: *Post-Fire Management and Restoration of Southern European Forests*, pp. 21–43. Springer.

Santín, C. and Doerr, S. H. (2016). Fire effects on soils: the human dimension. *Philosophical Transactions of the Royal Society B: Biological Sciences* **371**(1696), 20150171.

Santos, J. L., Martins, A., Novais, A. and Canadas, M. J. (2021). A choice-modelling approach to inform policies aimed at reducing wildfire hazard through the promotion of fuel management by forest owners. *Forests* **12**(4), 403.

Saražin, J. (2025). Accessibility of Slovenian Forests for Firetrucks. In: *Environmental Protection and Disaster Risks (EnviroRisks 2024)* (Dobrinkova, N. and Fidanova, S. editors). Lecture Notes in Networks and Systems, vol. 883. Springer. https://doi.org/10.1007/978-3-031-74707-6_10.

Sayer, J., Sunderland, T., Ghazoul, J., Pfund, J.L., Sheil, D., Meijaard, E., Ventera, M., Boedhihartonoa, A. G., Dayb, M., Garciab, C., van Oosten, C. and Buck, L. E. (2013). Ten principles for a landscape approach to reconciling agriculture, conservation and other competing land uses. *Proceedings of the National Academy of Sciences of the USA* **110**(21), 8349–8356.

Scherr, S. J. and McNeely, J. A. (2008). Biodiversity conservation and agricultural sustainability: towards a new paradigm of 'ecoagriculture' landscapes. *Philosophical Transactions of the Royal Society B: Biological Sciences* **363**(1491), 477–494. http://doi.org/10.1098/rstb.2007.2165.

Schils, R. L., Bufe, C., Rhymer, C., Francksen, R. M., Klaus, V. H., Abdalla, M. *et al.* (2022). Delivery of ecosystem services from permanent grasslands in Europe: a systematic review. In *Grassland at the Heart of Circular and Sustainable Food Systems* (Proceedings of the 29th General Meeting of the European Grassland Federation) (L. Delaby, R. Baumont, V. Brocard, S. Lemauviel-Lavenant, S. Plantureux, F. Vertès and J.L. Peyraud, editors), pp. 274–276. Caen: European Grassland Federation.

Schug, F., Bar-Massada, A., Carlson, A.R. *et al.* (2023). The global wildland–urban interface. *Nature* **621**, 94–99. https://doi.org/10.1038/s41586-023-06320-0.
Shafizadeh, F., Chin, P. P. S. and DeGroot, W. F. (1977). Effective heat content of green forest fuels. *Forest Science* **23**, 81–89.
Sil, Â. F., Azevedo, J., Fernandes, P. M., Regos, A., Vaz, A. S. and Honrado, J. P. (2019). (Wild) fire is not an ecosystem service. *Frontiers in Ecology and the Environment* **17**(8), 429–430.
Silveira, F. A., Ordóñez-Parra, C. A., Moura, L. C., Schmidt, I. B., Andersen, A. N., Bond, W. *et al.* (2022). Biome Awareness Disparity is BAD for tropical ecosystem conservation and restoration. *Journal of Applied Ecology* **59**(8), 1967–1975.
Skevaki, C, Nadeau, K. C., Rothenberg, M. E., Alahmad, B., Mmbaga, B. T., Masenga, G. G., Sampath, V., Christiani, D. C., Haahtela, T. and Renz, H. (2024). Impact of climate change on immune responses and barrier defense. *Journal of Allergy and Clinical Immunology* **153**(5), 1194–1205. https://doi.org/10.1016/j.jaci.2024.01.016.
Soliño, M., Yu, T., Alía, R., Auñón, F., Bravo-Oviedo, A., Chambel, M. R. *et al.* (2018). Resin-tapped pine forests in Spain: ecological diversity and economic valuation. *Science of the Total Environment* **625**, 1146–1155.
Soy-Massoni, E., Uyttewaal, K., Prat-Guitart, N. and Varela, E. (2022). Fire eaters: exploring consumer preferences for labelling extensive livestock products providing wildfire prevention services. *Land* **11**(5), 700.
Spadoni, G. L., Moris, J. V., Vacchiano, G., Elia, M., Garbarino, M., Sibona, E. *et al.* (2023). Active governance of agro-pastoral, forest and protected areas mitigates wildfire impacts in Italy. *Science of the Total Environment*, **890**, 164281. https://doi.org/10.1016/j.scitotenv.2023.164281.
Spalt, K. W. and Reifsnyder, W. E. (1962). Bark characteristics and fire resistance: a literature survey. Occasional paper, Southern Forest Experiment Station, New Orleans, La.
Stedman, R. C. (2004). Risk and climate change: perceptions of key policy actors in Canada. *Risk Analysis* **24**(5), 1395–1406.
Steel, Z. L., Miller, J. E., Ponisio, L. C., Tingley, M. W., Wilkin, K., Blakey, R. *et al.* (2024). A roadmap for pyrodiversity science. *Journal of Biogeography* **51**(2), 280–293.
Steffensen, V. (2020). *Fire Country: How Indigenous Fire Management Could Help Save Australia*. Hardie Grant Explore.
Stokes, S. C., Romanowski, K. S., Sen, S., Greenhalgh, D. G. and Palmieri, T. L. (2021). Wildfire burn patients: a unique population. *Journal of Burn Care & Research* **42**(5), 905–910.
Stoof, C. R. and Kettridge, N. (2022). Living with fire and the need for diversity. *Earth's Future* **10**, e2021EF002528. https://doi.org/10.1029/2021EF002528.
Stoof, C., Ribau, M. C., Moore, P. F. and Boustras, G. (2024). To solve the global wildfire crisis, don't just focus on flames. *Nature* **637**, 34.
Strahan, K., Whittaker, J., Handmer, J. (2018). Self-evacuation archetypes in Australian bushfire. *International Journal of Disaster Risk Reduction* **27**, 307–316.
Sudmeier-Rieux, K., Paleo, U. F., Garschagen, M., Estrella, M., Renaud, F. G. and Jaboyedoff, M. (2015). Opportunities, incentives and challenges to risk sensitive land use planning: Lessons from Nepal, Spain and Vietnam. *International Journal of Disaster Risk Reduction* **14**, 205–224.
Swain, D. L., Prein, A. F., Abatzoglou, J. T., Albano, C. M., Brunner, M., Diffenbaugh, N. S. *et al.* (2025). Hydroclimate volatility on a warming Earth. *Nature Reviews Earth & Environment* **6**(1), 35–50.
Tang, W., He, C., Emmons, L. and Zhang, J. (2024). Global expansion of wildland-urban interface (WUI) and WUI fires: insights from a multiyear worldwide unified database (WUWUI). *Environmental Research Letters* **19**, 044028. DOI 10.1088/1748-9326/ad31da.
Tedim, F., Leone, V. and Xanthopoulos, G. (2016) A wildfire risk management concept based on a social-ecological approach in the European Union: Fire Smart Territory. *International Journal of Disaster Risk Reduction* **18**, 138–153.
Tedim, F., McCaffrey, S., Leone, V., Delogu, G. M., Castelnou, M., McGee, T. K. and Aranha, J. (2020). What can we do differently about the extreme wildfire problem: an overview. In: *Extreme Wildfire Events and Disasters*, pp. 233–263. Elsevier.
Temperton, V. M., Buchmann, N., Buisson, E., Durigan, G., Kazmierczak, Ł., Perring, M. P., de Sá Dechoum, M., Veldman, J.W. and Overbeck, G. E. (2019). Step back from the forest and step up to the Bonn Challenge: how can a broad ecological perspective promote successful landscape restoration? *Restoration Ecology* **27**, 705–719.
Terrer, C. *et al.* (2020). A trade-off between plant and soil carbon storage under elevated CO_2. *Nature* **591**, 599–616. https://doi.org/10.1038/s41586-021-03306-8.
Thacker, F. E. N., Ribau, M. C., Bartholomeus, H. and Stoof, C. R. (2023). What is a fire resilient landscape? Towards an integrated definition. *Ambio* **52**(10), 1592–1602. https://link.springer.com/article/10.1007/s13280-023-01891-8.
Tikkanen, O. P., Martikainen, P., Hyvärinen, E., Junninen, K. and Kouki, J. (2006). Red-listed boreal forest species of Finland: associations with forest structure, tree species and decaying wood. *Annales Zoologici Fennici* **43**, 373–383.
Tinner, W., Conedera, M., Ammann, B. and Lotter, A. F. (2005). Fire ecology north and south of the Alps since the last ice age. *The Holocene* **15**(8), 1214–1226.
To, P., Eboreime, E. and Agyapong, V. I. (2021). The impact of wildfires on mental health: a scoping review. *Behavioral Sciences* **11**(9), 126.
Turco, M., Bedia, J., Di Liberto, F., Fiorucci, P., von Hardenberg, J., Koutsias, N. *et al.* (2016). Decreasing fires in mediterranean Europe. *PLoS ONE* **11**(3), e0150663.
Tzamtzis, I., Ganatsas, P., Kokkoris, I. P., Samaritakis, V., Botsis, D., Tsakaldimi, M., Tziritis, I., Kalevra, N. and Georgiadis, N. M. (2023). A sustainable strategy for reforestation and restoration of burnt natural areas in Mediterranean regions: a case study from Greece. *Sustainability* **15**, 15986.
UNDRR (2023). The Report of the Midterm Review of the Implementation of the Sendai Framework for Disaster Risk Reduction 2015–2030. Geneva, Switzerland: UNDRR.
UNEP (2022). Spreading like wildfire – the rising threat of extraordinary landscape fires. A UNEP Rapid Response Assessment. Nairobi.
Valese, E., Conedera, M., Held, A. C. and Ascoli, D. (2014). Fire, humans and landscape in the European Alpine region during the Holocene. *Anthropocene* **6**, 63–74.
Valkó, O, Török, P, Deák, B, Tóthmérész, B. (2014). Prospects and limitations of prescribed burning as a management tool in European grasslands. *Basic and Applied Ecology* **15**, 26–33.
Valkó, O. and Deák, B. (2021). Increasing the potential of prescribed burning for the biodiversity conservation of European grasslands. *Current Opinion in Environmental Science & Health* **22**, 100268. https://doi.org/10.1016/j.coesh.2021.100268.
van Daalen, K. R., Tonne, C., Semenza, J. C., Rocklöv, J., Markandya, A., Dasandi, N. *et al.* (2024). The 2024 Europe report of the Lancet Countdown on health and climate change: unprecedented warming demands unprecedented action. *The Lancet Public Health* **9**(7), e495–e522.
Varela, E., Górriz-Mifsud, E., Ruiz-Mirazo, J. and López-i-Gelats, F. (2018). Payment for targeted grazing: integrating local shepherds into wildfire prevention. *Forests* **9**, 464.
Varela, E., Pulido, F., Moreno, G. and Zavala, M. Á. (2020). Targeted policy proposals for managing spontaneous forest expansion in the Mediterranean. *Journal of Applied Ecology* **57**, 2373–2380. https://doi.org/10.1111/1365-2664.13779.
Veldman, J. W. *et al.* (2019). Comment on "The global tree restoration potential." *Science* **366**, eaay7976.
Verde, J. C., Torres, J.S., Marques, R., Franc, R., Flores, E., Casartelli, V., Marengo, A., Melinato, S., Mysiak, J., Salpina, D., Brăilescu, C., Marteil, E., Sørensen, J. and Spitoni, G. (2024). UCPM Wildfire peer review report: Italy 2024. https://doi.org/10.25424/cmcc-xx3k-we21.
Vigna, I., Millington, J., Ascoli, D., Comino, E., Pezzoli, A. and Besana, A. (2024). A picit jeu: agent-based modelling with serious gaming

for a fire-resilient landscape. *Journal of Environmental Management* **370**, 122529.
Vogel, J., Paton, E., Aich, V. and Bronstert, A. (2021). Increasing compound warm spells and droughts in the Mediterranean Basin. *Weather and Climate Extremes* **32**, 100312.
Wallenius, T. (2011). Major decline in fires in coniferous forests—reconstructing the phenomenon and seeking for the cause. *Silva Fennica* **45**(1), 139–155.
Weir, J. R. and Scasta, J. D. (editors). (2022). *Global Application of Prescribed Fire*. CSIRO Publishing.
White, A. R. (2024). The firestorm within: a narrative review of extreme heat and wildfire smoke effects on brain health. *Science of the Total Environment* **922**, 171239.
Wilgus, M.-L. and Merchant, M. (2024). Clearing the air: understanding the impact of wildfire smoke on asthma and COPD. *Healthcare* **12**(3), 307.
Wilkinson, S. L., Andersen, R., Moore, P. A., Davidson, S. J., Granath, G. and Waddington, J. M. (2023). Wildfire and degradation accelerate northern peatland carbon release. *Nature Climate Change* **13**, 456–461. https://doi.org/10.1038/s41558-023-01657-w.
Witze, A. (2020). Why Arctic fires are bad news for climate change. *Nature* **585**, 336–337.
Wooster, M. J. and Zhang, Y. H. (2004). Boreal forest fires burn less intensely in Russia than in North America. *Geophysical Research Letters* **31**(20). doi:10.1029/2004GL020805.
World Bank (2021). Investment in disaster risk management in Europe makes economic sense – executive summary of the report for DG ECHO. P91.
Wunder, S., Calkin, D. E., Charlton, V., Feder, S., de Arano, I. M., Moore, P. *et al.* (2021). Resilient landscapes to prevent catastrophic forest fires: socioeconomic insights towards a new paradigm. *Forest Policy and Economics* **128**, 102458.
Xanthopoulos, G., Caballero, D., Galante, M., Alexandrian, D., Rigolot, E. and Marzano, R. (2006). Forest fuels management in Europe. In *Fuels management-how to measure success: Conference proceedings*. Portland, OR: USDA Forest Service.
Zheng, B. *et al.* (2021). Increasing forest fire emissions despite the decline in global burned area. *Science Advances* **7**(39), eabh2646. doi:10.1126/sciadv.abh2646.

Appendix 1 Recent policy reports on wildfires

Camia, A., Liberta, G. and San-Miguel-Ayanz, J. (2017). Modeling the impacts of climate change on forest fire danger in Europe: sectorial results of the PESETA II Project. Luxembourg: Publications Office of the European Union. https://publications.jrc.ec.europa.eu/repository/bitstream/JRC105684/jrc105684.pdf.

Casartelli, V. and Mysiak, J. (2023). Union Civil Protection Mechanism - Peer Review Programme for disaster risk management: Wildfire Peer Review Assessment Framework (Wildfire PRAF).

de Rigo, D., Libertà, G., Houston Durrant, T., Artés Vivancos, T. and San-Miguel-Ayanz, J. (2017). Forest fire danger extremes in Europe under climate change: variability and uncertainty. EUR 28926 EN. Luxembourg: Publications Office of the European Union.

European Commission (2024). *2023* Among the five worst years for wildfires in europe, but 2024 provides some relief. (This report provides an overview of the wildfire seasons in 2023 and 2024, analysing the factors that led to severe wildfires and the measures that contributed to a less severe season in 2024.) https://joint-research-centre.ec.europa.eu/jrc-news-and-updates/2023-among-five-worst-years-wildfires-europe-2024-provides-some-relief-2024-11-19_en.

European Commission (2024). Wildfires: 2023 among the worst in the EU in this century. (This report highlights the severity of the 2023 wildfire season in the EU, discussing the contributing factors and the implications for future wildfire management.) https://joint-research-centre.ec.europa.eu/jrc-news-and-updates/wildfires-2023-among-worst-eu-century-2024-04-10_en.

European Commission Joint Research Centre (2023). Forest fires in Europe, Middle East and North Africa 2022. (This comprehensive report provides an analysis of the wildfire season across Europe and neighbouring regions, highlighting trends, impacts, and the effectiveness of prevention measures.) https://joint-research-centre.ec.europa.eu/jrc-news-and-updates/wildfires-eu-2022-was-second-worst-year-warning-changing-climate-2023-11-22_en.

European Commission Joint Research Centre (2024). Advance Report on Forest Fires in Europe, Middle East and North Africa 2023. (Offering preliminary insights into the 2023 wildfire season, this report discusses the conditions under which wildfires developed and their impact across the pan-European territory.) https://op.europa.eu/en/publication-detail/-/publication/88bc1891-f6f6-11ee-a251-01aa75ed71a1.

European Environment Agency (2022). Forest Fires in Europe: An Overview. (This report examines the increasing frequency and intensity of forest fires in Europe, attributing changes to climate dynamics and land use patterns. It emphasizes the need for integrated management strategies.) https://www.eea.europa.eu/publications/forest-fires-in-europe.

European Forest Fire Information System (EFFIS) Annual Fire Reports: EFFIS provides annual reports detailing forest fire incidents, affected areas, and trends across Europe. These reports are essential for understanding the evolving wildfire landscape. https://forest-fire.emergency.copernicus.eu/reports-and-publications/annual-fire-reports.

OECD (2023). Taming wildfires in the context of climate change. Paris: OECD Publishing. https://doi.org/10.1787/dd00c367-en.

Oom, D., de Rigo, D., Pfeiffer, H., Branco, A., Ferrari, D., Grecchi, R., Artés-Vivancos, T., *et al.* (2022). Pan-European wildfire risk assessment. EUR 31160 EN. JRC130136. Luxembourg: Publications Office of the European Union. https://doi.org/10.2760/9429.

Project WUITIPS. Wildland-urban interface fire touristic infrastructure protection solutions, living lab of knowledge transfer. https://civil-protection-knowledge-network.europa.eu/projects/wuitips.

UNEP (2022). Spreading like wildfire – the rising threat of extraordinary landscape fires. A UNEP Rapid Response Assessment. Nairobi.

USDA Forest Service (2022). Wildfire Crisis Strategy: Confronting the Wildfire Crisis. United States Department of Agriculture. FS-1187a. Washington, D.C. USA. 25 p. Available at: https://www.fs.usda.gov/managing-land/wildfire-crisis.

Appendix 2 Examples of long-term proactive initiatives showing the application of policy options 1–8

For each option, the name and geographical location of the initiative are shown together with the relevant reference.

Policy option 1. Adopt an integrated approach to wildfire risk reduction, combining proactive and reactive wildfire risk policies, and integrating climate change adaptation		
ZIFs	Portugal	Fernandes and Simões (2024)
AIGP	Portugal	https://www.dgterritorio.gov.pt/paisagem/ptp/aigp
Mosaico	Spain	Pulido *et al.* (2023)
RAPCA	Spain	Varela *et al.* (2018)
Rioja	Spain	Lasanta *et al.* (2022)
Ramats de Foc	Spain	Soy-Massoni *et al.* (2022)
Landa Carsica	Italy	Ascoli *et al.* (2023)
PRE-FEU/CFAVS	Italy	https://cfavs.it/it-it/servizi-/
LIFE Granatha	Italy	Ascoli *et al.* (2023)
Omikron	Greece	Ascoli *et al.* (2023)
Policy option 2. Adopt nature-based solutions for wildfire risk reduction		
AIGPs	Portugal	https://www.dgterritorio.gov.pt/paisagem/ptp/aigp
Mosaico	Spain	Pulido *et al.* (2023)
RAPCA	Spain	Varela *et al.* (2018)
Ramats de Foc	Spain	Soy-Massoni *et al.* (2022)
Landa Carsica	Italy	Ascoli *et al.* (2023)
LIFE Granatha	Italy	Ascoli *et al.* (2023)
Policy option 3. Acknowledge the ecological and cultural role of fire, and being prepared for living with more frequent fires		
Official programme	Portugal	Davim *et al.* (2022)
LIFE Montserrat	Spain	Ascoli *et al.* (2023)
LIFE Granatha	Italy	Ascoli *et al.* (2023)
Piemonte	Italy	Ascoli *et al.* (2023)
Landa Carsica	Italy	Ascoli *et al.* (2023)
Policy option 4. Build educational and risk communication capacity to increase wildfire awareness and preparedness across generations in urban and rural populations, and across science, policy, and practice		
Kythira project	Greece	Mauri *et al.* (2023)
ONF	France	https://hal.science/hal-04152846v1
Official programme	France	Mauri *et al.* (2023), https://agriculture.gouv.fr/
Policy option 5. Adopt landscape management to reduce vulnerability to wildfire		
ZIFs	Portugal	Fernandes and Simões (2024)
AIGPs	Portugal	https://www.dgterritorio.gov.pt/paisagem/ptp/aigp
Mosaico	Spain	Pulido *et al.* (2023)
RAPCA	Spain	Varela *et al.* (2018)
Rioja	Spain	Lasanta *et al.* (2022)
Ramats de Foc	Spain	Soy-Massoni *et al.* (2022)
Landa Carsica	Italy	Ascoli *et al.* (2023)
PRE-FEU/CFAVS	Italy	https://cfavs.it/it-it/servizi-/

LIFE Granatha	Italy	Ascoli *et al.* (2023)
Omikron	Greece	Ascoli *et al.* (2023)
Policy option 6. Harmonize the current sectoral policies to reduce wildfire risk		
AGIF	Portugal	https://www.agif.pt/
Policy option 7. Reduce urban sprawl and foster compact urban areas through urban and regional planning to reduce risk		
PPU Barcelona	Spain	https://www.diba.cat/es/web/incendis/ppu
PDPFCI Gard	France	https://www.gard.gouv.fr/Media/Files/Guide-de-normalisation-des-interfaces-amenagees2
Policy option 8. Foster the adoption of private sustainable management practices to decrease landscape vulnerability		
AIGPs	Portugal	https://www.dgterritorio.gov.pt/paisagem/ptp/aigp
Mosaico	Spain	Pulido *et al.* (2023)
CPF	Spain	Ascoli *et al.* (2023)
PRE-FEU/CFAVS	Italy	https://cfavs.it/it-it/servizi-/
Pratomagno	Italy	Ascoli *et al.* (2023)
Omikron	Greece	Ascoli *et al.* (2023)

EASAC is a network of the following European national academies and academic bodies. All EASAC member academies have endorsed this report in accordance with EASAC procedures. These include that all efforts have been made — with the nominations for the working group, during the writing phase of the report and through the independent review procedure — to ensure that this report reflects the best available scientific evidence. EASAC focuses with its recommendations on addressing topics and challenges for Europe at the transnational scale, and recognises that some of its member academies may need to weigh in national issues in the advice to their governments.

The Austrian Academy of Sciences
The Royal Academies for Science and the Arts of Belgium
The Bulgarian Academy of Sciences
The Croatian Academy of Sciences and Arts
The Cyprus Academy of Sciences, Letters and Arts
The Czech Academy of Sciences
The Royal Danish Academy of Sciences and Letters
The Estonian Academy of Sciences
The Council of Finnish Academies
The Académie des sciences (France)
The German National Academy of Sciences Leopoldina
The Academy of Athens
The Hungarian Academy of Sciences
The Royal Irish Academy
The Accademia Nazionale dei Lincei (Italy)
The Latvian Academy of Sciences
The Lithuanian Academy of Sciences
The Royal Netherlands Academy of Arts and Sciences
The Norwegian Academy of Science and Letters
The Polish Academy of Sciences
The Academy of Sciences of Lisbon
The Romanian Academy
The Slovak Academy of Sciences
The Slovenian Academy of Sciences and Arts
The Spanish Royal Academy of Sciences
The Swiss Academies of Arts and Sciences
The Royal Swedish Academy of Sciences
The Royal Society (United Kingdom)
Academia Europaea
ALLEA

The affiliated network for Europe of

iap SCIENCE HEALTH POLICY
the interacademy partnership

EASAC contributes to the implementation of the

SUSTAINABLE DEVELOPMENT GOALS

EASAC Secretariat
Austrian Academy of Sciences
Dr. Ignaz Seipel-Platz 2
1010 Vienna
Austria

tel: +43 1-515-811208
secretariat@easac.eu