Joint Research Centre

SCIENCE FOR POLICY BRIEF

Forest resilience against wildfires

Integration from preparedness to restoration

2026

'Climate change is making each summer hotter, harsher, and more dangerous. This is why we have to radically step up our efforts into climate resilience and adaptation, and nature-based solutions.'

Ursula von der Leyen – State of the Union speech September 2025.

HIGHLIGHTS

- **Treat** fire resilience as strategic investment for our long-term capacity to remain competitive, secure resources, and adapt to climate.
- **Reduce** institutional vulnerability and enhance the Union's capacity to manage transboundary risks.
- **Leverage** EU monitoring infrastructure for harmonised assessment, strengthening anticipatory governance while reducing crisis-driven responses.
- **Integrate** fire management and risk assessment into spatial and environmental planning and infrastructure development, safeguarding energy systems, transport, water security, ecosystems and rural economies.
- **Prioritize** restoration of burned areas as opportunities for risk prevention and long-term climate adaptation.
- **Invest** in prevention and adaptation, **stabilise** supply chains, **protect** carbon sinks and biodiversity, and **reinforce** capacity to tackle climate risks.

Fire-Resilient Forests as a Pillar of European Strategic Autonomy

1. Strengthening fire resilience of our forests

Wildfire risk in Europe is a structural challenge to our strategic autonomy. Forests underpin timber supply, industries, carbon sequestration, biodiversity, water regulation, rural livelihoods, and energy security.

Strengthening fire resilience must be treated as a strategic investment in the EU's long-term capacity to remain competitive, resource-secure and climate-adaptive.

2. Implement integrated fire management

A framework from prevention, preparedness, suppression and recovery to long-term adaptation. Would ensure cross-sector coordination, harmonised monitoring, and science-based decision-making across Member States.

Reducing institutional vulnerability and enhancing Europes capacity to manage transboundary risk.

3. Leverage EU monitoring infrastructure for risk-informed decision-making

Strategic autonomy requires robust monitoring systems. The EU already possesses key infrastructures that can be operationally integrated:

- European Forest Fire Information System (EFFIS) for fire occurrence and risk mapping.
- European Forest Observatory (EUFO) for forest condition and structural attributes.
- European Soil Observatory (EUSO) for soil vulnerability and post-fire erosion risk.

Enabling harmonised assessments, strengthening anticipatory governance and reducing crisis-driven responses.

4. Fire risk into climate and land policies

Fire risk must be a standard criterion within EU climate adaptation, forest, biodiversity, agricultural policies. Targeting vulnerabilities through diversification, spatial discontinuities, and management and promoting biodiversity increases resilience and recovery capacity.

Embedding wildfire risk into planning and infrastructure development safeguards energy systems, transport, water security, ecosystems, and rural economies.

5. Prioritise strategic recovery zones

Burned areas should be treated as priority zones for coordinated intervention. Immediate actions must reduce erosion, hydrological instability, and downstream impacts. Simultaneously, recovery strategies must enhance long-term resilience and ecosystem integrity through risk-informed restoration, local species selection, and structural heterogeneity.

Opportunity to manage burned areas strategically, breaking cycles of degradation and repeated high-severity fires.

6. Focus investment on prevention and adaptation

Funding towards preventive landscape management, adaptation, and resilience-building. Public funding mechanisms can incentivize private-sector engagement, long-term stewardship, and monitoring commitments.

Preventive investment lowers long-term economic losses, stabilises bioeconomy supply chains, protects carbon sinks and biodiversity, and reinforces our capacity to act independently in the face of escalating climate risks.

Why are forests at risk?

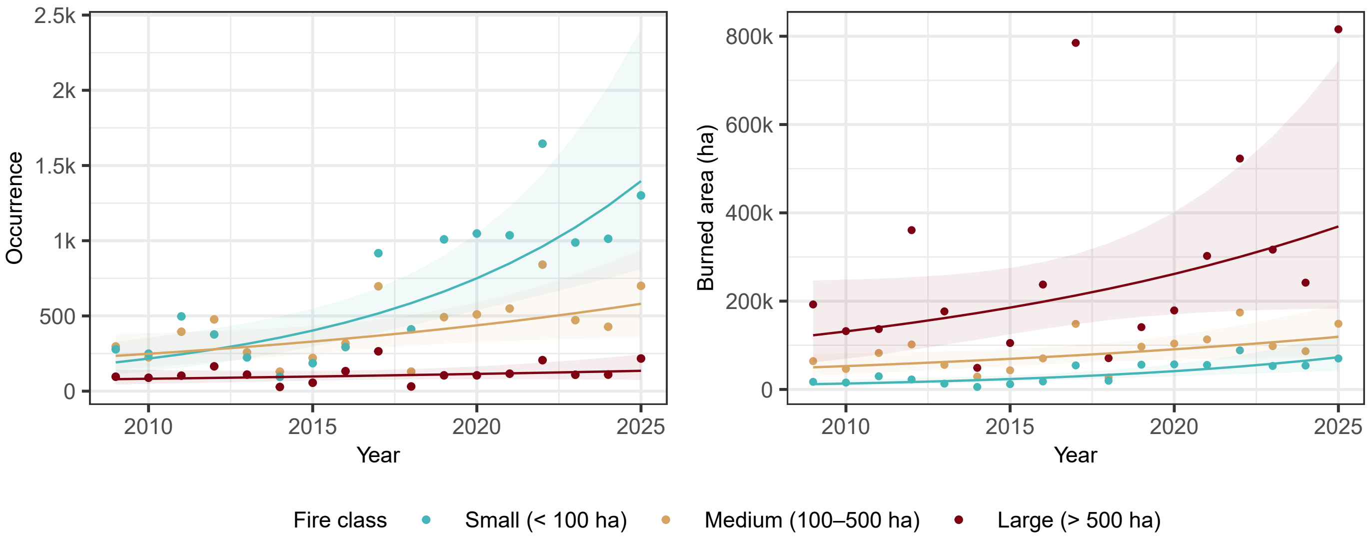
Wildfire events are increasing in frequency and intensity across Europe (Fig. 1) because of interacting climatic, ecological, and socio-economic drivers[1]. Anthropogenic climate change is a central factor[2], with rising temperatures, more frequent and intense heatwaves, declining soil and vegetation moisture. Longer fire seasons create conditions conducive to extreme wildfire events[3,4].

Climate change is driving a decline in forest resilience, the capacity of forests to withstand and recover from disturbances[5,6]. Heat and drought stress increase tree mortality and vulnerability to **pests and diseases**, leading to widespread forest dieback in several European regions[7]. Cumulative disturbances are critical. Pest outbreaks and disease-driven mortality generate large amounts of dead biomass, increasing fuel loads and the likelihood of high-severity fires[8]. In turn, pests thrive during post-fire period, affecting recovery[9].

Wildfire risk is strongly shaped by **socio-economic dynamics**. Land abandonment and reduced forest management have led to fuel accumulation and landscape homogenization, while decades of fire suppression have further increased fuel continuity[10,11]. At the same time, urban expansion into forested areas and the wildland-urban interface has increased exposure of people, infrastructure, and economic assets, amplifying wildfire impacts[12–14].

These processes are no longer confined to southern Europe. While Mediterranean regions remain hotspots, recent events show a clear expansion of wildfire risk into central and northern European countries, where forests and institutions are often less adapted to large-scale fires[15,16]. This challenges the traditional geographic assumptions about wildfire risk in Europe.

Figure 1 – Fire occurrence and burned area in EU by fire size classification (2009-2025).



Source: Source: Source data from EFFIS.

What is at stake?

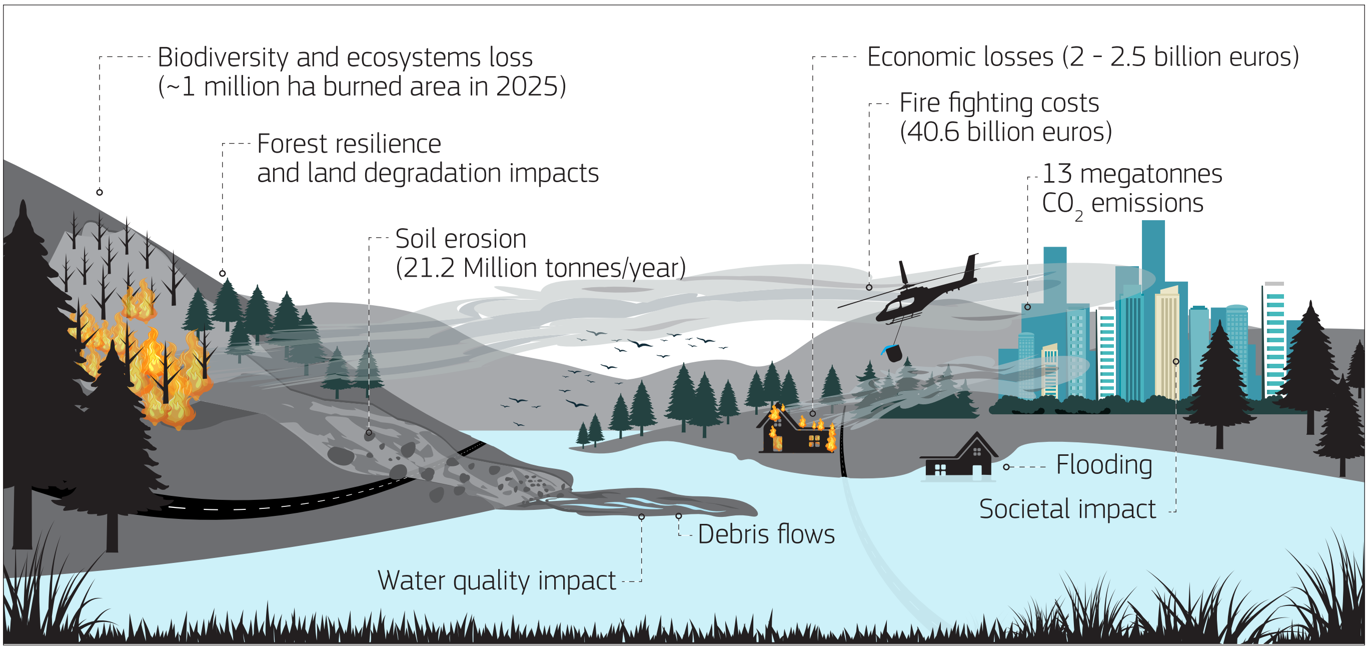
Wildfires lead to economic losses (Fig. 2) of around 2-2.5 billion euros annually[17,18], with a significant public expenditure on emergency response (40.6 billion euros in 2023)[19]. These impacts extend to people, the economy and the environment. In 2025, 1 million ha of land burned in the EU, three times the 2006-2024 average.

Wildfires not only impacted forest (13% burned area), and other natural areas (43%), but also agricultural land (21%), with losses of productivity, infrastructure, and human lives[20]. Despite the low contribution of EU fires to the global CO_2 budget, in 2025 wildfire-related emissions hit a record in EU and UK[21], undermining EU efforts towards climate neutrality. Furthermore, the increasing trend of high-severity fires outside the boundaries of historical occurrence, have the potential to further deteriorate forest resilience, increase the loss of ecosystems services, and drive long-term ecosystem degradation[9,22].

We are reacting instead of preventing.

Globally, wildfire disaster-related expenditure remains reactive rather than preventive[23]. The EU is no exception. However, recent evidence suggests a gradual shift by Member States[17], which are increasingly prioritising preventive investments to reduce long-term losses and escape the "firefighting trap", whereby repeated post-disaster response crowds out risk reduction and preparedness[10]. Nonetheless, the same analysis also finds funding to tackle forest fires to be frequently allocated under time pressure, while long-term sustainability of the financed actions was not ensured.

Figure 2 – Wildfire impacts and associated cost in the EU



Source: Joint Research Centre. Data: Firefighting costs in 2023[19], Economic losses in 2025[17,18], CO_2 Emissions for 2025[21], Annual post-fire soil erosion 2001-2019[9].

A forest without vulnerabilities

Forests exhibiting higher levels of naturalness are typically more resilient and resistant than mono-specific or even-aged forests[24,25]. This suggests that higher levels of naturalness in forest ecosystems help cope with, and recover from, natural disturbances, such as wildfires, drought, windthrow, insect and pathogen outbreaks[24–26].

A resilient forest

High forest resilience and resistance generally emerge from the combination of traits associated with natural ecosystem functioning, functional diversity, structural and compositional diversity, and strong microclimatic buffering. Forests closer to natural conditions tend to maintain diverse species assemblages with several species performing similar ecological roles[27]. At the same time, heterogeneous stands help limit disturbance spread and create a mosaic of microhabitats[28].

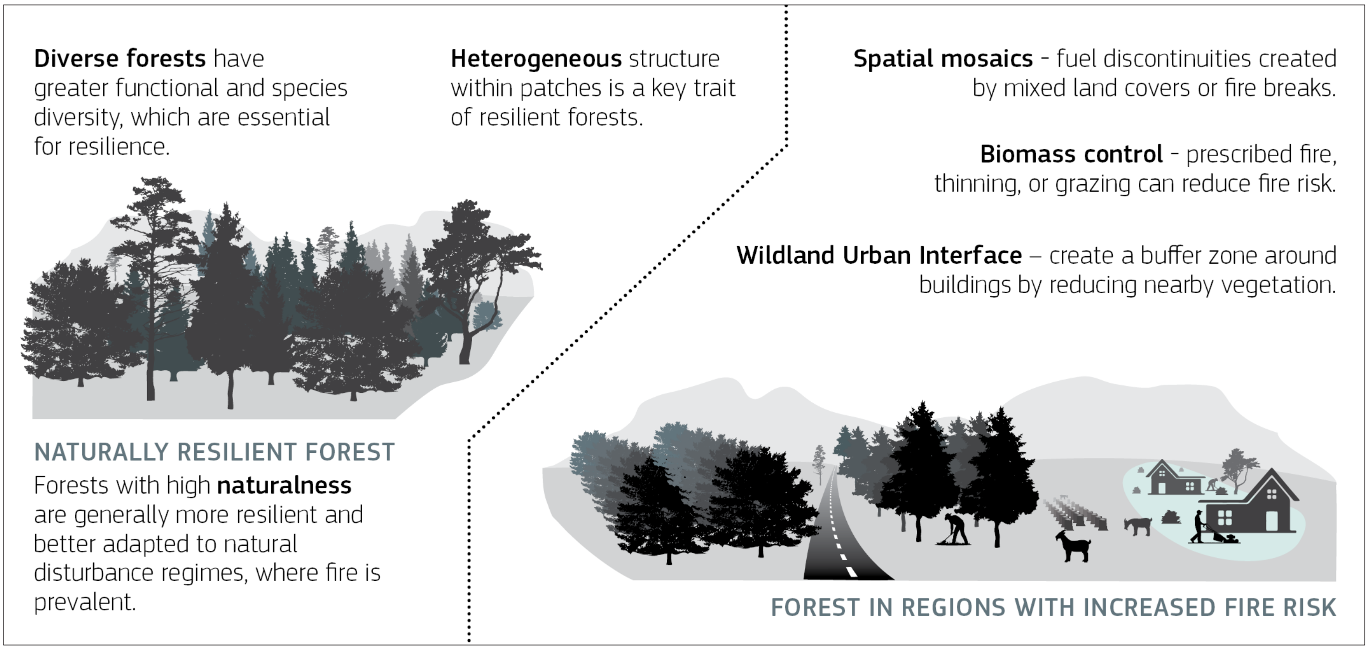
Box I - Definitions

Resilience is the capacity of an ecosystem to withstand (absorb) external pressures and, over time, return to its pre-disturbance state[29]. When viewed over an appropriate time span, a resilient forest ecosystem is able to maintain its principal characteristics in terms of composition, structure, and functions[5,24].

Naturalness describes the historical evolution of forests, reflecting land use legacies and current management[30–33]. The degree of naturalness largely depends on the time since the last silvicultural intervention and the intensity of management. This shapes forest traits based on management objectives[34]

These structural features, together with dense canopies and well-developed litter layers, regulate temperature and moisture conditions, protecting ecosystem processes during climatic extremes. The integration of these traits enhances ecosystem stability, reduces vulnerability to disturbances, and supports recovery after disturbance events.

Figure 3 – Resilience, Naturalness and Management.



Source: Joint Research Centre.

Risk-informed planning and management

Europe can build fire-resilient forest landscapes by restoring and maintaining spatial mosaics (fuel discontinuities, mixed land covers, and less-flammable stands) by shifting policy from suppression-dominant responses towards risk-informed prevention and adaptation. Fire risk is spatially uneven, therefore fire-resilient landscapes require planning that integrates data on forest cover, fuels, and structural attributes with wildfire likelihood, and maps of values-at-risk (e.g. settlements, critical infrastructure, high-value ecosystems).

Fire management and risk, where relevant, should be taken into account in nature conservation and restoration planning (e.g. Natura 2000 management plans and national restoration plans under the Nature Restoration Regulation), and, reciprocally, wildfire risk planning should integrate biodiversity considerations. Given that warming and drying trends are increasing, coupled with the frequency of fire-conducive conditions and lengthening fire seasons in many regions[6], anticipatory planning is more important than ever, especially avoiding dangerous fuel accumulation[35,36].

Integrated fire management requires systematic monitoring before and after fires[37]. Prior to fire, spatially explicit monitoring of multidimensional diversity (e.g. specific, structural and functional), forest health, and fuel condition enables the identification of areas where human, ecological, and socio-economic losses would be highest. Especially those in the wildland-urban interface[38], where high ignition frequency and greater human exposure amplify safety concerns[12,13].

After fire, continued monitoring is essential to track disturbance impacts, assess recovery trajectories, and evaluate the effectiveness of restoration and mitigation measures. Without such feedback, post-fire interventions risk being inefficient or maladaptive, ultimately undermining long-term forest resilience.

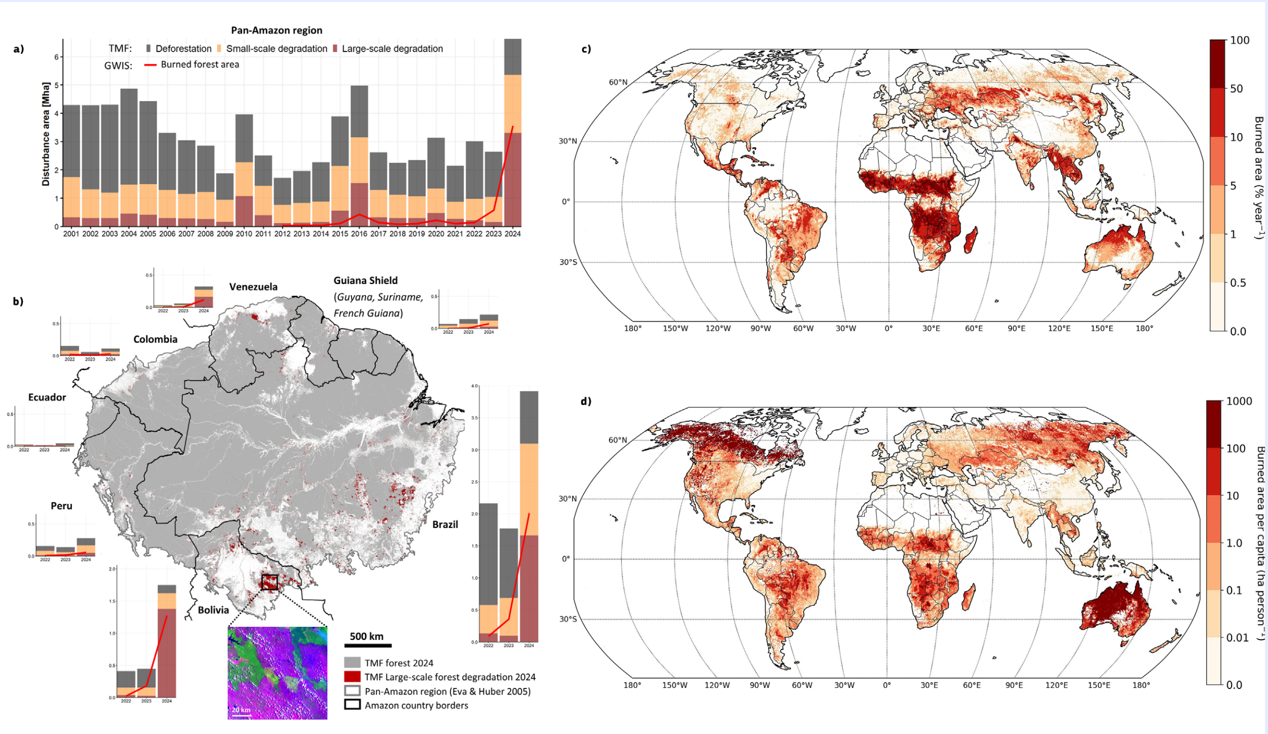
Monitoring identifies forest vulnerabilities outside the window of disturbance, while supporting informed land management decisions aimed at improving forest resilience and reducing wildfire risks.

Box II - Wildfires are a global problem

Wildfire is a global problem, generating profound economic impacts. These are increasingly seen in ecosystems historically considered to be fire-resistant, such as the Amazon rainforest (Fig. 4), where fire occurrence is undermining resilience and amplifying vulnerability[39]. At the same time, trends in global burned area remain a major concern due to their implications for biodiversity, carbon balance, land degradation, and socio-ecological stability[40].

This underscores the need for integrated fire management, spanning from prevention to post-fire recovery, as promoted by global initiatives such as the FAO Fire Management Hub, articulating common design principles, such as cross-sector coordination, science–policy integration, harmonized monitoring, and capacity building, into structured multi-level frameworks at EU scale.

Figure 4 – Examples of impacts of wildfires impacts globally. (a) Pan-Amazon Tropical Moist forest disturbances (2001-2024). (b) Tropical Moist Forest Map 2024 forest degradation and recent forest disturbance. Mean annual (c) burned area and (d) burned area per capita (2002-2022).



Source: Joint Research Centre.

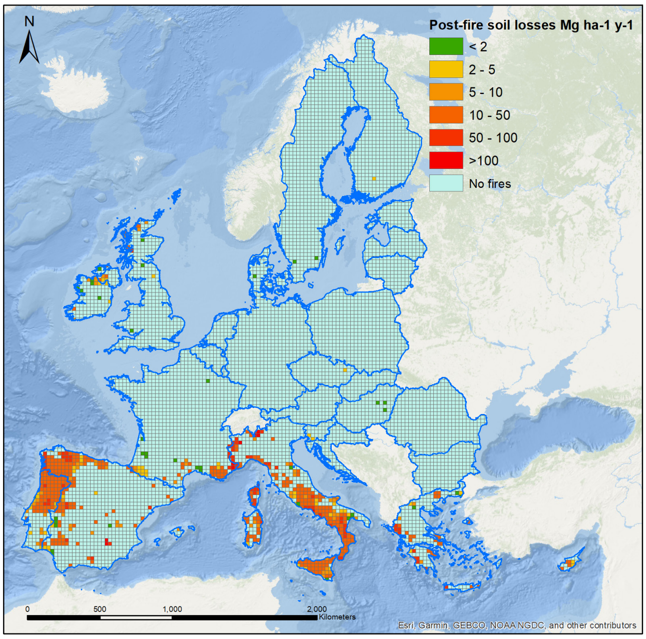
Post-fire strategies

Attention on wildfires typically peaks during active combat but rapidly declines once fire suppression is achieved, despite critical post-fire processes extending throughout recovery. These phases, which can span decades depending on ecosystem type and disturbance severity, strongly determine long-term forest resilience, landscape stability, and future fire risk, and therefore should not be overlooked.

Following high intensity fires, the loss of vegetative cover, combined with changes in hydrological processes, increases the risk of erosion, flash floods and landslides, particularly during intense rainfall events[41]. It is estimated that post-fire soil erosion is responsible for 21.2 million tonnes of soil being displaced every year in the EU (Fig. 5).

The transport of ash, charred material and soil to water bodies can compromise water quality, disrupt drinking-water supplies, and damage aquatic ecosystems[42,43] (as observed in Portugal following the 2017 wildfires[44–46]).

Figure 5 – Post-fire soil erosion estimations for EU and UK, for the first year following the 2017 wildfires (25km grid)



Source: Figure from Vieira et al. (2023)

Figure 6 – Experimental and operational mulch treatment implementation in Yeres wildfire (Castilla y León, Spain), Sept. 2025.

Source: Photographs provided by Girona-García A., research developed in the scope of the EROSINK (PID2023-146991NA-I00, MICIU, Spain.

Immediate priorities

These immediate post-fire issues highlight the importance of rapid risk assessment and timely management response. Risk-reduction objectives can be embedded into recovery actions to reduce future risks and strengthen long-term resilience[47]. Targeted approaches are especially needed for severely burned areas, steep slopes, watersheds, and critical infrastructure at risk[22]. Tools are available for post-fire risk assessment, monitoring and mitigation[22]. Early efforts focus on ensuring the safety of communities and responders, erosion control (Fig. 6)[48] and the prevention of on- and off-site impacts, while protecting values at risk, including water infrastructures[49]. However, evidence shows that certain activities, such as poorly planned salvage logging in sensitive areas, can exacerbate soil damage and hinder recovery[50].

Recovery focused on resilience and climate

Post-fire recovery depends on the fire regime, burn severity, ecosystem type, and post-fire climatic conditions[51]. Traditionally, forests not prone to fire or those subject to severe or recurrent fires may require different recovery efforts, while forests that are adapted to fire may regenerate naturally. However, the increase in the frequency and severity of wildfires might constrain or delay recovery due to systematic impacts on soil and reduced availability of seeds, limiting natural regeneration[52,53].

In severe cases, vegetation shifts might be observed after wildfire, potentially promoting the spread of invasive alien species [54].

Post-fire recovery strategies should be informed by burn severity, natural regeneration potential, nature conservation and restoration objectives, risk of erosion, and fire history, prioritizing forest resilience and climate change adaptation[55,56]. Natural regeneration has gained recognition as an effective and cost-efficient alternative to conventional reforestation[57] and can be complemented with seeding, tree planting, soil treatment, and management of invasive species.

Avoiding maladaptation

Post-fire restoration must incorporate wildfire risk assessment to improve forest resilience. Establishing guidelines for implementing post-fire interventions is crucial, in the absence of a robust evaluation, to avoid maladaptation (ie. more harmful than helpful) and increased wildfire risk over time[56]. An important aspect here is strengthening long-term monitoring of post-fire recovery, as this is essential to evaluate the effectiveness of such interventions and avoid an unintentional increase in the vulnerability to future fires[58]. It is recognised that post-fire practices, such as large monoculture planting, high tree densities, or with flammable species, can facilitate the spread of high-intensity fires, especially when management is limited or non-existent[59,60]. In Mediterranean ecosystems, eucalypt and pine tree plantations, characterised by fuel continuity and homogeneity, have burned more severely and have a lower recovery.

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