Forest Management and Wildfire Resilience: What the Science Says

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The summer of 2026 saw a surge in forest fires across Europe, including in regions that had until now been largely spared: more than 2,000 hectares burned in the Fontainebleau Forest and over 42,000 hectares in the Gironde heathlands in France, and almost 175,000 hectares in Spain. By the end of 2025, the European Forest Institute reported that the total area burned across the European Union had exceeded one million hectares—twice the area burned in 2024—making it the worst year recorded since 2006, when the European Forest Fire Information System (EFFIS) began collecting data (Held et al., 2026). In response to these events, public debate has often polarised around the same instinctive reaction: intervene more, clear the undergrowth, remove dead wood, and create firebreaks.

This article provides a synthesis of the available scientific literature on the ecological determinants of forest resilience to wildfire and on the forest management approaches supported by this evidence. Its conclusion is unequivocal: nature builds its own resilience, whereas human intervention has, more often than not, weakened forest ecosystems in the face of climate-related risks.

The European Commission—hardly an institution that could be accused of environmental activism—has itself acknowledged this reality by publishing, in 2023, the guidelines for **Closer-to-Nature Forest Management (CNFM)**, whose objective is to reconcile the long-term resilience of forests to environmental change, including wildfire risk, with timber production (European Commission, 2023a, 2023b; Geraci et al., 2025). This framework has been incorporated into the EU Forest Strategy for 2030 under the European Green Deal and is based on the most comprehensive synthesis of contemporary forestry knowledge to date, notably that of Huth et al. (2025). In this work, 55 experts from Germany, Switzerland, Austria and other European institutions establish a robust scientific consensus on forest management recommendations, each accompanied by a level of scientific confidence inspired by the methodology of the Intergovernmental Panel on Climate Change (IPCC). This consensus challenges long-outdated assumptions and management practices that urgently need to be abandoned because they increase the flammability of our forests, including current approaches to so-called "dead" wood and understorey vegetation. The underlying conclusion is clear: biodiversity enhances the resilience of forests to wildfire. It must therefore be preserved and restored wherever possible.

These practices are beginning to be implemented, with varying degrees of effectiveness, through the voluntary sustainable forest management certification systems operating across Europe. They can be summarised into three guiding principles, whose practical implementation and ecological relevance are explained below (Geraci et al., 2025):

1. **A multi-layered forest structure and an unbroken canopy maintain a humid forest microclimate:** even-aged plantations and clear-cutting should be phased out.
2. **Natural regeneration that promotes high levels of native broadleaf species and genetic diversity accelerates adaptation:** monocultures, particularly those dominated by conifers, should be avoided.
3. **Biodiversity also maintains water within living forest soils:** habitat trees, dead wood, pastoral grazing, beavers and other natural processes all contribute. We must stop compacting forest soils and stop treating understorey vegetation as the principal culprit.

Closer-to-nature forest management is generally at least as profitable—and often more profitable—than intensive forestry, owing to lower operating costs, greater resilience to storms, droughts, diseases and pests, and more stable, higher-quality timber production over the long term. It also enables income diversification through non-timber forest products and ecosystem services—including carbon sequestration, biodiversity conservation, water regulation and recreation—thereby reducing dependence on the highly volatile timber market alone. Finally, through its 2021–2027 funding programmes, the European Union supports this transition via several financial instruments, including the Common Agricultural Policy (CAP), State aid schemes and payments for ecosystem services, designed to offset transition costs and encourage sustainable, multifunctional forest management (European Commission, 2023a).

The State of European Forests: Reality Is Far Removed from the Romantic Image

European forests cover approximately 40% of the continent's land area, representing nearly 170 million hectares, more than 80% of which are considered available for timber production (European Parliament, 2024). However, this area rarely corresponds to the image of a diverse natural forest. Around 70% of European forests consist of trees planted in the same year and are therefore structurally even-aged (Aszalós et al., 2022); 80% contain no more than three tree species, while one-third are pure monocultures, most commonly of conifers (pine or spruce) or eucalyptus (European Parliament, 2024). As will be shown below, this structural and compositional uniformity constitutes one of the principal drivers of wildfire vulnerability. The situation has worsened in recent years: using satellite imagery, Ceccherini et al. (2020), in a study published in *Nature*, reported a 50% increase in the area of European forests subjected to clear-cutting after 2015 compared with the preceding period—a trend directly at odds with the wildfire-resilient forest management recommendations discussed below.

The Optimal Forest Stand Structure for Maintaining a Humid Forest Microclimate: A Closed Canopy and Multiple Vegetation Layers

Contrary to widespread belief, it is not understorey vegetation or so-called "dead" wood that should be blamed for forest fires, but rather the intensive forestry practices that have dominated over recent decades. De Frenne et al. (2019), writing in *Nature Ecology & Evolution*, demonstrated at the global scale the thermal buffering effect exerted by closed forest canopies on temperatures beneath the canopy. By analysing nearly one hundred forest sites across five continents, they showed that forests significantly cool the understorey during periods of extreme heat while warming it during cold periods. Most importantly, this thermal buffering effect becomes even stronger as external temperatures become more extreme. A recent study by Verdonck et al. (2025, *Journal of Applied Ecology*) reached similar conclusions for Belgian forests, showing that even small canopy openings significantly reduce humidity within forests. More strikingly, where tree harvesting reduced canopy cover by approximately 50%, the thermal buffering effect disappeared entirely and temperatures within the forest became even higher than in the surrounding open landscape.

A multi-layered vegetation structure and the absence of large canopy gaps are therefore the principal factors maintaining a cool and humid forest microclimate, thereby reducing wildfire risk during droughts. Such a multi-layered structure is created by trees and understorey vegetation belonging to different age classes and, consequently, different height classes. A closed canopy limits evaporation by intercepting solar radiation and reducing wind speed near the forest floor. A vertically complex forest further reinforces this effect by slowing the upward movement of warm, moisture-laden air towards the canopy.

Forestry should therefore abandon even-aged plantations and clear-cutting in order to preserve continuous canopy cover. This conclusion directly challenges thinning practices, which remain widespread in European forestry on the assumption that they "reduce competition" between trees and "allow more light to reach the forest floor". This ecological justification for thinning is not supported by current scientific evidence. Using a demo-genetic model published in *Evolutionary Applications*, Godineau et al. (2023) showed that the systematic removal of young trees, as commonly practised in forestry, can reduce the long-term vigour of forest stands by as much as 80%. Although this modelling result deserves further empirical confirmation, it raises serious questions about routine thinning, if only from the perspective of long-term productivity.

In particular, the felling of the last remaining ancient trees in European forests—often mistakenly referred to simply as "old" trees—creates large canopy gaps proportional to the diameter of their crowns. The justification based on their supposed old age is fundamentally flawed. Trees are long-lived organisms and, as they age, they continue to grow, become more robust, sequester increasing amounts of carbon, and provide ever more valuable structural habitats for biodiversity. In this respect, they represent the exact opposite of the common human perception of ageing. Consequently, cutting down a tree simply because it is considered "old" is ecologically nonsensical and undermines the resilience of forest ecosystems. Yet truly ancient trees have now become exceedingly rare across Europe: two-hundred-year-old trees are scarce, while three-hundred-year-old trees have virtually disappeared. More generally, trees in production forests are typically harvested precisely when they reach their peak rate of carbon sequestration—between approximately 30 and 80 years of age, depending on the species (Nabuurs et al., 2015). For reasons of short-term economic return, this practice stands in direct contradiction with the European Union's objective of achieving climate neutrality by 2050.

Allowing Forests to Develop Naturally Increases Tree Biodiversity, Reduces Extreme Temperatures, Maintains Humidity and Enhances Productivity

Increasing tree species richness—that is, the number of tree species present within a forest stand—can reduce peak summer temperatures by as much as 4°C when comparing a monoculture with a stand composed of 24 species (Schnabel et al., 2025). Tree biodiversity also increases humidity while enhancing forest growth and productivity (Park et al., 2026). Diversifying our woodlands and forests therefore strengthens their resilience to increasingly unpredictable climatic events. This is reflected in the growing frequency of wildfires across Europe and elsewhere, which predominantly affect monoculture plantations rather than mixed stands composed of numerous tree species, particularly where broadleaved species are present, as these are generally less flammable than conifers (Popovic Z. et al., 2021).

Intraspecific genetic diversity—that is, the presence of individuals with different genetic make-ups within the same species—is equally important. It increases the likelihood that some individuals, or genetic variants, will be better adapted than others to future climatic conditions. In contrast to monocultures, maintaining high levels of genetic diversity represents the forest ecosystem's principal ecological insurance policy for long-term survival. This adaptive evolutionary mechanism, which maximises resilience under unpredictable environmental conditions, is known as **bet hedging**. Within this context, the use of **assisted migration** remains controversial among forest ecologists and has not yet achieved scientific consensus. By contrast, there is strong evidence that allowing forests to develop through **natural dynamics**, without continuous human intervention, restores forest biodiversity more effectively than active management (Landridge et al., 2023).

The Biodiversity of Habitat Trees, Dead Wood and Beavers Also Maintains Moisture in Forest Soils

A widespread misconception in public debate attributes a major role to so-called "dead" wood in the spread of forest fires and regards its removal as an obvious preventive measure. The scientific literature, however, has reached a robust consensus in the opposite direction. These findings have led the European Commission to require that two of the seven indicators used by

Member States to assess the ecological condition and resilience of forests under the Nature Restoration Regulation (EU 2024/1991) concern dead wood itself—a highly significant policy signal.

In one of the most influential scientific papers ever published on the subject, Harmon et al. (1986) demonstrated that fallen logs function as natural water reservoirs during rainfall events, absorbing hundreds of litres of water and releasing it only very gradually. Logs lying on the forest floor also reduce surface runoff and soil evaporation while maintaining the moisture conditions required for decomposition and for soil organisms. The authoritative reference work *Biodiversity in Dead Wood* (Stokland et al., 2012), published by Cambridge University Press, further quantifies this effect. Beneath a large fallen log, soil moisture during dry periods is typically between 10% and 30% higher than in adjacent exposed soils; summer soil temperatures are between 2 and 6°C lower; and soil moisture remains elevated for several days or even several weeks after rainfall. The authors describe these areas as **"moisture refugia"**.

Moreover, dead wood and habitat trees support an extraordinary amount of living biomass. Every kilogram of dead wood hosts between 10 and 70 grams of fungi, bacteria, algae, lichens, mosses, nematodes, mites, springtails, saproxylic insects and their predators. Approximately 30% of all forest species depend, directly or indirectly, on dead wood during some stage of their life cycle. Because living tissues are composed of roughly 70% water, this associated biodiversity also contributes to the moisture-buffering capacity of dead wood during drought. At present, however, this ecological function remains limited by the relatively small quantities of dead wood retained in managed European forests—typically only 10 to 20 m^3 per hectare—whereas old-growth forests in Europe commonly contain between 30 and 300 m^3 per hectare (European Commission, 2023b).

These findings concern large-diameter dead wood, including habitat trees as well as standing and fallen trunks. The situation differs for dense understorey shrubs, whose accumulation is partly linked to the abandonment of traditional grazing practices (Coughlan M.R., 2014) and which are frequently portrayed as the principal cause of the increasing frequency and intensity of today's forest fires. While it is true that excessive quantities of fine, dry vegetation facilitate wildfire spread during periods of severe drought, this risk is in reality closely linked to the simplification of forest structure and the opening of the canopy. By drying the forest microclimate, canopy openings promote the ignition of fine woody debris and shrubs, as demonstrated by Brown et al. (2022).

Selective understorey clearance, and more generally the targeted management of fine fuels around inhabited areas—and around ecologically valuable natural areas requiring particular protection—remains a useful preventive measure, as does the strategic creation of forest firebreaks. Firebreaks are nevertheless difficult to design in a truly effective manner, and the scientific evidence primarily demonstrates their usefulness in facilitating access for firefighting services (Syphard A.D. et al., 2011; Young J.D. et al., 2024). However, they appear to have little effect in preventing the spread of mega-fires once these extend beyond distances of approximately 100 metres, while potentially contributing to significant drying of soils and atmospheric conditions within the forest areas they open up. Firebreaks and mandatory cleared strips—now required in countries such as France—ultimately resemble sticking plaster applied to cancer if the underlying causes of forest vulnerability are left unaddressed.

Healthy Forest Soils, Wetlands and Beavers: Natural Allies Against Wildfire

Forest soils rich in organic matter—and therefore in living organisms—are porous and able to absorb water, replenishing soil water reserves instead of allowing rainfall to run off the surface. It is therefore unsurprising that soil compaction caused by the heavy machinery used in mechanised logging substantially reduces the water-storage capacity of forest soils. Wherever possible, mechanised timber extraction should be replaced by less invasive and less destructive techniques, including the use of draft horses.

In addition, forest wetlands—such as ponds, pools and small watercourses—form a network in which water is temporarily retained before gradually infiltrating the soil. These wetlands also act as physical barriers that slow the spread of fire while providing essential drinking sites for wildlife. Preserving and restoring these forest wetland networks therefore requires an end to unnecessary drainage practices.

The return of the Eurasian beaver, after its near disappearance from many regions of France and elsewhere in Europe, represents another major ecological asset. Fairfax et al. (2020) showed that during five major wildfires in the western United States, vegetation degradation was approximately three times lower in areas occupied by beavers than in comparable areas where they were absent.

Landscape Connectivity at the Regional Scale

Beyond measures aimed at improving resilience within individual forest stands, the fragmentation of Europe's forests remains a major and often underestimated source of vulnerability. At the landscape scale, the objective should be to restore ecological connections between isolated forest blocks, enabling biodiversity to move freely and ensuring that the genetic variants best adapted to changing environmental conditions can spread naturally. Such migratory dynamics are essential to the medium-term persistence of forest ecosystems.

Forests cannot survive indefinitely as isolated habitat islands surrounded by biodiversity-poor landscapes consisting of cities, industrial agriculture and transport infrastructure. Geographic isolation of forest patches that are too small ultimately leads to their gradual ecological decline.

The current situation in Europe is particularly concerning. According to the report *Forest Landscape in Europe – Pattern, Fragmentation and Connectivity* (Publications Office of the European Union, 2013), 40% of European forests have a non-forest edge within 100 metres, while 70% of forest areas are separated from one another by more than one kilometre. This degree of fragmentation restricts the dispersal of seeds and animal species, preventing the natural re-establishment of the full mosaic of ecological succession stages—from pioneer and young stands to mature and old-growth forests—across the landscape.

Under natural forest dynamics, disturbances such as wildfire recur on cycles of approximately 50 to 150 years and typically affect areas of between 30 and 100 km². This represents the minimum landscape scale at which a complete mosaic of successional stages can persist while allowing species to migrate over time between disturbed and undisturbed areas. Very few forest landscapes of this size remain in Europe today. Restoring ecological corridors between forest blocks therefore represents one of the most important measures for strengthening resilience at the landscape scale, complementing management interventions undertaken within individual forest stands.

Conclusion: It Is Time to Base Forest Policy on Science

To date, relatively few studies have compared the relative importance of the different drivers of forest fires across Europe. Ochoa et al. (2024) addressed this question using wildfire ignition data collected over the past twenty years and demonstrated that climatic aridity is by far the dominant factor influencing wildfire risk. In other words, reducing forest fires requires prioritising all practices that: (i) mitigate climate change; and (ii) maintain the high levels of humidity characteristic of healthy forest ecosystems. Ecological science has consistently shown that biodiversity plays a central role in both respects.

Ecological research increasingly converges on a conclusion that often runs counter to the intuitive reactions prompted by dramatic images of catastrophic wildfires. It is not an excess of nature—dead wood, dense understorey vegetation or ancient trees—that makes forests vulnerable to fire. Rather, vulnerability results from the structural and functional simplification of forests brought about by decades of monocultures, drainage and clear-cutting. European policy frameworks—including the 2023 Closer-to-Nature Forest Management Guidelines, the 2024 Nature Restoration Regulation and the EU Forest Strategy for 2030—have incorporated these scientific findings. However, implementation on the ground continues to lag well behind both current scientific knowledge and the preferences expressed by European citizens themselves.

Under the new climatic conditions that Europe must now face, we urgently need to prepare for successive shocks—including heatwaves, droughts and wildfires—that threaten the long-term habitability of our territories. This requires clear strategic leadership and coordination, improved early-warning systems, stronger firefighting and civil protection capacities, investment in modern equipment, greater citizen participation and solidarity, and reinforced European cooperation.

Yet disaster-response plans alone will not be sufficient. Policymakers also have a responsibility to develop a genuine strategy for transforming Europe's forests, grounded in a clear understanding of the ecological processes that generate resilience. The challenge, both now and in the future, is not simply to extinguish fires. It is to reshape our landscapes so that they remain habitable under a changing climate. To achieve this, we must learn to work with nature and its systemic dynamics rather than wage a battle against them that we cannot hope to win.

Public preferences, as documented by several independent surveys, are not aligned with current dominant forest management practices. A synthesis published by the European Forest Institute (2021) on public attitudes towards forests in Europe shows that citizens place considerably greater value on the non-productive functions of forests—including biodiversity conservation, carbon storage and protection against natural hazards—than on timber production, and generally favour forests showing few visible signs of exploitation. Likewise, visitors consistently prefer older, structurally complex and less intensively managed forests for recreational purposes (Edwards et al., 2012).

In summary, strengthening the resilience of European forests to wildfire and climate change requires:

- promoting forestry based on closer-to-nature principles, with continuous forest canopy cover and multi-layered stand structures;
- avoiding clear-cutting, thinning and the systematic removal of ancient trees, while accepting that forests should be allowed to develop through natural processes without constant human intervention;
- increasing both tree species diversity and genetic diversity within forest stands, particularly by favouring native broadleaved species adapted to local ecological conditions;
- protecting forest soils from compaction caused by heavy machinery and restoring forest wetlands together with their natural hydrological functioning;
- maintaining and increasing the volume of large-diameter dead wood, both standing and fallen, with particular attention to habitat trees;
- restoring ecological connectivity between forest landscapes through regional wildlife corridors.

The time to act is now.

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