bioagora
Knowledge Synthesis for Policy
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Deadwood and Fire Risk in Europe

HIGHLIGHTS

- The volume of dead wood generated by natural disturbances is highly variable among European forest ecosystems and can represent a large portion of the fuel available to burn during a forest fire.
- However, pieces of deadwood burn slowly and therefore contribute only little to fire intensity.
- Fine fuels such as branches and dead needles, attached to deadwood can have a significant effect on fire intensity.
- Salvage logging after a large-scale natural disturbance does not normally reduce the amount of fine fuels and may therefore not reduce fire risk.

1. DEADWOOD AS A FUEL

Fuels of wildfires can be classified into two broad categories. The first category includes only living vascular plants that actively control their hydration and typically keep relatively high-water content even during droughts. The second category includes all other fuels, i.e., soil organic matter, litter, deadwood, and non-vascular plants such as mosses and lichens. The moisture content of these other forest fuels is passively determined by past and recent weather conditions. The drying rate is faster, the higher the air temperature and wind speed, and the lower the relative humidity.

POLICY CONTEXT
Deadwood is considered a biodiversity indicator in forest ecosystems. Understanding its link with fire risk is necessary to inform current policy discussions between the European Commission and Member States in both the Nature Restoration law and EU Forest policy. DG ENV thus requested a synthesis of knowledge to identify a) links between deadwood characteristics and fire risk in the different biogeographic regions of Europe, and b) forest management approaches for reconciling the biodiversity objectives of deadwood management with forest fire risk prevention.

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In addition to weather conditions, the speed of drying depends fundamentally on the surface-to-volume ratio of the piece of fuel. The evaporation of moisture depends on the surface area, but the amount of water that can be held in the piece depends on its volume. Therefore, mosses, lichens, needles, dead leaves, twigs and fine branches and cured grass can dry rapidly in a few hours, while large-diameter pieces of deadwood may take months to dry, especially if covered in water-repellent bark (Johnson 2001). In addition to the individual surface-to-volume ratio effect, the amount of water in dead fuels will also depend on their location and connectivity to other potentially moister materials such as soil.

What is deadwood?

Deadwood, or dead wood, is all woody material that is not part of living plants and exceeds a diameter threshold of 10 cm (IPCC 2006). Deadwood is standing in case of dead standing trees, or lying on the ground. Deadwood can also be buried in soil or in rare cases hanging from living trees. Only those parts of a larger piece that exceed the 10 cm diameter threshold are considered deadwood. The term woody debris is not used in this brief even though it is commonly used elsewhere. Woody debris is often divided into coarse woody debris that typically corresponds to deadwood in this brief and fine woody debris that is classified into litter here. Fuels having a larger surface to volume ratio than deadwood are referred as fine fuels.

In an event of fire, a high moisture content of fuels slows down the spread of fire, as the evaporation of water from pieces of fuels delays their ignition. Therefore, fast-drying fine dead fuels, are important in enabling the ignition and rapid spread of fire. Only when dry weather conditions have lasted for a long time, other fuels, such as deadwood, become important. Another mechanism in which the high surface-to-volume ratio is important in the event of fire is not related to water: the high surface to volume ratio of fine fuels enables rapid heating, volatilization and combustion of these fuels and therefore allows rapid spread and high intensity of a fire.

More than half of deadwood in Europe is lying on the forest floor (State of Europe’s Forests 2020). In normal conditions the surface touching the soil is not only slowing down the drying process by reducing the area from which evaporation occurs, but also the capillary rise of water from the soil, especially on clay and silt soils, can significantly increase the water content of deadwood. Stumps and pieces of lying deadwood that are partly buried in soil are exposed much more to soil moisture than other pieces that are supported by rocks or other pieces of deadwood. Typically, a smaller portion of deadwood is in the form of standing dead trees or standing dead trees (State of Europe’s Forests 2020). Their base is influenced by soil moisture but most of the volume is far from the forest floor and therefore dries faster in rainless periods.

The decomposition stage of deadwood varies from solid wood that has died recently to pieces that can hardly be recognised and are at the limit of being classified as litter or soil. After death, most of the moisture of living wood evaporates within a few months under dry conditions. Thereafter, varying moisture content patterns have been reported for the decomposition process typically lasting at least years but often decades in Europe (Přívětivý and Šamonil 2021). The flammability of deadwood is probably mainly dependent on its moisture content and not directly its stage of decay, but e.g., changes in porosity will certainly influence ignition and burning.

2. DEADWOOD IN A FIRE

The moisture content of deadwood is determined more straightforwardly by weather conditions than that of vascular plants. However, because of its very small surface to volume ratio, it dries very slowly and in normal climate conditions, may still be relatively moist during the peak of a normal fire season. However, this will have to be considered in terms of climate change. Secondly, its low surface to volume ratio means that even when dry, most of wood is far from the surface and is therefore not contributing to the fire process before the surface is first combusted. This means that deadwood in normal conditions may only have a minor role in the ignition and spread of fire. In extreme conditions affected by prolonged dry periods a large amount of deadwood can significantly contribute to the energy released at the fire front.

Once the fine fuels have been fully combusted, deadwood may continue burning for hours or smouldering even weeks, contributing significantly to the total carbon dioxide and energy released per unit area in the fire and therefore its severity, i.e., impacts on vegetation and soil (Brown 2003, Knapp 2015). This prolonged combustion can worsen human health impacts from the smoke, and it may cause new fires with advancing fire fronts.

The position of deadwood influences fire risk via two separate mechanisms. As described above, contact to soil slows down the drying process and more decayed deadwood lying on a moist clay or silt soil may never reach a moisture content enabling ignition if not surrounded by dry fuels. However, forest fuels should be sufficiently continuous and porous to efficiently carry the fire spread. The most flammable position of deadwood is probably lying but with only limited contact to the moist soil. Deadwood of advanced stages of decay is rarely in this position as it has lost much of its rigidity and is therefore rarely supported by rocks or another deadwood.

Deadwood may play a minor role in lightning-caused ignitions. Weather conditions are normally wet during the thunderstorm, but a smouldering standing dead tree that is influenced less from the weather conditions in the near past can therefore still be relatively dry. These standing dead trees can hold the fire for days enabling a later spread, but these situations are rare (Larjavaara et al. 2005). There is some evidence of another, rather peculiar way, in which standing dead trees can be the source of spotting new fires long after the fire front has passed (Page et al. 2013). Another mechanism in which deadwood influences spotting fires is via ignition. Deadwood is likely to be more easily ignited by landing embers because of the lower wood density and potentially porous surface.

The impact of dead wood on fire risk is small but it is important to note that this depends on the diameter limit that is used to define deadwood. In this brief, we only consider diameters larger than 10 cm (see the definition in the text box), and the situation changes completely if fine woody debris from 1 to 10 cm is defined to be deadwood and not litter. Accumulation of dead twigs and branches on the forest floor can increase the fire risk tremendously if the climatic conditions preclude their rapid decomposition (Hicke et al., 2012, Palmero-Iniesta et al. 2017).

3. REGIONAL VARIATION

In Mediterranean regions, deadwood is particularly important for biodiversity as these ecosystems are characterised by low nutrient availability and frequent drought periods. Apart from providing habitat for many species that are adapted to Mediterranean forests, deadwood also provides nutrients and moisture for other communities, allowing them to thrive in these challenging environments. Mediterranean forest-types are the European ecosystems more prone to wildfire risk both currently and under the predicted climate change scenarios. Owing to a long history of intense forest exploitation, the presence of deadwood is rare in Mediterranean forests, unless there has been a previous disturbance such as a fire. Already for this reason, deadwood cannot be considered a significant driving fire risk in Mediterranean-type forests in comparison to other characteristics: i.e., high horizontal and vertical (ladder fuel) continuity of forests owing to the decrease in forest management and rural depopulation. An exception to the minor role of deadwood in fire risk can be immediately following other disturbances (e.g., drought, pest outbreaks, windstorms) owing to the presence of fine woody fuels attached to deadwood. This needs to be considered by forest managers. There is a wide scientific and technical consensus on the need to increase the presence of deadwood in Mediterranean-type forests to ameliorate biodiversity. A potential way to conciliate this objective with fire prevention would be to focus on the conservation of large pieces of deadwood (e.g., > 17.5 cm in REDBOSQUES, IBP) as they are the ones more valuable from a biodiversity point of view and the least problematic for wildfire risk.

In temperate Europe finding the correct balance between standing, fallen and stump deadwood and wildfire prevention has been defined in some countries guidance (Forestry Commission, 2014), however further research is needed to provide the empirical evidence needed to improve decision making.

In boreal Europe, important fuels in surface fires include mosses, lichens, and litter such as dry needles

(Tanskanen et al. 2007). Litter decomposes fast relative to its production and does not generally accumulate on the forest floor. The fire season is short and typically lasts on average only a few weeks peaking in June (Larjavaara et al. 2004). Crown fires are rare in boreal Europe but could potentially develop under extreme fire weather conditions in dense stands, especially of spruces. It is unlikely that deadwood would significantly increase the risk of ignition or spread of a surface fire. Similarly, it is difficult to think of an important role of deadwood in torching or spreading a crown fire. There is some anecdotal evidence of burning embers of bark from birch standing dead trees to cause spot fires potentially enabling spread of fire over breaks such as rivers and roads, but this mechanism is likely to be rare and unimportant.

4. DEADWOOD AND FIRE RISK AFTER LARGE SCALE NATURAL DISTURBANCES

Much of the naturally produced deadwood in forests results from moderate and high severity disturbances. Storms, insect outbreaks, droughts, windstorms, and wildfires alter the conditions for additional wildfires by moving some of the live standing biomass to the dead pool on the ground or as standing dead trees. The dense structure of fine, dead, and therefore dryer fuels are potentially more flammable than the more dispersed, live fuels in an intact canopy (Cannon et al. 2017). They can increase combustion duration and fire intensity for some time (Buma and Wessman 2011) although this evidence is not consistent in all cases (ex. Hicke et al. 2012, Talucci & Krawchuk 2019). With this in mind, salvage logging (cutting and removing timber after disturbances) often aims to reduce fuels and intensity of potential future fires (Müller et al. 2019).

Salvage logging reduces the amount of standing and lying live and dead fuels after disturbances, thereby reducing total ecosystem fuels and the risk of crown fire in the short term (Fraver et al. 2011). But the temporal trajectory of salvage logging effects on surface fuels is more complex (Peterson et al. 2015; Leverkus et al. 2020). With the exception of windthrows, the amount of lying deadwood is initially unaffected by salvage logging, as the delay in standing dead tree collapse in naturally disturbed sites and the removal of trunks from salvaged sites yield an initial absence of deadwood on the ground in both scenarios (Leverkus et al. 2020). The gradual collapse of dead trees progressively increases lying deadwood in unlogged areas (Peterson et al. 2015), thereby potentially increasing the severity of subsequent fire (Buma and Wessman 2011). But whereas coarse fuels can increase the ground-level impact of fire severity (Monsanto & Agee 2008, Buma and Wessman 2011), it is fine fuels that primarily drive key fire characteristics such as rate of spread and flame length, as described previously (Dunn and Bailey 2015, Palmero-Iniesta et al. 2017). Salvage logging tends to increase fine fuels via mechanical abrasion during tree removal and the accumulation of slash (branches, tops, and bark) during initial on-site log processing (Gilmore et al. 2003; Donato et al. 2006), except through intensive, whole-tree removal approaches (Johnson et al. 2013). This can increase fire risk compared to non-salvaged scenarios. Fine surface fuels may remain constant for decades after beetle outbreaks or fire in some conditions –thereby mitigating fire likelihood for at least a decade (Buma et al. 2020)– while they immediately increase after salvage logging for up to 4-5 years (Fig. 4a in Peterson, Dodson & Harrod 2015; Leverkus et al. 2020). At later stages, the effect of logging is a reduction in fine fuels due to faster decay in salvaged stands and the addition of dead branches from the canopy to the surface in non-salvaged stands (Fig. 4b in Peterson, Dodson & Harrod 2015).

What does fire risk mean?

Fire risk is a general term encompassing both the likelihood of a fire and its intensity if it occurs. The likelihood is dependent on probability of ignition and more importantly spread of fire. We do not consider risk to human lives or structures (fire damage) to influence fire risk.

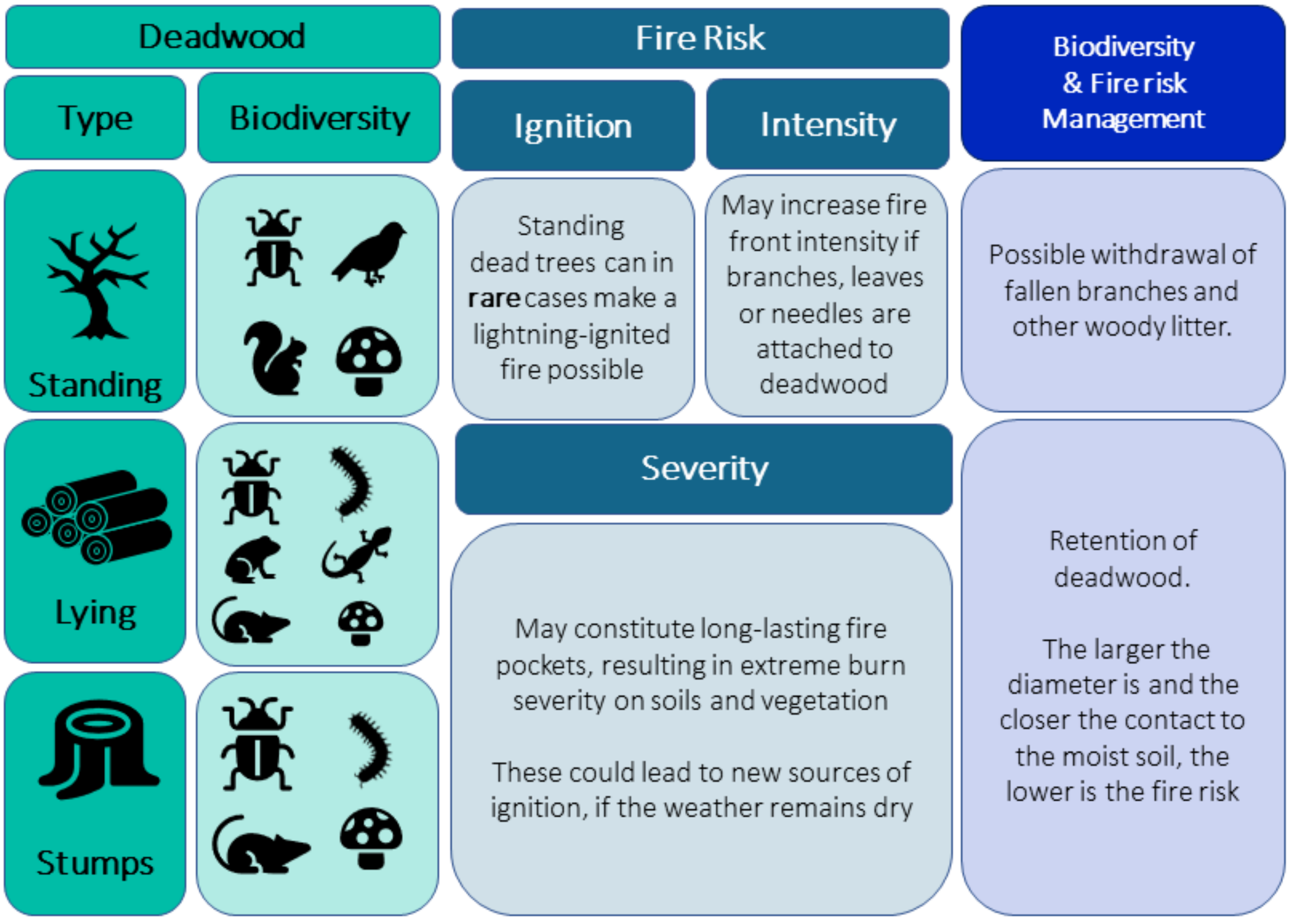

Figure 1 Summary of the main implications of deadwood presence in the forest, in terms of the benefited biological groups, fire risk, and suggested management options, indicated in the present document.

It should be noted that, after disturbances, shrub and tree regeneration outweigh deadwood as fuels and they drive fire risk as the stand develops. Salvage logging can alter flammability by affecting regeneration, yet whether it increases or reduces regeneration is case-specific (Leverkus et al. 2021). However, greater flammability and fire severity can be driven indirectly by actions frequently associated with salvage logging, such as planting conifers (Thompson, Spies & Ganio 2007).

Salvage logging may reduce shading and increase wind speeds after fire and beetle outbreaks and thus increase ground temperature slightly (Lindenmayer et al. 2009; Griffin et al. 2013), ultimately producing drier fuels and greater potential fire spread and intensity (Fraver et al. 2011; Hood et al. 2017). However, such effects, while locally important, are likely to be outweighed by those of weather (Fernandes et al. 2014) and thus susceptible to climate change.

5. MANAGING DEADWOOD FOR BIODIVERSITY CONSIDERING FIRE RISK

Deadwood is a frequently overlooked, yet critical element for the conservation of biodiversity and the promotion of forest functions and services (Thorn et al. 2020). Managing deadwood in a way that balances biodiversity goals with forest fire prevention requires a thorough approach that considers the entire forest ecosystem, the type of forest, the configuration of the landscape, the bioregion, and the fire risk.

As explained, deadwood influences fire risk only little but when fine fuels attached to deadwood are considered the picture may change. To manage dead trees with branches and leaves still attached, one possible approach is to maintain a mosaic of areas with more deadwood across the forest landscape, which can provide habitat for biodiversity and contribute to reducing forest fire risk in some patches. Other approaches include managing forest structure and composition to reduce fuel loading and create conditions that are less prone to severe fires, while also maintaining deadwood habitat. However, the implementation of these approaches may be influenced by a range of factors, such as forest ownership patterns, socio-economic conditions, pedo-climatic conditions, and national or institutional frameworks and regulations for forest management. Promoting a diverse forest structure with a combination of tree species, age classes, and canopy cover can create a forest ecosystem that is less susceptible to severe fires and more resilient. A diverse forest structure can also provide a variety of habitats and resource niches for different species, including those that rely on deadwood. Moreover, retaining large deadwood pieces in forests with a diverse structure may foster biodiversity objectives while maintaining a healthy forest ecosystem. Crucial for fire risk is the surface to volume ratio. Large pieces imply little fire risk even when their volume is high. In biodiversity management however, large pieces are normally valued higher. In contrast, large abundances of smaller-diameter pieces could be reduced to reduce fire risk while having a lesser impact on biodiversity. These management approaches may be particularly relevant in regions or areas where fire risk is not very high. More deadwood relative to more intensive forestry could increase fire risk. In areas with a high risk of severe fires, specific treatments such as thinning and the partial removal of deadwood at strategic points can be necessary to prevent wildfire spread, as well as the zoning of forests to reduce or remove deadwood in certain locations that can threaten life, property, and the wider environment (Forestry Commission, 2014).

Prescribed burning can be an effective tool for reducing the risk of severe fires by decreasing fuel loading, particularly fine wood debris, and creating fuel break lines. When conducted under adequate weather, soil and fuel moisture conditions, soil burn severity, and the impact on deadwood are expected to be minimal and potentially positive as many organisms are dependent on burned deadwood. Fire has a considerable effect on retention tree dynamics. It hastens the death of trees, increases the amount of standing dead trees, and creates diverse dead wood habitats. Prescribed fire appears to provide a good diversity of essential habitats during relatively long post-harvest periods when combined with a reasonable level of retention forestry (Heikkala et al., 2014).

Beyond the management of individual stands, attention should be given to reduce the risk of large wildfires in extended contiguous forest and non-forest landscapes. Large areas with high loads of deadwood cover should be fragmented by wildfire protection corridors. Like in wide fuel breaks, such corridors would be heavily thinned, i.e., the number of standing trees per ha reduced, the understorey and surface fuels, including deadwood removed by mechanical means. These corridors would halt the spread of large wildfires and / or allow a wildfire to be controlled due to better and safe access for fire suppression teams – with the overall aim of safeguarding the function of areas with high loads of deadwood. Maintenance of wildfire protection corridors would be achieved by regularly removing surface fuels (litter layer, grass-herb and litter layer, understory / natural regeneration) by mechanical treatment (e.g., shredding fire fuels and thus creating compact layers of organic material, which would keep soil moisture and lower-level fuel moisture wet), by prescribed grazing (silvo-pastoral or other agroforestry land use) or prescribed burning (Goldammer 2020, 2021).

6. KNOWLEDGE GAPS

Based on general knowledge on fire behaviour, it is likely that in most conditions deadwood is not significantly contributing to fire risk. This has discouraged fire scientists from conducting experimental studies. If deadwood is extremely abundant or if its presence influences abundance of other fuels, such as attached branches and leaves, experimental studies could quantify its role on fire risk and enable later more in-depth analysis of the role of deadwood for biodiversity and in defining fire risk focused on European bioregions and forest types.

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Process of treatment of the request

The writing of this brief was part of the development phase of the future Science Service for Biodiversity, which the BioAgora project is currently leading in collaboration with the KCBD. The fast request for synthesis of knowledge was received first by the KCBD through its the new ticketing system, a novel online tool currently under test for policy DGs to submit knowledge requests linked to biodiversity, and then transmitted to BioAgora.

TIMELINE

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