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# Climate change and forest ecosystems vulnerability

**Forests cover around one third of the land surface in Europe. They provide key ecosystem services that contribute to human well-being and climate mitigation. Forests are vulnerable systems because the long life-span of trees limits rapid adaptation to drastic environmental changes. Southern and northern Europe are particularly susceptible to natural disturbances because of the interplay between forest characteristics and the background climate. Rising temperature combined with changes in precipitation over the past two decades has likely reduced plant defence mechanisms and increased their vulnerability to insect outbreak disturbances, especially in high-latitude regions. Global warming will likely increase natural disturbances in the future, especially those from fires and insect outbreaks that are more severely affected by climate.**

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## Forest vulnerability across Europe

Of the 26 billion tonnes of forest biomass in Europe that is potentially vulnerable to natural disturbances, nearly half (46%) is threatened by windthrows, 29% by forest fires and 25% by insect outbreaks.

There is substantial spatial variation in the vulnerability of forests to different natural disturbances (Figure 1). Vulnerability to windthrows is highest in northern Europe, especially in Norway, as well as in southern Europe. In these regions, up to 60% of the stand biomass is potentially vulnerable in areas affected by windthrows. There is a south-north gradient of increasing vulnerability to fires and insect outbreaks, with the highest vulnerability in northern Europe, particularly in the Scandinavian Peninsula and European Russia, where areas affected by these disturbances may lose up to 30% of stand biomass.

**KEY MESSAGES**

## Significant vulnerability to natural disturbances

Presently around two thirds of total above ground forest stand biomass in the EU+UK is potentially vulnerable to natural disturbances.

## Both southern and northern Europe are particularly susceptible

Southern and northern Europe are regions with forests particularly susceptible to windthrows, fires and insect outbreaks.

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## About PESETA IV

The JRC PESETA IV project aims to better understand the biophysical and economic consequences of climate change. It does this by using projections of climate change for Europe from several climate models along with a set of climate change impact models. The project covers several sectors that are relevant to society and the natural environment, such as freshwater, agriculture, and coasts.

**ec.europa.eu/jrc/en/peseta-iv**

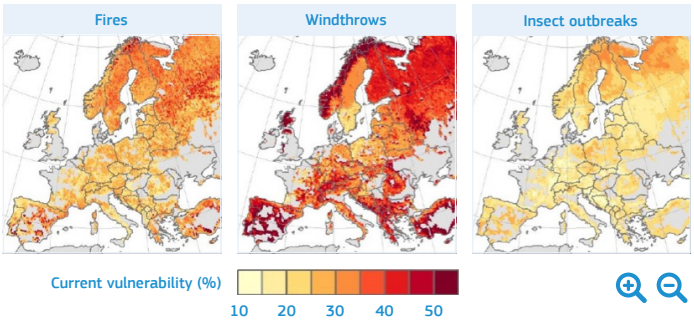


**Figure 1. Forest vulnerability to three major natural disturbances expressed as the share (%) of biomass that would be lost in case of each disturbance. Areas with less than 10% forest area are shaded grey.**

## Drivers of forest vulnerability

Forest vulnerability to fires and windstorms is largely controlled by forest characteristics, notably above ground biomass, growing stock volume, leaf area index, tree age and tree density. Forest structural characteristics have more important effects than climate and landscape conditions for fire and windstorm disturbances over most of Europe (Figure 2), although climate features can exert a strong control on fire disturbance in parts of northern Europe and on windthrow disturbance in eastern Russia.

For insect outbreaks, climate conditions play a more prominent role. In particular, anomalies in precipitation and temperature are key drivers of forest vulnerability to insects in most of northern Europe, alpine regions, and European Russia, while forest characteristics are critically important in most forests of central and southern Europe.

Overall, landscape features have a minor effect on vulnerability to natural disturbances.

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## Recent trends in forest vulnerability

When aggregating over Europe and the different disturbances considered in PESETA IV, a clear increasing trend in biomass vulnerability emerges over the past two decades, with a change of about 0.04 tonnes per square hectare per year.

An increasing amount of forests have become vulnerable to insect outbreaks, particularly in high-latitude areas. Regional trends can exceed 0.12 tonnes per square hectare per year.

No clear trends have been detected in forest vulnerability to windthrows and fires, although temporal variations in vulnerability to these two disturbances show a mixed spatial pattern.

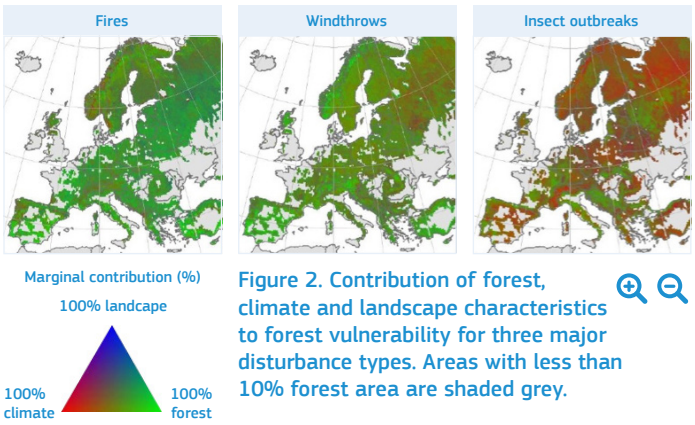


**Figure 2. Contribution of forest, climate and landscape characteristics to forest vulnerability for three major disturbance types. Areas with less than 10% forest area are shaded grey.**

## Implications of global warming

Other analysis conducted by PESETA IV on windstorms shows no clear trend in extreme wind speeds with global warming.

The PESETA IV forest fire analysis projects a climate-driven increase in fire danger in most of Europe, especially in southern regions. Rising temperatures and more spells of dryness with global warming, especially in southern Europe, could lead to increasing biomass loss from insect outbreaks and fires.

It is therefore likely that with increasing levels of global warming, forest disturbances are more likely to occur.

### Approach

Contact information: Giovanni Forzieri, JRC Bioeconomy Unit.

The vulnerability of European forests to three major natural disturbances was assessed: fires, windstorms and insect outbreaks (bark beetles, defoliators and sucking insects). Vulnerability is expressed as the degree to which forest ecosystems are affected when exposed to a disturbance. It is quantified in terms of relative biomass loss. Such estimates should, therefore, not be conflated with risk levels, as they do not integrate information on the probability of occurrence of disturbances (hazard).

For each disturbance type, a machine learning model was derived to predict biomass loss of plant functional types based on a number of forest, climate and landscape parameters:

- Forest parameters include factors that describe the forest state and productivity, such as biomass, growing stock volume, leaf area index, tree age, tree density and tree diameter.
- Climate parameters include long term averages and anomalies of temperature and precipitation in the years preceding the disturbance, as well as extremes of wind and aridity in the year of the disturbance.
- Landscape parameters include population density, spatial vegetation variability metrics and geomorphological characteristics.

The vulnerability models were calibrated and validated using a large set of records of forest areas affected by natural disturbances over the period 2000-2017. The vulnerability models were then used to extrapolate in space and time the annual vulnerability of forests. Based on the resulting time series, spatial patterns and temporal variations in vulnerability were evaluated.