ICP FORESTS
BRIEF #5
2021

ICP FORESTS

ICP Forests

Tree health is deteriorating in the European forests

KEY MESSAGES

1. Crown defoliation is an indicator of overall tree health and reflects the effects of environmental stressors

2. The proportion of fully foliated trees has declined over the past 30 years, while mean defoliation has increased, particularly since 2010

3. Insects (among biotic factors) and drought (among abiotic factors) are the most frequently reported causes of tree damage

4. Recent episodes of severe drought have increased crown defoliation and reduced tree growth. This may be exacerbated by air pollution

Clean Air 40 YEARS

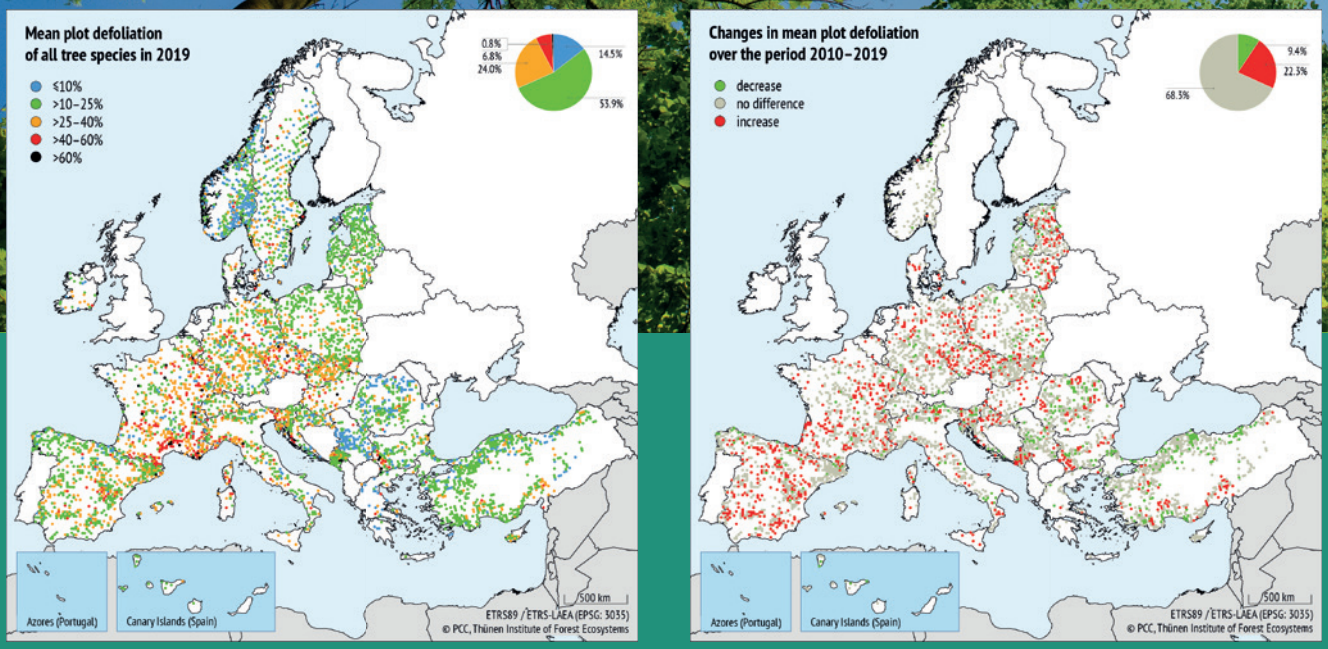
wge Working Group on Effects of the Convention on Long-range Transboundary Air Pollution

THÜNEN

ICP FORESTS
BRIEF #5
2021

ICP Forests has monitored the European forests since the late 1980s. This Brief describes temporal and spatial developments in tree defoliation, a widely adopted indicator of forest health and vitality. Crown defoliation is defined as the loss of foliage on a tree compared to a fully foliated reference tree.

The defoliation data were obtained from the transnational crown condition surveys (ICP Forests Level I) carried out annually between 1990 and 2019 by 36 countries on around 7440 plots and up to 145,000 trees. In addition to defoliation, data on the occurrence of biotic and abiotic factors responsible for tree damage were recorded.



Almost a third of monitoring plots show moderate to severe defoliation

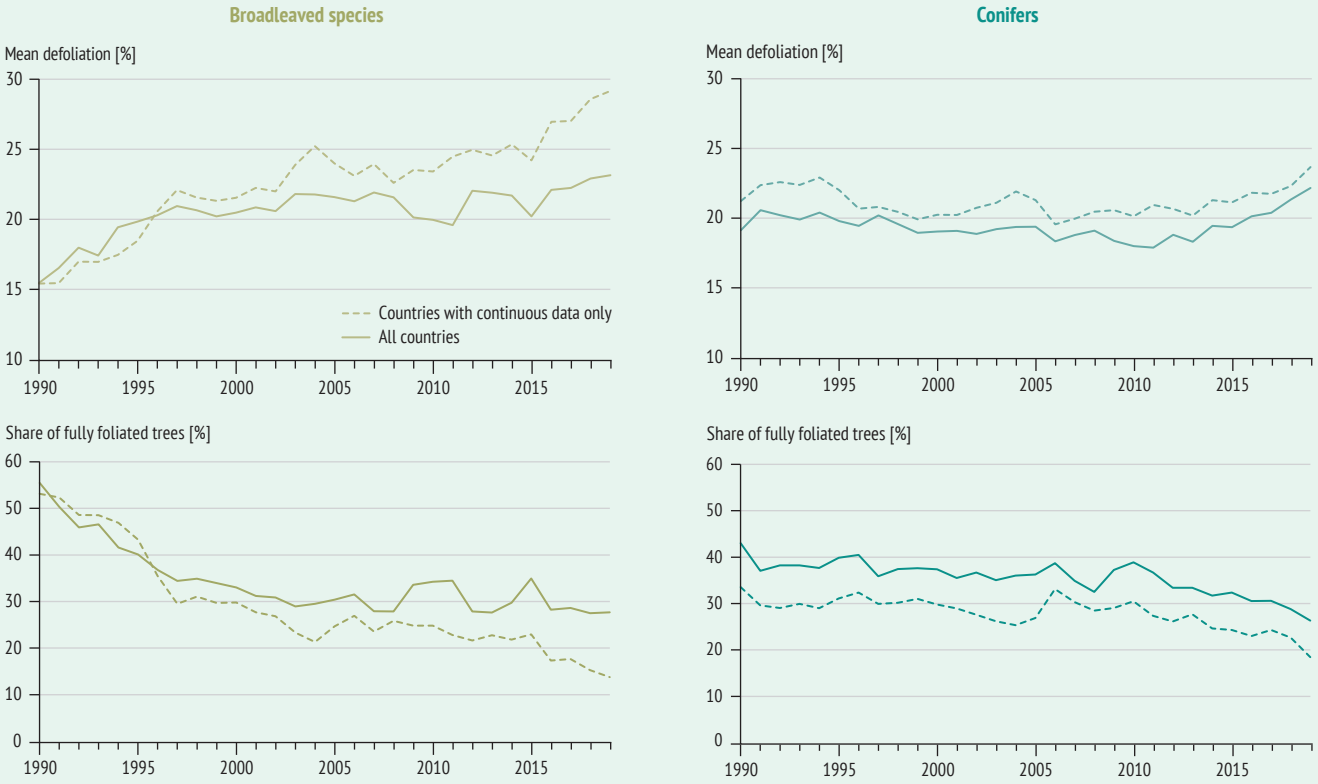
In 2019, mean defoliation was similar for conifers (22.2%) and broadleaved species (23.2%). While only 0.7% of trees were classified as dead (100% defoliation), a large share of plots (31.6%) fell within the moderate to severe crown defoliation categories (Figure 1, left). Plots with mean defoliation over 40% were primarily located in a band from the Pyrenees in southern France to north-western Italy, as well as from central and northern France through Germany and into Czechia, Slovakia and Hungary, Slovenia and western Bulgaria. Although mean defoliation between 2010 and 2019 remained unchanged on the majority of plots (68.3%), it did increase on 22.3% of plots and decreased (i.e., tree condition improved) on only 9.4% of plots (Figure 1, right).

▲ **Figure 1.** Mean plot defoliation of all tree species in 2019 (left) reported as defoliation classes: none (blue), slight (green), moderate (orange and red), severe (black). The percentages refer to needle/leaf loss in the crown compared to a reference tree, with the pie chart showing the percentage of plots per defoliation class. Changes in mean plot defoliation over the period 2010–2019 (right) with the pie chart showing the share of plots per direction of change. Note: Trends for Sweden could not be calculated due to annual changes in plot selection.

Fewer healthy trees in European forests than 30 years ago

There has been a significant increase in mean defoliation in broadleaved species over the past 30 years. For conifers an overall trend is less clear, but there has been a distinct increase since 2010 (Figure 2, upper). The proportion of fully foliated trees decreased significantly in both broadleaved species and conifers between 1990 and 2019 (Figure 2, lower), and was matched by an increase in the share of trees with defoliation higher than 25% and 60% (not shown). This pattern is even more pronounced for countries with continuous datasets (Figure 2, dashed lines). While tree ageing is an important factor in long-term forest health, defoliation has several environmental drivers. Among others, precipitation deficit has been shown to play a key role. For example, Figure 2 clearly shows a peak in mean defoliation after the 2003 drought episode.

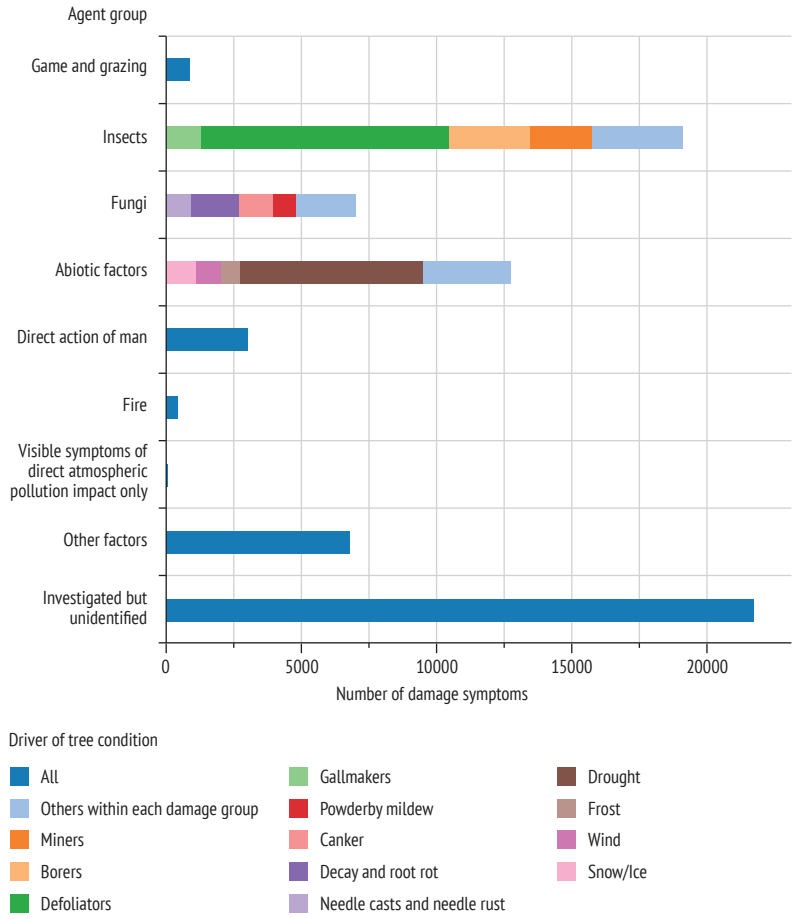
▼ **Figure 2.** Temporal trends in mean defoliation (upper) and for the share of fully foliated trees (0–10% defoliation) (lower) for broadleaved species (left) and conifers (right) obtained after resampling (1000 iterations per year). Continuous lines indicate data from all 36 countries that submitted data, while the dashed lines indicate data from the 10 countries that submitted data every year between 1990 and 2019. All trends except for those in the upper right graphic are statistically significant. Note: Adjustments in assessment methods may have happened in different countries.



Insect defoliators and drought are most frequently reported drivers of tree condition

Visible signs of tree damage were found on almost half of the trees monitored in 2019. Insects (especially defoliators) were the most frequently reported biotic factor causing tree damage, while drought was the main abiotic factor reported (Figure 3). The number of damage symptoms recorded per tree was higher for broadleaved species than for conifers. In particular, it was highest for evergreen and deciduous temperate oaks, and lowest for Norway spruce and Scots pine.

► **Figure 3.** Number of visible symptoms of tree damage reported in 2019 and the factors responsible, where known.



Role of climate change and air pollution in recent defoliation

Air pollution leading to an increase in nitrogen deposition and an increase in ground-level ozone concentrations can exacerbate climate change-related effects. For example, depending on the site, nitrogen deposition may stimulate tree growth, but may also lead to a nutrient imbalance, a change in the below-ground mycorrhizal community, and an increase in water demand, thus predisposing the trees to more severe damage by drought. In 2018, a particularly severe episode of drought affected large parts of central and northern Europe causing widespread early-wilting of foliage, severe defoliation, and a rapid and significant reduction in tree growth.

Final remarks

Tree health is deteriorating in Europe. Variability and long-term changes in climate, nitrogen deposition, and their interplay with insects and pathogens continue to be the main environmental factors affecting forest condition in Europe and beyond. Long-term monitoring data are important for evaluating the health status of forests and their response to the changing environment. The ICP Forests tree condition data thus represent a key asset for helping disentangle the contributions of individual factors to tree vitality, and thus to identifying solutions for improving the resilience and adaptive capacity of European forests.

Tree defoliation: an integrative indicator of forest condition

Since the 1980s, crown defoliation has been used as a proxy for tree health and vitality, and has been associated with reduced growth and the probability of a tree dying.

Although during the 1980s the deposition of sulphur and nitrogen due to air pollution was seen as the main cause of defoliation, it is clear that defoliation is also influenced by many other factors, including changes in soil and climatic condition, weather extremes, insect attacks, and fungal infestations. The implementation of air pollution abatement policies in recent decades has reduced the direct pressure of air pollutants on forests, however nitrogen deposition and ground-level ozone concentrations remain very high in many European regions (see also ICP Forests Briefs Nos. 2, 3 and 4).

Although not specific in terms of causal relationships, defoliation represents a useful integrative early warning indicator for the response of forest ecosystems to environmental change.

Suggested reading

Brun P et al., 2020. Large-scale early-wilting response of Central European forests to the 2018 extreme drought. Global Change Biology. https://doi.org/10.1111/gcb.15360

Eichhorn J et al., 2020 Part IV: Visual assessment of crown condition and damaging agents. In: Manual on Methods and Criteria for Harmonized Sampling, Assessment, Monitoring and Analysis of the Effects of Air Pollution on Forests. UNECE ICP Forests Programme Co-ordinating Centre, Thünen Institute of Forest Ecosystems, Eberswalde, Germany. http://icp-forests.org/Manual.htm

Ferretti M et al., 2021. Tree canopy defoliation can reveal growth decline in mid-latitude temperate forests. Ecological Indicators. https://doi.org/10.1016/j.ecolind.2021.107749

Rohner B et al., 2021. Tree vitality indicators revealed a rapid response of beech forests to the 2018 drought. Ecological Indicators. https://doi.org/10.1016/j.ecolind.2020.106903

Sousa-Silva R et al., 2018. Tree diversity mitigates defoliation after a drought-induced tipping point. Global Change Biology. https://doi.org/10.1111/gcb.14326

Norway spruce

0% defoliation

65% defoliation

European beech

10% defoliation

75% defoliation

The above photos show examples of fully foliated and severely defoliated trees for Norway spruce (*Picea abies* (L.) H.Karst.) and European beech (*Fagus sylvatica* L.), two frequent species in European forests.

Defoliation assessments consider the part of the tree crown not subject to competition from neighbouring trees. They are undertaken using harmonised methodology (www.icp-forests.org/Manual.htm). Results are presented in terms of a proportional scale in 5% steps, classified according to five categories: fully foliated (0–10%), slightly defoliated (>10–25%), moderately defoliated (>25–60%), severely defoliated (>60–99%) and dead (100%). Defoliation is one of the Indicators for the Maintenance of Forest Health and Vitality adopted by FOREST EUROPE, the brand name of the Ministerial Conference on the Protection of Forests in Europe (FOREST EUROPE, 2020. State of Europe's Forests 2020. https://foresteurope.org/).

United Nations Economic Commission for Europe (UNECE) Convention on Long-range Transboundary Air Pollution (Air Convention) International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests)

ICP FORESTS
BRIEF #5
2021

ICP FORESTS

The data underlying this Brief were collected through ICP Forests. Monitoring sites are maintained by the ICP Forests member states and a wide range of environmental parameters and ecosystem responses are regularly assessed. See ICP Forests Brief #1 for further details.

For further information, please contact:
Programme Co-ordinating Centre of ICP Forests
Dr Kai Schwärzel, Head
Thünen Institute of Forest Ecosystems
Alfred-Möller-Str. 1, Haus 41/42
16225 Eberswalde, Germany
Email: pcc-icpforests@thuenen.de
http://icp-forests.net

ICP Forests Brief #5
December 2021

Authors: Nenad Potočić[1], Volkmar Timmermann[2], Mladen Ognjenović[1], Till Kirchner[3], Anne-Katrin Prescher[3], Marco Ferretti[4]
[1]Croatian Forest Research Institute
[2]Norwegian Institute of Bioeconomy Research (NIBIO)
[3]Thünen Institute of Forest Ecosystems
[4]Swiss Federal Research Institute WSL
Series editor: Alexa K Michel
Copy editor: Carolyn Symon, carolyn.symon@btinternet.com
Design & layout: Burnthebook.co.uk
Printing: Mertinkat, Eberswalde, Germany
Cover photo: MNStudio/Shutterstock.com

ISSN 2569-5657 (print) ISSN 2625-0985 (online)
10.3220/ICP1638780772000

Recommended citation: Potočić N, Timmermann V, Ognjenović M, Kirchner T, Prescher A-K, Ferretti M (2021) Tree health is deteriorating in the European forests (ICP Forests Brief No. 5). Programme Co-ordinating Centre of ICP Forests, Thünen Institute of Forest Ecosystems. https://doi.org/10.3220/ICP1638780772000

Acknowledgements: Thanks are extended to all countries, their staff, and other participating scientists who have contributed to the ICP Forests programme. This co-operation is the foundation of the Programme's continuing success.

icp-forests.net