2024

# Forest Condition in Europe

## The 2024 Assessment

ICP Forests Technical Report under the UNECE Convention on Long-range Transboundary Air Pollution (Air Convention)

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

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Alexa Michel, Katrin Haggenmüller, Till Kirchner, Anne-Katrin Prescher, Kai Schwärzel, Lena Wohlgemuth (editors)

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)
**http://icp-forests.net**

ICP FORESTS

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# SUMMARY


The International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) is one of the most comprehensive programs within the Working Group on Effects (WGE) under the UNECE Convention on Long-range Transboundary Air Pollution (Air Convention). To provide a regular overview of the program's activities, the ICP Forests Programme Co-ordinating Centre (PCC) yearly publishes an ICP Forests Technical Report, which summarizes research highlights and provides an opportunity for all participating countries to report on their national ICP Forests activities. The PCC also invites all ICP Forests Expert Panels (EP), Working Groups, and Committees to publish a comprehensive chapter on their most recent results from regular data evaluations.

This 2024 Technical Report presents results from 32 of the 42 countries participating in ICP Forests. Part A presents research highlights from the January–December 2023 reporting period, including:

- a concise overview by the EP Chairs of the most relevant key findings in the scientific literature in the forest-relevant, priority themes for the WGE strategic planning: N deposition, ozone, heavy metals, air pollution/climate change interactions;
- a list of 49 scientific publications for which ICP Forests data and/or the ICP Forests infrastructure was used;
- a list of presentations given at the FORECOMON 2023;
- a list of all 25 official requests for ICP Forests data.

Part B focuses on regular evaluations from within the program. This year the Technical Report includes the following chapters:

- Atmospheric throughfall deposition in European forests in 2022
- Meteorological conditions in European forests in 2022
- Tree crown condition in 2023.

Part C includes national reports on ICP Forests activities from the participating countries.

Online supplementary material complementing Part B is available online[1].

For contact information of all authors and international ICP Forests delegates, please refer to the Annex at the end of this document. For more information on the ICP Forests program, we kindly invite you to visit the ICP Forests website[2].

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Following is a summary of the presented results from regular evaluations in ICP Forests (Part B).

Atmospheric deposition is an important pathway by which atmospheric pollutants reach even remote areas, such as rural forest ecosystems. Pollutants generated by industry, traffic, agriculture, and other human activities are emitted into the atmosphere and can be transported to distant areas, where they are deposited mainly by wet deposition of compounds dissolved in rain, snow, sleet or the like, and by dry deposition of gases and particles on forest canopies.

The amount of deposited pollutants can be modelled, but *in-situ* measurements are needed because of the relatively high local variability of deposition caused by the distribution of pollutant sources and the properties of the receptor ecosystems, like forest type or local topography.

Chapter 6 of this report focuses on atmospheric throughfall deposition (i.e. deposition collected with samplers below the tree canopy in a forest stand) of acidifying, acid-buffering, and eutrophying compounds in European forests in 2022.

As in previous years, high throughfall deposition of nitrate and ammonium in 2022 was mainly found in central Europe, with some plots also extending from the UK to Lithuania and southern Sweden to Greece.

Sulphate deposition has substantially decreased since the start of the monitoring in some countries as early as in 1985 but high throughfall deposition is still found close to large point sources, mainly in central and south-eastern Europe. In the southern part of Europe, sulphate deposition is also influenced by episodic deposition of Saharan dust and volcanic activity.

Calcium and magnesium deposition can buffer the acidifying effect of atmospheric deposition. High calcium throughfall deposition was mostly reported from a large area in central and southern Europe. High magnesium deposition was found all across Europe.

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Temperature and precipitation patterns, especially during the vegetation period, play a key role in climate change impacts on forests. Chapter 7 on meteorological conditions in European forests in 2022 focuses on presenting and interpreting air temperature and precipitation data from ICP Forests Level II sites in 2022 and compares them with long-term mean values for different climatic regions in Europe.

According to the European State of the Climate 2022 report, 2022 was the second warmest year on record, with the hottest summer ever recorded in Europe. At ICP Forests Level II sites, it was also generally warmer and drier than the long-term average. In almost all climate zones, the air temperature at the sites in 2022 was at


[1] http://icp-forests.net/page/icp-forests-technical-report

[2] http://icp-forests.net

least 1 °C higher and the annual precipitation was reduced by -15 to -45% compared to the long-term average across Europe.

However, the health and vitality of forests is more strongly influenced by extreme temperatures than by average conditions. In this respect, heat and frost events are of particular interest. In 2022, maximum air temperatures of more than 40° C were observed in Spain, Slovenia, Serbia, and Greece. A significant increase in the number of days with temperatures above 30 °C was observed in all but one climatic region. Most Level II sites in the continental climate zones showed a significant reduction in late frost events by more than 50–100% compared to the long-term average, and in line with the very warm weather in 2022.

Tree crown defoliation and occurrence of biotic and abiotic damage are important indicators of forest health. Unlike assessments of tree damage, which can in some instances trace tree damage to a single cause, defoliation is an unspecific parameter of tree vitality, which can be affected by a number of anthropogenic and natural factors. Combining the assessment of damage symptoms and their causes with observations of defoliation allows for a better insight into the condition of trees, and the interpretation of the state of European forests and its trends in time and space is made easier. Chapter 8 on tree crown condition presents results from tree condition assessments on the large-scale, representative, transnational monitoring network (Level I) of ICP Forests carried out in 2023, as well as long-term trends for the main tree species and species groups.

In 2023, the overall mean defoliation for all species was 24.0%. There was a very slight increase of 0.1 percentage points (%p) in mean defoliation as compared to 2022, mainly due to an increase of 0.3%p for conifers, while defoliation of broadleaves remained unchanged. The strongest increase in defoliation occurred in deciduous temperate oaks (+1.7%p) and in Mediterranean lowland pines (+1.3%p), while the strongest decrease was recorded in evergreen oaks (-0.8%p) and common beech (-0.5%p).

Trend analyses show a considerable increase in defoliation of evergreen oaks (7.5%p) and Norway spruce (5.8%p) over the past 20 years. The increase in defoliation for common beech (4.7%p) was also relatively large, while the increase in defoliation for Scots pine and Mediterranean lowland pines was more moderate. The results of the trend analyses were not significant for deciduous temperate oaks, deciduous (sub-) Mediterranean oaks and Austrian pine.

This year there was no change in the percentage of trees with damage symptoms (49%) compared to 2022. As in previous years, the number of damage symptoms per assessed tree was substantially higher for broadleaves than for conifers (0.86 vs. 0.57, respectively). Insects, abiotic causes, and fungi were the most common damage agent groups for all species, comprising altogether more than half of all damage records. Tree mortality in 2023 was 1.1% (1 164 trees), an increase of 0.2 %p compared to the year before. While mortality rates for the main species and species groups ranged from 0.5 to 1.5%, mortality of *Betula pubescens* and *Fraxinus excelsior* was much higher at 4.5% and 7.9% respectively.

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## ONLINE SUPPLEMENTARY MATERIAL

Online supplementary material complementing Chapter 8 is available at
http://icp-forests.net/page/icp-forests-technical-report

# FOREWORD

## Dear Reader,

there are increasingly alarming signals from the European forests. While our forests are a recognized central asset for mitigating climate change and achieving the ambitious climate targets set e.g. by the EU Climate Law[1], their ability to fulfill the expectation in terms of carbon sequestration and provision of ecosystem services is more and more challenged[2,3]. Not surprisingly, the Bonn Ministerial Decision after the 9th FOREST EUROPE Ministerial Conference[4] acknowledged the unprecedent nature of the current climate crisis, underlined that preserving forest health is essential to forest resilience and emphasized that transboundary co-operation is essential for a better assessment of forest vulnerability and risks.

The pan-European monitoring system installed under the ICP Forests can play an important role in this context[5]. For this reason, it is my pleasure and honor to introduce the Technical Report "Forest Condition in Europe. The 2024 Assessment". This report provides the most recent account of selected results obtained by the largest long-term internationally co-ordinated and harmonized forest monitoring program in Europe – the ICP Forests.

The 2024 Report emphasizes the positive signals in relation to the continuous and distinct reduction of N and S deposition across Europe (Part B, Chapter 6). Although some hot spots still exist and calls for further reduction of emissions, the observed declining trends represent a clear success of the UN ECE Air Convention, which represents the institutional framework under which ICP Forests operates.

At the same time, however, the Report shows how the year 2022 was warmer and drier than the long-term average (Part B, Chapter 7). Measurements carried out at our Level II plots showed that in many cases mean temperatures "were more than 1.5 °C warmer than normal", especially during the vegetative period. Maximum temperatures higher than 35 up to 40 °C were recorded also in the forest of central Europe. Alongside, precipitation was significantly lower than the long-term average, especially in continental, oceanic, and mediterranean climates.

This overall tendency towards hotter and drier conditions can probably contribute to explaining the forest condition observed in the 2023 Level I survey (Part B, Chapter 8). Although slightly, defoliation and mortality continues to increase and can be associated with a number of observed symptoms of damage, among which insects (defoliators and bark beetles in particular), fungi (decays and root rot) and abiotic agents (in particular drought) were the most frequent ones.

It is always worth emphasizing the value of the multi-media (from atmosphere, to biosphere, lithosphere and hydrosphere) and multi-level concept (interconnected large-scale survey for status and change detection – Level I – to highly equipped sites for drivers-response relationships – Level II) at the basis of the ICP Forests: a program that was initially conceived to monitor the effects of air pollution provides now invaluable data also to assess the response of forests to climate change.

This requires enduring commitment, perseverance, and support. As every year, my gratitude goes to the Air Convention bodies, the Lead Country of the ICP Forests (Germany), all the participating Countries (see their reports in Part C), the Programme Co-ordinating Centre, Groups, Panels, Committees and – last but not least – all the Experts who "make" the ICP Forests and that contributed in preparing this report.

I wish you an informative and stimulating reading.

**Marco Ferretti**
**Chairman of the ICP Forests**
**Swiss Federal Research Institute WSL**

[1] European Climate Law. Regulation (EU) 2021/1119 of the European parliament and of the council of 30 June 2021 establishing the frame- work for achieving climate neutrality and amending regulations (EC) no 401/2009 and (EU) 2018/1999 ('European Climate Law'). PE/27/2021/ REV/1

[2] Forzieri G, Dakos V, McDowell NG, et al. (2022) Emerging signals of declining forest resilience under climate change. Nature 608:534-539. https://doi.org/10.1038/s41586-022-04959-9

[3] Riedel T et al. (2024) Der Wald in Deutschland. Ausgewählte Ergebnisse der vierten Bundeswaldinventur. Bundesministerium für Ernährung und Landwirtschaft (BMEL) (Ed.), 58 pp

[4] Bonn Ministerial Decision – Sustainable Forest Management as a Tool to Enhance Forest Resilience (2024). https://foresteurope.org/wp-content/uploads/2024/10/Bonn-Ministerial-Decision.pdf (accessed 28.11.2024)

[5] Ferretti M (2024) Europe must join forces to monitor its forests. Nature 626: 954. https://doi.org/10.1038/d41586-024-00558-y

# 1 INTRODUCTION

The UNECE Convention on Long-range Transboundary Air Pollution (Air Convention[1]) was the first international treaty to limit, reduce, and prevent air pollution and to provide information on its effects on a wide range of ecosystems, human health, crops, and materials. Since its establishment in 1979, it has been extended by eight protocols, advancing the abatement of the emission of sulphur (S), nitrogen oxides ($NO_x$), ground-level ozone ($O_3$), volatile organic compounds (VOC), persistent organic pollutants (POP), heavy metals (HM), and particulate matter (PM), including black carbon. The International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) is one of seven subsidiary groups (six ICPs and a joint Task Force with WHO) that report to the Working Group on Effects (WGE) under the Air Convention. It is led by Germany; its Programme Co-ordinating Centre is based at the Thünen Institute of Forest Ecosystems in Eberswalde, while its Chairperson Dr Marco Ferretti is based at the Swiss Federal Research Institute WSL.

ICP Forests is an extensive long-term forest monitoring network covering Europe and beyond. It was established in 1985 with the aim to collect, compile, and evaluate data on forest ecosystems across the UNECE region and monitor forest condition and development over time.

ICP Forests provides scientific knowledge on the effects of air pollution, climate change, and other stressors on forest ecosystems. It monitors forest condition at two intensity levels:

- The Level I monitoring is based on 5706 observation plots (as at 2023) on a systematic transnational grid of 16 x 16 km throughout Europe and beyond to gain insight into the geographic and temporal variations in forest condition.
- The Level II intensive monitoring comprises 640 plots (as at 2022, Table 1-1) in selected forest ecosystems with the aim to clarify cause-effect relationships between environmental drivers and forest ecosystem responses.

Quality assurance and quality control procedures are coordinated by committees within the program, and the ICP Forests Manual[2] ensures a standard approach for data collection in forest monitoring among the 42 participating countries. ICP Forests data is available upon request[3]; an open ICP Forests dataset providing an overview of the data, including general plot descriptions and information on data availability per plot over time, can be directly downloaded from the ICP Forests website[4].

Transnational long-term forest monitoring under ICP Forests has been a pioneering initiative that has proven to be successful in detecting, understanding, and modelling changes in forest ecosystems over the past 39 years. Under recent climatic changes, it is even more relevant than ever.

The yearly published ICP Forests Technical Report series summarizes the program's annual results and has become a valuable source of information on European forest ecosystem changes with time. This 2024 Technical Report of ICP Forests, its online supplementary material, and other information on the program can be downloaded from the ICP Forests website[5].

## Program highlights in 2023

### People

- We are extremely grateful to Sabine Augustin (Ministry contact Switzerland), Suzanne Benham (NFC UK), Sıtkı Öztürk (NFC Türkiye), and Sören Wulff (NFC Sweden), who all retired in 2023, for their longstanding co-operation, their expertise, and dedication to ICP Forests. We will greatly miss them.
- We would also like to thank Tom Levanič from the Slovenian Forestry Institute for chairing the EP Growth from 2014 to 2023.

### The Data Unit

- The data unit at the Programme Co-ordinating Centre (PCC) of ICP Forests is constantly improving the data management, data availability and usability, and information flow within the program and to the scientific community and the public. The following developments of the data unit were recently accomplished:
  - Missing period information has been gapfilled in DEM;
  - The units of ozone values (in AQ survey) have been standardized over all survey years.
  - A new form EV1 in System Installation Level I was introduced to the database. This enables to submit, e.g., liming management.
  - A coordinate report was made available, which is constantly updated to detect discrepancies in the coordinates.
  - As part of a campaign, many coordinate corrections were transferred to the database.
  - In C1/CC, the new damage status has been partly implemented.
  - A review of the litterfall database structure has started.

[1] https://unece.org/environment-policy/air
[2] http://icp-forests.net/page/icp-forests-manual
[3] http://icp-forests.net/page/data-requests
[4] http://icp-forests.org/open_data/
[5] http://icp-forests.net/page/icp-forests-technical-report

### Outreach and reporting

- The latest results from the Working Group on Quality Assurance and Quality Control on the 25th Needle/leaf Interlaboratory Comparison Test 2022/2023 with 43 laboratories from 22 countries, the 12th Deposition and Soil Solution Working Ringtest 2023 with 35 labs from 22 countries, and the 10th Soil Ringest 2021 with 32 labs from 21 countries are published. These reports can be downloaded from the ICP Forests website[1].
- The number of reported international, peer-reviewed publications using data that had either originated from the ICP Forests database or from ICP Forests plots remains high at 49 in 2023[2], thereby proving the relevance and use of the ICP Forests data and infrastructure in various research areas such as atmospheric deposition (esp. of nitrogen and sulphur), ozone concentrations, heavy metals, climate effects, tree condition and damage causes, forest biodiversity and deadwood, nutrient cycling, tree physiology, phenology, forest soils, and soil carbon.
- New e-learning courses on the UNECE Air Convention[3] have been published by the UN CC:e-Learn affiliation program. The course on the Convention and its protocols in English and Russian aims to raise awareness about air pollution, sources, effects, ways to prevent it, and the Convention as a framework for cooperation on cleaner air. Another e-learning course is on emission inventory development under the Convention, also available in English and Russian.
- ICP Forests works under the Working Group on Effects under the Air Convention. A new information source for the effects-related work of all ICPs under the Convention is the new website of the Working Group on Effects.

### Program meetings

- The EMEP Steering Body and Working Group on Effects under the UNECE Air Convention met on 7–8 February 2023 and 11–15 September 2023[4], to discuss the progress in activities and further development of effects-oriented activities, e.g., with regard to the 2024–2025 workplan for the implementation of the Convention and the review of the Gothenburg protocol.

  The revision process will include, e.g., the following issues: new emission reduction commitments for the pollutants currently covered by the Gothenburg Protocol; potential revisions of technical annexes including with regard to their level of ambition and scope; how to deliver further reductions of black carbon emissions; whether and how to address methane emissions; how to achieve additional ammonia emission reductions; overarching, collective risk-based target(s) to reduce risk to health and ecosystems in the region; and how to achieve integrated approaches among climate, energy, and air policies.
- At the Joint Expert Panel Meeting (27–31 March 2023) in Vienna, Austria, experts from six Expert Panels and Working Groups (AAQ, Biodiversity, Deposition, Foliage & Litterfall, Soil & Soil Solution, QA/QC in Labs) discussed current issues and developments in their respective field. We are very grateful to Anita Zolles (NFC Austria) and her colleagures from the Austrian Federal Research and Training Centre for Forests, Natural Hazards and Landscape BFW for the organization.
- The 10th ICP Forests Scientific Conference FORECOMON and the 39th ICP Forests Task Force Meeting, with 67 participants from 25 countries, were held online, 6–8 June 2023.
- The Programme Co-ordinating Group (PCG), Quality Assurance Committee, and Scientific Committee met in Berlin, 22–23 November 2023, to discuss current issues and the ICP Forests' further progress.

## Acknowledgements

We wish to thank the Federal Ministry of Food and Agriculture (BMEL) and all participating countries for the continued implementation and financial support of the ICP Forests. We also thank the United Nations Economic Commission for Europe (UNECE) and the Thünen Institute for the partial funding of the ICP Forests Programme Co-ordinating Centre, and the Swiss Federal Research Institute WSL for supporting the ICP Forests Chairperson Dr Marco Ferretti.

For the last 39 years the success of ICP Forests has depended on the continuous support from 42 participating countries and the expertise of many dedicated individuals. We would like to hereby express again our sincere gratitude to everyone involved in the ICP Forests and especially to the participating countries for their ongoing commitment and co-operation in forest ecosystem monitoring across the UNECE region.

For a complete list of all countries that are participating in ICP Forests with their responsible Ministries and National Focal Centres (NFC), please refer to the Annex.

[1] http://icp-forests.net/page/working-group-on-quality
http://icp-forests.net/page/icp-forests-other-publications
[2] http://icp-forests.net/page/publications
[3] https://unece.org/environmental-policy/air/e-learning
[4] https://unece.org/environment-policy/air

Table 1-1: Overview of the number of Level II plots per survey and country for which 2022 data were submitted to the ICP Forests Database by 1 December 2024

| | Air quality | Crown condition | Deposition | Foliage | Ground vegetation | Ground vegetation biomass | Growth and yield | Leaf area index | Litterfall | Meteorology | Ozone injury | Phenology | Soil | Soil solution |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Austria | | | 15 | 15 | | | | | | 6 | | | | |
| Belgium | 5 | 12 | 9 | | 11 | | 5 | 5 | 5 | 4 | | 5 | 2 | 9 |
| Bulgaria | 4 | 4 | 4 | 4 | 4 | | | | 3 | 4 | 2 | 1 | | 3 |
| Croatia | | 7 | 5 | 7 | | | 5 | | 4 | | 2 | 4 | | 3 |
| Cyprus | 1 | 4 | 2 | | | | | | | 2 | | | | 2 |
| Czechia | | 15 | 7 | | | | 7 | | 7 | 12 | | 6 | | 7 |
| Denmark | | 4 | 4 | | | | 3 | | 4 | 4 | | 3 | | 4 |
| Estonia | | 6 | 6 | | | | | | 1 | 1 | | | | 5 |
| Finland | | | 7 | | | | 1 | | | 8 | | | | 8 |
| France | 14 | 93 | 27 | | | | 93 | | 13 | 13 | 14 | | | 14 |
| Germany | 32 | 69 | 84 | 48 | 31 | 17 | 43 | 27 | 38 | 61 | 8 | 40 | 2 | 77 |
| Greece | | 4 | 3 | | | | | | 4 | 4 | 3 | 3 | | 2 |
| Hungary | | 7 | | | | | | 7 | | | | | | |
| Italy | 6 | 28 | 7 | | | | | | | | 6 | | | 4 |
| Latvia | | 3 | 3 | | | | | | 3 | | | | | 3 |
| Lithuania | 3 | 9 | 3 | | | | | | 3 | 1 | 9 | 1 | | 3 |
| Luxembourg | | 4 | | | | | | | | | | | | |
| Norway | | 2 | 3 | | | | | | | | | | | 3 |
| Poland | 12 | 133 | 12 | | | | | | | 12 | | | | 12 |
| Romania | 4 | 11 | 5 | | | | 4 | 3 | | 4 | 4 | 4 | | 5 |
| Serbia | | 5 | 5 | 3 | 5 | | 3 | 3 | 5 | 5 | | 5 | | 3 |
| Slovakia | 3 | 9 | 7 | | | | | | | 6 | 3 | | | 4 |
| Slovenia | 10 | 10 | 4 | | | | | | | 10 | | 9 | | 4 |
| Spain | 14 | 14 | 14 | | | | 14 | 14 | 14 | 14 | 14 | 14 | | 5 |
| Sweden | | | 51 | | | | | | | | | | | |
| Switzerland | 6 | 17 | 14 | | | | 18 | 4 | | 18 | 6 | 7 | | |
| Türkiye | | 50 | | | | | | | | | | | | |
| UK | 7 | | 7 | | | | 5 | 2 | 5 | 7 | | | | 7 |
| **Total** | **121** | **520** | **308** | **77** | **51** | **17** | **201** | **65** | **109** | **196** | **71** | **102** | **4** | **187** |

# PART A

# ICP Forests-related research highlights

2

# FOREST CONDITION AND ENVIRONMENTAL DRIVERS IN EUROPE – RECENT EVIDENCE FROM SELECTED STUDIES

*Marco Ferretti, Lars Vesterdal, Marcus Schaub, Kai Schwärzel, Roberto Canullo, Nathalie Cools, Bruno De Vos, Stefan Fleck, Elena Gottardini, Leena Hamberg, Aldo Marchetto, Tiina M. Nieminen, Diana Pitar, Nenad Potočić, Stephan Raspe, Pasi Rautio, Tanja Sanders, Andreas Schmitz, Volkmar Timmermann, Liisa Ukonmaanaho, Monika Vejpustková, Arne Verstraeten, Peter Waldner, Lena Wohlgemuth, Lothar Zimmermann*

## Introduction

Marco Ferretti, Lars Vesterdal, Marcus Schaub, Kai Schwärzel

Forests are increasingly threatened by climate change-related factors, and the knowledge and understanding of forest dynamics is necessary to identify management solutions for forest resilience while maintaining biodiversity and provision of ecosystem services. Continued monitoring is essential to document progress to reduce air pollution impacts on forests, an important factor affecting the health and sustainability of forest ecosystems around the world, especially under the concurrent pressure exerted by annual meteorological fluctuations and long-term climate change.

The data generated by the monitoring networks installed under ICP Forests demonstrates its high relevance at scientific and political levels. The ecosystem-oriented approach includes the main biotic and abiotic stressors that may impact our forests, and therefore enables identification of the role of air pollution. Yet, it is important to contextualize ICP Forests results within the larger picture offered by studies originating from other research and monitoring initiatives.

Here we present a brief overview prepared by the Expert Panels (EPs) and edited by the Scientific Committee of ICP Forests. EPs were asked to provide an overview of main evidence and key findings in their subject areas over the past year with particular focus on prioritized topics of the Working Group on Effects (WGE) under the UNECE Air Convention: nitrogen (N) deposition, ozone ($O_3$), heavy metals and air pollution-climate change interactions. EPs based their input on scientific publications that were selected if (1) peer-reviewed; (2) from the reporting year or the year before, if not yet included; (4) covering emerging issues; and (5) relevant to the UNECE Air Convention.

In the following, we summarize the main evidence according to three main ecosystem compartments: atmosphere, forest vegetation, and forest soil. Given the interrelationships and the continuous fluxes and cycles of pollutants, carbon, water and nutrients across the three compartments, some overlap exists among the different chapters. Connection and interrelationships are particularly important in view of the interactions between the abiotic and biotic environment, and specifically for air pollution, deposition, climate change, and extreme events.

## Recent evidence from selected studies

### ATMOSPHERE

#### Atmospheric deposition

Arne Verstraeten, Peter Waldner, Andreas Schmitz, Aldo Marchetto

Two studies at European scale provided new insights into forest ecosystem N cycling. Guerrieri et al. (2024) found evidence of substantial canopy nitrification through the analysis of the natural $\Delta^{17}O$ isotopic tracer in bulk precipitation and throughfall collected in beech and Scots pine stands across an N deposition gradient based on ten ICP Forests Level II plots. Additional genetic analysis of foliar samples enabled identification of archaea and specialized bacteria as the main taxa governing this process. Strikingly, the results imply that throughfall deposition probably underestimates the share of reduced N ($NH_4^+$) in total deposition and, ultimately, its impact on forest ecosystems. Findings are also relevant to the debate on widespread ecosystem N saturation versus ecosystem oligotrophication and can be used to improve canopy budget models. Verstraeten et al. (2023) compared throughfall deposition fluxes during the spring in homogeneous stands of beech, oak, spruce, and pine with airborne pollen concentrations of the dominant tree genus measured in nearby cities. Particularly for beech they found a positive relationship between the airborne pollen concentrations and throughfall fluxes of potassium, ammonium, organic nitrogen, and carbon. On the other hand, the results indicated that pollen or associated micro-organisms can reduce the amount of nitrate in throughfall. From this it can be concluded that the estimation of throughfall element fluxes is significantly affected by tree pollen.

Two studies conducted in Greek forests focused on the cycling and status of boron and cobalt respectively (Michopoulos et al. 2023a, 2023b). They are remarkable because these elements are not included in the standard list of parameters commonly assessed in the ICP Forests deposition survey, but both are essential plant micronutrients. Evidence was found that small amounts of boron and cobalt undergo long-range transport through the atmosphere and reach the forest canopy mainly through dry deposition.

### Ambient air quality

Diana Pitar, Elena Gottardini

In the last year, air quality research and monitoring activities focused on determining pollutant trends, especially ozone and its precursors, using models in which in situ and remote sensing data serve as inputs (Gaudel et al. 2024, Wang et al. 2024). Also, Shah at al. (2024) found that ozone trends increase not only due to its "traditional precursors", but also due to increased particulate nitrate photolysis. Considering climate change and air pollution changes, statistical downscaling projects decreasing ground-level ozone concentrations in the European area under the moderate SSP2-4.5 scenario, but increasing concentrations under the pessimistic SSP3-7.0 scenario (Hertig et al. 2023). Therefore, the effects of ozone on vegetation may become more and more pronounced. In line with this, Ferretti et al. (2024) showed that high summer ozone concentrations and foliar symptoms slightly decreased in European forests over the period 2005–2018. Ozone concentrations were higher in the Mediterranean and the Alpine biogeographic regions. Ozone has a significant effect on symptoms in the most sensitive species. Also, it was shown that symptoms tend to be driven by functional leaf traits.

## FOREST VEGETATION

### Forest growth

Tanja Sanders, Monika Vejpustková

Over the last years forests across Europe have shown increasing mortality and overall decreasing growth (Vacek et al. 2023, Rybar et al. 2023). This trend, driven by hotter droughts, is modified by nitrogen deposition as reported in a study by Dietrich et al. (2024). Several tree species in Central Europe change their response to climate at high nitrogen input, albeit in both directions. Similar results were found in a study by Cuciurean et al. (2024) who investigated the input of air pollution on forests. They found that pollutants impaired tree growth and that trees accumulated heavy metals in the wood, the concentrations of which decreased over time as pollution decreased.

In general, annual growth reductions of around 40% were found across all trees since 2018 (Thom et al. 2023). However, the variations among individuals and species were quite high (Thom et al. 2023) and large differences were found at a regional and species-specific level (Pretzsch et al. 2023). One of the species with growth reduction seems to be European beech (*Fagus sylvatica*) showing a marked decline under drought conditions (Rukh et al. 2023) and high nitrogen input (Karlsson et al. 2023, Dietrich et al. 2024).

Overall, the development towards more extreme temperatures and recurring droughts has a measurable impact on Europe's forests. While some species benefit from the rising temperatures, some will decline under the drier conditions and the picture of our forest will therefore continue to change.

### Forest health

Nenad Potočić, Volkmar Timmermann

Recurrent climate-driven disturbances impact the health of European forests, which respond with increased tree crown defoliation, dieback, and mortality. Prompted by numerous reports on European beech suffering from severe growth reductions, early leaf senescence, leaf browning, and crown dieback, a paper by Rukh et al. (2023) explored the resistance of European beech to climate change, comparing the effects of major recent (2003 and 2018/2019) droughts in Central Europe. The results point to the conclusion that enhanced drought exposure of beech trees could push them beyond their hydraulic safety margins, with synergistic effects of drought-related impacts potentially leading to lower recovery and subsequent tree death. In order to better predict the future beech vitality in Central Europe, the authors recommend investigating both short- and long-term legacy effects of defoliation and its influence on growth after droughts.

Tree crown defoliation is the most widely used parameter for monitoring forest health, however, it is not a cause-specific indicator of tree vitality. On the contrary, physiological processes associated with defoliation can affect a tree's water relations, photosynthesis and carbon metabolism, growth, and nutrient balance. Bussotti et al. (2024) discussed relations of defoliation with various underlying physiological processes, environmental impacts, and other established vitality parameters, and suggested the inclusion of various physiological variables into forest monitoring that would enhance our level of understanding of the causes of tree decline and provide data to feed process-based models to predict forest tree mortality.

Tree mortality is an objective forest health indicator particularly suitable for long-term and large-scale studies of forest condition. Mortality rates, however, can be subject to different interpretations, related mostly to whether the trees removed in forest operations are included in the definition of mortality. An additional difficulty stems from the nature of forest monitoring, where assessments are repeated in annual or even multi-annual cycles, and the actual reasons for the removal of trees are unknown, i.e., we cannot determine whether trees were alive or dead at the time of extraction. Using data from the annual Level I surveys in Poland from 2009 to 2022 for pine, spruce, oak, and birch, Lech and Kamińska (2024) found that the calculated mortality rates depended on how removals were treated in the analysis. Based on data on defoliation and the severity of damage assessed prior to tree removal, the authors suggest that trees removed by sanitation cuts should be included when calculating mortality in managed forest stands.

### Forest nutrition

Liisa Ukonmaanaho, Lena Wohlgemuth

Common beech (*Fagus sylvatica*) is an ecologically and economically important tree species of European forests, which has been suffering from recent drought events due to climate change. Beech foliar nutritional status can serve as an insightful indicator to monitor the vitality of this common tree species and perform damage assessments. In this context, two recent studies have addressed impacts on beech health under varying climatic conditions/drought using foliar nutrient analysis.

Based on 28 beech plots of the ICP Forests Level I network, Ognjenović et al. (2023) found that differences in beech foliar nutrient concentrations between trees of high and low defoliation rate are influenced by climatic parameters such as mean/maximum annual temperature and mean annual precipitation as well as environmental parameters such as altitude, soil silt fraction, and soil exchangeable calcium (Ca). Examples of these differences include foliar Ca, for which the odds of low defoliation beech trees to exhibit high foliar Ca concentrations was found to be 90% higher with increasing mean annual precipitation than for high defoliation beech trees. However, a universal relation between foliar nutrition and defoliation of beech could not be established based on the investigated data, which was limited to Croatia in geographic extent. More research on the impact of environmental factors on foliar nutrition is therefore necessary including climatic gradients of a wider geographic area.

Marušić et al. (2023) investigated how drought conditions impact nutrient uptake by beech saplings and how the interplay between nutrient availability and drought stress affects physiology, growth, and biomass accumulation of young beech trees. Among other observations, the authors detected that foliar nitrogen and potassium concentrations were affected in saplings previously exposed to prolonged drought, regardless of fertilization dose. During the course of drought, fertilization significantly lessened the immediate effect of drought on foliar nitrogen concentrations. Fertilization also played a significant role in the recovery of phosphorus levels after drought, emphasizing the importance of phosphorus availability for beech forest vitality.

### Meteorological trends and effects on forests

Stefan Fleck, Stephan Raspe, Lothar Zimmermann

A review on impacts and damages of the European multi-year drought and heat event 2018–2022 on forests (Knutzen et al. 2023) combined information on European-wide SPEI maps of summer respectively spring and summer for these years with country-specific information on forest damage as well as ICP Forests data. Damage by heat and drought was categorized by physiological reasons, pests, and forest fires. The following trends were derived: (1) Relative defoliation rates of broadleaves are higher than that of conifers in every country with the exception of Czechia; (2) the incidence of wood destroyed by insects is extremely high in central Europe and Sweden; (3) although forest fires can be related to heat and drought, they are superimposed by other anthropogenic influences; (4) forests in central Europe were particularly affected, while forests in the northern and Alpine zones were less affected, and adaptations to heat and drought can still be observed in the southern zone; (5) although 2021 was an average year in several regions, high levels of damage were still observed indicating strong legacy effects of 2018–2020.

In a methodological study on interception in two even-aged (40–60 years) temperate oak (deciduous) and Norway spruce (coniferous) forests in Denmark, Andreasen et al. (2023) report precipitation and throughfall for 13 and 11 months, respectively. One site was part of the ICP Forests Level II programme, the other was part of the Integrated Carbon Observation System ICOS. Canopy structure parameters relevant for interception were derived from these data. The observation-based interception loss was compared to predictions obtained by the analytical Gash interception model using the derived canopy structure parameters. One year with the same precipitation was simulated at both sites (526 mm), and the interception loss was 35% for the deciduous forest and 51% for the coniferous forest. These simulated values were similar to field observations of interception loss amounting to 35% in the deciduous and 46% in the coniferous forest. As a main result, improved agreement between observation-based and predicted interception loss is obtained in the deciduous forest using canopy structure parameters for the leafless and full-foliage periods instead of annual average values.

### Forest species composition and diversity

Leena Hamberg

Occupancy patterns of birds, mammals, plants, and phytoplankton between protected and unprotected sites in Finland were investigated across four decades (Santangeli et al. 2023). Mixed impacts of protected areas were found, with only a small proportion of species explicitly benefiting from protection, mainly through slower rates of decline inside protected areas. The results suggested that the current protected area network can partly contribute to slow down species declines, but alone they will not suffice to halt the biodiversity crisis. Thus, coverage, connectivity, and management should be improved to enhance the efficiency of protected areas towards bending the curve of biodiversity loss. Protection can contribute to shape species occurrences, but the effects are highly species-specific and depend on key features of the protected areas, such as the timing of protection and the size of the protected area.

In coniferous forests in Finland, the effects of broadleaved tree admixture, tree species richness, stand density, and shrub cover on the number of vascular plant species were studied by using data from ICP Forests Level I sample plots in 2006 (Salemaa et al. 2023). Vascular species richness and herb cover generally increased with increasing proportion of broadleaved trees and tree species richness, but high stand density and extensive shrub cover reduced the positive biodiversity effects. An increase in proportion of broadleaved trees correlated positively with calcium and negatively with C:N of the organic layer, and therefore, nutrient input from easily decomposable birch leaf litter was considered to promote species richness and herb cover via improved nutrient availability in the soil.

Bryophytes growing on different substrates were identified in ICP Forests Level I and Level II monitoring plots in close-to-nature managed forests in Slovenia (Kutnar et al. 2023a). The bedrock and tree species composition were important drivers of bryophyte species diversity and composition. Functional diversity and composition of bryophytes were also significantly affected by bedrock and soil, but somewhat less so by tree species composition. In another study, Kutnar et al. (2023b) compared species richness and trait diversity as well as species composition and trait composition between vascular plant and bryophyte assemblages. The number of all bryophytes was positively correlated with vascular species richness. However, since both congruences and discrepancies in the drivers controlling the diversity and composition of the two groups at taxonomic and functional trait levels were found, the authors recommended long-term maintenance of the structural and compositional heterogeneity of stands also in the future.

A study in Italy revealed that the sampling approach of ICP Forests Level I plots performed better in estimating understory vascular plant species richness and diversity than the sampling approach called preferential sampling (Alessi et al. 2023). In the preferential approach, vegetation plots were selected at environmentally homogeneous sites on the basis of expert selection, and variable numbers and sizes of plots were used to characterize plant communities. The preferential approach, including a larger set of sample plots, was better in detecting forest specialist species and plant diversity hotspots. Based on the results, the authors suggested that both sampling approaches could be used in combination for better conservation and monitoring to detect multiple aspects of plant community diversity.

### FOREST SOIL

Nathalie Cools, Bruno De Vos, Tiina M. Nieminen

In Italy, Andreetta et al. (2023) showed that the soil type is an important environmental factor to explain soil organic carbon storage across ICP Forests Level I plots. However, in boreal forests Merilä et al. (2023) showed the relative importance of tree species along a latitudinal gradient based on ICP Forests Level II plots. In France, Saenger et al. (2024) found a significant increase in the surface soil carbon stock between two ICP Forests Level II soil inventories. Conversely the relative increase of the total nitrogen stocks was lower in the surface soil and a general and sharp decline of total nitrogen was detected in the subsoil. These results led to a substantial increase in C/N ratio over the whole soil profile. A second finding was that the recovery from soil acidification depends on the initial base saturation status. In highly acidified contexts, increased soil acidification over the profile was observed, while exchangeable base cation pools increased. On the other hand, less acidic soils saw their global buffer capacity enhanced.

In Sweden, Karlsson et al. (2024) found that the reduced deposition load has improved the acidification status of the soil solution but the forest ecosystems are far from fully recovered, with low buffering capacity (ANC – Anion Neutralising Capacity) and thus show low resilience towards inputs of acidity. The sulphur concentrations in the soil solution have decreased, and on many of the most acidified sites ANC has increased substantially but is still below zero. Several less acidified sites have increased pH values in soil solution, but there are also some examples of decreased pH values. Forest ecosystems in southwest Sweden are often close to N saturation, with frequent leakage of $NO_3$ from the root zone, which does not appear to have changed over the last 35 years. It is concluded that continued monitoring of soil water chemistry is important to follow the forest soil recovery progress in a changing climate.

It becomes more and more evident that the forest soil microbiome, i.e., bacteria, archaea, and fungi, plays an essential role in response to eutrophication caused by nitrogen deposition. Baldrian et al. (2023) found that nitrogen deposition substantially affects the forest soil microbial processes, especially in the temperate zone. The soil microbiome drives multiple crucial steps in the biogeochemical cycles (Meena et al. 2023). Several studies highlight the relative importance of the fungal communities. Based on DNA sequencing of soil samples from 238 ICP Forests Level II plots across a northeast–southwest gradient in Europe, Anthony et al. (2024) demonstrated that fungal, but not bacterial, composition and richness are correlated with tree growth rates and tree biomass carbon stocks. In France, Cissé et al. (2023) found that glomalin-related soil protein (GRSP), thought to be of fungal origin, makes up a distinct fraction of soil organic matter (SOM) in forest soils. Digging deeper into plant-microorganism-soil interactions will help to predict the future of forests and identify management strategies to increase ecosystem stability and alleviate climate change effects. Currently soil biota and their functioning are not included in the ICP Forests soil monitoring programme, however, recent scientific findings provide strong arguments for inclusion of soil biota community and diversity indicators in the future monitoring programme.

## Conclusions

Marco Ferretti, Lars Vesterdal, Marcus Schaub

Climate change is dramatically affecting our forests, together with lasting effects of air pollution and acidification. On one side, there are reports of widespread increased tree mortality and reduced growth, although with some regional differences. On the other side, the complex dynamics of air pollution across forest ecosystems, and the complexity of related measurements, have been pointed out. In synthesis:

- Canopy processes, phenology, and leaf traits can have an important role for the measured deposition levels, e.g., on N-related species and other nutrients, and on the onset of ozone visible symptoms.

- Despite some stagnation of the temporal trend in ozone concentration, ozone is still causing visible symptoms on a variety of broadleaved species.
- Forest health and growth were extensively affected, mostly by climate-change related factors but also in combination with atmospheric deposition of N and foliar nutrition, although with yet unclear patterns.
- In terms of biodiversity, the role of the composition of the tree species layer, the stand structure, the shrub coverage, and the bedrock were found important for vascular species and Bryophytes.
- In parts of Europe, soil has not yet recovered from previous high acidification loads. Soil type and tree species have been confirmed as strong drivers of soil carbon stocks across Europe, and dynamics observed in soil carbon differed between topsoil and subsoil. In addition, soil microbiota is emerging more and more as an important driver of forest growth – and likely of forest health.

ICP Forest is unique in its role as a pan-European, science-based monitoring programme and shows how maintenance of up-to-date information on tree vitality status and trends is fundamental. The combined detection of changes and the process understanding is highly needed to build future resilient forests.

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# 3 OVERVIEW OF ICP FORESTS-RELATED PUBLICATIONS (JANUARY – DECEMBER 2023)

Between January and December 2023, data that had either originated from the ICP Forests database or from ICP Forests plots were part of several international, peer-reviewed publications in various research areas, thereby expanding the scope of scientific findings beyond air pollution effects. These are compiled in the following list.

In addition, many publications – not reported here – cite the ICP Forests Manual[1], which reflects the high value and appreciation of standardized methods in forest ecosystem research.

The following overview includes only those 49 English online and in print publications from 2023 that have been reported to the ICP Forests Programme Co-ordinating Centre by the publication date of this report and have been added to the list of ICP Forests publications on the program's website[2].


Alessi N, Bonari G, Zannini P, et al (2023) **Probabilistic and preferential sampling approaches offer integrated perspectives of Italian forest diversity.** J Vegetation Science 34:e13175. https://doi.org/10.1111/jvs.13175

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4

# FORECOMON 2023 – THE 10TH FOREST ECOSYSTEM MONITORING CONFERENCE

2023 FORECOMON

The 10th Forest Ecosystem Monitoring Conference *Forest Monitoring in the Anthropocene - Results, Approaches, and perspectives* was hosted by the German Federal Ministry of Food and Agriculture, the ICP Forests Scientific Committee, and the ICP Forests Programme Co-ordinating Centre. It was held online on 6 June 2023 in conjunction with the ICP Forests Task Force Meeting and had been reduced to one afternoon.

### Background

Forest ecosystems play a key role in the ongoing global change as they possess a great proportion of terrestrial carbon and biodiversity. Their response to the large-scale environmental changes of our time such as anthropogenic air pollution, rising air temperatures, changing rainfall patterns, and increasing occurrence of weather extremes (drought, heat, floods, storms etc.) have crucial implications for terrestrial flora, fauna and human societies.

Forests are growing in local, national, and global importance for ecosystem services such as timber production, water purification, carbon sequestration and soil erosion control. Although societal expectations of forest and forestry are expanding, the provision of these key ecosystem services is becoming more and more endangered. To assess the impact of global change on forest ecosystems and their resilience, long-term data series are indispensable to evaluate the status, new phenomena, trends and processes in forest ecosystems. These data series are the foundation for scientifically sound decision making. Consequently, the need for target-oriented cooperation within and between international monitoring networks is clear.

More than three decades of monitoring effects of air pollution within ICP Forests operating under the UNECE Air Convention have furnished a harmonized and standardized asset: long-term data series. These allow scientists, stakeholders and policy makers to assess the status, investigate the processes and forecast changes of European forest ecosystems and their functioning in a dynamic environment.

### Program

The conference addressed scientists and experts from ICP Forests, the wider UNECE community under and beyond the Working Group on Effects (WGE), partners and stakeholders, and interested scientists and experts interested in long-term trends and extreme events in forests. Especially, researchers using ICP Forests data in their projects, evaluations, and modelling exercises were invited.

The following list includes all oral presentations that were given online at the 10th FORECOMON Conference. All conference abstracts are available from the FORECOMON 2023 website[1].

Session 1 - Forest monitoring in the Anthropocene - the results.
Session chair: Lena Wohlgemuth

Andreetta A, Chelli S, Bonifacio E, et al. [Presentation]
**Impacts of environmental and pedological factors on soil organic carbon storage in Italian forests**

Salomon R, Steppe K, and Dendrought2018 consortium [Presentation]
**Heatwave effects on tree stem growth and dehydration: A tree-level perspective across large spatial scales**

Eghdami H & Werner W [Presentation]
**Long time series of Ozone Flux Modelling for forest tree species in Central Europe**

Etzold S, Sterck F, Bose AK, et al. [Presentation]
**A few days determine the growth of temperate trees**

Caldararu S et al. [Presentation]
**Long-term ecosystem nitrogen limitation from foliar δ15N data and a land surface model**

Zhu J et al. [Presentation]
**Variation in leaf morphological traits of European beech and Norway spruce over two decades in Switzerland**

Cacciatori C et al. [Presentation]
**Cryptogamic diversity dynamics and their response to climate trends in ICP Forests Level II sites in Poland**

[1] https://forecomon2023.thuenen.de/

Session 2 - Forest monitoring in the Anthropocene – new approaches and perspectives. Session chair: Arne Verstraeten

Gessler A [Presentation]

**New approaches for monitoring forest functioning - crossing scales from the cellular metabolome to the stand wide photochemical reflectance index**

Rasilo T, Bäck J, Mirtl M [Presentation]

**Integrated approach to long-term observations in ecosystems, critical zone and socio-ecology (eLTER)**

Gielen B & Janssens I [Presentation]

**Status of the ICOS ecosystem network and how it may interact with ICP Forests**

Petzold R, Peters A, Luong TT, et al. [Presentation]

**The Soil Moisture Traffic Light - From measurements of the Level II plots to reliable real-time model estimates for forest managers**

5

# NEW DATA REQUESTS FROM PROJECTS USING ICP FORESTS DATA

ICP Forests welcomes scientists from within and outside the ICP Forests community to use ICP Forests data for research purposes. Data applicants must fill out a data request form and send it to the Programme Co-ordinating Centre (PCC) of ICP Forests and consent to the ICP Forests Data Policy. For more information, please refer to the ICP Forests website[1].

The following list provides an overview of all 25 requests for ICP Forests data made between January and December 2023. All past and present ICP Forests data uses are listed on the ICP Forests website[2].

| ID[3] | Institution | Name of Applicant | Project Title | External/ Internal[4] |
|---|---|---|---|---|
| 284 | Norwegian Institute of Bioeconomy Research (NIBIO) | Johannes Breidenbach | PathFinder: Towards an Integrated Consistent European LULUCF Monitoring and Policy Pathway Assessment Framework | External |
| 285 | University of Edinburgh | Tim Green | Modeling and analysis of carbon-climate interactions in northern latitude ecosystems | External |
| 287 | Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) | Yuman Sun, Marco Ferretti | Spatio-temporal development of forest condition in Europe | Internal |
| 288 | ETH Zürich, Switzerland | Amanda Mathys | Expansion of ecological, silvicultural and technical knowledge on forest fires | External |
| 289 | ETH Zürich, Switzerland | Marius Floriancic | Retention processes in litter and deadwood across the Alps | External |
| 292 | Centre for Ecological Research and Forestry Applications (CREAF) | Jordi Vayreda Duran | Evaluation of past changes in ecosystem services and biodiversity in forests and restoration priorities under global change impacts (GREEN-RISK) | External |
| 293 | Swiss Federal Institute for Forest, Snow and Landscape (WSL) | Peter Waldner | Nitrate leaching risk mapping under future conditions (NitLeach3) | Internal |
| 294 | INRAE, Aix-Marseille University, UMR RECOVER | Maxime Cailleret | Validation of the ForCeeps-Sureau model | External |
| 296 | Unité Evolution et Diversité Biologique - Centre National pour la Recherche Scientifique | Jérôme Chave | Validation of remote sensing aboveground biomass products at EU scale | External |
| 297 | Massachusetts Institute of Technology | César Terrer | Temporal trends of soil carbon stock in intact systems and the role of climate | External |
| 299 | LWF | Wolfgang Falk | Climate change induced mortality and growth trends as a basis for comparative nationwide assessments of tree species suitability in Germany (MultiRiskSuit) | External |

[1] http://icp-forests.net
[2] http://icp-forests.net/page/project-list
[3] ID-numbering started in 2011.
[4] Internal Evaluations can be initialized by the Chairperson of ICP Forests, the Programme Co-ordinating Centre, the Expert Panel Chairs and/or other bodies under the Air Convention. Different rights and obligations apply to internal vs. external data users.

| ID[3] | Institution | Name of Applicant | Project Title | External/ Internal[4] |
|---|---|---|---|---|
| 300 | GFZ | Alexandra Runge | Verification and validation of the Forest4model datacube | External |
| 301 | Princeton University | Minjin Lee | Coupling microbial and rhizosphere dynamics within the land model LM4.1 | External |
| 302 | WSL | Charlotte Grossiord | ReCLEAN: Reactive nitrogen at the CLimate, Energy, Agriculture, water, and health Nexus | External |
| 303 | University of Greifswald | Aron Garthen | Forest ecosystem functioning in response to wetter winters along a large climatic gradient (WetWin) | External |
| 304 | Natural Rescource Instititue of Finland (LUKE) | Raisa Mäkipää | Holisoils + (Soil and Health) Benchmarks + C-cut | External |
| 305 | European Molecular Biology Laboratory (EMBL) | Jordi van Gestel | Longitudinal investigation of microbial interactions between bacteriovores eukaryotes and bacteria in forest soils | External |
| 306 | University of Applied Sciences Weihenstephan-Triesdorf | Jörg Ewald | WINALP 21 - Mountain forests fit for climate change | External |
| 308 | ETH Zurich | Gina Marano | Simulating the impacts of drought-induced tree mortality at the stand scale | External |
| 309 | Royal Botanic Gardens Kew | Guillaume Delhaye | Large-scale diversity, distribution and fate of Europe | External |
| 310 | Global Change Research Institute CAS | Ruzena Janoutova | ENVision: a platform for analysing natural ecosystems using aerial and satellite data | External |
| 311 | Swiss Federal Institute for Forest, Snow and Landscape Research WSL | Claudia Guidi | Uncovering root contribution to soil carbon in European forests under changing climate | External |
| 312 | University of Basel | Christine Alewell | AI4SoilHealth: Accelerating collection and use of soil health information using AI technology to support the Soil Deal for Europe and EU Soil Observatory | External |
| 316 | Peking University | Qingshui Yu | Above- and belowground biodiversity linkages across the globe | External |
| 319 | Ecological and Forestry Applications Research Centre CREAF | Marcos Fernández Martínez | Elemental ecology: towards an element-based functional ecology (STOIKOS) | External |

# PART B
# Reports on individual surveys in ICP Forests

# 6 ATMOSPHERIC DEPOSITION IN EUROPEAN FORESTS IN 2022

*Aldo Marchetto, Katrin Haggenmüller, Till Kirchner, Alexa Michel, Andreas Schmitz, Arne Verstraeten, Peter Waldner*

## Introduction

The atmosphere contains a large number of substances of natural and anthropogenic origin. A large part of these can settle, be adsorbed to receptor surfaces, or be included in rain and snow and finally reach land surface as wet and dry deposition.

Sulphur deposition almost completely occurs in the form of sulphate ($SO_4^{2-}$), derived from marine aerosol and from sulphuric acid formed in the atmosphere by the interaction of gaseous sulphur dioxide ($SO_2$) with water.

$SO_2$ emissions derive mainly from coal combustion, but also from vehicle fuel combustion, volcanoes, forest fires, and other sources, and have increased since the 1850s, causing an increase in sulphate deposition and deposition acidity, which can only partly be buffered by the deposition of base cations, mainly calcium ($Ca^{2+}$) and magnesium ($Mg^{2+}$).

Natural sources of nitrogen (N) in the atmosphere are mainly restricted to the emission of laughing gas ($N_2O$) and molecular nitrogen gas ($N_2$) during denitrification and the conversion of $N_2$ into nitrogen oxides ($NO_x$) during lightning. However, human activities cause high emissions of $NO_x$ during combustion processes, and of ammonia ($NH_3$) from agriculture and farming. Nitrogen atmospheric wet deposition can be found in the form of nitrate ($NO_3^-$) and ammonium ($NH_4^+$).

Nitrogen compounds have significant effects on forest ecosystems: They are important plant nutrients that - when in excess - may lead to ecosystem eutrophication, and strongly influence plant metabolism (e.g., Silva et al. 2015), forest ecosystem processes (e.g. Meunier et al. 2016), and biodiversity (e.g., Bobbink et al. 2010)., and can also act as acidifying compounds (Bobbink and Hettelingh 2011).

In the last century, human activities led to a dramatic increase in the deposition of nitrogen and sulphur compounds but emission and deposition of sulphur and to a lesser extent nitrogen have significantly decreased in the last decades (Waldner et al. 2014; EEA 2016; Rogora et al. 2016, 2022) due to successful air pollution abatement under the UNECE Air Convention.

## Materials and methods

Atmospheric deposition is collected on the ICP Forests Level II intensive monitoring plots under the tree canopy (throughfall samplers, Fig. 6-1, left), along tree trunks in beech stands (stemflow samplers, Fig. 6-1, right), and in a nearby clearance (open-field samplers). Throughfall samples are used to estimate wet deposition, which is the amount of pollutants carried in by rain and snow, but they also include dry deposition from particulate matter and gases collected by the canopy and having been washed-off. The total deposition to a forest, however, also includes nitrogen taken up by leaves and organic nitrogen compounds. Its input can be estimated by applying canopy exchange models.

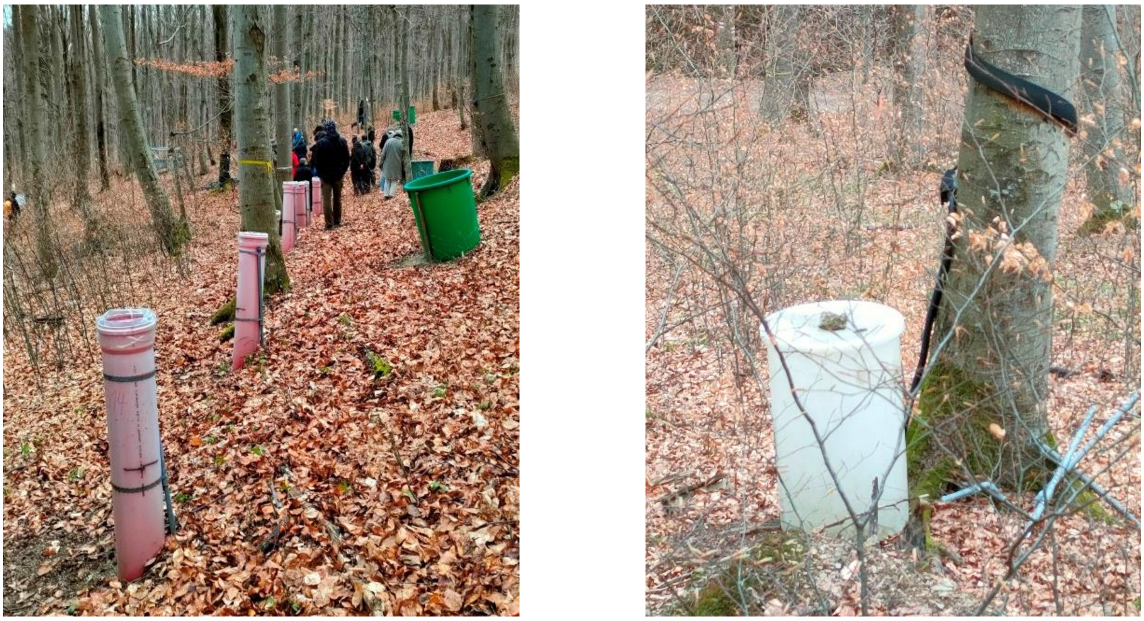

**Figure 6-1: Throughfall samplers (left) and stemflow sampler (right) on Level II plot 'Klausen-Leopoldsdorf' in European beech (*Fagus sylvatica*) stand located west of Vienna, Austria. Images: Arne Verstraeten**

It is important to note the different behaviour of individual ions when they interact with the canopy: in the case of sodium ($Na^+$), chloride ($Cl^-$), and sulphate, the interaction is almost negligible and it can be assumed that their throughfall deposition equals the sum of wet and dry deposition. This is not the case for other ions, such as ammonium: Tree canopies and their associated microbial communities strongly interact with them. For example, tree leaves can take up ammonium ions and release potassium ($K^+$) ions and organic compounds, thereby changing the composition of throughfall deposition.

Sampling, analysis, and quality control procedures are harmonized on the basis of the ICP Forests Manual (Clarke et al. 2022). Quality control and assurance include laboratory ring-tests, the use of control charts, and conductivity and ion balance checks on all samples (König et al. 2016). In calculating the ion balance, the charge of organic compounds was considered proportional to the dissolved organic carbon (DOC) content following Mosello et al. (2005, 2008).

In this report, we present the results of the 2022 annual throughfall deposition sampling from 281 permanent Level II intensive monitoring plots, following the ICP Forests Manual. Fourteen plots were excluded because the duration of sampling covered less than 90% (329 days) of the year, and 86 other plots were marked as "not validated" because the conductivity check was passed for less than 30% of the analyses of the year, or the laboratory did not participate in the mandatory Working Ring Test, or did not pass the minimum requirement of the test. For further 4 sites, data for magnesium were rejected because the laboratory did not pass the test for that variable. The same applies to one site for ammonium.

As the deposition of marine aerosol represents an important contribution to the total deposition of sulphate, calcium, and magnesium, a sea-salt correction was applied, subtracting from the deposition fluxes the marine contribution, calculated as a fraction of the chloride deposition according to the ICP Integrated Monitoring Manual (FEI 2013).

The color classes on the presented maps (low, medium, high) have been chosen to visualize the spatial distribution of deposition rates across Europe and do not necessarily correspond to the ecological impact of the deposition.

## Results

The heterogeneous spatial distribution of emission sources and receptors and the complex orography of parts of Europe result in a marked spatial variability of atmospheric deposition. However, on a broader scale, regional patterns in deposition arise.

In the case of nitrate and ammonium, high and moderate throughfall deposition was mainly found in central Europe, from Belgium to Germany to Poland, extending southward to Switzerland, Austria, Italy, and Slovenia, but some plots with high deposition were also reported from other countries (Figs. 6-2, 6-3).

Negative effects of nitrogen deposition on forests can become evident when inorganic nitrogen deposition (i.e. the sum of nitrate and ammonium deposition) exceeds a specific threshold, known as the critical load. Critical loads can be defined for each forest site by modeling, but more generic critical loads (empirical critical loads) are also being used, ranging between 3 and 17 kg N $ha^{-1}$ $y^{-1}$ depending on forest type and ecosystem compartment (Bobbink et al. 2022). In 2022, throughfall inorganic nitrogen deposition higher than 10 kg $ha^{-1}$ $y^{-1}$ was mainly measured in central Europe, including Belgium, Germany, Poland, Czechia, Austria, Switzerland, Slovenia and northern Italy (Fig. 6-4), but high deposition was also found in other countries, like France, the UK, Denmark, Sweden, Serbia, Greece, and Cyprus. Because total nitrogen deposition on forests is higher than throughfall nitrogen deposition (Braun et al. 2022), the critical loads for nitrogen are likely still exceeded in a large part of Europe.

Sulphate deposition has substantially decreased since the start of the monitoring in some countries as early as in 1985 but high throughfall sulphate deposition is still found close to large point sources. In southern Europe, sulphate deposition is also influenced by volcanic emission and by the episodic deposition of Saharan dust. In 2022, high and moderate throughfall deposition of sulphate (corrected for the marine contribution) was found mainly in central and south-eastern Europe with a small number of sites in Germany, Poland, Czechia, Slovakia, Croatia, Serbia, Bulgaria, Greece, and Cyprus (Fig. 6-5).

Although not considered atmospheric pollutants, calcium and magnesium are also analyzed in the ICP Forests deposition monitoring network, as their deposition can buffer the acidifying effect of atmospheric deposition and protect soil from acidification. High (sea-salt corrected) calcium throughfall deposition was mostly reported from a large area in central and southern Europe (Fig. 6-6). High magnesium deposition was found all across Europe (Fig. 6-7).

### Deposition trends in European forests over time

Atmospheric deposition of nitrogen and sulphur compounds markedly decreased in the last years, yet at different rates. Considering 133 plots for which deposition values were validated for the whole period 2017–2022, throughfall deposition of oxidized nitrogen, reduced nitrogen and non-marine sulphur in 2020–2022 was lower than in 2017–2019 by 24%, 12% and 31%, respectively (Fig. 6-8, left panel), while the differences in the amount of precipitation between the two periods were negligible.

In a subset of 49 plots mainly located in central and eastern Europe (shown in red in Fig, 6-8, central panel), a strong decrease in oxidized nitrogen deposition was recorded between 2019 and 2020, probably partly because of the reduction in nitrogen oxide emission during the COVID-19 pandemic lockdown. In those plots, oxidized nitrogen deposition increased again in 2021 and 2022, without reaching the level of the 2017–2019 period (Fig. 6-8, right panel).

EVALUATIONS

## Conclusions

Sulphate throughfall deposition has substantially decreased since the start of the monitoring nearly 40 years ago and today high sulphate deposition is mainly restricted to areas close to large point sources and in central and south-eastern Europe. High throughfall deposition of inorganic nitrogen is still observed throughout central Europe, with high ammonium deposition having been measured in a wider area than nitrate. A significant decrease in nitrogen emission across Europe was detected in 2019-2020 and might be associated with the COVID-19 pandemic lockdown.

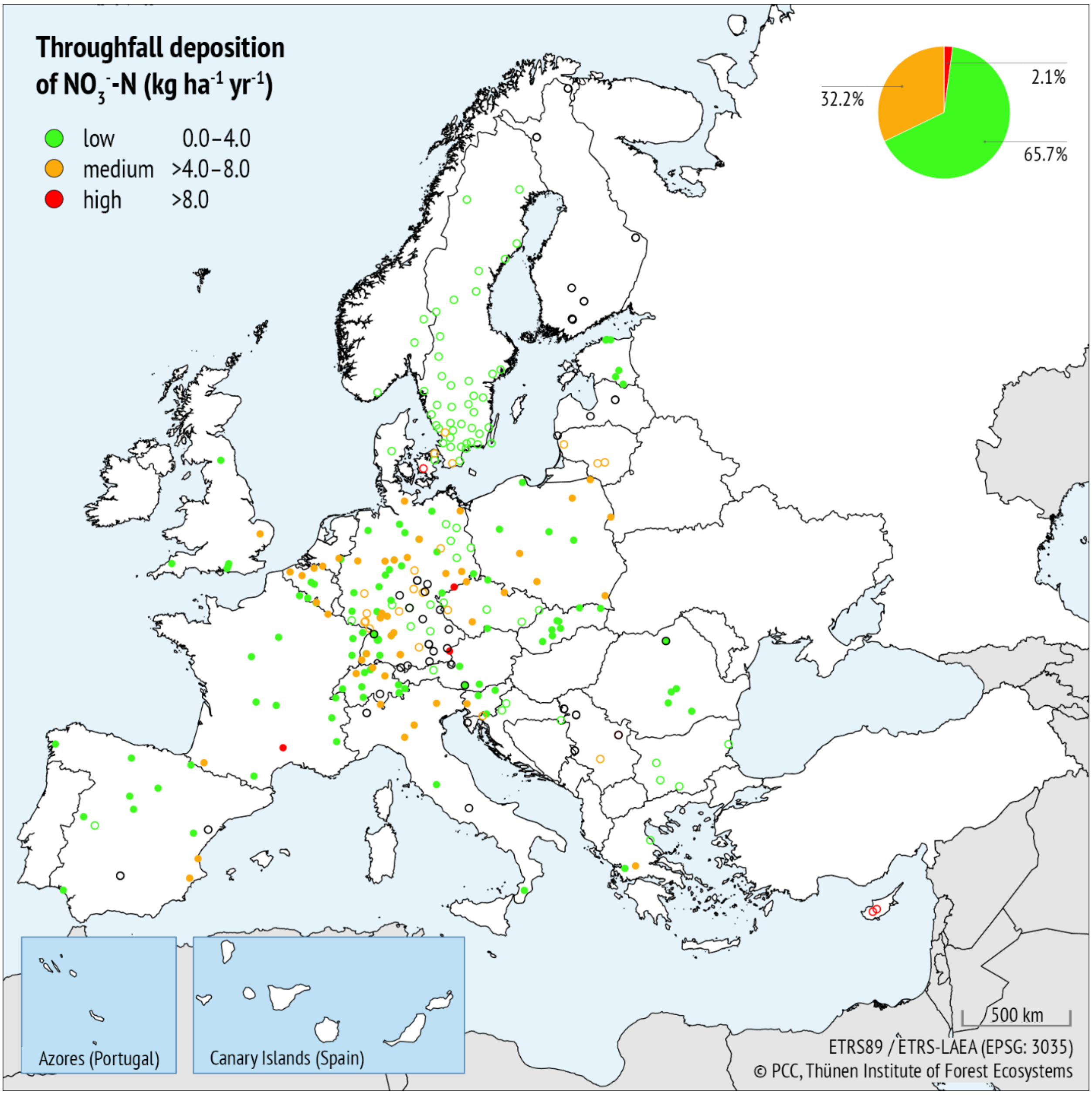


**Figure 6-2: Throughfall deposition of nitrate-nitrogen (kg $NO_3^-$-N $ha^{-1}$ $yr^{-1}$) measured in 2022 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network.** Colored dots: validated data. Colored circles: not validated data. Black circles: monitoring period shorter than 330 days or irregular sampling. The pie chart shows the percentage of plots with low, medium, and high deposition for validated data only.

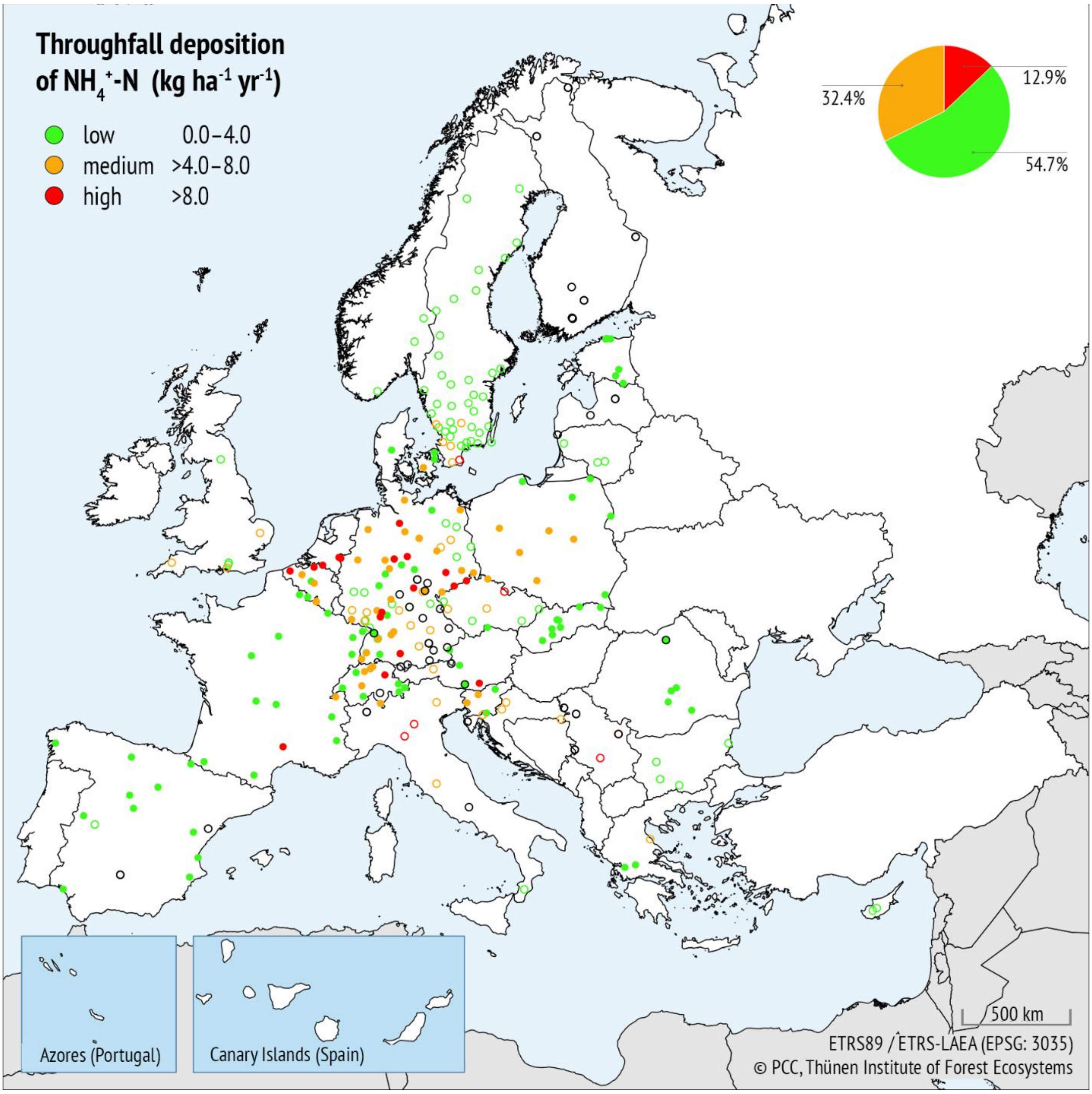


**Figure 6-3: Throughfall deposition of ammonium-nitrogen (kg $NH_4^+$-N ha$^{-1}$ yr$^{-1}$) measured in 2022 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network.** Colored dots: validated data. Colored circles: not validated data. Black circles: monitoring period shorter than 330 days or irregular sampling. The pie chart shows the percentage of plots with low, medium, and high deposition for validated data only.

EVALUATIONS

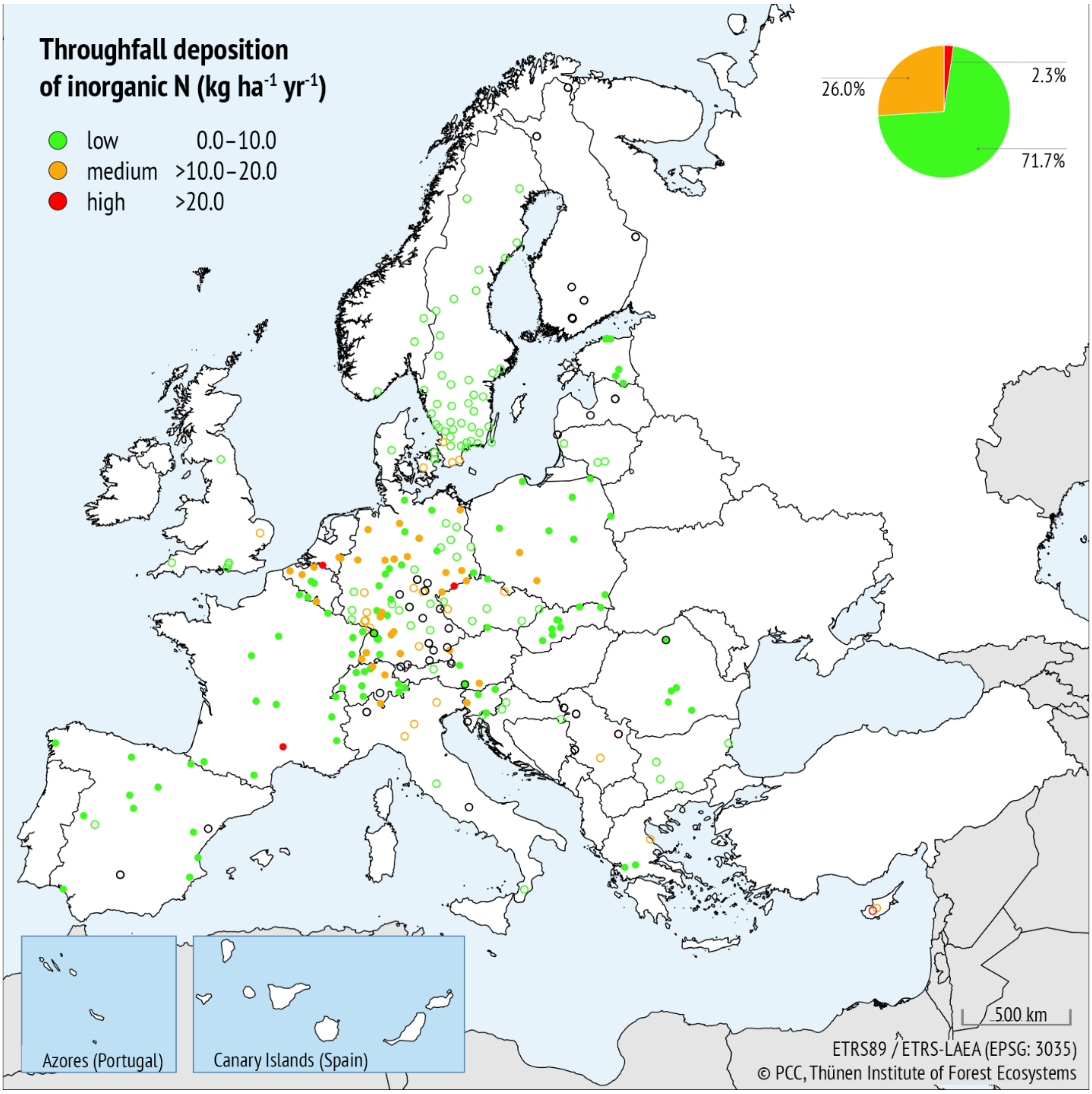


**Figure 6-4: Throughfall deposition of inorganic nitrogen (kg $NO_3^-$-N + $NH_4^+$-N ha$^{-1}$ yr$^{-1}$) measured in 2022 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network.** Colored dots: validated data. Colored circles: not validated data. Black circles: monitoring period shorter than 330 days or irregular sampling. The pie chart shows the percentage of plots with low, medium, and high deposition for validated data only.

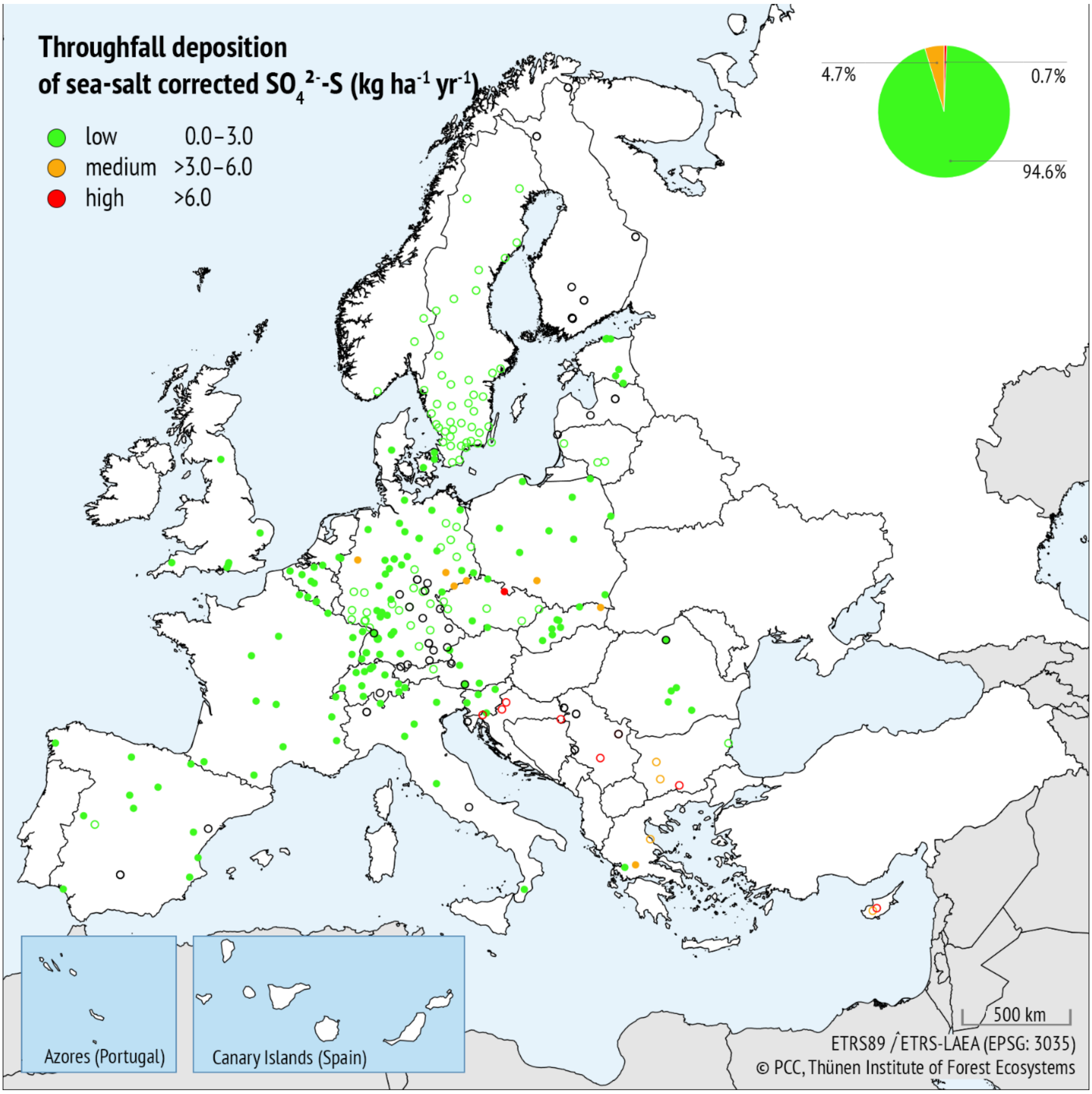


**Figure 6-5: Throughfall deposition of sea-salt corrected sulphate-sulphur (kg $SO_4^{2-}$-S ha$^{-1}$ yr$^{-1}$) measured in 2022 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network.** Colored dots: validated data. Colored circles: not validated data. Black circles: monitoring period shorter than 330 days or irregular sampling. The pie chart shows the percentage of plots with low, medium, and high deposition for validated data only.

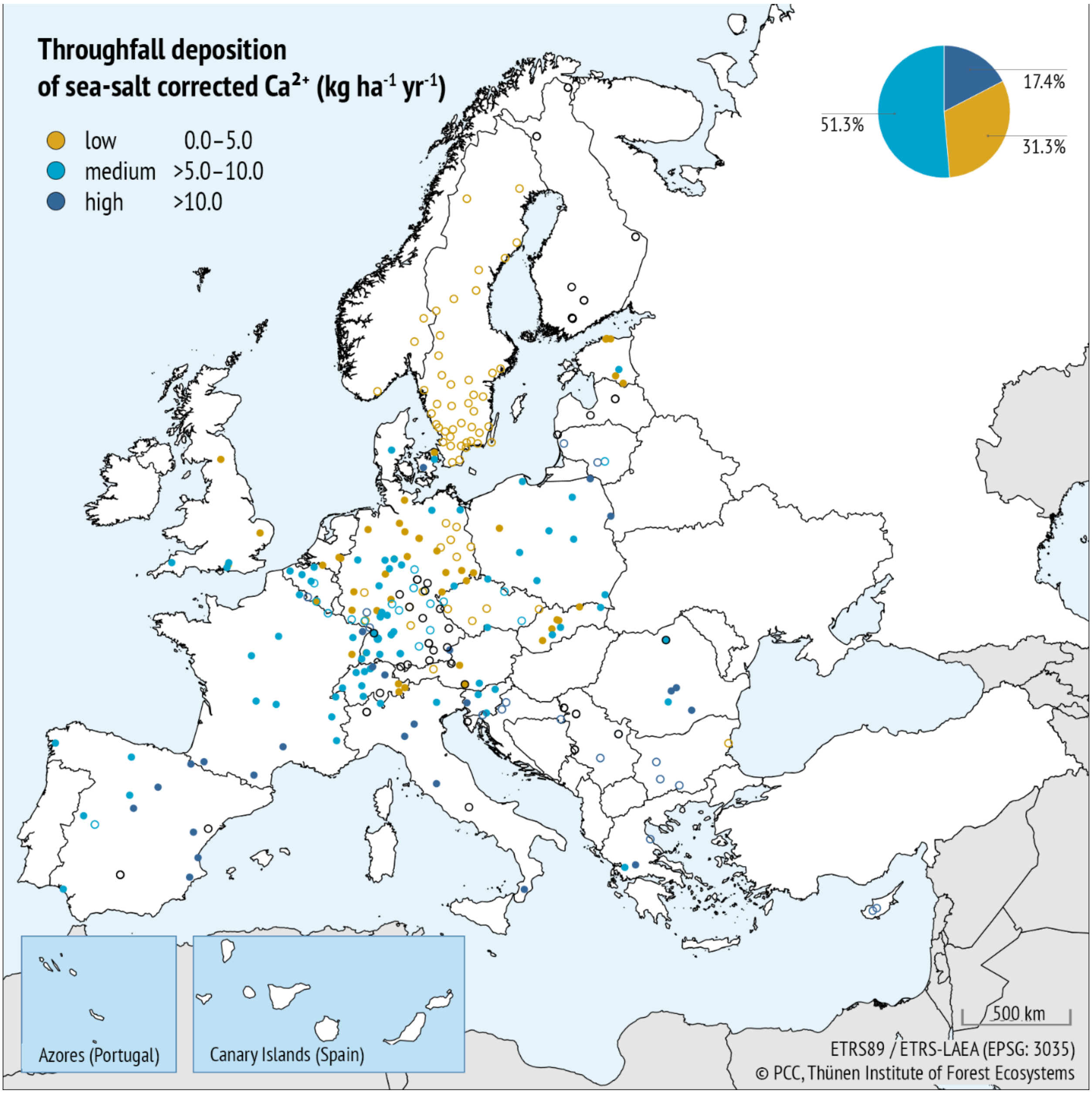


**Figure 6-6: Throughfall deposition of sea-salt corrected calcium (kg $Ca^{2+}$ $ha^{-1}$ $yr^{-1}$) measured in 2022 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network.** Colored dots: validated data. Colored circles: not validated data. Black circles: monitoring period shorter than 330 days or irregular sampling. The pie chart shows the percentage of plots with low, medium, and high deposition for validated data only.

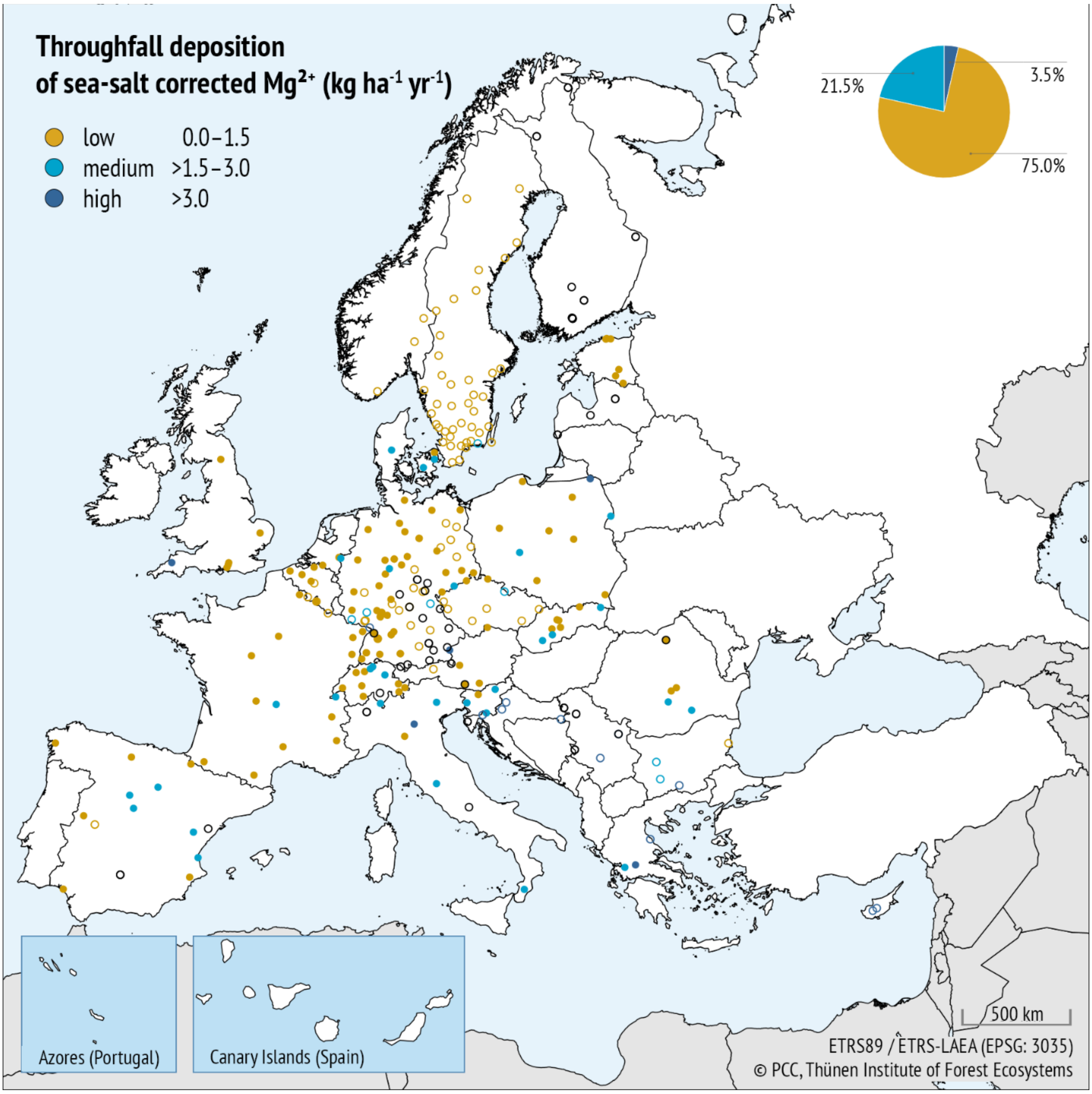


**Figure 6-7: Throughfall deposition of sea-salt corrected magnesium (kg $Mg^{2+}$ $ha^{-1}$ $yr^{-1}$) measured in 2022 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network.** Colored dots: validated data. Colored circles: not validated data. Black circles: monitoring period shorter than 330 days or irregular sampling. The pie chart shows the percentage of plots with low, medium, and high deposition for validated data only.

EVALUATIONS

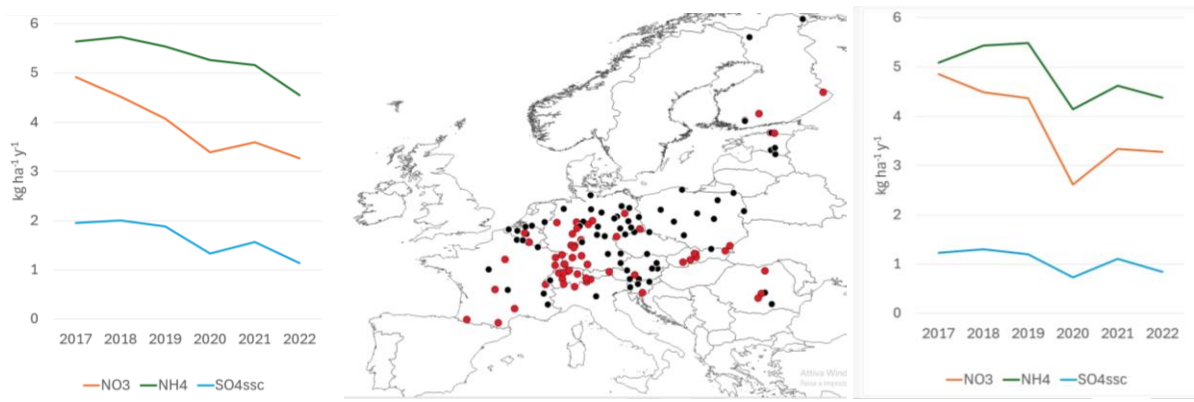


**Figure 6-8: Average throughfall deposition of nitrogen and sulphur compounds (left panel) in 133 plots for which deposition values were validated for the whole period 2017–2022 (map in the central panel). The right panel shows the average values for a subset of 49 plots (marked in red in the central panel) in which oxidized nitrogen deposition dropped by more than 25% between 2019 and 2020 (right panel).**

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7

# METEOROLOGICAL CONDITIONS IN EUROPEAN FORESTS IN 2022

*Lothar Zimmermann, Stephan Raspe, Tim Schütt, Alexa Michel, Kai Schwärzel*

## Introduction

Weather and climate affect composition, structure, growth, health, and dynamics of forest ecosystems. Observing weather conditions and their seasonal variations on forest monitoring plots is therefore essential for identifying and interpreting trends in forest condition as well as their interactions with other stressors such as air pollution, diseases, or pests. Against this background, the ICP Forests Level II plots were equipped with meteorological measurement devices as early as the 1990s.

Meteorological monitoring at the Level II plots provides local, inside forest area information on the basic driving and influencing factors for forest ecosystems. The main objectives of the meteorological monitoring at the Level II plots are:

- to describe the meteorological conditions and changes at the Level II plots;
- to investigate the meteorological conditions as a basis for a better understanding of the state of forest ecosystems and their interrelationships;
- to identify and investigate stress indices and factors for trees on the plot like extreme weather conditions and events (e.g., frost, heat, droughts, storms, floods);
- to build up long time series that fulfil requirements of further analysis (statistics and modelling) of ecosystem responses under current and changing environmental conditions (e.g. water balance calculations, soil water availability for the stand, growth, nutrient cycling) as well as integrated evaluations in various aspects of the Level II plots (e. g. crown condition assessment, deposition, increment) (Raspe et al. 2020).

Temperature and precipitation patterns play a key role in climate change impacts on forests. This chapter, therefore, focuses on presenting and interpreting air temperature and precipitation data from 2022 in comparison with long-term mean values for different climatic regions in Europe. Meteorological stations were allocated to climatic regions according to the well-known Koeppen-Geiger climate classification scheme with the aim to aggregate values from Level II plots and show changes across European climatic regions. Details on the aggregation can be found in Zimmermann et al. (2023). The most frequent Koeppen climatic regions in Europe are (1) C-climates, which are temperate climates such as the CfB atlantic temperate (beech climate) or the warm to hot Mediterranean climate (Csb, Csa), and (2) D-climates, which are continental climates from the humid continental (Dfa, Dfb: oak climate) to the subarctic (Dfc: birch climate), and also to the Mediterranean-influenced warm-summer humid continental climate (Dsa) (Tab. 7-1, Fig. 7-1).

**Table 7-1: Number of meteorological stations at Level II plots in different climatic regions in 2022.** For criteria, please refer to Table 3 in Beck et al. 2018.

| Code | Description of climate | Name | Stations |
|---|---|---|---|
| BSk | Arid, steppe, cold | Cold semi-arid climate | 6 |
| Cfa | Temperate, no dry season, hot summer | Humid subtropical climate | 2 |
| Cfb | Temperate, no dry season, warm summer | Temperate oceanic climate | 18 |
| Csa | Temperate, dry summer, hot summer | Hot-summer Mediterranean climate | 4 |
| Csb | Temperate, dry summer, warm summer | Warm-summer Mediterranean climate | 2 |
| Dfa | Cold, no dry season, hot summer | Hot-summer humid continental climate | 1 |
| Dfb | Cold, no dry season, warm summer | Warm-summer humid continental climate | 103 |
| Dfc | Cold, no dry season, cold summer | Subarctic climate | 22 |
| Dsb | Cold, dry summer, warm summer | Mediterranean-influenced warm-summer humid | 1 |
| | | TOTAL | 159 |

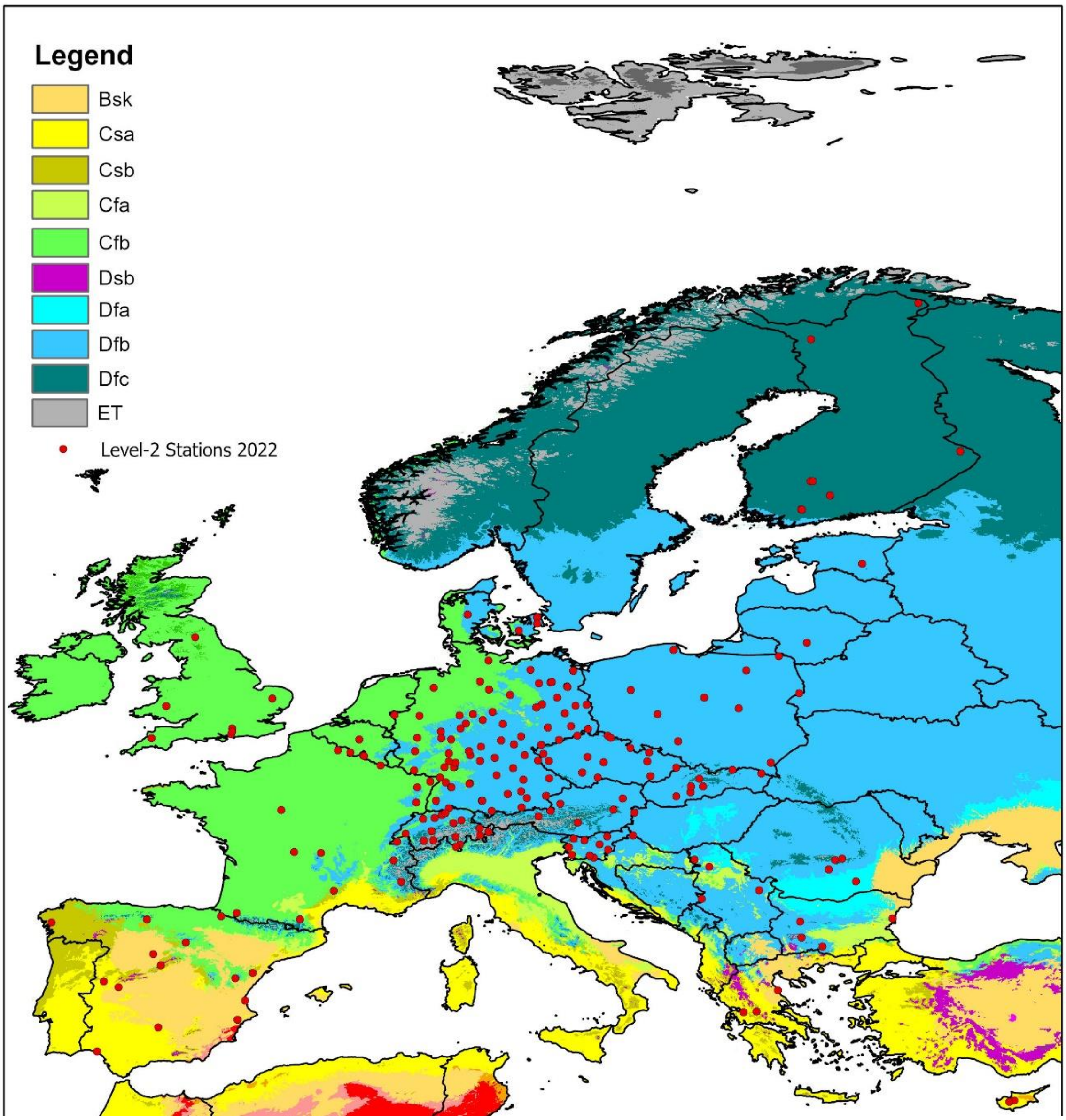


**Figure 7-1: Map of Level II stations with gap-filled time series of meteorological data for 2022 and for different climatic regions** (Table 7-1 acc. to Beck et al. 2018)

## Climate and weather in Europe 2022

According to the European State of the Climate 2022 Report (Copernicus Climate Change Service (C3S) 2023), the year 2022 was the second warmest year on record in Europe (+ 0.9 °C to reference period 1991-2020). For many countries in southwestern Europe, the year was even the warmest since records began. But temperatures in northeastern Scandinavia were also above average (1991-2020). There were many more warm periods than cool periods in 2022. The year as a whole was as much as 10% drier than average.

In winter, precipitation varied between regions, with wetter-than-average conditions in northern and eastern Europe and drier-than-average conditions in southwestern Europe. Spring was drier than average across most areas. May was the driest month with 21–28% less precipitation than average. In March and May, daily maximum temperatures were up to 8°C above average. The summer in 2022 was definitely the warmest since 1950 (+1.4 °C above 1991–2020 average) even surpassing the previous warmest summer 2021. In southwestern and western areas, up to 30% more warm days occurred than average, highlighting the frequency of high temperature extremes in line with a changing climate. During summer large parts of Europe were affected by exceptional heatwaves, and in western Europe the highest temperatures were around 10°C above the typical summer maximum temperatures. In July, air temperatures in the UK reached 40°C for the first time on record.

Summer and spring in 2022 were drier than average across most areas, which can be attributed to periods of drought. Driest anomalies were found in Germany, Spain, and the UK. Central

European countries experienced a prolonged drought. High temperatures and dry conditions contributed to the spread and intensification of wildfires, with the second largest burnt area on record, with very large fires in south-eastern Europe and the Mediterranean region. September was the wettest month with 13–21% more precipitation. October was the warmest on record and December started cold but turned exceptionally warm towards the end of the year. In northern Europe a cold wave was registered in December.

## Materials and methods

Meteorological data was available for 2022 from 159 ICP Forests Level II sites for generating this report. Details on the meteorological measurements, the equipment used, the quality standards, and the procedures for closing gaps in the ICP Forests program can be found in Zimmermann et al. (2023) and in Raspe et al. (2013). In this chapter, we only present air temperature and precipitation data in 2022 and compare it with their long-term average (1990–2022).

## Results

## Air temperature

### Deviations of annual mean air temperature

The year 2022 was generally warmer than the long-term average (Fig. 7-2). The largest positive deviations were observed primarily in the UK, Germany, Switzerland, France, Spain, and Serbia, while the deviation was somewhat smaller in Finland, the Baltic states, Poland, Slovakia, Slovenia, and Romania.

### Deviation of mean air temperature in the vegetation period

During the vegetation period, it was warmer than the long-term average in most parts of Europe (Fig. 7-3). Many Level II plots in Spain, France, Switzerland, and western Germany recorded mean temperatures that were more than +1.5 °C warmer than normal. In Denmark, eastern Germany, Austria, Poland, Czechia, Slovakia, Slovenia, and Romania, the positive deviation was smaller, with few plots even showing almost no change. Interestingly, the Finnish, Polish, and Romanian stations also showed positive anomalies, while their deviations from the annual temperatures were moderate (Figs. 7-2, 7-3).

### Annual mean air temperature in different climatic regions

To complement the picture of annual mean air temperature at specific Level II plots during the year 2022, averages for Level II plots in different climatic regions were calculated. Figure 7-4 shows that in almost all climate zones, the air temperature in 2022 on Level II plots was at least 1 °C higher than the long-term average. Exceptions are the subarctic (Dfc) and hot-summer Mediterranean (Csa) zones with slighter increases.

### Temperature stress indicators

The health and vitality of forests is more strongly influenced by extreme temperatures than by average conditions. In this respect, heat and frost events are of particular interest.

#### Heat

In 2022, maximum air temperatures during the vegetation period at Level II plots from the British Isles to Belgium, the Netherlands, Germany, and Poland were between 36 °C and 40 °C. Maximum temperatures of more than 40° C were observed in Spain, Slovenia, Serbia, and Greece (Fig. 7-5).

Another indicator of the risk of heat stress in forests is the number of hot days with a maximum temperature of 30 °C and more. A significant increase in the number of days with temperatures above 30 °C was observed in climatic regions that were also exposed to such high temperatures in the past (Fig. 7-6). For the majority of Level II plots in the cold semi-arid climate (BSk), the humid subtropical climate (Cfa), the temperate oceanic climate (Cfb), the Mediterranean climates (Csa and Csb), and the humid continental climates (Dfa and Dfb), there was a significant increase in extremely hot days compared to the long-term average (Fig.7-6) and almost twice as many hot days were counted in some climate zones (e.g., Cfb or Csb) in 2022. A slightly lower – but still remarkable – increase in hot days of around 30% and more was observed in other climate zones such as the humid subtropical (Cfa) or the humid continental climate zones Dfa, Dfb).

#### Late frost

Late frost occurs when the minimum daily temperature falls below 0 °C after the start of the vegetation period. This can cause damage to young shoots or blossoms on trees, especially shortly after bud burst. The number of frost days in the growing season can therefore be seen as an indicator of late frost stress.

In 2022, most Level II plots in the continental climate zones (Dfx), showed a significant decrease in late frost events compared to the long-term average by more than 50 to 100%, indicating the very warm weather in 2022. Fewer frost days were usually also observed in the climate stations in the temperate climate zones (Csx, Cfb). The Level II plots in the humid subtropical climate (Cfa) were an exception to this general trend, with almost four times the number of frost days compared to the long-term average (Fig. 7-7).

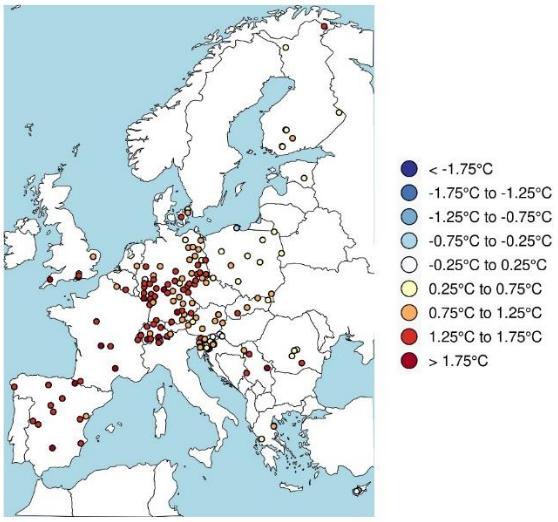


**Figure 7-2: Deviation of annual air temperature (in °C) in 2022 from the long-term average (1990–2022) on Level II plots. Spanish data originate from a measurement height of 7 m.**

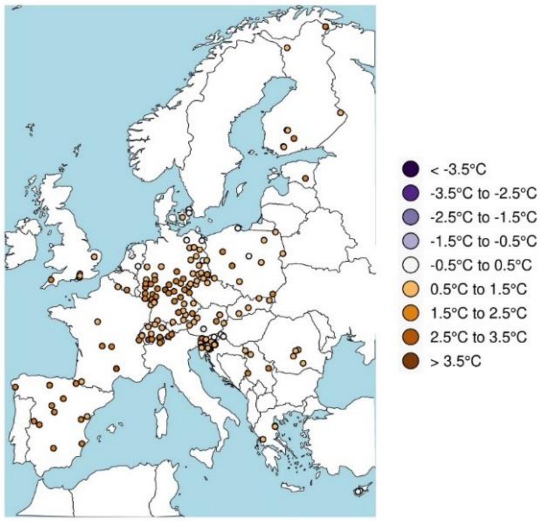


**Figure 7-3: Deviation of mean air temperature in the vegetation period in 2022 from the long-term average (1990–2022) (in °C) on Level II plots. Spanish data originate from a measurement height of 7 m.**

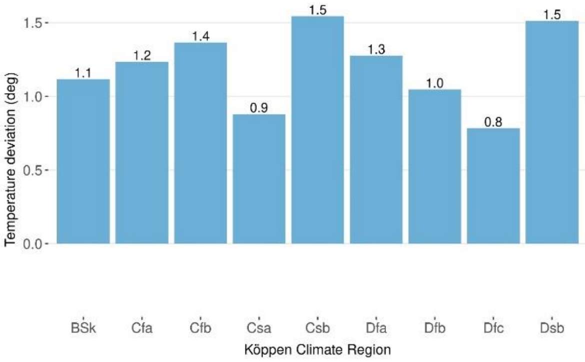


**Figure 7-4: Deviation (in °C) of annual mean air temperature in 2022 from the long-term average (1990–2022) on Level II plots in different Koeppen climatic regions.** For explanation of acronyms and for number of Level II plots in each climatic region, please refer to Tab. 7-1 and Fig. 7-1.

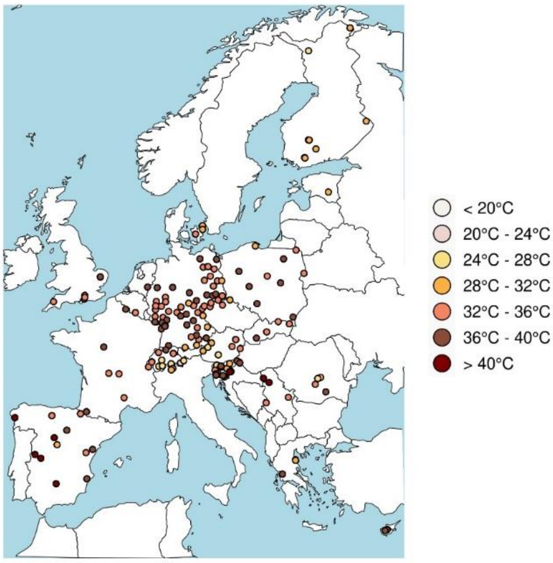


**Figure 7-5: Maximum air temperature (°C) in the vegetation period in 2022 on Level II plots.** Spanish data originate from a measurement height of 7 m.

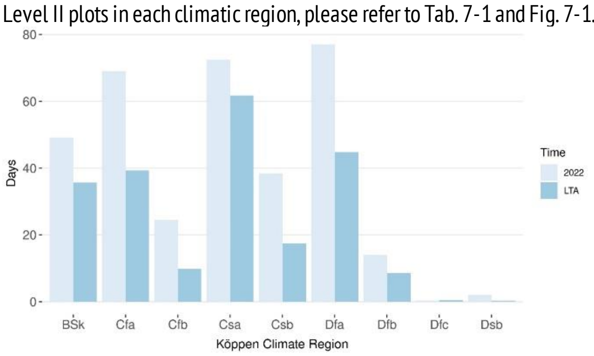


**Figure 7-6: Number of hot days (Tmax ≥ 30 °C) in 2022 and long-term annual average (LTA, 1990–2020) on Level II plots in different Koeppen climatic regions.** For explanation of acronyms and for number of stations in each climatic region, please refer to Tab. 7-1 and Fig. 7-1.

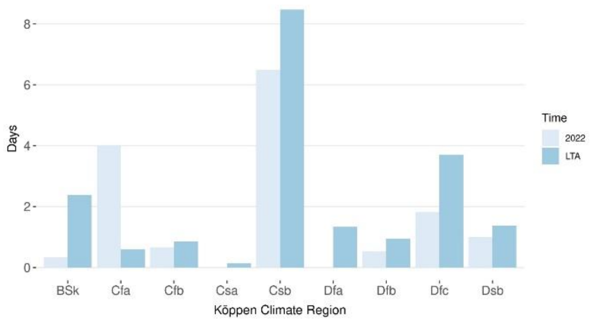


**Figure 7-7: Number of late frost days (Tmin in vegetation period < 0°C) in 2022 and long-term annual average (1990–2022) on Level II plots in different Koeppen climatic regions**. For explanation of acronyms and for number of stations in each climatic region, please refer to Tab. 7-1 and Fig. 7-1.

EVALUATIONS

## Precipitation

### Deviation in annual precipitation

In general, 2022 was significantly drier than normal across Europe (Fig. 7-8) with a reduction in annual precipitation by -15 to -45% on average. In Germany and Czechia, quite a few stations show no change or even a slight increase in precipitation, which also applies to a number of stations in Austria, Spain, northeastern Poland, and Finland. In the UK, all but one Level II plot in the south show decreasing precipitation while in Spain precipitation was either increasing or decreasing. In France and south-eastern Europe, annual precipitation decreased on all Level II plots.

For the majority of Level II plots in continental climates (Dfx) as well as in the more oceanic (Cfa) and Mediterranean climates (Csx), precipitation was significantly drier than normal. Plots in the Mediterranean-influenced warm-summer humid continental climate (Dsb), the temperate oceanic climate, and the cold semi-arid climate (BSk) had wetter conditions than normal (Fig. 7-9).

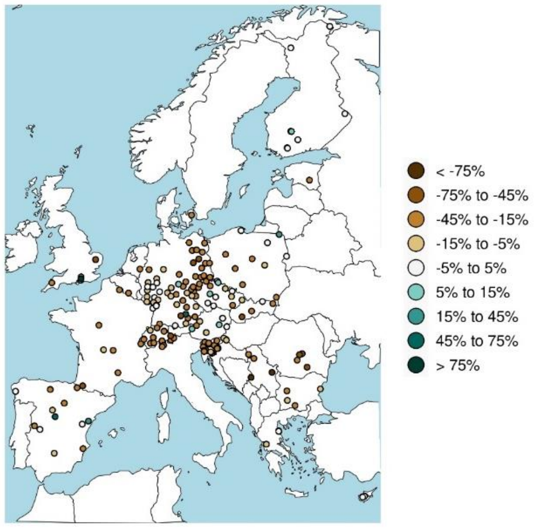


**Figure 7-8: Deviation (in %) of the total annual precipitation in 2022 from the long-term yearly average (1990–2022) on Level II plots.**

### Precipitation in the vegetation period

The amount of precipitation during the growing season is of particular importance for the water supply of forests. With regard to the deviation of the amount of precipitation in the vegetation period from the long-term average, the majority of Level II plots in Europe showed a significant decrease, with the exception of a few individual stations in Czechia, north-eastern Poland, southern Germany, and Austria, which recorded an increase due to heavy rainfall events (Fig. 7-10). The decrease was extremely high in south-eastern Europe and in Spain but also at individual stations in southern England and eastern Germany. Even in the Swiss Alps, the majority of stations showed negative deviations. Exceptions were single stations in Cyprus, Greece, and Spain where, in contrast, a clear positive deviation was found.

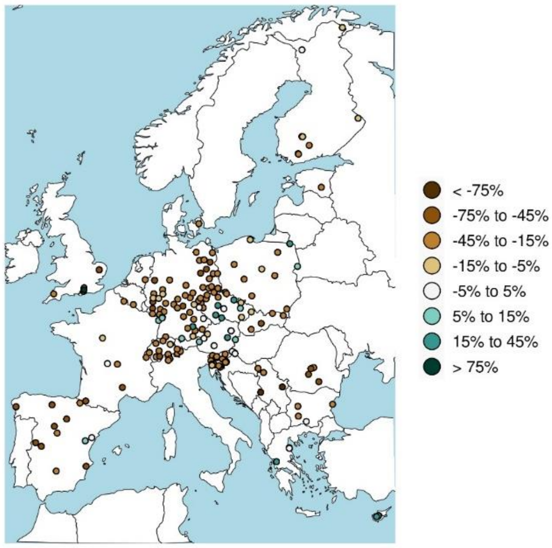


**Figure 7-10: Deviation (in %) of the precipitation in the vegetation period in 2022 from the long-term average (1990–2022) on Level II plots.**

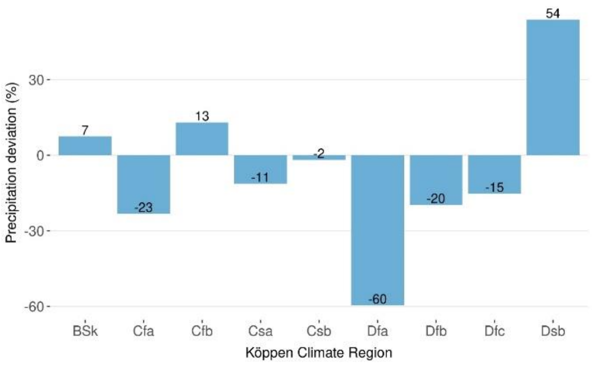


**Figure 7-9: Deviation (in %) from the long-term average of the annual precipitation on Level II plots in different Koeppen climatic regions. For explanation of acronyms and for number of stations in each climatic region, please refer to Table 7-1 and Figure 7-1.**

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8

# TREE CROWN CONDITION IN 2023

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## Highlights

In 2023, we witnessed a very slight increase of 0.1 percentage points (%p) in mean defoliation as compared to 2022, mainly due to an increase of 0.3%p for conifers, while defoliation of broadleaves remained unchanged. The strongest increase in defoliation occurred in deciduous temperate oaks (+1.7%p) and in Mediterranean lowland pines (+1.3%p), while the strongest decrease was recorded in evergreen oaks (-0.8%p) and common beech (-0.5%p).

Trend analyses show a considerable increase in defoliation of evergreen oaks (7.5%p) and Norway spruce (5.8%p) over the past 20 years. The increase in defoliation for common beech (4.7%p) was also relatively large, while the increase in defoliation for Scots pine and Mediterranean lowland pines was more moderate. The results of the trend analyses were not significant for deciduous temperate oaks, deciduous (sub-) Mediterranean oaks and Austrian pine.

This year there was no change in the percentage of trees with damage symptoms (49%) compared to 2022. As in previous years, the number of damage symptoms per assessed tree was substantially higher for broadleaves than for conifers (0.86 vs. 0.57, respectively). Insects, abiotic causes, and fungi were the most common damage agent groups for all species, comprising altogether more than half of all damage records. Tree mortality in 2023 was 1.1% (1 164 trees), an increase of 0.2 %p compared to the year before. While mortality rates for the main species and species groups ranged from 0.5 to 1.5%, mortality of Betula pubescens and Fraxinus excelsior was much higher at 4.5% and 7.9% respectively.

## Introduction and scientific background

Tree crown defoliation and occurrence of biotic and abiotic damage are important indicators of forest health. As such, they are considered within the Criterion 2, "Forest health and vitality", one of six criteria adopted by Forest Europe (formerly the Ministerial Conference on the Protection of Forests in Europe – MCPFE) to provide information for sustainable forest management in Europe.

Defoliation surveys are conducted in combination with detailed assessments of biotic and abiotic damage causes. Unlike assessments of tree damage, which can in some instances trace the tree damage to a single cause, defoliation is an unspecific parameter of tree vitality, which can be affected by a number of anthropogenic and natural factors. Combining the assessment of damage symptoms and their causes with observations of defoliation allows for a better insight into the condition of trees, and the interpretation of the state of European forests and its trends in time and space is made easier.

This chapter presents results from the crown condition assessments on the large-scale, representative, transnational monitoring network (Level I) of ICP Forests carried out in 2023, as well as long-term trends for the main species and species groups.

## Methods of the 2023 survey

The assessment of tree condition in the transnational Level I network is conducted according to European-wide, harmonized methods described in the ICP Forests Manual by Eichhorn et al. (2020, see also Eichhorn and Roskams 2013).

### Defoliation

Defoliation is the key parameter of tree condition within forest monitoring describing a loss of needles or leaves in the assessable crown compared to a local reference tree in the field or an absolute, fully foliated reference tree from a photo guide. Defoliation is estimated in 5% steps, ranging from 0% (no defoliation) to 100% (dead tree). Defoliation values are grouped into five classes (Table 8-1). In the maps presenting the mean plot defoliation and in Table 8-3, class 2 is subdivided into class 2-1 (> 25–40%) and class 2-2 (> 40–60% defoliation).

**Table 8-1: Defoliation classes**

| Defoliation class | Needle/leaf loss | Degree of defoliation |
|---|---|---|
| 0 | up to 10% | None |
| 1 | > 10–25% | Slight (warning stage) |
| 2 | > 25–60% | Moderate |
| 3 | > 60–< 100% | Severe |
| 4 | 100% | Dead (standing dead trees only) |

Table 8-2 shows countries and the number of plots assessed for crown condition parameters from 2014 to 2023, and the total number of sample trees submitted in 2023. The number of trees used for analyses differs from the number of submitted trees due to the application of various data selection procedures. Both the number of plots and the number of trees vary in the course of time, for example due to mortality or changes in the sampling design.

Table 8-2: Number of plots assessed for crown condition parameters from 2014 to 2023 in countries with at least one Level I crown condition survey since 2014, and total number of sample trees submitted in 2023

| Country | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | Plots 2023 | Trees 2023 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Andorra | 11 | 12 | | | | | | | | | |
| Belarus | | 377 | | | | | | | | | |
| Belgium | 53 | 53 | 53 | 53 | 52 | 52 | 51 | 51 | 51 | 47 | 609 |
| Bulgaria | 159 | 159 | 159 | 160 | 160 | 160 | 160 | 159 | 160 | 160 | 5 598 |
| Croatia | 103 | 95 | 99 | 99 | 99 | 97 | 98 | 95 | 97 | 97 | 2 328 |
| Cyprus | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 360 |
| Czechia | 138 | 136 | 136 | 135 | 132 | 132 | 127 | 121 | 117 | 118 | 4 163 |
| Denmark | 20 | 20 | 19 | 19 | 19 | 19 | 19 | 18 | 18 | 17 | 411 |
| Estonia | 96 | 97 | 98 | 98 | 98 | 98 | 95 | 95 | 93 | 92 | 2 136 |
| France | 545 | 542 | 533 | 527 | 521 | 515 | 512 | 509 | 504 | 526 | 10 786 |
| Germany | 422 | 424 | 421 | 416 | 410 | 421 | 416 | 409 | 405 | 402 | 9 531 |
| Greece | 57 | 47 | 23 | 36 | 40 | 45 | 38 | 33 | 35 | 27 | 629 |
| Hungary | 68 | 67 | 67 | 66 | 68 | 68 | 68 | 69 | 71 | 70 | 1 522 |
| Ireland | | | | | | 28 | 30 | 33 | 31 | 33 | 727 |
| Italy | 244 | 234 | 246 | 247 | 249 | 237 | 240 | 256 | 256 | 255 | 4 971 |
| Latvia | 116 | 116 | 115 | 115 | 115 | 115 | 115 | 115 | 115 | 115 | 1 742 |
| Lithuania | 81 | 81 | 82 | 82 | 81 | 81 | 81 | 81 | 81 | 81 | 1 959 |
| Luxembourg | 4 | 4 | 4 | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 96 |
| Moldova, Rep. of | | | | 9 | 9 | | | | | 9 | 218 |
| Montenegro | 49 | 47 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 1 176 |
| Norway | 687 | 554 | 629 | 630 | 623 | 687 | 604 | 629 | 627 | 616 | 6 105 |
| Poland | 365 | 361 | 353 | 352 | 348 | 346 | 343 | 343 | 341 | 340 | 6 763 |
| Romania | 241 | 242 | 243 | 246 | 246 | 247 | 226 | 234 | 237 | 239 | 5 804 |
| Serbia | 128 | 127 | 127 | 126 | 126 | 127 | 126 | 126 | 126 | 123 | 2 858 |
| Slovakia | 107 | 106 | 103 | 103 | 101 | 100 | 99 | 97 | 99 | 101 | 4 517 |
| Slovenia | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 1 073 |
| Spain | 620 | | 620 | 620 | 620 | 620 | 620 | 620 | 620 | 620 | 14 880 |
| Sweden | 842 | 839 | 701 | 618 | 760 | 849 | 841 | 733 | 629 | 774 | 2 588 |
| Switzerland | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 49 | 49 | 1 041 |
| Türkiye | 531 | 591 | 586 | 598 | 601 | 597 | 599 | 580 | 579 | 584 | 13 445 |
| TOTAL | 5 793 | 5 437 | 5 572 | 5 513 | 5 636 | 5 800 | 5 667 | 5 565 | 5 453 | 5 607 | 108 036 |

### Damage cause assessments

The damage cause assessment of trees consists of three major parts. For a detailed description, please refer to Eichhorn et al. (2020) and Timmermann et al. (2016).

- Symptom description
  Three main categories indicate which parts of a tree are affected: (a) leaves/needles; (b) branches, shoots, buds, and fruits; and (c) stem and collar. A further specification of the affected part along with a symptom description is given.
- Determination of the damage cause (causal agents / factors)
  The main groups of causal agents are insects, fungi, abiotic factors, game and grazing, direct action of man, fire, and atmospheric pollutants. In each group, a more detailed description is possible through a hierarchical coding system.
- Quantification of symptoms (damage extent)
  The extent is the estimated damage to a tree, specifying the percentage of affected leaves/needles, branches or stem circumference due to the action of the causal agent or factor.

### Additional parameters

Several other tree, stand, and site parameters are assessed, providing additional information for analysis of the crown condition data. For the full information, please refer to Eichhorn et al. (2020). Analysis of these parameters is not within the scope of this report.

### Tree species

For the analyses in this report, the results for the four most abundant species are shown separately in figures and tables. *Fagus sylvatica* is analyzed together with *F. sylvatica* ssp. *moesiaca*. Some species belonging to the *Pinus* and *Quercus* genus were combined into species groups as follows:

- Mediterranean lowland pines (*Pinus brutia*, *P. halepensis*, *P. pinaster*, *P. pinea* )
- Deciduous temperate oaks (*Quercus petraea* and *Q. robur*)
- Deciduous (sub-) Mediterranean oaks (*Quercus cerris*, *Q. frainetto*, *Q. pubescens*, *Q. pyrenaica* )
- Evergreen oaks (*Quercus coccifera*, *Q. ilex*, *Q. rotundifolia*, *Q. suber* ).

Of all trees submitted from the Level I network in 2023, *Pinus sylvestris* was the most abundant tree species (16.6% of all trees), followed by *Fagus sylvatica* (incl. ssp. *moesiaca*, 12.0%), *Picea abies* (11.0%), *Pinus nigra* (5.0%), *Quercus petraea* (4.4%), *Quercus robur* (4.3%), *Quercus ilex* (3.7%), *Quercus cerris* (3.1%), *Pinus brutia* (2.9%), *Betula pubescens* (2.6%), *Pinus halepensis* (2.3%), *Quercus pubescens* (2.2%), *Abies alba* (2.1%), *Betula pendula* (2.1%), *Pinus pinaster* (1.9%), and *Carpinus betulus* (1.9%).

Most Level I plots with crown condition assessments contained one (49.1%) or two to three (37.9%) tree species per plot. On 10.5% of plots, four to five tree species were assessed, and only 2.5% of plots featured more than five tree species. In 2023, 52.1% of all submitted trees were broadleaves and 47.9% conifers. The species percentages differ slightly for damage assessments, as selection of trees for assessments in participating countries varies.

### Statistical analyses

For calculations, selection procedures were applied in order to include only correctly coded trees in the sample (Tables 8-4 and 8-5). For the calculation of the mean plot defoliation of all species, only plots with a minimum number of three trees were analyzed. For analyses at species level, three trees per species had to be present per plot. These criteria are consistent with earlier evaluations (e.g. Wellbrock et al. 2014, Becher et al. 2014) and explain the discrepancy in the distribution of trees in defoliation classes between Table 8-3 below and Table S1-1 in the online supplementary material[1].

Trends in defoliation were calculated according to Sen (1968) and their significance tested by the non-parametric Mann-Kendall test (tau). These methods are appropriate for monotonous, single-direction trends without the need to assume any particular distribution of the data. Due to their focus on median values and corresponding robustness against outliers (Sen 1968, Drápela and Drápelová 2011, Curtis and Simpson 2014), the results are less affected by single trees or plots with unusually high or low defoliation. The regional Sen's slopes for Europe were calculated according to Helsel and Frans (2006). For both the calculation of Mann-Kendall's tau and the plot-related as well as the regional Sen's slopes, the rkt package in the R statistical software environment (Marchetto 2015) was used. All queries and statistical analyses were conducted in the R/RStudio software environment (R Core Team 2016).

Figures 8-2a-j show (1) the annual mean defoliation per plot, (2) the change of mean defoliation across plots over the years, and (3) the trend of defoliation based on the regional Sen's slope calculations for the period 2004–2023. For the Mann-Kendall test, a significance level of $p \leq 0.05$ was applied. All Sen's slope calculations and yearly over-all mean defoliation values were based on consistent plot selections with a minimum of three trees per species and per plot. Maps of defoliation trends for the period 2014–2023 can be found in the online supplementary material[1]. For all trend calculations, plots were included if assessments were available for at least 80% of the years of interest, ensuring a satisfactory period of data to base the trend lines on. Plots will fall into or drop out of the sample depending on the number of

[1] http://icp-forests.net/page/icp-forests-technical-report

times the data from the same plot is reported within the period in question, and this may have an effect on the trend lines.

### Quality assurance and control (QA/QC)

Since ICP Forests is a pan-European monitoring program, stemming from various national initiatives that had already been in place when the program started operating, the methods of monitoring employed in ICP Forests partly reflect the initial differences of these systems. In line with that, initially no consistent, 'top-down' quality assurance (QA) approach was adopted and the emphasis was placed more on the quality control (QC) issues. A lot of effort has been invested into the development of the monitoring methodology in terms of harmonization and intercalibration of methods, and, where this was not possible, into the intercomparison of results obtained by different methods.

Quality assurance and control measures for crown condition assessments are organized at multiple levels: At national level, regular calibration trainings of the survey teams and control assessments in the field are conducted. Data submission to the ICP Forests collaborative database is regulated by protocols and check procedures. International cross-comparison courses (field and photo ICCs) ensure the possibility to compare data across participating countries (Eickenscheidt 2015, Dănescu 2019, Meining et al. 2019).

In recent years, the International Photo Cross-Comparison Course (Photo ICC), held every two years, has developed into an important and effective tool of the ICP Forests quality assurance program for the assessment of crown condition in Europe. In 2023, an Online photo test for quality assurance of the forest condition survey for Central Europe has been held. The aim of this pilot study was to compare the usual analogue photo (printed images of tree crowns) assessment with the assessment of the same images in a digital form, to check whether a web application can be used to compare the assessments of participating teams.

To implement the digital Photo ICC, a website was developed, which was only accessible to the participating teams. Altogether, 85 teams from 11 countries participated in the Photo ICC 2023. All teams were invited to assess a set of 30 crown pictures for each of these tree species: Norway spruce (*Picea abies*), Scots pine (*Pinus sylvestris*), European beech (*Fagus sylvatica*), and pedunculate oak (*Quercus robur*). All pictures were assessed using the "widest span" method of determining the lower limit of assessable crown as described in the ICP Forests Manual (Eichhorn et al. 2020). In order to make the results more comparable, the same pictures as in the Photo ICC 2021 were used for the digital Photo ICC 2023. In total, 9298 assessments were made.

The comparison of the analog and the digital method shows a high level of agreement across all four tree species, with small differences in the assessment of defoliation which are within the usual range of estimation accuracy of previous analog Photo ICCs. Individual differences between countries show that assessable crown is a very important factor for crown condition assessments, and that it affects the results and their comparability. As observed in previous Photo ICCs, the results for trees with medium to higher defoliation scores presented a higher deviation from the mean than for trees with lower defoliation scores. Therefore, this range of defoliation should be the focus of field team training. Finally, the analysis shows that the digital Photo ICC is a worthwhile alternative to the established analog version, providing the same benefits in terms of QA/QC, with the aided benefits of lower material costs and easier access to the pictures, which transfers to a potentially higher number of participants in future Photo ICCs.

### National surveys

In addition to the transnational surveys, national surveys are conducted in many countries, relying on denser national grids and aiming at the documentation of forest condition and its development in the respective country. Since 1986, various densities of national grids (1x1 km to 32x32 km) have been used due to differences in the size of forest area, structure of forests, and forest policies. The results of defoliation assessments on national grids are presented in the online supplementary material[1]. Comparisons between the national surveys of different countries should be made with great care because of differences in species composition, site conditions, and methods applied.

## Results of the transnational crown condition survey

### Defoliation

The transnational crown condition survey in 2023 was conducted on 107 818 trees on 5 598 plots in 27 countries (Table 8-2). Out of those, 101 912 trees were assessed in the field for defoliation (Table 8-3).

The overall mean defoliation for all species was 24.0% in 2023; based on a slight increase in defoliation of 0.3%p for conifers and no change for broadleaves in comparison with 2022 (Table 8-3). Broadleaved trees showed a higher mean defoliation than coniferous trees (24.6% vs. 23.3%), as in previous years. Correspondingly, conifers had a higher frequency of trees in the defoliation classes 'none' and 'slight' (70.5% combined) than broadleaves (66.8%) and a lower frequency of trees with more than 60% defoliation (3.1% vs. 5.3%). Norway spruce had the highest share of standing dead trees (1.2%), and common beech the lowest (0.4%).

Among the main tree species and tree species groups, deciduous temperate oaks and evergreen oaks displayed the highest mean defoliation (29.3% and 27.8%, respectively). Common beech had the lowest mean defoliation (21.9%). The strongest increase in defoliation compared to 2022 occurred in deciduous temperate oaks (+1.7%p) and in Mediterranean lowland pines (+1.3%p), the strongest decrease in evergreen oaks (-0.8%p) and common beech (-0.5%p), while there were only minor changes for the other species and species groups.

Mean defoliation of all species at plot level in 2023 is shown in Figure 8-1. Two thirds (65.7%) of all plots had a mean defoliation up to 25%, and only 1.8% of the plots showed severe defoliation (more than 60%). While plots with defoliation up to 10% were located mainly in Norway, Serbia, Romania, and Türkiye, plots with slight mean defoliation (11-25%) were found across Europe. Clusters of plots with moderate to severe mean defoliation were found from the Pyrenees through southeast (Mediterranean) France to northern Italy, but also from central and northern France through Germany and into Czechia, Slovakia, and Hungary, as well as in western Bulgaria and central parts of Norway and Sweden.

The following sections describe the species-specific mean plot defoliation in 2023 and the over-all trend and yearly mean plot defoliation from 2004 to 2023. For maps on defoliation of individual tree species in 2023, and trends in mean plot defoliation from 2014 to 2023, please refer to the online supplementary material[1].

**Table 8-3: Percentage of trees assessed in 2023 according to defoliation classes 0-4 (class 2 subdivided), mean defoliation for the main species or species groups (change from 2022 in parentheses), and the number of trees in each group.** Class 4 contains standing dead trees only. Dead trees were not included when calculating mean defoliation.

| Main species or species groups | Percentage of trees per defoliation class<br>Class 0 (0-10%) | Class 1 (>10-25%) | Class 2-1 (>25-40%) | Class 2-2 (>40-60%) | Class 3 (>60-99%) | Class 4 (100%) | Mean defoliation | No. of trees |
|---|---|---|---|---|---|---|---|---|
| Scots pine (*Pinus sylvestris*) | 21.7 | 52.3 | 16.0 | 6.6 | 2.5 | 0.9 | 22.7 (-0.2) | 17 470 |
| Norway spruce (*Picea abies*) | 28.6 | 37.3 | 22.0 | 7.4 | 3.5 | 1.2 | 23.3 (+0.1) | 11 128 |
| Austrian pine (*Pinus nigra*) | 26.1 | 43.9 | 16.9 | 7.9 | 4.4 | 0.8 | 24.0 (-0.1) | 5 310 |
| Mediterranean lowland pines | 11.3 | 56.6 | 23.2 | 5.7 | 2.7 | 0.5 | 24.9 (+1.3) | 8 026 |
| Other conifers | 29.5 | 42.3 | 18.0 | 6.4 | 3.3 | 0.5 | 22.3 (+0.8) | 7 969 |
| Common beech (*Fagus sylvatica*) | 33.3 | 37.7 | 18.0 | 6.9 | 3.8 | 0.4 | 21.9 (-0.5) | 12 677 |
| Deciduous temperate oaks | 17.4 | 36.6 | 25.9 | 12.4 | 6.9 | 0.8 | 29.3 (+1.7) | 9 283 |
| Dec. (sub-) Mediterranean oaks | 30.1 | 39.5 | 17.2 | 7.9 | 4.5 | 0.9 | 23.0 (-0.4) | 7 984 |
| Evergreen oaks | 7.1 | 53.5 | 25.3 | 8.6 | 4.6 | 0.9 | 27.8 (-0.8) | 4 642 |
| Other broadleaves | 27.3 | 43.6 | 14.9 | 6.6 | 6.0 | 1.6 | 24.1 (-0.2) | 17 423 |
| **TOTAL** | | | | | | | | |
| Conifers | 23.3 | 47.2 | 18.9 | 6.7 | 3.1 | 0.8 | 23.3 (+0.3) | 49 903 |
| Broadleaves | 25.6 | 41.2 | 18.9 | 8.1 | 5.3 | 1.0 | 24.6 (0.0) | 52 009 |
| **All species** | 24.5 | 44.1 | 18.9 | 7.4 | 4.2 | 0.9 | 24.0 (+0.1) | 101 912 |

[1] http://icp-forests.net/page/icp-forests-technical-report

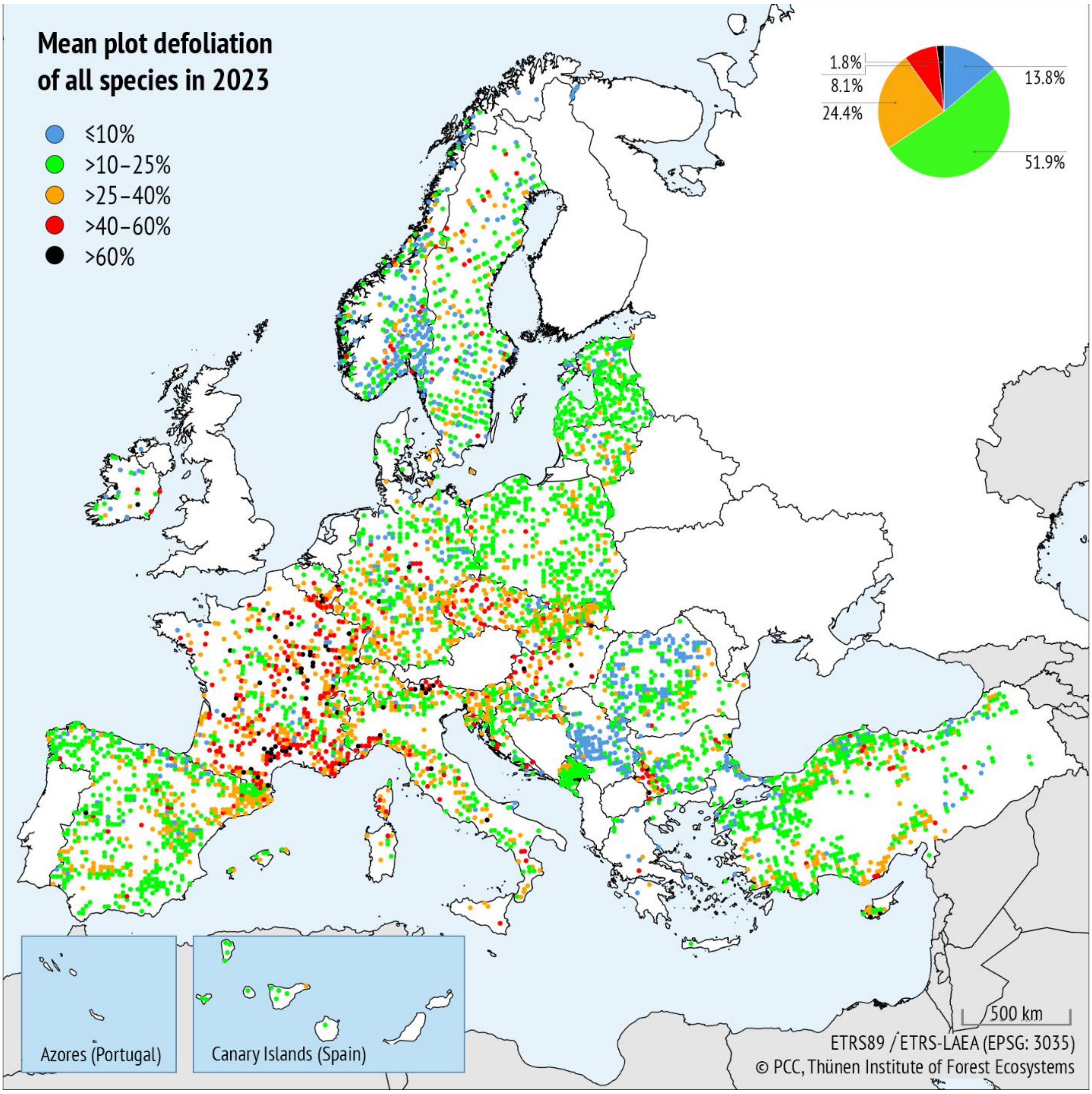
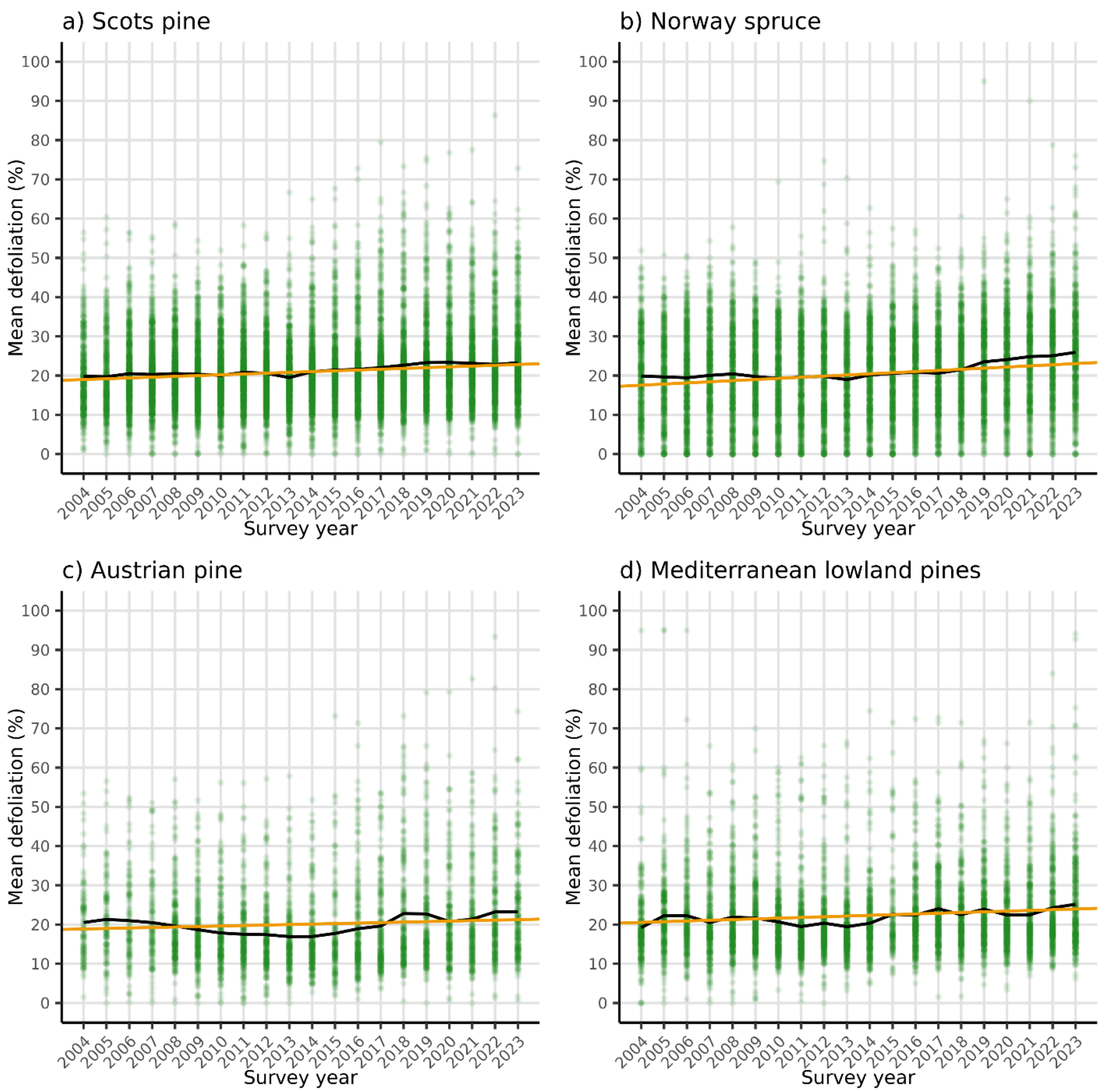
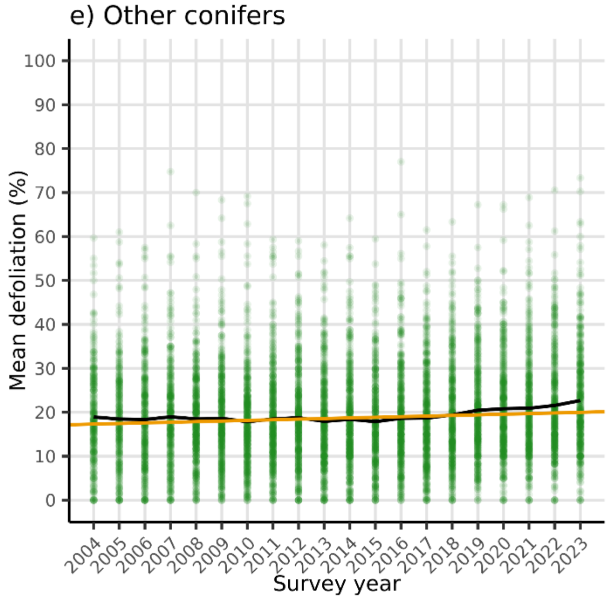



**Figure 8-1: Mean plot defoliation of all species in 2023, shown as defoliation classes.** The legend (top left) shows defoliation classes ranging from none (blue), slight (green), moderate (orange and red), to severe (black) defoliation. The percentages refer to the needle/leaf loss in the crown compared to a reference tree. The pie chart (top right) shows the percentage of plots per defoliation class. Dead trees are not included.

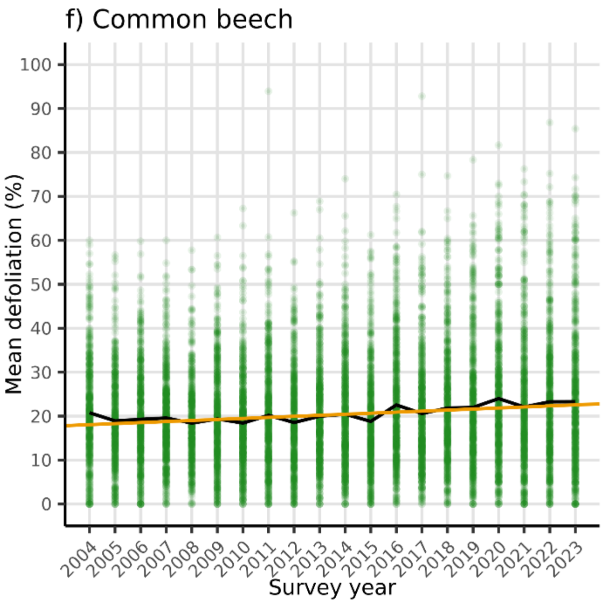


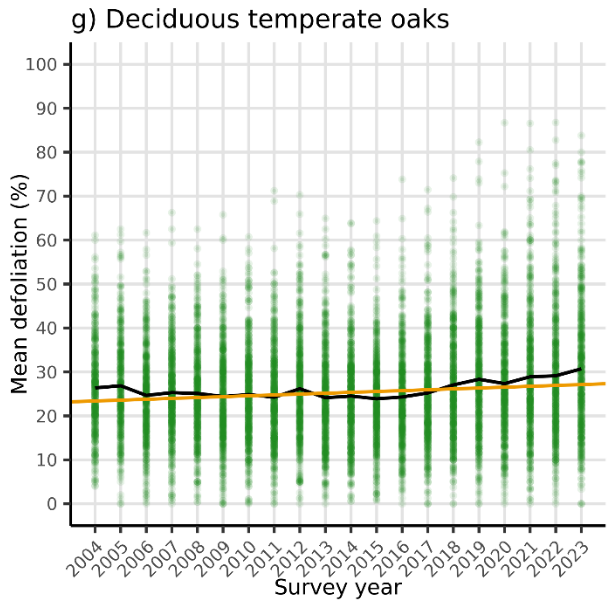



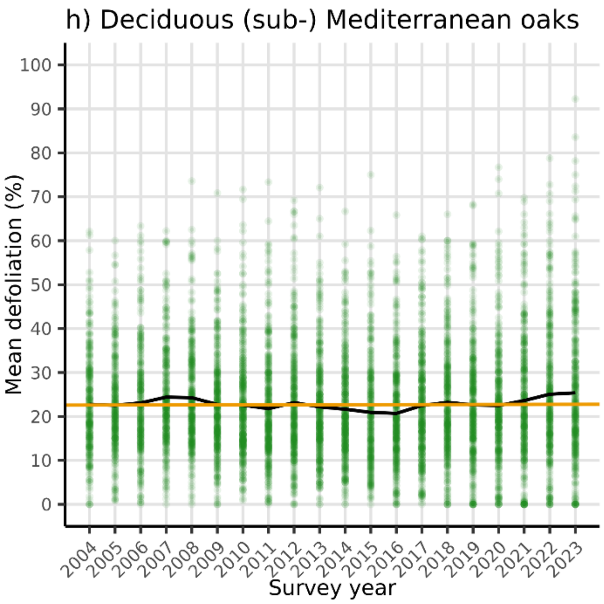

**Figures 8-2 a-e: Over-all trend (orange line) and annual mean defoliation across plots (black line) at Level I plots from 2004–2023;** points represent annual plot mean values:
**(a) Scots pine** (regional Sen's slope = 0.2019, $p < 0.001$)
**(b) Norway spruce** (regional Sen's slope = 0.2894, $p < 0.001$)
**(c) Austrian pine** (regional Sen's slope = 0.1249, *n.s.*)
**(d) Mediterranean lowland pines** (regional Sen's slope = 0.1792, $p < 0.01$)
**(e) Other conifers** (regional Sen's slope = 0.1407, $p < 0.01$)

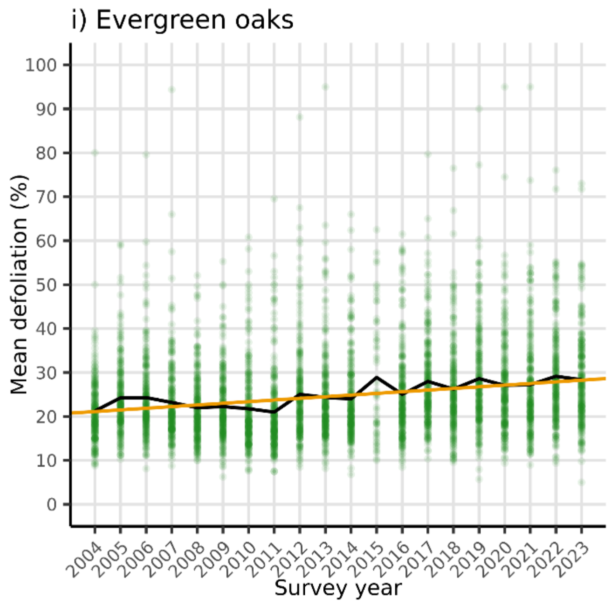
*n.s.* = not significant

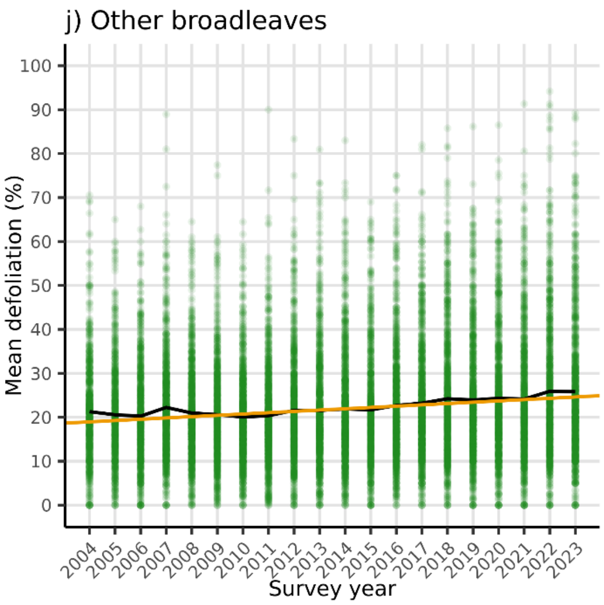
EVALUATIONS




**Figures 8-2 f-j: Over-all trend (orange line) and annual mean defoliation across plots (black line) at Level I plots from 2004–2023;** points represent annual plot mean values:
**(f) Common beech** (regional Sen's slope = 0.2369, $p < 0.001$)
**(g) Deciduous temperate oaks** (regional Sen's slope = 0.1965, *n.s.*)
**(h) Deciduous (sub-) Mediterranean oaks** (regional Sen's slope = 0.0090, *n.s.*)
**(i) Evergreen oaks** (regional Sen's slope = 0.3760, $p < 0.001$)
**(j) Other broadleaves** (regional Sen's slope = 0.2980, $p < 0.001$)
*n.s.* = not significant

### Scots pine

Scots pine (*Pinus sylvestris*) is the most frequent tree species in the ICP Forests Level I network (Table 8-3). It has a wide ecological niche due to its ability to grow on dry and nutrient poor soils and has frequently been used for reforestation. Scots pine is found over large parts of Europe from northern Scandinavia to the Mediterranean region and from Spain to Türkiye (and is also distributed considerably beyond the UNECE region).

In 2023, Scots pine trees showed mean defoliation of up to 10% on 15.3% of plots and slight (>10–25%) mean defoliation on 63.3% of the plots (please refer to the online supplementary material[1], Figure S1-1). Defoliation of Scots pine trees on 21.0% of the plots was moderate (>25–60% defoliation, class 2) and only on 0.4% of the plots severe (>60% defoliation, class 3). Plots with the lowest mean defoliation were primarily found in countries surrounding the Baltic sea, whereas plots with comparably high defoliation were located in Czechia, western Slovakia, south-eastern France, and western Bulgaria.

There has been a significant trend of mean plot defoliation of Scots pine over the course of the last 20 years with an increase of 4%p (Figure 8-2a). Within the chosen period data on mean defoliation across plots show very little fluctuation in regards to the trend line with the highest value recorded in 2019.

### Norway spruce

Norway spruce (*Picea abies*) is the second most frequently assessed conifer species within the ICP Forests monitoring program. The area of its distribution within the participating countries ranges from Scandinavia to northern Italy and from north-eastern Spain to Romania. Favoring cold and humid climate, Norway spruce at the southern edge of its distribution area is found only at higher elevations. Norway spruce is very common in forest plantations effectively enlarging its natural distribution range.

In 2023, spruce trees on over one fifth (21.2%) of all Norway spruce plots had mean defoliation up to 10%, and further 41.5% had only slight defoliation (please refer to the online supplementary material[1], Figure S1-2). On 35.8% of the plots spruce defoliation was moderate (>25–60% defoliation), while severe mean defoliation was recorded on 1.5% of the plots. Plots with low mean defoliation were found mostly in Scandinavia and the Balkan region. Plots with high mean defoliation values were mostly located in central Europe.

The 20-year trend in mean plot defoliation of Norway spruce shows an increase of almost 6%p (Figure 8-2b). The annual mean values have been on a steady rise and above the trend line since 2019, with the highest ever mean value recorded in 2023.

### Austrian (Black) pine

Austrian pine (*Pinus nigra*) is one of the most important native conifers in southern Europe, growing predominantly in mountain areas from Spain in the west to Türkiye in the east, with scattered occurrences as far north as central France and northern Hungary. This species can grow in both dry and humid habitats with considerable tolerance for temperature fluctuations. Two subspecies are recognized, along with a number of varieties, adapted to various environmental conditions.

Austrian pine had a mean defoliation of up to 10% on 9.8% of the plots containing this species, and between 11 and 25% on 57.2% of plots (please refer to the online supplementary material[1], Figure S1-3). Defoliation was moderate on 30.9% of the plots (>25-60% defoliation) and severe on 2.1% of the plots. Plots with less than 10% mean defoliation were mostly located in Türkiye, while plots with higher defoliation were scattered throughout the region.

The 20-year trend in mean plot defoliation of Austrian pine shows large fluctuations (Figure 8-2c). From 2010 to 2014 the annual mean plot defoliation was lower than the trend, but it has been above the trend line since then, reaching its absolute maximum in 2018.

### Mediterranean lowland pines

Four pine species are included in the group of Mediterranean lowland pines: Aleppo pine (*Pinus halepensis*), maritime pine (*P. pinaster*), stone pine (*P. pinea*), and Turkish pine (*P. brutia*). Most plots dominated by Mediterranean lowland pines are located in Spain, France, and Türkiye, but they are also important species in other Mediterranean countries. Aleppo and maritime pine are more abundant in the western parts, and Turkish pine in the eastern parts of this area.

Mediterranean lowland pine plots had mean defoliation of up to 10% on 3.2% of plots and 59.9% of plots had defoliation between 11 and 25% (please refer to the online supplementary material[1], Figure S1-4). Defoliation was moderate on 35.2% of the plots, and severe on 1.7%. Most of plots with defoliation up to 25% were located in Türkiye and Spain. Plots with moderate to severe mean defoliation values were mostly located in the proximity to the coastline of the western Mediterranean Sea.

For Mediterranean lowland pines, the trend shows an increase in defoliation of 3.6%p over the past 20 years (Figure 8-2d), with annual values staying mostly close to the trend line.

[1] http://icp-forests.net/page/icp-forests-technical-report

### Common beech

Common beech (*Fagus sylvatica*) is the second most frequently assessed species on Level I plots in 2023 and by far the most frequently assessed deciduous tree species within the ICP Forests monitoring programme (Table 8-3). It is found on Level I plots from southern Scandinavia in the North to southernmost Italy, and from the Atlantic coast of northern Spain in the West to the Bulgarian Black Sea coast in the East.

In 2023, common beech had up to 10% mean defoliation on 22.7% of the beech plots (please refer to the online supplementary material[1], Figure S1-5). On 40.9% of plots, beech trees were slightly defoliated (>10–25% defoliation), moderate mean defoliation was recorded on 33.0%, and severe defoliation on 3.4% of plots. Most plots with lower mean defoliation were located in eastern Europe, while plots with severe defoliation were predominantly located in France and Germany.

The 20-year trend in mean plot defoliation of common beech shows an increase of 4.7%p (Figure 8-2f). Annual mean values generally stay close to the trend line, but there were three larger deviations from this trend, in 2004, 2016, and 2020 – the highest ever mean plot defoliation of 23.9% was recorded in 2020. In 2004, the annual mean plot defoliation was higher than the trend as a result of the drought in the preceding year which affected large parts of Europe (Ciais et al. 2005, Seidling 2007, Seletković et al. 2009). This is in line with the reported lagged increase in beech defoliation after drought (e.g. Dobbertin 2005, Ognjenović et al. 2022), although the response can also be immediate, as was shown by Rohner et al. (2021).

### Deciduous temperate oaks

Deciduous temperate oaks include pedunculate and sessile oak (*Quercus robur* and *Q. petraea*) and their hybrids. They cover a large geographical area in the UNECE region: from southern Scandinavia to southern Italy and from the northern coast of Spain to the eastern parts of Türkiye.

In 2023, mean defoliation of temperate oaks was up to 10% on 7.8% of the plots, and from >10 to 25% on 37.5%. Moderate mean defoliation (>25–60%) was recorded on 51.2% of plots and severe defoliation (more than 60% defoliation) on 3.4% of the plots (please refer to the online supplementary material[1], Figure S1-6). Plots with severe defoliation were located mostly in parts of central Europe and France, while plots with mean defoliation up to 25% were mainly found in the east of the continent.

While the rise in mean plot defoliation of deciduous temperate oaks in the past 20 years has been relatively prominent (3.9%p), this increase is not statistically significant. Generally, the changes in the defoliation status of deciduous temperate oaks are not very fast. A good example is a delayed recovery of oak defoliation after the drought year 2003 (Figure 8-2g), or a larger deviation from the trend line in 2019, possibly due to the effects of drought events in 2018 and 2019 (JRC 2019). In 2023 we recorded the highest ever mean defoliation of deciduous temperate oaks in the past 20 years.

### Deciduous (sub-) Mediterranean oaks

The group of deciduous (sub-) Mediterranean oaks includes Turkey oak (*Quercus cerris*), Hungarian or Italian oak (*Q. frainetto*), downy oak (*Q. pubescens*), and Pyrenean oak (*Q. pyrenaica*). The range of distribution of these oaks is confined to southern Europe, as indicated by their common names.

Mediterranean oaks had mean defoliation up to 10% on 14.7% of plots, and between 10 and 25% on 47.9% of plots, yielding a total of 62.6% of plots with mean defoliation up to 25% for these oaks in 2023. More than a third (34.1%) of plots showed moderate, and 3.2% severe mean defoliation for Mediterranean oaks (please refer to the online supplementary material[1], Figure S1-7). Plots with low mean defoliation were located predominantly in the Balkans, while plots with higher mean defoliation were found mostly in Hungary and southeastern France.

There has been no significant trend in mean plot defoliation for deciduous (sub-) Mediterranean oaks for the past 20 years (Figure 8-2h). Mean plot defoliation values generally stay fairly close to the trend line.

### Evergreen oaks

The group of evergreen oaks consists of kermes oak (*Quercus coccifera*), holm oak (*Q. ilex*), *Q. rotundifolia* and cork oak (*Q. suber*). The occurrence of this species group as a typical element of the sclerophyllous woodlands is confined to the Mediterranean basin.

Only 1.2% of the evergreen oak plots had mean defoliation up to 10%, and there were 45.7% of the plots in the range >10 to 25% mean defoliation (please refer to the online supplementary material[1], Figure S1-8). Moderate defoliation was recorded on 51.8%, and severe defoliation on 1.2% of plots. The majority of plots with defoliation over 40% were located along the shoreline of the northwest Mediterranean.

Based on the trend analysis, evergreen oaks had the largest increase (7.5%p) in defoliation of all analyzed species and species groups over the last 20 years (Figure 8-2i). The defoliation development pattern for evergreen oaks is characterized by larger positive and negative deviations from the trend line, sometimes lasting for several years, although lately values stay mostly above the trend line.

[1] http://icp-forests.net/page/icp-forests-technical-report

## Damage causes

In 2023, damage cause assessments were carried out on 101 727 trees on 5 497 plots and in 26 countries. On 49 992 trees (49.0%) at least one symptom of damage was found, which is the same level as in 2022. In total, 73 031 observations of damage were recorded (multiple damage symptoms per tree were possible). Both fresh and old damage was reported.

The average number of recorded damage symptoms per assessed tree (ratio, Table 8-4) was higher for the broadleaved tree species and species groups than for the conifers. It was highest for deciduous temperate oaks and evergreen oaks with 1.08 and 1.07 symptoms per tree on average, and lowest for Norway spruce with 0.44 symptoms per tree. Compared to 2022, the number of recorded damage symptoms and the ratios have been increasing for several species and species groups, and especially for deciduous temperate oaks.

**Table 8-4: Number of damage symptoms and assessed trees, and their ratio for the main tree species and species groups in 2023.** Multiple damage symptoms per tree and dead trees are included.

| Main species or species groups | N damage symptoms | N trees | Ratio |
|---|---|---|---|
| Scots pine (*Pinus sylvestris*) | 10 282 | 17 268 | 0.60 |
| Norway spruce (*Picea abies*) | 4 726 | 10 693 | 0.44 |
| Austrian pine (*Pinus nigra*) | 3 209 | 5 317 | 0.60 |
| Mediterranean lowland pines | 4 966 | 8 035 | 0.62 |
| Other conifers | 4 617 | 7 777 | 0.59 |
| Common beech (*Fagus sylvatica*) | 9 078 | 11 149 | 0.81 |
| Deciduous temperate oaks | 9 480 | 8 808 | 1.08 |
| Dec. (sub-) Mediterranean oaks | 6 851 | 8 001 | 0.86 |
| Evergreen oaks | 4 964 | 4 645 | 1.07 |
| Other broadleaves | 14 858 | 20 034 | 0.74 |
| **Total** | | | |
| Conifers | 27 800 | 49 090 | 0.57 |
| Broadleaves | 45 231 | 52 637 | 0.86 |
| **All species** | 73 031 | 101 727 | 0.72 |

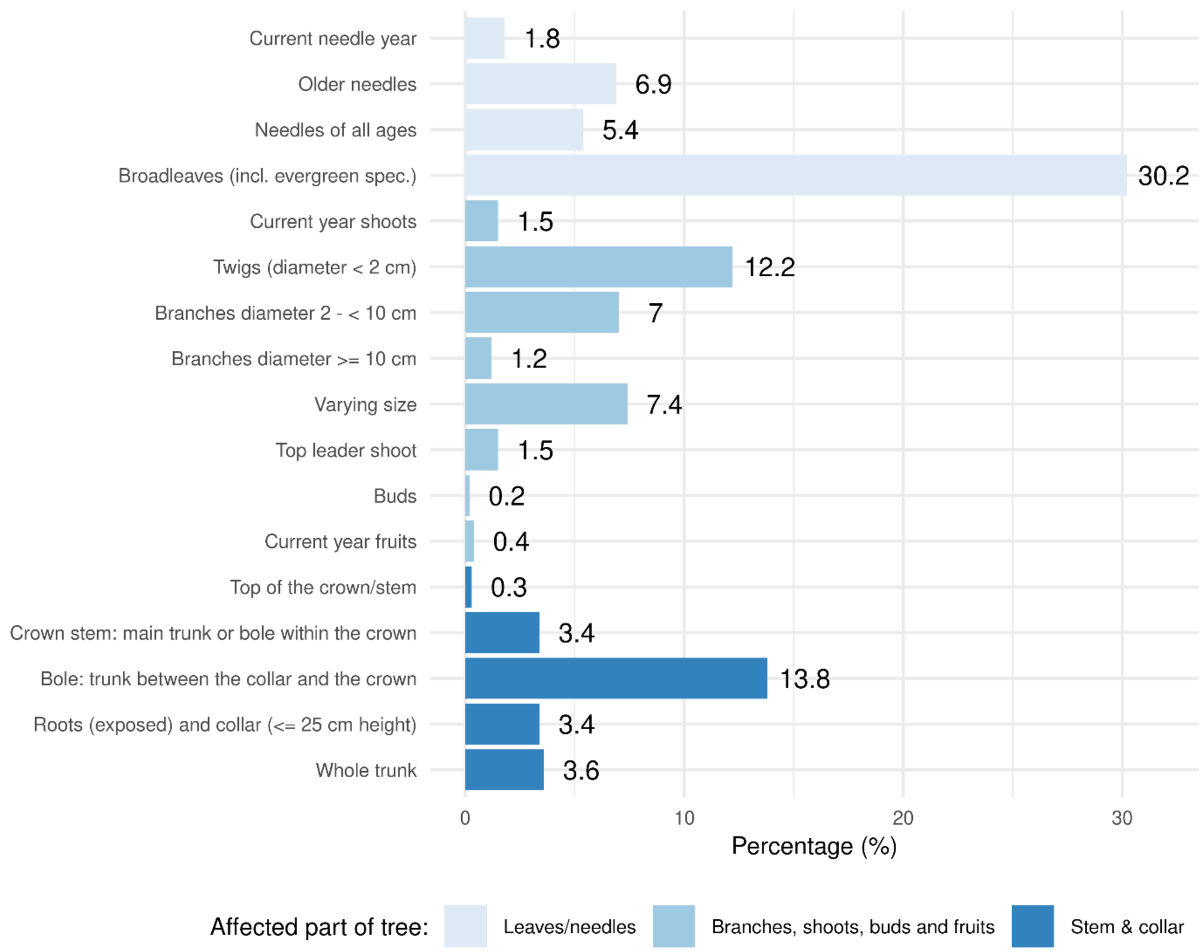



**Figure 8-3: Percentage of recorded damage symptoms in 2023 (n=71 853), affecting different parts of a tree.** Multiple affected parts per tree were possible. Dead trees are not included.

### Symptom description and damage extent

Most of the reported damage symptoms were observed on the leaves of broadleaved trees (30.2%), followed by twigs and branches (27.8%), and stems (21.0%; Figure 8-3). Needles were also often affected (14.1%), while roots, collar, shoots, buds, and fruits of both broadleaves and conifers were less frequently affected.

More than half (54.6%) of all recorded damage symptoms had an extent of up to 10%, 35.6% had an extent between 10% and 40%, and 9.8% of the symptoms covered more than 40% of the affected part of a tree.

### Causal agents and factors responsible for the observed damage symptoms

Insects were the predominant cause of damage and responsible for 24.0% of all recorded damage symptoms (Figure 8-4). Within the group of insects, 38.9% of damage symptoms were caused by defoliators. Wood borers were responsible for 18.4%, leaf miners for 12.9%, sucking insects for 9.9%, and gallmakers for 5.9% of the damage caused by insects.

Abiotic factors were the second major causal agent group responsible for 18.6% of all damage symptoms. Within this agent group, more than half of the symptoms (53.7%) were attributed to drought, while snow/ice and hail caused 11.8%, wind 9.2%, frost 3.4%, and heat/sun scald 3.3% of the symptoms.

The third major identified cause of tree damage were fungi with 11.2% of all damage symptoms. Of those, 23.2% showed signs of decay and root rot fungi, followed by dieback and canker fungi (14.7%), powdery mildew (13.1%), needle cast and needle rust fungi (12.1% each), blight (9.8%) and leaf spot fungi (5.4%).

Direct action of man refers mainly to impacts of silvicultural operations, mechanical/vehicle damage, forest harvesting, or resin tapping. This agent group accounted for 4.7% of all recorded damage symptoms. The damaging agent group 'Game and grazing' was of minor importance (1.2%). Fire caused 0.7% of all damage symptoms. The agent group 'Atmospheric pollutants' refers here only to damage caused by direct atmospheric pollution impact. Visible symptoms of direct atmospheric pollution impact, however, were very rare (0.03% of all damage symptoms). Other factors were responsible for 10.8% of all reported damage symptoms. Apart from these identifiable causes of damage symptoms, a considerable proportion of symptoms (28.8%) could not be identified in the field.

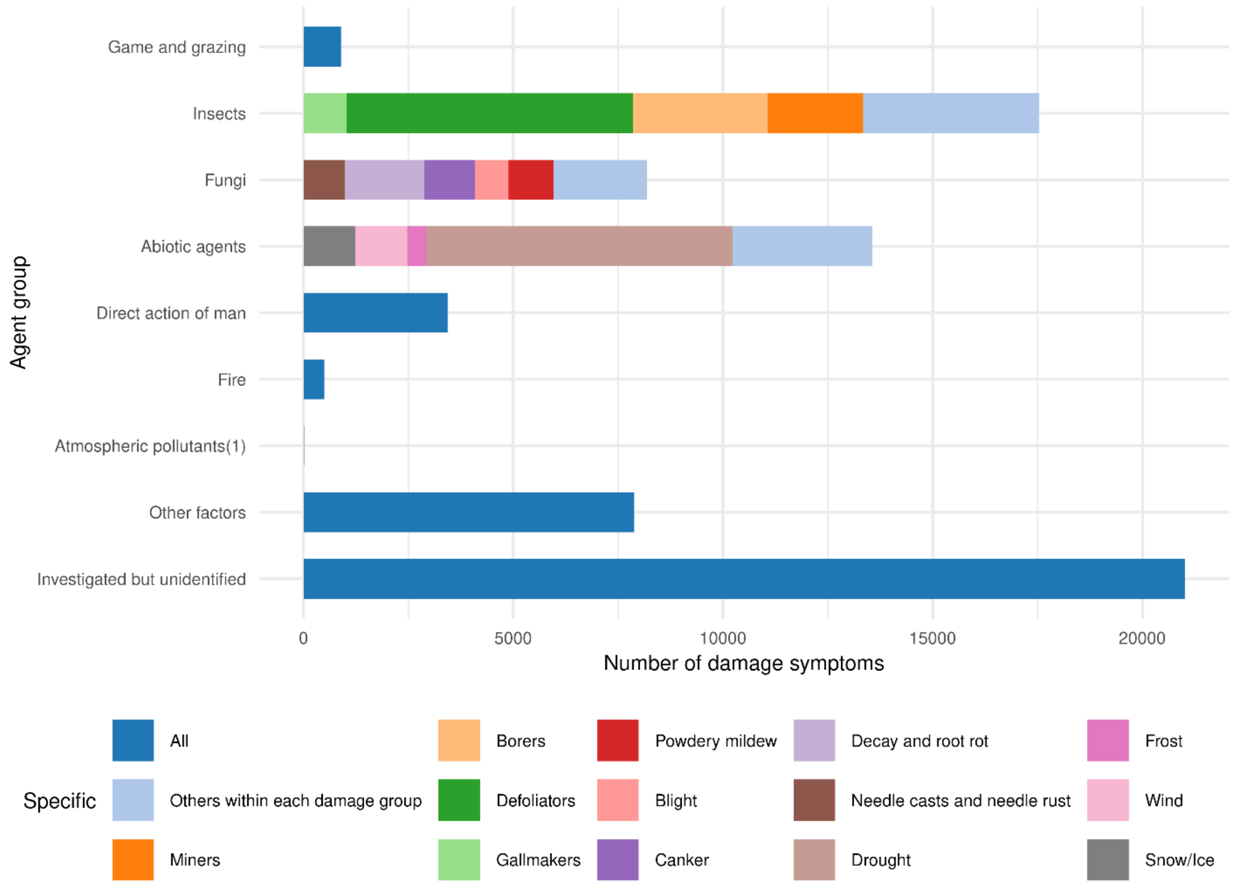



**Figure 8-4: Number of damage symptoms (n=73 031) according to agent groups and specific agents/factors in 2023.** Multiple damage symptoms per tree were possible, and dead trees are included. (1) Visible symptoms of direct atmospheric pollution impact only

The occurrence of damaging agent groups differed between major species or species groups (Figure 8-5). Insects were the most important damaging agent group for common beech (causing 39.1% of all damage in beech), deciduous temperate oaks (37.6%), deciduous (sub-) Mediterranean oaks (32.7%), and Austrian pine (21.5%), while insect damage was not so common in Scots pine (8.3%) and Norway spruce (5.2%). Abiotic factors caused by far the most damage in evergreen oaks (46.3%) and Mediterranean lowland pines (38.4%), and the least in Austrian pine (9.3%). Fungi were important damaging agents for Austrian pine (18%), deciduous temperate oaks (16.2%), and evergreen oaks (16%). Direct action of man was of little importance for most species, apart from Norway spruce (16.8%) and Scots pine (8.6%). Damage from game and grazing played a minor role for all species and species groups except for Norway spruce (9.9%). Fire affected mostly Mediterranean species: 2% of Austrian pines, 1.4% of Mediterranean lowland pine trees, and 1% of deciduous (sub-) Mediterranean oaks were affected. Other identified factors, such as competition, European mistletoe (*Viscum album*), and European ivy (*Hedera helix*), were prominent in Scots pine (26.6%) and Austrian pine (21.3%). The percentage of recorded but unidentified damage symptoms was small in evergreen oaks (9.5%) but large for Norway spruce (40.3%), Scots pine (31.2%), and deciduous (sub-) Mediterranean oaks (32.3%).

The most important specific damaging agents for common beech were mining insects causing 21.5% of the damage symptoms, followed by defoliators (10.5%), drought (4.6%), and silvicultural operations (3.5%). Defoliators were also frequently causing damage on deciduous temperate oaks (10.8%), while powdery mildew (10%), borers (8.1%), sucking insects (6.7%), drought (6.2%), and competition (3.6%) also were significant. For deciduous (sub-) Mediterranean oaks, defoliators (8.9%) were the most common damaging agents, followed by borers (8.8%), drought (8.7%), sucking insects (8.5%), and European ivy (3.4%). Drought was by far the most important single damaging agent for evergreen oaks (42.9%), but also borers (13.4%), decay and root rot fungi (11.2%), blight (3.8%), and defoliators (3.1%) had an impact on these oak species.

Most damage symptoms in Scots pine were caused by various effects of competition (14.7%), followed by *Viscum album* (7.6%), borers (5.6%), silvicultural operations (5.4%), drought (4.6%), wind (4.2%), and needle cast/needle rust fungi (4%). For Norway spruce, silvicultural operations (10.6%), competition (6.9%), red deer (6%), mechanical/vehicle damage (5.7%), snow/ice (4.4%), and borers (3.2%) were most important. Defoliators were causing most damage (19.2%) on Austrian pine trees, but *Viscum album* (17%), needle cast/needle rust fungi (10.5%), drought (5.2%), and blight (5.1%) also caused considerable damage. Mediterranean lowland pines were mostly affected by drought (29.5%), defoliators (14.3%), sucking insects (6%), *Viscum album* (4.7%), and snow/ice (4.6%).

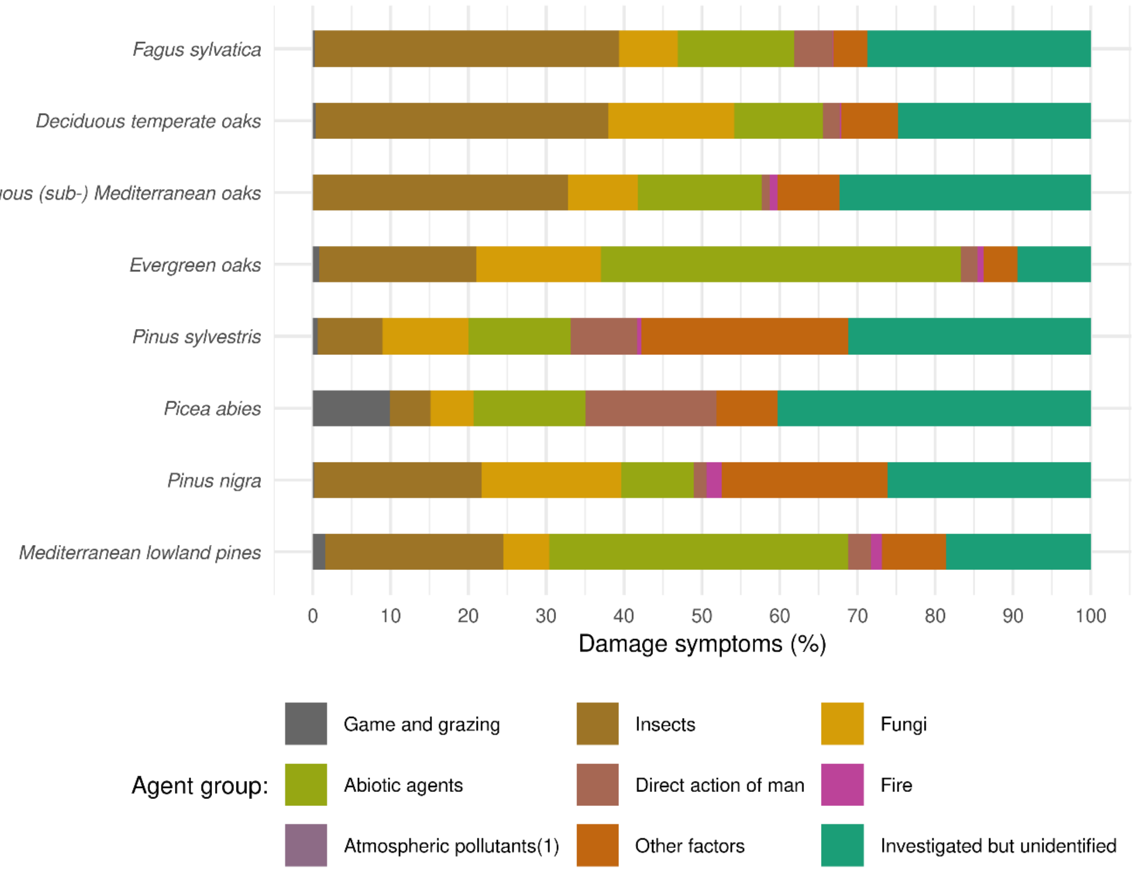



**Figure 8-5: Percentage of damage symptoms by agent group for each main tree species and species group in 2023.** (1)Visible symptoms of direct atmospheric pollution impact only

EVALUATIONS

#### Regional importance of the different agent groups

Damage caused by abiotic factors was reported from 1 991 Level I plots (36%) in 2023, occurring frequently throughout Europe. Countries most affected by abiotic factors were Spain, Slovenia, Montenegro, and Cyprus.

Damage caused by insects was observed on 1 845 European Level I plots, which corresponds to 34% of all plots with damage assessments. With some exceptions (Scandinavia, Ireland, northern Germany, Czechia, and the Baltic countries), a high proportion of plots was thus affected by insects throughout Europe.

The agent group 'Fungi' was responsible for damage on 1 383 European Level I plots (25%) and was frequently occurring in many countries. Low occurrence of damage by fungi was observed in Scandinavia, Ireland, northern Germany, Italy, Romania, Türkiye, and Greece.

The damaging agent group 'Direct action of man' impacted trees on 1 051 plots (19%) and was most frequently occurring in eastern parts of Europe and south-western Germany.

Damage caused by game and grazing was most frequently observed in the Baltic countries, Hungary, and Spain. In total, 289 Level I plots (5%) had trees damaged by this agent group.

There were 54 plots (1%) with damage inflicted by fire, most of them located in Spain.

For maps showing incidents of various agent groups, please refer to the online supplementary material[1].

#### Tree mortality and its causes

There were 1 164 new dead trees in the damage assessment 2023 (703 broadleaves and 461 conifers, Table 7-5). This results in a mortality rate of 1.1%, which represents an increase compared to 2022 (0.9%). The highest numbers of dead trees among the main tree species and species groups were found for Scots pine (171 trees, corresponding to a mortality rate of 1%), Norway spruce (156 trees, corresponding to 1.5%), deciduous temperate oaks (112 trees, corresponding to 1.3%), and deciduous (sub-) Mediterranean oaks (78 trees, corresponding to 1%). Mortality rates for the other main species and species groups were below 1%. Among other broadleaves, particularly high numbers of dead trees were found for downy birch (*Betula pubescens*, 124 trees, corresponding to a mortality rate of 4.5%), and European ash (*Fraxinus excelsior*, 71 trees, corresponding to 7.9%).

Most dead trees were reported from Norway (215, mostly broadleaves and mainly downy birch), France (165, mainly oak species), Spain (125, mainly *Quercus ilex* and *Pinus nigra*), Bulgaria (77, mainly Scots pine), and Germany (72, also mainly Scots pine). The main cause of mortality to broadleaved trees on Level I plots was abiotic factors (Figure 8-6), followed by fire, fungi, and insects. Fire was causing the death of most coniferous trees, followed by abiotic agents, insects, and fungi. The determination of the cause of tree death is often very difficult; it could not be identified for more than 60% of the dead trees in 2023.

Main specific causes of death that could be identified in the field for the main tree species and species groups are given in Table 8-5. Mortality in European ash was mainly caused by ash dieback, and in downy birch by *Epirrita autumnata*.

**Table 8-5: Number of dead trees, mortality rates and main specific causes of death that could be identified in the field for the main tree species and species groups in 2023.**

| Main species or species groups | N dead trees | Mortality rate (%) | Main specific cause of death |
|---|---|---|---|
| Scots pine (*Pinus sylvestris*) | 171 | 1.0 | Fire |
| Norway spruce (*Picea abies*) | 156 | 1.5 | *Ips typographus* |
| Austrian pine (*Pinus nigra*) | 42 | 0.8 | Fire |
| Mediterranean lowland pines | 43 | 0.5 | Drought |
| Other conifers | 49 | 0.6 | |
| Common beech (*Fagus sylvatica*) | 69 | 0.6 | Various fungi |
| Deciduous temperate oaks | 112 | 1.3 | Wind |
| Dec. (sub-) Mediterranean oaks | 78 | 1.0 | Fire & drought |
| Evergreen oaks | 43 | 0.9 | Fire & drought |
| Other broadleaves | 401 | 2.0 | |
| **Total** | | | |
| Conifers | 461 | 0.9 | |
| Broadleaves | 703 | 1.3 | |
| **All species** | **1 164** | **1.1** | |

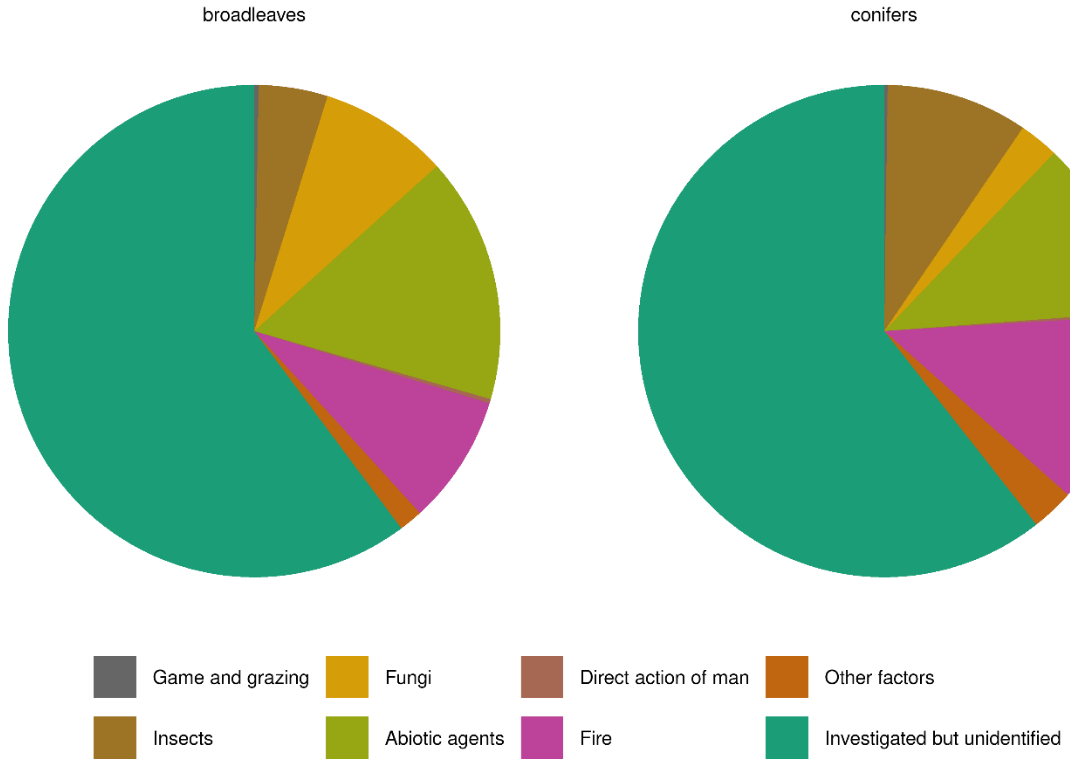



**Figure 8-6: Percentage of damaging agent groups causing mortality of broadleaved and coniferous trees in 2023 (n = 1 164)**

[1] http://icp-forests.net/page/icp-forests-technical-report

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# PART C
# National reports of participating countries in ICP Forests

9

# NATIONAL REPORTS OF COUNTRIES PARTICIPATING IN ICP FORESTS

All participating countries in ICP Forests were invited to submit summary reports on their ICP Forests activities. Many countries have taken this opportunity to highlight recent developments and major achievements from their many national forest monitoring activities.

All written reports have been slightly edited, primarily for consistency, and are presented below. The responsibility for the national reports remains with the National Focal Centres and not with the ICP Forests Programme Co-ordinating Centre. For contact information of the National Focal Centres, please refer to the Annex.

## Andorra

### National Focal Centre

Silvia Ferrer Lopez, Maria Salas Sopena – Department of Environment and Sustainability | Ministry of Environment, Agriculture and Livestock. Government of Andorra

### Main activities/developments

The assessment of tree crown condition, Level I, was conducted on 12 plots of the national 4x4 km grid, following the ICP Forests Manual. The assessment in 2023 included 290 trees: 119 *Pinus sylvestris*, 139 *Pinus uncinata*, 27 *Abies alba*, and 5 *Betula pendula*, covering the main subalpine forests in Andorra.

### Major results/highlights

Results for 2023 continue to show a worsening of crown condition, being the worst condition registered in recent years.

Scots pine (*Pinus sylvestris*) and mountain pine (*Pinus uncinata*) are the species that have presented the most severe affectation in the crown, especially the last 5 years. Scots pine has increased the percentage of moderate defoliation class (with the 48.7% of the trees in this class) and mountain pine has slightly increased its moderate class (51.1%). European silver fir (*Abies alba*) is the species less affected, with the majority of trees (all in the same plot) in the not defoliated class, although a slight increase in slightly defoliation class was registered (7.4%). Finally, birch trees (*Betula pendula*) also registered an increase in the moderate defoliation class. In terms of overall defoliation, there has been registered an increase in moderate defoliation (from 39.3% in 2022 to 45.5% in 2023), and as in the previous year 0.7% of the sampled trees were dead.

The worsening in crown condition in the last 5 years is related to unfavorable climatic conditions during the vegetative period with lower rainfall and higher temperatures compared to the reference period (1981–2020).

Regarding causes of damage, in 2023, 22% of the sampled trees presented symptoms of damage, this percentage has slightly increased compared to the previous year. The most common identified causes of damage were abiotic causes followed by biological agents such as the fungus *Cronartium flaccidum*. In 2023 *Ips acuminatus* has also been detected. The presence of *Thaumetopoea pityocampa* has not been detected in the sampled plots, although it is visible in the forests of Andorra.

### Outlook

Andorra joined Level I of ICP Forests in 2004 with 3 plots. Since 2006 the survey has been conducted annually increasing the number of plots to 12. Furthermore, since 2021 besides the crown condition survey following the ICP Forests Manual, Andorra has been monitoring the evolution of pathologies with the collaboration of expert pathologists.

## Austria

### National Focal Centre

Anita Zolles, Austrian Research Centre for Forests (BFW)

### Main activities/developments

Crown condition assessments on the Level I plots and on the Level II plots in Austria were already discontinued in 2011 and all 135 Austrian Level I plots were abandoned. Monitoring activities on the 16 Austrian Level II plots are continued. In 2022, on all 16 plots wet deposition was collected and analyzed. Foliage samples were taken on all 16 plots. On 6 out of the 16 Austrian Level II plots – Level II core plots – also meteorological measurements, including measurement of temperature and moisture of the soil, were continued as well as collections of litterfall, chemical analysis of soil solution and measurements of tree increment via mechanical and electronic girth bands. Hemispheric photographs were taken at all 6 Level II core plots to obtain Leaf Area Index.

### Major results/highlights

The results of the measurements and the chemical analyses on the Austrian Level II plots can be found at: http://www.waldmonitoring.at

### Outlook

The monitoring activities on the 16 plots will be continued on a similar level as within the past years. This includes regular investment in measurement facilities and replacement of broken equipment.

The six core-monitoring plots are included in the network of sites for monitoring the negative impacts of air pollution upon ecosystems under the National Emissions Ceilings (NEC) Directive (2016/2284/EU). These plots will form the basis for collecting and reporting the information concerning forest ecosystems required under the NEC Directive.

## Belgium Flanders

### National Focal Centre

Level I: Geert Sioen
Level II: Arne Verstraeten (NFC), Peter Roskams
Research Institute for Nature and Forest (INBO)

### Main activities/developments

The Level I survey was performed on 78 plots and 1473 sample trees (4x4 km grid). 58.4% of the sample trees are broadleaves and 41.6% are conifers. The most important tree species are *Pinus sylvestris* (31.4%), *Quercus robur* (26.9%), *Fagus sylvatica* (10.0%), *Pinus nigra* subsp. *laricio* (9.8%), and *Q. rubra* (6.3%). Species with fewer sample trees are pooled together in subsets with 'other broadleaves' (15.2%) or 'other conifers' (0.4%).

### Major results/highlights

In 2023, 22.6% of the sample trees were classified as damaged. 21.7% of the trees showed moderate leaf loss and defoliation was severe on 0.6%. The mortality rate was 0.3%. Mean defoliation of all trees was 22.5%.

The level of damage was high in *Q. robur* and *P. nigra*. 33.5% of the oaks and 28.3% of the pines were considered as damaged and mean defoliation was 24.6% and 23.0% respectively. *P. sylvestris* and 'other broadleaves' showed the best condition, with 13.4% and 15.2% in defoliation classes 2-4. Mean defoliation in these subsamples was 21.5% and 21.9%. Crown condition of *F. sylvatica* and *Q. rubra* was considered as moderate. Mean defoliation was 21.2% in *F. sylvatica* and 22.8% in *Q. rubra*. The share of damaged trees amounted to 24.5% and 26.9% respectively.

14.1% of the trees showed moderate to severe discoloration, with a higher proportion in broadleaves compared to conifers (24.0% and 0.3%).

Defoliators impacted the health status of *Q. robur* and *Q. rubra*. More than one-third of the trees were moderately to severely affected by defoliators (34.8% and 36.6% respectively). Mildew infection (*Microsphaera alphitoides*) was severe in several *Q. robur* plots. Moderate to severe discoloration of infected leaves was observed in 49.1% of the oak trees. In several *Q. robur* plots with a high mean defoliation, crowns showed symptoms of both insect damage and fungal infection. In pine plots, fungal infection by *Sphaeropsis sapinea* caused dieback of shoots, twigs and branches. Severe crown dieback due to *S. sapinea* was observed in 3.0% of *P. sylvestris* and 8.3% of *P. nigra*.

Compared to the previous year, weather circumstances were rather favorable. Fewer trees showed storm damage or drought symptoms. Moderate to high fructification was almost absent in *Q. robur* but frequent in *F. sylvatica* (respectively 1.0% and 19.8%).

Compared to the previous survey, crown condition improved. Mean defoliation of common sample trees decreased by 0.8 percentage points and the share of damaged trees by 3.3 percentage points. The share of trees with moderate to severe defoliation decreased by 1.3 percentage points in broadleaves and 6.2 percentage points in conifers. All tree species revealed a better condition, except *Q. rubra*. From 1995 to 2023, the trend in defoliation increased in *F. sylvatica*, *Q. robur,* and 'other broadleaves'. Defoliation of *P. sylvestris* and *Q. rubra* showed no trend and defoliation in *P. nigra* performed a decreasing trend.

*Hymenoscyphus fraxineus* is still causing crown deterioration and dieback in *Fraxinus excelsior*. In 2014, a survey was started, partly on Level I plots. In 2023, crown condition assessments were conducted on 224 ash trees in 26 plots. Dead trees included, the share of damaged trees was 60.3% and mean defoliation 55.7%. After nine years of monitoring 31.3% of the sample trees had died.

In two Level II plots (in the Sonian forest and Wijnendale forest), we counted and collected seeds under the canopy of individual *F. sylvatica* trees for an international project aiming to identify the main drivers of changes in masting patterns. Data from both sites (1999–2021) were also included in the MASTREE+ dataset.

### Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2

Sioen G, Verschelde P, Roskams P (2023) Bosvitaliteitsinventaris 2022. Results of the crown condition survey (Level I). Research Institute for Nature and Forest, Report 2023 (4). INBO, Brussels (in Dutch). ISSN:1782-9054, https://doi.org/10.21436/inbor.90109478

NATIONAL REPORTS

## Outlook

The Level I and the Level II program will be continued. In 2024, soil and litter samples will be collected both in (transnational) Level I plots and Level II plots.

# Belgium Wallonia

## National Focal Centre

Elodie Bay, SPW – Public Service of Wallonia

## Main activities/developments

In 2023, data were collected on 7 plots for Level II/III and on 45 plots for Level I.

## Major results/highlights

A relatively warm winter followed by a cool start to spring accentuated the differences in the start of the growing season between species: early for larch and hornbeam and late for oak, Douglas-fir and birch. The beginning of summer was dry and very hot, but July and August were normal. Autumn, which was warm, but with normal precipitation, contributed to delaying senescence for the majority of species.

Here are the trends for the main species based on the summer defoliation record:

- The poor health situation of oaks in 2023 is probably linked to spring caterpillar attacks, as in 2012. Given the similarity of the situations, and the favorable development after 2012, we can hope that the oaks will resist this new crisis well.
- The situation of the beech trees is poor and continues to deteriorate slowly. Repeated droughts could explain recent deterioration, but do not cause (at least not yet) pronounced deterioration or abnormal mortality.
- The health situation of larches and Douglas-firs is degraded but has tended to gradually improve since 2019.
- Finally, the situation of spruce trees is very worrying because since 2019 more than half of the remaining trees have been seriously or very seriously degraded, despite the numerous sanitary cuts carried out since then.

Level II and Level III plots, monitored now for 25 years in the Walloon Region, also leads to interesting observations:

- Why does the pH of soil solutions not increase (or very little), unlike that of rainwater?

  (1) Protons brought in by rain are not the main source of acid in the soil. Respiration (roots and microorganisms), decomposition of organic matter, absorption of nutrient cations by roots and nitrification (transformation of ammonium into nitrate) are major sources of acidity in soils. When ammonium fallout is high (which is the case in Wallonia), nitrification could constitute the main source of acidity in forest soils. Note that in these soils, nitrification is not inhibited by acidity, because it is carried out by fungi. The fact that ammonium fallout is high and does not decrease could therefore explain the lack of change in the pH of the solutions in the long term.

  (2) The pH of soils depends on the supply of acidity (protons) but also, and above all, on their neutralization. The main neutralization mechanisms are the absorption of nitrate by the roots and the alteration of minerals. If nitrate absorption by the roots decreases (for example after cutting), nitrate concentrations increase and the pH tends to decrease (which explains the fluctuations observed). On the other hand, weathering of minerals maintains the pH within a certain range, which depends on the strength of the minerals present. In the presence of very weak minerals (e.g. limestone), the pH of the soil will be high regardless of the acid addition. This is called the buffering power of the soil. Thanks to this mechanism, the pH of a soil will decrease little when the acid supply increases but rises very little when it decreases.

- Why does the phosporus content of leaves decrease?

  (1) In the mineral horizons of the soil, phosphorus is very little available because it is strongly bound (adsorbed) to the surface of iron oxides (= major component of all soils). Since sulphate has an affinity for these same surfaces, the high concentrations during the peak of air pollution would have competed for fixation sites, which would have made phosphorus more available to the roots. The sharp reduction in sulphate fallout since the 1990s could therefore cause a simultaneous reduction in the availability of phosphorus.

  (2) The production of fruit by trees consumes their nutrient reserves, particularly phosphorus. Fruiting peaks that are more marked and more frequent than before could cause a gradual depletion of their reserves, which would be reflected in the concentrations in the leaves. However, we do not have data on fruiting before 1998 in order to document the situation prior to this monitoring.

## Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2

Please refert to our annual reporting on forest health (in French), which includes ICP Forests data on http://owsf.environnement.wallonie.be. Data are also included in the Walloon Regional Environmental Report (in French) on http://etat.environnement.wallonie.be.

## Outlook

- Future developments of the ICP Forests infrastructure

- Replacement of a spruce plot by a Douglas-fir plot on Level II/III. The Douglas-fir being a species of interest in our region, but not yet present in this intensive network.

- Planned research projects, expected results
  - Data collected on the plot of Douglas-fir selected for Level II/III will contribute to a study on the vulnerability of Douglas-fir at a regional scale.

# Bulgaria

## National Focal Centre

Genoveva Popova, Executive Environment Agency (ExEA)

## Main activities/developments

### Level I

In 2023, large-scale forest monitoring (Level I) was conducted in 160 permanent sample plots on 5598 sample trees. Evaluations were carried out on four coniferous species: *Pinus sylvestris*, *Pinus nigra*, *Picea abies* and *Abies alba,* and nine braodleaved species – *Fagus sylvatica*, *Fagus orientalis*, *Quercus cerris*, *Quercus frainetto*, *Quercus petraea*, *Quercus rubra*, *Carpinus betulus*, *Castanea sativa,* and *Tilia platyphyllos*. The total number of monitored conifer trees was 2429 (43.4%), while that of broadleaves was 3169 (56.6%).

Within the Level I forest monitoring, in 2023 the following activities were conducted:

- crown condition assessments in all 160 Level I sample plots (SPs);
- analysis of leaves/needles samples (foliar analysis) in 31 Level I SPs;
- collection and analysis of soil samples in 21 Level I SPs – the physical and physicochemical properties, chemical composition by genetic horizons and layers;
- survey of floristic composition and the phytocenotic structure of the shrub-grass synusia in the plant communities of different associations in 31 Level I SPs;
- estimation of growth and yield of stands in 21 Level I SPs – determination of diameter, height, and volume of stand.

### Level II

The following activities were conducted within the framework of the intense forest monitoring program:

- assessment of tree crowns and damage factors in 4 permanent Level II sample plots (SPs);
- collection and analysis of atmospheric deposition in all 4 Level II SPs;
- collection and analysis of soil solution in all 4 Level II SPs;
- collection and analysis of litterfall samples in 3 Level II SPs;
- monitoring of air quality indicators – all 4 SPs from Level II;
- monitoring of meteorological parameters in all 4 Level II SPs;
- evaluation of ozone injuries in 2 Level II SPs;
- phenological survey in the Vitinya core-plot (SP0001).

The Forest Monitoring Program in Bulgaria operates within the framework of the National System for Environmental Monitoring (http://eea.government.bg/bg/nsmos).

Monitoring activities are carried out in collaboration with the Forest Research Institute under the Bulgarian Academy of Sciences and the University of Forestry, Sofia.

## Major results/highlights

The results of the large-scale monitoring program conducted in relation to crown defoliation showed that in 2023 the monitored deciduous trees were in better condition than in 2022, with 78.5% in class 0 (not defoliated) and 1 (slightly defoliated). The percentage among coniferous trees was 53.3%. The results show the increasing number of healthy and slightly defoliated trees, with 3.9% and 0.8% respectively for deciduous and coniferous trees.

In the sample plots, among the biotic factors of impact, representatives of both contributing stressors (leaf pathogens and defoliant insects) and secondary stressors (xylophagous insects and facultative parasites) were found. The occurrence of unfavorable climatic conditions can cause mass damage and sudden calamities of insect pests and outbreaks of dangerous fungal pathogens.

The increased development of fungal pathogens on the roots and stems (*Armillaria mellea*, *Heterobasidion annosum*), branches (*Diplodia sapinea*), and needles (*Lecanosticta acicola*, *Dothistroma septosporum*, *Cyclaneusma minus*, *C. niveum*, etc.) contributes to the deteriorated condition of *Pinus sylvestris* and *P. nigra* stands. Prolonged periods of drought during the growing season contribute to a physiological weakening of the trees and make them more susceptible to insect attacks and pathogens. In some areas, a strong presence of the invasive oak lace bug (*Corythucha arcuata*) has been established. The presence of this invasive species has been a real threat to oak forests.

The observations in the sample plots for intensive monitoring (Level II) were focused on the influence of different stressors and the reaction of the ecosystem. The results of 2022 showed the following:

The main stress factor in the coniferous monitoring sample plots Yundola (SP0003) and complex background station (CBS) Rozhen (SP0005), in consecutive years, has been ozone again. The short-term target norm for vegetation protection was exceeded 1.6 times, while that for the forest protection 2.4 times. The calculated values of AOT40 for CBS Rozen in 2022 also increase, as the short-term target norm was exceeded 1.3 times, and that for forest protection is slightly exceeded with 10% compared to the previous year. During the entire 5-year period (2018-2022), the AOT40 indicator has values above the norm for forest protection, and on average for the period, it exceeds the norm 2.2 times. For the sample plots, on which deciduous tree species were observed, it was found that for SP Vitinia AOT40 in 2022 increased significantly compared to 2021. The long-term target norm for vegetation protection was exceeded 3.3 times, and the norm for forest protection 1.68 times. In 2022, the concentration of ozone in the area of the SP Staro Oriahovo decreased. Ozone exposure indices with accumulation above 40ppb (AOT40), which had increased in 2020, decreased significantly in 2022, and did not exceed the norms for both vegetation and forests.

The combination of dry weather conditions and high temperatures on different days in the summer months (July and August) continues to have an adverse effect on the condition of different tree species and is one of the main stressors.

## Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2


Belilov S, Mirchev P, Georgiev G, et al. (2023) Expansion of the pine processionary moth (*Thaumetopoea pityocampa*) in northern Bulgaria. Forest science 1, 71-85.

Georgieva M, Georgiev G, Mirchev P, et al. (2023) Health status of Norway spruce (*Picea abies*) and silver fir (*Abies alba*) in the Biosphere Reserve 'Parangalitsa'. In Proceeding of the 32nd International Conference of 'Ecology and management of forest resources', 29-30 June 2023, Sofia, 83-89.

Georgieva M, Georgiev G, Mirchev P, et al. (2023) Monitoring of the health status of *Castanea sativa* in the Belasitsa mountain, southwest Bulgaria. Silva Balcanica 24(3): 35-42. doi: 10.3897/silvabalcanica.24.e116036


## Outlook

The program for forest ecosystem monitoring (Level I and II) in Bulgaria is permanent and is operationalized as part of the National System for Environmental Monitoring.

Within the framework of the BG16FFPR002-3.003 Optimizing the infrastructure of networks (with monitoring sites) to implement forest ecosystem monitoring schemes in the country project, which starts in 2024, it is planned to build 6 new, permanent sample plots, equipped to implement the intensive forest monitoring schemes, and to re-equip the installations for collecting samples of atmospheric precipitation deposits, tree fall and lysimeter waters at the existing Level II sample plots. With the establishment of 6 new Level II sample plots, each of the regions into which the country is conditionally divided for the purposes of large-scale forest monitoring will have a sample plot for intensive forest monitoring.

# Croatia

## National Focal Centre

Nenad Potočić, Croatian Forest Research Institute

## Main activities/developments

The annual intercalibration course for crown condition assessment was successfully completed, and the annual crown condition survey was conducted on Level I plots. Level II activities were continued on all seven intensive monitoring plots, but in a restricted manner due to reduced financing: sampling of deposition and measurements by fixed girth bands were not performed on plot 106, and a low level of monitoring intensity was continued on plots 105 and 111.

## Major results/highlights

### Level I

Ninety-seven sample plots (2328 trees) on the 16 x 16 km grid network were included in the survey 2023, 1990 broadleaved and 338 coniferous trees.

The percentage of trees of all species within classes 2-4 remained at a high level with 33.3%, compared with 34.0% in 2022, 31.8% in 2021 and 30.1% in 2020. Broadleaves in 2023 had a lower percentage of trees within defoliation classes 2-4 (30.4%) than conifers (50.9%), respectively.

Most defoliated tree species in Croatia in 2023, based on the percentage of trees in classes 2-4, were *Pinus nigra* (85.9%), with worryingly high values in the last three assessments, and *Fraxinus angustifolia* (78.3%), with a significant increase from last year. The least defoliated species were *Fagus sylvatica* (16.1%) and *Quercus pubescens* (26.3%), both with lower values than last year.

The most widespread damage was damage to leaves (36.0%), followed by damage to the trunk (33.0%), and finally damage to branches, shoots and buds (31.0% of all recorded damage). Most of tree damage was caused by insects (21.7%), especially sucking insects (10.0%). Next were abiotic agents with 17.7%, and fungi with 11.7% of all damage. Direct human activity accounted for 6.3% of all damage to forest trees. Despite a high number of recorded damage symptoms, damage extent was mostly in category 1 (0-10%).

Unlike in 2022, when persistent low levels of rainfall in combination with high temperatures, led to widespread drought conditions, in 2023 high mean annual temperatures were joined by high to very high precipitation sums in most parts of Croatia, although the spring was cold and humid. These circumstances were reflected in the slow development of *Corythuca arcuata* populations, but also resulted in a higher damage by fungi in comparison with 2022.

On 19 July 2023, a strong windstorm with wind speeds over 200 kph hit the lowlands of Croatia, causing widespread damage to forest stands. In our data this is reflected by an approximate tenfold increase of wind damage to *Quercus robur*, and a roughly four times increased mortality rate of all species in comparison with average annual values.

### Level II

In 2023, the damage from *Corythuca arcuata* on plots 109 and 110, and the damage from *Rhynchaenus fagi* (plots 103 and 105) was rather low. Most of the damage was related to windstorm with several trees broken or uprooted.

Deposition of nitrogen and acid compounds recorded in 2022 10-13 kg N ha$^{-1}$ yr$^{-1}$, so not close to the limit values. Ground-level ozone concentrations in June and October were close to limit values, but leaf symptoms suggesting oxidative stress were not found.

## Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2

Potočić N, Seletković I, Jakovljević T, et al (2024) Oštećenost šumskih ekosustava Republike Hrvatske – izvješće za 2023. godinu [The damage status of forest ecosystems in Croatia – a report for 2023] Hrvatski šumarski institut/Croatian Forest Research Institute. Jastrebarsko, Croatia. https://www.icp.sumins.hr/Izvjesca/O%C5%A1te%C4%87enost_%C5%A1umskih_ekosustava_Republike_Hrvatske_u_2023._godini.pdf

## Outlook

Croatia will continue forest monitoring in the same intensity as in 2023, also keeping its active role in the work of the ICP Forests.

# Cyprus

## National Focal Centre

Soteres Soteriou, Konstantinos Rovanias
Silviculture, Management and Publicity Sector – Research Section

## Main activities/developments

### General information

Cyprus has been participating in the ICP Forests program since 2001. The systematic network of 19 permanent plots, which had been established in Cyprus State forests aims at the collection of the necessary data relevant to:

- visual assessment of the forest crown condition,
- sampling and analysis of forest soil,
- sampling and analysis of forest soil solution,
- sampling and analysis of needles and leaves of forest trees,
- estimation of growth and yield of forest stands,
- sampling and chemical analysis of deposition (precipitation, snow, hail),
- meteorological observations,
- assessment of forest ground vegetation,
- monitoring of air quality and assessment of ozone injury on forests.

These plots are divided into two categories according to the type of observations to be done and data to be collected:

- Systematic large-scale monitoring plots
  Fifteen plots, covering an area of 0.1 ha each, have been established for monitoring Calabrian pine (*Pinus brutia*), black pine (*Pinus nigra*), and Cyprus cedar (*Cedrus brevifolia*) ecosystems. In these plots, annual observations of crown condition and periodic sampling and analysis of soil and needles are carried out.
- Intensive monitoring plots
  Four plots, covering an area of 1 ha each, have been established for monitoring Calabrian pine (*Pinus brutia*) and black pine (*Pinus nigra*) ecosystems. In two of these plots, all research activities mentioned above are carried out. These plots are equipped with appropriate instruments and equipment for the collection of samples, data, and information. The other two plots are partially equipped and only some research activities are carried out.

### Cooperation and submission of data and results

There is a close cooperation of the Cyprus Department of Forests and the ICP Forests Programme Co-ordinating Centre (PCC) in Eberswalde. There is also co-operation with Expert Panels, which are responsible for the scientific work of the program.

For the implementation of the program, collaboration has been developed among the Department of Forests and other governmental departments such as the Department of Agriculture, Department of Labor Inspection, and the Department of Meteorology. The chemical analysis of water and soil solution had been undertaken by the Department of Agriculture, while we are at close conduct with the Cyprus Agricultural Research Institute for any future supplementary chemical analysis. Furthermore, there is exchange of information between the National Focal Centre and the Department of Labor Inspection, which runs the program "Network on Assessing Atmospheric Air Quality in Cyprus". The Meteorological Service contributes to the program with technical support and maintenance of the Automatic Weather Stations.

Processing and submission of the relevant data is the responsibility of the Cyprus Department of Forests.

## Major results/highlights

Using ICP Forests findings, along with the expertise and long experience of the scientific personnel of the department, the Department of Forests adopts and applies mostly repeated actions, which are designed to adapt forest stands (natural and artificial) to face climate change. The objective of these actions is to reduce emissions and increase the absorption of greenhouse gases. These actions can be grouped into three main areas as listed in the Statement of Forest Policy:

- protecting forests against forest fires,
- adaptation of forests to climate change and enhancing the contribution of forests in addressing climate change and improvement of main forests and forested areas,
- improvement and expansion of forests.

Such measures are:

- protection of forests from illegal logging: with the implementation of Law 139 (I) / 2013 is controlled most the available firewood locally and criminal penalties for any illegal or uncontrolled logging and/or disposal of the local timber market without authorization,
- reforestation of Amiantos asbestos Mine as well as restoration of abandoned mines in co-operation with the competent authorities (Department of Geological Survey and the Mines Service), and
- protection of forests and enhancement of their structure and resistance to climate change through the Rural Development Program 2014–2020.

In particular, in the Rural Development Program, a number of activities and actions have been integrated under Measure 8 (Investments in forest area development and improvement of the viability of forests). The Action 8.5.3 includes thinning operations in thick stands created by afforestation/reforestation, with the purpose of:

- improving the structure of forests created by afforestation or/and reforestation operations. Furthermore, they will help in the adaptation of forest stands to climate change as well as contribute to the adaptation of forest stands to climate change, the reduction of emissions and increase the absorption of greenhouse gases.
- The implementation of targeted thinning is expected to improve stability and resilience to other disturbances, such as drought, increase in average temperatures and prolonged heat waves (as a result of climate change).

### Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2

No non-peer reviewed publications/reports have been published.

### Outlook

- The Cyprus Department of Forests will continue to participate in the ICP Forests program under the current regime.
- Although not falling under the ICP Forests targets, the Cyprus Department of Forests is running a number of research projects such as on biomass production and an investigation of different techniques in order to reduce the irrigation rate in new plantations during the summer period.

## Czechia

### National Focal Centre

Vít Šrámek, Forestry and Game Management Research Institute (FGMRI)

### Main activities/developments

Regular assessment of Level I plots of the transnational grid continued on 117 plots in 2023. The assessment of defoliation and other parameters associated with crown condition was done on 4 033 trees in total. The number of assessed plots was the same as in 2022, which can be considered as a sign of receding bark-beetle outbreak that had destroyed a significant number of monitoring sites during 2018-2022.

In total, 15 Level II monitoring plots were assessed in 2023. New dataloggers as well as the independent air humidity, air temperature and global radiation sensors were installed on seven Level II core plots.

The ICP Forests network and data were used in several national research projects that are worked on in co-operation with other institutions: Czech University of Life Sciences Prague, Mendel University Brno, Institute of Botany of the Czech Academy of Sciences, Institue of Forest Ecosystem Research. On selected plots of Level I and Level II, a continuous monitoring of stem size variation using point dendrometers was performed along with parallel measurements of microclimate parameters (air humidity and temperature, soil moisture and temperature). The fate of soil organic carbon was studied on ICP Forests plots that had to be harvested – often as a part of large clearcuts – as a result of bark beetle infestation. Also for studies on forest management influence on soil carbon stocks the ICP Forests soil data were used.

### Major results/highlights

The weather course during the growing season was generally favorable compared to previous years, although the year 2023 was the hottest in the history of meteorological records. April and May were the only months, when the average temperature was the same or lower than the value of long-term normal (1991-2020). This, with the relatively abundant rainfall from January to April (119% of the long-term normal) led to a convenient condition for forest vegetation at the beginning of the growing season. The drought period that started in some regions during the end of June or middle July was terminated by heavy rainfall in August. Another drought season appeared during the second half of an abnormally hot September and in October (3.5°C and 2.9°C warmer than the long-term normal, respectively) but without a pronounced effect on vegetation.

A moderate decrease in the percentage of strong defoliation (>60–100%) in most tree categories can be attributed to favorable weather conditions. In conifers of both age categories (up to 59 years and older than 59 years), there was no significant change in the percentage representation of defoliation classes compared to the previous year. Among coniferous species, a slight improvement was observed only in older Scots pine (*Pinus sylvestris*) stands due to a decrease in the percentage of defoliation in class 3 from 13.5% in 2022 to 11.4% in 2023, while the percentage of defoliation in class 2 has increased accordingly.

In broadleaves no substantial changes occurred in comparison with the last year. European beech (*Fagus sylvatica*) represents the healthiest species with the highest representation in the defoliation classes 0 and 1 (0–25%) throughout the entire monitoring period. For oak (*Quercus* sp.) the situation worsened slightly as the representation of defoliation class 2 increased from 63.5% in 2022 to 66.1% in 2023 with a concomitant decrease in the classes 0 and 1. Defoliation class 2 is the most represented in oak stands in the long term.

Besides the health status assessment, monitoring of deposition, soil solution, litterfall, and tree phenology continued on seven core plots of Level II in 2003 as well as the continuous measurement of soil parameters (soil temperature, soil moisture and soil water potential) and stem radial growth with girth bands and electronic circumference dendrometers.

Long-term tredns in the chemistry of soil solution were evaluated for Level II plots where gravitational soil water is sampled under the humus layer and at the depth of 30 cm of mineral soil. Especially at the formerly strongly acidified sites a moderate increase of pH is observed, the decrease of sulphate ($S\text{-}SO_4^{2-}$) concentration is even more common. A decrease of total nitrogen in soil solution was detected only on plot 2251 "Luisino údolí" with the historically highest deposition of this element. The increasing concentration of aluminium is proven for plot 2103 "Všeteč". The Ca/Al ratio in mineral soil is dropping under a value of 1.0 in some years which constitutes a potential risk for soil biota and fine roots in this European beech stand. Such a low value of Ca/Al is, however, also observed on highland Norway spruce Level II plots. On plot 2116 "Želivka", part of the forest was felled down in 2023 due to a bark beetle outbreak, which can significantly affect the measurement of the soil solution - by both, problems with sampling (flooded sampling pits) and leaching from the forest floor.

## Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2


Please refer to our national reporting on forest condition (in Czech and English) which includes ICP Forests data on https://www.vulhm.cz/en/monitoring-of-forest-state/icp-forests-2/download/

Fabiánek P (2023) Monitoring zdravotního stavu lesa (Forest health condition monitoring). In: Knížek M, Liška J, editors (2023) Výskyt lesních škodlivých činitelů v roce 2022 a jejich očekávaný stav v roce 2023. Zpravodaj ochrany lesa. Supplementum 2023:65-69. Výzkumný ústav lesního hospodářství a myslivosti, Jíloviště.


## Outlook

In 2024, a joint expert workshop with Slovak colleagues from the NFC ICP Forests will be held on May 22–24. The workshop will be focused on the long-term ecosystem monitoring within the framework of the ICP Forests program and comparison of results and achievements between the two countries.

The 11th Forest Ecosystem Monitoring Conference FORECOMON (2024) will take place in Prague on June 11–12. This conference will be hosted by the Forestry and Game Management Research Institute (FGMRI). The title of the conference is *Monitoring for future forests*. The FORECOMON 2024 will be followed by the 40th Task Force Meeting of ICP Forests, taking place on 13–14 June.

Dendrometric measurements are planned on all Level I plots for the years 2024 and 2025, which is in line with the 5-year periodic dendrometric survey on intensive monitoring plots. On Level II plots that are threatened or already felled down due to a bark beetle outbreak, the monitoring of carbon and nutrient cycles should be continuously followed. Soil sampling is envisaged on all Level II plots for the period 2025–2026.

# Denmark

## National Focal Centre

Morten Ingerslev, Department of Geosciences and Natural Resource Management, University of Copenhagen

## Main activities/developments

Forest monitoring (Level II, Level I and NFI plots). However, forest health data from the NFI plots, although collected, is not available, due to administrative changes highlighted in the following section.

## Major results/highlights

At the end of the year 2023, the Ministry of Environment decided not to renew the contract for the National Forest Inventory (NFI) for Denmark. Consequently, data from the NFI field work is no longer available for inclusion in the evaluaton of forest health in Denmark, reducing the number of crown condition trees by 80%. Based on the remaining Level I and Level II plots, it is only possible to comment on the health status of beech (*Fagus sylvatica*), oak (*Quercus robur*), and Norway spruce (*Picea abies*).

For oak and Norway spruce, the average defoliation on these plots increased in 2023 to 31% and 22%, respectively, and beech stayed at a high defoliation (25%). The high defoliation in beech and oak was a trend, which had started already in 2022, reversing the improvement of forest health after the drought of 2018. For Norway spruce, defoliation had previously decreased every year since 2019, which was the last year of the green spruce aphid (*Elatobium abietinum*) infestation causing defoliation in Sitka spruce and Norway spruce. In 2023, the very dry months of May and June changed into a wet July and August, with July 2023 having the highest precipitation recorded in Denmark for this month since 1874. These weather extremes may have had an impact on the general forest health for a number of tree species, together with heavy mast in oak.

It should be noted that the observed defoliation in 2023 is based on a much smaller dataset, which may not be representative of Danish forest health conditions owing to the absence of data from statistically representative sample plots previously provided by the NFI. Hence, observed trends may be the result of a loss of continuity in the collection of forest data rather than actual developments in forest health, although the trends in defoliation for the previous five years (2017–2022) are the same for beech, oak and Norway spruce with or without NFI data.

## Outlook

### Future developments of the ICP Forests infrastructure

The number of Level I plots may be increased in 2024 to compensate for the loss of NFI data. However, this depends on the financial situation of the Danish forest monitoring, which so far is uncertain.

# Estonia

## National Focal Centre

Vladislav Apuhtin, Estonian Environment Agency

## Main activities/developments

The health status of 2641 trees was assessed at the observation points of the Level I forest monitoring network and on the sample plots of the intensive forest monitoring (Level II). Out of the assessed trees, 1588 trees were Scots pine (*Pinus sylvestris*), 787 Norway spruce (*Picea abies*), and 266 deciduous species, mainly silver birch (*Betula pendula*).

On Level II plots the following forest monitoring activities were carried out in 2023:

- chemical analyses of the deposition water collected throughout the year on 6 sample plots;
- chemical analyses of soil solution collected during 7 months (from April to October) on 5 sample plots;
- samples of litterfall were collected on one plot according to ICP Forests requirements;
- foliar samples were collected on 6 sample plots in December 2023;
- soil samples were collected on 27 Level I plots.

## Major results/highlights

### Level I

The total share of not defoliated trees, 42.8%, was 5%p lower than in 2022. The share of not defoliated conifers, 42.0%, was lower than the share of not defoliated broadleaves, 48.9%, in 2023.

The share of trees in classes 2 to 4, moderately defoliated to dead, was 10.2% in 2023 and 8.6% in 2023. The share of conifers and broadleaves in defoliation classes 2 to 4 were 10.1% and 10.5%, accordingly.

According to the observation data the condition of Scots pine has decreased compared to 2022. The share of not defoliated pines (defoliation class 0) was 43.3% in 2023, 5.7%p lower than in 2022. The share of pines in classes 2 to 4, moderately defoliated to dead, did not significantly change compared to 2022. The share of spruces without crown damage was only 38% (38.3% in 2022) and the share of trees with defoliation rate 10–25% was 44.1% (46.1% in 2022). A long term increase of defoliation of Norway spruce may be observed. Compared to 2022, the share of healthy birches has decreased by 13.5%p in 2023.

All trees included in the crown condition assessment on Level I plots are also regularly assessed for damage. In 2023, 5.8% of the living trees observed had some insect damage (mainly defoliators) and 14.3% of them (mainly Scots pines) had symptoms of fungal disease. Only 34% of the trees had no identifiable symptoms of any damage.

Visible damage symptoms recorded on Scots pine were mainly attributed to pine shoot blight (pathogen *Gremmeniella abietina*). Symptoms of shoot blight were recorded on 14.9% of the observed pine trees in 2023, compared to 11.1% in 2022. Norway spruces mostly suffered due to bark beetle (*Ips typographus*) attacks, old moose damage, and root rot (pathogen *Heterobasidion parviporum*). Broadleaves, especially silver birch, suffered due to defoliators (*Operophtera* spp).

### Level II

The annual average pH of the precipitation under throughfall was varying mainly between 5.5 and 6.5. In 2023, observations showed some slight decrease of pH compared to 2022 on all plots where bulk deposition was collected; no changes were detected on thoughfall plots. The content of chemical elements and compounds in analyzed precipitation water was low. Compared to several past years, the content of ammonium and sodium ions increased in bulk deposition on the plots in the northern part of Estonia. Generally, in 2023 the precipitation was unevenly distributed in Estonia.

Long-term studies (25 years) show that the content of sulphate ions in the soil water has decreased on all sample plots. The content (concentration) of calcium, magnesium, and potassium ions has slightly decreased in the soil water on sample plots in the north of Estonia.

### Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2


Apuhtin V, Timmusk T, Ejrpais M (2024) Forest Monitoring, Report of the survey 2023, Estonian Environment Agency, Tartu

Yearbook Forest 2022, Estonian Environment Agency


### Outlook

The forest monitoring activities in Estonia will continue for both levels (Level I and Level II) in 2024.

## Finland

### National Focal Centre

Päivi Merilä, Natural Resources Institute Finland

### Main activities/developments

In 2023, altogether eight Level II plots were monitored for atmospheric deposition, soil solution chemistry, and meteorology. As two of the plots are in sapling stands, monitoring activities on the six plots representing mature forests also included litterfall, foliar chemistry, and crown condition surveys. In addition, tree increment was monitored using girth bands by manual recordings. The monitoring data of the year 2021 was submitted to the ICP Forests data base.

### Major results/highlights

Merilä et al. (2023) reported carbon stocks (CS) and transfers on 15 Finnish Level II plots (seven Scots pine and eight Norway spruce forests) located along a 1000 km latitude (60-69 °N). Total site CSs ranged between 81–260 Mg ha$^{-1}$. The largest ecosystem component CSs were tree stems, mineral soil, and humus layer, representing 30 ± 2%, 28 ± 2%, and 13 ± 1% of total CS, respectively. The northern sites had an average of 58% less C than the southern sites. Humus layer CS was the only compartment showing no latitudinal trends. Northern sites had a significantly larger fine and small root CS and understory CS than southern sites. Most CS compartments were significantly correlated with litterfall C transfer components. Dissolved organic carbon (DOC) flux in throughfall was positively correlated with the aboveground tree compartment CS. In conclusion, the study showed patterns of C distribution in major boreal forest ecosystems along latitudinal and fertility gradients, which may serve as a reference for Earth system models and in the evaluation of their projections.

Salemaa et al. (2023) investigated how the proportion of broadleaved trees of total basal area, tree species richness, stand density, and shrub cover were reflected in the number of vascular plant species and percentage cover of herbs and bilberry (*Vaccinium myrtillus*). The response of site fertility indicators, i.e., C:N ratio and extractable calcium concentration in the soil organic layer, to broadleaved species in mixed forests was also studied. The study was based on the data on understory vegetation, soil, and stand properties in forests on mineral soil, inventoried on the Level I sample plot network (study sites n = 307) in Finland in 2006. Birches (*Betula* sp.) were the main broadleaved species. Vascular species richness and herb cover generally increased with increasing proportions of broadleaved trees and tree species number both on mesic and xeric sites but decreased with increasing stand density on mesic sites. An increase in the proportion of broadleaved trees and stand density resulted in decreased bilberry cover in the southern boreal zone, probably due to stand shading, but in increased cover in the middle boreal zone. As an increase in the proportion of broadleaved trees correlated positively with calcium and negatively with C:N of the organic layer, the authors suggest that nutrient input from easily decomposable birch leaf litter promotes species richness and herb cover via improved nutrient availability in the soil. Generally, slight increase in broadleaved trees benefitted the understory plant richness, given that stand density is not too high.

### Outlook

Level II monitoring activities continue on Level II plots in Finland. Finnish Level II plots are planned to become included in the eLTER network and three of them also belong to the ICP Integrated Monitoring Programme. The data from these three plots are also used to fulfill the information needs of the national emission ceiling directive (NECD).

In late summer 2023, a pilot instrumentation for in situ measurements of soil solution quality was installed on the spruce plot in Tammela (Level II plot nr. 12). The functioning of the equipment remains to be tested during the next growing season.

## France

### National Focal Centre

Level I: Fabien Caroulle, Forest Health Department
Level II: Manuel Nicolas, Office National des Forêts (ONF)

## Main activities/developments

### Level I

In France, the ICP Forests Level I network is used in spring to assess foliar damage resulting from defoliators.

At regional scale, the ICP Forests Manual is used on networks specially designed to follow the evolution of forest health, in a context of global warming.

At last, the ICP Forests protocol is also used in the southern part of France in autumn to follow the health of evergreen oak stands.

### Level II

As the French Level II monitoring network (RENECOFOR) has reached its initially defined 30-yr horizon, an agreement was found to prolong its long-term activities and to further develop them, with funding from the Ministry of Ecological Transition and the Ministry of Agriculture and Food.

The monitoring activities already in place are continued with the same objectives and surveys. Specifically in 2023, tree assessments (phenology, health, annual growth, and foliar nutrition) were carried out on all 102 plots of the Level II network, while atmospheric deposition, meteo, soil solution, litterfall, and ozone (concentrations in the air and symptoms visible on the vegetation) surveys were continued on the same subset of plots.

In addition, new efforts have been made to consolidate and further develop the network. First, the plot network design must be adapted to run for potentially 100 years or more, which supposes to cope with natural disturbances and final cuttings in an increasing number of stands. And one important thing for this purpose is to keep the memory of the precise location of all the measurements carried out so far, to be able to reuse the same exact location in the future, even after severe damage or plot replacement. In 2023, the recruitment of two field teams – one at the ONF and the other at the University of Louvain – made it possible to significantly accelerate the campaign for georeferencing all trees and monitoring devices within the plots. While 32 plots could be mapped between 2021 and 2022, 61 more were mapped in 2023, and the last 9 will be mapped by June 2024.

In 2023 again, additional measurements were also needed in plots under the threat of severe disturbances. Final assessments could be quickly made on trees before the harvest of one spruce plot newly attacked by bark beetles, in the Ardennes. An extra periodic growth assessment was carried out, and the sample trees – that used to be surveyed every year for their crown condition and phenology – were cored to retrospectively measure their annual growth and sampled for genetic characterization.

## Major results/highlights

### Level I

Our ICP Forests plots are helpful to follow the main trends in forest health in France; and thus are very useful to fulfill the requirements of sustainable management indicators. Throughout their evolution, we can assess long-term and large-scale trends in forest health such as:

- the impact of droughts on forests (conifer and broadleaf forests);
- the impact of invasive species such as *Hymenoscyphus fraxineus* on ash trees;
- the mortality rate by plot.

### Level II

The mapping of Level II plots opens up new possibilities for the use of existing monitoring data, e.g., to take into account the effect of competition in the evaluation of tree responses to environmental changes, or to validate remote-sensing products. As an example, a first study was already published about the estimation of the above-ground biomass based on multi-stream remote-sensing data and its comparison against biomass calculated from measurements carried out in the RENECOFOR plots (Schwartz et al. 2023).

## Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2

Clesse M (2023) Multi-site study of the response of the chemical fertility of forest ecosystems in a context of change (atmospheric deposition and tree species substitution). PhD thesis, Université de Lorraine, Nancy, 295 p

## Outlook

### Level I

Since 2021, we asses trees on the Level I network according to a new method that several forest health experts established. It is named “DEPERIS”, and it consists of two measures assessed in the tree crown:

- branch mortality rate
- lack of little shoots (broadleaved) or needles (conifers).

We then determine a grade, which is a combination of those two measures and quickly indicates the level of vitality of the tree.

We hope that this method will provide us with more consistent information about tree decline in the future.

### Level II

Efforts are to be further intensified in 2024 to extend the monitoring of forest ecosystems in the long term, and to further develop the RENECOFOR network.

- As regard to the continuation of the monitoring activities already in place, it is planned to repeat the periodic growth and ground vegetation surveys in 2024–2025 (like every 5 years), as well as to launch the 3rd soil sampling campaign for a probable duration of 4 to 5 years to cover all the 102 plots.

- Studies must be continued to support the choices to be made for the evolution of the network of plots, and to update the sampling strategy of the French forests by the network. For each plot that requires to be replaced after having been harvested or heavily disturbed, the aim is to support the choice of a new location suited to maintain or increase the range of ecological contexts covered nationally by the network for a given main tree species. In view of a potential extension of the network to the Mediterranean forests (that was not initially represented), another aim is to propose a sampling strategy for the creation of new plots to cover the range of distribution of one or two Mediterranean tree species in French forests.
- Other options for the further development of the monitoring activities should be explored, e.g., for the equipment of the most intensively monitored plots (already equipped for atmospheric deposition, meteo, and soil solution) with soil humidity sensors and electronic dendrometers.
- Improved access to data is also planned through work on the publication of thematic datasets in the form of data papers and on a Dataverse webportal.

## Germany

### National Focal Centre

Juliane Henry, Federal Ministry of Food and Agriculture

### Main activities/developments

#### Level I

The national training course for the forest condition survey in Germany took place 20–23 June 2024 in Gotha, Germany. The course was organized by the Thünen Institute of Forest Ecosystems in co-operation with Thüringen Forst.

In 2023, a pilot study on testing an online Photo ICC started with different countries co-ordinated by the Thünen Institute. The aim is to test how well an online Photo ICC could be conducted in contrast to the existing Photo ICC with pictures.

#### Level II

Monitoring activities continued on 68 Level II plots. Disturbances due to drought, storm, and insect infestation affect an increasing number of plots, limiting the operability on some. Work on a common strategy for the next decades of intensive forest monitoring at Level II plots continued. At a workshop held in Freising, 19 participants agreed on a framework extending the current network design. Its implementation will modernize the Level II network and specifically aims at informing decision makers in forestry.

In September, the annual meeting of the technical staff took place in Göttingen with a field trip to "Lange Bramke", a heavily disturbed Level II plot. The meeting, which attracted 31 participants, served as an exchange platform for technical challenges and included the presentation of measurement equipment and handling by manufacturers and users.

Acoustic recordings have started on nine Level II plots to explore the potential of (bio-) acoustic quantification of biodiversity. The work is part of a pilot study, the AkWamo project, and aims at evaluating the use of soundscapes as an indicator for critical changes of forest condition, especially the diversity of bird species. It includes the development of an IT infrastructure required for routine acustic measurements within a monitoring network.

### Major results/highlights

#### Level I

Since the surveys began in 1984, the proportions of damage classes 2 to 4 and the mean defoliation of all tree species have increased. The most significant changes were observed in 2019. Overall, the damage remains at a very high level and, depending on the tree species, has not changed at all or only very slightly compared to the previous year. There was no significant improvement in the condition of the forest, but there was also no significant deterioration compared to 2022.

In the case of spruce, the proportion of significant defoliation increased from 40% to 43%. The warning level accounted for 40% (cf. 2022: 36%). Without crown thinning it was 17% (cf. 2022: 24%). The mean defoliation fell slightly from 29.6% to 28.6%. Compared to other tree species, spruce has the highest mortality rate. Fructification is significantly lower compared to 2022.

Compared to the previous year, the proportion of significant crown thinning in pine fell from 28% to 24%. The warning level accounted for 53% in 2023 (cf. 2022: 59%). The proportion without thinning increased from 13% to 23%. The average crown thinning fell from 23.9% to 22.3% in 2023. The fruiting of pine trees increased slightly compared to 2022. Thus, 50% of all trees fruited, of which around 29% was medium and 4% heavily fruiting.

In case of beech, the proportion of significant defoliation increased by one percentage point to 46%. The warning level accounted for 39% (cf. 2022: 34%). The proportion without thinning worsened to 15% (cf. 2022: 21%). The mean defoliation deteriorated slightly to 28.5%. The results show that 31% of the beech trees have fruited. This was a higher proportion than in the previous year.

In the case of oak, the proportion of clear defoliation increased from 40% to 44%. In contrast, the proportion of the warning class fell slightly from 41% to 39%. The proportion without thinning also fell slightly from 19% to 17%. The average defoliation increased slightly from 26.1% to 27.6%, which is statistically not significant The fruiting of oak trees has decreased significantly compared to 2022.

All figures and data of the crown condition report are published are published at: https://blumwald.thuenen.de/wze/aktuelle-ergebnisse-der-wze#c15802

In 2023, the mortality rate and causes have been calculated in addition to existing indicators.

#### Level II

Unoccupied aerial vehicles (UAV) offer the possibility to enhance ground observations and measurements at intensive monitoring plots. In pilot studies in a beech stand at the Britz Research Station, the merits of UAV-based assessments have been shown for the measurements of tree heights as well as for the identification of phenological stages at the stand level. Krause & Sanders (2023) further investigate possibilities offered by precise thermal imagery at the individual tree level. The study shows that close-range single-shot thermal imaging in conjunction with synchronous meteorological data. This can provide information for a range of applications including the quantification of drought stress.

Soil and forest stand parameters collected at Level II plots in Middle Germany were used to make reliable estimates of the main factors of the water balance and to validate and evaluate simulated water balance model results. The study by Thi et al. (2023) further allowed the development of drought indicators. As part of the project, a web-based information platform was developed that provides high resolution data on soil moisture for the federal state Saxony ('Soil Moisture Traffic Light').

To assess the accuracy of potassium estimation in forest dry deposition, a simulation experiment was carried out in rural Germany by Schmitz et al. In canopy budget models (CBM), the ratio of base cation to $Na^{+}$ is assumed to be similar in wet and dry deposition. The assumption was tested based on air quality measurements from a rural background station in Melpitz. While the ratio varied substantially between years, using different correction factors in CBM calculations at nearby ICP Forests sites had little effect on calculated deposition rates.

### Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2

Schmitz A (2023) Underestimation of potassium in forest dry deposition? A simulation experiment in rural Germany. EGU General Assembly Conference Abstracts.

### Outlook

To assess water availability as well as the risk of drought stress in forests, a high-resolution water balance model is currently developed as part of the TroWaK project using data from Level II plots for parametrization and validation. In addition to currently available parameters, additional output variables will allow the assessment of risks due to abiotic and biotic damages suffered due to droughts at the scale of Germany.

## Greece

### National Focal Centre

Panagiotis Michopoulos, Athanassios Bourletsikas, Kostas Kaoukis – Hellenic Agricultural Organization DIMITRA, Institute of Mediterranean Forest Ecosystems (www.fria.gr)

### Main activities/developments and major results/highlights

#### Level I

#### Crown condition assessment

In Greece, the crown condition assessment for the year 2023 was carried out on 27 Level I plots, which corresponds to the 27% of the total installed plots. The number of assessed broadleaves was 388 and of conifers 241, with 629 trees in total.

In the year 2023, it was found that 77.1% of the trees assessed belonged to the classes "No defoliation" and "Slight defoliation" indicating a decline for the forest ecosystems compared with 2022. The corresponding values were 67.6% and 83.0% for conifers and broadleaves, respectively. However, the common sample of assessed trees between the last two years (2022 and 2023) was rather small to lead us to safe conclusions regarding the decline of the observed phytosanitary status of the ecosystems. Abiotic factors were the main causes for the loss of needles and leaves, followed by insect attacks.

Table 1 shows the results of the crown condition assessment survey for all tree species.

Crown condition assessment (Level I plots) (in %)

| | All tree species | Conifer species | Broadleaved species |
|---|---|---|---|
| **No defoliation** | 38.6 | 23.2 | 48.2 |
| **Slight defoliation** | 38.5 | 44.4 | 34.8 |
| **Moderate defoliation** | 12.4 | 23.7 | 5.4 |
| **Severe defoliation** | 3.5 | 6.6 | 1.5 |
| **Dead trees** | 7.0 | 2.1 | 10.1 |

#### Level II

In Greece, there are four Level II plots. Plot 1 is dominated by evergreen broadleaved vegetation (maquis, with mainly *Quercus ilex*), plot 2 by Hungarian oak (*Quercus frainetto*), plot 3 by beech (*Fagus sylvatica*) and plot 4 by Bulgarian fir (*Abies borisii-regis*). Plots 2 and 3 are located close to each other as they are situated on the same mountain. Full scale activities take place in plots 1, 2 and 4.

Precipitation and temperature in the four plots have been measured for 51 years in the maquis, 27 years in the oak and beech, and 51 years in the fir plot. Annual precipitation in 2022 in the maquis and fir plots decreased by 14% and 20% respectively, while in the oak and beech plots it increased by 4.4% (see the following table).

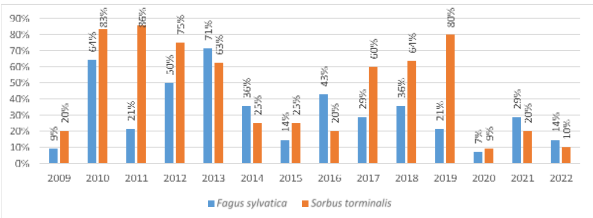
**Precipitation and temperature values in the Level II plots in 2022**

| | Maquis plot | | Oak and beech plots | | Fir plot | |
|---|---|---|---|---|---|---|
| | Precip. [mm] | Temp. [°C] | Precip. [mm] | Temp. [°C] | Precip. [mm] | Temp. [°C] |
| **2022** | 916 | 15.8 | 1329 | 13.5 | 1158 | 10.9 |
| **Mean** | 1063 | 15.4 | 1273 | 12.7 | 1451 | 10.2 |

It is important to note, that the highest monthly precipitation (240 mm) of the last 51 years was recorded in June in the maquis plot.

### Ozone Injury

With regard to the symptoms of ozone injury we had the following results: In the broadleaves and fir plots, no injury was observed, whereas in the beech plot signs of ozone injury in *Fagus sylvatica* and *Sorbus torminalis* were detected (s. figure below).




**Percentage of damage in leaves of *Fagus sylvatica* and *Sorbus torminalis* in time since 2009**

### Crown condition assessment (Level II)

On the four Level II plots, crown condition was assessed in 2023 on a total of 163 trees (35 conifers and 128 broadleaves). A significant increase in defoliation compared to 2022 was recorded in all assessed trees. The increased percentage of dead broadleaves is due to the felling of 3 beech trees for management reasons. Modelling of the water availability for vegetation may improve our ability to explain spatio-temporal defoliation patterns along with other phenological stages.

**Crown conditition assessment (Level II plots) (in %)**

| Species | Year | No defoliation | Slight defoliation | Moderate defoliation | Severe defoliation | Dead trees |
|---|---|---|---|---|---|---|
| **Conifers** | **2014** | 47.1 | 20.6 | 23.5 | 2.9 | 5.9 |
| | **2015** | 38.2 | 23.5 | 32.4 | 2.9 | 2.9 |
| | **2016** | 29.4 | 47.1 | 17.6 | 5.9 | 0.0 |
| | **2017** | 31.4 | 54.3 | 8.6 | 5.7 | 0.0 |
| | **2018** | 40.0 | 34.3 | 22.9 | 2.7 | 0.0 |
| | **2019** | 48.6 | 40.0 | 8.6 | 0.0 | 2.9 |
| | **2020** | 42.9 | 37.1 | 20.0 | 0.0 | 0.0 |
| | **2021** | 28.6 | 45.7 | 25.7 | 0.0 | 0.0 |
| | **2022** | 20.0 | 65.7 | 14.3 | 0.0 | 0.0 |
| **Broadleaves** | **2014** | 48.5 | 41.2 | 7.4 | 2.2 | 0.7 |
| | **2015** | 47.1 | 35.3 | 10.3 | 4.4 | 2.9 |
| | **2016** | 43.2 | 41.7 | 9.8 | 5.3 | 0.0 |
| | **2017** | 49.6 | 33.8 | 10.5 | 5.3 | 0.8 |
| | **2018** | 51.5 | 33.3 | 9.8 | 1.5 | 3.8 |
| | **2019** | 39.2 | 26.2 | 29.2 | 3.9 | 1.5 |
| | **2020** | 54.3 | 31.8 | 11.6 | 1.6 | 0.8 |
| | **2021** | 49.2 | 43.0 | 7.0 | 0.8 | 0.0 |
| | **2022** | 19.4 | 55.8 | 20.2 | 0.8 | 3.9 |

### Deposition

The following table shows the deposition fluxes (bulk and throughfall) of the major ions in the maquis, oak, and fir plots in 2022. The nutrient fluxes were not as high as in 2021 because of the lower water fluxes in 2022. It can be seen that there was retention of ammonium-N by the tree canopies in the fir plot (throughfall < bulk fluxes), whereas the nitrate-N retention took place in the maquis plot. This finding shows the efficiency of forests to absorb N from any source. The fluxes of nitrates were far higher than those of ammonium in all plots indicating dry deposition. The very high flux of Ca in the fir plot should also be attributed to the dry deposition of Ca derived from Saharan dust by means of winds. The sulphate-S fluxes were higher in the throughfall in all plots. According to the literature, the sulphate-S is mostly deposited in dry form, whereas the Mg and K deposition is connected with the process of ion leaching from inside the plant cells. The fluxes of sulphate-S in the maquis plot were low in comparison with the other two plots. The dry deposition of sulphate-S in the oak and fir plots may have been derived from fossil fuel combustion for heating purposes.

**Fluxes (kg ha$^{-1}$ yr$^{-1}$) of major ions in deposition (throughfall (T) and bulk (B)) in three forested plots in Greece in 2022**

| Plots | Dep. | Ca | Mg | K | $SO_4^{2-}$-S | $NH_4^+$-N | $NO_3^-$-N | mm |
|---|---|---|---|---|---|---|---|---|
| **Maquis** | T | 11.2 | 3.74 | 47.4 | 5.43 | 1.51 | 2.15 | 779 |
| | B | 8.50 | 1.78 | 3.62 | 4.43 | 0.68 | 2.21 | 990 |
| **Oak** | T | 19.9 | 9.60 | 66.7 | 12.1 | 0.511 | 3.94 | 1221 |
| | B | 9.3 | 2.97 | 10.2 | 7.96 | 0.508 | 3.87 | 1543 |
| **Fir** | T | 31.5 | 8.57 | 32.4 | 11.2 | 0.53 | 7.52 | 971 |
| | B | 10.5 | 2.30 | 11.5 | 7.59 | 6.54 | 4.33 | 1279 |

### Litterfall

The following table shows the total masses and fluxes of some nutrients in the foliar and the non-foliar fractions of three plots. It can be observed that the oak plot had the highest values. It is interesting that Mn had by far the highest fluxes in the oak plot. This is due to the nature of the parent material (mica schist) of the plot. This kind of parent material gives rise to acid soils in which Mn is in abundance.

The non-foliar litter had high amounts of Ca and K. This is an important fact, especially for forests situated in acid soils because the depletion of base cations is a frequent event. It is recommended to leave the remnants of loggings in these kind of soils in the forest so that the stock of base cations can be preserved in the future,

**Total masses (TM, mg ha$^{-1}$ yr$^{-1}$) and fluxes (kg ha$^{-1}$ yr$^{-1}$) of major nutrients in the litterfall fractions in three forested plots in Greece in 2022**

| Foliar | TM | Ca | Mg | K | S | N | P |
|---|---|---|---|---|---|---|---|
| Maquis | 3.2 | 46.2 | 4.54 | 10.4 | 26.2 | 2.45 | 1.64 |
| Oak | 4.8 | 72.4 | 9.91 | 10.9 | 55.3 | 3.20 | 5.92 |
| Fir | 3.2 | 64.0 | 4.16 | 9.40 | 33.6 | 3.55 | 1.21 |
| **Non-foliar** | **TM** | **Ca** | **Mg** | **K** | **S** | **N** | **P** |
| Maquis | 3.7 | 27.0 | 3.96 | 15.7 | 27.7 | 1.91 | 0.48 |
| Oak | 3.9 | 45.1 | 4.09 | 14.5 | 26.3 | 1.64 | 1.81 |
| Fir | 2.0 | 23.1 | 2.64 | 7.24 | 26.3 | 2.16 | 0.51 |

## Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2

Bourletsikas A, Proutsos N, Argyrokastritis I (2023) Use of gridded data for the evaluation of ten radiation-based potential evapotranspiration models in a forest ecosystem in Greece. In: Proceedings of the 12th World Congress of EWRA on Water Resources and Environment, 27 June–1 July 2023, Thessaloniki, Greece, 277-278

## Outlook

We are planning to enrich the scientific team dealing with forest ecosystems and taking part in the ICP Forests monitoring by including tree physiology and forest genetics. In addition, modelling of the water availability for vegetation may improve our ability to explain spatio-temporal defoliation patterns along with other phenological stages. Models can be constructed to complete the components in order to predict the hydrochemical budgets of nutrients and/or heavy metals to complete the components of the hydrological cycle.

# Hungary

## National Focal Centre

Kinga Nagy, Gergely Pápay
National Land Centre, Department of Forestry

## Main activities/developments

Level I, the large-scale health condition monitoring, is co-ordinated and carried out by the experts of the National Land Centre – Department of Forestry. The annual survey includes 78 permanent sample plots with 1872 potential sample trees in total, on a 16 x 16 km grid.

In 2023, 78 permanent plots with 1521 sample trees were included in the crown condition assessment. The survey was carried out between 15 July and 15 August. The percentage of broadleaves was 90.9%, while the percentage of conifers was 9.1%.

## Major results/highlights

From the total number of sample trees surveyed, 21.1% were without visible defoliation, which shows an increase in comparison with 2022 (10.9%). The percentage of the slightly defoliated trees was 32.4%, and the percentage of all trees within ICP Forests defoliation classes 2-4 (moderately damaged, severely damaged and dead) was 46.4%. The rate of the dead trees was 3.3% and 2.0% of all sample trees died in the surveyed year. The dead trees remain in the sample as long as they are standing but the newly died trees can be separated. The mean defoliation for all species was 32.3%. These values signal an improvement compared to a very dry 2022, although they do not reach the level of the previous years.

Relatively big differences can be observed between the tree species groups in respect of the defoliation rates. In 2023, *Quercus robur* (pedunculate oak) and Quercus petraea (sessile oak) were the most defoliated and damaged tree species groups again, with 0.6% and 0.2% of undamaged trees, respectively. For several years now, a long-term decline in the health condition could be observed in these groups. *Quercus cerris* (Turkey oak) and *Pinus nigra* (black pine) are also among the most severely damaged tree species.

The least defoliated tree species was *Carpinus betulus* (common hornbeam) with 22% mean defoliation. This is a higher number than in 2022 (17.5%).

Discoloration can rarely be observed in the Hungarian forests, 89.1% of living sample trees did not show any discoloration.

Although the damage caused by insects, abiotic causes, and fungi were dominant in general, the rates of the damaging agents showed differences in proportions between the tree species groups respectively.

In 2023, insects were the most frequent damaging agent (34.7%). Most of the observed damage was caused by defoliators and sucking insects. In recent years, the oak lace bug (*Corythucha arcuata*) has been spreading across the Hungarian forests (as well as in Europe's) and it has become a common and dangerous pest of *Quercus* species. Abiotic damage was the second most frequent damaging agent with 26.0%.

Fungal damage (19.5% of all damage) was observed most frequently on *Pinus nigra* (fungi affected 50.0% of sample trees in this group).

### Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2

"Erdeink egészségi állapota 2023-ban" The annual national report on the health condition of the Hungarian forests, which includes ICP Forests plot data is available (in Hungarian) online: http://www.nfk.gov.hu/EMMRE_kiadvanyok_jelentesek_prognozis_fuzetek_news_536

"Erdészeti Mérő- és Megfigyelő Rendszer, 2023" An annual leaflet about the key findings of the Forest Monitoring and Observation System (FMOS, Hungarian acronym: EMMRE). Forest health condition monitoring is an important part of the FMOS. The leaflet is available online in Hungarian: http://www.nfk.gov.hu/EMMRE_kiadvanyok_jelentesek_prognozis_fuzetek_news_536

### Outlook

Examination of the health status of forests in Hungary is one of the priority areas of forestry monitoring. We are committed to maintain the current large-scale health monitoring system, the provision and development of the necessary infrastructure is ongoing.

## Ireland

### National Focal Centre

Thomas Cummins, University College Dublin

### Main activities/developments

Crown condition assessments at 35 Level I plots were undertaken in 2023 (Survey C1), based on a systematic grid of 16km x 16km. All of the Level I plots are co-located with National Forest Inventory (NFI) plots. The fieldwork was performed in July and August by the Forest Service within the Department of Agriculture, Food and the Marine (DAFM). Establishment of Ireland's National Ecosystem Monitoring Network (NEMN) for reporting under the National Emission Reduction Commitments Directive continues, with most activity in vegetation recording of open habitats, plus water quality monitoring in aquatic habitats, and soil and moss sampling of forest ecosystems. Atmospheric ammonia monitoring at two forest sites was active in 2023, with bulk deposition monitoring for establishment at three open habitats in 2024.

### Major results/highlights

2023 crown condition continues a series since 2019, and helps to link historic ICP Forests datasets to future data from NECD monitoring to include two Level II forest sites, Roundwood and Brackloon.

Of the 35 Level I plots, 29 contributed to crown condition data in 2023. This is due to clearfelling activity at six of the plots in recent years.

### Outlook

- Bulk precipitation sampling at two Level II sites for establishment in 2024.
- Continued development of a passive-sampling ammonia network, including two Level II forest sites, supported by planned active samplers, during 2024.
- Continued crown condition assessments at 35 Level I plots in 2024.

## Italy

### National Focal Centre

Giancarlo Papitto, Office Projects, Conventions, Environmental Education – Carabinieri Corps

### Main activities/developments

The survey of Level I in 2023 took into consideration the condition of the crown of 4971 selected trees in 255 plots belonging to the EU network 16x16 km. The results given below relate to the distribution of frequencies of the indicators used, especially transparency – which in our case we use for the indirect assessment of defoliation and the presence of known causes attributable to both biotic agents and abiotic factors. For the latter, not so much the indicators we analyzed the frequencies of affected plants, but the comments made as to each plant may have multiple symptoms and more agents.

### Major results/highlights

Defoliation data are reported according to the usual categorical system (class 0:0-10%; class 1: >10-25%; class 2: >25-60%; class 3: >60%; class 4: tree dead).

By analyzing the sample for groups of species, conifers and broadleaves, it appears that deciduous foliage has a lower transparency than conifers: 23.3% of conifers versus 16.1% of broadleaves in the class 0 of transparency, while 45.2% of deciduous foliage versus 45.1% of conifers is included in the classes 2 to 4.

From a survey of the frequency distribution of the parameter for transparency, species were divided into two age categories (<60 and ≥60 years). Among the young conifers (<60 years), and of trees in the classes 2 to 4 result: the two Mediterranean pines with the highest values *Pinus pinea* (84.4%) and *Pinus halepensis* (61.9%), *Pinus nigra* (36.6%), *Picea sylvestris* (33.0%), while *Picea abies* (17.6%) is the young conifer in the best conditions.

Among the old conifers (≥60 years), of trees in the classes 2 to 4 with the species appear to be worse quality of foliage on *Pinus sylvestris* (77.1%), then *Picea abies* (63.4%), *Larix decidua* (54.0%) and *Abies alba* (45.3%), while *Pinus cembra* (32.1%) was the conifer in better condition.

Among the young broadleaves (<60 years), *Castanea sativa, Ostrya carpinifolia, Quercus pubescens* and *Fagus sylvatica* have respectively 73.4%, 55.7%, 44.1%, and 57.6% of trees in the classes 2 to 4, while others *Quercus cerris* have a lower frequency (26.4%) always in classes 2 to 4.

Among the old broadleaves (≥60 years) in the classes 2–4, *Castanea sativa* has 75.5%, *Quercus pubescens* 35.7%, *Fagus sylvatica* 30.3%, *Fraxinus ornus* 34.0%, while with 25.0% *Quercus ilex* has the lowest level of defoliation of trees in the classes 2–4.

Overall, there is a slight degradation from the 2022 data, which already marked a large criticality of canopy condition through the defoliation index, compared to the previous period.

Starting from 2005, a new methodology for a deeper assessment of damage factors (biotic and abiotic) was introduced. The results of a first overall screening for all plants are shown below.

Out of a total of 4971 trees monitored, 8990 symptoms were detected. Of the trees with symptoms 4950 (55.1%) were recognized while 4040 (45.0%) symptoms were not identified.

Most of the observed symptoms were attributed to insects (21.2%), subdivided into defoliators (15.6%), lignicolous (1.9%) galls and mining (1.28%), following symptoms attributed to fungi (4.8%) the most significant are attributable to "dieback and canker fungi" (3.2%), then those assigned to abiotic agents, the most significant are attributable to hail (2.9%) and drought (2.9%).

### Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2

Bussotti F, Papitto G, Di Martino D, et al. Extreme climatic events, biotic interactions and species-specific responses drive the year-by-year changes in tree crown defoliation and mortality in Italian forests. Findings and evidence from the ICP Forests Level I monitoring network – 2001–2022.

### Outlook

Currently, Italy has a total of 255 Level I plots and 32 plots in Level II monitoring and it is planned to maintain those plots also in future.

## Latvia

### National Focal Centre

Level I: Uldis Zvirbulis
Level II: Andis Lazdiņš, Linards Ludis Krumšteds
Latvian State Forest Research Institute "Silava"

### Main activities/developments

Latvia continued its assessment at Level I. The forest condition survey 2023 in Latvia was carried out on 115 Level I NFI plots. The major results of 2023 are based on data from this dataset.

In 2023, the relevant works were performed within the framework of the Level II monitoring:

- Air quality monitoring, using diffusive samplers twice a month (June–October)
- Foliage tree needle sampling once every two years
- National crown condition survey
- Deposition monitoring from bulk, throughfall, stemflow
- Soil solution monitoring from lysimeters
- Litterfall sampling twice a month in months with no snow cover (usually March–November/December, may differ from year to year).

### Major results/highlights

On Level I plots defoliation and damage symptoms of 1728 trees were assessed, of which 72% were conifers and 28% broadleaves. Of all tree species, 11.1% were not defoliated, 84.0% were slightly defoliated, and 4.9% moderately defoliated to dead. Compared to 2022, the proportion of not defoliated trees has decreased by 0.8%, the proportion of slightly defoliated has increased by 0.6%, but the proportion of moderately defoliated to dead trees has increased by 0.2%. In 2023, the proportion of not defoliated conifers was 6.4% higher than that of not defoliated broadleaves, the proportion of slightly defoliated broadleaves was 0.9% higher than that of slightly defoliated conifers. The proportion of trees in defoliation classes moderately defoliated to dead for conifers was 3.5% higher than for broadleaves.

Mean defoliation of *Pinus sylvestris* was 19.8% (19.6% in 2022). The share of moderately damaged to dead trees increased at 5.9% (4.6% in 2021). Mean defoliation of *Picea abies* was 17.9% (19.0% in 2022). The share of moderately damaged to dead trees in spruce decreased at 5.6% (7.5% in 2022). The mean defoliation of *Betula* spp. was 18.8% (19.0% in 2022). The share of trees in defoliation classes moderately to dead was 2.4% (compared to 2.3% in 2022).

In 2023, there was a noticeable surge in the average defoliation of trees within the Valgunde sample plot, reaching a remarkable record of 20.8%. This represented a substantial increase of 4.8% compared to the preceding year of 2022. Similarly, the Taurene sample plot experienced an uptick in average defoliation, reaching 19.1%, reflecting a 1% rise from the previous year. However, the increase in defoliation was minimal in the Rucava sample plot, registering at only 0.1%.

2023 marked the second consecutive year of very low total precipitation in the Valgunde sample plot, resulting in some instances, where water collection vessels remained empty, impeding sample collection efforts. Total precipitation for the year amounted to 406 mm in open fields, 340 mm through tree canopies, and a mere 18 mm along tree trunks. The reduced precipitation also translated to lower soil moisture levels, with collected water quantities below the humus layer measuring 12.5 L, at a depth of 20 cm measuring 8.3 L, and at depths of 40-70 cm measuring 6.6 L. In terms of pH levels, Valgunde's data for 2023 did not show any deviations from previously reported values. However, in the Taurene and Rucava sample plots, the most acidic precipitation was recorded in tree trunk runoff, with pH levels at 4.8 ± 0.2 in Valgunde and Rucava and 5 ± 0.4 in Taurene. Conversely, the highest average pH values were recorded in open-field precipitation at 6.5 ± 0.1 in Valgunde, 6.3 ± 0.1 in Taurene, and 6.2 ± 0.2 in Rucava. Analysis of nitrogen content in precipitation since 2011 indicated a significant decrease with negligible year-to-year variation. The highest nitrogen content was observed in the Rucava sample plot, reaching 3.5 mg/L in tree trunk runoff, while the lowest dissolved total nitrogen (DTN) content was recorded in Taurene's open field precipitation at 0.9 mg/L. Continuing a trend observed over the past three years, soil pH levels decreased annually across all soil depth samples in 2023. Soil pH levels ranged from 4.3 below the humus layer to 4.6 at a depth of 20 cm, and 4.3 at depths of 40-70 cm.

In terms of tree growth, total annual growth across all 15 tree bands in the Valgunde sample plot reached 24.5 mm in 2023, with individual tree growth varying between 0.4 mm and 2.3 mm. Similarly, in the Taurene sample plot, total annual growth reached 27.5 mm, with individual tree growth ranging from 0.1 mm to 3.7 mm. In the Rucava sample plot, total annual growth reached 31.9 mm, with individual tree growth varying from 0.2 mm to 3.6 mm.

### Outlook

Latvia has 115 NFI Level I plots and it is planned to continue observations at this level. ICP Forests Level II monitoring plots have not registered any disturbances in monitoring quality or signs of possible problems. No new monitoring plots are scheduled and the total amount of 3 plots is recognized as enough to describe ecological processes in the country. Latvian State Forest Research Institute "Silava" is determined to continue the long-term monitoring and sample analysis for the Level II inventory as it has previously since the year 2004.

## Lithuania

### National Focal Centre

Marijus Eigirdas, Lithuanian State Forest Service

### Main activities/developments

#### Level I

In 2023, a forest condition survey was conducted on 1061 sample plots, of which 81 plots were in the transnational Level I network and 980 plots in the National Forest Inventory network. In total, 6507 sample trees representing 17 tree species were assessed. The main tree species assessed were *Pinus sylvestris*, *Picea abies*, *Betula pendula*, *Betula pubescens*, *Populus tremula*, *Alnus glutinosa*, *Alnus incana*, *Fraxinus excelsior*, *Quercus robur*.

#### Level II

In 2023, the intensive forest monitoring was carried out in ten Intensive Monitoring Plots (IMP). The monitoring surveys performed at ten IMP included the visual assessment of crown condition and damaging agents, the assessment of ozone injury, and foliage sampling and analysis. In three Level II plots the following surveys were conducted: soil solution collection and analysis, atmospheric deposition in bulk and throughfall, litterfall sampling, assessment of the concentration of sulphur dioxide ($SO_2$), nitrogen dioxide ($NO_2$), and ammonia ($NH_3$) (with passive samplers), phenological observations for Norway spruce, Scots pine, and pedunculate oak.

### Major results/highlights

#### Level I

In one year, the mean defoliation of all tree species decreased slightly to 22.2% (22.8% in 2022). 15.9% of all sample trees were not defoliated (class 0), 62.7% were slightly defoliated, 19.6% were assessed as moderately defoliated and 21.4% as severely defoliated and dead (defoliation classes 2-4).

Mean defoliation of conifers (23.4%) did not change from the previous year (23.4% in 2022) and mean defoliation of deciduous trees slightly decreased to 20.2% (21.7% in 2022).

*Pinus sylvestris* is the dominant tree species in Lithuanian forests and annually accounts for about 39% of all sample trees. Mean defoliation of *Pinus sylvestris* increased slightly to 24.9% (24.7% in 2022). A slightly increasing defoliation trend was observed between 2008 and 2023 from 20.4% to 24.9%.

Since 2006 *Populus tremula* mean defoliation and the share of trees in defoliation classes 2-4 were the lowest. In 2023, the mean defoliation of *Populus tremula* was 16.7% (15.5% in 2022) and the proportion of trees in defoliation classes 2-4 was 8.8%, compared to 7.4% in 2022.

The condition of *Fraxinus excelsior* remained the worst of all observed tree species. The share of defoliation in this tree species was the highest since 2000. Mean defoliation decreased to 26.3% (30.8% in 2022). The share of trees in defoliation classes 2-4 increased to 30.4% (29.4% in 2022).

29% of all sample trees had some kind of identifiable damage symptoms. The most frequent damage was caused by abiotic agents (about 8.6% in 2023) in the period of 2011–2022. The highest share of damage symptoms was assessed for *Fraxinus excelsior* (57%), *Populus tremula* (43%), *Alnus incana* (40%), *Picea abies* (38%), the least for *Alnus glutinosa* (16%) and *Betula sp.* (19%).

#### Level II

The mean crown defoliation of all tree species varied insignificantly in the period from 1995 to 2022, and the growing conditions of Lithuanian forests can be defined as relatively stable.

In 2023, the mean crown defoliation was 17.4% and it was 0.9% higher compared with 2022. The highest crown defoliation was found for European ash (20.4%) and pedunculate oak (19.4%). 6.4% trees had biotic and abiotic damage, with 0.7% average tree mortality. This was slightly lower compared with 2022. 33% of trees were asigned to 0 defoliation class, 55% to defoliation class 1, 10.3% to defoliation class 2, and 0.5 to defoliation class 3.

The air pollution deposition survey, carried out since 2000, showed that sulphur deposition under tree crowns has constantly decreased. During the last decade, the amount of sulphur deposition in the open area has varied between 3 to 6 kg $ha^{-1}$ $y^{-1}$. Multi-annual (2008–2023) average of sulphur deposition under tree canopy was 5.2 $ha^{-1}$ $yr^{-1}$.

In 2023, the average annual $SO_2$ concentration was in line with the multi-anual average, while three-fold higher compared with 2022. The average annual $NO_2$ concentration within monitoring plots varied from 5.12 to 8.03 µg/$m^3$.

In 2023, visually visible ground-level ozone-related damages were assessed in ten IMP. The foliage injuries possibly caused by ground-level ozone was found in one IMP on *Salix caprea* leaves.

#### New IMP establishment in 2023

To increase the representativeness of the monitoring network and to monitor more diverse forest ecosystem types in Lithuania, an additional IMP has been established in the Dubrava Forest Reserve. The IMP represents a natural not drained upland bog ecosystem covered by woody vegetation.

#### Collaboration with other programs and projects

In 2023, joint activities with the LIFE OrgBalt project "Demonstration of climate change mitigation potential of nutrients rich organic soils in Baltic States and Finland (Project code: LIFE18 CCM/LV/001158)" were continued. The greenhouse gas emissions from organic soil were estimated in ICP Forests Level II IMP.

### Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2

Žemaitis P., Armoška E., Kulbokas G. 2023. Wood decay and Norway spruce vulnerability to wind inflicted damage in monospecific and mixed stands. 10th IUFRO conference Wind & trees. Italy.

Armoška E., Žemaitis P. 2023. Butt rot and Norway spruce vitality – butt rot induced crown defoliation and changes in tree radial increment CYSENI 2023: 19th International Conference for Young Scientists on Energy and Natural Science Issues.

## Luxembourg

### National Focal Centre

Philippe Schmitz, Administration de la nature et des forêts

### Main activities/developments

Every year we present our results of the national plant-health inventory. This inventory is based on the analysis of crown condition, which is carried out on about 50 plots throughout the country. The survey is based on a 4x4 km grid. This data is also part of our Level I data submission.

### Major results/highlights

The gradual deterioration in the phytosanitary health of the trees observed, already noticeable since 2019, continues this year. There has been a 1% decrease in the proportion of trees in the sample showing no visible signs of damage (class 0). If we consider damage class 2, 55% of trees are in a state of moderate to severe deterioration. However, depending on the evolution of weather conditions, these class 2 trees have the capacity to recover and move up to a higher category (class 0 or 1). In this way, they continue to fulfil an important ecological function.

Worryingly, however, 12.3% of the trees studied are currently in an advanced state of decline or have already died (classes 3 and 4).

Across all tree species, in the summer of 2023:

- 14.5% of trees show no damage (damage class 0),
- 18.2% of trees are slightly damaged (damage class 1),
- 55.0% of trees are moderately to severely damaged (damage class 2),
- 12.3% of trees are dying (damage classes 3 and 4).

### Outlook

Level I crown condition data will be uploaded again after the upcoming survey period.

## Moldova, Republic of

### National Focal Centre

Dumitru Galupa, Gheorghe Florenţă | Forest Research and Management Institute (ICAS), Moldsilva Agency

### Major results/highlights

The crown condition assessment in 2023 was conducted on nine permanent plots within the Level I network (16x16 km grid), encompassing a total of 218 broadleaf trees. The analysis of this year's results was not compared to the previous year's data due to the unavailability of submissions for 2022. Additionally, the

Republic of Moldova has initiated efforts with a new team to enhance the accuracy and comprehensiveness of future reporting.

Based on the data collected this year, the prevalence of trees falling within defoliation classes 2-4 across all broadleaved species was recorded at 17.9%. Among the primary species surveyed, notable occurrences were observed in *Fraxinus excelsior* (22%) and *Quercus robur* (20%), whereas *Quercus petraea* and *Quercus pubescens* exhibited lower incidences within the 2-4 defoliation classes (approximately 12% each). *Carpinus betulus* and *Quercus rubra* were identified as the least affected species, with all specimens categorized under defoliation class 0 (0-10%), although this assessment is tempered by the limited sample size.

## Outlook

Forest monitoring in the Republic of Moldova will continue with the assessment of crown condition at Level I within the 16x16 km network, wich will be extended in the following years with new plots.

In future years, monitoring activities will expand to the Level II network, initiating with specialized surveys. These surveys will commence independently of the current lack of a specialized laboratory for detailed chemical analyses of foliar chemistry, soil solution chemistry, and atmospheric deposition.

Establishing future collaborations to enhance these analytical capabilities remains a priority. Such efforts are essential for comprehensive monitoring, understanding forest health, assessing environmental impacts, and informing effective forest management strategies. Therefore, ICAS has initiated a collaboration project MONFORGENDIV (financed by the Romanian Ministry of Research, Innovation and Digitalization), focused on forest monitoring activities with the National Institute for Research and Development in Forestry (INCDS) „Marin Drăcea” in Romania.

# Norway

## National Focal Centre

Volkmar Timmermann, Norwegian Institute of Bioeconomy Research (NIBIO)

## Main activities/developments

Norway is represented in 6 Expert Panels (Soil, Foliage, Crown, Growth, Vegetation and Deposition), in the Working Group QA/QC, and is holding the co-chair in EP Crown. In 2023 we participated in several expert panel meetings, in the Task Force meeting in June (online) and in the PCG meeting in Berlin in November. We contributed to the chapter on crown condition in the ICP Forests Technical Report. Our lab participated in the 25$^{th}$ Needle/Leaf Interlaboratory Comparison Test and in the 12$^{th}$ Deposition and Soil Solution Ringtest 2022/2023. We also took part as partner in the Norwegian LTER network.

### Level I / Norwegian national forest monitoring

The Norwegian national forest monitoring is conducted on sample plots in a systematic grid of 3 x 3 km in forested areas of the country (3 x 9 km in mountain forests and 9 x 9 km in birch forests in Finnmark). The plots are part of the National Forest Inventory (NFI), who also is responsible for crown condition assessments including damage. The NFI has five-year rotation periods, and since 2013 monitoring has been following these with five-year intervals, i.e. monitoring is not carried out annually on the same plots. The plots are circular with an area of 250 m$^2$. Defoliation assessments are done on Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*) only, while damage assessments are conducted on all tree species present on the plots.

Our national forest monitoring in 2023 included defoliation assessments on 5 623 Norway spruce and 5 001 Scots pine trees on 1 864 plots, and damage assessments on 19 697 trees (30+ species, incl. spruce and pine) on 2 596 plots in total from early May until mid of October. The regular national training and calibration course for the field workers from the NFI was conducted in May. Some of our field workers participated in the ICP Forests first online photo test for quality assurance of the forest condition survey for Central Europe in November/December 2023.

In 2022, 626 plots were part of the transnational ICP Forests Level I grid (16x16 km = 1 plot pr. 256 km$^2$), and defoliation and/or damage data for 6 105 trees belonging to 25 species were reported to ICP Forests.

### Level II

At our three Level II sites, the following surveys are conducted by NIBIO: crown condition and damage, tree growth, foliar chemistry, ground vegetation, soil solution chemistry, and atmospheric deposition in bulk and throughfall. Chemical analyses are carried out in-house. Ambient air quality (incl. ozone) is measured at two plots (Birkenes and Hurdal) and meteorology at one (Birkenes) by the Norwegian Institute for Air Research (NILU). Data from the Level II surveys carried out by NIBIO are reported to ICP Forests annually.

## Major results/highlights

### Norwegian national forest monitoring

In 2023, mean defoliation for Norway spruce was 17.3%, and 14.5% for Scots pine in our national monitoring. There was an increase in mean defoliation for both spruce (+0.5%) and pine (+1.1%) compared to 2022.

| | Percentage of trees per defoliation class | | | | | | |
|---|---|---|---|---|---|---|---|
| | Class 0 | Class 1 | Class 2 | Class 3 | Class 4 | Mean defoliation | No. of trees |
| Norway spruce (*Picea abies*) | 47.0 | 30.9 | 17.5 | 4.3 | 0.4 | 17.3 (+0.5) | 5 645 |
| Scots pine (*Pinus sylvestris*) | 44.5 | 42.6 | 11.3 | 1.5 | 0.2 | 14.5 (+1.1) | 5 012 |

Of the almost 20 000 trees assessed for damage in 2023, 11.6% had symptoms of damage. The highest proportion of damage

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(15.2%) was observed for birch trees (*Betula* sp.), followed by Norway spruce (12%), other deciduous trees (10.2%), and Scots pine (7.2%). By far the most common causes of damage for all species were abiotic factors (mainly snow breakage and windthrow), inducing 37.4% of all recorded damage symptoms. Fungi were responsible for 11.8% (primarily spruce needle rust and birch rust), and insects for 9.9% of the damage symptoms (mostly birch moths). Game and grazing caused 3.6% of all damage symptoms, direct action of man 1.7%, and fire and other known factors 0.3% each. A considerable number of symptoms (35.1%) could not be identified in the field.

Mortality rates were 4.0‰ for Norway spruce, 2.2‰ for Scots pine, 8.7‰ for birch, 8.8‰ for other deciduous species and 5.6‰ on average for all assessed tree species in 2023.

#### Norwegian intensive forest monitoring:

At our Level II sites, the highest levels of anthropogenic sulphur- and inorganic nitrogen-containing compounds in air were measured at Birkenes due to long-range transported air pollution. The UNECE's "critical value" of 5000 ppb-hours for tropospheric ozone in forests was not exceeded in Norway in 2022. The reduction in deposition of non-marine sulphate in precipitation has led to a corresponding significant reduction of non-marine sulphate in soil solution as well. We could, however, detect a tendency towards slightly increasing concentrations of aluminium and decreasing pH in soil solution in 2022.

### Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2


Skogskader.no [Forest damage reporting, interactive database]: https://skogskader.nibio.no/

Timmermann V, Børja I, Clarke N, et al (2023) Skogens helsetilstand i Norge. Resultater fra skogskadeovervåkingen i 2022. [The state of health of Norwegian forests. Results from the national forest damage monitoring 2022.] NIBIO Rapport 9(132) 2023: 80 pp. https://hdl.handle.net/11250/3103278

Viken KO (2023) Landsskogtakseringens feltinstruks – 2023. [Manual of the Norwegian NFI – 2023.] NIBIO BOK 9(5) 2023: 170 pp + annexes. https://hdl.handle.net/11250/3104906


### Outlook

- Monitoring at Level I will continue as part of our national forest monitoring conducted by the NFI.
- We plan to participate in the next Needle/Leaf and Deposition/Soil Solution ringtests.
- The ICOS C-flux tower started its measurements at one of our Level II sites (Hurdal) in 2021. At this site NILU also has one of their EMEP sites, opening for a broad collaboration between ICOS, EMEP, and ICP Forests.
- We are in the process of adding our Level II sites in Birkenes and Hurdal to national LTER site clusters as part of the European eLTER network.

## Poland

### National Focal Centre

Paweł Lech, Forest Research Institute (IBL)

### Main activities/developments

The Forest Research Institute is responsible for the implementation of all forest monitoring activities in Poland and works closely with the General Inspectorate of Environmental Protection (GIOŚ) and the State Forests Enterprise (LP). Poland is represented in six Expert Panels (Soil & Soil Solution; Forest Growth; Biodiversity; Crown Condition and Damage Causes; Deposition; Meteorology, Phenology & LAI) as well as in the Working Group QA/QC in Laboratories, where our representative Dr Anna Kowalska serves as chair.

#### Level I

In 2023, the forest condition survey was conducted on 2071 Level I plots of the national 8 km x 8 km grid and a total number of 41420 trees were assessed. Of these, the assessment results of 340 plots on a 16 km x 16 km grid (European network) with 6800 trees were submitted to the ICP Forests Database. The fieldwork took place in July and August.

#### Level II

In 2023, measurements of weather parameters, air quality, and chemical analysis of deposition (open field and throughfall) and soil solution were conducted on 12 Level II plots. In addition, continuous measurements of dbh and water availability of the trees were carried out on one plot with oak as the dominant tree species. Additionally, ground vegetation studies were conducted on 148 plots of the Level II national grid in 2023.

### Major results/highlights

#### Level I

In 2023, the average defoliation of all species was 21.9%, that of conifers 22.1%, and that of deciduous trees 21.5%. The percentage of healthy trees (with leaf loss of 10% or less) was 10.7% for all species, and the percentage of trees with leaf loss of more than 25% was 16.5%.

The percentage of healthy trees (14.2%) and the percentage of trees with leaf loss of more than 25% (17.2%) were higher for deciduous than for coniferous species (8.5% and 16.1%, respectively). The percentage of trees in the early warning class with leaf loss between 11% and 25% was 72.8% for all species, 75.4% for conifers and 68.6% for broadleaves.

Among the three main conifer species, *Abies alba* had the lowest mean defoliation of 19.0%, with 21.8% of trees falling into class 0, and 11.1% into classes 2-4. *Pinus sylvestris* was characterized by a lower proportion of trees in class 0 (8.0%), a higher proportion of trees in classes 2-4 (15.0%) and a higher mean defoliation (21.9%) than *Abies alba*. *Picea abies* was characterized by the highest proportion of trees in classes 2-4 (33.6%) and a highest mean defoliation (27.2%) compared to the other surveyed major tree species (coniferous and deciduous).

In 2023, as in the previous years, the highest average defoliation among deciduous trees was observed in *Quercus* spp. – 25.2%. Only 3.8% of oaks had a leaf loss of 10% or less and 29.7% of trees fell into leaf loss classes 2-4. A slightly better condition was observed for *Betula* spp. (7.8% trees in class 0, 16.4% of trees in classes 2-4 and the mean defoliation was 22.5%). *Fagus sylvatica* remained the tree species with the best health condition compared to the other surveyed coniferous and deciduous species. A proportion of 27.2% of the beech trees showed leaf loss of 10% or less, only 6.2% of trees were in classes 2-4 and the mean defoliation was 16.8%. *Alnus* spp. was slightly more defoliated (21.1% of trees in class 0, 8.9% of trees in classes 2-4 and the mean defoliation was 18.8%) than *Fagus sylvatica*.

In 2023, *Pinus sylvestris*, *Fagus sylvatica*, *Quercus* spp. and *Betula* spp. were almost in the same health condition throughout the country compared to the previous year. The condition of *Picea abies and Abies alba* slightly deteriorated, while the condition of *Alnus* spp. slightly improved.

#### Level II

Meteorological measurements on the Level II plots showed that 2023 was warmer (about 0.6 °C) and significantly wetter (approx. 35%) than 2022. Although rainfall was more abundant in 2023, a great part of the precipitation occurred outside the growing season, between October and December in particular.

The analytical results of the measurements carried out in 2023 on 12 Level II plots regarding air quality, deposition, and the concentration of elements in soil solution will be evaluated in the second half of 2024 and published in next year's Technical Report.

The $SO_2$ concentration in the air in 2022 ranged from 63% to 108% of the concentration in 2021 and the $NO_2$ concentration ranged from 86% to 115%. On all plots, $SO_2$ and $NO_2$ concentrations in ambient air in 2022 followed the general trend of decreasing concentrations of air pollutants observed in recent years, as shown over the years 2011–2022 on all Level II plots. The pH of precipitation, both above and below the tree crowns of the forest stands in most of the Level II plots, showed a significant ($p \leq 0.05$) upward trend in recent years, which was accompanied by a decrease in the deposition of sulphur in the form of sulphates. Soil conditions remained stable in most Level II plots during the period studied; any changes in the amount of deposition in recent years were reflected to a lesser extent in changes in the chemical composition of the soil solutions.

### Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2

Lech P, editor (2023) Forest Condition in Poland in 2022. Synthesis of the report „ Health condition of forest in Poland in 2022 based on monitoring study". Instytut Badawczy Leśnictwa, Sękocin Stary

### Outlook

In addition to routine monitoring activities, the following projects were launched in 2017 and 2022 using forest monitoring data and/or the infrastructure:

- Evaluation of acidification and eutrophication of forest ecosystems in Poland in respect to the critical load concept (ended in 2024).
- Analysis of water conditions in forest ecosystems by evaluation of indicators of the health status of forest stands.

## Romania

### National Focal Centre

Ovidiu Badea, Stefan Leca
National Institute for Research and Development in Forestry (INCDS) "Marin Drăcea"

### Main activities/developments

#### Level I

The crown condition survey was performed in 2023 by National Institute for Research and Development in Forestry (INCDS) „Marin Drăcea" experts in 234 plots of the 16x16 km Level I network. A total number of 5616 trees were assessed of which 903 were coniferous trees (16%) and 4713 broadleaf trees (84%).

#### Level I

In Romania, 12 Level II plots are considered for intensive monitoring activities, of which 4 (core plots) are equipped with specific sensors and instruments for gathering accurate information on forest ecosystem changes. In 2023, 2 new intensive monitoring plots were installed in the south (*Quercus* spp) and in the north (*Picea abies* and *Abies alba* mixed forest) of Romania to be included in the Romanian Level II network, and new equipment to monitor climate parameters, air quality, growth and sap flow sensors were installed.

Besides the regular monitoring activities, in 2023:

- the Romanian team (NFC and national experts) participated in the 39th ICP Forests Task Force Meeting (online, June 2023), in the Joint EP Meeting on AAQ, Biodiversity, Deposition, Foliage & Litterfall, Soil & Soil Solution, and QA/QC in Labs – Vienna (March 2023) and organized the

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24th ICC - for visible ozone symptoms in Brasov, 4–8 September 2023 with 18 participants from seven countries.

- Data for air quality, ozone injury, biodiversity, deposition, soil and soil solution were corrected and resubmitted.

### Major results/highlights

In 2023, the mean defoliation of all tree species from the Romanian Level I network was 15.4%, 0.8% lower than in 2022. A slight improvement of the health status of trees expressed by mean defoliation percentage was observed for both conifers and broaleaves with 15.5% in 2022 and 14.1% in 2023 and 16.3% in 2022 and 15.8% in 2023, respectively.

The highest mean defoliation was recorded for poplar (31.9%), oak (23.4%), black locust (19.7%), and hornbeam (18.8%) among broadleaves, and pine (37%) among conifers. Reduced values, below the national average, were observed for beech (12.2%), spruce (13.3%), fir (12.0%), and lime (12.9%).

Compared to the previous year, the frequency of damaged trees (defoliation above 25%) has decreased from 13.1% in 2022 to 11.8% in 2023 for all trees, with the most notable improvement in the trees' health status being observed for coniferous trees, from 16.7% of damaged trees in 2022 to 11.6% in 2023. For broadleaves no significant changes have been observed.

The level of mortality (defoliation class 4) remains low (0.8%) for all species, dead trees being recorded for both species groups, the highest mortality rate being attributed to species like black locust, poplar, pine, or oak.

From the field data analysis regarding fruiting intensity in 2023, it was found that fruiting was present in 43% of the evaluated trees, with 31% having scarce, 10% common, and only 2% abundant fruiting.

### Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2

The Annual Report of the Romanian Environment Status in 2022. VI.1.3. Forest health status. Ministry of Environment, Waters and Forests

The Annual Report of the Romanian Forest Status in 2022. Ministry of Environment, Waters and Forests

The ICP Forests Technical Report 2023 (national report for Romania)

### Outlook

The Romanian NFC represented by the National Institute for Research and Development in Forestry (INCDS) „Marin Drăcea" is permanently seeking financing possibilities for developing new research (related to climate change effects on different forest indicators) in order to maintain the ongoing long-term monitoring activities and fulfill the reporting obligations regarding the negative impacts of air pollution on forest ecosystems under the National Emissions Ceilings (NEC) Directive (2016/2284/EU) and other national and international technical reports.

In 2023, INCDS participated as coordinator or partner in several project poposals, aimed at the development of the Level II monitoring tehnology and infrastructure and widening of future research activities.

By Government Decision, INCDS is responsible and will be financed to carry on activities to be reported under NEC directive for forest ecosystems (all Level II core plots being part of the Romanian NECD network). Furthermore, the Romanian experts are involved in replication activites of the Life MODERn (NEC) - LIFE20 GIE/IT/000091 project that aims to test and recommend new relevant indicators for NEC directive reporting.

## Serbia

### National Focal Centre

Dr Ljubinko Rakonjac, Principal Research Fellow
Institute of Forestry, Belgrade

### Main activities/developments

The National Focal Center at the Institute for Forestry has been continuously participating in the international program ICP Forests, with the goal of achieving further improvement and harmonization with other approaches of forest ecosystem monitoring and management. Monitoring is conducted on 130 Level I sample plots and 5 Level II sample plots. The main activities in 2023 included the improvement of the work within ICP Forest through developing an ICP Forests data database for Level I and Level II, which is harmonized with data from the national forest inventory, forest management planning, forest protection and other data (Forest Information System).

In 2023, the base for additional activities within this program has been established, since there is initiative to start work in the Expert Panel on Ambient Air Quality. Through this program, the Institute of Forestry constantly works on strengthening the co-operation with all relevant institutions in the field of forestry and environmental protection: forest estates of the public enterprise "Srbijašume" and "Vojvodinašume", public enterprises that manage national parks, as well as forest owners and other users of forest resources.

### Major results/highlights

The total number of trees assessed on all Level I sampling plots was 2879 trees, of which 341 were conifer trees and a considerably higher number (2538) were broadleaf trees.

The results of the available data analysis and the assessment of the degree of defoliation of individual conifer and broadleaf species are (%): *Abies alba* (None 94.2, Slight 2.9, Moderate 1.4, Severe 0.0 and Dead 1.5); *Picea abies* (None 91.8, Slight 1.4, Moderate 0.7, Severe 6.1 and Dead 0.0); *Pinus nigra* (None 50.0, Slight 19.6, Moderate 10.9, Severe 13.0 and Dead 6.5); *Pinus sylvestris* (None 95.0, Slight 3.8, Moderate 0.0, Severe 0.0 and Dead 1.2). The degree of defoliation calculated for all conifer trees is as follows: no defoliation 87.4% trees, slight defoliation 4.7% trees, moderate 2.0% trees, severe defoliation 4.4% trees and dead 1.5% trees.

Broadlead tree species defoliation (%): *Carpinus betulus* (None 84.6, Slight 9.1, Moderate 4.5, Severe 0.9, Dead 0.9); *Fagus moesiaca* (None 90.7, Slight 5.9, Moderate 1.5, Severe 1.1, Dead 0.8); *Quercus cerris* (None 82.4, Slight 14.1, Moderate 2.6, Severe 0.7, Dead 0.2); *Quercus frainetto* (None 94.9, Slight 3.3, Moderate 1.0, Severe 0.8, Dead 0.0); *Quercus petraea* (None 69.0, Slight 25.7, Moderate 3.3, Severe 1.0, Dead 1.0) and the rest (None 66.3, Slight 16.3, Moderate 13.0, Severe 2.4, Dead 2.0). The degree of defoliation calculated for all broadleaf species is as follows: no defoliation 82.5% trees, slight defoliation 11.0% trees, moderate 4.4%, severe defoliation 1.2 % trees and dead 0.9 % trees.

## Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2

All national publications in English are available at: http://www.forest.org.rs/?icp-forests-serbia


Marković M, Gagić-Serdar R, Češljar G, et al. (2023) System of monitoring the crown condition on ICP Forests sample plots Level I in Serbia with a special view of biotical damage on points with oak as the edifier. XIV International Scientific Agriculture Symposium " AGROSYM 2023", Jahorina, 05-08 October 2023, Bosnia and Herzegovina. https://enauka.gov.rs/handle/123456789/879497

Rakonjac Lj, Češljar G, Đorđević I, et al (2023) Monitoring and assessment of air pollution impacts and its effects on forest ecosystems in Republic of Serbia – forest condition monitoring, Level I and II. Institute of forestry, Belgrade


## Outlook

In the next period, the development of the ICP Forests Infrastructure will be mainly on strengthening work in our laboratories and involvement in different ring test analysis (deposition, foliar, and soil analysis). This will also include acquiring new laboratory istruments for conducting different chemical analyses. Also, activities on starting monitoring of ambient air quality has been initiated since during 2024 effort will be on adding this expert panel as permanent monitoring.

# Slovakia

## National Focal Centre


Pavel Pavlenda, National Forest Centre (NLC)


## Main activities/developments

Activities related to the Level I and Level II monitoring continued in 2023 to the same extent as in previous years. The Level I survey was performed on 101 plots between July 10 and August 4 (after a one day national calibration course for crown condition assessment). In total, defoliation, discoloration, and damage symptoms of trees were assessed on 3760 trees. Intensive monitoring continued on 7 plots for crown condition, growth, foliage chemistry, atmospheric deposition, and meteorological assessment. Other surveys were conducted only on selected plots. We tried to update technical equipment and instruments to minimize data gaps in measured parameters.

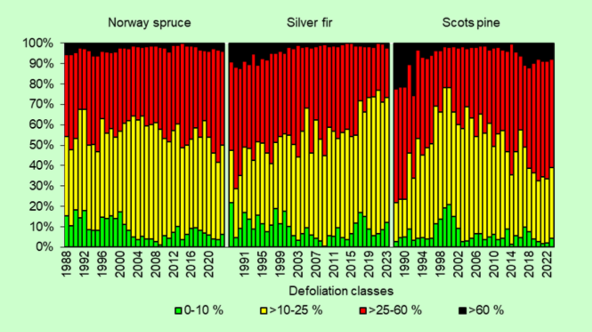
Besides standard data submission to the central database of ICP Forests, we co-operated with the Slovak Environmental Agency to fulfill reporting obligations of the NEC Directive for the assessment of forest ecosystems.

## Major results/highlights

Based on the share of trees in defoliation classes 2-4, the results of defoliation over the last 15 years show a slightly deteriorating health status of conifers and a stabilized health status of deciduous tree species. Fluctuations in individual years are primarily caused by climatic factors.

After 2022, when the highest average defoliation of both deciduous and coniferous trees was recorded, the health status of trees in 2023 improved to the level of previous years. The share of trees in defoliation classes 2-4 in 2023 was 29.8% for deciduous trees (40.2% in 2022) and 50.6% for coniferous trees (58.0% in 2022). The average defoliation of all tree species together was 25.9%, the average defoliation of deciduous trees 23.4% and conifers 30.5%. The highest mean defoliation was observed for *Robinia pseudoacacia* (37.8%), *Fraxinus excelsior* (34.8%), and *Pinus sylvestris* (34.7%). The poor condition of *Fraxinus excelsior* in lowland areas is caused by drought and the attack of the fungus *Chalara fraxinea*. The only tree species with a continuous decrease in defoliation since the very beginning of the forest monitoring (1988) is *Abies alba*. In 2023, a significant improvement in health status was observed compared to 2022. However, the trend of a slight deterioration in health status observed since 2005 still persists.

The trend of the radial increment in *Fagus sylvatica*, *Carpinus betulus*, and *Pinus sylvestris* is decreasing in the last two decades (correlated with the increase of defoliation), while the increase of *Picea abies* and *Quercus* sp. is still relatively stable. *Abies alba* is a tree species with a positive trend not only in defoliation, but also in growth, and is showing recovery after a decline in the 1980s.




## Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2

Pavlenda P, Sitkova Z, Rybar J, Pajtik J (2023) Reakcia ihličnatých drevín na extrémne suché leto 2022 podľa najnovších údajov monitoringu lesov na Slovensku. [Reaction of conifers to the extremely dry summer of 2022 according to the latest forest monitoring data in Slovakia]. APOL Časopis lesníckej ochranárskej služby, 4, 1: 45-50

Sitkova Z, Rybar J, Pavlenda P (2023) Sucho 2022 v kontexte dlhodobých klimatických trendov v lesoch Slovenska. [Drought 2022 in the context of long-term climate trends in the forests of Slovakia]. APOL: Časopis lesníckej ochranárskej služby. 4, 1:64-72

## Outlook

The Level I and the Level II programme will continue based on a contract for 2024. In addition to routine monitoring activities, we intend to improve complex data evaluations and publications of results.

Research project CALTER on Level II plot 204 as a part of set LTER plots focusing on carbon fluxes will be finished in 2025, second workpackage of the project TreeAdapt dealing with the issue of forest monitoring will be finished in 2026. A lot of project proposals will be prepared and submitted to support specific research topics of forest ecology and monitoring.

# Slovenia

## National Focal Centre

Mitja Skudnik, Daniel Žlindra, Anže Martin Pintar
Slovenian Forestry Institute (SFI)

## Main activities/developments

In 2023, the Slovenian national forest health inventory was carried out on 44 systematically arranged sample plots (grid 16 x 16 km) (Level I). The assessment encompassed 1026 trees, 337 coniferous and 689 broadleaved trees. The sampling scheme and the assessment method was the same as in the previous years (at each location four M6 (six-tree) plots).

In 2023, deposition and soil solution monitoring was performed on all four Level II "core" plots. On all ten plots the ambient air quality monitoring (ozone) was done with passive samplers and ozone injuries were assessed. The foliar samples were taken from five trees of the main tree species on all ten plots. On eight plots the phenological observations were carried out. On seven plots growth was monitored with mechanical dendrometers.

## Major results/highlights

- The mean defoliation of all tree species was estimated to be 31.0% (compared to last year the defoliation was lower by 0.6%).
- Mean defoliation in 2023 for coniferous trees was 30.8% (in 2022 it was 30.1%).
- Mean defoliation in 2023 for broadleaved trees was 31.1% (in 2022 it was 32.3%).
- The defoliation of conifers is remaining on a very high level, with additional signs of increase in 2023. In the past the main reason was the bark beetle outbreak after large ice storm break in 2014, stretching all over 2016, 2017, 2018. The impact of the 2022 summer drought is still reflected in the conifers' defoliation rate.
- In 2023, the defoliation of broadleaves decreased for the first time in 8 years. One of the reasons for the high defoliation level could still be the effect of the ice storm (fungi effect) in 2014 and some other insect attacks. However, the main reason for the past increase of defoliation is unknown. The decrease of defoliation in 2023 could be affected by the high amount of precipitation in summer 2023, which followed the summer drought in 2022.
- The total share of damaged and dead trees (with more than 25% defoliation) decreased compared to the previous year from 45.5% to 40.8% in 2023.
- The percentage of damaged broadleaves has increased from 35% in 2019, 36.5% in 2020, 41.3% in 2021 to 44.0% in 2022 and decresed to 37.7% in 2023.
- The percentage of damaged conifers has increased from 40.6% in 2017 to 42.7% in 2019. In 2020, it slightly decreased to 41.1%, then increased to 44.1% in 2021 and to 48.6% in 2022. In 2023, the percentage of damaged coniferous trees slightly decreased to 47.2%.
- Average ozone concentrations in the growing season of 2023 ranged from 16 to 50 µg/m$^3$ on monitored plots which is a significant decrease compared to the previous year. On all ten plots the 14-days ozone concentrations remain under 80 µg/m$^3$ during the whole growing season. On three of them the highest 14-days average concentration was higher than 60 µg/m$^3$ but never exceeded 80 µg/m$^3$. The peak was detected between mid-June and mid-July.

- The highest 14-days average concentration was 64 µg/m$^3$ and 50 µg/m$^3$ on average on the most ozone-polluted plot, which is the same as last year.

### Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2

Ferlan M, Grah A, Kermavnar J, et al (2023) Poročilo o spremljanju stanja gozdov za leto 2022 = Report on health status of forests 2022. Ljubljana: Slovenian Forestry Institute, pp 89. https://www.gozdis.si/novice/porocilo-o-spremljanju-stanja-gozdov-2022/

## Spain

### National Focal Centre

Elena Robla González, Asunción Roldán Zamarrón,
Forest Inventory and Statistics Department | Subdirectorate General of Forest Policy and Fight against Desertification | Directorate General for Biodiversity, Forests and Desertification | Ministry for Ecological Transition and Demographic Challenge (MITECO)

### Main activities/developments

As a very brief summary, Spanish forest damage monitoring comprises:

- European large-scale forest condition monitoring (Level I): 14 880 trees on 620 plots
- European intensive and continuous monitoring of forest ecosystems (Level II): 14 plots

Level I and Level II surveys, data analysis, and reporting were carried out in 2023 as planned. Data were submitted to ICP Forests, employed for national and international reporting, provided to different stakeholders, and are available online (https://www.miteco.gob.es/es/biodiversidad/temas/inventarios-nacionales/redes-europeas-seguimiento-bosques.html).

Several data reviews were carried out as requested by the different Expert Panels from ICP Forests.

The expertlist has been enlarged and updated. The Spanish team (NFC and national experts) participated in the annual ICP meetings during 2023:

- April 2023: ICP Forests Combined Expert Panel Meeting (online)
- June 2023: 39th Task Force Meeting of ICP Forests (online)
- June 2023: 10th Scientific Conference FORECOMON 2023 (online)

### Major results/highlights

#### Level I

Mean defoliation observed in 2023 is 23.1% (considering all trees from Level I plots but excluding harvested trees). This is considered “slight” defoliation (class1: 11-25%), showing almost no change from 2022 (mean defoliation observed in 2022 was 23.1%). A good number of species show defoliation values over 25%, including some of the most Mediterranean species (*Quercus suber*, *Q. ilex*, *Q. faginea*, *Olea europaea*, *Juniperus thurifera*, *Q. pubescens*, *Castanea sativa*, *Pinus nigra*).

Regarding damage from different agents, 39.1% of the sampled trees showed no damage in 2023 (5815 trees), which is lower than the results from 2022 (5944 undamaged trees). The most abundant group is “Abiotic agents”, which is responsible for 41.8% of the detected damage (2.6% lower than in 2022), where drought causes 85.1% of the damage. “Insects” is the second group, being responsible for 24.8% of the detected damage (0.3% higher than in 2022). A decreasing trend in damage caused by defoliators in broadleaved species has been observed, but the damage caused by *Gonipterus scutellatus* in Eucalyptus are stable, while damage by *Thaumetopoea pityocampa* continued to increase in 2023. With regard to damage caused by wood borers, a slight increase has been observed, influenced by a higher incidence of attacks by *Coraebus florentinus* in *Quercus* and by *Phoracantha semipunctata* in Eucalyptus.

#### Level II

Results of Level II are complex and diverse. A summary can be obtained by consulting the publications mentioned in the next chapter.

### Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2

#### Level I

Maintenance and Data Collection. European large-scale forest condition monitoring (Level I) in Spain: 2023 results at national level and for every Autonomous Community (*Mantenimiento y toma de datos de la Red Europea de seguimiento a gran escala de los Bosques en España (Red de Nivel I): Resultados 2023).*

Evaluation of reference parameters from Level I plots for *Pinus halepensis*, 1987-2023 (Evaluación de los parámetros de referencia de la Red de Nivel I para *Pinus halepensis*, 1987-2023)

#### Level II

European intensive and continuous monitoring of forest ecosystems, Level II. 2022 Report. (*Red europea de seguimiento intensivo y continuo de los ecosistemas forestales, Red de Nivel II*)

These reports will be available at: https://www.miteco.gob.es/es/biodiversidad/temas/inventarios-nacionales/redes-europeas-seguimiento-bosques.html

## Outlook

Nowadays, data from ICP Forests are providing very useful information not only for monitoring the state of vegetation (data used for national and international reports), but also to fulfil the international requirements of climate change information. Litter, deadwood, and soil surveys are currently the main data source to assess carbon variation in these forestry pools.

In the framework of a collaboration between the National Institute for Agricultural and Food Research and Technology (INIA-CSIC) and the Ministry for the Ecological Transition and the Demographic Challenge (MITECO), several issues are in progress:

- Level I surveys are being carried out at a regional level by different regions (Autonomous Communities) in Spain. Both national and regional sources are integrated in a common database, which improves the information and potential analysis.
- Spanish National Forest Inventory-type plots were installed with the same centre plot location as Level I plots, in order to fill in the gaps in area estimation and complete the information with regard to the living biomass and stand variables. Dasometric parameters (mean diameter, basal area, mean height of living trees) are measured in Level I plots every 6 years. Further developments and data analysis are being developed in this line.
- Trend analysis of the vegetation health status and monographic studies focused on different species and causal agents are being developed on the basis of data from Level I surveys.
- INIA is working with data from Level II sites with the EU-funded projects "Pathfinder" (https://pathfinder-heu.eu) and MRV4SOC ("Monitoring, Reporting and Verification of Soil Organic Carbon and Greenhouse Gas Balance": https://cordis.europa.eu/project/id/101112754)

In addition, Level II sites are included in the Spanish branch of the Long Term Ecological Research Network (LTER) (https://lter-spain.csic.es/), and researchers from foreign entities collected data in some Level II plots for different purposes.

In 2024, work is expected to continue without incidences, and current research projects will continue to advance. Some research proposals based on Level I / Level II data could be confirmed.

## Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2

Suárez Herrera S, Cañellas I, Alberdi I, Hernández L, Moreno Fernández D, Oliveira N, Roldán A, Montes F, Adame P (2023) Seguimiento del estado de los bosques españoles: análisis de los daños causados por *Viscum album* subsp. *austriacum*. Revista Montes 155: 22-27. https://www.revistamontes.net/Buscador.aspx?id=15412

# Sweden

## National Focal Centre

Cornelia Roberge – Swedish University of Agricultural Sciences

## Main activities/developments

Monitoring activities continued on Level I. In 2009, a revised sampling design for Level I plots was implemented, where an annual subset of the Swedish NFI monitoring plots are measured. The Swedish NFI is carried out on a five years interval and accordingly the annual Level I sample is remeasured every fifth year. Defoliation assessments are carried out only on *Picea abies* and *Pinus sylvestris* sub-sample trees, while damage assessments are done on all sub-sample trees. The Swedish Throughfall Monitoring Network (SWETHRO) has delivered data on deposition, soil solution, and air quality to the Level II programme on a yearly basis.

## Major results/highlights

The major national results, based on the whole Swedish NFI sample, but concern only forests of thinning age or older. The proportion of trees with more than 25% defoliation for *Picea abies* is 22% and for *Pinus sylvestris* is 10%. Large temporal annual changes are seen on a regional level. The mortality rate in 2023 was for *Pinus sylvestris* 0.2% and for *Picea abies* 0.6%. The severe damage caused by spruce bark beetle (*Ips typographus*) in southern Sweden has continued after the dry summer in 2018. A Target-tailored Forest Damage Inventory (TFDI) of spruce trees killed by spruce bark beetle have been undertaken over the last few years. The results from the inventory showed that 5.1 million $m^3$ Norway spruce were killed during 2022. The inventory for spruce bark beetle damage during 2023 were made in a smaller area and the estimated volume of killed trees amounted to 2.2 million $m^3$.

In northern Sweden, there is concern for the young forest, mainly the pine forest. Several causes of damage interact. During 2022 a sample inventory of forest condition and damage in young forest in northern Sweden within the TFDI program was carried out. The results showed that just under 40% of all main tree stems have a damage. Grazing by wildlife dominate among the distinguishable known causes of damage, especially in pine. Fresh damage caused by moose were observed at 11% of the pine trees. Damage by resin top disease (*Cronartium flaccidum*) occurs throughout the area, however larger damage of resin top disease are mainly seen in the northern part. Otherwise as before significant damage problems in Sweden are due to pine weevil (*Hylobius abietis*) (in young forest plantations), browsing by ungulates, mainly elk, (in young forest), and root rot caused by *Heterobasidion annosum*. Data from Sweden on forest condition, deposition, soil solution, and air quality are besides in the ICP Forests Technical Report also included in several national reports and scientific publications. Data are also used to follow-up of Swedish Envoronmental objectives. Data are used in many "data requests", where participating researchers gain access to Swedish data.

### Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2

National reports are available for the Swedish NFI SLU National Forest Inventory | Externwebben on the link Publication list | Externwebben (slu.se) and the SWETHRO Publications - IVL Svenska Miljöinstitutet.

### Outlook

Monitoring activities on Level I will continue as previously. Also, data from SWETHRO on the Level II programme will continue. In 2024, another Target Tailored Forest Damage Inventory (TFDI) of damage caused by spruce bark beetles will be carried out in southern Sweden.

## Switzerland

### National Focal Centre

Arthur Gessler, Peter Waldner, Marcus Schaub, Stefan Hunziker, Anne Thimonier, Katrin Meusburger – Swiss Federal Research Institute WSL

### Main activities/developments

Besides the regular monitoring activities and data analyses on the Level I and Level II plots, particular emphasis was put on the following topics:

- On selected Level II plots combinations of drone- and aircraft-based hyperspectral remote sensing approaches were combined with ground-based assessments to construct a toolbox that allows to combine forest monitoring with remote sensing products on the larger scale. In addition, the HyPlant sun-induced fluorescence (SiF) sensor was tested at Swiss ICP Forests sites. This allows direct linkage to the future data products of the FLEX satellite misson (which uses a comparable SiF sensor) planned to be launched by ESA in 2025.
- Intensive studies are performed that assess mortality risks on the country scale with the help of machine learning approaces and how mortality is temporally related to defoliation trajectories.
- Assessment of the interactive impact of heat, drought, and mycorrhizal networks on the resistance and resilience of tree seedlings.

### Major results/highlights

Defoliation is increasing from 1990 to present: Over time, we see a clear increase in the average defoliation of both conifers and deciduous trees since 1990. In addition, the years in which the condition of the tree crowns improved have become more rare since around 2010, and the recovery of the trees was mostly less pronounced. This can be observed in particular for deciduous trees, where a reduction in defoliation (i.e., a recovery) compared to the previous year was only seen in four years after 2010. Similar to the average defoliation, the proportion of damaged trees also increased over time. In addition, an increase in the proportion of severely damaged trees and mortality has been observed in deciduous trees since around 2004.

Drought stress is the main driver for the observed defoliation trends: The long-term observations indicate that the increasing drought stress is mainly responsible for the deterioration of the crown condition in recent decades. This can mainly be attributed to the rising temperatures and thus the increased loss of water from the trees to the atmosphere.

High defoliation is a good predictor for future mortality risk: When trees surpass a particular defoliation threshold that is species-dependent but averages at about 70%, the risk of mortality in the following 4-6 years strongly increases. Thus, defoliation can serve as an early warning signal for the future mortality risk of trees.

### Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2

Hunziker S, Hug C, Gessler A (2024) Der Zustand der Baumkronen in den Schweizer Wäldern. In: Brockerhoff E. G. (ed.) Waldschutzüberblick 2023, Eidg. Forschungsanstalt für Wald, Schnee und Landschaft WSL, Birmensdorf, 14-15

Gessler A (2024) New approaches for monitoring forest functioning in a changing climate-crossing scales from molecular mechanisms to stand wide processes (No. EGU24-2683). Copernicus Meetings

Fawcett D, D'Odorico P, Ginzler C, Gessler A (2024) Investigating remotely sensed spectral indicators of tree vitality across scales and forest types (No. EGU24-16131). Copernicus Meetings

Garnot VSF, de Boer M, Spafford L, et al. (2024) SwissPhenoCam: Country-scale automated tree-phenology tracking from webcam imagery (No. EGU24-10858). Copernicus Meetings

### Outlook

- Linking ground-based monitoring with remote sensing; nowcasting of tree functioning underchanging climatic conditions

- WSL is a partner in the EU Project FORWARDS, where the Europe-wide assessment of global change and extreme events on forests is focused on. There are now first projects with and in future additional grants to external groups (preferentially to groups involved in ICP Forests) for complementary infrastructure and monitoring techniques
- WSL continues to contribute to the EU projects eLTER_PLUS[1] and eLTER_PPP[2] towards the harmonization of Standard Observations from existing networks (incl. ICP Forests) across Europe

# Türkiye

## National Focal Centre

Kamuran Birinci, Özlem Aktaş – Ministry of Forestry and Water Works, General Directorate of Forestry, Department of Combatting Forest Pests

## Main activities/developments

Participation in the ICP Forests monitoring network since 2006 in order to monitor the health of forests in our country and in the Level I and Level II programs was implemented based on the monitoring sites.

In 2023, on 584 Level I and 52 Level II monitoring plots the crown status and visual damage assessment was conducted and annual reports were published.

The preparations were completed to carry out the classified analyses on 680 Level I and 52 Level II monitoring plots suitable for taking soil samples from the 850 monitoring plots set up in 2015. In 2024, The analyses results will be uploaded to the ICP Forests database.

All measurements related to tree growth were completed for the 2015 and 2020 years on 52 Level II monitoring plots. In 2025, the third 5-year measurements will be made.

Following the detection studies carried out for the first time in 2018 in 52 Level II monitoring plots of the Vegetation and Biodiversity composition, detection studies were carried out throughout 2023, and there were 717 herbaceous and woody species.

Needle-leaf samples were taken on 52 Level II monitoring plots in 2015, 2017, 2019, 2021, and 2023. Analyses have been completed and the data will be transferred to the database in 2024.

Intensive monitoring was planned for 18 of the 52 Level II monitoring plots. Precipitation, deposition, litterfall, soil solution, phenological observations, and air quality sampling began to be studied. The analyses of the samples taken in the years 2017–2023 have been completed and will be transferred to the database after internal checking.

In 2023, 52 Level II monitoring plots were monitored for ozone damage. No ozone damage was found.

A laboratory was established in İzmir for the analysis of the samples taken from the monitoring plots in the Directorate of Aegean Forestry Research Institute. All requirements were completed and activated. In 2018, 2019, 2021, and 2023 water and needle-leaf and rash and soil ring tests were performed and passed.

The collected data are stored in the national database and the reports are taken from the database.

## Major results/highlights

In the Level II monitoring area, 1548 sampling was done for sulphur dioxide ($SO_2$), ammonia ($NH_3$), Ozone ($O_3$) and nitrogen dioxide ($NO_2$) cycles related to air quality. $NH_3$, $NO_2$, and $O_3$ pollutants were within the lower and upper limit values. It was determined that 15 (3.78%) of the $SO_2$ samples were above the upper limit value of 40 µg/m$^3$. 14 of these exceedances occurred in June and one in September.

On 584 Level I and 52 Level II monitoring plots, 21 075 trees in total were monitored. The avarage loss of leaves/needles detected was 20.4%, 38% for Level I and 19.8% for Level II. 25 kinds of insects, fungi, viruses, etc. that cause damage on the selected trees observed were monitored.

## Publications/reports published with regard to ICP Forests data and/or plots and not listed in Chapter 2

Temerit A, Adigüzel U, Firat Y, et al. Forest Ecosystems Monitoring Level I and Level II Programmes in Turkey. National Focal Centre. ISBN: 978-975-8273-92-8

Öztürk S, Tolunay D, Karakaş A, et al. Health State of Forests in Turkey (2008-2012). National Focal Centre. ISBN: 978-605-4610-44-0

Öztürk S Monitoring of forest ecosystems crown status evaluation photo cat-alog. National Focal Centre. ISBN: 978-605-393-038-9

Öztürk S Turkey oaks diagnosis and diagnostic guide. National Focal Centre. ISBN: 978-975-8273-92-8

Öztürk A (2016) Some botanical characteristics of maple (Acer) species naturally occurring in Turkey. National Focal Centre. General Directorate of Forestry. Journal of Forestry Research 2016/2 A, Volume 1(4), ISSN: 2149-0783

[1] https://elter-ri.eu/elter-plus

[2] https://elter-ri.eu/elter-ppp

## United Kingdom

### National Focal Centre

Caitlin Lewis – Forest Research

### Main activities/developments

- Retirement of previous site manager (Sue Benham) in April and start of new site manager (Caitlin Lewis) in June. Caitlin Lewis benefited from training on a CLEANFOREST STSM to visit Level II plots in Belgium.
- Elena Vanguelova, Sue Benham and Rona Pitman published a chapter "Responses of forest ecosystems to regional trends in nitrogen deposition" in the book "Atmospheric Nitrogen Deposition to Global Forests"
- Through a collaboration with the University of Edinburgh, funding was secured to install novel acoustic devices at two Level II sites (Alice Holt and Kielder Forest) in 2024 to monitor vertebrate activity.
- Engagement in the CLEANFOREST COST Action and attendance at the annual meeting in Thessaloniki and core group meeting in Bertinoro.
- Tree talker devices were installed at three Level II plots.
- Regarding two new Level II plots that were established late 2021: 2023 was the first time soil chemistry and foliar chemistry data was obtained for these plots, and the submission of throughfall and soil solution chemistry and meteorological data from 2022 was the first submissions for these two sites to the Level II database.
- Crown condition survey work at oak dominated Level I plots has been established, field survey work was undertaken in 2023 with additional data processing and engagement project scheduled to begin in 2024. In 2024 we aim to establish a framework for wider reporting, allowing forest owners and managers to monitor oak trees and woodland under their care. Ultimately, we hope that this case study of oak could be extended to include wider range of tree species.

### Major results/highlights

In their chapter "Responses of forest ecosystems to regional trends in nitrogen deposition", Vanguelova et al. reported trends in wet deposition at four UK Level II sites, finding significant declines 1996-2013/19 at all sites except for Thetford Forest, which is strongly influenced by emissions from surrounding agricultural activities.

### Outlook

In 2021 two new Level II plots were established under the UK Government's Natural Capital Ecosystem Assessment programme, of which the initial phase is due to end in 2025/26. The continuation of the NCEA programme is under consideration.

We continue to test new technologies into Level II plots, with plans to install tree talker devices and soil moisture and temperature probes in all plots by April 2025, and continued integration of innovative biodiversity monitoring equipment. We expect these technologies to answer questions around the role of vertebrates and invertebrates on chemical fluxes in forest ecosystems, and associated effects on tree health and growth.

We are working on analyses of European-wide Level II nitrate leaching data, investigating effects of former land use and topsoil nutrient availability on the capacity of forest soils to retain N inputs. We are also working on using Level II data to calibrate a biochemical model to simulate nitrate leaching fluxes under climate change scenarios and following changes in forest management.

The Level II plots continue to be utilized by external researchers for projects on LiDAR scanning and green house gas fluxes. Future plans revitalise the branding of "Research Forests" for the forests with a Level II plot will encourage further use of the areas around the plots for additional research.

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as of 1 December 2024

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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
http://icp-forests.net

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