40 YEARS ICP FORESTS

2025

Forest Condition in Europe

The 2025 Assessment

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

UNECE
Convention on 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 (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

Contact

Programme Co-ordinating Centre of ICP Forests
Kai Schwärzel, Head
Thünen Institute of Forest Ecosystems
Alfred-Möller-Str. 1, Haus 41/42
16225 Eberswalde, Germany
Email: pcc-icpforests@thuenen.de

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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 2025 Technical Report presents results from 32 of the 42 countries participating in ICP Forests. Part A presents research highlights from the January–December 2024 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 80 scientific publications for which ICP Forests data and/or the ICP Forests infrastructure was used;
- a list of 18 presentations and 33 posters at the ICP Forests Scientific Conference FORECOMON 2024 in Prague;
- a list of all 32 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 2023
- Meteorological conditions in European forests in 2023
- Tree crown condition in 2024.

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].

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

Atmospheric deposition is an important pathway by which pollutants can 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, but also by dry deposition, which includes several processes such as gravitational settling (particles) or adsorption on forest canopies (particles and gases).

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 uneven distribution of pollutant sources, local topography, tree species composition, and canopy structure.

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 2023.

As in previous years, high values of nitrate deposition were primarily found in central Europe but also in Belgium, Denmark, and northern Italy. The number of plots with high ammonium deposition was greater than for nitrate, and high values were found all across Europe except for northern and north-eastern countries. High throughfall deposition of the sum of inorganic and organic nitrogen was recorded primarily in central Europe, but also in Belgium, Italy, and some plots in other countries.

Sulphate deposition has significantly decreased since the start of the monitoring and currently the highest depositions are found in central and southeastern Europe.

Calcium and magnesium deposition can buffer the acidifying effect of sulphur and nitrogen deposition. High values of calcium deposition are reported in southern and southeastern Europe, mainly related to the deposition of Saharan dust, and in central Europe. High values of magnesium deposition occurred mainly in central and southeastern Europe.

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 2023 focuses on presenting and interpreting air temperature and precipitation data from ICP Forests Level II sites

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

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

in 2023 and compares them with long-term mean values for different climatic regions in Europe (1990–2020).

According to the European State of the Climate 2023 report, 2023 was the second warmest year on record. Much of southeastern Europe, as well as parts of western and central Europe, experienced their warmest year on record, and the season was marked by periods of extreme weather.

At the ICP Forests sites, annual mean air temperature and mean air temperature during the vegetation period was higher in 2023 than the long-term average (1990–2020) with some regions experiencing up to 3.5 °C higher mean temperatures than normal.

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. Level II plots in five countries experienced maximum air temperatures above 40 °C in 2023 and the number of hot days above 30 °C was higher than the long-term average in six out of eight European climate regions according to Koeppen. All climate regions experienced fewer late frost days than normal.

Both, precipitation over the course of the year and in the vegetation period in 2023 was highly unusual with distinct geographical patterns. It was more than 75% higher in western, central, and northern Europe, and up to 75% lower in southern and southeastern Europe.

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 2024, as well as long-term trends for the main tree species and species groups.

In 2024, the overall mean defoliation for all species was 24.2%. There was a very slight increase of 0.2 percentage points (%p) in mean defoliation as compared to 2023, mainly due to an increase of 0.5%p for broadleaves, while defoliation of conifers remained almost unchanged (0.1%p decrease). The strongest increase in defoliation occurred in deciduous (sub-) Mediterranean oaks (+2.1%p), while the strongest decrease was recorded in Norway spruce (-0.8%p). Deciduous temperate oaks had the highest (29.7%) and Norway spruce the lowest (22.4%) mean defoliation.

Trend analyses show a considerable increase in defoliation of evergreen oaks (+7.1%p), common beech (+6%p), Norway spruce (+5.5%p), and deciduous temperate oaks (+5%p) over the past 20 years. The increase in defoliation for Scots pine and Mediterranean lowland pines (+3.7 and +3.3%p, respectively) was more moderate. The results of the trend analyses were not significant for deciduous (sub-) Mediterranean oaks and Austrian pine.

The percentage of trees with damage symptoms (48.6%) was almost the same as in 2023 (-0.5%p). As in previous years, the number of damage symptoms per assessed tree was substantially higher for broadleaves than for conifers (0.86 vs. 0.55, 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 2024 was 1.1% (1 145 trees), i.e. at the same level as in the year before. While mortality rates for the main species and species groups ranged from 0.6 to 1.6%, mortality of *Betula* spp. and European ash was higher with 2.4% and 7%, respectively.

CONTENTS

ONLINE SUPPLEMENTARY MATERIAL

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

FOREWORD

Dear Reader,

the ICP Forests celebrates its 40th anniversary in 2025. In the middle of the 1980's European forests were suffering from air pollution and acid rain. These led, especially in the so-called "Black Triangle" region on the borders of Germany, Czechoslovakia, and Poland, to the pronounced decline of forests, which raised concerns among experts and society. The political situation was not easy at that time, Europe was divided by the Iron Curtain into western and eastern parts. Concerns for the future of our forests, however, led to something that was difficult to imagine until then – to the birth of a common European monitoring program and I am happy to recall that the former Czechoslovakia played an important role in the process and even led the Programme Co-ordinating Centre for Eastern Europe, PCC EAST, during the first decade.

Since the very beginning, the ICP Forests program worked with uniform methods, starting with the assessment of forest health based on defoliation and with a gradually expanding portfolio of other parameters. An important step forward was the establishment of the second level of the program – the Intensive Monitoring of Forest Ecosystems in the mid-1990's. Thanks to this, we currently have available long-term harmonized data on the forest environment (meteorology, soil properties, atmospheric deposition, air pollution) as well as on the state of our forests (forest health, growth, phenology, foliage chemistry, litterfall amount and composition).

A lot has changed during the last 40 years. The European Union has been established and spread, the air pollution by sulphur and nitrogen has decreased significantly but new challenges and threats have emerged in the meantime.

In the field of forestry, these are mainly concerns related to the development of forests in times of climate change and the requirements to reconcile the principles of forest management with the strengthening of forest stability and resilience, enhancing biodiversity, and meeting very diverse demands of society. The demand for harmonized data on forests is growing as evidenced by several EU strategies (e.g. New EU Forest Strategy for 2030, EU Biodiversity Strategy for 2030) or upcoming regulations or directives (e.g. EU Forest Monitoring Law, EU Soil Monitoring Law). Practical solutions sometimes clash with the differing experiences of Member States, the intentions of the European Commission and the interests of Members of the European Parliament. The ICP Forests program is an example of how common agreement was achievable even in times of much more complicated international relations and should also serve as the solid basis for a harmonized methodological approach with existing long-term data series that can be expanded and used to support society-wide visions in the field of forests and forest management.

Marek Výborný
Minister of Agriculture of the Czech Republic

On-site participants of the 40th ICP Forests Task Force Meeting in Prague, 13–14 June 2024

FOREWORD

Dear Reader,

in the year of the 40th Anniversary of the ICP Forests, it is my pleasure to introduce the 2025 Assessment of the Forest Condition in Europe. This report is the last of a series that started in 1987, when the results of the first international survey on "forest damage" were published. The 2025 edition provides an account of the most recent results obtained by the largest long-term, internationally co-ordinated and harmonized forest monitoring program in Europe.

The 2025 report provides further evidence that our forests are under pressure. In 2024, defoliation recorded on Level I plots continued to increase, with a trend that accelerated over the past ten years, and with a distinct evidence of drought-related symptoms on trees. Available meteorological data from Level II plots revealed that the year 2023 was warmer than the long-term average, also in the vegetative period. On the other side, precipitation increased over large parts of Europe, with perhaps the exception of southern and south-eastern countries. Deposition of sulphur (S) and nitrogen (N) showed distinct spatial patterns in 2023, with high N deposition levels mainly recorded in central Europe and generalized low levels of S deposition. Though not reported here (but see the Anniversary Report), it is worth mentioning that – although locally still high – both N and S deposition has substantially reduced over the past decades.

The pan-European monitoring system installed under the ICP Forests plays a unique role in tracking the condition of our forests over the long term and at a large scale. Forests develop in a multivariate dimension: For this, 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.

It is for this reason that a program initially conceived to monitor the effects of air pollution is able to provide now invaluable data also to assess the response of forests to climate change. A clear demonstration of this value is shown by the high demand of ICP Forests data from the scientific community, resulting in an increasing number of publications in high-impact journals.

While rewarding, these results require enduring commitment, perseverance, and support. For this reason, 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 who 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 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 5730 observation plots (as at 2024) 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 639 plots (as at 2023, 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 co-ordinated 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 40 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 2024

People

- We are extremely grateful to our colleague Peter Roskams for his dedication to ICP Forests and his expertise and friendship shared with us. Peter retired in 2024 after being involved since 1987 and taking on various positions, e.g. as Chair of the EP Crown Condition and Damage Causes, NFC representative for Belgium-Flanders, and member of the Programme Co-ordinating Group.
- We are also extremely grateful to Panagiotis Michopoulos (NFC Greece), who also retired in 2024, for his longstanding co-operation, expertise, and dedication to ICP Forests.
- Our thanks also go to many other international colleagues who have served on the various Expert Panels over many years and who have retired or moved on to other activities in 2024.

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:
  - Manual changes for Growth (new attributes and dictionaries);
  - Litterfall database reconstruction accomplished:
    - Form LFM (littefall measurements) has been split-up into three new Forms: LFD (dry weights), LFC (chemical analysis), and LFA (area and mass).
    - The main purpose of the litterfall database conversion was to make the submission of data clearer, to minimize inadvertent errors/inconsistencies, and to simplify the analysis considerably.

[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

- In addition to that the fraction codes have been revised to make them more complete and precise.
- Data discrepancies have been corrected as far as possible.

Outreach and reporting

- The latest results from the Working Group on Quality Assurance and Quality Control on the 27th Needle/leaf Interlaboratory Comparison Test 2024/2025 with 42 laboratories from 24 countries, the 13th Deposition and Soil Solution Working Ringtest 2024 with 35 labs from 22 countries, and the 10th Soil Ringest 2021 with 32 labs from 21 countries were 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 80 in 2024[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.
- The ICP Forests data has become a valuable resource for international scientists from across the world and a wide range of disciplines. In 2024, the PCC has received 32 requests for ICP Forests data for studies ranging from soil microbiology to AI technology.
- A range of 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 aims to raise awareness about air pollution, sources, effects, ways to prevent it, and the Convention as a framework for co-operation on cleaner air. Another e-learning course is on emission inventory development under the Convention, also available in English and Russian.

Program meetings

- The EMEP Steering Body and Working Group on Effects under the UNECE Air Convention met on 28 February–1 March 2024 and 9–13 September 2024[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. Joint thematic sessions were held to discuss the topics: (1) nature restoration and air pollution, (2) managing uncertainties, and (3) the impact of climate change policies on air pollution.
- At the Joint Expert Panel Meeting (18–22 March 2024) in Athens, Greece, 74 experts from four Expert Panels and Working Groups (Deposition; Growth; Meteo, Phenology, and LAI; Soil Solution) discussed current issues and developments in their respective field. We are very grateful to Panagiotis Michopoulos (NFC Greece) and his colleagures from the Hellenic Agricultural Organization "DEMETER" for the organization.
- The 11th ICP Forests Scientific Conference FORECOMON and the 40th ICP Forests Task Force Meeting, with 65 participants from 24 countries, was held in Prague, Czechia, 10–14 June 2024 and organized by the Forestry and Game Management Research Institute under the auspices of the Czech Ministry of Agriculture and the Czech Ministry of Environment.
- The Programme Co-ordinating Group (PCG), Quality Assurance Committee, and Scientific Committee met in Berlin, 20–21 November 2024, to discuss current issues and progress of the ICP Forests.

Acknowledgements

We wish to thank the Federal Ministry of Agriculture, Food and Regional Identity (BMLEH) 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 40 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

Table 1-1: Overview of the number of Level II plots per survey and country for which 2023 data were submitted to the ICP Forests Database by 2 April 2025

	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										
Belgium	5	12	9	12			5	5		7		5		5
Bulgaria	4	4	4						3	4	2	1		3
Croatia		7	4	7					4		2	4		3
Cyprus	1	4	2							2				2
Czechia		15	7	8			7		7	12		6		7
Denmark		4	4	4	4	4	3		4	4		3		4
Estonia		6	6	6					1	1				5
Finland		6	7	6						8				8
France			27	93			87			13	14			14
Germany	30	70	88	36	21	14	47	12	14	81	8	58	1	72
Greece		4	3	4					3	4	4			2
Hungary		7	9					7						
Italy	6	29	8		9						6			7
Latvia	1	3	3	3				3	3					3
Lithuania	3	9	3	9					3	1	9	1		3
Norway		3	3	3										3
Poland	12	133	12							12				12
Romania	4	11	4	4			4	3		4		4		4
Serbia		5	5	3	5		3	3	5	3		5		3
Slovakia	3	9	7	8						6	8			4
Slovenia	10	10	4							10		8		4
Spain	14	14	14	14			14	14	14	14	14	14		5
Sweden			50											
Switzerland	6	17								18	8			
Türkiye		52												
United Kingdom	7		7	7			5		6	7				7
Total	**106**	**434**	**305**	**242**	**39**	**18**	**175**	**47**	**67**	**211**	**75**	**109**	**1**	**180**

PART A
ICP Forests-related research highlights

2

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

Lars Vesterdal, Marcus Schaub, Kai Schwärzel, Marco Ferretti, Nathalie Cools, Bruno De Vos, Stefan Fleck, Leena Hamberg, František Máliš, Aldo Marchetto, Tiina M. Nieminen, Diana Pitar, Andrei Popa, Nenad Potočić, Stephan Raspe, Tanja Sanders, Andreas Schmitz, Volkmar Timmermann, Monika Vejpustková, Arne Verstraeten, Peter Waldner, Lena Wohlgemuth, Lothar Zimmermann

Introduction

Forests are increasingly threatened by climate change-related factors, and drivers associated with air pollution continue to play a role for forest ecosystem functioning. Knowledge and a better understanding of temporal forest dynamics is necessary to identify management practices to foster forest resilience, maintain biodiversity, and provide ecosystem services. Continued monitoring is essential to document progress in reducing the impact of air pollution on forests, an important factor affecting the health and sustainability of forest ecosystems around the world, especially under the concurrent pressures of annual meteorological fluctuations and long-term climate change.

The data generated by the monitoring networks installed under ICP Forests demonstrate their 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 in combination with climate change. 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 – 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, including nitrogen (N) deposition, ozone (O_3), heavy metals and air pollution-climate change interactions. EPs based their input on scientific publications from ICP Forests or elsewhere 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, nutrients, and water across the three compartments, some overlap exists among the different chapters. Linkages 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

A European-scale study investigated the phyllosphere microbiomes of beech leaves and Scots pine needles along a nitrogen deposition gradient (Sangiorgio et al. 2024). Functional genes linked to carbon and nitrogen cycling such as nitrate reduction, nitrogen fixation and ureolysis varied with tree species and N deposition levels, thereby shedding light on canopy nitrogen transformation and uptake processes that may play a more important role on the intercellular level than previously assumed. Further research is needed to better understand the implications for total nitrogen deposition estimates.

Hůnová (2024) reviewed factors influencing fog deposition, presenting its contribution to atmospheric deposition at high altitude sites in Czechia. Total atmospheric sulphur depositions for the years 2014–2022 were estimated at sites within the Swedish Throughfall Monitoring Network (Pihl Karlsson et al. 2024). These estimates were derived using canopy budget modelling, based on measurements of bulk deposition, throughfall and dry deposition, the latter quantified with string sampler under a roof at 11 sites. The results indicate that the coniferous forest canopies in Sweden absorb approximately 0.1-0.8 kg S ha^{-1} yr^{-1}, with uptake being particularly pronounced during summer months.

Ambient air quality

Over the past year, research on air quality and its effects on vegetation has advanced significantly. Lukasová et al. (2025) investigated the sensitivity of Pinaceae species in the High Tatra Mountains to elevated ozone levels, revealing that these species are vulnerable to concentrations well above typical ambient levels, with notable variation in ozone tolerance among species. Wang et al. (2024) analyzed tropospheric ozone pollution in Europe, identifying high concentrations in northwest Europe, Poland, and southeastern coastal areas. Their projections suggest further increases in certain regions, emphasizing the need for co-ordinated management strategies. Vieira et al. (2025) used the JULES model to simulate the effects of ozone on gross primary production in European forests, finding significant reductions in productivity linked to ambient ozone exposures, with outcomes influenced by local vegetation and climate. Similarly, Cheesman et al. (2024) examined the effects of ground-level ozone on tropical forests, detecting a marked decline in net primary productivity – particularly across Asia – leading to diminished carbon sequestration. Their findings highlight the critical importance of mitigating ozone formation to sustain forest productivity and ecosystem services.

FOREST VEGETATION

Forest growth

Forest growth is affected by a complex interplay of various environmental factors. While climate change and atmospheric deposition continue to impose increasing stress (Vallicrosa et al. 2024), there are also notable signs of resilience within forest ecosystems. In Hungary, for example, research into the 2022 heatwave and drought – which followed a prolonged dry spell from 2018 to 2021 – showed a surprising resilience of forest stands, even after significant water deficits of up to 204 mm (Bolla et al. 2024). In the Carpathian Mountains, Norway spruce was found to be increasingly vulnerable to climate change, with resilience varying along elevational gradients (Popa et al 2024a,b). Monitoring indicated a 14% loss in summer foliage, yet forests showed notable recovery by 2023. Satellite imagery corroborated these observations, highlighting the severe drought effects in 2022, followed by signs of recovery. This finding aligns with broader European trends, where tree mortality and defoliation are closely linked to recurring climate-driven disturbances (Bussotti et al. 2024). At the continental scale, projections suggest a decline in beech growth in northwestern central Europe and in the Mediterranean, while growth is expected to increase in the high-elevation zones of the Alps and Carpathian Mountains under various climate scenarios.

To support adaptive forest management, hybrid simulation models have been employed – such as one used in Germany's low mountain ranges (Byun et al. 2024) –, which evaluates how different silvicultural approaches (e.g. plantation, continuous cover forestry, and forest reserves) influence tree growth. These simulations, grounded in local expertise and mid-term monitoring data, provide valuable guidance on tailoring forest management practices to promote long-term forest health and productivity.

Understanding intra-annual tree growth patterns is also crucial, and dendrometers are key tools in this effort. High-resolution data from electronic band dendrometers, coupled with wood anatomical analyses, have proven instrumental in assessing how climatic variations – particularly temperature and soil moisture – affect tree growth (Debel et al. 2024; Krause and Sanders 2024). Observations from contrasting years such as 2020 and 2021 show that warmer, drier conditions tend to reduce tree growth (Kleese et al. 2024), whereas cooler, wetter years promote more substantial tree ring formation.

Nitrogen deposition continues to play a significant role in forest growth dynamics, especially in relation to varying climatic conditions. While increased nitrogen input can enhance conifer growth up to a certain threshold, it may negatively affect broadleaf tree species. The sensitivity to nitrogen deposition varies with the climatic context: Cooler regions favor conifer responses, while warmer climates amplify the response of broadleaved species. Understanding these interactions is essential for forecasting future forest growth patterns under climate change.

In summary, these studies underscore the complexity of forest growth under climate change, shaped by drought, nitrogen deposition, and forest management practices. The integration of advanced monitoring tools – such as dendrometers and satellite imagery – is crucial for developing informed and resilient forest management strategies.

Forest health

In recent years, the frequency and intensity of forest disturbances have increased significantly, leading to widespread defoliation, crown dieback, and tree mortality across Europe. The ICP Forests monitoring network provides a unique platform for tracking these changes and assessing the impacts of heatwaves, droughts, and other extreme climatic events on forests. The extended data series also enable the assessment of long-term defoliation and mortality trends, providing insights into the adaptive potential of different forest tree species under current and projected climate conditions. To better understand the complex interactions between tree- and ecosystem responses and changing environmental conditions, new methodological approaches – particularly the integration of remote sensing technologies combined with traditional field assessments for ground truthing – are being increasingly adopted.

Xu et al. (2025) leveraged annual field data from the German National Forest Condition Survey (Waldzustandserhebung, WZE) to assess crown defoliation of European beech during the drought-impacted years from 2016 to 2022. The study focused on the German federal states of Schleswig-Holstein, Lower Saxony, and Hesse, using a combination of static geo-ecological parameters (derived from digital elevation models and soil data) and dynamic indicators from Sentinel-2 vegetation indices and soil moisture estimates. Dynamic variables significantly improved model performance, with soil moisture emerging as a key predictor. The results underscore the importance of incorporating vegetation indices in future modeling efforts to enhance the accuracy of defoliation mapping.

In Türkey, Ciftci et al. (2024) analyzed the relationships between recent climate variability and tree health across 277 ICP Forests Level I plots spanning the Black Sea and Mediterranean regions. Six key species were assessed for defoliation and vitality responses using long-term data (2008–2020) on normalized difference vegetation index (NDVI), alongside climate records. Time-lagged correlations revealed species-specific sensitivities to temperature and precipitation, with temperature generally exerting a stronger influence. Trees in the Mediterranean region demonstrated greater resilience to drought and climatic extremes. Legacy effects of defoliation and NDVI reductions were found to persist for at least two years, highlighting the long-term impact of stress events.

Ecke et al. (2024) introduced an innovative approach combining UAV-based remote sensing with traditional field monitoring across 235 Level I plots in Bavaria from 2020 to 2022. High-resolution multispectral drone imagery was analyzed using Convolutional Neural Networks to identify five main tree species and assess their crown condition. Despite diverse weather conditions, forest structures, and site characteristics, the method effectively classified health status and detected dead trees. The authors advocate for broader adoption of UAV-integrated monitoring across the ICP Forests network to improve efficiency, reduce fieldwork demands, and enable standardized assessments at scale.

A pan-European assessment of defoliation chronologies was performed by Rukh et al. (2024) on 414 ICP Forests Level I beech plots, between 1995 and 2022, with the temporal trends, spatial variation, tree-specific patterns as well as climate sensitivity of defoliation investigated at plot level. Depending on the defoliation trends, plots were categorized as follows: (1) plots with increasing defoliation trends indicating declining vitality; (2) plots with no trends indicating stable crown condition; and (3) plots with decreasing defoliation trends indicating an increase in vitality. Spatial variation was found among these plots but no regional grouping or clustering. Defoliation was found to be sensitive to climatic variables, mainly to temperature but also precipitation, albeit only for a small percentage of plots. This response depended on the month of the year. Climate sensitivity of defoliation varied across space and plots of different trend categories. It also differed along a monthly water balance gradient, further indicating the role of site-specific water availability in mediating the responses to climatic variables. The study provides basis for long-term defoliation studies, and is a crucial building block to assess beech vitality in a changing climate.

Bussotti et al. (2024) assessed the response of main tree species to severe climatic events across 261 ICP Forests Level I plots in Italy. Since 2010, a notable trend of increasing defoliation and mortality has been observed in both conifers and broadleaves. Alpine conifers, particularly Norway spruce (*Picea abies*), suffered from bark beetle outbreaks and recurring droughts, while deciduous broadleaved trees in temperate regions showed the most severe defoliation during the driest and hottest years in 2012, 2017 and 2021–2022. Downy oak (*Quercus pubescens*) demonstrated strong resilience, with crowns recovering after defoliation events. The Mediterranean forests showed no consistent trends but experienced impacts at the most drought-prone coastal sites. The findings reaffirm that the current ICP Forests network represents an indispensable infrastructure for assessing species-specific responses to climate change.

Forest fruiting

Fruit biomass is a key indicator of tree reproductive success and plays an important role in forest resilience and recovery following disturbance. Within the ICP Forests database, litterfall dry weight data for fruits and seeds are available from a total of 281 Level II plots. These data are particularly valuable for studying the dynamics of tree species that exhibit masting behavior, such as European beech (*Fagus sylvatica*).

During mast years, beech trees produce an exceptionally high number of fruits in a synchronized manner across stand, regional, or even continental scales. This synchrony enhances reproductive success by improving pollination efficiency and reducing seed predation through predator satiation. Mast seeding in beech is believed to be climate-driven, making seed production especially sensitive to changes in weather patterns under ongoing climate change.

In a large-scale study of European beech that incorporated ICP Forests litterfall data, Foest et al. (2024) investigated the potential breakdown of masting – defined as a decline in interannual variation and synchrony of seed production – which could compromise reproductive success. They found that masting breakdown was associated with June–July temperatures, that are elevated relative to long-term summer averages of respective study sites. Notably, this indicates that the risk of masting breakdown is not confined to beech forests in already warm climates. As such, ongoing climate warming is likely to disrupt masting behavior of beech, with negative implications for the sustainability of this dominant forest species.

Complementary findings by Hacket-Pain et al. (2025) showed that increased reproductive effort in beech led to a 28% reduction in annual growth, independent of concurrent summer droughts. This indicates that reproductive investment itself contributes to growth decline, potentially compounding the effects of mast collapse.

Together, these studies highlight the need to expand seed and fruit monitoring within the ICP Forests network to better understand how climate change is affecting reproduction and growth in beech and other masting tree species.

Meteorological trends and effects on forests

Current understanding of climate and climate change impacts on biodiversity and ecosystem functioning is often based on macroclimate data available at spatial scales that are much coarser than the microclimatic conditions experienced by microorganisms. Zellweger et al. (2024) combined microclimatic measurements across different habitats and vertical heights with a novel radiative transfer model to map daily temperatures during the vegetation period at 10 m spatial resolution across Switzerland, which provided the basis for deriving microclimatic parameters on a country-wide scale. The results showed strong horizontal and vertical variability in microclimate temperature, particularly for maximum temperatures at 5 cm above the ground and within the topsoil. Compared to macroclimate conditions as measured by weather stations outside forests, diurnal air and topsoil temperature ranges inside forests were reduced for example by up to 3.0 and 7.8 °C.

Češljar et al. (2024) related SPEI data to forest defoliation and tree desiccation-induced mortality after prolonged drought period on ICP Forests plots in a National Park in western Serbia. The results suggest that even if mixed coniferous-deciduous forests are often considered less vulnerable to natural influences, these forest ecosystems can become vulnerable regardless of tree species composition due to multi-year droughts.

Ciftci et al. (2024) compared forest health data from 277 ICP Forests Level I plots in Turkey for six tree species grown along the Black Sea and the Mediterranean with long-term data from satellite measurements of the normalized difference vegetation index (NDVI) and with climatic ECMWF (European Centre for Medium-Range Weather Forecasts) variables. Correlations and cross-correlations of climate variables and tree health and vitality revealed that temperature had a stronger effect on most species than precipitation. Time-lagged correlations were analyzed for seven-time lags to evaluate any legacy effects. Species in the Mediterranean seemed to be more resistant to droughts and climatic variations than the species along the Black Sea. Legacy effects of defoliation and NDVI have lasted for at least 2 years.

Forest understory species composition and diversity

Kermavnar and Kutnar (2024) studied potential climate change and eutrophication effects on understory vegetation in Slovenian ICP Forests Level II plots. In montane beech sites and alpine spruce forests, thermophilization was detected whereas eutrophication effects were most significant on nutrient-poor sites. The study indicated ongoing ecological homogenization of the understory vegetation, i.e., plant communities at sites positioned at the ends of the climate and eutrophication gradients were losing their original diversity and were converging towards those at mid-gradient sites that generally exhibited smaller changes.

ICP Forests Level I and Level II plots have been used for studies of understory functional diversity, trait distributions, and invasive species. In Italian ICP Forests Level I plots, Chelli et al. (2024) found that the functional diversity of forest understory vegetation (specific leaf area, plant size, seed mass, and bud bank) was affected by climate, soil, and forest structure.

Boreal forest understory plant community trait distributions in ICP Forests Level I plots in Finland were modified by different selection types (directional, stabilizing, and divergent selection), and the selection type acting on individual traits may change over time (Kaarlejärvi et al. 2024). In the ICP Forests plots in Bulgaria, invasive alien plant species were found frequently in plots affected by human activity (Glogov et al. 2024).

The amount of deadwood – an important component for forest biodiversity – was investigated in ICP Forests Level I plots in 19 European countries (Augustynczik et al. 2024). Conifer-dominated areas had lower deadwood amounts compared to broadleaved-dominated areas and mixed forests. Deadwood amounts increased with aboveground biomass and average forest age up to approximately 150 years old.

FOREST SOIL

Forest soil acidification is a slow, long-term process mainly caused by air pollution from industry and agriculture, releasing nitrogen and sulphur into the atmosphere. Despite a decrease in nitrogen and sulphur deposition in recent decades, soil acidification continues to increase (Skidmore et al. 2024) and remains a persistent challenge to European forest health. Rousseau et al. (2024) found that in Dutch and German forest soils, bacterial diversity continues to decline under severe acidification. In the Ore Mountains, Novotny et al. (2024) showed that the prevailing acid soils are often deficient in exchangeable calcium and magnesium, and show a decrease in available phosphorus. This is reflected in the foliage chemistry, where a nutrient imbalance has been observed. This poses a risk on our future forests and therefore, forest management must take these aspects into account (Du et al. 2024).

The important role of old-growth and minimally disturbed forests in long-term carbon sequestration was demonstrated by Motkan et al. (2025). They showed that temperate forests in Central Europe that have remained unmanaged with little to no historical human impact tend to store significantly more soil C than recently managed forests.

Deadwood as an important input to maintain soil C stocks was studied in the Norwegian ICP Forests Level II plots (Stokland and Alfredsen 2024). Norway spruce (*Picea abies*) wood decomposition transferred 39–47% of the initial wood carbon to the soil carbon pool in different soil types. Results indicated that the carbon flux from deadwood to the soil carbon pool is higher in boreal forests than in temperate and tropical forests, due to different decay mechanisms (brown vs. white rot) in the respective forest ecosystems.

Air pollution can lead to the accumulation of heavy metals in forest soils, posing potential risks to ecosystem and human health. Ballabio et al. (2024) showed, based on LUCAS soil inventories covering all land uses, that 72.6% of the European topsoils do not contain any detectable concentrations of Cd. The mean measured concentration in woodlands is 0.17 mg kg^{-1} soil and is comparable with the overall mean of cadmium (Cd) in topsoils across Europe. Although the ICP Forests 2021 Technical Report showed higher average values in the topsoils of ICP Forests plots, similar spatial distribution patterns at the European scale were observed.

Conclusions

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

- Molecular studies of the phyllosphere microbiome indicates that canopy N cycling processes vary with tree species and N deposition levels, suggesting a more important role of canopy N transformations for total N deposition processes than previously assumed.
- Ozone concentrations continue to be high in specific regions of Europe, and significant reductions in productivity are reported highlighting the importance of mitigating ozone formation to sustain forest productivity and ecosystem services.
- Forest growth was extensively affected by climate-change related factors, but the sensitivity to nitrogen deposition varies with climatic context and tree species. Understanding climate change, N deposition and forest type interactions is essential for forecasting future forest growth patterns under climate change.
- Forest health remains concerning with increased defoliation and mortality mainly attributed to climate extremes. Innovative approaches combining remote sensing with traditional field monitoring are recommended to improve efficiency of health monitoring, and enable standardized assessments at scale.
- Climate warming is likely to disrupt fruiting patterns of beech forests, with negative implications for regenerative success and wood production and eventually also for the sustainability of this dominant forest species.
- Forest understory plant communities are affected by both climate change and eutrophication with resultant changes in species and trait diversity, and the plant communities seem to become more similar across different environmental gradients.
- Forest soils in several regions have not yet recovered from previous high acidification loads with consequences for soil microbiome diversity and nutrient availability. Forest management intensity was confirmed as a driver of soil carbon stocks, and the carbon flux from deadwood to the soil carbon pool was higher in boreal forests than in temperate and tropical forests. The spatial pattern of forest soil Cd across the ICP Forests plots was largely in agreement with that reported from the LUCAS soil monitoring network, but Cd levels were higher in ICP Forest plots.

ICP Forest is unique in its role as a pan-European, science-based monitoring program and shows how maintenance of up-to-date information on tree vitality status and trends is indispensable. The combination of detecting changes along with an improved understanding of the underlying processes is required to maintain future resilient forests.

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3

OVERVIEW OF ICP FORESTS-RELATED PUBLICATIONS (JANUARY–DECEMBER 2024)

Between January and December 2024, 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 80 English online and in print publications from 2024 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].

Aas ER, De Wit HA, K. Berntsen T (2024) **Modeling boreal forest soil dynamics with the microbially explicit soil model MIMICS+ (v1.0).** Geosci Model Dev 17:2929–2959. https://doi.org/10.5194/gmd-17-2929-2024

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

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4

FORECOMON 2024 – THE 11TH FOREST ECOSYSTEM MONITORING CONFERENCE

The 11th Forest Ecosystem Monitoring Conference *Monitoring for future forests* was organized under the auspices of the Czech Ministers of Agriculture Marek Výborný and of Environment Petr Hladík, the Czech Forestry and Game Management Research Institute, the ICP Forests Scientific Committee, and the ICP Forests Programme Co-ordinating Centre. It was held online on 11-12 June 2024 in conjunction with the ICP Forests Task Force Meeting.

Background

European forests are increasingly affected by climate change-driven stressors, which in combination with air pollution strongly reduces tree health and increases the risk of tree mortality. This poses a threat not only to wood production, but also to other ecosystem services such as biodiversity, water, soil protection, carbon sequestration, and recreation. Long-term forest monitoring plays an indispensable role to address the influence of global change on forest ecosystems including their resilience toward specific climate extremes and air pollution.

Since almost 40 years ICP Forests monitors the interactive effects of air pollution, climate, site, and stand factors on our forests under the UNECE Air Convention. This has resulted into a unique harmonized and standardized asset of long-term data, which allows scientists, stakeholders, and policy makers to assess status, trends, and functioning of European forest ecosystems in a changing environment.

The goal of FORECOMON 2024 was to highlight the unique ICP Forests data series and to demonstrate how data are used to support the development of future monitoring activities in European forests. Besides scientists, stakeholders and decision and policy makers are welcome to join the discussions on opportunities and needs of future forest monitoring.

Contributions were welcome addressing how forest monitoring can identify relevant current and future pressures and responses, and how timely development of new monitoring schemes can support the development of resilient forests that fulfill the various functions and services to society.

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 and poster presentations at the 11th FORECOMON Conference. All conference abstracts are available from the FORECOMON 2024 website[1].

Session 1: Long-term forest ecosystem processes as affected by air pollution, drought or other extreme weather events

Presentations

Delhaye G, Arrigoni E, van der Linde S, et al: **Spatiotemporal drivers of ectomycorrhizal diversity in Europe**

Dirnböck T, Kobler J: **Multi-decadal drought and disturbance effects on forest carbon sequestration in a mountain forest landscape**

Etzold S, Gessler A, Hug C, et al: **25 years of forest growth in Swiss Level II plots**

Foest J, Bogdziewicz M, Pesendorfer M, et al: **Rising summer temperatures dampen masting of European beech (*Fagus sylvatica*) across range**

Hartmann H, Storch F, Preidl S, et al: **Monitoring forest damage to shape future forests**

Krám P, Čuřík J, Veselovský F, et al: **Soil water dissolved organic carbon patterns at spruce sites with geochemically contrasting substrate in the last three decades**

Pitar D, Hůnová I, Gottardini E, et al: **Air quality in European forests – ozone and nitrogen dioxide trends in the ICP Forests Level II network**

Sun Y, Shackleton R, Ferretti M: **Crown density, growth and carbon sequestration in European forests over the period 1990–2022**

Žemaitis P, Armoška E, Stakėnas V, et al: **Norway spruce health and vulnerability in Lithuania – wind, decay and *Ips typographus* as the main drivers**

[1] https://forecomon2024.thuenen.de/

Posters

Buculei A, Iacoban C, Popa A, et al: **Assessment of atmospheric deposition in context of climate warming in Romanian forest ecosystems**

Cuciurean CI, Sidor CG, Leca S, Badea O: **Phenophase dynamics of European beech and sessile oak in the intensive forest monitoring plot of Mihăești, part of the Level II ICP Forests network**

Damnjanović S, Kaňa J, Tahovská K, Kopáček J: **Changes in forest floor P availability in an unmanaged mountain spruce forest after bark beetle-induced tree dieback: a 15-years study from Šumava mountains**

Fadrhonsová V, Šrámek V, Novotný R: **Development of soil chemistry on Level II plots in the Czech Republic**

Galić Z, Karaklić V, Samardžić M: **First data of carbon dioxide (CO_2) emission from soil in two Level II monitoring plot in Serbia**

Gottardini E, Cristofolini F, Cristofori A, et al: **Pollen deposition in throughfall samples at sixty ICP Forests plots throughout Europe**

Göttlein A, Weis W, Raspe S: **35 years of monitoring at „Höglwald"– documentation of chemical climate change and its impact on the ecosystem**

Ingerslev M, Alban M, Gundersen P, Vesterdal L: **Temporal trends in nitrogen and sulfur throughfall fluxes and soil solution concentrations**

Kaňa J, Tahovská K, Choma M, et al: **Changes in soil phosphorus availability in unmanaged spruce forest after bark beetle attack – from dieback to recovery**

Marra E, Viviano A, Manzini J, et al: **Investigate the effect of soil water depth on ozone-induced visual foliar injury**

Nikagolla D, Čapek P, Choma M, et al: **On the relationship between forest status following bark-beetle disturbance and mineral nitrogen in soils of unmanaged mountain catchments: long-term in-situ monitoring**

Pitar D, Leca S, Mărmureanu L, et al: **Measured vs modelled: ozone concentrations in the Romanian forest plots (ICP Forests Level II and LTER)**

Popa A, Popa I, Leca S, Badea O: **Intra-annual tree growth patterns in Level II ICP Forests plots from Romania**

Rybár J, Sitková Z, Pavlenda P, et al: **Development of mortality rates in Carpathian temperate forests**

Smart S, Seaton F, Sier A, et al: **Fifty years of change across forest ecosystems in Britain: a story of interacting drivers and historical legacy effects**

Tahovská K, Choma M, Kaštovská E, et al: **Response of soil microbes to long-term nitrogen input in spruce forest: results from Gårdsjön whole catchment N-addition experiment**

van Straaten O, Grün F, Evers J: **Transformation of forest humus forms in northwest Germany across three decades**

Wohlgemuth L, Krüger I, Jonard M, et al.: **Environmental impacts on foliar nutrient trends of ICP Forests Level II data**

Zolles A, Vospernik S: **Analysis of the effects of soil parameters on radial stem growth for four spruce stands in Austria**

Session 2: Novel monitoring approaches to support the development of resilient forests

Presentations

Anthony MA: **From soils to canopy: a call to collaborate to disclose foliar microbiome diversity and function**

Černý J, Čepl J, Lange H: **Optimisation of the measurement design for precise Green Leaf Area Index (GLAI) estimation by gap fraction methods in mature Norway spruce stands**

Gril E, Nicolas M, Spicher F, et al: **Forest microclimate: how to quantify and predict the temperature buffering capacity of canopies**

Guerrieri R, Càliz J, Mattana S, et al: **Quantifying tree canopy nitrification across European forests by combining stable isotope and molecular analyses**

Guidi C, Cools N, Deroo H, et al: **From litter to soil carbon - harmonizing soil carbon stock estimates for a common European forest monitoring system**

Knapp N, Dühnelt P, Bielefeldt J, Wellbrock N: **From single trees to country-wide maps: modeling tree mortality across Germany based on Level I data**

Molnár T, Manninger M, Szabó O, Koltay A: **Satellite-based forest health survey on ICP Forest Level II plots in Hungary**

Principe A, Oliveira A, Nunes A, et al: **Scaling up tree mortality and survival in Mediterranean oak woodlands**

Shackleton R, Ferretti M: **Towards Advanced Forest Inventory and Monitoring (AIM): a Swiss example**

Posters

Češljar G, Đorđević I, Rakonjac L, et al: **Identification of the decline of individual trees due to the impact of drought using a database (Defoliation) as a „health card" of previous events**

Fririon V, Davi H, Oddou-Muratorio S, Lefèvre F: **Can silviculture foster forest genetic evolution? A demo-genetic modelling approach accounting for within-stand individual variability estimated from ICP Forests data**

Gollobich G, Gartner K, Zolles A, et al: **Comparison of open land precipitation regimes with forest stand precipitation regimes and calculation of interception rates on the ICP Forests core plot „Klausenleopoldsdorf"**

Hůnová I, Brabec M, Malý M: **Ambient ozone behaviour near the ground: Insight into seven-year continuous measurements at a rural Central European site tall tower**

Korakaki E, Michopoulos P: **Chlorophyll contents and their relationships with nutrients and δ13C**

Krasylenko Y, Missarov A, Čihák T, Brovkina O: **Monitoring of the European mistletoe distribution based on remote sensing data**

Lukovic M, Gessler A, Zweifel R: **AI-assisted time-series analysis**

Mc Kenna A, Wellbrock N, Knapp N: **Investigating the relationship between crown defoliation and remote sensing indicators of vitality at the single tree level**

Meusburger K, Bernhard F, Gessler A, Köchli R, et al: **How can water isotopes improve predictions of the water balance**

Michopoulos P, Bourletsikas A, Argyrokastritis I, et al: **Arsenic and cadmium in the hydrological cycle and soil in a maquis broadleaved evergreen forest stand in Greece. Sources of some uncertainties**

Novotný R, Vlasáková L, Šrámek V, Buriánek V: **Impacts of ground-level ozone on vegetation in Czechia – assessment using visible foliar symptoms, AOT40F and MDA**

Schmitz A, Ahrends B, Herrmann H, et al: **Underestimation of potassium in forest dry deposition? – A simulation experiment in rural Germany**

Vejpustková M, Tričkovič N: **Monitoring of tree growth with different types of dendrometers**

Zink M, Boehmer F, Korres W, et al: **The International Soil Moisture Network (ISMN): providing a permanent service for environmental assessments**

Participants of the 11th ICP Forests Scientific Conference FORECOMON in Prague, Czechia, 11–12 June 2024

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 32 requests for ICP Forests data made between January and December 2024. 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]
311	WSL	Claudia Guidi	Uncovering root contributions to soil carbon in European forests under changing climate	Internal
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
313	WSL	Julia Schwarz	Are early-warning signals of tree mortality based on radial growth synchronized with drought resilience losses and what is the role of defoliation?	External
314	Imperial College London, European Research Council (ERC - REALM project), University of Reading (LEMONTREE project)	Iain Colin Prentice	The Reinventing Ecosystem And Land-surface Models (REALM) project, and the LEMONTREE (Land Ecosystem Models based On New Theory, obseRvations and ExperimEnts) CNP working group.	External
315	IIASA	Andrey LD Augustynczik	ForestNavigator	External
317	Helmholtz-Centre for Environmental Research	Felix Sauke	Modelling the influence of alternative reforestation scenarios on carbon and nutrient exports from forest sites after forest diebacks in the central German Harz region	External
318	University of Florence	Enrico Marchi	Drough monitoring for forest disturbances prevention and assessment-PNRR Spoke 5 CN 1	External
320	Nanjing University	Yongguang Zhang	The effects of tree species diversity on ecosystem functioning	External
321	Laboratoire des Sciences du Climat et de l'Envirionnement (LSCE)	Philippe Ciais	Machine learning from remote sensing data to monitor forests from tree to globe	External
322	School of Ecology and Environmental Sciences, Yunnan University	Suhui Ma	The impact of structural complexity on tree diversity, biomass, productivity, and their relationships in European forests	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]
323	UK Centre for Ecology & Hydrology	Ajinkya Deshpande	COST-Action CA21138 – Joint effects of CLimate Extremes and Atmospheric depositioN on European FORESTs (CLEANFOREST)	External
324	Ghent University, Forest & Nature Lab	Kris Verheyen	ForBioMon – Boosting FORest BIOdiversity MONitoring in Europe through smart combination of existing data	External
325	Swiss Federal Research Institute for Forest, Snow and Landscape Research WSL	Arthur Gessler	Study the mortality and decreased vitality of Scots pine trees (*Pinus sylvestris*) caused by biotic and abiotic factors (drought and insect infestation), focusing on the stand related factors that influence these outcomes	Internal
326	Programme Co-ordinating Centre (PCC), Thünen Institute of Forests Ecosystems	Lena Wohlgemuth	Status, trends and environmental impacts on foliar nutrients and their relation to defoliation and growth	Internal
327	CREAF Centre for Ecological Research and Forestry Applications, Autonomous University of Barcelona	Jordi Vayreda Duran	Advancing process-based modelling to project forest dynamics and associated ecosystems at the stand and regional scales (BOMFORES)	External
328	KTH Royal Institute of Technology	Chen Lu	Study on the influence of wetland and stream functions on the cross-media transport of DOC (dissolved organic carbon) in the atmosphere	External
329	Oath Inc.	Anna Edlund	Utilizing computational modeling to identify beneficial microbial species for tree growth and health	External
330	KU Leuven	Margaux Boeraeve	The consequences of nitrogen-induced shifts in fungal and bacterial communities for carbon cycling in temperate forests	External
331	University of Udine	Giorgio Alberti	WILDCARD (Effects of rewilding in forests and agricultural lands on carbon sequestration and diversity)	External
332	Hochschule Anhalt	Anika Groß	MeineWaldKI: KI-basiertes Monitoring und Analyse der Entwicklung des ökologischen Waldzustandes	External
333	Institute of Geochemistry - Chinese Academy of Sciences	Longyu Jia	Mercury biogeochemical cycle under global change	External
334	TU Braunschweig	Sarah Kistner	Improving the resilience of native tree species to climate change-induced stress by utilizing sulfur-induced resistance/tolerance (SiRT)	External
335	FVA - Forest Research Institute Baden-Württemberg	Jonas Hinze	MultiRiskSuit	External
337	Swedish University of Agricultural Sciences (SLU)	Ruben Valbuena	FORWARDS - The ForestWard Observatory to Secure Resilience of European Forests	External
338	French National Institute for Agriculture, Food, and Environment (INRAE)	Yi Xiao	Estimation of forest diversity and phenology at the tree level from high resolution remote sensing and machine learning	External
339	GAF AG	André Stumpf	European Environment Agency (EEA) – Copernicus Land Monitoring Service (CLMS) – Vegetated Land Cover Characteristics – Forest Type Nomenclature extension assessment under framework contract EEA/DIS/R0/21/013	External
340	Johann Heinrich von Thünen Institute	Johannes Hertzler	MoniFun	External

ID[3]	Institution	Name of Applicant	Project Title	External/ Internal[4]
341	Karlsruher Institut für Technologie (KIT) – Institut für Meteorologie und Klimaforschung – Atmosphärische Umweltforschung (IMK-IFU)	Pia Labenski	Drought-induced early leaf senescence in European temperate forests	External
342	Northeast Forestry University, Harbin City	Liu Ruiqiang	The impact of mycorrhizal types on soil organic carbon storage in forest ecosystem	External
343	Bursa Technical University	Yunus Barış Odabaşı	The effect of riparian buffer zones on pollutant filtering and water quality in different land uses (forest, agriculture, grassland): a case study from the Aladağ stream basin	External
344	Centre for Research on Ecology and Forestry Applications (CREAF) – Autonomous University of Barcelona (UAB)	Zhijing Yu	Exploring soil carbon accumulation using ICP Forests dataset: Linking forest productivity and soil carbon dynamics	External
345	University of Reading	Dominic T Robson	Tree Migration Modelling for LEMONTREE	External

https://www.wordclouds.com/

Figure 5-1: Word cloud from project titles of data requests 2024

PART B

Reports on individual surveys in ICP Forests

6 ATMOSPHERIC DEPOSITION IN EUROPEAN FORESTS IN 2023

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

Introduction

The atmosphere contains a large number of substances of natural and anthropogenic origin. A large fraction of these substances can settle, be adsorbed to receptor surfaces, or be included in rain and snow, and eventually reach the land surface as wet and dry deposition. In the last century, human activities led to a dramatic increase in the deposition of nitrogen and sulphur compounds, reaching peak levels approximately in the 1970s–80s.

Sulphur deposition today occurs almost completely 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 result from anthropogenic combustion processes, volcanoes, and forest fires and have increased since the 1850s in the wake of the Industrial Revolution, causing an increase in sulphate deposition and deposition acidity. This can, however, be partially 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 NO_X during lightning. However, human activities cause high emissions of nitrogen oxides (NO and NO_2, together called NO_x) during combustion processes, and of ammonia (NH_3) from agriculture and farming. Nitrogen in 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 but in excess may lead to ecosystem eutrophication; they 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 they 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 and center), along tree trunks in beech stands (stemflow sampler, 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 and stomata exchange models.

Figure 6-1: Snow samplers (left) and throughfall sampling gutter system (center) in a Level II plot with Norway spruce and stemflow sampler (right) in a European beech plot near Žďár nad Sázavou, Czechia. 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^+) and chloride (Cl^-), the interaction is almost negligible, and it can be assumed that their throughfall and stemflow deposition equals the sum of wet and dry deposition. For sulphate, small amounts (< 0.8 kg ha^{-1} y^{-1}) are reported to be taken up by the canopy in areas with very low sulphate deposition, such as northern Sweden (Pihl Karlsson et al. 2024).

Other ions, such as ammonium, are strongly affected by tree canopies and their associated microbial communities. For example, tree leaves can take up ammonium ions and release potassium (K^+) ions and organic compounds, thereby changing the composition of throughfall deposition. Biochemical conversion (e.g. nitrification) is also common (Guerrieri et al. 2024).

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 2023 annual throughfall deposition sampling from 288 permanent Level II intensive monitoring plots, collected following the ICP Forests Manual. Ten plots were excluded because the duration of sampling covered less than 90% (329 days) of the year and 60 other plots were marked as "not validated" because the conductivity check was passed for less than 30% of the analyses of the year. Further data were excluded because the laboratory did not participate in the mandatory Working Ring Test (18 plots), or did not pass the minimum requirement of the test for a specific variable: 9 plots for ammonium, 11 for total nitrogen, and 4 for sulphate and chloride.

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 uneven distribution of emission sources and receptors and the complex orography of Europe result in a marked spatial variability of atmospheric deposition. However, on a broader scale, regional patterns in deposition become apparent. In the case of nitrate and ammonium, high and moderate throughfall deposition was found all across Europe, except for northern and north-eastern countries, but mainly in central Europe (Figs. 6-2, 6-3).

Negative effects of nitrogen deposition on forests can become evident when total inorganic deposition of nitrogen 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 the forest canopy, a part of the deposited nitrogen may be taken up by leaves and microorganisms in the phyllosphere, transformed into organic nitrogen, or even released. For this reason, throughfall nitrogen deposition is only a rough estimate of the actual deposition reaching the forest floor, but its geographical distribution can be used to estimate the deposition patterns over large areas.

In 2023, throughfall deposition of inorganic and organic nitrogen higher than 10 kg ha^{-1} y^{-1} was mainly measured in most of central Europe, including Germany, Czechia, Poland, Slovakia, Switzerland, Slovenia, but also in the UK, Spain, Belgium, Romania, and Italy (Fig. 6-4).

Throughfall deposition of sulphate (corrected for the marine contribution) was relatively low in most of Europe. The highest values were found at a small number of sites in Austria, Czechia, Hungary, and Greece (Fig. 6-5).

Calcium and magnesium are also analyzed in the ICP Forests deposition monitoring network as their deposition can buffer the acidifying effects of atmospheric deposition and protect the soil from acidification. High values of (sea-salt corrected) calcium and/or magnesium throughfall deposition were mostly recorded in the Mediterranean region (Spain, France, Italy, Greece) extending north and east to Belgium, Switzerland, Austria, Slovenia, Romania, and a few plots in Denmark, Germany, Poland, and Hungary (Figs. 6-6, 6-7).

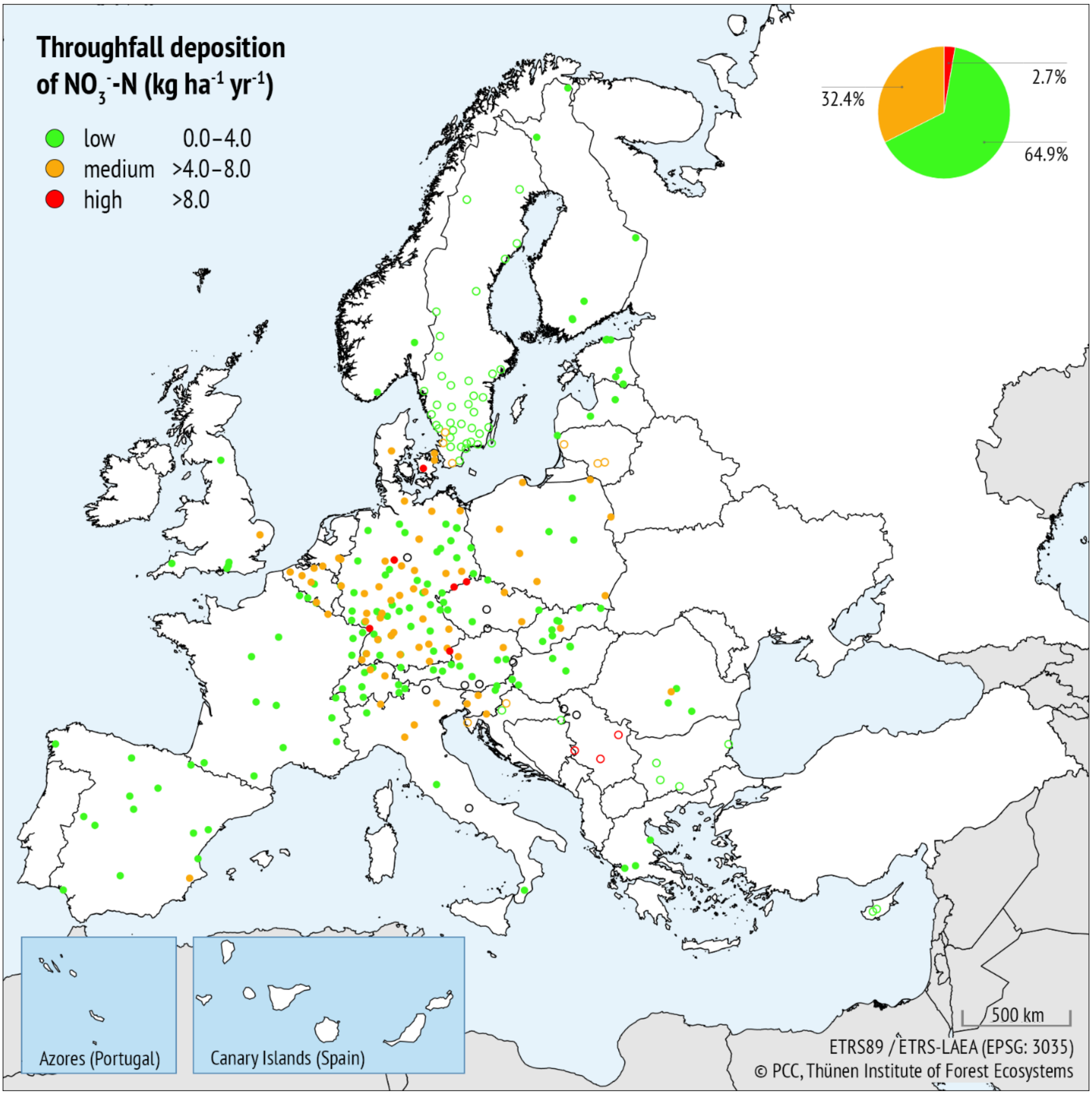

Figure 6-2: Throughfall deposition of nitrate-nitrogen (kg NO_3^--N ha^{-1} yr^{-1}) measured in 2023 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network. Colored dots: validated data. Colored circles: not validated data. Black circles: monitoring period shorter than 330 days or irregular sampling. The pie chart shows the percentage of plots with low, medium, and high deposition for validated data only.

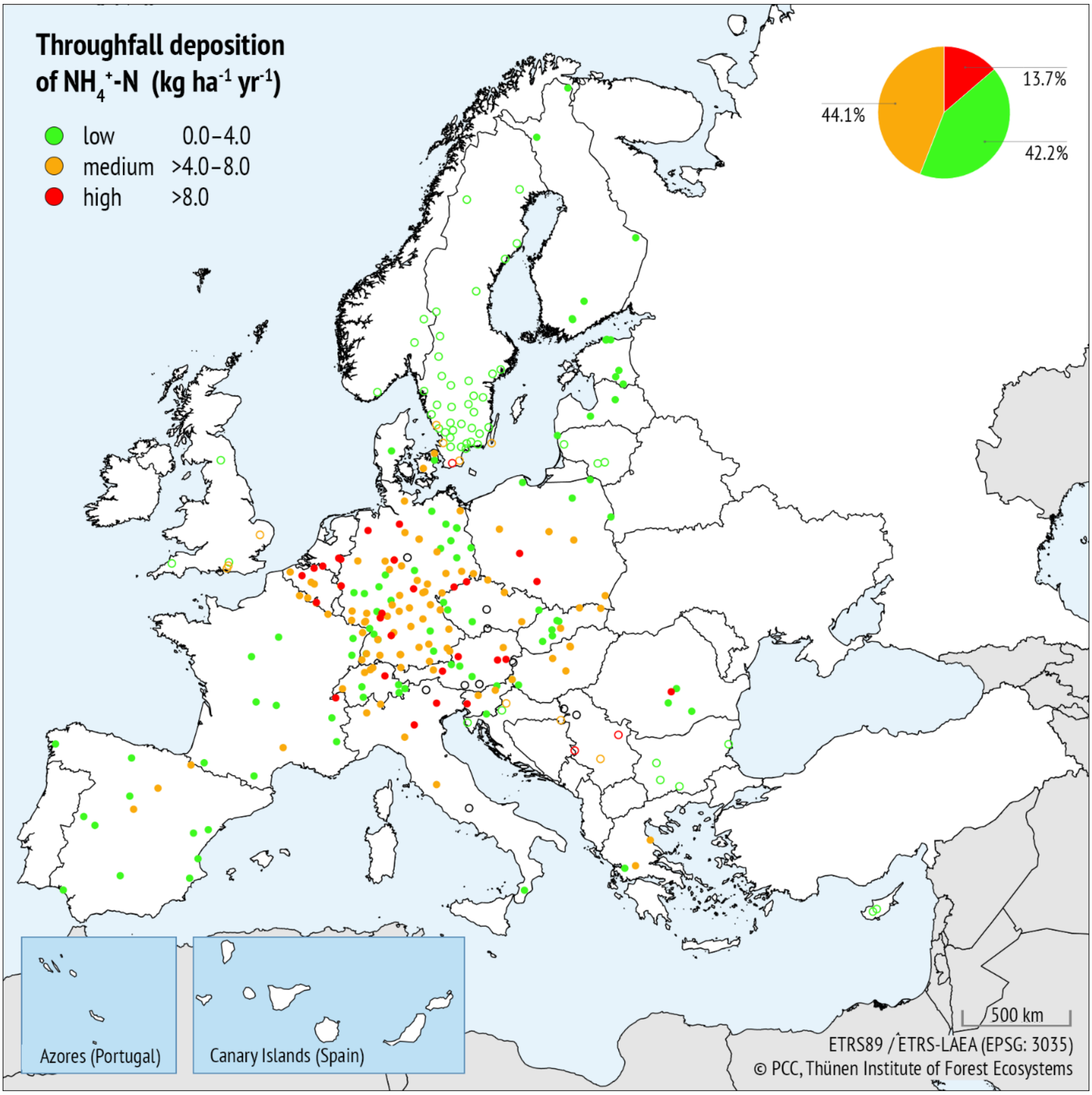

Figure 6-3: Throughfall deposition of ammonium-nitrogen (kg NH_4^+-N ha^{-1} yr^{-1}) measured in 2023 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network. Colored dots: validated data. Colored circles: not validated data. Black circles: monitoring period shorter than 330 days or irregular sampling. The pie chart shows the percentage of plots with low, medium, and high deposition for validated data only.

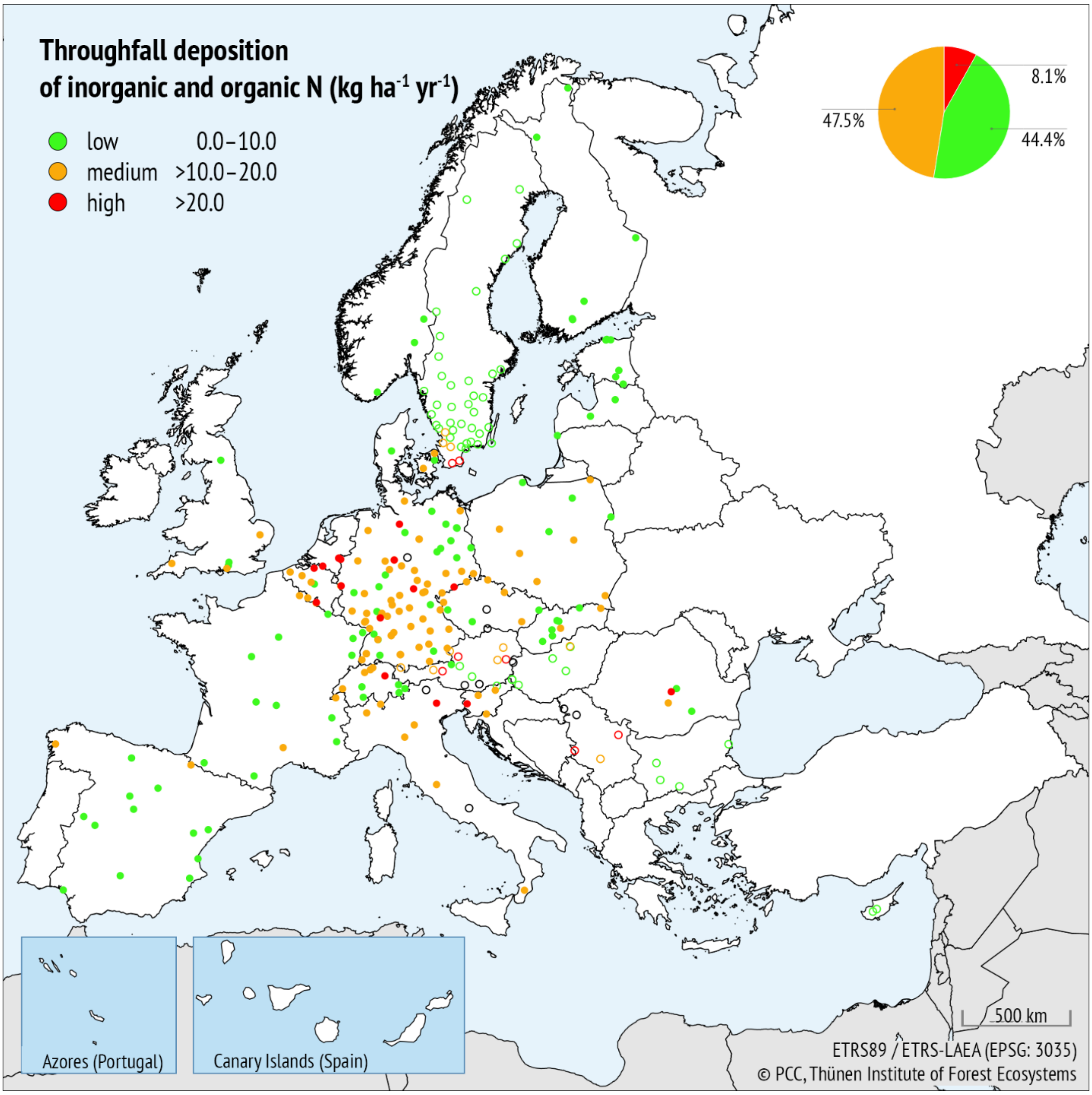

Figure 6-4: Throughfall deposition of the sum of inorganic and organic nitrogen (kg ha^{-1} yr^{-1}) measured in 2023 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network. Colored dots: validated data. Colored circles: not validated data. Black circles: monitoring period shorter than 330 days or irregular sampling. The pie chart shows the percentage of plots with low, medium, and high deposition for validated data only.

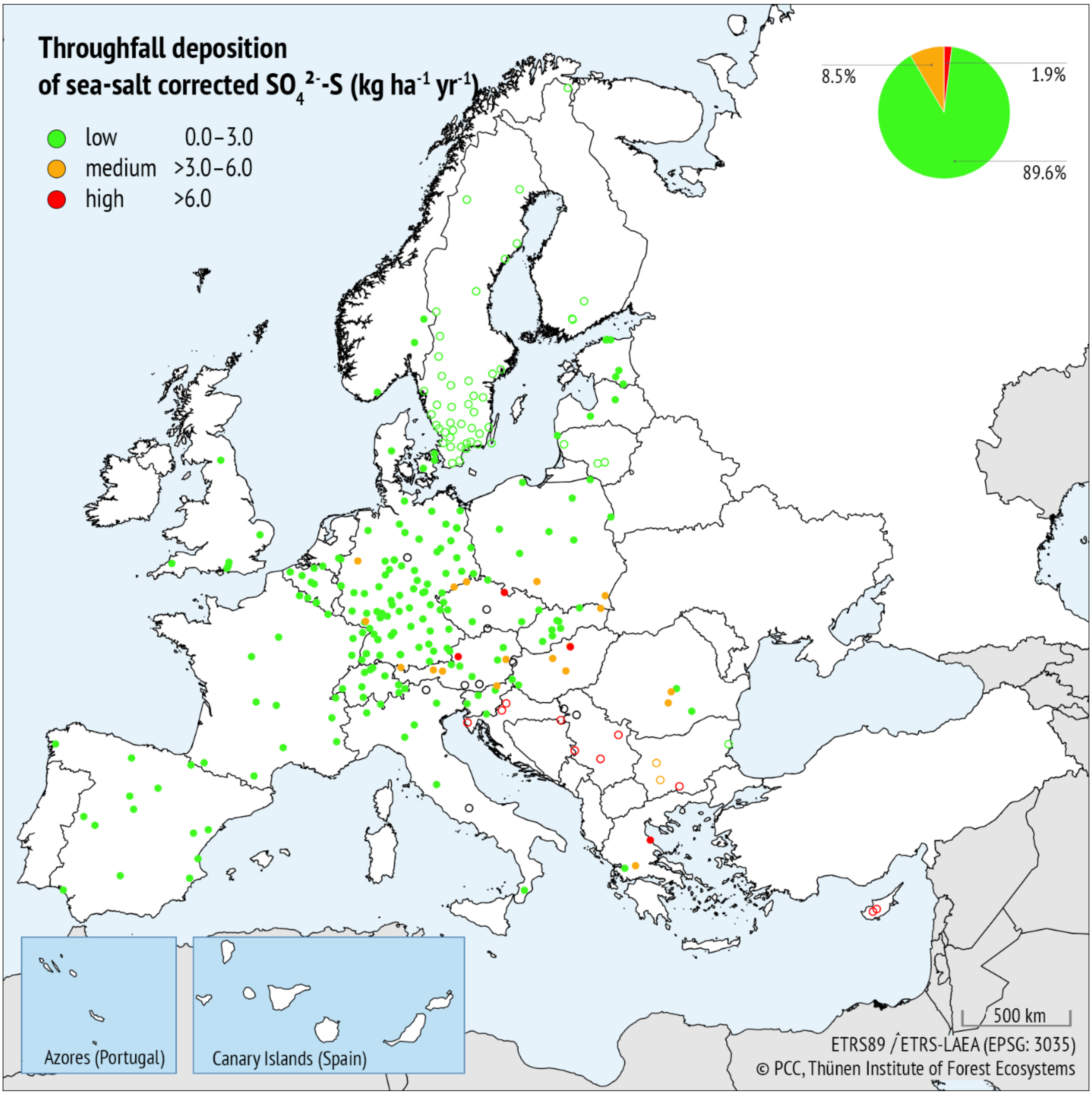

Figure 6-5: Throughfall deposition of sea-salt corrected sulphate-sulphur (kg SO_4^{2-}-S ha^{-1} yr^{-1}) measured in 2023 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network. Colored dots: validated data. Colored circles: not validated data. Black circles: monitoring period 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.

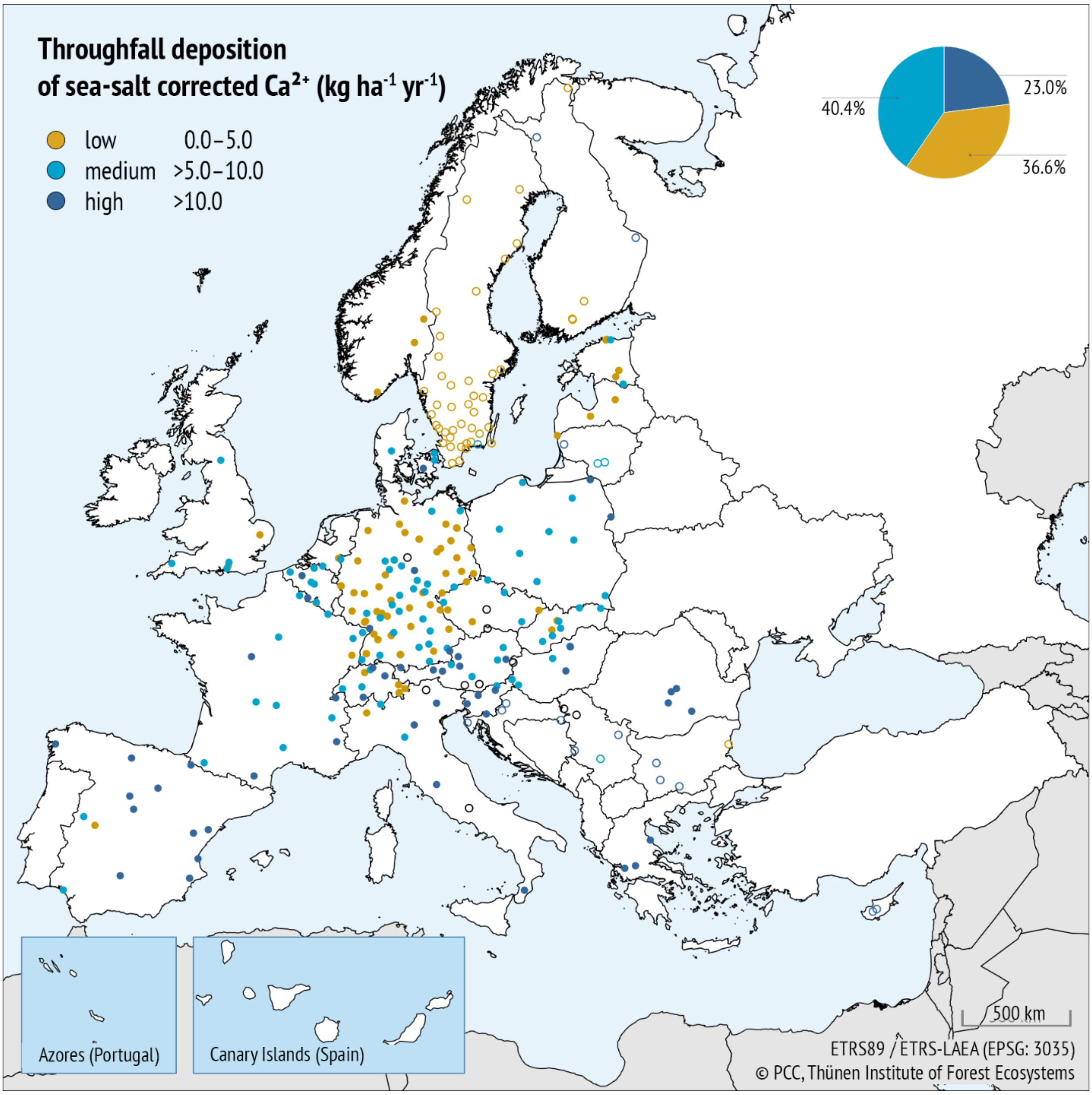

Figure 6-6: Throughfall deposition of sea-salt corrected calcium (kg Ca^{2+} ha^{-1} yr^{-1}) measured in 2023 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network. Colored dots: validated data. Colored circles: not validated data. Black circles: monitoring period shorter than 330 days or irregular sampling. The pie chart shows the percentage of plots with low, medium, and high deposition for validated data only.

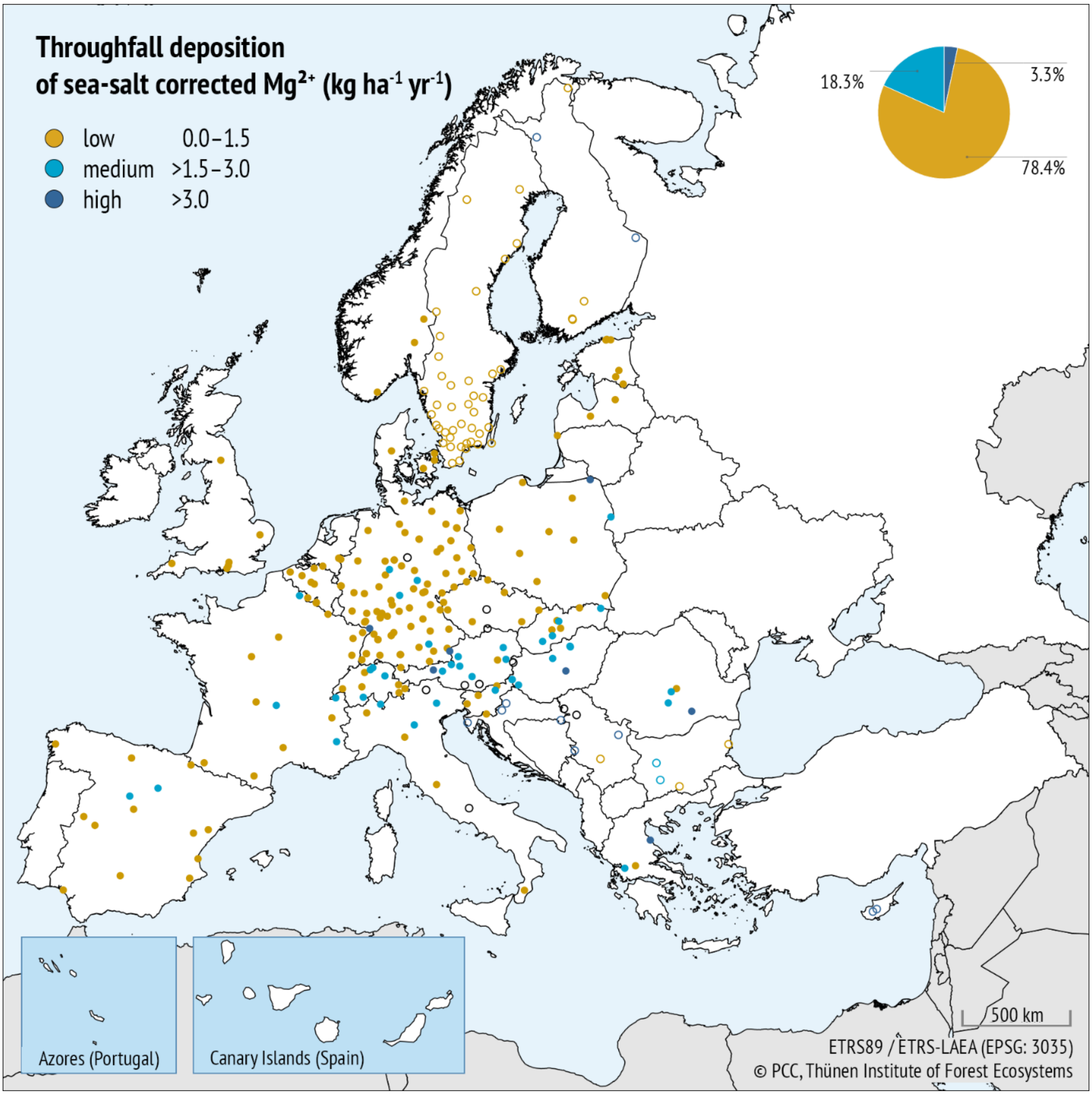

Figure 6-7: Throughfall deposition of sea-salt corrected magnesium (kg Mg^{2+} ha^{-1} yr^{-1}) measured in 2023 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network. Colored dots: validated data. Colored circles: not validated data. Black circles: monitoring period shorter 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

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7

METEOROLOGICAL CONDITIONS IN EUROPEAN FORESTS IN 2023

Lothar Zimmermann, Tim Schütt, Alexa Michel, Kai Schwärzel

Introduction

Weather and climate influence the 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 for understanding their interactions with other stressors such as air pollution, diseases, and pests. Against this background, the ICP Forests Level II plots were equipped with meteorological instruments as early as the 1990s.

Meteorological monitoring at these plots provides local, inside forest area information on the key driving and influencing factors affecting 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 these conditions as a basis for better understanding the state of forest ecosystems and their interrelationships,
- to identify and study stress indices and factors affecting the trees on the plots, such as extreme weather events (e.g., frost, heat, drought, storms, floods),
- to establish long time series that meet the needs for further analysis (e.g., statistical evaluation and modeling) of ecosystem responses under current and changing environmental conditions, such as water balance calculations, tree soil water availability, growth, and nutrient cycling, as well as integrated assessments of various aspects of Level II plots (e. g. crown condition assessment, deposition, increment) (Raspe et al. 2020).

Temperature and precipitation patterns play a key role in how climate change impacts forests. This chapter therefore focuses on presenting and interpreting air temperature and precipitation data from 2023 in comparison with long-term mean values for different climatic regions in Europe. Meteorological stations were assigned to climatic regions according to the widely used Koeppen-Geiger climate classification scheme, with the aim to aggregate values from Level II plots and show changes across European climatic zones. Further details on the aggregation can be found in Zimmermann et al. (2023).

The most frequent Koeppen climatic regions in Europe are C-climates, which are temperate climates, such as the CfB atlantic temperate (beech climate) or the warm to hot Mediterranean climate (Csb, Csa), and D-climates, which are continental climates ranging from the humid continental (Dfa, Dfb: oak climate) to the subarctic (Dfc: birch climate), and also include 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 2023. 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	7
Cfa	Temperate, no dry season, hot summer	Humid subtropical climate	1
Cfb	Temperate, no dry season, warm summer	Temperate oceanic climate	32
Csa	Temperate, dry summer, hot summer	Hot-summer Mediterranean climate	6
Csb	Temperate, dry summer, warm summer	Warm-summer Mediterranean climate	3
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	113
Dfc	Cold, no dry season, cold summer	Subarctic climate	20
Dsb	Cold, dry summer, warm summer	Mediterranean-influenced warm-summer humid	1
		Total	184

EVALUATIONS

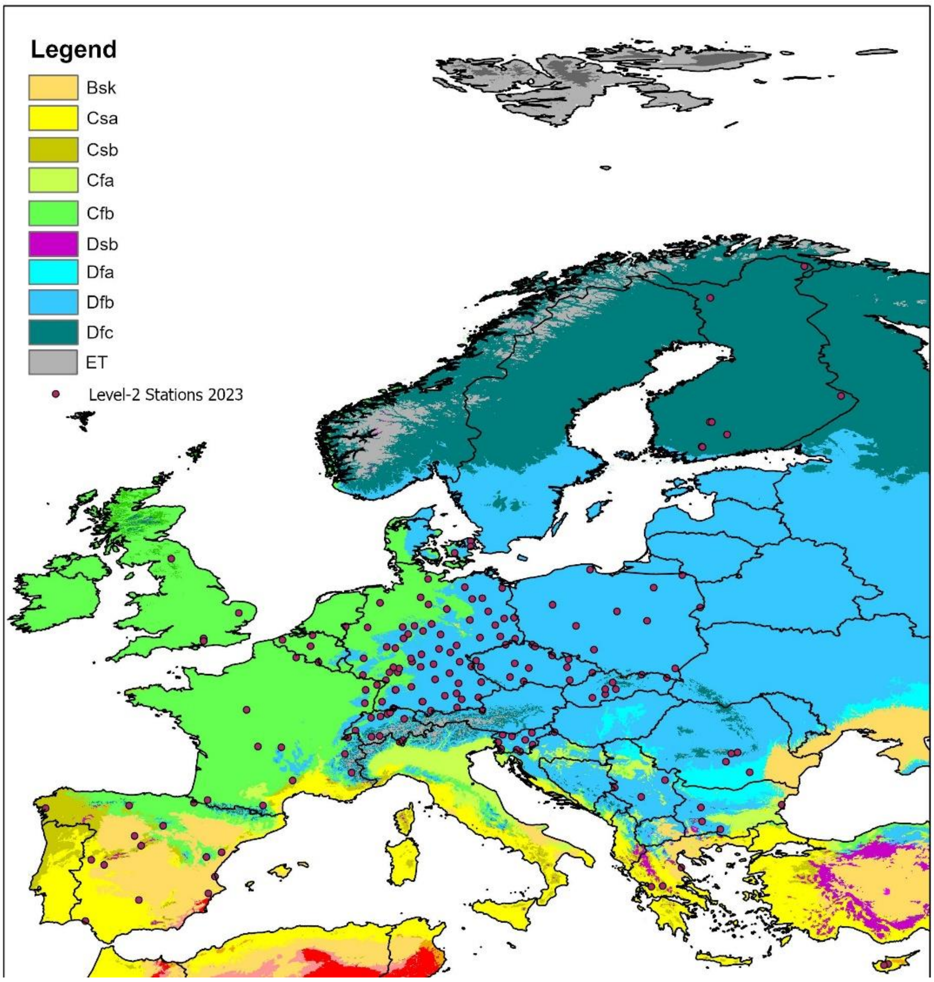

Figure 7-1: Map of Level II stations with gap-filled time series of meteorological data for 2023 and for different climatic regions (Table 7-1 acc. to Beck et al. 2018)

Climate and weather in Europe 2023

Again second warmest year with an "extended" summer

According to the European State of the Climate 2023 Report (Copernicus Climate Change Service (C3S) 2024), the year 2023 was the second warmest year on record in Europe with temperatures 1.1 °C above the reference period 1991–2020 – even surpassing the previous year. The three warmest years on record in Europe have all occurred since 2020, and the ten warmest since 2007. Much of southeastern Europe, as well as parts of western and central Europe, experienced their warmest year on record. Overall, 2023 was up to 7% wetter than average. Most of Europe experienced wetter-than-average conditions, with the exception of areas west of the Black Sea, and across the southern Iberian Peninsula, which faced dry conditions from February to April.

During the winter, precipitation varied between regions, with wetter-than-average conditions in northern and eastern Europe as well as the Iberian Peninsula – except along its Mediterranean coast. In contrast, the United Kingdom, France, southern Italy, and Greece experienced drier-than-average conditions. Spring was drier than average on the Iberian Peninsula and in areas along the Baltic Sea. In May and June, much of northern Europe experienced below-average precipitation, while Italy and Greece had wetter than normal conditions.

The summer of 2023 was the fifth warmest since 1950, with 0.8 °C above the 1991–2020 average, following the record-breaking summers of 2022 and 2021. Despite this ranking, the season was marked by periods of extreme weather. There were large contrasts in temperature and precipitation, sometimes even from month to month – variability that seasonal averages tend to obscure. Northwestern Europe recorded its warmest June on record, while Mediterranean areas experienced well-above-average precipitation. In July, this pattern was almost reversed. The month was also marked by widespread fires in Portugal, Spain, Italy, and especially Greece, which experienced the largest wildfire ever recorded in the European Union (EU), burning approximately 960 km^2. In August, southern Europe experienced above-average temperatures. September 2023 was also significantly warmer than average, making it the warmest September on record in Europe and effectively extending the summer. Much of Europe was affected by heat waves during this "extended" summer period. By the end of August, large parts of southern Europe, particularly the Iberian Peninsula, were experiencing precipitation deficits that led to drought conditions. By late September, most of the Iberian Peninsula had recovered, but parts of eastern Europe transitioned into extreme drought. In November and December, most of Fennoscandia was drier than average. However, from November to December the majority of Europe experienced wetter-than-average soil moisture conditions, partly due to storms. This unusually high soil moisture contributed to flooding events later in December.

Materials and methods

Meteorological data for 2023 were available from 184 ICP Forests Level II sites and were used to generate this report. Detailed information on the meteorological measurements, equipment used, quality standards, and procedures for gap filling can be found in Zimmermann et al. (2023) and in Raspe et al. (2013). This chapter focuses exclusively on air temperature and precipitation data from 2023, comparing them with their long-term average from the period 1990–2020.

Results

Air temperature

Deviation of annual mean air temperature

2023 warmer than the long-term average

The year 2023 was warmer than the long-term average, with positive deviations on all Level II plots across Europe (Fig. 7-2). The largest positive deviations – temperatures of more than 1.75 °C above the 1991–2020 reference period – were observed on Level II plots in northwestern Spain, Belgium, central Germany, Romania, and Serbia with a maximum deviation of +3.5 °C, while the deviation was smallest (0.0–0.25 °C) in one plot each in western Germany, northern Poland, and eastern Finland, and generally lower in the outer European regions.

Deviation of mean air temperature in the vegetation period

2023 warmer also in vegetation period

The vegetation period was also warmer than the long-term average on all Level II plots across Europe (Fig. 7-3), with the highest deviation with more than +3.5 °C having been observed in Estonia. The temperature was around 0.5–2.5 °C higher than normal on most plots, with only a few plots reaching higher values. The lowest deviation of up to 0.5 °C was found on only a few plots in central and northern Europe.

Annual mean air temperature in 2023 exceptionally high in all European climatic regions

To complement the picture of annual mean air temperature at specific Level II plots during the year 2023, averages were calculated for Level II plots across different climatic regions. Figure 7-4 shows that, with the exception of the Dfa and Dfc climate zones, air temperature at the Level II plots in 2023 were approximately 1 °C above the long-term average. In the Dfa region (hot-summer humid continental climate) the deviation reached 2 °C while in the Dfc region (subarctic climate), the deviation (0.5 °C) was only slightly above the long-term average.

Temperature stress indicators

High temperatures and frequent hot days but fewer frost events

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 2023, the maximum air temperature during the growing season exceeded 40 °C in southern, central, and southeastern Europe on nine Level II plots in Spain, Germany, Czechia, Slovakia, and Romania. Air temperatures between 36 °C and 40 °C were found also in southern, central, and southeastern Europe on plots in Spain, Germany, Czechia, Poland, Serbia, Greece, and Cyprus. Lower maximum air temperatures below 28 °C were found in the UK, but also on plots in northern, central, and southeastern Europe (Fig. 7-5).

Another indicator of the risk of heat stress in forests is the number of hot days, defined as those with a maximum temperature of 30 °C or higher. The hot-summer Mediterranean climate (Csa) and the hot-summer humid continental climate (Dfa) show the most dramatic differences, each with more than 75 hot days in 2023 compared to around 65 and 33 days in the long-term average, respectively. The cold semi-arid BSk region experienced 47 days of high temperature in 2023, which is above the long-term average of 36 days. The same positive trend is observed in the temperate oceanic climate (Cfb), exhibiting approximately 14 hot days compared to the long-term average of 5 days, and in the Mediterranean-influenced warm-summer humid (Dsb) climate with 3 hot days compared to the long-term average of nearly 0. The warm-summer humid climates (Csb, Dfb) show a near-normal number of extreme hot days, with only slight variations. Only the subarctic climate region (Dfc) shows an opposite trend where the six hot days in 2023 are below the long-term average of around 10 days.

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 flowers 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 2023, all climate zones experienced fewer late frost days compared to the long-term average, with the highest reduction in the Dfa (hot-summer humid continental climate), in which no late frost day occurred compared to just over 3 days in the long-term average. Notable reductions also occurred in the temperate oceanic climate (Cfb) and subarctic climate (Dfc), a smaller reduction in the warm-summer humid continental climate (Dfb). The cold semi-arid (BSk), the Mediterranean-influenced warm-summer humid continental climate (Dsb), and the Mediterranean climate zones (Csa, Csb) maintained consistently low occurrences of frost days in both periods (Fig 7.7).

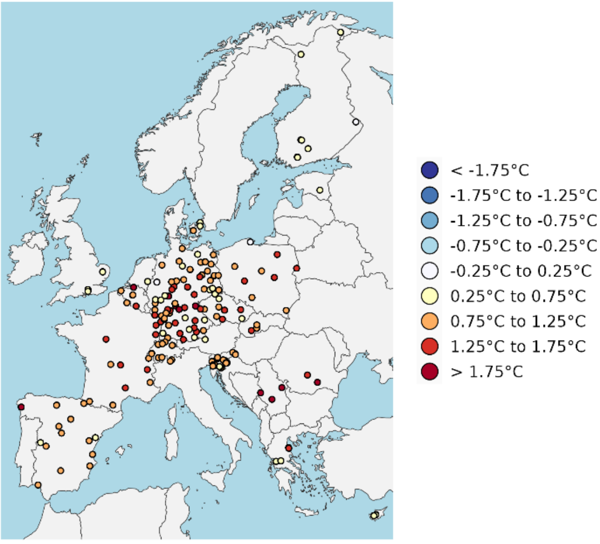

Figure 7-2: Deviation of annual mean air temperature (in °C) in 2023 from the long-term average (1990–2020) on Level II plots. Spanish data originate from a measurement height of 7 m.

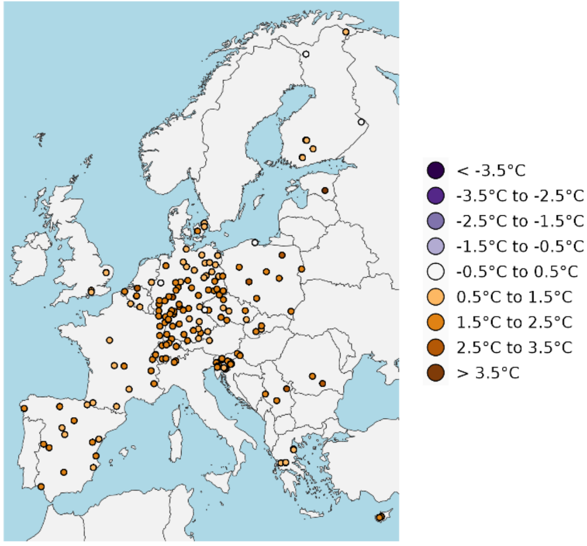

Figure 7-3: Deviation of mean air temperature in the vegetation period in 2023 from the long-term average (1990–2020) (in °C) on Level II plots. Spanish data originate from a measurement height of 7 m.

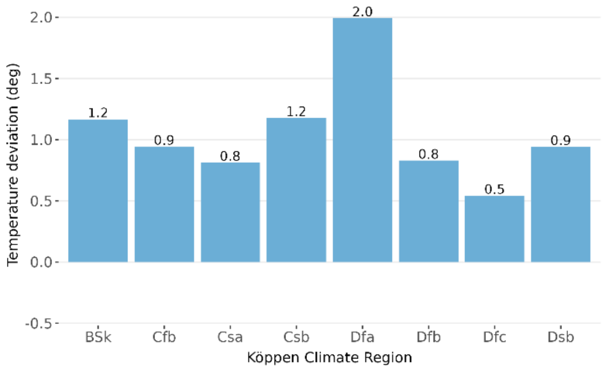

Figure 7-4: Deviation (in °C) of annual mean air temperature in 2023 from the long-term average (1990–2020) on Level II plots in different Koeppen climatic regions. For explanation of acronyms and for number of Level II plots in each climatic region, please refer to Tab. 7-1 and Fig. 7-1.

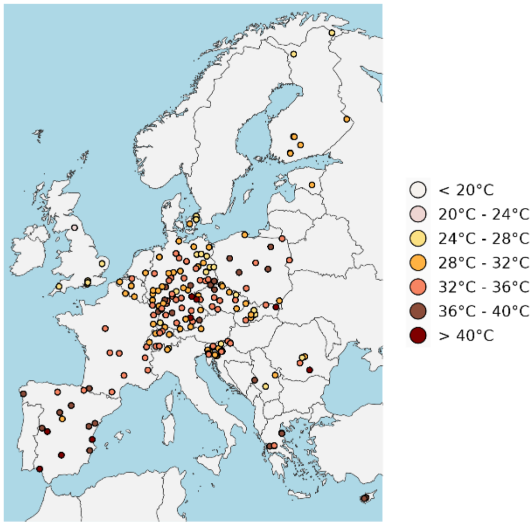

Figure 7-5: Maximum air temperature (°C) in the vegetation period in 2023 on Level II plots. Spanish data originate from a measurement height of 7 m.

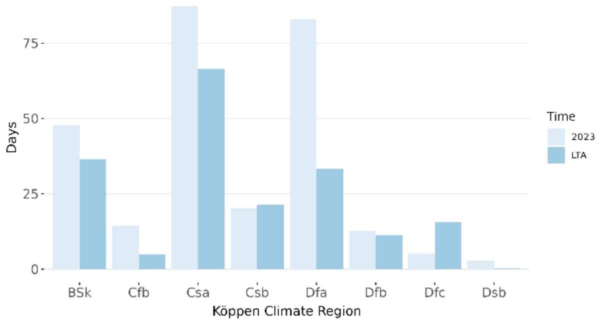

Figure 7-6: Number of hot days (Tmax ≥ 30 °C) in 2023 and long-term annual average (LTA, 1990–2020) on Level II plots in different Koeppen climatic regions. For explanation of acronyms and for number of stations in each climatic region, please refer to Tab. 7-1 and Fig. 7-1.

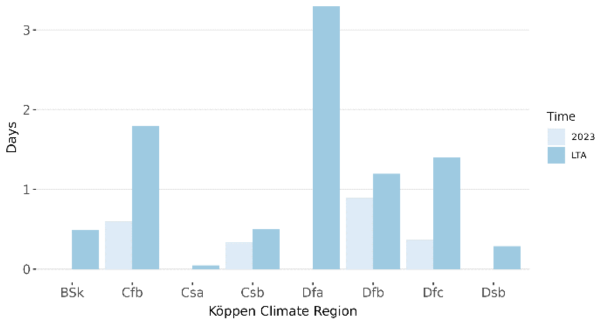

Figure 7-7: Number of late frost days (Tmin in vegetation period < 0°C) in 2023 and long-term annual average (1990–2020) on Level II plots in different Koeppen climatic regions. For explanation of acronyms and for number of stations in each climatic region, please refer to Tab. 7-1 and Fig. 7-1.

Precipitation

Mostly wetter than average except for southern regions

Deviation in annual precipitation

An analysis of the 2023 precipitation patterns across Europe compared to the long-term average (1990–2020) reveals significant geographical contrasts, with western, central, and northern Europe experiencing substantial precipitation increases (more than +75%), while southern and southeastern regions faced slight to high deficits compared to the long-term average (1990–2020) (Fig. 7-8). The Köppen climate classification analysis (Fig. 7-9) quantifies these trends: The one plot within the hot-summer humid continental climate region (Dfa) demonstrated the most severe deficit (-59%), followed by a slight reduction in the plots with Mediterranean-influenced climates (Dsb, Csa). Plots in the subarctic climate (Dfc) experienced the largest precipitation surplus (+61%), and significant precipitation increases were also recorded in the temperate oceanic (Cfb; +44%), warm-summer Mediterranean (Csb; +37%), and the warm-summer humid continental (Dfb; +39%) regions. The semi-arid (BSk) region experienced a moderate surplus (+18%), while the humid subtropical climate (Cfa) showed no deviation from normal precipitation patterns.

Deviation in precipitation in the vegetation period

Precipitation in the 2023 vegetation period follows the same geographical pattern as annual precipitation (Fig. 7-10). Most regions across Europe experienced substantial precipitation surpluses with annual values greater than 75% above normal at numerous Level II plots, except for eastern Finland, Spain, southern France, and southeastern Europe, where precipitation was unusually low (up to > 75% less precipitation than normal).

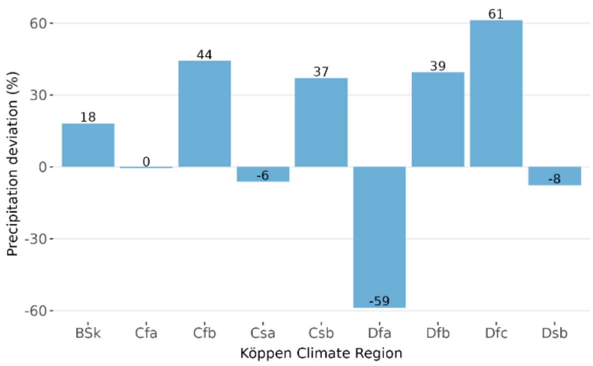

Figure 7-9: Deviation (in %) from the long-term average of the annual precipitation on Level II plots in different Koeppen climatic regions. For explanation of acronyms and for number of stations in each climatic region, please refer to Table 7-1 and Figure 7-1.

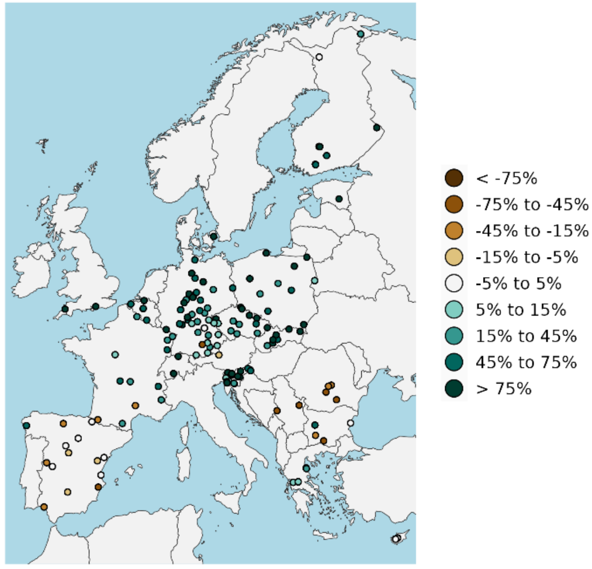

Figure 7-8: Deviation (in %) of the total annual precipitation in 2023 from the long-term yearly average (1990–2020) on Level II plots.

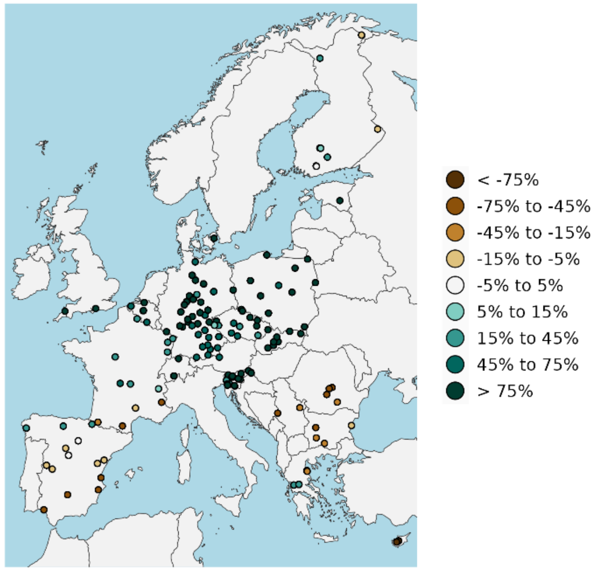

Figure 7-10: Deviation (in %) of the precipitation in the vegetation period in 2023 from the long-term average (1990–2020) on Level II plots.

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8

TREE CROWN CONDITION IN 2024

Volkmar Timmermann, Nenad Potočić, Anne-Katrin Prescher, Alexa Michel, Katrin Haggenmüller, Till Kirchner

Highlights

In 2024, our sample remained stable with 27 participating countries and the largest number of assessed plots since 2019. We witnessed a very slight increase of 0.2 percentage points (%p) in mean defoliation as compared to 2023, mainly due to an increase of 0.5%p for broadleaves, while defoliation of conifers remained almost unchanged (0.1%p decrease). The strongest increase in defoliation occurred in deciduous (sub-) Mediterranean oaks (+2.1%p), while the strongest decrease was recorded in Norway spruce (-0.8%p). Deciduous temperate oaks had the highest (29.7%) and Norway spruce the lowest (22.4%) mean defoliation.

Trend analyses show a considerable increase in defoliation of evergreen oaks (7.1%p), common beech (6%p), Norway spruce (5.5%p), and deciduous temperate oaks (5%p) over the past 20 years. The increase in defoliation for Scots pine and Mediterranean lowland pines (3.7 and 3.3%p, respectively) was more moderate. The results of the trend analyses were not significant for deciduous (sub-) Mediterranean oaks and Austrian pine.

The percentage of trees with damage symptoms (48.6%) was almost the same as in 2023 (-0.5%p). As in previous years, the number of damage symptoms per assessed tree was substantially higher for broadleaves than for conifers (0.86 vs. 0.55, 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 2024 was 1.1% (1 145 trees), i.e. at the same level as in the year before. While mortality rates for the main species and species groups ranged from 0.6 to 1.6%, mortality of *Betula* spp. and European ash was higher with 2.4% and 7% respectively.

Introduction and scientific background

Tree crown defoliation and the 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 2024, as well as long-term trends for the main species and species groups.

Methods of the 2024 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 2015 to 2024, and the total number of sample trees submitted in 2024. 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 2015 to 2024 in countries with at least one Level I crown condition survey since 2015, and total number of sample trees submitted in 2024

Country	2015	2016	2017	2018	2019	2020	2021	2022	2023	Plots 2024	Trees 2024
Andorra	12										
Belarus	377										
Belgium	53	53	53	52	52	51	51	51	47	47	580
Bulgaria	159	159	160	160	160	160	159	160	160	160	5 597
Croatia	95	99	99	99	97	98	95	97	97	96	2 304
Cyprus	15	15	15	15	15	15	15	15	15	15	361
Czechia	136	136	135	132	132	127	121	117	118	120	4 123
Denmark	20	19	19	19	19	19	18	18	17	25	627
Estonia	97	98	98	98	98	95	95	93	92	93	2 157
France	542	533	527	521	515	512	509	504	526	501	10 087
Germany	424	421	416	410	421	416	409	405	402	409	9 713
Greece	47	23	36	40	45	38	33	35	27	34	802
Hungary	67	67	66	68	68	68	69	71	70	70	1 494
Ireland					28	30	33	31	33	31	682
Italy	234	246	247	249	237	240	256	256	255	250	4 854
Latvia	116	115	115	115	115	115	115	115	115	115	1 747
Lithuania	81	82	82	81	81	81	81	81	81	81	1 936
Luxembourg	4	4	3	3	4	4	4	4	4	4	96
Montenegro	47	49	49	49	49	49	49	49	49	49	1 175
Norway	554	629	630	623	687	604	629	627	616	679	6 627
Poland	361	353	352	348	346	343	343	341	340	336	6 695
Republic of Moldova			9	9							
Romania	242	243	246	246	247	226	234	237	239	227	5 542
Serbia	127	127	126	126	127	126	126	126	123	124	2 908
Slovakia	106	103	103	101	100	99	97	99	101	101	4 420
Slovenia	44	44	44	44	44	44	44	44	44	43	1 030
Spain		620	620	620	620	620	620	620	620	620	14 880
Sweden	839	701	618	760	849	841	733	629	774	848	2 814
Switzerland	47	47	47	47	47	47	47	49	49	49	1 009
Türkiye	591	586	598	601	597	599	580	579	584	585	13 414
TOTAL	5 437	5 572	5 513	5 636	5 800	5 667	5 565	5 453	5 598	5 712	107 674

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 (in bold below) 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 for the analyses as follows:

- Mediterranean lowland pines (*Pinus brutia*, *P. halepensis*, *P. pinaster*, *P. pinea*), containing 7.5% of all trees in the 2024 sample,
- deciduous temperate oaks (*Quercus petraea* and *Q. robur*), accounting for 8.6% of all trees,
- deciduous (sub-) Mediterranean oaks (*Quercus cerris*, *Q. frainetto*, *Q. pubescens*, *Q. pyrenaica*), amounting to 7.4% of the trees,
- evergreen oaks (*Quercus coccifera*, *Q. ilex*, *Q. rotundifolia*, *Q. suber*), representing 4.3% of all trees.

Of all trees submitted from the Level I network in 2024, ***Pinus sylvestris*** was the most abundant tree species (16.6% of all trees), followed by ***Fagus sylvatica*** (incl. ssp. *moesiaca*, 11.9%), ***Picea abies*** (11.2%), ***Pinus nigra*** (5.1%), *Quercus petraea* (4.3%), *Quercus robur* (4.2%), *Quercus ilex* (3.7%), *Quercus cerris* (3.1%), *Pinus brutia* (2.9%), *Betula pubescens* (2.9%), *Pinus halepensis* (2.4%), *Betula pendula* (2.2%), *Quercus pubescens* (2.1%), *Abies alba* (2.1%), *Pinus pinaster* (1.8%), and *Carpinus betulus* (1.8%). All other species accounted for less than 1.5% of the trees each. Altogether, more than 130 tree species are represented in the sample.

Most Level I plots with crown condition assessments contained one (49%) or two to three (38.2%) tree species per plot. On 10.3% of plots, four to five tree species were assessed, and only 2.5% of plots featured more than five tree species. In 2024, 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 2005–2024. 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 2015–2024 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

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

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fall into or drop out of the sample depending on the number of 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, Meining et al. 2024).

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 2025, both a field ICC and an online photo ICC will be conducted.

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 2024 was conducted on 107 674 trees on 5 712 plots in 27 countries (Table 8-2). Out of those, 101 564 trees were assessed in the field for defoliation (Table 8-3).

Table 8-3: Percentage of trees assessed in 2024 according to defoliation classes 0–4 (class 2 subdivided), mean defoliation for the main species or species groups (change from 2023 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 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*)	21.9	52.4	15.9	6.8	2.4	0.6	22.6 (-0.1)	17 559
Norway spruce (*Picea abies*)	30.2	37.7	20.6	7.7	2.7	1.0	22.4 (-0.8)	11 374
Austrian pine (*Pinus nigra*)	22.6	45.5	18.5	8.1	4.8	0.5	24.9 (+0.9)	5 359
Mediterranean lowland pines	9.8	58.7	21.8	6.2	2.3	1.2	24.7 (-0.2)	8 004
Other conifers	28.9	41.5	18.5	7.3	3.1	0.6	22.6 (+0.3)	7 911
Common beech (*Fagus sylvatica*)	32.0	36.7	19.6	7.5	3.8	0.3	22.7 (+0.8)	12 610
Deciduous temperate oaks	15.3	38.2	26.0	13.0	6.8	0.5	29.7 (+0.4)	9 045
Dec. (sub-) Mediterranean oaks	25.5	38.7	21.0	9.2	5.1	0.5	25.1 (+2.1)	7 910
Evergreen oaks	6.8	57.8	22.0	8.0	5.1	0.3	27.4 (-0.4)	4 563
Other broadleaves	25.9	45.0	15.4	6.5	5.6	1.5	24.1 (0.0)	17 229
TOTAL								
Conifers	23.0	47.6	18.6	7.1	2.8	0.8	23.2 (-0.1)	50 207
Broadleaves	23.8	41.9	19.8	8.5	5.3	0.8	25.2 (+0.5)	51 357
All species	**23.4**	**44.8**	**19.2**	**7.8**	**4.1**	**0.8**	**24.2 (+0.2)**	**101 564**

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

The overall mean defoliation for all species was 24.2% in 2024, an increase of 0.2%p in comparison with 2023; a slight decrease in defoliation of conifers (0.1%p) and a 0.5%p increase for broadleaves was recorded (Table 8-3). Broadleaved trees showed a higher mean defoliation than coniferous trees (25.2% vs. 23.2%), as in previous years. This was mainly due to a larger share of coniferous trees in the defoliation class 1 (> 10–25% defoliation).

Among the single main species and species groups, deciduous temperate oaks and evergreen oaks displayed the highest mean defoliation (29.7% and 27.4%, respectively) while Norway spruce had the lowest mean defoliation (22.4%, down 0.8%p from the previous year). The strongest increase in defoliation compared to 2023 occurred in deciduous (sub-) Mediterranean oaks (+2.1%p).

Among main tree species, Norway spruce had the highest (1.0%), and common beech the lowest share of standing dead trees (0.3%) while among species groups, 'Other broadleaves' had the largest share (1.5%), followed by Mediterranean lowland pines (1.2%) and the lowest share of standing dead trees was recorded in evergreen oaks (0.3%).

Mean defoliation of all species at plot level in 2024 is shown in Figure 8-1. Roughly two thirds (65.4%) of all plots had a mean defoliation up to 25%, and only 1.5% of the plots showed severe defoliation (more than 60%). While plots with defoliation up to 10% were located mainly in Norway, Romania, and Serbia, plots with slight mean defoliation (> 10–25%) were found predominantly in Spain, Türkiye, Poland, and the Baltic countries. Plots with mean defoliation up to 40% were found across Europe, but plots with mean defoliation higher than 40% were mostly located in France, Italy, western Czechia, Hungary, and Bulgaria.

The following sections describe the species-specific mean plot defoliation in 2024 and the over-all trend and yearly mean plot defoliation from 2005 to 2024. For maps on defoliation of individual tree species in 2024, and trends in mean plot defoliation from 2015 to 2024, please refer to the online supplementary material.

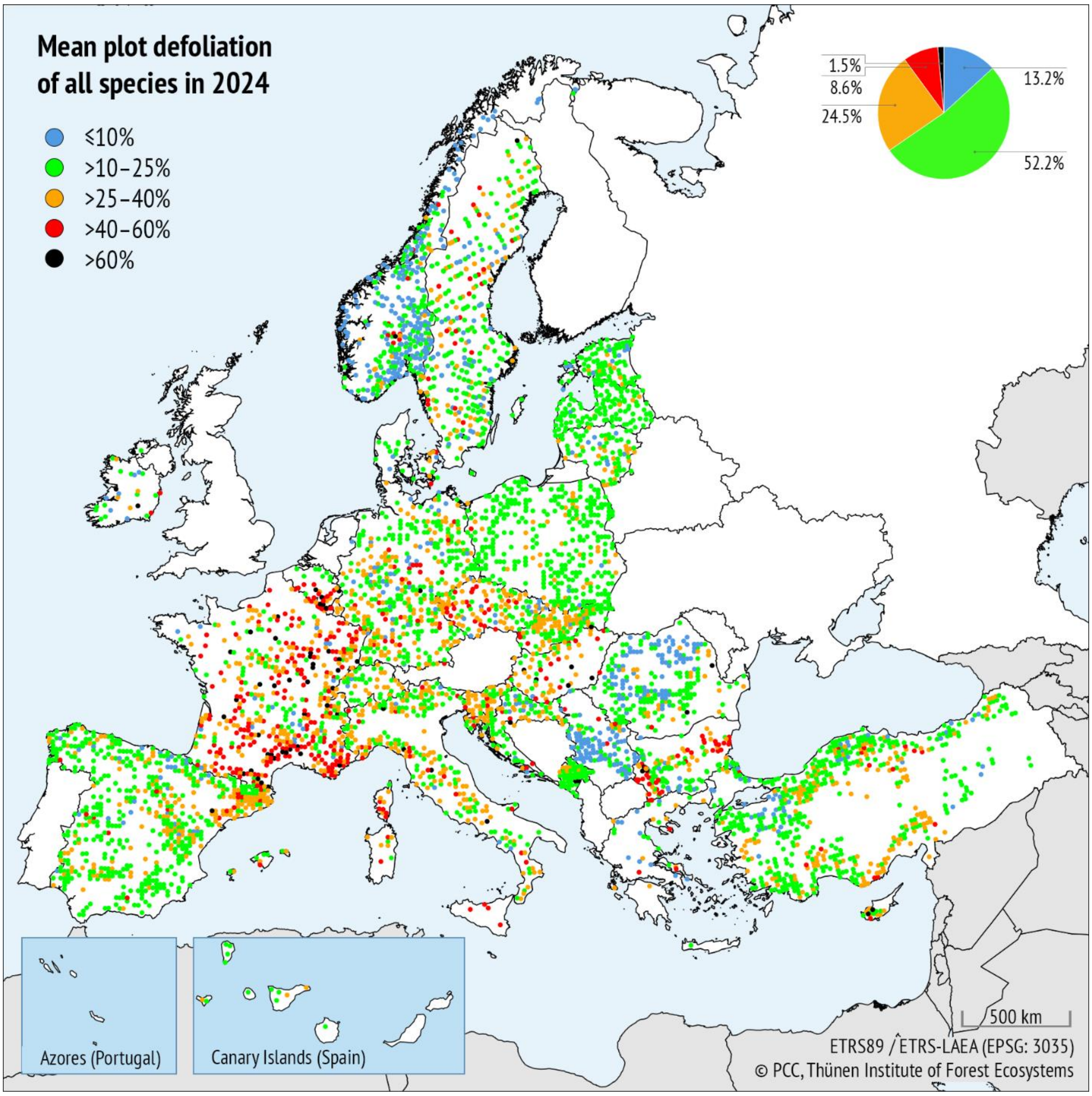
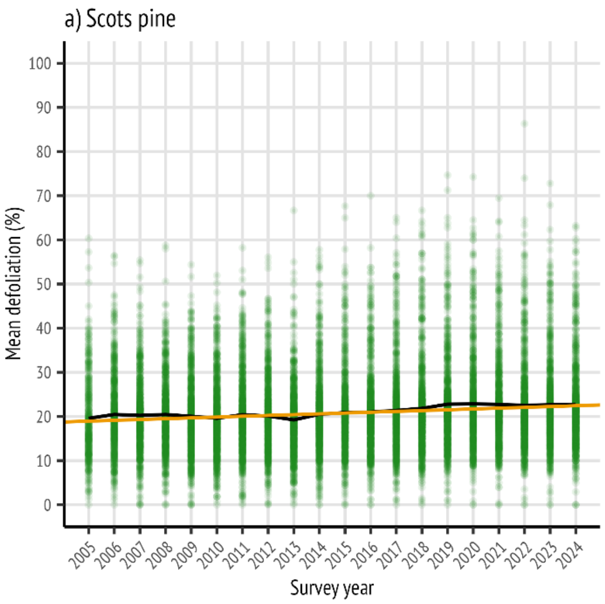
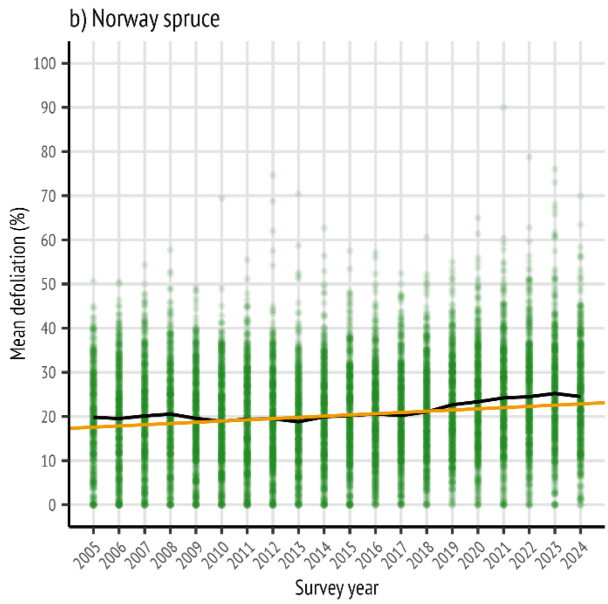
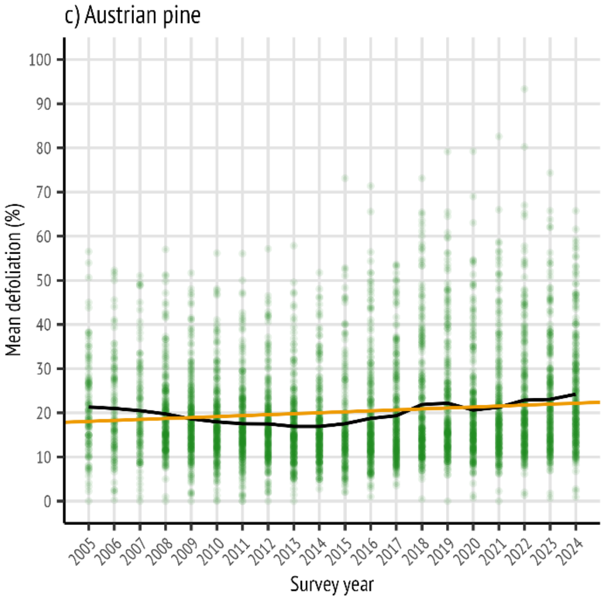
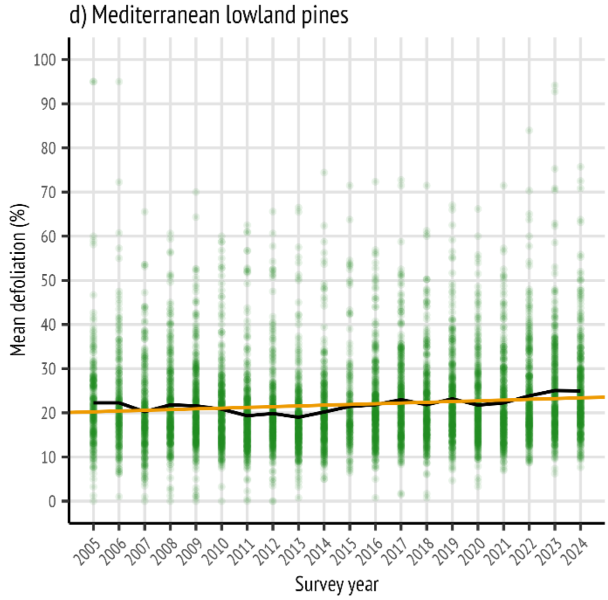


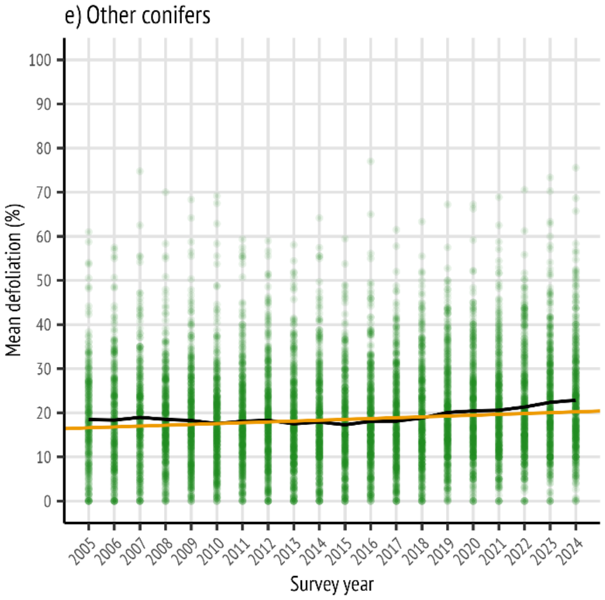
Figure 8-1: Mean plot defoliation of all species in 2024, shown as defoliation classes. The legend (top left) shows defoliation classes ranging from none (blue), slight (green), moderate (orange and red), to severe (black) defoliation. The percentages refer to the needle/leaf loss in the crown compared 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 2005–2024; points represent annual plot mean values:

(a) Scots pine
(regional Sen's slope = 0.1835, $p < 0.001$)

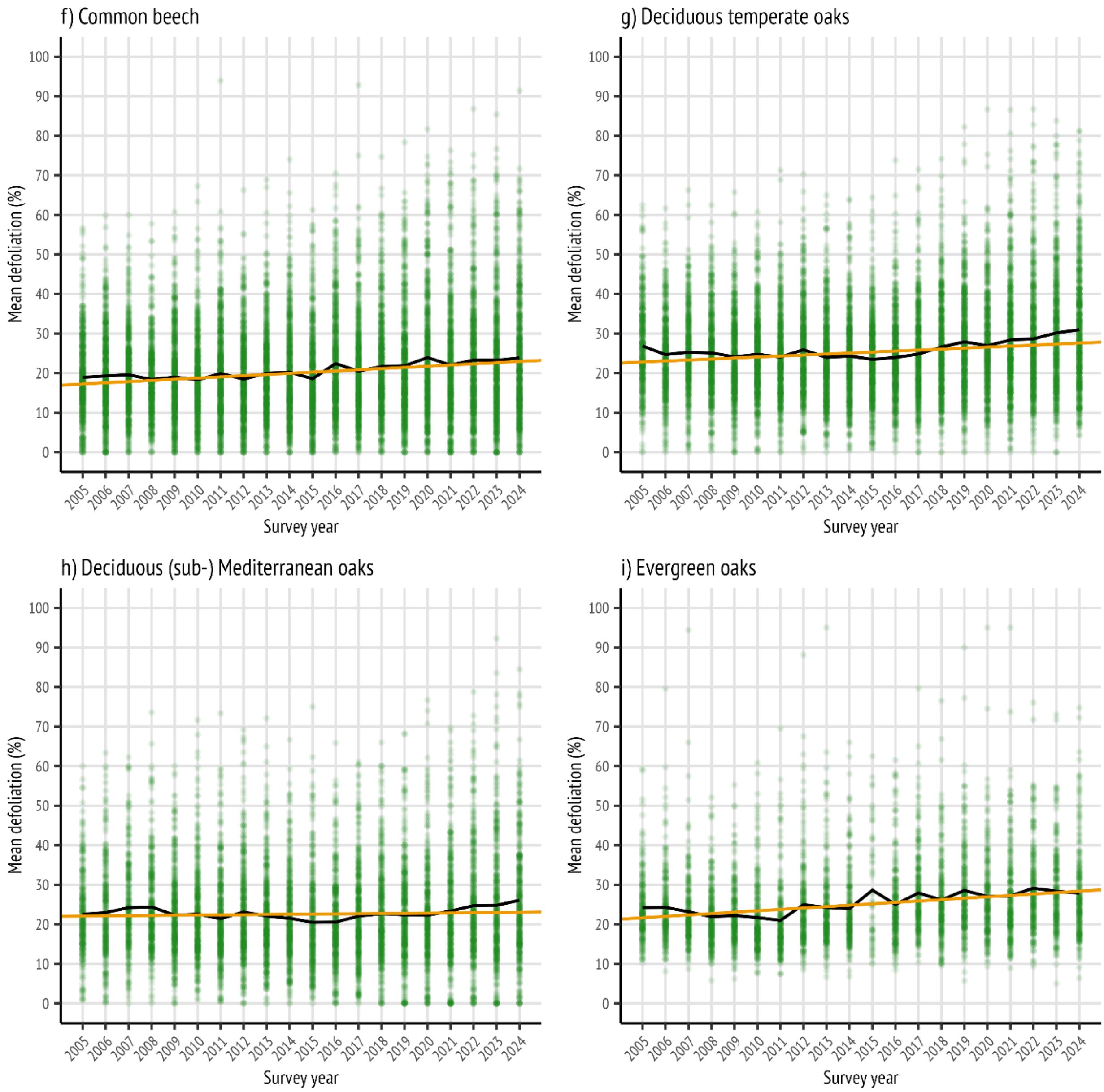
(b) Norway spruce
(regional Sen's slope = 0.2769, $p < 0.001$)

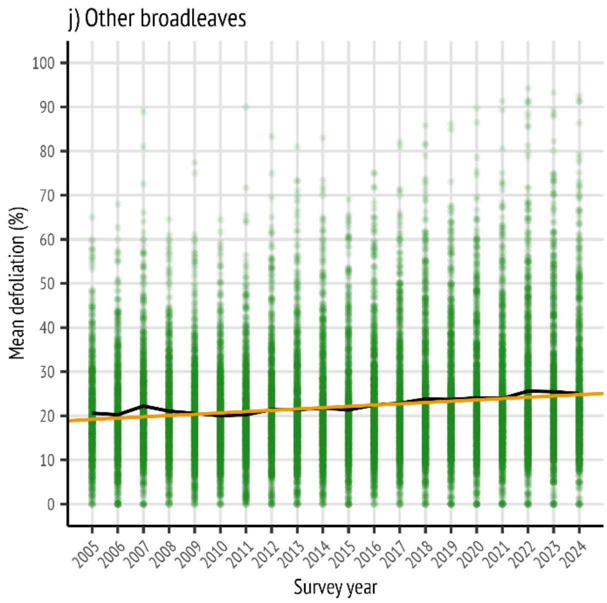
(c) Austrian pine
(regional Sen's slope = 0.2165, *n.s.*)

(d) Mediterranean lowland pines
(regional Sen's slope = 0. 1659, $p < 0.05$)

(e) Other conifers
(regional Sen's slope = 0.1899, $p < 0.05$)

n.s. = not significant





Figures 8-2 f-j: Over-all trend (orange line) and annual mean defoliation across plots (black line) at Level I plots from 2005–2024; points represent annual plot mean values:

(f) Common beech
(regional Sen's slope = 0.2993, *p* < 0.001)
(g) Deciduous temperate oaks
(regional Sen's slope = 0.2511, *p* < 0.05)
(h) Deciduous (sub-) Mediterranean oaks
(regional Sen's slope = 0. 0499, *n.s.*)
(i) Evergreen oaks
(regional Sen's slope = 0. 3536, *p* < 0.01)
(j) Other broadleaves
(regional Sen's slope = 0.2956, *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 2024, Scots pine trees showed mean defoliation of up to 10% on 15.7% of plots and slight (>10–25%) mean defoliation on 62.4% of the plots (please refer to the online supplementary material[1], Figure S1-1). Defoliation of Scots pine trees on 21.5% 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, but also in the Pyrenees and southern coast of the Black 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 3.7%p (Figure 8-2a). Within the chosen period data on mean defoliation across plots show very little fluctuation in regard to the trend line with the highest value 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 2024, spruce trees on over one fifth (22.3%) of all Norway spruce plots had mean defoliation up to 10%, and further 43.5% had only slight defoliation (please refer to the online supplementary material[1], Figure S1-2). On 33.1% of the plots spruce defoliation was moderate (>25–60% defoliation), while severe mean defoliation was recorded on 1.0% of the plots. Plots with low mean defoliation were found mostly in Scandinavia and the Balkan region, while plots with high mean defoliation values were located mostly in central Europe.

The 20-year trend in mean plot defoliation of Norway spruce shows an increase of almost 5.5%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 in 2023 and a slight drop in 2024.

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 8.7% of the plots containing this species, and between 11 and 25% on 55.4% of plots (please refer to the online supplementary material[1], Figure S1-3). Defoliation was moderate on 34.9% of the plots (>25–60% defoliation) and severe on 1.0% of the plots. Plots with less than 10% mean defoliation were mostly located in Türkiye, Bulgaria and Spain, while plots with higher defoliation were scattered throughout the distribution area.

Mean plot defoliation of Austrian pine showed large fluctuations over the past 20 years (Figure 8-2c), with the lowest value in 2014. Since then, mean plot defoliation has been rising each year (with the exception of 2020), reaching its maximum in 2024. However, there is no significant 20-year trend.

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 60.3% of plots had defoliation between 11 and 25% (please refer to the online supplementary material[1], Figure S1-4). Defoliation was moderate on 35.3% of the plots, and severe on 1.2%. 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 northeastern Spain and southern France.

Mean plot defoliation for Mediterranean lowland pines has been at the highest levels in 2023 and 2024. Although annual mean defoliation values showed some variability, still there is a significant trend showing an increase of 3.3%p over the past 20 years (Figure 8-2d).

[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 program (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 2024, common beech had up to 10% mean defoliation on 20.5% of the beech plots (please refer to the online supplementary material[1], Figure S1-5). On 41.9% of plots, beech trees were slightly defoliated (>10–25% defoliation), moderate mean defoliation was recorded on 34.7%, and severe defoliation on 2.9% 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 6%p (Figure 8-2f). Annual mean values generally stayed close to the trend line, but there were two larger deviations from this trend, in 2016 and 2020. Drought in the preceding year seems to significantly affect beech crown condition (Ciais et al. 2005, Dobbertin 2005, Seidling 2007, Seletković et al. 2009, Ognjenović et al. 2022), although the response can happen in the very same year 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 2024, mean defoliation of temperate oaks was up to 10% on 7.1% of the plots, and from >10 to 25% on 37.9%. Moderate mean defoliation (>25–60%) was recorded on 51.3% of plots and severe defoliation (more than 60% defoliation) on 3.8% 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.

With the data for 2024, and the highest value of mean defoliation in the past 20 years, the prominent trend (5.0%p) of deciduous temperate oaks defoliation has become 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, which lasted until 2006 (Figure 8-2g).

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 11.5% of plots, and between 10 and 25% on 45.2% of plots in 2024. This year there was an overall worsening of crown condition – as much as 40.9% of plots showed moderate mean defoliation (in comparison with 34.1% in 2023), and 2.4% severe mean defoliation (please refer to the online supplementary material[1], Figure S1-7). Plots with low mean defoliation were located predominantly in the Balkans and Spain, while plots with higher mean defoliation were mostly found in southeastern France and around the Black Sea.

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 stayed 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 50.8% 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 less plots (46.0% in comparison with 51.8% in 2023), and severe defoliation on 2.0% of plots. The majority of plots with defoliation over 40% were located along the shoreline of the northwest Mediterranean, while the mean defoliation was less in the central Spain.

The trend for evergreen oaks showed the largest, significant increase (7.1%p) in defoliation of all analyzed species and species groups over the last 20 years (Figure 8-2i). The development in mean annual plot defoliation for evergreen oaks is characterized by larger positive and negative deviations from the trend line, sometimes lasting for several years, although lately values have mostly been above the trend line.

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

Damage causes

In 2024, damage cause assessments were carried out on 101 995 trees on 5 633 plots and in 26 countries. On 49 594 trees (48.6%) at least one symptom of damage was found, which is about the same level as in 2023. In total, 72 213 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 1.12 and 1.01 symptoms per tree on average, and lowest for Norway spruce with 0.42 symptoms per tree. Compared to 2023, the number of recorded damage symptoms and the ratios have been slightly increasing for broadleaves (with the exception of evergreen oaks) and decreasing for conifers (except for Austrian pine).

Table 8-4: Number of damage symptoms and assessed trees, and their ratio for the main tree species and species groups in 2024. 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*)	9 923	17 348	0.57
Norway spruce (*Picea abies*)	4 641	11 000	0.42
Austrian pine (*Pinus nigra*)	3 288	5 366	0.61
Mediterranean lowland pines	4 632	8 011	0.58
Other conifers	4 480	7 712	0.58
Common beech (*Fagus sylvatica*)	9 040	11 082	0.82
Deciduous temperate oaks	9 641	8 589	1.12
Dec. (sub-) Mediterranean oaks	6 989	7 917	0.88
Evergreen oaks	4 612	4 586	1.01
Other broadleaves	14 967	20 384	0.73
Total			
Conifers	26 964	49 437	0.55
Broadleaves	45 249	52 558	0.86
All species	**72 213**	**101 995**	**0.71**

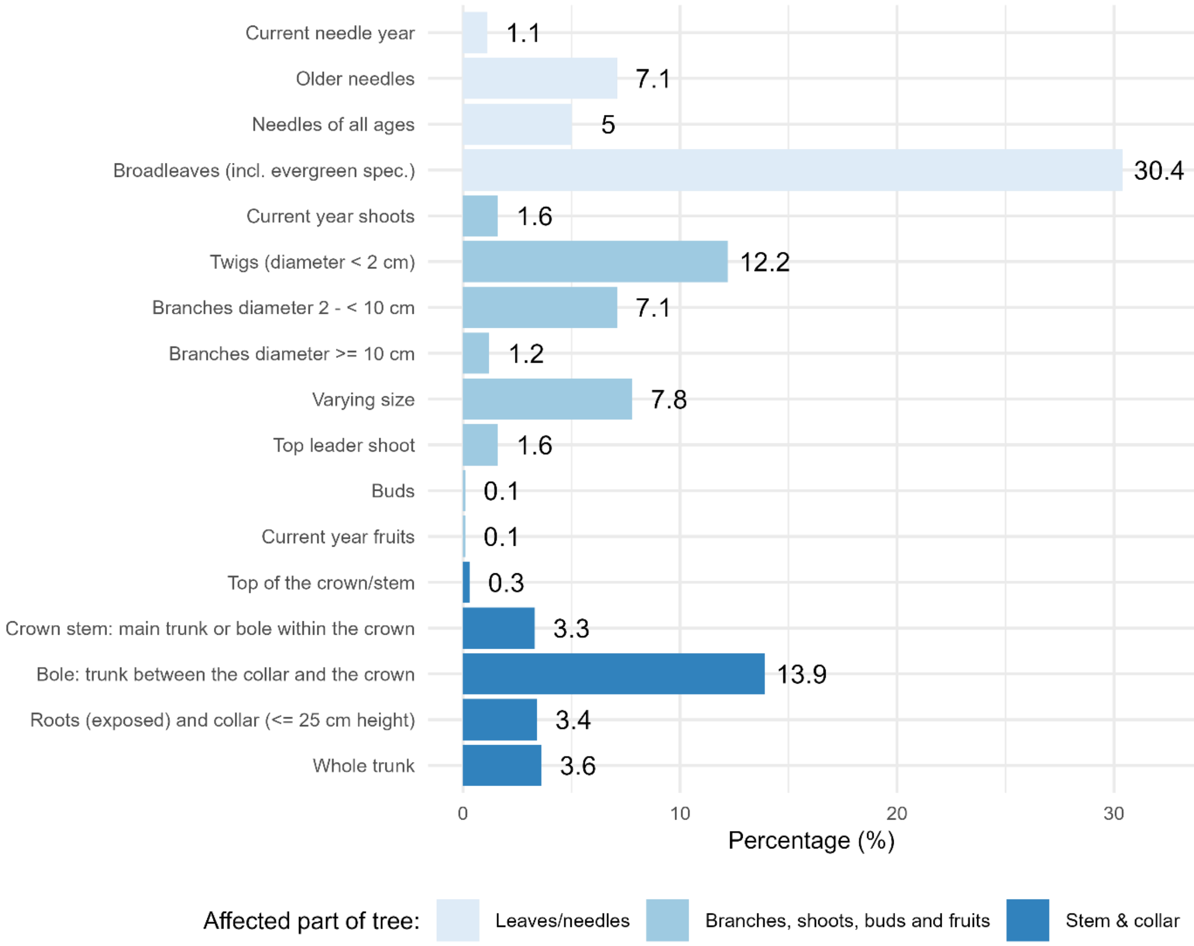


Figure 8-3: Percentage of recorded damage symptoms in 2024 (n=71 063), affecting different parts of a tree. Multiple affected parts per tree were possible. Dead trees are not included.

EVALUATIONS

Symptom description and damage extent

Most of the reported damage symptoms were observed on the leaves of broadleaved trees (30.4%), followed by twigs and branches (28.3%), and stems (21.1%; Figure 8-3). Needles were also often affected (13.2%), while roots, collar, shoots, buds, and fruits of both broadleaves and conifers were less frequently affected.

More than half (55.9%) of all recorded damage symptoms had an extent of up to 10%, 34% had an extent between 10% and 40%, and 10.1% 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 23.5% of all recorded damage symptoms (Figure 8-4). Within the group of insects, 37.3% of damage symptoms were caused by defoliators. Wood borers were responsible for 18.7%, leaf miners for 13.4%, sucking insects for 13.2%, and gallmakers for 5.1% of the damage caused by insects.

Abiotic factors were the second major causal agent group responsible for 18.2% of all damage symptoms. Within this agent group, more than half of the symptoms (51.1%) were attributed to drought, while snow/ice and hail caused 10.4%, wind 9.3%, frost 4.4%, and heat/sun scald 3.0% of the symptoms.

The third major identified cause of tree damage were fungi with 11.9% of all damage symptoms. Of those, 23.2% showed signs of decay and root rot fungi, followed by powdery mildew (14.4%), dieback and canker fungi (13.6%), needle cast and needle rust fungi (12.6%), blight (10.0%), and leaf spot fungi (6.2%).

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 0.6% 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 (0.01% of all damage symptoms). Other factors were responsible for 10.6% of all reported damage symptoms. Apart from these identifiable causes of damage symptoms, a considerable proportion of symptoms (29.4%) could not be identified in the field.

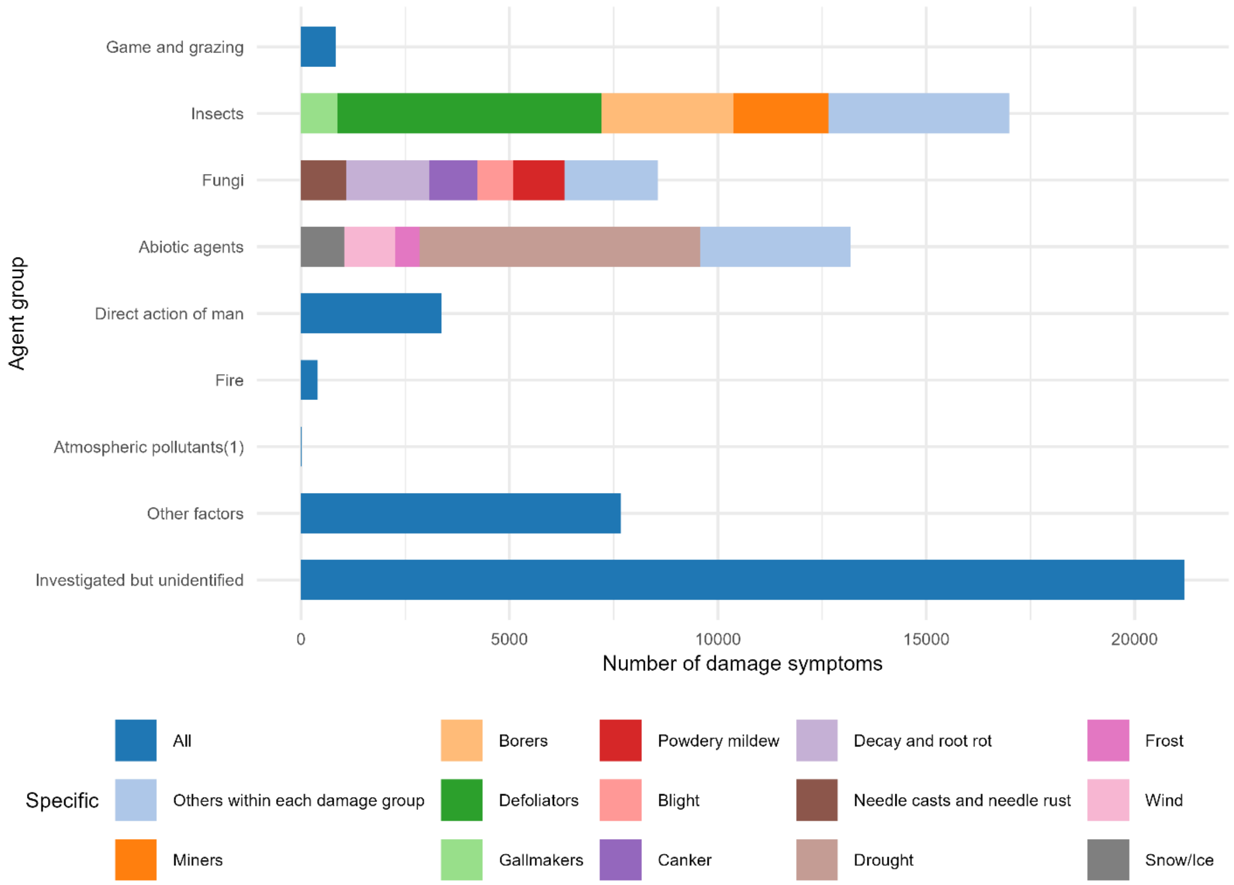


Figure 8-4: Number of damage symptoms (n=72 213) according to agent groups and specific agents/factors in 2024. Multiple damage symptoms per tree were possible, and dead trees are included. (1) Visible symptoms of direct atmospheric pollution impact only

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 38.4% of all damage in beech), deciduous temperate oaks (37.3%), and deciduous (sub-) Mediterranean oaks (33.1%), while insect damage was not so common in Scots pine (8.4%) and Norway spruce (4.7%). Abiotic factors caused by far the most damage in evergreen oaks (40.3%) and Mediterranean lowland pines (38.3%), and the least in Austrian pine (10.6%). Fungi were important damaging agents for Austrian pine (18.3%), evergreen oaks (18.2%), and deciduous temperate oaks (17.7%), but not so for Norway spruce (4.6%). Direct action of man was less important for most species, apart from Norway spruce (14.8%) and Scots pine (8.9%). Damage from game and grazing played a minor role for all species and species groups except for Norway spruce (9.0%). Fire affected mostly Mediterranean species: 1.2% of Austrian pines and 1.4% of Mediterranean lowland pine trees were affected. Other identified factors, such as competition, European mistletoe (*Viscum album*), and European ivy (*Hedera helix*), were prominent in Scots pine (26.3%) and Austrian pine (19.6%). The percentage of recorded but unidentified damage symptoms was small in evergreen oaks (10.8%), but large for Norway spruce (46.9%), Scots pine (31.1%), deciduous (sub-) Mediterranean oaks (30.6%), and Austrian pine (30.5%).

The most important specific damaging agents for common beech were mining insects, causing 21.7% of the damage symptoms, followed by defoliators (10.8%), drought (5.6%), and silvicultural operations (3.3%). Powdery mildew (11.3%) was frequently causing damage on deciduous temperate oaks, while defoliators (10.2%), sucking insects (10.1%), borers (7.5%), drought (6.7%), and competition (3.5%) also were significant. For deciduous (sub-) Mediterranean oaks, sucking insects (9.7%) were the most common damaging agents, followed by defoliators (8.7%), borers (8.0%), drought (6.9%), decay and root rot fungi (3.4%), and European ivy (3.3%). Drought was by far the most important single damaging agent for evergreen oaks (36.6%), but also borers (14.0%), decay and root rot fungi (12.8%), blight (4.1%), and defoliators (4.0%) had an impact on these oak species.

Most damage symptoms in Scots pine were caused by various effects of competition (14.3%), followed by *Viscum album* (7.7%), borers (6.1%), silvicultural operations and needle cast/needle rust fungi (5.4% each), drought (4.6%), and wind (4.3%). For Norway spruce, silvicultural operations (9.5%), red deer and other Cervidae (8.4%), competition (6.9%), mechanical/vehicle damage (4.9%), and snow/ice (3.0%) were most important. Defoliators were causing most damage (15.8%) on Austrian pine trees, but also *Viscum album* (15.6%), needle cast and needle rust fungi (10.3%), blight (5.5%) and drought (5.3%) caused considerable damage. Mediterranean lowland pines were mostly affected by drought (28.2%), defoliators (9.5%), sucking insects (7.3%), *Viscum album* (5.1%), snow/ice (4.0%), and borers (3.5%).

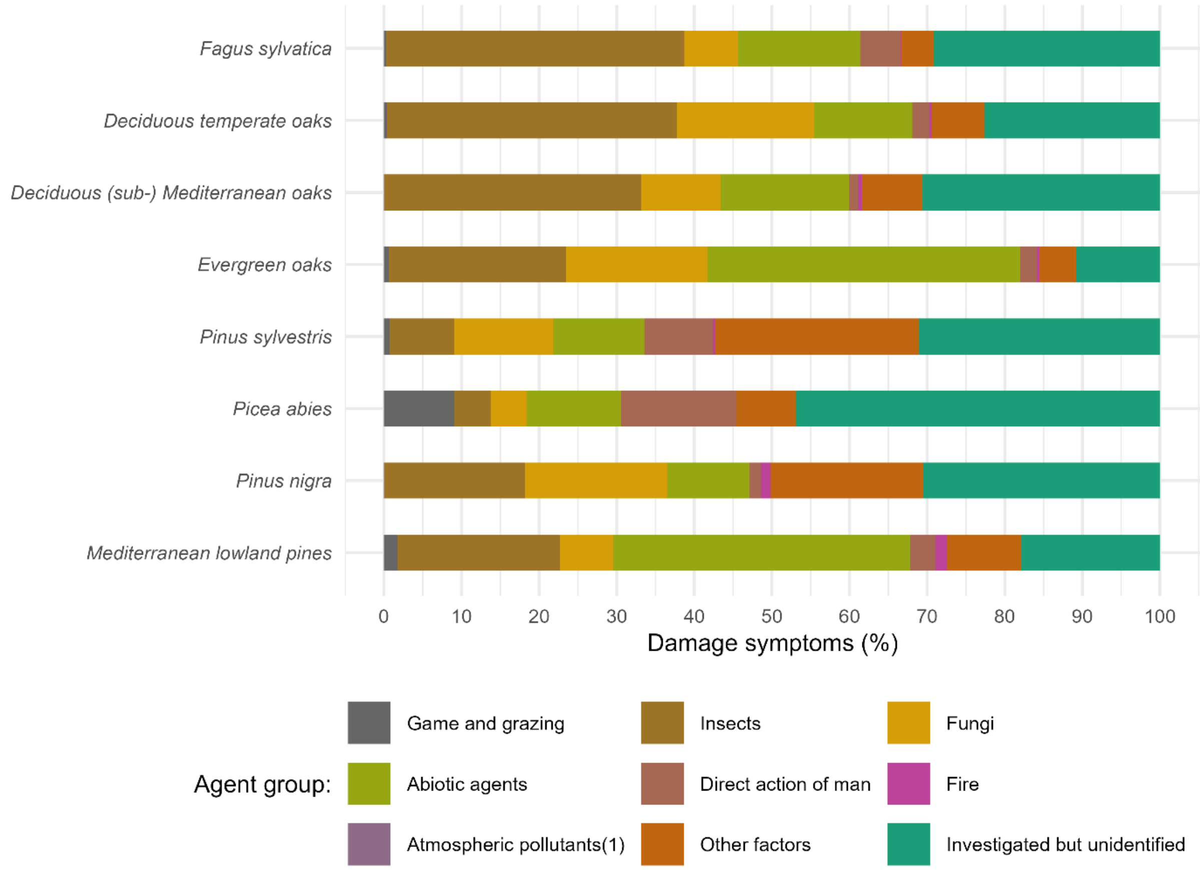


Figure 8-5: Percentage of damage symptoms by agent group for each main tree species and species group in 2024. (1) Visible symptoms of direct atmospheric pollution impact only

EVALUATIONS

Regional importance of the different agent groups

Damage caused by abiotic factors was reported from 1 971 Level I plots (35%) in 2024, occurring frequently throughout Europe. Countries most affected by abiotic factors were Spain, Slovenia, Montenegro, and Cyprus.

Damage caused by insects was observed on 1 839 European Level I plots, which corresponds to 32.6% 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 1 419 European Level I plots (25.2%) 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 1 039 plots (18.4%) 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, 296 Level I plots (5.3%) had trees damaged by this agent group.

There were 53 plots (0.9%) 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 1 145 new dead trees in the damage assessment 2024 (619 broadleaves and 526 conifers, Table 8-5). This results in a mortality rate of 1.1%, which is the same as in 2023. The highest numbers of dead trees among the main tree species and species groups were found for Norway spruce (178 trees, corresponding to a mortality rate of 1.6%), Scots pine (154 trees, corresponding to 0.9%), and Mediterranean lowland pines (98 trees, corresponding to 1.2%). 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 birches (*Betula* spp., 130 trees, corresponding to a mortality rate of 2.4%), and European ash (*Fraxinus excelsior*, 55 trees, corresponding to 7.0%).

Most dead trees were reported from Spain (181, mainly *Pinus halepensis* and *Quercus ilex*), Norway (155, mostly broadleaves and mainly downy birch), France (99, mainly oak species and other broadleaves), Germany and Sweden (94 and 92, resp., mainly Norway spruce and Scots pine), and Bulgaria (75, mainly beech, Scots and Austrian pine). The main cause of mortality to broadleaved trees on Level I plots was abiotic factors (Figure 8-6), followed by fungi and insects. Insects were causing the death of most coniferous trees, followed by abiotic agents and fungi. The determination of the cause of tree death is often very difficult in the field; it could not be identified for around 60% of the dead trees in 2024.

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 birches by abiotic factors.

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 2024.

Main species or species groups	N dead trees	Mortality rate (%)	Main specific cause of death
Scots pine (*Pinus sylvestris*)	154	0.9	Root rot, snow/ice, wind
Norway spruce (*Picea abies*)	178	1.6	Borers: *Ips typographus*
Austrian pine (*Pinus nigra*)	35	0.7	Borers & blight (*Sphaeropsis sapinea*)
Mediterranean lowland pines	98	1.2	Borers: *Tomicus* spp. et al.
Other conifers	61	0.8	Competition, wind
Common beech (*Fagus sylvatica*)	64	0.6	Blight: *Biscogniauxia nummularia*
Deciduous temperate oaks	66	0.8	Drought
Dec. (sub-) Mediterranean oaks	46	0.6	Drought, wind
Evergreen oaks	37	0.8	Mud/land slide, drought
Other broadleaves	406	2.0	Ash dieback
Total			
Conifers	526	1.1	
Broadleaves	619	1.2	
All species	**1 145**	**1.1**	

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

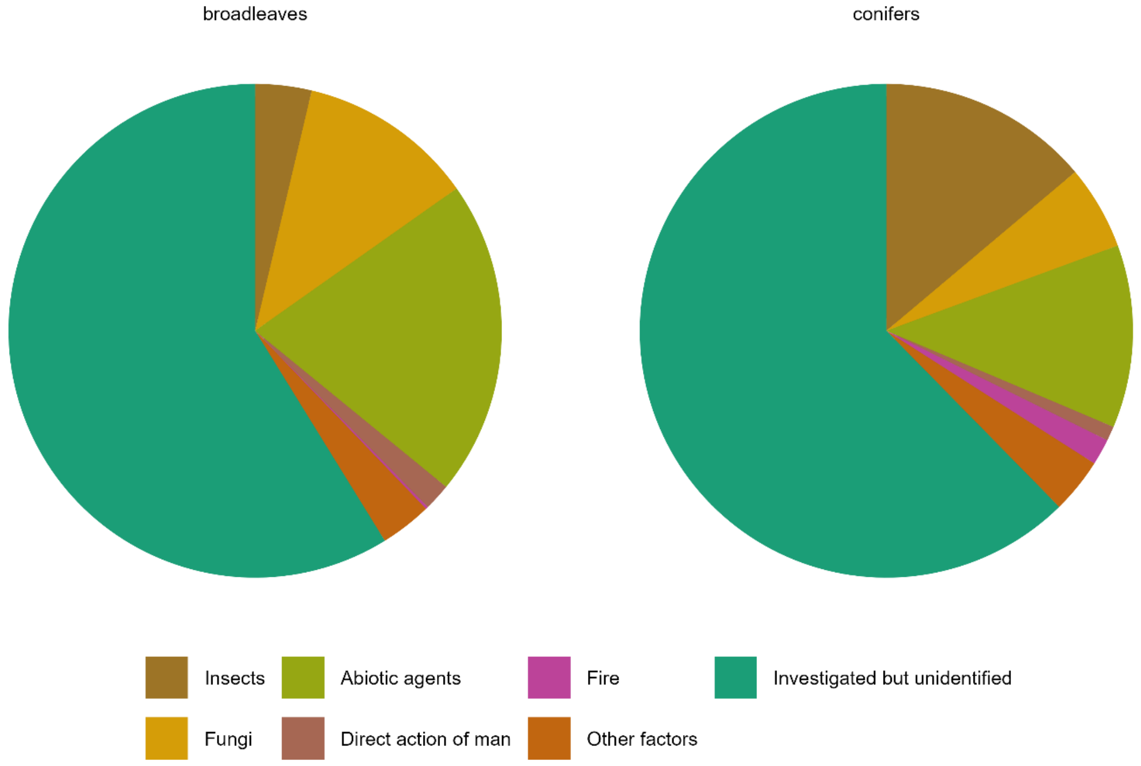


Figure 8-6: Percentage of damaging agent groups causing mortality of broadleaved and coniferous trees in 2024 (n = 1 145)

[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 for 2024, was the 20th survey in Andorra, it was conducted on 12 plots of the national 4x4 km grid and included 289 trees: 118 *Pinus sylvestris*, 139 *Pinus uncinata,* 5 *Betula pendula*, and 27 *Abies alba*, covering the main subalpine forests in Andorra.

Major results/highlights

In 2024, tree crown condition has slightly improved compared to the worsening trend observed in recent sampling campaigns, with 2023 which recorded the poorest crown condition in recent times. Data indicate that years with higher levels of crown defoliation and discoloration coincide with periods of unfavorable climatic conditions during the growing season. Over the past three years, the climate has been characterized by below-average precipitation and above-average temperatures relative to the 1981–2010 reference period. These climatic anomalies likely account for the widespread decline in crown vitality observed across all 12 monitoring stations. In 2024, some months recorded precipitation levels exceeding the reference values, this fact could explain the slight improvement registered.

In terms of overall defoliation, compared to the previous year, 2023, there has been a significant reduction in moderate defoliation, decreasing from 45.5% in 2023 to 22.1% in 2024. This reduction is reflected in a corresponding increase in the proportion of trees classified as having no defoliation (rising from 42.8% in 2023 to 53.3% in 2024) and those with slight defoliation (increasing from 9.3% to 22.5%). The percentage of severely defoliated trees has remained stable, representing 1.7% of the sampled individuals.

Regarding causes of damage, in 2004, 24.2% of the studied trees showed some sign or symptom of damage. The main types of damage observed were mechanical damage of abiotic origin, followed by mechanical damage of biotic origin, and damage caused by the fungus *Cronartium flaccidum*. The presence of individuals with damage caused by the insect *Ips acuminatus* was also recorded. These results are very similar to those from last year's survey.

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. In 2015, a new plot, composed entirely of silver firs (*Abies alba*) was added, in order to enable a more representative survey of this species. Furthermore, since 2021 besides the crown condition survey following the ICP Forests protocol, 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 2021, wet deposition was collected on all 16 plots 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 the measurement 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. The site "Zöbelboden" will be added to the Austrian contribution as a Level II core site.

In 2025, two new projects will start at the Level II sites:

- The project AI4ecoservices will focus on stand and open air climate differences and their modeling using satellite data; furthermore within the project all Level II core sites will be sampled for eDNA (soil).
- The project TreeNET AT will focus on drought monitoring. Within the project the sites Klausen Leopoldsdorf and Unterpullendorf will be equipped with addiational measurement devices (point dendrometers and soil moisture measurements) to create a drought monitoring system.

Belgium Flanders

National Focal Centre

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

Main activities/developments

The regional Level I survey is based on a 4x4 km grid. On a total of 78 plots, 1476 trees were assessed. 57.5% of the sample trees are broadleaves and 42.5% are conifers. The main tree species are *Pinus sylvestris* (32.3%), *Quercus robur* (26.6%), *Fagus sylvatica* (10.0%), *P. nigra subsp. laricio* (9.8%), and *Q. rubra* (6.4%). Less represented broadleaves are gathered in a subset with 'other broadleaves' (14.5%). Examples of tree species in this subsample are *Castanea sativa*, *Q. petraea*, *Betula pendula*, *Fraxinus excelsior*, *Acer pseudoplatanus*, *Alnus glutinosa* and *Populus spp.* Other conifer species are barely represented (0.4%).

Major results/highlights

Considering all species, 22.4% of the trees in the Level I survey were classified as damaged. Mean defoliation was estimated to be 23.2%. Defoliation was moderate in 20.9% of the sample trees. Severe defoliation was limited to 0.7% and the mortality rate was 0.8%.

The share of broadleaves with more than 25% defoliation was 29.0% and the proportion of conifers 13.5%. Mean defoliation in *Q. robur* and *P. nigra* was high compared to the overall mean in broadleaves and conifers. Damage was highest in *Q. robur*, with 39.4% of the sample trees in defoliation classes 2-4. Mean defoliation in *Q. robur* was 27.6%. The share of moderately to severely defoliated *P. nigra* trees was 24.1%, with a mean defoliation of 22.8%.

The least affected species was *P. sylvestris*. 10.3% of the trees were classified as damaged. Mean defoliation was 21.9%.

Considering other broadleaved species, the proportion of trees with moderate to severe defoliation was low in *Q. rubra* and the 'other broadleaves', respectively 16.0% and 15.9%. The mean defoliation score was 20.3% in *Q. rubra* and 20.5% in 'other broadleaves'. *F. sylvatica* revealed a better condition than *Q. robur* but defoliation was higher compared to *Q. rubra* and 'other broadleaves'. Mean defoliation in *F. sylvatica* was 22.3% and the proportion of trees in defoliation classes 2-4 was 28.6%.

The most frequently observed symptoms were insect defoliation, leaf and needle discoloration, crown dieback, wounds and slime or resin flow. 11.3% of the trees showed moderate to severe insect defoliation. More than one-third of *Q. robur* showed moderate to severe leaf loss, caused by insects (34.9%). 0.5% of all sample trees showed moderate to severe shoot dieback. Moderate to severe twig dieback was observed in 4.3% of the trees and moderate to severe branch dieback in 2.5%. *F. sylvatica* showed, compared to *Q. robur*, less insect defoliation but a higher proportion of trees with moderate to severe crown dieback. *Sphaeropsis sapinea* and *Hymenoscyphus fraxineus* caused dieback of shoots, twigs and branches in *Pinus sp.* and *Fraxinus excelsior*.

10.3% of the sample trees showed moderate to severe discoloration. In several plots *Q. robur* suffered from mildew infection (*Microsphaera alphitoides, syn. Erysiphe alphitoides*). Moderate to severe discoloration was attributed to fungal infestation in 32.6% of the oak trees.

Dry and hot periods did not occur. Precipitation was high with storm damage in a few plots. Moderate to high fructification was 7.4% in *Q. robur* and 33.3% in *F. sylvatica*. In *F. sylvatica* seed production was remarkable because in several plots moderate to high fructification was observed three years in a row.

Compared to a year before, a slight increase in defoliation was observed. The share of damaged trees increased with 0.4 percentage points and the mean defoliation with 1.2 percentage points. Crown condition improved in conifers but deteriorated in broadleaves, with the exception of *Q. rubra*. There was a significant increasing trend in defoliation between 2005 and 2024, but not for *Q. rubra* and *P. nigra*. Considering *P. sylvestris*, the increasing trend was significant from 2005 to 2024 but not for a longer period (1995–2024).

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 a second year as a contribution to an international project aiming to identify the main drivers of changes in masting patterns. We hosted Dr Ivan Limić for a Short-Term Scientific Mission under the COST-Action CA21138 'CLEANFOREST' during which he conducted an experiment at ISOFYS - Ghent University intended to study the effects of pollen and associated microorganisms on N compounds in precipitation.

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

Sioen G, Verschelde P, Roskams P (2024) Bosvitaliteitsinventaris 2023. Results of the crown condition survey (Level I). Research Institute for Nature and Forest, Report 2024 (13). INBO, Brussels (in Dutch). ISSN:1782-9054, https://doi.org/10.21436/inbor.102411295

Outlook

The Level I and the Level II program will be continued.

Belgium Wallonia

National Focal Centre

Elodie Bay, SPW – Public Service of Wallonia

Main activities/developments

In 2024, data were collected on 7 plots for Level II/III and on 45 plots for Level I.

Major results/highlights

2024 was a rainy, hot, and dim year. Humid weather conditions of 2024 have favorized the development of numerous pathogenic fungi on needles and leaves. Early bud break led to damage from late frost in April.

Pedunculate oak is currently in poorer health than sessile oak. Both have been severely affected by caterpillars and powdery mildew attacks. In the driest part of the country, numerous trunk leaks have been observed.

Beech has been slowly deteriorating since 2010. In 2024, an increase in necrosis and insect bites on the trunks was observed.

The spruce bark beetle crisis is coming to an end. The volume of bark beetle-affected wood has returned to normal. However, the health of the spruce remains very poor.

Contarinia attacks on Douglas-fir trees have dropped to an average of 8.3% of needles this year.

The 2024 plantings had a very good recovery rate, with an average recovery rate of 93% in the fall.

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

Please refer 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 2024, 160 permanent sample plots (PSP) with 5600 evaluated sample trees were surveyed. Four coniferous species were observed: *Pinus sylvestris* L., *Pinus nigra* Arn., *Picea abies* (L.) Karst, and *Abies alba* Mill., and nine deciduous tree species: *Fagus sylvatica* L., *Fagus orientalis* Lipsky, *Quercus petraea* (Matt.) Liebl., *Quercus frainetto* Ten., *Carpinus betulus* L., *Quercus rubra* L., *Tilia platyphyllos* Scop., and *Castanea sativa* Mill.

The total number of the observed coniferous trees was 2430 (43.4%), and deciduous trees – 3170 (56.6%).

Main activities:

- Assessment of the health status of tree crowns in all 160 PSPs;

- Sampling of leaves/needles and leaf analysis in 30 Level I PSPs;
- Taking soil samples in 19 PSPs and analysis of physical and physicochemical properties, chemical composition by genetic horizons and layers;
- Study and description of the floristic composition and phytocenotic structure of the shrub-grass sinuses in the plant communities from different associations in 30 PSPs;
- Biometric measurements in 19 PSPs.

Level II

Main activities:

- Assessment of the health status of tree crowns and damaging factors in the 4 permanent sample areas (PSP);
- Collection and analysis of atmospheric deposits in all 4 PSPs;
- Collection and analysis of soil solutions in all 4 Level II PSPs;
- Collection and analysis of wood waste samples in 3 PSPs;
- Monitoring of air quality indicators in all 4 PSPs;
- Monitoring of meteorological parameters in all 4 PSPs;
- Evaluation of damages from ozone in 2 PSPs;
- Phenological study in Vitinja PSP-core (PSP 0001).

The program for the monitoring of forest ecosystems in Bulgaria operates within the framework of the National Environmental Monitoring System (http://eea.government.bg/bg/nsmos).

The monitoring activities are carried out in co-operation with the Forest Research Institute under the Bulgarian Academy of Sciences (BAS) and the University of Forestry, Sofia.

Major results/highlights

The results of the crown defoliation assessment show that in 2024 the condition of the observed coniferous and broadleaved tree species is approximately the same – in category 0+1 of the broadleaved species are 54.2%, and in the case of conifers - 50.9%.

Of the observed coniferous species up to 60 years old - *Pinus sylvestris* and *P. nigra*, the condition trend is preserved, with *P. sylvestris* being in better condition (60.0% are in category 0+1), while for *P. nigra* it is 52.0%.

Of the observed coniferous tree species over 60 years old *P. sylvestris* trees continue to be in the worst condition. In 2023 non-defoliated and slightly affected by defoliation, trees were 38.7%, and in 2024 – 30.8%. The health condition is better for *P. nigra*, which is 42.4% in category 0+1, followed by *Abies alba* with 81.6% and in the best condition according to the "defoliation" indicator is *Picea abies* with 87.9% healthy and slightly damaged trees.

Of the deciduous tree species up to 60 years old, *Fagus orientalis* is in very good condition, in which 100% of the observed trees are in category 0+1, followed by *Q. frainetto* – 93.3%. Of the observed broadleaved tree species over 60 years old, in very good condition are *Quercus petraea* - 76.5%, followed by *Q. frainetto* - 58.6% and *Fagus sylvatica* - 54.5%. With the largest percentage of trees in the 4th category are the stands of *Carpinus betulus* - 4.7%.

In the studied forest stands and plantations, among the biotic impact factors, there are representatives of both contributing stressors (leaf pathogens and defoliant insects) and secondary stressors (xylotrophic insects and facultative parasites).

The deteriorating health status of *Pinus sylvestris* and *P. nigra* plantations is due to the increased development of fungal pathogens on the roots, stems, branches, and needles (*Heterobasidion annosum*, *Diplodia sapinea*, *Cyclaneusma minus*, *C. niveum*, etc.) and insect pests (*Ips acuminatus*, *Tomicus piniperda*, *T. minor*, *Phaenops cyanea*, etc.). Prolonged periods of drought during the growing season contribute to their development, leading to a physiological weakening of the trees.

In *Fagus sylvatica* stands in 2024, *Orchestes fagi* has caused mass leaf damage, but the newly established fungal pathogen *Biscogniauxia nummularia* and *Nectria* sp. pose a greater threat, damaging the non-renewable tissues (bark and sapwood) of tree trunks and branches. The fungal pathogen *B. nummularia* was found for the first time in beech sample plots, whose occurrence is associated with prolonged periods of drought.

Damage caused by the fungal pathogen *Biscogniauxia* sp. was detected on the stems of *Carpinus betulus* for the first time. The pathogen is a serious threat to the survival of the species in the conditions of climate changes and prolonged droughts. On the leaves of the oak trees in some areas, a severe development of anthracnose was observed, with the main causative agent the ascomycete fungus *Apiognomonia errabunda*.

The invasive insect pest *Corythucha arcuata* is widespread in all the surveyed sample plots of *Quercus frainetto*, *Q. petraea,* and *Q. cerris*. In the sample plots with *Q. frainetto*, and *Q. petraea*, the main cause of the deteriorating health condition is tracheomycosis caused by *Ceratocystis roboris*.

The presence of abiotic damage including clearcuts, are objective prerequisites for attacks by xylophages and development of fungal diseases, which should be taken into account in forest management.

Large areas of coppice forests are mature and have deteriorated the physiological and health conditions.

The observations in the sample plots for intensive monitoring (Level II) were focused on the influence of different stress factors and the reaction of the ecosystem.

The results of 2023 showed that the main stress factor for the observed spruce stands in the permanent sample plots 'Yundola' (PSP 0003) and complex background station (CBS) 'Rozhen' (PSP 0005) was ozone. Regardless of the fact that in 2020 the ozone exposure index with accumulation above 40ppb (AOT40) in the SP 'Yundola' decreased, in 2023 the short-term permissible norm for vegetation protection exceeded 1.35 times, and the norm for forest protection – 2.0 times. Averaged over the 5-year period, the forest protection standard exceeded 1.62 times. The calculated values of AOT40 for CBS 'Rozhen' in 2023 decreased and not exceeded the short-term permissible norm for

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vegetation, but has still exceeded the norm for forests 1.2 times. During the entire 5-year period (2019–2023), the AOT40 index had values above the norm for forest protection, and on average for the period it exceeded the norm 2 times.

For the sample plots, where broadleaved tree species were observed, it was found that in the 'Vitinia' PSP, the value of the AOT40 index in 2023 remains high. The long-term permissible norm for vegetation protection was exceeded 3.2 times, and the norm for forest protection – 2 times. On average, for the 5-year period, the norm for forest protection was exceeded 1.62 times. In 2023 the concentration of ozone in the area of the PSP Staro Oryahovo was increasing significantly. The AOT40 indices are increasing compared to the previous years, with the AOT40 for vegetation exceeding the standard by about 2 times, and for forests the norm is exceeded 1.3 times.

The combination of high temperatures and prolonged drought, especially in the summer months (July, August, September) continues to have an adverse effect on the condition of various tree species and to be one of the main stress factors.

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

Belilov S, A Stojanova, G Georgiev (2024) New eurytomid parasitoids of bark beetles in pine plantations in Ihtimanska Sredna Gora Mountains, Bulgaria. Historia naturalis bulgarica, 46 (11):297-302

Georgieva M, Trencheva K, Dobreva M, et al (2024) First records of *Microstroma album* (Desmazières) Saccardo, 1878 (Basidiomycota: Microstromataceae) and *Phylloxera glabra* (von Heyden, 1837) (Hemiptera: Phylloxeridae) in oak stands in Bulgaria. Historia naturalis bulgarica 46(5), National Museum of Natural History. https://doi.org/10.48027/hnb.46.053

Georgieva M, Georgiev G, Ivanov V, Hristova M (2024) First records of *Biscogniauxia mediterranea* (De Not.) Kuntze on *Quercus rubra* L. in Bulgaria. Historia naturalis bulgarica, 46(10):265-271. National Museum of Natural History, https://doi.org/10.48027/hnb.46.102

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.

In 2024, the implementation of the project No. BG16FFPR002-3.003 "Optimization of the infrastructure of networks (with monitoring sites) for the implementation of forest ecosystem monitoring schemes in the country", financed by the "Environment" Program 2021–2027, began. The aim of the project is to expand the intensive monitoring network. Within the framework of the project, 6 new, permanent sample plots will be built, equipped to implement the schemes for intensive monitoring of forest ecosystems and re-equipment of the installations for collecting samples of atmospheric deposits from precipitation, tree fall and lysimeter waters of the existing Level II sample plots. With the designation of 6 new Level II sample plots, each of the regions into which Bulgaria is conditionally divided for the purposes of large-scale monitoring, will have a sample plot for intensive 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. In 2024 we successfully added the Damage status parameters into the assessment and reporting system. Level II activities were continued on all seven intensive monitoring plots.

Major results/highlights

Level I

Ninety-six sample plots (2266 trees) on the 16 x 16 km grid network were included in the survey 2024, with 1907 broadleaved and 359 coniferous trees assessed.

The percentage of trees of all species within classes 2-4 has been on a slight increase lately with 34.0% in comparison with 33.3% in 2023. Defoliation of broadleaves within defoliation classes 2-4 was also slightly increased in 2024 (32.6%) in comparison with 2023 (30.4%) while the crown condition of conifers was improved (41.5 vs. 50.9% in 2023).

Most defoliated tree species in Croatia in 2024, based on the percentage of trees in classes 2-4, were *Pinus nigra* (81.3%) and *Fraxinus angustifolia* (61.7%). The least defoliated species were *Pinus halepensis* (16.4%) and *Quercus pubescens* (19.0%). A significant worsening of *Fagus sylvatica* crown condition was recorded, with the highest ever recorded percentage of trees in classes 2-4 (29.4%) compared to only 16.1% in 2023.

The most widespread damage was damage to leaves (37.0%), followed by damage to the trunk (32.4%), and finally damage to branches, shoots, and buds (30.6% of all recorded damage). Most of tree damage was caused by insects (27.2%), especially sucking insects (13.9%). Next were abiotic agents with 14.5%, and fungi with 9.4% (powdery mildew 4.3%) of all damage. Direct human activity accounted for 6.6% of all damage to forest trees. Drought accounted for 4.9% of all damage. Despite a high number of recorded damage symptoms, damage extent was mostly in category 1 (0-10%).

Level II

Crown condition on our intensive monitoring plots usually depends a lot on biotic factors, but in 2024 the damage from Corythuca arcuata on plots 109 and 110, and the damage from Rhynchaenus fagi (plots 103 and 105) was not significant. Deposition of nitrogen recorded in 2024 on plots 109 and 110 was close, but not over the limit value of 15 kg N ha-1 g-1. Ground-level ozone concentrations in summer, autumn, and winter months were over 90 ppb, but not over the limit value. Nevertheless, 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, Medak J, et al (2025) Oštećenost šumskih ekosustava Republike Hrvatske – izvješće za 2024. godinu (The damage status of forest ecosystems in Croatia – a report for 2024) Hrvatski šumarski institut/Croatian Forest Research Institute. Jastrebarsko, Croatia. www.icp.sumins.hr/

Outlook

Financing of the national forest monitoring program in 2023 remains at a reduced level, therefore sampling of deposition and measurements of changes in circumference by fixed girth bands will not be performed on plot 106, and a low level of monitoring intensity will continue on plots 105 and 111.

Cyprus

National Focal Centre

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

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.

Co-operation and submission of data and results

There is a close co-operation 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),
- 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).

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 runs 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 120 plots in 2024. Assessment of defoliation and other parameters related to crown condition was carried out on a total of 4 045 trees. The number of assessed plots increased slightly compared to previous years when it was reduced due to the ongoing bark beetle outbreak. On half of the Level I plots the dendrometrical parameters were measured synchronously with dendrometric measurements on the Intensive Monitoring plots which take place during the vegetative dormancy season 2024/25.

At Level II, the health status was assessed in 2024 on a total of 15 monitoring plots. During the growing season, ground vegetation was also assessed on all plots. Continuous monitoring of environmental parameters continued on the seven core plots of Level II.

Major results/highlights

The weather course during the growing season (April–September) was generally favorable for forest condition, although its average temperature 15.3°C was 1.7°C higher than the long-term (1991-2020) climatic normal. The average temperature was higher than the normal also in winter months with the exception only of November, when it was 0.7°C lower. High temperature was balanced with higher amount of precipitation which reached 570 mm during the vegetation season compared to the climatic normal of 467 mm. The only serious drought period was thus recorded in the first half of September. The more favorable climate during the growing season was reflected in a continued slight decrease in the representation of the severe defoliation class (>60-100%) for the main forest tree species (spruce, pine, oak, beech).

Compared to last year, in older coniferous species (over 59 years old), there was recorded a change in larch (*Larix decidua*) with an increase in the moderately severe defoliation class (>25-60%) and in fir (*Abies alba*), which, on the contrary, experienced a slight improvement with a shift of representation from defoliation class 2 (>25-60%) to classes 0 and 1. In young coniferous species (up to 59 years old), there was a deterioration in pine (*Pinus sylvestris*), larch (*Larix decidua*) and fir (*Abies alba*), in which the representation of defoliation class 2 increased while class 1 decreased.

In deciduous trees of older age categories, the health status of oak (*Quercus petraea, Quercus robur*) improved by reducing the representation of defoliation class 2 while class 1 increased. In beech (*Fagus sylvatica*) there was a slight improvement, defoliation class 0 increased while class 1 decreased. In alder (*Alnus* sp.), there was a slight deterioration with a shift from defoliation class 1 to class 2. Mortality continued to increase in ash (*Fraxinus excelsior*), the representation of class 4 defoliation (100%) increased by 2.7%p. In younger deciduous trees, there was a significant improvement in oak, the representation of class 0 increased by 17.1%p while the representation of classes 1 and 2 decreased. There were no significant changes in beech, while birch (*Betula pendula*) showed a slight deterioration in its health, defoliation class 1 decreased by 5.2%p while class 2 increased. Other younger broadleaf trees showed a slight improvement, the representation of class 2 decreased by 6.5%p while the representation of classes 0 and 1 increased.

Besides the health status assessment, monitoring of deposition, soil solution, litterfall, and tree phenology continued on seven core plots of Level II in 2004 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.

The concentrations of the monitored elements in the soil solution on the areas of Level II (gravitational soil water flowing through the upper organic horizon and soil water in the mineral soil at a depth of 30 cm are monitored) fluctuate within the usual range of values. On some plots, a slight increase in the pH of the soil water is noticeable, in some places there is also a slight decrease in the concentrations of sulfates (S-SO_4^{2-}) in both horizons. At the plot 2251 Luisino údolí, a slight decrease in the concentrations of nitrates, as well as in total nitrogen, is also recorded. A slight increase is noticeable in the case of potentially harmful Al concentration on plots 2103 Všeteč and 2161 Želivka. On the plot 2161 Želivka, a part of the forest stand was cut down due to a bark beetle outbreak, which significantly affected the measurement of the soil solution. In periods after significant rains, the collection of soil solution samples is more or less impossible due to flooding of the probe, measuring equipment and storage containers with stagnant water.

Especially the north-eastern part of Czechia was affected by floods which followed after extremely intensive rains on September 13–15. Huge damage to buildings, transport infrastructure, including forest roads, were recorded. During this period the highest national one-day amout of precipitation 386 mm (14.09.2024) was measured on station Švýcárna, which is a part of our ICP Forests Level II network.

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 (2024) Monitoring zdravotního stavu lesa (Forest health condition monitoring). In: Knížek M (ed.): Výskyt lesních škodlivých činitelů v roce 2023 a jejich očekávaný stav v roce 2024. Zpravodaj ochrany lesa. Supplementum 2024:66-70. Výzkumný ústav lesního hospodářství a myslivosti, Jíloviště.

Outlook

The first cycle of regular dendrometric measurements will be completed on Level I plots by the end of March 2025. The dendrometric measurements on intensive monitoring plots will be completed at the same time. Soil sampling is planned for all Level II plots during 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), with additional Level I plots included for crown condition survey to compensate for the loss of NFI data. Ambient Air Quality (AAQ) measurements have now been implemented in all four Level II plots.

Major results/highlights

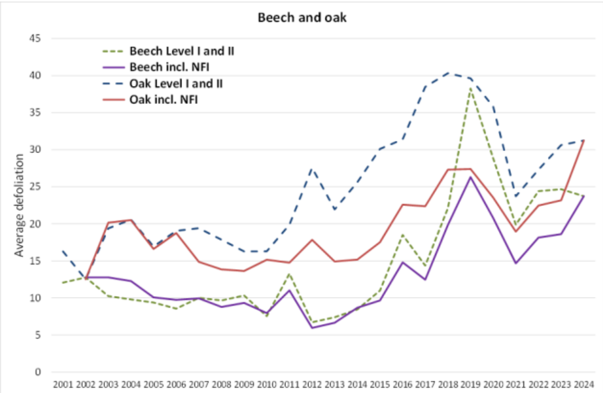
The health status results have previously been based on Level I and II plots in combination with observations from the NFI. The observations from NFI are no longer available due to cessation of crown condition monitoring in the Danish NFI, hence we have increased the number of Level I plots. However, we still end up with a notable lower number of plots and trees compared to previous years. Based on Level I and II plots, mainly the health status of beech (*Fagus sylvatica*), oak (*Quercus robur* and *Q. petraea*), and Norway spruce (*Picea abies*) can be evaluated and compared to previous years. For other conifers and broadleaves some trends can be seen, but the data basis is too narrow to support any firm conclusions.

In 2024, average defoliation decreased for Norway spruce and slightly for Scots pine. The average defoliation for Norway spruce was 16%, and the percentage of damaged trees was also 16%. Sitka spruce had a sharp increase in defoliation, whether comparing Level I plots only or including NFI data for 2023. However, the number of monitored Sitka spruce trees and Scots pine trees in 2024 were only 10% of the trees evaluated, when NFI data was included in 2023. There was no data for other conifers.

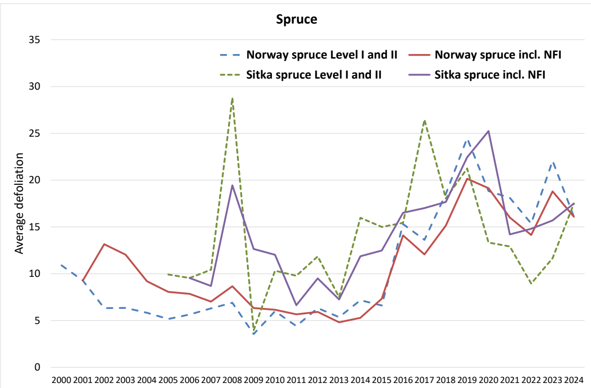
The average defoliation remained at 24% for beech, but 40% of the trees were damaged. The number of damaged trees was much higher than in 2023 (22%), but if comparing with just Level I and II plots in 2023, there was actually a small reduction in the percentage of damaged trees in 2024. Two new Level I plots with beech and one with oak were started in 2024, so the number of monitored trees was one third of the previous years, when NFI data was included. The average defoliation remained around 31% for oak, when excluding NFI data both years, but if including NFI data in 2023, the average defoliation increased (artificially) from 23% to 31%. 58% of oak trees were damaged, compared to 30% in 2023 (with NFI data included), but if using only Level I and II plot data in 2023, the difference is small. Other broadleaves, mainly maple and ash, showed a small decrease in average defoliation, but the number of monitored trees is low.

It should be noted that the observed defoliation in 2024 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 six years (2017–2023) are the same for beech, oak, Norway spruce with or without NFI data. The average defoliation of oak seems much higher on the Level I and II plots, and the same trend can be observed for beech and Norway spruce. For Sitka spruce it is opposite, because there is only one Level I stand, which is very young.



Average defoliation of beech and oak on Level I and II plots only (dotted lines), compared with results including NFI data. Crown condition data were available from NFI from 2003-2023 for oak and from 2002-2023 for beech.



Average defoliation of Norway spruce and Sitka spruce on Level I and II plots only (dotted lines), compared with results including NFI data. Crown condition data were available from NFI from 2001-2023 for Norway spruce and from 2007-2023 for Sitka spruce.

Estonia

National Focal Centre

Vladislav Apuhtin, Estonian Environment Agency

Main activities/developments

The health status of 2665 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).

On Level II plots the following forest monitoring activities were carried out in 2024:

- chemical analyses of the deposition water collected throughout the year on 6 sample plots;
- chemical analyses of soil solution collected during 9 months (from March to November) on 5 sample plots;
- samples of litterfall were collected on one plot according to ICP Forests requirements;
- foliar samples collected in December 2023 were analyzed;
- soil samples collected in 2023 were analyzed;
- the coverage and species composition of the ground vegetation was assessed on 6 sample plots;
- the growth of observation trees was measured on all plots.

Major results/highlights

Level I

The total share of not defoliated trees, 39.9%, was 2.9%p lower than in 2023. The share of not defoliated conifers, 39.1%, was lower than the share of not defoliated broadleaves, 45.1%, in 2024.

The share of trees in classes 2 to 4, moderately defoliated to dead, was 10.2% in 2024. The share of conifers and broadleaves in defoliation classes 2 to 4 were 10.4% and 9.1%, respectively.

According to the observation data, the condition of Scots pine and silver birch has decreased, the condition of Norway spruce has slightly improved compared to 2023. The majority of Scots pine observation trees (38.6%) were healthy (defoliation rate 0–10%) and slightly defoliated 52.7% in 2024. The share of spruces without crown damages was 40.4% (38.0% in 2023) and the share of trees with defoliation rate 10–25% was 44.0% (44.1% in 2023). Compared to 2023, the share of healthy birches has decreased 6.1%p in 2024 and compared to 2022, by as much as 19.5%p.

All trees included in the crown condition assessment on Level I plots are also regularly assessed for damage. In 2024, 4.9% of the living trees observed had some insect damage (mainly defoliators) and 18.6% of them (mainly Scots pines) had symptoms of fungal disease. Only 33% of trees had no identifiable symptoms of any damage.

Results from the forest soil monitoring conducted between 2020 and 2023 indicate that soil pH has not changed significantly over the past 15 years, while organic carbon stocks have slightly improved. The levels of extracted macro- and microelements have generally increased, but the levels of exchangeable elements have decreased.

Level II

In 2024, a total of 1410 precipitation samples were collected from Level II forest monitoring sites in Estonia, which were used to calculate annual pollution loads and analyze chemical composition. Overall, precipitation amounts remained within the average range for Estonia. The concentrations of chemical elements and compounds in precipitation water were mostly low, with higher concentrations occurring mainly in drier months.

Ground vegetation studies are conducted every five years. The species composition of spruce stands is more diverse than that of pine stands, while coverage is the opposite. Changes vary between sample plots compared to the previous period.

At Level II sample plots, the growth of observation trees is measured every five years. The results indicate a slowdown in stand volume increment and an increase in tree mortality.

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

Apuhtin V, Nael J, Ehrpais M (2025) Forest Monitoring, Report of the survey 2024, Estonian Environment Agency, Tartu

Yearbook Forest 2023, Estonian Environment Agency

Outlook

The forest monitoring activities in Estonia will continue for both levels (Level I and Level II) in 2025.

Finland

National Focal Centre

Päivi Merilä, Natural Resources Institute Finland

Main activities/developments

In 2024, 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 and crown condition surveys. In addition, tree increment was monitored using girth bands by manual recordings. The monitoring data of the year 2022 was submitted to the ICP Forests database.

Major results/highlights

A study by Kaarlejärvi et al. (2024) utilizing BioSoil data (2006) with earlier nationwide systematic understory vegetation survey data (1985–1986,1995) from Finland introduced a model-based framework to build multidimensional community trait distributions and illustrated how it can be used to detect signs of ecological selection and to identify possible underlying mechanisms. Applying this framework to a large natural community dataset, they found evidence that directional, stabilizing, and divergent selection concurrently shape boreal forest understory communities along environmental gradients. Their results also suggest that the type of selection acting on a trait may change from divergent to stabilizing over time, as succession proceeds. Finding that multiple selection types are possible over time brings novel insights to ecological theory, which often assumes that traits are either under stabilizing or directional selection. In these study communities with varying ages, densities and habitat qualities, interacting and alternating selection forces create multiple trait trade-offs selecting for species with specific trait combinations. As a result, they observed a reduction in the overall functional diversity of boreal forest understory communities along a density gradient.

Outlook

In 2025, 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 program. The data from these three plots are also used to fulfill the information needs of the National Emission Ceilings Directive (NECD).

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 (on a sub-network of plots mostly populated by oaks) to assess foliar damage resulting from defoliators activity.

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 Manual is also used in the southern part of France in autumn to follow the health of evergreen oak stands.

Level II

Since the French Level II monitoring network (RENECOFOR) reached its initially defined 30-yr horizon, an agreement was found to prolong its long-term activities, and to further develop them, with fundings 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. Concretely in 2024, tree assessments (phenology, health, and annual growth) were carried out on all 102 plots of the Level II network, while atmospheric deposition, meteo, soil solution, litterfall, and ozone survey (concentrations in the air and symptoms visible on the vegetation) were continued on the same subset of plots. Also, like every five years, a periodic growth assessment campaign was successfully conducted in all the plots during the 2024–2025 dormancy season. Prior to this campaign, a training course including a field intercomparison exercise was organized in September with all the field crew leaders involved in these assessments throughout the French territory. And, in preparation for the ground vegetation assessment campaign planned for 2025, a field intercomparison exercise was also organized with all the botanical experts in July in Rouen.

In addition, efforts have been amplified to consolidate and further develop the Level II network.

- First, the field campaign launched in 2021 for georeferencing all trees and monitoring devices within the plots was finalized in June 2024. The collected coordinates were already helpful to find again all the trees (even the smallest ones) in the periodic growth assessment campaign, and in return periodic growth assessments are now used as an opportunity to update the plot maps with new trees to be included after they had reached the 5-cm diameter threshold required for the growth survey.
- Efforts have been continued to redesign the database system, initially developed under the Paradox software, to migrate to a widely used open-source software (PostgreSQL). And a new task was launched to prepare, document, and publish open datasets, for all surveys, on the governmental repository *recherche.data.gouv.fr.* In collaboration with INRAe, this task also aims to ensure the interoperability of the published datasets with other research data sources, through a semantic modelling approach based on the Extensible observation ontology (OBOE).
- A new tree coring campaign was launched by AgroParisTech in collaboration with UC Louvain and ONF, to study the annual tree growth response since the first coring campaign made after the installation of the Level II plots in 1994. Kristoffel Jacobs was hired for this purpose for a 30-month postdoctoral contract funded by the ALAMOD research project. All Level II plots are targeted, except those with too few adult trees remaining from the initial stand after severe disturbances or final harvest. A total of 30 trees are sampled in the buffer zone of each plot.
- Preliminary work was launched in view to create 15 new plots to extend the Level II monitoring to ecosystems dominated by the most widespread Mediterranean tree species: *Quercus pubescens* and *Quercus ilex*. As a first step, the ecological distribution of each of these tree species in France was studied on the basis of an extensive set of NFI plot data, and a clustering approach was used to determine and map the main categories of pedoclimatic conditions to be sampled. The next step in 2025 will be to prospect sites covering all these categories of pedoclimatic conditions and meeting all the practical requirements for establishing Level II plots.
- Preparatory work was also initiated to implement new surveys, to better evaluate the water and nutrient budget, and the response of trees to water stress. Electronic girth bands were bought by the end of 2024, to equip 20 sample trees per plot (already annually monitored for health, growth, and phenology) in a subset of 27 plots (installation planned in 2025). Equipment was also prospected for the acquisition and installation of soil moisture monitoring devices within the next 3 years, in the 14 most instrumented of these 27 plots (with meteorology, bulk and throughfall deposition, soil solution chemistry, and litterfall monitored for more than 30 years).

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.

Outlook

Level I

Since 2021, we asses trees in 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

In addition to the developments already launched in 2024, the 3rd soil sampling campaign will be initiated in 2025, with the aim to sample all the Level II plots within 3 to 5 years. A collaboration was signed with the ENS (Paris Sciences et Lettres) to constitute the first field crew to start this field campaign. The results will be eagerly awaited to shed light on the evolution of forest soil properties over 30 years, and to help better understand and model the dynamics of soil organic carbon stocks.

New projects are also foreseen by different research partners to further equip the Level II plots, to study e.g. the microclimate, the diversity of birds and bats (using automated passive acoustic recorders), or the determinants of beech fruiting in comparison with those of oak fruiting.

Germany

National Focal Centre

Juliane Henry, Federal Ministry of Food and Agriculture

Main activities/developments

Level I

In 2024, the forest condition was assessed on 409 plots with 9816 trees of 38 tree species. The distribution of tree species was as follows: pine 29%, beech 21%, spruce 19%, oak 9%, other broadleaves 14%, other conifers 8%. The distribution of tree species has thus changed significantly since the dry years of 2018–2020. Due to the widespread dieback of spruce, pine has become the most common tree species in Germany.

In 2024, field surveys for the third iteration of the soil, stand, and nutrition inventory will be completed. Harmonized guidelines for soil sampling for biodiversity monitoring and soil chemistry have been developed in co-ordination between ICP Forests and the EU LUCAS inventory. A training course was held on the profile approach according to WRB.

The EU project "MoniFun" was launched in January 2024 with the aim of developing a blueprint for a harmonized European Forest Multifunctionality Monitoring System (EFMMS) to support policy makers and stakeholders in assessing and promoting sustainable forest ecosystems in Europe. In the project, experts from many countries are working together to define a comprehensive list of indicators and propose suitable variables that can be monitored by combining data from national forest inventories (NFI), the ICP Forests network, and remote sensing. The Thünen Institute is involved in the proposal of soil and disturbance indicators.

Level II

Monitoring activities continue on all Level II plots. Campaigns to collect soil samples have either been completed or are in the final planning stages. Activities to equip plots with additional or newer sensors are on-going. Here, the focus on many plots lies on expanding soil-moisture measurements. First measurements with Cosmic-Ray Neutron Sensing were made on selected plots. A research project of the Technical University Dresden and the LWF currently compares the performance of different approaches to measure and model transpiration and soil moisture in the context of forest monitoring. Results, which include data from 13 Level plots, show the need to increase soil moisture sensors on heterogenous sites to obtain reliable results. Detailed guidelines are expected in 2025.

An additional request to the site operators showed twenty out of 68 plots to be affected by severe forest disturbance between 2021 and 2024. Biotic agents such as insects and fungi were the most frequently reported causes followed by storms and drought. All major tree species stocked on the various plots have been affected, with spruce showing the highest rate of disturbances (12 out of 19 plots) including four sites which were completely destroyed.

In September, the annual meeting of the technical staff took place in Brandenburg with field trips to the Level II site "Kienhorst" as well as the intensive hydrological research station "Britz". Over 30 participants discussed their experiences and the challenges they face operating Level II plots. Representatives from four manufacturers presented instruments and new sensors.

Major results/highlights

Level I – Crown condition

Despite the relatively favorable weather conditions in 2024 and the previous year 2023, the proportion of significant defoliation (36%, previous year 36%) and the warning level (43%, previous year 44%) remain high for all tree species since 2019. Trees in the sample that are more than 60 years old are above average affected. The proportion of trees with significant crown defoliation is 43% and only 16% for trees under 60 years of age. For spruce (from 28.6% to 27.2%) and "other broadleaved species" (from 26% to 23.6%) there was a slight improvement in the average crown defoliation. However, this may be an effect of the widespread dieback of Norway spruce. (Dead trees are replaced by new trees). The average defoliation of pine (22.5%) and beech (28.5%) remains at about the same level. Pine has the best average crown condition of the species groups considered, although there has also been a significant deterioration since 2019. Oak (from 27.6% to 29.3%) and "other conifers" (from 22.7% to 25.3%) have deteriorated significantly. Oak is the tree species with the highest average defoliation. A strikingly high proportion of 51% have significant crown defoliation, 33% are in the warning stage and only 16% have no crown defoliation. This is due to oak feeding communities, with the oak splendour beetle playing a major role in some areas. However, oak is also the oldest tree species on average and is therefore particularly vulnerable. Otherwise, the damage percentages show very slight improvements for spruce, beech, and other broadleaved trees (ALB) and slight deteriorations for pine and other conifers (ANB). Strong fruiting was observed in all species. In the case of beech, heavy fruiting occurred for the third year in a row. This has not been observed before in the time series. The mortality rate increased for oak, ALB and spruce and decreased slightly for pine and ALB, so that the overall mortality rate remained at the previous year's level of 0.9%, which is well above the long-term level from before 2019. The loss rate (trees harvested as planned and unplanned due to storm damage, drought, and bark beetle) continued to fall from 4.7% to 3.6%. For spruce it decreased from 9.0% to 5.7%, about half of which was due to biotic factors (bark beetles).

The dead trees on the Level I plots were used by Knapp et al. (2024) in combination with a wide range of environmental predictor variables from the domains of climate, topography, soil, land cover, and deposition to fit logistic regression models of mortality. These models allowed the derivation of country-wide mortality maps for spruce, pine, beech, oak, and other conifers and broadleaves pooled at annual temporal resolution covering the period 1998–2022.

Level II

Based on data from forest sites across Europe including German Level II plots, Göttlein (2024) presented threshold values for the sulphur nutritional status of European silver fir from cumulative concentration distributions. The presented values are close to those previously pubished for Norway spruce and Scots pine, although calculated S/N thresholds suggest a comparatively higher demand for sulphur. A time-lag between reduction of SO_2 emissions and the reduction of sulphur concentrations in needles suggests that soil stored sulphur is recycled for longer periods of time.

Wind damage is one of the major causes of forest disturbance in Germany. However, regionalization of windthrow risk models is often based on extensive data that is only available for few regions and thus limits the use of the models in many countries. As part of the WINMOL project, Stadelmann et al. (2025) showed that single tree data from German Level II plots can be suitable to improve the predictive capacity of the model ForestGALES for all tree species.

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

König N, Krinninger M, Geppert F, Sanders TGM (2024) Messung der nassen Quecksilberdeposition unter dem Kronendach von Wäldern. Vergleich von drei Standorten mit unterschiedlicher Belastung (Measurement of wet mercury deposition under the canopy of forests at three sites with different loads; final project report [online].) Dessau-Roßlau: Umweltbundesamt, 117 p, Texte UBA 135/2024

Krüger I, Andreae H, Chmara I, et al. (2024) Wandel und Beständigkeit des intensiven Umweltmonitorings (Monitoring change and securing consistency: the future of intensive forest monitoring). AFZ Der Wald 79(13):12-16

Rölleke H, Kroiher F, Hester Z, et al. (2024) Quantification of biological diversity using (bio-)acoustic methods - Integration into forest monitoring. Eberswalde: Thünen Institute of Forest Ecosystems, 2 p, Project Brief Thünen Inst 2024/19a, DOI:10.3220/PB1719228636000

Outlook

Level I

In January 2025, the "ForestPulse" project started with the aim of implementing a national remote sensing-based forest information system for mapping forest cover, tree species distribution, tree vitality, disturbances, and forest structure in Germany. The information products will be generated based on Sentinel-2 time series and airborne laserscanning point clouds and using the NFI and Level I plots for calibration and validation. In the project, the Thünen Institute is collaborating with the University of Trier, the HAWK Göttingen and the forest research institutes in Rhineland-Palatinate, Baden-Württemberg, and North-West Germany.

The mortality models developed by Knapp et al. (2024) are currently being integrated into process-based forest simulation models at various research institutes in collaboration with the Thünen Institute. First results for spruce with the LPJ-GUESS model were published by Anders et al. (2025) from Senckenberg BiK-F.

Level II

In December 2024, the project "Stoffbilanz" started with the aim to evaluate nutrient budgets at intensive forest monitoring sites in Germany (up to 170 sites including all Level II plots) as well as to quantify significant ecosystem processes in typical forest ecosystems on the basis of harmonized methods. As part of the project, the most important ecosystem fluxes in ecosystems (at minimum deposition and soil solution) are assessed and a nutrient budget is calculated for the most important nutrients. Missing elements of the nutrient balance at individual plots are estimated using transfer functions. The nutrient budgets will allow the simulation of future developments and serve as a basis for advice tools for the forestry sector. All forest research institutes of the federal states as well as the Thünen Institute participate in the project.

Greece

National Focal Centre

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

Main activities/developments and major results

Level I

Crown condition assessment

In Greece, the 2024 crown condition assessment survey was conducted on 34 Level I plots, representing 34% of the total installed plots. A total of 801 trees were assessed, including 499 broadleaf trees and 302 conifers, marking a 27% increase compared to the previous year. For another year, the common sample of the assessed trees remained small.

Despite the 27.3% increase in assessed trees, the proportions of trees in the first two defoliation categories ("No" and "Slight") remained relatively stable at 69.2%, with a slight decline of 7.9%p compared to 2023. Additionally, two burnt plots assessed in 2023 were not replaced this year, contributing to a 6.0%p decrease in the number of dead trees. The shifts in defoliation categories were primarily absorbed into the "Moderate" category. Abiotic factors were the leading cause of needle and leaf loss, followed by insect attacks. The table below presents 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	45.6	25.2	57.9
Slight defoliation	23.6	30.5	19.4
Moderate defoliation	26.5	35.7	20.9
Severe defoliation	3.3	7.3	1.0
Dead trees	1.0	1.3	0.8

Level II

In Greece, there are four Level II plots. Plot 1 has an evergreen broadleaved vegetation (maquis, with mainly *Quercus ilex*), plot 2 has Hungarian oak (*Quercus frainetto*), plot 3 has beech (*Fagus sylvatica*) and plot 4 has 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 have been recorded for 52 years in the maquis and fir plots and for 28 years in the oak and beech plots. In 2023, precipitation variability was relatively low. In contrast, average temperature increased across all three areas, with the most significant rises observed in the oak and beech plots (11.7%) and the fir plot (9.8%), while the maquis plot experienced a smaller increase of 6.5%.

Rainfall and temperature values in three forested plots in Greece in 2023

	Maquis plot		Oak and beech plots		Fir plot	
	Rain [mm]	Temp. [°C]	Rain [mm]	Temp. [°C]	Rain [mm]	Temp. [°C]
2023	1078.7	16.4	1365	14.3	1473	11.2

Crown condition assessment (Level II)

The 2024 crown condition assessment on the four Level II plots included 164 trees (35 conifers and 129 broadleaves). Compared to 2023 results, the phytosanitary condition of the trees has significantly improved, with a notable shift in defoliation levels from the "Slight" and "Moderate" categories to the "No defoliation" category. Specifically, 32.7% of conifers moved from the "Slight" category to "No defoliation," while 31.6% of broadleaf trees transitioned, primarily from the "Moderate" category (17.7%). Additionally, the replacement of three dead beech trees contributed to the overall improvement in broadleaf tree health.

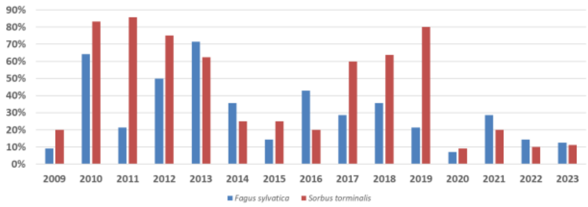
Modelling water availability for vegetation could enhance our understanding of spatio-temporal defoliation patterns along with other phenological stages.

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

	Year	No defoliation	Slight defoliation	Moderate defoliation	Severe defoliation	Dead trees
Conifers	**2022**	20.0	65.7	14.3	0.0	0.0
	2023	52.7	34.9	11.6	0.8	0.0
Broadleaves	**2022**	19.8	57.1	20.6	0.8	1.6
	2023	51.4	45.7	2.9	0.0	0.0

Ozone Injury

Ozone injury symptoms were only observed in the beech plot, specifically affecting *Fagus* and *Sorbus* species, as shown in the figure below.



Deposition

The table below presents the deposition fluxes (bulk and throughfall) of the major ions in the maquis, oak, and fir plots in 2023, along with the amount of precipitation and pH. The highest precipitation was recorded in the fir plot, while the lowest was in the maquis plot. As in previous years, the pH of the oak plot remained lower than the other plots in both bulk and throughfall deposition. The $SO4^{2-}$ -S fluxes in the maquis plot were rather high, taking into account that bulk deposition pH was not low. It is probable that both fertilization (a lot of farming in the area) and sea salts (The $SO4^{2-}$ -S ion is a sea derived ion) contributed to the increased fluxes. The ions Ca, Mg, and K showed enrichment in throughfall deposition fluxes. The behavior of NH_4^+ -N and NO_3^- -N ions differed: NH_4^+ -N was enriched in throughfall, whereas NO_3^- -N exhibited enrichment only in the maquis plot. Typically, the nitrates are enriched in throughfall due to dry deposition and microbial transformation of ammonium. It is probable that there were no oxidation processes on the leaves surfaces to transform nitrates into ammonium.

Fluxes (kg ha^{-1} yr^{-1}) of major ions, precipitation (mm) and pH in deposition (throughfall (T) and bulk (B)) in three forested plots in Greece in 2023

Plots	Dep.	Ca	Mg	K	SO_4^{2-}-S	NH_4^+-N	NO_3^--N	pH	mm
Maquis	**T**	47.3	6.28	45.0	16.9	1.56	3.81	5.63	937
	B	13.6	2.70	7.26	13.0	1.57	2.13	5.87	1172
Oak	**T**	21.1	6.43	39.2	9.21	7.71	3.38	4.81	1186
	B	18.7	3.64	6.42	10.9	4.91	4.83	4.99	1555
Fir	**T**	17.1	4.32	24.4	7.59	1.11	4.19	5.42	1321
	B	16.5	1.99	3.59	6.93	0.74	4.56	5.62	1677

Litterfall

In 2023, the most striking aspect of litterfall was the exceptionally high amount of wood in the oak plot, accounting for approximately 40% of the total litterfall—nearly equal to the amount of foliar litterfall. This was due to a heavy storm in September of 2023, which deposited a significant amount of woody debris on the forest floor. In contrast, foliar litter dominated in the other plots, making up 66% of the total litterfall in the maquis plot and 67% in the fir plot. The amount of N varied among plots, with the highest values observed in the foliar litter of the fir plot, followed closely by the maquis plot. The oak plot, situated on acidic soil derived from schist, exhibited high Mn flux but had the lowest Mg and Ca fluxes in the foliar litterfall. This suggests that the soil of this plot is prone to acidification and requires careful monitoring.

Total masses (TM, mg ha^{-1} yr^{-1}) and fluxes (kg ha^{-1} yr^{-1}) of nutrients in the litterfall fractions in three forested plots in Greece in 2023

Foliar	TM	Ca	Mg	K	N	P	Mn	P
Maquis	3.99	110	1.27	2.19	26.8	0.411	4.52	3.99
Oak	1.41	39.4	0.466	0.691	14.5	0.222	2.77	1.41
Fir	3.57	68.2	0.905	1.98	27.6	0.654	2.28	3.57
Non-foliar	**TM**	**Ca**	**Mg**	**K**	**N**	**P**	**Mn**	**P**
Maquis	1.89	17.3	0.42	1.61	8.53	0.22	0.50	1,89
Oak	2.05	24.4	0.66	0.88	17.7	0.251	2.50	2.05
Fir	1.76	22.7	0.52	1.22	14.6	0.36	0.80	1.76

Outlook

Future developments of the ICP Forests infrastructure

- We plan to initiate full-scale activities on Level II Plot #3, which features beech (*Fagus sylvatica*), and potentially expand our Level II plots.

Planned research projects, expected results

- A research proposal incorporating three of our Level II plots was submitted to the European Forest Institute as part of the Horizon Europe-funded project FORWARDS.
- Integrating measured soil moisture profiles with sap-flow sensors-set to be installed on Level II plots will offer insights into hydrological processes, nutrient and heavy metal cycles, and phenological patterns stages related to water availability.

Participation in ICP Forests groups

- Participation in the ad-hoc group for Water Budget Modeling, the ad-hoc group for the assessment of the physiological conditions of trees at Level II plots.
- Initiative to establish and co-ordinate an ad-hoc group on forest genetic and epigenetic monitoring.
- In March 2024 we organized the Joint Expert Panel Meeting in Athens, Greece.

Hungary

National Focal Centre

Kinga Nagy, Gergely Pápay
Ministry of Agriculture, Division of Forest Planning

Main activities/developments

Level I, the large-scale health condition monitoring is co-ordinated and carried out by the experts of the Ministry of Agriculture, Division of Forest Planning. The annual survey includes 78 permanent sample plots with 1872 potential sample trees totally on a 16 x 16 km grid.

In 2024, 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 percenatage of broadleaves was 90.9% while the percenatege of conifers was 9.1%.

Major results/highlights

From the total number of sample trees surveyed, 17.2% were without visible defoliation, which shows a decrease in comparison with 2023 (21.1%), although it is still higher than it was in the extreme drought year 2022. The percentage of the slightly defoliated trees was 35.5%, and the percentage of all trees within ICP Forests defoliation classes 2-4 (moderately damaged, severely damaged, and dead) was 47.4%. The rate of the dead trees was 4.3% and 1.3% of all sample trees died in the surveyed year. The dead trees remain in the sample while they are standing but the trees having died recently can be separated. The mean defoliation for all species was 35.3%. This value shows a slight increase compared to the previous one, which was 32.3%.

Relatively big differences can be observed between the tree species groups in respect of the defoliation rates. Among deciduous species, clearly oaks, especially *Quercus robur* and *Quercus cerris* were the most affected, we found virtually no specimen without visible defoliation. The least defoliated tree species was *Carpinus betulus* with 21.8% mean defoliation. This is a very similar value compared to the previous year (22%). *Pinus nigra* trees were also severely defoliated, only 3.0% of the specimen were unaffected.

Discoloration can rarely be observed in the Hungarian forests, 88.5% 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 2024, insects were the most frequent damaging agents (33.5%). 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

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of *Quercus* species. The frequency of abiotic damage was the second most frequent damaging agent with 27.0%. Fungal damage (20.6% of all damage) was observed most frequently on *Pinus nigra* (fungi affected 39.4% 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 2024-ben" 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

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, UCD School of Agriculture and Food Science, University College Dublin

Main activities/developments

Crown condition assessments at 35 Level I plots were undertaken in 2024, 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 crown condition field asessment was performed in July and August 2024 by Forest Inspectorate staff, within the Department of Agriculture, Food and the Marine (DAFM). Of the 35 Level I plots visited, 31 plots contributed to crown condition data in 2024, with a total of 682 trees assessed. The remaining 4 plots, where no tree assessment occurred, had undergone harvesting operations in recent years.

Ammonia monitoring using UKCEH Alpha-type passive-diffusive samplers is underway at Level II open sites, under NEC Directive monitoring carried out by Ireland's Environmental Protection Agency. Expected bulk-deposition sampling is not yet operational, but still planned. Funding application for design of a soil solid survey was not successful.

Major results/highlights

74% of the trees assessed in 2024 were conifer species, with broadleaf species accounting for 26%. In terms of species, 60% of the trees assessed were Sitka spruce (*Picea sitchensis*), 9% were alder (*Alnus glutinosa*), 8% were lodgepole pine (*Pinus contorta*), 7% were ash (*Fraxinus excelsior*), and 5% were birch (*Betula sp.*).

The percentage of all species within the defoliation class 0 (0-10% defoliation) is 48%. Defoliation class 1 (>10-25% defoliation) accounts for 26% of all trees assessed, while class 2 (>25-60%) is 16% of trees and class 3 (>60-<100% defoliation) is 4%. Circa 6% of all trees assessed were categorized in class 4 (100% defoliation).

The poor health condition of ash trees in the assesment is significant. 62% of the ash trees assessed are dead, owing to the impact of ash dieback disease (*Hymenoscyphus fraxineus*) in recent years.

Outlook

- Future developments under NEC Directive monitoring by Ireland's Environmental Protection Agency is expected.
- A new group to communicate and, where appropriate, co-ordinate across the several ICPs operating in Ireland under the Air Convention is proposed, led by the Department of the Environment, Climate and Communications, for development during 2025.

Italy

National Focal Centre

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

Main activities/developments

The survey of Level I in 2024 took into consideration the condition of the crown of 4852 selected trees in 251 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 agents and known causes attributable to both biotic and abiotic. 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). Most plants (82.3%) are in classes 1 to 4, while 41.3% are in classes 2 to 4.

By analyzing the sample for conifers and broadleaves, it appears that deciduous trees have a higher transparency than conifers: 24.8% of conifers versus 15.1% of broadleaves in the class 0 of transparency, while 43.3% of deciduous trees versus 35.6% of conifers were 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). For the young conifers (<60 years) and for classes 2 to 4 the results were: the two Mediterranean pines with the highest values *Pinus pinea* (84.8%) and *Pinus nigra* with (60.0%), while *Picea abies* (26.0%), *Picea sylvestris* (23.9%), and *Pinus halepensis* (4.7%) were the young conifers with the best condition.

Among the old conifers (≥60 years) in the classes 2 to 4, the species appearing to be of the worst quality of foliage were *Pinus sylvestris, Picea abies* (66.2%), then *Pinus nigra* (36.1%), while *Abies alba* (32.9%), *Larix decidua* (20.3%) and *Pinus cembra* (8.5%) were the conifers with the best condition.

Among the young broadleaves (<60 years), *Castanea sativa, Quercus pubescens, Ostrya carpinifolia,* and *Fagus sylvatica* have respectively 69.8%, 52.8%, 49.0%, and 37.5% of trees in the classes 2 to 4,while *Quercus cerris* has a lower frequency (33.9%) in classes 2 to 4.

Results for old broadleaves (≥60 years) in the classes 2 to 4, *Quercus pubescens* (53.2%), *Castanea sativa* (48.1%), *Fagus sylvatica* (40.6%) and *Quercus ilex* (39.4%), while *Fraxinus ornus* (11.1%) has the lowest level of defoliation of trees in the classes 2 to 4.

Overall, there is a slight improvement from the 2023 data, mainly due to the better conditions of conifers, while broadleaves trees did not significantly change.

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 of all plants are shown below:

Out of a total of 4852 trees monitored, 8876 symptoms were detected and 951 (19.6%) trees were without symptoms. Of the trees with symptoms, 4840 (54.5%) were identified while 4036 (45.5%) of the symptoms were not identified.

Most of the observed symptoms were attributed to insects (21.6%), subdivided into defoliators (15.8%), lignicolous (2.1%) galls (1.4%), and mining (1.2%). Of the symptoms attributed to fungi (4.2%) the most significant were attributable to "dieback and canker fungi" (2.7%), then those assigned to abiotic agents, the most significant are attributable to hail (3.2%) and drought (3.6%).

Outlook

Currently, Italy has a total of 251 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, Emīls Mārtiņš Upenieks
Latvian State Forest Research Institute "Silava"

Main activities/developments

Latvia continued its assessment at Level I. The forest condition survey 2024 in Latvia was carried out on 115 Level I NFI plots. The major results of 2024 are based on data from this dataset.

In 2024, the relevant works were performed within the framework of the Level II monitoring:

- Air quality monitoring, using diffusive samplers twice a month (June–October)
- National crown condition survey
- Deposition monitoring from bulk, throughfall, and 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)
- LAI measurements.

Major results/highlights

On Level I plots defoliation and damage symptoms of 1731 trees were assessed, of which 72% were conifers and 28% broadleaves. Of all tree species, 12.4% were not defoliated, 83.1% were slightly defoliated and 4.6% moderately defoliated to dead. Compared to 2023, the proportion of not defoliated trees has increased by 1.3%p, the proportion of slightly defoliated has decreased by 1.0%p, but the proportion of moderately defoliated to dead trees has decreased by 0.3%p. In 2024, the proportion of not defoliated conifers was 2.5%p higher than that of not defoliated broadleaves, the proportion of slightly defoliated broadleaves was by 3.2%p higher than that of slightly defoliated conifers. Proportion of trees in defoliation classes moderatly defoliated to dead for conifers was 0.7%p higher than for broadleaves.

Mean defoliation of *Pinus sylvestris* was 19.5% (19.8% in 2023). The share of moderately damaged to dead trees decreased to 4.1% (5.9% in 2023). Mean defoliation of *Picea abies* was 19.1% (17.9% in 2023). The share of moderately damaged to dead trees for spruce increased to 6% (5.6% in 2023). The mean defoliation level of *Betula spp.* was 18.8% (18.8% in 2023). The share of trees in defoliation classes moderately to dead increased to 4.1% (compared to 2.4% in 2023).

The average tree defoliation in the Valgunde Level II monitoring plot since 2024 has decreased to 15.6 ± 0.9%p, which is 5.2%p lower than in 2023 and more closely aligns with the average defoliation levels observed in previous years. Accordingly, in

2024, defoliation in Valgunde was the lowest among all three Level II monitoring plots. In the Taurene monitoring plot, the average tree defoliation has continued to gradually increase since 2020, reaching 20.1 ± 1.2%p in 2024, which is 0.9%p higher than in 2023. Consequently, the highest defoliation in 2024 was recorded in Taurene, differing from 2023 when the highest defoliation was observed in the Valgunde plot, where the situation improved significantly in 2024. No significant changes in average defoliation were observed in Rucava, where it was 16.1 ± 1.5%p in 2024—only 0.2%p lower than in 2023—maintaining a stable trend that has been observed since 2020.

In 2024, the cone yield has significantly increased in the Taurene monitoring plot. The average fruiting class has risen to 2.0, which is higher by 0.3 than in 2023. As a result, it has become very similar to the values observed in Valgunde and Rucava, where the fruiting class is rated at 2.1. In the other monitoring plots, no changes in cone yield compared to 2023 have been observed. In all monitoring plots, a pronounced dominance of fruiting class 2.0 is evident, reaching 57% of trees in Valgunde, 48% in Taurene, and 74% in Rucava.

The total litter biomass in Valgunde in 2024 increased to 4,880 kg ha^{-1}, which is 1,304 kg ha^{-1} higher than in 2023. In Taurene, litter biomass rose to 3,424 kg ha^{-1}—nearly three times the value observed in 2023 (1,166 kg ha^{-1}). In Rucava, litter biomass increased to 4,266 kg ha^{-1}, also marking a significant rise compared to 2023, when it was only 1,717 kg ha^{-1}. In all monitoring plots, the increase is primarily linked to the litter biomass of the main tree species fruits and seeds (pinecones), as well as a rise in twig and branch litter. In Taurene, the litter biomass of secondary tree species fruits and seeds also increased substantially—from just 10 kg ha^{-1} in 2023 to 520 kg ha^{-1} in 2024.

In 2024, record-high soil water volumes were observed in Valgunde at all depths. Below the humus layer, it measured 35.3 L, up to 20 cm depth—36.7 L, but the highest volume was recorded at 40–70 cm depth with 51.3 L. The significantly elevated soil water volume, which far exceeded observations from previous years, is explained by the flooding events in July 2024 that also affected the specific monitoring plot area.

Regarding the chemical element input via precipitation in 2024, potassium input with rainwater was 9.07 kg ha^{-1}—approximately twice as high as in 2023 (4.48 kg ha^{-1}) and the highest recorded in the entire observation period, exceeding the average value nearly three times (3.28 kg ha^{-1}). In contrast, the N-NO_3 input was the lowest observed, at just 0.49 kg ha^{-1}, roughly three times lower than the average of the whole observation period (1.60 kg ha^{-1}).

In 2024, the diameter growth of sample trees in Valgunde and Taurene was lower than in the previous year. The total growth in Valgunde reached just 13.8 mm, which is 10.7 mm less than in 2023. In Taurene, the total growth was 19.3 mm, 8.2 mm less than the previous year. The only monitoring plot where no significant decline was observed in 2024 is in Rucava, where the total growth was 30.5 mm—only 1.4 mm less than in the previous year.

Outlook

Latvia has 115 NFI Level I plots and it is planned to continue observations at this level. The Latvian State Forest Research Institute "Silava" plans to continue the Level II monitoring in the same manner as it has been conducted until now. The number of sample plots is not planned to be changed, as the 3 existing plots are considered sufficient to characterize ecological processes within Latvia's territory.

Lithuania

National Focal Centre

Marijus Eigirdas, Lithuanian State Forest Service

Main activities/developments

Level I

In 2024, the forest condition survey was conducted in 1,016 sample plots, including 81 plots in the transnational Level I network and 935 plots in the National Forest Inventory network. In total, 6,529 sample trees representing 17 tree species were assessed. The main tree species assessed included *Pinus sylvestris, Picea abies, Betula pendula, Betula pubescens, Populus tremula, Alnus glutinosa, Alnus incana, Fraxinus excelsior, Quercus robur.*

Level II

In 2024, intensive forest monitoring was conducted across ten Intensive Monitoring Plots (IMPs). The condition of trees was assessed based on 545 observation trees, which included 212 spruces (38.9%), 131 pines (24.0%), 80 silver and downy birches (14.7%), 60 oaks (11.0%), 40 black alders (7.3%), 12 ash trees (2.2%), 8 maples, 1 white alder, and 1 aspen. The monitoring survey at the ten IMPs encompassed a visual assessment of crown condition, the identification of damaging agents, evaluation of ozone injury, and foliage sampling for subsequent analysis. In addition, three of the Level II plots underwent further detailed investigations, including the collection and analysis of soil solution, the measurement of atmospheric deposition (both bulk and throughfall), and litterfall sampling. Air quality was also assessed by measuring the concentration of sulphur dioxide (SO_2), nitrogen dioxide (NO_2), and ammonia (NH_3) using passive samplers. Phenological observations were carried out for Norway spruce, Scots pine, and pedunculate oak.

Major results/highlights

Level I

In one year, the mean defoliation of all tree species slightly decreased to 21.9% (22.2% in 2023). 17.4% of all sample trees were not defoliated (class 0), 62.3% were slightly defoliated, 18.5% were assessed as moderately defoliated and 20.3% as severely defoliated and dead (defoliation classes 2-4).

Mean defoliation of conifers decreased and was equal to 22.8% (23.4% in 2023) and for deciduous defoliation slightly decreased to 20.6% (20.2% in 2023).

Pinus sylvestris is the dominant tree species in Lithuanian forests and annually accounts for about 35% of all sample trees. Mean defoliation of *Pinus sylvestris* decreased slightly to 24.5% (24.9% in 2023). A trend of slightly increasing defoliation was observed between 2008 and 2023, rising from 20.4% to 24.9%.

Since 2024 *Alnus glutinosa* has shown the lowest mean defoliation and the share of trees in defoliation classes 2-4 were the lowest. In 2024, the mean defoliation of *Alnus glutinosa* was 18.5% (19.4% in 2023) and the proportion of trees in defoliation classes 2-4 was 9.2%, compared to 10.6% in 2023.

The condition of *Fraxinus excelsior* remained the worst of all observed tree species. The share of defoliation in this tree species has been the highest since 2000. Mean defoliation is yet to change and has remained at 26.3% (26.3% in 2023). The share of trees in defoliation classes 2-4 decreased to 29.2% (30.4% in 2023).

28% of all sample trees had identifiable symptoms of damage. The most frequent source of damage were abiotic agents (about 8.8% in 2024) in the period of 2011–2024. The highest share of symptoms of damage were noted among *Fraxinus excelsior* (56%), *Alnus incana* (40%), *Populus tremula* (39%), *Picea abies* (36%), the least for *Betula sp.* (18%) and *Alnus glutinosa* (19%).

Level II

The mean crown defoliation of all tree species varied insignificantly in the period from 1995 to 2024, indicating that the growing conditions of Lithuanian forests have been relatively stable over this period.

In 2024, mean crown defoliation was 17.5%, representing a 0.1 percentage point increase compared to 2023. The highest levels of crown defoliation were observed in European ash (25.8%) and pedunculate oak (19.5%). A total of 5.5% of trees exhibited both biotic and abiotic damage. Defoliation classifications were as follows: 31.4% of trees were assigned to the 0 defoliation class, 58.4% to class 1, 8.9% to class 2, 0.5% to class 3, and 0.7% to class 4.

Air pollution deposition surveys, conducted since 2000, have indicated a consistent decrease in sulphur deposition under tree crowns. Over the last decade, sulphur deposition in open areas has ranged from 3 to 6 kg ha^{-1} yr^{-1}. The average sulphur deposition under tree canopies during this period was slightly lower compared to open areas. Ammonium (NH_4^+-N) deposition under tree crowns has similarly shown a steady decline.

In 2024, the average annual concentration of SO_2 ranged from 0.65 to 2.36 µg/m^3, with a mean of 1.39 µg/m^3, which was consistent with the multi-annual average and slightly lower than in 2023. The average annual concentration of NO_2 within the monitoring plots varied between 5.6 and 8.03 µg/m^3. The average annual NH_3 concentration in 2024 ranged from 1.76 µg/m^3 to 3.14 µg/m^3, which was below the long-term average.

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

Žemaitis P, Armoška E, Stakėnas V, et al. (2024) FORECOMON 2024 – The 11th Forest Ecosystem Monitoring Conference. Norway spruce health and vulnerability in Lithuania – wind, decay and *Ips typographus* as the main drivers. Prague, Czechia

Černiauskas V, Varnagirytė-Kabašinskienė I, Araminienė V (2024) Chemical changes in precipitation under different coniferous tree canopies. International conference CYSENI 2024, Lithuania

Černiauskas V, Varnagirytė-Kabašinskienė I, Araminienė V, Stakėnas V (2024) Trends in chemical transformations of precipitation in conifer stands. 37th ICP Vegetation Task Force Meeting. Lithuania

Luxembourg

National Focal Centre

Hanna Teuchert, Nature and Forest Agency

Main activities/developments

The Nature and Forest Agency oversees the annual crown condition data collection as part of the Level I forest health monitoring program. This includes presenting the results of the national plant condition inventory, which evaluates the health of forest trees across Luxembourg. The 2024 survey, conducted from July 15 to August 15, utilized a 4x4 km grid system and covered 50 of 51 plots.

Major results/highlights

Since the initiation of crown condition monitoring in 1984, tree damage has generally increased, highlighting the need for continuous surveys to guide adaptive forest management. The most severe decline in tree vitality occurred in 2019 due to prolonged drought and heat, with a sharp drop in healthy trees and alarmingly high damage levels.

Forest condition varies by tree species, age classes, and site conditions, with some shifts in damage class distribution between 2023 and 2024. Healthy trees (damage class 0) consistently comprised about 15% of the population in both years. Mild crown thinning (damage class 1) improved in 2024, with the proportion of trees increasing from 18% in 2023 to 26% in 2024, while moderately damaged trees (class 2) decreased by 7%p. In 2024, the proportion of severely damaged trees (damage class 3) increased by 1%p, while the number of dead trees (class 4) decreased by 3%p.

Species-specific trends were observed in 2024. Beech trees showed a 14%p increase in class 1, alongside a 14%p reduction in those with moderate crown thinning (damage class 2). Oaks and other broadleaf trees showed a 9%p increase in recovery to damage class 1, while damage classes 2 to 4 collectively decreased by 10%p. However, oak coppice worsened, with an 8%p rise in severe damage or dead trees (damage classes 3 and 4). Among spruce and conifers, the mortality rate (class 4) decreased by 7%p, with 37% of trees showing no crown thinning, a percentage relatively similar to 2023.

Overview of damage classes for all tree species in summer 2024:

- 15% without damage (class 0)
- 26% with mild crown thinning (class 1)
- 48% with moderate crown thinning (class 2)
- 9% severely damaged (class 3)
- 1% dead (class 4).

Outlook

Level I crown condition monitoring will continue in 2025 using consistent data collection methodologies to ensure long-term comparability and to further support adaptive forest management strategies.

Moldova, Republic of

National Focal Centre

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

Major results/highlights

In 2024, within the nine permanent plots of the Level I network (16x16km) in the Republic of Moldova, a total of 218 deciduous trees were evaluated. The average defoliation was 23.4%, *Quercus petraea* and *Quercus pubescens* being the most affected species.

Based on the data collected in 2024, the prevalence of trees falling within defoliation classes 2-4 across all broadleaved species was 31.9%, observing an increase of the affected trees when compared to the 2023 assessment. Among the primary species surveyed, notable occurrences were observed in *Quercus petraea* (25.7%), *Quercus pubescens* (24.2%), whereas *Fraxinus excelsior* (23.9%) and *Quercus robur* (21.1%) exhibited lower percentages within the 2-4 defoliation classes (approximately 10% each).

The increase within the 2-4 defoliation classes can be explained through the intensity of damages, specific to the 2024 vegetation season, especially the occurrence of *Microsphaera alphitoides* and *Corythucha arcuata* on *Quercus spp.*

Outlook

In 2024, monitoring activities concerning the Level II network in hte Republic of Moldova were relaunched. A new Level II monitoring plot was installed within the Scientifical Site "Codrii", in a mature *Quercus robur* stand (approx. 90 years old), representative for the Moldavian forest ecosystems. Several basic monitoring equipments were installed in 2024 covering tree growth measurements (automatic point dendrometers and girth bands) and meteorological assessments (meteo station and in-plot TRH sensors). Moreover, classical tree inventory measurements were performed to assess the biophysical parameters (DBH, height, increment core samples)

The assessment of crown condition within the 16 x16 km network will be extended in 2025 and new plots will be included in forested areas.

All these activities will be facilitated through the MONFORGENDIV project (financed by the Romanian Ministry of Research, Inovation and Digitalization), that is focused on forest monitoring. This project is conducted in collaboration with the National Institute for Research and Development in Forestry (INCDS) „Marin Drăcea" in Romania as part of a plethora of other future similar projects, which aim at developing the national forest monitoring network.

Norway

National Focal Centre

Volkmar Timmermann, Norwegian Institute of Bioeconomy Research (NIBIO)

Main activities/developments

Norway is represented in six Expert Panels (Soil solution, Foliage, Crown, Growth, Vegetation, and Deposition), in the Working Group QA/QC, and is holding the co-chair in EP Crown. In 2024 we participated online in the Expert Panel meetings for Growth, Depo, and Soil solution, in the Task Force meeting in June (online) and in the PCG meeting in Berlin in November (also online). We contributed to the chapter on crown condition in the ICP Forests Technical Report – The 2024 Assessment. Our lab participated in the 26th Needle/Leaf Interlaboratory Comparison Test and in the 13th Deposition and Soil Solution Ringtest 2023/2024. 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. The sample trees are selected with a relascope.

Our national forest monitoring in 2024 included defoliation assessments on 5 857 Norway spruce and 4 785 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, carried out 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.

In 2024, 679 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 6 627 trees belonging to 25 species were reported to ICP Forests.

Level II

Our three Level II sites Birkenes, Hurdal, and Osen are situated along a gradient from 59°N, 8°E to 61°N, 12°E. All plots are dominated by Norway spruce, and the northernmost plot also contains a large share of Scots pine. The following surveys are conducted by NIBIO: crown condition and damage, tree growth, foliar chemistry, ground vegetation, soil and soil solution chemistry, and atmospheric deposition in bulk and throughfall. Chemical analyses are mostly carried out in-house. Ambient air quality (incl. ozone) is measured at two plots (Birkenes and Hurdal) and meteorology at one (Birkenes) by 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 2024, mean defoliation for Norway spruce was 16.3%, and 12.4% for Scots pine in our national monitoring. This represents a decrease in mean defoliation for both spruce (-1.1%p) and pine (-2.1%p) compared to 2023.

	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*)	48.1	32.4	15.4	3.7	0.4	16.3 (-1.1)	5 857
Scots pine (*Pinus sylvestris*)	51.8	38.8	8.5	0.7	0.2	12.4 (-2.1)	4 785

Of the almost 20 000 trees assessed for damage in 2024, 11% had symptoms of damage. The highest proportion of damage (15.8%) was observed for birch trees (*Betula* sp.), followed by other deciduous trees (13.7%), Norway spruce (9.2%), and Scots pine (5.3%). By far the most common causes of damage for all species were abiotic factors (mainly snow breakage and windthrow), inducing 24.8% of all recorded damage symptoms. Fungi were responsible for 17% (primarily spruce needle rust and birch rust), and insects for 14% of the damage symptoms (mostly birch moths). Game and grazing caused 4% of all damage symptoms, direct action of man 1.6%, fire 0.2% and other known factors 0.4%. A considerable number of symptoms (38.1%) could not be identified in the field.

Mortality rates were 3.6‰ for Norway spruce, 1.9‰ for Scots pine, 6.1‰ for birch, 9.8‰ for other deciduous species and 4.7‰ on average for all assessed tree species in 2024.

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 the southernmost plot, Birkenes, due to long-range transported air pollution. The UNECE's "critical value" of 5000 ppb-hours for tropospheric ozone in forests was exceeded at one station in southeastern Norway in 2023. 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. Nitrogen and calcium contents in spruce needles were decreasing at all plots and sulphur content at the southernmost plot in 2023, while potassium contents were increasing at all plots. Vegetation analyses at Birkenes showed that there has been a significant increase in percentage cover of *Vaccinium myrtillus* and larger mosses, while the percentage cover of smaller mosses (in particular liverworts) decreased. Crown defoliation increased at all plots.

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, Aspholm PE, Børja I, et al (2025) Skogens helsetilstand i Norge. Resultater fra skogskadeovervåkingen i 2023. [The state of health of Norwegian forests. Results from the national forest damage monitoring 2023.] NIBIO Rapport. In press

Outlook

- Financing for both Level I and II for 2025 is secured.
- Monitoring at Level I will continue as part of our national forest monitoring conducted by the NFI.
- Needle sampling and analyses of chemical contents at Level II will be conducted during autumn 2025.
- We plan to participate in the next Needle/Leaf and Deposition/Soil Solution ringtests.

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 Forest Enterprise (LP). Poland is represented in six Expert Panels (Soil and 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 Anna Kowalska serves as chair.

Level I

In 2024, the forest condition survey was conducted on 2 058 Level I plots on a national grid of 8 km x 8 km, and a total number of 41 160 trees of 40 species were assessed (61.6% were conifers and 38.4% were deciduous). Of these, the assessment results of 336 plots on a 16 km x 16 km grid (European network) with 6 720 trees were submitted to the ICP Forests database. The fieldwork took place in July and August.

Level II

In 2024, measurements of weather parameters, air quality, and chemical analyses of deposition (open field and throughfall under the canopy) 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, growth measurements were conducted on 133 plots of the Level II national grid in fall 2024.

Major results/highlights

Level I

In 2024, the average defoliation of all species was 21.3%, that of conifers 21.6% and that of deciduous trees 20.7%. The percentage of healthy trees (with leaf loss of 10% or less) for all species was 11.9%, and the percentage of trees with leaf loss of more than 25% was 13.9%.

The percentage of healthy trees and the percentage of trees with leaf loss of more than 25% were higher for deciduous species than for coniferous species (16.5% and 14.5% compared to 9.1% and 13.6%, respectively). The percentage of trees in the early warning class with leaf loss between 11% and 25% was 74.1% for all species, 77.3% for conifers, and 69.0% for broadleaves.

Among the three main conifer species, *Abies alba* had the lowest mean defoliation of 17.6%, with 27.9% of trees falling into class 0 and 9.1% into classes 2–4. *Pinus sylvestris* was characterized by a lower proportion of trees in class 0 (8.4%), a higher proportion of trees in classes 2–4 (13.2%) and a higher mean defoliation (21.6%) than *Abies alba*. *Picea abies* was characterized by the lowest proportion of trees with a leaf loss of up to 10% (4.9%), the highest proportion of trees in classes 2–4 (21.5%) and the highest mean defoliation (24.4%) compared to the other surveyed species (except *Quercus* spp.).

In 2024, as in the previous year, the highest average defoliation among deciduous trees was observed in *Quercus* spp. – 24.3%. Only 4.5% of oaks had leaf loss of 10% or less and 26.0% of trees fell into leaf loss classes 2–4. A slightly better condition was observed for *Betula* spp. (7.8% trees in class 0, 13.9% of trees in classes 2–4 and the mean defoliation was 22.0%). *Fagus sylvatica* remained the tree species with the best health condition compared to the other surveyed species (coniferous and deciduous). A proportion of 37.1% of the beech trees showed no symptoms of defoliation, only 5.0% trees were in classes 2–4 and the mean defoliation was 15.7%. *Alnus* spp. was slightly more defoliated (21.9% of trees were in class 0, 6.7% of trees in classes 2–4 and the mean defoliation was 18.2%) than *Fagus sylvatica*.

In 2024, the condition of the trees (all species combined) slightly improved compared to the previous year. A significant improvement was observed in *Picea abies*, *Abies alba*, and *Fagus sylvatica*. The proportion of trees with a defoliation level of 10% or less increased by 1.6, 6.1, and 9.9 percentage points, respectively. The proportion of trees with more than 25% defoliation decreased by 12.1, 2.1, and 1.1 percentage points and the average defoliation of these three tree species decreased by 2.8, 1.4, and 1.1 percentage points, respectively.

Level II

The results of the analysis of the meteorological measurements on the Level II plots showed that 2024 was warmer than 2023. It was also characterized by significantly lower annual precipitation than 2023, but similar precipitation was recorded during the growing season. This indicates less favourable thermal and humidity conditions in 2024 compared to the previous year.

The analytical results of the measurements carried out in 2024 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 2025 and published in next year's Technical Report.

The SO_2 concentration in the air in 2023 ranged from 63% to 106% of the concentration in 2022 and the NO_2 concentration ranged from 83% to 105%. On all the plots, SO_2 and NO_2 concentrations in the ambient air in 2023 followed the general trend of decreasing concentrations of air pollutants observed over the years 2011–2023 on all Level II plots. Both above and below the tree crowns of the forest stands in most of the Level II plots, the pH of precipitation 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 solution.

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

Lech P, editor (2024) Forest Condition in Poland in 2023. Synthesis of the report „ Health condition of forest in Poland in 2023 based on monitoring study". Instytut Badawczy Leśnictwa, Sękocin Stary

Outlook

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

- 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

The National Institute for Research and Development in Forestry (INCDS) plays a pivotal role in Romania's contribution to the ICP Forests monitoring activity, both nationally and within the broader European context. Since the early 1990s INCDS is conducting forest health assessments, collecting crucial data on crown condition (Level I) and the impacts of environmental stressors like air pollution and climate change (Level II). INCDS specialists are involved in all ICP Forests Expert Panels where our representatives Diana Pitar (EP Ambient Air Quality) and Andrei Popa (EP Forest Growth) serves as chair and co-chair, respectively.

In 2024, the crown condition survey was performed in 227 plots of the 16x16 km Level I network. A total number of 5448 trees were assessed of which 880 were coniferous trees (16%) and 4568 broadleaf trees (84%).

In Romania, 14 Level II plots are considered for intensive monitoring activities of which 6 (core plots) are being equipped with specific sensors and instruments to monitor climate parameters, air quality, deposition, growth, and sap flow for gathering acurate information on forest ecosystems changes.

In accordance with the ICP Forests activities the Romanian forest monitoring experts participated in the following events:

- Role and fate of forest ecosystems in a changing world, January 15–19, 2024, Bangkok, Thailand
- Joint Expert Panel Meeting, Athens, 18–22 March 2024, Athens, Greece
- FORECOMON 2024 - The 11th Forest Ecosystem Monitoring Conference, June 10–12, 2024, Prague, Czechia
- 40th ICP Forests Task Force Meeting, Prague, June 13–14, 2024, Prague, Czechia
- 26th IUFRO World Congress, June 23–29, 2024, Stockholm, Sweden
- Annual National Crown Condition Intercalibration Course, June 29, 2024 - Brasov, Romania.

Major results/highlights

In 2024, the share of damaged trees (defoliation above 25%) was 11.6%, 0.2%p lower than in 2023.

For all species 50.9% were rated as healthy (defoliation class 0), 37.5% as slightly defoliated (class 1), 9.1% as moderately defoliated (class 2), 2% as severely defoliated (class 3), and 0.5% were found dead (class 4).

The mean defoliation of all tree species from the Romanian Level I network was 16.0%, 0.6%p higher than in 2023. A slight improvement of the health status of trees expressed in mean defoliation was observed for conifers from 15.5% in 2023 to 13.6 % in 2024 following the downward trend of recent years. For broadleaves no significant changes have been observed.

The level of mortality (defoliation class 4) remains low (0.5%) 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.

The causal factors contributing to the deterioration of tree health are mainly represented by biotic agents, correlating with a significant percentage of symptoms whose etiology could not be definitively determined under in-situ evaluation conditions. A comparative assessment of susceptibility to pathogens between conifers and broadleaves reveals a significant quantitative difference, with angiosperms exhibiting an approximately 50% higher incidence of damage simptoms compared to gymnosperms. Symptom severity indicates a low to moderate intensity manifestation, with maximum frequencies recorded in damage extent classes 1-3, suggesting a satisfactory adaptive and regenerative capacity of the forest ecosystems. This distribution of damage intensity can be interpreted as an indicator of ecosystem resilience in the face of current biotic pressures.

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 2023. VI.1.3. Forest health status. Ministry of Environment, Waters and Forests

The Annual Report of the Romanian Forest Status in 2023. Ministry of Environment, Waters and Forests

National Activity Report by Romania in the ICP Forests 2024 Technical Report

Outlook

The ongoing activity of developing the monitoring infrastructure for Romania's forest ecosystems, co-ordinated by INCDS, continued in 2024 with the installation of new plots and equipment. Furthermore, starting in 2024, the Ministry of Environment, Waters and Forests, through a government decision, is suporting the EU National Emissions Ceilings (NEC) Directive (2016/2284/EU) monitoring and reporting activity in Romania. The information provided by the existing ICP Forests Level II monitoring plots, together with three new plots installed in biogeographically representative areas for Romania, represents the main data source used for fulfilling the reporting obligations according to the Directive.

Within the famework of the Horizon Europe Project – FORWARDS, the European Forest Institue has granted INCDS to develop a new and innovative research project, which aims to enhance the understanding of climate change impacts on Central Eastern European oak forests by integrating advanced monitoring techniques, including field measurements and remote sensing. This project will be implemented in two Level II core plots in Romania mainly represented by oak spp. vulnerable to climate change.

Serbia

National Focal Centre

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

Main activities/developments

The National Focal Center at the Institute of Forestry has continuously participated in the international ICP Forests program, aiming to further enhance and align its efforts with other approaches in forest ecosystem monitoring and management. Monitoring is carried out on 130 Level I and 5 Level II sample plots. In 2024, key activities focused on advancing the work within the ICP Forests program by implementing new infrastructure and upgrading existing technology for collection of data. This includes improvement of current instruments within ICP Level II sample plots as well as improvement of internal databases storage. During 2023–2024 activities on measuring leaf area index (collection of full data) were established, and by that, all activities within the Expert Panel on Meteorology, Phenology, and Leaf Area Index are now conducted. In 2024, the base for additional activities within this project have been established and there is an initiative to start work on establishing a national expert panel on ambient air quality. Because of this, several project proposals were sent to different institutions in Serbia and abroad, in order to get funds for acquiring the necessary equipment. Through this project, the Institute of Forestry continually works to strengthen co-operation with all relevant institutions in the fields of forestry and environmental protection, including the forest estates of the public enterprises "Srbijašume" and "Vojvodinašume", public enterprises that are managing national parks, private forest owners and their associations, and other users of forest resources.

Major results/highlights

The total number of trees assessed on all sampling points was 2879 trees, of which 359 were conifer trees and a considerably higher number, i.e. 2520, were broadleaf trees. The conifer tree species with their number of trees and percentage were: *Abies alba* 65 (2.3%), *Picea abies* 145 (5.0%), *Pinus nigra* 69 (2.4%), *Pinus sylvestris* 80 (2.8%). The most represented broadleaf tree species were: *Carpinus betulus* 117 (4.1%) , *Fagus moesiaca* 818 (28.4%), *Quercus cerris* 462 (16.0%), *Quercus frainetto* 381 (13.2%), *Quercus petraea* 199 (6.9%), and other species 543 (18.9%).

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

Outlook

In the upcoming period, the development of the ICP Forests infrastructure will primarily focus on strengthening laboratory capacities and increasing participation in various ring test analyses. This will include the acquisition of new instruments to support a wider range of chemical analyses. Additionally, in 2025 the Forest Information System (FIS), i.e. an internal database will become fully operational. This system will enhance the processes of data collection, storage, and analysis.

Efforts to initiate ambient air quality monitoring began in 2023, with the goal of establishing this as a permanent monitoring component. Collaboration has been established with the Environmental Protection Agency of Serbia, and the National Focal Center at the Institute of Forestry will work, during 2025, together with its responsible ministry to find appropriate mechanisms (financial and organizational) to include this activity in permanent monitoring.

Slovakia

National Focal Centre

Pavel Pavlenda, National Forest Centre

Main activities/developments

In 2024, the teams responsible for the crown condition assessment carried out the survey on 101 Level I plots (16x16 km grid) between 8 July and 2 August (after a one-day calibration training course). In total, defoliation, discoloration, and damage symptoms of trees were assessed on 3757 trees.

Intensive monitoring (Level II) surveys continued on 7 plots for crown condition, growth, atmospheric deposition and meteorological assessment. Other sureveys (air quality, soil solution, litterfall, phenology) were conducted only on a limited number of plots.

Besides regular assessments, in the year 2024 also soil sampling and chemical analyses continued (the survey is planned to be completed in 2025).

Co-operation with teams of experts (remote sensing, process-based ecosystem modelling) enabled broader aspects of data evaluation and brought new results on forest ecosystems. Some Level II plots are included in research projects, e.g. plot 204 Polana (also an LTER site) is a base for additional soil respiration measurements within the project "Soil carbon fluxes in dominant forest ecosystems along an elevation gradient in the Western Carpathians".

The 12th Czecho-Slovak expert seminar was organized together with FGMRI from Czechia. The seminar was held on 22–24 May 2024 in the Veľká Fatra National Park (Slovakia). The agenda of this seminar focused on the results of long-term ecological research and monitoring of forests where national activities within the ICP Forests are the dominant part, however, also specific local or regional challenges are included.

Major results/highlights

Defoliation of trees is usually evaluated using two main indicators: mean defoliation and percentage of trees with defoliation >25%. Based on both indicators, the results of defoliation over the previous 15 (17) years show a slightly deteriorating health status of conifers and a stabilized health status of deciduous tree species. Fluctuations in individual years were primarily caused by climatic factors, with a significant peak in 2022.

After 2022 (when the highest average defoliation of both deciduous and coniferous trees was recorded), the health status of most tree species improved in 2023 to the level of previous years. The percentage of trees in defoliation classes 2-4 in 2024 was 24.1% for deciduous trees (40.2% in 2022, 29.8% in 2023) and 47.8% for coniferous trees (58.0% in 2022, 50.6% in 2023). The average defoliation of all tree species together was 25.9%, the average defoliation of deciduous trees was 22.6% and of conifers 29.1%. The highest mean defoliation was observed for *Robinia pseudoacacia, Fraxinus excelsior*, and *Pinus sylvestris.* The poor condition of *Fraxinus excelsior* in lowland areas is caused by drought and the damage by *Chalara fraxinea*. The only tree species with a continuous decrease in defoliation since the very beginning of the forest monitoring (1988) was *Abies alba*. However, in 2024 the mean defoliation *of Abies alba* slightly increased.

Improvement in the health status was observed compared to 2023 (and 2022) for almost all main tree species (*Fagus sylvatica, Quercus sp., Carpinus betulus, Picea abies).* In the long-term, the mortality of *Picea abies* is rather high and is related to bark beetle outbreaks.

The trend of the radial increment of *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

NFC Slovakia does not publish annual reports in last years, the most important results are published in annual reports related to state of forestry in Slovakia in general (Green Report) and in dozens of articles and contributions in conference proceedings mostly at national level.

Outlook

Monitoring activities will continue on all Level I plots (including several newly established/substituted plots) and on 7 Level II plots. Soil sampling and analyses will continue in 2025.

Developments of the infrastructure on plots of intensive monitoring depends on projects, so we submitted several project proposals. The main topics are carbon balance in forests and adaptation of forests to climate change.

One of the most important expected outcomes of the project of applied research "TreeAdapt" funded by MARD of the Slovak Republic is a publication – synthesis of results and knowledge from long-term monitoring of forest ecosystems. This is the most important challenge of the National Focal Centre and the forest monitoring team.

Slovenia

National Focal Centre

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

Main activities/developments

In 2024, the Slovenian national forest health inventory was carried out on 44 systematically arranged sample plots (grid 16 × 16 km) (Level I). The assessment encompassed 1025 trees, 339 coniferous and 686 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 2024, 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 assessed on seven of them. 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 30.7% (compared to last year the defoliation was lower by 0.3%p).
- Mean defoliation in 2024 for coniferous trees was 31.5% (in 2023 it was 30.8%).
- Mean defoliation in 2024 for broadleaved trees was 30.3% (in 2023 it was 31.1%).
- The defoliation of conifers remains at a very high level, with an additional increase in 2024. In the past, the main known reason was the bark beetle outbreak after large ice storm break in 2014, stretching all over 2016, 2017, 2018. Impact of the 2022 summer drought is still reflected in the conifer defoliation rate.
- In 2024, the defoliation of broadleaves decreased for the second time in 8 years. One of the reasons for the high level of defoliation could still be the effect of the ice storm (fungi effect) in 2014 and some other insect attacks.
- The total proportion of damaged and dead trees (with more than 25% defoliation) increased compared to the previous year from 40.8% to 41.9% in 2024.
- The percentage of damaged broadleaved trees increased from 35.0% in 2019, 36.5% in 2020, 41.3% in 2021 to 44.0% in 2022, decreased to 37.7% in 2023 and increased to 38.8% in 2024.
- The percentage of damaged conifers increased from 40.6% in 2017 to 42.7% in 2019. In 2020, it slightly decreased to 41.1% and then increased to 44.1% in 2021 and to 48.6% in 2022. In 2023, the percentage of damaged conifers decreased slightly to 47.2% and then increased to 48.1% in 2024.
- Average ozone concentrations in the growing season of 2024 were from 31 to 96 µg/m^3 on monitored plots which is again for about one third higher than in the previous year. On two plots the average ozone concentration was below 40 µg/m^3, on five of them below 80 µg/m^3, on the other three the average ozone concentration was above 80 µg/m^3.
- On only one plot the 14-days ozone concentration remained under 80 µg/m^3 (62 µg/m^3) during the whole growing season. On all others the maxima was between 95 and 193 µg/m^3.
- We noticed three seasonal peaks on all plots: in April, May and August.

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Outlook

- In 2024 we employed experts on data processing. We started to publish more and more of our results.
- In 2025 some infrastructural renewing will continue.

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 2024 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 by the national experts and NFC as requested by the different Expert Panels from ICP Forests.

The Spanish team (NFC and national experts) participated in the annual ICP meetings during 2024:

- March 2024: ICP Forests Joint Expert Panel Meeting, Athens, Greece
- June 2024: 40th Task Force Meeting of ICP Forests (online)
- September 2024: Meeting of the Working Group on Quality in Laboratories, Ljubljana (Slovenia); Expert Panel Meeting of Biodiversity and Ground Vegetation (online); Photo exercise for assessing visible ozone injuries (online)

Major results/highlights

Level I

Mean defoliation observed in 2024 is 23.0% (considering all trees from Level I plots but excluding harvested trees). This is considered slight defoliation (class1: 11-25%), showing some change from 2023 (mean defoliation observed in 2023 was 23.1%). As in previous years, a good number of species show defoliation values over 25%, including some of the most Mediterranean species (*Olea europaea*, *Castanea sativa*, *Juniperus thurifera*, *Quercus pubescens*, *Quercus faginea*, *Pinus halepensis*, *Quercus suber*, *Quercus ilex*, *Pinus nigra*). Moderate defoliations are mainly observed in different areas from the Autonomous Communities of Castilla-La Mancha, Baleares, Extremadura, the South of Aragón and some areas of Andalucía, but this is especially relevant in Cataluña, where 73% of plots show moderate defoliation, and 5% show severe defoliation. Moderate and severe defoliation is mostly associated with drought and high temperatures in former years.

Regarding damage from different agents, 41.0% of the sampled trees showed no damage in 2024 (6107 trees). These results are slightly better than those from 2023 (39.1% of undamaged trees). The most abundant group is "Abiotic agents", which is responsible for 38.6% of the detected damage (3.2% lower than in 2023), where drought causes most of the damage. "Insects" is the second group, being responsible for 25.4% of the detected damage (0.6% higher than in 2023). *Thaumetopoea pityocampa* on *Pinus* is the most abundant defoliator, while, with regard to wood borers, the most abundant damage have been caused by *Coraebus florentinus* and *Cerambyx* on *Quercus*.

Level II

Results from the Level II network are difficult to summarize. Data and reports are available in 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: 2024 results at national level and for every Autonomous Community. Reports and historical database available.

Evaluation of reference parameters from Level I plots for *Pinus pinaster,* 1987–2024

Level II

European intensive and continuous monitoring of forest ecosystems (Level II) in Spain: 2023 and 2024 general results, and per plot. Reports and historical database available.

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

Several publications based on Level I and Level II networks have been submitted to the 9th Spanish Forest Congress and are under review (9cfe.congresoforestal.es).

Outlook

Data from ICP Forests provide very useful information, not only for monitoring the state of vegetation (data used for national and international reports), but also to fulfil the current international requirements of forest and climate change information under different EU regulations. Multiple data requests have been received for scientific activities and projects.

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

- Level I surveys are carried out at a regional level by different Autonomous Communities in Spain. Both national and regional sources are harmonized and integrated in a common database, which is updated periodically. This integrated database offers many potential applications. A preliminary methodology was developed for the FRA (Forest Resource Assessment) and JPEDC (Joint Pan-European Data Collection) reporting processes, and it is currently being improved.
- 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. The second cycle of dasometric measurements has been completed in 2024, so new developments are expected.
- 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 and from the integrated database.
- 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 INIA are actively involved.

CSIC-INIA researchers are working with data from ICP Forests sites within the EU-funded projects:

- "Pathfinder" (pathfinder-heu.eu)
- "MRV4SOC - Monitoring, Reporting and Verification of Soil Organic Carbon and Greenhouse Gas Balance" (cordis.europa.eu/project/id/101112754)
- "Sensoforest" (funded by Forwards project: forwards-project.eu)

In 2025, works are expected to continue without incidences, and current research projects will continue to advance.

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

Spanish experts participated in several peer-reviewed scientific ICP Forests-related publications, already listed on the ICP Forests website (icp-forests.net/page/scientific-publications): i) Anthony, M.et al., 2024 (doi: 10.1038/s41467-024-46792-w); ii) Ferretti, M. et al, 2024 (doi: 10.1016/j.ecolind.2023.111486).

Sweden

National Focal Centre

Cornelia Roberge – Swedish University of Agricultural Sciences

Main activities/developments

Monitoring activities continued on Level I. Since 2009 an annual subset of the Swedish NFI monitoring plots are measured and reported. The Swedish NFI is carried out on a five-year interval and accordingly the Level I plots are 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 program on a yearly basis.

Major results/highlights

The major national results are based on the whole Swedish NFI sample in forests of thinning age or older. The proportion of trees with more than 25% defoliation for *Picea abies* is 23% and for *Pinus sylvestris* it is 12%. In 2024, large temporal annual changes were seen on a regional level. The mortality rate in 2024 was 0.2% for *Pinus sylvestris* and 0.4% for *Picea abies*. The severe damage caused by spruce bark beetle (*Ips typographus*) in southern Sweden after the dry summer in 2018, have now subsided according to a Target-tailored Forest Damage Inventory (TFDI) of spruce trees killed by spruce bark beetle during 2024. The results from the inventory showed that 315 thousand m^3 of Norway spruce were killed during 2024 in the inventoried area.

In northern Sweden, there is concern for the young forest, mainly the pine forest. Several causes of damage interact. Additionally some concern surrounding damage to birches have been noted, but with no large-scale impact on national scale statistics. Browsing by wildlife dominate among the distinguishable known causes of damage, especially in pine. Fresh damage caused by moose (*Alces alces*) 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 according to previous TFDI. Otherwise, significant damage problems in Sweden are similar to previously due to pine weevil (*Hylobius abietis*) (in young forest plantations), browsing by ungulates, mainly moose (in young forest), and root rot caused by *Heterobasidion annosum*. Data from Sweden on forest condition, deposition, soil solution, and air quality are included in the ICP Forests Technical Report, several national reports, and scientific publications (see links below). Data are also used to follow-up Swedish Environmental objectives and shared 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 from SWETHRO *Publications - IVL Svenska Miljöinstitutet*.

Outlook

Monitoring activities on Level I will continue as previously. Also, data from SWETHRO on the Level II program will continue. In 2025, no Target-tailored Forest Damage Inventory (TFDI) is planned. In March 2025, a new website is launched to enable the collection of citizen-science reports on forest damage on a new national platform *Skogsskada*.

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:

- We continued developing a toolbox to better combine and link ground-based monitoring with remote sensing. This covers the collection RGB, multispectral and hyperspectral imagery at several Level I and II sites with drones and aircrafts.
- Within the UpScale project (funded by the Swiss National Science Foundation, SNF), we apply machine learning algorithms to identify tree species, mortality, and crown defoliation from aerial photography using Level I and II defoliation data as ground truthing.
- In country-scale assessments, we determined warm and wet springs followed by hot and dry summers as a major driver/risk for tree mortality. We assume that favorable spring conditions lead to a structural overshoot of aboveground biomass, which makes trees more susceptible to subsequent droughts.
- We advanced the water balance model LWFBrook90 with a water isotope module. This allows us to constrain water fluxes in the forest ecosystem using water isotope information from soil solution samples.
- Determination of ^{14}C age of soils and input signals, reflected in tree rings, were made in an SNF project.
- A first repetition of a rapid biodiversity assessment campaign started, and a seed production, seed predation, and tree regeneration survey was continued on the majority of Level II plots.
- Analyses of changes in acidification indicators between first and second soil inventory on the Level I plots (8x8 km grid) and the change in C and N between first and second soil inventory on five Level II plots were made.

Major results/highlights

Defoliation has risen since the 1990s. There has been a clear upward trend in the average defoliation rates of both coniferous and deciduous trees since 1990. Since about 2011, the average defoliation rate has fluctuated at a high level. In the case of deciduous trees, the frequency of years in which tree crown conditions have improved has diminished since 2009, and any observed recovery in trees has generally been less marked than in earlier years. Like the average defoliation rates, the number of damaged trees has also increased over the years. Furthermore, there has been a rise in the number of severely damaged trees and mortality rates among deciduous trees since approximately 2004. Moist years such as 2024 might provide some relief, but this has not resulted in a large-scale improvement of tree crown conditions since about 2011. Sites within Switzerland that show a long-term tendency for increased defoliation match with areas where satellite-based greenness (NDVI) and gross primary productivity (GPP based on GOSIF) show a reduction. The same areas are likely to show strong tree species shifts in the future, as indicated by species distribution models.

Drought stress is a major factor driving the observed trends in defoliation. Long-term observations indicate that escalating levels of drought stress are primarily responsible for the deterioration of crown conditions documented over recent decades. This phenomenon relates not only to alterations in precipitation quantity and frequency but is also linked to rising temperatures, which enhance the rate of water loss from trees to the atmosphere via vapor pressure deficit (VPD). To disentangle the effects of soil and atmospheric drought, an in-depth study has

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been conducted at an experimental long-term monitoring site, Pfynwald (see vpdrought.wsl.ch).

High defoliation is a good predictor for decreased growth and future mortality risk. Machine learning approaches have shown that defoliation is one of the most important predictors of tree growth. The defoliation rate of individual trees is also associated with a particular mortality risk, which begins to increase clearly at defoliation rates around 35%. In addition, trees that exceed a defoliation threshold usually seem unable to recover, and about 80-90% of these trees die within a few years, even without further increased stress exposure. This threshold may be linked with the carbon supply of heterotrophic tissues. Thus, defoliation can serve as an early warning signal for the future mortality risk of trees.

Forest damages in beech occurred in 2024. Spring temperatures in Switzerland increased strongly since the late 1980s. Cold snaps in April 2024 resulted in late frost and caused damage in beech stands at around 1000 m a. s. l. (observed at 3 Level I plots and 1 Level II plot in the Jura mountains).

Species differ in root water uptake strategies. Stable water isotopes in soil solution samples revealed that oak, beech, and maple access deeper water pools during droughts more effectively than fir and spruce. These differences highlight species-specific adaptations to water scarcity, providing insights into which trees are more resilient under drought conditions.

Tree-ring isotope patterns reflect stable water sources. While shallow soil water showed pronounced seasonal changes in its chemical signature, the tree rings of both beech and spruce trees displayed more stable patterns. This suggests that trees rely on deeper, more consistent water sources or that chemical changes occur as the water moves through the tree before being stored in the wood.

Higher carbon-to-nitrogen ratios reduce nitrogen leaching. Forest soils with higher C/N ratios exhibited lower levels of nitrogen leaching, even under high nitrogen deposition. Over time, these sites also showed a stronger increase in nitrogen than carbon concentrations and a corresponding decline in soil C/N ratios between the first and second soil inventory (1990s and 2022), highlighting a shift in soil nutrient dynamics and the potential for altered ecosystem functions.

In collaboration with eLTER, Switzerland is contributing three Level II (LWF) and three long-term experimental sites to the eLTER ERIC Step-1-Application, which will be submitted in spring 2025.

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

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Lehmann M, Diao H, Holloway-Phillips M, et al. (2024) *Hydrogen and oxygen isotopes in tree-ring cellulose as indicators of source water variations*, EGU General Assembly, Vienna, Austria, 14–19 Apr 2024, EGU24-11920, https://doi.org/10.5194/egusphere-egu24-11920

Waldner P, Musso A, Moreno Duborgel M, et al. (2024) *Nitrogen deposition effects on forest ecosystems: Linking N leaching patterns to long-term dynamics of soil C/N ratios in Swiss ICP Forests Level II Plots*, EGU General Assembly, Vienna, Austria, 14–19 Apr 2024, EGU24-18305, https://doi.org/10.5194/egusphere-egu24-18305

Outlook

- Linking ground-based monitoring with remote sensing; nowcasting of tree functioning under changing climatic conditions; integrating additional real-time sensor networks into the classical monitoring schemes
- 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 the 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 and eLTER_PPP towards the harmonization of Standard Observations from existing networks (incl. ICP Forests) across Europe.
- The Swiss Level II plot will be included in the "SMURF" project to map microclimatic soil moisture patterns and their relationship to vegetation structure in Switzerland.

Türkiye

National Focal Centre

Çağlar Başsüllü – General Directorate of Forestry

Main activities/developments

As of 2024, Turkey has 850 Level I observation plots, of which 593 are actively monitored and 257 are under surveillance. In 587 plots, crown condition and damage assessments were conducted on 13 217 trees. The monitoring includes needle/leaf loss, discoloration, and damage factors to evaluate forest health.

Major results/highlights

Needle/leaf loss trends (2013–2024): The national average needle/leaf loss rate increased by approximately 10% over the last decade. In the Mediterranean region, needle/leaf loss rose from 16–20% (2013–2017) to 20–28% (2018–2024). In contrast, the Eastern Black Sea and Marmara regions showed an overall decrease in needle/leaf loss rates.

Risk assessment of crown condition: The highest levels of crown deterioration were observed in areas exposed to climate stress, pests, and land-use changes. Regional comparisons indicate that drought-prone areas exhibited more significant crown degradation, while humid coastal regions demonstrated more stability in tree health.

Damage Assessment: 6 832 trees exhibited damage, primarily caused by biotic stressors such as insects, fungi, and pathogens. Among the affected trees, over 40% showed damage from insect infestations, while fungal infections and other pathogens accounted for 35%. Abiotic factors, such as storm damage, drought stress, and pollution, affected approximately 25% of recorded cases.

Outlook

- Integration of remote sensing technology (satellite & UAV) and AI-driven data analysis to enhance accuracy and efficiency
- Research on climate change impacts, biotic stressors, and pollution-related forest health decline
- Carbon sequestration assessments to evaluate the role of forests in mitigating climate change
- Strengthening forest management policies based on long-term ICP Forests data to ensure sustainable forest ecosystems.

United Kingdom

National Focal Centre

Caitlin Lewis – Forest Research, UK

Main activities/developments

Monitoring at seven Level II sites continued as normal. Two of these sites were established under the Government's Natural Capital Ecosystem Assessment (NCEA) program in 2022, and will continue to support monitoring at these two sites until 2028. Additional air pollution monitoring (NH_3, NO_2, O_3) has also been supported by the NCEA program at all seven sites since 2022. The NCEA also supported the resampling of 40 Biosoil sites in 2024 – samples were collected and are nearing completion of laboratory analyses. Forest Research also submitted UK Level II data to UKCEH to support the APIENS project, which co-ordinates national reporting of air pollution impacts on ecosystem condition.

In addition to routine Level II activities, AI-supported acoustic devices for monitoring bats and birds were tested at one Level II site (Alice Holt), and audiomoths were deployed in another (Kielder). Tree Talker devices, capable of measuring sap flow, microclimate, tree growth and oscillation, were installed in three Level II plots. We continue to engage heavily in the CLEANFOREST COST Action, which hopes to use ICP Forests data to support working group activities. A major project on predisposition factors to Acute Oak Decline, established in 2019/20 following the increasing concern for oak health in the south of the UK, concluded its initial phase, with hopes to secure funding for future experiments from 2025.

Major results/highlights

- Analysis of throughfall chemistry data from broadleaf sites suggests evidence of caterpillar infestations in 2023 at all sites. Evidence of caterpillar infestations at our longest running broadleaf site suggests such events have become more common in the past decade.
- Analysis of initial data at our two newest Level II plots suggests a foliar P deficiency in the riparian woodland site, and that the ancient woodland site has a low Ca:Al ratio in soil solution, and could therefore be a sensitive to future changes in soil pH.

Outlook

- Continuation of monitoring at the two newest Level II plots established in 2022 until 2028.
- Plan to conduct crown condition and dead wood surveys at most Level II plots in 2025.
- Plan to install soil moisture probes at three Level II plots.
- Upscaling deployment of acoustic monitoring at two Level II plots.
- Plan to complete long-term trend analysis of ground vegetation in UK Level II plots.
- Sampling at additional Biosoil plots continues under NCEA. The Department for Energy Security and Net Zero and Forestry Commission are also supporting the resampling of Biosoil sites in Scotland.

ANNEX

CONTACTS

as of 20 June 2025

UNECE | ICP Forests

UNECE – LRTAP Convention
Albena Karadjova
United Nations Economic Commission for Europe – LRTAP Convention Secretariat
Palais des Nations, 8-14, Ave. de la Paix
1211 Geneva 10, SWITZERLAND
Email: albena.karadjova@un.org

ICP Forests Lead Country
Juliane Henry
Federal Ministry of Food and Agriculture - Ref. 515 | Postfach 14 02 70
53107 Bonn, GERMANY
Email: juliane.henry@bmel.bund.de; 515@bmel.bund.de

ICP Forests Chairperson
Marco Ferretti
Swiss Federal Research Institute WSL
Zürcherstr. 111
8093 Birmensdorf, SWITZERLAND
Email: marco.ferretti@wsl.ch

ICP Forests Programme Co-ordinating Centre (PCC)
Kai Schwärzel, Head of PCC
Thünen Institute of Forest Ecosystems
Alfred-Möller-Str. 1, Haus 41/42
16225 Eberswalde, GERMANY
Email: kai.schwaerzel@thuenen.de
http://icp-forests.net

Expert panels | Working groups | Committees

Expert Panel on Ambient Air Quality
Diana Pitar, Chair
National Institute for Research and Development in Forestry "Marin Drăcea" (INCDS) | Bd. Eroilor 128
077190 Voluntari, Judetul Ilfov, ROMANIA
Email: diana.silaghi@icas.ro

Barbara Baesso Moura, Co-Chair
Institute of Research on Terrestrial Ecosystems (IRET)
National Research Council (CNR)
Via Madonna del Piano 10, Sesto Fiorentino (Florence), ITALY
Email: barbara.baessomoura@cnr.it

Volkmar Timmermann, Co-Chair
Norwegian Institute of Bioeconomy Research (NIBIO) | P.O. Box 115
1431 Ås, NORWAY
Email: volkmar.timmermann@nibio.no

Expert Panel on Biodiversity and Ground Vegetation Assessment
Leena Hamberg, Chair
Natural Resources Institute Finland LUKE
Latokartanonkaari 9
00790 Helsinki, FINLAND
Email: leena.hamberg@luke.fi

František Máliš, Co-Chair
National Forest Centre | T.G. Masaryka 22
96001 Zvolen, SLOVAKIA
Email: malis@nlcsk.org

Expert Panel on Crown Condition and Damage Causes
Nenad Potočić, Chair
Croatian Forest Research Institute (CFRI)
Cvjetno naselje 41
10450 Jastrebarsko, CROATIA
Email: nenadp@sumins.hr

Expert Panel on Deposition
Arne Vestraeten, Chair
Research Institute Nature and Forests (INBO) | Gaverstraat 4
9500 Geraardsbergen, BELGIUM
Email: arne.verstraeten@inbo.be

Peter Waldner, Co-Chair
Swiss Federal Research Institute WSL
Zürcherstr. 111
8903 Birmensdorf, SWITZERLAND
Email: peter.waldner@wsl.ch

Andreas Schmitz, Co-Chair
State Agency for Nature, Environment and Consumer Protection of North Rhine-Westphalia (LANUV) | Leibnizstraße 10
45659 Recklinghausen, GERMANY
Email: andreas.schmitz@lanuv.nrw.de

Expert Panel on Foliar Analysis and Litterfall
Pasi Rautio, Chair
Natural Resources Institute Finland (LUKE)
PO Box 16, Eteläranta 55
96301 Rovaniemi, FINLAND
Email: pasi.rautio@luke.fi

Liisa Ukonmaanaho, Co-Chair (Litterfall)
Natural Resources Institute Finland (LUKE)
Latokartanonkaari 9
00790 Helsinki, FINLAND
Email: liisa.ukonmaanaho@luke.fi

Expert Panel on Forest Growth

Tanja Sanders, Chair
Thünen Institute of Forest Ecosystems
Alfred-Möller-Str. 1, Haus 41/42
16225 Eberswalde, GERMANY
Email: tanja.sanders@thuenen.de

Monika Vejpustková, Co-Chair
Forestry and Game Management Research Institute | Strnady 136
252 02 Jíloviště, CZECHIA
Email: vejpustkova@vulhm.cz

Andrei Popa, Co-Chair
National Institute for Research and Development in Forestry "Marin Drăcea"
Calea Bucovinei 73 bis
725100 Campulung Moldovenesc, ROMANIA
Email: popa.andrei.dorna@gmail.com

Expert Panel on Meteorology, Phenology and Leaf Area Index

Lothar Zimmermann, Chair
Bavarian State Institute of Forestry LWF
Hans-Carl-von-Carlowitz-Platz 1
85354 Freising, GERMANY
Email: lothar.zimmermann@lwf.bayern.de

Stephan Raspe, Co-Chair (Phenology)
Bavarian State Institute of Forestry LWF
Hans-Carl-von-Carlowitz-Platz 1
85354 Freising, GERMANY
Email: stephan.raspe@lwf.bayern.de

Stefan Fleck, Co-Chair (LAI)
Northwest German Research Institute NW-FVA | Grätzelstr. 2
37079 Göttingen, GERMANY
Email: stefan.fleck@nw-fva.de

Expert Panel on Soil and Soil Solution

Bruno De Vos, Chair
Research Institute for Nature and Forest (INBO) | Gaverstraat 4
9500 Geraardsbergen, BELGIUM
Email: bruno.devos@inbo.be

Nathalie Cools, Co-Chair
Research Institute for Nature and Forest (INBO) | Gaverstraat 4
9500 Geraardsbergen, BELGIUM
Email: nathalie.cools@inbo.be

Katrin Meusburger, Co-Chair (Soil Solution)
Swiss Federal Research Institute WSL
Zürcherstr. 111
8903 Birmensdorf, SWITZERLAND
Email: katrin.meusburger@wsl.ch

Forest Soil Co-ordinating Centre (FSCC)

Nathalie Cools, Chair
Research Institute for Nature and Forest (INBO) | Gaverstraat 4
9500 Geraardsbergen, BELGIUM
Email: nathalie.cools@inbo.be

Forest Foliar Co-ordinating Centre (FFCC)

Michael Tatzber, Chair
Austrian Research Centre for Forests BFW
Seckendorff-Gudent-Weg 8
1131 Wien, AUSTRIA
Email: michael.tatzber@bfw.gv.at

Quality Assurance Committee

Manuel Nicolas, Chair
Office National des Forêts
Boulevard de Constance
77300 Fontainebleau, FRANCE
Email: manuel.nicolas@onf.fr

Scientific Committee

Lars Vesterdal, Chair
University of Copenhagen, Department of Geosciences and Natural Resource Management | Rolighedsvej 23
1958 Frederiksberg C, DENMARK
Email: lv@ign.ku.dk

Marcus Schaub, Co-Chair
Swiss Federal Research Institute WSL
Zürcherstr. 111
8903 Birmensdorf, SWITZERLAND
Email: marcus.schaub@wsl.ch

Working Group on Quality Assurance and Quality Control in Laboratories

Anna Kowalska, Chair
Forest Research Institute
Sękocin Stary, 3 Braci Leśnej Street
05-090 Raszyn, POLAND
Email: a.kowalska@ibles.waw.pl

Tamara Jakovljević, Co-Chair
Croatian Forest Research Institute CFRI
Cvjetno naselje 41
10450 Jastrebarsko, CROATIA
Email: tamaraj@sumins.hr

Michael Tatzber, Co-Chair
Austrian Research Centre for Forests BFW
Seckendorff-Gudent-Weg 8
1131 Wien, AUSTRIA
Email: michael.tatzber@bfw.gv.at

Ministries | National Focal Centres (NFC)

Albania Ministry	Ministry of the Environment, Forests and Water Administration (MEFWA) Dep. of Biodiversity and Natural Resources Management Rruga e Durrësit, Nr. 27, Tirana, ALBANIA Email: info@moe.gov.al
NFC	National Environment Agency Bulevardi "Bajram Curri", Tirana, ALBANIA Email: jbeqiri@gmail.com, kostandindano@yahoo.com Julian Beqiri (Head of Agency), Kostandin Dano (Head of Forestry Department)
Andorra Ministry, NFC	Ministeri de Turisme I Medi Ambient Departament de Medi Ambient C. Prat de la Creu, 62-64, 500 Andorra la Vella, Principat d'Andorra, ANDORRA Email: silvia_ferrer_lopez@govern.ad Silvia Ferrer
Austria Ministry	Bundesministerium für Land- und Forstwirtschaft, Regionen und Wasserwirtschaft Marxergasse 2, 1030 Wien, AUSTRIA Email: martin.noebauer@bml.gv.at Martin Nöbauer
NFC	Austrian Research Centre for Forests (BFW) Seckendorff-Gudent-Weg 8 1131 Wien, AUSTRIA Email: anita.zolles@bfw.gv.at, silvio.schueler Anita Zolles, Silvio Schüler
Belarus Ministry	Ministry of Forestry of the Republic of Belarus Myasnikova st. 39 220048 Minsk, BELARUS Email: mlh@mlh.gov.by Petr Semashko
NFC	Forest Inventory Republican Unitary Company "Belgosles" Zheleznodorozhnaja st. 27 220089 Minsk, BELARUS Email: mlh@mlh.gov.by Valentin Krasouski
Belgium *Wallonia* Ministry	Service public de Wallonie SPW ARNE – Département de la Nature et des Forêts – Direction des Ressources Forestières Avenue Prince de Liège, 7 5100 Jambes, BELGIUM Email: michel.baillij@spw.wallonie.be Michel Baillij
NFC for Level I	SPW ARNE – Départment de l'Etude du milieu Naturel et Agricole Avenue Maréchal Juin, 23 5030 Gembloux, BELGIUM Email: elodie.bay@spw.wallonie.be Elodie Bay
NFC for Level II	Earth and Life Institute / Environmental Sciences (ELI-e) Université catholique de Louvain Croix du Sud, 2 - L7.05.09 1348 Louvain-La-Neuve, BELGIUM Email: hugues.titeux@uclouvain.be Hugues Titeux
Flanders Ministry	Vlaamse Overheid (Flemish Authorities) Agency for Nature and Forest (ANB) Koning Albert II-laan 20 1000 Brussels, BELGIUM Email: carl.deschepper@lne.vlaanderen.be Carl De Schepper
NFC	Research Institute for Nature and Forest (INBO) | Gaverstraat 4 9500 Geraardsbergen, BELGIUM Email: arne.verstraeten@inbo.be Arne Verstraeten
Bulgaria Ministry	Ministry of Environment and Water National Nature Protection Service 22, Maria Luiza Blvd. 1000 Sofia, BULGARIA Manol Genov
NFC	Executive Environment Agency at the Ministry of Environment and Water Monitoring of Lands, Biodiversity and Protected Areas Department 136 Tzar Boris III Blvd., P.O. Box 251 1618 Sofia, BULGARIA Email: forest@eea.government.bg Genoveva Popova

Canada
Ministry, NFC
N.N.

Environment and Climate Change Canada / Government of Canada
Email: dominique.pritula@canada.ca
Dominique Pritula

Croatia
Ministry, NFC
Croatian Forest Research Institute
Cvjetno naselje 41
10450 Jastrebarsko, CROATIA
Email: nenadp@sumins.hr
Nenad Potočić

Cyprus
Ministry, NFC
Ministry of Agriculture, Rural Development and Environment
P.O Box 24136, 1701 Nicosia, CYPRUS
Email: ssotiriou@fd.moa.gov.cy
Soteris Soteriou

Czechia
Ministry
Ministry of Agriculture of the Czech Republic | Forest Management
Tešnov 17, 117 05 Prague 1, CZECHIA
Email: tomas.krejzar@mze.cz
Tomáš Krejzar

NFC
Forestry and Game Management Research Institute (FGMRI)
Strnady 136, 252 02 Jíloviště, CZECHIA
Email: sramek@vulhm.cz
Vít Šrámek

Denmark
Ministry
Ministry of Green Transition and Aquatic Environment | Tolderlundsvej 5
5000 Odense C, DENMARK
Email: skov@sgav.dk, pka@sgav.dk
Pernille Karlog

NFC
University of Copenhagen | Department of Geosciences and Natural Resource Management | Rolighedsvej 23
1958 Frederiksberg C, DENMARK
Email: moi@ign.ku.dk
Morten Ingerslev

Estonia
Ministry
Ministry of the Environment
Forest Department
Narva mnt 7a, 15172 Tallinn, ESTONIA
Email: maret.parv@envir.ee
Maret Parv

NFC
Estonian Environment Agency (EEIC)
Mustamäe tee 33, Tallinn 10616, ESTONIA
Email: vladislav.apuhtin@envir.ee
Vladislav Apuhtin

Finland
Ministry
Ministry of Agriculture and Forestry
Natural Resources Department
Hallituskatu 3 A, P.O. Box 30
00023 Government, FINLAND
Email: juha.roppola@gov.fi
Juha Roppola

NFC
Natural Resources Institute Finland (LUKE)
Oulu Unit | PO Box 413
90014 Oulun yliopisto, FINLAND
Email: paivi.merila@luke.fi
Päivi Merilä

France
Ministry, NFC for Level I
Ministère de l'Agriculture, de l'Agroalimentaire et de la Forêt
Département de la santé des forêts
251, rue de Vaugirard
75732 Paris cedex 15, FRANCE
Email: milene.gentils@agriculture.gouv.fr, fabien.caroulle@agriculture.gouv.fr
Milène Gentils, Fabien Caroulle

NFC for Level II
Office National des Forêts
Département recherche, développement, innovation - Bâtiment B
Boulevard de Constance
77300 Fontainebleau, FRANCE
Email: manuel.nicolas@onf.fr
Manuel Nicolas (Level II)

Germany
Ministry, NFC
Bundesministerium für Ernährung und Landwirtschaft (BMEL) - Ref. 515
Rochusstr. 1, 53123 Bonn, GERMANY
Email: juliane.henry@bmel.bund.de; 515@bmel.bund.de
Juliane Henry

Greece
Ministry
Hellenic Republic Ministry of Environment and Energy | Secretariat General for the Forests | Directorate General for the Forests and the Forest Environment
Terma Alkmanos str., 115 28 Ilisia, Athens, GREECE
Email: k.koutla@prv.ypeka.gr, p.drougas@prv.ypeka.gr
Katerina Koutla, Panagiotis Drougas

NFC
Institute of Mediterranean Forest Ecosystems | Hellenic Agricultural Organisation "ELGO DIMITRA"
Terma Alkmanos, Ilisia, GR11528, Athens, GREECE
Email: ekorakaki@elgo.gr
Evi Korakaki

Hungary Ministry	Ministry of Agriculture Department of Forest Management Kossuth Lajos tér 11 1055 Budapest, HUNGARY Email: tamas.akos.balogh@am.gov.hu Ákos Balogh
NFC for Level I	National Land Centre Department of Forestry Frankel Leó út 42-44 1023 Budapest, HUNGARY Email: zoltan.stuller@am.gov.hu Zoltán Stuller
NFC for Level II	University of Sopron Bajcsy-Zsilinszky u. 4. Sopron 9600, Hungary Email: manninger.miklos@uni-sopron.hu Miklós Manninger
Ireland Ministry	Department of Agriculture, Food and the Marine – Forest Sector Development Agricultural House, Kildare Street, Dublin 2, D02 WK12, IRELAND Email: shane.flanagan@agriculture.gov.ie Shane Flanagan
NFC	University College Dublin (UCD) UCD School of Agriculture and Food Science Belfield, Dublin 4, IRELAND Email: thomas.cummins@ucd.ie Thomas Cummins
Italy Ministry, NFC	Comando Unità Tutela Forestale, Ambientale e Agroalimentare Carabinieri Carabinieri Corps – Office for Studies and Projects Via Giosuè Carducci 5, 00187 Roma, ITALY Email: giancarlo.papitto@carabinieri.it Giancarlo Papitto
Latvia Ministry	Ministry of Agriculture Forest Department Republikas laukums 2, Riga 1981, LATVIA Email: lasma.abolina@zm.gov.lv Lasma Abolina
NFC	Latvian State Forest Research Institute „Silava" 111, Rigas str, Salaspils, 2169, LATVIA Email: uldis.zvirbulis@silava.lv Uldis Zvirbulis
Liechtenstein Ministry, NFC	Amt für Umwelt (AU) Dr. Grass-Str. 12, Postfach 684, 9490 Vaduz, FÜRSTENTUM LIECHTENSTEIN Email: olivier.naegele@llv.li Olivier Nägele
Lithuania Ministry	Ministry of Environment A. Jakšto g. 4 | 0110 Vilnius, LITHUANIA Email: aurimas.saladzius@am.lt Aurimas Saladžius
NFC	Lithuania State Forest Service Pramones ave. 11a 51327 Kaunas, LITHUANIA Email: albertas.kasperavicius@amvmt.lt, gintaras.kulbokas@amvmt.lt Albertas Kasperavicius, Gintaras Kulbokas
Luxembourg Ministry, NFC	Ministère de l'Environnement, du Climat et du Développement durable - Administration de la nature et des forêts 81, avenue de la Gare 9233 Diekirch, LUXEMBOURG Email: martine.neuberg@anf.etat.lu, pascal.armborst@anf.etat.lu, hanna.teuchert@anf.etat.lu Martine Neuberg, Pascal Armborst, Hanna Teuchert
Moldova, Rep. of Ministry, NFC	Forest Research and Management Institute (ICAS), Moldsilva Agency 124 bd. Stefan cel Mare 2001 Chisinau, REPUBLIC OF MOLDOVA Email: icas@moldsilva.gov.md Dumitru Galupa, Gheorghe Florenţă
Montenegro Ministry	Directorate for Agriculture, Hunting and Water Management Rimski trg 46, PC "Vektra" 81000 Podgorica, MONTENEGRO Email: ranko.kankaras@mpsv.gov.me Ranko Kankaraš
NFC	University of Montenegro, Faculty of Biotechnology | Mihaila Lalića 1 81000 Podgorica, MONTENEGRO Email: ddubak@t-com.me Darko Dubak
Netherlands Ministry, NFC	National Institute for Public Health and Environment RIVM Antonie van Leeuwenhoeklaan 9 3721 MA Bilthoven, THE NETHERLANDS Email: albert.bleeker@rivm.nl Albert Bleeker

North Macedonia
Ministry
Ministry of Agriculture, Forestry and Water Economy, Dep. for Forestry and Hunting
2 Leninova Str., 1000 Skopje,
NORTH MACEDONIA
Email: vojo.gogovski@mzsv.gov.mk
Vojo Gogovski

NFC
Ss. Cyril and Methodius University
Faculty of Forestry
Department of Forest and Wood Protection
Blvd. Goce Delcev 9, 1000 Skopje,
NORTH MACEDONIA
Email: nnikolov@sf.ukim.edu.mk, irpc@sumers.org
Nikola Nikolov, Srdjan Kasic

Norway
Ministry
Norwegian Environment Agency
P.O. Box 5672 Torgarden
7485 Trondheim, NORWAY
Email: gunnar.skotte@miljodir.no
Gunnar Carl Skotte

NFC
Norwegian Institute of Bioeconomy Research (NIBIO)
P.O.Box 115, 1431 ÅS, NORWAY
Email: volkmar.timmermann@nibio.no
Volkmar Timmermann

Poland
Ministry
Ministry of Climate and Environment
Department of Forestry and Hunting
Wawelska Str. 52/54
00922 Warsaw, POLAND
Email: radoslaw.kanabus@mos.gov.pl
Radosław Kanabus

NFC
Forest Research Institute
Sękocin Stary, 3 Braci Leśnej Street
05-090 Raszyn, POLAND
Email: j.wawrzoniak@ibles.waw.pl, p.lech@ibles.waw.pl
Jerzy Wawrzoniak, Pawel Lech

Portugal
Ministry, NFC
Instituto da Conservação de Natureza e das Florestas (ICNF)
Avenida da República, 16 a 16B
1050-191 Lisboa, PORTUGAL
Email: helena.martins@icnf.pt, jose.uva@icnf.pt
Helena Martins, José Sousa Uva

Romania
Ministry
Ministry of Environment, Waters and Forests, Directorate Policies and Strategies in Silviculture
Calea Plevni 46-48, Sector 1
010233 Bucharest, ROMANIA
Email: claudiu.zaharescu@mmediu.ro
Claudiu Zaharescu

NFC
National Institute for Research and Development in Forestry "Marin Drăcea" (INCDS)
Bd. Eroilor 128
077190 Voluntari, Judetul Ilfov, ROMANIA
Email: obadea@icas.ro, stefan.leca@icas.ro
Ovidiu Badea, Stefan Leca

Russian Federation
Ministry, NFC
N.N.

Serbia
Ministry
Ministry of Agriculture, Forestry and Water Management | Directorate of Forests
SIV 3, Omladinskih brigada 1
11070 Belgrade, SERBIA
Email: sasa.stamatovic@minpolj.gov.rs
Sasa Stamatovic

NFC
Institute of Forestry
Kneza Viseslava 3
11000 Belgrade, SERBIA
Email: ljubinko.rakonjac@forest.org.rs; ljrakonjac@yahoo.com
Ljubinko Rakonjac

Slovakia
Ministry
Ministry of Agriculture of the Slovak Republic
Dobrovičova 12
81266 Bratislava, SLOVAKIA
Email: henrich.klescht@land.gov.sk
Henrich Klescht

NFC
National Forest Centre - Forest Research Institute | ul. T.G. Masaryka 22
962 92 Zvolen, SLOVAKIA
Email: pavlenda@nlcsk.org
Pavel Pavlenda

Slovenia
Ministry
Ministry of Agriculture, Forestry and Food (MKGP) | Dunajska 56-58
1000 Ljubljana, SLOVENIA
Email: simon.poljansek@gov.si, robert.rezonja@gov.si
Simon Poljansek, Robert Režonja

NFC
Slovenian Forestry Institute (SFI)
Večna pot 2, 1000 Ljubljana, SLOVENIA
Email: tom.levanic@gozdis.si,
primoz.simoncic@gozdis.si,
anzemartin.pintar@gozdis.si
Tom Levanič, Primož Simončič,
Anže Martin Pintar

Spain
Ministry
Subdirectorate General for Forest Policy and Fight against Desertification, Directorate General for Biodiversity, Forests and Desertification - Ministry for the Ecological Transition and the Demographic Challenge
Gran Vía de San Francisco, 4-6, 5ª pl.
28005 Madrid, SPAIN
Email: eenriquez@miteco.es
Elsa Enríquez Alcalde

NFC
Directorate General for Biodiversity, Forests and Desertification - Ministry for the Ecological Transition and the Demographic Challenge
Gran Vía de San Francisco, 4-6, 5ª pl.
28005 Madrid, SPAIN
Email: erobla@miteco.es,
arzamarron@miteco.es
Elena Robla González, Asunción Roldán-Zamarrón

Sweden
Ministry
Swedish Environmental Protection
10648 Stockholm, SWEDEN
Email: stina.ausmeel@naturvardsverket.se
Stina Ausmeel

NFC
Swedish University of Agricultural Sciences, Department of Forest Resource Management, Skogsmarksgränd 17,
901 83 Umeå, SWEDEN
Email: cornelia.roberge@slu.se
Cornelia Roberge

Switzerland
Ministry
Department of the Environment, Transport, Energy and Communications (DETEC), Federal Office for the Environment (FOEN), Forest Division
3003 Bern, SWITZERLAND
Email: verena.liedschulte@bafu.admin.ch
Verena Liedschulte

NFC
Swiss Federal Research Institute WSL
Zürcherstr. 111, 8903 Birmensdorf,
SWITZERLAND
Email: peter.waldner@wsl.ch
Peter Waldner

Türkiye
Ministry, NFC
Monitoring of Forest Ecosystems Division | Department of Combating Forest Pests | General Directorate of Forestry
Beştepe Mahallesi Söğütözü Caddesi No: 8/1, 06560 Yenimahalle-Ankara, TÜRKIYE
Email: caglarbassullu@ogm.gov.tr,
sedasaranay@ogm.gov.tr
Caglar Bassullu, Seda Saranay Kayar

Ukraine
Ministry
State Forest Resources Agency of Ukraine
International Cooperation, Science and Public Relation Division
9a Shota Rustaveli, 01601 KYIV, UKRAINE
Email: lpolyakova@ukr.net
Liubov Poliakova

NFC
Ukrainian Research Institute of Forestry and Agroforestry Melioration (URIFFM)
Pushkinska 86, Kharkiv 61024, UKRAINE
Email: buksha@uriffm.org.ua;
buksha@ukr.net
Ihor Buksha

United Kingdom
Ministry, NFC
Centre for Forest Management – Forest Research
Alice Holt Lodge, Wrecclesham
Farnham Surrey GU10 4LH, UK
Email: caitlin.lewis@forestresearch.gov.uk
tom.nisbet@forestresearch.gov.uk
elena.vanguelova@forestresearch.gov.uk
Caitlin Lewis, Tom Nisbet, Elena Vanguelova

United States of America
Ministry, NFC
N.N.

Editors | Authors

Nathalie Cools
Research Institute Nature and Forests (INBO) | Geraardsbergen, BELGIUM
Email: nathalie.cools@inbo.be

Bruno De Vos
Research Institute Nature and Forests (INBO) | Geraardsbergen, BELGIUM
Email: bruno.devos@inbo.be

Marco Ferretti
Swiss Federal Research Institute WSL
Birmensdorf, SWITZERLAND
Email: marco.ferretti@wsl.ch

Stefan Fleck
Northwest German Research Institute NW-FVA | Göttingen, GERMANY
Email: stefan.fleck@nw-fva.de

Katrin Haggenmüller
Programme Co-ordinating Centre (PCC) of ICP Forests | Thünen Institute
Eberswalde, GERMANY | Email: katrin.haggenmueller@thuenen.de

Leena Hamberg
Natural Resources Institute Finland (Luke) | Helsinki, FINLAND
Email: leena.hamberg@luke.fi

Till Kirchner
Programme Co-ordinating Centre (PCC) of ICP Forests | Thünen Institute
Eberswalde, GERMANY
Email: till.kirchner@thuenen.de

František Máliš
National Forest Centre
Zvolen, SLOVAKIA
Email: malis@nlcsk.org

Aldo Marchetto
National Research Council (CNR), Institute of Ecosystem Study (ISE)
Verbania (VB), ITALY
Email: aldo.marchetto@cnr.it

Alexa Michel
Programme Co-ordinating Centre (PCC) of ICP Forests | Thünen Institute
Eberswalde, GERMANY
Email: alexa.michel@thuenen.de

Tiina M. Nieminen
Natural Resources Institute Finland (Luke) | Helsinki, FINLAND
Email: tiina.m.nieminen@luke.fi

Diana Pitar
National Institute for Research and Development in Forestry “Marin Drăcea” (INCDS)
Voluntari, Judetul Ilfov, ROMANIA
Email: diana.silaghi@icas.ro

Andrei Popa
National Institute for Research and Development in Forestry “Marin Drăcea” | Campulung Moldovenesc, ROMANIA
Email: popa.andrei.dorna@gmail.com

Nenad Potočić
Croatian Forest Research Institute
Jastrebarsko, CROATIA
Email: nenadp@sumins.hr

Anne-Katrin Prescher
Programme Co-ordinating Centre (PCC) of ICP Forests | Thünen Institute
Eberswalde, GERMANY
Email: anne.prescher@thuenen.de

Stephan Raspe
Bavarian State Institute of Forestry LWF
Freising, GERMANY
Email: stephan.raspe@lwf.bayern.de

Tanja Sanders
Thünen Institute of Forest Ecosystems
Eberswalde, GERMANY
Email: tanja.sanders@thuenen.de

Marcus Schaub
Swiss Federal Research Institute WSL
Birmensdorf, SWITZERLAND
Email: marcus.schaub@wsl.ch

Andreas Schmitz
State Agency for Nature, Environment and Consumer Protection of North Rhine-Westphalia (LANUV)
Recklinghausen, GERMANY
Email: andreas.schmitz@lanuv.nrw.de

Tim Schütt
Programme Co-ordinating Centre (PCC) of ICP Forests | Thünen Institute
Eberswalde, GERMANY
Email: tim.schuett@thuenen.de

Kai Schwärzel
Programme Co-ordinating Centre (PCC) of ICP Forests | Thünen Institute
Eberswalde, GERMANY
Email: kai.schwaerzel@thuenen.de

Volkmar Timmermann
Norwegian Institute of Bioeconomy Research (NIBIO) | Ås, NORWAY
Email: volkmar.timmermann@nibio.no

Monika Vejpustková
Forestry and Game Management Research Institute | Jíloviště, CZECHIA
Email: vejpustkova@vulhm.cz

Arne Verstraeten
Research Institute Nature and Forests (INBO) | Geraardsbergen, BELGIUM
Email: arne.verstraeten@inbo.be

Lars Vesterdal
University of Copenhagen, DENMARK
Email: lv@ign.ku.dk

Peter Waldner
Swiss Federal Research Institute WSL
Birmensdorf, SWITZERLAND
Email: peter.waldner@wsl.ch

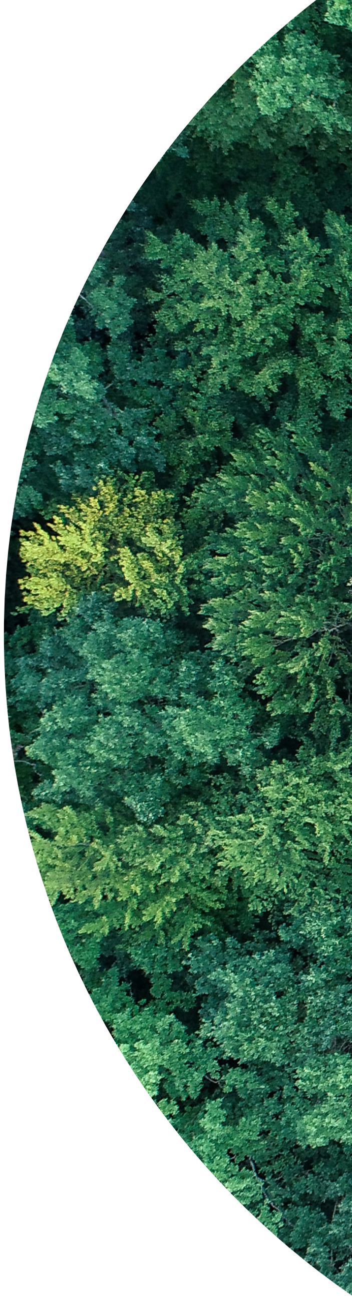
Lena Wohlgemuth
Programme Co-ordinating Centre (PCC) of ICP Forests | Thünen Institute
Eberswalde, GERMANY
Email: lena.wohlgemuth@thuenen.de

Lothar Zimmermann
Bavarian State Institute of Forestry LWF
Freising, GERMANY
lothar.zimmermann@lwf.bayern.de

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



Contact
Programme Co-ordinating Centre of ICP Forests (PCC)
Thünen Institute of Forest Ecosystems
Alfred-Möller-Str. 1, Haus 41/42
16225 Eberswalde, Germany
Email: pcc-icpforests@thuenen.de

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