2023

Forest Condition in Europe

The 2023 Assessment

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

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Alexa Michel, Till Kirchner, Anne-Katrin Prescher, and 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

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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 2023 Technical Report presents results from 31 of the 42 countries participating in ICP Forests. Part A presents research highlights from the January–December 2022 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 65 scientific publications for which ICP Forests data and/or the ICP Forests infrastructure were used;
- a list of all 29 official requests for ICP Forests data between January and December 2022.

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

- Atmospheric throughfall deposition in European forests in 2021
- Meteorological conditions in European forests in 2021
- Tree crown condition in 2022
- ICP Forests member states' view on the current ICP Forests Strategy and future activities.

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 persons responsible in this programme, please refer to the Annex at the end of this document. For more information on the ICP Forests programme, 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 atmospheric pollutants reach even remote areas, such as 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 similar, and by dry deposition of gases and particles on forest canopies.

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

Chapter 5 of this report focuses on atmospheric throughfall deposition of acidifying, acid-buffering, and eutrophying compounds in European forests in 2021.

As in the previous years, high throughfall deposition of nitrate and ammonium in 2021 was mainly found in central Europe, but single plots with high deposition values were also reported from other parts of Europe. The number of plots with high ammonium deposition was, however, larger than for nitrate.

Sulphate deposition has decreased very much since the start of the monitoring and currently the highest throughfall deposition is still found close to large point sources, mainly in eastern and southern Europe. In the southern part of Europe, sulphate deposition is also influenced by volcanic emission and by the episodic deposition of Saharan dust.

Calcium and magnesium deposition can buffer the acidifying effect of atmospheric deposition. High values of calcium and magnesium throughfall deposition were mostly reported from a large area in central, eastern and southern Europe, mainly related to the deposition of Saharan dust.

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

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

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

Europe-wide network of forest meteorological stations provides site-specific forest meteorological data, including air temperature, relative humidity, precipitation, wind speed and direction, global radiation, soil moisture and temperature. In combination with data from other ICP Forests surveys (e.g. tree growth, crown condition, phenology, ground vegetation, soil), these data can be used to analyze the effect of the atmospheric environment and its change over time on vitality and development of forest ecosystems.

Temperature and precipitation patterns play a key role in climate change impacts on forests. Chapter 6 on meteorological conditions in European forests in 2021 focuses on presenting and interpreting air temperature and precipitation data from 2021 in comparison with long-term mean values for different climatic regions in Europe.

The year 2021 was warmer than the long-term average in southern, southeast and a few other plots in Europe and cooler in west-central and western Europe. In contrast to the year as a whole, it was significantly warmer than normal during the vegetation period in most of Europe (often by up to +1.5 °C). In 2021, maximum temperatures above 36 °C during the vegetation period occurred at Level II plots in southern and SE-Europe, but also on one Level II plot in Hungary and a few in Germany. The majority of Level II plots in Central Europe showed maximum temperatures during the vegetation period between 24 °C and 36 °C. The number of hot days and late frost events and their deviation from the long-term average depended on the climatic region.

The distribution of total annual precipitation in 2021 shows a more or less normal pattern. The highest annual precipitation was found in the Alps and mountain stations in Greece and the lowest in Spain and in east-central and south-eastern Europe. The deviation of total precipitation in 2021 from the long-term average (1990–2020) is less than 45% in either direction on the majority of plots and seldom reaches higher values. In general, the year 2021 was slightly drier than normal all across Europe.

Tree crown defoliation and occurrence of biotic and abiotic damage are important indicators of forest condition. 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. Chapter 7 on tree crown condition presents results from crown condition assessments on the large-scale, representative, transnational monitoring network (Level I) of ICP Forests carried out in 2022, as well as long-term trends for the main tree species and species groups.

The transnational crown condition survey in 2022 was conducted on 105 696 trees on 5 453 plots in 27 countries. Out of those, 101 190 trees were assessed in the field for defoliation. The overall mean defoliation for all species was 23.8% in 2022; an increase in defoliation of 0.6%p for conifers and 1.4%p for broadleaves in comparison with 2021. Broadleaved trees showed a higher mean defoliation than coniferous trees (24.7% vs. 23.0%), as in previous years. Among the main tree species and tree species groups, deciduous temperate oaks and evergreen oaks displayed the highest mean defoliation (27.7% and 28.6%, respectively). Common beech had the lowest mean defoliation (22.4%). The strongest increase in defoliation compared to 2021 occurred in evegreen oaks (+2%p) and in Austrian pine (+1.9%p), while there was no increase in Scots pine and only a small increase in Norway spruce (0.2%p) and deciduous temperate oaks (+0.3%p). Defoliation increased in all species and species groups compared to 2021, except in Scots pine.

In 2022, damage cause assessments were carried out on 99 920 trees on 5 339 plots and in 26 countries. On 49 004 trees (49.0%) at least one symptom of damage was found, which is 2.6%p higher than in 2021 (46.4%).

Insects were the predominant cause of damage and responsible for 23.4% of all recorded damage symptoms. Within the group of insects, 38.7% of damage symptoms were caused by defoliators.

Abiotic agents were the second major causal agent group responsible for 20.3% of all damage symptoms. Within this agent group, more than half of the symptoms (55.6%) were attributed to drought, while snow, ice and hail caused 11.2%, wind 7.5%, heat/sun scald 3.5% and frost 3.4% of the symptoms.

Before preparing a new ICP Forests Strategy for the period 2024 to 2030, it was decided at the last meeting of the Programme Co-ordinating Group, on the one hand, to gather information on the views of the ICP Forests member states on the current strategy and its value, and on the other hand, to take into account the ideas of partners in the drafting of a new strategy through an online questionnaire.

This questionnaire consisted of 24 questions on the relevance and validity of the current strategy, on the priorities of the member countries in relation to forest environmental monitoring, and on the countries' views on the future of program-related monitoring activities. The results are summarized in Chapter 8.

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ONLINE SUPPLEMENTARY MATERIAL

Online supplementary material complementing Chapter 7 is available at
http://icp-forests.net/page/icp-forests-technical-report

FOREWORD

Dear Reader,

Our forests are under pressure. Together with continued high level of Nitrogen (N) deposition, climate and weather extremes are increasingly challenging the resistance and resilience of forests in the UN ECE region and beyond. For this reason, long-term, reliable monitoring of the condition of our forest ecosystems is "more relevant than ever" (this report, p. 7).

It is my great pleasure and honor to introduce the ICP Forests Technical Report "Forest Condition in Europe. The 2023 Assessment". This report provides the most recent account of selected results obtained by the largest long-term internationally co-ordinated and harmonized forest monitoring program in Europe – the ICP Forests. Compared to the previous versions, the 2023 Report includes a brand new part on meteorology, a survey on the view of Member states on the ICP Forests strategy, and the new strategy for the period 2024–2030 as approved by the Task Force of the program at its 39th meeting in 2023.

Out of the many activities carried out within the program, the 2023 Report emphasized that deposition of inorganic N deposition remained at high level (10-20 kg ha-1 yr-1) over large parts of central Europe (see Part B, Chapter 5) and that air temperatures were tendentially higher and precipitation considerably lower than long-term average, although with differentiated geographical patterns (Part B, Chapter 6). For example, deviations from long-term average maximum temperatures were pronounced not only at the plots in southern Europe, but also at the north European sites. At the same time defoliation continues to increase together with the frequency of observed damage (+2.6% than in 2021). It is worth noting that abiotic agents are now reported as the second most recognized cause of damage to trees, and that - among all the abiotic agents - drought accounts for 55.6% of the records. Actually, during the summer 2022, leaf browning due to heat and drought was obvious in central and southern Europe (see Widespread visible effects of 2022 drought on forest vegetation - ICP Forests (icp-forests.net). Unfortunately, recent observations suggest that such a condition has continued also in the summer 2023.

ICP Forests is part of the UN ECE Air Convention (the first multi-national and multi-lateral environmental agreement) and operates (i) at pan-European scale, (ii) in the long term, and (iii) with a concept that connect a large-scale survey for status and change detection (our Level I) to highly equipped sites for drivers-response relationships (our Level II). Thanks to this, a program that was initially conceived to monitor the effects of air pollution proves now useful to assess the response of forests to climate change.

The value of our data grows every year and already now in many countries the data series is longer than 30 years. For this enduring commitment, my gratitude goes to the Air Convention bodies, the Lead Country of the ICP Forests (Germany), all the participating Countries, the Program Co-ordinating Center, Groups, Panels, Committees and – last but not least – all the Experts who "make" the ICP Forests.

I wish you an informative and stimulating read.

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 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 performance 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 5628 observation plots (as at 2022) 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 628 plots (as at 2021, Table 1-1) in selected forest ecosystems with the aim to clarify cause-effect relationships between environmental drivers and forest ecosystem responses.

Quality assurance and quality control procedures are coordinated by committees within the programme, 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 38 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 2023 Technical Report of ICP Forests, its online supplementary material, and other information on the programme can be downloaded from the ICP Forests website[5].

Programme highlights in 2022

People

- We are extremely grateful to Alfred Fürst from the Austrian Research Centre for Forests BFW in Vienna for his many years of active involvement in ICP Forests. He had been Chair of the Forest Foliar Co-ordination Centre (FFCC) from 2000–2021 and the WG QA/QC in Laboratories from 2017–2022, and co-chair of the EP Foliage and Litterfall from 2001–2017. Anna Kowalska from the Polish Forest Reserach Institute and Tamara Jakovljević from the Croatian Forest Research Institute have been appointed new chair and co-chair of the WG QA/QC in Labs.
- We would also like to thank Daniel Žlindra from the Slovenian Forestry Institute for co-chairing the EP Deposition for 15 years. Andreas Schmitz from the German State Agency for Nature, Environment and Consumer Protection of North Rhine-Westphalia (LANUV) was appointed as a new co-chair.
- We also welcome Monika Vejpustková from the Czech Forestry and Game Management Research Institute (FGMRI) as an additional co-chair of the EP Growth; Leena Hamberg from the Natural Resources Institute Finland (LUKE) as new co-chair of the EP Biodiversity and Ground Vegetation; and Lothar Zimmermann from the Bavarian State Institute of Forestry (LWF) as new chair of the EP Meteo/Phenology/LAI.

Programme developments

- A new Ad hoc Working Group on Tree Physiology was established within the EP Crown Condition and Damage Causes and it is still looking for experts in forest ecophysiology willing to participate[6].

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

[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
[6] Please contact: Filippo.Bussotti@unifi.it and Martina.Pollastrini@unifi.it.

information flow within the programme and to the scientific community and the public. The following developments of the data unit were recently accomplished:

- Two new surveys (Soil Level I & Assessment of Epiphytic Lichen Diversity) were implemented in the database;
- Based on the unification of data structures over time which took place over the last few years, many data series could be harmonized, in cooperation with the corresponding Expert Panels and national partners;
- For several surveys, gap-filling, aggregation and reporting scripts were developed and implemented at the PCC.

Outreach and reporting

- The results from the Working Group on Quality Assurance and Quality Control on the 24th Needle/leaf Interlaboratory Comparison Test 2021/2022 with 47 laboratories from 25 countries, the 11th Deposition and Soil Solution Working Ringtest 2021/2022 with 39 labs from 23 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 65 in 2022[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 sulfur), 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.
- A new e-learning course on the UNECE Air Convention[3] has been published by the UN CC:e-Learn affiliation program. It is a self-paced online course that aims to raise awareness about air pollution and its effects, ways to prevent and reduce harmful emissions and the Convention and its protocols as an international framework for co-operation on cleaner air.
- A new report on "Review and revision of empirical critical loads of nitrogen for Europe" by the Coordination Centre for Effects (CCE) of the ICP Modelling and Mapping was published. Several scientists and experts from different ICPs were involved, including colleagues from ICP Forests. It features a chapter on "Effects of nitrogen deposition on forests and other wooded land" and provides updated numbers for empirical critical loads for different forests. Considering the new insights and literature of the last 10 years, several empirical critical loads were downsized, thus, indicating a higher sensitivity to N loads than supposed in the former report from 2011.

Programme meetings

- The EMEP Steering Body and Working Group on Effects under the UNECE Air Convention met on 21–24 March 2022 and 12–16 September 2022[4], to discuss the progress in activities and further development of effects-oriented activities, e.g. with regard to the 2022–2023 workplan for the implementation of the Convention, the update of the WGE/EMEP scientific strategy, the review of the Gothenburg protocol, and collaborations with other international organizations.
- At the Joint Expert Panel Meeting (5–7 April 2022) in Prague, Czechia, 76 registered participants from 22 European countries joined in person or online and discussed current issues and developments in three Expert Panels and Working Groups. We are very grateful to Vít Šrámek (NFC Czechia) and his colleagures from the Czech Forestry and Game Management Research Institute for the organization.
- The 38th ICP Forests Task Force Meeting was held online, 2–11 3 June 2022, with 77 participants from 28 countries.
- The 10th ICP Forests Scientific Conference FORECOMON was postponed to 2023.
- The Programme Co-ordinating Group (PCG), Quality Assurance Committee, and Scientific Committee met in Berlin, 23–24 November 2022, to discuss current issues and the ICP Forests' further progress.

Acknowledgements

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

For the last 38 years the success of ICP Forests depends 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://unccelearn.org/course/view.php?id=150&page=overview
[4] https://unece.org/environment-policy/air

Table 1-1: Overview of the number of Level II plots per survey and country for which 2021 data were submitted to the ICP Forests Database by 8 June 2023

	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	16						6				
Belgium	5	12	9	12			5	5		7		5		9
Bulgaria	4	4	4						3	4	2			
Croatia	2	7	6	7					4		2	4		3
Cyprus	1	4	2	4						2				2
Czechia		15	7				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			1			8				8
France		95	27	95			90			13				14
Germany	42	63	84	58	34	13	40	22	37	79	15	38		61
Greece	1	4	3	4					4	4	4	3		3
Hungary		7	9		7			7		8	6			
Italy	6	29	7							7	6			4
Latvia	1	3	3	3					3					3
Lithuania	3		3	9						1	9			3
Norway		3	3	3	1									3
Poland	12	133	12							12				12
Romania	4		5	4	12		12	3	4	4		3		5
Serbia		5	5	5	5		3	3	5	3	5	5		3
Slovakia	3	9	7							6	4			4
Slovenia	10	10	4											4
Spain	14	14	14	14			14	14	14	14	14	14		5
Sweden			49											
Switzerland	6	17	14		18			18		18				9
Turkey		50												
UK			5	4			3	1	4	4				5
Total	**114**	**500**	**314**	**254**	**81**	**17**	**178**	**73**	**90**	**217**	**67**	**81**	**0**	**176**

PART A
ICP Forests-related research highlights

2

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

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

REVIEW

Introduction

Marco Ferretti, Lars Vesterdal, Marcus Schaub

The quantification of forest ecosystem behavior in a changing climate is necessary for impact assessment and for forest restoration to maintain biodiversity and provision of forest ecosystem services. Continued efforts to reduce air pollution levels will be important for the health and sustainability of forest ecosystems around the world, especially under the concurrent pressure exerted by climate fluctuations and changes.

The data generated by the monitoring networks installed under ICP Forests clearly demonstrates its high relevance at scientific and political levels. This is largely due to the ecosystem approach adopted and the concept behind: without the evaluation of all biotic and abiotic stressors that may have an impact on our forests, it is not possible to identify the role of air pollution. For the same reasons, 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 reviewed by the Scientific Committee of ICP Forests. EPs were asked to provide an overview of main evidence and key findings in their subject areas over the past year and as prioritized within the Working Group on Effects (WGE) strategic planning under the UNECE Air Convention: nitrogen (N) deposition, ozone (O_3), heavy metals, and air pollution-climate change interactions.

EPs based their input on ca. five arbitrarily selected papers based on the ICP Forests network and others. Scientific publications were selected if (1) peer-reviewed; (2) from the reporting year or the year before, if not yet included; (3) covering emerging issues; and (4) relevant to the UNECE Air Convention. A further requirement, i.e., that studies should include data from more than one country, was not always considered, as important studies were also carried out at national level.

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

Recent evidence from selected studies

ATMOSPHERE

Atmospheric deposition

Arne Verstraeten, Peter Waldner, Andreas Schmitz, Aldo Marchetto

Recent work focused on modelling of total N deposition inputs to forests based on throughfall N deposition and long-term trends in N and organic carbon deposition at the global scale.

Braun et al. (2022) developed a statistical model for calculating total N deposition as a function of throughfall N deposition. The model is based on data from studies in selected European countries with measured throughfall N deposition and simultaneous estimates of total N deposition derived from combinations of measurements and detailed modelling. The model may provide an alternative to more complex canopy budget models and has the advantage that no information on bulk or wet deposition is required, making it more widely applicable. The model can be used within a range of 0-20 kg ha^{-1} yr^{-1} throughfall N deposition.

Templer et al. (2022) studied long-term changes in atmospheric N inputs and stream N fluxes in forest and grassland dominated watersheds across Europe, North America, and East Asia. They found that declining trends in bulk N deposition coincided with decreasing nitrate concentrations in stream water.

Spatial and temporal patterns of bulk dissolved organic carbon (DOC) deposition were studied by Liptzin et al. (2022) using data from 70 sites across the globe. For one third of the sites with long-term datasets (>10 years), a significant decline in DOC concentrations over time was observed, most likely as the result of decreases in anthropogenic emissions of volatile organic compounds (VOC) and organic particulates. Seasonal and latitudinal patterns of DOC in atmospheric deposition were most consistent with biogenic emissions.

Tropospheric ozone (O_3)

Diana Pitar, Elena Gottardini

Paoletti et al. (2022) emphasized the need to reconcile present critical levels and dose-response functions to estimate O_3-induced biomass losses, and recommended the use of O_3-induced foliar visible injury (O_3FVI) as a forest-health indicator for setting up epidemiology-based critical levels to protect forests from adverse O_3 effects.

A study in western Germany (Rhineland-Palatinate), studied the relationships between surface O_3 (expressed as concentration- and flux-based metrics), water stress on tree growth from 1998 to 2019, basal area increment (BAI), and fructification of European beech (*Fagus sylvatica* L.) and Norway spruce (*Picea abies* L. H. Karst.) (Eghdami et al. 2022). A random forest analysis showed that soil water content and daytime O_3 mean concentrations were the best predictors of BAI at all sites. The highest mean score of fructification was observed during dry years, while low or no fructification was observed in most humid years. Combined effects of drought and O_3 pollution influenced tree growth decline in European beech and Norway spruce the most.

Baesso Moura et al. (2022) compared O_3FVI recorded in southern European forest sites with O_3FVI reproduced in a Free-air O_3 eXposure (FO3X) experiment, finding that major parts of symptom expressions were similar in the field and the FO3X. O_3FVI decreased by the presence of various species and suggested the importance of continuous monitoring activities in the field for the further analyses. They also found that individual species in the field expressed FVI at much higher levels of exposure/flux than at the FO3X.

In northern Italy, Faralli et al. (2022) identified site and plant characteristics as well as functional leaf traits associated with the occurrence and severity of O_3FVI in *Viburnum lantana* (an O_3-sensitive species) and at the scale of an individual site. *Viburnum lantana* plants growing at one site of the ViburNeT monitoring network (Trentino, North Italy) experiencing high O_3 levels were surveyed in relation to (1) sun exposure, (2) shading effect from neighboring vegetation, (3) plant height, and (4) presence and severity of O_3FVI. They found that plants at high irradiation levels had significantly lower SLA ($p<0.05$), higher trichome density (Tr) ($p<0.01$) and greater Chlorophyll ($p<0.01$) when compared to shaded and/or west- and north-exposed plants, thus indicating a strong influence of site-specific characteristics on leaf trait plasticity. Also, O_3FVI at leaf level were associated with lower SLA ($p<0.001$) and higher Tr in the abaxial leaf surface ($p<0.05$). Both leaf traits showed significant differences also within the south and east exposed plant category, thus suggesting the increase in leaf thickness and Tr as a potential adaptive strategy under multiple stress conditions. Their results provide evidence of a strong relationship between O_3FVI, leaf traits and site-specific variables, offering new insights for interpreting data on the impact of O_3 on vegetation.

Going into more detail, Turc et al. (2022) demonstrated that early Hypersensitive Response-like (HR-like) markers can provide reasonably specific, sensitive and reliable quantitative structural estimates of O_3 stress for e.g. risk assessment studies, especially if they are associated with degenerative and thylakoid-related injury in chloroplasts from mesophyll.

FOREST VEGETATION

Forest growth

Tanja Sanders, Monika Vejpustková

ICP Forests growth data was used for an innovative study on the role of ectomycorrhizal fungi composition. While these results cannot provide a clear causality or directionality, the study provides clear evidence that slow and fast growth of broadleaves and coniferous trees is linked to the ectomycorrhizal fungi composition (Anthony et al. 2022).

Etzold et al. (2022) not only used climate parameters to explain species-specific growth but investigated the role of day length. Within the window provided by day length, air and soil moisture were the main factors to explain radial growth; while the number of days with growth largely determined annual growth, the overall length of growth period contributed less.

Both results show that more influencing factors and especially non-linear intra-annual and species-specific growth dynamics need to be implemented in tree and forest models to reduce uncertainties in predictions under climate change (de Wergifosse et al. 2022).

However, extreme drought events during the growth period remain the main cause of growth decline or the production of false growth rings due to a within-year halt of growth. To obtain high-resolution data for a better analysis of individual tree responses, point dendrometers were used to calculate tree water deficit, thereby providing evidence on the timing of stem shrinking (Krause and Sanders 2022).

Deficit of precipitation is also influencing the ground water level, which together with mean air temperature from June to August was found to influence the annual radial increment of Scots pine in Slovakia. Besides growth, these two factors also significantly correlated with crown defoliation (Pajtík et al. 2022). It was suggested that there will be increased Scots pine die-back on sandy soils in regions with low precipitation.

Forest health

Nenad Potočić, Volkmar Timmermann

The greatest threat to forest ecosystems in Europe probably comes from changing climate, but there is a great uncertainty related to the magnitude and character of climate change, particularly at the regional level. A number of papers addressing tree vitality on country level was published in the last couple of years, offering detailed regional insights into the health status of forest trees in relation to climate change effects, while others explore a more large-scale, European-wide approach. With ongoing climate change fostering frequent occurrence of extreme climate events, it is not surprising that drought has become a global driver of forest health, and that its effects on forest health are at the center of recent scientific interest.

Gazol and Camarero (2022) based their analysis on two independent data sources, including the ICP Forests Level I dataset, identifying hotspots of forest mortality and showing that their occurrence is partially explained by the simultaneous occurrence of extreme droughts and heat waves. These results are mirrored by George et al. (2022a) who found that European forests show consistent signs of drought-induced dieback, which can be partly explained by anomalies in soil moisture and the occurrence of droughts during the last 25 years.

Abiotic, environmental stressors (such as drought) not only cause damage to trees by disturbing physiological processes such as water transport and uptake of nutrients, but also make forest trees more susceptible to damage from biotic agents such as fungi or insects. In European coniferous forests, recent heat wave-associated droughts have regionally increased the mortality rates associated with bark beetle infestations. This trend is likely to continue under more frequent extreme events of drought and heat in the coming decades. Analyzing resistance of five host tree species to bark beetle attack and beetle-induced mortality based on ICP Forests Level I data, Jaime et al. (2022) suggested that the joint influence of drought events and bark beetle disturbance threatens the persistence of coniferous forests, highlighting the importance of studying disturbance interactions for the health of European forests.

Extreme weather events are not restricted to drought, but include also the changes in the intensity and frequency of precipitation. In their analysis of ash mortality in Europe, George et al. (2022b) found that the survival of ash was significantly lower in locations with excessive water regime and which experienced more extreme precipitation events during the last two decades.

Forest nutrition

Pasi Rautio, Liisa Ukonmaanaho

The highlighted studies from the last year focused on uptake of mercury (Hg) in the foliage or Hg fluxes with litterfall of different tree species on the one hand, and on the basic dynamics and modelling of litterfall fluxes of different tree species on the other hand.

Wohlgemuth et al. (2022) investigated controls on foliar stomatal Hg(0) uptake by combining Hg measurements of 3569 foliage samples across Europe with data on tree species traits and environmental conditions. The most relevant parameter impacting daily foliar stomatal Hg(0) uptake was tree functional group (deciduous versus coniferous trees). On average, they measured 3.2 times higher daily foliar stomatal Hg(0) uptake rates in deciduous leaves than in coniferous needles.

In Spain, Mendez-Lopez et al. (2022) assessed the pool of Hg in the aboveground biomass (leaves, wood, bark, branches and twigs), the Hg flux to soils through litterfall over two years (by sorting fallen leaves, twigs, reproductive structures and miscellaneous materials) and its accumulation in the soil profile in a deciduous forest dominated by *Betula alba*. They found that birch leaves are the major contributor to Hg deposition flux by litterfall, and that woody tissues represent the largest Hg reservoir in the aboveground birch biomass. In soil, the highest Hg concentrations were found in the organic horizons, but the mineral soil still seems to be the major pool of Hg, exempt from environmental disturbances.

In Estonia, Uri et al. (2022) aimed to estimate average annual litter flux quantities and composition in Scots pine, Norway spruce and birch (*Betula pendula* and *Betula pubescens*) stands, as well as to compile regional litterfall models for estimating the annual litter flux. Although the annual litter flux depended on site quality index and stand age, no significant relationship was found between stand basal area and litter flux. Average annual canopy litterfall was similar for the studied tree species and for all studied tree species. The relative proportion of needles or leaves in the total annual litter flux declined with stand age, due to the increased share of twigs and other fractions in the litter of older stands. The developed models of litter flux allow to estimate the annual litter production of the canopy for the studied tree species on the basis of site quality index and stand age in Estonia.

Impacts of drought and heat waves on forest trees

Stefan Fleck, Stephan Raspe, Lothar Zimmermann

The impact of droughts and heat waves in Europe on forest trees was analyzed and illustrated by several recent studies. While droughts are characterized by low water input from precipitation and affect tree survival by restricted water uptake from the soil, heat waves are characterized by high temperature and lead to higher evaporative demand of the atmosphere surrounding tree canopies. Gazol and Camarero (2022) differentiated between both impacts and showed that 46% of the mortality events in Europe corresponded with the co-occurrence of both factors in the survey year, i.e. with years with low precipitation as well as high temperatures. Also the growth of oak species is more linked to the combination of both factors expressed as climatic water balance (CWB = precipitation − evaporative demand) than to temperature alone (Bose et al. 2021). Oak growth was especially susceptible to low CWB occurring in spring. The co-occurrence of dry phases with high evaporative demand also provided an explanation for sudden vitality decline and dieback of Scots pine in the Swiss Rhone valley (Hunziker et al. 2022), especially since precipitation observed between 1981 and 2018 in this area did not decrease.

The effects of high temperatures and low precipitation were disentangled with high-resolution dendrometer measurements across 53 sites in Europe, showing that growth was not reduced in the 2018 heatwave, but trees experienced a depletion of water reserves leading to twice the temporary stem shrinkage than usual (Salomon et al. 2022). Especially conifers were less capable of rehydrating overnight than broadleaves. The co-occurrence of low precipitation and high temperature, characterized by the Standardized Precipitation-Evaporation Index SPEI, was also shown to play a key role in modulating the resistance of coniferous forests to bark beetle attacks during the 2010–2018 period (Jaime et al. 2022), thereby providing an explanation for the frequent observation of bark-beetle induced conifer mortality after dry and hot years (e.g. Cesljar et al. 2022). The influence of hot and dry years on conifer resistance to bark-beetle attack is, however, mediated by the proximity to the respective climatic optima of the host trees and bark beetles.

Forest understory community composition and diversity

Roberto Canullo, Leena Hamberg

Several studies took advantage of long-term data from the ICP Forests systematic network (Level I) and intensive monitoring network (Level II) for studies of biodiversity.

A multi-taxon study has been conducted in Finland (Antão et al. 2022) to quantify the responses of various organisms to climatic change over decades along bioclimatic zones, in terms of relative shifts within each species' niche. Vascular plant abundance datasets have been included from the systematic forest monitoring network (Level I), on sites surveyed in 1985, 1995, and 2006 with a standard protocol for the understory monitoring. The authors found substantial shifts in the relative positions of species within their climatic niche, while turnover among decades was limited. Mean annual temperature, total precipitation, and – particularly – duration of snow cover, explain an increasing proportion of variation in plant species occurrences over time and with increasing latitude. Birds, mammals, butterflies, moths, plants, and phytoplankton responded to climatic change at higher latitudes.

On the same systematic network of sample plots in Finland, understory vegetation was surveyed in 1985–1986 together with ground macrolichens. Tonteri et al. (2022) studied the response of the abundance of ground lichens to forest management practices, related stand structure and co-existing plant species. Results showed different underlying factors for lichen decline, including an increase in canopy cover and shading, as well as disturbance caused by regeneration cutting and soil preparation. The reduction in lichen cover was related to an increase in bryophyte abundance.

Molina-Venegas et al. (2022) investigated the phylogenetic and functional diversity patterns of forest understory angiosperms in Alpine, Continental, and Mediterranean regions of Italy, by using the data from Level I plots. The aim was to identify eco-evolutionary signals in extant regional species assemblages. By analyzing the biogeographical elements, the authors found that species restricted to climatically harsh regions (winter-Alpine and summer-Mediterranean elements) were phylogenetically and functionally clustered, whereas widespread species were characterized by overdispersion. The intermediate Continental region showed randomly sorted species. In the Alpine region, a clear signature of functional diversity differentiation between closely related species appeared, suggesting the role of recent speciation events; phylogenetic niche conservatism appears more important in the Mediterranean region. The aboveground traits played a major role in shaping the functional syndromes, across all the biogeographic elements.

Kermavnar et al. (2022) studied the plant communities on 50 plots (Level I and Level II) in Slovenia. Floristic composition was linked to climate, soil pH, and light conditions, while functional groups showed strong relations with forest stand characteristics, including canopy cover (due to management). Phenological traits of understory were negatively related to canopy cover and broadleaf proportion; functional traits (Grimes' Strategies, competitive, stress-tolerant and ruderal) were affected by shade index (positively for C-species proportion, negatively for S-species scores); an inverse relation was also found for stress-tolerant and ruderal species proportion to pH and annual temperature, respectively.

Bryophyte species richness and the hemerophobic bryophyte proportion in managed forests through Poland have been reported by Cacciatori et al. (2022). The study addressed bryophytes on all substrates (living trees, standing and lying dead wood, ground and rocks) at 132 Level II plots. Surveys have been performed at 5-year intervals (1998–2019) and sites were characterized by elevation, dominant tree species, and stand age. No temporal trends were revealed, but a proportional increase in bryophyte species richness with elevation was observed. Strong differences emerged for young stands, with spruce forest hosting a much higher number of species. Dominant tree species exhibited the strongest impact on species community composition.

Bryophytes were also studied in relation to nitrogen deposition by Weldon et al. (2020). They included 187 plots within the ICP Forests and ICP IM programmes at the European scale, covering the period 1994–2016. Coniferous forests showed lower functional diversity and Pielou evenness than broadleaf-dominated forests. Throughfall nitrogen deposition was significantly associated with increased bryophyte community nitrogen preference (especially in younger forests) and a decrease in species evenness. The authors concluded that nitrogen deposition is likely to adversely affect forest bryophyte communities, having negative impacts in terms of increased dominance of nitrophilic species at the expense of N-sensitive species and a decrease in species evenness.

FOREST SOIL

Bruno De Vos, Nathalie Cools, Tiina Nieminen

Atmospheric acid deposition has decreased considerably since the 1980s following clean-air policies. Numerous studies have shown soil acidification though recent studies indicate the recovery from this human-induced soil acidification. In Lower-Saxony, Germany, Ahrends et al. (2022a) could show a trend reversal or a stagnation of the acid-base status at a strong acidification level. The recovery was faster under deciduous trees compared to coniferous stands. In the UK (Vanguelova et al. 2022) and in Germany (Ahrends et al. 2022b), the authors found diverse patterns for individual nutrient balances due to the combined effects of changing deposition, climate and forest harvesting.

Heavy metal deposition has been picked up by several case studies on the ICP Forests Level II plots, e.g., in Greece (Michopoulos et al. 2022) and in Switzerland (Chen et al. 2022). The latter study found an accumulation of Hg in the thick forest floor of a mor humus type and in the spodic horizon. By comparing these findings with a research site in China they concluded that the vertical distribution pattern of Hg is influenced by humus form and soil type.

Related to soil organic carbon storage, Lukina et al. (2022) concluded based on the Russian soil survey data that the most dynamic factor affecting the carbon cycle is the forest biota, while Boruvka et al. (2022) concluded for Czechia that predictors of soil carbon stocks are best developed at the regional scale. In Finland, Mäkelä et al. (2022) concluded that ectomycorrhizal fungi are an important driver of the lower carbon use efficiency at greater latitudes. On the Finnish Level II plots, Lindroos et al. (2022) could show a significant increase of soil carbon after a monitoring interval of 21 years. Jochheim et al. (2022) attributed the differences in seasonal pattern of soil CO_2 efflux between coniferous and deciduous tree species to different phases of tree physiological activity.

Based on the Finnish soil monitoring data, Launiainen et al. (2022) improved the prediction of soil hydraulic properties, which are essential in estimating drought risks. In Switzerland, soil data helped to understand the changes in the water fluxes within the forest ecosystem during drought stress (Meusburger et al. 2022).

Conclusions

Marco Ferretti, Lars Vesterdal, Marcus Schaub

While air pollution to forests has considerably changed since the 1980s, it may still have significant effects on forest ecosystems, also in combination with increasing pressure from climate change. Reduced growth and increased susceptibility to drought damage, pests and pathogens were frequently reported. It is evident from this summary of main evidence and key findings in Expert Panel areas that ICP Forests data can play an important role for a wide range of scientific advancements supporting impact and risk assessment and mitigation potential.

(i) Air pollution, especially N deposition and tropospheric ozone, continues to affect forest ecosystems. Today, several forest ecosystem compartments (from trees to ground vegetation, mosses and lichens, including their diversity, composition of soil and soil solution) and processes (tree nutrition, tree growth, soil acidification, N and P cycling) are still affected by air pollution, namely by N deposition, ground-level O_3, and heavy metals. While the acidity of precipitation is decreasing due to successful reduction of anthropogenic S emissions, N deposition is becoming more ammonium-dominated, and effects of local ammonia-emitting sources remain a challenge to modelling and mapping. Advances in N throughfall modeling, better understanding of O_3 impact on vegetation and of Hg uptake, flux and accumulation were reported. There is a significant need for continuous monitoring to assess the influence of the mitigative action on the reported effects.

(ii) Air pollution changes and its effects on forests are diversified. N deposition levels remain high in several European regions and have been found to affect tree growth, lead to imbalances in tree nutrition and to soil acidification, and affect the composition of understory communities of plants, mosses, and lichens. O_3 has been reported to affect tree growth, fruiting, and foliar condition, although its effect is modulated by a number of site and plant traits. The multi-level, multi-media monitoring concept of ICP Forests proves to be essential to assess and model the condition of forest ecosystems, and to favor comparisons between models and measurements.

(iii) New insights to explain ecosystem responses. Novel methods and approaches provide new opportunities to unravel the mechanisms, processes and organism interactions by which ecosystems respond to air pollution and climate change. Examples include the studies of ectomycorrhizal community composition and bryophytes at ICP Forests Level II plots, and the interaction between climatic stressors and bark beetles on Level I plots. The role of the soil microbiome and its diversity for vitality, growth and nutrition of forest trees under increasing stress from air pollution and climate change is a crucial topic for integration in long-term forest monitoring and research.

(iv) Climate change – a key driver and modifier of air pollution effects. Recent drought episodes coupled with high air temperatures in different parts of Europe have been shown to affect tree vitality, growth, nutrition and phenology at different scales. In addition, windstorms hit several regions across Europe, causing devastating damage. Both disturbance factors (drought and windstorms) lead to subsequent bark beetle infestations. It is likely that extreme events related to climate change will increase in frequency, and this will cause additional pressure on European forests. When considering the enduring pressure caused by air pollution in different forms and the projected increasing frequency of climate change-related events, there is an urgent need to better understand their interactions. This remains an area of clear concern for the Air Convention, and where progress in scientific understanding and assessment is pertinent.

The role of a pan-European, science-based monitoring in ensuring up-to-date information on tree vitality status and trends remains fundamental. The continuous steady increase of scientific outputs originating from the monitoring networks under ICP Forests is a clear demonstration of its high relevance for a better understanding of the response of forests to air pollution and environmental stressors.

REVIEW

References

Ahrends B, Fortmann H, Meesenburg H (2022a) **The influence of tree species on the recovery of forest soils from acidification in Lower Saxony, Germany.** Soil Systems 6:40. https://doi.org/10.3390/soilsystems6020040

Ahrends B, von Wilpert K, Weis W, et al (2022b) **Merits and limitations of element balances as a forest planning tool for harvest intensities and sustainable nutrient management—A case study from Germany.** Soil Systems 6:41. https://doi.org/10.3390/soilsystems6020041

Antão LH, Weigel B, Strona G, et al (2022) **Climate change reshuffles northern species within their niches.** Nat Clim Chang 12:587–592. https://doi.org/10.1038/s41558-022-01381-x

Anthony MA, Crowther TW, van der Linde S, et al (2022) **Forest tree growth is linked to mycorrhizal fungal composition and function across Europe.** ISME J 16:1327–1336. https://doi.org/10.1038/s41396-021-01159-7

Baesso Moura B, Carrari E, Dalstein-Richier L, et al (2022) **Bridging experimental and monitoring research for visible foliar injury as bio-indicator of ozone impacts on forests.** Ecosyst Health Sustain 8:2144466. https://doi.org/10.1080/20964129.2022.2144466

Borůvka L, Vašát R, Šrámek V, et al (2022) **Predictors for digital mapping of forest soil organic carbon stocks in different types of landscape.** Soil Water Res 17:69–79. https://doi.org/10.17221/4/2022-SWR

Bose AK, Scherrer D, Camarero JJ, et al (2021) **Climate sensitivity and drought seasonality determine post-drought growth recovery of *Quercus petraea* and *Quercus robur* in Europe.** Sci Total Environ 784:147222. https://doi.org/10.1016/j.scitotenv.2021.147222

Braun S, Ahrends B, Alonso R, et al (2022) **Nitrogen deposition in forests: Statistical modeling of total deposition from throughfall loads.** Front For Glob Change 5:1062223. https://doi.org/10.3389/ffgc.2022.1062223

Cacciatori C, Czerepko J, Lech P (2022**) Long-term changes in bryophyte diversity of central European managed forests depending on site environmental features.** Biodivers Conserv 31:2657–2681. https://doi.org/10.1007/s10531-022-02449-y

Češljar G, Jovanović F, Brašanac-Bosanac L, et al (2022**) Impact of an extremely dry period on tree defoliation and tree mortality in Serbia.** Plants 11:1286. https://doi.org/10.3390/plants11101286

Chen C, Huang JH, Meusburger K, et al (2022) **The interplay between atmospheric deposition and soil dynamics of mercury in Swiss and Chinese boreal forests: A comparison study.** Environ Pollut (307)119483. https://doi.org/10.1016/j.envpol.2022.119483

de Wergifosse L, André F, Goosse H, et al (2022). **Simulating tree growth response to climate change in structurally diverse oak and beech forests.** Sci Total Environ 806, 150422. https://doi.org/10.1016/j.scitotenv.2021.150422

Eghdami H, Werner W, De Marco A, Sicard P (2022) **Influence of ozone and drought on tree growth under field conditions in a 22 year time series.** Forests 13:1215. https://doi.org/10.3390/f13081215

Etzold S, Sterck F, Bose AK, et al (2022) **Number of growth days and not length of the growth period determines radial stem growth of temperate trees.** Ecology Letters 25:427–439. https://doi.org/10.1111/ele.13933

Gazol A, Camarero JJ (2022) **Compound climate events increase tree drought mortality across European forests.** Sci Total Environ 816:151604. https://doi.org/10.1016/j.scitotenv.2021.151604

George J-P, Bürkner P-C, Sanders TGM, et al (2022a). **Long-term forest monitoring reveals constant mortality rise in European forests.** Plant Biology 24 (7):1108-1119. https://doi.org/10.1111/plb.13469

George J-P, Sanders TGM, Timmermann V, et al (2022b) **European-wide forest monitoring substantiate the neccessity for a joint conservation strategy to rescue European ash species (*Fraxinus* spp.).** Sci Rep 12:4764. https://doi.org/10.1038/s41598-022-08825-6

Faralli, M., Cristofolini, F., Cristofori, A., et al (2022) **Leaf trait plasticity and site-specific environmental variability modulate the severity of visible foliar ozone symptoms in *Viburnum lantana*.** Plos one 17(7), e0270520. https://doi.org/10.1371/journal.pone.0270520

Hunziker S, Begert M, Scherrer SC, et al (2022) **Below average midsummer to early autumn precipitation evolved into the main driver of sudden Scots pine vitality decline in the Swiss Rhône valley.** Front For Glob Change 5:874100. https://doi.org/10.3389/ffgc.2022.874100

Jaime L, Batllori E, Ferretti M, Lloret F (2022) **Climatic and stand drivers of forest resistance to recent bark beetle disturbance in European coniferous forests.** Glob Change Biol 28:2830–2841. https://doi.org/10.1111/gcb.16106

Jochheim H, Wirth S, Gartiser V, et al (2022) **Dynamics of soil CO_2 efflux and vertical CO_2 production in a European beech and a Scots pine forest** Front For Glob Change 5:826298. https://doi.org/10.3389/ffgc.2022.826298

Kermavnar J, Kutnar L, Marinšek A (2022) **Variation in floristic and trait composition along environmental gradients in the herb layer of temperate forests in the transition zone between Central and SE Europe.** Plant Ecol 223:229–242. https://doi.org/10.1007/s11258-021-01203-8

Krause S, Sanders TG (2022) **Mapping tree water deficit with UAV thermal imaging and meteorological data.** https://doi.org/10.21203/rs.3.rs-1996287/v1

Launiainen S, Kieloaho A-J, Lindroos A-J, et al (2022) **Water retention characteristics of mineral forest soils in Finland: Impacts for modeling soil moisture.** Forests 13, 1797. https://doi.org/10.3390/f13111797

Lindroos A-J, Mäkipää R, Merilä P (2022) **Soil carbon stock changes over 21 years in intensively monitored boreal forest stands in Finland.** Ecol Indic 144,109551. https://doi.org/10.1016/j.ecolind.2022.109551

Liptzin D, Boy J, Campbell JL, et al (2022) **Spatial and temporal patterns in atmospheric deposition of dissolved organic carbon.** Global Biogeochemi Cy 36, e2022GB007393. https://doi.org/10.1029/2022GB007393

Lukina N, Kuzetsnova A, Geraskina A, et al (2022) **Unaccounted factors determining carbon stocks in forest soils.** Russian Meteorology and Hydrology 47(10):791–803. https://doi.org/10.1016/j.scitotenv.2022.158937

Mäkelä A, Tian X, Repo A, et al (2022) **Do mycorrhizal symbionts drive latitudinal trends in photosynthetic carbon use efficiency and carbon sequestration in boreal forests?** Forest Ecol Manag 520, 120355. https://doi.org/10.1016/j.foreco.2022.120355

Méndez-López M, Parente-Sendín A, Calvo-Portela N (2023). **Mercury in a birch forest in SW Europe: Deposition flux by litterfall and pools in aboveground tree biomass and soils.** Sci Total Environ 856:158937. https://doi.org/10.1016/j.scitotenv.2022.158937

Meusburger K, Trotsuik V, Schmidt-Walter P, et al. (2022) **Soil–plant interactions modulated water availability of Swiss forests during the 2015 and 2018 droughts.** Glob Change Biol 28(20):5928–5944. https://doi.org/10.1111/gcb.16332

Michopoulos P, Kostakis M, Solomou A, et al (2022) **Total and bioavailable heavy metals in the soils of two adjacent forests.** Global NEST Journal 24(1):65–73. https://doi.org/10.30955/gnj.004204

Molina-Venegas R, Ottaviani G, Campetella G, et al (2022) **Biogeographic deconstruction of phylogenetic and functional diversity provides insights into the formation of regional assemblages.** Ecography 2022(5), e06140. https://doi.org/10.1111/ecog.06140

Pajtík J, Sitková Z, Marčiš P, et al (2022) **Radial increment and defoliation of *Pinus sylvestris* (L.) on sandy soils relate to summer temperatures and ground water level.** Central European Forestry Journal 68(2):78–90. https://doi.org/10.2478/forj-2022-0002

Paoletti E, Sicard P, Hoshika Y,et al (2022) **Towards long-term sustainability of stomatal ozone flux monitoring at forest sites.** Sustainable Horizons 2, 100018. https://doi.org/10.1016/j.horiz.2022.100018

Salomón RL, Peters RL, Zweifel R, et al (2022) **The 2018 European heatwave led to stem dehydration but not to consistent growth reductions in forests.** Nat Commun 13:28. https://doi.org/10.1038/s41467-021-27579-9

Templer PH, Harrison JL, Pilotto F, et al (2022) **Atmospheric deposition and precipitation are important predictors of inorganic nitrogen export to streams from forest and grassland watersheds: a large-scale data synthesis.** Biogeochemistry 160:219–241. https://doi.org/10.1007/s10533-022-00951-7

Tonteri T, Hallikainen V, Merilä P, et al (2022) **Response of ground macrolichens to site factors, co-existing plants and forestry in boreal forests.** Appl Veg Sci 25(4):e12690. https://doi.org/10.1111/avsc.12690

Turc B, Jolivet Y, Cabané M, et al (2023) **Ante-and post-mortem cellular injury dynamics in hybrid poplar foliage as a function of phytotoxic O_3 dose.** Plos one:18(3), e0282006. https://doi.org/10.1371/journal.pone.0282006

Uri V, Kukumägi M, Aosaar J, et al (2022) **Litterfall dynamics in Scots pine (*Pinus sylvestris*), Norway spruce (*Picea abies*) and birch (*Betula*) stands in Estonia.** Forest Ecol Manag 520: 120417. https://doi.org/10.1016/j.foreco.2022.120417

Vanguelova E, Benham S, Nisbet T (2022) **Long term trends of base cation budgets of Forests in the UK to inform sustainable harvesting practices.** Appl Sci 12,2411. https://doi.org/10.3390/app12052411

Weldon J, Merder J, Ferretti M, Grandin U (2022) **Nitrogen deposition causes eutrophication in bryophyte communities in central and northern European forests.** Annals of Forest Science 79:24. https://doi.org/10.1186/s13595-022-01148-6

Wohlgemuth L, Rautio P, Ahrends B, et al (2022) **Physiological and climate controls on foliar mercury uptake by European tree species.** Biogeosciences 19:1335-1353. https://doi.org/10.5194/bg-19-1335-2022

3

OVERVIEW OF ICP FORESTS-RELATED PUBLICATIONS (JANUARY – DECEMBER 2022)

Between January and December 2022, 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 65 English online and in print publications from 2022 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].

Adame P, Alberdi I, Cañellas I, et al (2022) **Drivers and spread of non-native pests in forests: The case of *Gonipterus platensis* in Spanish Eucalyptus plantations.** Forest Ecol Manag 510:120104. https://doi.org/10.1016/j.foreco.2022.120104

Ahrends B, Fortmann H, Meesenburg H (2022a) **The influence of tree species on the recovery of forest soils from acidification in Lower Saxony, Germany.** Soil Systems 6:40. https://doi.org/10.3390/soilsystems6020040

Ahrends B, von Wilpert K, Weis W, et al (2022b) **Merits and limitations of element balances as a forest planning tool for harvest intensities and sustainable nutrient management—a case study from Germany.** Soil Systems 6:41. https://doi.org/10.3390/soilsystems6020041

Alekseev AS, Chernikhovskii DM (2022) **Assessment of the state of forests based on joint statistical processing of Sentinel-2B remote sensing data and the data from network of ground-based ICP-Forests sample plots.** OJE 12:513–528. https://doi.org/10.4236/oje.2022.128028

Antão LH, Weigel B, Strona G, et al (2022) **Climate change reshuffles northern species within their niches.** Nat Clim Chang 12:587–592. https://doi.org/10.1038/s41558-022-01381-x

Anthony MA, Crowther TW, van der Linde S, et al (2022) **Forest tree growth is linked to mycorrhizal fungal composition and function across Europe.** ISME J 16:1327–1336. https://doi.org/10.1038/s41396-021-01159-7

Borůvka L, Vašát R, Šrámek V, et al (2022) **Predictors for digital mapping of forest soil organic carbon stocks in different types of landscape.** Soil Water Res 17:69–79. https://doi.org/10.17221/4/2022-SWR

Braun S, Ahrends B, Alonso R, et al (2022) **Nitrogen deposition in forests: Statistical modeling of total deposition from throughfall loads.** Front For Glob Change 5:1062223. https://doi.org/10.3389/ffgc.2022.1062223

Cacciatori C, Czerepko J, Lech P (2022) **Long-term changes in bryophyte diversity of central European managed forests depending on site environmental features.** Biodivers Conserv 31:2657–2681. https://doi.org/10.1007/s10531-022-02449-y

Caldararu S, Thum T, Yu L, et al (2022) **Long-term ecosystem nitrogen limitation from foliar δ 15 N data and a land surface model.** Glob Change Biol 28:493–508. https://doi.org/10.1111/gcb.15933

Camarero JJ, Gazol A (2022) **Climate change and forest health: Detecting dieback hotspots.** In: Forest Microbiology, Vol. 2: Forest Tree Health. Elsevier, pp 99–106. https://doi.org/10.1016/B978-0-323-85042-1.00024-0

Češljar G, Jovanović F, Brašanac-Bosanac L, et al (2022) **Impact of an extremely dry period on tree defoliation and tree mortality in Serbia.** Plants 11:1286. https://doi.org/10.3390/plants11101286

Čihák T, Vejpustková M (2022) **Biomass allocation and carbon stock in Douglas fir and Norway spruce at the tree and stand level.** Central European Forestry Journal 68:163–173. https://doi.org/10.2478/forj-2022-0005

De Marco A, Sicard P, Feng Z, et al (2022) **Strategic roadmap to assess forest vulnerability under air pollution and climate change.** Global Change Biology 28:5062–5085. https://doi.org/10.1111/gcb.16278

Eghdami H, Werner W, Büker P, Sicard P (2022a) **Assessment of ozone risk to Central European forests: Time series indicates perennial exceedance of ozone critical levels.** Environ Research 203:111798. https://doi.org/10.1016/j.envres.2021.111798

Eghdami H, Werner W, De Marco A, Sicard P (2022b) **Influence of ozone and drought on tree growth under field conditions in a 22 year time series.** Forests 13:1215. https://doi.org/10.3390/f13081215

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

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

Eliades M, Bruggeman A, Djuma H, et al (2022) **Testing three rainfall interception models and different parameterization methods with data from an open Mediterranean pine forest.** Agricultural and Forest Meteorology 313:108755. https://doi.org/10.1016/j.agrformet.2021.108755

Enescu RE, Ciuvăț AL, Dincă L, et al (2022) **Nutrition cycles in sessile oak (*Quercus petraea* Liebl.), Norway spruce (*Picea abies* L.Karst) and European beech (*Fagus sylvatica* L.) stands from Central Romania.** Open J Environ Biol 7:026–032. https://doi.org/10.17352/ojeb.000031

Etzold S, Sterck F, Bose AK, et al (2022) **Number of growth days and not length of the growth period determines radial stem growth of temperate trees.** Ecology Letters 25:427–439. https://doi.org/10.1111/ele.13933

Frolov P, Shanin V, Zubkova E, et al (2022) **Predicting biomass of bilberry (*Vaccinium myrtillus*) using rank distribution and root-to-shoot ratio models.** Plant Ecol 223:131–140. https://doi.org/10.1007/s11258-021-01199-1

Gazol A, Camarero JJ (2022) **Compound climate events increase tree drought mortality across European forests.** Science of The Total Environment 816:151604. https://doi.org/10.1016/j.scitotenv.2021.151604

George J-P, Sanders TGM, Timmermann V, et al (2022) **European-wide forest monitoring substantiate the neccessity for a joint conservation strategy to rescue European ash species (*Fraxinus* spp.).** Sci Rep 12:4764. https://doi.org/10.1038/s41598-022-08825-6

Gessler A, Ferretti M, Schaub M (2022) **Editorial: Forest monitoring to assess forest functioning under air pollution and climate change.** Frontiers in Forests and Global Change. https://doi.org/10.3389/ffgc.2022.952232

Ghafarian F, Wieland R, Lüttschwager D, Nendel C (2022) **Application of extreme gradient boosting and Shapley Additive explanations to predict temperature regimes inside forests from standard open-field meteorological data.** Environmental Modelling & Software 156:105466. https://doi.org/10.1016/j.envsoft.2022.105466

Ho B, Kocer BB, Kovac M (2022) **Vision based crown loss estimation for individual trees with remote aerial robots.** ISPRS Journal of Photogrammetry and Remote Sensing 188:75–88. https://doi.org/10.1016/j.isprsjprs.2022.04.002

Hunziker S, Begert M, Scherrer SC, et al (2022) **Below average midsummer to early autumn precipitation evolved into the main driver of sudden Scots pine vitality decline in the Swiss Rhône Valley.** Front For Glob Change 5:874100. https://doi.org/10.3389/ffgc.2022.874100

Iacoban C, Curcă M, Cuciurean CI, et al (2022) **Comparison between the parameters of throughfall and bulk deposition measured in two laboratories using the same methods.** Food and Environment Safety 21(3):218-229. https://doi.org/10.4316/fens.2022.021

Jaime L, Batllori E, Ferretti M, Lloret F (2022) **Climatic and stand drivers of forest resistance to recent bark beetle disturbance in European coniferous forests.** Global Change Biology 28:2830–2841. https://doi.org/10.1111/gcb.16106

Jochheim H, Lüttschwager D, Riek W (2022a) **Stem distance as an explanatory variable for the spatial distribution and chemical conditions of stand precipitation and soil solution under beech (*Fagus sylvatica* L.) trees.** Journal of Hydrology 608:127629. https://doi.org/10.1016/j.jhydrol.2022.127629

Jochheim H, Wirth S, Gartiser V, et al (2022b) **Dynamics of soil CO_2 efflux and vertical CO_2 production in a European beech and a Scots pine forest.** Front For Glob Change 5:826298. https://doi.org/10.3389/ffgc.2022.826298

Kaoukis K, Bourletsikas A, Tsagari C, et al (2022) **Trend analysis of long-lasting air temperature and precipitation time series in a mountainous fir forest in central Greece. Implications for nitrogen uptake by plants.** Global NEST Journal. https://doi.org/10.30955/gnj.004291

Karhu K, Alaei S, Li J, et al (2022) **Microbial carbon use efficiency and priming of soil organic matter mineralization by glucose additions in boreal forest soils with different C:N ratios.** Soil Biology and Biochemistry 167:108615. https://doi.org/10.1016/j.soilbio.2022.108615

Kermavnar J, Kutnar L, Marinšek A (2022) **Variation in floristic and trait composition along environmental gradients in the herb layer of temperate forests in the transition zone between Central and SE Europe.** Plant Ecol 223:229–242. https://doi.org/10.1007/s11258-021-01203-8

Launiainen S, Kieloaho A-J, Lindroos A-J, et al (2022) **Water retention characteristics of mineral forest soils in Finland: Impacts for modeling soil moisture.** Forests 13:1797. https://doi.org/10.3390/f13111797

Lindroos A-J, Mäkipää R, Merilä P (2022) **Soil carbon stock changes over 21 years in intensively monitored boreal forest stands in Finland.** Ecological Indicators 144:109551. https://doi.org/10.1016/j.ecolind.2022.109551

Liptzin D, Boy J, Campbell JL, et al (2022) **Spatial and temporal patterns in atmospheric deposition of dissolved organic carbon.** Global Biogeochemical Cycles 36. https://doi.org/10.1029/2022GB007393

Lovreškov L, Radojčić Redovniković I, Limić I, et al (2022) **Are foliar nutrition status and indicators of oxidative stress associated with tree defoliation of four Mediterranean forest species?** Plants 11:3484. https://doi.org/10.3390/plants11243484

Lukina NV, Kuznetsova AI, Geraskina AP, et al (2022) **Unaccounted factors determining carbon stocks in forest soils.** Russ Meteorol Hydrol 47:791–803. https://doi.org/10.3103/S1068373922100077

Mäkelä A, Tian X, Repo A, et al (2022) **Do mycorrhizal symbionts drive latitudinal trends in photosynthetic carbon use efficiency and carbon sequestration in boreal forests?** Forest Ecology and Management 520:120355. https://doi.org/10.1016/j.foreco.2022.120355

Mauri A, Girardello M, Strona G, et al (2022) **EU-Trees4F, a dataset on the future distribution of European tree species.** Sci Data 9:37. https://doi.org/10.1038/s41597-022-01128-5

Meusburger K, Trotsiuk V, Schmidt-Walter P, et al (2022) **Soil–plant interactions modulated water availability of Swiss forests during the 2015 and 2018 droughts.** Global Change Biology 28:5928–5944. https://doi.org/10.1111/gcb.16332

Michopoulos P, Bourletsikas A, Karetsos G, et al (2022a) **Distribution and cycling of nutrients in a mountain fir ecosystem in central Greece.** Forestry Ideas 28(1):30-44

Michopoulos P, Kostakis M, Bourletsikas A, et al (2022b) **Concentrations of three rare elements in the hydrological cycle and soil of a mountainous fir forest.** AFR 65:155–164. https://doi.org/10.15287/afr.2022.2300

Michopoulos P, Kostakis M, Solomou A, et al (2022c) **Total and bioavailable heavy metals in the soils of two adjacent forests.** Global NEST Journal. https://doi.org/10.30955/gnj.004204

Molina-Venegas R, Ottaviani G, Campetella G, et al (2022) **Biogeographic deconstruction of phylogenetic and functional diversity provides insights into the formation of regional assemblages.** Ecography 2022:. https://doi.org/10.1111/ecog.06140

Moura B, Carrari E, Dalstein-Richier L, et al (2022) **Bridging experimental and monitoring research for visible foliar injury as bio-indicator of ozone impacts on forests.** Ecosystem Health and Sustainability 8(1):2144466. https://doi.org/10.1080/20964129.2022.2144466

Ognjenović M, Seletković I, Marušić M, et al (2022a) **The effect of environmental factors on the nutrition of European beech (*Fagus sylvatica* L.) varies with defoliation.** Plants 12:168. https://doi.org/10.3390/plants12010168

Ognjenović M, Seletković I, Potočić N, et al (2022b) **Defoliation change of European beech (*Fagus sylvatica* L.) depends on previous year drought.** Plants 11:730. https://doi.org/10.3390/plants11060730

Pajtík J, Sitková Z, Marčiš P, et al (2022) **Radial increment and defoliation of *Pinus sylvestris* (L.) on sandy soils relate to summer temperatures and ground water level.** Central European Forestry Journal 68:78–90. https://doi.org/10.2478/forj-2022-0002

Paoletti E, Sicard P, Hoshika Y, et al (2022) **Towards long-term sustainability of stomatal ozone flux monitoring at forest sites.** Sustainable Horizons 2:100018. https://doi.org/10.1016/j.horiz.2022.100018

Rimal S, Djahangard M, Yousefpour R (2022**) Forest management under climate change: A decision analysis of thinning interventions for water services and biomass in a Norway spruce stand in south Germany.** Land 11:446. https://doi.org/10.3390/land11030446

Rukh S, Schad T, Strer M, et al (2022) **Interpolated daily temperature and precipitation data for Level II ICP Forests plots in Germany.** Annals of Forest Science 79:47. https://doi.org/10.1186/s13595-022-01167-3

Salomón RL, Peters RL, Zweifel R, et al (2022) **The 2018 European heatwave led to stem dehydration but not to consistent growth reductions in forests.** Nat Commun 13:28. https://doi.org/10.1038/s41467-021-27579-9

Schellenberger Costa D, Otto J, Chmara I, Bernhardt-Römermann M (2022) **Estimating historic N- and S-deposition with publicly available data – An example from Central Germany.** Environmental Pollution 292:118378. https://doi.org/10.1016/j.envpol.2021.118378

Vallicrosa H, Sardans J, Maspons J, et al (2022) **Global distribution and drivers of forest biome foliar nitrogen to phosphorus ratios (N:P).** Global Ecol Biogeogr 31:861–871. https://doi.org/10.1111/geb.13457

Vanguelova E, Benham S, Nisbet T (2022) **Long term trends of base cation budgets of forests in the UK to inform sustainable harvesting practices.** Applied Sciences 12:2411. https://doi.org/10.3390/app12052411

Weldon J, Merder J, Ferretti M, Grandin U (2022) **Nitrogen deposition causes eutrophication in bryophyte communities in central and northern European forests.** Annals of Forest Science 79:24. https://doi.org/10.1186/s13595-022-01148-6

Wohlgemuth L, Rautio P, Ahrends B, et al (2022) **Physiological and climate controls on foliar mercury uptake by European tree species.** Biogeosciences 19:1335–1353. https://doi.org/10.5194/bg-19-1335-2022

Zhu J, Thimonier A, Etzold S, et al (2022) **Variation in leaf morphological traits of European beech and Norway spruce over two decades in Switzerland.** Front For Glob Change 4:778351. https://doi.org/10.3389/ffgc.2021.778351

4

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 29 requests for ICP Forests data between January and December 2022. 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]
246	European Environment Agency (EEA)	Annemarie Bastrup-Birk	Forest Information System for Europe (FISE)	External
247	University of Bristol	Tommaso Jucker	Global drivers of tree crown allometry	External
248	Thünen Institute of Forest Ecosystems	Line Grottian, Tanja Sanders	Development and validation of the modelling of storm damage in forests (WinMol)	External
250	Technical University of Munich	Fanxiang Meng, Annette Menzel	Drivers of seed production of tree species in Germany	External
251	University of Antwerp	Vaidehi Narsingh	Artificial Intelligence for Carbon fertilisation effect - Generating global maps for nutrients foliar concentration	External
253	University of Waikato	Christopher Lusk, Xiaobin Hua	Mycorrhizas, alternative stable states, and landscape partitioning in south-temperate forests	External
254	University of Bonn	Timo Stomberg	Evaluating plant health and ecosystem conditions using multispectral satellite imagery and machine learning	External
258	Polish Academy of Science	Carlos Bautista	Linking satellite indicators and ground data on forest productivity to predict brown bear damages in Europe	External
259	INRAE	Georges Kunstler	Crown allometry and Tree fecundity analysis (DECLIC and FORBIC ANR Projects)	External
260	Pyrenean Institute of Ecology	J. Julio Camarero	Interactive effects of mistletoe and drought on tree growth, defoliation and forest dieback	External
261	Yangzhou University	Zhang Keliang	Resisting climatic stress based on the evolutionary proximate trees	External
262	Norwegian Meteorological Institute	Hilde Fagerli	CAMS2_40 - Regional Air Quality products, Task 4041 Deposition	External
263	Institute for Environmental Studies	Marthe Wens	European Drought Observatory for Resilience and Adaptation (EDORA)	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]
264	International Institute for Applied Systems Analysis	Wenjia Cai	Leaf area constrained by soil nutrient status with eco-evolutionary optimality principles	External
265	Thünen Institute of Forest Ecosystems	Kai Schwärzel	Long-term monitoring of forest ecosystems: Status, changes, and trends	Internal
266	Freie Universität Berlin	Christopher Schiller, Fabian Fassnacht	Examining forest decline in Central Europe using satellite time series data and deep learning methods	External
267	Thünen Institute of Forest Ecosystems	Tanja Sanders	Climate resilient forests - Recognising the potential in the natural spectrum and using it for forestry purposes	Internal
269	SWETHRO	Gunilla Pihl Karlsson	Recovery from acidification and excess nitrogen in Swedish forests - Trend analysis of deposition and soil solution chemistry 1992-2022	External
270	Freie Universität Berlin	Jonathan Költzow, Fabian Faßnacht	Future Forest: Mapping major tree species distribution in Germany	External
271	Natural Resources Institute Finland (Luke)	Simone Bianchi	NORSIM - NORdic tree growth SIMulator	External
272	Swiss Federal Institute for Forest, Snow and Landscape Research (WSL)	Eckehard Brockerhoff	Relationships between mast seeding events and populations of tree seed-dependent birds	External
273	University of Zagreb	Mateo Gašparović	Automatic monitoring of narrow-leaved ash forests by remote sensing methods and Copernicus data	External
274	Swiss Federal Institute for Forest, Snow and Landscape Research (WSL)	Volodymyr Trotsiuk	A framework of predicting tree growth using machine learning tools	External
277	Thünen Institute of Forest Ecosystems	Shah Rukh, Tanja Sanders	A pan-European assessment of the vitality and growth of European beech. A drought analysis of the foliation responses across various climatic gradients	Internal
278	Swiss Federal Institute for Forest, Snow and Landscape Research (WSL)	Johanna Malle, Dirk Karger	High-resolution land surface modelling across the Alps	External
279	Berlin University of Applied Sciences	Pit Wagner, David Linner	How can a web app in combination with an IoT system help to record and visualize the health status of forests in a clearer, more transparent and comprehensible way?	External
280	University of Reading	Caitlin Lewis	Former land use impacts on the capacity of forest soils to retain N-inputs	External
281	Leibniz Institute of Freshwater Ecology and Inland Fisheries	Doris Düthmann	Multi-decadal variations in catchment evapotranspiration and their drivers	External
282	Karlsruhe Institute of Technology, Thünen Institute of Forest Ecosystems	Pia Labenski, Tanja Sanders	Expansion of ecological, silvicultural and technical knowledge on forest fires	Internal

PART B

Reports on individual surveys in ICP Forests

5

ATMOSPHERIC DEPOSITION IN EUROPEAN FORESTS IN 2021

Aldo Marchetto, Char Hilgers, Till Kirchner, Alexa Michel, Andreas Schmitz, Arne Verstraeten, Peter Waldner

Introduction

The atmosphere contains a large number of substances of natural and anthropogenic origin. A large part of them can settle, be adsorbed to receptor surfaces, or be included in rain and snow and finally reach 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.

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

SO_2 emissions derive mainly from coal combustion and also from vehicle fuel combustion, volcanoes, forest fires, and other sources, and have increased since the 1850s, causing an increase in sulphate deposition and deposition acidity, which can be partly 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 N_2O and N_2 during denitrification and the conversion of molecular nitrogen gas (N_2) into NO_x during lightning. However, human activities cause high emissions of nitrogen oxides (NO_x) during combustion processes, and of ammonia (NH_3) deriving from agriculture and farming. They are found in atmospheric deposition in the form of nitrate (NO_3^-) and ammonium (NH_4^+).

Nitrogen compounds have significant effects on the ecosystem: they are important plant nutrients that - when in excess - may lead to ecosystem eutrophication, and 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). They can also act as acidifying compounds (Bobbink and Hettelingh 2011).

Emission and deposition of sulphur and to a lesser extent nitrogen have decreased in the last decades (Waldner et al. 2014, EEA 2016, Rogora et al. 2022)

Materials and methods

Atmospheric deposition is collected on the ICP Forests intensive monitoring plots under the tree canopy (throughfall samplers, Fig. 5-1, left) and with open-field samplers (Fig. 5-1, right) in a nearby clearance. Throughfall samples are used to estimate wet deposition, i.e. 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. The total deposition to a forest, however, also includes nitrogen taken up by leaves and organic nitrogen compounds. It can be estimated by applying canopy exchange models.

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

Sampling, analysis and quality control procedures are harmonized on the basis of the ICP Forests Manual (Clarke et al. 2022).

Quality control and assurance include laboratory ring-tests, the use of control charts, and performing conductivity and ion balance checks on all samples (König et al. 2010). 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 2021 annual throughfall deposition sampling from 287 permanent plots, collected following the ICP Forests Manual. Sixteen plots were excluded because the duration of sampling covered less than 90% (329 days) of the year, and 106 other plots were marked as ”not validated” because the conductivity check was passed for less than 30% of the analysis of the year, or the laboratory did not participate in the mandatory Working Ring Test, or did not pass the minimum requirement of the test. For further 4 sites, data for one specific variable (ammonium) were rejected because the laboratory did not pass the test for that variable.

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 parts of Europe results in a marked spatial variability of atmospheric deposition. However, on a broader scale, regional patterns in deposition arise. As in the previous years, high values of nitrate deposition in 2021 were mainly found in Germany, Denmark, the most southern part of Sweden, Poland, and Lithuania. The number of plots with high ammonium deposition was, however, larger than for nitrate, particularly in Belgium, Germany, Switzerland, Austria, northern Italy, Slovenia, eastern England and the most southern part of Sweden (Figs. 5-2, 5-3).

It is generally assumed that negative effects of nitrogen deposition on forests become evident when the total deposition of inorganic nitrogen (i.e. the sum of nitrate and ammonium deposition) exceeds a specific threshold, known as the critical load. Critical loads can be evaluated for each site by modeling, but more generic critical loads (empirical critical loads) are also being evaluated, ranging between 3 and 17 kg N ha^{-1} yr^{-1} depending on the type of forest and ecosystem compartment (Bobbink et al. 2022). In 2021, throughfall inorganic nitrogen deposition higher than 10 kg ha^{-1} yr^{-1} was mainly measured in most of central Europe, including Germany, Poland, Austria, Switzerland, Slovenia, Croatia, but also in Belgium, Denmark, northern Italy and other countries (Fig. 5-4). Throughfall inorganic nitrogen deposition higher than 20 kg ha^{-1} yr^{-1} was recorded in Belgium, Germany, southern Sweden, and Austria. Because total nitrogen deposition on forests is higher than throughfall nitrogen deposition (Braun et al. 2022), the critical loads for nitrogen are likely still exceeded in large parts of Europe.

Sulphate deposition has very much decreased since the start of the monitoring and currently the highest throughfall deposition is still found close to large point sources. In the southern part of Europe, sulphate deposition is also influenced by volcanic emission and by the episodic deposition of Saharan dust. In 2021, throughfall deposition of sulphate (corrected for the marine contribution) higher than 3 kg S ha^{-1} yr^{-1} was found on a small number of sites in Croatia, Serbia, Bulgaria, Germany, Poland, Czechia, Slovakia, and Austria, and at a site in southern Italy influenced by volcanic emission (Fig. 5-5). Throughfall sulphate deposition higher than 6 kg ha^{-1} yr^{-1} was recorded in Croatia, Serbia, Bulgaria and near the borders of Czechia with Germany and Poland.

Calcium and magnesium are also analyzed in the ICP Forests deposition monitoring network, as their deposition can buffer the acidifying effect of atmospheric deposition, protecting soil from acidification. High values of (sea-salt corrected) calcium throughfall deposition were mostly found in a large area in central, eastern and southern Europe, mainly related to the deposition of Saharan dust (Fig. 5-6). High magnesium deposition was found primarily in southeastern Europe (Fig. 5-7).


Figure 5-1: Throughfall samplers on a Level II plot (left) and open-field samplers on a neighboring meadow (right) in Schorfheide, Germany (Images: Berit Michler)

Conclusions

Sulphate throughfall deposition has very much decreased since the start of the monitoring and currently high sulphate deposition is restricted to areas close to large point sources, mainly in eastern and southern Europe. High throughfall deposition of inorganic nitrogen is still observed throughout central Europe, with high ammonium depositions being found in a wider area than high nitrate deposition.

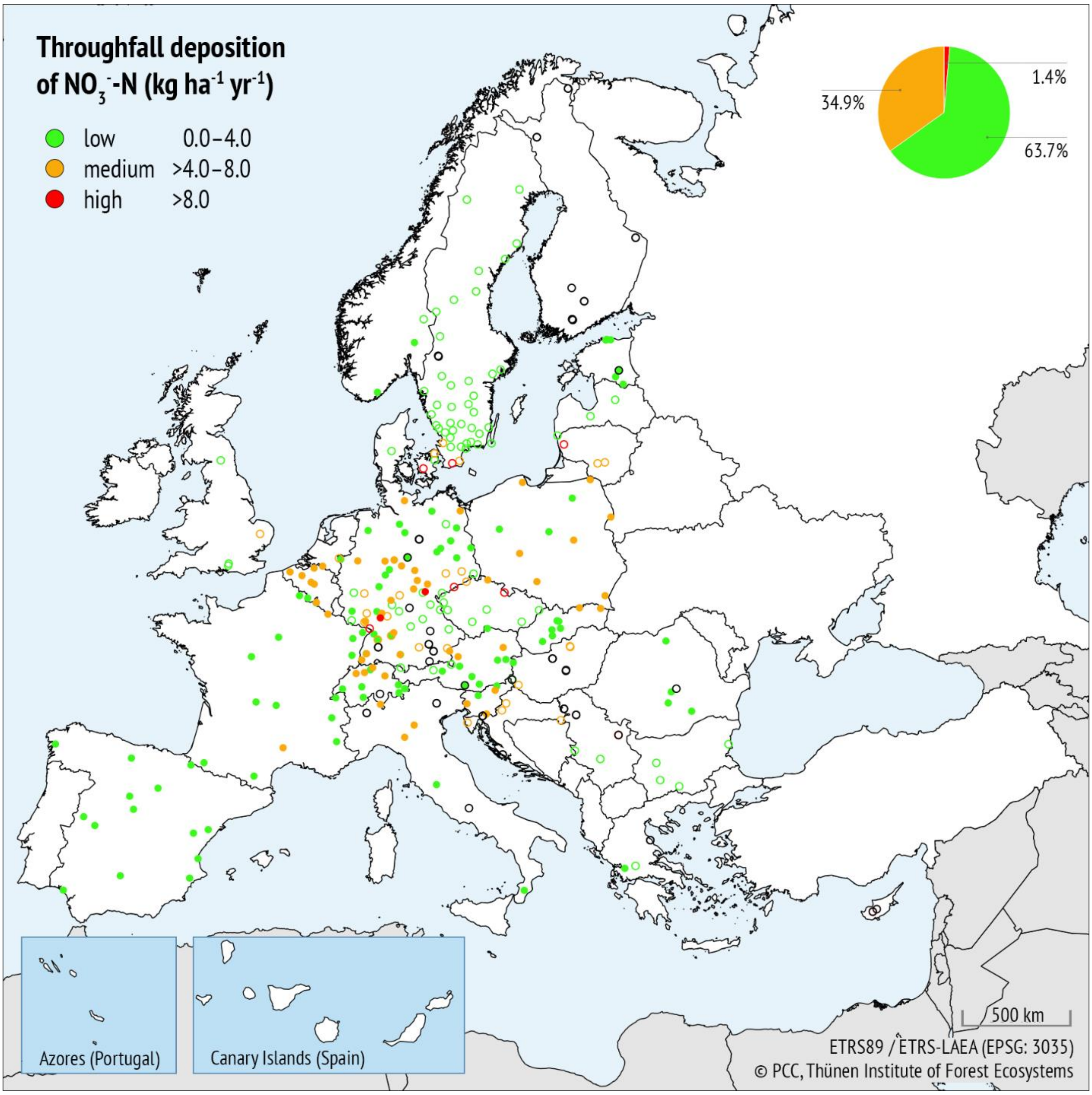

Figure 5-2: Throughfall deposition of nitrate-nitrogen (kg NO_3^--N ha^{-1} yr^{-1}) measured in 2021 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network. Colored dots: validated data. Colored circles: not validated data. Black circles: monitoring period shorter than 330 days or irregular sampling.

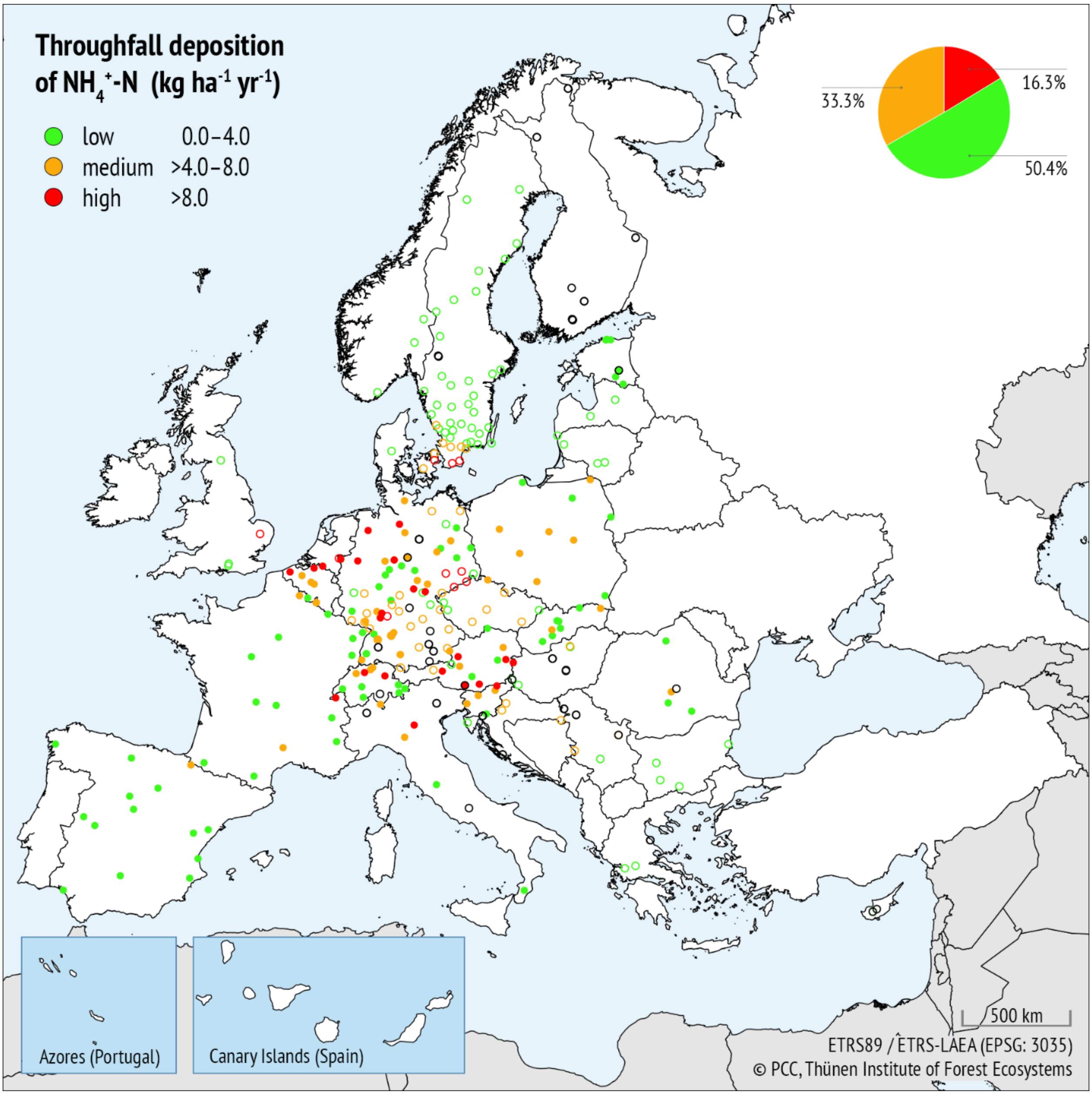

Figure 5-3: Throughfall deposition of ammonium-nitrogen (kg NH_4^+-N ha^{-1} yr^{-1}) measured in 2021 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network. Colored dots: validated data. Colored circles: not validated data. Black circles: monitoring period shorter than 330 days or irregular sampling.

EVALUATIONS

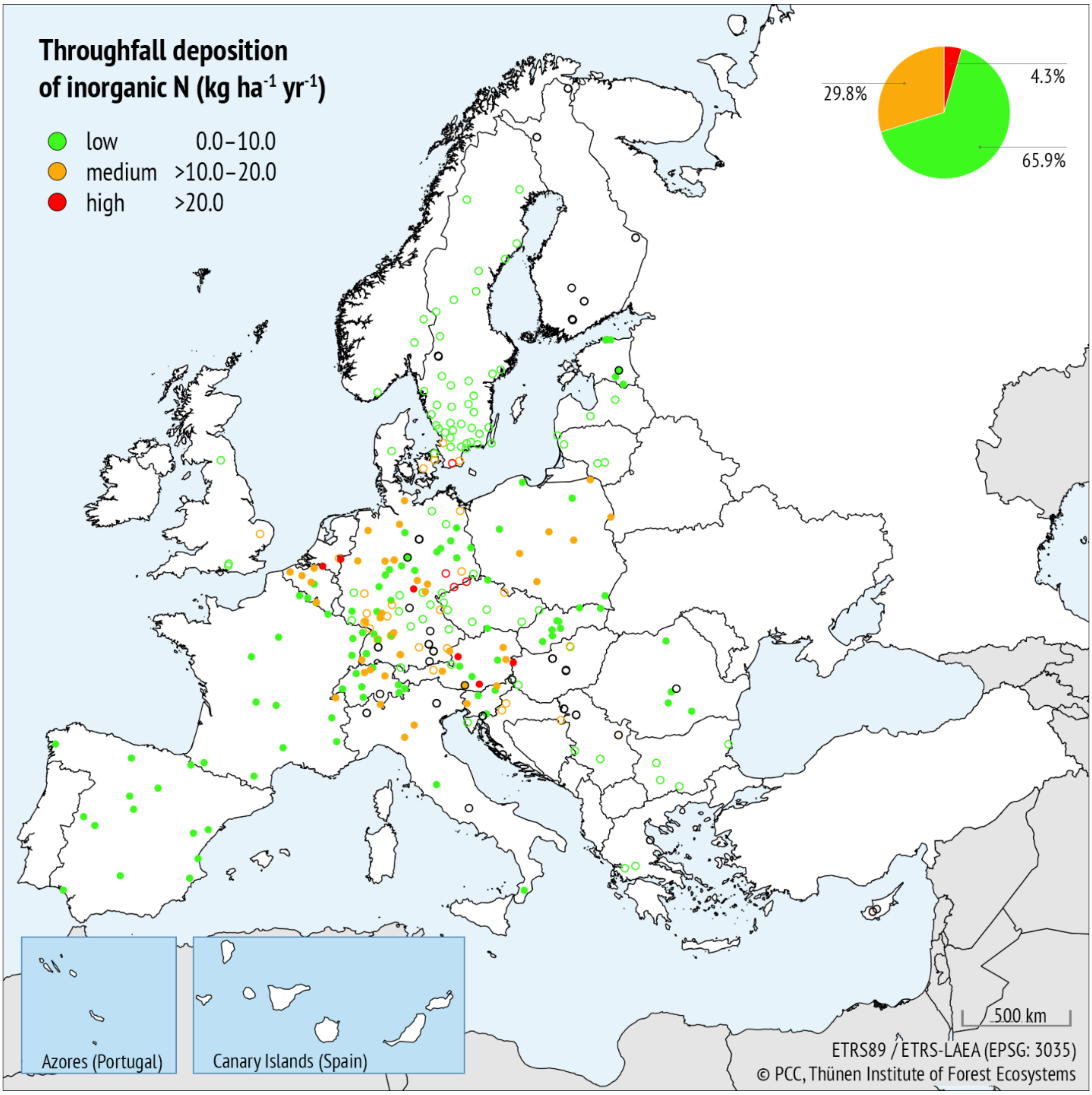

Figure 5-4: Throughfall deposition of inorganic nitrogen (kg NO_3^--N + NH_4^+-N ha^{-1} yr^{-1}) measured in 2021 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network. Colored dots: validated data. Colored circles: not validated data. Black circles: monitoring period shorter than 330 days or irregular sampling.

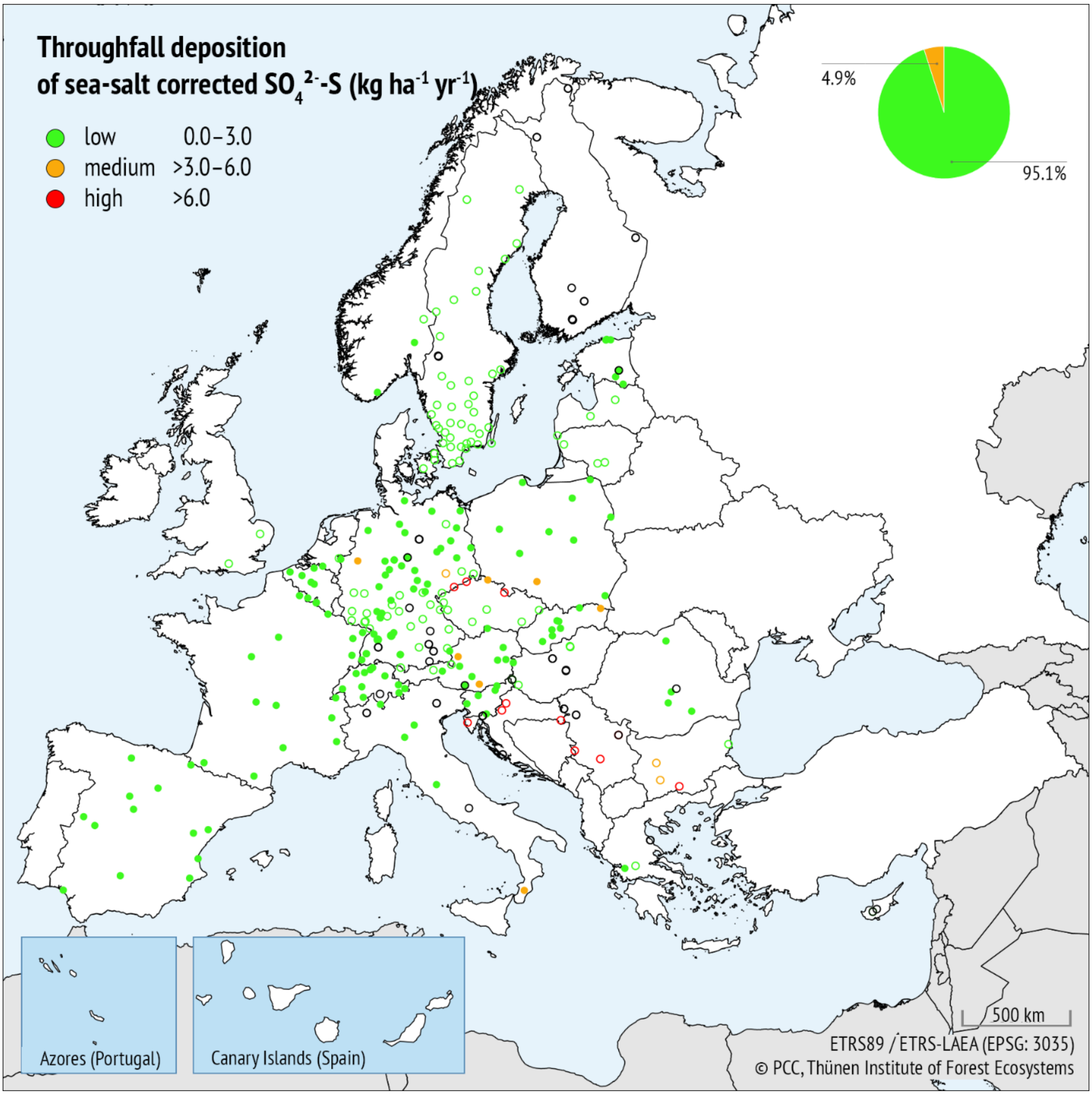

Figure 5-5: Throughfall deposition of sea-salt corrected sulphate-sulphur (kg SO_4^{2-}-S ha^{-1} yr^{-1}) measured in 2021 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network. Colored dots: validated data. Colored circles: not validated data. Black circles: monitoring period shorter than 330 days or irregular sampling.

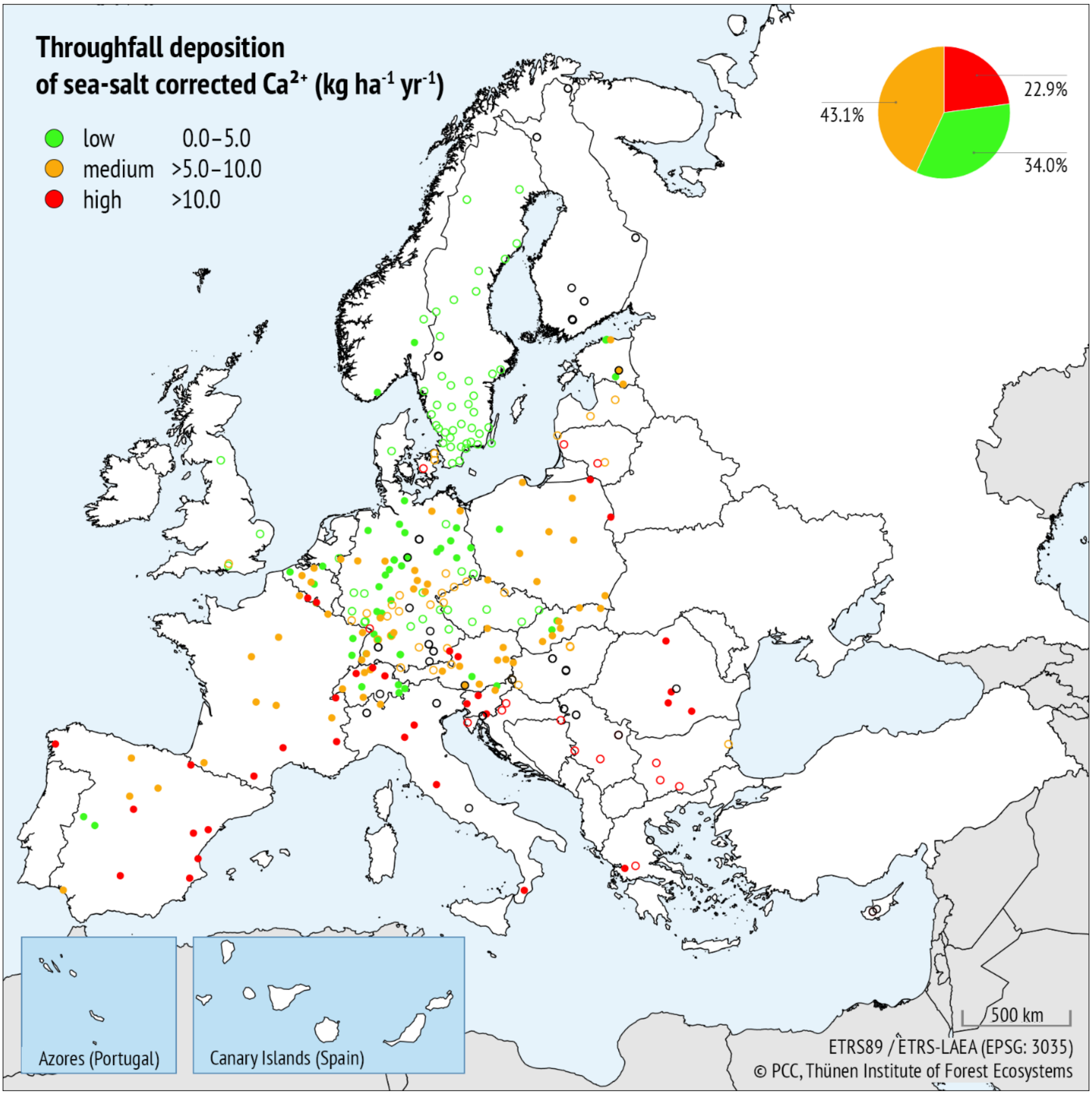

Figure 5-6: Throughfall deposition of sea-salt corrected calcium (kg Ca^{2+} ha^{-1} yr^{-1}) measured in 2021 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network. Colored dots: validated data. Colored circles: not validated data. Black circles: monitoring period shorter than 330 days or irregular sampling.

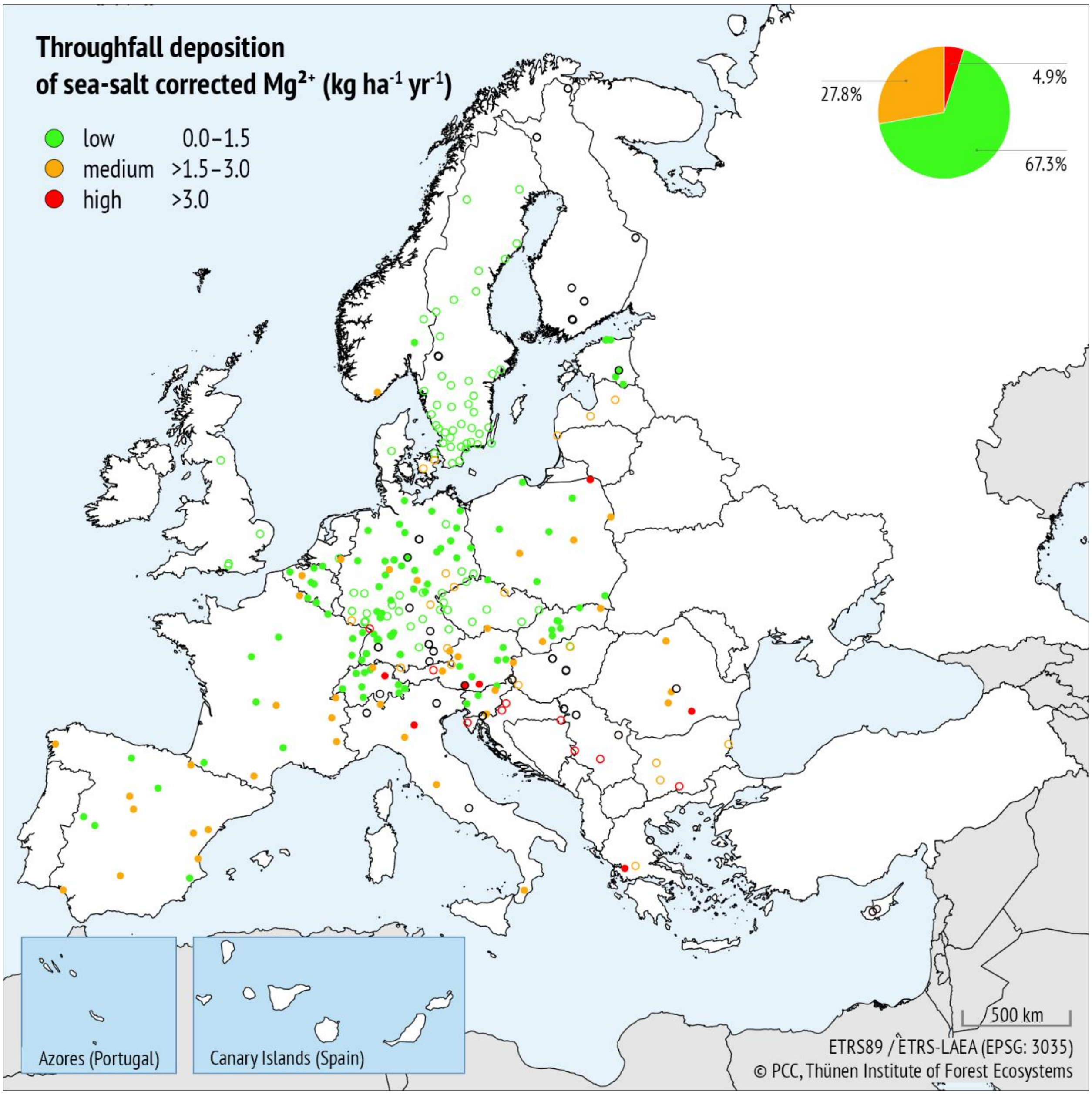

Figure 5-7: Throughfall deposition of sea-salt corrected magnesium (kg Mg^{2+} ha^{-1} yr^{-1}) measured in 2021 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network. Colored dots: validated data. Colored circles: not validated data. Black circles: monitoring period shorter than 330 days or irregular sampling.

References

Bobbink R, Hettelingh JP, eds (2011) **Review and revision of empirical critical loads and dose-response relationships.** Coordination Centre for Effects, National Institute for Public Health and the Environment (RIVM). ISBN 978-90-6960-251-6. https://rivm.openrepository.com/handle/10029/260510

Bobbink R, Hicks K, Galloway J, et al (2010) **Global assessment of nitrogen deposition effects on terrestrial plant diversity: a synthesis.** Ecol Appl 20:3059. https://doi.org/10.1890/08-1140.1

Bobbink R, Loran C, Tomassen H, eds (2022) **Review and revision of empirical critical loads of nitrogen for Europe.** Dessau-Rosslau: German Environment Agency.

Bobbink R, Hicks K, Galloway J, et al (2010) **Global assessment of nitrogen deposition effects on terrestrial plant diversity: a synthesis.** Ecol Appl 20:3059. https://doi.org/10.1890/08-1140.1

Braun S, Ahrends B, Alonso R, et al (2022) **Nitrogen deposition in forests: Statistical modeling of total deposition from throughfall loads.** Frontiers in Forests and Global Change 5: 1–9. https://doi.org/10.3389/ffgc.2022.1062223

Clarke N, Žlindra D, Ulrich E, et al (2022) **Part XIV: Sampling and Analysis of Deposition.** In: UNECE ICP Forests Programme Co-ordinating Centre (ed): Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests. Thünen Institute of Forest Ecosystems, Eberswalde, Germany, 34 p + Annex. http://www.icp-forests.org/manual.htm

EEA (2016) **Emissions of the main air pollutants in Europe** – European Environment Agency, Copenhagen, Denmark. https://www.eea.europa.eu/data-andmaps/indicators/main-anthropogenic-air-pollutantemissions/

FEI (2013) **Data calculation (Annex 7).** In: Manual for Integrated Monitoring. http://www.syke.fi/nature/icpim, accessed 23.04.2020.

König N, Kowalska A, Brunialti G, et al (2016) **Part XVI: Quality Assurance and Control in Laboratories.** In: UNECE ICP Forests Programme Coordinating Centre (ed): Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests. Thünen Institute of Forest Ecosystems, Eberswalde, Germany, 46 p. + Annex. http://www.icp-forests.org/manual.htm

Meunier CL, Gundale MJ, Sánchez IS, Liess A (2016) **Impact of nitrogen deposition on forest and lake food webs in nitrogen-limited environments.** Glob Change Biol 22: 164–179. https://doi.org/10.1111/gcb.12967

Mosello R, Amoriello M, Amoriello T, et al (2005) **Validation of chemical analyses of atmospheric deposition in forested European sites.** J Limnol 64:93–102

Mosello R, Amoriello T, Benham S, et al (2008) **Validation of chemical analyses of atmospheric deposition on forested sites in Europe: 2. DOC concentration as an estimator of the organic ion charge.** J Limn 67:1–14

Rogora M, Colombo L, Marchetto A, et al S (2016) **Temporal and spatial patterns in the chemistry of wet deposition in Southern Alps.** Atm Envir 146:44–54. https://doi.org/10.1016/j.atmosenv.2016.06.025

Silva LCR, Gómez-Guerrero A, Doane TA, Horwath WR (2015) **Isotopic and nutritional evidence for species- and site specific responses to N deposition and elevated CO_2 in temperate forests.** J Geophys Res Biogeosci 120:1110–1123. https://doi.org/10.1002/2014JG002865

Waldner P, Marchetto A, Thimonier A, et al (2014) **Detection of temporal trends in atmospheric deposition of inorganic nitrogen and sulphate to forests in Europe.** Atmos Environ 95:363–374. https://doi.org/10.1016/j.atmosenv.2014.06.054

6

METEOROLOGICAL CONDITIONS IN EUROPEAN FORESTS IN 2021

Lothar Zimmermann, Stephan Raspe, Char Hilgers, Kai Schwärzel, Alexa Michel

Introduction

Weather and climate affect composition, structure, growth, health, and dynamics of forest ecosystems (Geiger 1961; Baumgartner 1967a, b; Lee 1978, 1980; Mitscherlich 1981; Swank and Crossley 1988; Chang 2006). Observing weather conditions and their seasonal variations on forest monitoring plots is therefore essential for identifying and interpreting trends in forest condition. Furthermore, weather data are needed to identify and understand interactions with other stressors such as air pollution, diseases, or pests. Against this background, the ICP Forests Level II plots were equipped with meteorological measurement devices as early as the 1990s. The resulting Europe-wide network of forest meteorological stations provides site-specific forest meteorological data including air temperature, relative humidity, precipitation, wind speed and direction, global radiation, and soil moisture and temperature. In combination with data from other ICP Forests surveys (e.g. tree growth, crown condition, phenology, ground vegetation, soil), these data can be used to analyze the effect of the atmospheric environment and its change over time on vitality and development of forest ecosystems.

For a better understanding of the effects of the atmosphere on forests, data interpretation should always be aimed at improving the process-based understanding of soil-forest-atmosphere interactions. Mayer and Schmidt (1991) identified atmospheric stress factors as e.g. late frost or heat periods, which are potentially relevant for states of and processes in forests.

The main objectives of the meteorological monitoring at the Level II plots are:

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

Temperature and precipitation patterns play a key role in climate change impacts on forests (Kirilenko and Sedjo 2007). This chapter, therefore, focuses first on presenting and interpreting air temperature and precipitation data from 2021 in comparison with long-term average values (1990–2020) for different climatic regions in Europe. Level II meteorological stations were allocated to climatic regions according to the well-known Koeppen-Geiger climate classification scheme with the aim to aggregate values from Level II plots and show changes across European climatic regions. The classification comprises here four main classes and 10 sub-types (Beck et al. 2018). It is based on threshold values and seasonality of monthly air temperature and precipitation. Considering vegetation as "crystallized, visible climate", this classification aims to empirically map biome distributions around the world: different regions in a similar climate class share common vegetation characteristics (Beck et al. 2018). The most frequent Koeppen climatic regions in Europe are (1) C-climates, which are temperate climates e.g. CfB atlantic temperate (beech climate) up to warm to hot Mediterranean climate (Csb, Csa), and (2) D-climates, which are continental climates from humid continental (Dfa, Dfb: oak climate) to subarctic (Dfc: birch climate) and also to Mediterranean-influenced warm-summer humid continental climate (Dsa) (Tab. 6-1). The distribution of the Level II meteorological stations across Europe is shown in Figure 6.1. The allocation to climatic regions results in a large difference in the number of stations in the individual categories. Therefore, the informative value of individual subgroups is partially limited.

Climate and weather in Europe 2021

Weather conditions in 2021 in Europe were much cooler than in most recent years, but still warmer than for the reference period (1991–2020). In early spring, many parts of Europe saw a transition from unusually warm to unusually cold temperatures, with frost-related impacts. Summer was the warmest on record and brought also several extreme events. In July, above-average soil moisture, a slow-moving low-pressure system, and record precipitation across Belgium, Germany, and eastern France resulted in extreme flooding. A long-lived and intense heatwave in the Mediterranean, combined with very dry conditions, led to high levels of heat stress and intense wildfires. Although summer was the warmest on record, with + 1.0 °C above average, spring was less than 0.5 °C cooler than average. For the year as a whole, the most-above-average temperatures were found around the Black Sea, in southeastern Europe, and in western Russia. Temperatures in Scandinavia, and to a lesser extent in central Europe, were cooler than average. (EU-Copernicus-ECMWF 2022).

Table 6-1: Number of meteorological stations (n) at Level II plots in different climatic regions in 2021. For criteria, please refer to Table 3 in Beck et al. 2018.

Code	Description of climate	Name	n
BSk	Arid, steppe, cold	Cold semi-arid climate	7
Cfa	Temperate, no dry season, hot summer	Humid subtropical climate	5
Cfb	Temperate, no dry season, warm summer	Temperate oceanic climate	36
Csa	Temperate, dry summer, hot summer	Hot-summer Mediterranean climate	5
Csb	Temperate, dry summer, warm summer	Warm-summer Mediterranean climate	4
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	135
Dfc	Cold, no dry season, cold summer	Subarctic climate	22
Dsb	Cold, dry summer, warm summer	Mediterranean-influenced warm-summer humid	1
ET	Polar, tundra	Tundra climate	1
		TOTAL	217

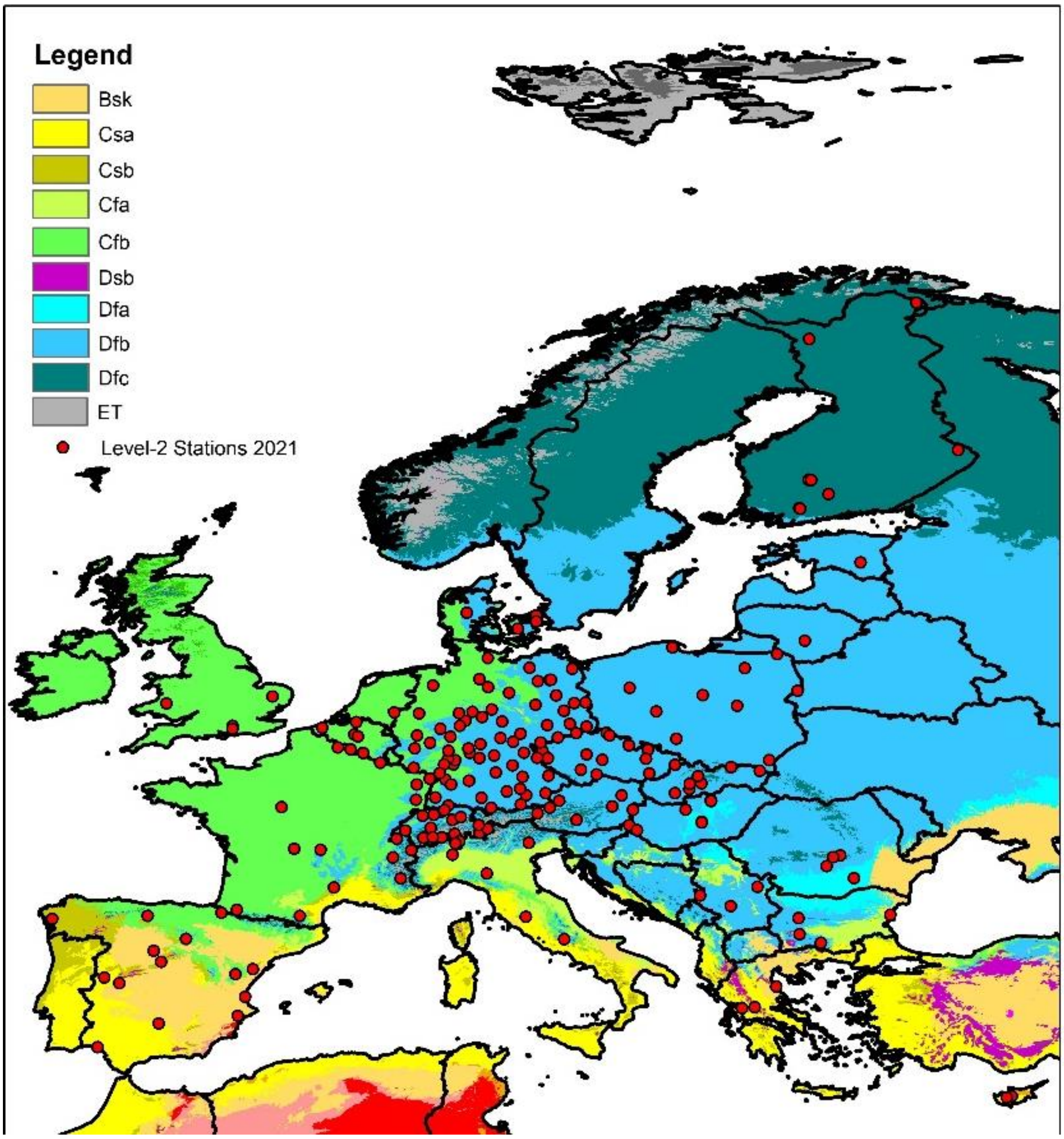

Figure 6-1: Map of Level II stations with gap-filled time series of meteorological data for 2021 and for different climatic regions (Table 6-1 acc. to Beck et al. 2018).

Materials and methods

Meteorological monitoring in the ICP Forests program includes measurements of standard surface meteorological variables according to international recommendations by the World Meteorological Organization (WMO 2008). In order to represent the specific climatic conditions of a forest, while being aware of potential errors due to the large spatial variability of meteorological data, all meteorological measurements were taken at an open field station within the forest area in close proximity to a Level II plot or from a weather station nearby.

Technical equipment, sensors and their placement are in accordance with WMO standards (WMO - No. 8, No. 100, No. 168) and are compatible with national weather service networks. For details on the recorded parameters, the measurement design, data handling, as well as on quality assurance and quality control standards within the ICP Forests program, please refer to Raspe et al. (2013 and 2020). In this chapter, we only present air temperature and precipitation data in 2021 and compare it with their long-term average (1990–2020).

Air temperature sensors are installed in a passively ventilated solar radiation shield for accurate ambient measurements. Mast-mounted sensors are positioned at a height of 2 m above ground level, on the north side of the mast. Only stations with a measurement height between 1.2 and 3.0 m were included in the analysis. Precipitation was measured with a tipping bucket or weighing rain gauges 1 m above the ground located in a relatively flat, open area. The orifice of the gauge is a horizontal plane, open to the sky.

Meteorological measurements are made quasi-continuously and are then aggregated to daily values (means or sums) with a minimum requirement on the completeness of 95% for air temperature and 100% for precipitation.

Data were cleaned according to ranges of plausible values as given in the ICP Forests Manual (Raspe et al. 2020) and checked for duplicates. Missing values in daily air temperature and the daily sum of precipitation were filled by adjusting modelled values from the ERA5-Land data set from the Copernicus Climate Change Service – Climate Data Store (Copernicus Climate Change Service (C3S) 2017). ERA5-Land is a climate reanalysis model at a resolution of 9 km. It is available on an hourly basis for many climate variables, but because the 9 km grid is much coarser than ICP Forests' near-plot observations, we applied some adjustments to the modelled ERA5-Land values.

For air temperature, we applied a linear regression for each plot, finding a slope and intercept that related ICP Forests' non-missing observations on the forest plot (for all years of observation) to the modelled ERA5-Land values on their 9 km grid. This worked well for altitude differences. For 183 plots on which air temperature was measured in 2021, 52% of plots had at least one missing value that required gap filling, but overall only 7% of daily values were filled per plot on average. Statistics in Table 6-2 indicate good agreement for air temperature.

Table 6-2: Statistics of the deviation between observed daily values and the adjusted ERA5 values

Parameter	Mean difference	Absolute difference	Median difference
Air temperature	0.00 °C	0.96 °C	0.00 °C
Precipitation	0.01 mm	2.04 mm	-0.02 mm

Precipitation is a notoriously difficult variable to fill for a particular location, because of large variation in precipitation amounts over relatively small distances. Where available, we used precipitation amounts collected in the ICP Forests deposition survey. These are generally collected as the sum of precipitation over a two-week period. To then find a daily precipitation amount, we distributed the sum of precipitation found in the deposition survey according to the daily precipitation amount in ERA5-Land. Where deposition data was unavailable, we used the ERA5-Land amount directly. For 204 plots on which precipitation was measured in 2021, 46% of plots had missing values during the year that required gap filling and this resulted in only 7% of values filled per plot on average. Statistics in Table 6-2 indicate fairly good agreement for precipitation.

In order to be able to classify the weather conditions in 2021, the measurement data from 2021 were compared with the long-term average of the climatological normal period 1990–2020. For this purpose, the time series of the individual measuring stations were partially extended backwards to 1990 with the help of the ERA5-Land data set.

Results

Air temperature

Mean annual air temperature

In general, mean air temperatures of ICP Forests Level II plots show differences between stations, with high annual temperatures in the Mediterranean region, moderate temperatures in central Europe and colder temperatures in northern Europe (Fig. 6-2). Extreme low values could be found in northern Finland and at higher situated plots in the Alps. Figure 6-2 also shows that the year 2021 was warmer than normal in southern, southeast and a few other plots across Europe and cooler in west-central and western Europe.

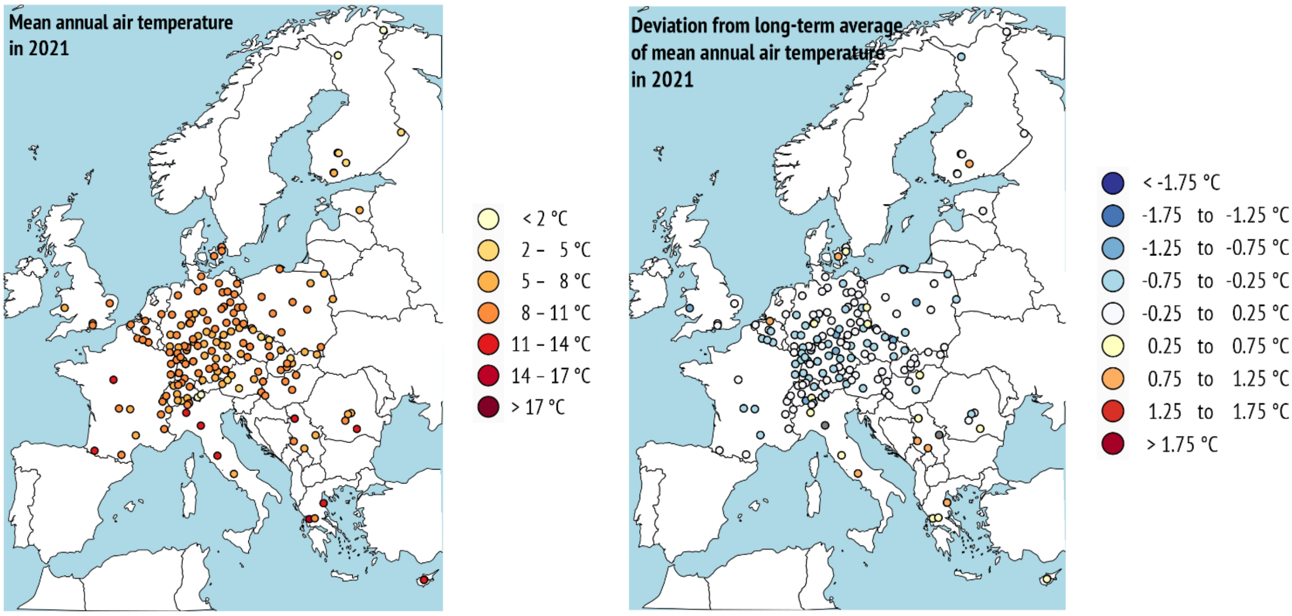

Figure 6-2: Mean annual air temperature (°C) in 2021 (left) and deviation of annual air temperature (°C) in 2021 from the long-term average (1990–2020) on Level II plots.

Mean air temperature in the vegetation period

For air temperature in the vegetation period (Fig. 6-3), we see a more continental influence on Level II plots in east-central Europe starting in north-east Germany and increasing eastwards. High temperatures occur in southern and SE-Europe, low temperatures in western, west-central Europe and in the Alps. In contrast to the year as a whole, it was significantly warmer than the long-term average during the vegetation period in most of Europe, with only some plots showing negative deviations. In western-central and western Europe and also at same sites in southern Europe (Greece) and east-central Europe (e.g. Hungary, Serbia), the temperature was slightly colder than the long-term average, although some plots in these regions also show positive temperature deviations (Fig. 6-3).

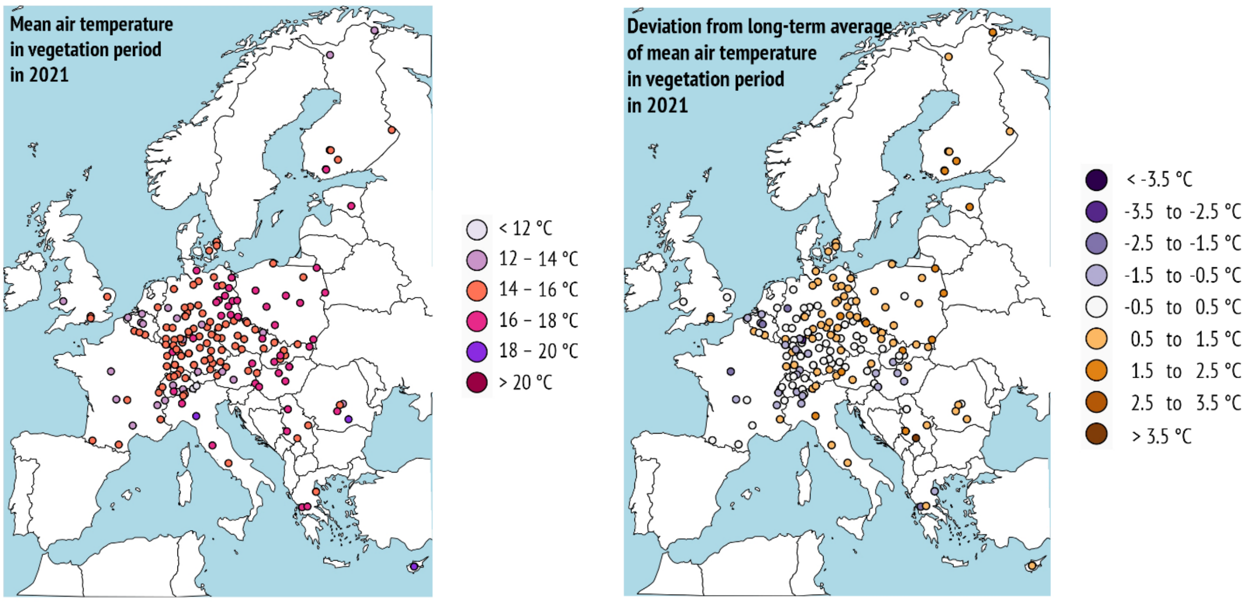

Figure 6-3: Mean air temperature (°C) in the vegetation period in 2021 (left) and deviation of mean air temperature (°C) in the vegetation period in 2021 from the long-term average (1990–2020, right) on Level II plots.

Annual mean air temperature in different climatic regions

To complement the picture of annual mean air temperature at Level II plots during the year 2021, averages for different climatic regions were calculated. For the majority of Level II plots in continental climates (Dfa, Dfb, Dfc, Dsb) as well as in the temperate oceanic climate (Cfb), air temperature was near normal, while Mediterranean climates (Csa and Csb), the humid subtropical climate (Cfa) and cold semi-arid climate (Bsk) showed significant warmer conditions in 2021 than the long-term average (Fig. 6-4). However, it must be noted that the number of Level II plots varies greatly in the different climatic regions (Table 6-1).

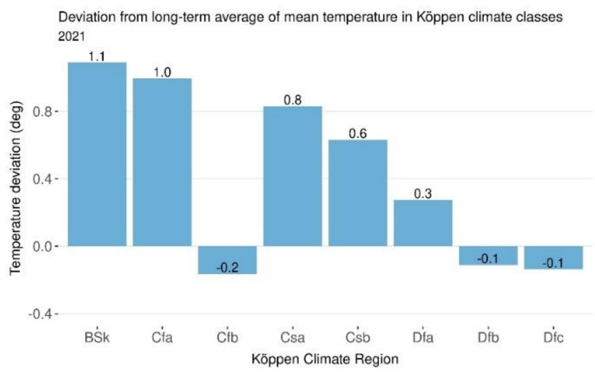

Figure 6-4: Deviation of annual mean air temperature in 2021 from the long-term average (1990–2020) on Level II plots in different Koeppen climatic regions. For explanation of acronyms and for number of Level II plots in each climatic region, please refer to Table 6-1 and Figure 6-1).

Temperature stress indicators

The health and vitality of forests are affected more by extreme temperatures than by mean values. Heat and frost events are of special interest in this respect.

Heat

In 2021, maximum temperatures above 36 °C during the vegetation period occurred at Level II plots in southern and SE-Europe, but also on one Level II plot in Hungary and a few in Germany. The majority of Level II plots in central Europe showed maximum temperatures during the vegetation period between 24 °C and 36 °C (Fig. 6-5). Forests all across southern Europe were confronted by unusual hot days in 2021. Above long-term average maximum air temperatures in the vegetation period, partly up to +3.5 °C and more were found in southern and south-eastern Europe due to a pronounced heat wave (Fig. 6-5). But also in Finland, northeast Germany, and the United Kingdom the maximum air temperature in 2021 was significantly higher compared to the long-term average. In contrast, Belgium, Switzerland, Czechia, some regions of France, and large parts of Germany were significantly cooler compared to the long-term average, with a very pronounced negative deviation of up to -3.5 °C and more on some Level II plots (Fig. 6-5).

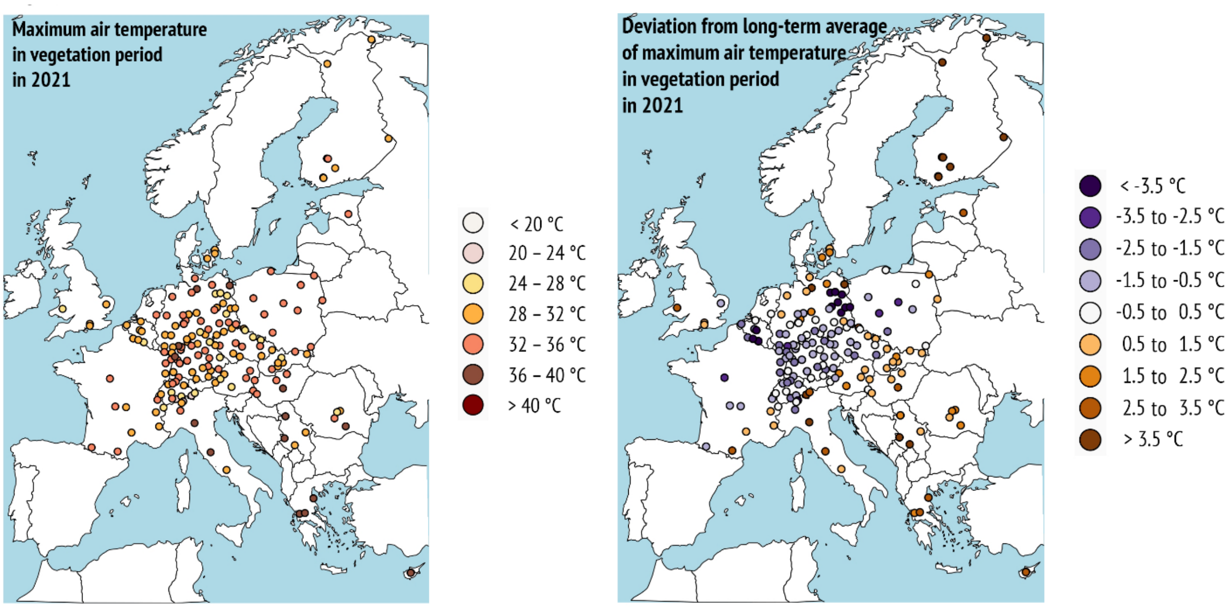

Figure 6-5: Maximum air temperature (°C) in the vegetation period in 2021 (left) and deviation of the maximum air temperature (°C) in the vegetation period in 2021 from the long-term average (1990–2020) (right) on Level II plots.

Another indicator of the risk of heat stress on forests is the number of hot days with a temperature maximum above 30 °C. For the majority of Level II plots in a humid continental climate (Dfa, Dfb), there was no increase in extreme hot days compared to the long-term average, only the one station with Dfa-climate showed a marked increase of nearly more than 20 hot days. An increase of around 10 hot days compared to the long-term average occurred in the cold semi-arid steppe climate (Bsk), the humid subtropical climate (Cfa), and the Mediterranean climates (Csa, Csb) (Fig. 6-6).

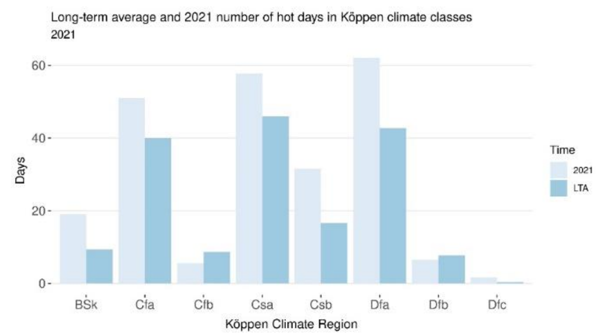

Figure 6-6: Number of hot days (Tmax ≥ 30 °C) in 2021 and long-term yearly average (1990–2020) on Level II plots in different Koeppen climatic regions. For explanation of acronyms and for number of stations in each climatic region, please refer to Table 6-1 and Figure 6-1.

Late frost

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

In 2021, an exceptional deviation from normal was observed on Level II plots with humid subtropical climate (Cfa), temperate oceanic climate (Cfb), and cold semi-arid climate (Bsk); instead of 1 to 2 frost days, up to 7 frost days were observed on these plots in 2021 compared to the long-term average (Fig. 6-6).

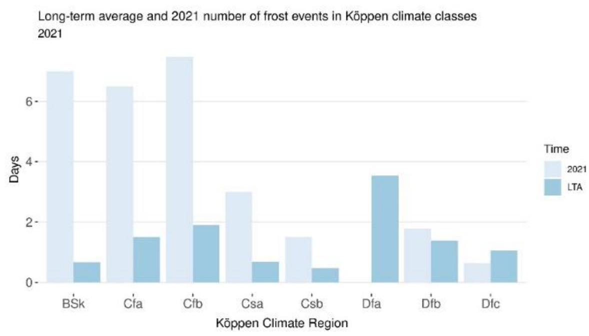

Fig. 6-7: Number of late frost days (Tmin in vegetation period < 0 °C) in 2021 and long-term yearly average (1990–2020) on Level II plots in different Koeppen climatic regions. For explanation of acronyms and for number of stations in each climatic region, please refer to Table 6-1 and Figure 6-1.

Precipitation

Annual precipitation

The distribution of total annual precipitation in 2021 on Level II plots shows a more or less normal pattern. The highest annual precipitation was found in the Alps and mountain stations in Greece and the lowest in Spain as well as in east-central and south-eastern Europe (Fig. 6-8).

The deviation of total precipitation in 2021 from the long-term average (1990–2020) is less than 45% in either direction on the majority of plots and seldom reaches higher values. Towards the Mediterranean Sea, especially in Serbia, northern Italy, and Spain higher negative deviations were found. In general, the year 2021 was slightly drier than normal all across Europe (Fig. 6-8). However, exceptions can be found, e.g., in Greece, Bulgaria, Spain, north-eastern Germany, and in the mountain regions on the German-Czech, Czech-Polish, and Slovak-Polish borders.

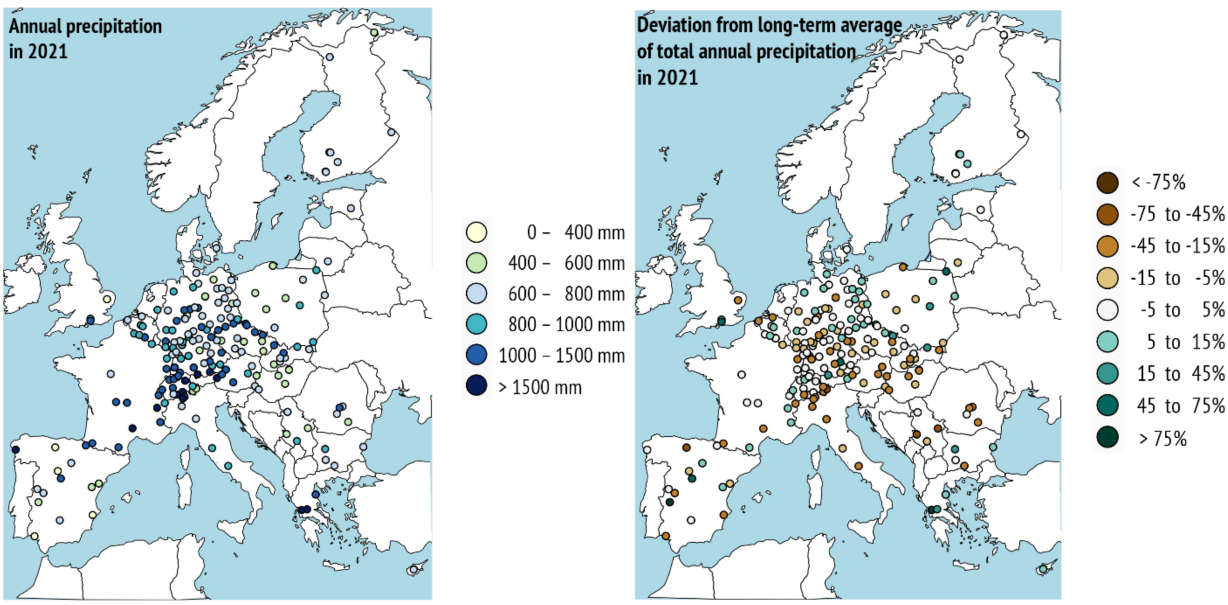

Fig. 6-8: Annual precipitation in mm (l/m²) in 2021 (left) and deviation of the total annual precipitation in 2021 from the long-term yearly average (1990–2020) (in %, right) on Level II plots.

This is also evident from the mean precipitation amounts in the different European climatic regions. For the majority of Level II plots in continental climates and temperate climates without dry seasons, precipitation was significantly (Dfa, Cfa) or slightly (Dfb, Dfc, Cfb) lower than normal, while in Mediterranean climates it was significantly (Dsb) or slightly wetter (Csa, Csb) than the long-term average (Fig. 6-9).

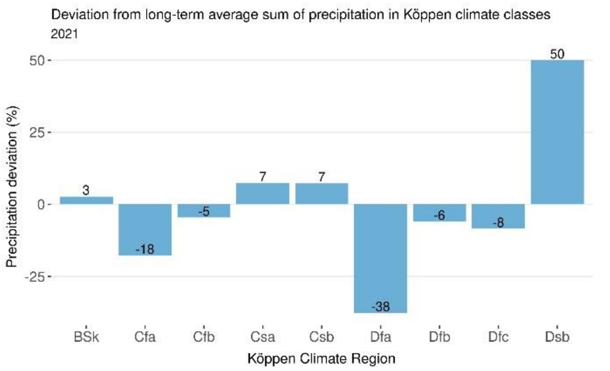

Fig. 6-9: Deviation from the long-term average of the annual precipitation on Level II plots in different Koeppen climatic regions. For an explanation of acronyms and for number of stations in each climatic region, please refer to Table 6-1 and Figure 6-1.

Precipitation in the vegetation period

The amount of precipitation during the growing season is of particular importance for the water supply of forests. In 2021, very low values below 150 mm were found on Level II plots in northern Finland, northern Spain, and Cyprus. The highest values were measured in the Alps and the Greek mountains (Fig. 6-10).

Regarding the deviation of the precipitation in the vegetation period in 2021 from the long-term average, the majority of Level II plots in Belgium, western Germany, and Switzerland show positive deviations likely due to the exceptional flood-producing rainfall in July. The largest part of central and SE-Europe show more negative deviations except for two plots in Greece, while Spain gives a mixed picture. In general, a heterogeneous picture may result from small-scale variations of summer thunderstorms. In the Swiss Alps, more than 75% more precipitation was measured in 2021 compared to the long-term average. South of the Alps in Italy and in SE-Europe, however, Level II plots were exclusively drier than normal during the vegetation period in 2021. One plot in Serbia was especially extremely dry (Fig. 6-10).

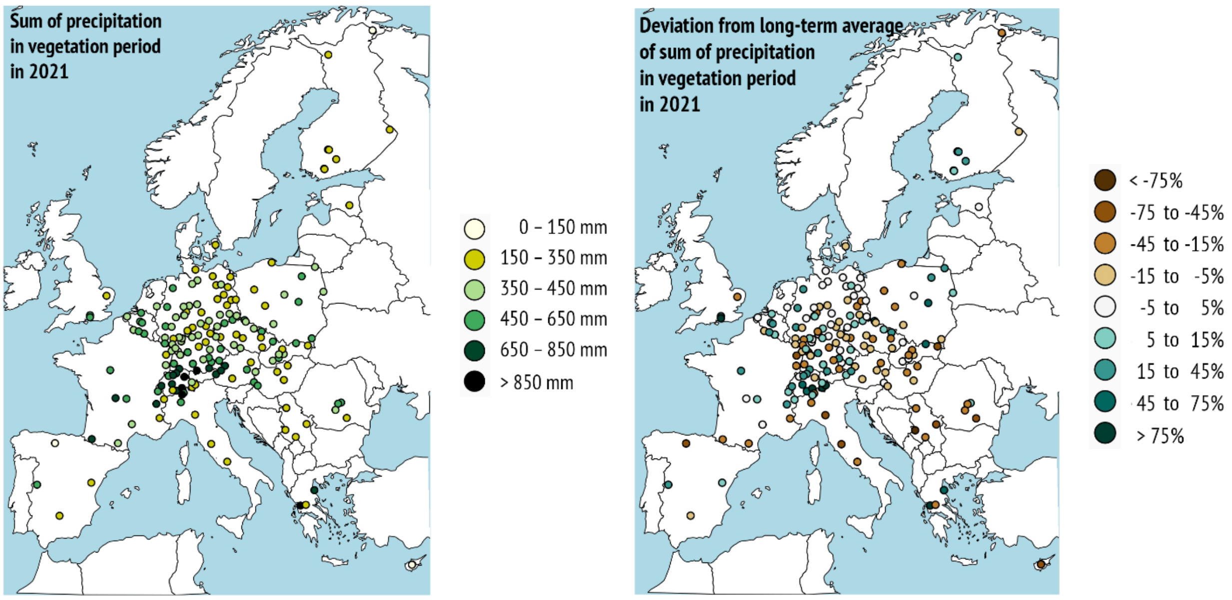

Figure 6-10: Precipitation (in mm (l/m^2)) in the vegetation period in 2021 and deviation (in %) of the precipitation in the vegetation period in 2021 from the long-term average (1990–2020) on Level II plots.

Literature

Baumgartner A (1967a) **Developments in forest meteorology - Teil I.** Forstwiss. Cbl. 86:156-175 (in German)

Baumgartner A (1967b) **Developments in forest meteorology - Teil II.** Forstwiss. Cbl. 86: 201-220 (in German)

Beck HE, Zimmermann NE, McVicar TR, et al (2018) **Data descriptor: Present and future Koeppen-Geiger climate classification maps at 1-km resolution.** Nature Scientific Data 5:180214. https://doi.org/10.1038/sdata.2018.214

Chang M (2006) **Forest hydrology. An introduction to water and forests.** CRC Press, 474 p.

Copernicus Climate Change Service (C3S) (2017) **ERA5: Fifth generation of ECMWF atmospheric reanalyses of the global climate.** Copernicus Climate Change Service Climate Data Store (CDS), 2022-02-13. https://cds.climate.copernicus.eu/cdsapp#!/home

EU-Copernicus-ECMWF (2022) **European State of the Climate. Summary 2021.** https://climate.copernicus.eu/esotc/2021

Geiger R (1961) **Climate near the ground.** Braunschweig, Friedr. Vieweg & Sohn, pp. 646 (in German)

Kirilenko AP, Sedjo RA (2007) **Climate change impacts on forestry.** PNAS 104(50):19697-19702. https://doi.org/10.1073/pnas.070142410

Lee R (1978) **Forest microclimatology.** New York, Columbia University Press, pp. 276

Lee R (1980) **Forest hydrology.** New York, Columbia University Press, pp. 349

Mitscherlich G (1981) **Forest, growth and environment. Vol. 2: Forest climate and water balance.** Frankfurt am Main, J.D. Sauerländer's Publ.; pp. 402 (in German)

Mayer H, Schmidt J (1991) **Application of climatological data as forest assessment parameters.** Forstwiss. Cbl. 110:338–343 (in German)

Raspe S, Bastrup-Birk A, Fleck S, et al (2013) **Monitoring methods for atmosphere-related variables in forests – Meteorology.** In: Feretti M, Fischer R (ed.): Forest Monitoring. Developments in Environmental Science 12, Elsevier, pp. 319-336

Raspe S, Fleck S, Beuker E, et al (2020) **Meteorological Measurements. Version 2020-1.** In: UNECE ICP Forests, Programme Co-ordinating Centre (ed.): Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests. Thünen Institute of Forest Ecosystems, Eberswalde, Germany, 18 p. + Annex. http://www.icp-forests.org/manual.htm

Swank WT, Crossley DA (1988**) Forest hydrology and ecology at Coweeta.** Springer, 469 pp. https://doi.org/10.1007/978-1-4612-3732-7

WMO (2008) **Guide to meteorological instruments and methods of observation.** World Meteorological Organization -8 8 1-681. https://library.wmo.int/index.php?lvl=notice_display&id=12407

7

TREE CROWN CONDITION IN 2022

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Highlights

In 2022, we witnessed a slight increase in mean defoliation as compared to year 2021, with a smaller change for conifers (0.6 percentage points, %p) than for broadleaves (1.4%p). While no change in mean defoliation was recorded for Scots pine and a very small increase for Norway spruce (0.2%p) and deciduous temperate oaks (0.3%p), larger increases were recorded for other main species and species groups, especially for Austrian pine (1.9%p) and evergreen oaks (2.0%p).

Trends show a considerable increase in defoliation of evergreen oaks over the past 20 years (7.3%p). On the other hand, the increase in defoliation for deciduous temperate oaks (3.2%p) and common beech (3.9%p) has been relatively low, while the increase of defoliation for Scots pine, Mediterranean lowland pines and Norway spruce was moderate. Trends were not significant for deciduous (sub-) Mediterranean oaks and Austrian pine.

This year a 2.6%p rise in the number of trees with damage symptoms was recorded, and the overall number of recorded damage symptoms was also higher than in 2021. As in previous years, the number of damage symptoms per assessed tree was substantially higher for broadleaves than for conifers (0.84 vs. 0.56, 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 2022 was 0.9% (873 trees). Mortality rates for the main species and species groups ranged from 0.3 to 0.7% (except for Norway spruce with 1.9%), and the main causes of mortality were abiotic factors, followed by insects, fungi and fire.

Introduction and scientific background

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

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

This chapter presents results from the crown condition assessments on the large-scale, representative, transnational monitoring network (Level I) of ICP Forests carried out in 2022, as well as long-term trends for the main species and species groups.

Methods of the 2022 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 7-1). In the maps presenting the mean plot defoliation and in Table 7-3, class 2 is subdivided into class 2-1 (> 25–40%) and class 2-2 (> 40–60% defoliation).

Table 7-1: 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 7-2 shows countries and the number of plots assessed for crown condition parameters from 2013 to 2022, and the total number of sample trees submitted in 2022. 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.

EVALUATIONS

Table 7-2: Number of plots assessed for crown condition parameters from 2013 to 2022 in countries with at least one Level I crown condition survey since 2013, and total number of sample trees submitted in 2022

Country	2013	2014	2015	2016	2017	2018	2019	2020	2021	Plots 2022	Trees 2022
Andorra	11	11	12								
Belarus	373		377								
Belgium	8	8	8	53	53	52	52	51	51	51	540
Bulgaria	159	159	159	159	160	160	160	160	159	160	5599
Croatia	105	103	95	99	99	99	97	98	95	97	2328
Cyprus	15	15	15			15	15	15	15	15	360
Czechia		138	136	136	135	132	132	127	121	117	4 176
Denmark	20	20	20	19	19	19	19	19	18	18	433
Estonia	96	96	97	98	98	98	98	95	95	93	2180
France	550	545	542	533	527	521	515	512	509	504	10 076
Germany	417	422	424	421	416	410	421	416	409	405	9 566
Greece		57	47	23	36	40	45	38	33	35	822
Hungary	68	68	67	67	66	68	68	68	69	71	1 546
Ireland							28	30	33	31	676
Italy	247	244	234	246	247	249	237	240	256	256	4 751
Latvia	115	116	116	115	115	115	115	115	115	115	1 753
Lithuania	79	81	81	82	82	81	81	81	81	81	1 965
Luxembourg	4	4	4	4	3	3	4	4	4	4	96
Moldova, Rep. of					9	9					
Montenegro	49			49	49	49	49	49	49	49	1 175
Norway	618	687	554	629	630	623	687	604	629	627	5 183
Poland	364	365	361	353	352	348	346	343	343	341	6 791
Romania	236	241	242	243	246	246	247	226	234	237	5 755
Serbia	121	128	127	127	126	126	127	126	126	126	2 857
Slovakia	108	107	106	103	103	101	100	99	97	99	4 418
Slovenia	44	44	44	44	44	44	44	44	44	44	1 088
Spain	620	620		620	620	620	620	620	620	620	14 880
Sweden	740	842	839	701	618	760	849	841	733	629	2 284
Switzerland	47	47	47	47	47	47	47	47	47	49	1 038
Türkiye	583	531	591	586	598	601	597	599	580	579	13 360
TOTAL	5 797	5 699	5 345	5 557	5 498	5 636	5 800	5 667	5 565	5 453	105 696

Damage cause assessments

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

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

Additional parameters

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

Tree species

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

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

Of all trees submitted from the Level I network in 2022, *Pinus sylvestris* was the most abundant tree species (16.6% of all trees), followed by *Fagus sylvatica* (incl. ssp. *moesiaca*, 12.0%), *Picea abies* (11.1%), *Pinus nigra* (5.1%), *Quercus robur* (4.3%), *Quercus petraea* (4.3%), *Quercus ilex* (3.7%), *Quercus cerris* (3.2%), *Pinus brutia* (3.0%), *Betula pubescens* (2.4%), *Pinus halepensis* (2.4%), *Quercus pubescens* (2.2%), *Abies alba* (2.2%), *Betula pendula* (2.0%), *Pinus pinaster* (1.8%), and *Carpinus betulus* (1.8%).

Most Level I plots with crown condition assessments contained one (47.9%) or two to three (39.2%) tree species per plot. On 10.6% of plots, four to five tree species were assessed, and only 2.4% of plots featured more than five tree species. In 2022, 51.7% of all submitted trees were broadleaves and 48.3% 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 7-4 and 7-5). 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 7-3 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.

Figures 7-2a-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 2003–2022. 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 2013–2022 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. All queries and statistical analyses were conducted in the R/RStudio software environment (R Core Team 2016).

Quality assurance and control (QA/QC)

Since ICP Forests is a pan-European monitoring programme, stemming from various national initiatives that had already been

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

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

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

In recent years, the International Photo Cross-Comparison Course (Photo ICC), held every two years, has developed into an important and effective tool of the ICP Forests quality assurance program for the assessment of crown condition in Europe. Teams from 21 different European countries participated in the Photo ICC 2021 – more than ever before (Meining et al. 2021, internal report). As in the previous years, the survey comprised photos of tree species from three European regions: Northern (*Picea abies* and *Pinus sylvestris*), Central *(Picea abies*, *Pinus sylvestris*, *Fagus sylvatica*, *Quercus robur* and *Q. petraea*), and Mediterranean Europe (*Pinus pinaster*, *Pinus sylvestris* and *Quercus ilex*). Each team assessed a photo set of 30 pictures for each tree species. In total, 37 047 defoliation scores were included in the Photo ICC 2021.

The determination of the assessable crown naturally has a major influence on the assessment of trees, therefore participating teams were asked to assess defoliation using both their own national method and the widest span method, which was set as a reference standard for this survey. The results indicate noticeably larger differences between national teams when using the national method due to different assessable crown definitions. On the other hand, the use of standardized picture series can reduce assessment bias, with the additional advantage that crown condition survey standard remains fairly constant even in the case of personnel changes, and indeed, the consistency of the crown condition assessment in comparison with previous Photo ICCs could be confirmed for most species.

As observed in previous photo courses (Meining et al. 2019), the results for trees with higher defoliation levels presented a significantly higher deviation from the mean than the results for trees with lower defoliation levels. The differences in the assessment results between the field and reference teams may indicate a lack of harmonization for some countries, but the results of the Photo ICC 2021 show, in general, a good level of agreement in defoliation assessments between the participating countries.

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 2022 was conducted on 105 696 trees on 5 453 plots in 27 countries (Table 7-2). Out of those, 101 190 trees were assessed in the field for defoliation (Table 7-3).

The overall mean defoliation for all species was 23.8% in 2022; an increase in defoliation of 0.6%p for conifers and 1.4%p for broadleaves in comparison with 2021 (Table 7-3). Broadleaved trees showed a higher mean defoliation than coniferous trees (24.7% vs. 23.0%), as in previous years. Correspondingly, conifers had a higher frequency of trees in the defoliation classes 'none' and 'slight' (71.3% combined) than broadleaves (67.0%) and a lower frequency of trees with more than 60% defoliation (3.0% vs. 5.0%). Norway spruce had the highest share of standing dead trees (1.6%), common beech, Austrian pine and deciduous (sub-) Mediterranean oaks the lowest (0.2% each).

Among the main tree species and tree species groups, deciduous temperate oaks and evergreen oaks displayed the highest mean defoliation (27.7% and 28.6%, respectively). Common beech had the lowest mean defoliation (22.4%). The strongest increase in defoliation compared to 2021 occurred in evegreen oaks (+2.0%p) and in Austrian pine (+1.9%p), while there was no increase in Scots pine and only a small increase in Norway spruce (0.2%p) and deciduous temperate oaks (+0.3%p). Defoliation increased in all species and species groups compared to 2021, except in Scots pine.

Mean defoliation of all species at plot level in 2022 is shown in Figure 7-1. Two thirds (65.9%) of all plots had a mean defoliation up to 25%, and only 1.4% of the plots showed severe defoliation (more than 60%). While plots with defoliation up to 10% were located mainly in Norway, Serbia, Romania, and Türkiye, plots with slight mean defoliation (11-25%) were found across Europe. Clusters of plots with moderate to severe mean defoliation were found from the Pyrenees through southeast (Mediterranean) France to west Italy, but also from central and northern France through Germany and into Czechia, Slovakia and Hungary, as well as in western Bulgaria and central parts of Norway and Sweden.

The following sections describe the species-specific mean plot defoliation in 2022 and the over-all trend and yearly mean plot defoliation from 2003 to 2022. For maps on defoliation of individual tree species in 2022, and trends in mean plot defoliation from 2013 to 2022, please refer to the online supplementary material[1].

Table 7-3: Percentage of trees assessed in 2022 according to defoliation classes 0-4 (class 2 subdivided), mean defoliation for the main species or species groups (change from 2021 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*)	21.6	52.6	15.8	6.8	2.7	0.5	22.9 (+/-0.0)	17 327
Norway spruce (*Picea abies*)	29.1	36.5	21.9	7.7	3.1	1.6	23.1 (+0.2)	11 388
Austrian pine (*Pinus nigra*)	27.2	43.3	16.2	8.4	4.8	0.2	24.1 (+1.9)	5 414
Mediterranean lowland pines	13.2	58.4	19.8	5.8	2.1	0.6	23.7 (+1.6)	7 977
Other conifers	31.1	42.5	16.6	6.6	2.8	0.4	21.5 (+0.7)	7 951
Common beech (*Fagus sylvatica*)	31.3	38.4	20.0	6.6	3.5	0.2	22.4 (+1.5)	12 435
Deciduous temperate oaks	17.7	40.8	25.5	10.0	5.5	0.4	27.6 (+0.3)	8 980
Dec. (sub-) Mediterranean oaks	26.2	43.5	18.1	8.3	3.8	0.2	23.4 (+1.4)	7 921
Evergreen oaks	6.7	52.4	26.5	9.1	5.0	0.3	28.6 (+2.0)	4 628
Other broadleaves	27.7	42.6	14.8	6.9	6.3	1.8	24.3 (+1.7)	17 169
TOTAL								
Conifers	24.1	47.2	18.0	7.0	3.0	0.7	23.0 (+0.6)	50 057
Broadleaves	24.7	42.3	19.5	7.8	5.0	0.8	24.7 (+1.4)	51 133
All species	**24.4**	**44.7**	**18.8**	**7.4**	**4.0**	**0.7**	**23.8 (+1.0)**	**101 190**

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

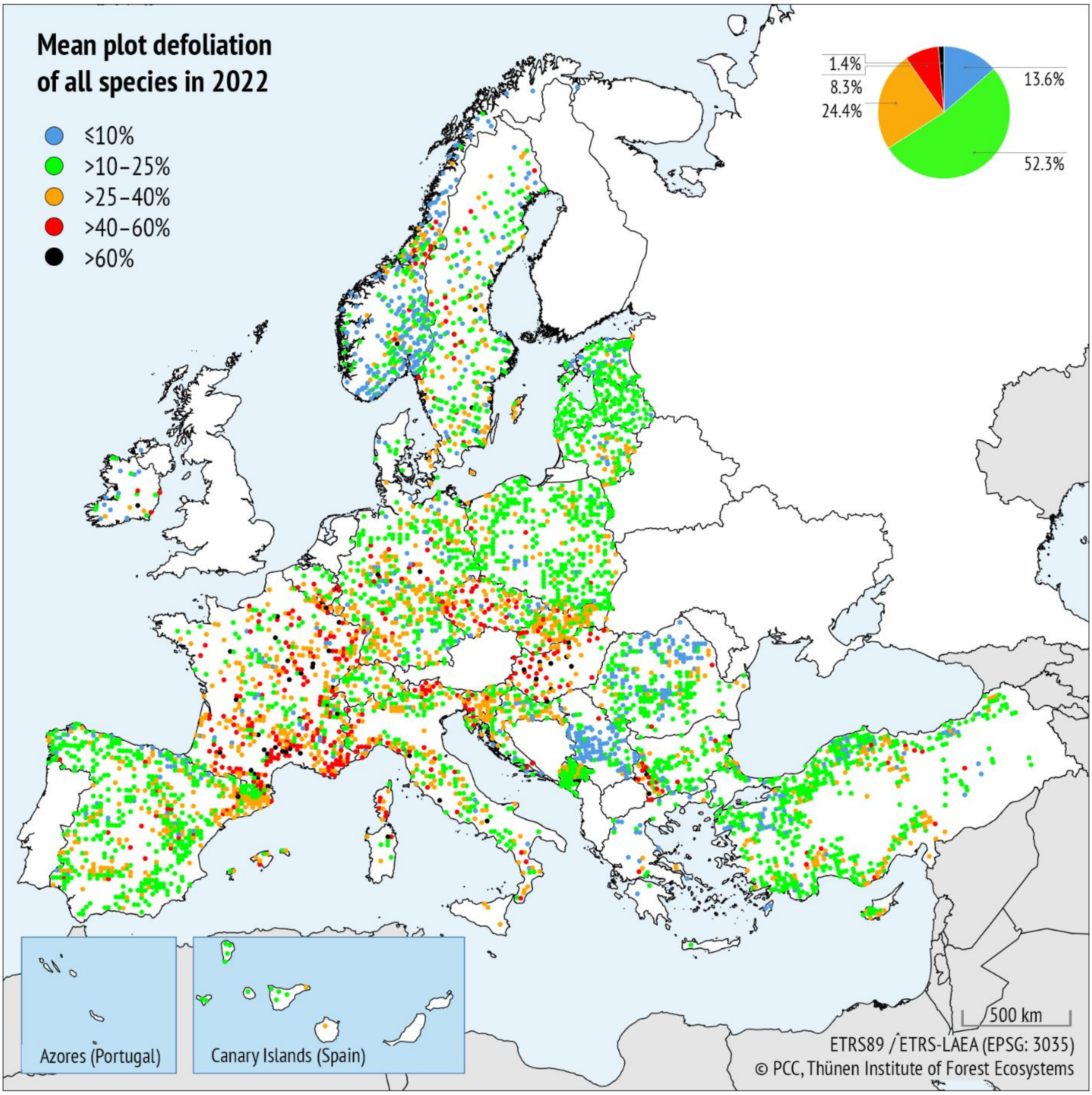
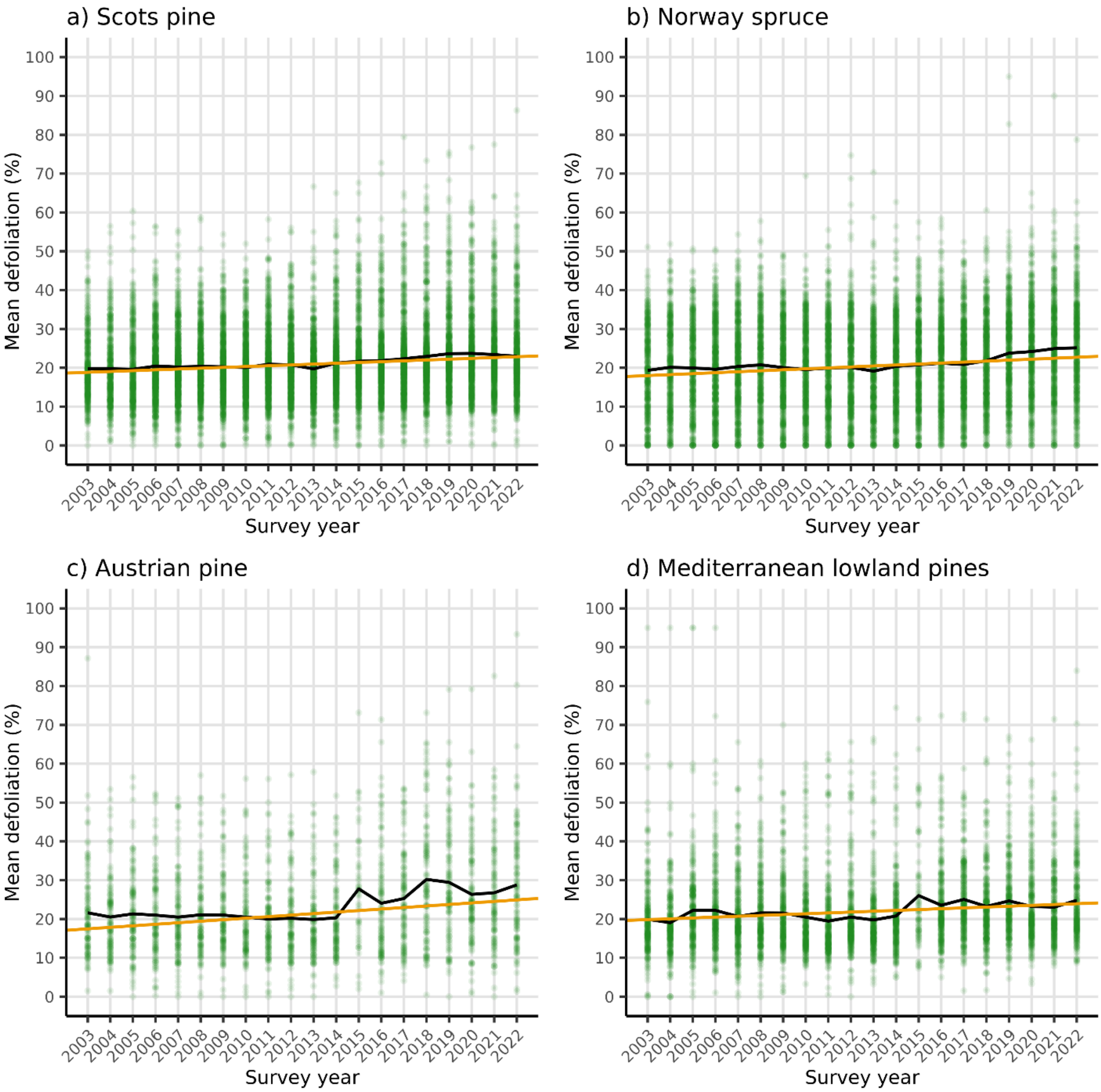
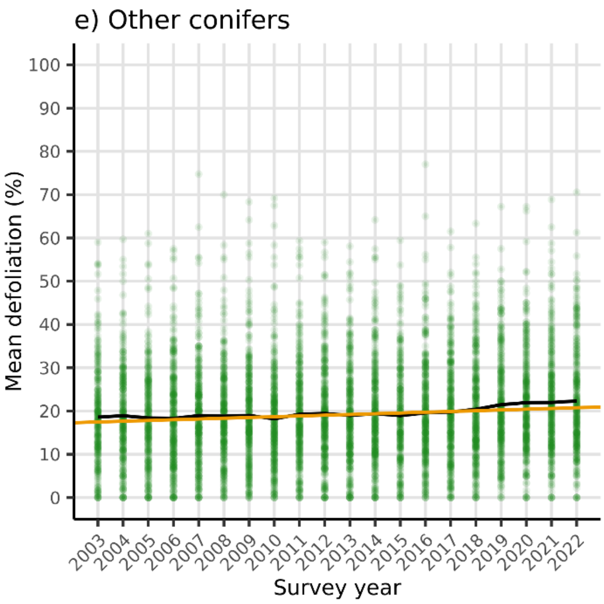


Figure 7-1: Mean plot defoliation of all species in 2022, shown as defoliation classes. The legend (top left) shows defoliation classes ranging from none (blue), slight (green), moderate (orange and red), to severe (black) defoliation. The percentages refer to the needle/leaf loss in the crown compared to a reference tree. The pie chart (top right) shows the percentage of plots per defoliation class. Dead trees are not included.

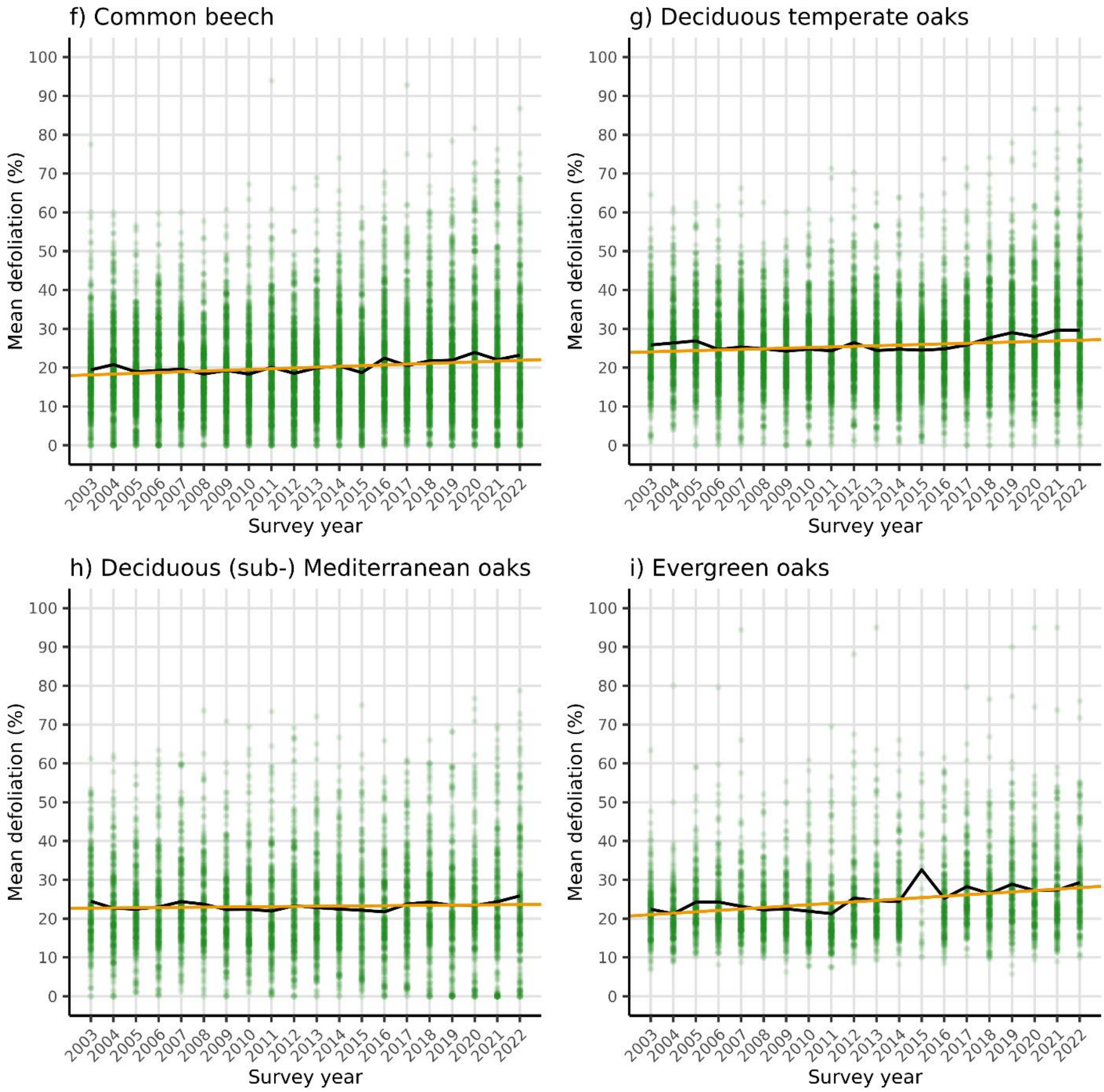


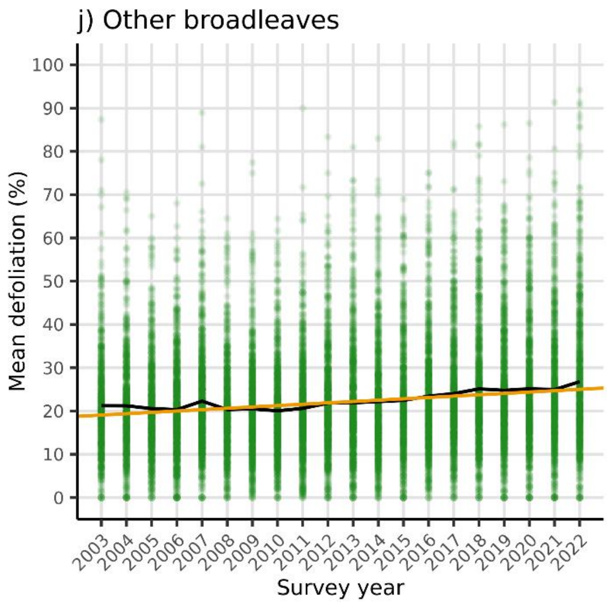


Figures 7-2 a-e: Over-all trend (orange line) and annual mean defoliation across plots (black line) at Level I plots from 2003–2022; points represent annual plot mean values:

(a) Scots pine (regional Sen's slope = 0.2113, $p < 0.001$)
(b) Norway spruce (regional Sen's slope = 0.2481, $p < 0.001$)
(c) Austrian pine (regional Sen's slope = 0.3925, *n.s.*)
(d) Mediterranean lowland pines (regional Sen's slope = 0.2158, $p < 0.05$)
(e) Other conifers (regional Sen's slope = 0.1733, $p < 0.001$)

n.s. = not significant





Figures 7-2 f-j: Over-all trend (orange line) and annual mean defoliation across plots (black line) at Level I plots from 2003–2022; points represent annual plot mean values:

(f) Common beech (regional Sen's slope = 0.1963, $p < 0.01$)

(g) Deciduous temperate oaks (regional Sen's slope = 0.1577, $p < 0.05$)

(h) Deciduous (sub-) Mediterranean oaks (regional Sen's slope = 0.0476, *n.s.*)

(i) Evergreen oaks (regional Sen's slope = 0.3658, $p < 0.001$)

(j) Other broadleaves (regional Sen's slope = 0.3127, $p < 0.001$)

n.s. = not significant

Scots pine

Scots pine (*Pinus sylvestris*) is the most frequent tree species in the ICP Forests Level I network (Table 7-3). 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 2022, Scots pine trees showed mean defoliation of up to 10% on 15.4% of plots and slight (>10–25%) mean defoliation on 61.6% of the plots (please refer to the online supplementary material[1], Figure S1-1). Defoliation of Scots pine trees on 22.2% of the plots was moderate (>25–60% defoliation, class 2) and only on 0.8% of the plots severe (>60% defoliation, class 3). Plots with the lowest mean defoliation were primarily found in southern Norway, Estonia, and parts of Spain and Türkiye, whereas plots with comparably high defoliation were located in Czechia, western Slovakia, south-eastern France, and western Bulgaria.

There has been a significant trend of mean plot defoliation of Scots pine over the course of the last 20 years with an increase of 4.2%p (Figure 7-2a). The mean defoliation across plots showed some fluctuation towards the end of the chosen reporting period, with mean defoliation values steadily above the trend line since 2015, and 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 programme. 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 2022, spruce trees on over one fifth (21.5%) of all Norway spruce plots had mean defoliation up to 10%, and further 40.3% had only slight defoliation (please refer to the online supplementary material[1], Figure S1-2). On 37.5% of the plots, spruce defoliation was moderate (>25–60% defoliation), while severe mean defoliation was recorded on 0.6% of the plots. Plots with low mean defoliation were found mostly in Scandinavia and the Balkan region. Plots with high mean defoliation values were mostly located in central Europe.

The 20-year trend in mean plot defoliation of Norway spruce shows an increase of almost 5%p (Figure 7-2b). The annual mean values have been on a steady rise and above the trend line since 2019, with the highest ever mean value recorded in 2022.

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 12.1% of the plots containing this species, and between 11 and 25% on 58.2% of plots (please refer to the online supplementary material[1], Figure S1-3). Defoliation was moderate on 27.6% of the plots (>25-60% defoliation) and severe on 2.1% of the plots. Plots with less than 10% mean defoliation were mostly located in Türkiye and northern Spain, while plots with higher defoliation were scattered throughout the region.

The 20-year trend in mean plot defoliation of Austrian pine shows large fluctuations since 2014 (Figure 7-2c). From 2010 to 2014 the annual mean plot defoliation was lower than the trend, but it has been above the trend line since then, reaching its absolute maximum in 2018.

Mediterranean lowland pines

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

Mediterranean lowland pine plots had mean defoliation of up to 10% on 3.5% of plots and 65.1% of plots had defoliation between 11 and 25% (please refer to the online supplementary material[1], Figure S1-4). Defoliation was moderate on 30.4% of the plots, and severe on 1.0%. Most of plots with defoliation up to 25% were located in Türkiye and Spain. Plots with moderate to severe mean defoliation values (>40% defoliation) were mostly located in the proximity to the coastline of the western Mediterranean Sea.

For Mediterranean lowland pines, the trend shows an increase in defoliation of 4.3%p over the past 20 years (Figure 7-2d), with annual values staying mostly close to the trendline.

[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 2022 and by far the most frequently assessed deciduous tree species within the ICP Forests monitoring programme (Table 7-3). 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 2022, common beech had up to 10% mean defoliation on 20.6% of the beech plots (please refer to the online supplementary material[1], Figure S1-5). On 41.3% of plots, beech trees were slightly defoliated (>10–25% defoliation), moderate mean defoliation was recorded on 35.4%, and severe defoliation on 2.8% 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 3.9%p (Figure 7-2f). Annual mean values generally stay close to the trend line, but there were three larger deviations from this trend, in 2004, 2016, and 2020 - the highest ever mean plot defoliation of 23.9% was recorded in 2020. In 2004, the annual mean plot defoliation was higher than the trend as a result of the drought in the preceding year which affected large parts of Europe (Ciais et al. 2005, Seidling 2007, Seletković et al. 2009).

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 2022, mean defoliation of temperate oaks was up to 10% on 8.3% of the plots, and from >10 to 25% on 42.1%, therefore more than half of the plots had no or slight mean defoliation. Moderate mean defoliation (>25–60%) was recorded on 46.6% of plots and severe defoliation (more than 60% defoliation) on 3.1% 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.

A significant increase in mean plot defoliation (3.2%p) has been recorded for deciduous temperate oaks in the past 20 years. Generally, the changes in the defoliation status are not very fast for deciduous temperate oaks. A good example is the increase of oak defoliation in the drought year 2003, followed by a delayed recovery (Figure 7-2g). The largest deviation of the mean defoliation from the trend line happened in 2019, possibly due to the effects of drought events both in 2018 and 2019 (JRC 2019). The rise of defoliation continued in 2021, with no further change in 2022.

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 12.6% of plots, and between 10 and 25% on 49.5% of plots, yielding a total of 65.3% of plots with mean defoliation up to 25% for these oaks in 2022. More than a third (35.5%) of plots showed moderate, and 2.4% severe mean defoliation for Mediterranean oaks (please refer to the online supplementary material[1], Figure S1-7). Plots with lower mean defoliation were located predominantly in Serbia, while plots with higher mean defoliation were found mostly in Hungary and southeastern France.

There has been no significant trend in mean plot defoliation for deciduous (sub-) Mediterranean oaks for the past 20 years (Figure 7-2h). Mean plot defoliation values generally stay very 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 2.0% of the evergreen oak plots had mean defoliation up to 10%, and there were 42.5% 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 54.2%, and severe defoliation on 1.2% of plots. The majority of plots with defoliation over 40% were located along the shoreline of the northwest Mediterranean.

Based on the trend analysis, evergreen oaks had the largest increase (+ 7.3%p) in defoliation of all analyzed species and species groups over the last 20 years (Figure 7-2i). The defoliation development pattern for evergreen oaks is characterized by larger deviations from the trend line, sometimes lasting for several years.

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

Damage causes

In 2022, damage cause assessments were carried out on 99 920 trees on 5 339 plots and in 26 countries. On 49 004 trees (49.0%) at least one symptom of damage was found, which is 2.6%p higher than in 2021 (46.4%). In total, 70 300 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 7-4) was higher for the broadleaved tree species and species groups than for the conifers. It was highest for evergreen oaks with 1.09 symptoms per tree on average, and lowest for Norway spruce with 0.42 symptoms per tree. Compared to 2021, both the number of recorded damage symptoms and the ratios have been increasing for all species and species groups, except for deciduous temperate oaks, which had a decrease in number of observed damage symptoms.

Table 7-4: Number of damage symptoms and assessed trees, and their ratio for the main tree species and species groups in 2022. Multiple damage symptoms per tree and dead trees are included.

Main species or species groups	N damage symptoms	N trees	Ratio
Scots pine (*Pinus sylvestris*)	10 437	16 950	0.62
Norway spruce (*Picea abies*)	4 445	10 582	0.42
Austrian pine (*Pinus nigra*)	3 123	5 420	0.58
Mediterranean lowland pines	4 851	7 988	0.61
Other conifers	4 508	7 725	0.58
Common beech (*Fagus sylvatica*)	8 852	10 945	0.81
Deciduous temperate oaks	7 697	8 486	0.91
Dec. (sub-) Mediterranean oaks	6 997	7 929	0.88
Evergreen oaks	5 029	4 628	1.09
Other broadleaves	14 361	19 267	0.75
Total			
Conifers	27 364	48 665	0.56
Broadleaves	42 936	51 255	0.84
All species	**70 300**	**99 920**	**0.70**

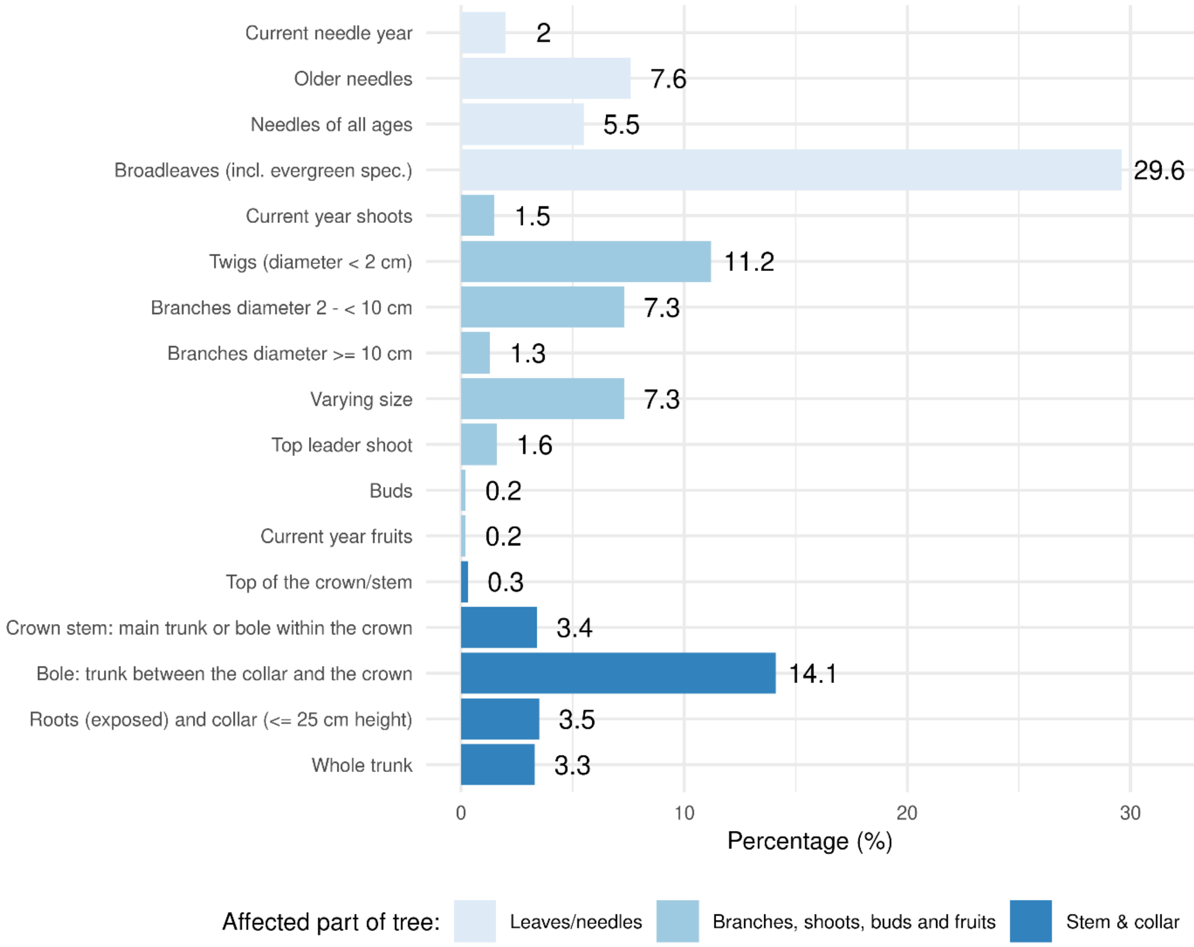


Figure 7-3: Percentage of recorded damage symptoms in 2022 (n=69 407), affecting different parts of a tree. Multiple affected parts per tree were possible. Dead trees are not included.

Symptom description and damage extent

Most of the reported damage symptoms were observed on the leaves of broadleaved trees (29.6%), followed by twigs and branches (27.1%), and stems (21.3%; Figure 7-3). Needles were also often affected (15.1%), while roots, collar, shoots, buds, and fruits of both broadleaves and conifers were less frequently affected.

More than half (54.9%) of all recorded damage symptoms had an extent of up to 10%, 35.6% had an extent between 10% and 40%, and 9.6% 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 23.4% of all recorded damage symptoms (Figure 7-4). Within the group of insects, 38.7% of damage symptoms were caused by defoliators. Wood borers were responsible for 18.8%, leaf miners for 13.2%, sucking insects for 11.7%, and gallmakers for 5.7% of the damage caused by insects.

Abiotic factors were the second major causal agent group responsible for 20.3% of all damage symptoms. Within this agent group, more than half of the symptoms (55.6%) were attributed to drought, while snow/ice and hail caused 11.2%, wind 7.5%, heat/sun scald 3.5% and frost 3.4% of the symptoms.

The third major identified cause of tree damage were fungi with 10.5% of all damage symptoms. Of those, 25% showed signs of decay and root rot fungi, followed by dieback and canker fungi and needle cast and needle rust fungi (15.2% each), blight (10.2%) and powdery mildew (6.1%).

Direct action of man refers mainly to impacts of silvicultural operations, mechanical/vehicle damage, forest harvesting, or resin tapping. This agent group accounted for 4.6% of all recorded damage symptoms. The damaging agent group 'Game and grazing' was of minor importance (1.2%). Fire caused 0.7% of all damage symptoms. The agent group 'Atmospheric pollutants' refers here only to damage caused by direct atmospheric pollution impact. Visible symptoms of direct atmospheric pollution impact, however, were very rare (0.03% of all damage symptoms). Other factors were responsible for 11.0% of all reported damage symptoms. Apart from these identifiable causes of damage symptoms, a considerable number of symptoms (28.4%) could not be identified in the field.

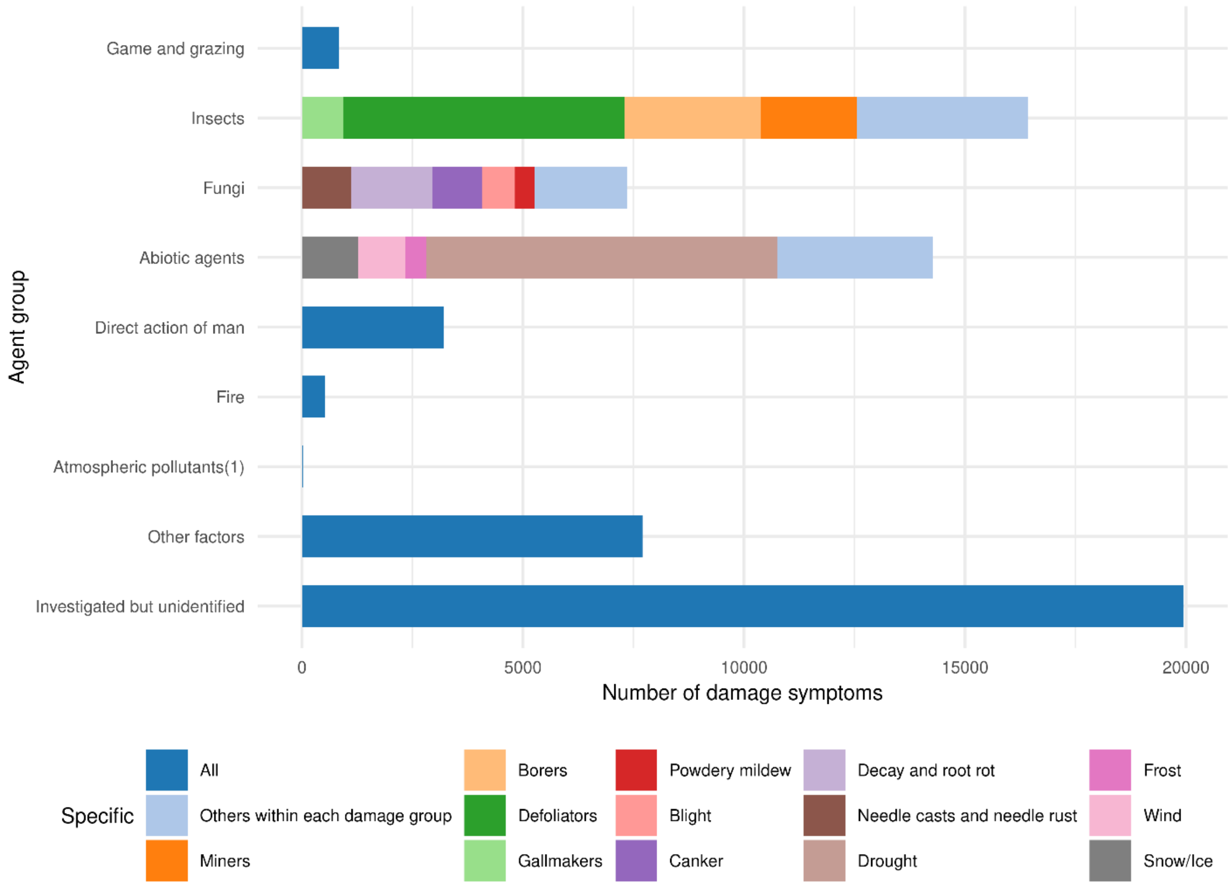


Figure 6-4: Number of damage symptoms (n=70 300) according to agent groups and specific agents/factors in 2022. Multiple damage symptoms per tree were possible, and dead trees are included. (1) Visible symptoms of direct atmospheric pollution impact only

EVALUATIONS

The occurrence of damaging agent groups differed between major species or species groups (Figure 7-5). Insects were the most important damaging agent group for deciduous temperate oaks (causing 38.7% of all damage), common beech (36.1%) and deciduous (sub-) Mediterranean oaks (32.6%), while insect damage was not so common in Scots pine (8.2%) and Norway spruce (7.4%). Abiotic factors caused by far the most damage in evergreen oaks (46.8%) and Mediterranean lowland pines (40.9%), and the least in Austrian pine (12.4%) and Scots pine (11.5%). Fungi were important damaging agents for Austrian pine (19.4%), and evergreen oaks (15.6%). Direct action of man was of little importance for most species, apart from Norway spruce (15.5%) and Scots pine (7.9%). Damage from game and grazing played a minor role for all species and species groups except for Norway spruce (10%). Fire affected mostly Mediterranean species: 2.3% of Mediterranean lowland pine trees, 2.1% of Austrian pines and 0.8% of evergreen oaks were affected. Other identified factors, such as competition, European mistletoe (*Viscum album)* and European ivy (*Hedera helix*), were prominent in Scots pine (25.9%) and Austrian pine (20.7%). The percentage of recorded but unidentified damage symptoms was small in evergreen oaks (10.6%) but large for Norway spruce (40.3%), Scots pine (33.2%), and deciduous (sub-) Mediterranean oaks (31.3%).

The most important specific damaging agents for common beech were mining insects causing 20.3% of the damage symptoms, followed by defoliators (9%), drought (6.5%), and silvicultural operations (4.0%). Defoliators were also frequently causing damage on deciduous temperate oaks (11.7%), while sucking insects (9.1%), borers (8.6%), drought (6.3%), powdery mildew (4.9%), and competition (3.1%) were also significant. For deciduous (sub-) Mediterranean oaks, drought (11.4%) was the most common damaging agent, followed by defoliators (9.4%), sucking insects (8.8%), borers (8.4%), and European ivy (3.6%). Drought was by far the most important damaging agent for evergreen oaks (43.6%), but also borers (12.5%), decay and root rot fungi (11.1%), defoliators (4%), and blight (3.6%) had an impact on these oak species.

Most damage symptoms in Scots pine were caused by various effects of competition (14.2%), followed by *Viscum album* (7%), needle cast/needle rust fungi (5.4%), borers (4.9%), silvicultural operations (4.9%), wind and drought (3.6% each). For Norway spruce, silvicultural operations (10.2%), competition (7.2%), red deer (6.3%), borers (5.1%), mechanical/vehicle damage (4.8%), and snow/ice (4.5%) were most important. Defoliators were causing most damage (18.1%) on Austrian pine trees, but *Viscum album* (16.6%), needle cast/needle rust fungi (11.5%), drought (7.1%), and blight (5.4%) also caused considerable damage. Mediterranean lowland pines were mostly affected by drought (29.6%), defoliators (7.2%), sucking insects (6.6%), snow/ice (4.9%), and *Viscum album* (4.8%).

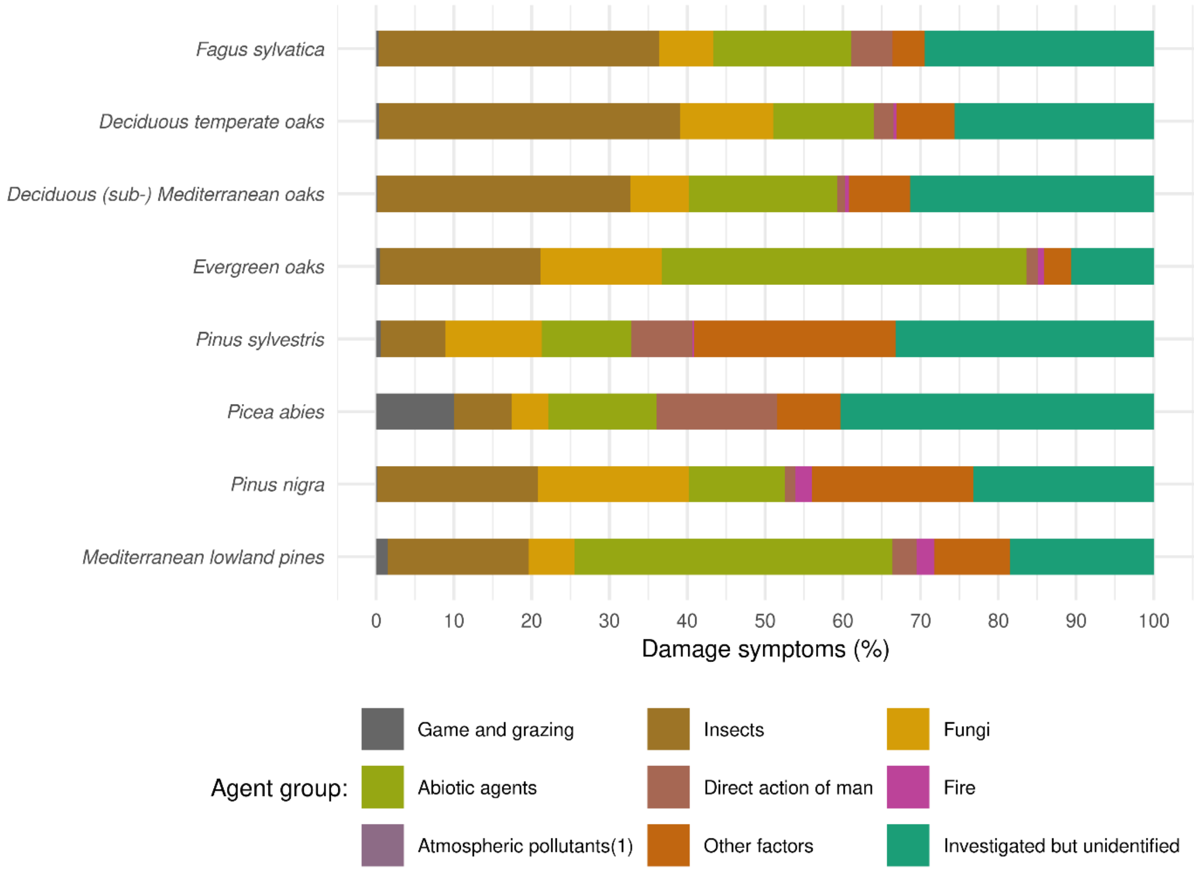


Figure 7-5: Percentage of damage symptoms by agent group for each main tree species and species group in 2022. (1) Visible symptoms of direct atmospheric pollution impact only

Regional importance of the different agent groups

Damage caused by abiotic factors was reported from 2 008 Level I plots (38%), occurring frequently throughout Europe. Countries most affected by abiotic factors were Spain, Slovenia, Montenegro, and Cyprus.

Damage caused by insects was observed on 1 731 European Level I plots in 2022, which corresponds to 32% 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 1 321 European Level I plots (25%), and was frequently occurring in many countries, most notably in Estonia, Slovenia, Montenegro, parts of Serbia, Poland, Bulgaria, and Spain. Low occurrence of damage by fungi was observed in Norway, Sweden, Italy, Türkiye, and Greece.

The damaging agent group 'Direct action of man' impacted trees on 1 027 plots (19%) and was most frequently occurring in eastern parts of Europe and south-western Germany.

Damage caused by game and grazing was most frequently observed in the Baltic countries, Hungary, and Spain. In total, 280 Level I plots (5%) had trees damaged by this agent group.

There were 59 plots (1%) with damage inflicted by fire, most of them located in Spain.

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

Tree mortality and its causes

There were 873 (0.9%) new dead trees in the damage assessment 2022 (466 broadleaves and 407 conifers). The highest numbers of dead trees were found for Norway spruce (206 trees, corresponding to a mortality rate of 1.9%), downy birch (*Betula pubescens,* 134 trees, corresponding to 5.5%), and Scots pine (104 trees, corresponding to 0.6%). Mortality rates for the main species and species groups were in the range from 0.3 to 0.7% (with the exception of Norway spruce). Most dead trees were reported from Norway (201, mainly downy birch), Germany (121, mainly Norway spruce), Türkiye (90, mainly *Pinus brutia*), and Italy (71). The main cause of mortality to both coniferous and broadleaved trees were abiotic factors (Figure 7-6), followed by insects, fungi, and fire. The determination of the cause of tree mortality is often very difficult; it could not be identified for more than 60% of the dead trees in 2022.

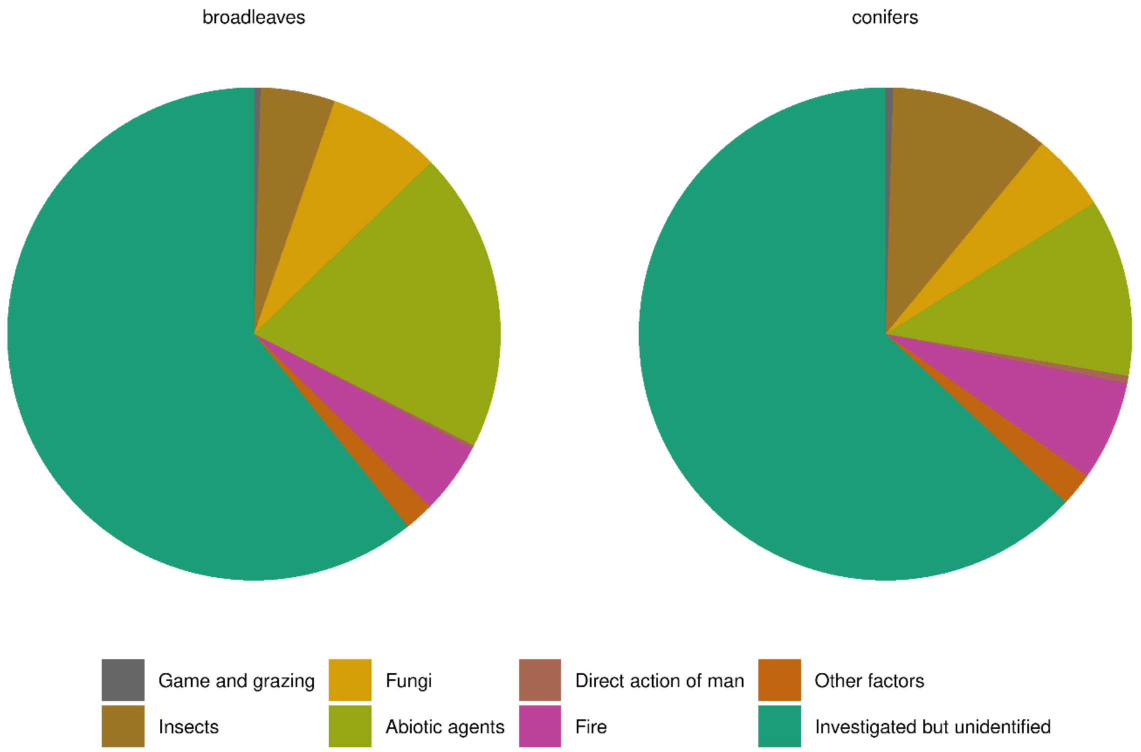


Figure 7-6: Percentage of damaging agent groups causing mortality of broadleaved and coniferous trees in 2022 (n = 873)

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

References

Becher G, Lorenz M, Haelbich H, et al (2014) **Tree crown condition and damage causes.** In: Michel A, Seidling W, Lorenz M, et al (eds) Forest Condition in Europe: 2013 Technical Report of ICP Forests, Thünen Working Paper 19:10–54

Ciais P, Reichstein M, Viovy N, et al (2005) **Europe-wide reduction in primary productivity caused by the heat and drought in 2003.** Nature 437:529–533

Curtis CJ, Simpson GL (2014) **Trends in bulk deposition of acidity in the UK, 1988-2007, assessed using additive models.** Ecol Indic 37:274–286

Dănescu A (2019) **Results of the International Cross-Comparison Course 2019 for Central and Northern Europe.** https://www.icp-forests.org/DocsCrown/Report_FieldICC_June_2019-min.pdf

Drápela K, Drápelová I (2011) **Application of Mann-Kendall test and the Sen's slope estimate for trend detection in deposition data from Bílý Kříž (Beskydy Mts., the Czech Republic) 1997-2010.** Beskydy (Brno) 4(2):133–146

Eichhorn J, Roskams P (2013) **Assessment of Tree Condition.** In: Ferretti M, Fischer R (eds) Forest Monitoring – Methods for terrestrial investigations in Europe with an overview of North America and Asia. Elsevier, Amsterdam, 139–167

Eichhorn J, Roskams P, Potočić N, et al (2020) **Part IV: Visual Assessment of Crown Condition and Damaging Agents.** Version 2020-3. In: UNECE ICP Forests Programme Coordinating Centre (ed.): Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests. Thünen Institute of Forest Ecosystems, Eberswalde, Germany, 49 p. ISBN: 978-3-86576-162-0. http://icp-forests.net/page/icp-forests-manual

Eickenscheidt N (2015) **Results of the International Cross-Comparison Course** in Witzenhausen, Germany, 11–13 June 2014

Helsel DR, Frans LM (2006) **Regional Kendall test for trend.** Environ Sci Technol 40(13):4066–4073

JRC (2019) **Map: Europe – Drought Situation: June–July 2019.** https://erccportal.jrc.ec.europa.eu/ercmaps/ECDM_20190822_Europe_Drought.pdf

Marchetto A (2015) **rkt: Mann-Kendall Test, Seasonal and Regional Kendall Tests.** R package version 1.4. https://CRAN.R-project.org/package=rkt

Meining S, Morgenstern Y, Wellbrock N, et al (2019) **Results of the European Photo International Cross-comparison Course 2017** (Photo-ICC 2017) https://www.icp-forests.org/DocsCrown/Results_Photo%20ICC%202017_final.pdf

Meining S., Morgenstern Y., Wellbrock N., Knapp, N.; **Results of the European Photo International Cross-comparison Course 2021 (Photo ICC 2021) as a part of the quality assurance of the crown condition assessment.** https://www.icp-forests.org/DocsCrown/Report_PhotoICC2021Report_E_V3.pdf

R Core Team (2016) **A language and environment for statistical computing.** R Foundation for Statistical Computing. Vienna [http://www.R-project.org/]

Seidling W (2007) **Signals of summer drought in crown condition data from the German Level I network.** Eur J For Res 126:529–544

Seletković I, Potočić N, Ugarković D, et al (2009) **Climate and relief properties influence crown condition of Common beech (Fagus sylvatica L.) on Medvednica massif.** Periodicum Biologorum Vol 111(4):435–442

Sen PK (1968) **Estimates of the regression coefficient based on Kendall's tau.** J Am Stat Assoc 63:1379–1389

Timmermann V, Potočić N, Sanders T, et al (2016) **Tree crown condition and damage causes.** In: Michel A, Seidling W (eds). Forest Condition in Europe: 2016 Technical Report of ICP Forests. BFW-Dokumentation 23/2016, Vienna, pp. 20–59

Wellbrock N, Eickenscheidt N, Haelbich H (2014) **Tree crown condition and damage causes.** In: Michel A, Seidling W (eds) Forest Condition in Europe: 2014 Technical Report of ICP Forests, BFW-Dokumentation 18/2014, Vienna, pp. 11–71

8

ICP FORESTS MEMBER STATES' VIEW ON THE CURRENT ICP FORESTS STRATEGY AND FUTURE ACTIVITIES

Kai Schwärzel, Anne-Katrin Prescher

Background and aims of the questionnaire

The current ICP Forest Strategy was adopted at the 32nd Task Force meeting in 2016, and expires at the end of 2023. Therefore, at the meeting of the Programme Co-ordinating Group (PCG) in November 2022, a working group was formed to develop a new strategy for the period 2024 to 2030. At this meeting, it was decided to ask the member states' views on the strategy by means of a questionnaire. The aim was, on the one hand, to get to know the views of the ICP Forests member states on the strategy currently in force and, on the other hand, to take account of the partners' ideas in the development of the new strategy.

The questionnaire consisted of 24 questions, divided into questions on the relevance and validity of the current strategy, on the priorities of the member countries in relation to forest environmental monitoring, and on the countries' views on the future of program-related monitoring activities.

ICP Forests member states' view on the current strategy

22 out of currently 31 active member states of ICP Forests have completed the questionnaire and two other countries have partially answered it. 88% of the member states participating in the survey are familiar with the current strategy, and all countries that participated in the survey agree or strongly agree with the objectives of the current ICP Forestry Strategy listed below:

- Forest condition. Provide a continued overview on forest health, vitality, forest soil condition and biodiversity status in relation to anthropogenic (air pollution, atmospheric deposition, climate change) and natural stressors.
- Cause-effect relationships. Contribute to a better understanding of cause-effect relationships between anthropogenic as well as natural stressors and forest condition and processes.
- High quality data. Provide high quality and open access data managed in one central database for risk assessment for forests across Europe, large-scale and long-term trend analyses as well as model validation and calibration, serving also as a reference for global assessments.
- Research Infrastructure. Develop and maintain highly equipped forest measurement stations as central data hubs and standardized forest monitoring and research infrastructures (RI) across Europe.

We then asked whether the objectives and actions listed in the current strategies for achieving the ICP Forests vision are still valid. For this purpose, we defined different priority levels and asked the member states to answer this question from a national perspective and from an international perspective. Table 1 summarizes the member states' responses separately for national and international priorities. This table shows that the objectives and measures of the current strategy remain an essential or high priority for member states at the international level. With some exceptions, this is also true when member states look at objections and activities from a national perspective. The exceptions are objectives and activities that are more relevant to the program at the international level, such as "Stress the global importance of air pollution monitoring by closer co-operation with networks outside Europe" or "Follow-up on relevant international policy issues and offer collaborations". Of course, this plays a lesser role at the national level and therefore the priority from a national perspective is much lower than from an international perspective.

Another issue in evaluating the ICP Forests Strategy currently in place was whether goals or actions were missing. This question was denied by 81% of the member states participating in the survey. However, it was noted that the strategy highlights air pollution, but changes in climate and biodiversity should play a more visible role. Other comments were that ICP Forests should increase the visibility of ICP Forests methods and data to encourage collaboration with other networks, or that linking remote sensing technologies and ICP Forests data would be desirable.

Table 8-1: Priorities of objectives and measures of the current strategy from the perspective of member states, separated into international and national (in brackets) perspectives.

Objectives and actions	Priority		
	No answer No or low priority	Neutral	Essential / high
Intensify coordination of the national monitoring activities by offering standardized infrastructure to potential users	4% (4%)	12% (27%)	84% (69%)
Broaden the scope of monitoring	4% (4%)	12% (12%)	84% (84%)
Follow-up on relevant international policy issues and offer collaborations	0% (0%)	0% (31%)	100% (69%)
Strive for long-term financing of activities	0% (4%)	4% (12%)	96% (84%)
Increase the visibility of ICPF	0% (0%)	8% (12%)	92% (88%)
Foster a high quality and transparent database	0% (0%)	4% (8%)	96% (92%)
Strive towards maintaining used field measurement methods at the latest state of the art to guarantee for high quality data	0% (4%)	8% (19%)	92% (77%)
Explore new tools and technologies	4% (12%)	31% (31%)	66% (57%)
Use monitoring data for testing cause-effect relationships, long-term trend analyses, modelling	0% (0%)	8% (15%)	92% (85%)
Enhance cooperation with sister ICPs	4% (15%)	8% (54%)	88% (31%)
Stress the global importance of air pollution monitoring by closer cooperation with networks outside Europe	12% (31%)	4% (42%)	86% (27%)
Encourage and increase future collaborations with other research activities and monitoring platforms	0% (4%)	15% (23%)	85% (73%)
Feed information into other bodies/programs (e.g. FAO, Forest Europe)	0% (16%)	8% (23%)	92% (41%)

National use of the current ICP Forests Strategy

We were also interested in learning whether the strategy was receiving attention at the national level. 65% of the countries participating in the survey have used or referred to the current strategy in their national work in the last 5 years, and 61% of the countries participating in the survey are planning to use the ICP Forests Strategy in their national work in the years to come. In 13 of the 24 countries (54%) participating in the survey, the current ICP Forests Strategy has helped to strengthen national monitoring activities. Moreover, the current ICP Forests Strategy has helped secure long-term funding for national monitoring activities (infrastructure and staff) in a third (33%, 8 countries) of the countries participating in the survey.

Member states' views on expanding the ICP Forests activities

The third part of the questionnaire dealt with the future of ICP Forests. We asked whether the focus of ICP Forests should be expanded, and for this we listed concrete topics for increasing its scope. 89% of the countries participating in the survey agreed that the ICP Forests activities need to be expanded to better address rising issues other than air pollution. Table 8-2 shows the member states' priorities for the proposed topics, which are increasingly relevant in research, practice, and policy.

For 88% of the countries participating in the survey, the expansion of the strategy through topics such as 'Interaction with climate change and extremes' or 'Impact on carbon sequestration' are of high to essential priority. And for about half of the countries participating in the survey, topics such as 'Water purification' or 'Heavy metals as additional pollutants' are of high to essential priority for the new strategy. Other topics such as 'Pesticides/Insecticides', 'Microplastics', or 'Per- & polyfluoroalkyl substances' were considered as less relevant for ICP Forests.

Summary and conclusions

The survey results show that the current strategy is still relevant and timely. The strategy has helped in many member states to (i) strengthen monitoring activities and (ii) secure financial resources for monitoring infrastructure and staff. However, financial resources for monitoring infrastructure and personnel are always an issue; more activities to secure the program are highly desirable. Activities to expand the program were included in the new ICP Forests Strategy (s. b.).

Table 8-2: Member states' priorities for proposed topics to expand the ICP Forest Strategy.

Objectives and actions	Priority		
	No answer No or low priority	Neutral	Essential / high
Interaction with climate change and extremes	8%	4%	88%
Impact on carbon sequestration	8%	4%	88%
Impact on biodiversity	12%	8%	80%
Heavy metals as additional pollutants	23%	31%	46%
Impact on water purification	23%	31%	46%
Pesticides/ insecticides as additional pollutants	46%	31%	23%
Microplastics as additional pollutants	35%	46%	19%
Per- & polyfluoroalkyl substances as additional pollutants	35%	46%	19%

STRATEGY OF ICP FORESTS 2024–2030

This strategy is based on the previous ICP Forests Strategy 2016–2023, which has been revised by (in alphabetical order) Nathalie Cools, Bruno De Vos, Marco Ferretti, Char Hllgers, Alexa Michel, Anne-Katrin Prescher, Marcus Schaub, Kai Schwärzel, and Lars Vesterdal. It has been approved by the ICP Forests Task Force in July 2023.

I ICP FORESTS in short

The 'International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests' (ICP Forests) is a work program within the 'Working Group on Effects' (WGE) of the 'Convention on Long-range Transboundary Air Pollution' (Air Convention or CLRTAP) under the United Nations Economic Commission for Europe (UNECE). ICP Forests is led by a Chairperson and administered by its Programme Co-ordinating Centre (PCC). The general assembly of the participating countries is the Task Force (TF) of ICP Forests. The Programme Co-ordinating Group (PCG), the Scientific Committee (SC), the Quality Assurance Committee (QAC), the Expert Panels (EP), the Working Groups (WG), and the National Focal Centres (NFC) contribute to the Program.

II Mission statement

The mission of ICP Forests is to carry out multifunctional long-term monitoring of forests within the UNECE region and beyond, and to provide scientific knowledge on the effects of air pollution, climate change, and other stressors to forest ecosystems.

III Aims

ICP Forests pursues the following aims:

- **Forest condition.** Provide a continued overview on forest health, vitality, forest soil condition, and biodiversity status in relation to anthropogenic (air pollution, atmospheric deposition, climate change) and natural stressors.
- **Cause-effect relationships.** Contribute to a better understanding of cause-effect relationships between anthropogenic as well as natural stressors and forest condition and processes.
- **High quality data.** Provide high quality and open access data managed in one central database for risk assessment for forests across Europe, large-scale and long-term trend analyses as well as model validation and calibration, serving also as a reference for global assessments.
- **Research Infrastructure.** Develop and maintain highly equipped forest measurement stations as central data hubs and and research infrastructures (RI) to support standardized forest monitoring across Europe.

iV Features of the current programme

ICP Forests works at two levels:

- The systematic large-scale monitoring **(Level I)** provides periodic overviews of the spatial and temporal variation in forest health, vitality, and forest soil condition.
- The intensive monitoring **(Level II)** is carried out on permanent, highly equipped forest monitoring plots to foster integrative studies on cause-effect relationships based on consistent and harmonized long-term data series.

All monitoring activities are described in the "Manual on methods and criteria for harmonized sampling, assessment, monitoring, and analysis of the effects of air pollution on forests". This ensures reliable and consistent information and quality assurance by a standardized approach for data collection and evaluation.

Quality assurance and control

A consistent quality assurance is guaranteed for the set-up of methods, data collection, submission, validation, as well as reporting and publishing. This includes field checks, inter-calibration and cross-comparison courses, inter-laboratory ring tests, data validation procedures, and internal reviewing.

Data and database

A large range of data is provided. All data are stored in a central database and managed according to agreed guidelines as laid down in the Manual. Data are available for internal and external use upon request.

Evaluation, reporting and publishing

ICP Forests

- publishes annual **technical reports** on main scientific topics including long-term effects from e.g. acidification, eutrophication, ozone and other relevant impacts on forest ecosystems;
- publishes **ICP Forests Briefs** with concise information on the monitoring program and its latest scientific findings addressing policymakers and the interested public;
- publishes **scientific papers** in peer-reviewed scientific journals addressing the scientific community;

- organizes scientific conferences and strives to publish **proceedings** to foster the exchange among scientists, stakeholders and policy makers;
- encourages participating countries to publish **national forest reports**, which complement and support the ICP Forests dissemination efforts.

V Vision for the future

Our vision is a European-wide forest monitoring infrastructure, integrating multiple levels and providing high-quality, transparent, robust, and open access data (i) on the status and trends of forest health, vitality, productivity, and biodiversity; (ii) on risks of forests being exposed to anthropogenic and natural stressors (separately and combined), and (iii) on progress in achieving relevant policy goals to reduce such risks.

VI Objectives and actions

We focus on new challenges for forest health, vitality, and diversity in relation to the impact of transboundary air pollution and climate change to further develop the ICP Forests program in the next period (2024–2030). To support the work towards our vision, ICP Forests is committed to:

- **intensify the co-ordination** of the national monitoring activities by offering standardized methodologies, research infrastructure and facilities to potential users, such as forest authorities, environmental agencies, and research institutions, for additional research activities complementing the central purpose and data, thereby deriving improvements and/or extensions such as long-term experimental monitoring sites to the program;
- **broaden the scope of monitoring activities** for the unique long-term data series of traits and processes in forest ecosystems by investigating topics such as climate change effects, ecosystem services (carbon sequestration, water provision and purification), heavy metals as additional pollutants, and biodiversity across extended spatial and temporal scales;
- **follow-up on relevant international policy issues** by offering collaboration and scientific expertise background for forest related policies and providing advice to national and European policy makers;
- **strive for long-term financing** of activities, particularly including the maintenance of existing infrastructure and required staff as well as exploring more mechanisms for sustainable funding;
- **increase the visibility** of the program to improve the acknowledgement as well as the funding opportunities by (i) organizing scientific conferences, conference sessions, and workshops (partly in co-operation with other ICPs and forest research organizations), (ii) publishing peer-reviewed scientific articles in highly ranked journals and brochures, and educational videos for the general public and political stakeholders, (iii) launching a new comprehensive ICP Forests website, and (iv) regularly assessing the need for the use of social media;
- **foster a high quality and transparent database** and work towards open access to researchers and stakeholders;
- **strive towards maintaining field measurement methods** at the latest state-of-the-art to guarantee for high-quality data; a review of the Manual every five years and Expert Panel meetings continuously promote the awareness and discussions on the latest methodologies and instrumentation while continuing the existing time series;
- **explore new tools and technologies** (e.g. satellites, remote sensors, proximal sensing, new analytical instruments, modelling tools, information technology) and strive to incorporate them into the program;
- **use monitoring data for** developing cause-effect relationships, long-term trend analyses, modelling (calibration, parameterization, and validation) and evaluating effects of forest management and environmental policy strategies;
- **enhance co-operation with other ICPs** to promote integrated and cross-sectorial evaluations and reporting as well as unified measurement protocols through e.g. mutual funding and scientific conferences;
- **stress the global importance of air pollution monitoring** and increase the motivation to common activities by closer collaboration with monitoring networks inside and outside of Europe, such as NADP (USA) and EANET (East Asia), and by inviting members from SEE and EECCA countries into the ICP Forests network;
- **encourage and increase future collaborations** with other research activities and monitoring platforms by joint use of research infrastructures, open data access, data harmonization, federated databases, and large-scale scientific evaluations and hereby attain possibilities for an even more comprehensive terrestrial monitoring research program;
- **feed information into other bodies and programs** such as the FAO Forest Resources Assessment (FRA 2015 and its long-term strategy), the Ministerial Conference on the Protection of Forests in Europe (*Forest Europe*), the UN Convention on Biological Diversity (CBD), the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), the Framework Convention on Climate Change (UNFCCC), and other appropriate bodies, e.g. of the European Commission (EC).

VII Adoption

This strategy of ICP Forests is fully in line with the Long-term strategy for the Convention (2020–2030, ECE/EB.AIR/142/Add.2)[1], the Strategy for scientific bodies under the Convention on Long-range Transboundary Air Pollution (2022–2030 and beyond, ECE/EB.AIR/2022/10)[2], and the most recent work plan (ECE/EB.AIR/148/Add.1[3]) for the effects-oriented activities of the WGE under the Convention.

This document was adopted at the 39th Meeting of the Program Task Force of ICP Forests, 6–8 June 2023. By the end of 2023, ICP Forests develops a plan for how and when to work towards implementation of each of the actions. In the year 2027, a mid-term review of this strategy will take place.

VIII Diversity statement

ICP Forests is largely based on the scientific and technical development carried out within Expert Panels, Committees, and Working Groups. In appointing the chairs and vice-chairs for all these, ICP Forests strives for a high degree of diversity. ICP Forests welcomes participation in leadership from all ICP Forests member states, and positions itself against discrimination, as defined in the Secretary-General's Bulletin ST/SGB/2019/8 of the UN.[4]

APPENDIX 1: Area of implementation and member states

The ICP Forests Strategy 2024–2030 is targeted at all 51 Parties (as of January 2023) of the UNECE Convention on Long-range Transboundary Air Pollution (Air Convention): Albania[5], Armenia[6], Austria, Azerbaijan[3], Belarus[3], Belgium, Bosnia and Herzegovina[2], Bulgaria[2], Canada, Croatia[2], Cyprus, Czechia, Denmark, Estonia, Finland, France, Georgia[3], Germany, Greece[2], Hungary, Iceland, Ireland, Italy, Kazakhstan[3], Kyrgyzstan[3], Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Monaco, Montenegro, Netherlands, Norway, North Macedonia[2], Poland, Portugal, Republic of Moldova[2], Romania[2], Russian Federation[3], Serbia[2], Slovakia, Slovenia[2], Spain, Sweden, Switzerland, Türkiye[2], Ukraine[3], United Kingdom, United States of America, and the European Union.

ICP Forests has 42 members (as of January 2023): Albania, Andorra, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Montenegro, Netherlands, Norway, North Macedonia, Poland, Portugal, Republic of Moldova, Romania, Russian Federation, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Türkiye, Ukraine, United Kingdom, and the United States of America.

[1] https://unece.org/fileadmin/DAM/env/documents/2018/Air/EB/correct_numbering_Decision_2018_5.pdf

[2] https://unece.org/sites/default/files/2022-12/2215606E.pdf

[3] https://unece.org/sites/default/files/2023-06/ECE_EB.AIR_148_Add.1-2209220E.pdf

[4] Secretary-General's Bulletin ST/SGB/2019/8 (https://undocs.org/ST/SGB/2019/8) *1.2 Discrimination is any unfair treatment or arbitrary distinction based on a person's race, sex, gender, sexual orientation, gender identity, gender expression, religion, nationality, ethnic origin, disability, age, language, social origin or other similar shared characteristic or trait. Discrimination may be an isolated event affecting one person or a group of persons similarly situated, or may manifest itself through harassment or abuse of authority.*

[5] South East Europe (SEE) Programme of the EU

[6] Eastern Europe, Caucasus, and Central Asia (EECCA) region of the OECD

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
Ministry of Environment, Agriculture and Sustainability

Main activities/developments

The assessment of tree crown condition, Level I, was conducted on 12 plots of the national 4x4 km grid following the ICP Forests Manual. The assessment in 2022 included 290 trees (2 more trees have been sampled to replace 2 dead trees): 119 *Pinus sylvestris*, 139 *Pinus uncinata*, 5 *Betula pendula* and 27 *Abies alba*, covering the main subalpine forests in Andorra.

Major results/highlights

Results for 2022 showed a worsening trend in terms of crown condition, being the worst condition registered in recent years.

Pinus sylvestris and *Pinus uncinata* have have been affected the most severe in the crown, especially in the last 3 years, whereas *Abies alba* has been affected little in the crown.

In terms of overall defoliation, threre has been registered an important increase in moderate defoliation (from 19.4% in 2021 to 39.3% in 2022) to the detriment of the slight defoliation class. The percentage of not defoliated trees remains constant with 12% of the sampled trees.

The worsening in crown condition in the last 4 years is related to unfavorable climatic conditions during the vegetative period with lower rainfall and higher temperatures compared to the reference period (1981–2020).

Regarding causes of damage, in 2022, 20.3% of the trees showed signs of damage. The most common identified causes of damage were abiotic causes (wind damage, lightning scars, etc.) followed by biological agents such as the fungus *Cronartium flaccidum*. The presence of *Thaumetopoea pityocampa* has been decreasing in the last years, disappearing from all plots in 2021. In 2022, it has been detected in just one individual of *Pinus sylvestris*.

Outlook

Andorra joined Level I of ICP Forests in 2004 with 3 plots. Since 2006 the survey has been conducted annually increasing the number of plots to 12. Furthermore, since 2021 besides the crown condition survey following the ICP Forests 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 on all 16 plots wet deposition was collected and analyzed. Foliage samples were taken on all 16 plots. On 6 out of the 16 Austrian Level II plots – Level II core plots – also meteorological measurements, including measurement of temperature and moisture of the soil, were continued as well as collections of litterfall, chemical analysis of soil solution and measurements of tree increment via mechanical and electronic girth bands. Hemispheric Photographs were taken at all 6 Level II core plots to obtain Leaf Area Index. Work on the second soil survey has started in June 2021. The analysis of the collected samples will be finished within 2023.

In 2022, a new project on tree growth and artificial intelligence started; within the project tree growth characteristics will be assessed. Furthermore the influence of different obtained parameters on tree growth will be analyzed. As part of the project dendrometers on all 6 core measurement sites have been renewed. Anita Zolles started her PhD in autumn 2022 and will work on the dendrometer data obtained at the six core sites.

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.

We are planning to test IOT sensors (soil moisture and climate data) at our monitoring site in Mondsee.

Belgium Flanders

National Focal Centre

Level I: Geert Sieon
Level II: Arne Verstraeten (NFC), Johan Neirynck
Research Institute for Nature and Forest (INBO)

Main activities/developments

The Level I survey was performed on 78 plots and 1486 trees (865 broadleaves and 621 conifers, 4x4 km grid). The most important tree species are *Pinus sylvestris* (31.6%), *Quercus robur* (26.9%), *Fagus sylvatica* (10.0%), *Pinus nigra* subsp. *laricio* (9.8%), and *Q. rubra* (6.3%). Other broadleaved species are pooled in a subset with 14 species (together 15.0%). There are only a few other coniferous species in the survey (0.4%).

Major results/highlights

26.5% of the Level I sample trees were rated as damaged. Mean defoliation was 24.0% and 0.7% of the trees had died. The share of trees in defoliation classes 2-4 was higher in broadleaves compared to conifers (28.2% and 24.3%). Mean defoliation was highest in conifers, with 24.1% compared to 23.9% in broadleaves. Defoliation was high in *Quercus robur* and *Pinus nigra*, with 35.7% and 39.3% of the trees considered as damaged. *Quercus rubra* was the least affected species, with 9.7% of the trees showing more than 25% defoliation. The share of trees with moderate to severe leaf loss was 19.8% in *Pinus sylvestris*, 23.3% in 'other broadleaves' and 26.8% in *Fagus sylvatica*.

10.7% of the trees showed moderate to severe discoloration. The share of trees with more than 10% discoloration was highest in *Quercus robur* (22.3%). Oak mildew (*Microsphaera alphitoides*) infection was the main cause of discoloration on *Quercus robur*. The share of trees with moderate to severe discoloration was 10.8% in 'other broadleaves' and less than 10% in *Fagus sylvatica*, *Quercus rubra* and *Pinus spp*.

Fungal infection and insect defoliation are the main causes of biotic damage. The share of trees, moderately to severely affected by defoliators was high, especially in *Quercus robur* (38.0%). *Sphaeropsis sapinea* is a disease, known to become more infectious on weakened trees. Dieback of shoots, twigs and branches of *Pinus sylvestris* and *Pinus nigra* increased but was still limited. Shoot dieback was moderate to severe in 1.9% of *Pinus sylvestris* and 2.8% of *Pinus nigra*. Moderate to severe twig dieback was observed in 6.4% of *Pinus sylvestris* and 3.4% of *Pinus nigra*.

Weather circumstances impacted the health status. Storm events during winter caused damage in several plots. A part of the trees showed discoloration or defoliation caused by summer drought.

Seed production improved in comparison to 2021. In 33.6% of *Fagus sylvatica* and 16.8% of *Quercus robur* trees fruiting was common to abundant.

Compared to 2021 the share of trees with more than 25% defoliation increased by 8.1%p. Mean defoliation increased by 2.2%p. Crown condition deteriorated in all species, except in *Quercus rubra*. From 1995 to 2022, increasing trends in defoliation were significant for *Fagus sylvatica*, *Quercus robur*, the total of broadleaves, and the total of all species. *Pinus nigra* was the only species with a significant improvement in crown condition.

A survey on the condition of *Fraxinus excelsior* started in 2014, partly in Level I plots. In 2022, crown condition assessments were performed on 29 plots and 251 trees. Crown condition of *Fraxinus* was still deteriorating. The cause of the poor health status is *Hymenoscyphus fraxineus*. Since the start of the monitoring, 29.1% of the sample trees died.

For Level II, a study on long-term changes (8-16 years, available data till 2021) in the groundwater levels in 4 plots was carried out. Groundwater levels declined significantly in 3 plots. With the very wet year 2021 excluded, the decline was significant in all plots. Trends were more downward for the yearly mean and yearly highest groundwater levels, indicating that the impact is most pronounced during summer.

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

Sioen G, Verschelde P, Roskams P (2022) Bosvitaliteitsinventaris 2021. Results of the crown condition survey (Level I). Research Institute for Nature and Forest, Report 2022 (7). INBO, Brussels (in Dutch). ISSN:1782-9054, https://doi.org/10.21436/inbor.71783042

Verstraeten A, Neirynck J (2022) Daling van de grondwaterstanden in 4 Vlaamse bossen. Drop in the groundwater levels in 4 Flemish forests. Research Institute for Nature and Forest, Internal report. INBO, Brussels (in Dutch).

Outlook

The Level I and the Level II program will be continued, as well as the additional survey on the condition of *Fraxinus excelsior*. In certain core plots, the monitoring activities will be further developed in the prospect of eLTER Standard Observations.

Belgium Wallonia

National Focal Centre

Elodie Bay, SPW – Public Service of Wallonia

Main activities/developments

In 2022, data were collected on 7 plots for Level II/III and on 46 plots for Level I. To determine the cuttings and ageing of trees of the samples that had occurred since 2010 in Level I, a complete revision of the plots was conducted this winter.

A complete inventory of trees over a larger radius was carried out on each of the plots. With these data, the rules for selecting the trees to be observed were adapted to guarantee the representativeness of the sample. The number of spruce plots was also reduced due to bark beetle problems, this being offset by an increase in the numbers observed per plot. Plots with less than 50% coverage will be excluded from monitoring and replaced as appropriate.

Major results/highlights

A warm winter followed by a very cool start to spring accentuated the differences in the start of the growing season: early in the north and late in the south. The summer broke heat records and the drought impacted the stands located on difficult sites. Autumn, which was humid, made it possible to attenuate the negative effects of summer by allowing most species to continue their growing season until "normal" dates. However, in some southern plots, leaf fall occurred exceptionally early.

Since the 2022 observations were made before the peak of the drought, its direct effects are not visible in the network results. On the other hand, its indirect effects will probably be marked in the years to come.

- Although the peak of the bark beetle attack has passed, new damage continues to be observed, triggering the implementation of sanitary cuts. On the other hand, the health of the remaining trees, even in the absence of bark beetle attacks, is generally very poor, particularly since 2019, probably also due to the succession of drought episodes.
- The beeches have presented a worrying health situation since the beginning of the monitoring period. We observe small peaks in defoliation during years of high fruiting, but this phenomenon linked to the reallocation of nutrient resources is reversible. After deducting this effect, we observe a significant increase from 2019 to 2020, followed by a stabilization from 2020 to 2022. The impact of the dry periods of 2018 and 2020 therefore does not seem direct. The climatic conditions of the following summers (quite dry and very hot in 2019; very humid and cool in 2021) could accentuate or attenuate the effects of severe droughts.
- The increase in oak defoliation in 2019 was explained by an upsurge in spring caterpillars, but these attacks have since decreased. The sharp deterioration observed in 2021 would therefore be linked to another factor. It could also be a delayed effect of the droughts of 2018 and 2020, or on the contrary an effect of excessive humidity in 2021.
- For Douglas-fir, the sharp increase in defoliation in 2019 was attributed to a sharp increase in *Contarinia pseudotsugae* populations. The situation seems to have gradually improved since then. However, we occasionally observe old stands decimated by *Armillaria* attacks. The recovery of Douglas-fir plantations remains chaotic.
- In larch, the high defoliation values are mainly linked to a simplification of the architecture, with no significant branch mortality. No specific symptoms were observed. This simplification of branching could be linked to competition (current or ancient) for light, as well as to the conversion of lateral branches into fruiting branches. Fruiting is often very abundant in mature individuals.

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

See 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
  - Implementation of the sample revision on Level I

- 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 on 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 2022, large-scale forest monitoring (Level I) was conducted in 160 permanent sample plots on 5599 sample trees. Evaluations were carried out on four coniferous species: *Pinus sylvestris*, *Pinus nigra*, *Picea abies* and *Abies alba,* and nine braodleaved species - *Fagus sylvatica*, *Fagus orientalis*, *Quercus cerris*, *Quercus frainetto*, *Quercus petraea*, *Quercus rubra*, *Carpinus betulus*, *Castanea sativa* and *Tilia platyphyllos*. The total number of monitored conifer trees was 2429 (43.6%), while that of broadleaves was 3170 (56.4%).

Within the Level I forest monitoring, in 2022 the following activities were conducted:

- crown condition assessments in all 160 Level I sample plots (SPs);
- analysis of leaves/needles samples (foliar analysis) in 33 Level I SPs;
- analysis of soil samples in 18 Level I SPs - the physical and physicochemical properties, chemical composition by genetic horizons and layers;
- floristic composition and the phytocenotic structure of the shrub-grass sinusia in the plant communities of different associations in 33 Level I SPs;
- growth and yield of stands in 12 Level I SPs - determination of diameter, height and volume of stand.

Level II

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

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

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

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

Main activities were:

- Monitoring and Assessing Forest Health, March 2022
- Expert Panel on Ambient Air Quality meeting, April 2022
- Core Group of ESB Chapter AQ and Chapter OZ, November 2022
- Combined Expert Panel Meeting April 5-7, 2022, Prague, Czechia

Major results/highlights

The results of the large-scale monitoring programme conducted in relation to crown defoliation showed that in 2022 the monitored deciduous trees were in better condition than in 2021, with 74.6% showing class 0 (not defoliated) and 1 (slightly defoliated). The percentage among coniferous trees was 52.4%. Overall, there was an estimated reduction in the number of healthy and slightly defoliated trees, with 2.2% and 0.8% respectively for deciduous and coniferous trees. A slight decrease was reported in the share of class 4 (dead) trees, which is due to the establishment of new sample plots where all monitored trees were in good health condition.

In the studied sample plots, among the biotic factors of impact, representatives of both contributing stressors (leaf pathogens and defoliant insects) and secondary stressors (xylophagous insects and facultative parasites) were found. In 2022, mass attacks from fungal diseases and insect pests was not established.

In some areas, a strong presence of the invasive oak lace bug (*Corythucha arcuata*) has been established. The pest has expanded its distribution by increasing its population density compared to last year. The presence of this invasive alien species is seen as a real threat to oak forests in Bulgaria.

The increased development of fungal *pathogens Heterobasidion annosum*, *Dothistroma septosporum*, *Lecanosticta acicola*, *Cyclaneusma minus* contributes to the deteriorated condition of *Pinus sylvestris* and *P. nigra*. For spruce, attacks by the bark beetle *Ips typographus* are a potential danger.

Beech is not threatened by aggressive insect pests and destructive pathogens, but is highly sensitive to abiotic impacts. In 2022, damage from the main insect pests, *Orchestes fagi* and *Mikiola fagi*, was reported to be insignificant.

The health status of the *Castanea sativa* has deteriorated due to infection by *Cryphonectria parasitica*, causing necrosis on the stems and branches.

The observations in the sample plots for intensive monitoring (Level II) were focused on the influence of different stressors and the reaction of the ecosystem. The results of 2021 showed the following:

The main stress factor in the coniferous monitoring sample plots Yundola (SP0003) and the complex background station (CBS) Rozhen (SP0005), in consecutive years, has been ozone again. Irrespective of the fact that for the last 2 years the AOT40 indicator in the Yundola station region decreased, over the last 5 years the short-term target norm for vegetation protection was exceeded 1.2 times, while that for forest protection 2.3 times. The calculated values of AOT40 for CBS Rozhen in 2021 also decreased, as the short-term target norm for vegetation protection was not exceeded, and it is still 2 times higher than the target norm for forest protection. The ozone concentration in the area of the SP Staro Oryahovo is also higher, as the calculated AOT40 is 1.5 times higher than the target norm for forest protection.

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

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

Georgiev G, Georgieva M, Belilov S, et al (2022) Early detection of *Ips typographus* infestations by using Sentinel-2 satellite images in windthrow affected Norway spruce forests in Smolyan region, Bulgaria. Silva Balcanica 23(2). Pensoft 27-34.

Georgieva M, Belilov S, Dimitrov S, et al (2022) Application of remote sensing data for assessment of bark beetle attacks in pine plantations in Kirkovo Region, the Eastern Rhodopes. Forests 13(4), 620, MDPI Open Access Publishing, 2022, 1-15.

Georgieva M, Georgiev G, Mirchev P, Belilov S (2022) Sanitary state of the forests in the area of the Regional Directorate for Forestry of Kardzhali for the period 2011-2021. Forest Science, Special issue II:111-118.

Zaemdzhikova G, Markoff I, P. Mirchev P (2022) An indicator species of global warming in Bulgaria. Comptes rendus de l'Académie bulgare des Sciences 75(1):62-70.

Outlook

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

All Level II sample plots are included in the national network of monitoring sites in accordance with Art 9(1) of the NEC Directive. The data collected from these sites will provide a significant part of the information related to indicators used for monitoring the impacts of air pollution on terrestrial ecosystems (Art 10 (4(a))).

Croatia

National Focal Centre

Nenad Potočić, Croatian Forest Research Institute

Main activities/developments

The annual intercalibration course for crown condition assessment was successfully completed, and the annual crown condition survey was conducted on Level I plots. Level II activities were continued on all seven intensive monitoring plots.

Major results/highlights

Level I

Ninety-seven sample plots (2328 trees) on the 16 x 16 km grid network were included in the survey 2022, 1966 broadleaved and 362 coniferous trees.

The percentage of trees of all species within classes 2-4 has been on a slight increase lately - in 2022 it was 34.0% compared to 31.8% in 2021 and 30.1% in 2020. Broadleaves in 2022 had a lower percentage of defoliation within defoliation classes 2-4 (31.9%) than conifers (45.3%), respectively.

Most defoliated tree species in Croatia in 2022, based on the percentage of trees in classes 2-4, were *Pinus nigra* (82.4%) and *Fraxinus angustifolia* (58.0%). The least defoliated species were *Pinus halepensis* (26.5%) and *Quercus pubescens* (27.2%). A significant worsening of *Fagus sylvatica* crown condition was recorded, with the highest ever recorded percentage of trees in classes 2-4 (27.4%) compared to only 16.6% in 2021.

The most widespread damage was damage to leaves (36.0%), followed by damage to branches, shoots and buds (32.1%), and finally damage to the trunk (31.9% of all recorded damage). Most of tree damage was caused by insects (25.3%), especially sucking insects (14.1%). Next were abiotic agents with 19.8%, and fungi with 7.2% of all damage. Direct human activity accounted for 6.5% of all damage to forest trees. Despite a high number of recorded damage symptoms, damage extent was mostly in category 1 (0-10%).

Drought was a major damage factor in 2022. According to the C3S ERA5 dataset, several countries in western and southern Europe, including Croatia, saw the highest annual temperatures since at least 1950. Persistent low levels of European rainfall, in combination with high temperatures, led to widespread drought conditions.

Level II

Crown condition on our intensive monitoring plots usually depends a lot on biotic factors, but in 2022 the damage from *Corythuca arcuata* on plots 109 and 110, and the damage from *Rhynchaenus fagi* (plots 103 and 105) was significantly reduced.

Deposition of nitrogen and acid compounds recorded in 2022 on plots 109 and 110 was close, but not over the limit value of 15 kg N ha^{-1} yr^{-1}. Ground-level ozone concentrations in July were close to limit values. 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, Jakovljević T, et al (2023) Oštećenost šumskih ekosustava Republike Hrvatske – izvješće za 2022. godinu [The damage status of forest ecosystems in Croatia – a report for 2022] Hrvatski šumarski institut/Croatian Forest Research Institute. Jastrebarsko, Croatia. http://www.icp.sumins.hr

Outlook

Financing of the national forest monitoring programme in 2023 remains at a reduced level, therefore sampling of deposition and measurements of changes in circumference by fixed girth bands will be 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 Section

Main activities/developments

General information

Cyprus has been participating in the ICP Forests Program since 2001. The network of 19 permanent plots established in Cyprus State forests aims to collect the necessary data to support:

- 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, and
- monitoring of air quality and assessment of ozone injury on forests.

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

- Systematic large-scale monitoring plots
  Fifteen plots, covering an area of 0.1 ha each, have been established for monitoring Calabrian pine (*Pinus brutia*), Black pine (*Pinus nigra*), and Cyprus cedar (*Cedrus brevifolia*) ecosystems. In these plots, annual observations of crown condition and periodic sampling and analysis of soil and needles are carried out.

- Intensive monitoring plots
  Four plots, covering an area of 1 ha each, have been established for monitoring Calabrian pine (*Pinus brutia*) and Black pine (*Pinus nigra*) ecosystems. In two of these plots, all research activities mentioned above are carried out. These plots are equipped with appropriate instruments and equipment for the collection of samples, data, and information. The other two plots are partially equipped and only some research activities are carried out.

Cooperation and submission of data and results

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

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

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

Major results/highlights

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

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

Such measures are:

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

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

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

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

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

Outlook

- The Cyprus Department of Forests will continue to participate in the ICP Forests Program under the current regime.
- Although not falling under the ICP Forests targets, the Cyprus Department of Forests is running a number of research projects such as on biomass production and the 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

Level I regular assessment continued on 251 plots in 2022. The assessment of defoliation and other characteristics related to tree-crown condition was carried out on 8606 trees in total. A marked reduction in the total number of assessed plots and individual trees has occurred in the long run. The intensity of such a reduction began to increase in 2018, when the consequences of extensive damage to forest stands by bark beetle outbreaks and of other harmful factors (strong damaging wind, fungal pathogens) were manifested also on monitoring plots. As a result of an increase in salvage felling connected with stand regeneration, there gradually occur significant changes in the age and species composition of assessed stands that can disrupt the continuity of studied characteristics. It will require a specific approach to the assessment and interpretation of acquired data.

This year the co-operation of the NFC with the Czech University of Life Sciences Prague and Botanical Institute of the Academy of Sciences of the CR will continue in the field of continuous monitoring of stem size variation using point dendrometers while microclimate parameters (air humidity and temperature, soil moisture and temperature) will be measured in parallel.

In total, 15 Level II monitoring plots were assessed in 2022. The update of measuring equipment continued on seven core plots of Level II.

A joint expert seminar organized together with colleagues from the Slovak NFC was held on 11–13 May 2022 in the Podyjí National Park, Czechia. The agenda of this meeting included the results of monitoring within the ICP Forests program and their comparison between the two countries.

Major results/highlights

In comparison with the previous years the course of the growing season was much more benign. Temperatures in the particular months showed a deviation from the long-term average (1991-2020) from -2.1 to +2.5 °C and rainfall reached values in the range from 47 to 135% of the long-term average. It is noteworthy that the lowest value of monthly rainfall, 47% of the long-term average, occurred at the end of the vegetation period, in the month of October, when it was accompanied at the same time by the highest positive deviation of air temperature from the long-term average, +2.5 °C. The more benign course of climate in the growing season undoubtedly contributed to further improvement in the overall vitality of forest stands.

In the commercially most important category of mature conifers, similarly like in the last year, the defoliation percentage of class 2 (>25-60%) slightly changed when it increased from 70.8% in 2021 to 72.3% in 2022 while the defoliation percentages in class 0 and 1 (0-10%, >10-25%) decreased. In younger conifers (until 59 years of age) no greater change in the trend of defoliation occurred. In Norway spruce (*Picea abies*) a moderate impairment was observed as the defoliation percentage increased in class 2 (from 62.8% in 2021 to 65.2% in 2022) at the cost of class 0 (a decrease from 5.5% to 3.7%). In Scots pine (*Pinus sylvestris*) there was no obvious change in comparison with the previous year. In both main coniferous species, there was a slowdown and/or discontinuation of the positive trend of a slight decrease in defoliation in the last two years.

In broadleaves of the older age category (forest stands older than 59 years) no greater changes occurred in comparison with the last year. In younger broadleaves (stands younger than 59 years) a very moderate improvement was recorded when defoliation percentage increased in class 1 and defoliation percentage in class 2 decreased at the same time. The age category of older broadleaved stands shows differences between the main species. In oak (*Quercus* sp.) a moderate improvement was observed when the defoliation percentage in lower classes increased at the cost of higher classes. In beech (*Fagus sylvatica*) a moderate improvement of the condition continued for the second year when the percentage of healthy trees in class 0 increased from 24.6% in 2021 to 26.6% in 2022 while percent defoliation in class 1 and 2 proportionately decreased. In the long run, oak shows a dominant percentage of defoliation in medium class 2 and beech has the highest percentage in lower class 1.

Besides the evaluation of the health status, deposition, soil solution, litterfall and tree phenology were examined on seven core plots of Level II in 2022; soil characteristics (soil temperature, soil moisture and soil water potential) were continuously measured and stem radial growth was assessed using girth bands and electronic band dendrometers.

The results of monitoring the deposition of chemical compounds reveal the trend of a moderate decrease in sulphur deposition; on the contrary, nitrogen deposition is rather variable among years. On some plots a slight decrease in the total deposition of base elements was observed. The pH values of precipitation water are slightly increasing. The ongoing bark beetle outbreaks did not directly influence the deposition measurement on Level II plots; measurements are conducted in stands on all monitoring plots without necessary changes for the time being. In the course of 2021 automated stemflow collectors were installed on two plots with beech stands, hence for 2022 it will be possible to compare automatically measured amounts of stemflow with manual collections.

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

See 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 (2022) Monitoring zdravotního stavu lesa (Forest health condition monitoring). In: Knížek M, Liška J, editors (2022) Výskyt lesních škodlivých činitelů v roce 2021 a jejich očekávaný stav v roce 2022. Zpravodaj ochrany lesa. Supplementum 2022:64-68. Výzkumný ústav lesního hospodářství a myslivosti, Jíloviště. https://www.vulhm.cz/aktivity/vydavatelska-cinnost/zpravodaj-ochrany-lesa-supplementum/

Matula R, Svoboda M, Kopecký M, et al (2022) Nová monitorovací síť pro studium vlivu klimatu na lesy v České republice (New monitoring network to study the impact of climate on forests in the Czech Republic). Lesnická práce 101 (2):38-39, Kostelec nad Černými lesy. https://lmda.silvarium.cz/uuid/uuid:17f63f3c-1e0e-47a3-90ed-6c99df079585

Outlook

On Level I plots the activities will include regular dendrometric measurements on all plots with 5-year periodicity that will be synchronized with the dendrometric measurement on Level II plots (the next cycle is planned for the winter season 2024-2025). On Level II plots felled due to bark beetle outbreaks the monitoring of changes in carbon and nutrient cycles will continue. The collection of soil samples is envisaged to be done on all Level II plots for the period 2025-2026.

Denmark

National Focal Centre

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

Main activities/developments

Forest monitoring (Level II, Level I and NFI plots)

Major results/highlights

The national crown condition survey in Denmark showed only small changes in the forest health status of most tree species monitored. There was a slight decrease in the average defoliation of Norway spruce from 16% to 14%, and the average defoliation of Sitka spruce stayed on the same level as in 2021 (below 15%). Other conifers, mostly Scots pine and larch, also had lower defolation in 2022. For broadleaves the forest health monitoring showed a slight increase in average defoliation for beech (15% to 18%) and oak (19% to 23%), but average defoliation is still lower than a few years ago. The frequency of damaged trees (defoliation above 25%) increased from 15% in 2021 to 23% in 2022 for all monitored broadleaves, but dropped slightly from 13% to 11% for conifers. For beech, one of the main reasons for a higher average defoliation was fruiting, which was fairly widespread. Beech trees with heavy fruiting had a higher defoliation than trees with no or little fruiting. Ash is still impacted by ash dieback caused by the invasive fungus *Hymenoscyphus fraxineus*, but surprisingly the average defoliation decreased again in 2022 to 20%, the lowest since 2006 when the disease really began to impact ash forests in Denmark. Most of the apparent improvement is due to continuous removal of sick trees, meaning the population gradually consists of the most tolerant ash trees. The impact of ash dieback is also shown in the amount of ash found in the National Forest inventory, which shows that the frequency of ash has been halved since 2011.

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

Nord-Larsen T, Kvist Johannsen V, Riis-Nielsen T, Thomsen IM, Jørgensen BB (expected publication I 2023) Skovstatistik 2021 [Forest Statistics 2021] Unviversity of Copenhagen, 90 pp. [In Danish with English summary].

Outlook

Future developments of the ICP Forests infrastructure

We are currently testing and implementing methods for measuring ambient air quality and leaf area index.

Planned research projects, expected results

As mentioned previously, two of the four Danish Level II plots have been included in LTER-Denmark, eLTER and ILTER, and have obtained some national funding through the Roadmap2020 for increased cooperation between the intuitions within LTER-Denmark, and for expansion and updating of the Danish research infrastructures on these sites. In the coming period this will help funding the above-mentioned work re. implementing equipment for measuring ambient air quality and leaf area index, and hopefully this will in the future attract even more research co-operation using both Danish Level II data and the research infrastructures located at our Level II plots.

Estonia

National Focal Centre

Vladislav Apuhtin, Estonian Environment Agency

Main activities/developments

The health status of 2455 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). 1593 trees were Scots pines (*Pinus sylvestris*), 595 Norway spruces (*Picea abies*) and 267 deciduous species, mainly silver birch (*Betula pendula*). The observation period lasted from July 4 – October 31, 2022.

On Level II the following forest monitoring activities were carried out in 2022:

- chemical analyses of the deposition water collected throughout the year on 6 sample plots;
- chemical analyses of soil solution collected during 7 months (from April to October) on 5 sample plots;
- samples of litterfall were collected on one plot according to ICP Forests requirements;
- foliar samples collected in December 2021 were analyzed;
- soil samples were collected on 25 Level I plots.

Plot number 9, Tõravere, was attacked by bark beetles (*Ips typographus*) and as a result most of the sampling trees died. According to the ICP Forests Manual the plot was relocated and renamed to plot number 10 (Tõravere 2). All Level II activities will continue on the new plot from the beginning of 2023.

Major results/highlights

Level I

The total share of not defoliated trees, 47.8%, was 0.4%p higher than in 2021. The share of not defoliated conifers, 46.3%, was lower than the share of not defoliated broadleaves, 47.8%, in 2022.

The share of trees in classes 2 to 4, moderately defoliated to dead, was 8.6% in 2022 and 7.8% in 2021. The share of conifers and broadleaves in defoliation classes 2 to 4 were 9.4% and 8.6%, accordingly.

The share of not defoliated pines (defoliation class 0) was 49.0% in 2022, 1.9%p higher than in 2021. The share of pines in classes 2 to 4, moderately defoliated to dead, was 2.2%, lower than in 2021. The defoliation of Scots pines slightly improved in 2022. However the long-term trend of Scots pine defoliation shows no significant changes since 2010.

The health status of Norway spruces decreased in 2022. The share of spruces without crown damages was 38.3% and the share of trees with defoliation rate 10-25% was 46.1%. A long-term increase of defoliation in Norway spruce may be observed.

Compared to 2021, the share of healthy birches has improved by 8.7%p in 2022.

All trees included in the crown condition assessment on Level I plots are also regularly assessed for damage. In 2022, 3.8% of the living trees observed had some insect damage and 17.8% of them (mainly Scots pines) had symptoms of fungal diseases. Overall 42% of the trees had no identificable symptoms of any damage.

Visible damage symptoms recorded on Scots pine were mainly attributed to pine shoot blight (pathogen *Gremmeniella abietina*). Symptoms of shoot blight were recorded on 11.1% of the observed pine trees in 2022, compared to 10.0% in 2021. Norway spruces mostly suffered due to new bark beetle (*Ips typographus*) attacks, old moose damage, and root rot (pathogen *Heterobasidion parviporum*).

Level II

The annual average pH of the precipitation under throughfall was varying mainly between 5.5 and 6.5. In 2022, the observations showed some slight decrease of pH compared to 2021 on all plots. The content of chemical elements and compounds in analyzed precipitation water was low. Compared to several past years, the content of nitrogen compounds, sulfate and calcium ions decreased in bulk deposition on all plots. Generally, the amount of precipitation in 2022 was lower in all plots in the northern part of Estonia and in Tõravere but in Pikasilla and Karula it was on average level.

The pH of the soil solution varied between 3.7 and 6.2 throughout the observation period. The content (concentration) of the nutrition elements and chemical compounds dissolved in the soil water of pine stands was in most cases also below the level of 2.5 mg/l. In 2022, similarly to the past years, the content of Na^+, Ca^{2+} and Cl^- in soil solution was considerably higher than 2.5 mg/l on all spruce sample plots. The concentration of Mg^{2+} and SO_4^{2-} -S in spruce stand at Karepa and K^+ in Tõravere was essentially higher than the level of 2.5 mg/l.

The chemical analyses of foliage, gathered in 2021, indicated that the concentration of nutrient elements in needles of sample trees has improved, but it was still below optimum value on the pine stands.

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

Apuhtin V, Timmusk T, Ejrpais M (2023) Forest Monitoring, Report of the survey 2022, Estonian Environment Agency, Tartu 2023

Yearbook Forest 2021, Estonian Environment Agency

Outlook

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

Finland

National Focal Centre

Päivi Merilä, Natural Resources Institute Finland (Luke)

Main activities/developments

Altogether eight Level II plots were monitored for atmospheric deposition, soil solution chemistry, meteorology, and stand growth. As two of the plots are in sapling stands, monitoring activities on the six plots representing mature forests also included litterfall, crown condition, and stand growth. In addition, tree increment was monitored using girth bands by manual recordings. The monitoring data of the year 2020 was submitted to the ICP Forests Database.

Finnish Level II plots are planned to become included in the eLTER network and three of them also belong to the ICP Integrated Monitoring Programme. The data from these three plots are also used to fulfill the information needs of the National Emission Ceiling Directive (NECD).

Major results/highlights

The study of Lindroos et al. (2022) investigated the accumulation of soil carbon in 14 Level II plots located in mineral soil forests. Carbon stocks in soil were determined in 1995, 2006, and 2016. In addition, the study identified how changes in soil carbon stocks are linked with various soil factors and forest characteristics. In mature spruce- and pine-dominated forests where the growing stock volume increased, the soil acted as a carbon sink. In turn, natural damage and roundwood removals reduced soil carbon stocks. Carbon stocks were higher in spruce forests than in pine forests, and the high volume of plant litter correlated with the size of carbon stocks in forest soil. On average, carbon stocks in forest soil (organic layer and the first 40 cm of the mineral soil layer) increased annually by 36 grams per square metre. The more organic matter of vegetation origin a forest had and the higher fertility a site had, the higher was the growth rate of carbon stocks in forest soil layers.

Launiainen et al. (2022) statistically analyzed water retention characteristics (WRC) of mineral forest soils from over 130 sites in Finland, focusing on the humus layer and main root zone. The study sites included BioSoil, Level II and NFI plots. They showed that mineral forest soils can be grouped into five WRC classes that are well predictable from soil bulk density, organic matter content and clay fraction. However, they found that neither topsoil maps nor any combination of open geospatial data were able to predict WRC. Thus, in the absence of site-specific soil data, parameterizing WRC as a function of forest site fertility type was proposed. The study showed that drought risks were highest for dense mature forests at nutrient-poor, coarse-textured sites and lower for young stands on peatlands and lowland herb-rich sites with groundwater influence. The results improve hydrological predictions for Finnish forests, and the open dataset can contribute to the larger synthesis and development of boreal forest soil pedo-transfer functions.

Antão et al. (2022) analyzed four decades of data for 1478 species of birds, mammals, butterflies, moths, plants and phytoplankton along a 1200 km high latitudinal gradient in Finland. The vegetation data utilized included 1700 sites surveyed in 1985-86 and in 1995 and a subset of 443 sites resurveyed in the BioSoil project in 2006. The relative importance of climatic drivers varied non-uniformly with progressing climate change. While species turnover among decades was limited, the relative position of species within their climatic niche shifted substantially. A greater proportion of species responded to climatic change at higher latitudes, where changes were stronger. These diverging climate imprints restructure a full biome, which makes it difficult to generalize biodiversity responses and raising concerns about ecosystem integrity in the face of accelerating climate change.

Outlook

Level II monitoring activities will continue on Level II plots in Finland. The data is continuously utilized in research and to fulfill the information needs of the NEC Directive. The Natural Resources Institute Finland participates in the Horizon Europe funded project FORWARDS. FORWARDS will capitalize on data from existing networks such as ICP Forests. The project aims at reconciliation the current divide between forest information obtained from the ground and remote sensing by incorporating the concept of Monitoring Supersites and novel approaches to more comprehensively characterize cause-effect relationships of forest disturbances.

France

National Focal Centre

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

Main activities/developments

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:

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

Level II

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

Thus in 2022, monitoring activities were continued on the 102 plots of the Level II network, with the same objectives and surveys. In detail, tree assessments (phenology, health, annual growth, and foliar nutrition) were performed on all these plots, while atmospheric deposition, meteo, soil solution and litterfall have been monitored only on a subset of plots. Also, the ozone survey (concentrations in the air and symptoms visible on the vegetation), that had been stopped for the past 5 years, was restarted for 5 years on the 14 most intensively monitored plots.

However, an additional effort is required to make the RENECOFOR network able to run for potentially 100 years or more, with the same capacity to detect the effects of air pollution and other environmental factors on forest ecosystems. This involves gradually replacing the plots that have been severely disturbed or have entered the stand regeneration phase, and which no longer meet the site conditions required by the network design (adult stand, dominated by a tree species of interest, and homogeneous over the plot area). An evaluation was conducted about the situation of each of them, to identify those which may recover suitable conditions within 15 years, and those that really need to be relocated in another site.

In parallel, a field campaign was continued to precisely georeference all trees and devices within each plot, so to keep being able to reuse the same exact location in the future, even after severe storm damage or plot replacement. Tree coordinates will also be useful to evaluate the heterogeneity of the stand, and the effect of tree competition on measured growth. Thirty-four plots were mapped by the end of 2022, but two new field crews could be finally recruited and trained with the help of the University of Louvain (Belgium) and will accelerate the campaign in 2023.

Also, as the first two plots are reaching their final cut, the data series initiated in 1992 needed to be completed with a 3rd soil sampling and a final growth survey before trees were being felled. In addition, the sample trees, that have been surveyed every year for their crown condition and phenology, were cored to retrospectively measure their annual growth, and sampled for a genetic characterization. Finally, the opportunity was taken to experiment Terrestrial Lidar scanning in one plot of maritime pine with the aim to keep a full picture of the vegetation cover before the harvest.

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

Goudet M (2022) Systematic network of forest damages, 2021 overview. Forest Health Department. https://agriculture.gouv.fr/telecharger/131828

Outlook

Level I

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

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

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

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

Level II

In 2023, efforts are to be further intensified to ensure very long-term monitoring of forest ecosystems in the RENECOFOR network.

- With the help of the two newly recruited field teams, the mapping campaign will be greatly accelerated, and potentially finalized before the end of 2023, on the remaining 68 plots.
- Additional sampling and measurements will be carried out in three other plots, where Norway spruce stands are directly threatened by the presence of bark beetles.
- Decisions must be taken with the scientific board of the RENECOFOR network whether disturbed plots should be relocated, which depends on their stand development and probability to recover (or not) to suitable conditions within 15 years. If plots are being reinstalled, it must be decided whether this should happen at the same location (after soil preparation and replantation) or at a new site of interest (e.g., in warm and/or dry margins of tree species distribution, where impacts of climate change are more likely to be observed).
- Also, the 3rd campaign for soil sampling should be prepared for launch, if possible by the beginning of 2024, for a probable duration of 4 to 5 years to cover all the 102 plots. The first two campaigns allowed the first evaluation of the dynamics of forest soil properties with comparable measurements at the national scale, which revealed a significant carbon sink of 0.35 t C ha^{-1} yr^{-1} on average over 15 years. So, the 3rd campaign aims at finding out whether the same dynamics continued over 30 years and to help understand it.

Germany

National Focal Centre

Juliane Henry, Federal Ministry of Food and Agriculture

Main activities/developments

Level I

The national training course for the forest condition survey in Germany took place 21–24 June 2022 in Gotha, Germany. The course was organized by the Thünen Institute of Forest Ecosystems in co-operation with Thüringen Forst.

Level II

Monitoring activities continued on 68 Level II plots, although major disturbances on an increasing number of plots restricts the continuation of measurements in line with the ICP Forests Manual. Technical equipment and instruments are regularly up-dated. In recent years, soil moisture measurements were intensified on many plots. Data from all Level II plots was included in the 2022/2023 submission for the reporting under the NEC Directive. The current submission comprised data for the 2009–2020 period and from eight surveys.

In April, 21 participants met for a spring phenology calibration course in Freiburg. The course covered the field training complemented by a photo course. The course allowed participants to discuss and compare their assessment of ten trees per main tree species. Differences in assessment were partly due to experience but also to differences in the delimitation of the observed part of the crown. It included photographs taken from the ground as well as by UAV. The course showed that the use of photographs represents a very useful instrument to provide training and calibration independent of constraints by time and location.

At a workshop in June, twelve participants discussed topics of particular research interest of the coming years. The workshop was part of an ongoing process to build a common strategy for the next decades of monitoring at Level II plots in the light of (1) ongoing global change and the resulting shift in public expectations, (2) changes on the plots including an increase in stand heterogeneity and disturbances, and (3) additional assessment opportunities thanks to novel technologies. Fifteen thematic fields with a total of 51 subcategories were identified by the participants. The four with the highest priority were: forest management, especially with regard to water and nutrient availability, ecosystem services and loss of ecosystem functions, impact of nutrient inputs, and climate protection as well as adaption of forests to climate change. The process continues with further workshops.

In September, 39 participants took part in a meeting of the technical staff in Mecklenburg-Vorpommern. At the meeting, they visited the Level II plot Sandhof, discussed technical challenges, and shared experience with different measurement instruments.

Major results/highlights

Level I

The 2022 crown condition survey took place on 406 Level I plots with a total number of 9736 sample trees. 38 tree species were recorded in the survey. Of those, 78% belonged to the four main tree species: spruce, pine, beech and oak (pedunculate and sessile oak are evaluated together). All other tree species were combined into the groups "other conifers" and "other broadleaf trees" for the statistical evaluation. Around 73% of the trees recorded are older than 60 years.

In 2022, defoliation on 35% of the forest area was classified as moderate to severe. Mean crown defoliation increased from 25.7% in 2020 to 25.9% in 2022.

Picea abies: The percentage of defoliation classes 2 to 4 decreased from 46% to 40%. 36% of the trees were in the warning stage. The share of trees without defoliation was 24% (2021: 22%). Mean crown defoliation decreased from 29.8% to 29.6%

Pinus sylvestris: The percentage of defoliation classes 2 to 4 increased from 25% to 28%. 59% of the trees were in the warning stage. Compared to 2018, the value has increased significantly by 13%. The share of trees without defoliation was 13% (2021: 16%). Mean crown defoliation increased from 22.9 % to 23.9%.

Fagus sylvatica: The percentage of defoliation classes 2 to 4 isz 45% and did not increase or decrease (2022: 45%). 34% of the trees were in the warning stage. The share of trees without defoliation was 21% (2021: 16%). Mean crown defoliation decreased from 28.1 to 27.5%.

Quercus pertrea and Q. robur: The share of defoliation classes 2 to 4 slightly decreased from 41% to 40%. 41% of the trees were in the warning stage. The share of trees without defoliation was 19% (2021: 19%). Mean crown defoliation decreased slightly from 26.9% to 26.1%.

All tree species fruited more in 2022. A very strong fructification, however, did not occur. The dieback rate increased in 2022 for spruce. For the deciduous tree species and pine, however, on the other hand, it has fallen slightly. Especially the older trees over 60 years of age are affected by dieback. But younger trees also show a negative trend.

Level II

A data set with interpolated meteorological time series for 78 German Level II plots from 1961 to 2019 was published. The use of a spatial hybrid interpolation routine that combines simple linear regression and inverse distance weighting allowed gap filling and the extrapolation outside of the measurement period. This is a first step to make “ready-to-use” data more available.

The WINMOL project improves storm damage models for managed forests at various scales. As part of the project, data from Level II plots was used to test vulnerability models for temperate forests. Storm damage information at the scale of individual trees is available through the growth and the crown condition surveys. The data can be related to the maximum gust speeds of the strongest storm event of the respective years. Almost all Level II plots have been affected by storm events: corresponding damages are recorded for 9% of spruce, 3% of beech, 3% of pine, and 1% of oak trees.

In a pilot study on three Level II sites, mercury inputs by wet deposition and litterfall were analyzed under beech and spruce, as well as in the open field. Results show that in the open field, wet mercury deposition ranged between 3.8 and 8.0 µg m^{-2} yr^{-1} and mostly depended on rainfall: mercury concentrations were almost identical at all three sites and corresponded to the ranges of five available measuring stations in non-forest ecosystems. Under beech, inputs in the leafy phase were significantly higher than in the non-leafy phase. Yearly inputs under spruce were higher than under beech. Comparison of mercury inputs through wet deposition with litterfall shows that the latter is more important for total mercury inputs: inputs with a litterfall range between 9.4 and 24.6 µg m^{-2} yr^{-1}.

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

Grottian L, Stadelmann C, Krüger I, Natkhin M (2022) Storm damage in forests: Insights into Level II data. Eberswalde: Thünen Institute of Forest Ecosystems, 2 p, Project Brief Thünen Institute 2022/26a, https://doi.org/10.3220/PB1662532532000

Outlook

New research projects on Level II plots include the TroWaK and the AkWaMo project. TroWaK aims at developing a high-resolution water balance model. Data from Level II plots will be used to parameterize and validate the models. The results will be the basis for an assessment of the risk for abiotic and biotic damages in forests affected by drought conditions.

AkWaMo envisages the integration of bio accustic monitoring into a long-term monitoring systen. Eight Level II plots will be equipped with recording devices to collect data on forest soundscapes. These acoustic signatures provide information on the occurrence, abundance and behavior of birds and other species and will be linked to environmental parameters.

Greece

National Focal Centre

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

Main activities/developments and major results/highlights

Level I

Crown condition assessment

For the assessment of the crown condition in 2022, data was collected from 35 plots, representing 35% of the total number of the Level I plots in our country. More specifically, in 2022 the number of trees counted was 819, whereas in 2021 the number of trees was 768. Of the 819 trees, 580 were conifers and 239 broadleaves.

The following table shows the results of the crown assessment for all tree species.

Crown assessment (Level I plots) (in %)

	All tree species	Conifer species	Broadleaved species
No defoliation	54.6	50.7	64.6
Slight defoliation	25.9	26.6	21.8
Moderate defoliation	17.0	19.0	12.1
Severe defoliation	2.4	2.6	2.1
Dead trees	0.1	0.2	0.0

In 2022, it was found that 80.5% of the trees assessed belonged to the classes "No defoliation" and "Slight defoliation". The corresponding values were 78.3% and 85.8% for conifers and broadleaves, respectively. Abiotic factors were the main causes for the loss of needles and leaves, followed by insect aattacks.

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 in the four plots have been measured for 50 years in the maquis, 26 years in the oak and beech, and 50 years in the fir plot. There was a significant increase in rainfall in 2021 for the maquis plot (79%) and the fir plot (25.5%), whereas for the oak and beech plots it decreased by 5.5% (see table below).

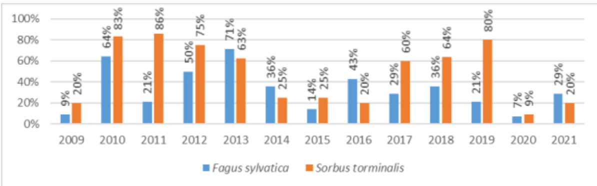
In addition, in all plots, the average annual air temperature was higher than the plot station's average value. More specifically, the increase was 2.0% in the maquis plot, 7.0% in the oak and beech plots, and 6.9% in the fir plot (see table below).

Rainfall and temperature values in three forested plots in 2021

	Maquis plot		Oak and beech plots		Fir plot	
	Temp. [°C]	Rain [mm]	Temp. [°C]	Rain [mm]	Temp. [°C]	Rain [mm]
2021	15.7	1907	13.6	1206	10.8	1828
Mean	15.4	1066	12.7	1275	10.1	1456

Ozone Injury

With regard to the symptoms of ozone injuries we have the following results: In the fir and maquis plots, no injury was observed, whereas in the oak and beech plots, which are located on same mountain, we found a few visible symptoms in beech (*Fagus sylvatica*) and checker trees (*Sorbus torminalis*). The percentages of damage in leaves of *F. sylvatica* and *S. torminalis* are shown in the below figure.



Crown condition assessment (Level II)

The crown assessment for the year 2021 in the four Level II plots comprised a total number of 163 trees (35 conifers and 128 broadleaves). The results showed an improvement in health in broadleaves and a small worsening in conifers compared to the results of previous years (see the following table).

Crown assessment (Level II plots) (in %)

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

Deposition

The table below shows the deposition fluxes (bulk and throughfall) of the major ions in the maquis, oak, and fir plots in 2021. The first, and rather striking, impression is that precipitation in the maquis plot was high in comparison with the mountainous plots. This was the reason that the fluxes of several ions were exceptionally high. It can be seen that there was retention of ammonium-N by the tree canopies of all plots (throughfall < bulk fluxes), whereas the nitrate-N retention took place in the fir and oak plots. This finding shows the efficiency of forests to absorb N from any source. The very high flux of Ca in the fir plot should be attributed to the dry deposition of Ca derived from the area of Africa by means of winds. The sulphate-S fluxes were higher in the throughfall in all plots. Sulphate-S is mostly deposited in dry form, whereas Mg and K depositions are connected with ion leaching from inside the plant cells. The dry deposition of sulphate-S in the oak and fir plots may have been caused by fossil fuel combustion for heating purposes.

Fluxes (kg ha^{-1} yr^{-1}) of major ions in deposition (throughfall (T) and bulk (B)) in three forest plots in 2021

Plots	Dep.	Ca	Mg	K	$SO4^{2-}$-S	NH_4^+-N	NO_3^--N	mm
Maquis	T	22.7	7.16	72.1	10.6	0.97	3.32	1607
	B	19.7	3.48	5.91	7.97	2.82	2.28	2068
Oak	T	16.6	4.61	17.1	16.1	3.91	2.33	848
	B	12.9	1.77	12.8	7.48	5.75	2.88	1189
Fir	T	41.4	4.88	26.4	9.4	0.95	2.01	1675
	B	18.5	1.94	6.73	7.2	3.23	2.55	2077

Litterfall

The percentage of foliar litter with regard to the total foliar mass was highest in the oak plot (81%). In the other plots, the percentages were: 68% for the maquis, 53% for the beech and 49% for the fir plot. The fluxes of all nutrients in the foliar fraction were higher in the oak plot probably because of the high quantites in foliar litterfall in 2021 (s. below table). The N flux in the foliar litterfall fraction was high in the oak plot but it had similar values (range 27-37 kg ha^{-1} yr^{-1}) in the rest of the plots.

In the non-foliar litter, the fir and beech plots had the highest mass amounts. The N amounts in the fir plot were impressive (higher than that in the foliar litterfall). The fir plot had also high amounts of P and S. The amounts of Ca and Mg in the oak and beech plots are important because both plots are situated on a mica schist parent material, which gives rise to acid soils. In these kinds of soils, Ca and Mg in litterfall fluxes can buffer the acidity. The amounts of Ca are high in the woody litterfall and for this reason it is advised that the logging remains should stay in forest soils to enrich the latter with base cations.

Total masses (TM, mg ha^{-1} yr^{-1}) and fluxes (kg ha^{-1} yr^{-1}) of major nutrients in litterfall in four forest plots in 2021

Foliar	**TM**	**Ca**	**Mg**	**K**	**S**	**N**	**P**
Maquis	3.04	42.3	4.48	10.8	2.57	27.1	1.47
Oak	5.79	102.0	12.1	12.0	5.38	52.9	3.01
Beech	2.97	66.3	5.79	2.97	2.42	20.4	0.76
Fir	3.63	93.6	4.75	11.8	3.53	37.2	3.61
Non-foliar	**TM**	**Ca**	**Mg**	**K**	**S**	**N**	**P**
Maquis	1.44	6.68	1.46	4.23	1.19	13.3	0.70
Oak	1.34	26.2	1.50	3.72	1.06	10.3	0.50
Beech	2.62	15.4	2.00	3.37	1.83	15.3	0.82
Fir	3.78	56.2	4.68	11.4	4.55	43.8	3.29

Outlook

We are planning to enrich the scientific team dealing with the forest ecosystems taking part in the ICP Forests monitoring to include tree physiology and forest genetics.

Hungary

National Focal Centre

Kinga Nagy, András Lászlók
National Land Centre, Department of Forestry

Main activities/developments

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

In 2022, 78 permanent plots with 1566 sample trees were included in the crown condition assessment. The survey was carried out between 15 July and 15 August. The percentage of broadleaves was 90.9%, while the percentage of conifers was 9.1%.

Major results/highlights

From the total number of sample trees surveyed, 10.9% were without visible defoliation, which shows a decrease in comparison with 2021 (22.8%). The percentage of the slightly defoliated trees was 22.7%, and the percentage of all trees within ICP Forests defoliation classes 2-4 (moderately damaged, severely damaged and dead) was 66.4%. The rate of the dead trees was 2.0% and 0.9% of all sample trees died in the surveyed year. The dead trees remain in the sample as long as they are standing but the newly died trees can be separated. The mean defoliation for all species was 41.3%.

Relatively big differences can be observed between the tree species groups in respect of the defoliation rates. In 2022, *Quercus robur* (pedunculate oak) was the most defoliated and damaged tree species group again. For several years now, a long-term decline in the health condition could be observed on *Quercus robur*. In 2022, there was no sample tree in defoliation class 0. The percentage of severely damaged trees within this species group increased from 10.8% (2021) to 22.7% (2022). *Quercus cerris* (Turkey oak) and *Pinus nigra* (black pine) are also among the most severely damaged tree species. In 2022, the percentage of the sample trees without defoliation is 1.5% for Turkey oak and 3% for black pine.

The least defoliated tree species was *Pinus sylvestris* (Scots pine) with 31% mean defoliation. The proportion of healthy *Carpinus betulus* (Common hornbeam) decreased dramatically within a year - from 59.3% to 17.5%.

Discoloration can rarely be observed in the Hungarian forests, 92.2% 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 2022, insects were the most frequent damaging agents (31.3%). Most of the observed damage was caused by defoliators and sucking insects. In recent years, the oak lace bug (*Corythucha arcuata*) has been spreading across the Hungarian forests (as well as in Europe's) and it has become a common and dangerous pest of *Quercus* species. Although in 2022, according to our observations the size of the populations decreased in comparison with the last year regarding the sample areas – perhabs due to severe droughts and heat waves. Abiotic damage was the second most frequent damaging agent: the proportion (29.5%) was barely less than the damage caused by insects.

Fungal damages (18.6% of all damages) were observed most frequently on *Quercus* species and *Pinus nigra* (fungi affected 46.2% of sample trees in this group). The relatively high frequency correlates with the general bad condition of the prior species groups.

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

"Erdeink egészségi állapota 2022-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

"Erdészeti Mérő- és Megfigyelő Rendszer, 2022" An annual leaflet about the key findings of the Forest Monitoring and Observation System (FMOS, Hungarian acronym: EMMRE). Forest health condition monitoring is an important part of the FMOS. The leaflet is available online in Hungarian: http://www.nfk.gov.hu/EMMRE_kiadvanyok_jelentesek_prognozis_fuzetek_news_536

Outlook

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

Ireland

National Focal Centre

Thomas Cummins, University College Dublin
John Redmond, Department of Agriculture, Food and the Marine

Main activities/developments

Monitoring of Level I forest crown condition has been undertaken in 2022. This work is undertaken by Department of Agriculture Food and the Marine at a subset of National Forest Inventory sites.

By end of 2022, installations have begun (last activity was in 2017) at Level II plots Roundwood (1, 18) and Brackloon (11). Monitoring of open-land deposition with twice-monthly sampling and analysis of mandatory components is ready for data reporting from January 2023. This work is operated by Ireland's new National Ecosystems Monitoring Network operated by Environmental Protection Agency, under commitements of the National Emission reduction Commitments Directive (NECD).

Data submissions have been undertaken to improve completeness of past datasets hosted on the ICP Forests database.

Outlook

Continued progressive development of continuous monitoring surveys under NEC Directive requirement, compatible with ICP Forests standards. Initially, bulk-deposition and ambient ammonia monitoring will be done.

Italy

National Focal Centre

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

Main activities/developments

The survey of Level I in 2022 took into consideration the condition of the crown of 4751 selected trees in 256 plots belonging to the EU Level I network on a 16x16 km grid. 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 damage from known causes attributable to both abiotic and biotic factors. For the latter, not so much the indicators we analyzed the frequencies of affected plants, but the comments made as to each plant may have multiple symptoms and more agents.

Major results/highlights

Defoliation data are reported according to the usual categorical system (class 0:0-10%; class 1: >10-25%; class 2: >25-60%; class 3: >60%; class 4: tree dead). Most trees (83.2%) are included in the classes 1 to 4; 44.0% are included in the classes 2 to 4.

By analyzing the sample for conifers and broadleaves, it appears that deciduous trees have a lower transparency than conifers: 23.2% of conifers versus 14.4% of broadleaves in the class 0 of transparency, while 44.3% of deciduous trees versus 43.2% of conifers are included in the classes 2 to 4.

Results were divided into two age categories (<60 and ≥60 years). Among the young conifers (<60 years), the percentage of trees in defoliation classes 2-4 was: *Pinus pinea* (100%) and *Pinus halepensis* (60.4%) with the highest values, *Pinus nigra* (42.3%) and *Pinus sylvestris* (38.7%), while *Picea abies* (12.7%) was in the best condition among the young trees.

Among the old conifers (≥60 years), the species appearing to be of the worst quality of foliage in the classes 2 to 4 was *Pinus sylvestris* (71.8% of trees), then *Picea abies* (54.8%), *Abies alba* (42.0%), *Larix decidua* (40.3%), while *Pinus nigra* (30.4%) was the conifer species with the best condition.

Among the young broadleaves (<60 years), *Castanea sativa*, *Ostrya carpinifolia*, *Quercus pubescens* and *Fagus sylvatica* have respectively 67.2%, 56.5%, 45.1%, and 47.7% of trees in the classes 2 to 4, while *Quercus cerris* has a frequency of 23.7% in classes 2 to 4.

Among the old broadleaves (≥60 years) in the classes 2 to 4, *Castanea sativa* has 72.8%, *Quercus pubescens* 34.1%, *Fagus sylvatica* 32.5%, *Fraxinus ornus* 29.6%, while with 26.6% *Quercus ilex* has the lowest level of defoliation of trees in the classes 2 to 4.

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

Out of a total of 4751 trees monitored, 8828 symptoms were detected and 883 trees (10%) were without symptoms. Of the 7945 trees with symptoms, 3461 (49.8%) symptoms were identified, while 3984 (50.2%) symptoms were not identified.

Most of the observed symptoms were attributed to insects (19.9%), subdivided into defoliators (13.4%), galls (1.6%), and bark beetle (2.2%). Others could be attributed to fungi (4.2%), with the most significant attributable to "dieback and canker fungi" (2.3%). Of those assigned to abiotic agents, the most significant was drought (8.2%).

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

Papitto G, Quatrini V, Cindolo C, Cocciufa C (a cura di) (2021) Rete NEC Italia – Monitoraggio degli ecosistemi terrestri. Lo stato delle foreste italiane. Pubblicato da Arma dei Carabinieri, Comando Unità Forestali, Ambientali e Agroalimentari - Roma.

Bussotti F, Papitto G, Di Martino D, Cocciufa C, Cindolo C, Cenni E, Bettini D, Iacopetti G, Pollastrini M (2022) Le condizioni delle foreste italiane stanno peggiorando a causa di eventi climatici estremi? Evidenze dalle reti di monitoraggio nazionali ICP Forests - CON.ECO.FOR. Forest@ 19, 74-81.

Bussotti F, Bettini D, Carrari E, Selvi F, Pollastrini M (2023) Cambiamenti climatici in atto: osservazioni sugli impatti degli eventi siccitosi sulle foreste toscane. Forest@ 20. 1-9.

Brunialti G, Frati L (2022) Diversità lichenica e intelligenza artificiale per un monitoraggio innovativo della qualità dell'aria nelle foreste italiane. Bozza di linea guida per l'acquisizione di immagini in campo. Report TDe R 132-2022/03 (V1R1).

Outlook

- Currently, Italy has a total of 256 Level I plots and 32 Level II monitoring plots and it is planned to maintain those plots in future.

Latvia

National Focal Centre

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

Main activities/developments

Latvia continued its assessment at Level I. The forest condition survey 2022 in Latvia was carried out on 115 Level I NFI plots. The major results of 2022 are based on data from this dataset.

In 2022, the relevant works were performed within the framework of the Level II monitoring:

- national crown condition survey
- deposition monitoring from bulk, throughfall, stemflow
- soil solution monitoring from lysimeters

- litterfall sampling twice a month in months with no snow cover (usually March–November/December, may differ from year-to-year).

Major results/highlights

Level I

On Level I plots defoliation and damage symptoms of 1730 trees were assessed, of which 73% were conifers and 27% broadleaves. Of all tree species, 11.9% were not defoliated, 83.4% were slightly defoliated, and 4.7% moderately defoliated to dead. Compared to 2021, the proportion of not defoliated trees has decreased by 0.4%p, the proportion of slightly defoliated has decreased by 0.4%p, but the proportion of moderately defoliated to dead trees has increased by 0.9%p. In 2022, the proportion of not defoliated conifers was 2.9%p higher than that of not defoliated broadleaves, the proportion of slightly defoliated broadleaves was 6.2%p higher than that of slightly defoliated conifers. The proportion of trees in defoliation classes moderatly defoliated to dead for conifers was 3.2%p higher than for broadleaves.

Mean defoliation of *Pinus sylvestris* was 19.6% (19.6% in 2021). The share of moderately damaged to dead trees decreased to 4.6% (5.5% in 2021). Mean defoliation of *Picea abies* was 19.0% (17.3% in 2021). The share of moderately damaged to dead trees in spruce increased to 7.5% (4.1% in 2021). The mean defoliation of *Betula* spp. was 19.0% (18.7% in 2021). The share of trees in defoliation classes moderately to dead was 2.4% (compared to 1.1% in 2021).

Visible damage symptoms were observed on 18.9% of the assessed trees (16.5% of the assessed trees in 2021). Most frequently recorded damages were caused by direct action of men – 26.3% (28.9% in 2021), animals – 21.7% (26.8% in 2021), insects – 22.6% (13.7% in 2021), abiotic factors – 17.7% (14.1% in 2021), fungi – 6.4% (13.0% in 2021), and unknown cause – 5.2% (3.5% in 2021). The greatest share of trees with visible damage symptoms was recorded for *Picea abies* (28.8%), *Pinus sylvestris* (18.2%) and the smallest for *Betula* spp. (10.3%).

Level II

Level II monitoring activities are still maintained and performed throughout 3 plots in Latvia. The location of the plots is in Valgunde, Taurene, and Rucava. This location dispersion is selected to ensure the representation of different meteorological conditions throughout the country. The Rucava plot is located near the coast of the Baltic Sea, the Taurene plot into the mainland, and the Valgunde plot between the two previously mentioned. Only major result differences from previously reported data are detected in the precipitation data in the Valgunde plot. During the 2022 monitoring year, the Valgunde plot in total collected 350 mm of precipitation in the open field, 291 mm through tree crowns, and 14 mm from bark collectors. The difference between the years 2021 and year 2022 is -342mm from open field collectors, -314 mm from precipitation throughout the tree crown, and -19 mm from tree bark precipitation. The average pH of precipitation is 6.1 from the open field, 6 from tree crowns, and 4.9 from stem bark collectors. The situation in crown condition data in all of the plots between the years 2021 and year 2022 did not show any major differences and the condition of the plots is relatively the same. Average defoliation and damage symptoms in each plot are determined at 17% in Rucava, 16% in Taurene, and 17% in Rucava. The average cone yield is 1.9 at Valgunde, 1.8 at Taurene, and 1.9 in Rucava which are in borderlines between a few cones to medium yield.

Outlook

Latvia has 115 NFI Level I plots and it is planned to continue observations at this level. For more than a decade, the Level II monitoring plots have been meticulously maintained, with data collection, processing, and reporting activities continuing without interruption since the project's installation. These monitoring plots serve as a crucial source of long-term data, enabling researchers to gain insights into current and historical conditions as well as changes occurring at the sites over time. To ensure that this valuable data stream remains available for future use, the tasks established at these monitoring sites must be maintained and sustained. In the year 2023, the Latvian State Forest Research Institute "Silava" is determined to continue the long-term monitoring and sample analysis for the Level II inventory as it has previously since the year 2004.

Lithuania

National Focal Centre

Marijus Eigirdas, Lithuanian State Forest Service

Main activities/developments

Level I

In 2022, a forest condition survey was conducted on 1013 sample plots, of which 82 plots were in the transnational Level I network and 931 plots in the National Forest Inventory network. In total, 5905 sample trees representing 17 tree species were assessed. The main tree species assessed were *Pinus sylvestris*, *Picea abies*, *Betula pendula*, *Betula pubescens*, *Populus tremula*, *Alnus glutinosa*, *Alnus incana*, *Fraxinus excelsior*, *Quercus robur*.

Level II

In 2022, the activities of intensive forest monitoring were carried out in nine Intensive Monitoring Plots (IMP). The activities performed at nine IMP included the visual assessment of crown condition and damaging agent, the assessment of ozone injury, foliage sampling and analysis. In three Level II plots the following surveys were conducted: soil solution collection and analysis, atmospheric deposition in bulk and throughfall, litterfall sampling, assessment of the concentration of sulphur dioxide (SO_2), nitrogen dioxide (NO_2), and ammonia (NH_3) (with passive samplers), phenological observations for Norway spruce, Scots pine, and pedunculate oak. In total, crown condition was assessed for 505 sample trees in 2022.

Major results/highlights

Level I

In one year the mean defoliation of all tree species increased slightly to 22.8% (22.3% in 2021). 16.1% of all sample trees were not defoliated (class 0), 60.6% were slightly defoliated, 21.4% were assessed as moderately defoliated and 23.3% as severely defoliated and dead (defoliation classes 2-4).

Mean defoliation of conifers increased slightly for both conifers to 23.4% (23.0% in 2021) and deciduous trees to 21.7% (21.3% in 2021).

Pinus sylvestris is the dominant tree species in Lithuanian forests and annually accounts for about 37% of all sample trees. Mean defoliation of *Pinus sylvestris* increased slightly to 24.7% (24.4% in 2021). A slightly increasing defoliation trend was observed between 2008 and 2022.

Since 2006, *Populus tremula* mean defoliation and the share of trees in defoliation classes 2-4 were the lowest. In 2022, the mean defoliation of *Populus tremula* was 15.5% (15.8% in 2021) and the proportion of trees in defoliation classes 2-4 was 7.4%, compared to 3.9% in 2021.

The condition of *Fraxinus excelsior* remained the worst of all observed tree species. The defoliation of this tree species was the highest since 2000. Mean defoliation decreased to 30.8% (31.4% in 2021). The share of trees in defoliation classes 2-4 decreased to 29.4% (34.7% in 2021).

28% of all sample trees had some kind of identifiable damage symptoms. The most frequent damage was caused by abiotic agents (about 8.3% in 2022) in the period of 2011 – 2022. The highest share of damage symptoms was assessed for *Fraxinus excelsior* (59%), *Alnus incana* (48%), *Picea abies* (37%), *Populus tremula* (30%), the least for *Betula* sp. (18%) and *Alnus glutinosa* (20%).

Level II

The mean defoliation of all tree species varied insignificantly in the period from 1997 to 2022, and the growing conditions of Lithuanian forests can be defined as relatively stable.

The mean defoliation of trees in Level II plots over the past 5 years ranged from 14 to 20%. In 2022, the highest crown defoliation was determined for downy birch (30.0%) and pedunculate oak (20.1%). In the last decade, the number of trees with visually identifiable biotic and abiotic damage was 10.4%, and the average tree mortality was 0.8%.

Air pollution deposition survey, carried out since 2000, showed that sulphur deposition under tree crowns has constantly decreased. During the last decade, the amount of sulphur deposition in the open area has varied between 3 and 5 kg ha^{-1} yr^{-1}. In the 2008 – 2021 period, the average sulphur deposition under tree canopy was 6.1 ha^{-1} yr^{-1}. Average nitrate deposition (NO_3–N) both in the open area and under tree crowns has varied from 5 to 7 kg ha^{-1} yr^{-1}. In the 2008 – 2021 period, the average nitrate deposition under tree canopy was 8.9 ha^{-1} yr^{-1}.

In 2022, the average SO_2 concentration has varied from 0.48 to 0.56 µg/m^3 in IMP. The average NO_2 concentration was 7.5 µg/m^3 (varied from 4.0 to 12.0 µg/m^3 in IMP), and it was lower than the multi-annual value (10.37 µg/m^3) (2008 – 2020). The average NH_3 concentration was 2.5 µg/m^3 (varied from 1.9 to 3.7 µg/m^3 in IMP), and it was slightly lower than in 2021.

Multi-annual (2017 – 2022) observations of visible ground-level ozone-related damages showed that the most frequently damaged tree species were *Alnus incana*, *Fraxinus excelsior* and *Alnus glutinosa*. In 2022, visually visible ground-level ozone-related damages were assessed on nine IMP. No foliage damage possibly caused by ground-level ozone was recorded.

New IMP establishment in 2023

In order to increase the representativeness of the monitoring network and to monitor more diverse forest ecosystem types in Lithuania, new IMP will be established in 2023. An IMP will be established in the Dubrava Forest Reserve and will represent a natural not drained upland bog ecosystem covered by woody vegetation.

Collaboration with other programmes and projects

In 2022, joint activities with the LIFE OrgBalt project "Demonstration of climate change mitigation potential of nutrients rich organic soils in Baltic States and Finland (Project code: LIFE18 CCM/LV/001158)" was initiated. The greenhouse gas emissions from organic soil were estimated in ICP Forests Level II IMP.

Luxembourg

National Focal Centre

Philippe Schmitz
Administration de la nature et des forêts

Main activities/developments

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

Major results/highlights

The positive trend in 2021 did not continue into 2022. Degradation resumes. For trees in poor condition and those that are decaying, values have reached a new high. The proportion of forest trees clearly damaged to death increased by 10%p compared to the previous year, while the proportion of sample trees without visible signs of damage decreased by 1%p. The average defoliation is slightly increased. Across all tree species, in the summer of 2022:

- 15.4% of trees have no damage (damage class: 0),
- 22.9% of the trees are slightly damaged (damage class: 1),
- 61.7% of the trees are clearly and/or heavily damaged (usually dying) or dead trees (damage class: 2, 3 and 4).

Outlook

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

Norway

National Focal Centre

Volkmar Timmermann, Norwegian Institute of Bioeconomy Research (NIBIO)

Main activities/developments

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

Level I / Norwegian national forest monitoring

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

Our national forest monitoring in 2022 included defoliation assessments on 5 556 Norway spruce and 4 915 Scots pine trees on 1 845 plots, and damage assessments on 19 198 trees (28+ species, incl. spruce and pine) on 2 570 plots in total from early May until mid of October. The regular national calibration course for the field workers from the NFI was again conducted in May after 2 years with cancellations due to COVID 19.

In 2022, 627 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 5 183 trees belonging to 23 species were reported to the ICP Forests Database.

Level II

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

Major results/highlights

Norwegian national forest monitoring

In 2022, mean defoliation for Norway spruce was 16.9%, and 13.8% for Scots pine in our national monitoring. There was a slight increase in mean defoliation for both spruce (+0.4%p) and pine (+0.6%p) compared to 2021.

	Percentage of trees per defoliation class						
	Class 0	Class 1	Class 2	Class 3	Class 4	Mean defoliation	No. of trees
Norway spruce (*Picea abies*)	47.4	31.5	16.5	4.2	0.4	16.9 (+0.4)	5 578
Scots pine (*Pinus sylvestris*)	49.7	38.5	10.5	1.0	0.3	13.4 (+0.6)	4 928

Of the more than 19 000 trees assessed for damage, 10.8% had symptoms of damage. The highest proportion of damage (14.7%) was observed for birch trees (*Betula* sp.), followed by other deciduous trees (13.4%), Norway spruce (9.7%) and Scots pine (5.6%). By far the most common causes of damage for all species were abiotic factors (mainly snow breakage and windthrow), inducing 34.6% of all recorded damge symptoms. Insects were responsible for 15.5% of the damage symptoms (mostly birch moths and European pine sawfly), and fungi for 10% (primarily birch rust and spruce needle rust).

Mortality rates were 3.9‰ for Norway spruce, 2.8‰ for Scots pine, 9.0‰ for birch, 12.6‰ for other deciduous species and 6.2‰ on average for all assessed tree species in 2022.

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

Timmermann V, Børja I, Clarke N, et al (2023) Skogens helsetilstand i Norge. Resultater fra skogskadeovervåkingen i 2021. [The state of health of Norwegian forests. Results from the national forest damage monitoring 2021.] NIBIO Rapport 9(39) 2023: 76 pp. https://hdl.handle.net/11250/3057207 (summary in English)

Viken KO (2021) Landsskogtakseringens feltinstruks – 2021. [Manual of the Norwegian NFI – 2021.] NIBIO BOK 2021: 154 pp + annexes. https://hdl.handle.net/11250/2826859

Outlook

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

Poland

National Focal Centre

Paweł Lech, Forest Research Institute (IBL)

Main activities/developments

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

Level I

In 2022, the forest condition survey was conducted on 2071 Level I plots (8 km x 8 km grid) and a total number of 41420 trees were assessed. Of these, the results of the assessment of 341 plots on a 16 km x 16 km grid (European network) with 6820 trees were submitted to the ICP Forests Database. The fieldwork took place in July and August.

Level II

In 2022, measurements of weather parameters, air quality, and chemical analysis of deposition (open field and throughfall) and soil solution were conducted on 12 Level II plots. In addition, continuous measurements of dbh and water availability of the trees were carried out on one plot with oak as the dominant tree species.

Major results/highlights

Level I

In 2022, the average defoliation of all species was 21.2%, that of conifers 21.3%, and that of deciduous trees 21.2%. The percentage of healthy trees (with leaf loss of 10% or less) was 14.4% for all species, and the percentage of trees with leaf loss of more than 25% was 15.5%.

The percentage of healthy trees (18.4%) and the percentage of trees with leaf loss of more than 25% (17.6%) were higher for deciduous than for coniferous species (12.0% and 14.2%, respectively). The percentage of trees in the early warning class with leaf loss between 11% and 25% was 70.1% for all species, 73.8% for conifers and 64.0% for broadleaves.

Among the three main conifer species, *Abies alba* had the lowest mean defoliation of 18.2%, with 25.7% of trees falling into class 0 and 9.9% into classes 2-4. *Pinus sylvestris* was characterized by a lower proportion of trees in class 0 (11.6%), a higher proportion of trees in classes 2-4 (13.3%) and a higher mean defoliation (21.1%) than *Abies alba*. *Picea abies* was characterized by the highest proportion of trees in classes 2-4 (27.3%) and the highest mean defoliation (25.0%) compared to the other surveyed major tree species (coniferous and deciduous). The proportion of spruce with a leaf loss of up to 10% was low at 7.8%.

In 2022, as in the previous year, the highest average defoliation among deciduous trees was observed in *Quercus* spp. (24.2%). Only 6.3% of oaks had a leaf loss of 10% or less and 27.0% of trees fell into leaf loss classes 2-4. A slightly better condition was observed for *Betula* spp. (11.3% of trees in class 0, 18.2% of trees in classes 2-4 and the mean defoliation was 22.4%). *Fagus sylvatica* remained the tree species with the lowest defoliation. A proportion of 35.2% of the beech trees showed no symptoms of defoliation, only 11.3% were in leaf loss classes 2-4 and the mean defoliation was 17.3%. *Alnus* spp. was slightly more defoliated than *Fagus sylvatica* (23.7% of trees were in class 0, 11.2% of trees in classes 2-4 and the mean defoliation was 19.2%).

In 2022, the condition of trees (all species combined) improved compared to the previous year. A significant improvement was observed in *Pinus sylvestris* and *Quercus* spp. and *Betula* spp. The proportion of trees with a defoliation level of 10% or less increased by 5.4 and 2.1%p, respectively. The proportion of trees with more than 25% defoliation decreased by 3.1 and 4.2%p and the average defoliation of these two species decreased by 1.5 and 1.7%p, respectively.

Level II

Meteorological measurements on 12 Level II plots showed that it was warmer and slightly drier in 2022 than in 2021, with a mean annual temperature about 0.8 °C higher. The annual precipitation total in 2022 was lower than in 2021 on 11 of 12 plots. In the 2022 growing season, precipitation was also lower than in 2021 on most plots, exceeding 200 mm decrease on two plots.

The analytical results of the measurements carried out in 2022 on 12 Level II plots regarding air quality, deposition and concentration of elements in the soil solution will be evaluated in the second half of 2023 and published in next year's Technical Report.

The SO_2 concentration in the air in 2021 ranged from 73% to 174% of the concentration in 2020 and the NO_2 concentration ranged from 84% to 124%. On about half of the plots, SO_2 and NO_2 concentrations in ambient air in 2021 did not follow the general trend of decreasing concentrations of air pollutants observed in recent years, as shown over the years 2011–2021 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 ($p \leqslant 0.05$) upward trend in recent years, which was accompanied by a decrease in the deposition of sulphur in the form of sulphates. Soil conditions remained stable in most Level II plots during the period studied; any changes in the amount of deposition in recent years were reflected to a lesser extent in changes in the chemical composition of the soil solutions.

Outlook

In addition to routine monitoring activities, the following projects were launched in 2019 and 2022 using forest monitoring data and/or the infrastructure:

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

Romania

National Focal Centre

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

Main activities/developments

Level I

In 2022, crown condition assessments were conducted on 238 Level I permanent sample plots. A total number of 5712 trees were assessed of which 954 were conifer trees (16.7%) and 4758 broadleaf trees (83.3%). By species, a total number of 6 species of conifers were evaluated, of which spruce is predominant (73%), followed by fir (21%) and 30 species of broadleaves, the most dominant species being beech (43.5%) followed by sessile oak (12.8%) and hornbeam (11.2%).

Level I

The intensive monitoring activities were carried out on 12 intensive monitoring plots for crown condition and damage cause assessments (12 plots); continuous and permanent measurements of tree stem variation (4 core plots); foliar samples for broadleaves and conifers (12 plots); phenological observations (4 plots); litterfall and LAI measurements (3 plots); ground vegetation assessments (12 plots); atmospheric deposition (5 plots); air quality measurements (4 plots); meteorological measurements (4 plots), chemical analysis for deposition samples, air pollutants passive samples (O_3, NO_2, NH_3), soil solution and foliar nutrients and validation and submission of the data base for all monitoring activities.

Major results/highlights

The mean defoliation recorded in 2022 in the Level I monitoring network in Romania is 16.2% which is 0.8%p higher than in 2021. By species groups we observed a slight decrease compared to the previous year for conifers from 16.0% in 2021 to 15.5% in 2022, and an increase of 1.1%p for broadleaves.

The share of damaged trees (defoliation classes 2-4) is 13.1% increasing by 1.1%p compared to 2021. The most affected species were pedunculate oak, Turkey oak and poplar among the deciduous trees, poplar trees being the most affected this year, the percentage of damaged trees increasing from 26.6% in 2021 to 40.9% in 2022. Low values, below the national average, were observed for beech, spruce, fir, linden, and hornbeam.

In contrast to previous years, there is a considerable decrease in the proportion of damaged oak trees, from 48.7% in 2018, 9.1% in 2019, 10.0% in 2020 to 7.3% in 2021, rising again this year to 15.7%.

Among the conifers, fir records the best health status with a proportion of damaged trees slightly increasing compared to 2020, from 11.0% to 13.5% in 2021 and 12.0% in 2022

As in previous years the mortality rate (defoliation class 4) was low (0.3%) for all species, dead trees being recorded for both species groups, the highest mortality rate being attributed to poplar species, hornbeam, black locust, or oak.

Abundant fruiting has been observed for more than 10% of the evaluated beech trees, and common and scare in more than 60%. A similar situation was being observed for spruce. We noticed also that in 2022 pedunculate oak had the highest level of fruiting among the deciduous species (30% of the evaluated trees with normal fruiting), followed by sessile oak, ash and beech.

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 2021. VI.1.3. Forest health status. Ministry of Environment, Waters and Forests

The Annual Report of the Romanian Forest Status in 2021. Ministry of Environment, Waters and Forests

Leca S. et al. (2022) Climate impact on the forest ecosystem health status in Romania. Revista de Silvicultură şi Cinegetică, Anul XXVII Nr. 51 | 2022, ISSN 1583 – 2112. http://progresulsilvic.ro/wp-content/uploads/2022.51-WEB.pdf (abstract in English).

Ienăsoiu G, Frink JP, Lazăr G, et al (2022). Plante identificate în pătura erbacee în retelele de cercetare sau monitorizare forestieră existente în România. Ghid/Indrumar ilustrat. Editura Silvică, ISBN: 978-606-8020-87-7.

Outlook

Concerning the future of the forest monitoring system, the Romanian NFC priorities are to (i) continuously upgrade and develop the field infrastructure and laboratory instruments in order to maintain and sustain the continuity of time series and the quality of the data (starting with 2023 a new research/monitoring project financed by the Romanian Ministry of Research, Innovation and Digitalisation will be implemented and new Level II monitoring plots will be installed as well as new field monitoring equipment like sap flow, growth, soil solution and meteorological sensors) and (ii) seeking financing possibilities for developing new research (related to climate change effects on different forest indicators) in order to fulfill the reporting obligations regarding the negative impacts of air pollution on forest ecosystems under the National Emissions Ceilings (NEC) Directive (2016/2284/EU) and other national and international technical reports. Also, in line with the recent ICP Forests strategy the novel forest monitoring and forecasting methods based on integration of remote sensing sensors, Earth-Observation (EO) data and in situ measurements developing will be continued.

Serbia

National Focal Centre

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

Main activities/developments

The National Focal Center at the Institute for Forestry has been continuously participating in the international program ICP Forests, with the goal of achieving further improvement and harmonization with other approaches of forest ecosystem monitoring and management. Monitoring is conducted on 130 Level I sample plots and 5 Level II sample plots. The main activities in 2022 included the improvement of the work within the ICP Forests program through the implementation of new and enhancement of the existing infrastructure. This includes the improvement of current instruments within Level II sample plots, as well as the improvement of internal database storage. In 2022, activities for 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 2021, bases for additional activities within this program have been established, since there is initiative to start work in the Expert Panel on Ambient Air Quality. Through this programme, the Institute of Forestry constantly works on strengthening the co-operation with all relevant institutions in the field of forestry and environmental protection: forest estates of the public enterprise "Srbijašume" and "Vojvodinašume", public enterprises that manage national parks, as well as forest owners and other users of forest resources.

Major results/highlights

The total number of trees assessed on all Level I sampling plots was 2886 trees, of which 336 were conifer trees and a considerably higher number (2550) were broadleaf trees.

The conifer tree species were: *Abies alba*, number (n) and percentage of trees: n=66, 2.3%; *Picea abies*: n=146, 5.0%; *Pinus nigra*: n=44, 1.5%; *Pinus sylvestris*: n=80, 2.8%. The most represented broadleaf tree species were: *Carpinus betulus*: n=122, 4.2%; *Fagus moesiaca*: n=820, 28.4%; *Quercus cerris*: n=501, 17.4%; *Quercus frainetto*: n=388, 13.4%; *Quercus petraea*: n=183, 6.3%; and other species n=536, 18.6%.

The degree of defoliation calculated for all conifer trees is as follows: no defoliation: 92.2% of trees, slight defoliation: 3.0%, moderate defoliation: 2.1%, severe defoliation: 2.7%, dead: 0.0%. Degree of defoliation calculated for all broadleaved species is as follows: no defoliation: 83.4% of trees, slight defoliation: 10.6%, moderate: 4.3%, severe defoliation: 1.7%, dead: 0.0%.

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 our site: http://www.forest.org.rs/?icp-forests-serbia

Rakonjac Lj, Češljar G, Đorđević I, et al (2022) Monitoring and assessment of air pollution impacts and its effects on forest ecosystems in Republic of Serbia – forest condition monitoring, Level I and II. Institute of forestry, Belgrade

Outlook

In the next period, development of ICP Forests Infrastructure will be mainly on strengthening work in our laboratories and involvement in different ring test analysis. This will also include acquiring new ICP spectrometer for conducting different chemical analyses. Beside this, during 2023 a Forest Information System (FIS) will be established and one part of this system is ICP Forests monitoring. This will improve the processes of data collection, storing and analysis.

Also, activities on starting monitoring of ambient air quality have been initiated. The aim is to include this survey into the monitoring permanently. Cooperation with Environmental Protection Agency of Serbia has been made and during 2023 the NFC Institute of Forestry will try to include their data on ambient air quality, as their monitoring station is near to our sample plot Level II on Kopaonik.

Slovakia

National Focal Centre

Pavel Pavlenda, National Forest Centre (NLC)

Main activities/developments

The crown condition survey in Slovakia in 2022 was conducted on 3 704 trees on 99 plots (out of 112 plots in total; 13 plots are without a measurable forest stand, mainly because of bark beetle outbreaks and sanitary cuts in the last decade). The survey took place between July 11 and August 5, which was at the end of very dry period.

Monitoring activities continued with a standard frequency 2 times per month on 7 Level II plots. Defoliation, increment, atmospheric deposition, meteorology and phenology are monitored on all the plots of the intensive monitoring, but other surveys (soil solution, air quality, litterfall, air quality, ozone damage) are limited only to selected plots.

Besides the regular monitoring activities and data analyses on the Level I and Level II plots, in 2022 the soil survey on Level I plots was continued. Field work is planned for 2024, laboratory analyses are expected to be completed in 2025. The soil survey on Level II plots was finished in 2022, including plots where forest stands had been destroyed or that are not anymore subject of intensive continuous activities due to several reasons (including budget cuts).

In 2022 two important national projects related to forest monitoring began. The dominant WP of the research project TreeAdapt focuses on the evaluation and knowledge synthesis of a long-term monitoring database.

The plot Polana – Hukavsky grun (as site of the LTER network) is one of 4 sites at which activities of the project CALTER (Soil carbon fluxes in dominant forest ecosystems along elevation gradient in the Western Carpathians) started in August 2022.

Major results/highlights

The mean defoliation for all tree species together has been increasing over the last 6 years, crown condition of broadleaved species as well as conifers deteriorated. A very dry first half-year in 2022 caused a substantial increase of defoliation and discoloration. 40.2% of broadleaved trees (compared to 28.8% in 2021) and 58.0% of coniferous trees (54.0% in 2021) were in defoliation classes 2-4. Mean defoliation of all species together was 29.3% (27.5% broadleaved tree species, 32.4% conifers). The highest mean defoliation was observed for *Fraxinus excelsior* (46.6%), *Robinia pseudoacacia* (36.2%), *Pinus sylvestris* (35.8%) and *Larix decidua* (35.5%). However, the biggest change of mean defoliation compared to 2021 was detected for *Fagus sylvatica* (from 22.0% to 26.5%) and *Carpinus betulus* (from 20.8% to 27.0%). The mean defoliation of *Fagus sylvatica* was the highest since the very beginning of the forest monitoring. The high values of defoliation were related also to higher discoloration (yellowing, browning) and high fructification. In general, the worst crown condition state (the strongest forest damage) was in the southern part of Slovakia on the edge between the Pannonian and Alpine biogeographic regions.

Mean defoliation of *Picea abies* was also very high (32.3%). On the other hand, *Abies alba* is the only tree species with decreasing defoliation in the last 3 decades and with negligible worsening in 2022.

Crown condition and high values of defoliation of tree species in 2022 can be linked to very dry conditions. An extreme deficit of precipitation and higher temperatures occurred between May and July. On all Level II plots the measured sum of precipitation was less than 50% of the mean precipitation (compared to the average precipitation May–July from 2011 to 2021) and on three of the Level II plots it was even about 20% of the May–July mean.

The trend of radial increment of *Fagus sylvatica*, *Carpinus betulus* and *Pinus sylvestris* has been decreasing in the last two decades (correlating with the defoliation increase), while increment of *Picea abies* and *Quercus* sp. is still relatively stable. *Abies alba* is the only tree species with a positive trend not only for defoliation but for increment as well.

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

Pavlenda P, Pajtík P, Sitková Z, Priwitzer T, Pavlendová P (2022) Manifestations of extreme drought on forest trees species in permanent monitoring plots of PMS Forests. APOL (2):97-94, (in Slovak)

Sitková Z, Barka I, Pavlenda P (2022) Signals and trends of climate change on forest localities in Slovakia. Outcomes of NFC for forestry practice. National Forest Centre, 16-29, (in Slovak)

Sitková Z, Konôpka M (2022) Climatological analysis of the year 2021 in Slovakia. APOL 3(3):255-263, (in Slovak)

Krupova D, Tothova S (2022) Mercury content in leaves of tree species in Slovakia. In: Influence of abiotic and biotic stresses on properties of plants 2022. Proceedings of scientific articles. Institute of forest eciology Zvolen, 44-48, (in Slovak)

Outlook

Monitoring activities will continue on all Level I plots (including several newly established/substituted plots) and on 7 Level II plots. Soil sampling will continue on Level I plots, evaluation of chemical analyses from resampled Level II plots is planned for 2022.

Besides the fulfillment of the international requirements of the NEC Directive and SFM indicators, we intend to aim much more at data evaluation in running research projects than in previous years. Data is expected to be used also in other projects (besides the above mentioned ones). Furthermore, we aim to improve our understanding of the observed long-term changes in tree nutrition by comparing it to long-term changes in the soil nutrient pools. Aspects of climate change effect on forests, e. g. drought effects on vitality and growth of trees are of increasing importance.

Data from ICP Forests both Level I and Level II monitoring are providing very useful information for the calibration of models, i.e. a biogeochemical model that simulates the storage and flux of water, carbon, and nitrogen between the ecosystem and the atmosphere, and within the components of the terrestrial ecosystem.

Slovenia

National Focal Centre

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

Main activities/developments

In 2022, the Slovenian national forest health inventory was carried out on 44 systematically arranged sample plots (grid 16 x 16 km) (Level I). The assessment encompassed 1056 trees, 344 coniferous and 712 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 2022, deposition and soil solution monitoring was performed on all four Level II core plots. On all ten plots the ambient air quality monitoring (ozone) was done with passive samplers and ozone injuries were assessed 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 31.6% (compared to last year the defoliation had increased by 0.9%p).
- Mean defoliation in 2022 for coniferous trees was 30.1% (in 2021 it was 29.4%).
- Mean defoliation in 2022 for broadleaved trees was 32.3% (in 2021 it was 31.3%).
- The defoliation of conifers is remaining on a very high level, with additional signs of increase in 20212 In the past the main reason was the bark beetle outbreak after large ice storm break in 2014, stretching all over 2016, 2017, 2018. In 2022, defoliation was also influenced by summer drought.
- The defoliation of broadleaves has increased in the past 7 years. One of the reasons could still be the effect of the ice storm (fungi effect) in 2014 and some other insect attacks. Still the main reason for the constant increase of defoliation is unknown. In 2022, defoliation was also influenced by the summer drought.
- The total share of damaged and dead trees (with more than 25% defoliation) again increased compared to the previous years from 33.8% to 42.2%, to 45.5% in 2022.
- The percentage of damaged broadleaves has persistently increased from 35% in 2019, 36.5% in 2020, 41.3% in 2021 to 44.0% in 2022.
- The percentage of damaged conifers has increased from 40.6% in 2017 to 42.7% in 2019. In 2020, it slightly decreased to 41.1%, then increased to 44.1% in 2021 and to 48.6% in 2022.
- Average ozone concentrations in the growing season of 2022 ranged from 27 to 74 µg/m^3 on monitored plots which is about one third higher than in the previous year. On six plots the 14-days ozone concentrations remain under 80 µg/m^3 during the whole growing season. On four of them the highest 14-days average concentration was higher than 80 µg/ m^3 but never exceeded 105 µg/ m^3. On two plots with higher ozone concentrations, we measured top values of 105 and 95 µg/m^3 in a 14-days period.
- The highest 14-days average concentration was 105 µg/m^3 and 74 µg/m^3 on average on the most ozone-polluted plot, which is not the same as last year.

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

Ferlan M, Grah A, Kermavnar J, et al (2021) Poročilo o spremljanju stanja gozdov za leto 2021 = Report on health status of forests 2021. Ljubljana: Slovenian Forestry Institute, pp 95. https://www.gozdis.si/f/docs/publikacije/Porocilo-o-stanju-gozdov-2021.pdf

Outlook

- In 2022, the fence of one IM (Level II) plot was completely renewed/repaired and one IM plot was newly fenced. Some repair work was also done on the IM (Level II) plots and will be continued in 2023.
- Co-operation with the Royal Botanic Gardens Kew in London in the field of ectomycorrhizal diversity in Europe.

Spain

National Focal Centre

Maria Pasalodos Tato, Elena Robla González, Asunción Roldán Zamarrón, Forest Inventory and Statistics Department, 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 2022 as planned. Data were submitted to the ICP Forests and provided to different stakeholders.

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

- April 2022: ICP Forests Combined Expert Panel Meeting (online)
- June 2022: 38th Task Force Meeting of ICP Forests (online)

Major results/highlights

Level I

Mean defoliation observed in 2022 is 23.1% (considering all trees from Level I plots but excluding harvested trees). This is considered "slight" defoliation (class1: 11-25%), but it shows an increase from 2021 (mean defoliation observed in 2021 was 21.7%). A good number of species show defoliation values over 25%, including some of the most Mediterranean species (*Quercus suber*, *Q. ilex*, *Olea europaea*, *Juniperus thurifera*, *Q. pubescens*, *Castanea sativa*, *Pinus nigra*).

Regarding damage from different agents, 40.0% of the sampled trees showed no damage in 2022 (5944 trees), which is lower than the results from 2021 (6847 undamaged trees). The most abundant group is "Abiotic agents", which is responsible for 44.3% of the detected damage (6.0%p higher than in 2021), where drought causes 87.4% of the damage. "Insects" is the second group, being responsible for 24.5% of the detected damage (2.2%p lower than in 2021). A decreasing trend in damage caused by defoliators in broadleaved species has been observed, while damage produced by *Thaumetopoea pityocampa* shows a slight increase in 2022. With regard to damage caused by wood borers, a slight decrease has been observed, influenced by a lower incidence of attacks by *Coraebus florentinus* on *Quercus* and by *Phoracantha semipunctata* on *Eucalyptus*.

Level II

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

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

Level I

Maintenance and data Collection. European large-scale forest condition monitoring (Level I) in Spain: 2022 results. Mantenimiento y toma de datos de la Red Europea de seguimiento a gran escala de los Bosques en España (Red de Nivel I: Resultados 2022)

Evaluation of reference parameters from Level I plots for *Quercus ilex*, 1987-2022 (Evaluación de los parámetros de referencia de la Red de Nivel I para *Quercues ilex*, 1987-2022)

Level II

European intensive and continuous monitoring of forest ecosystems, Level II. 2021 Report. (*Red europea de seguimiento intensivo y continuo de los ecosistemas forestales, Red de Nivel II*)

Spanish versions are available for download at: https://www.miteco.gob.es/es/biodiversidad/temas/inventarios-nacionales/redes-europeas-seguimiento-bosques.html

Outlook

Today, data from ICP Forests Level I monitoring provides very useful information not only for monitoring the state of vegetation, but also to fulfil the international requirements of climate change information. Litter, deadwood, and soil surveys are currently the main data source to assess carbon variation in these forestry pools.

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

- Level I surveys are being carried out at a regional level by different regions (Autonomous Communities) in Spain. Both national and regional sources are being integrated in a common database, which will improve the information and potential analysis.
- Spanish National Forest Inventory-type plots were installed with the same centre plot location as Level I plots, in order to fill in the gaps in area estimation and complete the information with regard to the living biomass and stand variables. Dasometric parameters (mean diameter, basal area, mean height of living trees) are measured in all Level I plots. Further developments and data analysis are being developed in this line.
- Trend analysis of the vegetation health status and monographic studies focused on different species and causal agents are being developed on the basis of data from Level I surveys.

In addition, Level I and Level II sites are included in the Spanish branch of the Long Term Ecological Research Network (LTER).

In 2023, work is expected to continue without incidences, and current work will continue to advance. In addition, the following research collaborations are planned:

- Data acquisition will be carried out at two Level II sites, as part of the "Pathfinder" European project (collaboration with INIA).
- Researchers from foreign entities will collect data in some Level II plots, for different purposes.

Sweden

National Focal Centre

Cornelia Roberge, Swedish University of Agricultural Sciences (SLU)

Main activities/developments

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

Major results/highlights

The major national results, based on the whole Swedish NFI sample, but concern only forests of thinning age or older. The proportion of trees with more than 25% defoliation is for *Picea abies* 23% and for *Pinus sylvestris* 13%. Large temporal annual changes are seen on a regional level, however, for *Pinus sylvestris* a slight increased defoliation in northern Sweden is observed during the last 10 years. The increased defoliation seen for *Picea abies* in southern Sweden in recent years seems to have declined. The mortality rate in 2022 was for *Pinus sylvestris* 0.7% and for *Picea abies* 0.8%. The severe damage caused by spruce bark beetle (*Ips typographus*) in southern Sweden has continued after the dry summer in 2018. A Target-tailored Forest Damage Inventory (TFDI) of spruce trees killed by spruce bark beetle was undertaken. The results from the inventory showed that 5.1 million m^3 Norway spruce forest was killed during 2022. In northern Sweden, there is a strong concern for the young forest, mainly the pine forest. Several causes of damage interact. During 2022 a sample inventory of forest condition and damage in young forest in northern Sweden within the TFDI program was carried out. The results showed that just under 40% of all main tree stems have a damage. Grazing by wildlife predominates among the known causes of damage, especially in pine. Fresh damage caused by moose were observed on 9% of the pine trees. Damage by resin top disease (*Cronartium flaccidum*) occurs throughout the area, however larger damage of resin top disease are mainly seen in the northern part. Otherwise as before significant damage problems in Sweden are due to pine weevil (*Hylobius abietis*) (in young forest plantations), browsing by ungulates, mainly elk, (in young forest), and root rot caused by *Heterobasidion annosum*.

Data from Sweden on forest condition, deposition, soil solution and air quality are besides in the ICP Forests Technical Report also included in several national reports. Data are used in many "data requests", where participating researchers gain access to Swedish data.

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

National reports are available for the Swedish NFI SLU National Forest Inventory | Externwebben (https://www.slu.se/en/Collaborative-Centres-and-Projects/the-swedish-national-forest-inventory/) and the SWETHRU Publications - IVL Svenska Miljöinstitutet (https://www.ivl.se/english/ivl/publications.html).

Outlook

Monitoring activities on Level I will continue as previously. Also, data from SWETHRO on the Level II programme will continue. Several studies are ongoing and among them studies on "Nitrogen deposition causes distinct eutrophication in bryophyte communities". In 2023, Target Tailored Forest Damage Inventories (TFDI) of damage caused by spruce bark beetle in southern Sweden will be carried out.

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:

- For the second year, additional Sanasilva inventories on an 8x8 km grid within a test region were carried out on 21 plots. These assessments will be gradually extended to further regions. First results indicate that local impacts of heat and drought events on forest health can be more clearly captured on the 8x8 than on the 16x16 grid.
- A combination of different novel and classical techniques for monitoring is intensively tested: Continuation of the assessments of defoliation and other physiological

parameters (such as the photochemical reflectance index) with drone-based methods on selected plots; assessing the metabolic profile of needles and roots of trees depending on defoliation.

- Assessment of epigenetic effects in the context of stress memory and acclimation to extreme conditions.
- Assessment of isotopic signal transfer from source water to tree rings.

Major results/highlights

The defoliation of all tree species remained constant between 2020 and 2021, whilst there was a slight decrease in the proportion of trees with a defoliation >25%. As in the year before, there were opposite defoliation changes of conifers and broadleaf trees, but they were now reversed. The defoliation of conifers decreased again after a maximum in 2021. Broadleaf trees, in contrast, showed a slight increase in defoliation compared to the year before. Spruce continues to show clear damage from bark beetles and increased mortality at some sites. However, this does not result in a clear trend for the whole of Switzerland on the 16x16 km network. An overall increase in mortality across all tree species is not observed on the Level I sites in 2022. The continuing high proportion of trees with high defoliation indicates that, due to changing climatic conditions and the high frequency of extreme years, there is no longer any fundamental recovery (such as most recently in 2009), and this could possibly be interpreted as an indication of reduced resilience of forests to dry periods which are expected to increase in the future. Dynamic modelling of plant available water may improve our ability to explain spatio-temporal defoliation patterns (Meusburger et al. 2022, s. page 18).

- We also observed for Scots pine in the dry inner alpine Rhone valley that mortality was affected by increasing atmospheric water demand. The longer-term trend towards higher potential evapotranspiration in spring and summer (mainly driven by increasing temperatures) leads to a depletion of the soil water resources in mid and late summer. Scots pine became thus more dependent on mid to late summer precipitation. Drought events at that time of the year started to drive Scots pine mortality within the last decades. It is therefore an interaction between continuously increasing atmospheric water demand and stochastically occurring drought periods that cause the increased occurrence of mortality events of Scots pine in Switzerland (Hunziker et al. 2022, s. page 18).

In Scots pine, high defoliation was also related to increased stress metabolites in leaves but a decrease in fine roots. We might assume that once a defoliation threshold is exceeded, the roots are not sufficiently supported with assimilates any longer.

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

Meusburger K, Bernhard F, Gessler A (2022) What stable water isotopes may tell us about belowground processes. In EGU General Assembly Conference Abstracts (pp. EGU22-1182)

Meusburger K, Hagedorn F, Walthert L (2022) Wasserverfügbarkeit in Schweizer Wäldern während der Trockenjahre 2015-2018 [*Water availability in Swiss forests during the drought years 2015 and 2018*]. In: Eidg. Forschungsanstalt für Wald, Schnee und Landschaft WSL (ed.) Waldböden - intakt und funktional. Forum für Wissen 2022. WSL Berichte Vol. 126, WSL Berichte Heft 126, WSL, Birmensdorf, 33-37. https://doi.org/10.55419/wsl:32004

Schaub M, Vesterdal L, De Vos B, et al (2022) FORECOMON 2021 – Review of the 9th ICP Forests Scientific Conference on Forest Ecosystem Monitoring. *In*: Michel A, Kirchner T, Prescher A-K, Schwärzel K (eds) Forest Condition in Europe: The 2022 Assessment. ICP Forests Technical Report under the UNECE Convention on Long-range Transboundary Air Pollution (Air Convention). Eberswalde: Thünen Institute. https://doi.org/10.3220/ICPTR1656330928000. pp. 25-28.

Schleppi P, Thimonier A (2022) Verwendung der hemisphärischen Fotografie im Wald [*Use of hemispherical photographs in forests*]. Zürcher Wald, 2: 38-40. www.zueriwald.ch/files/4516/5333/3466/ZW2_22_kl.pdf

Waldner P, Braun S, Brunner I, et al (2022) Stickstoff-Deposition in Schweizer Wälder und Nitrataustrag aus Waldböden [*Atmospheric deposition of nitrogen in Swiss forests and nitrate leaching from forest soils*]. In: Eidg. Forschungsanstalt für Wald, Schnee und Landschaft WSL (ed.) Waldböden - intakt und funktional. Forum für Wissen 2022, WSL Berichte Heft 126, WSL, Birmensdorf, 47-55. https://doi.org/10.55419/wsl:32006

Zweifel R, Basler D, Braun S, et al (2022) TreeNet Technischer Bericht [*TreeNet Technical Report*] 2022

Zacharias S, Schütze C, Anttila S, et al (2022) Discussion Paper on eLTER Standard Observations (eLTER SOs). Deliverable D3.1, Version 2.0, EU Horizon 2020 eLTER PLUS Project, Grant agreement No. 871128

Outlook

- Linking ground-based monitoring with remote sensing; nowcasting of tree functioning under extreme heat and drought events.
- 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 will be 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 (see Zacharias et al. 2022#).

Türkiye

National Focal Centre

Sıtkı Öztürk, Ministry of Forestry and Water Works, General Directorate of Forestry, Department of Combating Forest Pests

Main activities/developments

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

As of 2022:

- On 579 Level I and 50 Level II monitoring plots the crown status and visual damage assessment was conducted and annual reports were published.
- The preparations were completed to carry out the classified analyses on 680 Level I and 52 Level II monitoring plots suitable for taking soil samples from the 850 monitoring plots set up in 2015. The analyses will be finalized in 2023 and uploaded to the ICP Forests database.
- Needle-leaf samples were taken on 52 Level II monitoring plots in 2015, 2017, 2019, and 2021. Analyses have been completed and the data will be transferred to the database in 2023.
- All measurements related to tree growth were completed for the first 5 years on 52 Level II monitoring plots. In 2020, the second 5-year measurements were made.
- Intensive monitoring was planned for 18 of the 52 Level II monitoring plots. Precipitation, deposition, litterfall, soil solution, phenological observations and air quality sampling began to be studied. The analyses of the samples taken in the years 2017-2022 have been completed and will be transferred to the database after internal checking.
- Since 2014, meteorological data have been been obtained from 51 automatic meteorology observation stations. The 2014-2022 results of the meteorological stations will be uploaded to the ICP Forests database in 2023.
- In 2022, 52 Level II monitoring plots were monitored for ozone damage. No ozone damage was found.
- A laboratory was established in İzmir for the analysis of the samples taken from the monitoring plots in the Directorate of Aegean Forestry Research Institute. All requirements were completed and activated. In 2018, 2019 and 2021, water and needle-leaf and rash and soil ring tests were performed and passed.
- The collected data are stored in the national database and the reports are taken from the database.
- We contributed to the National Forest Inventory studies conducted by the Forest Administration and Planning Department.

Major results/highlights

- Ozone damage was encountered on the Level II monitoring plots 8, 12, 18, 29, 30, 51, and 52 within the scope of air quality monitoring made in 2017-2022.
- On 621 Level I and 52 Level II monitoring plots, 21 456 trees in total were monitored.
- 29 kinds of insects, fungi, viruses, etc. that cause damage on the selected trees observed were monitored.

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

TEMERİT A, ADIGÜZEL U, FIRAT Y, KİP HS, BİLGİ M. Forest Ecosystems Monitoring Level I and Level II Programmes in Turkey. National Focal Centre. ISBN: 978-975-8273-92-8

ÖZTÜRK S, TOLUNAY D, KARAKAŞ A, TAŞDEMİR C, AYTAR F, Umut ADIGÜZEL U, AKKAŞ ME. Health State of Forests in Turkey (2008-2012). National Focal Centre. ISBN: 978-605-4610-44-0

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

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

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

Outlook

Future developments of the ICP Forest infrastructure

In our country, the installation of the monitoring sites, which are planned to be installed at 16x16 km intervals in the Level I program, has been completed. Work started on the visual assessment of crown condition and damage factors, vegetation and biodiversity, tree growth, and soil sampling. A study on biodiversity was planned. Every 5 years, the studies are reported. In 2022, the report covering the years 2008-2022 will be prepared and shared by the end of June 2023.

Planned research projects, expected results

A chamber surveillance project was prepared to monitor the effects of climate change on 18 Level II plots where intensive monitoring is performed. It is also planned to put some meteorological data (soil temperature and humidity, etc.) and automatic air quality sampling sensors on the watchtowers to be established with this project.

United Kingdom

National Focal Centre

Suzanne Benham, Forest Research

Main activities/developments

The Level 2 plot network has been maintained during 2020 despite the conciderable challenges posed by COVID-19. Monitoring activities continue at 5 sites. Sample collections for deposition, soil solution, litterfall have been carried out. Monthly growth recording using permanent girth tapes continues and growth assements have been undertaken at all sites.

2020 was a year of weather extreems. It was the third warmest year on record and one of the top 10 wettest and sunniest on record. February was the fifth wettest with 237% of rainfall average, but the spring was both sunnier and drier than average. The summer saw record breaking heat waves, but autumn saw record breaking rainfall.

The main research focus in the UK continues to be the threat to UK forests from pests and diseases and their impact. Three percent of UK native woodlands are currently in an unfavorable condition due to pests and diseases. Ash dieback (*Hymenoscyphus fraxineus*) continues to attack and much of the Ash across the UK are now symptomatic. It is expected that the majority of ash trees will subsequently die from or be significantly affected by the disease in the coming years. Following the detection of an outbreak of Oak processionary moth (*Thaumetopoea processionea*) within the protected zone in 2019, OPM was again found on a very small number of trees within the protected zone and dealt with. Other pest detections of interst include Elm zig-zah sawfly (*Aproceros leucopoda*), Oriental chestnut gall wasp (*Dryocosmus kuriphilus*) and *Ips cembrae* found on Larix.

A cluster of issues to do with Acute oak decline has previously been identified in the South and West of the UK. The Forest Condition survey was reintroduced in 2019 on all oak sites. Results showed that whereas the oak condition was worse than in the last suvey (2007) it was not the worst survey year overall.

Two major new oak health programs are underway in the UK. The BAC-STOP project is developing understanding to guide how we may stop the spread of pathogenic bacteria that are causing Acute Oak Decline (AOD). This includes resolving the controversy of the role of the native beetle *Agrilus biguttatus* in the spread of AOD and testing the effects of drought stress on the disease.

The Future Oak project aims to identify beneficial microorganisms associated with oak trees to see if they can be used to improve oak tree fitness and suppress disease.

Within the ICP Forests monitoring methodology re-introduced at 85 oak plots in 2019, an additional study to phenotype 38 physical characteristics of the trees will be used to construct a decline index to characterize oak health.

Changes in δ13C,δ18O and δ15N isotopic composition of tree-ring material allowed us to study how changes in carbon dioxide and nitrogen availability have affected water-use efficiency over time across the UK. Water use efficiency was higher in conifer than broadleaf species and was most strongly influenced by changes in climate with a minor contribution from wet deposition of Nitrogen (Guerrieri et al 2020).

Outlook

- Funding remains under tight constraints in the UK. From the original network of 10 monitoring sites monitoring obligations under ICP Forests continue at five sites.
- We are investigating the possibility of increasing our monitoring activities further in line with ecosystem accounting initatives.
- As part of the Action Oak initative the Forest Condition Survey was re-introduced at 85 of the original UK oak plots from the 1987-2007 survey and will continue year on year.

ANNEX

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as of 1 July 2023

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Expert Panel on Foliar Analysis and Litterfall

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