ICP FORESTS

2021

Forest Condition in Europe

The 2021 Assessment

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

LRTAP Long-range Transboundary Air Pollution

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

THÜNEN

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The 2021 Assessment

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

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 2021 Technical Report presents results from 32 of the 42 countries participating in ICP Forests. Part A presents research highlights from the January–December 2020 reporting period, including:

- a concise overview by the EP Chairs of the most relevant key findings in the forest-relevant, priority themes for the WGE strategic planning: N deposition, ozone, heavy metals, air pollution/climate change interactions;
- a list of 82 scientific publications for which ICP Forests data and/or the ICP Forests infrastructure were used;
- a list of all 35 official requests for ICP Forests data between January and December 2020.

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

- atmospheric throughfall deposition in European forests in 2019;
- tree crown condition in 2020;
- heavy metals in forest floor and topsoil of ICP Forests Level I plots.

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).

Studying the effects of atmospheric pollution on forest ecosystems requires an evaluation of air quality and of the amount of pollutants carried to the forests by atmospheric deposition. Pollutant flux towards ecosystems through deposition mainly follows two pathways: wet deposition of compounds dissolved in rain, snow, sleet or similar, and dry deposition of particulate matter through gravity or adsorption on forest canopy for example. Chapter 5 presents results of atmospheric throughfall deposition of acidifying, buffering, and eutrophying compounds in 2019 in 290 ICP Forests Level II permanent monitoring plots throughout Europe.

High values of nitrate deposition were mainly found in central Europe (Germany, Denmark, Belgium, Czechia, Switzerland, and eastern Austria), while for ammonium they were also found in northern Italy and Poland. While most of central Europe receives a moderate amount of sulphate deposition, high values are mainly found close to the largest point sources, e.g. power stations burning coal and oil along with refineries. In the southern part of Europe, sulphate deposition is also influenced by volcanic emission and by the episodic deposition of Saharan dust. The influence of marine aerosols was relevant at sites in coastal areas.

Calcium and magnesium deposition can buffer the acidifying effect of atmospheric deposition. High values of calcium deposition are reported in southern Europe, mainly related to the deposition of Saharan dust, and in eastern Europe. The correction for the marine contribution of calcium matters mainly for sites in central Europe and in Spain. In the case of magnesium, however, the distribution of the highest values is markedly reduced by the sea salt correction.

It is important to note that the total deposition to the forest can be higher (typically for nitrate and ammonium) or lower (typically for buffering compounds) than the throughfall deposition, due to canopy exchange processes.

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 6 on tree crown condition in 2020 presents results from crown condition assessments on the large-scale, representative,

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

transnational monitoring network (Level I) of ICP Forests carried out in 2020, as well as long-term trends for the main tree species and species groups.

The transnational crown condition survey in 2020 was conducted on 107 520 trees on 5 663 plots in 27 countries. Out of those, 102 534 trees were assessed in the field for defoliation. The overall mean defoliation for all species was 23.3% in 2020, there was no change for conifers and a very slight increase in defoliation for broadleaves in comparison with 2019. Broadleaved trees showed a higher mean defoliation than coniferous trees (23.3% vs. 22.2%). Among the main tree species and tree species groups, evergreen oaks and deciduous temperate oaks displayed the highest mean defoliation (27.0% and 25.9%, respectively). Deciduous (sub-) Mediterranean oaks had the lowest mean defoliation (20.9%) followed by Mediterranean lowland pines (21.6%) and Austrian pine with 22.0%. Mediterranean lowland pines had the highest percentage (78.7%) of trees with ≤25% defoliation, while deciduous temperate oaks had the lowest (61.8%).

In 2020, damage cause assessments were carried out on 101 773 trees on 5 547 plots and in 26 countries. On 48 009 trees (47.2%) at least one symptom of damage was found, which is 1.6 percentage points less than in 2019 (48.8%).

Insects were the predominant cause of damage and responsible for 24.8% of all recorded damage symptoms. Within the group of insects, 44.1% of damage symptoms were caused by defoliators.

Abiotic agents were the second major causal agent group responsible for 17.3% of all damage symptoms. Within this agent group, half of the symptoms (50.7%) were attributed to drought, while snow and ice caused 9.2%, wind 7.7%, and frost 4.3% of the symptoms.

The Air Convention aims at reducing the pressure of air pollutants on the environment and human health, including heavy metals which can lead to soil contamination. Heavy metals can result from human activities and products (e.g. fertilizers, waste) or short-range air pollution from industry (e.g. smelters). Cadmium (Cd), lead (Pb) and mercury (Hg) are common air pollutants, being emitted mainly as a result of various industrial activities. Other trace metals like nickel (Ni), zinc (Zn), chromium (Cr) and copper (Cu) find their origin in the soil parent material.

Chapter 7 describes the concentrations and stocks of heavy metals in forest floor and topsoil of ICP Forests Level I plots during two soil inventories (1985–1996: 1000–1500 plots; 2006–2008: 3000–3500 plots) based on the combined Forest Soil Condition Database – Level I (FSCDB.LI).

Natural background concentrations differed between countries and biogeographical regions, where the boreal zone showed the lowest concentration levels for most heavy metals. Overall, concentrations of the heavy metals between both surveys for most plots, countries and biogeographical regions decreased, with larger changes in the forest floor compared to the mineral topsoil.

The observed spatial distribution patterns across Europe are comparable with those of the moss survey of ICP Vegetation and the EMEP deposition data for Cd, Pb, and Hg.

CONTENTS

ONLINE SUPPLEMENTARY MATERIAL

Online supplementary material complementing Chapter 6 is available at
http://icp-forests.net/page/icp-forests-technical-report

FOREWORD

As the new representative of Germany and lead country, I am honoured to introduce the 2021 Technical Report of the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests). ICP Forests has been a pioneering and successful initiative in transnational long-term forest ecosystem monitoring under the UNECE Air Convention since its establishment in 1985. The report demonstrates the wide range of activities and results gathered within the ICP Forests community.

The last year was characterized by the COVID-19 pandemic. The situation was and is still challenging us in all aspects of life. Thanks to the extensive technical options which are available, it was possible to participate in the 36th Task Force Meeting virtually. Hopefully soon, we will be able to meet each other and get directly in contact with one another to exchange information, ideas and our know-how as before.

Forests cover over 30% of the landscape in Europe and they provide a wide range of ecosystem services. With their potential for carbon sequestration they are playing an important role in climate change mitigation and adaptation. That is why it is becoming more and more important to ensure the effective transfer of knowledge gained from research and in practise. The increasing number of data requests and projects being based on the ICP Forests monitoring network shows the high reliability and appreciation of the users.

Climate change, e.g. droughts, heatwaves, storm, fire and insect calamities, challenges us and our forests, too. Germany lost 277.000 hectares of forest cover in the last years. The ICP Forests monitoring network contributes to a better understanding and describes the changes in forest health status. This is important to develop strategies and enhance forest adaptive capability. Moreover, calamities will have a strong impact on the plots and the condition of the investigated ecosystems, and it may even impair the continuation of some survey types. That means adaptability on both sides, ecosystem and monitoring practices.

At the beginning of my new position, I was very pleased to hear that ICP Forests was born in 1985, like me. That means the programme is in its best years to continue growing and to show more public presence. The ICP Forests network plays an increasingly visible and active role in scientific policy advice and knowledge transfer. My thanks goes to all passionate foresters, scientists and professionals joining the programme. I wish you continued success in your monitoring activities and thank you for the interest you have shown and work over the years.

Sincerely yours,
Juliane Beez
Federal Ministry of Food and Agriculture

DEAR READER,

It is my great pleasure to introduce the ICP Forests Technical Report on the condition of the European forests in its 2021 edition.

The report concentrates on three main subjects: atmospheric deposition, an enduring concern of our Programme; tree crown condition, the investigation with which ICP Forests started in the 1980s; and heavy metals in the forest floor and topsoil, a subject that – within our Programme – has been addressed only seldom in the past. These three subjects help in understanding the unicity and value of the ICP Forests.

Firstly, we measure atmospheric drivers: atmospheric deposition is just an example, and data and results presented here are relevant to the deposition of inorganic nitrogen, sulphur, and some basic cations (Part B, Ch. 5). It is worth noting, however, that we measure many other drivers at our Level II plots, from gaseous air pollutants (like ground-level ozone) to climate-related ones (like temperature and precipitation).

Secondly, we measure biological and chemical responses of forest to those drivers: tree crown condition and heavy metals are – again – just an example. While the 2021 Technical Report refers to crown defoliation and tree damage (Part B, Ch. 6), and for a series of heavy metals like cadmium, chromium, copper, mercury, nickel, lead, and zinc (Part B, Ch. 7), it is again important to mention the portfolio of investigations we carried out on ecosystem responses to biotic and abiotic drivers: tree growth and nutrition, biodiversity, phenology, soil nutrition and soil solution chemistry are also measurements taken on a routine basis at our Level II plots.

Thirdly, we do all this at continental scale, in a largely harmonized manner and since decades. In addition, we combine the case-study approach of the Level II intensive monitoring plots (that provides the basis for investigating drivers-response relationships) with the Level I systematic network (that provides the basis for upscaling our findings). The combination of these features makes ICP Forests unique. I am always fascinated when considering that this idea of multiple monitoring levels dates back to the 1980s, and that ICP Forests was able to implement it and keep it running.

News for this series of report is the condensed overview about the main findings in relation to air pollution and forests that appeared in scientific journals in 2020. A series of examples were selected and presented in Part A. In short, recent findings pointed at a number of adverse effects of nitrogen deposition and ozone on a variety of ecosystem compartments (above- and below-ground) and provided evidence of the permanent need for a continuous monitoring of our forests.

It is always my pleasure to remind that ICP Forests is part of the UNECE Air Convention, the oldest multi-national and multi-lateral environmental agreement in the world, and – at the time it was launched in 1979 – a visionary approach for protecting our forests and our environment. The values of ICP Forests data series grow every year as data series get longer: this is clearly reflected by the amount of data requests we receive and by the increasing number of publications using ICP Forests data (see Part A).

I would like to express here my gratitude and encouragement to the Air Convention bodies, the Lead Country, all the participating Countries, the Programme Co-ordinating Centre, Groups, Panels and Committees of the ICP Forests for their support with financial, human and intellectual resources – and with their enduring passion and commitment.

I wish you an informative and stimulating reading.

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

1 INTRODUCTION

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

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 5714 observation plots (as at 2020) 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 623 plots (as at 2018, 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 35 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 2021 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 2020

People

- We are very grateful to the following colleagues who had been with the ICP Forests for up to over 30 years and went into retirement in 2020. We will miss their expertise, dedication, and friendship and wish them all the best:
  - Endla Asi (NFC Estonia)
  - Ferdinand Kristöfel (NFC Austria)
  - Sigrid Strich (lead country representative and NFC Germany)
- The Task Force appointed Manuel Nicolas (NFC France, Level II) as new Chair of the ICP Forests Quality Assurance Committee during the 2020 Task Force Meeting. Mr Nicolas has reactivated this group with the aim to further advance the implementation of a consistent Quality Assurance approach valid throughout the various investigations carried out within the ICP Forests.
- We welcome Michael Tatzber from the Austrian Research Centre for Forests BFW in Vienna to ICP Forests. He is the new responsible for the Needle and Leaf Interlaboratory Comparison Test programme.

Data Unit

- The data unit at the Programme Co-ordinating Centre (PCC) of ICP Forests is constantly improving the data management, data availability and usability, and information flow within the programme and to the scientific community and the public. The following developments of the data unit were recently accomplished:
  - open data dataset available online[4],
  - "Data Availability Reports" which describe the current data bases in aggregated overviews,
  - continued revision of the data model (database structure) to harmonize data series,
  - additional new "aggregated data reports" to identify gaps and inconsistencies.

[1] https://www.unece.org/env/lrtap/welcome.html.html
[2] http://icp-forests.net/page/icp-forests-manual
[3] http://icp-forests.net/page/data-requests
[4] http://icp-forests.org/open_data/
[5] http://icp-forests.net/page/icp-forests-technical-report

Outreach and reporting

- Serious effects of the COVID-19 pandemic on the data collection, evaluation, and reporting of the forest monitoring under ICP Forests were reported from only very few countries; we thank all programme participants for their continuous effort and support in these difficult times.
- A new logo and corporate design of ICP Forests were established; a new website is still underway.
- The ICP Forests Manual[2] documents the harmonized methods for sampling and analysis as adopted by the participating countries of ICP Forests. It is substantially revised every 5 years. In 2020, 15 of 17 parts of the ICP Forests Manual were updated and subsequently approved by the Task Force.
- According to the new ICP Forests Brief No. 4[1] titled Increased evidence of nutrient imbalances in forest trees across Europe, tree nutrition is outside the optimal range on 30% of intensive monitoring sites across Europe. This may have implications for forest productivity and for the potential of forest ecosystems to respond to global environmental change.
- The results from the Working Group on Quality Assurance and Quality Control on the 23rd Needle/leaf Interlaboratory Comparison Test 2020/2021 with 48 laboratories from 23 countries and the 10th Deposition and Soil Solution Working Ringtest 2020 with 37 labs from 23 countries were published. These reports can be downloaded from the ICP Forests website[2].
- The State of Europe's Forests 2020[3] report was published by the FOREST EUROPE Liaison Unit Bratislava. The report provides comprehensive information on the status and trends in forests and forestry in Europe, based on the pan-European criteria for sustainable forest management. It is a result of co-operation with numerous experts, governments, as well as international organizations, including ICP Forests.
- The number of reported international, peer-reviewed publications using data that had either originated from the ICP Forests database or from ICP Forests plots rose again, from 62 in 2019 to 81 in 2020[4], thereby proving a still constantly increasing relevance and use of the ICP Forests data and infrastructure in various research areas such as atmospheric deposition, 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.

[1] http://icp-forests.net/page/icp-forests-briefs
[2] http://icp-forests.net/page/working-group-on-quality
http://icp-forests.net/page/icp-forests-other-publications
[3] https://foresteurope.org/publications/
[4] http://icp-forests.net/page/publications

Programme meetings

- The EMEP Steering Body and Working Group on Effects under the UNECE Air Convention met online 24-26 March 2020 and 14-18 September 2020[5], to discuss the progress in activities and further development of effects-oriented activities, e.g. with regard to the 2020-2021 workplan for the implementation of the Convention, the update of the WGE/EMEP scientific strategy, the review of the Gothenburg protocol, outreach beyond the UNECE region.
- The Expert Panels on Ambient Air Quality; Biodiversity and Ground Vegetation; Forest Growth; Meteorology, Phenology, and LAI met online, 9-12 March 2020, to discuss the current status and future developments of the programme in the different surveys.
- The 36th ICP Forests Task Force Meeting was organized by the Swiss Federal Research Institute WSL and held online, 11-12 June 2020, with 76 participants from 28 countries.
- The 9th ICP Forests Scientific Conference *Forest monitoring to assess forest functioning under air pollution and climate change* had to be postponed to 2021 due to the COVID-19 pandemic.
- The Programme Co-ordinating Group (PCG), Quality Assurance Committee, and Scientific Committee met in Berlin, 24-26 November 2020, 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.

Our sincere gratitude goes to Peter Waldner (NFC Switzerland) and his colleagues from the Swiss Federal Research Institute WSL for the organization of a smooth virtual 36th Task Force Meeting of ICP Forests, 11-12 June 2020. We would like to also express our appreciation for valuable comments from the ICP Forests community on draft versions of this report.

For more than 35 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.

[5] https://unece.org/environment-policy/air

Table 1-1: Overview of the number of Level II plots used in different surveys by the participating countries in 2018 as submitted to the ICP Forests database by 20 May 2021

Due to problems with the database in early 2021, submission of Level II data from 2019 has been interrupted. As a result, this table does not show the status of the data submission of 2019 but of 2018.

	Air quality	Crown condition	Deposition	Foliage	Ground vegetation	Ground vegetation biomass	Growth and yield	Leaf area index	Litterfall	Meteorology	Ozone	Phenology	Soil solution
Austria			15						6	6			
Belgium	5	8	9					5	5	4		5	9
Bulgaria	4	4	4	4					3	4	2	1	3
Croatia	2	7	4	7			6		4	2	2	4	
Cyprus	1	4	2							2			2
Czechia		16	7				7		7	10		6	7
Denmark		4	4				3		4	4		3	4
Estonia		6	6						1	1			5
Finland		6	7				1			8			8
France		93	25				10		10	13		82	14
Germany	35	85	65	50	21	14	11	16	43	78	8	51	50
Greece		4	3						4	4	3	2	3
Hungary		6											
Italy		30	8										
Latvia	1	2	3						3				3
Lithuania	3	9	3						3	1	9	1	2
Norway		3	3										3
Poland	12	135	12										12
Romania	4						4	3	3	4		3	5
Serbia		5	5		5				5	5	5	5	3
Slovakia	3	8	7							6	4		4
Slovenia	9	10	4										4
Spain	14	14	14				14	14	14	14	14	14	5
Sweden			51										
Switzerland	7	17	14							18	9		9
Turkey		52											
UK			5				3		4	5			5
Total	**100**	**528**	**280**	**61**	**26**	**14**	**59**	**38**	**119**	**189**	**56**	**177**	**160**

PART A
ICP Forests-related research highlights

2

FOREST CONDITION AND ENVIRONMENTAL DRIVERS IN EUROPE – RECENT FINDINGS AND PERSPECTIVES

Marco Ferretti, Nathalie Cools, Bruno De Vos, Stefan Fleck, Elena Gottardini, Tom Levanič, Tiina M. Nieminen, Diana Pitar, Nenad Potočić, Pasi Rautio, Tanja Sanders, Marcus Schaub, Volkmar Timmermann, Liisa Ukonmaanaho, Arne Verstraeten, Peter Waldner, Daniel Žlindra

Introduction

Marco Ferretti

ICP Forests reporting activity to stakeholders (e.g. Air Convention bodies, Participating countries) has been largely centered around data and results produced by the Programme but also from other related scientific sources.

Here we present a brief overview as prepared by all the ICP Forests Expert Panels (EPs) and reviewed by the Scientific Committee. EPs were asked to provide an overview of main evidence/key findings over the past year in the forest-relevant, priority themes for the Working Group on Effects (WGE) strategic planning: N deposition, ozone, heavy metals, air pollution/climate change interactions.

EPs based their input on max. five arbitrarily selected recent papers, i.e. those, EPs considered the most relevant in their own field. In the future, this activity will be further developed, with a more formal selection process for literature.

In the following, we summarize the main evidence according to two perspectives: the drivers-oriented perspective (i.e. atmospheric deposition and ozone as key drivers) and the response-oriented perspective (i.e. forest trees' growth, health, nutrition, phenology; acidification and eutrophication of forest soil). The response-oriented perspective is particularly important for the interactions between air pollution, deposition, climate change and extreme events.

Drivers-oriented perspective

Atmospheric deposition

Arne Verstraeten, Peter Waldner, Daniel Žlindra

Several studies yielded further insights into the effects of nitrogen (N) deposition and ground level ozone on forest ecosystem functioning. Braun et al. (2020) found clear indications that decreasing phosphorus and potassium concentrations in leaves of European beech are partly explained by excess N deposition. The study also revealed a negative relationship between foliar phosphorus concentrations and tropospheric ozone flux (POD1) in the preceding year.

Etzold et al. (2020) showed that N deposition is a factor at least as important as climate to modulate forest growth at European scale, with a tipping point for growth at around 30 kg N ha^{-1} yr^{-1}; higher inputs lead to reduced growth.

Salemaa et al. (2020) observed that throughfall deposition of dissolved organic nitrogen is a good predictor of the tissue total N content of three moss species in boreal forests. The accumulation of free ammonium in tissues collected at southern plots suggested that mosses are near the N saturation state already at a deposition rate of 3–5 kg N ha^{-1} yr^{-1}.

Roth et al. (2020) found that negative effects of N deposition on ground vegetation are often concealed by effects of tree layer composition, land-use legacies and soil pH as main determinants of the soil C/N ratio which was most closely related to the eutrophication state of the vegetation.

Guidelines for the protection of forest soils through liming were published by Andreae et al. (2020) based on the results of experiments conducted in forest stands in Saxony that were severely damaged by high sulphur depositions in the 1980s.

Ozone

Diana Pitar, Elena Gottardini

Temporal trends of ground-level ozone concentrations and temporal trends are variable and site-dependent. For instance, at Czech sites a steady increase from 2014 to the present has been reported (Hůnová et al. 2020), while in West Germany ozone concentrations did not show any significant trends during the 22-year study period 1998-2019. There, periods with elevated ozone were observed in parallel with elevated plant water stress. We, therefore, hypothesize that future (drier) climate conditions may protect plants from adverse ozone effects (Eghdami et al. 2020, Xu et al. 2020).

Furthermore, phytotoxic ozone levels are expected to directly or indirectly affect biodiversity, plant-insect interactions and soil microbial communities (Agathokleous et al. 2020). For ozone effects on tree growth, non-significant effects were found for pure, even-aged and managed European forests (Etzold et al. 2020), but Cailleret et al. (2020) propose to combine ozone-controlled experiments and long-term monitoring data with physiological and forest succession process-based models to disentangle between the forcing factors and to better understand ozone impacts at each ecosystem level.

The severity of ozone-induced visible foliar injury may be a result from the combination of multiple factors such as soil water content, air temperature, relative humidity, solar radiation, and ozone concentrations, through their influence on stomatal conductance and ozone uptake, respectively. Hence, Critical Levels based on flux-response functions to protect forests against adverse ozone effects have been proposed (Sicard et al. 2020).

Response-oriented perspective

Forest growth

Tom Levanič, Tanja Sanders

While atmospheric deposition of sulphur (S) and nitrogen (N) is slowly decreasing, levels of N in soils are still high, so that N remains one of the most important factors for forest growth at the European scale (Etzold et al. 2020). This also leads to legacy effects, where stand growth remained above expectations (Prietzel et al. 2020). However, as N is still readily available, other nutrients may become limiting, leading to new feedbacks of plant-available nutrients associated with decreasing recycling (Palmquist et al. 2020) and overall limited availability of some nutrients, such as phosphorus (P). This will prove increasingly important as nutrient availability, imbalances, and limitations affect climate-growth correlations in multiple ways, such that, for example, pines with good magnesium supply turn out to be less susceptible to drought (Sanders et al. 2020). However, prolonged drought may reduce the fertilizing effect of N on growth (Fenn et al. 2020), likely due to limited uptake capacity, thus limiting or altering the extent of fertilization, as also shown in Wang et al. (2020).

Overall, forest growth strongly depends on local deposition, nutrient availability, and climate, which poses challenges to modellers and foresters.

Forest health

Nenad Potočić, Volkmar Timmermann

Several aspects of climate change – especially rising summer temperatures, reduced precipitation, and the increasing frequency of severe drought events – have been found to impact the health of forests in Europe.

Effects range from (1) premature leaf yellowing and/or defoliation and moderate growth reduction, through (2) significant damage to tree crowns in the form of intense yellowing/leaf necrosis and high defoliation accompanied by a strong reduction in assimilation capacity, C sequestration and growth, to (3) increased tree mortality.

If considered at different geographical scales, (1) at the local level the effects may not be always apparent even following a strong drought, especially under favorable site conditions (e.g. Ognjenović et al. 2020); (2) at regional level, drought effects may be more apparent - in large parts of central Europe premature leaf senescence and reduced growth in deciduous tree species, especially beech, was recorded in 2018 (e.g. Rohner et al. 2021, Brun et al. 2020); and (3) pan-European analyses based on a large data sample are able to detect even more severe effects, such as an increased mortality risk with increasing temperatures for all major tree species in Europe, and with decreasing precipitation for some important conifers (e.g. Brandl et al. 2020).

Forest nutrition

Pasi Rautio, Liisa Ukonmaanaho

Etzold et al. (2020) conducted an analysis of recent forest growth to investigate how European forest growth has responded to changes in e.g. stand characteristics and air quality. They found that N deposition is as important as climate to affect forest growth in Europe, with a tipping point at around 30 kg N ha^{-1} yr^{-1}; higher inputs lead to reduced growth.

Penuelas et al. (2020) used ICP Forests data to study the nutritional status of forests potentially being affected by increased CO_2, N and S deposition, and climate change. They found that foliar concentrations of N, P, K, S and Mg decreased the last three decades with increasing CO_2.

Nussbaumer et al. (2020) analyzed Swiss beech data from the last 15–19 years to test the hypothesis that mast is controlled by flowering, and that after successful pollination, high amounts of fruits and seeds are produced. The study revealed that extreme summer heat and drought can act as an “environmental veto”, leading to early fruit abortion. They concluded that extreme summer heat and drought are therefore disrupting the heretofore assumed biennial fruiting cycle in beech.

Forest tree phenology

Stefan Fleck

Climate change is challenging the most widespread empirical phenological models for spring phenology and requires the calibration of process-based models: Asse et al. (2020) compared mechanistic and correlative models of spring phenology for five tree species such as *Betula pendula*, *Fraxinus excelsior*, *Picea abies*, *Corylus avellana*, *Larix decidua*. While correlative models were more accurate in estimating budburst in most years, they were less accurate than mechanistic models for unusually warm years.

Several phenological models for budburst and senescence of coniferous tree species were recently compared by Peaucelle et al. (2019), here the “Alternating Model” with only two parameters (Kramer 1994) performed best for pine and spruce.

The effect of extreme summer heat and drought on fruiting of *Fagus sylvatica* has been investigated by Nussbaumer et al. (2020). Even after successful pollination in spring, fruit development may be suppressed as a consequence of potential resource limitations induced by higher mean summer temperature (+1.5°C) and lower precipitation sums (-45%) during summer. Generalized linear models revealed a positive impact of cold summers (2 years before), followed by a warm summer (1 year before) with a dry spring in the current year on pollen concentration, as well as a positive impact of cold wet summers (2 years before) followed by a warm dry summer (one year before) on current year's fruit biomass.

The impact of observed cooler pre-season temperatures on pollination success of oak species was recently analyzed by Bogdziewicz et al. (2020). The combined effect of pre-season temperature and photoperiod delayed and shortened the pollen season of oaks, which leads to an expected decrease of pollination success through desynchronized flowering under conditions of global warming.

Forest soil acidification and eutrophication

Bruno De Vos, Nathalie Cools, Tiina Nieminen

Soil solid phase

The combined Level I Forest Soil Condition Database comprises heavy metal data for about 1000-1500 plots from the first inventory (1985-1996) and 3000-3500 plots from the second inventory (2006-2008); predominantly data of forest floor and topsoil (0-20 cm) compartments.

Heavy metal background concentrations differ among countries and biogeographical regions (Bommarez et al. 2021). The boreal zone shows the lowest concentration levels for most heavy metals. Overall decreases were observed in the concentrations of the heavy metals between both surveys for most plots, countries, and biogeographical regions with larger reductions in the forest floor compared to the mineral topsoil.

The observed spatial distribution patterns across Europe are comparable to those of the moss survey of ICP Vegetation and the EMEP deposition data for Cd, Pb and Hg.

Soil solution

Twenty years of soil solution monitoring in Switzerland revealed an ongoing, but site-specific soil acidification (Braun et al. 2020a). In strongly acidified soils, acidification indicators changed only slowly, possibly due to high buffering capacity of aluminium. In contrast, in less acidified sites an increasing acidification rate over time was observed, reflected by the continued decrease in the base cations to aluminum ratio (BC/Al ratio).

Furthermore, Braun et al. (2020a) demonstrated that the main driver of soil acidification is the high N deposition rate, causing cation losses and hampering sustainable nutrient balances for tree nutrition. Both N deposition and nitrate leaching have decreased since 2000, though the latter trend may be partly explained by increased drought in recent years. Nonetheless, those high N depositions are still affecting the majority of the forest sites. The interactions between N deposition and soil chemistry suggest an impaired uptake of K and P of beech stands in Switzerland at higher N loads (Braun et al. 2020b).

Conclusions

Marco Ferretti

There were several signals and suggestions for research and monitoring needs that emerge from the overview, and where ICP Forests can play an important role.

(i) Air pollution continues to affect forest ecosystems. Still today, several forest ecosystem compartments (from trees to ground vegetation, soil and soil solution) and processes (tree nutrition, tree growth, species diversity, soil acidification) are affected by air pollution, namely by N deposition, ground-level ozone, and heavy metals. The need for continuous monitoring remains.

(ii) Effects are diversified. For example, N deposition has been found to affect tree growth, lead to imbalances in tree nutrition, and promote soil acidification. Ozone has been reported as a potential threat to biodiversity, while effects on forest growth were less univocal. Heavy metals concentration in soil show similarities with deposition data and concentration in mosses. Also in terms of trends there is a diversified picture, with a generalized decrease of N deposition and heavy metals concentrations in the forest floor, and a more site-specific pattern for ground-level ozone. Once more, the multi-level, multi-media monitoring concept of ICP Forests proves to be essential, and – in case – should be reinforced with e.g. a remote sensing component.

(iii) Climate change as a strong driver. 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. Alongside, storms hit several sites across Europe, causing e.g. devastating windthrow. Both (drought and storms) caused subsequent bark beetle infestation. It is likely that extreme events related to climate change will increase in frequency, and this will cause additional pressure on European forests. Already today, drought is the most reported abiotic factor affecting trees on Level I plots. A scientific synthesis of climate records at e.g. the ICP Forests Level II sites over the past decades is now an urgent need.

(iv) Air pollution – climate change interaction is key. When considering the enduring pressure caused by air pollution in different forms and the increasing frequency of climate change-related events, there is an urgent need to better understand their interactions. A popular example here is the possible interaction between N deposition, ozone and drought. While a considerable body of knowledge exists in terms of experimental studies under controlled conditions, evidence from observational studies is still limited. Among others, this is an area of clear concern for the Air Convention, and where progress in scientific understanding and assessment is necessary.

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3 OVERVIEW OF ICP FORESTS-RELATED PUBLICATIONS (JANUARY – DECEMBER 2020)

Between January and December 2020, 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.

The following overview includes all 82 English online and in print publications from 2020 that have been reported to the ICP Forests Programme Co-ordinating Centre and added to the list of ICP Forests publications on the program's website[1].

Atmospheric deposition, ozone concentrations, and heavy metals

Ahrends B, Schmitz A, Prescher A-K, et al (2020) **Comparison of methods for the estimation of total inorganic nitrogen deposition to forests in Germany**. Frontiers in Forests and Global Change 3. https://doi.org/10.3389/ffgc.2020.00103

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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 35 requests for ICP Forests data between January and December 2020. All past and present ICP Forests data uses are listed on the ICP Forests website[2].

ID[3]	Name of Applicant	Institution	Project Title	External/ Internal[4]
180	Jan-Peter George	University of Tartu	Impact of climate change-type droughts across European forests during the last two decades	External
181	Ward Fonteyn	KU Leuven	Modelling the effects of extreme droughts on forest ecosystem functioning – Towards climate smart forestry	External
182	Ruth Stephan	University of Freiburg	Interreg Project "Alpine Drought Observatory (ADO)": WP 3 "Drought Impacts"	External
183	Jaegyun Byun	RWTH Aachen University	Predicting influence of management strategies on tree growth using a customized calibration for the growth and managements in Eifel region in Germany	External
184	Andrey L D Augustynczik	University of Freiburg	ConFoBi: Conservation of Forest Biodiversity in Multiple Use Landscapes of Central Europe	External
185	Christin Loran, Gert Jan Reinds	Umweltbundesamt DEU; Wageningen Environmental Research	Steady-State Critical Loads for eutropohication and acidification for European terrestrial ecosystems	Internal
186	Soisick Figueres	INRAE	Forêts-21	External
187	Mirela Beloiu	University of Bayreuth	Forest dynamics, tree health and climate change	External
188	Josep Penuelas	CREAF - Global Ecology Unit	Drivers affecting forest status across Europe - European forest defoliation in the last 30 years	External
190	Marco Lehmann	WSL Birmensdorf	Determining temporal changes in leaf physiology within an European forest network and how this affects forest growth and wood structure	External
192	Nicholas Clarke	Norwegian Institute of Bioeconomy Research NIBIO	Seasonality in Na/Cl molar ratios in bulk precipitation and throughfall	Internal
193	Heini Wernli	ETH Zurich	Dynamics and substructure of impact-defined extreme seasons, in present day and future RCP8.5 climate	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]	Name of Applicant	Institution	Project Title	External/ Internal[4]
194	Lasse Tarvainen	University of Gothenburg	Making the right choice – Impact of genetics on productivity of Norway spruce in a changing climate	External
195	Sabina Burrascano	Sapienza University of Rome	Distribution and spatial patterns of European forests categories	External
196	Lena Wohlgemuth	University of Basel	Seasonal impact of vegetation on atmospheric elemental mercury dry deposition	Internal
197	Dorit Julich	TU Dresden	Transition of sulfur nutrition from excessive supply to potential deficiency in spruce forest ecosystems in Central Europe	Internal
198	José I. Barredo	Joint Research Centre – European Commission	MAES - Mapping and Assessment of Ecosystems and their Services	External
200	Wolfgank Falk, Nenad Potočić	Bavarian Institute of Forestry	Alterations in the lifetime of forest stands: Spatial patterns and robustness of survival models in forestry	Internal
201	Wienand Kölle	Georg-August-Universität Göttingen	Can satellite-based weather index insurance hedge the risk of mortality or the survival probability of trees?	External
202	Pablo González-Moreno	University of Cordoba	Understanding the environmental drivers of Mediterranean oak decline at pan-European scale	External
203	Luciana Jaime Gonzalez	CREAF	Bioclimatic niche of insect pests and host trees in response to climate change	Internal
204	Ana Bastos	Max Planck Institute for Biogeochemistry	Impacts of the 2018/19 drought on European forests: From site to continental scale	External
205	Mathias Neumann	University of Natural Resources and Life Sciences Vienna	Phosphorus cycling in European forests	Internal
206	Jorge Curiel Yuste	Basque Center for Climate Change (BC3)	The role of soils in the vulnerability of Mediterranean forest to extreme droughts	External
207	Ieva Licite, Andis Lazdiņš	Latvian State Forest Research Institute "Silava"	Demonstration of climate change mitigation potential of nutrients rich organic soils in Baltic States and Finland	External
208	Dominik Sperlich	Albert-Ludwigs University Freiburg	Development of a climate-sensitive growth simulation model with economic component for the main tree species in Serbia and forest treatment strategies as basis for the decision-making of forest management under climate change (ANKLIWA-DS, WP3)	External
209	Hendrik Davi	INRAE, URFM, Ecologie des Fôrets Méditerranéennes	Modelling forest ecosystem services on Genetic Concervation Unit (project FORGENIUS)	External
210	TanShen	University Utrecht	Simulating canopy nitrogen content using optimality theory	External
211	Jérémy Cours	Institut national de recherche pour l'agriculture, l'alimentation et l'environnement (INRAE)	Evaluation of forest dieback effect on dead wood amount and ground vegetation biodiversity	External
212	Thilo Heinecke	Universiteit Antwerpen	Investigating the spatial variance of spring phenology across temperate European forests	External
213	Rachel Mason	The National Socio-Environmental Synthesis Center (SESYNC)	The ecological consequences of declining nitrogen concentration in plants worldwide	External

ID[3]	Name of Applicant	Institution	Project Title	External/ Internal[4]
214	Jaana Bäck, Johannes Peterseil	University of Helsinki	eLTER PLUS Advanced Community project Science Cases	Internal
215	Martin Gutsch	Potsdam Institute for Climate Impact Research (PIK)	Innovative forest Management Strategies for a resilient bioeconomy under climate change and disturbances (I-MAESTRO)	External
217	Romain Duquenne, Yannick Agnan	Université catholique de Louvain	Biogeochemical cycle of manganese in forest ecosystems: implications for soil organic carbon storage	External
219	Mikko Peltoniemi	Natural Resources Institute Finland (LUKE)	Potential of functional diversity for increasing the disturbance resiliency of forests and forest-based socio-ecological systems (FUNPOTENTIAL)	External

PART B

Reports on individual surveys in ICP Forests

5

ATMOSPHERIC DEPOSITION IN EUROPEAN FORESTS IN 2019

Aldo Marchetto, Peter Waldner, Arne Verstraeten, Daniel Žlindra

Summary

Studying the effects of atmospheric pollution on forest ecosystems requires an evaluation of air quality and of the amount of pollutants carried to the forests by atmospheric deposition. Pollutant flux towards ecosystems through deposition mainly follows two pathways: wet deposition of compounds dissolved in rain, snow, sleet or similar, and dry deposition of particulate matter through gravity or adsorption on forest canopy for example.

Pollutant deposition shows a relatively high local variability, related to the distribution of pollutant sources and the local topography, and *in-situ* measurement is needed to obtain accurate evaluations and to validate model estimates.

In 2019, the chemical composition of atmospheric deposition under the tree canopy was measured in 290 ICP Forests Level II permanent plots throughout Europe. In this report, we focus on acidifying, buffering, and eutrophying compounds in canopy throughfall deposition.

High values of nitrate deposition were mainly found in central Europe (Germany, Denmark, Belgium, Czechia, Switzerland, and eastern Austria), while for ammonium they were also found in northern Italy and Poland. While most of central Europe receives a moderate amount of sulphate deposition, high values are mainly found close to the largest point sources. In the southern part of Europe, sulphate deposition is also influenced by volcanic emission and by the episodic deposition of Saharan dust. The influence of marine aerosols was relevant at sites in coastal areas.

Calcium and magnesium deposition can buffer the acidifying effect of atmospheric deposition. High values of calcium deposition are reported in southern Europe, mainly related to the deposition of Saharan dust, and in eastern Europe. The correction for the marine contribution of calcium matters mainly for sites in central Europe and in Spain. In the case of magnesium, however, the distribution of the highest values is markedly reduced by the sea salt correction.

Introduction

The atmosphere contains a large number of substances of natural and anthropogenic origin. A large part of them can settle, or 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 exclusively 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.

Sulphur dioxide emission derives from coal and fuel combustion, volcanoes, and forest fires and has increased since the 1850s, causing an increase in the deposition of sulphate and in 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 decomposition of the nitrogen gas molecule in the air during lightning. However, human activities cause the emission of large amounts of nitrogen oxides (NO_x), released during combustions, 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 two effects on the ecosystems: They are important plant nutrients that can produce ecosystem eutrophication, and both have strong effects on 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), but they can also act as acidifying compounds (Bobbink and Hettelingh 2011).

Emission and deposition of nitrate and ammonium are recently decreasing, but the trend is less evident than for sulphate (Waldner et al. 2014; EEA 2016).

Materials and methods

Atmospheric deposition is collected on the ICP Forests permanent plots under the tree canopy (throughfall samplers, Fig. 5-1a) and in a nearby clearance (open field samplers, Fig. 5-1b,c). Throughfall samples are used to estimate wet deposition, i.e. the amount of pollutants carried out by rain and snow, but they also include dry deposition from particulate matter collected by the canopy. The total deposition to a forest, however, also includes nitrogen taken up by leaves directly or 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 sulphate, calcium and magnesium, the interaction is almost negligible and it can be assumed that throughfall deposition includes the sum of wet and dry deposition.

Other ions, such as nitrate and ammonium, interact with the tree canopy and the associated microbial communities. For example, tree leaves can uptake ammonium ions and release potassium (K+) ions and organic compounds. Certain microorganisms of the phyllosphere can convert ammonium into nitrate through a process called canopy nitrification (Guerrieri et al. 2015). These canopy interactions strongly affect the composition of throughfall deposition.

Sampling, analysis and quality control procedures are harmonized on the basis of the ICP Forests Manual (Clarke et al. 2016). Quality control and assurance include laboratory ring-tests, use of control charts and performing conductivity and ion balance checks on all samples (König et al. 2010). In calculating 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 consider the 2019 yearly throughfall deposition, collected on 290 permanent plots and following the ICP Forests Manual.

Eight plots were excluded because the duration of sampling covered less than 90% (329 days) of the year, and 65 other plots were marked as "not validated" because the conductivity check was passed for less than 30% of the analysis of the year. Other plots were also marked as the laboratory did not participate in the mandatory Working Ring Test, or did not pass the minimum requirement. This applied to 2 plots for sulphate, 9 for nitrate, 16 for ammonium, 8 for calcium, and 5 for magnesium.

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 (Cl^-) deposition according to the ICP Integrated Monitoring Manual (FEI 2013). Three more plots were marked for sea-salt corrected ions as the laboratory did not pass the test for chloride.

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. In the case of nitrate, high and moderate throughfall deposition was mainly found in central Europe, including Germany, Czechia, Poland, Austria, Italy, Slovenia and Belgium, but single plots with high deposition values are also reported in other countries (Fig. 5-2).

The central European area of high and moderate ammonium throughfall deposition is larger than for nitrate, with higher throughfall deposition values particularly in Germany, Belgium, and northern Italy, western Slovakia and Poland (Fig. 5-3).

It is generally considered that negative effects of nitrogen deposition on forests become evident when inorganic nitrogen deposition (i.e. the sum of nitrate and ammonium deposition) is higher than 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 10 and 25 kg ha^{-1} y^{-1} (Bobbink and Hettelingh, 2011). In 2019, throughfall inorganic nitrogen deposition higher than 10 kg ha^{-1} y^{-1} were mainly measured in central Europe, including Germany, Belgium, northern Italy, Switzerland, Austria, and Czechia (Fig. 5.4). Total deposition of nitrogen is typically a factor 1 to 2 higher than (below canopy) throughfall deposition, due to nitrogen being taken up by tree leaves in the canopy.

The area with high and moderate throughfall deposition of sulphate is smaller than for the nitrogen compounds (Fig. 5-5): High values are mainly found close to the largest point sources. In the southern part of Europe, sulphate deposition is also influenced by volcanic emission and by the episodic deposition of Saharan dust. The area of moderate deposition extends to most of central Europe from Belgium to Bulgaria. The influence of marine aerosols was relevant at sites in coastal areas, where the correction for sea-salt contribution led to low throughfall deposition values, without relevant alterations in the pattern described above (Fig. 5.6).

Figure 5-1: Throughfall (a) and open-field (b, c) collectors for rain in summer (a) and for snow in winter (b) in the northern Alps, Switzerland (Image: WSL)

Calcium and magnesium are also analysed 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 calcium throughfall deposition are mostly reported in central and southern Europe (Fig. 5-7). The correction for the marine contribution was less relevant than in previous years. (Fig. 5-8): High sea-salt corrected calcium deposition is mainly found in southern Europe (Spain, Italy, Slovenia, Romania, and Greece) where the influence of wind-blown Saharan dust is remarkable.

On the contrary, in the case of magnesium, the distribution of the highest values, including a large portion of southern and central Europe (Fig. 5-9), is markedly reduced by the sea salt correction (Fig. 5-10).

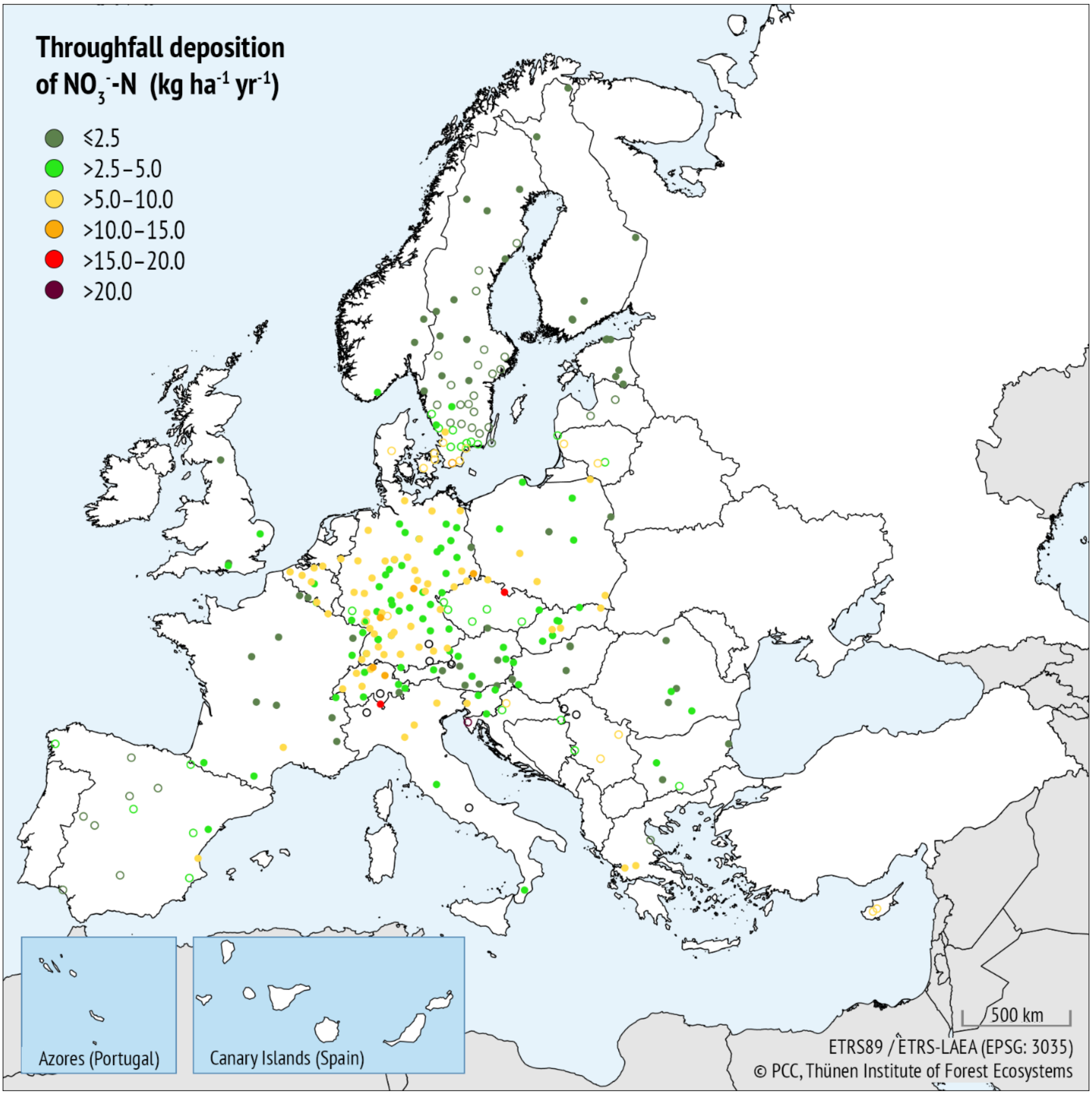

Figure 5-2: Throughfall deposition of nitrate-nitrogen (kg NO_3^--N ha^{-1} yr^{-1}) measured in 2019 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network. Colored dots: validated data. Colored circles: not validated data. Black circles: monitoring period shorter than 330 days.

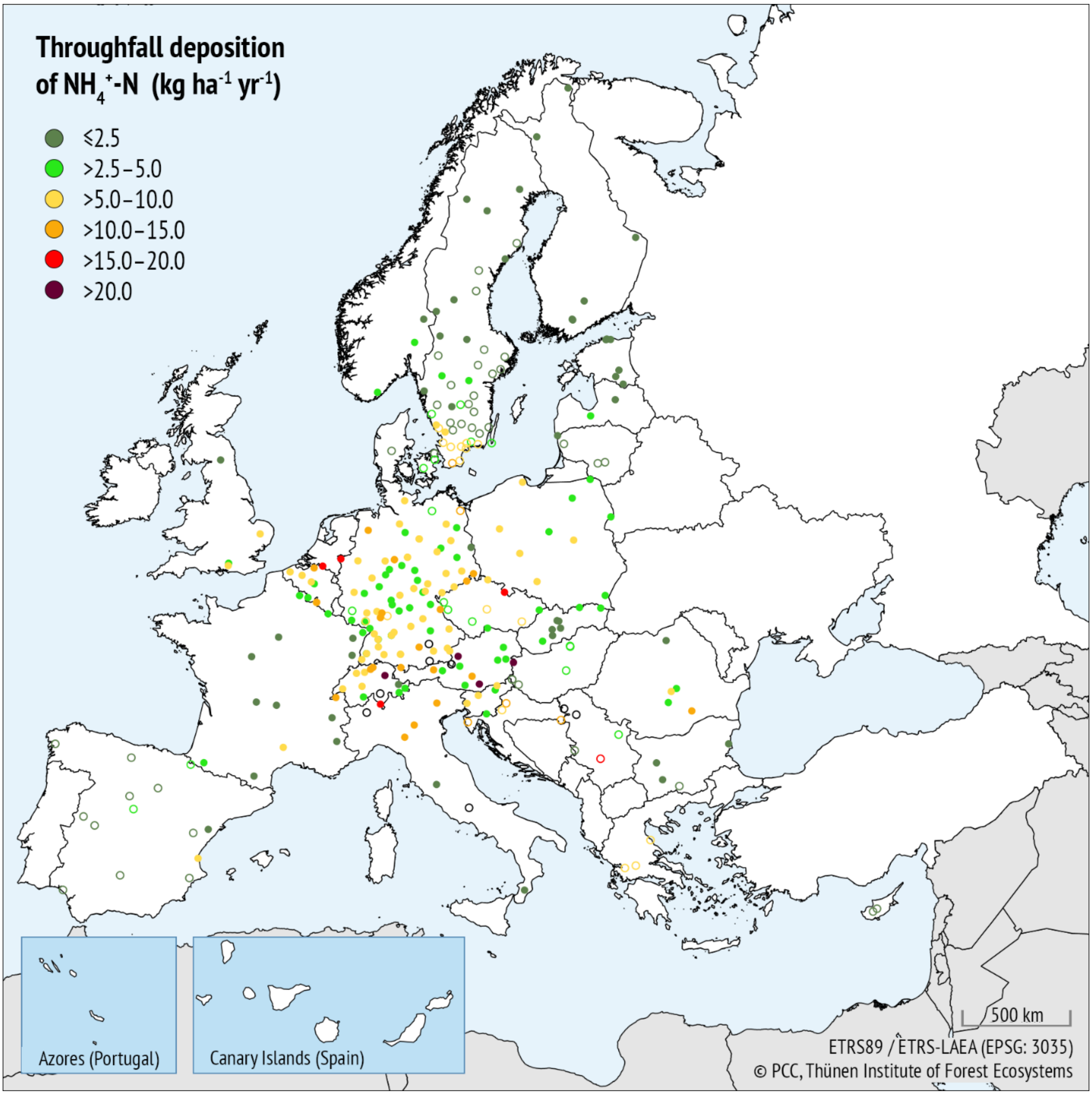

Figure 5-3: Throughfall deposition of ammonium-nitrogen (kg NH_4^+-N ha^{-1} yr^{-1}) measured in 2019 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network. Colored dots: validated data. Colored circles: not validated data. Black circles: monitoring period shorter than 330 days.

EVALUATIONS

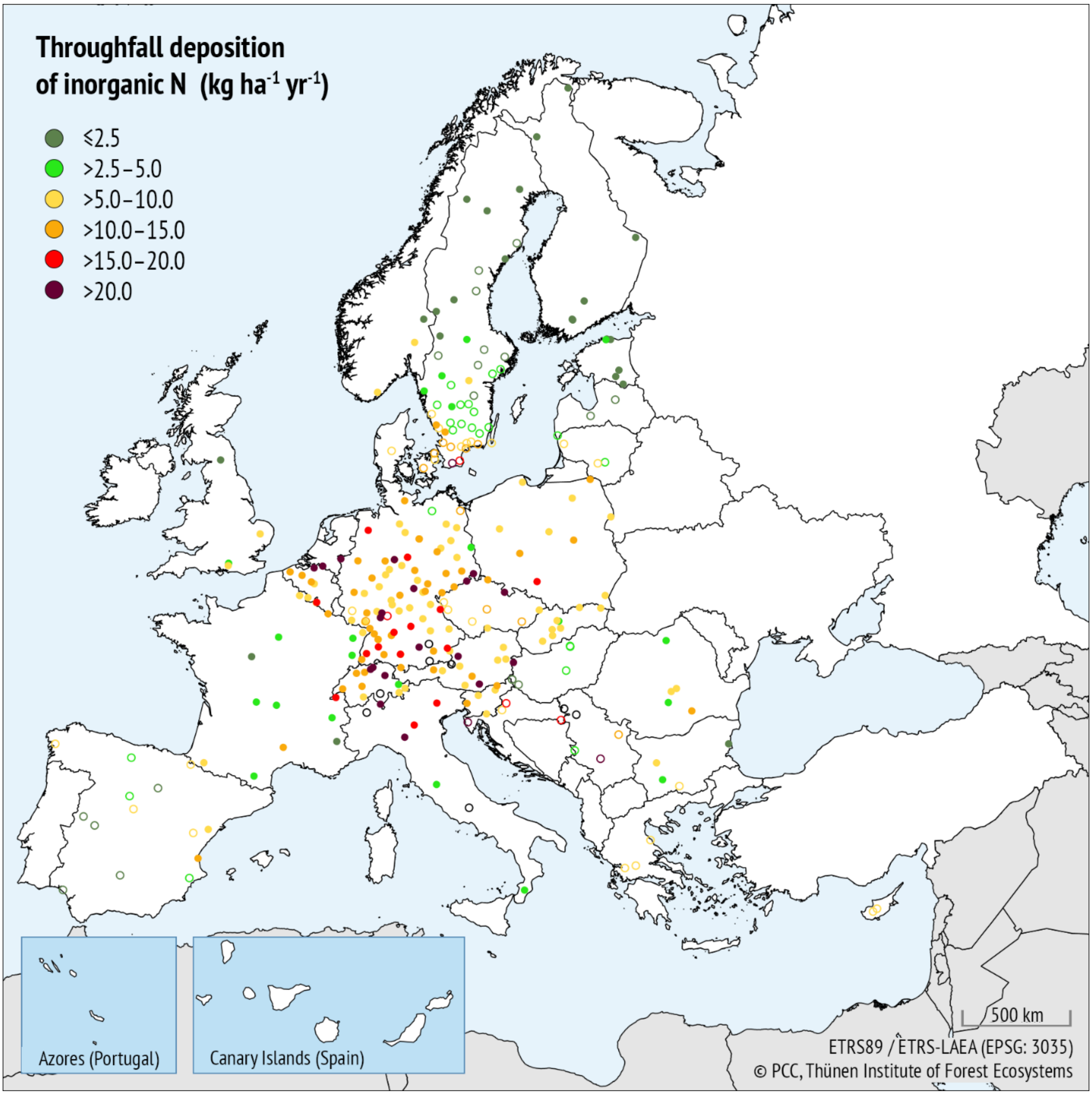

Figure 5-4: Throughfall deposition of inorganic nitrogen (NO_3^--N + NH_4^+-N) (kg N ha^{-1} yr^{-1}) measured in 2019 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network. Colored dots: validated data. Colored circles: not validated data. Black circles: monitoring period shorter than 330 days.

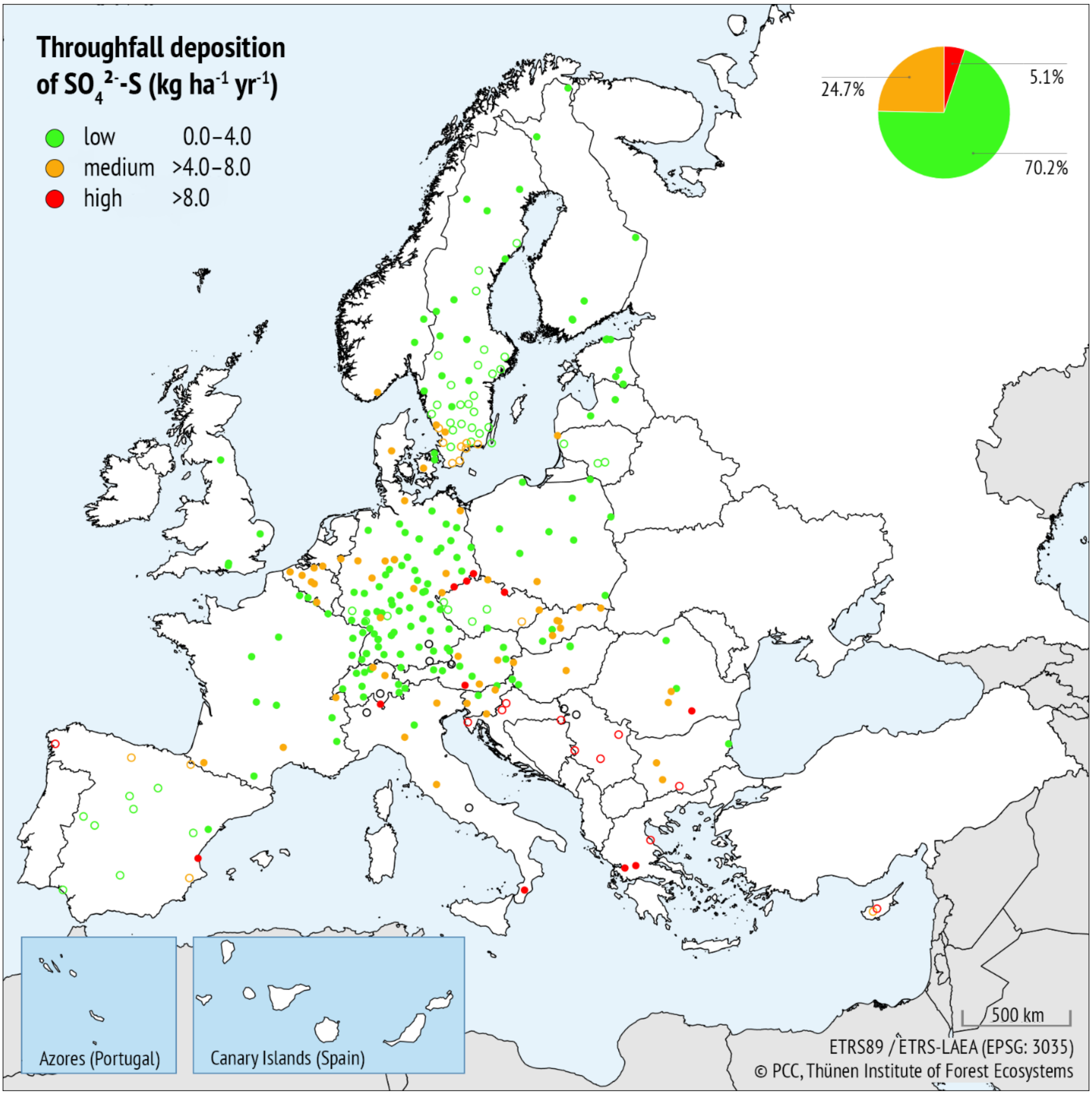

Figure 5-5: Throughfall deposition of sulphate-sulphur (kg SO_4^{2-}-S ha^{-1} yr^{-1}) measured in 2019 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network. Colored dots: validated data. Colored circles: not validated data. Black circles: monitoring period shorter than 330 days. Legend: low (green, 0.0–4.0 kg SO_4^{2-}-S ha^{-1} yr^{-1}), medium (yellow, >4.0–8.0 kg SO_4^{2-}-S ha^{-1} yr^{-1}), high (red, >8.0 kg SO_4^{2-}-S ha^{-1} yr^{-1}).

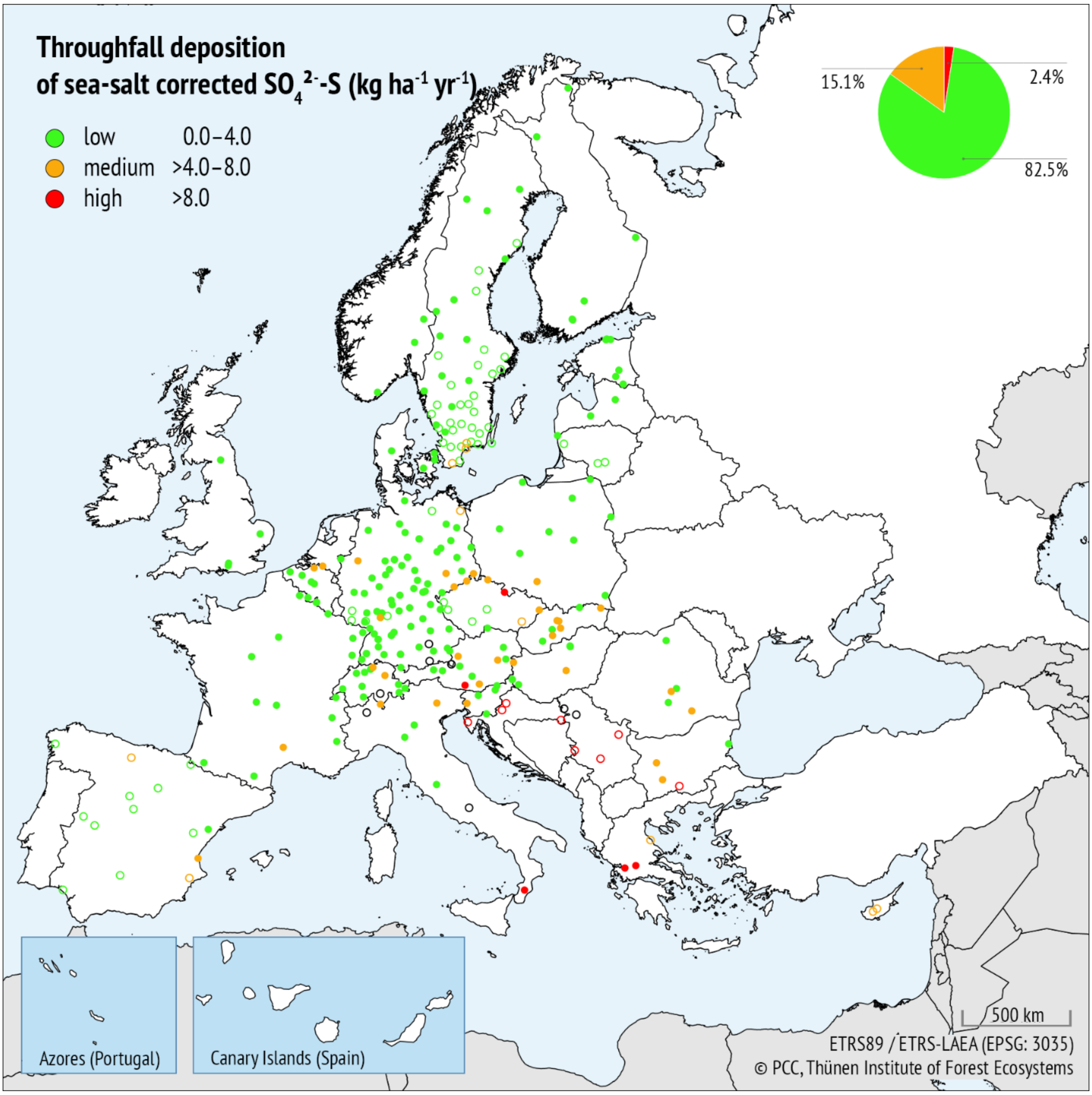

Figure 5-6: Throughfall deposition of sea-salt corrected sulphate-sulphur (kg SO_4^{2-}-S ha^{-1} yr^{-1}) measured in 2019 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network. Colored dots: validated data. Colored circles: not validated data. Black circles: monitoring period shorter than 330 days. Legend: low (green, 0.0–4.0 kg SO_4^{2-}-S ha^{-1} yr^{-1}), medium (yellow, >4.0–8.0 kg SO_4^{2-}-S ha^{-1} yr^{-1}), high (red, >8.0 kg SO_4^{2-}-S ha^{-1} yr^{-1}).

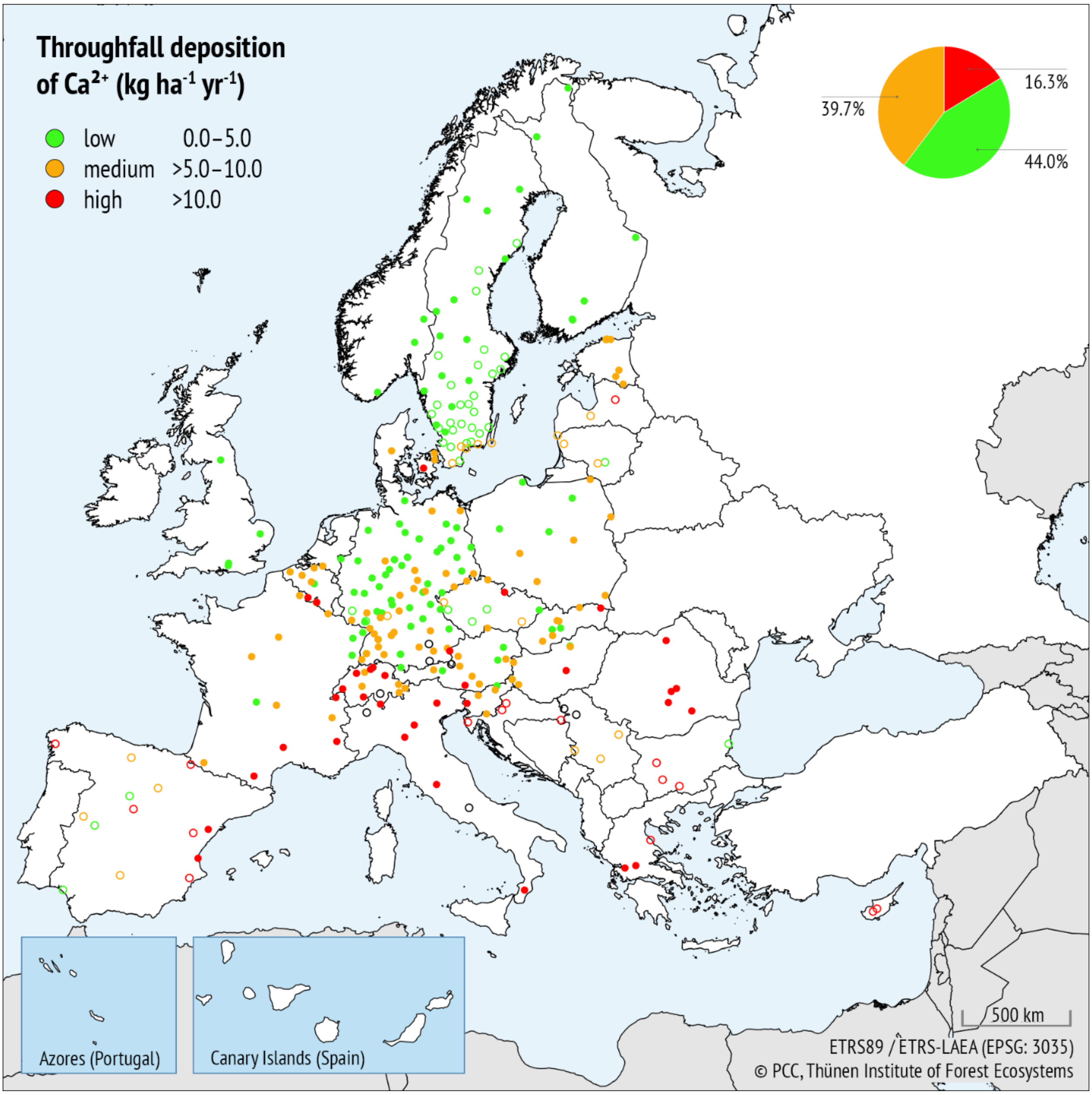

Figure 5-7: Throughfall deposition of calcium (kg Ca^{2+} ha^{-1} yr^{-1}) measured in 2019 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network. Colored dots: validated data. Colored circles: not validated data. Black circles: monitoring period shorter than 330 days. Legend: low (green, 0.0–5.0 kg Ca^{2+} ha^{-1} yr^{-1}), medium (yellow, >5.0–10.0 kg Ca^{2+} ha^{-1} yr^{-1}), high (red, >10.0 kg Ca^{2+} ha^{-1} yr^{-1}).

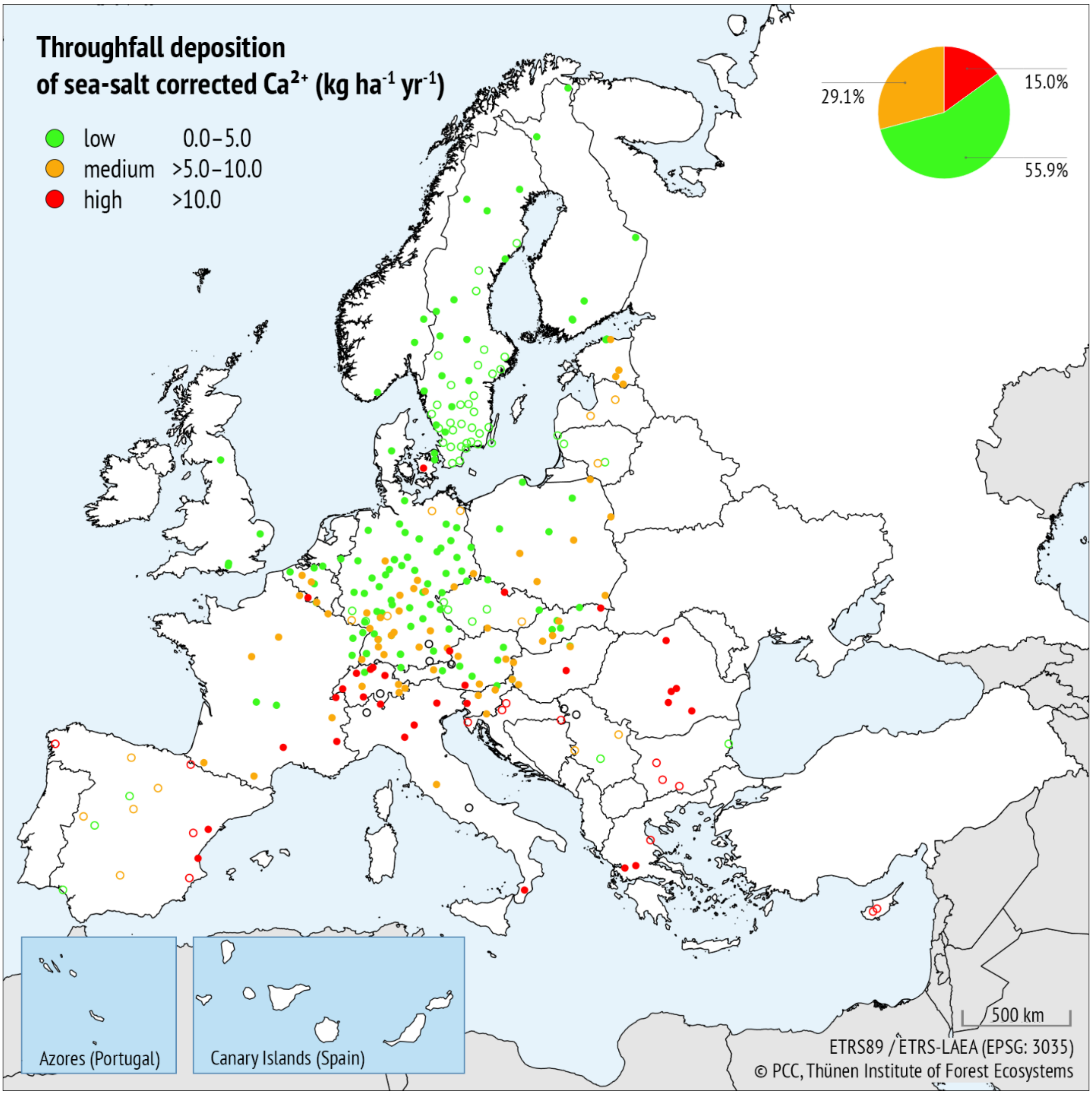

Figure 5-8: Throughfall deposition of sea-salt corrected calcium (kg Ca^{2+} ha^{-1} yr^{-1}) measured in 2019 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network. Colored dots: validated data. Colored circles: not validated data. Black circles: monitoring period shorter than 330 days. Legend: low (green, 0.0–5.0 kg Ca^{2+} ha^{-1} yr^{-1}), medium (yellow, >5.0–10.0 kg Ca^{2+} ha^{-1} yr^{-1}), high (red, >10.0 kg Ca^{2+} ha^{-1} yr^{-1}).

EVALUATIONS

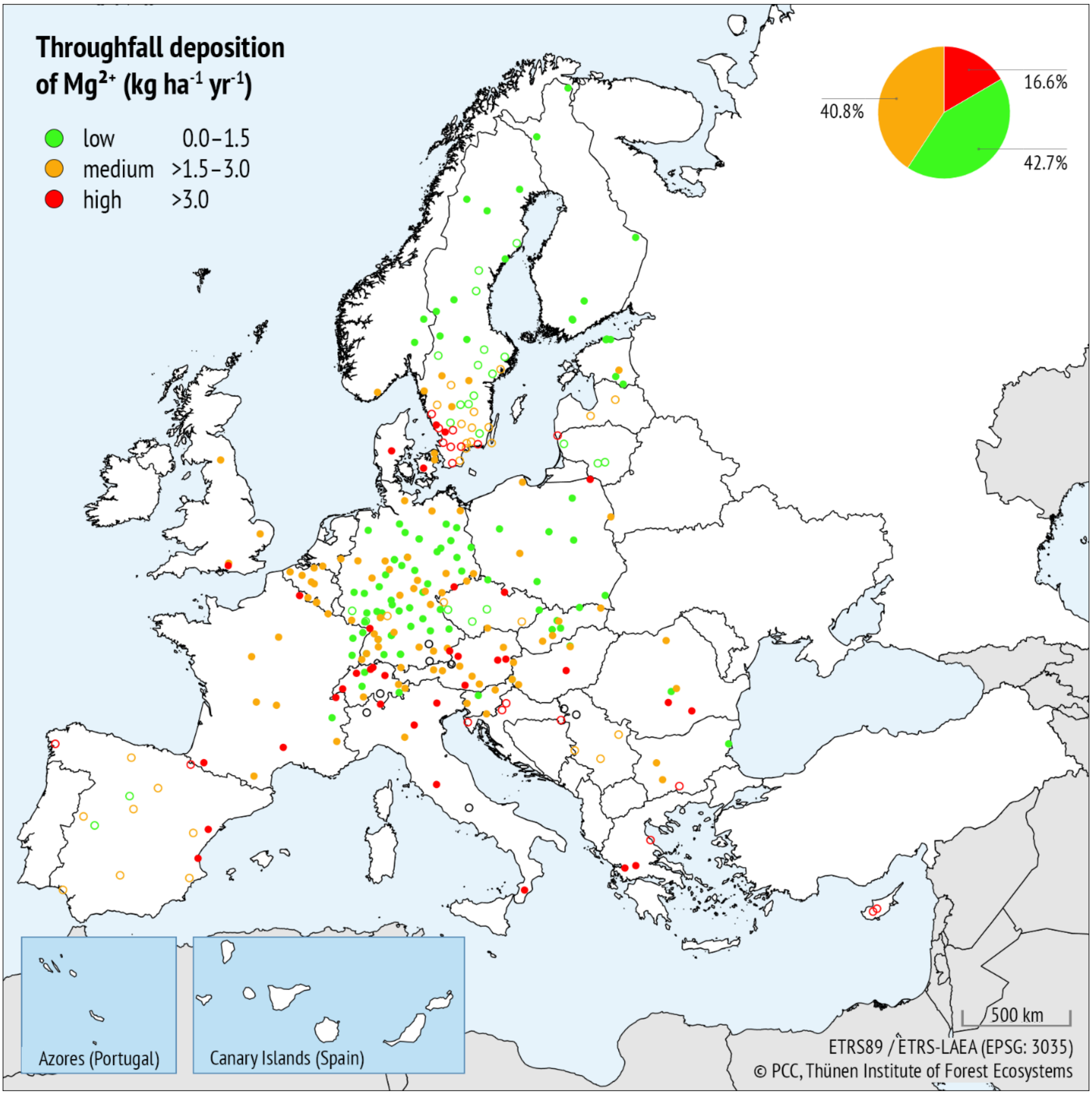

Figure 5-9: Throughfall deposition of magnesium (kg Mg^{2+} ha^{-1} yr^{-1}) measured in 2019 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network. Colored dots: validated data. Colored circles: not validated data. Black circles: monitoring period shorter than 330 days. Legend: low (green, 0.0–1.5 kg Mg^{2+} ha^{-1} yr^{-1}), medium (yellow, >1.5–3.0 kg Mg^{2+} ha^{-1} yr^{-1}), high (red, >3.0 kg Mg^{2+} ha^{-1} yr^{-1}).

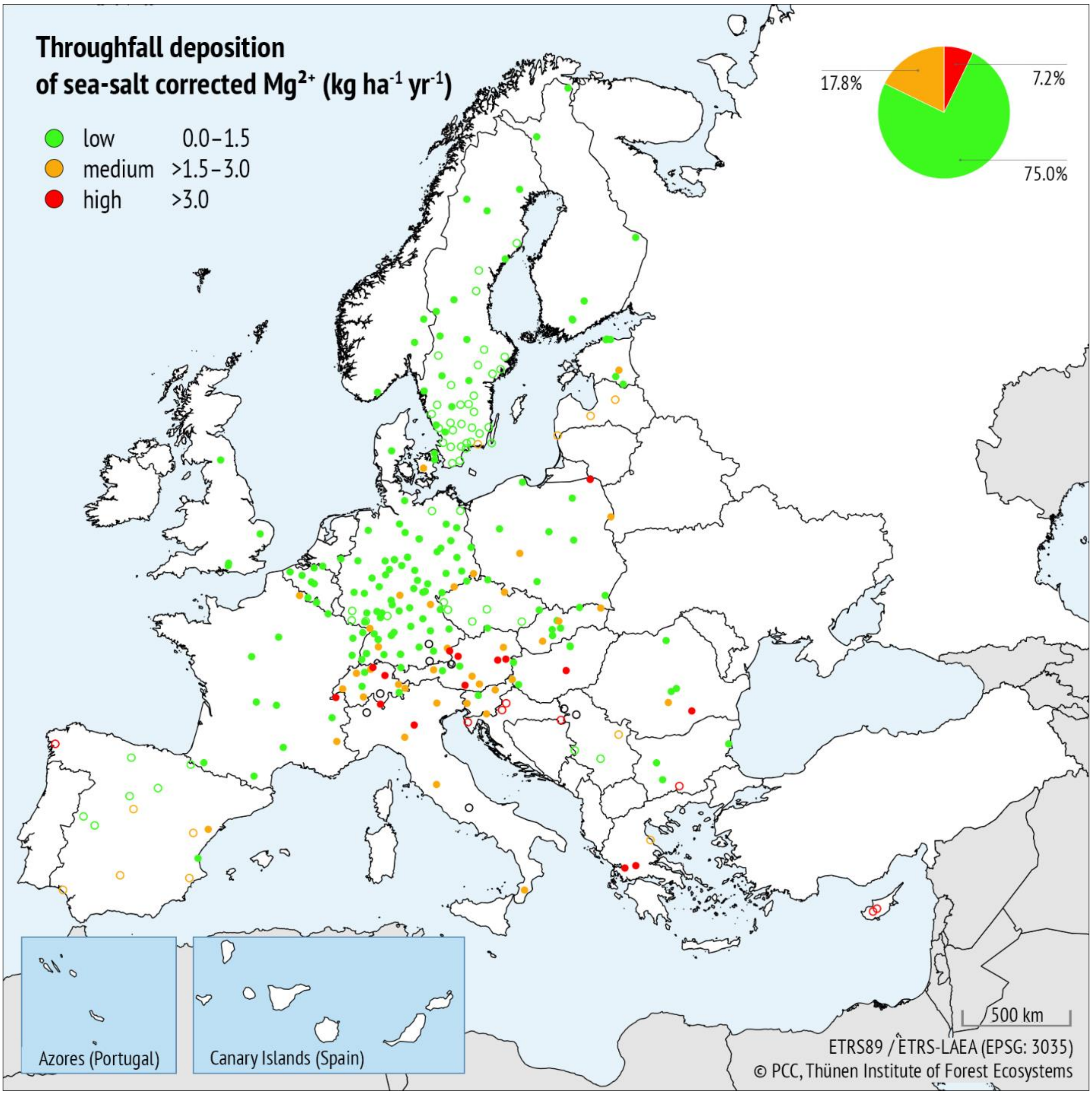

Figure 5-10: Throughfall deposition of sea-salt corrected magnesium (kg Mg^{2+} ha^{-1} yr^{-1}) measured in 2019 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network. Colored dots: validated data. Colored circles: not validated data. Black circles: monitoring period shorter than 330 days. Legend: low (green 0.0–1.5 kg Mg^{2+} ha^{-1} yr^{-1}), medium (yellow, >1.5–3.0 kg Mg^{2+} ha^{-1} yr^{-1}), high (red, >3.0 kg Mg^{2+} ha^{-1} yr^{-1}).

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6

TREE CROWN CONDITION IN 2020

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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 2020, as well as long-term trends for the main species and species groups.

Methods of the 2020 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. (2016, see also Eichhorn and Roskams 2013). Regular national calibration trainings of the survey teams and international cross-comparison courses (ICCs) ensure the quality of the data and comparability across the participating countries (Eickenscheidt 2015, Dănescu 2019, Meining et al. 2019).

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 6-1). In the maps presenting the mean plot defoliation and in Table 6-4, class 2 is subdivided into class 2-1 (> 25–40%) and class 2-2 (> 40–60% defoliation).

Table 6-1: 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 6-2 shows countries and the number of plots assessed for crown condition parameters from 2011 to 2020, and the total number of sample trees submitted in 2020. 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.

Damage cause assessments

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

Table 6-2: Number of plots assessed for crown condition parameters from 2011 to 2020 in countries with at least one Level I crown condition survey since 2011, and total number of sample trees submitted in 2020

Country	2011	2012	2013	2014	2015	2016	2017	2018	2019	Plots 2020	Trees 2020
Andorra	3	3	11	11	12						
Belarus	416		373		377						
Belgium	9	8	8	8	8	53	53	52	52	51	537
Bulgaria	159	159	159	159	159	159	160	160	160	160	5 599
Croatia	92	100	105	103	95	99	99	99	97	94	2 256
Cyprus	15	15	15	15	15			15	15	15	361
Czechia	136	135		138	136	136	135	132	132	127	4 590
Denmark	21	18	20	20	20	19	19	17	19	19	459
Estonia	98	97	96	96	97	98	98	98	98	95	2 286
Finland	717	785									
France	544	553	550	545	542	533	527	521	515	512	10 306
Germany	404	415	417	422	424	421	416	410	421	416	10 040
Greece				57	47	23	36	40	45	38	894
Hungary	72	74	68	68	67	67	66	68	68	68	1 511
Ireland		20							28	30	609
Italy	253	245	247	244	234	246	247	249	237	240	4 512
Latvia	203	203	115	116	116	115	115	115	115	115	1 756
Lithuania	77	77	79	81	81	82	82	81	81	81	1 957
Luxembourg			4	4	4	4	3	3	4	4	96
Moldova							9	9			
Montenegro	49	49	49			49	49	49	49	49	1 176
Norway	496	496	618	687	554	629	630	623	687	604	4 910
Poland	367	369	364	365	361	353	352	348	346	343	6 833
Romania	242	241	236	241	242	243	246	246	247	226	5 517
Russian Fed.	295										
Serbia	119	121	121	128	127	127	126	126	127	126	2 905
Slovakia	109	108	108	107	106	103	103	101	100	99	4 427
Slovenia	44	44	44	44	44	44	44	44	44	44	1 074
Spain	620	620	620	620		620	620	620	620	620	14 880
Sweden	640	609	740	842	839	701	618	760	849	841	3 119
Switzerland	47	47	47	47	47	47	47	47	47	47	1 019
Turkey	563	578	583	531	591	586	598	601	597	599	13 891
TOTAL	**6 810**	**6 189**	**5 797**	**5 699**	**5 345**	**5 557**	**5 498**	**5 634**	**5 800**	**5 663**	**107 520**

- 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. (2016). 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 assessed for crown condition on the Level I network in 2020, *Pinus sylvestris* was the most abundant tree species (16.9% of all trees), followed by *Picea abies* (11.6%), *Fagus sylvatica* (11.4%), *Pinus nigra* (5.1%), *Quercus petraea* (4.3%), *Quercus robur* (4.2%), *Quercus ilex* (3.6%), *Pinus brutia* (3.2%), *Quercus cerris* (3%), *Pinus halepensis* (2.4%), *Betula pubescens* (2.2%), *Quercus pubescens* (2.1%), *Abies alba* (2.1%), *Betula pendula* (2.1%), *Pinus pinaster* (1.8%) and *Carpinus betulus* (1.8%). Most Level I plots with crown condition assessments contained one (49.4%) or two to three (38.0%) tree species per plot. On 10.4% of plots four to five tree species were assessed, and only 2.2% of the plots featured more than five tree species. In 2020, 49.9% of the assessed trees were broadleaves and 50.1% 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 6-4 and 6-5). 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 6-4 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 & Drápelová 2011, Curtis & 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 & 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 (Marchetto 2015) was used.

Figures 6-2a-j show (1) the annual mean defoliation per plot, (2) the mean across plots and (3) the trend of defoliation based on the regional Sen's slope calculations for the period 2001–2020. For the Mann-Kendall test, a significance level of $p \leqslant 0.05$ 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 2011–2020 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 period of interest. All queries and statistical analyses were conducted in R/RStudio software environment (R Core Team 2016).

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.

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

Results of the transnational crown condition survey

Defoliation

The transnational crown condition survey in 2020 was conducted on 107 520 trees on 5 663 plots in 27 countries (Table 6-2). Out of those, 102 534 trees were assessed in the field for defoliation (Table 6-3).

The overall mean defoliation for all species was 23.3% in 2020; there was no change for conifers and a very slight increase in defoliation for broadleaves in comparison with 2019 (Table 6-3). Broadleaved trees showed a higher mean defoliation than coniferous trees (23.3% vs. 22.2%). Correspondingly, conifers had a higher frequency of trees in the defoliation classes 'none' and 'slight' (73.4% combined) than broadleaves (69.9%) and a lower frequency of trees with more than 60% defoliation (2.7% vs. 3.8%).

Among the main tree species and tree species groups, evergreen oaks and deciduous temperate oaks displayed the highest mean defoliation (27.0% and 25.9%, respectively). Deciduous (sub-) Mediterranean oaks had the lowest mean defoliation (20.9%) followed by Mediterranean lowland pines (21.6%) and Austrian pine with 22.0%. Mediterranean lowland pines had the highest percentage (78.7%) of trees with ≤25% defoliation, while deciduous temperate oaks had the lowest (61.8%). The strongest increase occurred in common beech (+1.5%) and the strongest decrease in evergreen oaks (-1.6%).

Mean defoliation of all species at plot level in 2020 is shown in Figure 6-1. More than two thirds (68.5%) of all plots had a mean defoliation up to 25%, and only 1% of the plots showed severe defoliation (more than 60%). While plots with defoliation up to 10% were located mainly in Norway, Serbia, Romania and Turkey, 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 coastal Croatia.

The following sections describe the species-specific mean plot defoliation in 2020 and the over-all trend and yearly mean plot defoliation from 2001 to 2020. For maps on defoliation of individual tree species in 2020, please refer to the online supplementary material[1].

Table 6-3: Percentage of trees assessed in 2020 according to defoliation classes 0-4 (class 2 subdivided), mean defoliation for the main species or species groups (change from 2019 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	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*)	21.5	52.1	15.9	7.0	2.8	0.7	23.1 (+0.3)	17 842
Norway spruce (*Picea abies*)	30.3	36.6	21.1	7.5	2.8	1.7	22.5 (+0.5)	12 175
Austrian pine (*Pinus nigra*)	29.4	46.7	13.9	5.9	3.9	0.2	22.0 (-0.9)	5 375
Mediterranean lowland pines	17.8	60.9	14.9	4.5	1.6	0.3	21.6 (-1.2)	8 198
Other conifers	33.4	42.3	15.6	5.9	2.4	0.4	20.7 (+0.5)	7 804
Common beech (*Fagus sylvatica*)	31.9	37.2	19.8	7.5	3.5	0.1	22.6 (+1.5)	12 316
Deciduous temperate oaks	19.7	42.1	25.4	8.7	3.6	0.5	25.9 (-1.0)	9 082
Dec. (sub-) Mediterranean oaks	32.0	42.9	16.3	6.2	2.3	0.3	20.9 (-0.4)	7 860
Evergreen oaks	8.0	57.0	21.9	8.5	4.2	0.4	27.0 (-1.6)	4 500
Other broadleaves	29.5	44.4	14.3	5.8	4.7	1.3	22.5 (+0.2)	17 382
TOTAL								
Conifers	25.6	47.8	16.7	6.4	2.7	0.8	22.2 (+/-0.0)	51 394
Broadleaves	26.8	43.1	18.6	7.0	3.8	0.7	23.3 (+0.1)	51 140
All species	**26.3**	**45.5**	**17.6**	**6.7**	**3.2**	**0.7**	**23.3 (+/-0.0)**	**102 534**

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

EVALUATIONS

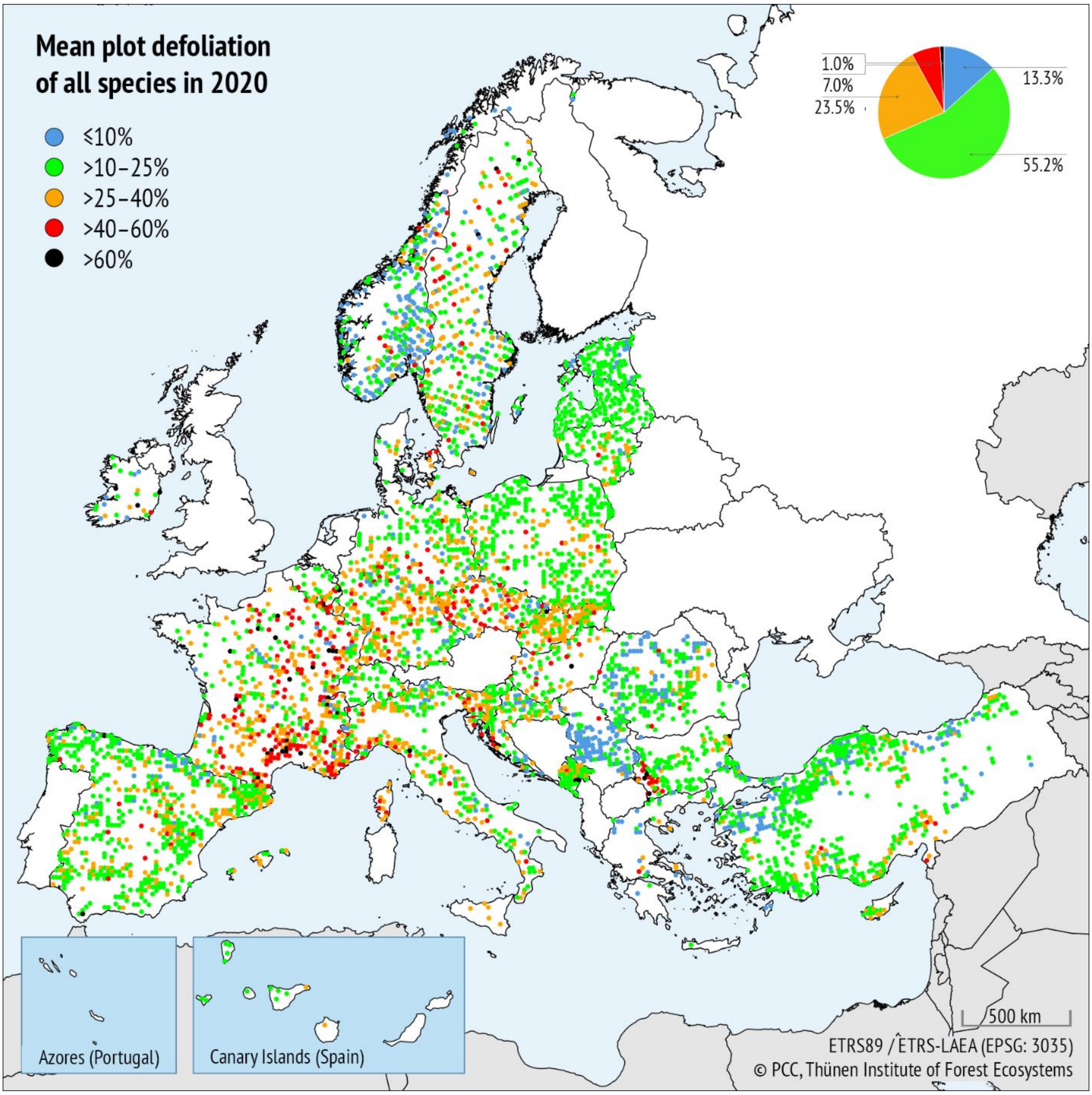
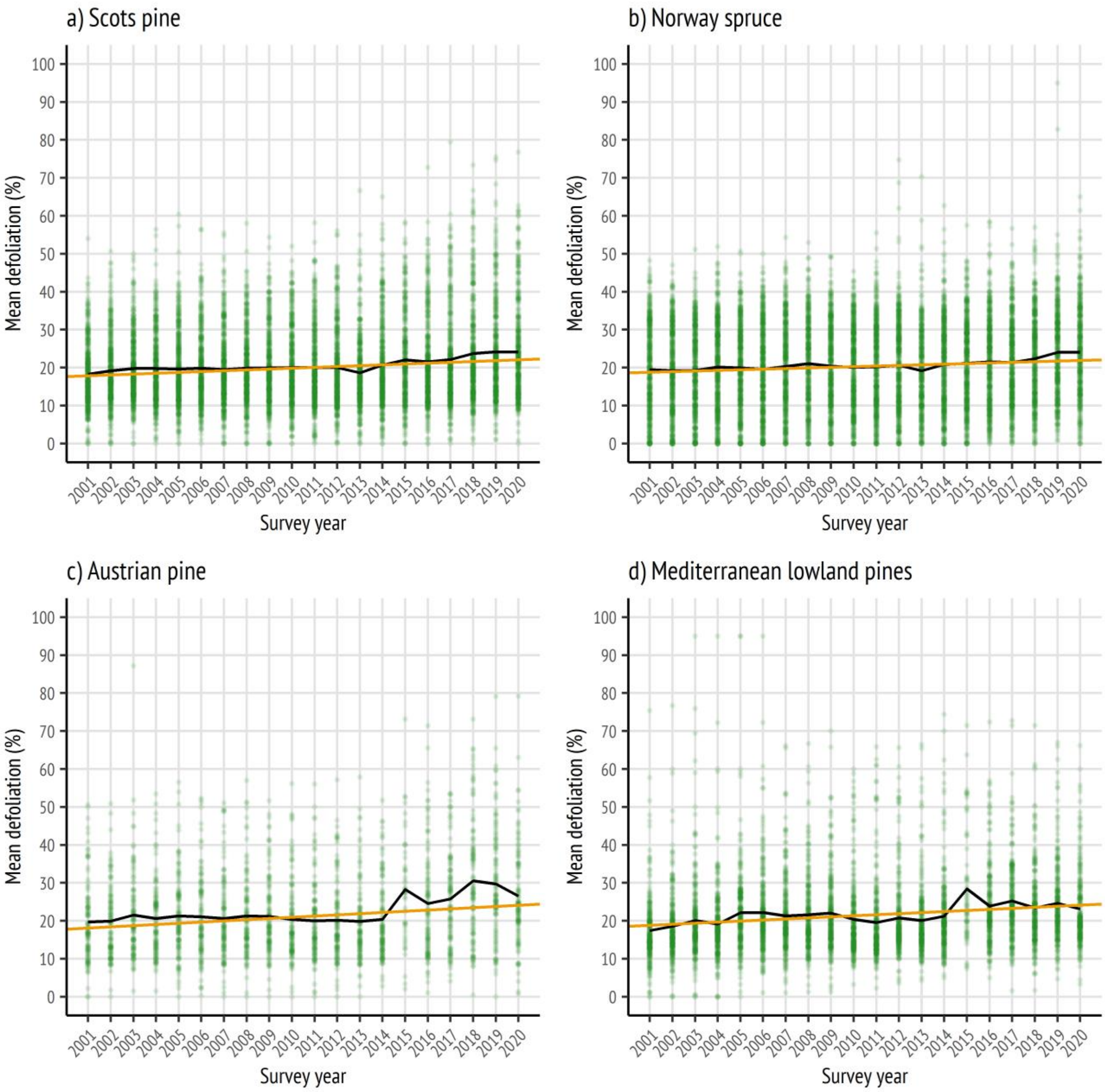
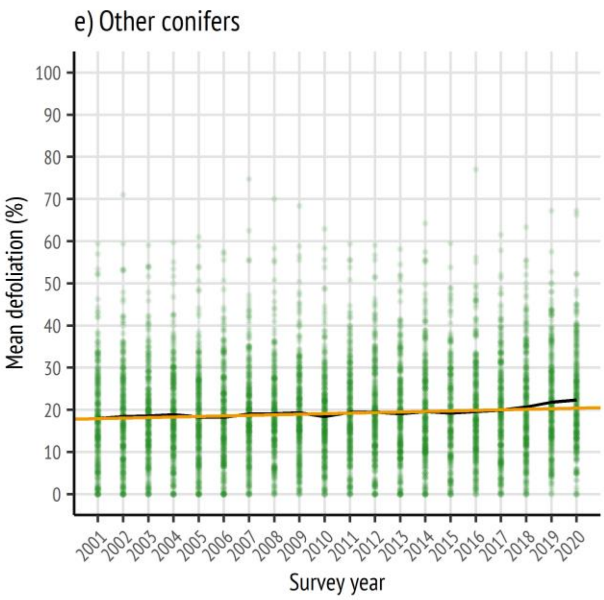
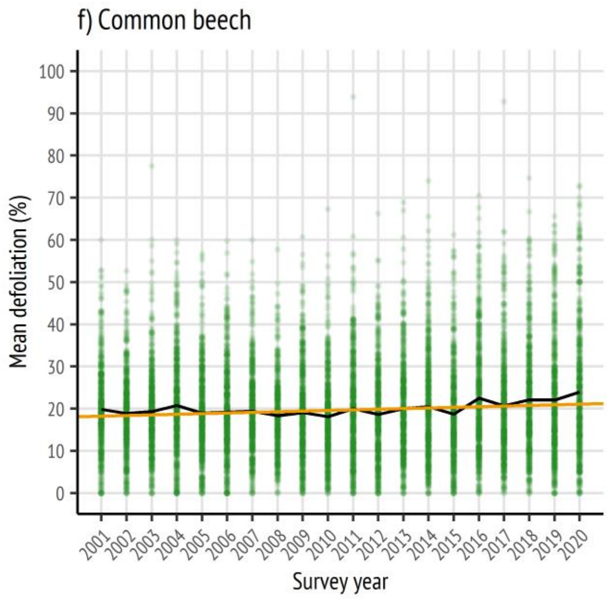


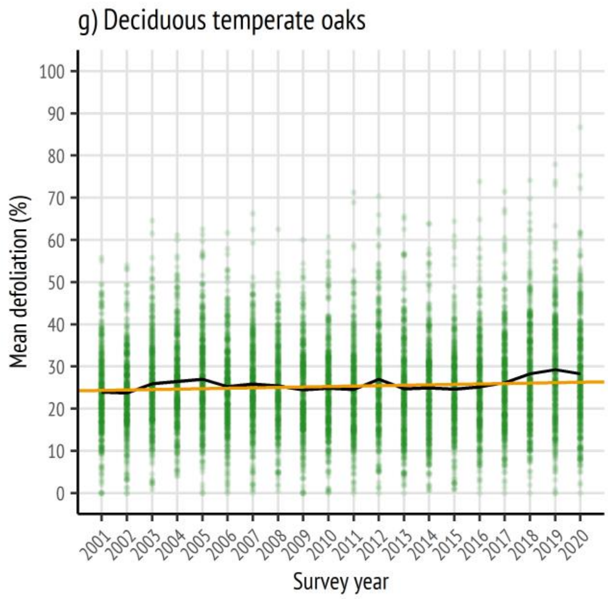
Figure 6-1: Mean plot defoliation of all species in 2020, shown as defoliation classes. The legend (top left) shows defoliation classes ranging from none (blue), slight (green), moderate (orange and red), to severe (black). The percentages refer to the needle/leaf loss in the crown compared to a reference tree. The pie chart (top right) shows the percentage of plots per defoliation class. Dead trees are not included.

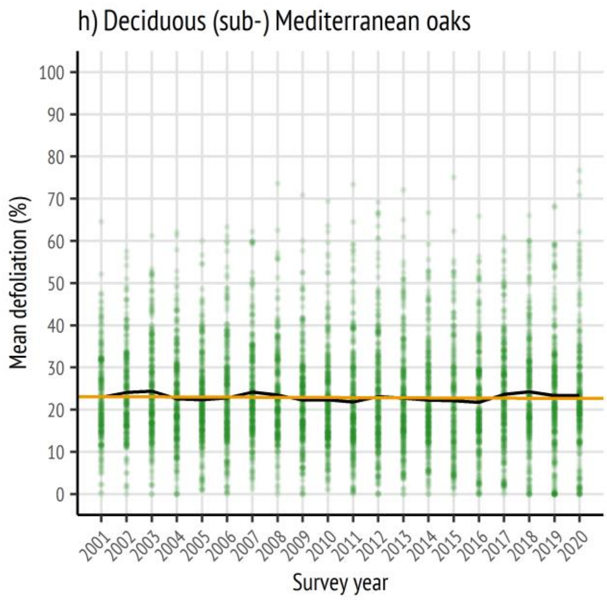


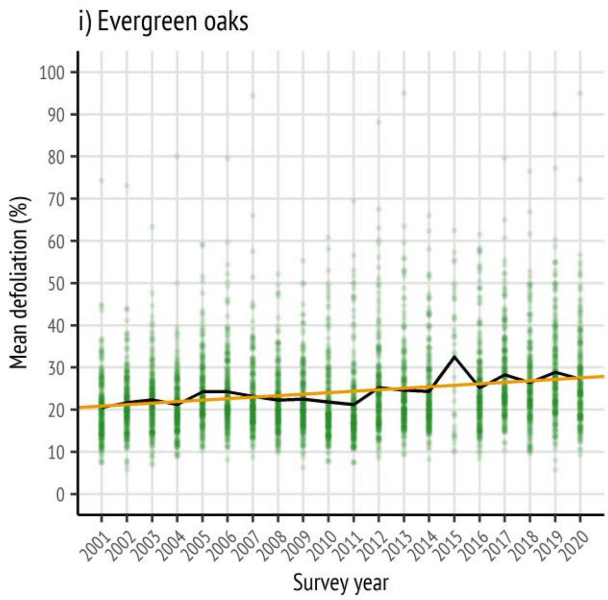


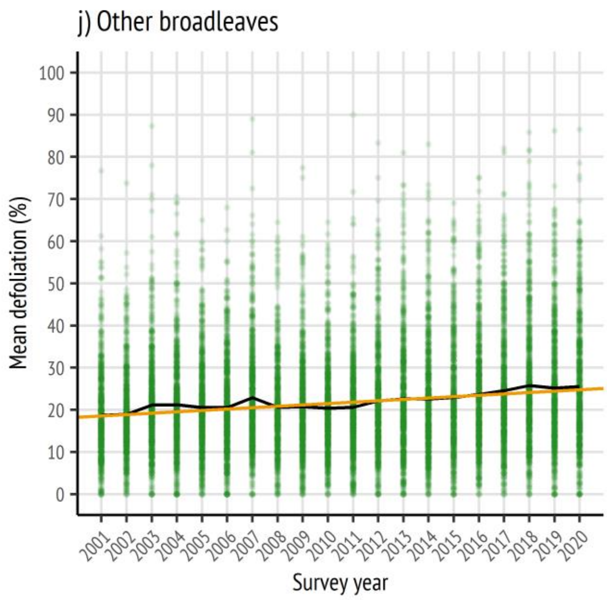
Figures 6-2 a-e: Over-all trend (orange line) and annual mean defoliation across plots (black line) at Level I plots from 2001–2020; points represent annual plot mean values:
(a) Scots pine (regional Sen's slope = 0.2204, $p < 0.001$)
(b) Norway spruce (regional Sen's slope = 0.1651, $p < 0.001$)
(c) Austrian pine (regional Sen's slope = 0.3155, $p < 0.05$)
(d) Mediterranean lowland pines (regional Sen's slope = 0.2803, $p < 0.01$)
(e) Other conifers (regional Sen's slope = 0.1289, $p < 0.001$)











Figures 6-2 f-j: Over-all trend (orange line) and annual mean defoliation across plots (black line) at Level I plots from 2001–2020; points represent annual plot mean values:
(f) Common beech (regional Sen's slope = 0.1484, *p* < 0.05)
(g) Deciduous temperate oaks (regional Sen's slope = 0.1013, *n.s.*)
(h) Deciduous (sub-) Mediterranean oaks (regional Sen's slope = -0.0231, *n.s.*)
(i) Evergreen oaks (regional Sen's slope = 0.3511, *p* < 0.001)
(j) Other broadleaves (regional Sen's slope = 0.3290, *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 6-3). 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 Turkey (and is also distributed considerably beyond the UNECE region).

In 2020, pine trees showed slight mean defoliation on 62.9% of the Scots pine plots (please refer to the online supplementary material[1], Figure S1-1). Defoliation of Scots pine trees on 22.4% of the plots was moderate (>25–60% defoliation, class 2) and only on 0.7% of the plots severe (>60% defoliation, class 3). Plots with the lowest mean defoliation were primarily found in southern Norway, Sweden and Estonia, 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 4.4% (Figure 6-2a). 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.

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 2020, spruce trees on roughly one fifth (21.5%) of all Norway spruce plots had defoliation up to 10%, and further 41.8% had only slight defoliation (please refer to the online supplementary material[1], Figure S1-2). On 27.8% of the plots spruce defoliation was moderate (>25–60% defoliation) and severe defoliation was recorded on only 0.5% of the plots. Plots with low mean defoliation were found mostly in Norway, Sweden and the Alpine region. Plots with high mean defoliation values were found in central Europe and parts of Scandinavia.

The 20-year trend in mean plot defoliation of Norway spruce shows an increase of 3.3% (Figure 6-2b). The annual mean values did not deviate much from the trend line except in the past two years.

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 Turkey 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 different environmental conditions.

Austrian pine had a mean defoliation of up to 10% on 12.2% of the plots containing this species, and between 11 and 25% on 66.5% of plots - in total 78.8% of plots had mean defoliation lower than 25% (please refer to the online supplementary material[1], Figure S1-3). Defoliation was moderate on 19.9% of the plots (>25-60% defoliation) and severe on 1.4% of the plots. Plots with less than 10% mean defoliation were mostly located in Turkey, while plots with higher defoliation were scattered throughout the region.

The 20-year trend in mean plot defoliation of Austrian pine shows an increase of 6.3% (Figure 6-2c). 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 Turkey, 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 4.3% of plots and 68.6% of plots had defoliation between 11 and 25% (please refer to the online supplementary material[1], Figure S1-4). Defoliation was moderate on 26.6% of the plots, and severe on 0.5%. Most of plots with defoliation up to 25% were located in Turkey 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 5.6% over the past 20 years (Figure 6-2d), with annual values mostly staying 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 2020 and by far the most frequently assessed deciduous tree species within the ICP Forests monitoring programme. 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 2020, common beech had up to 10% mean defoliation on 18.5% of the beech plots (please refer to the online supplementary material[1], Figure S1-5). On 43.6% of plots, beech trees were slightly defoliated (>10–25% defoliation), moderate mean defoliation was recorded on 34.2% and severe defoliation on 3.7% of plots. Most of plots with lower mean defoliation were located in central and 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 3.0% (Figure 6-2e). Annual mean values generally stay close to the trendline, but there were two previous larger deviations from this trend, in 2004 and 2016, along with the highest ever recorded mean plot defoliation of 23.9% 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). The effect of the drought affecting some European regions in 2018 is not very prominent.

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 Turkey.

In 2020, mean defoliation of temperate oaks was up to 10% on 7.4% of the plots, and from >10 to 25% on 44.4%, therefore more than half of the plots had no or slight mean defoliation. Moderate mean defoliation (>25–60%) was recorded on 47.0% of plots and severe defoliation (more than 60% defoliation) on 1.2% of the plots (please refer to the online supplementary material[1], Figure S1-6). Plots with severe defoliation were located mostly in France, while plots with mean defoliation up to 25% were mainly found in Romania, Croatia, Serbia and Turkey.

There has been no significant increase in mean plot defoliation 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 6-2f). 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).

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 16.2% of the plots, and on 53.9% of the plots between 10 and 25%, yielding a total of 70.1% of plots with mean defoliation up to 25% for these oaks in 2020. Less than a third (29.1%) of plots showed moderate, and only 0.8% 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, Bulgaria and Turkey, while plots with higher mean defoliation were found mostly in southeastern France.

There has been no significant trend in mean plot defoliation for deciduous (sub-) Mediterranean oaks for the past 20 years (Figure 6-2g). Mean plot defoliation values generally stay very close to the trendline.

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.

Very few (1.3%) of the evergreen oak plots had mean defoliation up to 10%, and there were 52.3% 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 45.1% of plots, and severe defoliation on 1.3%. The majority of plots with defoliation over 40% were located in southeastern France.

Based on the trend analysis, evergreen oaks have the highest increase in defoliation of all assessed species or species groups over the last 20 years (+7.0%, Figure 6-2h). The defoliation development pattern for evergreen oaks is characterized by larger deviations from the trendline.

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

Damage causes

In 2020, damage cause assessments were carried out on 101 773 trees on 5 547 plots and in 26 countries. On 48 009 trees (47.2%) at least one symptom of damage was found, which is 1.6% less than in 2019 (48.8%). In total, 68 593 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 6-4) was higher for the broadleaved tree species and species groups than for the conifers. It was highest for evergreen oaks with 1 and lowest for Norway spruce with 0.45 symptoms per tree. Compared to 2019, both the number of recorded damage symptoms and the ratios have been decreasing for all species and species groups, except for Scots pine and Norway spruce, and for the group of other conifers.

Table 6-4: Number of damage symptoms, assessed trees and their ratio for the main tree species and species groups in 2020. 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*)	10 067	17 483	0.58
Norway spruce (*Picea abies*)	5 105	11 438	0.45
Austrian pine (*Pinus nigra*)	3 091	5 385	0.57
Mediterranean lowland pines	4 551	8 212	0.55
Other conifers	4 196	7 694	0.55
Common beech (*Fagus sylvatica*)	8 826	10 964	0.80
Deciduous temperate oaks	8 003	8 619	0.93
Dec. (sub-) Mediterranean oaks	6 300	7 883	0.80
Evergreen oaks	4 511	4 502	1.00
Other broadleaves	13 943	19 593	0.71
Total			
Conifers	27 010	50 212	0.54
Broadleaves	41 583	51 561	0.81
All species	**68 593**	**101 773**	**0.67**

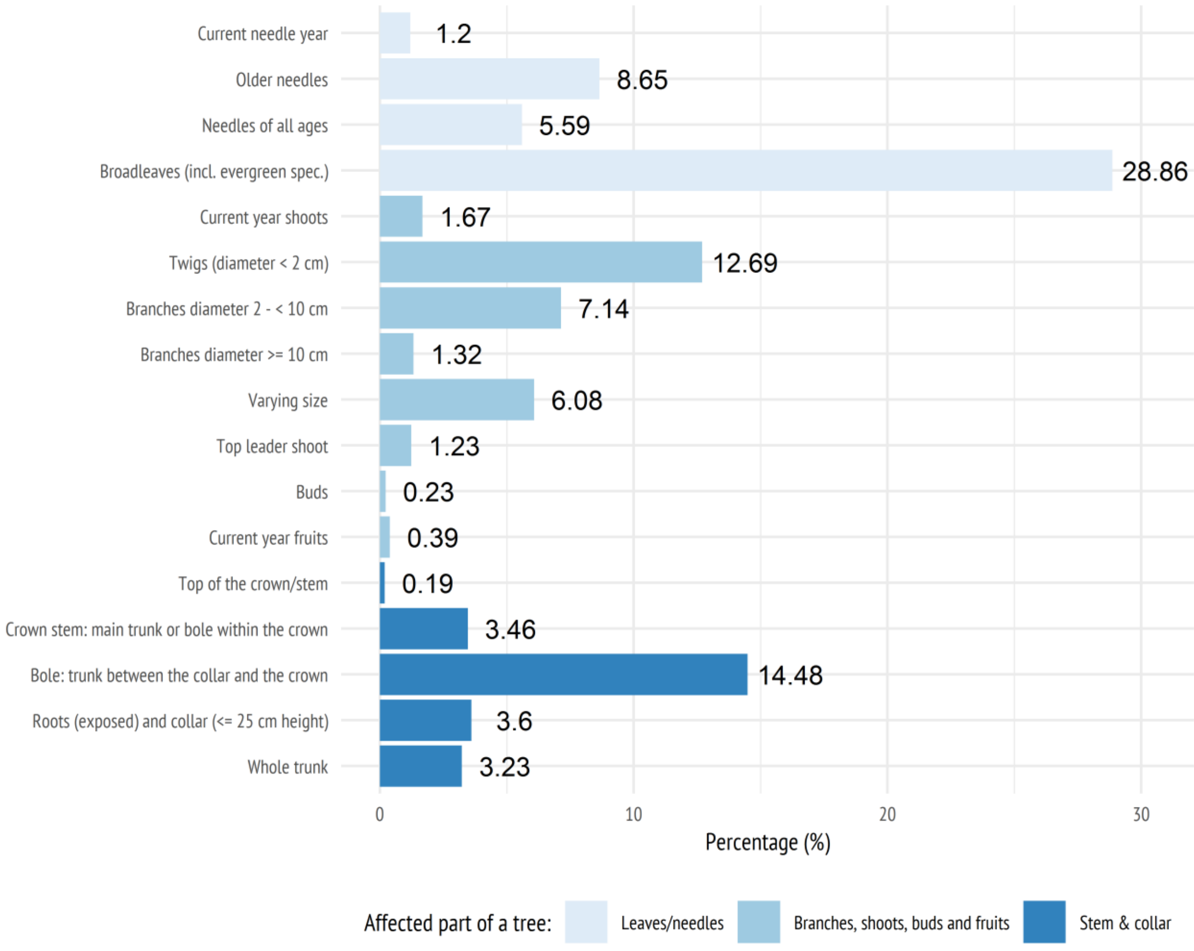


Figure 6-3: Percentage of recorded damage symptoms in 2020 (n=67 633), affecting different parts of a tree. Multiple affected parts per tree were possible. Dead trees are not included.

Symptom description and damage extent

Most of the reported damage symptoms were observed on the leaves of broadleaved trees (28.9%), followed by twigs and branches (27.2%), and stems (21.2%; Figure 6-3). Needles were also often affected (15.4%), while roots, collar, shoots, buds and fruits of both broadleaves and conifers were less frequently affected.

More than half (52.3%) of all recorded damage symptoms had an extent of up to 10%, 38% had an extent between 10% and 40%, and 9.7% of the symptoms covered more than 40% of the affected part of a tree.

Causal agents and factors responsible for the observed damage symptoms

Insects were the predominant cause of damage and responsible for 24.8% of all recorded damage symptoms (Figure 6-4). Within the group of insects, 44.1% of damage symptoms were caused by defoliators. Wood borers were responsible for 18.4%, leaf miners for 11.7%, sucking insects for 7.1%, and gallmakers for 6.6% of the damage caused by insects.

Abiotic factors were the second major causal agent group responsible for 17.3% of all damage symptoms. Within this agent group, roughly half of the symptoms (50.7%) were attributed to drought, while snow and ice caused 9.2%, wind 7.7%, and frost 4.3% of the symptoms.

The third major identified cause of tree damage were fungi with 10.6% of all damage symptoms. Of those, 24.4% showed signs of decay and root rot fungi, followed by needle cast and needle rust fungi (16.7%), dieback and canker fungi (16%), blight (9.5%) and powdery mildew (7.1%).

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 (1.3%). Fire caused 0.7% of all damage symptoms. The agent group 'Atmospheric pollutants' refers here only to incidents caused by local pollution sources. Visible symptoms of direct atmospheric pollution impact, however, were very rare (0.1% of all damage symptoms). Other causal agents were responsible for 10.2% of all reported damage symptoms. Apart from these identifiable causes of damage symptoms, a considerable number of symptoms (30.5%) could not be identified in the field.

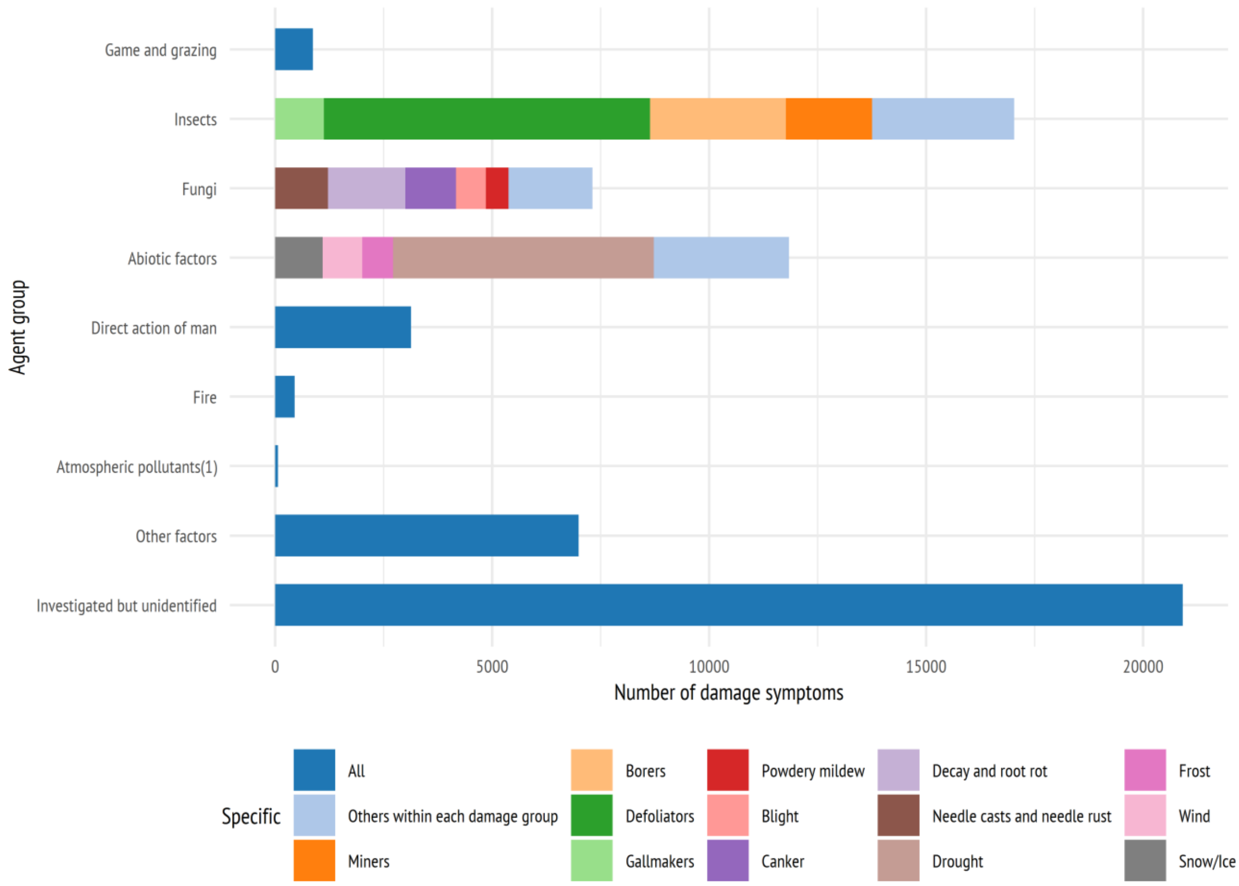


Figure 6-4: Number of damage symptoms (n=68 593) according to agent groups and specific agents/factors in 2020. Multiple damage symptoms per tree were possible, and dead trees are included. (1) Visible symptoms of direct atmospheric pollution impact only

EVALUATIONS

The occurrence of damaging agent groups differed between major species or species groups (Figure 6-5). Insects were the most important damaging agent group for deciduous temperate oaks (causing 39.3% of all damage), deciduous (sub-) Mediterranean oaks (33.7%) and common beech (33.4%), while insect damage was not so common in Scots pine (10.5%) and Norway spruce (8.1%). Abiotic factors caused by far the most damage in evergreen oaks (45%) and Mediterranean lowland pines (36.5%), and the least in Scots pine (8.1%). Fungi were important damaging agents for Austrian pine (18.5%), evergreen oaks (16.4%), Scots pine (13.7%) and deciduous temperate oaks (11.4%). Direct action of man was of little importance in general; it had the highest impact on Norway spruce (15.1%) and Scots pine (7.8%). Damage from game and grazing played a minor role for all species and species groups except for Norway spruce (10.4%). Fire affected mostly Mediterranean conifer species – 1.1% of Austrian pine and 1.0% of Mediterranean lowland pine trees were affected. The percentage of recorded but unidentified damage symptoms was small in evergreen oaks (9.1%) but large for Norway spruce (38.8%), common beech (35.6%), Scots pine (33.9%) and deciduous (sub-) Mediterranean oaks (33.7%).

The most important specific damaging agents for common beech were mining insects causing 16.9% of the damage symptoms, followed by defoliators (10.8%) and drought (4.5%). Defoliators were also frequently causing damage on deciduous temperate oaks (14.2%), while borers (8.3%), sucking insects (6.7%), powdery mildew (5.4%), and drought (5.2%) also were significant. For deciduous (sub-) Mediterranean oaks, defoliators (12.3%) were the most common damaging agents, followed by borers (7.3%), drought (6.6%) and gallmakers (5.5%). Drought was by far the most important damaging agent for evergreen oaks (42.4%), but also borers (13.9%), decay and root rot fungi (11.6%), and defoliators (5.4%) had a large impact on these oak species.

Most damage symptoms in Scots pine were caused by various effects of competition (10.8%), followed by *Viscum album* (8%), needle cast/needle rust fungi (6.5%) and borers (5.7%). For Norway spruce, borers (5.7%), red deer (5.6%) and mechanical/vehicle damage (5.5%) were most important. Defoliators were causing most damage (21.1 %) on Austrian pine trees, but *V. album* (16%), needle cast/needle rust fungi (11%), drought (5.6%) and blight (5.1%) also caused considerable damage. Mediterranean lowland pines were mostly affected by drought (28.1%), defoliators (12.9%) and sucking insects (5.4%).

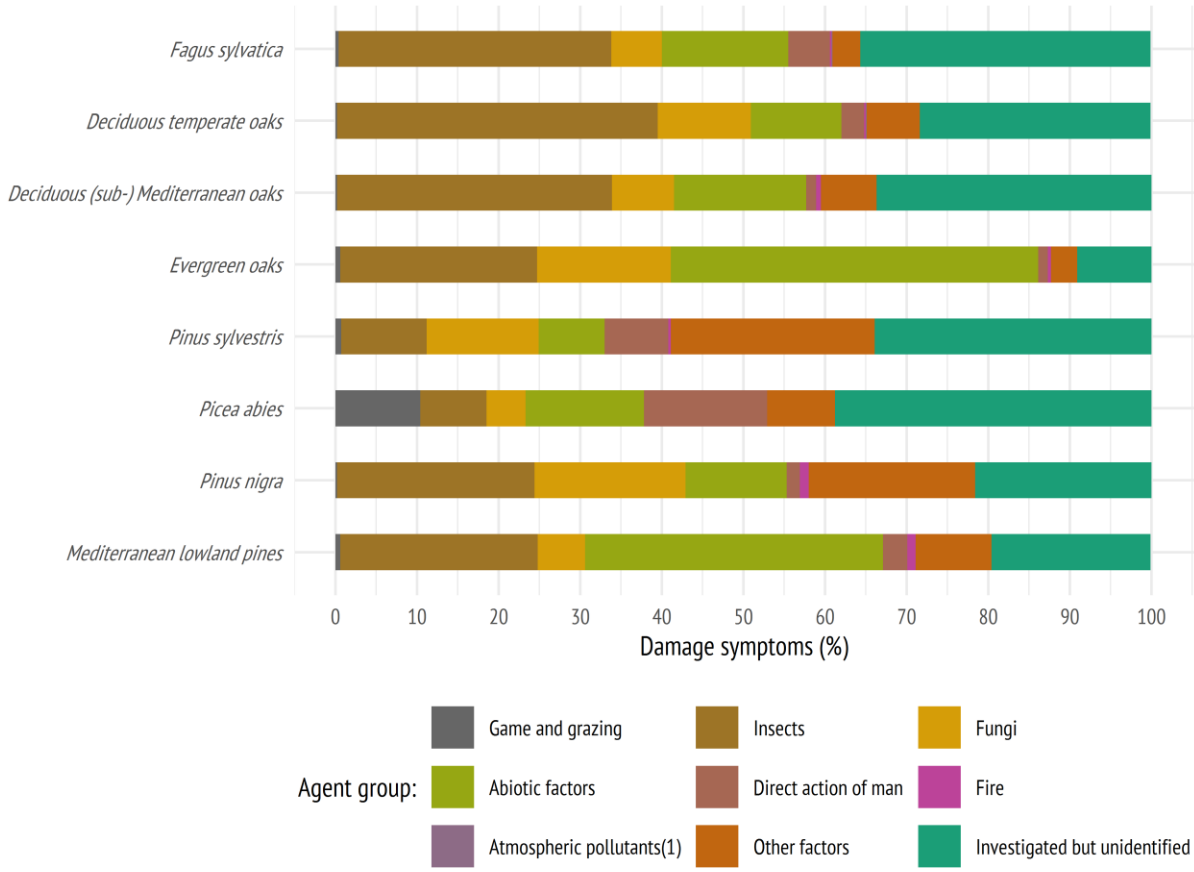


Figure 6-5: Percentage of damage symptoms by agent group for each main tree species and species group in 2020. (1) Visible symptoms of direct atmospheric pollution impact only

Regional importance of the different agent groups

Damage caused by insects in 2020 was observed on 1 843 European Level I plots, which corresponds to 33% of all plots with damage assessments. With some exceptions (Scandinavia, northern Germany, and the Baltic countries), a high proportion of plots was affected by insects throughout Europe.

Damage caused by abiotic factors was reported from 1 908 Level I plots (34%) throughout Europe. Countries most affected by abiotic factors were Spain, Slovenia, Montenegro, and Cyprus.

The agent group 'Fungi' was responsible for damage on 1 308 European Level I plots (24%) in 2020, and was frequently occurring in many countries, most notably in Estonia, Slovenia, Montenegro, parts of Serbia, Poland, Bulgaria, and Spain. Very low occurrence of damage by fungi was observed in Norway, Romania, Switzerland, Italy, Turkey, and Greece.

The damaging agent group 'Direct action of man impacted trees on 1 021 plots (18%), and was most frequently occurring in southern Sweden, eastern parts of Europe, and southern Germany.

Damage caused by game and grazing in 2020 was most frequently observed in the Baltic countries, Hungary, and Spain, and in parts of Poland and Germany. In total, 296 Level I plots (5%) had trees damaged by this agent group.

There were only 56 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 942 (0.93%) dead trees in the damage assessment 2020 (462 broadleaves and 480 conifers), a slight increase compared to 2019 (911 trees, 0.88%). The highest mortality rates were found for birch trees (*Betula pubescens* and *B. pendula*) with 3.1% (corresponding to 142 trees), Norway spruce (2.1%, 235 trees), Scots pine (0.8%, 148 trees) and deciduous temperate oaks (0.8%, 71 trees). Most dead trees were reported from Germany (176), Norway (174), France (151) and Spain (111). The main cause of mortality to both conifer and broadleaved trees were abiotic factors (Figure 6-6) followed by fungi and insects. The determination of the cause of tree mortality is often very difficult; it could not be identified for almost two thirds of the dead trees in 2020.

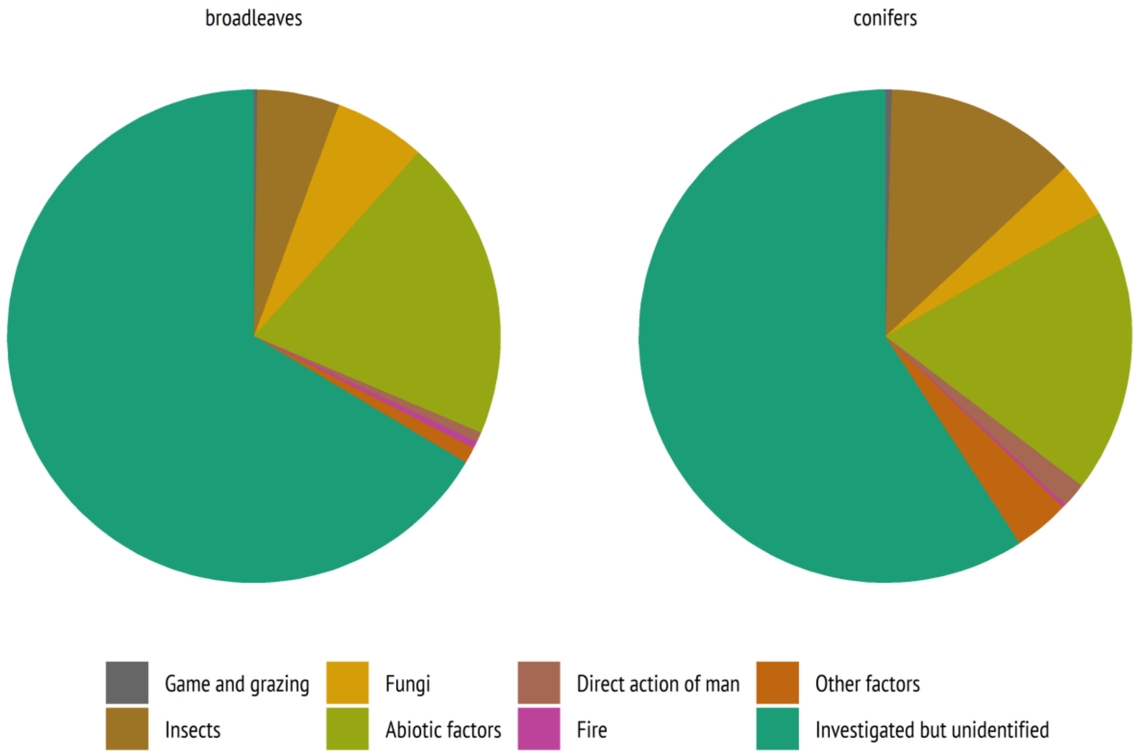


Figure 6-6: Percentage of damaging agent groups causing mortality of broadleaved and coniferous trees in 2020 (n = 942)

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

Conclusions

In 2020, the mean defoliation remained on the approximately same level as in 2019 with no change for conifers and only a very slight increase for broadleaves. Common beech had the highest increase in mean defoliation (1.5%), while evergreen oaks had the largest decrease (1.6%).

Based on the data of the past 20 years, the trends show a considerable increase in defoliation of Austrian pine, Mediterranean lowland pines and evergreen oaks (6.3%, 5.6% and 7.0%, respectively). On the other hand, the increase in defoliation for common beech (3.0%) and Norway spruce (3.3%) has been relatively low and the trend for Scots pine shows a moderate increase in defoliation of 4.4%. No trends were detected for deciduous (sub-) Mediterranean and temperate oaks.

As in previous years, the number of recorded damage symptoms per assessed tree was substantially higher for broadleaves than for conifers. Insects, abiotic causes and fungi were the most common damage agent groups for all species, comprising altogether more than half of all damage records. There was a decrease in the number of observed damage symptoms compared to 2019. Tree mortality increased slightly in 2020, mainly due to abiotic factors.

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7

HEAVY METALS IN FOREST FLOOR AND TOPSOIL OF ICP FORESTS LEVEL I PLOTS

BASED ON THE COMBINED FOREST SOIL CONDITION DATABASE – LEVEL I (FSCDB.LI)

Tine Bommarez, Nathalie Cools, and Bruno De Vos

Highlights

- The combined Forest Soil Condition Database stores heavy metal data for about 1000-1500 ICP Forests Level I plots in the first inventory (1985-1996, mainly forest floor) and 3000-3500 ICP Forests Level I plots in the second inventory (2006-2008, mainly forest floor and mineral topsoil).
- Natural background concentrations differ between countries and biogeographical regions, where the boreal zone shows the lowest concentration levels for most heavy metals.
- Overall, we see decreases in the concentrations of the heavy metals between both surveys for most plots, countries and biogeographical regions, with larger changes in the forest floor compared to the mineral topsoil.
- The observed spatial distribution patterns across Europe are comparable with those of the moss survey of ICP Vegetation and the EMEP deposition data for Cd, Pb, and Hg.

Introduction

The Air Convention aims at reducing the pressure of air pollutants on the environment and human health, including heavy metals which can lead to soil contamination. Heavy metals can result from human activities and products (e.g. fertilisers, waste) or short-range air pollution from industry (e.g. smelters). Cadmium (Cd), lead (Pb) and mercury (Hg) are common air pollutants, being emitted mainly as a result of various industrial activities. Other trace metals like nickel (Ni), zinc (Zn), chromium (Cr) and copper (Cu) find their origin in the soil parent material.

This study was a first exploration of the occurrence of heavy metals in forest soils measured during two soil inventories (S1: 1985-1996, S2: 2006-2008) on the plots of the ICP Forests Level I network. The objectives of the study were:

- to explore the spatial patterns and hotspots of heavy metals in the forest floors and topsoils throughout Europe;
- to investigate if there is a significant temporal change between the first and second soil survey;
- to evaluate whether the heavy metals concentrations and stocks exceed contamination or pollution levels;
- to compare the observed forest soil concentration levels with reference databases and maps of heavy metals in soils (LUCAS survey) or in mosses (ICP Vegetation survey) at the European scale.

Methods

The study is based on data from the Combined Forest Soil Condition Database (FSCDB.LI) of ICP Forests holding descriptive and analytical information of soil samples obtained from two soil surveys on the ICP Forests' Level I transnational systematic grid. The soil samples were analysed for their Cd, Cr, Cu, Hg, Ni, Pb and Zn aqua-regia extractable concentrations in the forest floor and mineral topsoil (0-10 cm), amongst other analyses. Because on most plots bulk densities were measured, the stocks could be calculated as well.

Heavy metal concentration in soils are often close to their quantification limit. This is the lowest measurable concentration that laboratory can measure in a reliable way. Appropriate statistical techniques were applied to work with low concentrations.

Sample geometric means were used as distribution metric and the bootstrapping technique to estimate 95% confidence intervals for evaluation of factor differences (e.g. the WRB Reference Soil Groups) and temporal changes. For each heavy metal, concentration and stock maps were produced. Their distribution patterns were related to environmental factors such as biogeographical region, soil group and humus form.

Results and discussion

Spatial distribution patterns

The spatial distribution pattern of heavy metals in forest floors and topsoils across European forests is metal specific. Regional hotspots with elevated metal concentrations compared to baseline levels are clearly visible on the maps and could be linked to local pollution sources and well-known contaminated areas.

Cadmium

Cadmium is a relatively rare metal, has no essential biological functions and can be highly toxic to plants and animals. The two major anthropogenic sources of Cd in soils are rock phosphate fertilizer and atmospheric deposition (Alloway 2012). Assuming phosphate fertilizer usage is rather limited in forests, atmospheric deposition must be the main cause of elevated levels of cadmium in forest soils. It is often associated with Zn, as Cd is a by-product of the smelting of Zn and other base metals.

We found average Cd concentrations ranging from 0.35 to 0.62 mg/kg in mineral topsoil, 0.40-0.65 mg/kg in forest floors and 0.26-0.60 mg/kg in peat soils. Cd shows a high spatial distribution. In most countries, Cd concentration in the forest floor is higher than in the mineral topsoil, indicating that deposition is the main source. Exceptions are the United Kingdom (UK) and Serbia (RS) where the Cd concentration in the topsoil is significantly higher than in the forest floor. This may be related to the parent material like sedimentary rock or black shales containing high natural Cd content. Furthermore, the Cd concentration in the forest floor across Europe varies less than in the mineral topsoil.

Industrial and mining areas are associated with elevated heavy metal topsoil concentrations (Tóth et al. 2016). A hotspot of elevated Cd concentration is clearly visible in the Upper Silesian mining district in south-central Poland (see Figure 7.1). High Cd concentrations in the area are known to be the consequence of historical Zn-Pb mining (Pan et al. 2010). Other regions with elevated Cd concentration in forest floors are the Ruhr region (Germany), Campine region (Belgium), northern Slovenia and eastern Slovakia. High mineral topsoil concentrations are observed in UK, Austria, Slovenia, and Serbia.

The mineral topsoils in the Boreal region generally show lower concentrations of Cd compared to the Alpine forest topsoils. Podzols are typical soils of boreal forests and Mor is here the dominant humus form. Both Podzols and Mors are associated with low Cd concentrations. Other sandy soils like Arenosols, also show low Cd concentrations, well below the limit of quantification.

On soil with secondary carbonates, like Calcisols, Cd concentrations are generally low. Usually Cd bio-availability in these soils is also low due to adsorption on calcite or precipitation as Cd-carbonates.

Histosols (peat soils) and Phaeozems are soils rich in organic matter. These soil types show the highest Cd concentrations, illustrating the affinity of this metal for organic matter. On the opposite, the Cd concentration in Regosols are usually low. These are relatively young soils, often low in organic carbon. Indeed, 70% of the Regosols in our dataset is located on the Scandinavian Peninsula, typically formed in unconsolidated deposits after the melting of the ice cap since the last ice age.

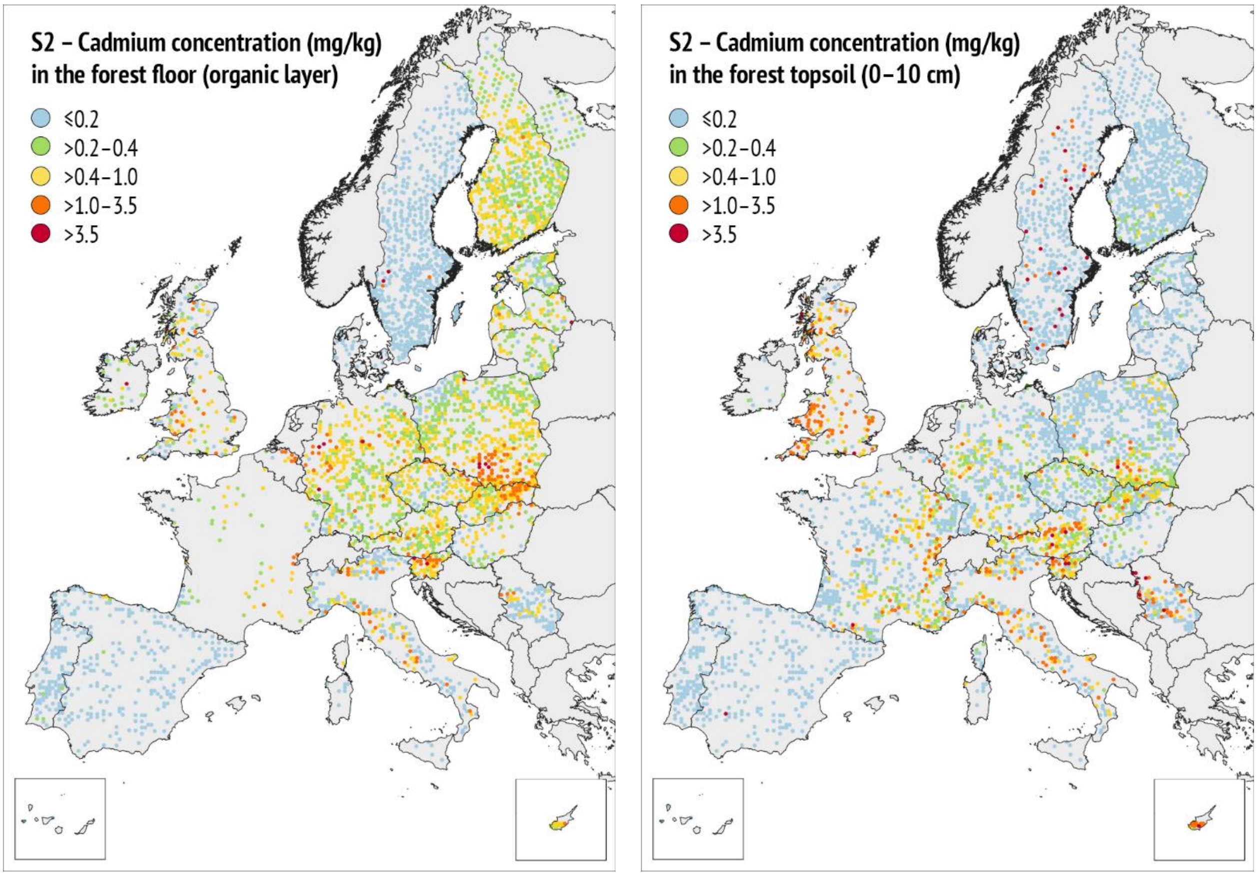


Figure 7-1: Spatial distribution maps of Cd concentration in forest floor (left) and mineral topsoil (right) of the second forest soil condition survey (S2).

EVALUATIONS

Chromium

Chromium concentrations are generally well quantifiable. Average Cr concentrations are 21-33 mg/kg in mineral soils, around 18 mg/kg in forest floors and 4-13 mg/kg in peat soils. On the majority of the plots, the Cr concentration in the forest floor is lower than in the topsoil, except for Spain and Poland. This shows that Cr concentrations are spatially very variable. The Boreal region hosts the lowest Cr concentrations, while the opposite is true for the Alpine region. Hence, the majority of the Cr content in soils is believed to be of lithological origin. Moreover, Cr is scarcely consumed by the vegetation, so no enrichment via plant litter is taking place.

Cr concentration is lowest in Podzols, Histosols and Arenosols, and highest in Calcisols and Phaeozems, and so show an opposite pattern compared to Cadmium. You see in Figure 7-2 that for example the Landes (France) with their poor sandy soils is an area with naturally low Cr concentration. In some regions, the contribution from wind-blown dust plays a significant role (Frontasyeva et al. 2020). This is for example the case for sandy soils in Poland showing elevated Cr concentrations.

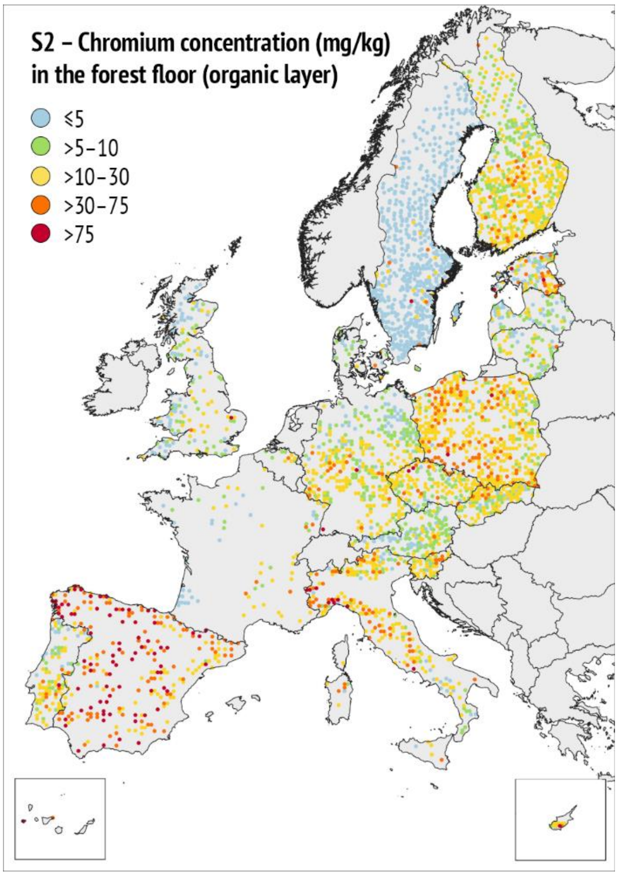
In semiterrestrial humus forms the concentrations are significantly lower than in well-aerated terrestrial forms, where there are concentration differences between Mor and the Moder/Mull forms. Since concentrations are higher in mineral soil, enhanced bioturbation in Mull and Moder types increases the concentration through mixing with mineral soil particles.

Nickel

The concentrations in mineral soil range from 15 to 32.7 mg/kg, but are much smaller in organic soil material: 3-11 mg/kg in peat soils and around 10 mg/kg in forest floors. In Boreal and Continental biogeographical regions, forest floor concentrations are usually higher than in mineral soil, whereas the opposite is true for the Alpine region.

The spatial distribution of Ni concentration across European forests shows a similar pattern to Cr. We found low Ni concentrations in Histosols and sandy soil groups (Arenosols, Podzols), but higher concentrations in, for example, Luvisols. This is in line with the findings of Alloway (2012) who stated that Ni and Cr concentrations are generally lower in coarse textured and peaty soils, and higher in clayey soils.

Comparison by humus type gives exactly the same pattern as for Cr, with lower Ni concentrations in semi-terrestrial humus, medium Ni concentrations in Mor and higher Ni concentrations in Moder and Mull forms. This is expected as Cr and Ni have similar geochemistry. Ni load is classified as critical in certain areas like northern Slovakia, central Germany and northern Italy. As was the case for Cr stocks, critical zones derived from topsoil Ni stocks are not reflected in forest floor Ni stocks and vice versa.



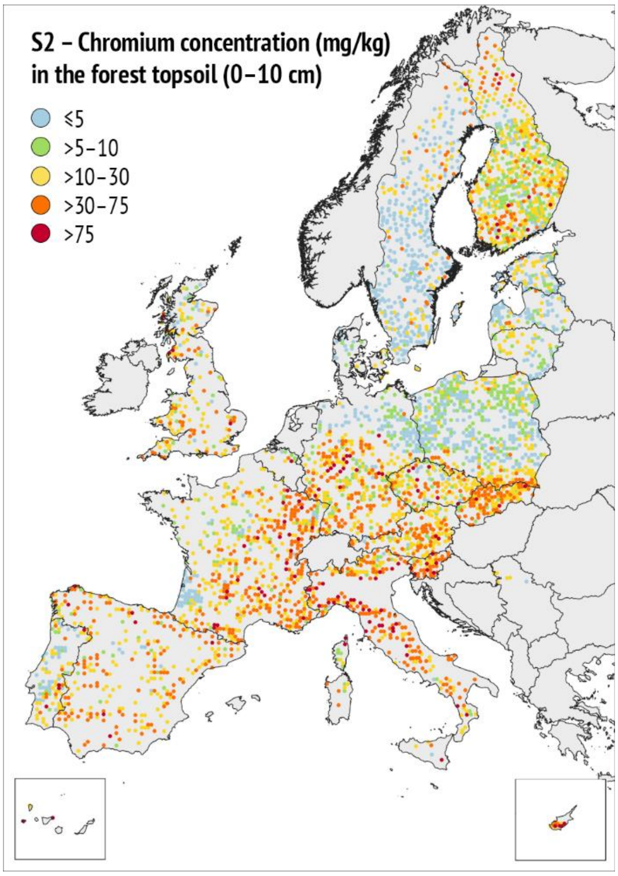


Figure 7-2: Spatial distribution maps of Cr concentration in forest floor (left) and mineral topsoil (right) of the second forest soil condition survey (S2).

Copper

Average Cu concentrations in our dataset range from 10 to 22 mg/kg in mineral soils, from 11 to 16 mg/kg in forest floors and from 6 to 17 mg/kg in peat soils. The concentration in the forest floor is usually higher than in the forest topsoil. Exceptions are found in Italy, Slovenia and Austria, and this is also reflected in the Alpine and partly Mediterranean bioregion. Yet unexplained is the high concentration of Cu in Danish forest floors, compared to their very low mineral soil concentrations near the limit of quantification.

The higher concentration in forest floors might reflect a relatively high contribution of atmospheric deposition to the total Cu content in the forest soil. The Boreal region hosts on average lower Cu concentrations in the forest topsoil than other biogeographical regions (Figure 7-3). This is presumably linked with the dominance of Podzols and Mor-humus and the tendency of Cu to be stabilized by organic matter through adsorption.

Geographically, high Cu concentrations in the forest topsoil can be found in the Mediterranean as the Apennine peninsula hosts high natural concentrations of Cu (Ballabio et al. 2018), as well as Trodos mountain range in Cyprus and southwestern Spain. Important anthropogenic sources of Cu are mining and Cu-Ni melting. For example, the hotspot around the urban industrial centres of Krompachy in Slovakia is due to metallurgic activities (Bobro et al. 2000). The load of Cu is also critical in the Black Triangle region along the Czech-Polish-German border. Note that critical stocks for Cu are reached in the forest floor, but apparently not in the mineral topsoil (Figure 7-4). Thus, the forest floor compartment seems to be a better indicator for Cu contamination than the mineral topsoil.

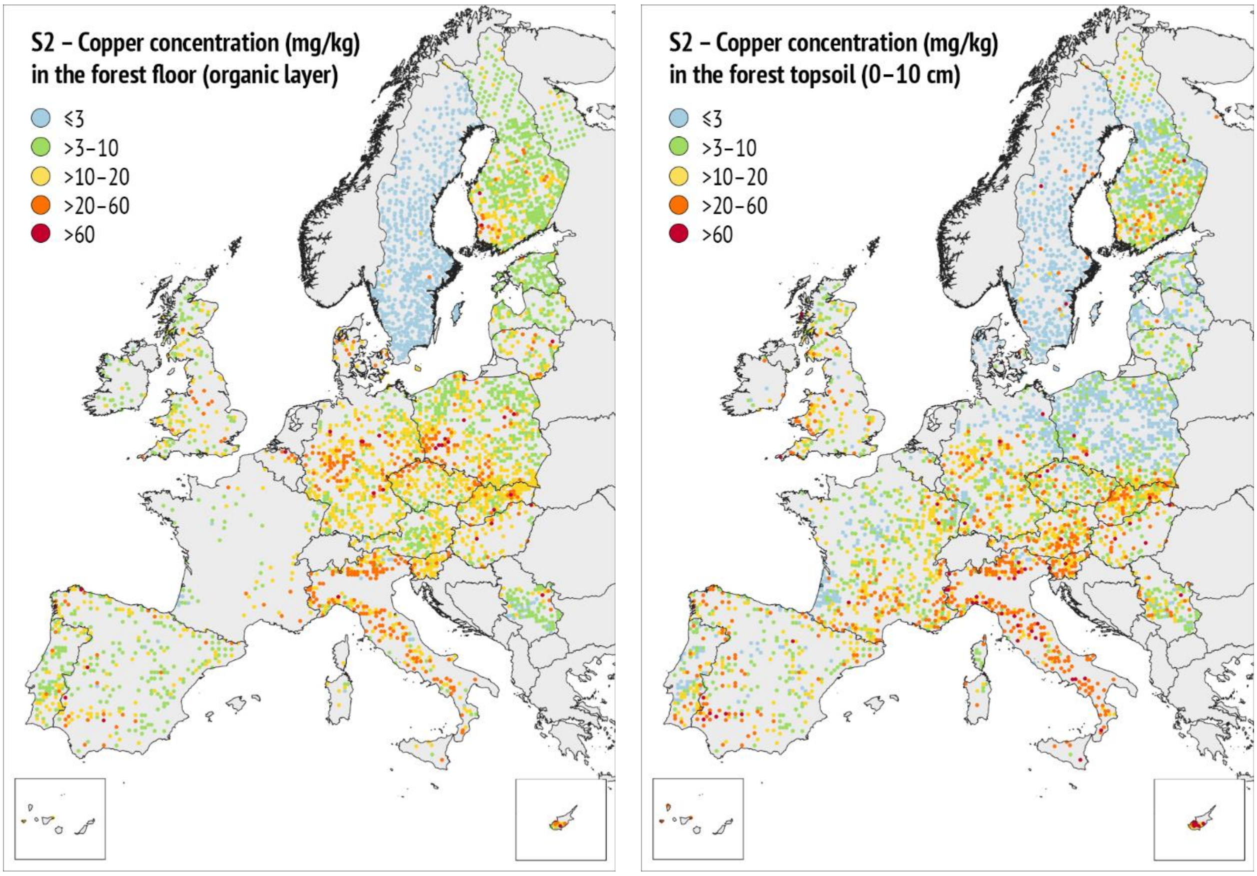


Figure 7-3: Spatial distribution maps of Cu concentration in forest floor (left) and mineral topsoil (right) of the second forest soil condition survey (S2).

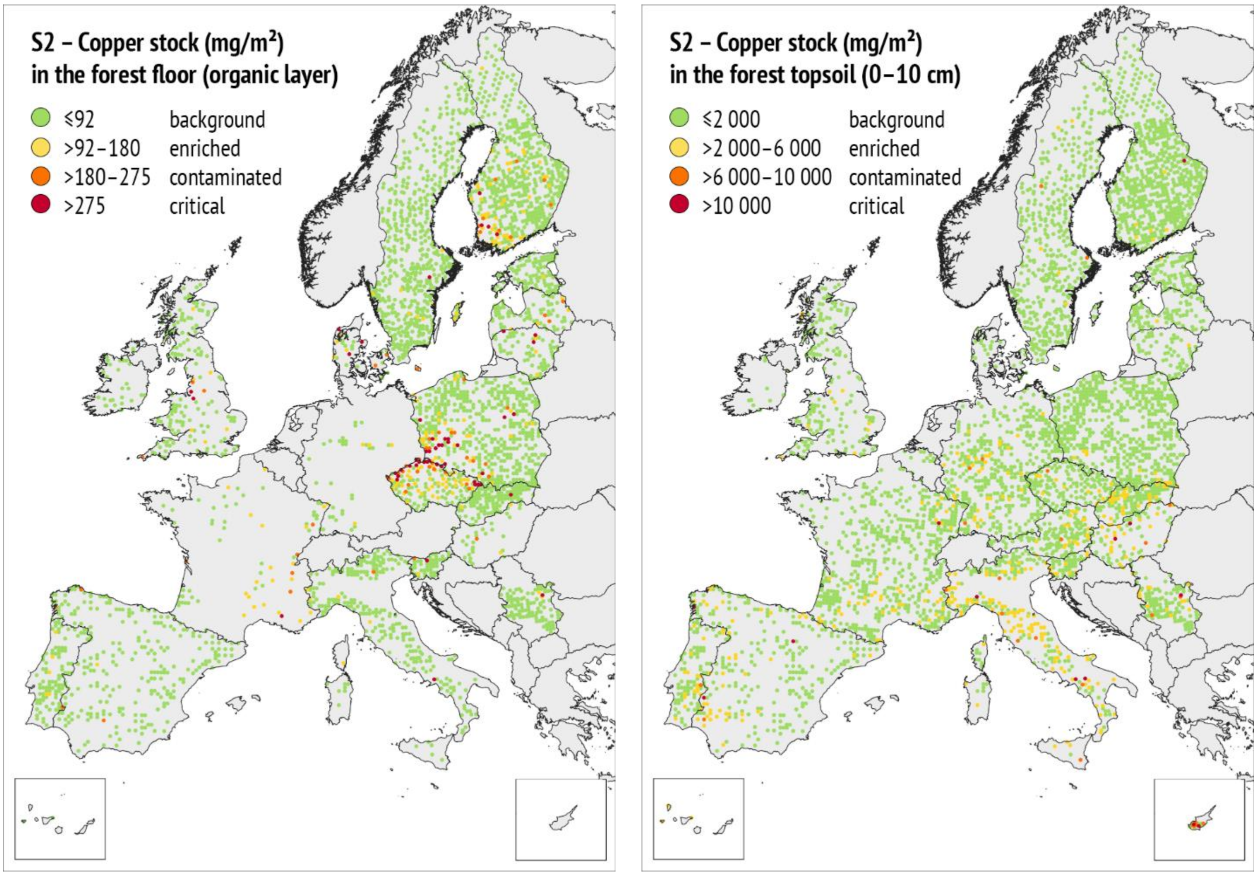


Figure 7-4: Spatial distribution maps of Cu stocks in forest floor (left) and mineral topsoil (right) of the second forest soil condition survey (S2).

Lead

Soil is a sink for anthropogenic Pb and there are several well-known major Pb sources like mining and melting activities, contamination from vehicle exhausts and application of sludges. Alloway (2012) stated that most soil datasets support the hypothesis that much of the observed Pb in soil in many areas has originated from anthropogenic emissions, leading to low-level contamination of about 30-100 mg/kg.

Our data reveal average concentrations in mineral topsoil around 30-40 mg/kg and 10-15 mg/kg in subsoil (between 20 and 80 cm). This finding points towards significant deposition effects. Concentrations in the forest floors are generally higher (40-65 mg/kg) and even more elevated (30-340 mg/kg) in peat soils. This illustrates the strong affinity of Pb for organic matter.

Stratified according to biogeographical region, we see the lowest Pb concentrations in the Boreal zone where the concentration is higher in the forest floor higher than in mineral soil (Figure 7-5). In the Mediterranean region, the concentrations are rather low but they show higher values in the mineral soil compared to the forest floor.

No clear patterns are seen when stratifying following the WRB Reference Soil Group. Stratified according to humus type, semi-terrestrial and the Mull humus forms show lower concentrations than the remaining terrestrial forms.

High levels of lead in forest floors can be found in North Rhine-Westphalia, southern Poland and along the border of the Czech Republic with Germany and Poland. The Harz Mountains of Germany are important for the extraction of ore (mainly Cu, Pb and Zn) (Pan et al. 2010). This location is clearly marked on the maps as polluted with Pb.

Contamination patterns are better indicated by forest floor than topsoil concentrations. Critical Pb stocks in forest floors do not always correlate well with stocks in topsoils and vice versa (Figure 7-6).

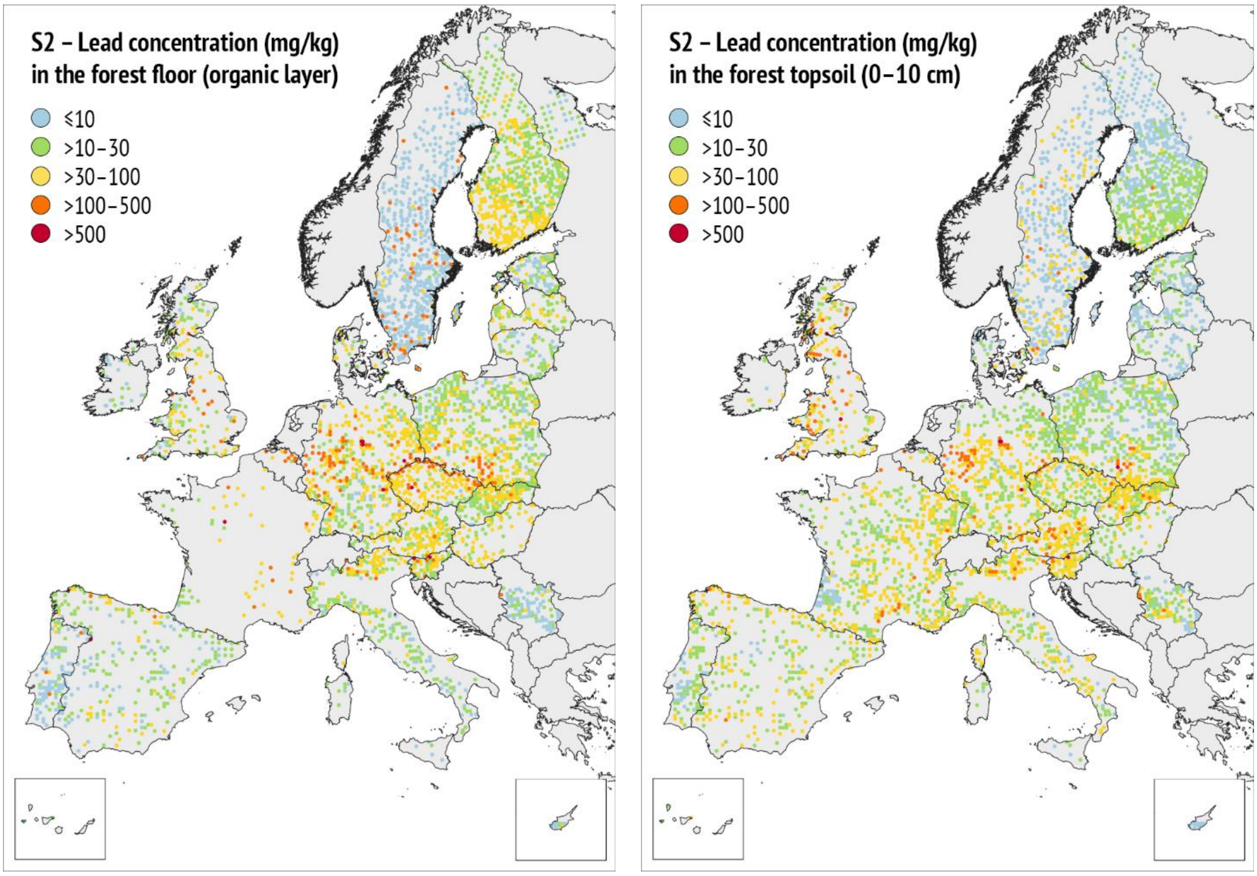


Figure 7-5: Spatial distribution maps of Pb concentration in forest floor (left) and mineral topsoil (right) of the second forest soil condition survey (S2).

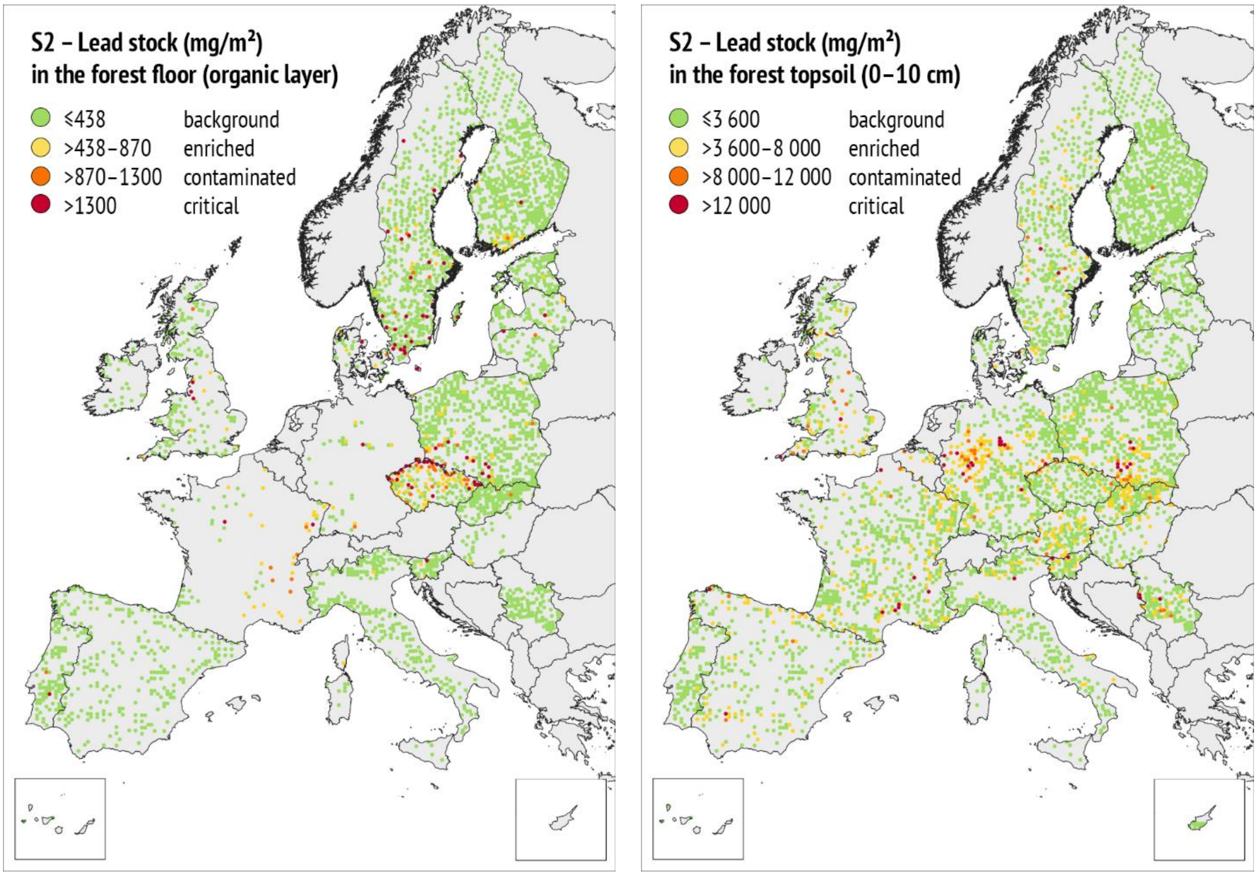


Figure 7-6: Spatial distribution maps of Pb stocks in forest floor (left) and mineral topsoil (right) of the second forest soil condition survey (S2).

Zinc

Together with Cd, Zn is the most mobile and potentially bioavailable element. It is an essential trace element for humans, animals and plants, though in high concentrations it can be toxic. The average total Zn content in the lithosphere is approximately 80 mg/kg. In sedimentary rocks the highest concentrations are found in shales and clayey sediments (80-120 mg/kg), while sandstones, limestones and dolomites hold lower concentrations (10-30 mg/kg) (Alloway 2012).

The mean Zn concentration in mineral soil is between 40 and 70 mg/kg and around 70 mg/kg in forest floors but is lower in peat soils (20-60 mg/kg). Except for the Mediterranean region, concentrations of Zn in forest floors are generally higher compared to the mineral top soils. The difference between forest floor and upper soil concentrations is often quite large, suggesting Zn cycling by trees.

The variation in Zn concentration in the forest floor when stratified according to the WRB Reference Soil Group (IUSS WG on WRB, 2006) is rather low. The difference in the mineral top soil is somewhat more explicit. Andosols show the highest Zn levels (around 100 mg/kg) while Podzols, Arenosols and Albeluvisols have lowest concentrations (<20 mg/kg). Mor, Histomors and Anmoors (Zanella et al. 2006) show slightly smaller concentrations than other humus forms, but differences are mostly non-significant.

Zones with elevated concentrations are found in Slovakia and southern Poland, the Campine region in Belgium close to the (former) Zn melters, the Ruhr area in Germany, northern Italy and Slovenia (Figure 7-7).

Contaminated and critical levels are exceeded in forest floors in southern Sweden but this is not reflected in topsoil stocks (Figure 7-8).

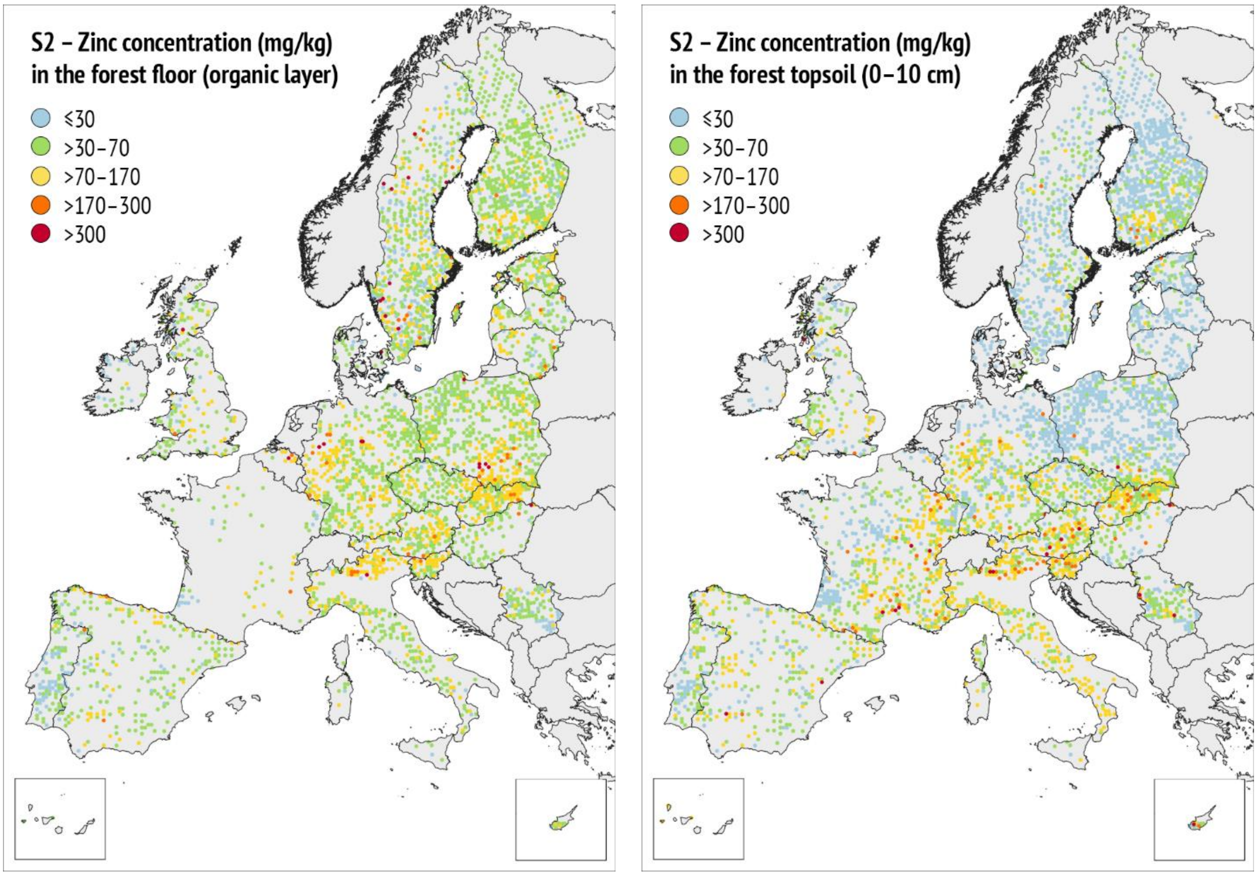


Figure 7-7: Spatial distribution maps of Zn concentration in forest floor (left) and mineral topsoil (right) of the second forest soil condition survey (S2).

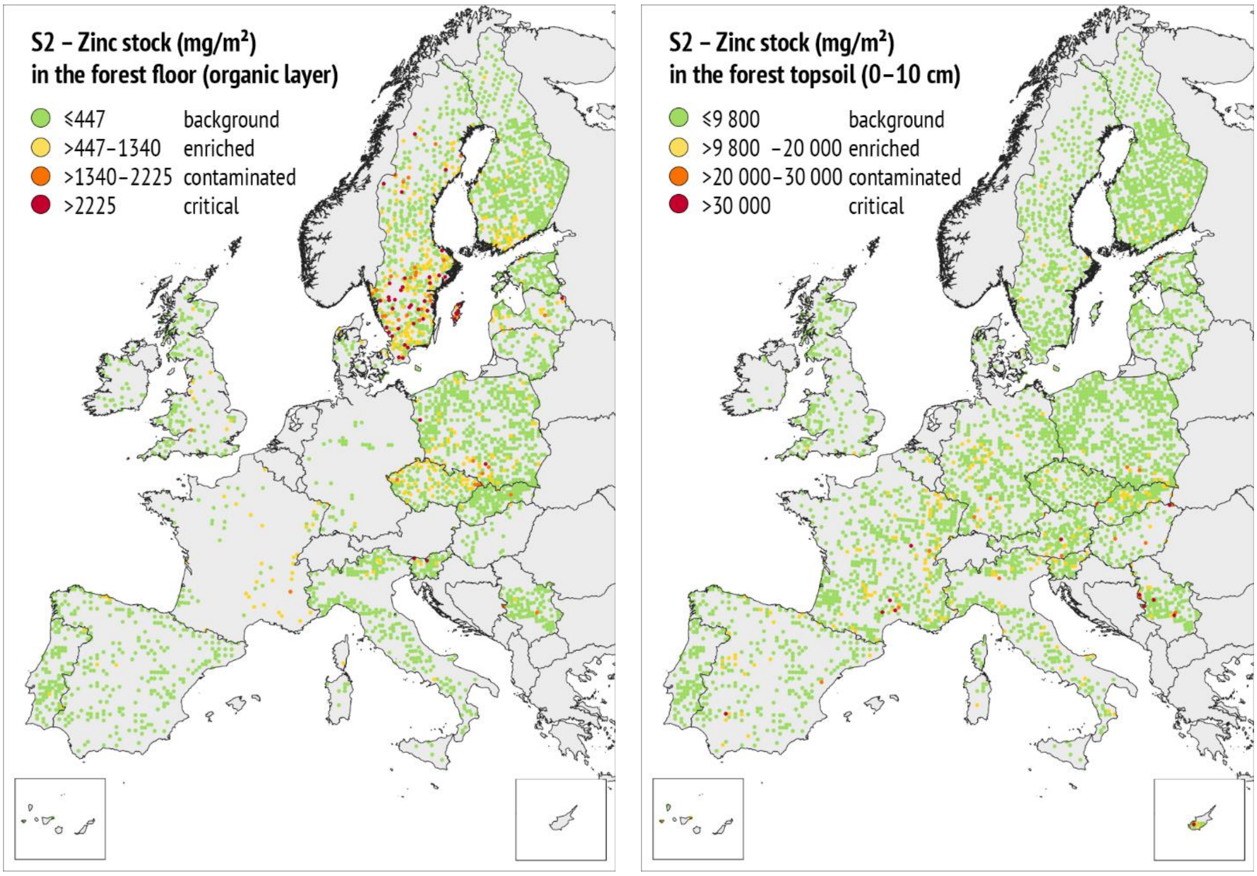


Figure 7-8: Spatial distribution maps of Zn stocks in forest floor (left) and mineral topsoil (right) of the second forest soil condition survey (S2).

Mercury

Mercury is of special concern because it is highly toxic to humans and animals and has neither a biological function nor a role in ecosystems. While deposition of most metals is decreasing in Europe, this is not the case for Hg. Hg is released in the environment by mining and smelting of ores, burning of fossil fuels (mainly coal), industrial production processes, and waste incineration (Alloway 2012).

Our summary statistics of Hg concentrations list mean levels ranging from 0.16 to 0.46 mg/kg in mineral soils, around 0.2 mg/kg in forest floors and 0.14-0.23 mg/kg in peat soils. Only 8 countries reported Hg data on Level I plots (Figure 7-9). Thus, the geographical scope of mercury analysis was limited in comparison with the analysis of other heavy metal concentrations.

For most countries that reported Hg concentrations, levels in forest floors were higher than in mineral soils. The UK showed mean concentrations around 0.3 mg/kg, while most other countries have topsoil concentrations below 0.1 mg/kg. Forest floor concentrations are about 0.2 mg/kg.

Nevertheless, some hotspots of human release are clearly visible. In the Baltic States, Germany and France, mercury concentrations in forest floors are generally higher than in forest topsoils (Figure 7-9), suggesting that forest floors are better indicators than topsoils. However, this is not the case for the UK, where concentration levels and stocks are greater in topsoils than in forest floors. Hotspots are also found in Slovakia and Lithuania.

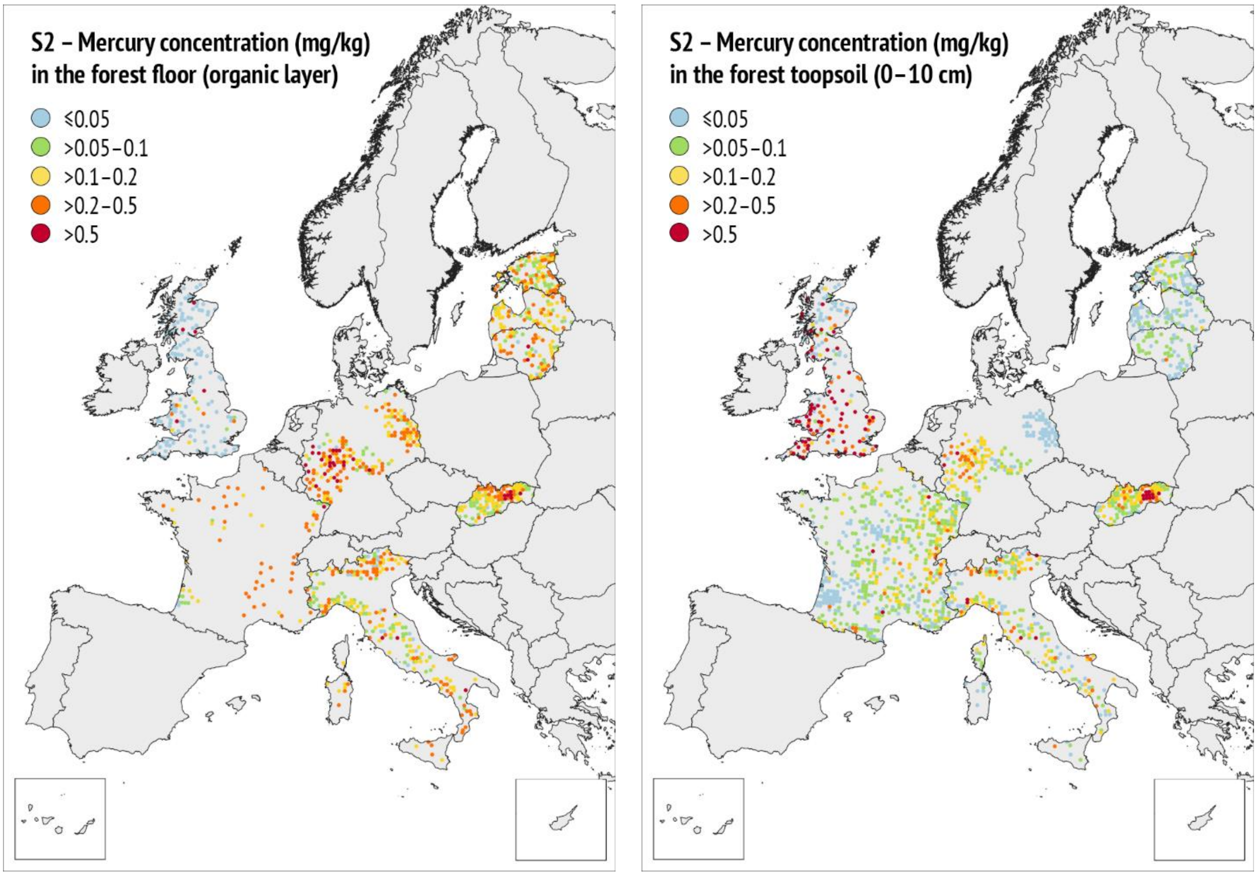


Figure 7-9: Spatial distribution maps of Hg concentrations in forest floor (left) and mineral topsoil (right) of the second forest soil condition survey (S2).

In conclusion, geochemically related metals (e.g. Ni and Cr) show similar spatial distribution patterns. WRB Reference Soil Groups and humus form help explaining large-scale differences in heavy metal concentrations. The heavy metal concentrations of Cd, Cu, Pb, Zn and Hg in the forest floor are generally higher than in the underlying mineral topsoil, indicating that forest floor concentrations are interesting indicators for heavy metal contamination, mainly due to air pollution. Substantial enrichment of Cd, Pb and Hg in forest floors compared to mineral soils was found.

Changes over time

Concentration changes could be assessed for nine countries only, mainly because heavy metal data of the first survey was lacking. Moreover, no paired measurements are available for Hg at all. More paired data is available for the forest floor than for mineral topsoil.

In general, the heavy metal concentration appears to have declined since the 1990s. However, the rate of change differs between countries. This is in line with the decrease observed in mosses and in deposition as reported in the literature, although the evolution of analytical techniques might have contributed to the magnitude of differences observed.

For about 750 to 1000 plots, paired observations in forest floors indicate a significant decrease for all metals between the two surveys. In absolute concentrations, Pb showed the largest decline (-18.6 mg/kg) and Cd the smallest (-0.24 mg/kg). Except for Cr a significant decrease is found in more than half of all paired plots. For Pb, 62% of the plots show a decrease. No significant change is found for 15 to 37% of the plots, depending on the heavy metal. About a quarter of plots still shows increasing concentrations in the forest floor, except for Pb. The agreement among the concentrations of the two surveys decreased in the order: Zn = Pb > Cu > Ni > Cd > Cr.

Temporal change in mineral topsoil could only be assessed on less than 500 plots (n=224-466) from few countries, so conclusions drawn at the EU scale are tentative. The decreases of Cd and Cr in topsoils are clearly significant, in contrast to Zn where no significant change is found. The Zn and Pb concentrations from the first survey explain for more than 80% the variation in the second survey, whereas this temporal agreement is intermediate for Cu, Ni and Cd and lowest for Cr. This is the same order as found for forest floors. It evidences the persistence of heavy metals in mineral soil and forest floors, especially for Pb.

Evaluation against contamination or pollution levels

In this study two approaches were tested to evaluate contamination levels in forest soils: the use of indicators and the use of national screening values.

The Geo-accumulation Index and the Nemorow Pollution Index showed polluted areas especially for Pb, Hg and Cd, but almost no pollution for Cr and Ni, and only regional hotspots for Cu and Zn. The Nemorow index could only be computed for 10 countries but it indicated that more than 55% of the Level I plots are slightly polluted and 7% are heavily polluted.

Another approach was to apply national screening values, for which we calculated median baseline and critical levels and compared these with estimated baselines and critical levels. The estimated baselines, computed as geometric means of the distribution including values below the quantification limit, are generally lower than the median of national baselines. Significant differences were found among estimated baseline values of biogeographical regions indicating that an evaluation scheme should be developed for each biogeographical region separately. This approach demonstrated that only few percentages of the Level I plots exceeded the critical levels and is classified as polluted, 5-10% are classified as enriched and for all metals more than 50% of the Level I plots are well below the baseline concentration level.

An evaluation scheme for heavy metal concentrations in the forest floor was tested and a Forest Floor Metal Contamination index (FFMCI) was calculated. Pb, Cd and Zn exceeded more the baseline levels than Ni, Cr and Cu. The FFMCI decreased over the two surveys, also when considering paired plots only. However, 56% (1st survey) and 70% (2nd survey) of the observed plots show background concentrations for all heavy metals in their forest floors.

Comparison with other reference databases

When comparing the observed forest soil heavy metals concentration levels with the LUCAS heavy metal topsoil database and maps, no significant differences for Ni and Cu concentrations were found. We did find higher levels for Cd, Cr, Pb and Hg in the Level I forest topsoils, compared to the interpolated LUCAS topsoil maps. Cd and Hg concentrations are a factor of 3.5 times higher than the predicted LUCAS concentrations at Level I plots, and Pb about twice as high, whereas Cr was higher by a factor of 1.23.

These results support the hypothesis that forest soils accumulate more heavy metals than agricultural land, especially for Cd, Hg and Pb. When qualitatively comparing both maps, regional hotspots of all metals from LUCAS maps are clearly correlated with increased levels at the Level I plots, as expected. Similarly, increased levels indicated by the maps of heavy metal concentrations in mosses, produced by ICP Vegetation, are also related to the concentration in forest floors and topsoil, albeit less strongly than with LUCAS data. The European-wide significant decline of heavy metal concentrations in mosses between 1990 and 2015 was also seen in the forest floor for all metals, but less pronounced. These temporal changes seem to suggest that Cd and Pb concentrations are indeed decreasing, but much slower than observed in mosses or by deposition time-series. Comparison with other datasets demonstrates clearly that heavy metals accumulate and reside in forest soils and that their concentration levels are slightly higher than in mosses and agricultural soils.

Future research opportunities

Future surveys

In order to investigate the evolution of the state of European forest soils, the engagement of each individual European country in the surveys and sample collecting with a harmonized protocol is paramount. Taking samples at fixed depths facilitates further data processing in a later stage of the research. Heavy metal records originating from deeper soil layers as reference level proved to be useful for comparison with topsoil concentrations and the calculation of various soil pollution indices. Concentration levels of deeper soil layers do not need to be repeated every 10-20 years, as they can serve as a baseline.

Therefore, it is recommended:

- in the next Level I survey to determine all metals (including Hg) mandatory in forest floors and M01 layers and if budget allows also in M12 and M24 layers; and
- at Level II plots to sample the whole soil profile up to 80 cm, to determine vertical distribution patterns of heavy metals.

We were unable to quantify the uncertainty related to (decentralized) analysis in national laboratories compared to a central lab, as has been done by JRC for carbon analysis during the BioSoil demonstration project (Hiederer et al. 2010). For about 10% of the S2 plots (526 plots) all samples were analysed in a central lab (INRA) in order to assess the between lab-variation. It is unclear if the data can still be retrieved from ESDAC or the ICP Forests National Focal Centres.

During the BioSoil project, about 3460 samples of the first survey (S1) taken from national soil archives (33 countries) were reanalysed by a central lab (INRA) (Hiederer et al. 2010). To our knowledge, data on heavy metals have never been published by the central lab. These data could be very helpful in completing our dataset.

Hence, centralized sample analysis of at least part of the samples should be considered in future forest soil surveys. Following the example of the BioSoil demonstration project, it could be worthwhile to re-analyse samples taken in both surveys to exclude the between-lab variation in results caused by the unavoidable evolution of analytical techniques.

Future data analysis

Due to the limited scope of this project, a lot of opportunities for further data exploration were still left unexplored. Boosted regression trees analysis, for example, could help to assess the influence of different parameters like pH, humus type, soil type and organic carbon content on heavy metal concentrations and pools and conversely, to assess the effect of heavy metal concentrations on litter decomposition and quality. The link with climatic variables, such as temperature (MAT) and precipitation (MAP) and geographical variables (altitude, slopes) is still left uncovered. In short: a statistical study selecting the best predictors for heavy metal concentration levels and stocks in EU forest soils is on our wish list.

Geostatistical mapping of the database also seems promising. Options include but are not limited to (1) kriging of concentrations to obtain continuous maps covering all European forests, (2) spatially correlating heavy metal concentrations with each other and with external databases of other heavy metal surveys at the European scale.

Although the Level I database has many advantages such as its geographical extent, it falls short for certain types of research questions. One such question for which the Level II database might be more suited is the vertical migration of heavy metals in forest soils. Which heavy metals accumulate in the forest floor and which heavy metals leach more easily into deeper soil layers? To answer this research question, a time series of the vertical distribution of heavy metals in soil profiles should be analysed to detect heavy metal migration and/or leaching and to reveal the processes behind these. This study suggests leaching of most metals from the forest floor downwards in the soil profile, which may be evidenced in soil solution at various depths which is monitored at Level II sites.

Finally, it would be interesting to see whether or not a link exists between heavy metal leaching and forest type or dominant tree species.

EVALUATIONS

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PART C
National reports of participating countries in ICP Forests

8 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 in the national 4x4 km grid, following the ICP Forests Protocol. The assessment included 288 trees, 116 *Pinus sylvestris*, 139 *Pinus uncinata*, 6 *Betula pendula* and 27 *Abies alba*, covering the main subalpine forests in Andorra.

Major results/highlights

Results showed that 2020 has been the worst in terms of crown condition. The defoliation and also discoloration for most trees were higher in 2020 than in previous years.

After several years of improved crown condition (2009–2016), the defoliation of Scots pine (*Pinus sylvestris*) and Mountain pine (*Pinus uncinata*) increased to the highest value ever recorded (2020). However, no significant trends in either Birch (*Betula pendula*) or Silver fir (*Abies alba*) have been observed.

Unfavorable climatic conditions during 2019 and 2020, which included low rainfall and higher temperatures during the vegetative period, could explain the growing defoliation and discoloration of major individuals.

The assessment of damage globally affected 14.2% of the sampled trees. This value is similar to recent years (slightly lower than in 2019). However, it should be noted that from 2014 to 2019 the number of affected individuals increased year by year. The origin of the types of recorded damage symptoms per assessed tree was similar to recent years. The most common identified causes of damage on the individuals in 2020 were abiotic causes (wind damages, lightning scars, etc.), followed by biological agents such as the fungus *Cronartium flaccidum*. We highlighted that in 2020 there has been a decrease in the presence of *Thaumetopoea pityocampa*, possibly due to warmer nights in the winter period (when the larvae are active), or to specific treatments for the pest.

Austria

National Focal Centre

Anita Zolles, Austrian Research Centre for Forests (BFW)

Main activities/developments

Anita Zolles took over the tasks of Ferdinand Kristöfel, who retired in April 2020, within the ICP Forest programme. 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 2020, wet deposition was collected on all 16 plots and analysed. 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 measurement of tree increment via mechanical and electronic girth bands. Hemispheric Photographs were taken at all 6 Level II core plots to obtain Leaf Area Index. Work on the second soil survey has started in June 2021 and will be finished within 2021. The assessment of biodiversity has started in spring 2021 and is expected to be completed in autumn 2021.

Major results/highlights

Two Level II plots (11-Mondsee, 17-Jochberg) were damaged by heavy snow in 2019 and were successfully reconditioned. Old deposition collectors will be renewed in 2021 at all sites. The results of the measurements and the chemical analyses on the Austrian level II plots can be seen at: www.waldmonitoring.at

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

Level II data was used in combination with data obtained by the Austrian bioindicator network to analyse mercury discharge in forests. At the Level II plots the obtained values were between 0.07-0.32 g/ha*yr, corresponding to a value of 750 kg Hg/yr over Austria. A corresponding article titled "Der Wald als Quecksilbersenke" was published in the journal "Forstzeitung"[1].

Moreover, Level II data contributed significantly to an updated national evaluation of indicators for sustainable forest management on behalf of the Austrian forest dialogue (BMLRT 2020[2]). Here, the deposition of aerial contaminants and the leaf area index as indicator for crown damages have been reported.

In June 2021, an analysis using meteorological as well as phenological measurements obtained at the Level II plot in Klausen Leopoldsdorf was presented at the 9th Forest Ecosystem Monitoring Conference (FORECOMON) and was also submitted to the special issue on *Forest Monitoring to assess Forest Functioning under Air Pollution and Climate Change* with Frontiers.

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 6 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.

[1] Fürst A, Tatzber M (2020) Der Wald als Quecksilbersenke, Forstzeitung 10, p. 26

[2] Linser S (2020) Indikatoren für nachhaltige Waldbewirtschaftung. Bundesministerium für Landwirtschaft, Regionen u. Tourismus (BMLRT), Vienna, 290 p. https://info.bmlrt.gv.at/dam/jcr:2d25b3e7-8f0c-4556-8041-0c84f8741746/Indikatoren%20f%C3%BCr%20nachhaltige%20Waldbewirtschaftung%202020.pdf

Belgium Flanders

National Focal Centre

Peter Roskams (until 31-08-2021), Arne Verstraeten
Research Institute for Nature and Forest (INBO)

Main activities/developments

In 2020, we were confronted with temporary lockdowns as the result of the COVID-19 pandemic. The capacity of our laboratory was heavily restricted, which led to delays in the analysis of samples, possibly affecting data quality. The impact of the lock-downs on the execution of fieldwork was, however, very limited.

A poster on long-term trends in ozone concentrations, indices and fluxes above a suburban mixed forest was presented at the 33rd Task Force Meeting of the UNECE ICP Vegetation in Riga. Another poster on the impact of pollen on throughfall biochemistry in European temperate and boreal forests was presented at the EGU2020 Sharing Geosciences Online Conference.

The Level I survey was performed on 73 plots and 1474 sample trees (4x4 km-grid). 826 broadleaves and 648 conifers were assessed. The main tree species are *Pinus sylvestris* (n=486), *Quercus robur* (n=390), *Pinus nigra* subsp. *laricio* (n=155), *Fagus sylvatica* (n=116) and *Quercus rubra* (n=93). Other broadleaved species, like *Castanea sativa*, *Quercus petraea*, *Betula pendula*, *Fraxinus excelsior*, *Alnus glutinosa*, *Acer pseudoplatanus* and *Populus sp.*, are gathered in the subset 'other broadleaves' (n=227). There are almost no other conifer species in the sample (n=7).

Major results/highlights

In Level I, mean defoliation was 24.1%, with 25.3% of the trees considered damaged. The mortality rate was 0.7%. The share of trees showing more than 25% defoliation was high in *Fagus sylvatica* (33.7%), *Quercus robur* (30.1%), *Pinus nigra* (30.3%) and 'other broadleaves' (32.2%). The share of trees in defoliation classes 2-4 was lower in *Pinus sylvestris* (16.2%) and *Quercus rubra* (16.1%).

In nine plots, trees were removed from the sample after a storm (n=20). Weather circumstances were warm and dry during spring and summer, with a long-lasting heat wave in August. Seed production was successful in *Quercus robur* and *Fagus sylvatica*. The proportion of trees with moderate to high fructification was 20.5% in *Quercus robur* and 14.7% in *Fagus sylvatica*.

On 7.1% of the trees, more than 10% of the crown showed discoloration. Damage due to defoliators was observed on 6.6% of the sample trees, most frequently on *Quercus robur*. Defoliators caused more than 10% defoliation on 22.8% of the *Q. robur* trees. The number of plots with caterpillar nests of

Thaumetopoea processionea on *Q. robur* increased compared to the previous year.

Crown condition deteriorated compared to the previous year. Mean defoliation increased significantly in *Fagus sylvatica* (+4.6 percentage points) and 'other broadleaves' (+2.0 percentage points). Significant changes were also detected for the total of broadleaves (+1.1 percentage points), conifers (+0.9 percentage points) and the overall total (+1.0 percentage points). *Quercus rubra* was the only species with a significant improvement in crown condition (-3.6 percentage points).

A precipitation deficit during the vegetation period in 2018, 2019 and 2020 caused drought symptoms. Crown deterioration and tree death was observed, often in combination with symptoms of insect damage or fungal infection, but mostly in forest stands outside the Level I survey. Damage was observed both in conifers (*Picea sp.*, *Pinus sp.*) and broadleaved species (*Fagus sylvatica*, *Acer pseudoplatanus*).

Compared to the very dry year of 2018, defoliation was significantly higher in *Quercus robur*, *Pinus sylvestris* and the 'other broadleaves'. The share of trees with more than 25% defoliation increased yearly in *Quercus robur*.

In 2014 a survey on the condition of *Fraxinus excelsior* was started, partly on Level I plots. A high proportion of trees is affected by *Hymenoscyphus fraxineus*. The share of trees with signs of *Armillaria sp.* or other wood rotting fungi increased every year. On a sample of 252 ash trees, 60.3% were classified as damaged, including 20.6% dead trees. Mean defoliation was 49.6%, dead trees included.

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

Neirynck J, Verstraeten A (2020) Long-Term Trends In Ozone Concentrations, Indices And Fluxes Above A Suburban Mixed Forest. Poster presented at the 33rd Task Force Meeting of the UNECE ICP Vegetation, 27–30 January 2020, Riga, Latvia. https://pureportal.inbo.be/portal/en/publications/longterm-trends-in-ozone-concentrations-indices-and-fluxes-above-a-suburban-mixed-forest(c60172e8-bd2d-465b-a640-f5f4ebee22d4).html

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Outlook

The Level I and the Level II programs will be continued, as well as the additional survey on the condition of *Fraxinus excelsior*.

Belgium Wallonia

National Focal Centre

Elodie Bay, SPW – Public Service of Wallonia

Main activities/developments

In 2020, data were collected in eight plots for Level II/III and in 48 plots for Level I.

Major results/highlights

The species began their growing season at the usual dates, except for spruce which had an early budburst. A generalized freezing occurred on 12 May and injured a lot of shoots. The spring climate was quite dry for trees and they had to face a severe heat wave during the summer. Climatic trends have normalized in the autumn. The development of insects was favored. We list some species-specific tendencies as follows:

- Spruce and Douglas-fir had to face serious insect damage, respectively by *Ips typographus* and by *Contarinia pseudotsugae*. Some more spruces of the network had to be cut down.
- The degraded status of beech is maintained. Since 2016, the average defoliation (fructification effect deducted) has increased from 35% to 40%.
- The average defoliation of oak is slightly decreasing, and spring damage due to defoliating caterpillars is decreasing. *Thaumetopoea processionea* has been identified in many places in Wallonia but not yet in the network.
- Larches have been added to the network in 2019. Their average defoliation reaches 40%.

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.

Bulgaria

National Focal Centre

Genoveva Popova, Executive Environment Agency (ExEA)

Main activities/developments

Level I

In 2020, 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* L., *Pinus nigra* Arn., *Picea abies* (L.) Karst and *Abies alba* Mill. in addition to nine deciduous tree species - *Fagus sylvatica* L., *Fagus orientalis* Lipsky, *Quercus cerris* L., *Quercus frainetto* Ten., *Quercus petraea* (Matt.) Liebl., *Quercus rubra* L., *Carpinus betulus* L., *Castanea sativa* Mill. and *Tilia platyphyllos* Scop. The total number of monitored coniferous trees was 2430 (43.2%), while that of deciduous trees was 3169 (56.8%).

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);
- the collection and analysis of atmospheric deposition in all 4 Level II SPs;
- the collection and analysis of soil solutions in all 4 Level II SPs;
- collection and analysis of litterfall samples in 3 Level II SPs;
- the collection and analysis of leaf and needle samples (foliar analysis) – in all 4 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 and 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/en/nsmos/index.html). Monitoring activities are carried out in collaboration with the Forest Research Institute under the Bulgarian Academy of Sciences and University of Forestry.

Major results/highlights

The results of the large-scale monitoring programme conducted in relation to defoliation showed that in 2020 both the state of coniferous and deciduous trees remained the same as in 2019. The monitored deciduous trees were in better condition, with 76.3% belonging to defoliation class 0 (not defoliated) and 1 (slightly defoliated). The percentage among coniferous trees was 51.9%. Overall, there was an estimated reduction in the number of healthy and slightly-defoliated trees, with 3.4% and 3.2% respectively for deciduous and coniferous trees. The share of class 4 (dead) trees among deciduous trees was 0.8% higher, whereas among coniferous tree species it was 1.4%.

The observations in the sample plots for intensive monitoring (Level II) were focused on the influence of different stress factors and the reaction of the ecosystem. The results of 2019 showed the following:

The main stress factor in the coniferous monitoring sample plots Yundola (SP0003) and complex background station (CBS) Rozhen (SP0005) has been ozone in consecutive years. Irrespective of the fact that for the last two years the AOT40 indicator in the Yundola station region decreased, over the last five years the short-term target norm for vegetation was exceeded 1.4 times, and that of forest protection 2.7 times. The calculated values of AOT40 for Rozhen in 2017 and 2018 also exceeded the level norm for forest protection and the short-term target norm for vegetation protection.

In 2019, in the Vitinya (SP0001) region, the rainfall was less acidic, but the ammonia and nitrate nitrogen and phosphate deposition increased. From the basic ions group the deposition of calcium, magnesium and potassium displayed higher values, as well as those of the metals Cu, Zn, Pb, Mn and Al. Larger amounts of base and acidic ions were deposited via stemflow in comparison to previous years. The precipitation in the other sample plots displayed an acidic reaction. In the Staro Oryahovo region (SP0004), the quantity of deposited acidic and base ions and those of metals were significantly smaller, likely as a result of the minimal amount of rainfall. In the Yundula region, there was an observed increase in open-field mixed deposition of some ions with acidic functions – ammonium nitrogen and phosphates, of base ions such as magnesium and potassium and metals – copper and zinc, and less so for cadmium and aluminum in relation to the previous year. In CBS Rozhen, the open-field mixed deposition showed larger quantities of ions with acidic and base functions, as with metals (with the exception of iron).

A stress factor in 2019 was the significantly lower amount of precipitation in comparison to 2018 which was recorded in all the test plots: Vitinya – 22% less and CBS Rozhen 27% less, while in Staro Oryahovo, the amount was 3.5 times lower and in

Yundula 1.8 times lower. The combination of dry weather conditions and high temperatures on different days in the summer months (July and August) could have had an unfavorable impact on the condition of different tree species.

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

Pavlova E, Pavlov D, Doncheva M, Bencheva S, Doychev D, Koleva-Lisama I, Kusmanova R, Kadinov G, Popova G (2020) Forest Ecosystem Monitoring. Biological indikators. Region Eastern Rhodopes, 144 p. ISBN: 978-954-749-120-5

Outlook

The programme for forest ecosystem monitoring (Level I and Level 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

NFC Croatia activities in 2020 were somewhat reduced due to the COVID-19 pandemic. Although the annual intercalibration course was deemed too high of a risk, the annual crown condition survey was conducted on the full set of Level I plots.

Major results/highlights

Level I

Ninety-four sample plots (2256 trees) on the 16 x 16 km grid network were included in the survey 2020 - 1919 broadleaved trees and 337 conifers.

The percentage of trees of all species within classes 2-4 has been relatively stable through the years - in 2020 it was 29.3% compared to 30.3% in 2019. Broadleaves have lower defoliation (26.0%) than conifers (48.7%) in comparison with 2019 (26.4% and 53.6% within classes 2-4, respectively). Although the sample is smaller, there is usually more interannual variation of defoliation for conifers.

Most defoliated tree species in Croatia in 2020, based on the percentage of trees in classes 2-4, were *Pinus nigra* (61.9%), *Fraxinus angustifolia* (55.9%) and *Abies alba* (53.3%). The least defoliated species were *Fagus sylvatica* (17.9%) and *Quercus pubescens* with 21.9% of trees in classes 2-4.

The most widespread was damage to branches, shoots and buds (36.8% of all recorded damage), followed by damage to leaves (35.0%), and finally on the trunk and butt end (28.2%). Most of tree damage was caused by insects (25.9% of all damage), especially sucking insects (12.5%) and defoliators (8.1%). Next were abiotic agents with 14.6%, and fungi with 5.6% of all damage. In 2020 drought was not a major damage factor (3.2%). Direct human activity accounted for 4.9% of all damage to forest trees. Despite a large number of recorded damage symptoms, damage extent was mostly in category 1 (0-10%).

Level II

Monitoring at Level II plots was standard, with the exception of deposition monitoring, which was conducted on only 4 out of 7 plots due to the reduced financing related to COVID-19 pandemic.

Crown condition on our intensive monitoring plots depends a lot on biotic factors: While on plot 106 (a silver fir stand) the majority of trees did not have any signs of damage, defoliators caused damage on all *Quercus pubescens* trees on plot 108; damage from beech leaf-mining weevil – *Rhynchaenus fagi* was recorded on almost all trees on plots 103 and 105; and needle necrosis caused by *Thyriopsis* sp. fungi was recorded on Aleppo pine trees on plot 111. *Corythuca arcuata* continues to cause significant damage to leaves of pedunculate oak trees in Croatia. Leaf necrosis as the consequence of oak lace bug attack was found on all trees on plots 109 and 110.

A significantly reduced deposition of nitrogen compounds was recorded on all our Level II plots in 2020 in comparison with the previous year, likely caused by COVID-19-related reduction in human activities. The amount of nitrogen was down to 2.8–12.6%, depending on the plot, of the input recorded in 2019. In spite of the decrease of the concentration of ozone precursors, the tropospheric ozone levels were not reduced by much. Nevertheless, symptoms suggesting oxidative stress caused by high ground-level ozone concentrations 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, Marjanović H, Indir K, Medak J, Anić M, Zorić N, Ognjenović M (2020) Oštećenost šumskih ekosustava Republike Hrvatske – izvješće za 2019. godinu. The damage status of forest ecosystems in Croatia – A report for 2019. Hrvatski šumarski institut/Croatian Forest Research Institute. Jastrebarsko, Croatia. www.icp.sumins.hr

Outlook

All standard NFC activities related to Level I and Level II monitoring are planned for 2021. The start of the 4-year project "Preservation of pedunculate oak (*Quercus robur* L.) stands with a focus on biotic damage factors" (project leader Dr Ivan Seletković), funded by the Ministry of Agriculture, Republic of Croatia as a part of the Green Tax Fund, is planned for this year.

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 Programme 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 cooperation 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 Meteorological Service. Until 2019, the laboratory part of the program (chemical analysis of water, soil solution, needles and soil) had been undertaken by the Department of Agriculture. The 2019 chemical analysis of needles and the 2020 chemical analysis of soil was undertaken by the Cyprus Agricultural Research Institute, while there is a possibility to collaborate with another organization for water and soil solution chemical analysis. Furthermore, there is an 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 the reduction of emissions and the increase of 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 cooperation with the Competent Authorities (the 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

Until now, no publications/reports have been published with regard to ICP Forests data and/or plots.

Outlook

- The Cyprus Department of Forests will continue to participate in the ICP Forest programme 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

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

Main activities/developments

Regular evaluation of Level I continued on 127 plots in 2020. Defoliation and other parameters related to the tree crown condition were evaluated on 4440 trees in total. The Czech University of Life Sciences in Prague and the Institute of Botany of the Academy of Sciences of Czechia in cooperation with the NFC carries out on selected plots continuous monitoring of stem size variation using point dendrometers, along with measurements of microclimate parameters (atmospheric humidity and temperature, soil moisture and temperature).

As for Level II plots, 15 plots in total were evaluated in 2020. The stand on one plot was felled as a result of the bark beetle outbreak. On Level II core plots, i.e. on seven plots, the maintenance and partial upgrade of technical equipment was underway.

Major results/highlights

In comparison with preceding years the weather pattern in the growing season was more favorable for tree vitality. Only at the beginning of the season, in the month of April, a significant rainfall deficit (43% of the normal precipitation in 1981-2010) in the whole area of Czechia was accompanied by an above-average temperature (deviation of +1.3 °C from the 1981-2010 normal temperature). Although the more favorable climate pattern during the growing season undoubtedly enhanced the overall vitality of forest stands, the mortality of forest tree species continued to be high locally. It was a consequence of severe drought impacts in preceding years and, to a considerable extent, it was a continuation of the outbreaks of subcortical insects, not only in spruce but also in pine stands. The bark beetle attacked spruce stands in northern and western Bohemia even at altitudes exceeding 900 m above sea level.

In the commercially most important category of mature conifer species, compared to the preceding year a smaller increase has occurred in share of defoliation class 2 (>25-60%) from 63.4% in 2019 to 66.0% in 2020, while representation in classes 3 (>60-99%) decreased. In younger conifers (less than 59 years of age) there was an increase in defoliation class 0 (0-10%) from 35.7% in 2019 to 39.2% in 2020, with a simultaneous moderate decrease in all other classes. In Norway spruce (*Picea abies*), class 0 increased from 4.0% in 2019 to 6.4% in 2020 - which is the highest recorded value in the last two decades – while representation of class 3 decreased. On the contrary, in Scotch pine (*Pinus sylvestris*) the long-term trend of a moderate defoliation increase is evident. We have to admit that average defoliation or representation of defoliation classes currently is not the best indicator of conifer health due to high mortality by bark beetle infestation. In 2020, the number of evaluated Norway spruce trees was 18% lower compared to 2017. A substantial part of these "missing" trees apparently were removed because of bark beetle calamity, without influencing defoliation figures.

In broadleaved tree species of the older age category (forest stands older than 59 years), no substantial changes were observed in comparison with the preceding year. In younger broadleaves (stands younger than 59 years of age) the share in class 0 increased from 31.7% in 2019 to 37.8% in 2020 with a corresponding decrease in class 1. In the age category of older broadleaved stands, there were differences between the main tree species. For oak (*Quercus* sp.) an improvement was obvious, when representation in class 0 (0-10%) and class 1 (>10-25%) increased with a corresponding decrease in the remaining classes 2-4. In beech (*Fagus sylvatica*) the situation was slightly worse: representation in class 1 dropped, with an obvious increase in class 2 which rose from 7% in 2019 to 10.6% in 2020.

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/

Outlook

Further improvement of technical equipment will continually be carried out on Level II core plots. Changes in carbon and nutrient cycles will be monitored on Level II plots felled due to bark beetle outbreaks.

A joint expert seminar organized together with Slovak colleagues from the NFC in Slovakia to be held in the Podyjí National Park, Czechia, has been shifted from the preceding year to the current year. The agenda of this meeting will be the results of monitoring within the ICP Forests programme and their comparison between the two countries.

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)

Regarding chemical laboratory analysis and improvements of methods and quality of results:

To improve the performance of the ICP-MS system, the peristaltic pump was replaced, and another type of pump tubing was chosen. The He collision gas was replaced with a better quality and the FAST system and settings were optimized. The acid concentration of the carrier and rinse solutions were changed to a slightly higher concentration to avoid carry over problems. The standards were made gravimetrically to improve accuracy and lower the risk of contamination. The procedure for the MWO digestions of leaves and needles were optimized to reduce risk of carryover from one digestion to the next. All nitric acid used for the ICP-MS determinations including rinse and carrier was made from sub boiling quality acid.

Major results/highlights

The national crown condition survey showed continued high average defoliation for most species, although with some improvement compared to 2019. The frequency of damaged trees (defoliation above 25%) dropped from 43% in 2019 to 26% in 2020 for all monitored broadleaves, and from 23% to 22% for conifers. Average beech defoliation decreased from a record high 26% in 2019 to 21% in 2020. For oak, average defoliation improved from 27% in 2018-19 to 23% in 2020, and ash is still impacted by ash dieback caused by *Hymenoscyphus fraxineus*, thus the average defoliation stayed around 30%. The amount of ash in Danish forest has been reduced by 50% since the arrival of ash dieback, mainly due to removal of sick trees. Norway spruce had a slight reduction in defoliation, but Sitka spruce still had high average defoliation (25%) and 34% of the trees were damaged. The relatively poor health is mainly due to carry-over effects of the drought in 2018, heavy masting in many species in 2019, especially beech, and the recent green spruce aphid (*Elatobium abietinum*) outbreak in 2018-20. We experienced another dry, warm spring, but the rest of the summer had fairly normal temperatures and precipitation.

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

Skovstatistik 2019 [Forests Statistics 2019] / Nord-Larsen T, Johannsen VK, Riis-Nielsen T, Thomsen IM, Jørgensen BB / Institut for Geovidenskab og Naturforvaltning, Københavns Universitet, 2020. 55 pp. [In Danish with English summary]

Outlook

Future developments of the ICP Forests infrastructure

- Implementation of LAI measurement systems
- Implementation of AAQ measurement systems
- Repeat soil sampling and analysis

Planned research projects, expected results

Soils have been sampled and analyzed for C and N at Level I sites as part of a larger national project sampling soils in two national monitoring networks of 130 (Nitrate Monitoring Network) and 280 (NFI) plots, respectively. Danish Level I plots (25) are a subset of the 130 plots. Soil C stocks for the entire network will be analyzed this year. Analysis of remaining soil properties can be done as later as samples are archived, but it will depend on external funding.

Estonia

National Focal Centre

Vladislav Apuhtin, Estonian Environment Agency

Main activities/developments

The health status of 2568 trees was assessed on the observation points of the Level I forest monitoring network and on the sample plots of the intensive forest monitoring (Level II). 1658 trees were Scots pines (*Pinus sylvestris*), 636 Norway spruces (*Picea abies*) and 274 were from deciduous species, mainly Silver birch (*Betula pendula*). The observation period lasted from July 15 to October 31, 2020.

On Level II the following forest monitoring activities were carried out in 2020:

- chemical analyses of the deposition water collected throughout the year on 6 sample plots;
- chemical analyses of soil solution collected during 8 months (from March to October) on 5 sample plots;
- samples of litterfall were collected on one plot;
- foliar samples collected in December 2019 on six sample plots were analyzed;
- soil samples were collected on 20 Level I plots.

Major results/highlights

Level I

The total share of not defoliated trees (conifers and broadleaves), 48.5%, was 1.2% lower than in 2019. The share of not defoliated conifers, 47.7%, was lower than the share of not defoliated broadleaves, 54.4%, in 2020.

The share of trees in classes 2 to 4, moderately defoliated to dead, was 6.2% in 2020 and 5.8% in 2019. The share of conifers and broadleaves in defoliation classes 2 to 4 was 6.3% and 5.5%, respectively.

The share of not defoliated pines (defoliation class 0) was 46.8% in 2020, 0.8% lower than in 2019. The share of pines in classes 2 to 4, moderately defoliated to dead, was 0.5% higher than in 2019. The defoliation of Scots pine slightly increased in 2020. However, the long-term trend of Scots pine defoliation showed no significant changes since 2010.

The health status of Norway spruces had remained unchanged for a couple of years but defoliation increased in 2020. The share of spruces without crown damages was 50.3% and the share of trees with a defoliation rate 10-25% was 42.4%. A long-term increase of defoliation of Norway spruce may be observed.

The health status of birches decreased in 2020. The share of healthy birches in 2020 was 8% lower than in 2019; this was mainly caused by insects and storms.

Numerous factors determine the condition of forests. Climatic factors, diseases and insects, as well as other natural factors have an impact on tree vitality. All trees included in the crown condition assessment on Level I plots are also regularly assessed for damage.

In 2020, 2.9% of the living trees observed had some insect damage, and 17.5% of them (mainly Scots pines) had symptoms of fungal diseases. Overall, 42.7% of trees had no identifiable symptoms of any damage.

Visible damage symptoms recorded on Scots pine were mainly attributed to pine shoot blight (pathogen *Gremmeniella abietina*). Symptoms of shoot blight were recorded on 10.7% of the observed pine trees in 2020, compared to 11.4% in 2019. Norway spruces mostly suffered due to old moose damages and root rot (pathogen *Heterobasidion parviporum*) – characteristic symptoms of root rot were observed on 1.9% of the sample trees.

Level II

The annual average pH of the precipitation under throughfall was varying, mainly between 5.5 and 6.5. In 2020, observations showed a slight increase of pH compared to 2019 on all plots. The content of chemical elements and compounds in analyzed precipitation water was low, except for the content of calcium in bulk deposition samples on the Karepa sample plot. Generally, the amount of precipitation in 2020 was similar to the previous year.

The pH of the soil solution varied between 3.8 and 6.7 throughout the observation period. The content 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 $mg \cdot l^{-1}$. In 2020, similarly to the past years, the content of Ca^{2+}, Mg^{2+} and Cl^{-} in soil solution was considerably higher than 2.5 $mg \cdot l^{-1}$ on all spruce sample plots. The concentration of Na^{+} and SO_4-S in the spruce stand at Karepa was essentially higher than the level of 2.5 $mg \cdot l^{-1}$.

The chemical analyses of foliage, gathered in 2019, indicated that the concentration of nutrient elements in pine needles and in spruce needles in Tõravere was below the optimum value. Only the concentration of calcium was optimal on all plots. Compared to the last period (2017/2018), the concentration of nutrient elements showed a slight decrease.

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

Forest Monitoring. Report of the survey 2020. Vladislav Apuhtin, Tiiu Timmusk, Heino Õunap, Helen Karu. Estonian Environment Agency, Tartu 2021

Yearbook Forest 2019, 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

In 2020, 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 included also litterfall, crown condition, and stand growth. In addition, tree increment was monitored using girth bands by manual recordings. The monitoring data of the year 2019 was submitted to the ICP Forests database.

Major results/highlights

In addition to our contribution to research papers based on international cooperation (Etzold et al. 2020, van Sundert et al. 2020, Forsius et al. 2021), several papers benefited from Finnish ICP Forests Level II data and BioSoil data. Based on data and material from Level II plots, Salemaa et al. (2020) reported that the equations predicting the N-tot deposition with N concentration of mosses (mossN%) showed a good fit both in forest sites and openings, especially in case of *Pleurozium schreberi*. However, the open site mossN% was found to be a preferable predictor of N deposition in monitoring studies to minimize the effect of tree canopies and N leachate from litterfall on the estimates. Further, an asymptotic form of mossN% vs. throughfall N-tot deposition curves in forests and free NH_4^+-N accumulation in tissues in the southern plots suggested mosses were near the N saturation state already at the N-tot deposition level of 3-5 kg $ha^{-1}yr^{-1}$.

Utilizing Finnish BioSoil data, Kaarlejärvi et al. (2021) found that human impacts on temporal biodiversity change in understory vegetation vary along environmental gradients. In boreal forests, the fertile habitats have a higher probability than nutrient-poor sites of changing their composition in response to anthropogenic disturbances. Resource availability and disturbance history may thus influence consequences of temporal turnover for ecosystem functioning.

Pohjanmies et al. (2021) used BioSoil vegetation and soil survey data and the respective Russian data to compare the Finnish Cajanderian and the Russian Sukachevian forest site type classification systems in terms of the understory community composition (that is supposed to define them), soil fertility and tree productivity (that they are expected to indicate), and biodiversity. The results showed that analogous types between the systems can be identified.

The cited scientific publications are listed on the ICP Forests website: http://icp-forests.net/page/scientific-publications.

Outlook

Monitoring activities will continue on eight Level II plots in Finland, and the data is continuously utilized in research and to fulfil the information needs of the NEC Directive. In addition to the UNECE ICP Forests programme, two EU related initiatives, the NEC Directive and the acceptance of the eLTER research infrastructure onto the EU's ESFRI roadmap, have strengthened the prospects of the Level II programme in Finland.

France

National Focal Centre

Level I: Frédéric Delport, Fabien Caroulle, Ministère de l'Agriculture et de l'Agroalimentaire

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.

Level II

Despite the exceptional containment measures decided by the authorities against the COVID-19 epidemic from March 2020, monitoring activities were able to continue on the 102 plots of the Level II network (RENECOFOR). In detail, tree assessments (phenology, health, annual growth, and periodical growth inventory in the dormancy period) were performed on all of these plots, while atmospheric deposition, meteo, soil solution and litterfall are monitored only on a subset of plots. Only ground vegetation assessments, usually repeated in spring and summer, could not be performed in 2020, but they were launched in spring 2021 in all the plots.

Outlook

Level I

Crown assessment in the ICP Forests network will carry on in the next years, without major changes.

The main research project is aimed at establishing links between defoliation and tree growth. This project was already the main subject of a PhD dealing with this topic concerning beech and fir, the next step will focus on oaks.

Level II

The French Level II network (RENECOFOR) will reach in 2022 its initially defined 30-yr horizon. An agreement has been found to prolong its activities in the future with funding from the Ministry of Ecological Transition and the Ministry of Agriculture and Food. Intensive monitoring is to be continued with the same objectives and surveys, but an additional effort is required to adapt the network to longer-term activity, by progressively replacing the plots that have entered or will enter the stand regeneration stage within the next 30 years (potentially half of the network) by new plots in adult stands. The exact location of the replaced plots will be recorded to keep the possibility to reuse them later. Material was acquired and tested in 2020 in view to progressively georeference all devices, infrastructure and numbered trees in every plot.

Germany

National Focal Centre

Juliane Beez, Federal Ministry of Food and Agriculture
Scientific support: Thünen Institute of Forest Ecosystems

Main activities/developments

Germany continued its assessment at Level I and II. The 2020 crown condition survey took place on 416 Level I plots with a total number of 10 076 sample trees. Level II data for 2019 have been submitted for 68 plots.

The national training course for the forest condition survey in Germany took place 23–24 June 2020 in Freising, Germany. The course was organized by the Thünen Institute of Forest Ecosystems in cooperation with the Bavarian State Institute of Forestry. It was attended by 14 participants and targeted the main tree species in Germany. The results indicated a lower reliability of defoliation assessments within Germany compared to 2019. Due to the COVID-19-pandemic a smaller number of experienced participants were able to join the training course.

The results of the Photo-ICC, presented at the inventory-leader-conference held in June 2020, showed a high homogeneity of defoliation assessments within Germany. The course was attended by 56 participants.

Major results/highlights

Crown condition (Level I)

In summer 2020, defoliation on 37% of the forest area was classified as moderate to severe (defoliation classes 2 to 4; this means defoliation >25%). This is an increase by 1 percentage point compared to 2019. 42% of the investigated forest area was in the warning stage (slightly defoliated). Only 21% (2019: 22%) showed no defoliation. Mean crown defoliation increased from 25.1% in 2019 to 26.5% in 2020. This is the highest mean crown defoliation ever recorded since the beginning of the surveys in 1984. The mortality rate showed a significant increase for coniferous trees.

Picea abies: The percentage of defoliation classes 2 to 4 increased from 36% to 44%. 35% (2019: 36%) of the trees were in the warning stage. The share of trees without defoliation was 21% (2019: 28%). Mean crown defoliation increased from 23.9% to 29.4%.

Pinus sylvestris: The share of defoliation classes 2 to 4 in 2020 remained stable at 26%. The share of the warning stage was 54% (2019: 56%). Only 20% showed no defoliation. Mean crown defoliation increased from 22.4% to 22.6%.

Fagus sylvatica: The share of trees in the defoliation classes 2 to 4 reached 55% (2019: 47%). 34% (2019: 37%) were in the warning stage. The share showing no defoliation was 11% (2019: 16%). Mean crown defoliation increased from 28.6% to 31.3%.

Quercus petraea and *Q. robur*: The share of moderately to severely defoliated trees decreased from 50% to 38%. The share of trees in the warning stage increased from 33% to 42%. The share without defoliation increased from 17% to 20%. Mean crown defoliation decreased from 28.2% to 25.3%.

Severe droughts and temperatures above the long-term average characterized the vegetation period 2020, as well as those in 2018 and 2019. An *Ips typographus* gradation is currently ongoing. Extraordinary fellings due to wind, drought and bark-beetle damage which occurred in 2018, 2019 and 2020 sum up to a total amount of 178 million cubic meters of timber. An area of 277 000 ha needs to be reforested.

Intensive forest monitoring (Level II)

Main research highlights from all Level II surveys were published in May 2020 in a brochure by the Federal Ministry of Food and Agriculture. The brochure (Krüger et al. 2020) outlines the effects of acidification, eutrophication, and climate warming on forest ecosystems to the general public

Air pollution effects on forest trees can be identified through imbalances in tree nutrition, such as the ratio of foliar nitrogen to foliar phosphorus. N:P ratios are outside of the optimal range on 36% of the intensive monitoring sites in Germany, which is a slightly higher percentage than in the whole of Europe (30%). We see a significant increase in N:P ratios across all German Level II plots, indicating an increasing imbalance in tree nutrition. As shown in a study published in December 2020, imbalances in tree nutrition are linked to the recent decline of CO_2 fertilization effects on photosynthesis (Wang et al. 2020).

Although we reached nearly 25 years of ground vegetation assessment, long-term analysis does not show consistent trends in biodiversity across Level II plots. Overall a total of 402 vascular plant species have been identified in the herb layer over the years, with up to 78 plant species found in one subalpine larch stand. The number of species per plot can be linked to soil properties such as base saturation. Diversity indices remained in the same range throughout the assessment period, with a decreasing trend on 14 plots vs an increasing trend on 13 plots. Ellenberg scores show an increase in acidification indicator on 70 % of plots as well as decreasing Ellenberg scores for soil nutrients on 70% of plots, but overall trends are not significant.

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

Krüger I, Sanders TGM, Holzhausen M, Schad T, Schmitz A, Strich S (2020) Am Puls des Waldes: Umweltwandel und seine Folgen - ausgewählte Ergebnisse des intensiven forstlichen Umweltmonitorings. Berlin: BMEL, 51 p

Sanders TGM, Krüger I, Holzhausen M (2020) Das intensive forstliche Monitoring - Level II. Eberswalde: Thünen-Institut für Waldökosysteme, 2 p, Project Brief Thünen Inst 2020/25, DOI:10.3220/PB1608106763000
PDF Dokument (nicht barrierefrei) 660 KB

Sanders TGM, Ziche D, Bolte A (2020) Ernährungssituation von Bäumen verändert Klima-Wachstums-Beziehung. Eberswalde: Thünen-Institut für Waldökosysteme, 2 p, Project Brief Thünen Inst 2020/18

Outlook

Our national working group on environmental monitoring of forests will further consider how to deal with changes on the Level II plots in a harmonized and coordinated way.

Greece

National Focal Centre

Panagiotis Michopoulos, Kostas Kaoukis – 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 2020, data was collected from 38 plots: 38% percent of the total number of Level I plots in our country. More specifically, in 2020, the number of trees counted was 886, whereas in 2019 the number of trees was 1055. From the 886 trees, 388 were conifers and 498 were 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	Broadleaf species
No defoliation	58.6	39.2	73.7
Slight defoliation	21.4	31.7	13.5
Moderate defoliation	17.5	24.5	12.1
Severe defoliation	2.2	4.4	0.4
Dead trees	0.3	0.3	0.4

It was found that 80.0% of all trees belonged to the classes “No defoliation” and “Slight defoliation”. The corresponding values were 70.9% and 87.2% for conifers and broadleaves, respectively. The major damage causes for needle loss in conifers were insects, European mistletoe and abiotic factors. With regard to broadleaves, the most important agents for the leaf loss were insect attack and abiotic factors.

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*). Full scale activities take place in plots 1, 2 and 4.

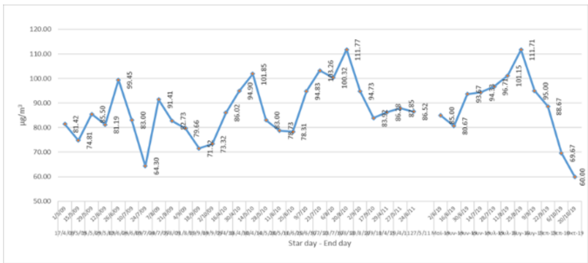
The annual rainfall in the study areas of the project was 5-12% higher than the average recorded in the years of operation of the meteorological stations. Also, in all plots, the average annual air temperature was higher than the plot station's average value. More specifically, the increase was 5.1% in the maquis plot (48 years), 8.5% in the oak and beech plots (24 years) and 7.0% in the fir (48 years) plot (see table below).

	Maquis plot		**Oak and beech plots**		**Fir plot**	
	Temp. ⁰C	Rain (mm)	Temp. ⁰C	Rain (mm)	Temp. ⁰C	Rain (mm)
2019	1200	16.1	13.7	1309	10.8	1626
Mean	1053	15.4	12.6	1275	10.1	1449

Air Quality

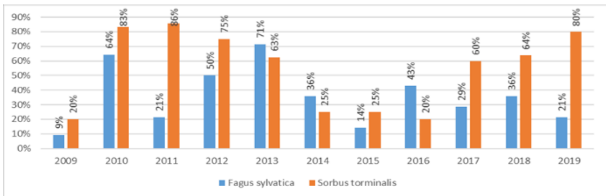
In 2019, diffusive ozone samplers were placed in the oak plot because in the past, high concentrations of ozone had been observed.

The below figure shows the results (ozone concentrations) over time. It can be seen that in 2019, we had high ozone concentrations in the ambient air of the oak plot.



Ozone Injury

With regard to the symptoms of ozone injuries we have the following results: In the fir and maquis plot, no injury was observed, whereas in the oak and beech plot, which happen to be in the same mountain, we had visible symptoms in beech (*Fagus sylvatica*) and checker trees (*Sorbus torminalis*). The percentages of damage are shown in the below figure.



Crown condition assessment (Level II)

The crown assessment for the year 2019 in the four Level II plots comprised a total of 165 trees (35 conifers and 130 broadleaves). The results showed an improvement in tree health in comparison with the results of the 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
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

Deposition

The following table shows the deposition fluxes (bulk and throughfall) of the major ions in the maquis, oak and fir plots in 2019. It can be seen that there was retention of ammonium-N by the canopy of the fir plot (throughfall < bulk fluxes), whereas the nitrate-N retention took place in the fir and oak plots. It is impressive that although the fir plot has a sufficient amount of N in the soil (BioSoil results), the N uptake by the fir canopies continues. As was expected, the fluxes of magnesium and potassium were higher in the throughfall deposition for all plots. The same happened with the calcium and sulphate-S fluxes. In the last case, the dry deposition played the most important role.

Fluxes (kg ha^{-1} yr^{-1}) of major ions in deposition (throughfall (T) and bulk (B)) in three forest plots in 2019

Plots	Dep.	Ca	Mg	K	$SO4^{2-}$-S	NH_4^+-N	NO_3^--N	mm
Maquis	T	17.1	4.52	40.8	8.51	4.23	3.71	933
	B	17.0	2.84	10.8	6.08	3.39	2.20	1260
Oak	T	20.6	7.85	24.3	11.6	6.22	1.80	905
	B	11.4	3.74	8.52	9.37	5.83	3.76	1365
Fir	T	17.5	3.71	43.8	9.14	3.19	2.69	1484
	B	13.9	1.66	7.09	6.93	7.50	3.48	1743

Litterfall

The percentage of foliar litter with regard to the total foliar mass was highest in the beech plot (87%). In the rest of the plots, the percentages were similar; 68% for the maquis, 64% for the oak and 62% for the fir plot. The fluxes of all nutrients in the foliar fraction, with the exception of P, were higher in the beech plot probably because of the high quantities in foliar litterfall in 2019. The P content in the fir plot was higher in both foliar and non-foliar fractions. The oak plot had low fluxes of Ca in both foliar and non-foliar litterfall. This can be important because the oak species are located on acid soil. In addition, the oak plot had low phosphorus fluxes in both foliar and non-foliar litterfall.

For the non-foliar litter, the fir plot had by far the highest amounts of all nutrients with the exception of N, which was higher in the oak plot. The non-foliar litter contributed an appreciable amount of nutrients in the foliar litter (apart from the beech plot in 2019). This is important when considering the removal of nutrient stocks through logging. The logging remains should stay on the forest floor to enrich the soil. This stands true especially for the wooden remains in acid forest soils. The oak stand is situated on a mica schist parent material, which gives rise to acid soils.

From the following table it can be seen that for the non-foliar litter (mainly twigs) in the oak plot, the quantities of calcium were almost half of those in the foliar fraction. If they are removed (during logging), a valuable buffer shield against a soil pH change will disappear.

Fluxes (kg ha^{-1} yr^{-1}) of major nutrients in litterfall in four forest plots in 2019

Foliar	Ca	Mg	K	S	N	P
Maquis	53.4	5.83	14.7	4.56	33.6	2.85
Oak	38.2	6.21	16.5	3.15	31.8	2.78
Beech	96.7	10.3	17.2	6.74	74.5	3.57
Fir	62.8	4.45	11.6	4.54	41.5	3.62
Non-foliar	**Ca**	**Mg**	**K**	**S**	**N**	**P**
Maquis	18.2	1.96	1.60	1.59	18.0	1.40
Oak	17.2	2.41	1.96	1.92	29.2	2.02
Beech	14.2	0.99	1.25	0.66	7.24	0.55
Fir	30.1	2.66	2.07	2.16	23.3	2.30

Hungary

National Focal Centre

Kinga Nagy, National Land Centre, Department of Forestry

Main activities/developments

Level I, the large-scale health condition monitoring, is coordinated 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 2020, 77 permanent plots with 1845 sample trees were included in the crown condition assessment (surveying was obstructed in one sample plot). The survey was carried out between 15 July and 15 August. The percentage of broadleaves was 90.7%, while the percentage of conifers was 9.3%.

Major results/highlights

Level I

From the total number of sample trees surveyed, 27.3% were without visible defoliation, which shows a little decrease in comparison with 2019 (31.6%). The percentage of slightly defoliated trees was 36.0%, and the percentage of all trees within ICP Forests defoliation classes 2-4 (moderately damaged, severely damaged and dead) was 36.7%. The rate of dead trees was 2.2% and only 1.0% of them 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 26.3%.

Relatively big differences can be observed between the tree species groups in respect of the defoliation rates. As in recent years, *Pinus nigra* (black pine) was the most defoliated and damaged tree species group in 2020: The percentage of the sample trees in the healthy category was around 3%. (It should be noted that only 1.8% of the sample trees were black pines.) For several years now, a long-term decline in the health condition could be observed on *Quercus robur* (pedunculate oak), in 2020 only 10% of the assessed sample trees were in the ICP Forests defoliation class 0.

Discoloration can rarely be observed in the Hungarian forests, 91.9% of living sample trees did not show any discoloration.

Although the damages caused by insects and fungi were dominant in general, the rates of the damaging agents showed differences in proportions between the tree species groups respectively. In 2020, the insects were the most frequent damaging agents (29.4%). Most of the observed damages were caused by defoliators and sucking insects, which in most cases occurred on *Robinia pseudoacacia* (black locust), *Quercus robur* and Q. *petraea*, and *other softwood species*.

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.

Fungal damages (24.9% on all plots) were observed on *Quercus* species and *Pinus nigra* at the highest rate. The relatively high frequency correlates with the bad condition of the prior species groups (which, in the case of *Quercus* species, were mostly caused by *Microsphaera quercina).*

Abiotic damages (19.3%) were the third most frequent damaging agents: most of the observed damages were due to drought or frost and wind. The frequency of the damages with unknown origin was 16.1%. The rates of the damages caused by other biotic agents (10.3%) and direct actions of man (6.4%) did not change significantly compared to the previous years. The game damages were generally not frequent (5.5%) but in some tree species groups (poplars, beech, *Robinia* and hornbeam) appeared more often. The frequency of the damages with unknown origin was only 3.2 %. The signs of fire damage were scarcely observed in the assessed stands (only 1%).

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

"Erdeink egészségi állapota 2020-ban" The annual national report on the health condition of the Hungarian forests, which includes ICP Forests plot data, is available (in Hungarian) online at http://www.nfk.gov.hu/EMMRE_kiadvanyok__jelentesek__prognozis_fuzetek_news_536

Outlook

The 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 and human resources are ongoing.

Ireland

National Focal Centre

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

Main activities/developments

Crown condition assessments on Level I plots were undertaken in 2020, supported by Ireland's Department of Agriculture, Food and the Marine. No other active monitoring under the ICP Forests programme was undertaken during 2020, while two Level II plots remain available for monitoring.

A new National Ecosystems Monitoring Network (NEMN) is being developed in Ireland to monitor and report negative impacts of air pollution on ecosystems (acidification, eutrophication, ozone damage and biodiversity loss) under Articles 9 and 10 of the National Emissions Ceilings Directive (NECD 2016/2284). Reporting is on four-yearly cycles, with the next reporting of monitoring sites and indicators in 2022 and data in 2023. This network will draw on ICP Forests methods for some monitoring, and will apply ICP Forests data quality approaches, allowing some data outputs to contribute to submissions for Ireland under ICP Forests. Initial monitoring in the network in 2021 will be in open habitats, with forests expected to be included in following years.

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

National Ecosystems Monitoring Network – Ireland. https://nemn.ucd.ie/

Outlook

It is hoped that during further development of Ireland's National Ecosystem Monitoring network, observations and data will conform to ICP Forests standards, in forest ecosystems using existing Level II plots, and that further harmonization between Ireland's NEMN and ICP Forests will occur. Crown condition assessments are expected to continue at Ireland's Level I sites.

Italy

National Focal Centre

Giancarlo Papitto, Carabinieri Corps – Office for Studies and Projects

Main activities/developments

The survey of Level I in 2020 took into consideration the condition of the crown of 4512 selected trees in 245 plots belonging to the 16x16 km Level I network. The results given below relate to the distribution of frequencies of the indicators used, especially transparency - which in our case we use for the indirect assessment of defoliation and the presence of known causes attributable to both biotic agents and abiotic factors. For the latter, not so much the indicators we analysed 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 (76.3%) is included in the classes 1 to 4; 36.1 % is included in the classes 2 to 4.

By analysing the sample for conifers and broadleaves, it appears that conifers have a lower transparency than deciduous trees: 38.2% of conifers versus 18.3% of broadleaves were in the class 0 of transparency, while 26.9% of conifers vs. 39.6% were included in the classes 2 to 4.

From a survey of the frequency distribution of the parameter for transparency, species were divided into two age categories (<60 and ≥60 years), among the young conifers (<60 years), *Pinus sylvestris* has 32.2% of trees in the classes 2 to 4, *Pinus nigra* has 43.2% of trees in the classes 2 to 4, while *Picea abies* with 6.0% in the young conifers is in the best conditions.

Among the old conifers (≥60 years), the species appearing to be of the worst quality of foliage was *Pinus sylvestris* (67.4% of trees in the classes 2 to 4), then *Picea abies* (27.2%), *Larix decidua* (25.2%) and *Abies alba* with 18.5% in the classes 2 to 4, while *Pinus cembra* (2.8%) was the conifer with the best condition.

Among the young broadleaves (<60 years), *Castanea sativa, Fagus sylvatica* and *Quercus pubescens* have respectively 66.5%, 43.8% and 37.9% of trees in the classes 2 to 4, while others *Fraxinus ornus* and *Quercus cerris* have a frequency range between 25.3% and 27.9% in classes 2 to 4.

Among the old broadleaves (≥60 years) in the classes 2-4, *Castanea sativa* has 90.2%, *Quercus pubescens* 44.4%, *Quercus ilex* 29.7%, and *Fagus sylvatica* 20.5%, while *Fraxinus ornus* with 17.1% has the lowest level of defoliation of trees in the classes 2-4.

For a deeper assessment of damage factors (biotic and abiotic) the main results are summarized below.

Most of the observed symptoms were attributed to insects (21.2%), subdivided into defoliators (17.4%), galls (1.7%), following symptoms attributed to fungi (4.5%) with the most significant attributable to "dieback and canker fungi" (2.3%), then those assigned to abiotic agents, the most significant attributable to hail (1.3%) and drought (1.0%).

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

Papitto G, Cindolo C, Cocciufa C, Brunialti G, Frati L, Pollastrini M, Bussotti F (a cura di) 2018. Lo stato di salute delle foreste italiane (1997-2017). 20 anni di monitoraggio della condizione delle chiome degli alberi. Published by Arma dei Carabinieri, Comando Unità Forestali Ambientali e Agroalimentari. Roma, 205 pp. Edizione aggiornata 2020.

Papitto G, Quatrini V, Cindolo C, Cocciufa C (a cura di) 2021. Rete NEC Italia - Monitoraggio degli ecosistemi terrestri. Lo stato delle foreste italiane. Rete di livello II del programma ICP FORESTS - CON.ECO.FOR. Rapporto su 20 anni di studi degli ecosistemi forestali. Published by Arma dei Carabinieri, Comando Unità Forestali Ambientali e Agroalimentari. Roma, 116 pp.

Papitto G, Cindolo C, Cocciufa C, Di Martino D, Pica T, Vittoria Santorsa M, Sotgiu S, De Cinti B, Marchetto A, Matteucci G, Bertini G, Cutini A, Fabbio G, Fares S, Moretti V, Piovosi M, Salvati L, Sorgi T, Andreetta A, Bussotti F, Carnicelli S, Cecchini G, Pollastrini M, Amici V, Brunialti G, Calderisi M, Frati L, Canullo R. 2019. LIFE13 ENV/IT/000813 Smart4Action – Layman's Report This publication was edited with the financial contribution of the European Union LIFE Program

Outlook

Currently, Italy has 253 Level I sites and 32 square areas in Level II monitoring and it is planned to maintain those plots also in future.

Latvia

National Focal Centre

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

Main activities/developments

Latvia continued its assessment at Level I. The forest condition survey 2020 in Latvia was carried out on 115 Level I NFI plots. The major results of 2020 are based on data from this dataset.

In 2020, the relevant works were performed within the framework of the Level II monitoring:

- National crown condition survey
- Deposition monitoring from bulk, throughfall, stemflow, lysimeters
- Litterfall sampling twice a month in months with no snow cover (usually March – November/December, may differ from year-to-year basis)
- Air quality monitoring, using diffusive samplers twice a month (June – October)

Installation of LAI (Leaf area index) measuring grids in all Level II monitoring plots

Major results/highlights

On Level I plots, defoliation and damage symptoms of 1727 trees were assessed, of which 73% were conifers and 27% broadleaves. Of all tree species, 10% were not defoliated, 86.6% were slightly defoliated and 3.5% moderately defoliated to dead. Compared to 2019, the proportion of not defoliated trees has decreased by 1.3%, the proportion of slightly defoliated has increased by 3.4%, but the proportion of moderately defoliated to dead trees has decreased by 2.0%. In 2020, the proportion of not defoliated conifers was by 4.7% higher than that of not defoliated broadleaves, the proportion of slightly defoliated broadleaves was by 4.2% higher than that of slightly defoliated conifers. The proportion of trees in defoliation classes 2-4 for broadleaves was 0.5% higher than for conifers.

Mean defoliation of *Pinus sylvestris* was 19.8% (20.0% in 2019). The share of moderately defoliated to dead trees constituted 3.3% (4.6% in 2019). Mean defoliation of *Picea abies* was 16.9% (18.7% in 2019). The share of moderately defoliated to dead trees for spruce decreased by 1.5% (4.2% in 2019). The mean defoliation level of *Betula* spp. was 19.3% (20.9% in 2019). The share of trees in defoliation classes moderately defoliated to dead was 3.8% (compared to 8.0% in 2019).

Visible damage symptoms were observed on 17.3% of the assessed trees (17.0% of the assessed trees in 2019). Most frequently recorded damages were caused by direct action of men (27.2%; 30.3% in 2019), animals (26.5%; 25.5% in 2019), insects (18.5%; 16.9% in 2019), abiotic factors (12.8%; 11.8% in 2019), and fungi (10.7%; 11.8% in 2019), and unknown cause – for 4.4% (3.8% in 2019). The distribution of damage causes was similar to recent years. The proportion of insect damages has increased thanks to the increase of damages by the European pine sawfly *Neodiprion sertifer*. The greatest share of trees with visible damage symptoms was recorded for *Picea abies* (27.0%), *Pinus sylvestris* (16.2%) and the smallest for *Betula* spp. (10.0%).

Outlook

Latvia has 115 NFI Level I plots and it is planned to continue observations at this level. Level II monitoring in Latvia is firmly established and has continued for more than a decade. Monitoring plots are well preserved and meet all standards for successful data gathering and processing, and for data submission. The main goal at the moment is to maintain these monitoring plots in pristine condition for future data gathering.

Lithuania

National Focal Centre

Marijus Eigirdas, Lithuanian State Forest Service

Main activities/developments

Level I

In 2020, the forest condition survey was carried out on 1036 sample plots from which 81 plots were on the transnational Level I grid and 955 plots were on the National Forest Inventory grid. In total, 6125 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*.

In 2020, forest soils were repeatedly monitored in 81 plots on the 16x16 km grid of the National Forest Inventory in Lithuania according to the recommendations of the ICP Forests Manual Part X: Sampling and Analysis of Soil. During the monitoring, soil profiles were described, the soil was sampled for chemical analysis and the mass of the forest floor was determined.

Level II

In 2020, intensive monitoring activities were carried out on nine intensive monitoring plots (IMP). The activities performed on the nine IMP included the visual assessment of crown condition and damaging agents, the assessment of ozone injury, ground vegetation, and tree growth. On three Level II plots, the following surveys were conducted: soil solution collection and analysis, atmospheric deposition in bulk and throughfall, and litterfall sampling. In addition, from May to October, the concentration of sulphur dioxide (SO_2), nitrogen dioxide (NO_2), and ammonia (NH_3) were determined in the ambient air with passive samplers. Phenological observations for Norway spruce, Scots pine, and pedunculate oak were performed in three IMP. The crown condition was assessed for a total of 506 model trees in 2020.

Major results/highlights

Level I

During one year the mean defoliation of all tree species has not changed and remained at 22.0% (22.0% in 2019). 15.0% of all sample trees were not defoliated (class 0), 66.1% were slightly defoliated and 18.9% were assessed as moderately defoliated, severely defoliated or dead (defoliation classes 2-4).

Mean defoliation of conifers slightly decreased up to 22.5% (22.6% in 2019) and has not changed for broadleaves 21.1% (21.1% in 2019).

Pinus sylvestris is a dominant tree species in Lithuanian forests and composes about 37% of all sample trees annually. Mean defoliation of *Pinus sylvestris* slightly decreased to 23.8% (24.4% in 2019), while in 2008-2019 there was observed a slightly increasing trend in defoliation.

Populus tremula had the lowest mean defoliation and the lowest share of trees in defoliation classes 2-4 since 2006. Mean defoliation of *Populus tremula* was 17.4% (18.0% in 2019) and the proportion of trees in defoliation classes 2-4 was 6.3% compared with 7.6% in 2019.

The condition of *Fraxinus excelsior* remained the worst among all observed tree species. This tree species had the highest defoliation since 2000. Mean defoliation decreased to 32.3% (27.4% in 2019). The share of trees in defoliation classes 2-4 increased to 42.9% (40.7% in 2019).

30% of all sample trees had some kind of identifiable damage symptom. The most frequent damage was caused by abiotic agents (about 8.5%) in the period of 2011–2020. The highest share of damage symptoms was assessed for *Fraxinus excelsior* (59%), *Alnus incana* (40%) and *Picea abies* (39%), *Populus tremula* (38%), the least for *Alnus glutinosa* (20%) and *Betula* sp. (23%).

Level II

The mean defoliation of all tree species varied insignificantly from 1997 to 2020, and the growing conditions of Lithuanian forests can be defined as relatively stable.

The average defoliation of trees in Level II plots ranged from 16–18% over the last 5 years. In April 2020, one Level II plot (No. 10) was severely damaged by wind. This resulted in 10% of the model trees being uprooted or broken. In this plot, the average tree defoliation increased from 14% in 2019 to 25% in 2020.

Air pollution deposition surveys, 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 3–5 kg ha^{-1} yr^{-1}. Average nitrate deposition (NO_3–N) both in the open area and under tree crowns has varied from 5–7 kg ha^{-1} yr^{-1}. Average ammonium deposition in the forest was about 4–5 kg ha^{-1} yr^{-1}, while in the open area it reached nearly 4 kg ha^{-1} yr^{-1}.

In 2020, average SO_2 concentration was 1.47 µg/m^3 in IMP. The average NO_2 concentration was 9.05 µg/m^3, and it was lower than the multi-annual value (10.37 µg/m^3) (2008-2020). The average NH_3 concentration was 2.67 µg/m^3, and it was slightly lower than the multi-annual value (3.94 µg/m^3) (2008-2020).

Multi-annual (2017-2020) observations of visible ground-level ozone-related damages showed that the most frequently damaged tree species were *Alnus incana, Fraxinus excelsior* and *Alnus glutinosa*. Ozone-related damages were not observed for *Quercus robur*, *Betula pubescens* and *Populus tremula*. In 2020, visually visible ground-level ozone-related damages were assessed on nine IMP. No foliage damages possibly caused by ground-level ozone were recorded.

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

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Agathokleous E, Feng Z, Oksanen E, Sicard P, Wang Q, Saitanis CJ, Araminiene V, Blande JD, Hayes F, Calatayud V, Domingos M, Veresoglo SD, Peñuelas J, Wardle DA, De Marco A, Li Z, Harmens H, Yuan X, Vitale M, Paoletti E. 2020. Ozone affects plant, insect, and soil microbial communities: A threat to terrestrial ecosystems and biodiversity. Science Advances 6 (33): eabc1176

Agathokleous E, Saitanis CJ, Feng ZZ, De Marco A, Araminiene V, Domingos M, Sicard P, Paoletti E. 2020. Ozone biomonitoring: A versatile tool for science, education and regulation. Current Opinion in Environmental Science & Health, 18: 7–13

Stakėnas V, Varnagirytė-Kabašinskienė I, Sirgedaitė-Šėžienė V, Armolaitis K, Araminienė V, Muraškienė M, Žemaitis P. 2020. Dead wood carbon density for the main tree species in the Lithuanian hemiboreal forest. European Journal of Forest Research. Published online: 12 August 2020. https://doi.org/10.1007/s10342-020-01306-3

Luxembourg

National Focal Centre

Martine Neuberg, Pascal Armborst, Georges Kugener, Danièle Murat, Bintner Robert, Administration de la nature et des forêts

Main activities/developments

We did our annual “inventaire phytosanitaire” (inventory of tree health) of our national and international fix points.

Norway

National Focal Centre

Volkmar Timmermann, Norwegian Institute of Bioeconomy Research (NIBIO)

Main activities/developments

Norway is represented in six 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 2020, we participated in the Task Force meeting in June (Zoom) and in the QA/QC and PCG meeting in November (Webex). We also took part as partner in the Norwegian LTER network. We contributed to the chapter on crown condition in the ICP Forests Technical Report and to Indicator 2.3 Defoliation in the 2020 FOREST EUROPE report. Our lab participated in the 23rd Needle/Leaf Interlaboratory Comparison Test 2020/2021 and in the 10th Deposition and Soil Solution Ringtest.

Level I / Norwegian national forest monitoring

The Norwegian national forest monitoring is conducted on sample plots on a systematic grid of 3 x 3 km in forested areas of the country. The plots are part of the National Forest Inventory (NFI), which 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 anymore. The plots are circular with an area of 250 m^2, and sample trees are selected with a relascope. Defoliation assessments are done on Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*) only, while damage assessments are conducted on all tree species found on the plots.

Our national forest monitoring in 2020 included defoliation assessments on 5 526 Norway spruce and 4 746 Scots pine trees on 1 830 plots, and damage assessments on 18 775 trees (28+ species incl. spruce and pine) on 2 533 plots in total, from mid-May until mid-October. The regular national field calibration course for the field workers from the NFI had to be cancelled due to the COVID-19 pandemic.

In 2020, 604 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 4 910 trees belonging to 23 species were reported to ICP Forests database.

Level II

At our three Level II sites, the following surveys are conducted: 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 2020, mean defoliation for Norway spruce was 16.5%, and 13.9% for Scots pine in our national monitoring. There was no change in mean defoliation for these two species compared to 2019.

When dividing into defoliation classes, 46.9% of the spruce trees and 44.4% of the pine trees were classified as not defoliated (defoliation class 0) in 2020. Class 1 (slight defoliation) comprised 32.4% of the spruce trees and 43.8% of the pine trees, while 17.3% and 11.0% of the spruce and pine trees fell into class 2 (moderate defoliation). Severe defoliation (class 3) was recorded for 3.0% of the spruce trees and for only 0.6% of the pine trees.

Mortality rates were 3.6‰ for Norway spruce, 2.1‰ for Scots pine, 8.8‰ for birch, 11.6‰ for other deciduous species and 5.8‰ on average for all assessed tree species in 2020.

Less damage was observed in 2020 than in 2019, and only 10.6% of all assessed trees had some symptom of damage (-1.9%-points compared to 2019). 8.8% of the spruce trees were damaged (-1.7%-points), 6.6% of the pines (-1.4%-points), 14.4% of the birches (*Betula* spp., -1.5%-points) and 13.4% of other deciduous species (-5.8%-points). The percentage of damaged oak trees (*Quercus* spp.) was still as high as it was in 2019 (28.5%), however, the number of oak trees in the sample is rather small (130 trees). The prevailing causes of damage for all tree species were abiotic factors with snow breakage, storm and drought as the most important ones. The second most important cause of damage was insects for birch (birch moths) and for other deciduous species, while it was fungi for spruce and pine. The percentage of unidentified damage causes was high and still increasing compared to earlier years (51.9% for all species, +7.1%-points), and it was especially high for spruce (66.2%). Little discoloration was observed in the conifers in 2020: only 6.6% of the spruce trees and 1.6% of the pine trees had discoloration of more than 10%.

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

Timmermann V, Andreassen K, Beachell AM, Brurberg MB, Børja I, Clarke N., Halvorsen R, Hylen G, Jepsen JU, Perminow JIS, Solberg S, Solheim H, Talgø V, Tollefsrud MM, Vindstad OPL, Økland B, Økland TI, Aas W (2020) Skogens helsetilstand i Norge. Resultater fra skogskadeover-våkingen i 2019. [The state of health of Norwegian forests. Results from the national forest damage monitoring 2019.] NIBIO Rapport 6(119). 89pp. https://nibio.brage.unit.no/nibio-xmlui/handle/11250/2681543 (abstract in English)

Outlook

- Monitoring at Level I will continue as part of our national monitoring conducted by the NFI.
- Needle samples for foliar analysis will be taken at our Level II plots in October 2021.
- We plan to participate in both the next Needle/Leaf and Deposition/Soil Solution ringtests.
- The ICOS C-flux tower will finally start its measurements at one of our Level II sites (Hurdal) during 2021. At this site NILU also has one of their EMEP sites, providing an opening for a broad collaboration between ICOS, EMEP and ICP Forests.

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 Ministry of Environment (MŚ), 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 is co-chair.

Level I

In 2020, the forest condition survey was conducted on 2 050 Level I plots (8 km x 8 km grid) and a total of 41 000 trees were assessed. The fieldwork took place in July and August. The results of the assessment carried out on 343 plots on a 16 km x 16 km grid (European network) and on 6 860 trees were submitted to the ICP Forests database.

Level II

Measurements of weather parameters, air quality, and chemical analysis of deposition (outside the canopy and in throughfall) and soil solution were made on 12 Level II plots. In addition, on four plots with four main tree species (Scots pine, Norway spruce, beech and oak) the continuous measurements of dbh and water availability of trees were carried out.

Major results/highlights

Level I

The average mean defoliation of all species was 23.1%, that of conifers 22.9%, and that of deciduous trees 23.4%. The percentage of healthy trees (with leaf loss of 10% or less) of all species was 8.0%, and the percentage of damaged trees (with leaf loss of more than 25%) was 19.4%.

The percentage of healthy (11.0%) and damaged (22.6%) trees was higher for deciduous species than for coniferous species (6.2% and 17.5%, respectively). The proportion of trees from the early warning class (slightly damaged trees, with defoliation between 11% and 25%) was: for all species - 72.6%, for coniferous species - 76.3% and for broadleaved species - 66.4%.

Among the three major conifer species, *Abies alba* had the lowest mean defoliation at 19.4%, with 18.6% of trees in class 0 and 9.8% in classes 2-4. *Pinus sylvestris* was characterized by a lower share of trees in class 0 (5.1%), a higher share of trees in classes 2-4 (17.5%) and a higher mean defoliation (23.0%) than Abies alba. *Picea abies* was characterized by a higher proportion of trees in classes 2-4 (22.4%) and a higher mean defoliation (24.3%) compared to Scots pine and fir. The percentage of healthy Norway spruce trees (with defoliation up to 10%) was 9.5%.

In 2020, as in the previous survey, the highest mean defoliation among deciduous trees was observed in *Quercus* spp. - 28.2%. Only 2.2% of oaks were without any symptoms of defoliation and 40.6% were in defoliation classes 2-4. A slightly better condition was observed in *Betula* spp. (4.9% trees without defoliation, 24.3% damaged trees (classes 2-4) and the mean defoliation level was 24.9%). *Fagus sylvatica* and *Alnus* spp. remained the deciduous tree species with the lowest defoliation. In 2020, a proportion of 19.2% of beech trees were without any symptoms of defoliation, only 10.8% were in defoliation classes 2-4, and the mean defoliation was 19.3%. Results for alder: 19.4% of trees without leaf loss, 8.7% of trees in classes 2-4, and mean defoliation was 19.0%.

In 2020, the condition of the assessed trees remained almost the same compared to the previous year.

Level II

Meteorological measurements on 12 Level II plots showed that 2020 was not as hot as 2019 or as extremely hot as it was in Poland in 2015. Average temperatures over the whole year were 5.6-10.5 °C, lower than 2019 at most sites. Maximum temperatures in 2020 were significantly lower than 2019 or 2015 at all plots, with a difference of up to more than 8 °C. Precipitation was slightly higher than in 2019, and significantly so during the growing season.

The results of deposition and concentration of elements in soil solution on 12 Level II plots in 2020 will be evaluated in the second half of 2021. In 2019, bulk deposition of mineral nitrogen compounds (NO_3 and NH_4) ranged from 3.5 to 9 kg N ha^{-1}. The throughfall deposition ranged from 6 to 16 kg N ha^{-1} and total estimated deposition of mineral nitrogen compounds ranged from 10 to 30 kg N ha^{-1}. Critical loads for nitrogen were exceeded on 9 of 12 plots. Deposition of SO_4 in forest stands ranged from 2 to 6 kg S ha^{-1}. Critical loads for acidity were exceeded on 2 plots.

Air SO_2 concentrations in 2020 were 2% to 27% lower than in 2019 on eight plots and 9% to 19% higher than in 2019 on 3 of 12 plots, one of which is located in the most polluted region of the country. On one plot, the concentration of SO_2 did not change compared to 2019. Concentrations of NO_2 decreased by 6% to 19% on most plots and remained at the same level as in 2019 on two plots. A general decreasing trend in gaseous pollutants on most plots in recent years continued.

Outlook

In addition to routine monitoring activities, the following projects were started in 2018 and 2019 and continued in 2020 using forest monitoring data and/or infrastructure:

- assessment of acidification and eutrophication of forest ecosystems in Poland in relation to the concept of critical loads;
- water cycle in forest ecosystems under climate change conditions; and
- coefficients of tree death/survival in Level I monitoring plots in Poland in 2007-2017 and their applicability in assessing the health status of the main forest tree species.

Romania

National Focal Centre

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

Main activities/developments

In Romania, all the ICP Forests Level I and Level II monitoring activities are carried out under the coordination of the National Institute for Research and Development in Forestry (INCDS) „Marin Drăcea” (NFC). Romanian experts are involved as members in all Expert Panels (Ambient Air Quality, Crown Condition and Damage Causes; Deposition; Forest Growth; Soil & Soil Solution; Biodiversity and Ground Vegetation; Meteorology, Phenology & LAI) as well as in the Working Group QA/QC in Laboratories. Since 2020 our representative holds the chair position of the Ambient Air Quality Expert Panel.

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

- the Joint Expert Panel Meeting of ICP Forests held by e-mail from March 10 to March 13, 2020;
- the 36th Task Force Meeting of ICP Forests by video conference from June 11, 2020 to June 12, 2020; and
- the online photo exercise for ozone-induced foliar symptoms on woody species, organized by the ICP Forests Ambient Air Quality Expert Panel.

Other forest monitoring related events:

- National Scientific Conference: The impact of global warming on the environment and society, Romanian Academy, January 2020;
- National Scientific Conference: International and Romanian scientific research - solutions for mitigating and adapting to climate change. Romanian Academy, February 2020; and

- the 4th and final meeting of the LIFE - MOTTLES project - web conference, 25th May 2020.

Despite the COVID-19 pandemic restrictions, in 2020 all the forest monitoring data collection and analyses were carried out as scheduled, in both Level I and Level II monitoring networks as follows:

- annual crown condition assessments on Level I plots (16x16 km);
- forest monitoring activities on Level II plots: crown condition and tree growth assessments (12 plots); continuous and permanent measurements of tree stem variation (4 plots); collecting 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
- validating and submitting the data base for all monitoring activities (Level I and Level II).

Major results/highlights

In 2020, the forest condition in Romania revealed a slight deterioration compared to the previous year. The share of damaged trees (defoliation classes 2-4) increased from 11.6% in 2019 to 12.9% in 2020.

From a total number of 5424 trees, 831 trees were conifers (15.3%) and 4593 broadleaves (84.7%), 50.6% were rated as healthy (defoliation class 0), 36.5% as slightly defoliated (class 1), 11.7% as moderately defoliated (class 2), 1.1% as severely defoliated (class 3) and 0.1% were found dead (class 4).

For deciduous species, the share of damaged trees was 12.1%, which was 0.9% higher than in 2019, but still lower than the values registered in the last years. *Fagus sylvatica* had the lowest share of damaged trees (7%), and similar to the previous years the highest values were registered by *Populus spp.* (24.6%), *Q. frainetto* (20.5%) and *Fraxinus spp.* (19.5%).

A more marked increase of the damaged trees percentage was registered in 2020 for conifers, from 13.7% (2019) to 17.5% (2020), *Abies alba* and *Picea abies* being the least affected species with a share of damaged trees of 11.0% and 15.7%, respectively.

For all trees and species, the mortality rate is low (0.1%), the highest values being registered for *Carpinus* spp. and *Robinia pseudoacacia* (0.4%).

Damage symptoms were reported for 40% of the total number of trees. The most important causes were attributed to defoliators and xylophage insects (22.1%) and fungi (15.5%).

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

- Badea O, De Marco A, Apostol E, Aponte C, Tanase MA. 2020. Forest Science for a Sustainable Forestry and Human Wellbeing. Elsevier, ISSN: 0048-9697. (Editor) Virtual special issue: https://www.sciencedirect.com/journal/science-of-the-total-environment/special-issue/109MF5R4CXZ
- Pascu I-S, Dobre A-C, Badea O, Tanase MA (2020, April). Retrieval of Forest Structural Parameters from Terrestrial Laser Scanning: A Romanian Case Study. FORESTS 11(4). doi: 10.3390/f11040392.
- Chivulescu S, Ciceu A, Leca S, Apostol B, Popescu O, Badea O (2020). Development phases and structural characteristics of the Penteleu-Viforata virgin forest in the Curvature Carpathians. iForest 13: 389-395. doi: 10.3832/ifor3094-013.
- Sicard P, De Marco A, Carrari E, Dalstein-Richier L, Hoshika Y, Badea O, Pitar D, Fares S, Conte A, Popa I, Paoletti E (2020). Epidemiological derivation of flux-based critical levels for visible ozone injury in European forests. Journal of Forestry Research 31:1509-1519. doi: 10.1007/s11676-020-01191-x.
- The Annual Report of the Romanian Environment Status in 2019. VI.1.3. Forest health status. Ministry of Environment, Waters and Forests http://www-old.anpm.ro/upload/150386_ANPM-PC_RSM%202019.pdf.
- The Annual Report of the Romanian Forest Status in 2019. Ministry of Environment, Waters and Forests
- The ICP Forests Technical Report – 2019.

Outlook

In the context of the New European Green Deal call, we submitted a project proposal under H2020 in which we intend to reinforce the research and monitoring activities in our ICP Forests plots (selected plots from the Level I and Level II networks placed in periurban areas) by developing an infrastructure for detecting and measuring the concentrations of GHG such as CO_2, i.e., the gas with the highest weight in GHG, but also CH_4 and tropospheric ozone (O_3) with the most harmful effect on the living conditions and health of citizen. Such infrastructure will provide robust knowledge on GHG and air pollution on the environmental and forestry sectors in Eastern and Southern Europe by networking existing sites from different programs (ICOS, ICP Forests, EMEP, EEA-EIOnet, LTER-Europe) in a novel-approach infrastructure. The current infrastructure will be upgraded with sensors for air quality (e.g., NO_2, SO_2), main GHGs (e.g., CO_2, CH_4, O_3), meteorological and forest health parameters and it will be used information from Copernicus Atmospheric Monitoring Service for main pollutants and GHG. Furthermore, satellite remote sensors (e.g., Sentinel 5p/TROPOMI; Sentinel-2, Sentinel-3, Pleiades Very High

Resolution) used in combination with field monitoring data will provide spatial and temporal perspectives for past, current and future information on climate change, GHG and air pollutant concentrations.

In the unfortunate scenario in which our proposal is not financed by the EU, we intend to develop our Level II network by equipping our plots with new sensors for measuring GHG, using national funds. Also, we are seeking financing possibilities for developing new research (related to climate change effects on different forest indicators), given the high quality of the long-term datasets for our ICP Forests plots, obtained by applying standardized manuals and protocols developed under the UNECE – ICP Forests Programme.

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 programme ICP Forests, with the goal of achieving further improvement and harmonization with other approaches to forests and forest ecosystem monitoring. Monitoring is conducted on 130 Level I sample plots and 5 Level II sample plots. The main activities in 2020 included the improvement of the work within the ICP Forests programme through the implementation of new and enhancement of the existing infrastructure with the application of modern technologies. This includes the improvement of current instruments within ICP Level II sample plots, as well as the improvement of internal database storage. During 2020, bases for additional activities within this project have been established, since leaf area index will be added in the next year as permanent activity. Through this project, the Institute of Forestry constantly works on strengthening the cooperation with all relevant institutions in the field of forestry and environmental protection: forest estates of 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 sampling plots was 2956 trees, of which 358 were conifer trees and a considerably higher number (2598) were broadleaf trees. The conifer tree species are: *Abies alba,* number of trees and percentage of individual tree species 67 (2.3%), *Picea abies* 144 (4.9%), *Pinus nigra* 67 (2.3%), *Pinus sylvestris* 80 (2.7%) and the most represented broadleaf tree species are: *Carpinus betulus,* number of trees and percentage of individual tree species 120 (4.1%), *Fagus moesiaca* 831 (28.1%), *Quercus cerris* 524 (17.7%), *Quercus frainetto* 397 (13.4%), *Quercus petraea* 196 (6.6%) and other species 530 (17.9%).

The results of the available data processing and the assessment of the degree of defoliation of individual conifer and broadleaf species (%) are: *Abies alba* (None 92.5, Slight 6.0, Moderate 0.0, Severe 1.5 and Dead 0.0); *Picea abies* (None 95.1, Slight 1.4, Moderate 2.1, Severe 1.4 and Dead 0.0); *Pinus nigra* (None 43.3, Slight 20.9, Moderate 25.4, Severe 10.4 and Dead 0.0); *Pinus sylvestris* (None 91.3, Slight 7.5, Moderate 0.0, Severe 1.2 and Dead 0.0). The degree of defoliation calculated for all conifer trees is as follows: no defoliation 84.1% trees, slight defoliation 7.2% trees, moderate 5.6% trees, severe defoliation 3.1% trees and dead 0.0% trees.

Defoliation for broadleaf species (%) is: *Carpinus betulus* (None 91.7, Slight 5.8, Moderate 2.5, Severe 0.0, Dead 0.0); *Fagus moesiaca* (None 86.8, Slight 8.2, Moderate 4.1, Severe 0.9, Dead 0.0); *Quercus cerris* (None 78.0, Slight 14.7, Moderate 6.7, Severe 0.6, Dead 0.0); *Quercus frainetto* (None 89.9, Slight 6.8, Moderate 5.4, Severe 1.5, Dead 0.0); *Quercus petraea* (None 72.6, Slight 13.4, Moderate 9.8, Severe 4.0, Dead 0.2) and the rest (None 82.1, Slight 11.0, Moderate 5.4, Severe 1.5, Dead 0.0). Degree of defoliation calculated for all broadleaf species is as follows: no defoliation 82.1% trees, slight defoliation 11.0% trees, moderate 5.4%, severe defoliation 1.5% trees and dead 0.0% trees.

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

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

Gagić-Serdar R, Stefanović T, Đorđević I, Češljar G, Marković M, Momirović N (2020) Forest ecosystems vitality monitoring (ICP Forests, Level I) with special emphasis to the affected part of the sample trees in the Republic of Serbia. Sustainable Forestry, 81-82. (81-92)

Outlook

Activities for monitoring of ambient air quality have been initiated. During 2021, efforts will focus on adding this survey to our permanent monitoring. Cooperation with the Environmental Protection Agency of Serbia has been made, and the NFC Institute of Forestry will try to include their data on ambient air quality during 2021, since their monitoring station is near to our sample plot Level II on Kopaonik. Also, during 2021 the survey for leaf area index will be established, and for this year data on three Level II sample plots will be collected and submitted to the ICP Forests database. The NFC Institute of Forestry will work on the ICP Forests infrastructure, mostly to improve work in our laboratories and our permanent involvement in ring tests. For 2021, the publishing of a paper with an impact factor is planned under the title *The impact of extreme climate events on tree defoliation as an indicator of the condition of the forests in Serbia*.

Slovakia

National Focal Centre

Pavel Pavlenda, National Forest Centre – Forest Research Institute Zvolen (NFC-FRI Zvolen)

Main activities/developments

Crown condition assessment on Level I plots (16 x 16 km grid) was conducted between 13 July and 14 August 2020. The number of Level I plots is decreasing due to bark beetle outbreaks and sanitary fellings and relatively large areas with young forest plantations. In the last two decades, the share of Norway spruce in tree species composition in forests of Slovakia fell from 26.8% to 22.5%, which is reflected also in the number of Level I plots and the decreasing number of assessed Norway spruce trees.

Standard activities of intensive monitoring continued on seven Level II monitoring plots at a rate of twice per month. One Level II plot was established after destruction of the original forest stand by windstorm. Defoliation, increment, atmospheric deposition, meteorology and phenology are being monitored at all these Level II plots but other surveys (soil solution, air quality, litterfall) are limited only to selected plots. After a gap of several years, sampling of needles and leaves was also conducted in 2019, and laboratory analyses finished in 2020.

We participated in many activities organized by ICP Forests bodies (2020 photo assessment – ICC course, ring tests of laboratories, meeting of Expert panels etc.). At the national level we co-operated with ICP Vegetation NFC with mosses sampling at forest sites near Level I monitoring plots.

An introductory study for the next large-scale soil sampling, analyses and assessment was elaborated as a base for feasible alternative selection. Soil sampling at Level II plots started in 2020 within a research project focussing on complex assessment of forest soils. Several other national research projects have been submitted to support research into specific topics related to forest ecology and activities of forest monitoring. We continue the trend of open co-operation with other research institutions and research programmes (e.g. validation of BGC Biome model for Central European region, integration of meteorological data in forest landscape), as well as with environmental institutions and agencies (NEC Directive obligations, UNFCCC and Kyoto reporting, climate change adaptation strategy etc.).

Major results/highlights

The results of the crown condition survey in 2020 show a similar state to 2019 for broadleaves, but a worsening one for conifers. The share of trees in defoliation classes 2-4 was 34.1% in broadleaves (34.8% in 2019) and 51.0% in conifers (45.3% in 2019). Mean defoliation of all tree species together was 27.9%, with mean defoliation of broadleaves 25.8% and conifers 31.3%. The highest level of damage was observed in *Fraxinus excelsior* (mean defoliation 47.6%), *European larch* (41.0%) and *Pinus sylvestris* (35.9%). As the number of sample trees for *Fraxinus excelsior* and *European larch* is rather low, the trends of crown condition are not so clear, but for *Pinus sylvestris* the trend of decline since 2000 is highly significant. On the other hand, the only tree species with continuous decrease of defoliation from the very beginning of forest monitoring (1988) is *Abies alba*. The highest mortality was observed in *Picea abies* in the last decade.

The trend of radial increment of *Fagus sylvatica*, *Carpinus betulus* and *Pinus sylvestris* is decreasing (correlated with defoliation increase) in the last two decades while the increment of *Picea abies* and *Quercus sp.* is still relatively stable. As already mentioned, specific results are for *Picea abies*: defoliation and increment of surviving trees is without increasing or decreasing trend, but a large number of trees died very rapidly due to bark beetle outbreaks which led to a drop in the number of assessed trees. *Abies alba* is the tree species with a positive trend, not only in defoliation but also in increment, and it shows recovery after a decline in the 1980s.

Deposition of sulphur and nitrogen does not show further decrease in the last years. The annual deposition of sulphur (in throughfall) varies between 3 and 9 kg ha^{-1} at all monitoring plots, and the annual deposition of nitrogen (in throughfall) varies between 5 and 10 kg ha^{-1}.

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

A national report on forest condition is not published annually, but the main defoliation data are included in the national green report (forestry status). For 2021, the publication of a report is planned.

Selected articles:

Sitková Z, Konôpka M. (2020) Climatological analysis of the weather during the year 2019 in Slovakia. APOL 1(2):113–120. (in Slovak)

Bičárová S, Shashikumar A, Richier LD, Lukasova V, Adamčíková K, Pavlendová H, Sitková Z, Buchholcerová A, Bilčík D (2020) The Response Of Pinus Species To Ozone Uptake In Different Climate Regions Of Europe. Central European Forestry Journal 66(4):255-268. ISSN 2454-034X. https://doi.org/10.2478/forj-2020-0027

Outlook

The monitoring program will be continued at all existing Level I plots on the 16x16 km grid and at seven Level II plots. The priority of the forest monitoring is to maintain the system and sustain the continuity of time series and data quality. Within current funding levels we have no plans to expand our monitoring activities. Also, the development of field infrastructure and laboratory instruments depends on additional financing, e.g. specific projects for infrastructure support or big research projects.

The aim of the NFC for next year is to improve the activities in research projects related to monitoring of forests and to continue the co-operation with other research institutions for complex data evaluation in all relevant environmental aspects.

Slovenia

National Focal Centre

Mitja Skudnik, Daniel Žlindra, Špela Planinšek, Slovenian Forestry Institute (SFI)

Main activities/developments

In 2020, 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, 343 coniferous and 713 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 2020, deposition and soil solution monitoring was performed on all four Level II "core" plots. On all ten plots the ambient air quality monitoring (ozone) was done with passive samplers and ozone injuries assessed on six of them. On eight plots the phenological observations were carried out. On six plots growth was monitored with mechanical dendrometers.

Major results/highlights

- The mean defoliation of all tree species was estimated to be 27.8% (compared to last year the situation is little better).
- Mean defoliation in 2020 for coniferous trees was 26.7% (in 2019 it was 28.7%).
- Mean defoliation in year 2020 for broadleaves was 28.35 % (in 2018 it was 27.6%).
- The defoliation of conifers is remaining on a very high level, with little sign of decrease in 2020. The main reason is the bark beetle outbreak after a large ice storm break in 2014, stretching all over 2016, 2017, 2018.
- The defoliation of broadleaves has slowly increasing over the past 5 years. The main reason could be the effect of ice storm (fungi effect) and some other insect attacks.
- The total share of damaged and dead trees (with more than 25% defoliation) again increased compared to the previous years from 33.8% to 37.7%, to over 38% in 2020!
- The percentage of damaged broadleaves has persistently increased from 34% in 2018, 35% in 2019 to 36.5% in 2020.
- The percentage of damaged conifers has increased from 40.6% in 2017 to 42.7% in 2019. In the past year 2020, it has slightly decreased to 41%.
- Average ozone concentrations in the growing season of 2020 ranged from 15 to 56 µg/m^3 on monitored plots which is a 25 to 50% reduction according to the previous year. On all 10 plots the 14-days ozone concentrations remained under 80 µg/m^3 during the whole growing season. On two plots with higher concentrations, we measured 74 and 75 µg/m^3 of ozone. On an additional one the ozone concentration was 68 µg/m^3. On the rest of the plots the ozone did not exceed the value of 60 µg/m^3 on a 14-days average.
- The highest 14-days average concentration was 75 µg/m^3 and 56 µg/m^3 on the most ozone-polluted plot.
- Regarding preliminary results on all Level II core plots, total bulk nitrogen (N) decreased on average by 30% (15–42%) to the previous year. In throughfall, on three plots total nitrogen decreased (13-40%) and increased on one (+4%). Sulphur (S) decreased on all four plots in bulk and throughfall on average by 22% (17-33%).

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

Skudnik M, Grah A, Pintar AM, Planinšek Š. Digitalni zajem podatkov o stanju krošenj in poškodovanosti gozdov za namene poročanja ICP Forests = Digital capture of tree crown condition and damage cause assesments for the purpose of ICP forests reporting. Gozdarski vestnik: slovenska strokovna revija za gozdarstvo. [Tiskana izd.]. 2020, letn. 78, št. 4, str. 185-194, ilustr. ISSN 0017-2723. http://dirros.openscience.si/IzpisGradiva.php?id=12070

Ferlan M, Grah A, Kermavnar J, Kutnar L, Ogris N, Pintar AM, Planinšek Š, Rupel M, Simončič P, Skudnik M, Žlindra D (avtor, urednik). Poročilo o spremljanju stanja gozdov za leto 2019 = Report on health status of forests 2019. Ljubljana: Gozdarski inštitut Slovenije, 2020. 1 spletni vir (1 datoteka PDF (102 str.) https://www.gozdis.si/f/docs/Publikacije/Porocilo_o_spremljanju_stanja_gozdov_za_leto_2019_final.pdf

Outlook

In 2020, one meteorological station was completely renewed/repaired (fallen and destroyed in spring) and additionally fenced. On one plot the fence was repaired. Some other minor repair work was done on other IM (Level II) plots and will continue in 2021. Some Level I plots were re-established in the past 4 years, due to major infrastructural projects or clearcuts (after ice storm, bark beetles).

Spain

National Focal Centre

Ana Isabel González and Belén Torres, Ministry for the Ecological Transition and the Demographic Challenge

Main activities/developments

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

Despite the pandemic situation, Level I and Level II surveys were carried out in 2020. Due to the lockdown, Level II data corresponding to March and April are missing.

Main activities were:

- National Intercalibration Course was cancelled because of the pandemic situation in Spain.
- March 2020: Attendance to ICP Forests Combined Expert Panel Meeting (video conference)
- June 2020: Attendance to ICP Forests Task Force Meeting (video conference)
- Others: Continuously updating the website

Major results/highlights

Level I

Mean defoliation observed in 2020 of all the trees of the Level I sample is 22.3%. Dead trees due to harvests were not included when calculating mean defoliation.

Results obtained from the 2020 surveys show a slight improvement in general assessed tree status, compared with mean values from the last 5-year period: The percentage of healthy trees has decreased (78.1%, compared to 76.5% on average in the last 5-year period), and damaged trees have decreased (20.0% of the assessed trees have defoliation over 25%, while the average is 20.7%). However, the percentage of dead or missing trees decreased slightly as well (1.9% in 2020 compared to 2.8% on average). Comparing broadleaves and conifers, both groups experience improvement, more clearly in conifers. In this group, the percentage of healthy trees increased slightly (79.2% in 2020, compared to 77.4% on average in the last 5-year period); and the percentage of damaged trees decreased (18.8% of trees). In the case of broadleaves, the percentage of healthy trees increased as well (77.1%, compared to 75.6% on average); the percentage of damaged trees decreased (21.5%).

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[1]

Forest Damage Inventory 2020 (Inventario de Daños Forestales 2020)

Maintenance and Data Collection. European Large-scale forest condition monitoring (Level I) in Spain: 2020 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 2020

Level II[2]

- European intensive and continuous monitoring of forest ecosystems, Level II. 2019 Report. (*Red europea de seguimiento intensivo y continuo de los ecosistemas forestales, Red de Nivel II*).

Spanish versions are available for download.

Outlook

Nowadays, data from ICP Forests Level I monitoring are providing very useful information to fulfil the international requirements of climate change information. Litter, deadwood and soil surveys are, and are going to be in the near future, the main source of data to assess the variation of carbon in these forestry pools.

Spanish National Forest Inventory-type plots have been installed with the same center plot location as Level I plots, in order to fill in the gaps in area estimation and complete the information as regards the living biomass and stand variables. Dasometric parameters such as mean diameter, basal area, and mean height of living trees are already measured in all Level I plots.

Moreover, regional Level I surveys are being carried out by different regions (autonomous communities) in Spain. An

[1] https://www.mapa.gob.es/es/desarrollo-rural/temas/politica-forestal/inventario-cartografia/redes-europeas-seguimiento-bosques/red_nivel_l_danos.aspx

[2] https://www.mapa.gob.es/es/desarrollo-rural/temas/politica-forestal/inventario-cartografia/redes-europeas-seguimiento-bosques/red_nivel_ll_danos.aspx

integrated database, containing data both from national and regional sources, has been constructed 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.

Mainly to fulfil the requirements of the NECD Directive, new soil surveys have been restarted in Level II plots in 2020.

Sweden

National Focal Centre

Sören Wulff, 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 measured. The Swedish NFI is carried out on a five years interval and accordingly the annual Level I sample is remeasured every fifth year. Defoliation assessments are carried out only on *Picea abies* and *Pinus sylvestris*, 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. Sweden participated in some of the meetings of the 2021 Joint Expert Panel Meeting of ICP Forests.

Major results/highlights

The major results for Level I concern only forests of thinning age or older and outside forest reserves. The proportion of trees with more than 25% defoliation is for *Picea abies* 22.3% and for *Pinus sylvestris* 11.6 %. Large temporal annual changes are seen on a regional level, however, after the dry summer in 2018 an increase of defoliated trees is seen for *Picea abies* in southern Sweden. For *Pinus sylvestris* a slight increased defoliation in northern Sweden is observed during the last 10 years. The mortality rate in 2019 was for *Pinus sylvestris* 0.37% and for *Picea abies* 0.51%. 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 7.9 million m^3 Norway spruce forest was killed during 2020. In northern Sweden there is a strong concern for the young forest, mainly the pine forest. Several causes of damage interact. Most important among them are resin top disease (*Cronartium flaccidum*) and browsing by ungulates – mainly elk. A study has been carried out on the future of the elm (*Ulmus sp.*) population on the island of Gotland. 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 are besides in the ICP Forests Technical Report also included in the state of Europe's Forest report 2020. Data are used in many "data requests", where participating researcher gain access to Swedish data.

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

Akselsson C, Kronnäs V, Stadlinger N, Zanchi G, Belyazid S, Karlsson PE, Hellsten S, Pihl Karlsson G. 2021. A Combined Measurement and Modelling Approach to Assess the Sustainability of Whole-Tree Harvesting—A Swedish Case Study. Sustainability 2021, 13, 2395. https://doi.org/10.3390/su13042395

Pihl Karlsson G, Hellsten S, Akselsson C, Karlsson PE. Tillståndet i skogsmiljön i olika län i Sverige - Resultat från Krondroppsnätet till och med 2018/19, (Följande län/delar: Halland Kronoberg, Västmanland, Värmland, Södermanland, Västra Götaland, Östergötland, Jönköping, Stockholm, Skåne, Kalmar, Blekinge & norra Sverige). 2020. IVL Rapport C389-390, C393, C400-406, C411-413.

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 resin top disease and a special inventory of damages caused by spruce bark beetle.

Switzerland

National Focal Centre

Arthur Gessler, Peter Waldner, Marcus Schaub, 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:

- The preparation of the 9th ICP Forests Scientific Conference on Forest Monitoring to Assess Forest Functioning under Air Pollution and Climate Change, 7-9 Jun 2021, WSL (https://forecomon2021.thuenen.de)
- The preparation of the ICP Forests - SwissForestLab - NFZ Summer School on FORMON Forest Monitoring to Assess Forest Functioning under Air Pollution and Climate Change, 22-28 Aug 2021, Davos, Switzerland

(https://www.wsl.ch/de/ueber-die-wsl/veranstaltungen-und-besuche-an-der-wsl/details/swissforestlab-summer-school-2021.html)

- At present, Level I assessments are carried out on a 16 x 16 km grid. We noticed that the sometimes very patchy impacts of the drought and heat years 2018 and 2019 could not be well captured with the given grid. Thus, we started to prepare a return to the 8x8 km grid to obtain higher spatial representativeness. In 2021, a first pilot assessment on 20 plots on the 8x8 km grid will be carried out.
- Drone-based assessment: We have last year finalized a project that was aimed at assessing various reflectance indices (PRI, NDVI, Chl/Car) at the experimental site Pfynwald, and the results show that plant drought stress can be sensitively detected and related to defoliation. We are at present preparing the implementation of regular drone-based measurements of the Level I and II crown condition.

Major results/highlights

After the clear increase in 2019 due to the extreme dry year 2018, crown defoliation decreased again in 2020. Nevertheless, crown defoliation remains at the high level that has set in since around 2011. The total crown defoliation of deciduous trees in 2020 was higher than in conifers. Compared to the previous year, crown defoliation increased moderately for deciduous trees and decreased significantly for conifers.

We applied drone-based estimates of the photochemical reflectance index (PRI), the chlorophyll to carotenoid ratio, NDVI and determined canopy temperature by thermal infrared photography. We could relate especially PRI to tree water availability, reduction of photosynthesis and increase in non-photochemical quenching, and these parameters were related to defoliation.

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

Eugster W, Baumgartner LP, Bachmann O, Baltensperger U, Dèzes P, Dubois N, Foubert A, Heitzler M, Henggeler K, Hetényi G, Hurni L, Müntener O, Nenes A, Reymond C, Röösli C, Rothacher M, Schaub M, Steinbacher M, Vogel H & the RoTaGeo team (2021) Geosciences Roadmap for Research Infrastructures 2025–2028 by the Swiss Geosciences Community. Swiss Academies Reports 16(4). https://scnat.ch/en/uuid/i/278a776c-8906-5b0f-ae91-ba70c5027d05-Geosciences_Roadmap

Nussbaumer A, Meusburger K, Schmitt M, Waldner P, Gehrig R, Haeni M, Rigling A, Brunner I, Thimonier A (2021) Verfrühter Fruchtabwurf in Schweizer Buchenbeständen im Hitze- und Trockensommer 2018. Schweizerische Zeitschrift für Forstwesen 172(3):166–175. [10.3188/szf.2021.0166]

Wohlgemuth T, Kistler M, Aymon C, Hagedorn F, Gessler A, Gossner MM, et al. (2020) Früher Laubfall der Buche während der Sommertrockenheit 2018: Resistenz oder Schwächesymptom? Schweizerische Zeitschrift für Forstwesen 171(5):257–269

Zweifel R, Etzold S, Walthert L, Köchli R, Eugster W (2020) TreeNet – wann wachsen unsere Bäume? Wald und Holz 101(5):20–23.

Zweifel R, Ginzler C, Psomas A, Braun S, Walthert L, Etzold S (2020) Baumwasserdefizite erreichten im Sommer 2018 Höchstwerte – war das aus dem All erkennbar? Schweizerische Zeitschrift für Forstwesen / Journal forestier suisse 171(5):302–305. [10.3188/szf.2020.0298]

Outlook

Future developments of the ICP Forests infrastructure:

- as detailed above we plan to perform Level I assessments on a denser grid and will add drone-based measurements to crown condition assessments;
- prototypes of an online data portal for near real-time access to selected datasets;
- establishment of a phenocam network;
- deep machine learning, image analyses and remote sensing;
- repetition of Soil Survey on Level I plots in Switzerland in the period 2021-2025; and
- investigation of soil and tree water cycles on Level II plots in the frame of a PhD project.

Planned research projects, expected results:

- Post Doc project on remote sensing and image analysis;
- set-up of air heating and drought structures (roofs) on a part of various Level II plots;
- intensive seedling recruitment and survival studies on Level II plots; and
- intensive phenology studies (including soil biota seasonal activity timing) on selected Level II plots.

Turkey

National Focal Centre

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

Main activities/developments

We have participated in the ICP Forests monitoring network since 2006 in order to monitor the health of forests in our country. Level I and Level II programs were implemented on the monitoring plots.

As of 2020:

- Every year, on 599 Level I and 52 Level II monitoring plots the crown status and visual damage assessment is conducted and annual reports are 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 2021 and uploaded to the ICP Forests database.
- Needle-leaf samples were taken on 52 Level II monitoring plots in 2015, 2017, and 2019. Analyses are continuing and will be uploaded to the ICP Forests database in 2021.
- All measurements and production 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. The transfer of the obtained data to the ICP Forests database will be completed by June 2021.
- 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. Analysis of deposition, soil solution and litterfall, phenological observations and air quality sampling results will be uploaded to the ICP Forests database in 2021.
- The installation of an automatic meteorology monitoring station has been completed on 51 Level II monitoring plots and meteorological data has begun to be received. The results of the meteorological stations will be uploaded to the ICP Forests database in 2021.
- Each year, 52 Level II monitoring plots are 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 are completed. In 2018 and 2019, 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.
- On 607 Level I and 52 Level II monitoring plots, 67 species are monitored on 21 456 trees in total.
- Vegetation and biological studies were carried out on 52 Level II and 33 Level I monitoring plots. The data obtained were transferred to the database.
- Data will be transferred to the ICP Forests database in 2021.
- It is planned to obtain codes from the ICP Forests Programme Co-ordinating Centre only for the species found in our country.

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, 2018, and 2019.
  In 2018, ozone loss was observed on the monitoring plots numbered 8, 10, 12, 18, 29, 30, 51, 52, and 54.
  In 2019, ozone loss was observed on the monitoring plots numbered 8, 11, 12, 18, 29, 30, 51, and 52,
  In 2020, high ozone values between 100.99 µg/m^3 and 141.79 µg/m^3 were observed on the monitoring plots numbered 10, 11, 12, 17, 18, 23, 27, 28, 29, 50, and 54.
- On 599 Level I and 52 Level II monitoring plots, 67 species are monitored on 21 478 trees in total.
- 29 kinds of insects, fungi, viruses, etc. are monitored.
- Tables and figures of further results are available from the NFC Turkey or Programme Co-ordinating Centre of ICP Forests.

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

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

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

Monitoring Of Forest Ecosystems Crown Status Evaluation Photo Catalog. ÖZTÜRK S. National Focal Centre. ISBN: 978-605-393-038-9

Turkey Oaks Diagnosis and Diagnostic Guide. ÖZTÜRK S. 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

Turkey Maple Diagnosis And Diagnostic Guide. Sıtkı ÖZTÜRK. National Focal Centre. General Directorate of Forestry. Journal of Forestry Research 2019, Volume 1(4), ISBN: 978 -605-031-436-6

Outlook

Future developments of the ICP Forest infrastructure

- In 2015–2019, soil, litterfall, needle and leaf, deposition and soil solution working ringtests were entered and positive results were obtained. Analysis studies are continuing.

- The tillage ring test was passed successfully.
- Samples sent from monitoring plots in the laboratory:

  (a) 7 000 unstructured soil samples, 14 000 volume weight and skeleton analyses;

  (b) a total of 2 531 age-dry weight analyses of 325 needle-leaf samples and 2 206 debris samples were performed.

Planned research projects, expected results

- A health status report will be prepared in 2021 by using the results obtained.
- Since 2018, sampling studies for sedimentation, soil solution, litter sample and phenological observations have been started and samples have been taken.
- Since 2017, air quality sampling has been done by passive sampling method.
- Data from automatic meteorology observation stations established in Level II observation sites will be reported at the end of 2021.
- The data obtained as a result of the observations were transferred to the database and it is planned to make the transfer to the ICP Forests database in 2021.

United Kingdom

National Focal Centre

Suzanne Benham, Forest Research

Main activities/developments

The Level II plot network has been maintained during 2020 despite the considerable 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 assessments have been undertaken at all sites.

2020 was a year of weather extremes. It was the 3rd 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 unfavourable condition due to pests and diseases. Ash die back (*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 (OPM, *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 interest include Elm zig-zag 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 (AOD) 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 survey (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 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 characterise 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 initiatives.
- As part of the Action Oak initiative, 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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United Nations Economic Commission for Europe (UNECE)
Convention on Long-range Transboundary Air Pollution (Air Convention)

International Co-operative Programme on Assessment and Monitoring
of Air Pollution Effects on Forests (ICP Forests)

ICP FORESTS
http://icp-forests.net

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