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Forest Condition in Europe
2015 Technical Report of ICP Forests

Report under the UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP)

Alexa Michel & Walter Seidling (Eds.)

LRTAP
Long-range Transboundary Air Pollution

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

BFW
Bundesforschungszentrum für Wald

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SUMMARY

This **2015 Technical Report** provides descriptive statistics of the ICP Forests 2014 large-scale (Level I) and 2013 intensive (Level II) forest monitoring in up to 24 of the 42 ICP Forests member states. It also includes numerical results and national reports of the 2014 national crown condition survey in 25 member states. Data analyses for this report focus on tree crown condition and tree damage causes in 2014 including trend analyses, relationships between defoliation of different forest tree species and modelled nitrogen deposition, changes in ground level ozone concentrations and exposures from 2000 to 2013, and the spatial variation of deposition across Europe in 2013. The report contains information on the 3rd ICP Forests Scientific Conference in Athens in May 2014 and lists all 33 projects and 36 scientific publications in 2014 for which ICP Forests data and/or the ICP Forests infrastructure were used. For additional maps, tables, and figures, please refer to the extensive annex at the end of this report.

The assessment of **tree crown condition** has been a core feature of the ICP Forests monitoring for 30 years. It is based on the concept that tree crowns are reflecting overall tree health and may therefore provide an early warning signal. This is the first Technical Report presenting temporal changes in tree defoliation without bias caused by the different number of plots from year to year. Only plots with temporarily consistent data were included and a median-based method robust against outliers was used (Mann-Kendall tau and Sen's slope estimates).

In 2014, the crown condition of 104 994 sample trees on 5 611 transnational Level I plots in 24 participating countries was assessed. The overall mean defoliation of all trees was 21.5%. Broadleaved trees showed a slightly higher mean defoliation than coniferous trees (22.8% vs. 20.3%). Of the main tree species and tree species groups, deciduous temperate oaks (*Quercus petraea* and *Q. robur*) and evergreen oaks (*Quercus coccifera*, *Q. ilex*, *Q. rotundifolia*, and *Q. suber*) had the highest mean defoliation (25.2% and 24.7%, respectively) as well as the highest proportion of severely damaged trees and dead trees. The lowest defoliation was found in Scots pine and in Mediterranean lowland pines (*Pinus brutia*, *P. halepensis*, *P. pinaster*, and *P. pinea*) with a mean of 20.7% and 20.8%, respectively. Between 1992 and 2014, defoliation of most species and species groups has slightly to moderately increased; only for Scots pine and Norway spruce no or only a slight statistically significant over-all change was found. Some increases in defoliation can be linked to direct factors like drought periods, thereby emphasizing the value of the combined assessment of defoliation and damaging agents.

The **causes of tree damage** were assessed on 97 293 trees on 5 400 plots in 22 countries. On 40.2% of the trees symptoms of damage of at least one defined agent group were recorded. Insects were the predominant cause of damage and had caused more than a quarter of all recorded damage symptoms (28.0%). Almost half of these insect-caused symptoms were attributed to defoliators (46.7%), which represented also the most frequent of all damage causes. The second major cause of tree damage was abiotic agents (15.5% of all damage symptoms). Within this agent group, half of the symptoms were attributed to drought (50.5%), while wind and frost had caused considerably less damage (8.5% and 4.5%, respectively). Fungi (including canker) were the third major causal agent (11.6%).

The **relationships between defoliation of four forest tree species and nitrogen deposition** modelled by the EMEP MSC-W chemical transport model are described including the interaction effects of stand age and country. It was found that defoliation reveals considerable dynamics from year to year with a varying predictor structure. These species-specific dynamics cause temporally unstable results in correlation-, regression-, and other statistical approaches. Only in the case of strong predictors like stand age in Norway spruce – and less distinct in other species – comparatively constant relationships were found. More subtle effects like those caused by long-term nitrogen inputs seem to be obscured by other influences.

Tropospheric ozone (O_3) concentrations from passive samplers have been monitored according to harmonized methodologies on ICP Forests intensive monitoring (Level II) sites since the year 2000 with the aim to (i) quantify ozone concentrations during the vegetation period (April-September), (ii) estimate the related ozone exposures of forest ecosystems, and (iii) detect temporal and spatial trends across Europe.

Season mean ozone concentrations ranged from 19 to 64 ppb with similar deviations from the median among the countries. A decreasing south-north gradient across Europe is apparent with the highest concentrations having been measured in Italy, southern Switzerland, the Czech Republic, Slovakia, and Greece. Mean AOT40 for 2000-2013 ranged from 2 to 67 ppm h. The AOT40 threshold of 5 ppm h set to protect forests from adverse ozone effects was exceeded in 18 out of 20 countries. An overall trend analyses, including all April–September data from 20 countries, revealed a significant decrease of 0.35 ppb ozone per year ($n = 29\ 356$; $p = 0.000$) from 2000 to 2013. When considering only sites with a data coverage of at least 4 years and 120 days (66%) between 1 April and 30 September, site-specific trend analyses did not reveal any uniform patterns across Europe.

The measurement of **atmospheric deposition** is one of the core activities of ICP Forests and it aims to quantify and qualify the acidifying, buffering, and eutrophying compounds deposited to forests. It is thus an important source of knowledge about the amount and type of anthropogenic and naturally emitted substances relevant for plants after they have been transported over more or less long distances by air. In this report, the spatial variation of deposition in Europe in 2013 is described for NH_4-N, NO_3-N, SO_4-S, Ca, and Mg. Maps for the input of calcium and magnesium are depicted with and without sea salt corrections.

- Central Europe is characterised by the highest **NH_4-N** deposition fluxes with fewer occurrences of high fluxes on plots in Spain, Belgium, Hungary, Romania, and northern Italy. The highest input with 17.6 kg N ha^{-1} a^{-1} was found on a spruce plot located in southern Germany. Very low deposition below 1 kg N ha^{-1} a^{-1} was mainly found in northern Europe but also in a few other regions.

- In general, the spatial pattern of **NO_3-N** deposition fluxes is similar to that of NH_4-N. The lowest deposition was found in northern Europe, with all plots in Finland below 1 kg N ha^{-1} a^{-1}. Deposition fluxes higher than 20 kg N ha^{-1} a^{-1} only occurred on Spanish plots with a maximum of 20.9 kg N ha-^{1} a^{-1}.

- High deposition of **SO_4-S** was observed on plots in Belgium and the ridges of the low mountain range extending from Germany to the Czech Republic. High values were also found on plots in Hungary, Spain, and Greece. The plot with the highest value of non-sea salt corrected sulphur (26.7 kg S ha^{-1} a^{-1}) was located in Spain, whereas sea salt corrected sulphur was highest on a plot in the Czech Republic (25.8 kg S ha^{-1} a^{-1}). The plots in France, Italy, Switzerland, and most of the plots in Germany and northern Europe had low deposition values. After sea salt correction, all plots in northern Europe and the United Kingdom were in the lowest range.

- The highest values of **calcium** input were found on plots in the Mediterranean basin and in regions of Eastern Europe. Plots with more than 30 kg Ca ha^{-1} a^{-1} were located in Cyprus, Greece, and Spain; the highest value being 64.2 kg Ca ha^{-1} a^{-1}. Very low calcium inputs below 2 kg Ca ha^{-1} a^{-1} prevailed in most of northern Europe. On those plots, sea salt corrections had only little effect.

- The deposition of **magnesium** is clearly seaborne. Without sea salt correction, plots within the highest range were distributed across all countries. Plots with fluxes higher than 10 kg Mg ha^{-1} a^{-1} were only located in Spain with a maximum value of 18.5 kg Mg ha^{-1} a^{-1}. After sea salt correction only 6% of all plots were in the highest range, none of them in northern Europe.

CONTENTS

1 INTRODUCTION

Alexa Michel, Walter Seidling

This year the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) celebrates its **30th Anniversary** and we wish to thank all members and friends of the Programme for 30 successful years of establishing a unique transnational monitoring network in which 42 countries have agreed to closely co-operate in combatting air pollution and its effects on forests. An Anniversary Report including the history and impacts of ICP Forests on policy and people will be published in addition to this report.

ICP Forests is constantly moving forward. The **most important recent activities of ICP Forests** include further developments in the domain of the data unit, reporting activities, and collaborations.

- 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. Recent developments of the data unit include the online availability of ICP Forests literature-, project-, and expert-databases[1], which provide a quick overview on scientific outcomes, activities, and experts of the Programme.

- ICP Forests has contributed to the joint report on trends of measured and modelled air pollutants and environmental responses to their reductions, a report which is being collaboratively prepared by **several International Co-operative Programmes (ICPs) and a Task Force** under the Working Group on Effects (WGE) and the European Monitoring and Evaluation Programme (EMEP) of the LRTAP Convention.

- One of the major goals of the LRTAP Convention is to co-operate more closely with countries outside of Europe, especially from **Eastern Europe, the Caucasus region, and Central Asia (EECCA)**. ICP Forests is well underway in this respect with four EECCA countries (Belarus, Moldova, the Russian Federation, Ukraine) already being members of ICP Forests and the Programme Co-ordinating Centre being currently in contact with two more.

The **2015 Technical Report of ICP Forests** can be downloaded from the ICP Forests website[2]. Please send comments and suggestions to PCC-ICPForests@ti.bund.de; we highly appreciate your feedback. For contact information of the authors of this report, please refer to ANNEX IV-4.

Participants of the field trip to the Gulf of Corinth during the 3rd Scientific Conference and 30th Task Force Meeting of ICP Forests, Greece.

[1] http://icp-forests.net/page/project-list; …/expertlist; …/scientific-publications
[2] http://icp-forests.net/page/icp-forests-technical-report

2 THE MONITORING SYSTEM OF ICP FORESTS

Walter Seidling, Alexa Michel

2.1 Background

In the late 1960s, large-scale acidification of surface waters in Scandinavia could clearly be connected to air pollution originating in the United Kingdom and central Europe. This ultimately led to a ministerial-level meeting in Geneva in November 1979 within the Framework of the UNECE on the Protection of the Environment, where the Convention on Long-range Transboundary Air Pollution (CLRTAP) was signed by more than 30 governments, including the USA and Canada, and by the European Community. The significance of this decision to collaborate under the LRTAP Convention can hardly be overrated as it was the first legally binding international agreement with the aim to jointly control acid rain across the UNECE region. (Menz and Seip 2004)

Shortly after the LRTAP Convention came into force in 1983, six International Co-operative Programmes (ICPs) and a Task Force were established under the Working Group on Effects (WGE) to study the effects of air pollution on a wide range of eco- and geosystems (i.e. ICP Forests, ICP Integrated Monitoring, ICP Modelling and Mapping, ICP Vegetation, ICP Waters), on technical materials (ICP Materials), and on human health (Task Force on Health). Together with the European Monitoring and Evaluation Programme (EMEP) which focuses on the emission and dispersal of air pollutants, a comprehensive system to trace adverse air-transported substances from the source to the sink had hence become available.

The International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) was established in 1985 under the UNECE Convention on Long-range Transboundary Air Pollution (CLRTAP) in response to wide public and political concern about the extensive forest damage observed in central Europe in the 1970s and 1980s. With the collection and compilation of data on the condition of forest ecosystems across the UNECE region, ICP Forests has not only consistently been addressing the scientific information needs of CLRTAP and the UNECE, thereby underpinning the advancement of air pollution abatement measures in Europe. But for the last 30 years it has provided quantitative policy-relevant information on monitored and modelled air pollution effects on forests that can be used by a variety of other national and international forest and environmental bodies and programmes besides CLRTAP, such as Forest Europe (FE, formerly the Ministerial Conference for Protection of Forests in Europe – MCPFE), the Convention on Biological Diversity (CBD), the Framework Convention on Climate Change (UNFCCC), the UN-FAO Forest Resources Assessment (FRA), and EUROSTAT of the EU. (ICP Forests 2006)

ICP Forests has defined two major aims as stated in its latest Strategy of ICP Forests 2007-2015 (ICP Forests 2006) that are still relevant today:

- Aim I: To provide a periodic overview of the spatial and temporal variation of forest condition in relation to anthropogenic and natural stress factors (in particular air pollution) by means of European-wide and national large-scale representative monitoring on a systematic network (Level I).
- Aim II: To gain a better understanding of cause-effect relationships between the condition of forest ecosystems and anthropogenic as well as natural stress factors (in particular air pollution) by means of intensive monitoring on a number of selected permanent observation plots spread over Europe and to study the development of important forest ecosystems in Europe (Level II).

An outstanding feature of both levels of the ICP Forests monitoring is the implementation of harmonized methods and additional measures for quality control and assurance in every member state and survey. The transnational harmonisation of methods has led to consistent sampling practices across Europe and makes ICP Forests unique in global forest monitoring efforts. All methods are clearly described in an extensive manual (ICP Forests 2010), which has been developed over the years and is presented by Ferretti & Fischer (2013) together with the respective scientific background of each of the surveys. ICP Forests also differs from other ICPs within the LRTAP Convention for its establishment of eight different expert panels with the aim to further develop the monitoring methods and standards of each survey (Table 2-1).

Table 2-1. Surveys at each monitoring intensity level.

Survey	Level I	Level II (standard)	Level II (core)
Air quality			continuously
Crown condition	annually	annually	annually
Deposition		continuously	continuously
Foliar chemistry	every 10 years	every 2 years	every 2 years
Ground vegetation diversity		every 5 years	every 5 years
Ground vegetation biomass			x
Litterfall			continuously
LAI			several times / year
Meteorology		continuously	continuously
Ozone			continuously
Soil condition	every 10 years	every 10 years	every 10 years
Soil solution			continuously
Soil water			annually
Tree growth		every 5 years	annually
Tree phenology			several times / year

At present, 42 countries are cooperating in ICP Forests. Of those, 27 are EU-Member States so that all EU countries except Malta are participating in the Programme. Of the 15 non-EU countries, nine are countries from Southeast Europe (SEE) or from Eastern Europe, the Caucasus, and Central Asia (EECCA). ICP Forests is further actively promoting membership across the wider UNECE region which is one of the major objectives of the LRTAP Convention at present.

2.2 The large-scale forest monitoring (Level I)

The large-scale monitoring (Level I) is an annual transnational survey to study the geographic and temporal variations in forest condition according to the guidelines stated in the ICP Forests Manual. It consists of more than 7 500 plots on a 16 x 16 km transnational grid across Europe (for an overview on Level I plots active in 2014, cf. Figure 2-1). The selection of plots lies in the responsibility of the member states and the overall density in each state is aimed at one plot per 256 km^2 forested area. For detailed information on the survey design, please refer to the ICP Forests Manual (ICP Forests 2010).

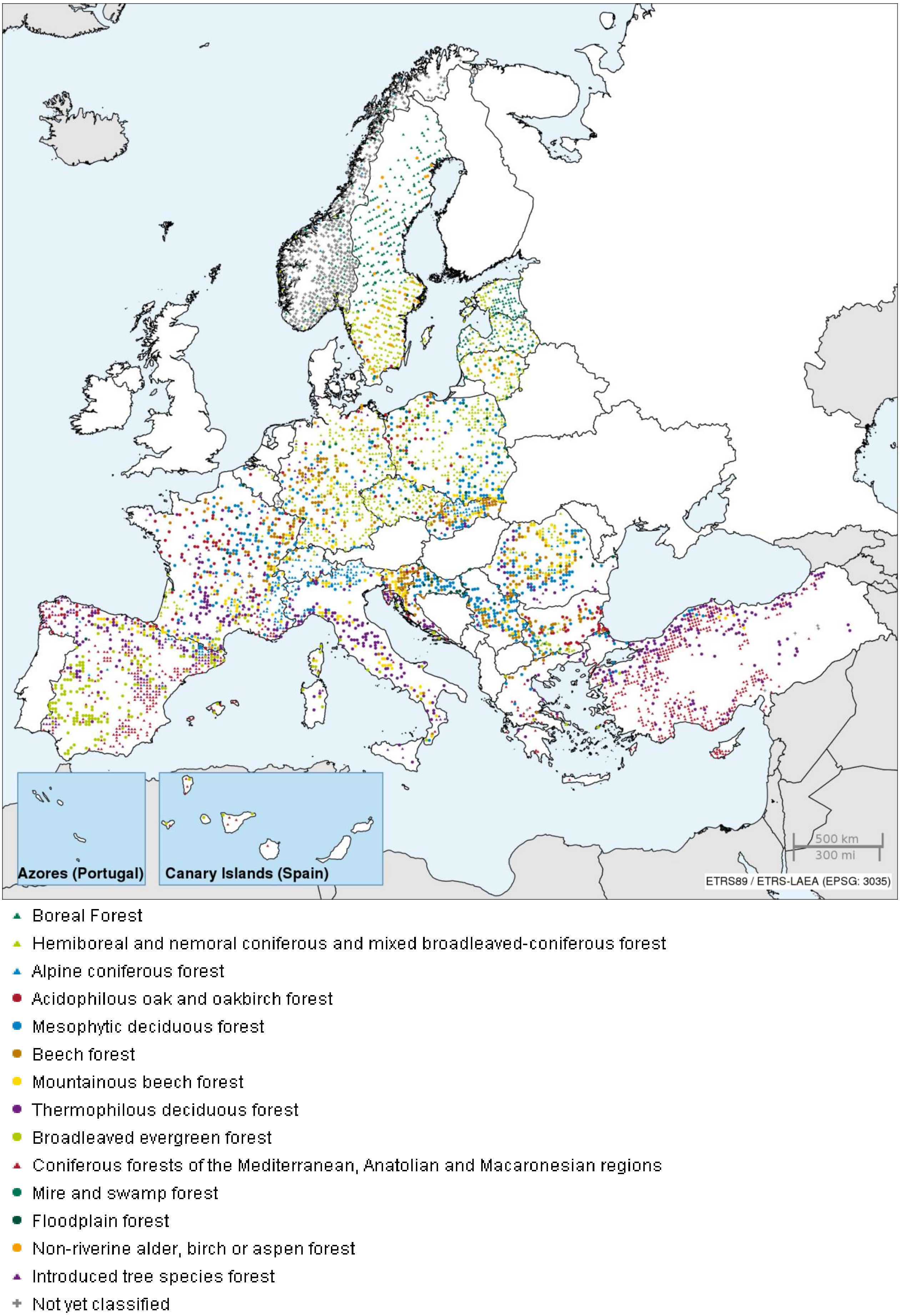

Figure 2-1. Level I plots classified according to European Forest Types (EFT).

Figure 2-2. Level II plots between 2006 and 2010, when external funding was still temporarily available, compared to 2013.

Although at first the aim of ICP Forests had been primarily to collect and evaluate data on the impact of air pollution on forest trees, the need for more ecosystem-oriented approaches became soon apparent. Thus, in the early 1990s annual assessments of crown condition on Level I were complemented by large-scale data on soil condition and on the nutritional status of foliage as a basis for more integrated evaluations (De Vries et al. 2000, Stefan et al. 1997, Vanmechelen et al. 1997). Since then a second survey on Level I plots on soil condition (De Vos & Cools 2011) and one on ground vegetation have been conducted within the BioSoil project under the Forest Focus Regulation (EC) No. 2152/2003.

In recent years some of the member states have moved their Level I plots from their original position to locations that are consistent with plots of their National Forest Inventories (NFI) or they select an annually varying subsample of plots. In these cases annual assessments are no longer performed on the same plots and this can cause constraints in time series and longitudinal analyses because of interruptions in the continuity of crown condition data series. The information drawn from the NFI surveys may, however, foster more biomass-oriented approaches instead (cf. Kovač et al. 2014).

2.3 The intensive forest ecosystem monitoring (Level II)

In addition to the large-scale Level I monitoring, the Programme for Intensive and Continuous Monitoring of Forest Ecosystems (Level II) was established in 1994 to study the interactions between crown condition, increment, and chemical composition of foliage and soils on additional permanent observation plots (De Vries et al. 2003). The overall aim of the Level II monitoring is to better understand specific cause and effect relationships in forest ecosystems, including the assessment of tree condition, soil condition, carbon sequestration, climate change, and biodiversity.

Each country selects its Level II plots for ecological and logistic reasons, the relevance of a specific forest ecosystem within a country, and the value of data series and their continuation. Figure 2-2 shows all plots on which Level II surveys were conducted in 2013 in comparison with the Level II plots assessed between 2006 and 2010 when external funding was temporarily still available.

2.4 References

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3 TREE CROWN CONDITION AND DAMAGE CAUSES

Walter Seidling, Serina Trotzer, Tanja Sanders, Volkmar Timmermann, Nenad Potočić, Alexa Michel

3.1 Tree crown condition and damage causes – Introduction

The assessment of tree crown condition has been a core feature of the ICP Forests monitoring for 30 years. It is an annual assessment within both the systematic Level I monitoring and the intensive Level II monitoring. It is based on the concept that tree crowns are reflecting overall tree health and may thus predict the ability of trees to survive and grow (Tkacz et al. 2013). Furthermore, tree crowns can easily and non-destructively be assessed by optical means from the ground.

Defoliation, the estimated difference of foliage in the assessed tree compared to a fully-foliated reference tree, is used as one early warning indicator for tree health together with e.g. symptoms of biotic as well as abiotic damage occurrences (Schomaker et al. 2007). The parameter 'defoliation' developed historically due to the observed lack of foliage on trees in the 1980s connected to high atmospheric deposition. At the same time the discoloration of leaves and needles was assessed. Today the assessment of crown defoliation in combination with damage cause assessments is widely applied to evaluate the condition of forest trees.

Regarding deposition, the high exchange surface with the atmosphere makes the foliage of trees susceptible for harmful gases (sulphur dioxide, ozone). Corresponding damage has been reported since the 19th century and can still be observed when the foliage of trees is exposed to high concentrations of noxious gases or aerosols, leading to both dead leaves or needles or different degrees of discoloration (Figure 3-1), depending on the severity (concentration in combination with duration) of the impact.

Figure 3-1. Crown (foliar) damage of spruce trees due to high concentration of SO_2 as a result of a chemical plant accident near Lenzing/Austria (photo by: DI Johann Reisenberger, 18 April 2012).

3.2 Tree crown condition – Materials and methods

The assessment of crown condition is conducted according to the methods described in the ICP Forests Manual by Eichhorn et al. (2010, see also Eichhorn et al. 2013). On each sampling plot, sample trees are selected according to the ICP Forests Manual and assessed for the amount of foliage missing compared to a reference tree, in the following referred to as defoliation. Besides defoliation and damaging agents, additional parameters are annually assessed providing information for the analysis of the crown condition data (Table 3-1). All data are checked for consistency by the participating countries and submitted online to the Programme Co-ordinating Centre (PCC) of ICP Forests.

Table 3-1. Tree, stand, and site parameters provided in the crown condition database.

Registry and location	Country	Member state in which the plot is assessed [code]
	Plot number	Identification of each plot
	Plot coordinates	Latitude and longitude [degrees, minutes, seconds]
	Date	Day, month, and year of observation
Physiography	Altitude [m a.s.l.]	Elevation above sea level, in 50 m steps
	Aspect [°]	Aspect at the plot, direction of strongest decrease of altitude in eight classes (N, E, … , NW) and 'flat'
Soil	Water availability	Three classes: insufficient, sufficient, excessive water availability to main tree species
	Humus type	Mull, moder, mor, anmor, peat or other
Stand related data	Forest type	14 forest categories according to EEA (2007)
	Mean age of dominant storey	Classified age, class size 20 years; class 1: 0–20 years,…., class7: 121–140 years, class 8: irregular stands
Additional tree related data	Tree number	Tree ID, allows the identification of each particular tree over all observation years
	Tree species	Species of the observed tree [code]

Certain criteria were defined prior to data analysis. Only plots with a minimum number of three trees per plot were analysed. For analyses at species level, three trees per species had to be present. These criteria are consistent with earlier evaluations (e.g. Wellbrock et al. 2014, Becher et al. 2014) and explain the discrepancy between the number of trees in Table 3-3 and ANNEX II.

The annual transnational tree crown condition survey in 2014 was conducted on 5 611 plots in 24 countries (Table 3-2). In total, 104 994 trees were assessed in the field for crown condition (Table 3-3). Both the number of plots and the number of trees may vary in the course of time between countries due to e.g. mortality or changes in the sampling design.

Table 3-2. Number of plots assessed for crown condition from 2004 to 2014 in countries with at least one Level I crown condition survey since 2004 according to the current database.

Country	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Andorra	3		3	3	3	3	3	3	3	11	11
Austria	136	136	135				135				
Belarus	406	403	398	400	400	409	410	416		373	
Belgium	29	29	27	27	26	26	9	9	8	8	8
Bulgaria	103	102	97	104	98	159	159	159	159	159	159
Croatia	84	85	88	83	84	83	83	92	100	105	103
Cyprus	15	15	15	15	15	15	15	15	15	15	15
Czech Republic	140	138	136	132	136	133	132	136	135		138
Denmark	20	22	22	19	19	16	17	18	18	18	
Estonia	92	92	92	93	92	92	97	98	97	96	96
Finland	594	605	606	593	475	886	932	717	785		
France	511	509	498	504	508	500	532	544	553	550	545
Germany	451	451	423	420	423	412	411	404	415	417	422
Greece		87				97	98				57
Hungary	73	73	73	72	72	73	71	72	74	68	
Ireland	19	18	21	30	31	32	29		20		
Italy	255	238	251	238	236	252	253	253	245	247	244
Latvia	95	92	93	93	92	207	207	203	203	115	116
Lithuania	63	62	62	62	70	72	75	77	77	79	81
Luxembourg	4	4	4	4	4					4	4
Montenegro							49	49	49	49	
Netherlands	11	11	11			11	11				
Norway	442	460	463	476	481	487	491	496	496	618	687
Poland	433	432	376	458	453	376	374	367	369	364	365
Portugal	139	125	124								
Romania	226	229	228	218		227	239	242	241	236	241
Russian Fed.						365	288	295			
Serbia	130	129	127	125	123	122	121	119	121	121	128
Slovakia	108	108	107	107	108	108	108	109	108	108	107
Slovenia	42	44	45	44	44	44	44	44	44	44	44
Spain	620	620	620	620	620	620	620	620	620	620	620
Sweden	775	784	790			857	830	640	609	740	842
Switzerland	48	48	48	48	48	48	48	47	47	47	47
Turkey				43	396	560	554	563	578	583	531
United Kingdom	85	84	82	32			76				
TOTAL	**6 152**	**6 235**	**6 065**	**5 063**	**5 057**	**7 292**	**7 521**	**6 807**	**6 189**	**5 795**	**5 611**

Table 3-3. Number of sample trees assessed for crown condition from 2004 to 2014 in countries with at least one Level I crown condition survey since 2004 according to the current database.

Country	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Andorra	72		74	72	72	73	72	72	72	264	264
Austria	3 586	3 528	3 425				3 087				
Belarus	9 682	9 484	9 373	9 424	9 438	9 615	9 617	9 583		8 709	
Belgium	681	676	618	616	599	599	216	230	207	206	194
Bulgaria	3 629	3 592	3 510	3 569	3 304	5 560	5 569	5 583	5 608	5 517	5 439
Croatia	2 009	2 046	2 109	2 013	2 015	1 991	1 992	2 208	2 400	2 520	2 472
Cyprus	360	361	360	360	360	362	360	360	360	360	361
Czech Republic	3 500	3 450	3 425	3 300	3 400	3 325	3 300	3 400	3 375		3 450
Denmark	480	528	527	442	452	384	408	432	411	420	
Estonia	2 201	2 167	2 191	2 209	2 196	2 202	2 348	2 372	2 348	2 329	2 329
Finland	11 210	11 528	11 489	11 199	8 812	7 182	7 946	4 217	4 676		
France	10 219	10 129	9 950	10 074	10 138	9 949	10 584	11 111	11 268	11 199	11 056
Germany	13 741	13 630	10 327	10 241	10 347	10 088	10 063	9 635	9 917	10 335	10 426
Greece		2 054				2 289	2 311				1 345
Hungary	1 710	1 662	1 674	1 650	1 662	1 668	1 626	1 702	1 655	1 519	
Ireland	400	382	445	646	679	717	641		489		
Italy	7 109	6 548	6 936	6 636	6 579	6 794	8 338	8 454	5 507	5 610	5 503
Latvia	2 290	2 263	2 242	2 228	2 184	3 911	3 888	3 797	4 172	1 746	1 746
Lithuania	1 487	1 512	1 505	1 507	1 688	1 734	1 814	1 846	1 847	1 907	1 956
Luxembourg	96	97	96	96	96					96	96
Montenegro							1 176	1 176	1 176	1 176	
Netherlands	232	232	230			247	227				
Norway	5 014	5 319	5 525	5 824	6 085	6 014	6 330	6 463	6 542	4 977	5 520
Poland	8 660	8 640	7 520	9 160	9 036	7 520	7 482	7 342	7 404	7 300	7 304
Portugal	4 170	3 749	3 719								
Romania	5 424	5 496	5 472	5 232		5 448	5 736	5 808	5 784	5 656	5 782
Russian Fed.						11 016	8 958	9 275			
Serbia	2 915	2 995	2 902	2 860	2 788	2 751	2 786	2 742	2 782	2 789	2 922
Slovakia	5 058	5 033	4 808	4 904	4 956	4 944	4 831	5 218	4 888	4 769	4 639
Slovenia	1 006	1 056	1 069	1 056	1 056	1 056	1 052	1 057	1 053	1 061	1 055
Spain	14 880	14 880	14 880	14 880	14 880	14 880	14 880	14 880	14 880	14 880	14 880
Sweden	11 255	11 422	11 186			2 591	2 742	2 057	1 991	2 188	2 775
Switzerland	748	807	812	790	773	801	795	1 105	1 122	1 047	1 048
Turkey				941	9 291	13 156	12 974	13 282	13 603	13 667	12 432
United Kingdom	2 040	2 016	1 968	768			1 803				
TOTAL	**135 864**	**137 282**	**130 367**	**112 697**	**112 886**	**138 867**	**145 952**	**135 407**	**115 537**	**112 247**	**104 994**

In 2014, 45.4% of the plots were dominated by broadleaved and 54.5% by coniferous trees (Figure 3-2). This distribution illustrates the natural predominance of coniferous species in boreal and mountainous regions as well as the preference of forest management for coniferous species outside their natural distributions.

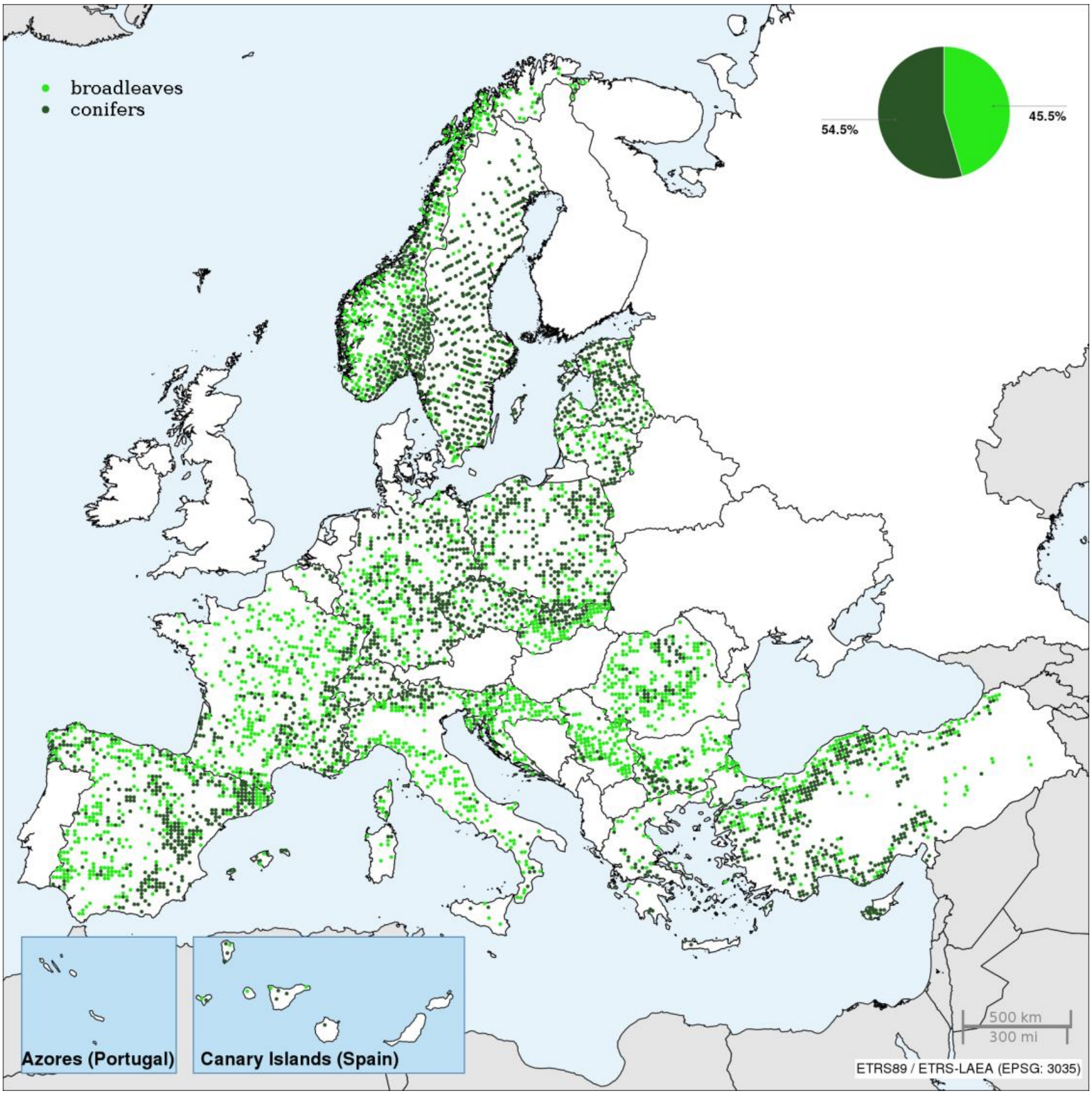


Figure 3-2. Distribution of Level I plots assessed in 2014 across the ICP Forests region and according to prevailing tree classification (broadleaves vs. conifers).

On all assessed Level I plots, *Pinus sylvestris* (17.2%) represented the most abundant tree species followed by *Picea abies* (12.6%), *Fagus sylvatica* (10.7%), *Pinus nigra* (5.0%), *Quercus petraea* (4.1%), *Q. robur* (3.9%), *Q. ilex* (3.8%), *Q. cerris* (2.9%), and *Pinus brutia* (2.9%). Some tree species belonging to the *Pinus* and *Quercus* genus were combined into species groups before further analysis:

- 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*).

Shares of the main species and species groups are visualized in Figure 3-3.

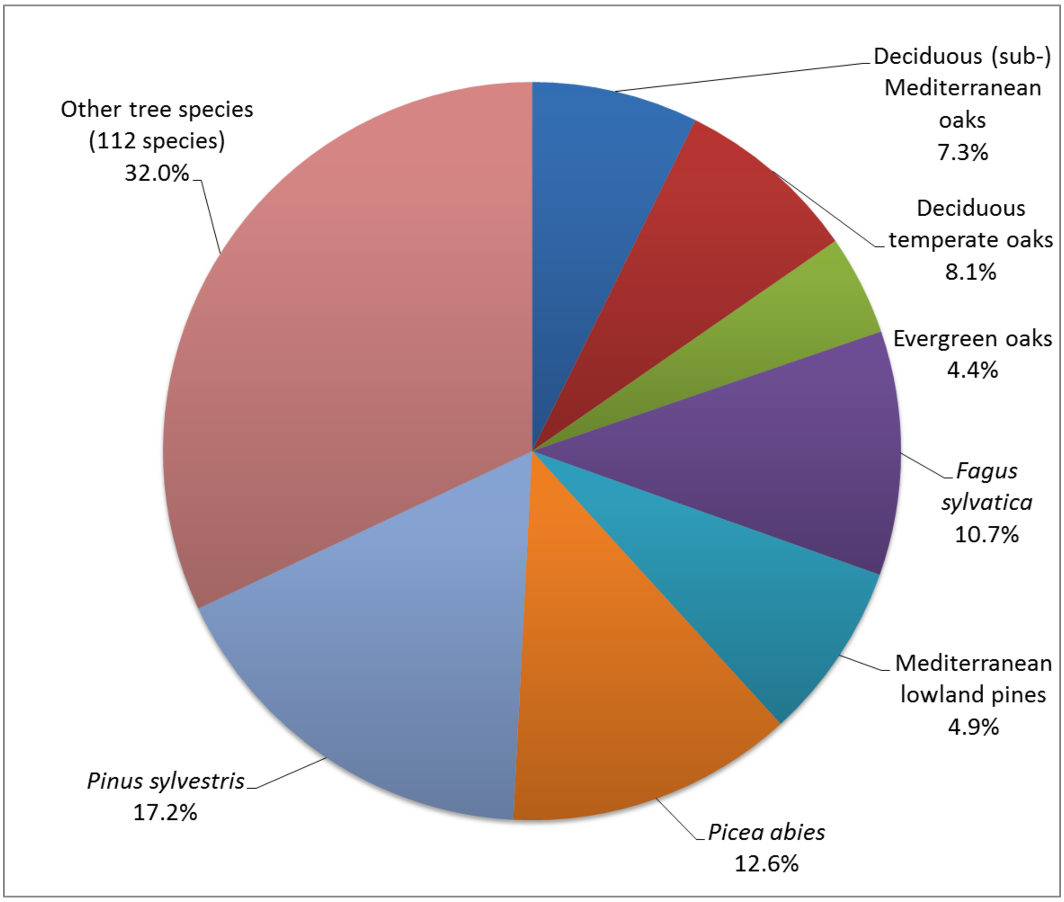


Figure 3-3. Percentage of trees with defoliation assessment in 2014 according to their listed tree species or species group.

In general, the assessed Level I plots contained one (42.2%) or up to three (44.5%) tree species per plot (Figure 3-4). Only 2.3% of all assessed Level I plots featured more than five tree species per plot, most of those were located in Italy, Slovenia, parts of France, Germany, and Lithuania.

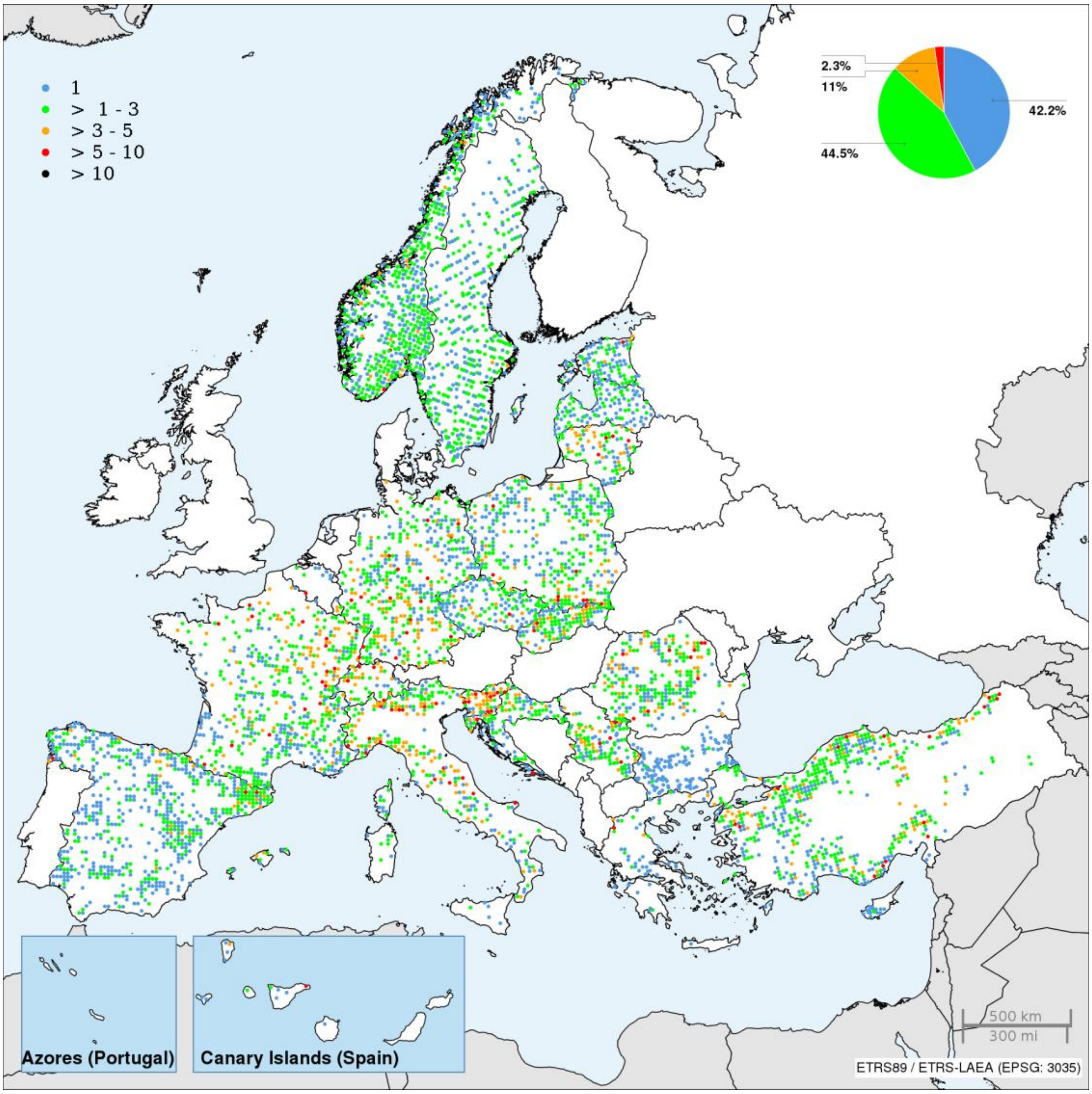


Figure 3-4. Number of tree species assessed on Level I plots in 2014.

Defoliation is a key parameter within forest monitoring describing a deficit 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). A totally defoliated tree which is still alive is coded with 99%. Defoliation values are grouped into five classes (Table 3-4). In the maps presenting the mean plot defoliation later in this chapter, class 2 is divided (> 25-40% and > 40–60%) in order to achieve a more proportional graduation of defoliation classes.

Table 3-4. 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

Trends in defoliation over time presented in this chapter 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 and they are robust against outliers (Sen 1968, Drápela & Drápelová 2011, Curtis & Simpson 2014). Therefore, trends are not influenced by individual outliers into one direction but are rather stable depicting the median of the slopes. 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 2014) in the R version 3.1.3 (R Core Team 2015) was used.

The maps with the over-all trend and yearly over-all mean defoliation display plot-related Sen's slopes, each singularly tested by Mann-Kendall's tau at a significance level of $p \leq 0.05$. All Sen's slope calculations were based on consistent plot selections. Plots were included when data were available over the years 1992–2014 with a minimum assessment length of 20 years or, for mapping purposes, over the years 2002–2014 with a minimum assessment length of 10 years. For that reason some plots or countries could not be included in the long-term time series analyses. For additional maps on the trends in defoliation over the years 2006–2014 with a minimum assessment length of 5 years, please refer to ANNEX I. Statistical analyses were performed with R version 3.1.3 (R Core Team 2015; Mann-Kendall test and Sen's slope) and SAS 9.4 (SAS Institute Inc. 2015).

3.3 Tree crown condition – Results

For a total of 100 176 trees defoliation values were included in the 2014 evaluations (Table 3-5). The overall mean defoliation was 21.5%; means ranged between 20.7% and 25.2% for the major species and species groups. Broadleaved trees showed a slightly higher mean defoliation than coniferous trees (22.8% vs. 20.3%). Correspondingly, conifers had a higher frequency of trees in the defoliation classes 'none' or 'slight' (79.2%) than broadleaves (72.7%).

Considering tree species and tree species groups, deciduous temperate oaks and evergreen oaks displayed the highest mean defoliation (25.2% and 24.7%, respectively) as well as the highest proportion of severely damaged trees (2.5% and 2.6%, respectively) and dead trees (1.2% and 1.1%, respectively). Scots pine and Mediterranean lowland pines had the lowest mean defoliation (20.7% and 20.8%, respectively). Among all major species and species groups, deciduous temperate oaks had the lowest share (64.5%) while Mediterranean lowland pines had the highest share (84.4%) of not or only slightly defoliated trees (≤ 25% defoliation).

Table 3-5. Percentage of trees in defoliation classes (cf. Table 3-4) and their mean defoliation rates for the main species or species groups.

Main species or species group	Percentage of trees in defoliation classes						Mean defo-liation	No. of trees
	Class 0 0–10%	Class 1 > 10–25%	Class 2 > 25–40%	Class 2 > 40–60%	Class 3 > 60%	Class 4 Dead		
Common beech (*F. sylvatica*)	34.3	38.4	18.9	5.7	2.0	0.7	21.3	10 969
Deciduous temperate oaks	20.7	43.8	24.8	7.0	2.5	1.2	25.2	8 372
Decid. (sub-)Mediterran. oaks	29.3	46.6	15.6	5.3	2.5	0.8	21.8	7 486
Evergreen oaks	8.5	66.3	16.0	5.5	2.6	1.1	24.7	4 595
Other broadleaves	34.2	40.6	13.9	5.5	3.8	1.9	22.5	16 708
Scot pine (*Pinus sylvestris*)	26.6	53.2	14.3	3.6	1.4	0.9	20.7	17 909
Norway spruce (*Picea abies*)	36.0	36.6	19.4	4.9	1.6	1.5	21.0	12 855
Mediterranean lowland pines	19.1	65.3	10.1	3.3	1.2	1.0	20.8	8 154
Other conifers	40.4	41.4	12.1	3.6	1.9	0.6	18.6	13 128
TOTAL								
Broadleaves	28.7	44.0	17.4	5.8	2.9	1.3	22.8	48 130
Conifers	31.2	48.0	14.3	3.9	1.5	1.0	20.3	52 046
All species	**30.0**	**46.1**	**15.8**	**4.8**	**2.1**	**1.1**	**21.5**	**100 176**

At plot level a similar pattern of mean defoliation was found than at the species-level (Figure 3-5). The highest proportion of plots displayed 'no' or 'slight' defoliation (54.9%), whereas only 0.7% of the plots had a mean plot defoliation of more than 60%. High mean plot defoliation was particularly clustered in central and southern Europe, and explicitly in southern and south-eastern France, northern Italy, the Czech Republic, Slovakia, and central Germany. Plots with a low mean defoliation were found in clusters across almost all of Europe, but mainly in south-eastern Norway, southern Sweden, Romania and Serbia as well as in Turkey and the north-western part of Germany.

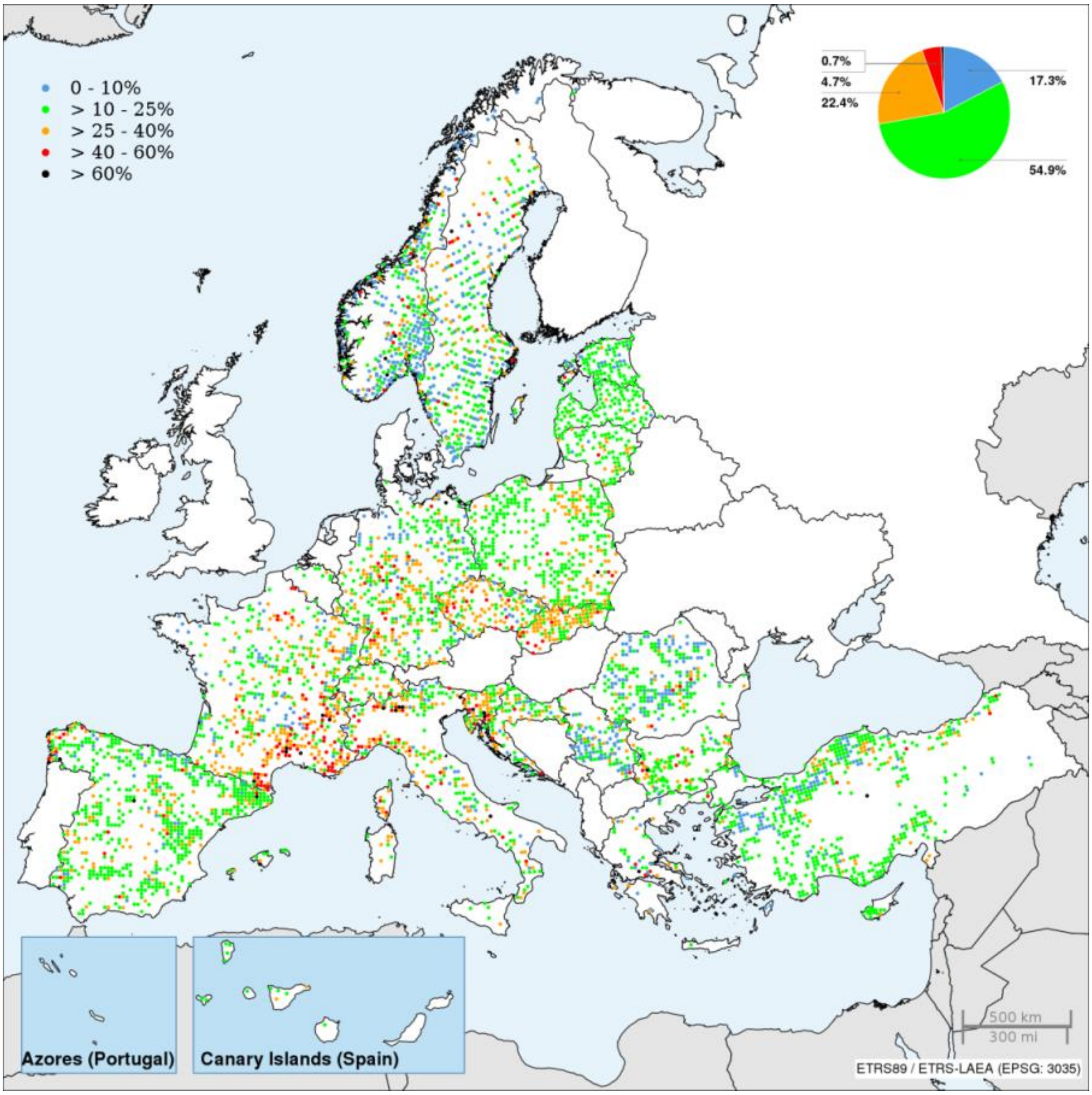


Figure 3-5. Mean plot defoliation of all species in 2014.

The following sections describe the species-specific mean plot defoliation in 2014, the over-all trend and yearly mean plot defoliation from 1992 to 2014, and significant changes of the trend in mean plot defoliation for the period 2002–2014. For additional maps of all tree species combined and of selected species and species groups for the period 2006–2014, please refer to ANNEX I.

Scots pine

Scots pine (*Pinus sylvestris*) has been the most frequently assessed tree species in Europe. It covers a wide ecological range due to its ability to grow on nutrient poor soils and has been frequently used for reforestations. It 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 2014, Scots pine displayed the lowest mean defoliation (20.7%) of all main species and species groups (Table 3-5). Trees in nearly four out of five Scots pine plots (79.7%) showed no or only slight mean defoliation (≤ 25% defoliation) (Figure 3-6). Defoliation on 20.2% of the plots was classified as moderate (>25-60% defoliation) and on 0.1% of the plots as severe. Scots pine, thus, had the lowest proportion of severely defoliated trees of all species or species groups considered in this chapter. Trees with no defoliation were primarily found in southern Norway whereas trees with comparably high defoliation were clustered in the Czech Republic, Slovakia, south-eastern France and Bulgaria.

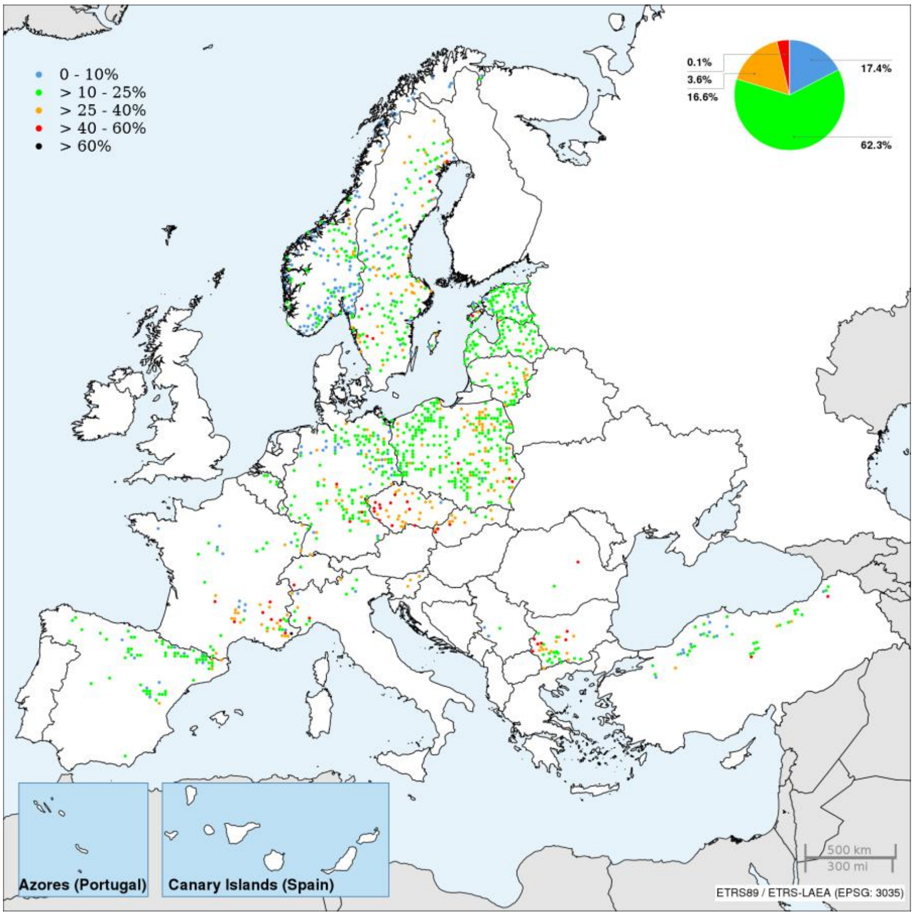


Figure 3-6. Mean plot defoliation of Scots pine (*Pinus sylvestris*) in 2014.

From 1992 to 2014, there was no over-all trend in mean plot defoliation of Scots pine (regional Sen's slope = 0, $p > 0.05$; Figure 3-7). The annual over-all mean defoliation hardly fluctuated over time although relative to the long-term mean a pronounced over-all mean value below average in 2000 and one above average in 2014 was observed.

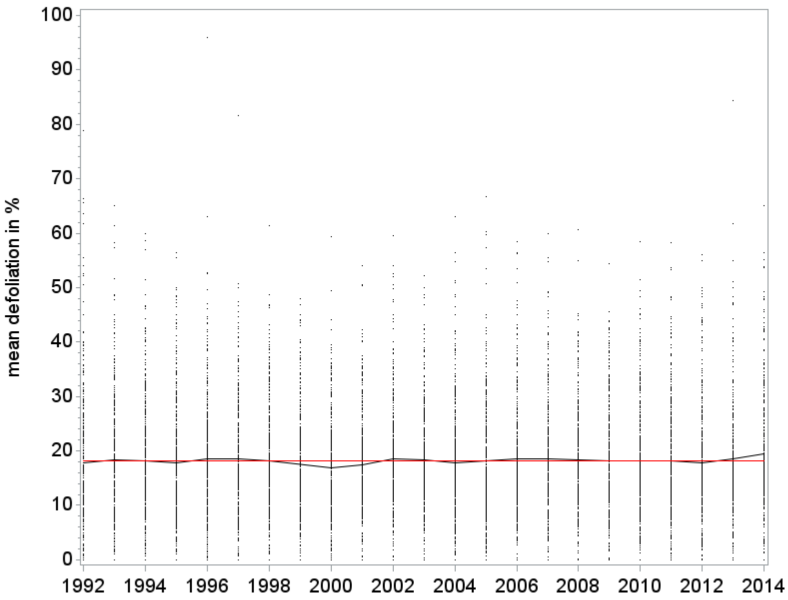


Figure 3-7. Over-all trend (regional Sen's slope = 0.0, p > 0.05; minimum length of time span: 20 years, red line) and yearly over-all mean defoliation (black line) of Scots pine at Level I sites; points represent annual plot means, for clarity these are not interconnected from year to year.

The map in Figure 3-8 displays changes in the trend in mean plot defoliation from 2002 to 2014. The share of Scots pine plots with significantly increasing defoliation (4.6%) was slightly lower than the share with significantly decreasing defoliation (6.5%). However, 88.9% of the plots showed no statistically significant change in mean plot defoliation between the years 2002 and 2014. Plots with increasing mean plot defoliation were clustered in Lithuania and Bulgaria but otherwise scattered individually across Europe.

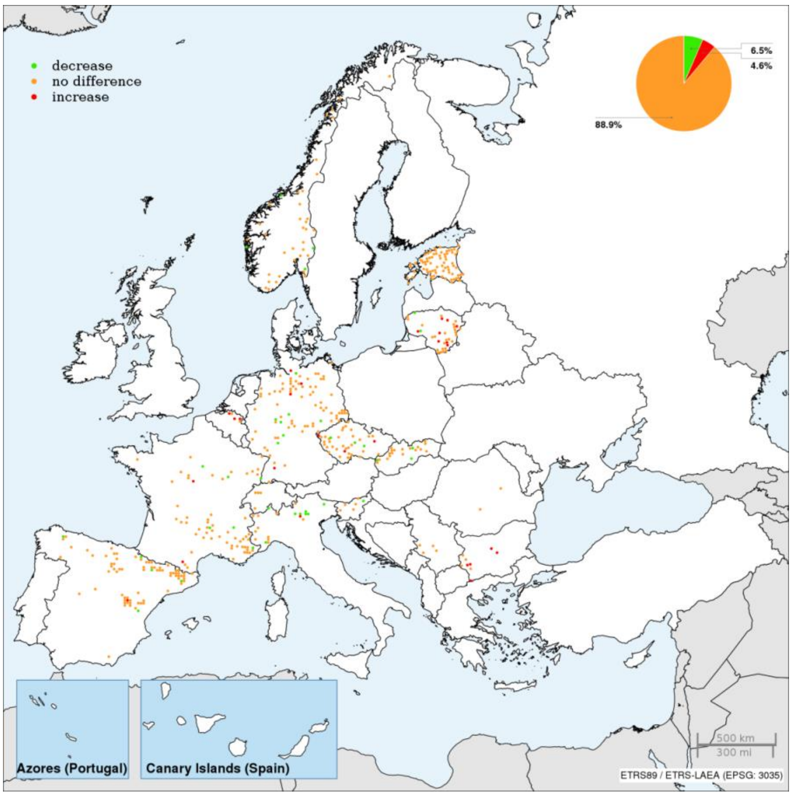


Figure 3-8. Trends in mean plot defoliation (Mann-Kendall test) of Scots pine between 2002 and 2014 with a minimum assessment length of 10 years.

Norway spruce

Norway spruce (*Picea abies*) is the second most frequently observed species on the Level I plots. The area of its distribution ranges from Scandinavia to northern Italy and from north-eastern Spain to Romania. Favouring cold and humid climate, Norway spruce is found at the southern edge of its distribution area only at higher elevations.

In 2014, trees in more than two-thirds of the Norway spruce plots (68.8%) were on average not or only slightly defoliated (≤ 25% defoliation; Figure 3-9). Plots with particularly low mean defoliation were clustered e.g. in Norway, eastern France, and Romania. Clusters of plots with mean defoliation values above 25% were mainly found in Slovakia, in the mountainous regions of the Czech Republic, in the Black Forest and other mountainous regions in Germany, in central and western parts of Slovenia, in the French Alps, and more scattered, in Norway and Sweden.

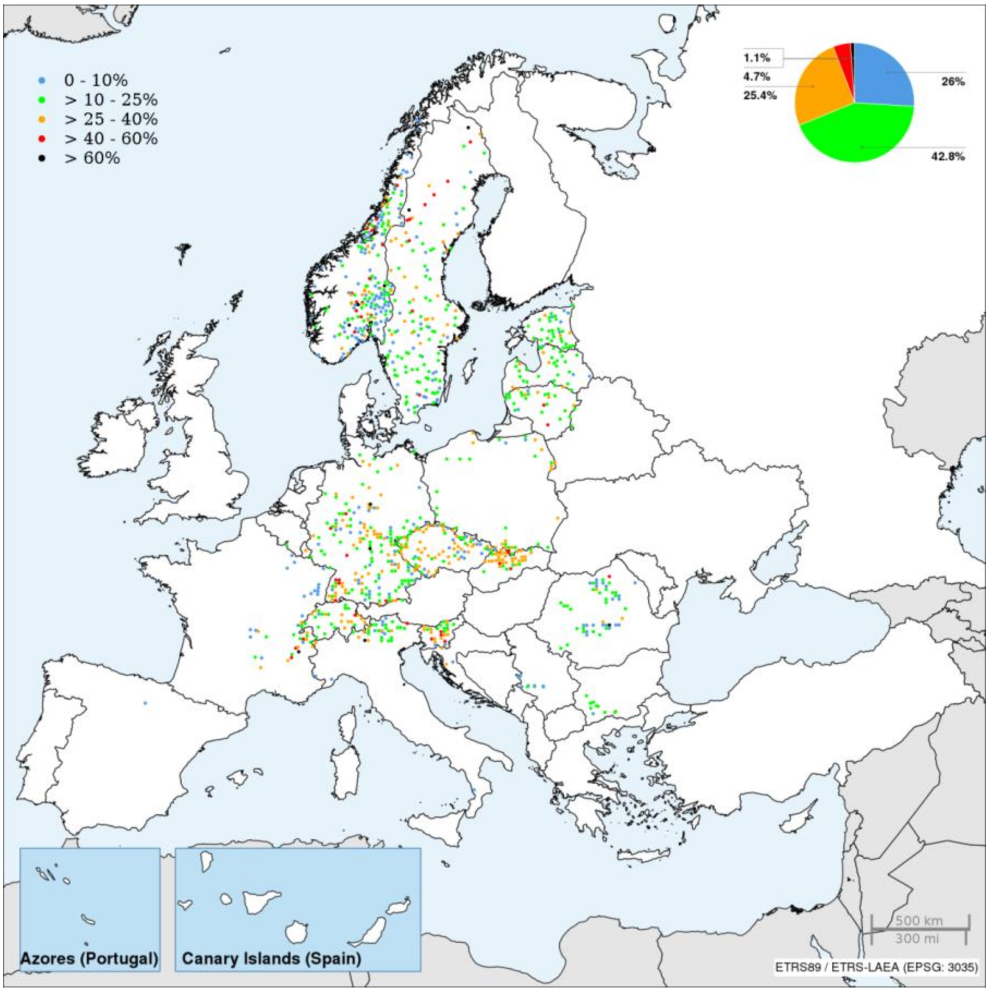


Figure 3-9. Mean plot defoliation of Norway spruce (*Picea abies*) in 2014.

From 1992 to 2014, a very slight but statistically significant increasing trend in mean plot defoliation of less than 1 percentage point every 10 years was observed (regional Sen's slope = 0.08 , p = 0.001; Figure 3-10). Deviations in the yearly mean plot defoliation of more than 2 percentage points from the trend line were determined only for the years 2013 and 2014.

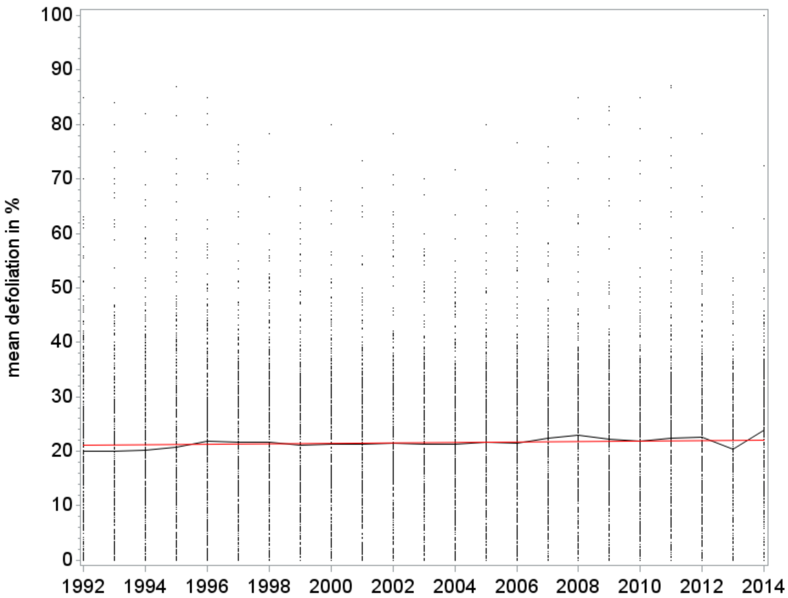


Figure 3-10. Over-all trend (regional Sen's slope = 0.081, p <0.001; minimum length of time span: 20 years, red line) and yearly over-all mean defoliation (black line) of Norway spruce at Level I sites; points represent annual plot means, for clarity these are not interconnected from year to year.

From 2002 to 2014, mean plot defoliation in twice as many Norway spruce plots had significantly decreased than increased (14.7% and 6.0%, respectively; Figure 3-11). For the majority of plots (79.3%), however, no statistically significant change was determined for the investigated time span.

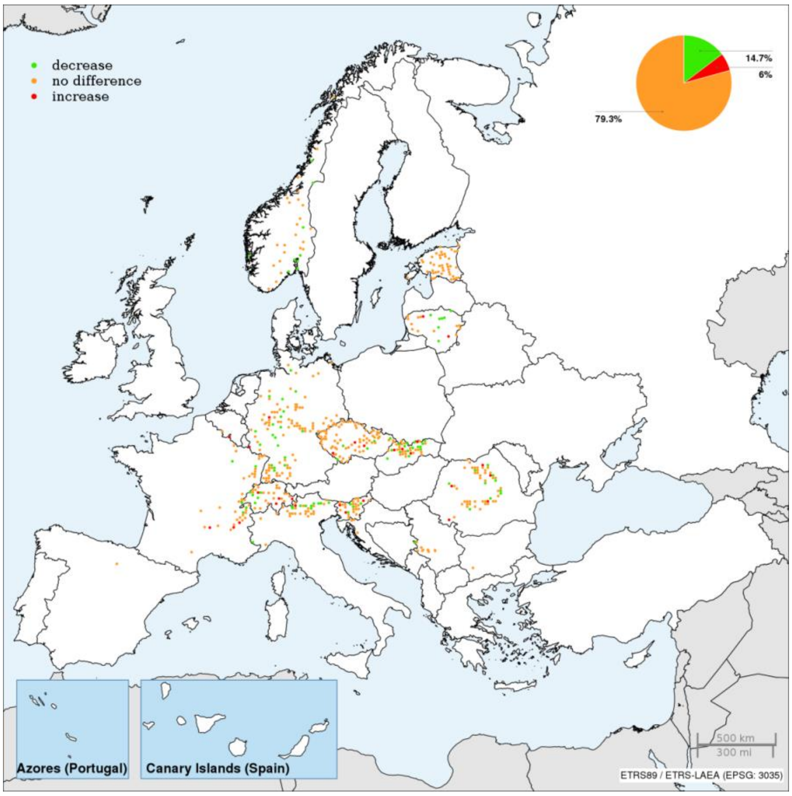


Figure 3-11. Trends in mean plot defoliation (Mann-Kendall test) of Norway spruce between 2002 and 2014 with a minimum assessment length of 10 years.

Mediterranean lowland pines

Four pine species were included in the group of Mediterranean lowland pines: Allepo pine (*Pinus halepensis*), maritime pine (*P. pinaster*), stone pine (*P. pinea*), and Turkish pine (*P. brutia*). These species occur in the Mediterranean region with warm and dry summers and mild and wet winters. Most plots dominated by Mediterranean lowland pines are located in Spain, some near the Atlantic and Mediterranean coasts in France, very few in Italy, Croatia, and Greece and again more in the lowlands of Turkey and Cyprus. At the species level, Allepo and maritime pine are more abundant in the western part as is Turkish pine in the eastern part of this area.

In 2014, trees in nearly four out of five plots with Mediterranean lowland pines (79.5%) were on average not or only slightly defoliated (Figure 3-12). Plots with higher mean defoliation values (>25% defoliation) were concentrated in south-eastern France but have also been found in other parts of the distribution area.

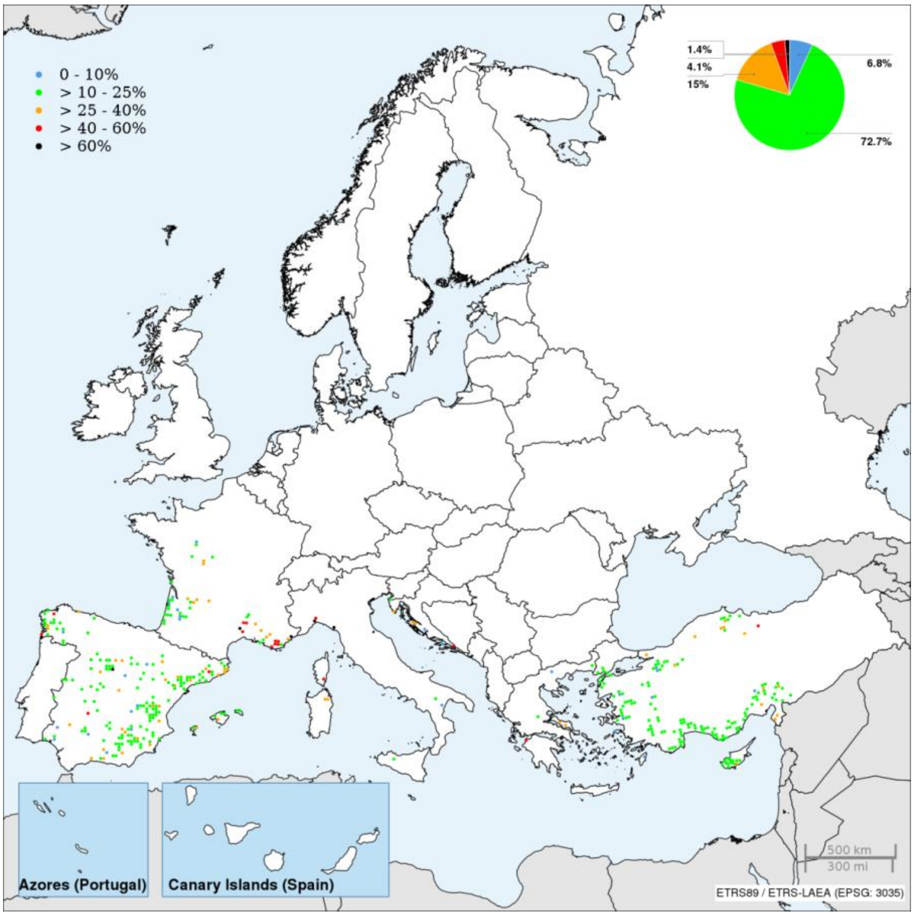


Figure 3-12. Mean plot defoliation of Mediterranean lowland pines (*Pinus halepensis*, *P. pinaster*, *P. pinea, P. brutia*) in 2014.

From 1992 to 2014, there was a distinct and highly significant increase in the trend in mean plot defoliation of 3 percentage points every 10 years (regional Sen's slope = 0.3, $p < 0.001$; Figure 3-13). In the years 1992 and 1993, the yearly over-all mean plot defoliation was distinctly lower than the long-term trend. In contrast, from 2003 to 2007 there was a period with values higher than the trend with a maximum deviation of approximately 3 percentage points in annual mean plot defoliation in 2005. All other deviations from the long-term trend were shorter in their temporal extent or smaller in quantity. In the last three years, there was no apparent deviation from the generally increasing over-all trend.

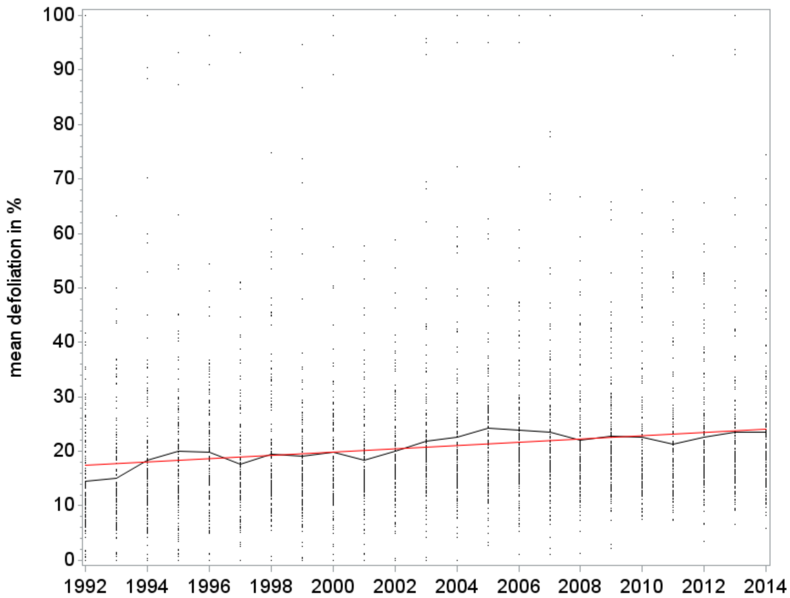


Figure 3-13. Over-all trend (regional Sen's slope = 0.3, p < 0.001; minimum length of time span: 20 years , red line) and yearly over-all mean defoliation (black line) of Mediterranean lowland pines (*Pinus halepensis*, *P. pinaster*, *P. pinea, P. brutia*) at Level I sites; points represent annual plot means, for clarity these are not interconnected from year to year.

While there was a significant increasing over-all trend in mean plot defoliation from 1992 to 2014 (Figure 3-13), mean plot defoliation was significantly changing only on a few individual plots from 2002 to 2014 (Figure 3-14). The steady increase in mean plot defoliation between the years 2001 and 2005 still seems to dominate the long-term trend. Since that period, mean plot defoliation has declined or at least stagnated as represented by a lack of a trend on 92.6% of the plots between 2002 and 2014.

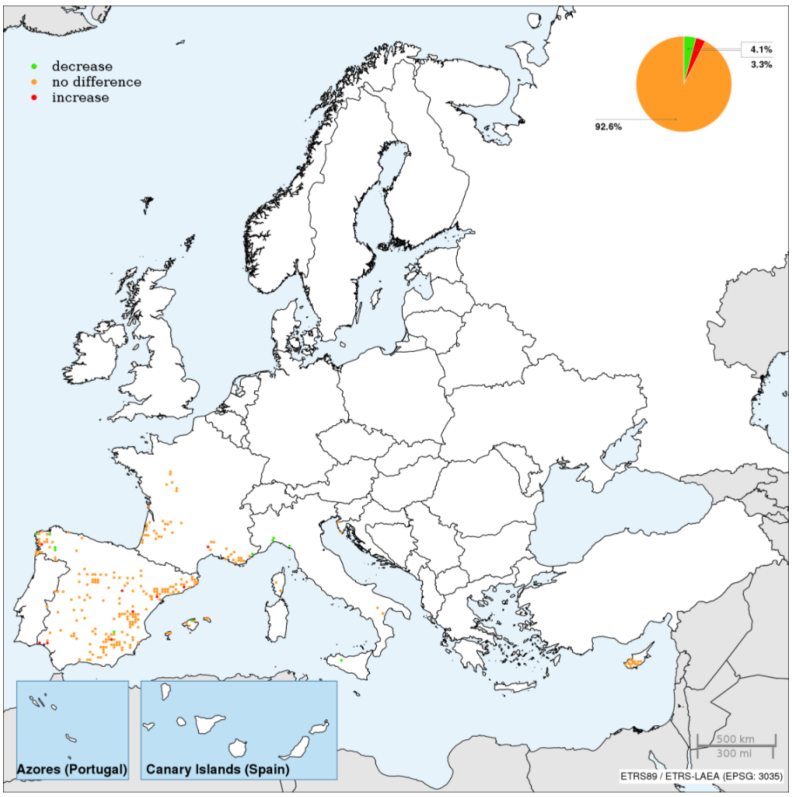


Figure 3-14. Trends in mean plot defoliation (Mann-Kendall test) of Mediterranean lowland pines (*Pinus brutia*, *P. halepensis*, *P. pinaster*, *P. pinea*) between 2002 and 2014 with a minimum assessment length of 10 years.

Common beech

Common beech (*Fagus sylvatica*) is the most frequently observed deciduous tree species within the ICP Forests monitoring programme. It is found on Level I plots from southern Scandinavia to southern Italy and from the northern coast of Spain to Bulgaria.

In 2014, common beech showed the largest percentage of plots with less than 10% mean plot defoliation of all the considered tree species and species groups (18.3%), and these plots were primarily located in Romania (Figure 3-15). On almost half of the monitored plots (46.8%), trees were on average only slightly defoliated so that on nearly two thirds of all beech plots defoliation was either absent or low (≤ 25% defoliation). Clusters of plots with moderate to severe mean defoliation values were located in Germany, Slovakia and southern France but were small in their spatial extent.

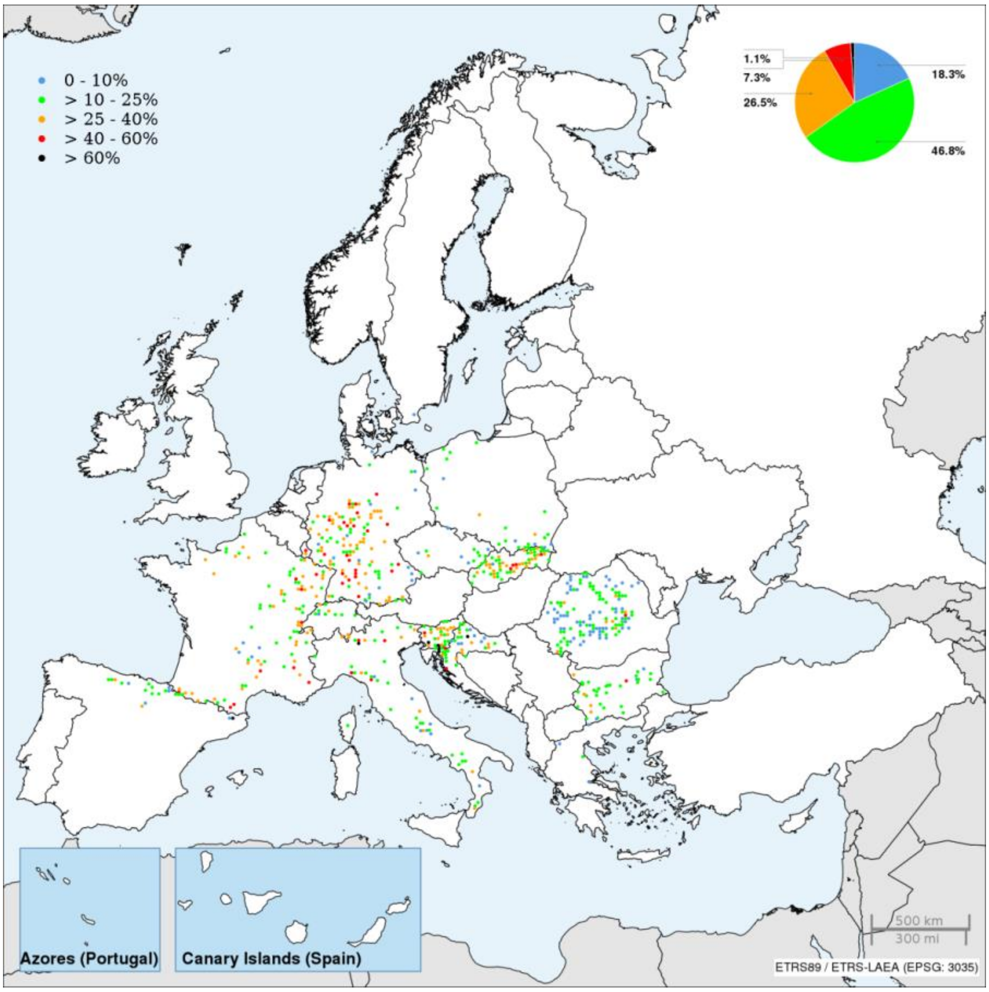


Figure 3-15. Mean plot defoliation of common beech (*Fagus sylvatica*) in 2014.

From 1992 to 2014, the over-all trend in mean plot defoliation in beech has been slightly increasing by approximately 2 percentage points every 10 years (regional Sen's slope = 0.2, $p < 0.001$; Figure 3-16). There were only few deviations from this trend. In 2014, for example, the annual over-all mean defoliation was more than 4 percentage points higher than the trend, possibly as a result of the drought in the preceding year which had affected large parts of Europe (Ciais et al. 2005, Seidling 2007). In 2011 another yet smaller peak is evident which may have been caused by a heat wave in Eastern Europe occurring in 2010. In years like 1993 or 2010 on the other hand, trees seemed to have been recovering as indicated by a negative deviation from the over-all trend.

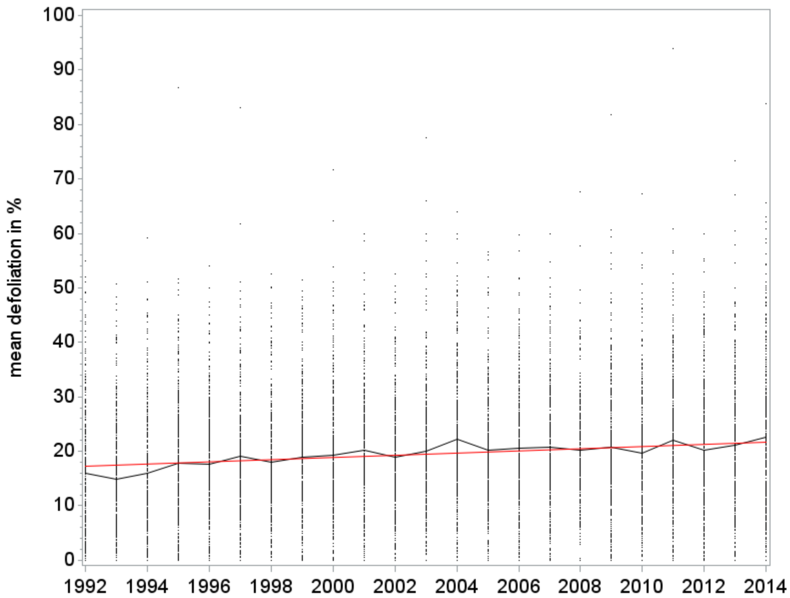


Figure 3-16. Over-all trend (regional Sen's slope = 0.2, p < 0.001; minimum length of time span: 20 years , red line) and yearly over-all mean defoliation (black line) of *Fagus sylvatica* at Level I sites; points represent annual plot means, for clarity these are not interconnected from year to year.

From 2002 to 2014, the increase in mean plot defoliation is statistically significant in 14.7% of the beech plots (Figure 3-17). No respective core area in geographical terms, however, can be identified. The same is true for plots on which trees had developed significantly denser crowns during the investigated time span (8.6%).

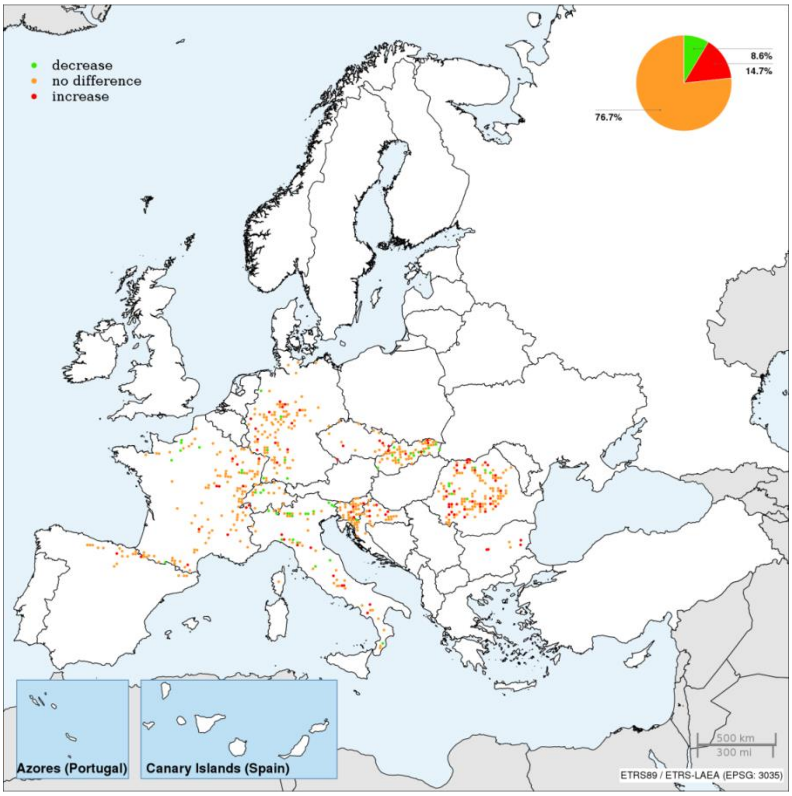


Figure 3-17. Trends in mean plot defoliation (Mann-Kendall test) of common beech between 2002 and 2014 with a minimum assessment length of 10 years.

Deciduous temperate oaks

Deciduous temperate oaks include *Quercus robur*, *Q. petraea* and their hybrids. They cover a large geographical area from southern Scandinavia to southern Italy and from the northern coast of Spain to the eastern part of Turkey.

In 2014, deciduous temperate oaks were on average not or only slightly defoliated (≤ 25% defoliation) in more than half of the plots (54.4%), moderately defoliated (>25–60% defoliation) in just less than half of the plots (44.9%) and severely defoliated (i.e. more than 60% defoliation) in 0.7% of the plots (Figure 3-18).

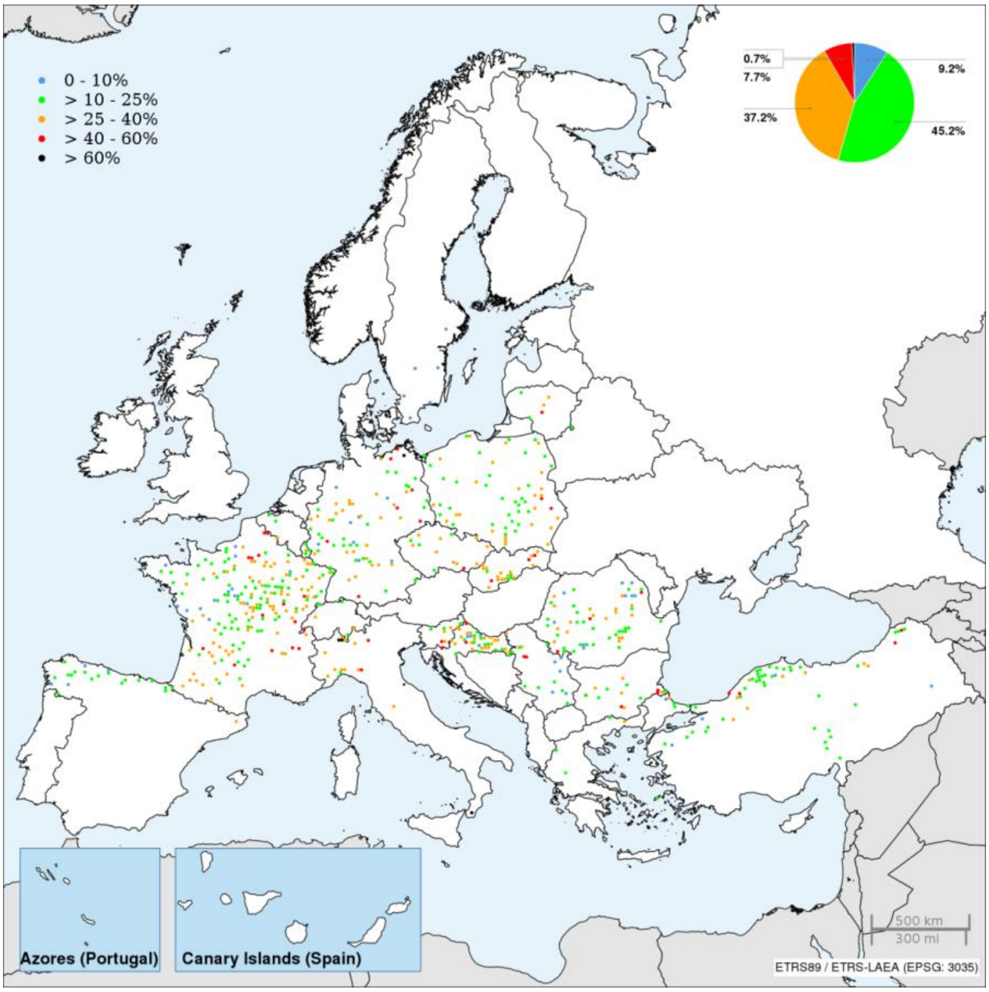


Figure 3-18. Mean plot defoliation of deciduous temperate oaks (*Quercus robur* and *Q. petraea*) in 2014.

Together with deciduous (sub-) Mediterranean oaks, deciduous temperate oaks showed the strongest increase of the over-all trend in mean plot defoliation from 1992 to 2014 with an increase of 0.333 percentage points per year (Figure 3-19). This means that over the last 23 years, over-all mean plot defoliation in this species group has increased by 3.3 percentage points every 10 years. In contrast to the trend line, the actual development, however, has not been linear. Between 1992 and 1997 there was a steeper than average increase in defoliation and from 2005 onwards a stagnation at a comparatively high level took place. Apart from these long-term dynamics, short-term developments can also be identified with a peak around 1997 and a second peak between 2003 and 2005. The latter can be connected with the drought year 2003 and its medium-term consequences for trees (delayed recovery).

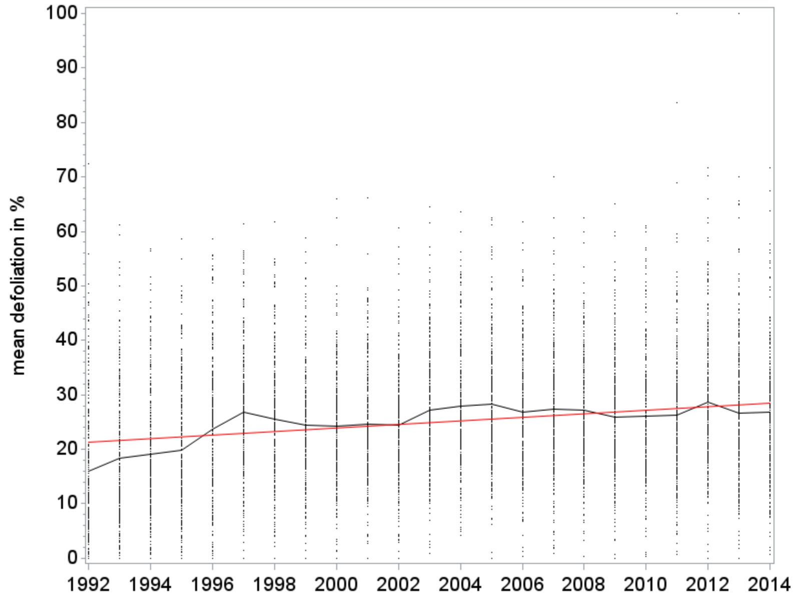


Figure 3-19. Over-all trend (regional Sen's slope = 0.333, p < 0.001; minimum length of time span: 20 years , red line) and yearly over-all mean defoliation (black line) of deciduous temperate oaks (*Quercus robur* and *Q. petraea*) at Level I sites; points represent annual plot means, for clarity these are not interconnected from year to year.

From 2002 to 2014, increasing and decreasing plot-related trends in mean defoliation were found for a similar number of plots (10% and 11.1%, respectively), while on almost 80% of the plots no statistically significant changes occurred during the investigated time span (Figure 3-20).

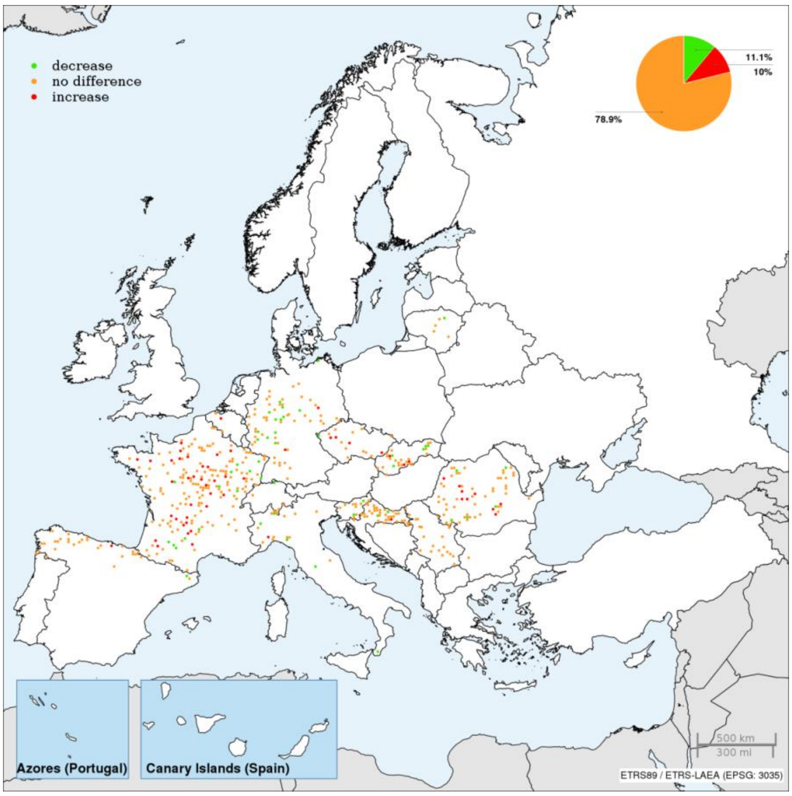


Figure 3-20. Trends in mean plot defoliation (Mann-Kendall test) of deciduous temperate oaks (*Quercus robur* and *Q. petraea*) between 2002 and 2014 with a minimum assessment length of 10 years.

Deciduous (sub-) Mediterranean oaks

The group of deciduous (sub-) Mediterranean oaks includes *Quercus cerris*, *Q. frainetto*, *Q. pubescens* and *Q. pyrenaica*. The range of distribution of these oaks is confined to southern Europe.

In 2014, trees in two thirds (66.6%) of the plots dominated by deciduous (sub-) Mediterranean oaks were on average not or only slightly defoliated (≤ 25% defoliation; Figure 3-21). These plots were spread all over the area of these oaks' distributions. Only 8.2% of the plots had a mean defoliation higher than 40% and those were largely clustered in southern France.

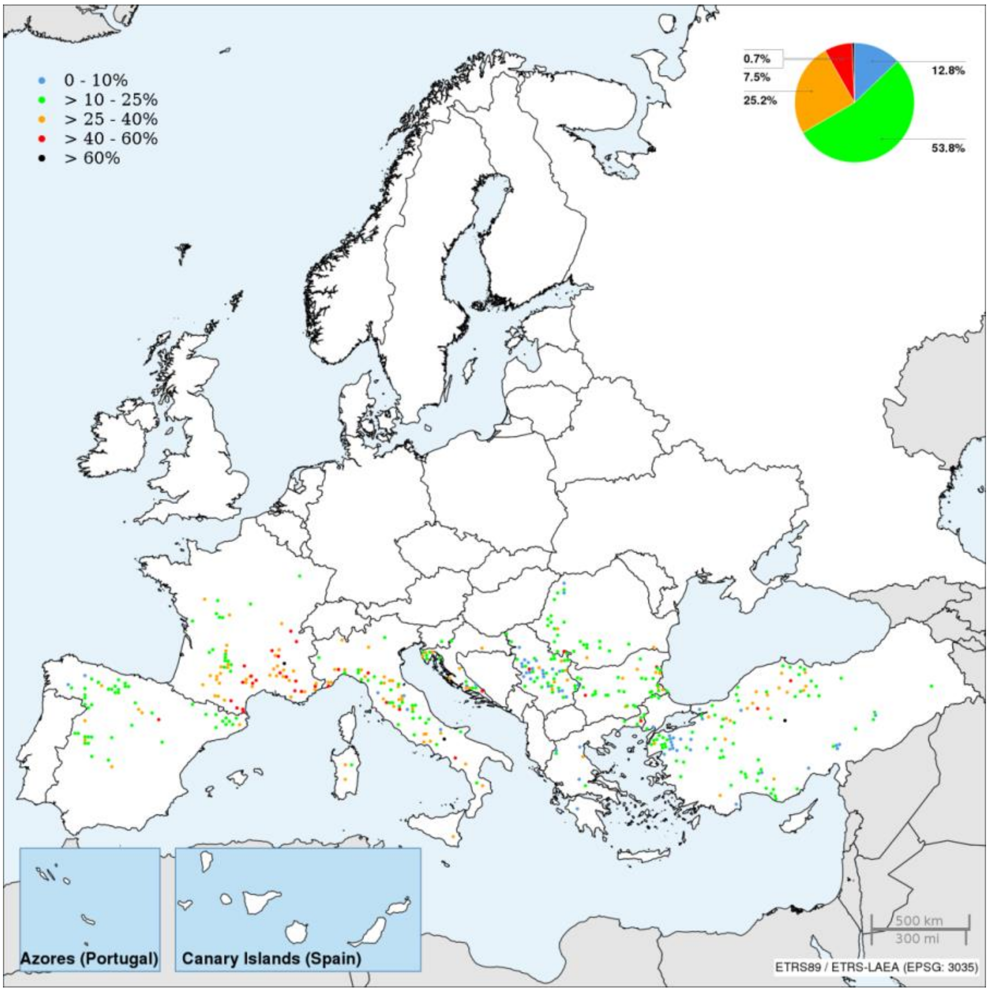


Figure 3-21. Mean plot defoliation of deciduous (sub-) Mediterranean oaks (*Quercus cerris*, *Q. frainetto*, *Q. pubescens*, *Q. pyrenaica*) in 2014.

From 1992 to 2014, the over-all trend in mean plot defoliation of deciduous (sub-) Mediterranean oaks showed the same increase of 1% percentage point every 3 years as the deciduous temperate oaks (regional Sen's slope = 0.333, $p < 0.001$). Mean plot defoliation strongly increased from 1992 to 1996 before levelling off in the consecutive years (Figure 3-22).

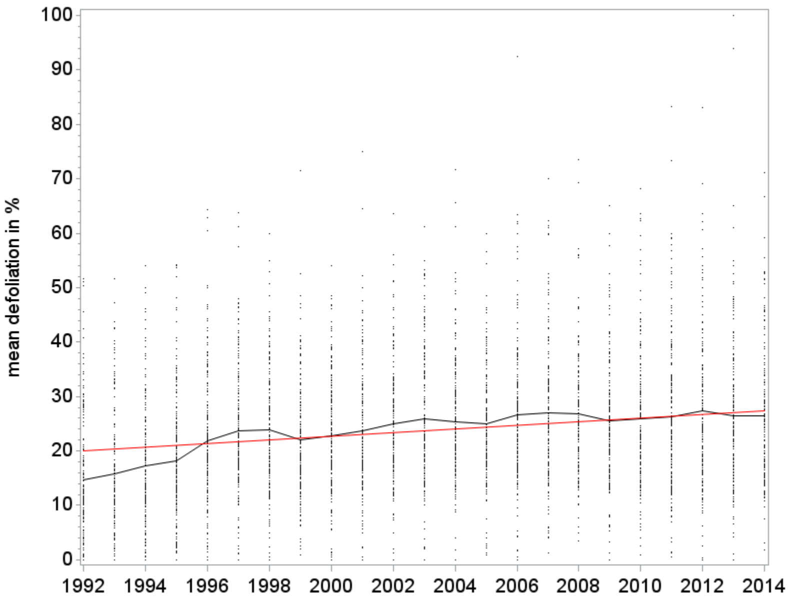


Figure 3-22. Over-all trend (regional Sen's slope = 0.333, p < 0.001; minimum length of time span: 20 years , red line) and yearly over-all mean defoliation (black line) of deciduous (sub-) Mediterranean oaks (*Quercus cerris*, *Q. frainetto*, *Q. pubescens*, *Q. pyrenaica*) at Level I sites; points represent annual plot means, for clarity these are not interconnected from year to year.

From 2002 to 2014, increasing and decreasing trends in mean plot defoliation were found for a similar number of plots (7.1% and 9.6%, respectively), while a total of 83.3% of the plots showed no statistically significant trends (Figure 3-23).

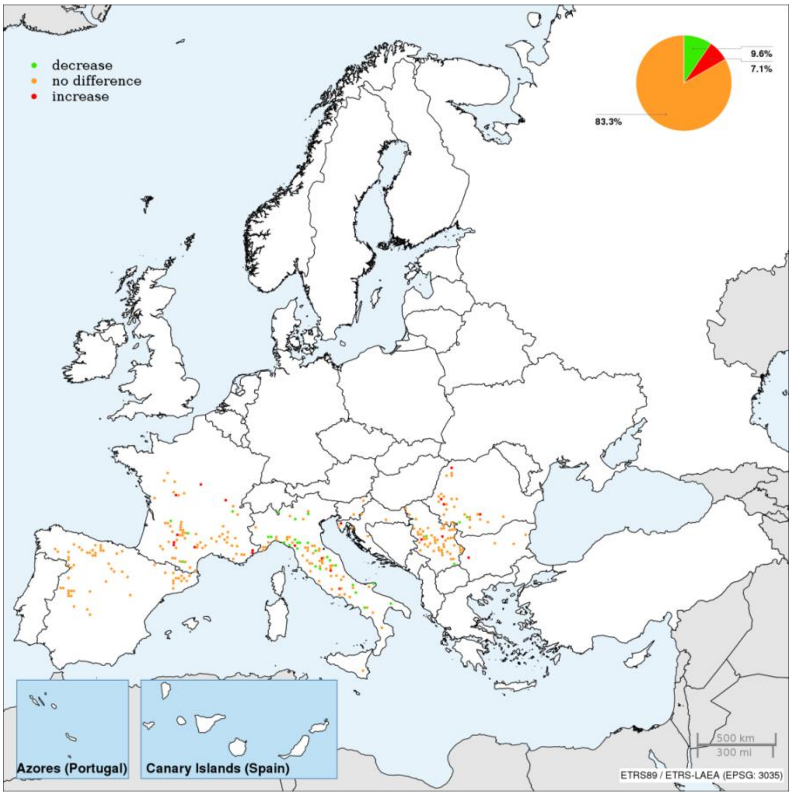


Figure 3-23. Trends in mean plot defoliation (Mann-Kendall test) of deciduous (sub-) Mediterranean oaks (*Quercus cerris*, *Q. frainetto*, *Q. pubescens*, *Q. pyrenaica*) between 2002 and 2014 with a minimum assessment length of 10 years.

Evergreen oaks

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

In 2014, trees in more than two out of three evergreen oak plots (68.8%) were on average not or only slightly defoliated (Figure 3-24). They were on average moderately defoliated on 30% of the plots and severely defoliated on 1.2% of the plots. Trees in southern France and Corsica showed on average particularly high defoliation.

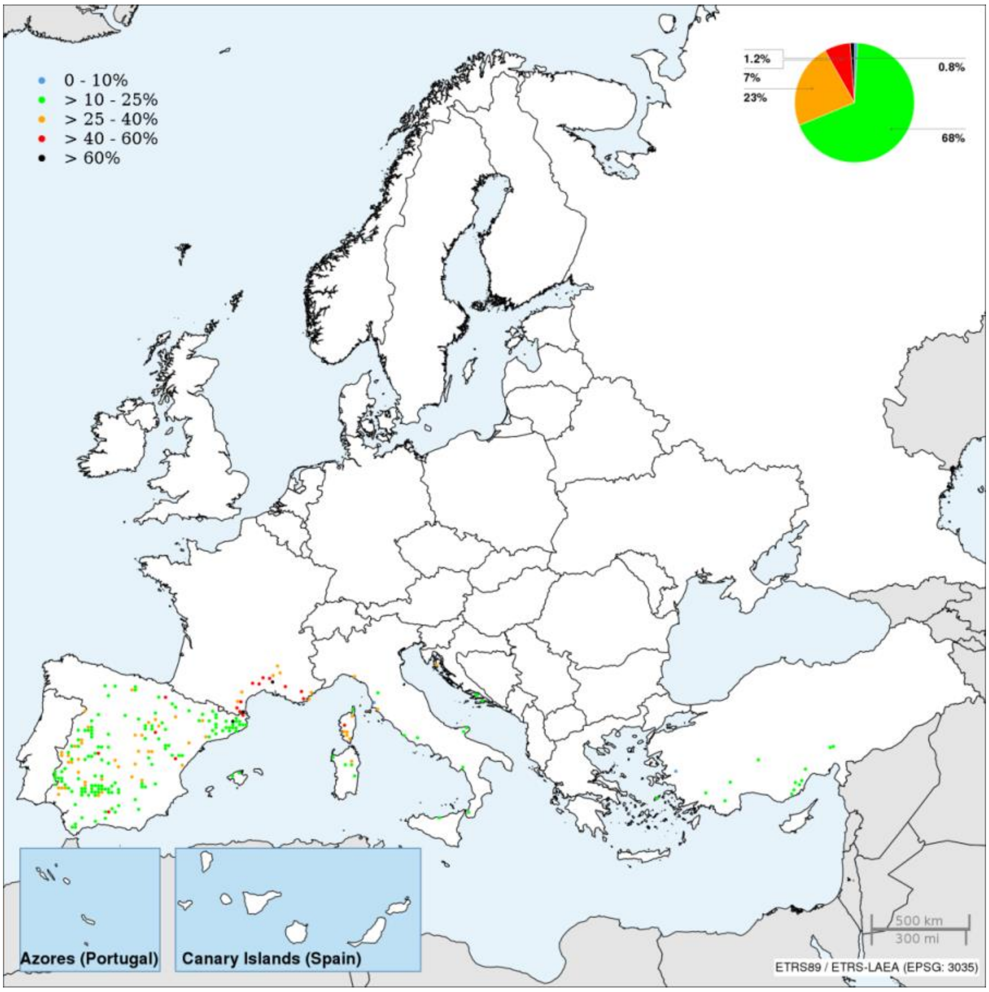


Figure 3-24. Mean plot defoliation of evergreen oaks (*Quercus coccifera*, *Q. ilex*, *Q. rotundifolia*, *Q. suber*) in 2014.

From 1992 to 2014, evergreen oak plots showed a continuous increasing over-all trend in mean defoliation with an increase of approximately 2.7 percentage points every 10 years (regional Sen's slope of 0.273, $p < 0.001$; Figure 3-25). However, several comparably large deviations from the linearly increasing trend were observed in both directions (e.g. 1992–1996, 1998, 2005–2006, and 2011).

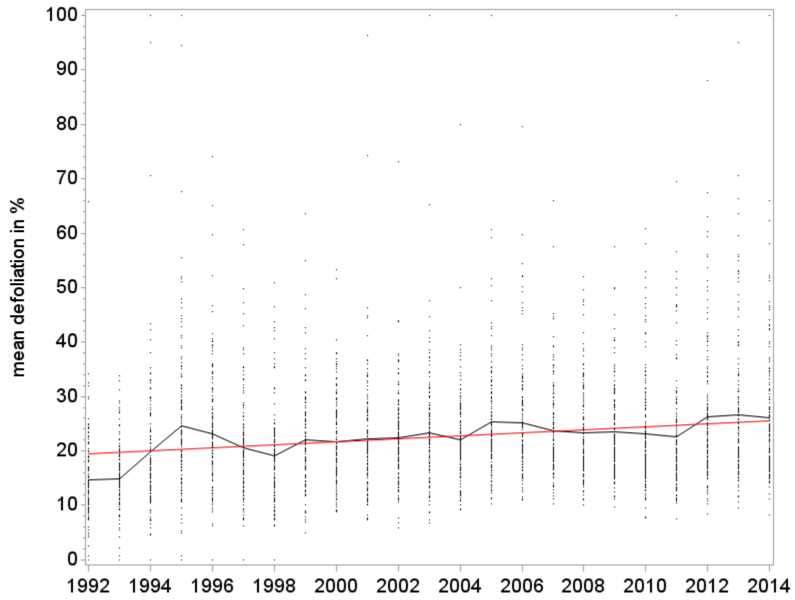


Figure 3-25. Over-all trend (regional Sen's slope = 0.273, p < 0.001; minimum length of time span: 20 years , red line) and yearly over-all mean defoliation (black line) of evergreen oaks (*Quercus coccifera*, *Q. ilex*, *Q. rotundifolia*, *Q. suber*) at Level I sites; points represent annual plot means, for clarity these are not interconnected from year to year.

From 2002 to 2014, increasing and decreasing trends in mean plot defoliation were found for a similar number of plots (3.4% and 4.3%, respectively), while there was no significant change over time in more than 90% of the plots (Figure 3-26).

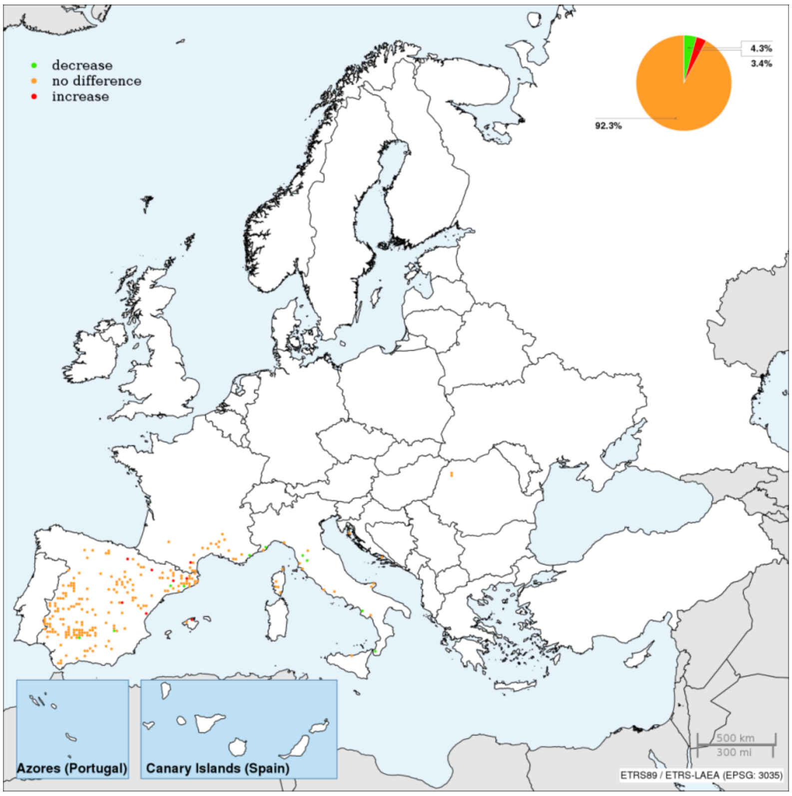


Figure 3-26. Trends in mean plot defoliation (Mann-Kendall test) of evergreen oaks (*Quercus coccifera*, *Q ilex, Q. rotundifolia*, *Q. suber*) between 2002 and 2014 with a minimum assessment length of 10 years.

3.4 Tree damage causes – Methods and materials

The **damage cause assessment** of trees is based on Eichhorn et al. (2010). It consists of three major parts:

- Symptom description
- Determination of the damage cause (causal agents / factors)
- Quantification of symptoms (damage extent).

Symptom description

Damage symptoms are the visible damage to trees. The description of damage symptoms indicates which part of a tree is affected and the type of symptom it shows. It focuses on important factors that may influence tree condition and it is important in the diagnosis of the causal agent and for the study of cause-effect mechanisms.

Three main categories indicate the affected part of a tree: (a) leaves/needles, (b) branches, shoots, and buds, and (c) stem and collar. For each affected part in the first two categories, also the position within the crown is given (Table 3-6).

Table 3-6. Affected parts of a tree and their location in the crown (Eichhorn et al. 2010).

Affected parts	Specification of affected part	Location in crown
Leaves/needles	Current needle year	Upper crown
	Older needles	Lower crown
	Needles of all ages	Patches
	Broadleaves (incl. evergreen species)	Total crown
Branches, shoots & buds	Current year shoots	Upper crown
	Twigs (diameter < 2 cm)	Lower crown
	Branches diameter 2 – < 10 cm	Patches
	Branches diameter ≥ 10 cm	Total crown
	Varying size	
	Top leader shoot	
	Buds	
Stem & collar	Crown stem: main trunk or bole within the crown	
	Bole: trunk between the collar and the crown	
	Roots (exposed) and collar (≤ 25 cm height)	
	Whole trunk	

Causal agents / factors

Causal agents are those thought to be directly responsible for the observed damage symptoms. Therefore, for each symptom description a causal agent should be determined, which is crucial for the study of cause-and-effect mechanisms. Causal agents are grouped into nine categories (Table 3-7). In each category a more detailed description is possible through a hierarchical coding system.

Table 3-7. Main categories of causal agents (Eichhorn et al. 2010).

Causal agents
Game and grazing
Insects
Fungi
Abiotic agents
Direct action of men
Fire
Atmospheric pollutants (visible symptoms of direct atmospheric pollution impact only)
Other factors
(Investigated but) unidentified

Damage extent

The extent is the estimated percentage of affected parts caused by the action as specified by causal agents. The extent is classified in eight classes (Table 3-8). In trees with multiple types of damage (and thus multiple extent classes), all extent values are evaluated individually.

Table 3-8. Classes of damage extent (Eichhorn et al. 2010).

Class	Extent
0	0%
1	1–10%
2	11–20%
3	21–40%
4	41–60%
5	61–80%
6	81–99%
7	100%

3.5 Tree damage causes – Results

In 2014, the causes of tree damage were assessed on 97 293 trees on 5 400 plots in 22 countries. The geographical distribution of all assessed plots is visualized in Figure 3-27. A total of 39 146 trees (40.2%) showed symptoms of damage of at least one defined agent group.

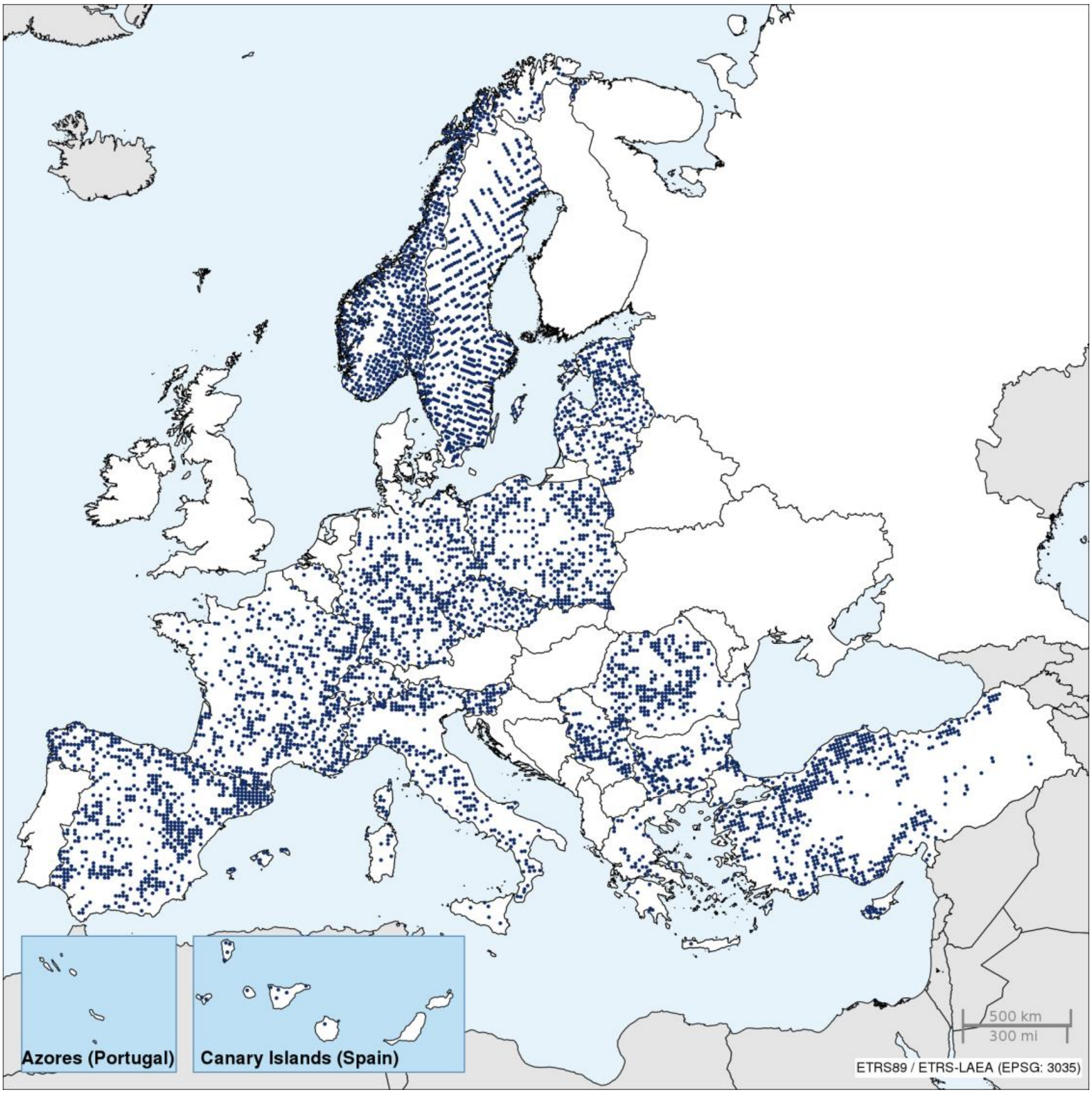


Figure 3-27. Plots with damage cause assessment in 2014.

Symptom description and damage extent

For a total of 6 397 damage symptoms, the affected parts of the tree and location in the crown were recorded during the damage assessments (Figure 3-28). Nearly half of the symptoms were determined on either twigs thinner than 2 cm (26.0%) or leaves (21.6%). Needles were the third major affected part of a tree (11.6%), while other parts were affected less frequently (≤ 10% each).

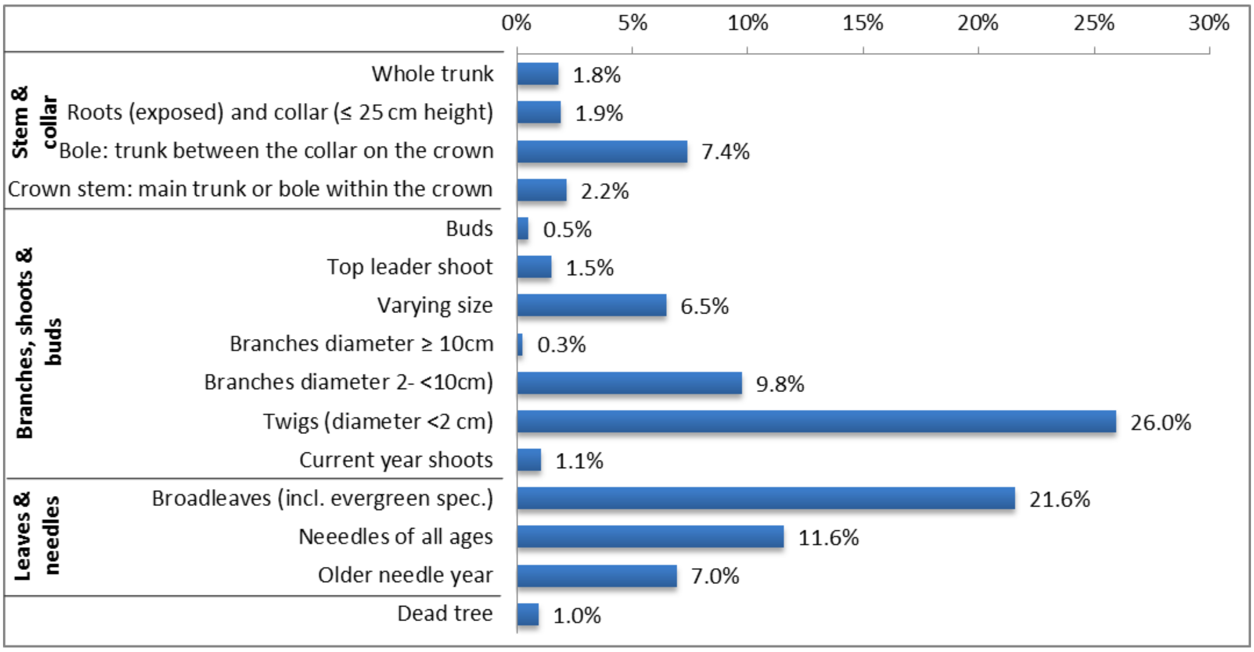


Figure 3-28. Damage symptoms according to specifications of the affected part of a tree (n=6 397). Trees could have more than one affected part.

More than half of all registered damage symptoms were in the lowest extent class 1 (52.5%, Figure 3-29; cf. Table 3-7), approximately one third (36.9%) were in the extent classes 2 and 3, and only 8.9% of the symptoms covered more than 40% of the affected part of a tree (extent classes 4 to 7).

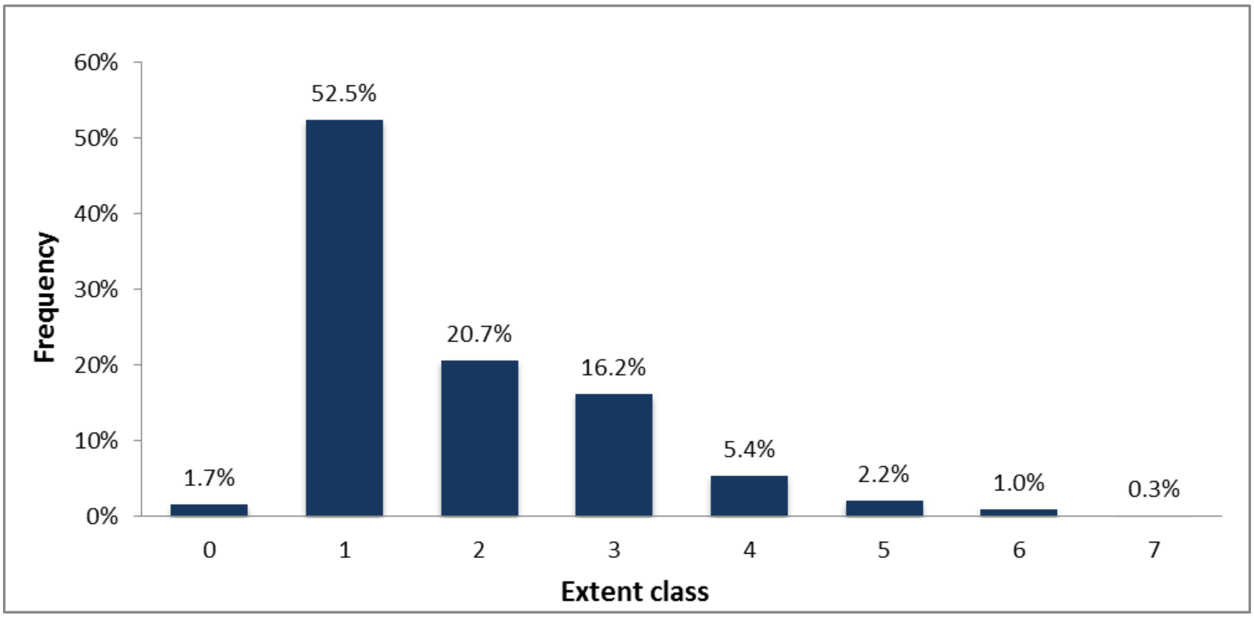


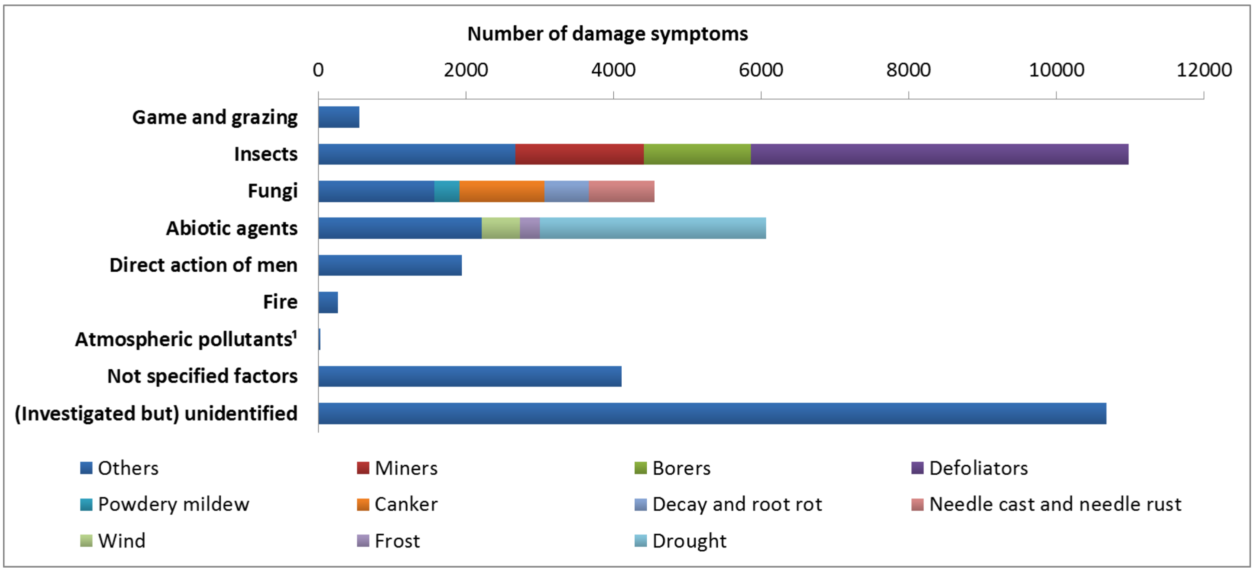
Figure 3-29. Damage symptoms according to their extent class in 2014 (n=6 281). In trees with multiple types of damage symptoms, all extent values were evaluated.

Causal agents/factors responsible for the observed damage symptoms

Insects were the predominant identified cause of damage and had caused more than a quarter of all recorded damage symptoms (28.0%; Figure 3-30). Almost half of these insect-caused symptoms were attributed to defoliators (46.7%), which represented also the most frequent of all damage causes. Leaf-mining insects were responsible for damage on 15.9% and wood-boring insects on 13.2% of the trees with insect-caused symptoms.

The second major identified cause of tree damage was abiotic agents (15.5% of all damage symptoms). Within this agent group, half of the symptoms were attributed to drought (50.5%), while wind and frost had caused considerably less damage (8.5% and 4.5%, respectively).

While fungi (including canker) was the third major causal agent (11.6%), the agent group 'Game and grazing' was of minor importance (1.4%) and may mainly be relevant in young tree stands. The agent group 'Fire' refers to local events at certain sites and was found primarily in Spain (0.7% of all damage symptoms) (Table 3-9). The agent group 'Atmospheric pollutants' also refers to local incidents mainly in connection with factories, power plants, etc. Visible symptoms of direct atmospheric pollution impact, however, were rare (0.1% of all damage symptoms). Figure 3-1 at the beginning of this chapter shows typical damage symptoms from direct atmospheric pollution, which can clearly be traced back to such events. Apart from these identifiable causes of damage symptoms, a considerable amount of symptoms could not be identified (27.3%) or was caused by other causal agents not explicitly listed here (10.5%).



[1] Visible symptoms of direct atmospheric pollution impact only (cf. Figure 3-1)

Figure 3-30. Damage symptoms according to agent group and specific agents/factors (n=39 146). Each agent group was only counted once per tree.

Table 3-9. Damage by agent groups and country for the year 2014 (n=39 146). Each agent group was only counted once per tree.

Country	Game and grazing	Insects	Fungi	Abiotic agents	Direct action of men	Fire	Atmospheric pollutants[1]	Other factors	(Investigated but) unidentified
Andorra	1	0	4	6	0	0	0	0	5
Belgium	0	17	36	7	9	0	0	0	88
Bulgaria	0	452	1 070	162	182	0	2	58	989
Cyprus	11	163	0	50	0	0	0	23	0
Czech Republic	90	4	9	94	27	0	0	25	28
Estonia	25	30	449	60	101	3	0	49	902
France	11	1 790	620	650	64	4	20	144	1 670
Germany	85	1 309	348	118	315	1	0	323	560
Greece	28	228	114	388	3	4	0	357	13
Italy	38	1 039	180	172	4	0	0	262	2 203
Latvia	75	54	35	42	110	0	0	2	7
Lithuania	30	64	78	114	76	1	0	37	103
Luxembourg	0	19	0	0	0	0	0	0	13
Norway	11	200	211	200	5	2	0	1	442
Poland	49	958	262	233	309	0	1	1 115	1 402
Romania	45	953	145	220	131	7	2	62	193
Serbia	0	254	116	25	21	6	0	6	50
Slovenia	3	192	97	97	57	0	0	34	317
Spain	36	2 116	631	3 115	337	211	0	1 038	90
Sweden	13	3	38	63	83	0	0	6	225
Switzerland	0	155	26	31	4	0	0	59	29
Turkey	0	977	84	215	99	24	0	503	1 347
TOTAL	**551**	**10 977**	**4 553**	**6 062**	**1 937**	**263**	**25**	**4 104**	**10 676**
TOTAL (%)	**1.4%**	**28.0%**	**11.6%**	**15.5%**	**4.9%**	**0.7%**	**0.1%**	**10.5%**	**27.3%**

[1] Visible symptoms of direct atmospheric pollution impact only (cf. Figure 3-1)

The occurrence of agent groups slightly differed between major species or species groups. Of all of the identified damage causes, insects were the most prominent in all species or species groups except for evergreen oaks, which were mainly affected by abiotic agents. For an overview of the recorded agent groups and their occurrence in the main species and species groups, please refer to Figure 3-31.

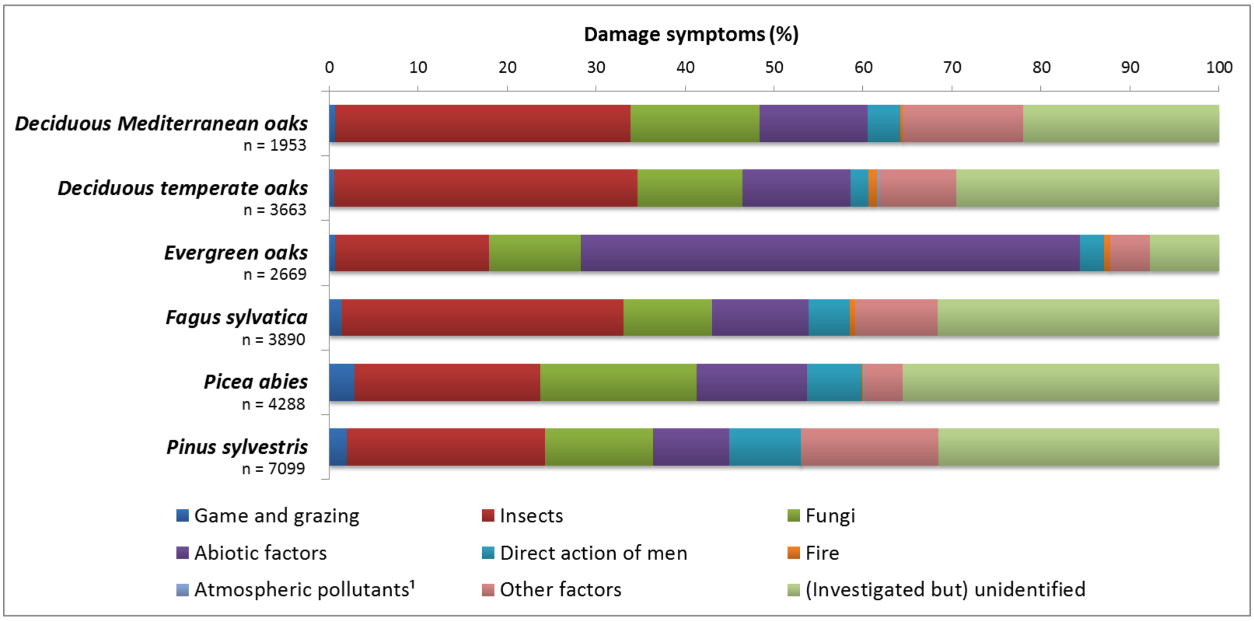


Figure 3-31. Damage symptoms according to agent group in the main tree species and species groups on Level I plots. [1] Visible symptoms of direct atmospheric pollution impact only (cf. Figure 3-1).

Geographic distribution of symptoms caused by different agent groups

Agent group 'Game and grazing'

In 2014, damage symptoms caused by game and grazing were mainly observed in the Baltic states with the highest amount of damage occurring on plots in Latvia (Figure 3-32). Plots with a high percentage of trees affected by game and grazing were also found in the mountainous border regions between the Czech Republic, Germany, and Poland, as well as on some sites in Germany and Romania. It is important to note that these results are not representative as they may be biased due to the fact that young trees, the main target trees for game and grazing, are underrepresented in the damage assessments.

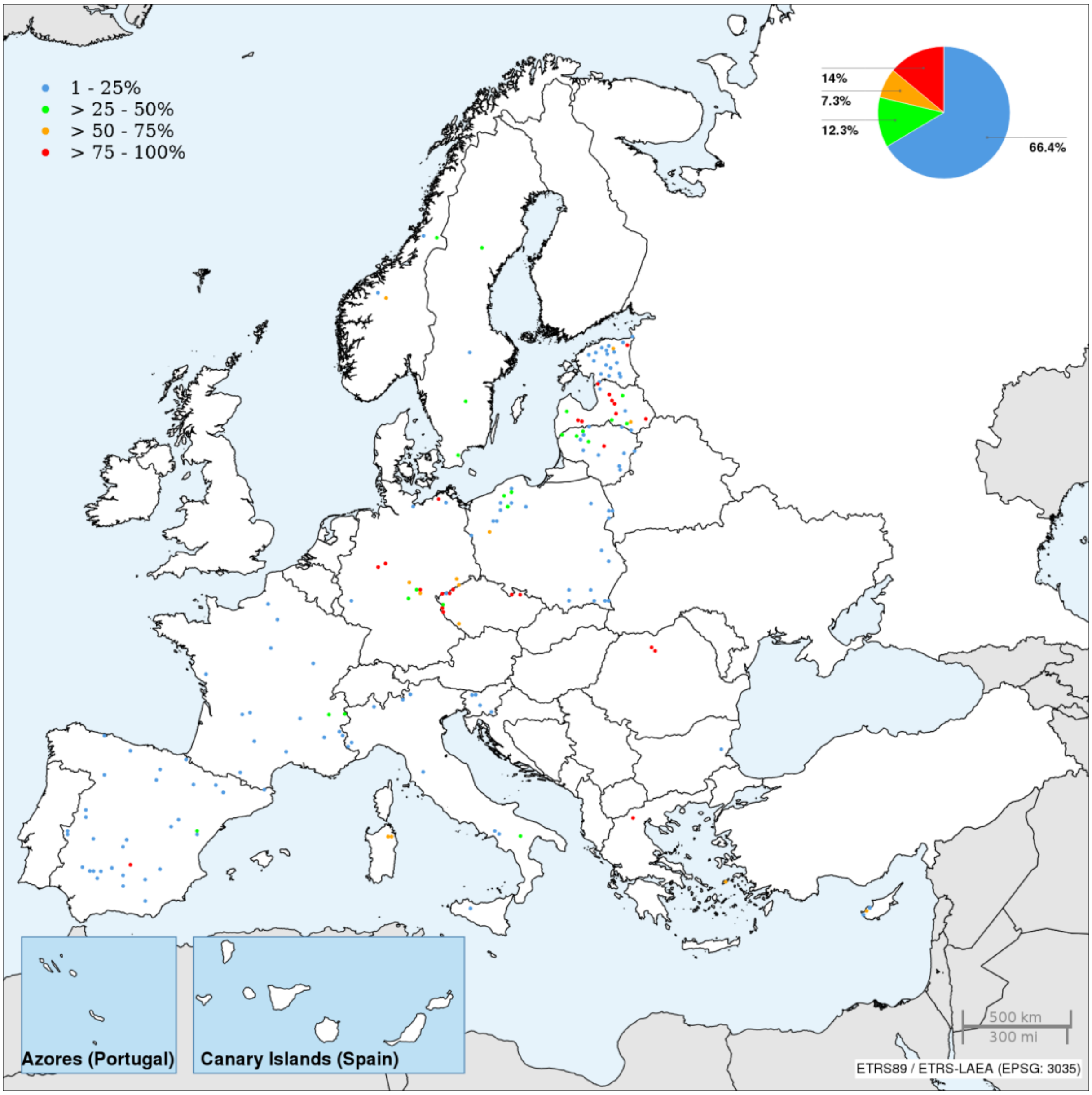


Figure 3-32. Share of trees per plot with recorded damage indicator 'Game and grazing' in 2014.

Agent group 'Insects'

The most frequently observed agent group was 'Insects'. This group shows distinct geographical patterns across Europe. In a quarter of all plots with insect-caused damage symptoms (25.5%), more than 75% of the trees were affected (Figure 3-33). This high infestation rate seems to be a typical feature of insect-caused damage to trees in forests. In Norway north of the polar circle, for example, on almost every plot with registered insect damage 75% to 100% of the trees were damaged. This applies also to many other regions in Europe and to Turkey. However, there are also many plots with lower percentages of affected trees. It has to be further investigated whether there were plot-specific causes for the percentage of affected trees at a given plot e.g. species composition (Jactel et al 2009).

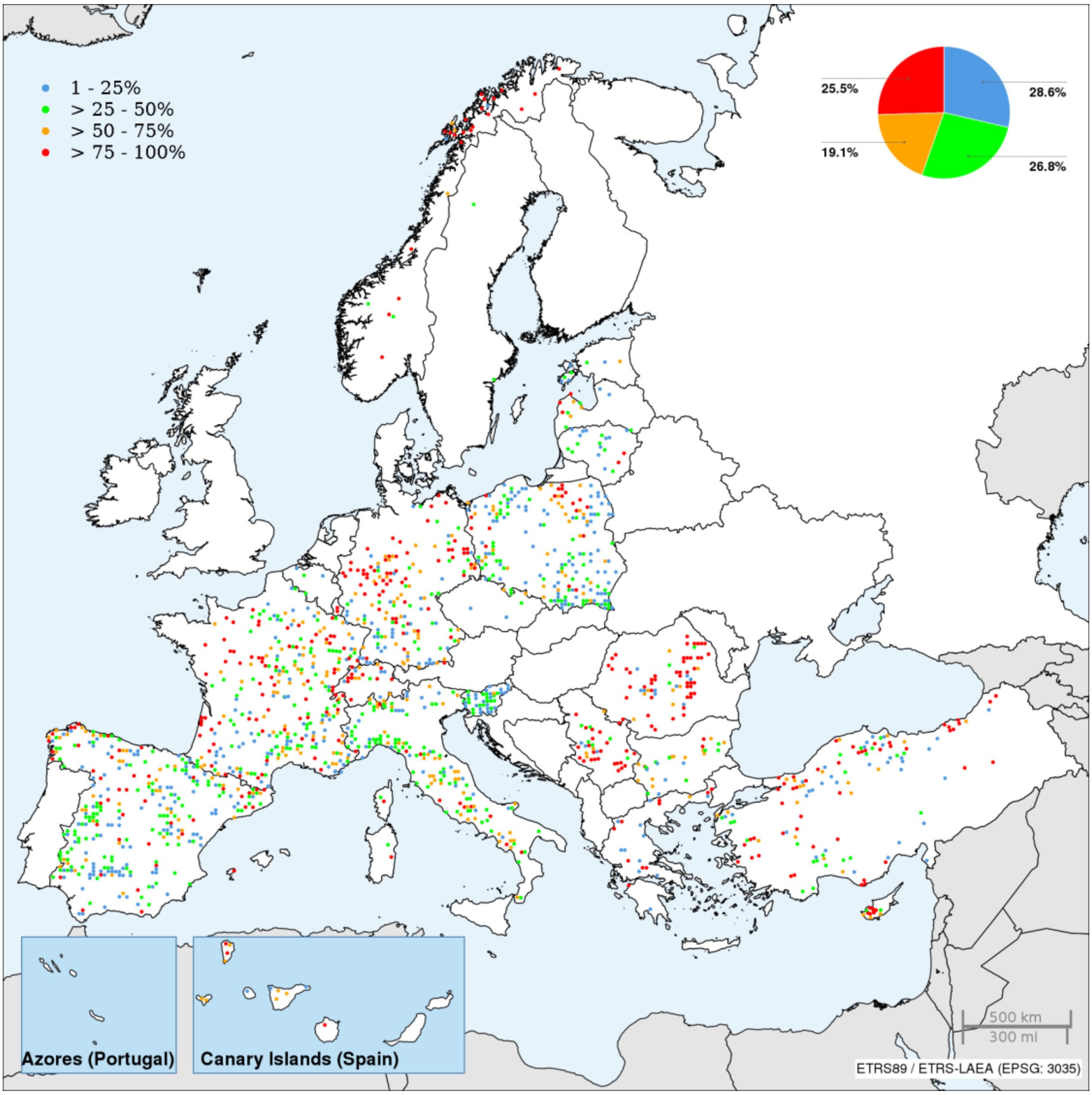


Figure 3-33. Share of trees per plot affected by tree damage indicator 'Insects' in 2014.

Agent group 'Fungi'

Fungi are the second most frequent biotic agent influencing tree health in general and crown condition in particular. In more than half of the plots (55%) with recordings of phytopathogenic fungi, up to a quarter of the trees were visibly affected (Figure 3-34). Only on 11.7% of the plots more than 75% of the trees had become infested.

Plot-related mass occurrences of fungi were less clustered than damage by insects in the participating countries, although there were slight aggregations in middle Norway, south-eastern France, Serbia and western Bulgaria. Plots with less than half of the trees with visible infections by phytopathogenic fungi were spread across the investigated area. There probably is a high number of unreported occurrences especially in plots with few affected trees. Still the collected data are a valuable source for studies on the large-scale patterns of phytopathogenic fungi in Europe.

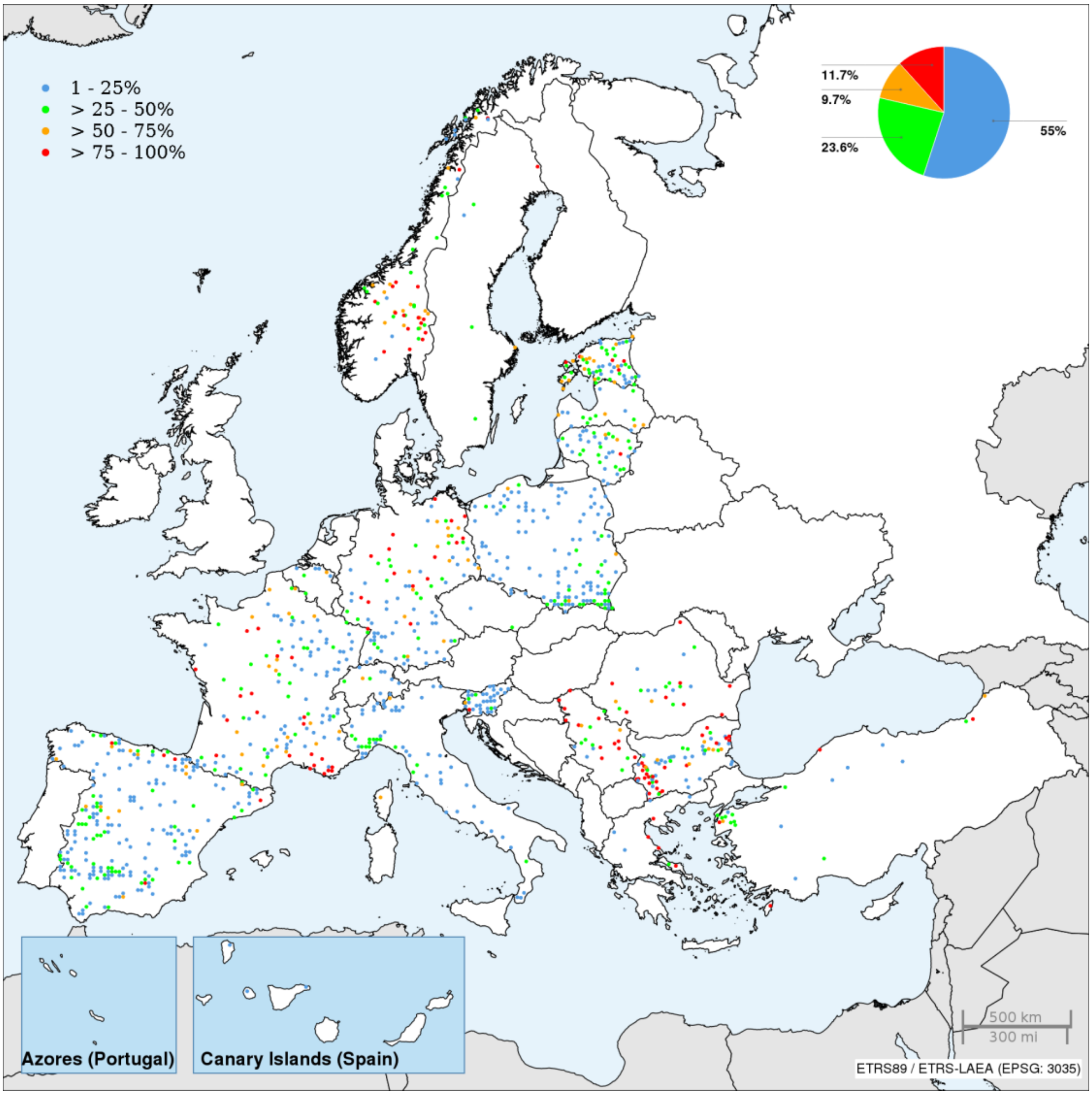


Figure 3-34. Share of trees per plot affected by tree damage indicator 'Fungi' in 2014.

Agent group 'Abiotic agents'

Abiotic agents comprise direct stress by e.g. drought, temperature, wind, or landslides. On almost half of the plots with damage by this agent group (49.1%) less than a quarter of the trees were visibly affected (Figure 3-35). More than half of the recorded damage by abiotic agents was caused by drought (50.5%). If drought was recorded, it had very often affected more than 75% of the trees in a plot, especially in eastern and parts of central Spain. Some minor aggregations of plots heavily affected by abiotic agents were found in south-western Norway, in the Czech-Polish border region, southern France, central Romania, Bulgaria, Greece and north-eastern Turkey. Plots with lower shares of affected trees were widely distributed across the participating countries.

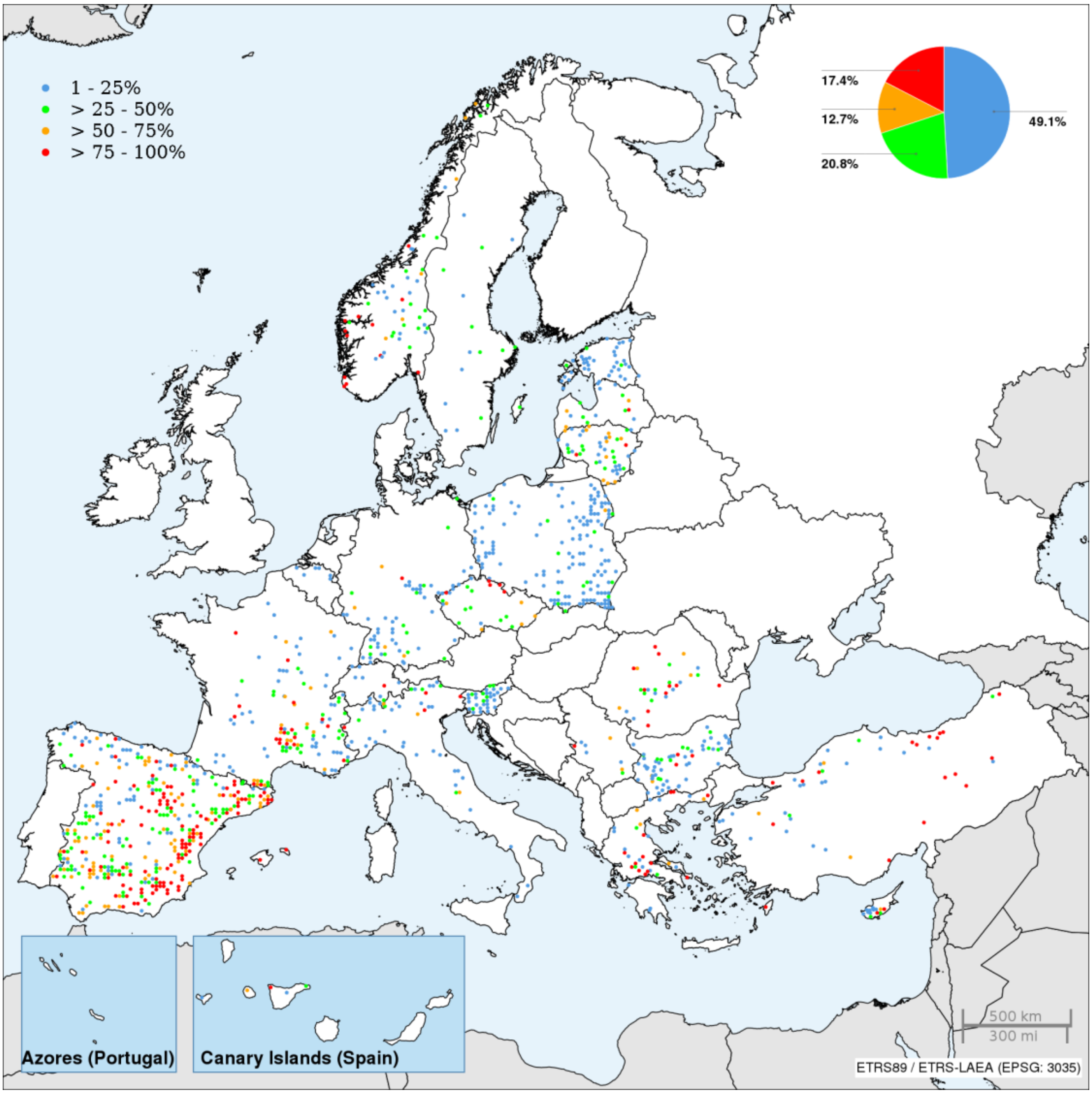


Figure 3-35. Share of trees per plot affected by tree damage indicator 'Abiotic agents' in 2014.

Agent group 'Direct action of men'

The damage agent group 'Direct action of men' refers mainly to impacts of silvicultural treatments like soil compaction related to the use of heavy machinery, mechanical injuries caused by skidding etc. and was responsible for 4.9% of all damage symptoms in 2014 (Table 3-9; 2% percentage points less than in 2013, Wellbrock et al. 2014). In the majority of plots (62.7%) less than 25% of the trees had been damaged (Figure 3-36). There were some slight aggregations of severe impacts from forestry actions in some of the participating countries.

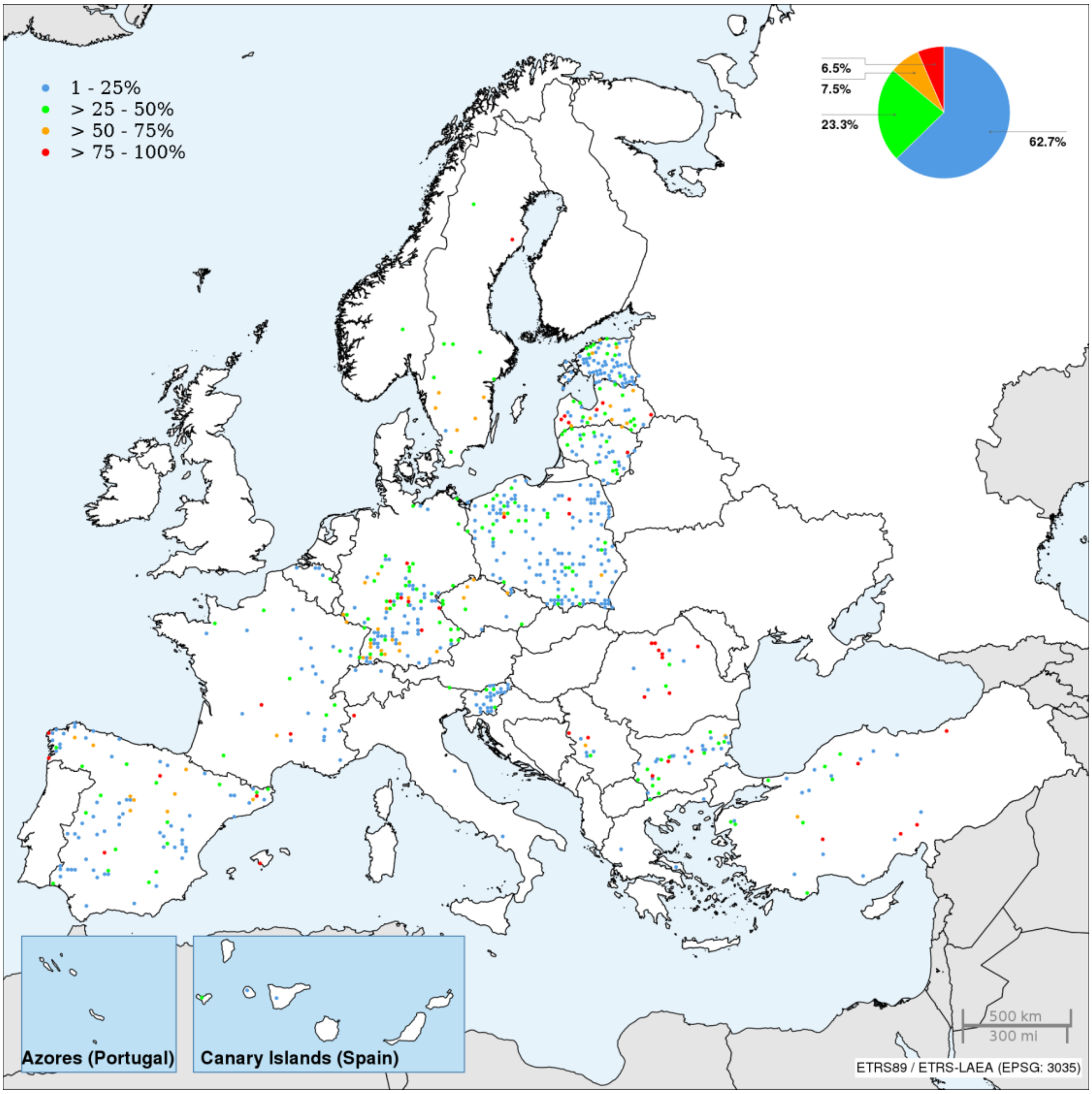


Figure 3-36. Share of trees per plot affected by tree damage indicator 'Direct action of men' in 2014.

Agent group 'Fire'

Less than 1% of all damage symptoms were caused by fire (Table 3-9). In 2014, most forest fires affecting Level I plots in the UNECE region had occurred in Spain (Figure 3-37). This finding coincides with the high frequency of plots in this country suffering from drought.

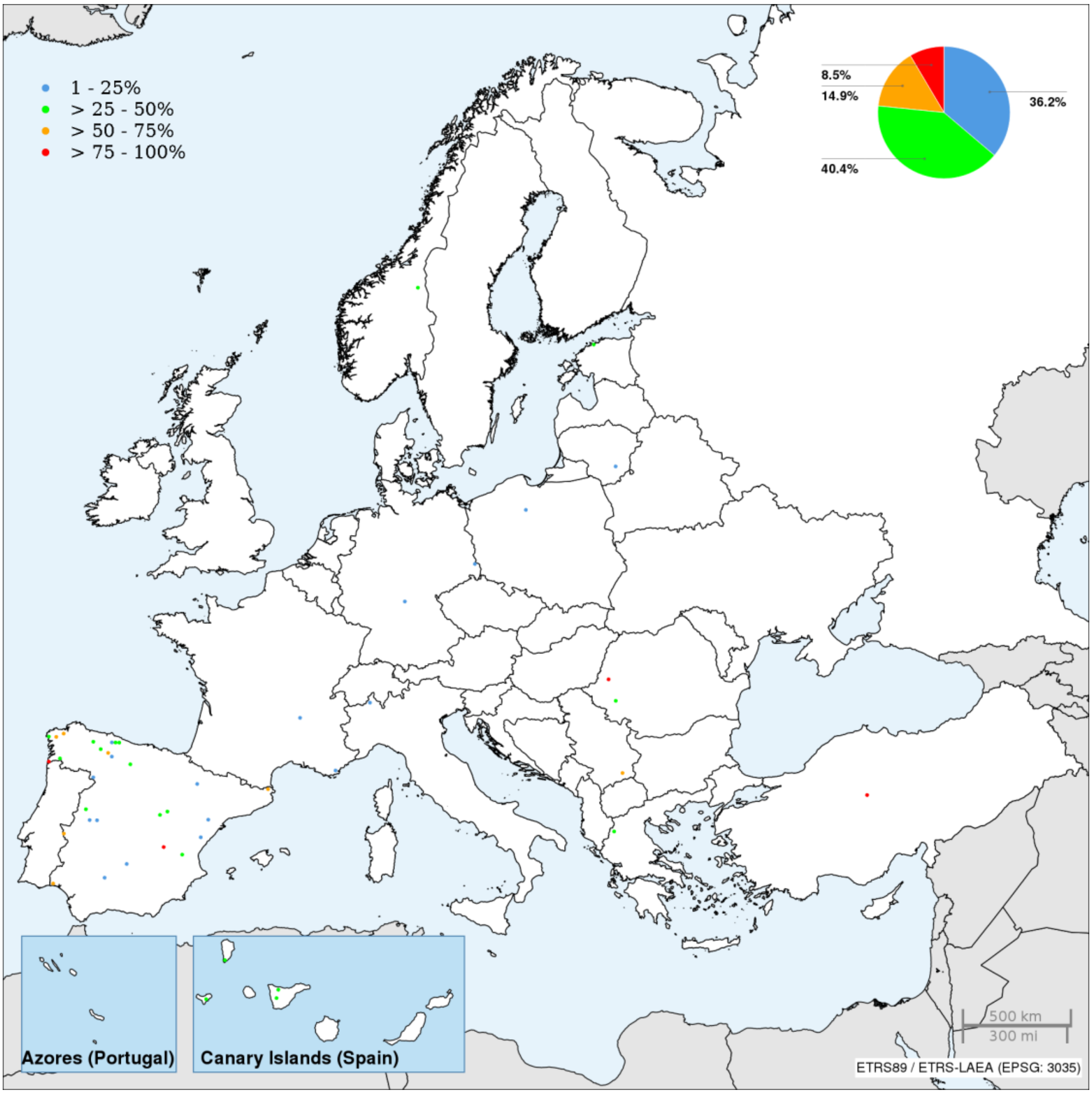


Figure 3-37. Share of trees per plot affected by tree damage indicator 'Fire' in 2014.

3.6 Tree crown condition and damage causes – Discussion

Defoliation is visually assessed according to European-wide, harmonized methods which have been described by Eichhorn et al. (2010). Regular calibration trainings of the survey teams (e.g. Ferretti 1998) and international intercomparison courses ensure the accurateness of the data and comparability across member states (e.g. Eickenscheidt 2015).

Defoliation is an unspecific indicator of tree health in the sense of Dobbertin (2005) who considers it as a tree response to any kind of external stress (drought, soil condition, shading etc.) or direct mechanical impact (feeding by insects, impact of hail). Tree age plays an intricate role in defoliation. It has repeatedly been shown that age influences defoliation estimates of trees (e.g. Klap et al. 2000; Solberg 1999). Age as an intrinsic factor could indeed be related to a concept of ‘vitality’ or ‘health’, with old trees being generally less vital or healthy than young ones and therefore more susceptible to e.g. insects. Lorenz et al. (1997) argue that the use of a local reference tree, representing the typical crown morphology and age of trees in the plot, reduces the possible effects of normal ageing on defoliation scores. Most countries have therefore adopted local reference trees as standards for their defoliation assessments (Eichhorn et al. 2010).

By including only plots with constant data over time and by using a median-based method robust against outliers (Mann-Kendall’s tau and Sen’s slope estimate) during the evaluation of the temporal changes in defoliation, this report avoids for the first time bias caused by different numbers of plots from year to year. The applied method is widely used in time series analyses in different environmental studies (e.g. Drápela & Drápelová 2011, Curtis & Simpson 2014).

Overall, the results show a slight to moderate worsening of crown condition (increased defoliation) over the period 1992 to 2014; only for Scots pine and Norway spruce no or only a slight statistically significant over-all change was found. Increases in defoliation could often be linked to direct factors like drought periods (e.g. in Spain in 2014), thereby emphasizing the value of the combined assessment of defoliation and damaging agents. Unfortunately a number of countries have stopped the assessment of crown condition or changed plot locations. This limits the possibilities to statistically model time-spatial developments. It is a considerable loss, as crown condition is also an important indicator of climate conditions, and therefore of impacts relating to a changing climate.

To retain crown condition as a valuable and sustainable source of information for different impacts to trees, efforts have to be continued to ensure a high comparability of the assessments and a sufficient number of countries have to continuously participate. In the future, ground- or air-based technical solutions (e.g. Solberg & Næsset 2007) may be evaluated for their applicability and potential inclusion as an additional feature to the current ground-based tree assessments.

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4 RELATIONSHIPS BETWEEN DEFOLIATION OF FOREST TREES AND MODELLED NITROGEN DEPOSITION

Walter Seidling, Henny Haelbich, Tanja Sanders

4.1 Introduction

Today, the reputation of nitrogen deposition in forest ecosystems is still disputed. While nitrogen may increase ecosystem productivity, its impacts on sustainability and biodiversity aspects of ecosystems are of adverse character or less known (Sutton et al. 2008, Winiwarter et al. 2011). For instance, it is suggested that nitrogen causes an initial growth increase of forest trees, which stagnates after several years (Körner 2000, Spiecker 1999). Högberg (2007) states that it is still unclear, whether the additional nitrogen actually increases tree growth, especially in coniferous trees. This might be due to the fact that other nutrients become limiting with increasing nitrogen input (Seith et al. 1996). For macro-lichen or mycorrhiza diversity a reduction was found in large-scale studies (Giordani et al. 2014, Cox et al. 2010b).

Within this context, the statistical relationships between defoliation of the four most important tree species as response variables and modelled nitrogen deposition were studied. Additionally the influence of age and a likely country-related bias were included.

4.2 Methods

Under ICP Forests, crown condition is annually assessed by member states on a 16 by 16 km grid across Europe (Eichhorn et al. 2010). This network constitutes the so-called extensive (Level I) forest monitoring network. 'Defoliation' denotes the loss of leaves or needles in comparison to a reference tree, which is imagined to have no loss of foliage (c.f. Chapter 3).

Defoliation is an unspecific indicator for tree health or – less anthropomorphic – tree performance. This means defoliation can be an indicator of direct or indirect impacts of air pollutants, but also climatic drought (e.g. Solberg 2004, Seidling 2007), activities of insects or fungi (Seidling & Mues 2005), or destructive weather events like hail or storm. Different intrinsic features like age or flowering (Innes 1994, Klap et al. 2000) as well as interactions between these and the previously quoted causal agents are of additional relevance. Therefore, defoliation has to be considered as an unspecific symptom integrating canopy development, branch and crown architecture, senescence as well as abscission of leaves (e.g. Chappelka & Freer-Smith 1995).

In general the parameter defoliation was averaged for each plot (Figure 4-1), species, and year. In order to absorb annual variations caused mainly by weather conditions or insect calamities, plot means can be averaged over certain time spans. To reduce the effect of methodologically caused differences (Seidling & Mues 2005), respective models have to be applied (Figure 4-2). In this study adjusted defoliation values were calculated according to Equation 1.

Plot defoliation (adjusted) = plot defoliation – country mean + overall mean (1)

Due to this approach the over-all defoliation remains stable, the inter country defoliation remains on equal level, while the country-related variation of defoliation is kept constant.

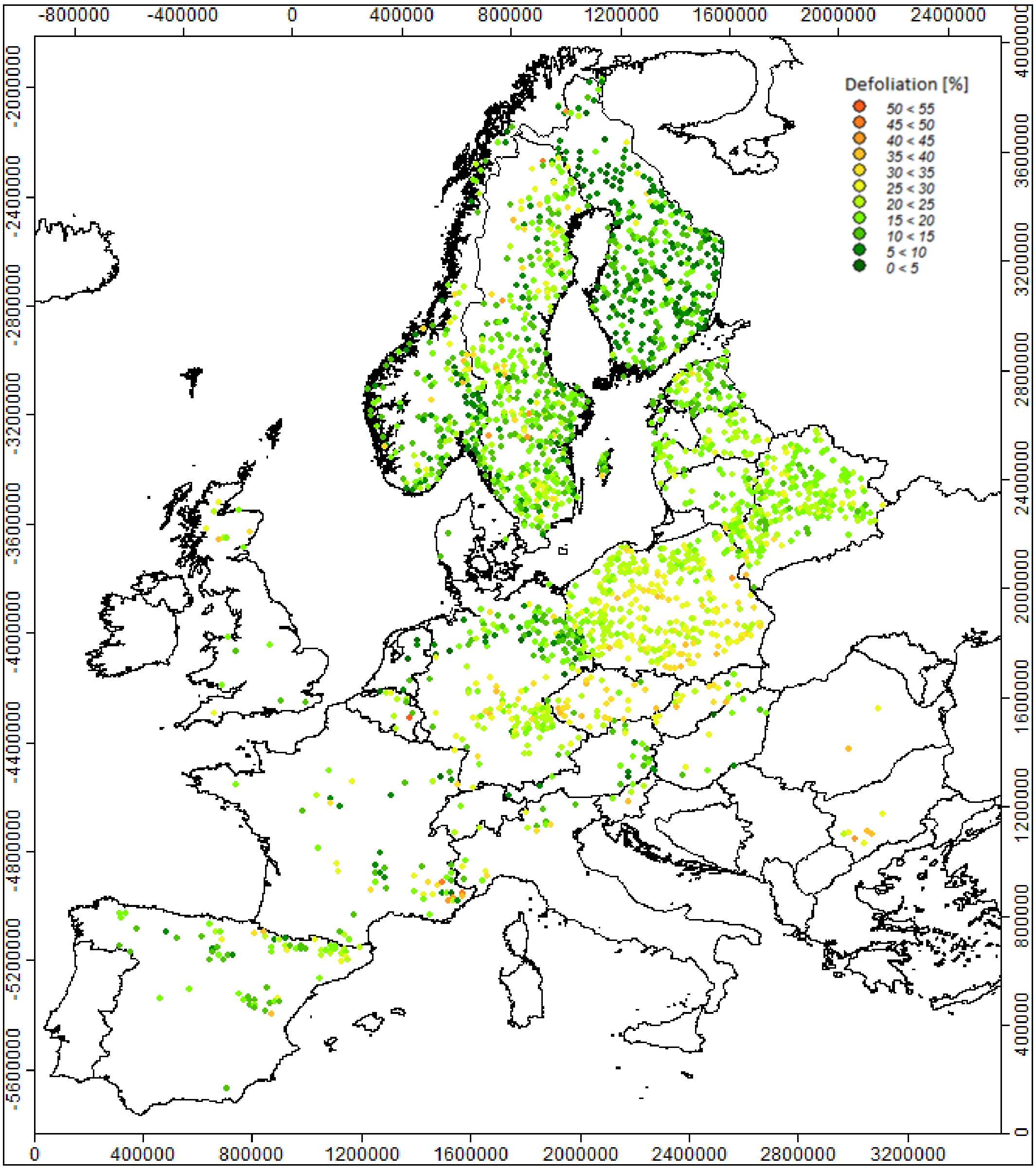

Figure 4-1. Plot-related defoliation estimates for Scots pine (*Pinus sylvestris*): medium-term means from 1999 to 2005.

Deposition of nitrogen is measured on the intensively investigated Level II plots within the ICP Forests Programme (Clarke et al. 2010). However, for the representative large-scale monitoring Level I network no respective measurements are available. Therefore, spatially interpolated values of oxidised and reduced nitrogen deposition based on values modelled by the EMEP MSC-W (EMEP 2013) were used. A technical description of the EMEP MSC-W chemical transport model can be found in Simpson et al. (2012). Model results were provided as gridded data in a 50 by 50 km resolution.

To combine the EMEP deposition values with the ICP Forests defoliation data the modelled EMEP deposition grid values were converted to a geographic coordinate system and interpolated. For this the midpoint of each EMEP grid cell was set to the original cell value. Between these point-related deposition values an interpolation on the base of a 5 by 5 km raster corresponding to the ICP Forests Level I system was performed. Interpolation was done using inverse-distance weights power of 2 and a search radius of 40 km. Mean deposition for the years 1999 to 2005 was used.

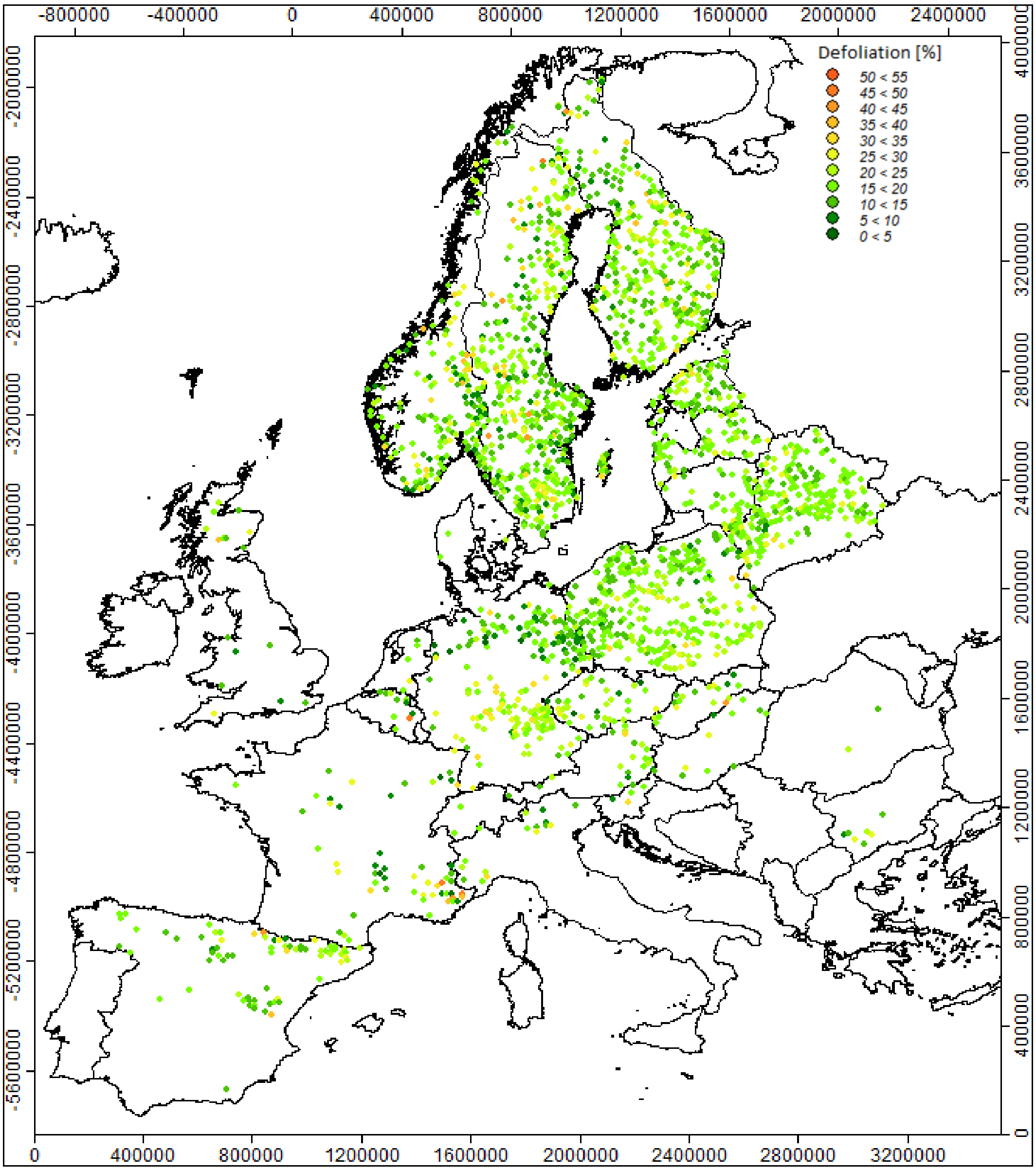

Figure 4-2. Plot-related medium-term defoliation estimates for Scots pine (*Pinus sylvestris*) adjusted for country-specific differences.

The concept of Critical Loads (CL, Nilsson & Grennfelt 1988) and its exceedances takes the capacity of each ecosystem to absorb inputs of nutrifying (or acidifying) nitrogen compounds into account. Inputs higher than the critical load may – according to the present knowledge – induce considerable changes of the ecosystems.

As a further predictor plot specific age classes (width = 20 years) transformed into class means were used. Uneven aged stands were set to an age of 110 years according to Seidling & Mues (2005) to avoid a loss of cases and minimize the bias.

Statistical relationships were investigated by bi- and multivariate linear correlation and regression analyses. As dependent variable the medium-term defoliation estimates over the years from 1999 to 2005 were used. Modelled oxidised, reduced, and total nitrogen (N_{ox}, N_{red}, N_{tot}) deposition as well as stand age was used as predictor variables or co-variables. Significance of the explanatory variables was tested with t-tests. Fractions of total variation in defoliation explained by the individual predictor were calculated over the standardized β coefficients. Correlations have been visualized by scatterplots. All statistical analyses were performed with the R package (R Core Team, 2015).

4.3 Results and discussion

Correlation analyses

Results of the correlation analyses using original plot-related averaged medium-term defoliation values as response variable and estimates for nitrogen deposition calculated for each plots as predictors are provided in Table 4-1. For Scots pine (*Pinus sylvestris*) a significant positive relationship was found for all three nitrogen types with the original defoliation estimates. Transposed into the coefficient of determination e.g. for reduced nitrogen this would mean that about 10% of the variance of defoliation is statistically determined by N deposition in a sense that higher N deposition coincides with higher defoliation (Table 4-1. Number of valid cases and product-moment correlation coefficients (r) between defoliation as dependent variable and three forms of original nitrogen deposition estimates as predictors as well as defoliation estimates adjusted for country-specific differences (PAD) as dependent variable. Bold letters indicate significance at the 5% level.). However, if defoliation values of Scots pine are adjusted for country-specific differences (cf. Seidling & Mues 2005) before the correlation analysis, no significant statistical effect remains. The positive relationship is even turned into a negative relationship.

Table 4-1. Number of valid cases and product-moment correlation coefficients (r) between defoliation as dependent variable and three forms of original nitrogen deposition estimates as predictors as well as defoliation estimates adjusted for country-specific differences (PAD) as dependent variable. Bold letters indicate significance at the 5% level.

	Original defoliation			**Adjusted defoliation**		
	r $N_{red.}$	**r $N_{ox.}$**	**r N_{tot}**	**r $N_{red.}$**	**r $N_{ox.}$**	**r N_{tot}**
Scots pine	**0.320**	**0.350**	**0.342**	-0.018	-0.013	-0.017
Norway spruce	**-0.085**	**-0.128**	**-0.104**	**-0.056**	**-0.113**	**-0.080**
Common beech	**0.097**	**0.109**	**0.109**	-0.026	-0.013	-0.023
Deciduous oaks	0.044	0.056	0.055	0.010	-0.001	0.007

For Norway spruce (*Picea abies*) a weak but statistically significant negative relationship was found between defoliation and nitrogen deposition (Table 4-1). In Norway spruce – different to Scots pine – reductions of defoliation with all kinds of higher nitrogen deposition were found, however, the respective coefficients of determination ($R^2 = r^2$) were only around 1%. Using any country-specific adjustment no general change of the relationships occurred, however, the respective relationships were even weaker.

For common beech (*Fagus sylvatica*) original defoliation values reveal a very faint positive statistical relationship with a respective coefficient of determination of a maximum of 1.2% (Table 4-1). As in Scots pine this relationship turned negative and insignificant if adjusted defoliation values were used. For both, pedunculated and sessile oak evaluated together, no significant correlation could be found at all.

Multiple regression models

Multiple regression models with age and nitrogen deposition as predictors of defoliation estimates for Norway spruce and Scots pine corroborate the importance of age for defoliation especially for Norway spruce (Table 4-2) as found previously by Klap et al. (2000) and Vitale et al. (2014). For this species more than 40% of the total variance of defoliation can be explained by age. Figure 4-3 illustrates this relationship with distinctively higher defoliation values for trees in higher age classes. The additional explained variance by nitrogen deposition –using $N_{ox.}$ as an example– is marginal in comparison to the influence of age. With absorbed country-specific differences (not depicted) the influence of age becomes even stronger; however, this does not apply for the influence of nitrogen deposition.

Table 4-2. Coefficients of determination (R^2) for multivariate regression models between original defoliation values as response and age classes and deposition estimates for Scots pine and Norway spruce, common beech and deciduous nemoral oaks as predictors.

	R^2 $N_{red.}$	R^2 age class	R^2 total	R^2 $N_{ox.}$	R^2 age class	R^2 total
Scots pine	0.110***	0.090***	0.199	0.129***	0.089***	0.218
Norway spruce	0.006***	0.417***	0.422	0.009***	0.414***	0.423
Common beech	0.010**	0.075***	0.085	0.012**	0.074***	0.086
Deciduous oaks	0.001	0.059***	0.060	0.001	0.059***	0.060

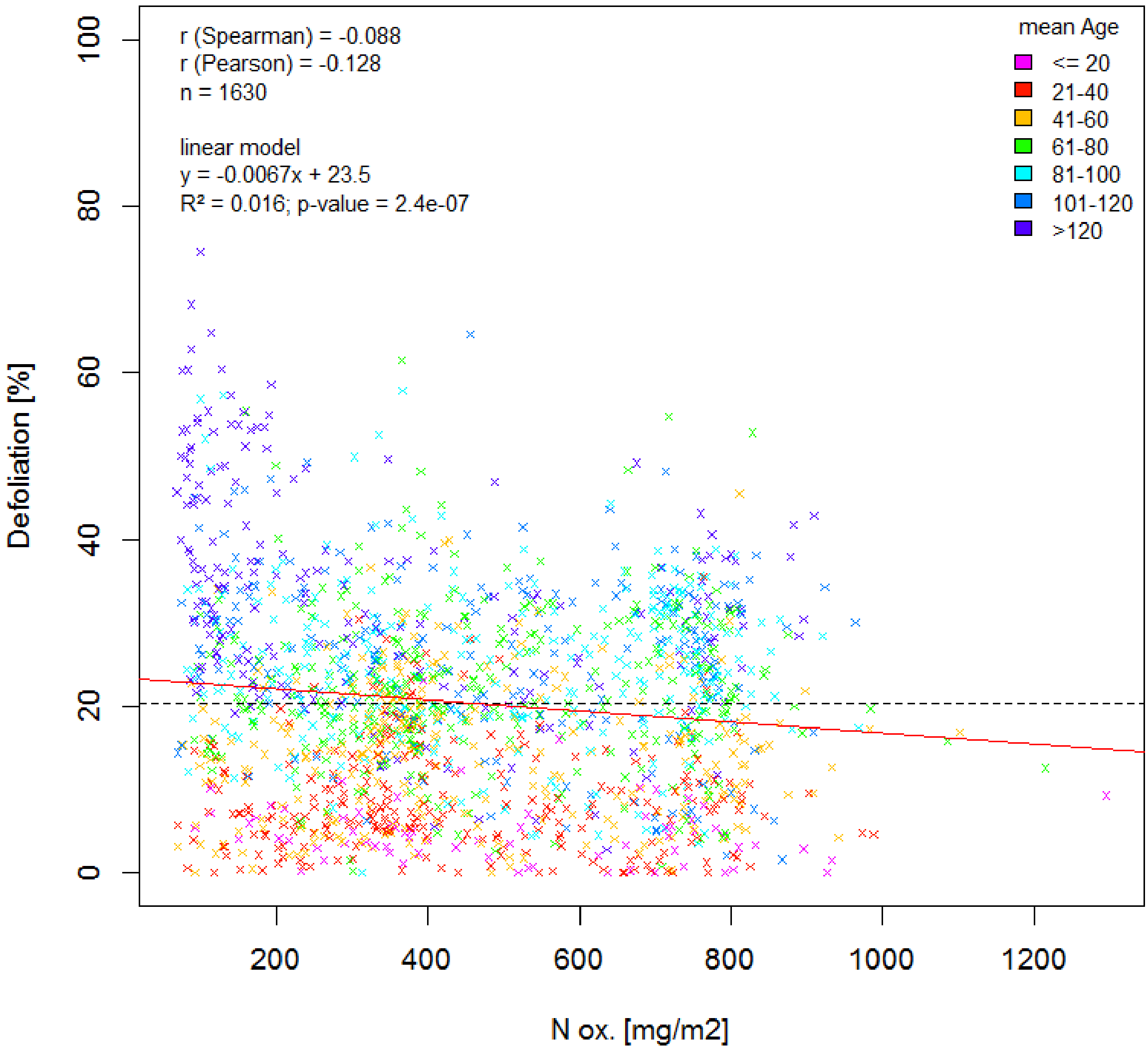

Figure 4-3. Defoliation values of Norway spruce across Europe against modelled oxidised nitrogen deposition values ($N_{ox.}$) under additional consideration of age class.

In Scots pine the influence of age and deposition is with around 10% explained variance approximately of the same order of magnitude. Absorbing country-specific differences before the regression marginalizes the influence of deposition to be non-significant (not depicted) and enhances the influence of age slightly by about 1 to 2%.

For the investigated deciduous tree species age plays a lesser role in explaining defoliation. For beech the explained variance of 1% for defoliation is very small, however, age is with a share of 7.5% of explained variance also not a very strong predictor. As described for common beech in Chapter 3, there is a high year-to-year variability, which seems to express short-term influences on crown condition in common beech by many different driving forces. Age seems not to be as predominating a factor for deciduous trees as for e.g. Norway spruce. Also the partial influence of nitrogen deposition is not becoming more pronounced, if age is additionally regarded in the multivariate model. For the two deciduous oak species, as in the bivariate model, no influence of nitrogen deposition can be found, while age is a significant predictor, however with 6% (9% if country adjusted defoliation values are used, not shown) the smallest amount of influence was shown among all the tree species studied.

Effects from gaseous nitrogen have been reported by Wright et al. (1987) to occur at NO_x concentrations greater than 20 ppb. Above this threshold water loss of leaves during drought periods was enhanced, however, such concentrations might rarely be observed nowadays at ICP Forests sites. Measurements with passive samplers on ICP Forests Level II plots (Schaub et al. 2010) revealed a maximum value of 16.2 ppb NO_x for the years 2009 to 2011 for Germany (U. Fischer, unpublished evaluations). Therefore, when looking at the role of nitrogen in the investigated ecosystems, we have mainly to consider indirect influences from both, the eutrophying and the acidifying impact of nitrogen inputs to forest ecosystems.

According to the tree disease concept of Manion (1981) with predisposing, inciting and contributing factors, we have to be aware that nitrogen deposition has mainly to be seen as predisposing. Those factors do per definition not directly cause tree diseases or injuries, but prepare the ground for certain inciting and contributing factors, that may influence tree health/performance. Two mechanisms related to N inputs have mainly to be considered:

- acidifying of soils with its negative consequences for the Ca/Al respectively BC/Al ratios in the soil solution and
- eutrophying effects on the ecosystem with nutrient imbalances (e.g. N/P ratio, e.g. Jonard et al. 2014, Veresoglou et al. 2014, Talkner et al. 2015), assumed higher susceptibility of trees against infestations by insects and/or fungi as well as changes of the mycorrhizas of forest trees (Cox et al. 2010a,b, Sus et al. 2014).

Again referring to Manion (1981), both processes have to be seen as predisposing and/or inciting factors within a complex cause-effect context of tree disease/performance. The findings of Hansen et al. (2007) suggest that a critical load for acidity based on a low molar Ca/Al or (Ca+Mg+K)/Al ratios in the soil solution might not simply enhance defoliation of forest trees.

In a recent study Vitale et al. (2014) analysed relationships between mean defoliation values of trees and a considerable number of predictors separately for the years 2001, 2006, and 2011. Classical linear correlation analyses confirmed for most investigated tree species a significant positive influence of stand age (for Norway spruce: r=0.387, common beech: r=0.160, pedunculate oak: r=0.132, Scots pine: r=0.087), which is comparable to this study. All other factors revealed correlation coefficients between predictor variables (air pollution variables: CL exceedances of N deposition, N-NHy, N-NOx all from EMEP estimates from the previous year), meteorological variables (mean precipitation, cumulated precipitation, mean temperature, n of days temperature > 20°C, n of days temperature < 0°C) on one side and defoliation on the other side, considerably varying between years and tree species.

In this context focussing on the use of medium-term defoliation values may stabilize results; however, one has to face the fact that defoliation is at least partly influenced by annually varying factors. The weather conditions of the current and of previous years have to be considered as one of the immediate drivers of crown condition. Such short-term influences should preferably be regarded within time-related approaches (time series analyses or more complex longitudinal approaches). After absorbing or filtering "noisy" short-term impacts, statistical modelling may reveal a more distinct picture on the medium- or long-term effects like acidifying and eutrophying of soils by N deposition. In this study year-to-year variation has widely been absorb by averaging over a time span of 6 years.

Random forest analysis (supplemented review)

Random Forest Analysis (RFA) conducted by Vitale et al. (2014) revealed importance values for a set of 16 predictors (cf. Figure 4-4) for each of the three years considered. The predictors can be summarized as those related to nitrogen deposition inclusive different variants of Critical Loads (CL) and CL exceedances, weather- and geographical related parameters, soil-related parameters, and finally stand age. Each of the five investigated tree species revealed a more or less characteristic profile of significance.

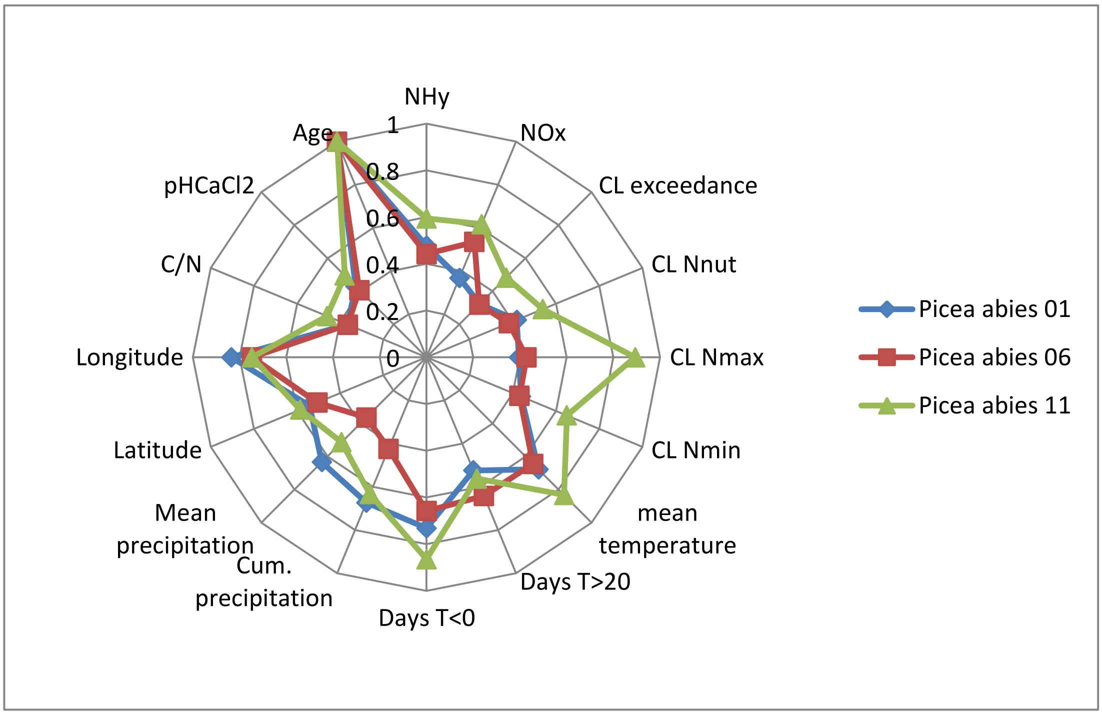

Figure 4-4. Yearly importance profiles for Norway spruce for the years 2001, 2006 and 2011 from RFA after Vitale et al. 2014, Tab. 7 - 9.

Age in Norway spruce was always the predominant factor determining defoliation fully corroborating the findings of this study. Only in one year, 2011, the maximum Critical Load for nitrogen CL N_{max} reached an importance value of almost 0.9 (Figure 4-4). In Scots pine (Figure 4-5) the number of frost days (n of days < 0°C) was in 2001 the most important predictor, while in 2006 and 2011 it was latitude. All other importance values hardly exceeded an importance value of 0.8.

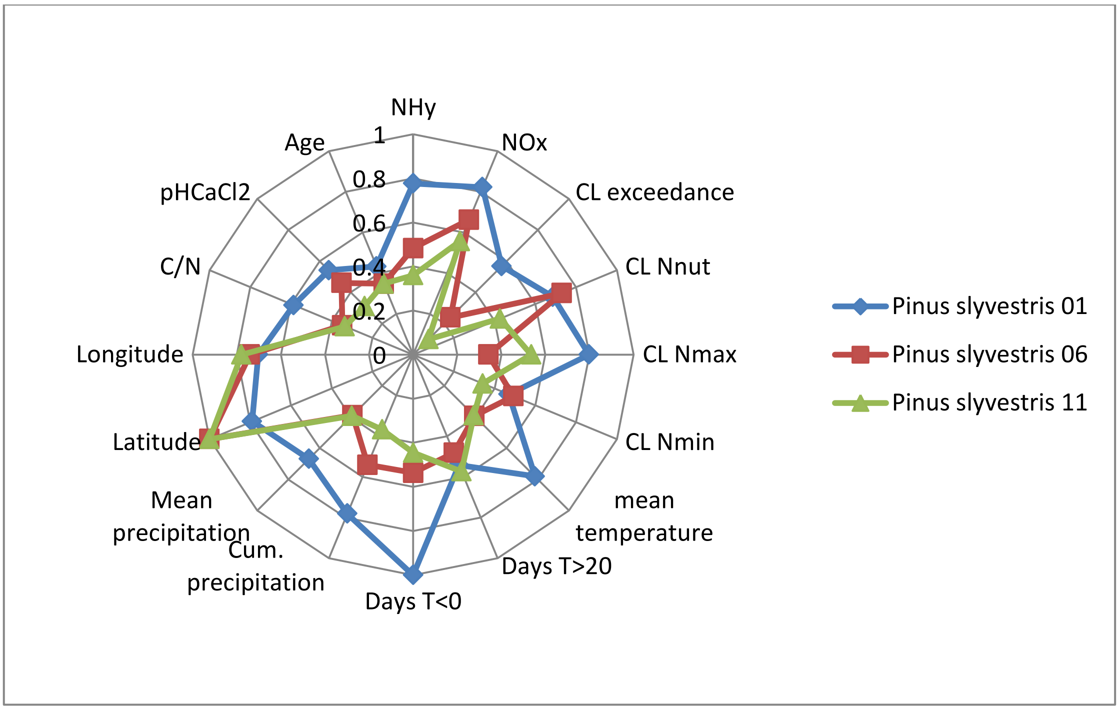

Figure 4-5. Yearly importance profiles for Scots pine for the years 2001, 2006 and 2011 from RFA after Vitale et al. (2014), Tab. 7 - 9.

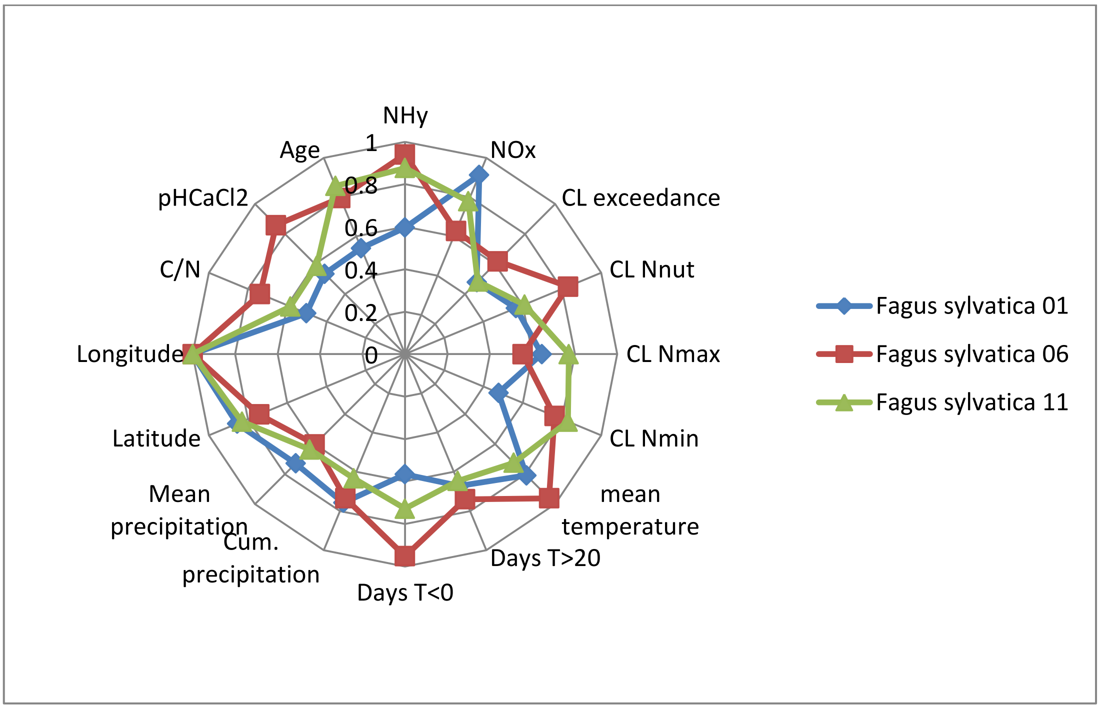

Figure 4-6. Importance profiles for common beech for the years 2001, 2006 and 2011 from RFA after Vitale et al. (2014), Tab. 7 - 9.

For common beech longitude is the most important predictor for all years. In 2001 oxidised N deposition was of higher importance while in 2006 reduced N was, together with frost days, of high relevance. For none of the species nitrogen depositions reached a continuous maximum or at least high importance values like it is the case for age in Norway spruce, however, in single years reduced or oxidised nitrogen deposition were in some species among the most important predictors. For holm oak (*Quercus ilex*), not reported here, in 2006 the highest importance was found for oxidised nitrogen, however, this was not the case in other years. Critical Load (CL) exceedances revealed no high importance in any of the investigated years, in any species.

Asking for the direction (negative or positive) of the relationships, classical correlation analysis has to be taken into account. Figure 4-7 displays the strength of the relationship between defoliation and reduced and/or oxidized nitrogen. The closest relationship was found for oxidized nitrogen for holm oak (*Quercus ilex*) in 2005/6 with r = 0.290 (corresponding an R^2 of 8.41). In 2005/2006 a significant correlation with nitrate deposition was found also in Scots pine and in Norway spruce. In the year 2001 defoliation was significantly related to nitrate deposition in beech and pedunculate oak, but not in the two later years. Deposition of ammonia is significantly correlated in beech, deciduous and evergreen oak as well as in pine, however, with the exception of Scots pine in different years. In Norway spruce even a significant negative relationship was found.

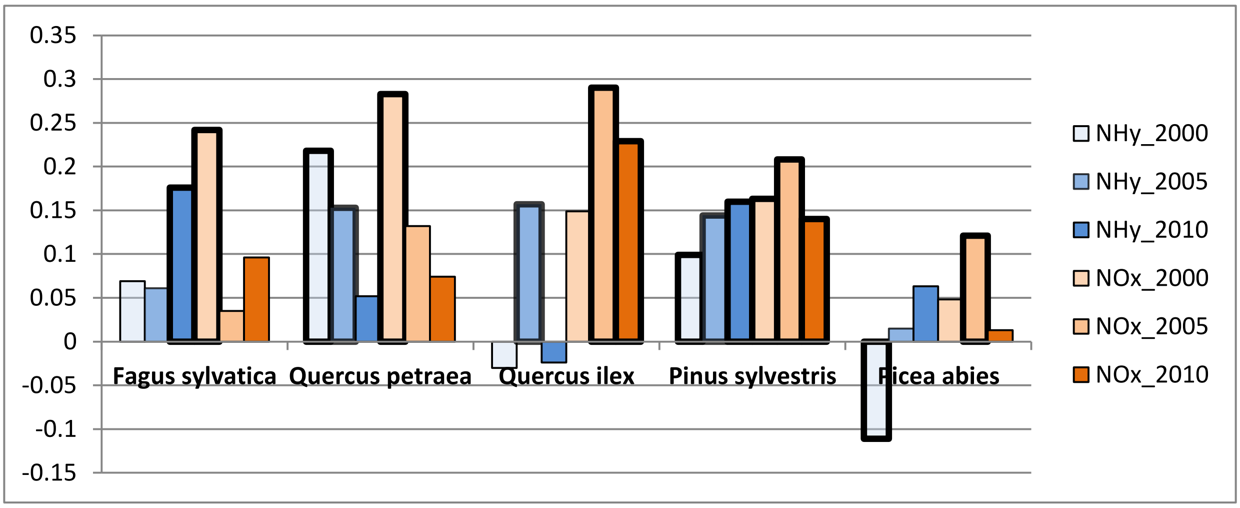

Figure 4-7. Species-specific profiles of Pearson correlation coefficients between crown defoliation in 2001, 2006 and 2011 (dependent variable) and atmospheric deposition of reduced (NH_y) or oxidized (NO_x) nitrogen derived from EMEP for in each case previous years 2000, 2005, and 2010 respectively. Bold edging indicates significance at $p < 0.05$.

4.4 Conclusions

It was found that defoliation reveals considerable dynamics from year to year with a varying predictor structure (cf. Seidling et al. 2007: Fig. 1 to 4). These species-specific dynamics cause temporally unstable results in correlation-, regression- and other statistical approaches with annual defoliation values as predictors. Only in the case of strong predictors like stand age in spruce – and less distinct in other species – comparatively constant relationships are found for each year or different time windows. More subtle influences like those caused by long-term nitrogen inputs on tree performance/health seem easily to be obscured by other influences. Such influences might best be detected by the use of medium- or even long-term average defoliation values or by the application of mixed model approaches with long-term time series involved. Another point complicating the evaluations are varying numbers and identities of plots. As defoliation seems to be strongly influenced by local or maximal regional drivers (see mean defoliation maps in Chapter 3), this variation causes a considerable amount of noise at higher spatial levels.

Further statistical modelling of tree performance (e.g. defoliation among other parameters like discoloration, biotic and abiotic damages, or mortality) has to be developed in order to get more consolidated models on tree performance. A meta-analysis of studies already performed may foster ideas about a comprehensive modelling on tree crown defoliation and on other parameters of tree condition.

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5 GROUND LEVEL OZONE CONCENTRATIONS AND EXPOSURES FROM 2000 TO 2013

Marcus Schaub, Matthias Haeni, Marco Ferretti, Elena Gottardini, and Vicent Calatayud

5.1 Introduction

Tropospheric ozone (O_3) concentrations from passive samplers have been monitored according to harmonized methodologies on ICP Forests intensive monitoring (Level II) sites, starting in the year 2000. The objective of measuring the concentrations of ozone is to contribute to a better understanding of the actual exposure of European forest ecosystems to air pollutants. In particular, we aim to (i) quantify ozone concentrations over the course of the vegetation period (April–September), (ii) estimate the related ozone exposures of forest ecosystems, and (iii) detect temporal and spatial trends across Europe.

5.2 Materials and methods

Passive sampling is the standard method for ozone concentration measurements adopted by ICP Forests (Schaub et al. 2010) and was verified by means of specific tests carried out in comparison with conventional monitors. It has been proven to be a valuable method at remote sites (e.g. Sanz et al. 2007; Gottardini et al. 2010; Hůnová et al. 2011) where the availability of electric power is often limited. By means of passive sampling, the determination of ambient air concentrations can be achieved at relatively low costs and with sufficient accuracy at the very forest site. Here, we analyzed the temporal and spatial trends for i) ozone concentrations (reported as volume:volume, in parts per billions, ppb) and ii) ozone exposure (reported as ozone Accumulated Over a Threshold of 40 ppb, AOT40) for the 2000-2013 period on Level II sites across Europe.

The results presented here are based on 29 356 measurement values from 203 sites and the following 20 countries: Austria (AUT), Belgium (BEL), Cyprus (CYP), Czech Republic (CZE), Estonia (EST), France (FRA), Germany (DEU), United Kingdom of Great Britain (GBR), Greece (GRC), Hungary (HUN), Ireland (IRL), Italy (ITA), Latvia (LVA), Luxembourg (LUX), Poland (POL), Romania (ROU), Slovakia (SVK), Slovenia (SVN), Spain (ESP) and Switzerland (CHE). In these countries, methods have been applied according to the ICP Forests Manual, Part XV on Monitoring Air Quality (Schaub et al., 2010). For quality assurance, only data measurements within the period from 1 April until 30 September that are higher than 5 ppb and lower than 140 ppb (plausibility check) have been considered (Table 5-1). As the exposure time of passive samplers differed from time to time and among sites, mean calculations were weighted according to exposure time. For seasonal means, only plots with a data coverage of 120-183 days have been considered. For trend analyses, only plots with a data coverage of at least four years have been considered where the Sen's slope method (Sen 1968) has been applied according to Bronaugh (2013). All statistical analyses have been conducted with R 3.1.1.

Table 5-1. Remaining number of measurement values, plots, site years, partners and countries after applying QA criteria.

QA criteria	No of values	No of plots	No of site years	No of partners	No of countries
Raw data	38 635	240	1 458	30	21
Filter NA and values before 2000	37 215	240	1 379	30	21
*u*g/m3 or ppb and min 5 ppb, max 140 ppb	35 043	222	1 285	29	21
Aggregate replicates	31 005	221	1 256	29	21
Only 1 April-30 Sept	31 005	221	1 256	29	21
120-184 days exposures period	29 356	203	1 040	28	20

5.3 Results

Season mean ozone concentrations ranged from 19 to 64 ppb with similar deviations from the median among the countries (Figure 5-1). A decreasing south-north gradient across Europe is apparent with the highest concentrations being measured in Italy, Southern Switzerland, the Czech Republic, Slovakia and Greece (Figure 5-2). In particular, the effects from the Alps and the Carpathian mountains become visible when applying an ordinary kriging between the plots. Ozone exposures in terms of AOT40 (EU Directive 2008/50 CE) have been assessed according to Ferretti et al. (2012). Mean AOT40 for 2000-2013 ranged from 2 to 67 ppm h (Figure 5-3). The AOT40 threshold of 5 ppm h set to protect forests from adverse ozone effects was exceeded on 18 out of 20 countries.

An overall trend analysis, including all April–September data from 20 countries and 2000-2013, reveals a significant decrease of 0.35 ppb per year ($n = 29'356$; $p = 0.000$) (Figure 5-4). When considering only sites with a data coverage of at least 4 years and 120 days (66% data coverage from 1 April until 30 September), site-specific trend analyses did not reveal any uniform pattern across Europe (Figure 5-5 and ANNEX III).

5.4 Discussion

ICP Forests ozone concentration data for the summer half-year and from in situ passive samplers reveal an overall decreasing trend of 0.35 ppb ozone per year over the period of 2000 to 2013. This slight decrease matches the findings in EMEP (2014) where 6-months modeled maximum values decreased by 0.1 - 0.5 ppb/year for the April-September period in most of Europe during 2000 to 2012. A number of studies of tropospheric ozone trends have been published in the last years, as summarized in Tørset et al. (2012) and Simpson et al. (2014). A fairly consistent picture has been found by Logan et al. (1999), Parrish et al. (2012), Derwent et al. (2013) and EEA (2014), with a flattening or even reduction in the ozone levels, most pronounced in summer. These studies also demonstrate the complexity of modeling ozone concentration trends, which underlines the great value of long-term air pollution measurements at the very forest site, also in view of model validation.

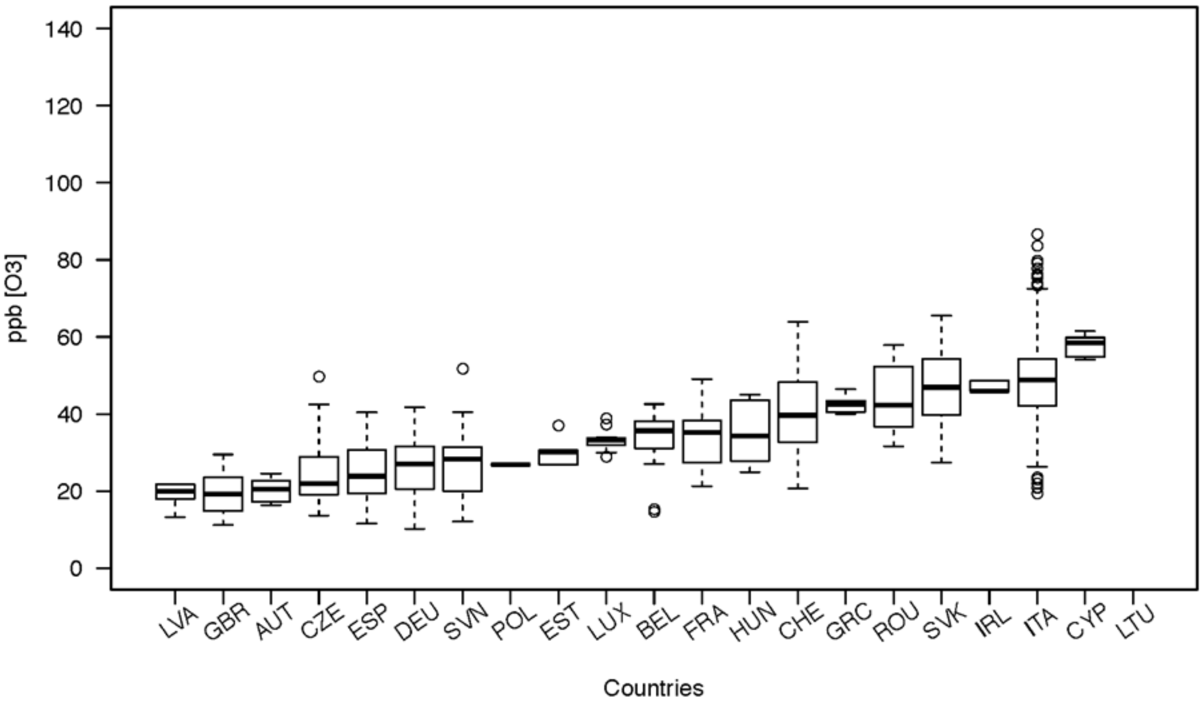

Figure 5-1. Box plots of April–September ozone concentration values from passive samplers processed data in 20 countries from 2000-2013 (n = 29 356).

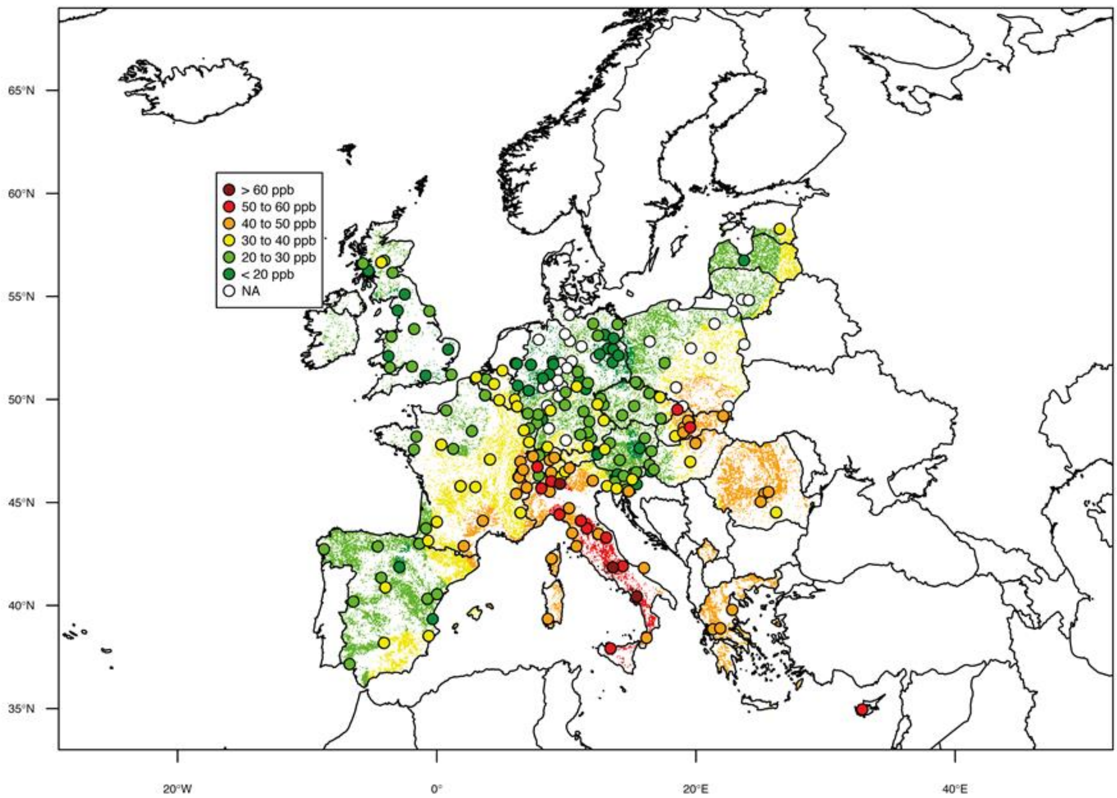

Figure 5-2. Spatial distribution of April–September mean ozone concentrations (ppb) from passive samplers on 203 plots and 20 countries during 2000-2013.

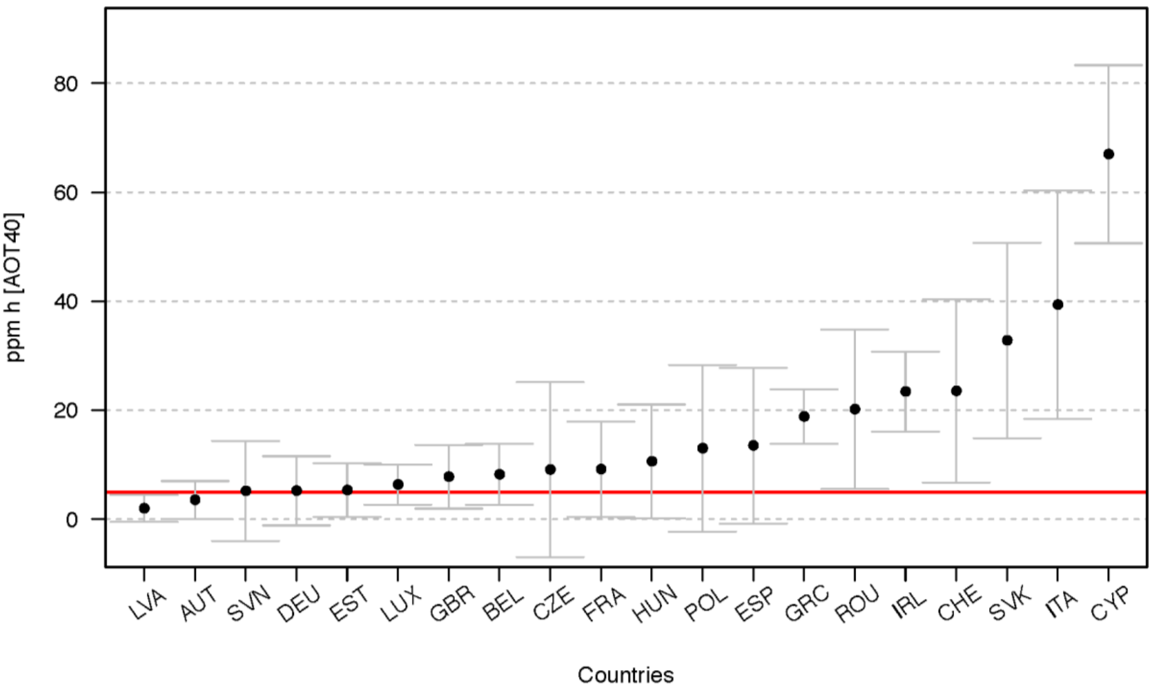

Figure 5-3. Mean AOT40 for 20 countries based on April–September passive ozone concentration values from 2000-2013.

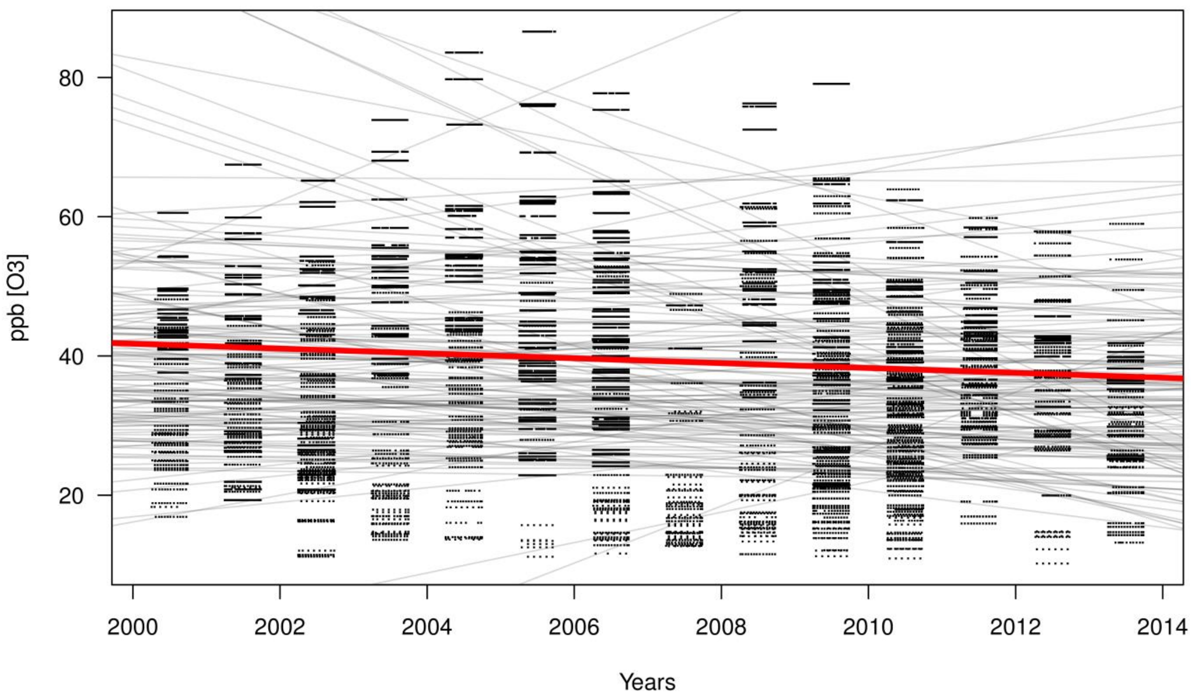

Figure 5-4. Scatter plot of April–September ozone concentration values (ppb) from passive samplers exposed in 20 countries from 2000 until 2013 with a significant decrease of 0.35 ppb/year (n=29 356; p=0.000).

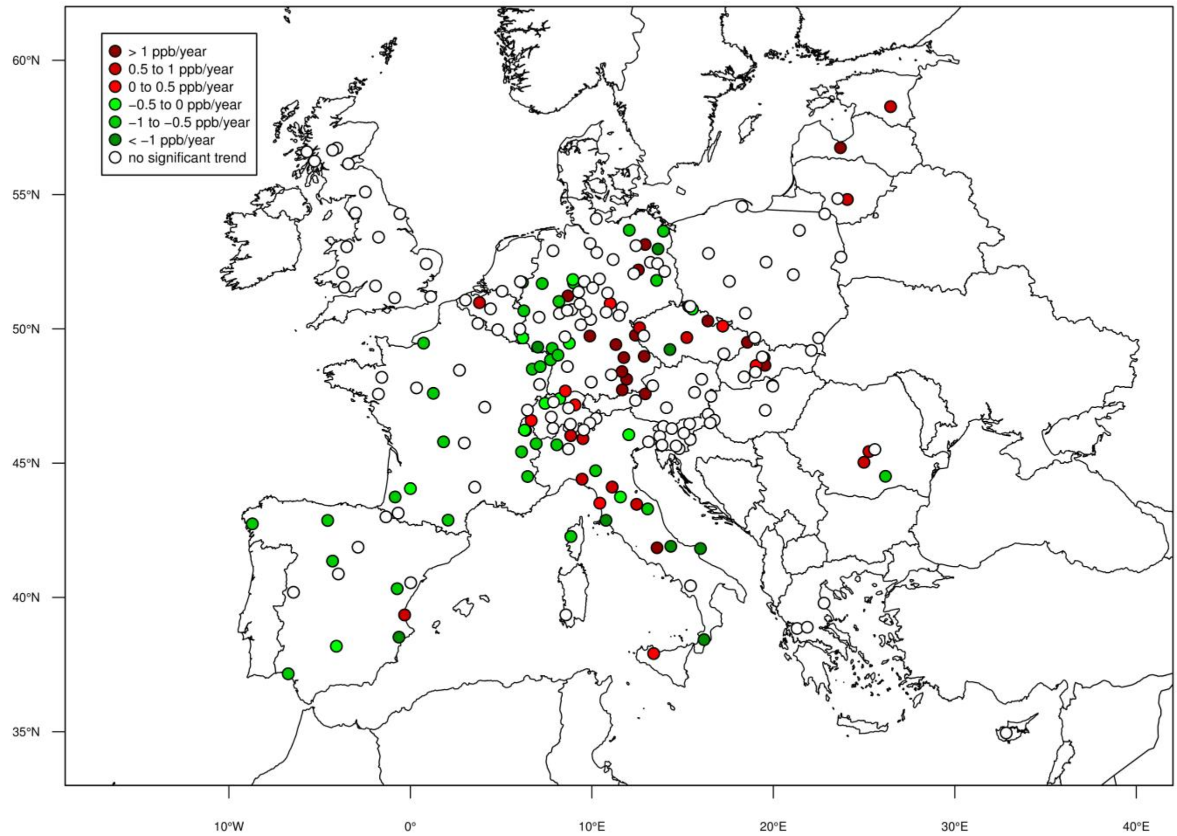

Figure 5-5. Spatial distribution of significant trends for weighted mean ozone concentrations on 203 sites with at least 4 years and 120 days per season (April–September) of data coverage from 2000-2013.

According to EEA (2014), in general the trend of the ozone concentration in summer is decreasing but increasing in winter (1380 monitoring stations in 29 countries). The ICP Forests database for ozone concentration comprises data from 240 forested sites and 21 countries. Data series from 37 sites, however, could not be considered for trend analyses as their data coverage was smaller than 4 years. It is therefore crucial to extend the data series of ozone concentrations on the already established sites.

Measurement of air pollutants in forests is important in order to evaluate the risk for vegetation and to document spatial patterns, temporal variability, and trends in areas not covered by conventional air quality monitoring networks. The presented results demonstrate that passive sampling represents a cost-effective and reliable method. Given the dense coverage of 240 forest monitoring sites from 21 countries where ozone measurement is carried out together with several other measurements on forest health, growth, nutrition, biodiversity and climate, the potential of the ICP Forests ozone data set is unique. Follow-up studies will focus on trend analyses based on more extended data series, and studies on the relationship between ozone, ozone-induced symptoms, tree health, and growth. Ozone data may be combined with extensive meteorological data series to be applied and tested for ozone flux modeling, in comparison with the respective EMEP outputs.

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6 SPATIAL VARIATION OF DEPOSITION IN EUROPE IN 2013

Uwe Fischer, Tanja Sanders

6.1 Introduction

The measurement of atmospheric deposition is one of the core activities of the intensive component (Level II) within the ICP Forests monitoring activities. It aims to quantify and qualify the acidifying, buffering, and eutrophying compounds deposited to forests. In surplus, long-term input of deposited substances can adversely affect whole ecosystems (e.g. de Vries et al. 2014). More sensitive compartments of the ecosystem, such as epiphytic lichens (e.g. Giordani et al. 2014) or vascular plants of the ground vegetation (e.g. Dirnböck et al. 2013) might respond earlier and to smaller inputs. However, it is also a major origin of macro- and micronutrients (Parker 1983) facilitating forest growth and development (e.g. Tipping et al. 2014).

Deposition sampling comprises the open field (bulk deposition) collection (Figure 6-1) and samplers installed under forest canopies (throughfall; Figure 6-2), the latter often complemented in beech and selected other broadleaves by the sampling of stemflow (Figure 6-3). On a number of plots wet-only samplers are additionally used. These open automatically at the onset of precipitation to avoid particulate and gaseous deposition which occurs during dry periods. Deposition sampling provides an important source of knowledge on the amount and type of anthropogenic or naturally emitted airborne substances.

Figure 6-1. Adjacent to the forest stand open field precipitation is measured which is not influenced by the exchange processes within the tree canopies.

Figure 6-2. Throughfall collectors are distributed across the plot. Throughfall is composed of wet, dry, and occult deposition. However, the exchange process within the tree canopy leads to a depletion of those ions taken up by the trees and an enrichment at the same time due to canopy leaching.

Figure 6-3. Stemflow collectors are permanently installed on the stems to collect any run-off from the branches and stem (here on *Fagus sylvatica* L.). Stemflow is, compared to throughfall, enriched in ions washed off the bark.

This chapter documents the most recent measurements of throughfall and – where available – stemflow deposition on Level II plots. Medium-term trends of SO_4-S, NO_3-N, and NH_4-N in bulk and throughfall deposition have – based on longer time series of sulphur (S), nitrogen (N) and base cations – recently been evaluated by Waldner et al. (2014). Ozone, a gaseous pollutant secondarily formed from precursor substances such as carbon monoxide (CO), methane (CH_4), and nitrogen oxides (NO_x), is measured mainly by passive samplers within an extra survey (Ambient Air Quality) and is separately discussed in Chapter 5.

6.2 Materials and methods

Throughfall measurements according to the ICP Forests Manual (Clarke et al. 2010) for the year 2013 were available for 237 plots across Europe. Deposition rates of nitrogen (derived from nitrate and ammonium), sulphur (derived from sulphate), calcium, and magnesium were calculated by multiplying the yearly amount of precipitation with the volume weighted mean concentration of the respective element. Contrasting to former reports stemflow was included for beech and other broadleaved stands, playing a significant role in the overall flux calculations.

Criterions for the exclusion of individual plot results were: (1) temporarily incomplete measurement periods, (2) insufficient data quality, or (3) implausible data. Only plots with a temporal coverage of at least 321 days which corresponds to a coverage of 90% per year were used. Individual element fluxes were excluded when data on more than 56 days were missing due to quality aspects. Plots with extreme outliers in annual deposition rates were tested by quality checks (ion charge balance and conductivity check, Clarke et al. 2010). When 70% of the individual data sets of any plot exceeded the quality thresholds the plot was excluded.

Sea salt, being one important component of dry deposition, is constituted mainly of sulphate, calcium, and magnesium. Therefore the deposition of these elements in coastal areas may originate from sea salt rather than from anthropogenic sources. To ensure the comparability between the plots, a sea salt correction (ICP Modelling and Mapping 2004) was applied according to the following formulas:

$$SO_4\text{-}S_{\text{non sea salt}} = SO_4\text{-}S_{\text{total}} - (Na_{\text{total}} * 0.120)$$
$$Ca_{\text{non sea salt}} = Ca_{\text{total}} - (Na_{\text{total}} * 0.043)$$
$$Mg_{\text{non sea salt}} = Mg_{\text{total}} - (Na_{\text{total}} * 0.228)$$

In some parts of southern and south-east Europe, however, significant quantities of sodium (Na) in the atmosphere can also originate from other sources than sea salt resulting in underestimated sea salt corrected fluxes (ICP Modelling and Mapping 2004).

6.3 Results

Central Europe is characterised by the highest **NH_4-N** deposition fluxes with fewer occurrences of high fluxes on plots in Spain, Belgium, Hungary, Romania and northern Italy (Figure 6-4). The highest input with 17.6 kg N ha^{-1} a^{-1} is found on a spruce plot located in southern Germany. Very low deposition below 1 kg N ha^{-1} a^{-1} is mainly found in northern Europe but can also be found in a few other regions.

In general, the spatial pattern for **NO_3-N** deposition fluxes is similar to NH_4 -N (Figure 6-5). The lowest deposition is found in northern Europe, with all plots in Finland below 1 kg N ha^{-1} a^{-1}. Contrary to NH_4 -N, the highest input of NO_3 -N is found in Spain. Deposition fluxes higher than 20 kg N ha^{-1} a^{-1} only occur on Spanish plots with a maximum value of 20.9 kg N ha^{-1} a^{-1}.

High deposition of **SO_4-S** is observed on plots in Belgium and the ridges of the low mountain range extending from Germany to the Czech Republic (Figure 6-6). Higher values are also found on plots in Hungary, Spain, and Greece. However, divergent to individual plots located in the United Kingdom and

Romania, their fluxes are either only marginally affected by seaborne deposition or the anthropogenic part is high enough to remain within the highest range. After sea salt correction all plots in northern Europe and the United Kingdom are in the lowest range (Figure 6-7). The plots in France, Italy, Switzerland, and most of the plots in Germany and northern Europe are marked by low deposition. The plot with the highest value of non-sea salt corrected sulphur (26.7 kg S ha^{-1} a^{-1}) is located in Spain, whereas sea salt corrected sulphur is highest on a plot in the Czech Republic (25.8 kg S ha^{-1} a^{-1}).

Calcium is an important element neutralizing acidifying inputs primarily derived from SO_2- and NO_Y-emissions. The highest values of calcium inputs (Figure 6-8) are found on plots in the Mediterranean basin and in regions of Eastern Europe. Plots with more than 30 kg Ca ha^{-1} a^{-1} are located in Cyprus, Greece, and Spain. By far the highest value with 64.2 kg Ca ha^{-1} a^{-1} is found on a plot in Spain. Very low calcium inputs below 2 kg Ca ha^{-1} a^{-1} prevail in most of northern Europe. Only few changes to the lower ranges can be realised by applying sea salt correction (for example in Norway, Denmark, and the United Kingdom, Figure 6-9). This is due to the small amount of calcium in sea salt spray.

In contrast to calcium, the deposition of **magnesium** is clearly seaborne. This results in significant lower fluxes after applying the sea salt correction. Without sea salt correction plots within the highest range are distributed over all countries (Figure 6-10). Plots with fluxes higher than 10 kg Mg ha^{-1} a^{-1} are only located in Spain with a maximum value of 18.5 kg Mg ha^{-1} a^{-1}. After sea salt correction only 6% of all plots are in the highest range, none of them in northern Europe (Figure 6-11). The maximum value of 6.5 kg Mg ha^{-1} a^{-1} is found in Germany, but this input is the result of an accidental wind-blown dispersal of liming components (pers. communication with the country). Considering the effect of liming, the highest flux is found in Romania (5.9 kg Mg ha^{-1} a^{-1}); other plots with higher inputs are located in Spain and Hungary.

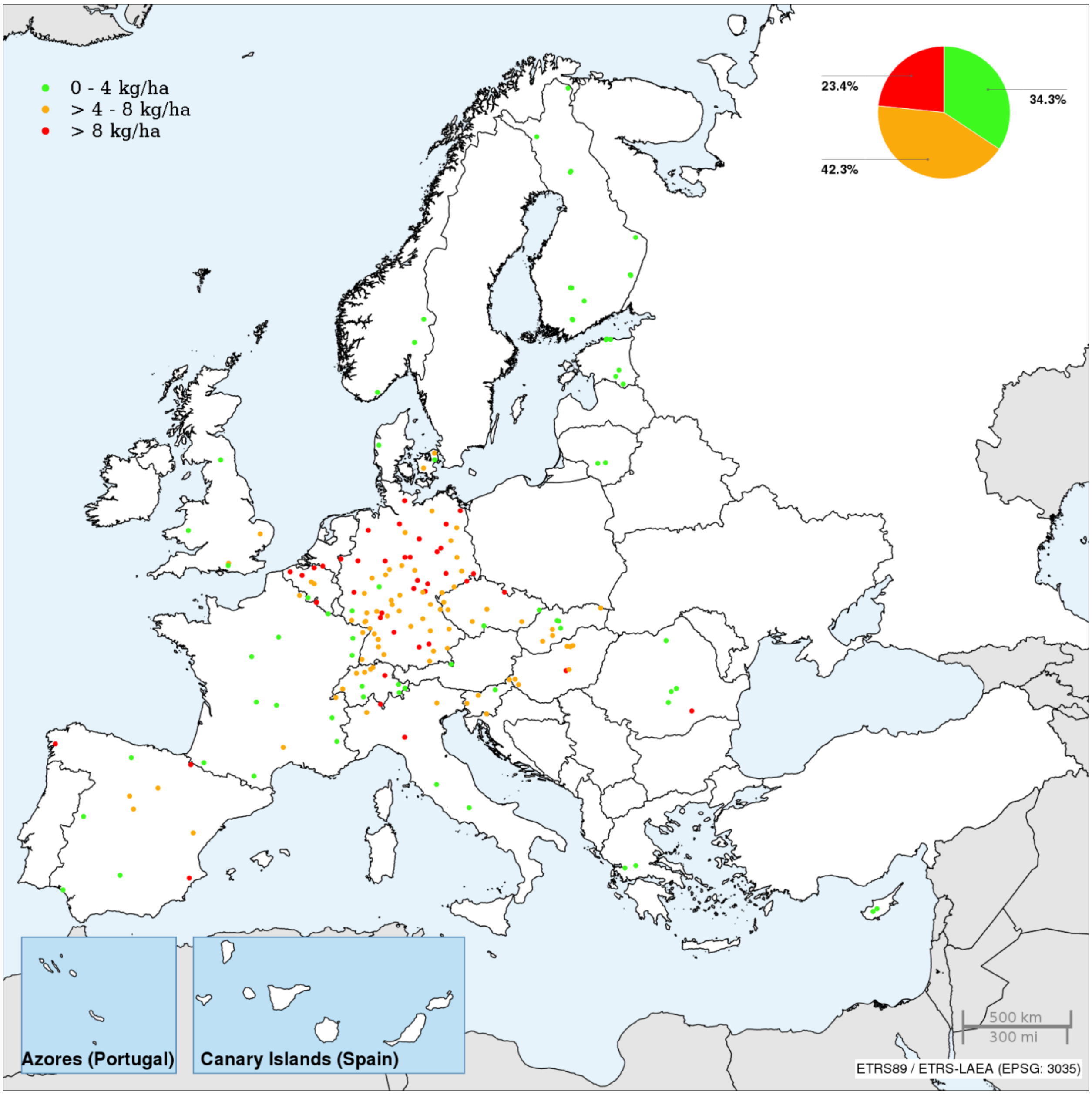

Figure 6-4. Throughfall (and stemflow where applicable) deposition of ammonium nitrogen (NH_4-N) in European forests in 2013.

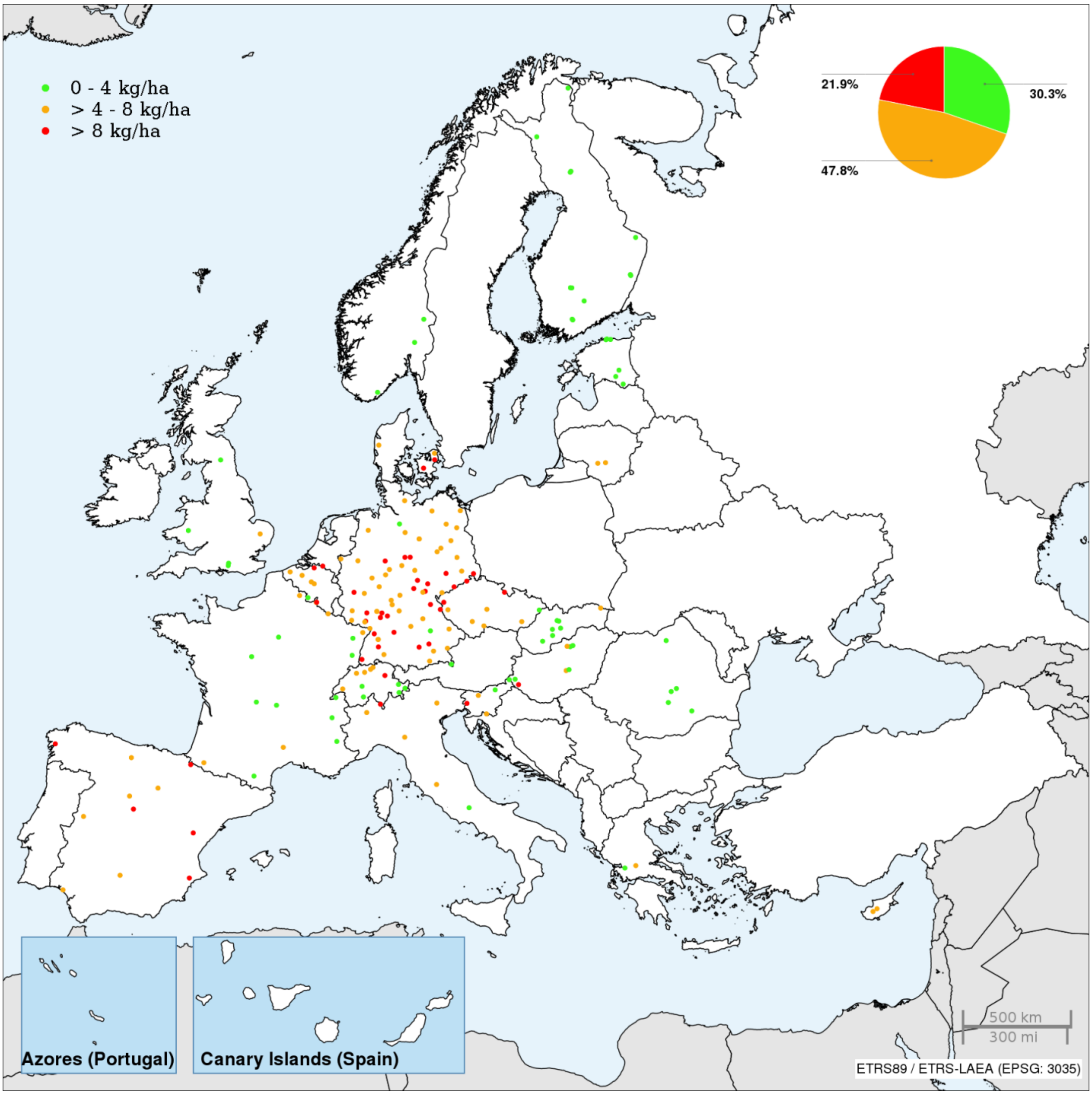

Figure 6-5. Throughfall (and stemflow where applicable) deposition of nitrate nitrogen (NO_3-N) in European forests in 2013.

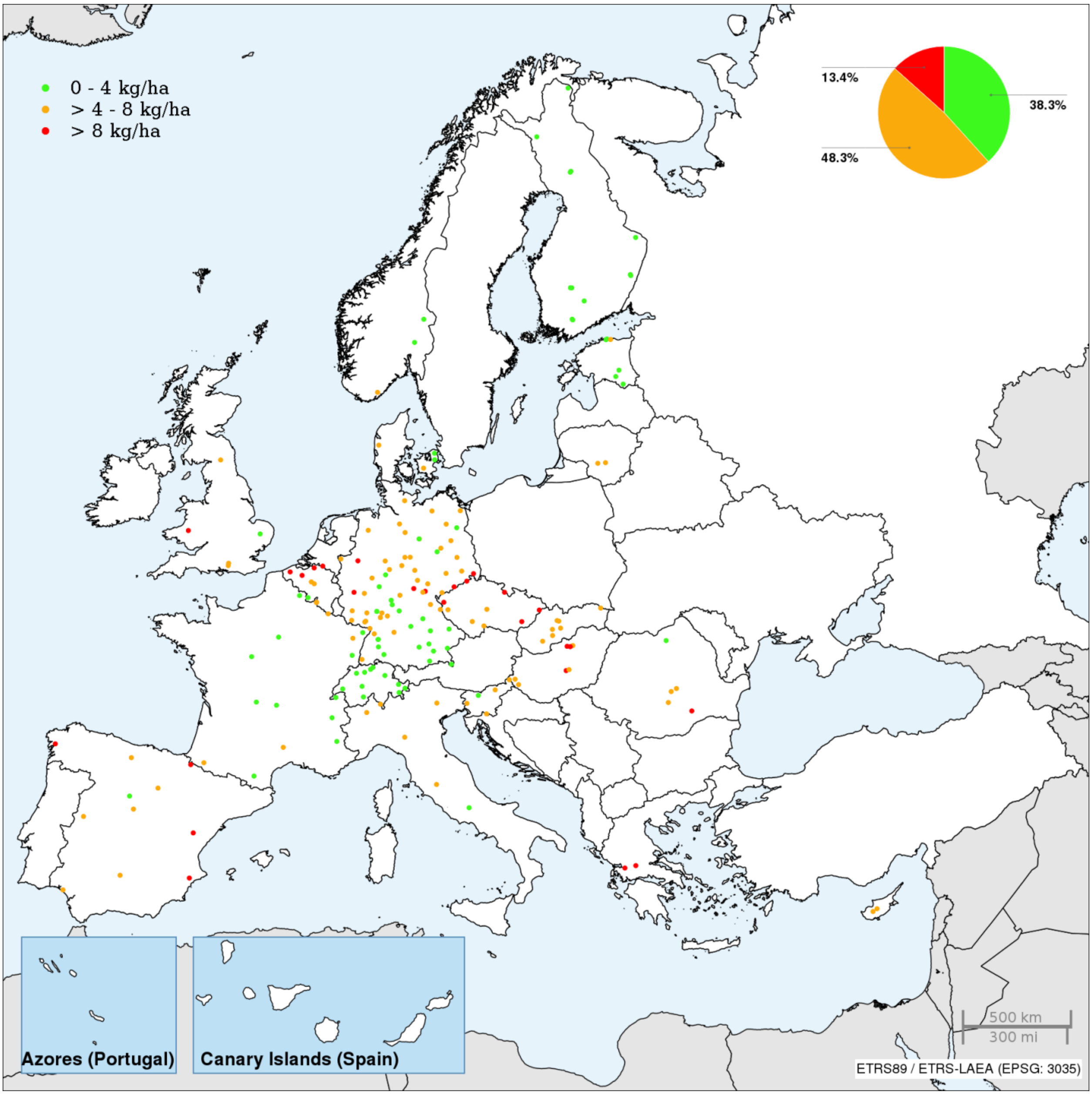

Figure 6-6. Throughfall (and stemflow where applicable) deposition of sulphate sulphur (SO_4-S) in European forests in 2013 without sea salt correction.

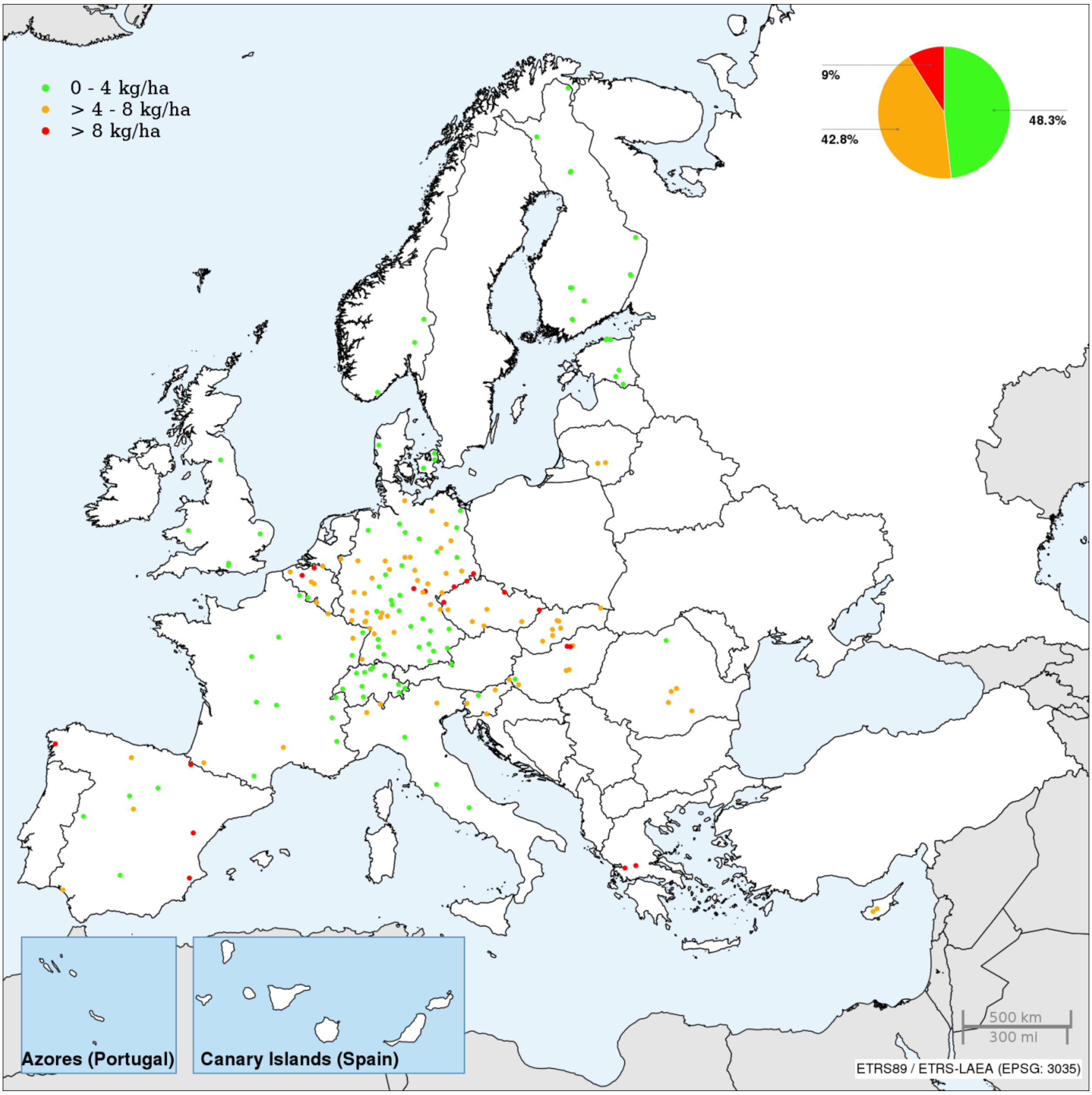

Figure 6-7. Sea salt corrected throughfall (and stemflow where applicable) deposition of sulphate sulphur (SO_4-S) in European forests in 2013.

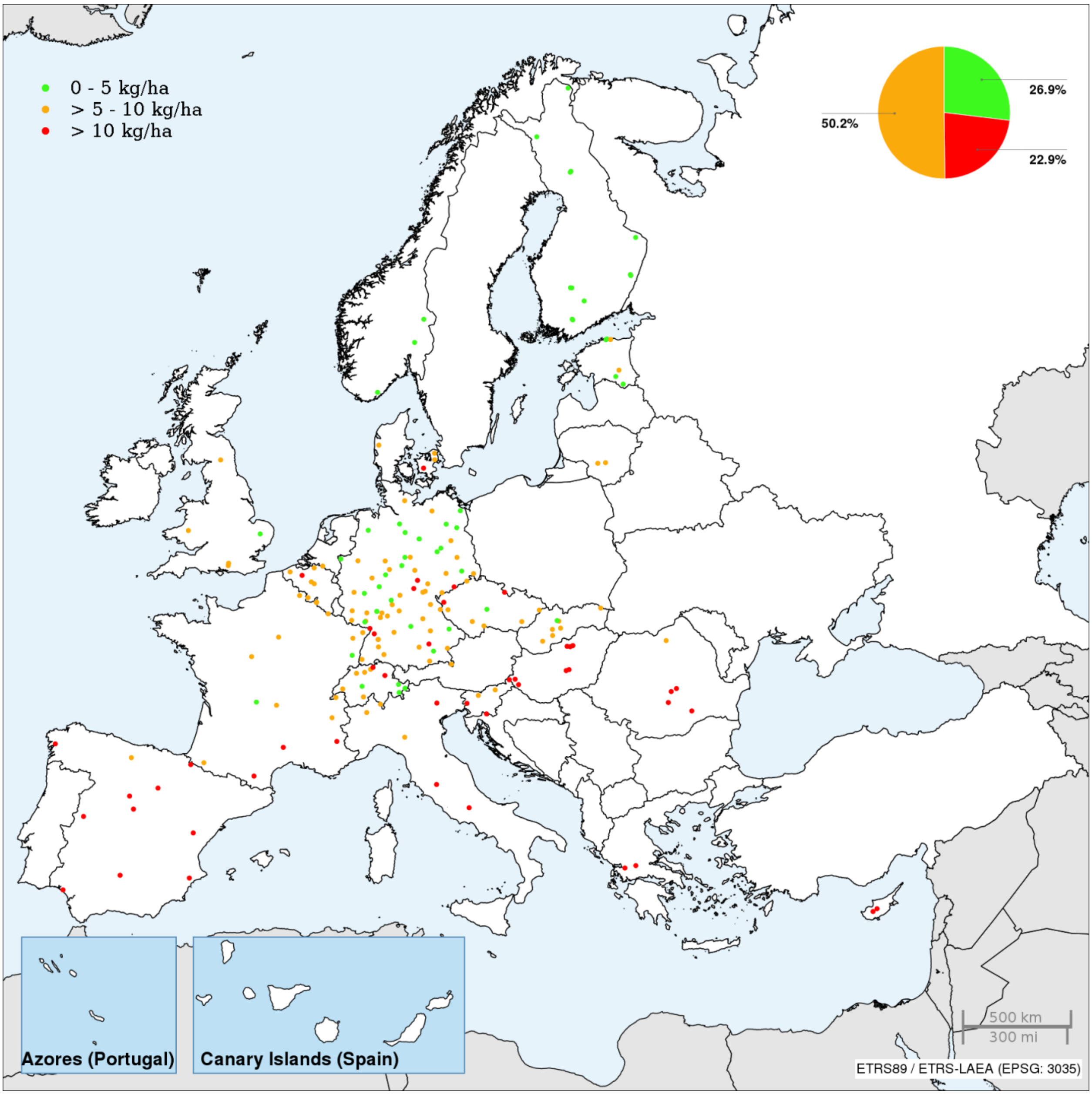

Figure 6-8. Throughfall (and stemflow where applicable) deposition of calcium in European forests in 2013 without sea salt correction.

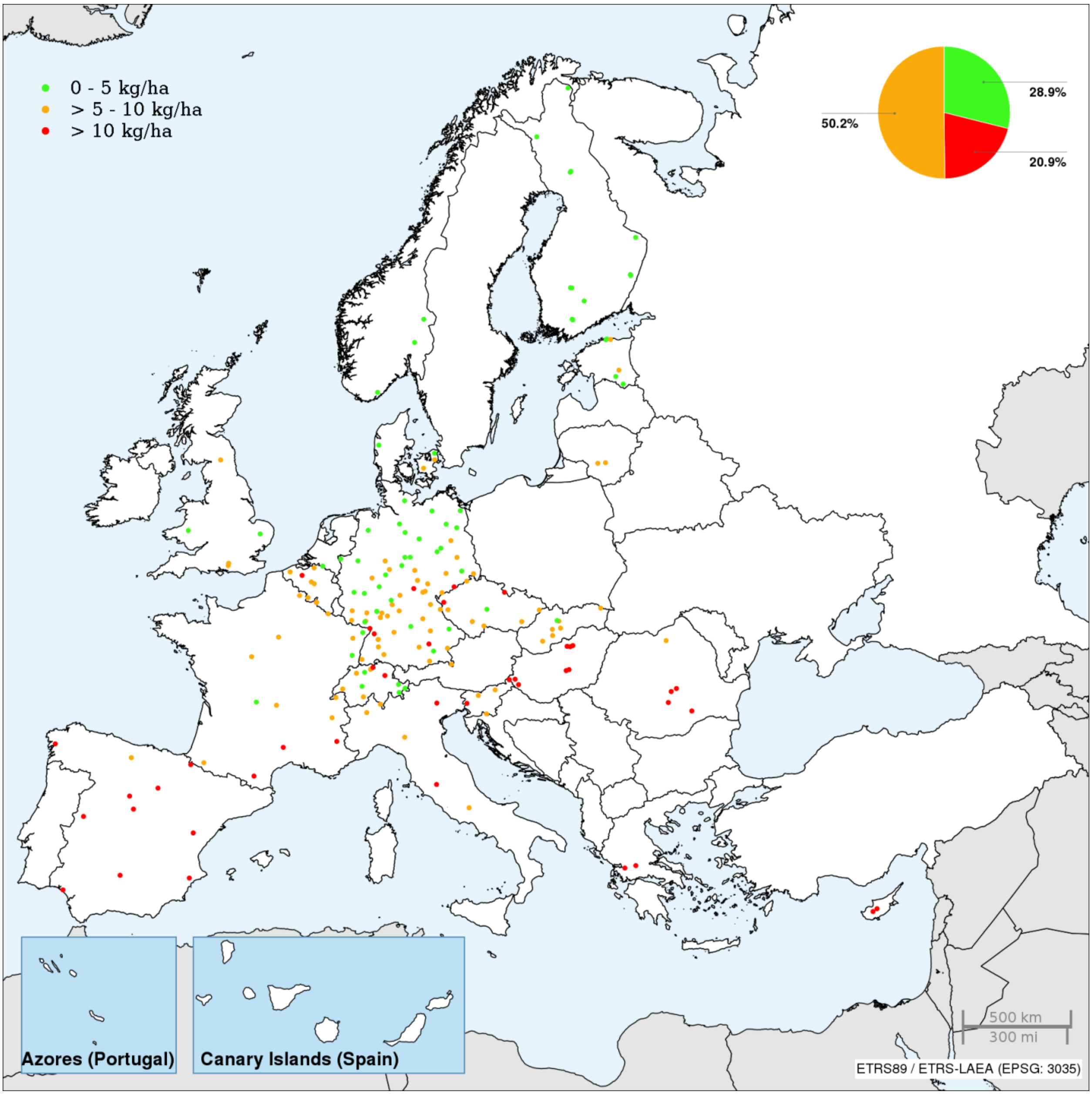

Figure 6-9. Sea salt corrected throughfall (and stemflow where applicable) deposition of calcium in European forests in 2013.

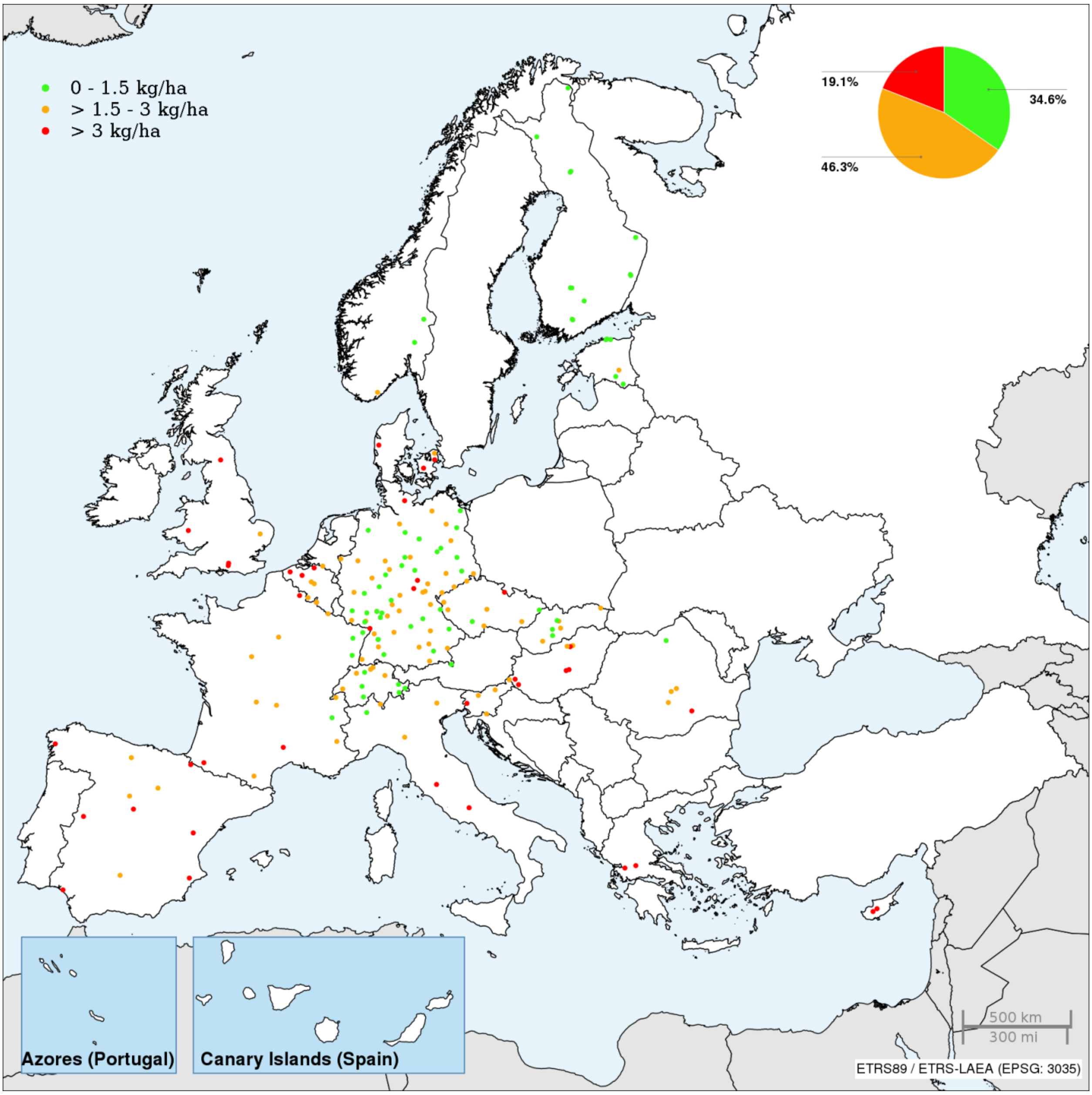

Figure 6-10. Throughfall (and stemflow where applicable) deposition of magnesium in European forests in 2013 without sea salt correction.

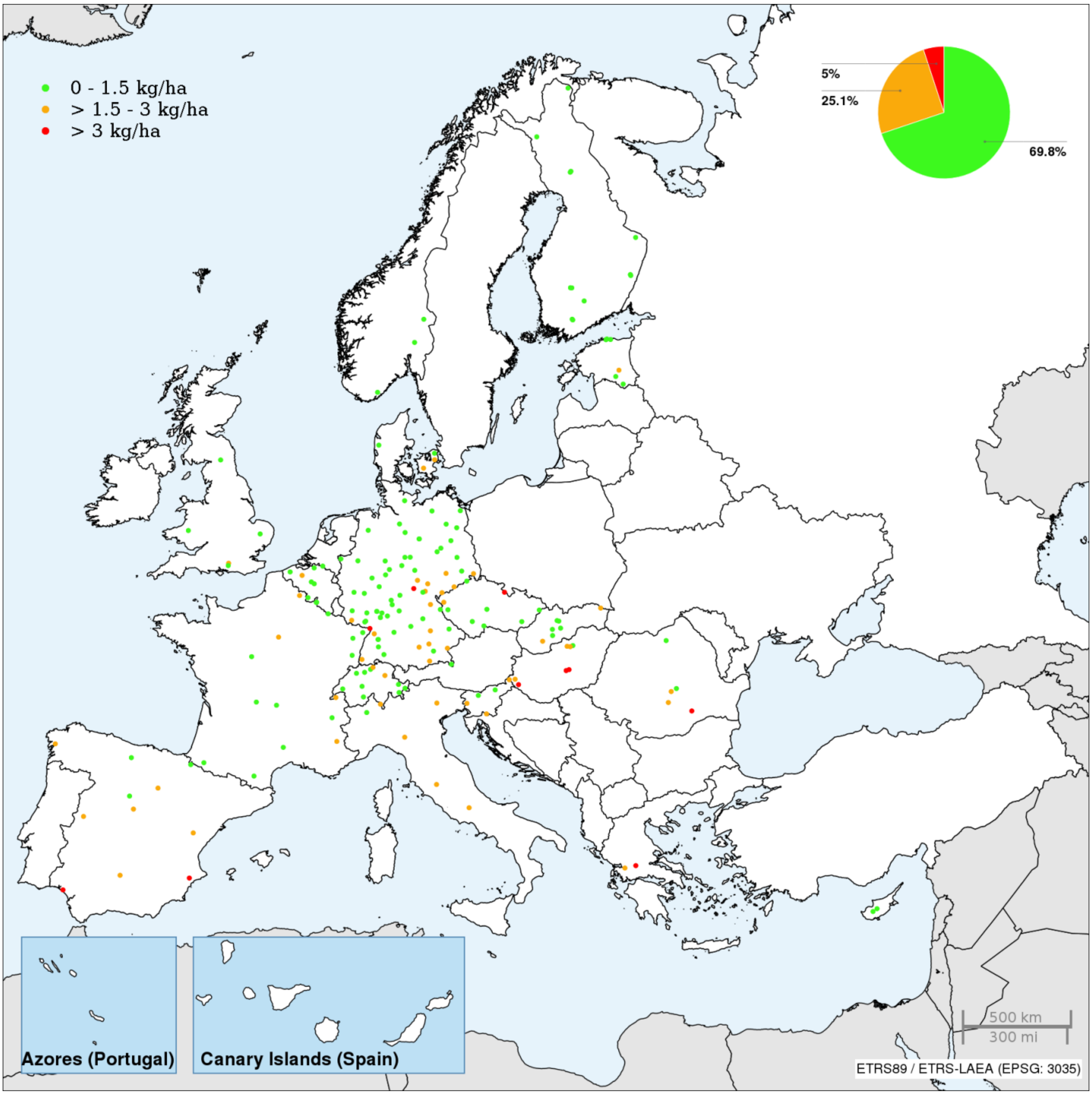

Figure 6-11. Sea salt corrected throughfall (and stemflow where applicable) deposition of magnesium in European forests in 2013.

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7 REVIEW OF THE 3RD ICP FORESTS SCIENTIFIC CONFERENCE, ATHENS, 26-28 MAY 2014

The 3rd ICP Forests Scientific Conference *Impact of nitrogen deposition and ozone on the climate change mitigation potential and sustainability of European forests* was held in Athens, Greece, on May 26–28, 2014.

Since 1985, the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) operating under the UNECE Convention on Long-range Transboundary Air Pollution has collected data on forest condition (health, growth, biodiversity, nutrition) and environmental factors (air chemistry, deposition chemistry, meteorology) across Europe. This data is used by a large number of scientists working on different policy relevant research questions. The 3rd ICP Forests Scientific Conference specifically addressed the role of environmental stressors, in particular tropospheric ozone and nitrogen deposition, on the ability of European forests to sequester carbon and on the long-term sustainability of their health, productivity, diversity, and ability to provide ecosystem services.

The conference was aimed at scientists and experts from ICP Forests in particular and the UNECE ICPs community in general including the ICP on Integrated Monitoring, ICP Vegetation, ICP Modelling and Mapping, ICP Waters, their partners and respective stakeholders, as well as interested scientists and experts from related fields. Researchers engaged in successful projects, evaluations and modelling exercises based on ICP Forests data, or working in co-operation with ICP Forests were encouraged to present and discuss their work and results.

Main topics

- Past, present, and predicted impact of nitrogen deposition and ozone (and their combination) on growth, carbon sequestration, biodiversity, and the full set of ecosystem services provided by forests
- Past, present, and predicted impact of other biotic and abiotic stressors and their interactions

Targets

- Policy and outreach: The conference provided an overview on the latest research in policy relevant fields, such as the impact of air pollution on the climate change mitigation potential of European forests, as well as on nutrient and water cycles, biodiversity, and forest health and vitality.
- Scientific platform: A comprehensive platform was offered for scientists working on the subjects to discuss scientific questions and share experiences.
- Data provider and user interface: The conference linked monitoring experts, researchers and modellers. Data users benefited from background information related to the data sets. Data providers profited from an advanced insight into latest statistical applications based on "their" data.

7.1 LIST OF PRESENTATIONS AT SCIENTIFIC CONFERENCE

The following list includes all presentations given at the 3rd ICP Forests Scientific Conference. All conference abstracts are available on the ICP Forests website[1] in *Seidling W, Ferretti M, Michel A, Michopoulos P, editors (2014) Impact of nitrogen deposition and ozone on the climate change mitigation potential and sustainability of European forests*.

Buriánek V, Novotný R, Hellebrandová K, Šrámek V. **Ground vegetation as an important factor in the biodiversity of forest ecosystems and its evaluation in regard to nitrogen deposition.**

Ferretti M, Amici V, Bertini G, Carnicelli S, Calderisi M, Fabbio G, Farina A, Marchetto A, Pompei E. **Improved SFM Criterion 2 indicators for Italian forests?**

Ferretti M, Bertini G, Calderisi M, Fabbio G, Marchetto A. **Changes in management, climate and nitrogen deposition explain recent deviation from expected growth in mature spruce and beech forests in Italy.**

Fischer R. **Keynote: Tracing atmospheric inputs throughout the nitrogen cycle – review from a European forest monitoring perspective.**

Fleck S, Ahrends B, Evers J, Riek W, Meesenburg H, Paar U. **Supraregional estimation of the base saturation of forest soils: a generalized linear model based on Level I data.**

Galić Z, Orlović S, Klašnja B, Stojanović D, Novčić Z. **Soil moisture and water quality monitoring in Quercetum petraeae stands.**

Gottardini E, Cristofolini F, Cristofori A, Ferretti M. **Do ecosystem services have a biological cost? Ozone and climate regulation by Norway spruce forests along an Alpine altitudinal transect in Trentino, northern Italy.**

Hayes F, Harmens H, Mills G. 2014. **Impacts of ozone and nitrogen on silver birch.**

Jakovljević T, Marchetto A, Bertini G, Potočić N, Seletković I. **Comparing two permanent plots in Croatia and Italy with different levels of nitrogen deposition.**

Johnson J, Cummins T, Aherne J. **Assessing the implications of atmospheric deposition and harvest-residue removal on nitrogen budgets in Irish forests.**

Levanič T, Potočić N, Seletković I, Jazbec A, Ugarković D, Indir K. **Comparison of various descriptors of tree vitality – a case study of a beech intensive monitoring plot in Croatia.**

Merilä P, Helmisaari H-S, Hilli S, Lindroos A-J, Nieminen TM, Nöjd P, Rautio P, Salemaa M, Ukonmaanaho L. **Above- and belowground carbon stocks in coniferous boreal forests in Finland.**

Michopoulos P, Bourletsikas A, Kaoukis K, Karetsos G, Tsagari C, Daskalakou E. **Nitrogen in a fir stand. Is there any risk of saturation?**

Nicolas M, Pascaud A, Croisé L, Brommundt J, Mettier R, Ammann L, Sauvage S, Mansat A, Probst A. **Estimations of N deposition impacts may be improved through deposition maps: comparing two independent approaches for mapping bulk deposition at French scale.**

Novotný R, Šrámek V, Lachmanová Z, Neudertová Hellebrandová K. **Forest tree nutrition and soil chemistry development on the intensive monitoring plots in the Czech Republic.**

Popa I, Badea O, Neagu S. **Influence of climate on tree health evaluated by defoliation in the Level I network (Romania).**

Proietti C, Anav A, Fischer R, Vitale M, Cionni I, De Marco A. **The impacts of climate change and air pollution on forest health condition.**

Salemaa M, Ilvesniemi H, Kryshen A, Lukina N, Merilä P. Oksanen J. **Ecological gradients of forest vegetation in eastern Fennoscandia.**

[1] http://www.icp-forests.net/page/icp-forests-other-publications

Schaub M, Buriánek V, Ferretti M, Gottardini E, Hayes F, Hůnová I, Jakovljević T, Karlsson PE, De Marco A, Miroslava M, Nicolas M, Novotny R, Pavlendova H, Rajkovic S, Silaghi D, Werner W, Calatayud V. **Keynote: Ozone concentration, exposure and foliar injury in European forests – a ten-year study on permanent monitoring plots.**

Sharps K, Mills G, Bacon J, Harmens H, Hayes F et al. **New ICP Vegetation smartphone app for recording incidences of ozone injury on vegetation.**

Šrámek V, Borůvka L, Fadrhonosová V, Drábek O, Jurkovská L, Tejnecký V, Novotný R. **Aluminium species in forest soils and their potential toxicity to Norway spruce and European beech stands in the Czech Republic.**

Tabaković-Tošić M. **The condition of tree crowns at the sample plots of Level I – reliable or unreliable indicators of the vitality of main conifer species in Serbian forests.**

Tabaković-Tošić M, Nevenić R, Češljar G. **Bark beetle outbreak in spruce communities on a sample plot (Level II) in the mountain Kopaonik in the period 2010-2013.**

Vanguelova E, Pitman R. **Impacts of N input on forests and forest soil biogeochemistry in Great Britain.**

Verstraeten A, Neirynck J, Cools N, Roskams P, Hens M. **Recovery from N saturation in Flemish forests under high N deposition.**

8 LIST OF ALL ICP FORESTS PROJECTS IN 2014

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 of ICP Forests thereby consenting 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 ICP Forests projects that were ongoing in 2014. In 2014, seven new projects started (s. ID number with *). All past and present ICP Forests data uses are listed on the ICP Forests website[2].

ID	Name of Applicant	Institution	Project Title	External/ Internal
7	Eileen Thorsos	Duke University	Effect of temperate and boreal tree traits on soil carbon stocks	External
8	Ivan Janssens	University of Antwerp	Study of the factors influencing DOC leaching from terrestrial ecosystems	External
12*	Arta Bārdule	Latvian State Forest Research Institute (Silava)	Information of analysis of needles and leaves and litterfall	External
16	Marcos Fernandez Martinez	Global Ecology Unit	Reproductive productivity and masting behaviour in multiple tree species from the European forests	External
17	Nils Hempelmann	Climate Service Center	Development of climate indices for Tree Species Distribution	External
21	Prof. Edward Tipping	Lancaster Environment Centre	Development, parameterisation and testing of the N14CPW model	External
23	Dr. Gerald Kändler	Forest Research Institute (FVA)	FunDivEUROPE (FUNctional significance of forest bioDIVersity in EUROPA - EU project number 265171)	External
24	Pedro Rodriguez Veiga	GMES Initial Operations - Network for Earth Observation Research Training (GIONET)	Global forest biomass mapping: integrating regional allometry, profiling LiDAR, and satellite imaging	External
25	Dr. Nicole Augustin	University of Bath	Spatial-temporal modelling of defoliation in European forests	External
26	Dr. Kirsti Ashworth	Institute for Meteorology and Climate Research, Atmospheric Environmental Research	LPJ-MLC: In-canopy ozone processes	External
27	Dr. David Cameron	Centre for Ecology and Hydrology	Environmental change impacts on the C- and N-cycle of European forests	External
30	Volker Mues	Institute for World Forestry	FORMIT, Grant Agreement No. 311970 under the 7th EU-Framework Programme "FORest management strategies to enhance the MITigation potential of European forests"	Internal
33	Bernhard Ahrens	Max Planck Institute for Biogeochemistry	Between-Site Variability of Turnover and Transport Parameters Calibrated with a Vertically Explicit SOM Model	External

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

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

ID	Name of Applicant	Institution	Project Title	External/ Internal
36	J. Julio Camarero	National Research Council of Spain (CSIC)	Mistletoe effects on tree growth and forest dieback	External
42	Franziska Schrodt	Max Planck Institute for Biogeochemistry	iTRY-Europe - Integrating trait observations and macroecological data across Europe	External
43	Dr. Sietse van der Linde	Imperial College London	What are the large-scale diversity, distribution and fate of Europe's forest mycorrhiza?	External
44	Peter Waldner	Swiss Federal Institute for Forest, Snow and Landscape Research (WSL)	Seed - Carbon allocation to fruits and seeds in European forests as a function of climate, atmospheric deposition and nutrient supply	External
45	Wesley Tack	Avia-GIS	EDENext - Biology and control of vector-borne infections in Europe	External
46	Sarah Mubareka	European Commission Joint Research Centre	Contribution to the Forest Information System for Europe: European Forestry Dynamics Model	External
47	Martina Roß-Nickoll	RWTH Aachen University, Institute for Environmental Research	Quantifying the effect of sustainable forest management: A case study in the Eiffel region	External
48	Susanne Jochner	Technische Universität München	Atmosphere - biosphere interactions	External
50	Gertjan Reinds	Alterra Wageningen UR	PROBS (PRobability Occurence of Plant Species)	External
51	Dr. Christine Rösch	Karlsruhe Institute of Technology	BioenNW - Delivering Local Bioenergy for North-West Europe	External
52	Dr. Steffen Taeger, Dr. Karl Mellert	Bavarian State Institute of Forestry (LWF)	MARGINS - Specification of threshold values for cultivation of tree species facing climate change using marginal occurrences	External
54*	Dr. Elke Keup-Thiel, Dr. Juliane Otto	Climate Service Center 2.0	Calculation of climate changes impacts indicators for tree species distribution	External
55*	Ivan Janssen	University of Antwerp	Effects of phosphorus limitations on Life, Earth system and Society (IMBALANCE-P)	External
56*	Elisabeth Graf Pannatier	Swiss Federal Institute for Forest, Snow and Landscape Research (WSL)	Temporal trends of dissolved organic carbon (DOC) in soil solution in European forests	Internal
58*	Henning Meesenburg	NW-FVA / EP Soil and Soil Solution	Temporal trends of dissolved organic carbon (DOC) in soil solution in European forests	Internal
59*	Gherardo Chirici	Università degli Studi di Firenze	Upscaling spatially explicit estimation of biophysical variables with remote sensing (UPSPEX)	Internal
60	Sebastiaan Luyssaert, Yuan Yan	Commissariat à l'énergie atomique et aux énergies alternatives (CEA)	ERC-DOFOCO: Do forests cool the Earth? Reconciling sustained productivity and minimum climate response with portfolios of contrasting forest management strategies	External
63	Jesus San-Miguel	European Commission - Joint Research Centre	Distribution maps of forest tree species	External
67	Dr. Stefan Fleck	Northwest German Forest Research Institute (NW-FVA)	LAI-estimations with allometry, litter collections, and optical measurements in relation to stand properties and microclimate	Internal
70*	Dr. Stefan Fleck	Northwest-German Forest Research Station	Preparation of the 2nd version of the aggregated soil database of the Level II second soil survey	Internal

9 LIST OF ALL SCIENTIFIC ICP FORESTS PUBLICATIONS IN 2014

The following list includes all online and in print publications in scientific journals in 2014 that contain data that either originate from the ICP Forests database or from ICP Forests plots and have been reported to the ICP Forests Programme Co-ordinating Centre. For a list of all ICP Forests publications, please refer to the ICP Forests website[1].

Baumgarten M, Weis W, Kühn A, May K, Matyssek R (2014) **Forest transpiration – targeted through xylem sap flux assessment versus hydrological modeling.** Europ J For Res 133(4): 677-690. doi: 10.1007/s10342-014-0796-4.

Braun S, Schindler C, Rihm B (2014) **Growth losses in Swiss forests caused by ozone: Epidemiological data analysis of stem increment of *Fagus sylvatica* L. and *Picea abies* Karst.** Environ Pollut 192: 129-138. doi: 10.1016/j.envpol.2014.05.016.

Camino-Serrano M, Gielen B, Luyssaert S, Ciais P, Vicca S, Guenet B, De Vos B, Cools N, Ahrens B, Arain MA, Borken W, Clarke N, Clarkson B, Cummins T, Don A, Graf Pannatier E, Laudon H, Moore T, Nieminen TM, Nilsson MB, Peichl M, Schwendenmann L, Siemens J, Janssens I (2014) **Linking variability in soil solution dissolved organic carbon to climate, soil type, and vegetation type.** Global Biogeochem Cy 28(5): 497-509. doi: 10.1002/2013GB004726.

Churakova O, Eugster W, Zielis S, Cherubini P, Etzold S, Saurer M, Siegwolf R, Buchmann N (2014) **Increasing relevance of spring temperatures for Norway spruce trees in Davos, Switzerland, after the 1950s.** Trees 28(1): 183-191. doi: 10.1007/s00468-013-0941-6.

Cools N, Vesterdal L, De Vos B, Vanguelova E, Hansen K (2014) **Tree species is the major factor explaining C:N ratios in European forest soils.** Forest Ecol Manag 311: 3-16. doi: 10.1016/j.foreco.2013.06.047.

De la Cruz AC, Gil PM, Fernández-Cancio Á, Minaya M, Navarro-Cerrillo RM, Sá¡nchez-Salguero P, Grau JM (2014) **Defoliation triggered by climate induced effects in Spanish ICP Forests monitoring plots.** Forest Ecol Manag 331: 245-255. doi: 10.1016/j.foreco.2014.08.010.

De Marco A, Proietti C, Cionni I, Fischer R, Screpanti A, Vitale M (2014) **Future impacts of nitrogen deposition and climate change scenarios on forest crown defoliation.** Environ Pollut 194: 171-180. doi: 10.1016/j.envpol.2014.07.027.

De Vries W, Dobbertin MH, Solberg S, van Dobben HF, Schaub M (2014) **Impacts of acid deposition, ozone exposure and weather conditions on forest ecosystems in Europe: an overview.** Plant Soil: 380(1-2): 1-45. doi: 10.1007/s11104-014-2056-2.

Didion M, Frey B, Rogiers N, Thürig E (2014) **Validating tree litter decomposition in the Yasso07 carbon model.** Ecol Model 291: 58-68. doi: 10.1016/j.ecolmodel.2014.07.028.

Eickenscheidt N,Wellbrock N (2014) **Consistency of defoliation data of the national training courses for the forest condition survey in Germany from 1992 to 2012.** Environ Monit Assess 186: 257-275. doi: 10.1007/s10661-013-3372-3.

Etzold S, Waldner P, Thimonier A, Schmitt M, Dobbertin M (2014) **Tree growth in Swiss forests between 1995 and 2010 in relation to climate and stand conditions: Recent disturbances matter.** Forest Ecol Manag: 311(1): 41-55. doi: 10.1016/j.foreco.2013.05.040.

Ferretti M, Marchetto A, Arisci S, Bussotti F, Calderisi M, Carnicelli S, Cecchini G, Fabbio G, Bertini G, Matteucci G, de Cinti B, Salvati L, Pompei E (2014) **On the tracks of nitrogen deposition effects on temperate forests at their southern European range – an observational study from Italy.** Glob Change Biol 20(11): 3423-3438. doi: 10.1111/gcb.12552.

Ferretti M, Calderisi M, Marchetto A, Waldner P, Thimonier A, Jonard M, Cools N, Rautio P, Clarke N, Hansen K, Merilä P, Potočić N (2014) **Variables related to nitrogen deposition improve defoliation models for European forests.** Ann For Sci. doi: 10.1007/s13595-014-0445-6.

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

Ferretti M, Nicolas M, Bacaro G, Brunialti G, Calderisi M, Croisé L, Frati L, Lanier M, Maccherini S, Santi E, Ulrich E (2014) **Plot-scale modelling to detect size, extent, and correlates of changes in tree defoliation in French high forests.** Forest Ecol Manag 311: 56-69. doi: 10.1016/j.foreco.2013.05.009.

Fischer R, Scheuschner T, Schlutow A, Granke O, Mues V, Olschofsky K, Nagel H-D (2014) **Effects evaluation and risk assessment of air pollutants deposition at European monitoring sites of the ICP Forests.** In: Air Pollution Modelling and its Application. Proceedings of the 32nd NATO/SPS International Technical Meeting on Air Pollution and its Application 2012 (eds Steyn DG, Builtjes PJH), Utrecht, The Netherlands. doi: 10.1007/978-94-007-5577-2_15.

Giordani P, Calatayud V, Stofer S, Seidling W, Granke O, Fischer R (2014) **Detecting the nitrogen critical loads on European forests by means of epiphytic lichens. A signal-to-noise evaluation.** Forest Ecol Manag 311: 29-40. doi: 10.1016/j.foreco.2013.05.048.

Gottardini E, Cristofori A, Cristofolini F, Nali C, Pellegrini E, Bussotti F, Ferretti M (2014) **Chlorophyll-related indicators are linked to visible ozone symptoms: Evidence from a field study in native Viburnum lantana L. plants in northern Italy.** Ecol Indic 39: 65-74. doi: 10.1016/j.ecolind.2013.11.021.

Harmens H, Schnyder E, Thöni L, Cooper DM, Mills G, Leblond S, Mohr K, Poikolainen J, Santamaria J, Skudnik M, Zechmeister HG, Lindroos A-J, Hanus-Illnar A (2014) **Relationship between site-specific nitrogen concentrations in mosses and measured wet bulk atmospheric nitrogen deposition across Europe.** Environ Pollut 194: 50-59. doi: 10.1016/j.envpol.2014.07.016.

Hůnová I, Maznová J, Kurfürst P (2014) **Trends in atmospheric deposition fluxes of sulphur and nitrogen in Czech forests.** Environ Pollut 184: 668-675. doi: 10.1016/j.envpol.2013.05.013.

Jonard M, Fürst A, Verstraeten A, Thimonier A, Timmermann V, Potočić N, Waldner P, Benham S, Hansen K, Merilä P, Ponette Q, de la Cruz A, Roskams P, Nicolas M, Croisé L, Ingerslev M, Matteucci G, Decinti B, Bascietto M, Rautio P (2014) **Tree mineral nutrition is deteriorating in Europe.** Glob Change Biol. doi: 10.1111/gcb.12657.

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Neuner S, Albrecht A, Cullmann D, Engels F, Griess VC, Hahn W A, Hanewinkel M, Härtl F, Kölling C, Staupendahl K, Knoke T (2014) **Survival of Norway spruce remains higher in mixed stands under a dryer and warmer climate.** Glob Change Biol 21(2): 935-946. doi: 10.1111/gcb.12751.

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Skudnik M, Jeran Z, Batič F, Simončič P, Lojen S, Kastelec D (2014) **Influence of canopy drip on the indicative N, S and δ15N content in moss *Hypnum cupressiforme*.** Environ Pollut 190: 27-35. doi: 10.1016/j.envpol.2014.03.016.

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Veresoglou SD, Peñuelas J, Fischer R, Rautio P, Sardans J, Merilä P, Tabakovic-Tosic M, Rillig MC (2014) **Exploring continental-scale stand health – N Environ Pollut : P ratio relationships for European forests.** New Phytol 202(2): 422-430. doi: 10.1111/nph.12665.

Verstraeten A, De Vos B, Neirynck J, Roskams P, Hens M (2014) **Impact of air-borne or canopy-derived dissolved organic carbon (DOC) on forest soil solution DOC in Flanders, Belgium.** Atmos Environ 83: 155-165. doi: 10.1016/j.atmosenv.2013.10.058.

Vitale M, Proietti C, Cionni I, Fischer R, De Marco A (2014) **Random forests analysis: a useful tool for defining the relative importance of environmental conditions on crown defoliation.** Water Air Soil Pollut 225: 1992. doi: 10.1007/s11270-014-1992-z.

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10 NATIONAL REPORTS ON THE 2014 NATIONAL CROWN CONDITION SURVEYS

Twenty-five countries have submitted numerical results of their 2014 national crown condition surveys and an additional written national report. All written reports have been slightly edited primarily for consistency and are presented below; the numerical results are compiled in ANNEX II. The responsibility for the national reports and numerical results 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 ANNEX IV-3.

Please note that in the national surveys the study design and number of plots can differ from the required 16 x 16 km grid used for the transnational analysis of tree crown condition and damage causes in Chapter 3 (Level I). Comparisons between the results of the national surveys of individual countries in this chapter may, therefore, be limited. Missing values in the tables and figures in ANNEX II may indicate that data for certain years are missing or they indicate substantial differences in the samples, e.g. due to changes in the grid or the participation of a new country, as described in this chapter. For an explanation of the defoliation and discolouration classes used, please refer to Table 3-4 in Chapter 3.

10.1 Andorra

The assessment of crown condition in Andorra in 2014 was conducted on 11 plots on the national 4x4 km grid and included 264 trees, 119 *Pinus sylvestris*, 137 *Pinus uncinata*, 5 *Betula pendula* and 3 *Abies alba*.

Results for 2014 showed an improving tendency in forest condition, as registered since 2009, with just a slow decrease in 2012. For all species, most of the trees were classified in defoliation and discolouration classes 0 and 1. Favourable climatic conditions in 2014 including high precipitation during the growing season could explain the good condition of the forests in terms of defoliation and discolouration.

With regard to defoliation, the large majority of trees of all species were classified as not defoliated (values ranging from 74.8% to 100%). Only *Betula pendula* presented severely defoliated trees (20%) although the significance of this result is low due to the reduced number of individuals of birch surveyed, all being on the same plot.

Results for discolouration were variable depending on the species. The majority of *Pinus sylvestris* trees (70.6%) were classified as not discoloured whereas the individuals of *Pinus uncinata* were mainly classified as slightly discoloured (53.5%) and not discoloured (45.3%). A large number of trees of the species *Abies alba* and *Betula pendula* were classified as not discoloured (66.7% and 80%, respectively), even though this last result is not very significant due to the reduced number of firs and birches surveyed.

The assessment of damage causes showed many causal agents, like wind, snow, falling trees, biological agents such as the fungus *Cronartium flaccidum*, rots and lightning scars, which overall affected 5.3% of the sampled trees.

10.2 Belgium

Belgium/Flanders

The regional survey was conducted on 71 plots of the 4x4 km grid, with a total of 1661 sample trees. The main species were *Pinus sylvestris* (556 trees), *Quercus robur* (389 trees), *P. nigra* subsp. *laricio* (n=171), *Fagus sylvatica* (n=118), *Q. rubra* (n=93) and *Populus sp*. (n=60). A sample with 'other broadleaves' (n=262) consisted of species like *Alnus glutinosa*, *Castanea sativa*, *Quercus petraea*, *Fraxinus excelsior*, *Acer pseudoplatanus* and *Betula pendula.* There were almost no other coniferous species in the survey (n=12).

21.1% of the sample trees showed more than 25% defoliation. The overall average defoliation was 23.4%. Severe defoliation was observed on 1.6% of the trees. There was a high mortality rate (1.2%) due to 14 dead trees in one plot. In this plot dieback of *Alnus glutinosa* was caused by *Phytophthora alni* and very wet site conditions. 9% of the trees were in defoliation class 0 and 69.9% in defoliation class 1. The condition of conifers was better compared to broadleaves. 27.3% of the broadleaved trees and 13.3% of the conifers were in defoliation classes 2-4. The mean defoliation was 25.3% in broadleaves and 21.1% in conifers.

Q. robur, *Populus sp*., *P. nigra* and the trees in the category 'other broadleaves' showed the worst crown condition. The share of damaged trees was 32.4% in *Q. robur*, 21.7% in *Populus sp*. and 35.5% in the 'other broadleaves'. The most affected coniferous species was *P. nigra* with 26.9% of the trees showing more than 25% defoliation. *P. sylvestris*, *Q. rubra* and *Fagus sylvatica* revealed a better condition compared to the other species, with 9.2%, 7.5% and 11% of the trees being damaged.

On 11.4% of the trees, more than 10% of the crown showed discoloration. Severe insect damage, with more than 10% leaf loss caused by defoliators, was assessed on 8.9% of the trees. The extent was high in *Q. robur*, with 33.2% trees with severe insect damage and 28.8% of the trees with remarkable yellow or brown discolouration. Oak trees suffered from a combination of insect attacks and mildew infestation (*Microsphaera alphitoides*). Defoliation was attributed to caterpillars from different moth species. Similar to the previous year, mortality of *Q. robur* was observed in several plots.

Forest condition slightly deteriorated. The proportion of common sample trees in defoliation classes 2-4 increased compared to 2013 with 2.6 percentage points and the mean defoliation with 0.9 percentage points. *P. nigra* was the only species with a lower share of damaged trees and a lower mean defoliation. The increase in defoliation was significant for *F. sylvatica*, *Q. rubra* and the sample with 'other broadleaves'.

Fructification was present in *Fagus sylvatica* but less abundant compared to the previous survey. In *Q. robur* and *Fraxinus excelsior*, fructification was almost absent. Fallen and broken trees were detected in several plots and 0.5% of the sample trees were removed for this reason.

A special survey on the condition of *Fraxinus excelsior* revealed a high level of damage. 430 trees were selected on 10 existing Level I plots and 43 additional plots from other monitoring surveys. The mean defoliation score was 33.5% and 39.1% of the *F. excelsior* trees were considered as being damaged. Symptoms of damage caused by the fungus *Hymenoscyphus pseudoalbidus* were noticed in eight Level I plots. In total, 83.7% of the trees showed symptoms of '*Chalara* ash dieback'. Most frequent symptoms on diseased trees were discolouration of the leaves and dead shoots, twigs or branches.

Belgium/Wallonia

The survey in 2014 concerned 373 trees on 42 plots, on a regional systematic grid that has been adapted since 2010 to fit with the national forest inventory. As the sample is different from the former data presented for Wallonia, results cannot be compared in long-term vision. However, it is possible to identify trends for the last four years.

Since 2010 spruce showed a slightly decreasing defoliation and reached 35% in 2014. After undergoing severe damage in the early 2000s (*Scolytidae* and drought), mean defoliation in beech again decreased and reached 33% in 2013. However, it has increased in 2014 because of severe damage of *Orchestes fagi*. Oaks showed their maximum defoliation in 2012 (50%). This could be explained by massive attacks of defoliating insects and *Oidium* in 2011 and 2012 (which also influenced the observation of trees and perhaps leading to bias). However, since 2013 this unusual value decreased to a mean defoliation of 18% for sessile oak and 34% for English oak in 2014.

10.3 Bulgaria

The forest condition survey in 2014 was conducted on 159 Level I permanent plots of the national systematic grid and included a total of 5439 sample trees. Observations on the defoliation, biotic and other stress factors were carried out on sample plots on the coniferous tree species *Pinus sylvestris* L., *Pinus nigra* Arn., *Picea abies* (L*.)* Karst. and *Abies alba* Mill., as well as on the deciduous tree species *Fagus sylvatica* L., *Quercus frainetto* Ten., *Quercus petraea* (Matt.) Liebl., *Quercus cerris* L., *Quercus rubra* L., *Tilia platyphillos* Scop. and *Carpinus betulus* L. The total number of the assessed coniferous sample trees is 2336 and the number of the deciduous trees is 3103.

The predominant part of the observed trees (74%) has a degree of defoliation up to 25%. The highest percentage of trees (21.7%) in the defoliation classes 2-4 show an average degree of defoliation (class 2). Compared to the results of the studies carried out in 2013, the percentage of healthy trees has increased by 8.7%, and the percentage of trees that are only slightly affected by defoliation trees has decreased by 1.2%. The share of highly defoliated and dead trees (defoliation classes 3-4) has decreased by about 2.5 percentage points.

The assessed deciduous trees are in better condition than the coniferous. 80.1% of the observed deciduous trees and 65.9% of the coniferous trees have a degree of defoliation up to 25 %. The best condition of the deciduous tree species up to 60 years of age has been determined in plantations of *Quercus rubra*, where 97.5% of the observed trees have a degree of defoliation up to 25%, followed by *Fagus sylvatica* L. (86.7%) and *Quercus frainetto* (80.9%). Above 60 years of age, the best condition has been determined in *Carpinus betulus*, where the degree of defoliation is no more than 60% followed by *Quercus frainetto* with 97.5% defoliation up to 60% and Fagus sylvatica where 95.5% of the trees have defoliation up to 25%. The crown condition of *Fagus sylvatica*, *Quercus cerris*, *Quercus frainetto* and *Quercus rubra* has improved compared to 2013. Only *Quercus petraea* is in a relatively worse condition, where the defoliation in classes 3-4 has slightly increased.

The best condition of the coniferous tree species above 60 years of age is determined in *Picea abies*, where 100 % of the observed trees had defoliation up to 25 %, followed by *Pinus sylvestris* (65%) and *Pinus nigra* (56.8%). The best condition of the observed plantations above 60 years of age shows *Picea abies,* where 89.7% of the trees had defoliation below 25%, followed by *Abies alba* – 88.9%. The plantations of *Pinus sylvestris* have the highest percentage of trees (9.7%) in the defoliation classes 3-4. Compared to 2013, the crown condition of *Picea abies* and *Pinus sylvestris* has improved and remains stable for the rest of the coniferous tree species.

The described biotic damage and their causes do not lead to significant changes in the condition of the assessed trees.

10.4 Croatia

One hundred and three sample plots (2472 trees) on the 16 x 16 km grid network were included in the survey 2014. In comparison with the survey in 2013, two plots were excluded due to forest management operations.

The percentage of trees of all species within classes 2-4 in 2014 (31.5%) was higher than in 2013 (29.1%), and highest in the last ten years. The percentage of broadleaves in classes 2-4 (28.1%) was also highest in the last ten years of survey. For conifers, the percentage of trees in classes 2-4 was 49.7%, a small increase from year 2013 (48.3%). There were 384 conifer trees and 2088 broadleaves in the sample.

Abies alba, with 62.4% trees in the classes 2-4, together with *Pinus nigra* (53.5%), remain our most defoliated tree species. The percentage of *Quercus robur* trees in classes 2-4 in the past ten years has been between 20 and 30%. This year we recorded 29.7% of moderately to severely defoliated oak trees. *Fagus sylvatica* remains one of the tree species with lowest defoliation with 25.5% trees in the defoliation class 2-4. In the last ten years of monitoring, this percentage varied from 5.1% in 2003 to 17.2% in year 2013. Although the defoliation of common beech is still relatively low, it is also constantly on the rise, especially in the past couple of years. With broadleaved trees, the deterioration of crown condition in 2014 was most prominent with *Fraxinus angustifolia*: the percentage of trees in classes 2-4 increased from 23.6% in 2013 to 49.1% in year 2014, which is the most significant change in crown condition of narrow-leaved ash in the last ten years.

10.5 Cyprus

The annual assessment of crown condition was conducted on 15 Level I plots during the period July–August 2014. The assessment covered the main forest ecosystems of Cyprus and a total of 361 trees (*Pinus brutia, Pinus nigra* and *Cedrus brevifolia)* were assessed. Defoliation, discoloration and the damaging agents were recorded.

A comparison of the results of the conducted survey with those of the previous year (2013) shows a decrease of 10.9% in class 0 (not defoliated). An increase of 6.5% in class 1 (slightly defoliated) and of 4.4% in class 2 (moderately defoliated) has been observed. A slight decrease of 0.3% has been observed in class 3 (severely defoliated). A tree of *Cedrus brevifolia* was recorded as dead tree (class 4, Dead).

From the total number of trees assessed (361 trees), 18.8% of them were not defoliated, 67.9% were slightly defoliated,12.2% were moderately defoliated, 0.8% were severely defoliated and 0.3% were dead. In the case of *Pinus brutia*, 19.3% of the sample trees showed no defoliation, 66% were slightly defoliated, 14.0% were moderately defoliated and 0.7% were severely defoliated. For *Pinus nigra*, 16.7% of the sample trees showed no defoliation, 80.6% showed slight defoliation and 2.8% were moderately defoliated. For *Cedrus brevifolia*, 16% of the sample trees showed no defoliation, 72% were slightly defoliated, 4% were moderately defoliated, 4% were severely defoliated and 4% were dead.

From the total number of trees assessed (361 trees), 100% of them were not discolored.

From the total number of sample trees surveyed, 41.7% showed signs of insect attacks and 18.1% showed signs of attacks by "*other agents*, *T8*" (lichens, dead branches and rat attacks). Also, 7.5% showed signs of both factors (insect attacks and other agent).

The major abiotic factors causing defoliation in some plots, during 2014, were the combination of climatic with edaphic conditions which resulted to secondary attacks by *Leucaspis spp*. and defoliator insects, to half of the trees.

10.6 Denmark

The Danish forest condition monitoring in 2014 was carried out via the National Forest Inventory (NFI) including the remaining Level I and II plots. Monitoring showed most tree species had satisfactory health status, but local problems occurred in several tree species, including ash, oak and Sitka spruce.

As in previous years ash (*Fraxinus excelsior*) showed extensive dieback due to the invasive pathogen *Hymenoscyphus fraxineus*. Average defoliation was 26% for all monitored ash trees, and 28 % of the trees had at least 30% defoliation, which is comparable to previous years even though sick ash trees are still harvested as fast as possible. Observations show the ash dieback disease is mainly a problem in forests whereas ash trees in cities, along roads and elsewhere in the open landscape are not affected to the same degree.

The warm and dry July 2013 gave expectations of an expansion of *Dendroctonus micans* on sandy soils, and the impact could be seen on the old Sitka spruce Level 1 plot, where one previously healthy tree suddenly died due to the bark beetle. The average defoliation of Sitka spruce rose from 7% to almost 12% and 13% of the monitored trees had more than 30% defoliation. The defoliation scores can also be attributed to a higher frequency of the green spruce aphid, *Elatobium abietinum*.

Norway spruce (*Picea abies*) stayed at a low average defoliation of 5% and 3% damaged trees, and the health situation for Norway spruce in Denmark is still excellent based on monitored stands. However, 2014 saw an additional population increase of the bark beetle *Ips typographus*, in spite of efforts to carry out sanitations of Norway spruce according to expert recommendations. Other conifers such as *Pinus*, *Larix* and *Abies* sp. stayed at the same low levels of defoliation of 10% or less, and the health of conifers in general can be considered satisfactory.

The average defoliation score of beech (*Fagus sylvatica*) increased slightly from 7% to almost 9%, and the frequency of damaged trees rose from 2% to 4%. However, this was not unexpected since the precipitation during the growth season was low in both 2013 and 2014. In addition, beech flowered and produced fruit in 2014, but in moderate amounts.

Oak (*Quercus robur* and *Q. petraea*) had a decrease in average defoliation from 15% to 13%. On the other hand incidences of dead and dying oaks, especially on soils with drainage problems, became more frequent. In addition we suspect the jewel bark beetle *Agrilus biguttatus* may have become established in Denmark. Investigations into the factors involved in local oak problems are underway.

Based on defoliation assessments on NFI plots and Level I & II, the results of the crown condition survey in 2014 showed that 75% of all coniferous trees and 67% of all deciduous trees were undamaged. 20% of all conifers and 24% of all deciduous trees showed warning signs of damage. The mean defoliation of all conifers was 7% in 2014, and the share of damaged trees was 5%. Mean defoliation of all broadleaves was 10%, and 9% of the trees had more than 30% defoliation.

10.7 Estonia

Forest condition in Estonia has been systematically monitored on the Level I sample points since 1988.In 2014, the defoliation assessment was carried out on 2329 trees. Thereby 1465 Scots pines (*Pinus* *sylvestris*), 582 Norway spruces (*Picea abies*) and 227 Silver birches (*Betula pendula*) were observed from July to October.

The total share of not defoliated trees, 49.5%, was by 1.8% higher than in 2013 and by 1.9% higher than in 2012. The share of not defoliated conifers, 48.3%, was lower than the share of not defoliated broadleaves, 72.7%, in 2014. The percentage of trees in classes 2 to 4, moderately defoliated to dead, was 6.7 in 2014 and 8.0 in 2013. Thus some slight decrease of defoliation in general occurred. The percentage of conifers and broadleaves in defoliation classes 2 to 4 was 6.9% and 5.7% accordingly.

Scots pine has traditionally been and remained the most defoliated tree species in Estonia. The share of not defoliated pines (defoliation class 0) was 46.1 % in 2014, by 3% higher than in 2013. The percentage of pines in classes 2 to 4, moderately defoliated to dead, was slightly lower than in 2013 – 6.8%. However no serious long-term trend of Scots pine defoliation since 2010 is visible. In 2010, the share of not defoliated pine trees increased from 38% to 45% and is keeping a similar level until now.

Concerning Norway spruce some slight long-term increase of defoliation occurred. The share of not defoliated trees (defoliation class 0) was 64% in 2010 and accordingly 54.6% and 54.0% in 2013 and 2014. The share of not defoliated trees was higher, 74.2% in younger stands with the age up to 60 years and 54.0% in older stands.

Compared to the year 2012 there has been a significant improvement in the condition of broadleaves during the last years. The percentage of broadleaves in classes 2 to 4, moderately defoliated to dead, was 5.7 in 2014. This is significantly lower than the 15.0% in 2012. The share of not defoliated silver birches was 59% in 2012 and even 73.6% and 76.2% accordingly in 2013 and 2014.

All trees included in the crown condition assessment on Level I plots are also regularly assessed for damage. Numerous factors determine the condition of forests. Climatic factors, disease and insect damage as well as other natural factors have an impact on tree vitality. In 2014, 3.3% of the trees observed had some insect damage and 33.4% of trees had identifiable symptoms of disease. Visible damage symptoms recorded for Scots pine were mainly attributed to pine shoot blight (pathogen *Gremmeniella abietina*). On 37% of the observed pine trees symptoms of shoot blight were recorded in 2014. Norway spruces mostly suffered due to root rot (pathogen *Heterobasidion parviporum*) – characteristic symptoms of the disease were observed on 8.8% of sample trees. No substantial storm damages and forest fires occurred in 2014.

10.8 France

In 2014, the forest damage monitoring in the French part of the systematic European network comprised 11 149 trees on 546 plots.

Although climatic conditions of the year were rather favourable to the forest vegetation due to a rainy summer and a mild winter, defoliation increased for some species: *Quercus pubescens* and *Q. ilex* for example. Nevertheless, other species such as *Q. petraea*, *A.alba* have a lower defoliation level than 2013: in fact, it is quite hard to determine a clear trend for all kind of species.

Death of sampled trees stayed at a relatively low level, except for a plot of young spruces which artificially raised the level of mortality of this species (4.1%) for this year. In fact, this increase is due to formerly supressed trees which are assessed after the dominant trees were felled a few years ago. They were heavily wounded and not used to direct light: they quickly fell prey of *Ips typographicus*, which hastily killed them.

The number of discoloured trees was still low except for poplar, beech, wild cherry and Aleppo pine.

Damage was reported on about a quarter of the sampled trees, mainly on broad-leaved species. The most important causes of damage were mistletoe (*Viscum album*) on *Pinus sylvestris,* chestnut canker (*Cryphonectria parasitica*) and the oak buprestid (*Coroebus florentinus*) on *Quercus* spp. Abnormally small leaves were observed on different species, specially on *Quercus* spp. (mainly on evergreen and pubescent oaks).

10.9 Germany

In 2014, 26% (2013: 23%) of the forest area was assessed as damaged, i.e. recorded with more than 25% of crown defoliation (damage classes 2 to 4); 41% (2013: 39%) were in the warning stage, and 33% (2013: 38%) showed no defoliation. The mean crown defoliation increased from 19.3% to 20.4%.

Since the beginning of the surveys in 1984, crown condition shows only little change, if the average defoliation rates over all tree species are considered. This is however the result of opposite trends of defoliation in broadleaved trees and conifers. The share of damaged broadleaved trees as well as the mean defoliation of broadleaved tree species has significantly increased since the mid-eighties. The crown condition of Norway spruce shows no clear trend, whereas Scots pine and other conifers have improved.

Picea abies: the percentage of damage classes 2 to 4 is 28%, compared to 24% in the previous year; 39% (2013: 38%) of the trees were in the warning stage. The share of trees without defoliation was 33% (2013: 38%). Mean crown defoliation increased from 18.8% to 20.2%.

Pinus sylvestris: the share of damage classes 2 to 4 was 12%, unchanged in comparison to 2013; 50% (2013: 42%) were in the warning stage; 38% (2013: 47%) showed no defoliation. The mean crown defoliation increased from 15.1% to 16.4%, but still remains below other tree species.

Fagus sylvatica: crown condition of beech deteriorated compared to 2013. The share of trees in damage classes 2 to 4 further increased from 35% in 2013 to 48% in 2014; 38% (2013: 42%) were classified in the warning stage. The share of trees without defoliation fell to only 14%. Mean crown defoliation increased from 23.6% to 27.6%. There is a link between the sharp increase in crown defoliation and fruiting which, once again, was intense in 2014. In general, defoliation is higher in years with intense fruiting. Over the past fifteen years, years where a high amount of trees showed moderate or intense fruiting were frequent. Fruiting years occurred in 2000, 2002, 2004, 2006, 2009, 2011 and 2014. Furthermore beech trees suffered from defoliation by the beech leaf miner (*Rhynchaenus fagi*) in 2014.

Quercus robur & *Q. petraea*: the share of damaged trees decreased from 42% to 36%. The share of trees in the warning stage was 40% (2013: 39%). 24% (2013: 19%) of oaks showed no defoliation. Mean crown defoliation decreased from 27.0% to 24.7%.

10.10 Greece

The crown assessment survey was carried out for the year 2014 on 57 Level I plots in Greece from 15 June 2014 till 15 October 2014. The total number of trees assessed was 1345, whereas 619 of them were trees of broadleaved species and the other 726 were trees of coniferous species.

The defoliation percentage of the broadleaved species for the class 0 was 49.2% and for the class 1 it was 33.9%. These figures are considered to represent a healthy tree condition. As regard to foliage loss in the classes 2, 3 and 4 of the broadleaved species, these were found to be 13.6%, 2.3% and 0.8%.

The main broadleaved species assessed in Greece (that means the species with the highest number of trees assessed) were *Quercus frainetto* with 169 trees, *Castanea sativa* with 72 trees and *Fagus sylvatica* with 57 trees. The defoliation percentages in the five defoliation classes of the *Quercus frainetto* and *Castanea sativa* species were found to be similar with those of the grand total of the broadleaved species. The condition of the *Fagus sylvatica* trees was found to be very healthy (with 86% not defoliated trees). The main symptoms assessed in the broadleaved species connected with foliage loss were insect attacks and abiotic factors.

The defoliation percentage of the conifers species for the class 0 was 43.9%, whereas for the class 1 it was 29.2%. These figures are also considered to represent a healthy tree condition although a little worse in comparison with the broadleaves. As regard to foliage loss in the classes 2, 3 and 4 of the conifer species, these were 18.6%, 6.6% and 1.5%.

The main conifer species assessed in Greece were *Abies cephalonica* with 167 trees, *Pinus nigra* with 116 trees and *Abies borisii-regis* with 121 trees. The defoliation percentages in the five defoliation classes (0, 1, 2, 3 and 4) of the *Abies cephalonica* species were found to be 25.8%, 25.2%, 29.4% 15.4% and 4.2%, respectively. That means that the *Abies cephalonica* trees were found to be in a worse health condition than the conifers in total. In a similar health tree condition was the *Abies borisii-regis* species. As regard to the *Pinus nigra* species, the defoliation percentages were found to be similar with those of the total conifer species but with an increase of the percentage of dead trees (3.4%).

The main symptoms assessed in the conifer species resulting in foliage loss were epiphytes, insect attacks and abiotic reasons.

10.11 Italy

The survey of Level I in 2014 took into consideration the condition of the crown by 4978 selected trees in 245 plots belonging to the EU network of 16x16 km. The results given below relate to the distribution of frequencies of the indicators used, especially transparency - which in our case we use for the indirect assessment of defoliation and the presence of agents known causes attributable to both biotic and abiotic. For the latter, not so much the indicators we analyzed the frequencies of affected plants, but the comments made as to each plant may have multiple symptoms and more agents.

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 (70.6%) is included in the classes 1 to 4; 30.8 % is included in the classes 2 to 4.

By analyzing the sample for groups of species, conifers and broadleaves, it appears that conifers have a transparency that is lower than that of the deciduous foliage: 40.6% of conifers and 33.3% of broadleaves are without any defoliation (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 pinea* and *Picea abies* have 75.0% and 32.6%, respectively, trees in the classes 2 to 4, *Pinus sylvestris* has 24.8%, *Pinus nigra* 27.9% of trees in the classes 2 to 4, but the best conditions were found in *Larix decidua* with 16.7%.

Among the old conifers (≥60 years), the species which appear to have the worst quality of foliage are *Pinus nigra* (22.7%), *Picea abies* (20.9%), *Abies alba* (16.9%) and *Larix decidua* with the 17.3% of trees in the classes 2 to 4, while *Pinus cembra* (8.8%) is a conifer in better condition.

Among the young broadleaves (<60 years), *Castanea sativa*, *Quercus pubescens* and *Quercus cerris* have 82.2%, 46.2% and 23.7%, respectively, of trees in the classes 2 to 4, while others have a frequency range between 20.8% and 21.5% in classes 2 to 4 distributed in different species: *Ostrya carpinifolia* (20.8%), *Fagus sylvatica* (21.5%).

Among the old broadleaves (≥60 years) in the classes 2 to 4, *Castanea sativa* has 85.5%, *Quercus pubescens* 48.9%, *Ostrya carpinifolia* 53.7%, *Fraxinus ornus* 25.0%, *Fagus sylvatica* 16.2% in classes 2 to 4); *Quercus ilex* (15.3%) has the lowest level of defoliation of trees in the classes 2 to 4.

Starting in 2005, a new methodology for a deeper assessment of damage factors (biotic and abiotic) was introduced. Most of the observed symptoms were attributed to insects (24.9%), subdivided into defoliators (19.7%), galls (3.2%). Other symptoms were attributed to fungi (5.6%), the most significant were “dieback and canker fungi” (3.5%). From those assigned to abiotic agents, the most significant were “hail” (2.3%).

10.12 Latvia

The forest condition survey 2014 in Latvia was carried out on 115 NFI plots. The national report of 2014 is based on data from this dataset.

In total, defoliation of 1743 trees was assessed, of which 77% were conifers and 23% broadleaves. Of all tree species, 10.6% were not defoliated, 84.3% were slightly defoliated and 5.1% moderately defoliated to dead. Comparing to 2013, the proportion of not defoliated trees has decreased by 1.0%, the proportion of moderately defoliated to dead trees has decreased by 1.3% but the proportion of slightly defoliated trees has increased by 0.2%. Unlike the previous year, when the proportion of trees in defoliation classes 2-4 was higher for conifers than for broadleaves, this year the proportion of trees in defoliation classes 2-4 was by 1.3% higher for broadleaves.

Mean defoliation of *Pinus sylvestris* was 20.2% (20.0% in 2013). The share of moderately damaged to dead trees constituted 5.2% (7% in 2013). Mean defoliation of *Picea abies* was 17.6% (17.2% in 2013). The share of moderately damaged to dead trees for spruce constituted 3.9% (5% in 2013). The mean defoliation level of *Betula spp*. was 19.6% (19.9% in 2013), showing a slight decrease of the defoliation level. The share of trees in defoliation classes 2-4 was 6.3% (compared to 4% in 2013. The mean defoliation level for *Populus tremula* was not changed and also in 2014 was 15.8%. Defoliation values observed in 2013 and 2014 are rather similar, one of the explanations is that the same dataset was used for defoliation assessments in both these years.

Visible damage symptoms were observed to a lesser extent than in the previous year (17.3% of the assessed trees in 2014 compared to 19.7% in 2013). Most frequently recorded damages were caused by direct action of men (35.1% of all cases; 32.2% in 2013), animals (21.4%; 24.0% in 2013), fungi (10.4%; 18.0% in 2013), abiotic factors (13.7%; 13.0% in 2013) and insects (17.0%; 10.1% in 2013). Other damage causes were recorded for 0.6% of all cases and unknown cause for 1.8% of all cases. The distribution of damage causes was different than last year. After considerable decrease in 2013, the proportion of insect damage has again increased. Although the proportion of damage by *Lymantria monacha* has sharply decreased, an increase in the population and damages by European pine sawfly, *Neodiprion sertifer*, has been observed and is likely to present further problems also in the coming years. The greatest share of trees with damage symptoms was recorded for *Picea abies* (26.5%) and the smallest for *Betula spp.* (14.8%).

10.13 Lithuania

In 2014 the forest condition survey was carried out on 1028 sample plots from which 81 plots were on the transnational Level I grid and 947 plots on the National Forest Inventory grid. In total 6306 sample trees representing 19 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.*

The mean defoliation of all tree species slightly increased up to 22.2% (21.6% in 2013). 20% of all sample trees were not defoliated (class 0), 58% were slightly defoliated and 22% were assessed as moderately defoliated, severely defoliated and dead (defoliation classes 2-4). Mean defoliation of conifers slightly decreased up to 21.7% (22.4% in 2013) and slightly increased for broadleaves up to 22.8% (20.4% in 2013).

Pinus sylvestris is a dominant tree species in Lithuanian forests and composes about 40% of all sample trees annually. Mean defoliation of *Pinus sylvestris* reached 23.1% (22.8% in 2013) with an increasing tendency since 2008.

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 18.9% (15.7% in 2013) and the proportion of trees in defoliation classes 2-4 was 12% compared with 4% in 2013.

Fraxinus excelsior condition remained the worst between all observed tree species. This tree species had the highest defoliation since year 2000. Mean defoliation increased to 40.9% (32.4% in 2013). The share of trees in defoliation classes 2-4 increased to 52% (45% in 2013).

24% of all sample trees had some kind of identifiable damage symptom. The most frequent damage was caused by abiotic agents (about 7%) in the period of 2011–2014. It is closely connected with the storm that hit the South-Eastern part of Lithuania on 08/08/2010. The highest share of damage symptoms was assessed for *Fraxinus excelsior* (53%), *Populus tremula* (33%) and *Alnus incana* (34%), the least for *Alnus glutinosa* (18%).

In general, the mean defoliation of all tree species has varied inconsiderably from 1997 to 2014 and the growing conditions of Lithuanian forests can be defined as relatively stable.

10.14 Luxembourg

In 2014 the forest condition survey was based on a 16 x 16 km grid, which included 93 sample trees on 4 permanent plots. On average over all tree species, none of the sample trees was showing no defoliation, 44.0% were assessed as damaged (classes 2-4), and 55.9% were in the warning stage. In 2014, 93.3% of conifers were in defoliation classes 2-4, 6.6% were slightly defoliated, and none was not defoliated. For broadleaves 34.6% were assessed as damaged (classes 2-4), 65.4% were slightly defoliated, and none showed no signs of defoliation.

10.15 Republic of Moldova

Favorable climatic conditions which prevailed in the spring and summer of 2014 had a positive impact on the condition of trees and shrubs. This is evidenced by an increasing number of trees with no signs of damage (defoliation class 0) of 43% and an increase of 11% compared to last year. Trees in defoliation classes 2-4 amounted to 19.9% this year, which is 5% lower than last year. In this year, the number of trees in defoliation class 2-4 decreased in almost all species of both deciduous and coniferous trees. In ash stands defoliation decreased by 10.2% and this year it was 16.7%. The same trend is observed in acacia plantations where defoliation has decreased compared to the previous year by 12% to 28%. In oak forests defoliation remained at the same level as last year and amounted to 22.6%. The same trend is observed in conifers and trees in defoliation classes 2-4 with 29.4%, which is 12% less than last year.

10.16 Norway

2014 was the second year in Norway with the new sampling design for Level I with annually one fifth of the NFI plots monitored and five year revision intervals on the plots, following the rotation of the National Forest Inventory (NFI). Crown condition assessments are from 2013 on only carried out for *Picea abies* and *Pinus sylvestris*, while damage assessments are carried out for all tree species present on the NFI plots. This new design produces good estimates of average national crown condition; however estimates of regional crown condition are probably less accurate. In 2014, the mean defoliation for *Picea abies* was 16.5%, and 12.7% for *Pinus sylvestris*. 2014 was the third year with a decrease in defoliation for pine. However, for Norway spruce a minor increase in defoliation was observed, resulting in the highest defoliation for spruce since 2007.

Of all the coniferous trees, 48.1% were rated not defoliated in 2014, which is a decrease of about 1%-point compared to the year before. 47.3% of the *Pinus sylvestris* trees were rated as not defoliated which is an increase of 3%-points. 48.7% of all Norway spruce trees were not defoliated, a decrease of 2%-points compared to the year before.

In crown discolouration we observed 8.3% discoloured trees for *Picea abies*, a decrease of about 1%-point from 2013. For *Pinus sylvestris*, 4.6% of the assessed trees were discoloured, an increase of about 1%-point from the year before.

The mean mortality rate for all species was 0.2% in 2014. The mortality rate was 0.3% and 0.1% for spruce and pine, respectively.

In general, the observed crown condition values result from interactions between climate, pests, pathogens and general stress. According to the Norwegian Meteorological Institute the summer (June, July and August) of 2014 was warm with a temperature 1.9° C higher than normal as an average for the country. In Western and Central Norway summer temperatures were 2-3° C higher than normal in the summer. July in 2014 had the highest mean temperature ever measured in a series since the year 1900 in Norway. The highest mean temperature was in Central Norway with 6° C above normal. Northern Norway had also high July mean temperature with 4° C above normal and, in addition, this region had only 40 % of normal precipitation this month. The summer precipitation was about 90 % of the normal as a mean for these three months. June and July climate is important for drought in spruce in dry localities, especially in the lowlands of Southeast Norway. There are of course large climatic variations between regions in Norway, ranging from 58 to 71°N.

10.17 Poland

In 2014 the forest condition survey was carried out on 2013 plots (grid 8 km x 8 km). Forest condition (all species total) remained almost at the same level compared to the previous year. 11.6% (13.7% in 2013) of all sample trees were without any symptoms of defoliation, a decrease by 2.1 percent points compared to 2013. The proportion of defoliated trees (classes 2-4) indicates an increase by 0.1 percent points to an actual level of 18.9% of all trees. The share of trees defoliated more than 25% decreased by

0.6 percent points for conifers and increased by 1.2 percent points for broadleaves. Mean defoliation for all species total amounts to 21.9%, with 21.8% for conifers and 22.2% for broadleaved trees.

9.5% of conifers were not suffering from defoliation. For 17.2% of the conifers defoliation of more than 25% (classes 2-4) was observed. *Pinus sylvestris*, *Picea abies* and *Abies alba* indicated almost the same condition compared to the previous year. With regard to the three main coniferous species, *Abies alba* remained the species with the lowest defoliation (18.6% trees in class 0, 16.2% trees in classes 2-4, mean defoliation amounting to 20.0%). *Pinus sylvestris* was characterized by a lower share of trees in class 0 (8.3%), a higher share of trees in classes 2-4 (16.7%) and higher mean defoliation (21.8%) than *Abies alba*. Otherwise *Picea abies* was characterized by quite a high share of trees in class 0 (16.2%), but as well higher share of trees in classes 2-4 (25.1%) and higher mean defoliation (23.1%) compared to *Pinus sylvestris* and *Abies alba*.

15.4% of assessed broadleaved trees were not defoliated. The proportion of trees with more than 25% defoliation (classes 2-4) amounted to 21.9%. As in the previous survey the highest defoliation amongst broadleaved trees was observed in *Quercus* spp. In 2014 a share of 4.7% of oak trees was without any symptoms of defoliation and 35.0% was in defoliation classes 2-4, mean defoliation amounting to 25.8%. A little better condition was observed for *Betula* spp. (7.5% trees without defoliation, 26.7% damage trees (classes 2-4) and mean defoliation amounting to 24.1%). *Fagus sylvatica* remained the broadleaves species with the lowest defoliation. In 2014 a share of 33.4% of beech trees was without any symptoms of defoliation, only 7.6% was in defoliation classes 2-4, mean defoliation amounting to 16.3%. *Alnus* spp. was more defoliated (20.9% trees without defoliation, 11.8% trees in classes 2-4, mean defoliation amounting to 19.8%) than *Fagus sylvatica.* Damage of *Fagus sylvatica*, *Betula* spp. and *Alnus* spp. increased compared to the previous year. For *Fagus sylvatica* and *Alnus* spp. the share of trees without any symptoms of defoliation decreased respectively by 6.0 and 9.5 percent points. For *Betula* spp. the share of trees defoliated by more than 25% increased by 4.1 percent points.

In 2014, discolouration (classes 1-4) was observed on 0.7% of the conifers and 1.6% of the broadleaves.

10.18 Romania

In the year 2014, the assessment of crown condition on the Level I network in Romania was carried out on the 16 x 16 km transnational grid for the period of 15 July to 15 September. The total number of sample trees was 5784, assessed on 241 permanent plots. From the total number of trees, 1119 were conifers and 4665 broadleaves. Trees on the missing plots (20) were harvested during the last years or unreachable due to natural hazards.

For all species, 54.4% of the trees were rated as healthy, 32.2% as slightly defoliated, 10.6% as moderately defoliated, 1.3% as severely defoliated and 1.6% were dead. The share of damaged trees (defoliation classes 2-4) was 13.5%.

For conifers, 13.7% of the trees were classified as damaged (classes 2-4). *Picea abies* was the least affected coniferous species with a share of damaged trees of 12.6% (defoliation classes 2-4), whereas *Abies alba* had 14.3%. For broadleaves, 13.0% of the trees were assessed as damaged or dead (classes 2-4). Among the main broadleaves species, *Fagus sylvatica* had the lowest share of damaged trees (9.5%). The most affected broadleaves species were *Quercus cerris* and *Q. frainetto* (16.1%), and *Q. robur* and *Q. petraea* (23.7%).

Compared to the last year, the overall share of damaged trees (classes 2-4) decreased by only a marginal 0.1 percentage point. Overall, this trend was mainly influenced by the high amount of precipitation registered during the vegetation season, seemingly contrasting with brief draughty periods during the summer, which facilitated an increasing occurrence of secondary damaging factors (e.g. defoliation insects and powdery mildew on oak species).

Biotic and abiotic damage factors were recorded on 30.3% of the sample trees. A large amount of the observed symptoms were attributed to insects (54%), fungi (8%) and abiotic factors (e.g. heat stress, frost, wind) (13%), anthropogenic including pollution (8%), other factors (6%), and unidentified factors (11%).

10.19 Serbia

In the region of the Republic of Serbia, 101 ICP Forests sampling plots are distributed along a 16 x 16 km grid and with an additional 29 new plots on a 4 x 4 km grid, the total number of sampling plots was altogether 130 (not including assessments in AP Kosovo and Metohija). Observations on Level I plots were performed according to the ICP Forests Manual of Methods.

During 2014, the researchers of the NFC Serbia - Institute of Forestry with collaborators from other institutions in Serbia have worked on all sampling points, made visual assessments of the crown condition and collected the other necessary field data.

The total number of trees assessed on all sampling points was 2943 trees, of which 336 were conifer trees and a considerably higher number i.e. 2607 were broadleaf trees. The conifer tree species were: *Abies alba,* number of trees and percentage of individual tree species 68 (20.2%), *Picea abies* 145 (43.2%), *Pinus nigra* 67 (19.9%), *Pinus sylvestris* 56 (16.7%) and the most represented broadleaf tree species were: *Carpinus betulus,* number of trees and percentage of individual tree species 114 (4.4%), *Fagus moesiaca* 841 (32.3%), *Quercus cerris* 543 (20.8%), *Quercus frainetto* 382 (14.7%), *Quercus petraea* 186 (7.1%) and other species 541 (20.8%).

The results of the available data processing and the assessment of the degree of defoliation of individual conifer and broadleaf species (in %) are: *Abies alba* (None 89.7, Slight 0.0, Moderate 1.5, Severe 7.3 and Dead 1.5); *Picea abies* (None 80.0, Slight 14.5, Moderate 4.8, Severe 0.7, Dead 0.0); *Pinus nigra* (None 34.3, Slight 20.9, Moderate 29.9, Severe 13.4, Dead 1.5); *Pinus sylvestris* (None 87.4, Slight 5.4, Moderate 1.8, Severe 5.4, Dead 0.0).

The degree of defoliation calculated for all conifer trees is as follows: no defoliation 74.1% trees, slight defoliation 11.3% trees, moderate 8.6% trees, severe defoliation 5.4% trees and dead 0.6%.

Individual tree species defoliation (%) are: *Carpinus betulus* (None 74.5, Slight 14.9, Moderate 5.3, Severe 5.3, Dead 0.0); *Fagus moesiaca* (None 81.6, Slight 12.6, Moderate 3.2, Severe 2.4, Dead 0.2); *Quercus cerris* (None 64.6, Slight 21.7, Moderate 10.3, Severe 2.8, Dead 0.6); *Quercus frainetto* (None 69.6, Slight 19.1, Moderate 7.3, Severe 3.2, Dead 0.8); *Quercus petraea* (None 48.9, Slight 33.9, Moderate 16.2, Severe 0.5, Dead 0.5) and the rest (None 58.4, Slight 21.8, Moderate 14.2, Severe 3.2, Dead 2.4).

Degree of defoliation calculated for all broadleaf species is as follows: no defoliation 68.9% trees, slight defoliation 19.0% trees, moderate 8.6%, severe defoliation 2.7% trees and dead 0.8% trees.

The data above show the presence of sample trees with moderate and severe degrees of defoliation, but this does not always signify the reduction of tree vitality caused by the effect of adverse agents (climate stress, insect pests, pathogenic fungi). It can only be a temporary phase of natural variability of crown density.

10.20 Slovenia

In 2014 the Slovenian national forest health inventory was carried out on 44 systematically arranged sample plots (grid 16 x 16 km). The assessment encompassed 1055 trees, 394 coniferous and 661 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). Report for the year 2013 includes only 1055 instead of 1056 trees. One of the plots had no trees with dbh bigger than 10 cm for the replacement of the felled tree.

The mean defoliation of all tree species was estimated to be 28.2%. Compared to the 2013 survey, the situation deteriorated for 2.3% (mean defoliation in 2013 was 25.9%). In year 2014 mean defoliation for coniferous trees was 27.6% (in year 2013 it was 25.3%) and for broadleaves 28.6% (year before 26.2%).

In 2014 the share of trees with more than 25% of defoliation (damaged trees) reached 38.3%. In comparison to the results of 2013, when the share of trees with more than 25% of unexplained defoliation was 30.9%, the value increased by 7.4 % percentage points.

The number of damaged coniferous trees increased from 34.3% in 2013 to 38.8% in 2014. Especially significant is the change of damaged trees for broadleaves where the share of damaged trees increased from 28.5% in 2013 to 38.4% in 2014. In the year 2013 the share of damaged coniferous was greater than the share of damaged broadleaves trees. But in the year 2014 the share of damaged broadleaves is just slightly (0.4%) under the share of damaged coniferous trees.

In general, the mean defoliation of all tree species has slightly increased since 1991. In comparison to year 2010 the mean defoliation deteriorated in year 2011, improved in 2012 and again deteriorated in 2013. The biggest change in the mean defoliation can be seen in the year 2014 due to the sleet damage in February 2014.

10.21 Spain

Results obtained from the 2014 inventory show a slight improvement in the general health condition of trees, when compared to the previous year. In 2014, 85.1% of the assessed trees looked healthy (compared to 83.4% of healthy trees obtained in 2013).

A percentage of 13.2% of all trees were included in defoliation classes 2 and 3 (indicating defoliation levels higher than 25%) whereas in 2013 this percentage was 15.9%. The number of dead trees decreased as well (1.6% in 2014 whereas in 2013 this percentage was 2.4%).

Recovery is more evident in the case of broadleaves (with a percentage of 81.6% compared to the 79.4% of last year). In the case of conifers, the percentage of healthy trees has also increased, although only slightly (88.6% this year and 87.4% in 2013).

The mortality of trees is mainly due to felling operations, like sanitary cuts and forest harvesting processes, as well as from decline processes related to isolated hydric shortages.

Concerning possible damaging agents affecting forest trees, there is a clear decrease in the number of abiotic damages recorded (damage due to drought widely decreased but still there are some old damages noticed in certain species); the same way, records from other abiotic damaging agents such as wind and snow have descended remarkably as well.

Damages directly related to biotic agents have a lower specific weight this year (the presence of defoliators decreased generally, although populations of pine processionary moth grew if compared to the previous year). Regarding fungi, a minimum presence of *Sirococcus conigenus* is recorded, and concerning parasitic phanerogams, the number of records remains at the same level as in previous years. The number of *Quercus* trees affected by the 'Seca' syndrome has not increased at the moment of the assessments.

The importance of atmospheric pollution in the evolution of forest condition is a factor which cannot be quantified directly, as it is frequently disguised by other kind of processes which are more apparent. However, in combination with other agents it can contribute to the degradation processes of forests.

10.22 Sweden

An annual monitoring of the most important sources of forest damage is carried out by the Swedish National Forest Inventory (NFI). Although the Swedish NFI is an objective and uniform inventory including data about forest damage in Swedish forests at national and regional scales, less common or less widespread occurrences of forests pests and pathogens are difficult to survey solely through large-scale monitoring programmes. Complementary target tailored forest damage inventories (TFDI) have therefor been introduced. TDFIs are developed to give a rapid response to requested information on specific damage outbreaks. The TDFIs are carried out in limited and concentrated samples, with flexible but robust methods and design.

The national results are based on assessment of the main tree species Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*) in the National Forest Inventory (NFI), and concern, as previously, only forest of thinning age or older. In total, 7795 trees on 3509 sample plots were assessed. The Swedish NFI is carried out on permanent as well as on temporary sample plots. The permanent sample plots, which represent 60 percent of the total sample, are remeasured every 5^{th} year.

The proportion of trees with more than 25% defoliation is for Norway spruce 24.4% and for Scots pine 13.7%. A minor increase in defoliation for both Scots pine and Norway spruce in southern Sweden is seen during the last ten years. In central and northern Sweden defoliation in Scots pine has increased during last three years. While a slight improvement is seen on Norway spruce in northern Sweden during recent years. There are some large temporal changes seen in defoliation levels at regional level however the majority of changes during recent years are minor.

Also in autumn 2014 Sweden was struck by several storms. Fortunately these storms caused only minor damage to the forests. However, a large number of wind felled trees were left in the forest in central Sweden after previous storms in autumn 2014. Wind-felled trees in small groups were spread over a large area. The total volume of spruce trees was 1.2 million m^3 in central Sweden in October 2014. The large amount of wind felled trees has increased the risk of rising populations of bark beetles. It is still likely that a considerable volume of wind-felled trees will be available for bark beetles in 2015. The primary choice for the bark beetle population during 2015 will be to utilize these still fresh wind-felled trees. However, the wind felled trees will not be enough so there is a risk of damage occurring on growing trees as well. The expected population increase also poses a large potential risk for a subsequent increase in damage to the growing forest.

The decline in Ash (*Fraxinus excelsior*) is continuing in southern Sweden. In northeastern Sweden problems with resin top disease (*Cronartium flaccidum*) in young pine stands remains. In the beginning of August a severe forest fire flared up in central Sweden and spread over an area of 14 000 ha. About 4 300 ha productive forest land was destroyed by the fire. Overall however the most important damage problems are, as previously, 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*.

10.23 Switzerland

In 2014, the defoliation increased again after a transient recovery phase in 2013. The proportion of 'significantly damaged trees', that are trees showing unexplained defoliation subtracting the percentage of defoliation due to known causes such as insect damage, or frost damage, between 30% and 100% (class 2–4) increased from 25.9% in 2013 to 30.5% in 2014. The basis for this data is the crown assessment for a total of 1017 trees. The percentage observed in 2014 is thus comparable to the latest maximum in 2012, where significantly damaged trees accounted for more than 31% of all trees assessed and clearly above the 23.8% long-term average of the last twenty years. The increase in proportion of significantly damaged trees was at the expense of trees with no defoliation. Their proportion decreased from 23.4% to 18.2%.

In general, a strong high frequency variation can be seen since the end of the 90s. Thus, after the significant increase in defoliation seen until the mid -90s, no clear long-term trend is visible since about 2000. The heavy increases in defoliation and the subsequent recovery coincide often with climatic events. The storm Lothar was responsible for the maximum in 2000 and the dry and hot summer of 2003 for the second peak. However, increases in defoliation from 2009 to 2012 cannot be explained completely by climatic events and also the 2014 increase cannot be directly attributed to meteorological extremes.

We however observed a tendency for insect damage to more strongly contributing to defoliation. This relationship is mainly visible in deciduous trees, where the beech leaf miner (*Rhynchaenus fagi*) is likely to have the greatest influence. After a clear decrease in infestation intensity in 2013, the population increased to a new maximum in 2014, thus showing patterns comparable to defoliation. Moreover, the increased frequency of mast years might contribute to an increase in defoliation and also to the strong year-to-year variations.

After a short relief in 2012, the ash dieback that started in Switzerland in 2008 caused another increase in defoliation in 2013 and 2014. A third of the ash trees are now severely affected but there is also a tendency that new replacement sprouts allow trees to produce relatively dense crowns.

The yearly mortality of all trees from all species assessed amounted to 1.1% indicating a slightly increased mortality with increased defoliation.

10.24 Turkey

Monitoring studies have been conducted on a grid of 16x16 km and crown conditions of 12 338 trees in 531 Level I sample plots have been evaluated in 2014. The average needle/leaf loss of all evaluated trees is 17.0%. The percentage of healthy trees (class 0-1) is 89.0% and the remaining 11.0% had a loss of greater than 25%. The annual average needle/leaf loss had slightly increased in comparison to last year.

The average defoliation of broadleaved species is 19.4%. Common tree species with the highest defoliation are *Quercus pubescens* (34.2%), *Alnus glutinosa* (24.3%), *Castanea sativa* (24.1%) and *Quercus petraea* (22.3%). The same species had the greatest needle/leaf loss in the last two years. Among the less common broadleaved species (each of which are presented by less than 20 individuals), *Corylus avellana, Ulmus glabra, Salix alba, Prunus avium, Populus nigra, Ostrya carpinifolia, Juglans* *regia* and *Fraxinus angustifolia* have 25% or greater defoliation. While 82.8% of all broadleaved trees showed no or slight defoliation (class 0-1), 17.2% of them were defoliated by more than 25% (class 2-4).

The average defoliation of coniferous species is 15.5%; 92.8% of all evaluated coniferous trees have needle loss of less than 25% (class 0-1), and the remaining 7.2% of them have over 25% needle loss (class 2-4). Junipers (*Juniperus foetidissima, J. excelsa, J. oxycedrus, J. communis*) have the highest needle loss among common conifers with defoliation values between 12.5% and 21.1%. As for pine species, defoliation values of *P. brutia*, *P. sylvestris* and *P. nigra* are 18.0%, 16.6% and 12.8%, respectively. In addition, the greatest needle loss was observed in *P. pinaster* (23.2%), which is a less common species and represented by only 14 sample trees in this monitoring study.

Among the biotic causes of damage, *Rhynchaenus fagi, Thaumetopoea* spp., *Agelastica alni*, *Tortrix viridana*, *Dendroctonus micans, Cryphonectria parasitica, Dryomyia lichtensteinii* and *Ips sexdentatus* are the most pronounced. The number of trees affected by *Thaumetopoea* spp. declined by 46% in comparison to last year. As in previous years, mistletoe (*Viscum alba*) is also among the leading damaging agents.

10.25 Ukraine

The assessment of indicators for monitoring Level I plots was carried out by specialists of State Forestry Enterprises under the methodological guidance experts from the Ukrainian Research Institute of Forestry and Forest Melioration (URIFFM) and officers from Regional Forest Administrations (RFA). Responsibility for QA/QC of forest monitoring data is placed to RFA and URIFFM. Experts from URIFFM are responsible for maintaining the national forest monitoring database.

In 2014, 31 977 sample trees were assessed on 1 346 permanent forest monitoring plots in 23 administrative regions of Ukraine. Observations were not carried out in the Crimea, Donetsk, and part of the Lugansk regions. Mean defoliation of conifers was 11.0% and of broadleaved trees 11.3%.

Generally the tree crown condition is satisfactory: the part of healthy (not defoliated) trees amounts to 65.6%. There are no sufficient changes in crown condition in 2014 compared to the previous year. For the total sample the percentage of healthy trees slightly increased (65.1% against 63.4%). The part of ‘damaged trees’ (with defoliation over 25%) includes 6.0% of the sample trees.

For broadleaves the part of healthy trees is 64.3%, and respectively the part of defoliated trees is 35.7%. From those the part of damaged trees (with defoliation over 25%) is 5.8%. For conifers the part of healthy trees is 67.4% and the part of damaged trees (with defoliation of more than 25%) amounts to 6.8%.

For the sample of common sample trees (CSTs) (31 708 trees) mean defoliation remained at the same level (11.2%) compared to the values of the previous year.

The lowest average defoliation is found in *Pinus sylvestris* trees (10.5%), middle values have *Quercus robur* (11.6%), *Fraxinus excelsior* (11.3%) and *Fagus sylvatica* (11.7%), and the highest average defoliation is found in trees of *Picea abies* (13.1%).

ANNEX

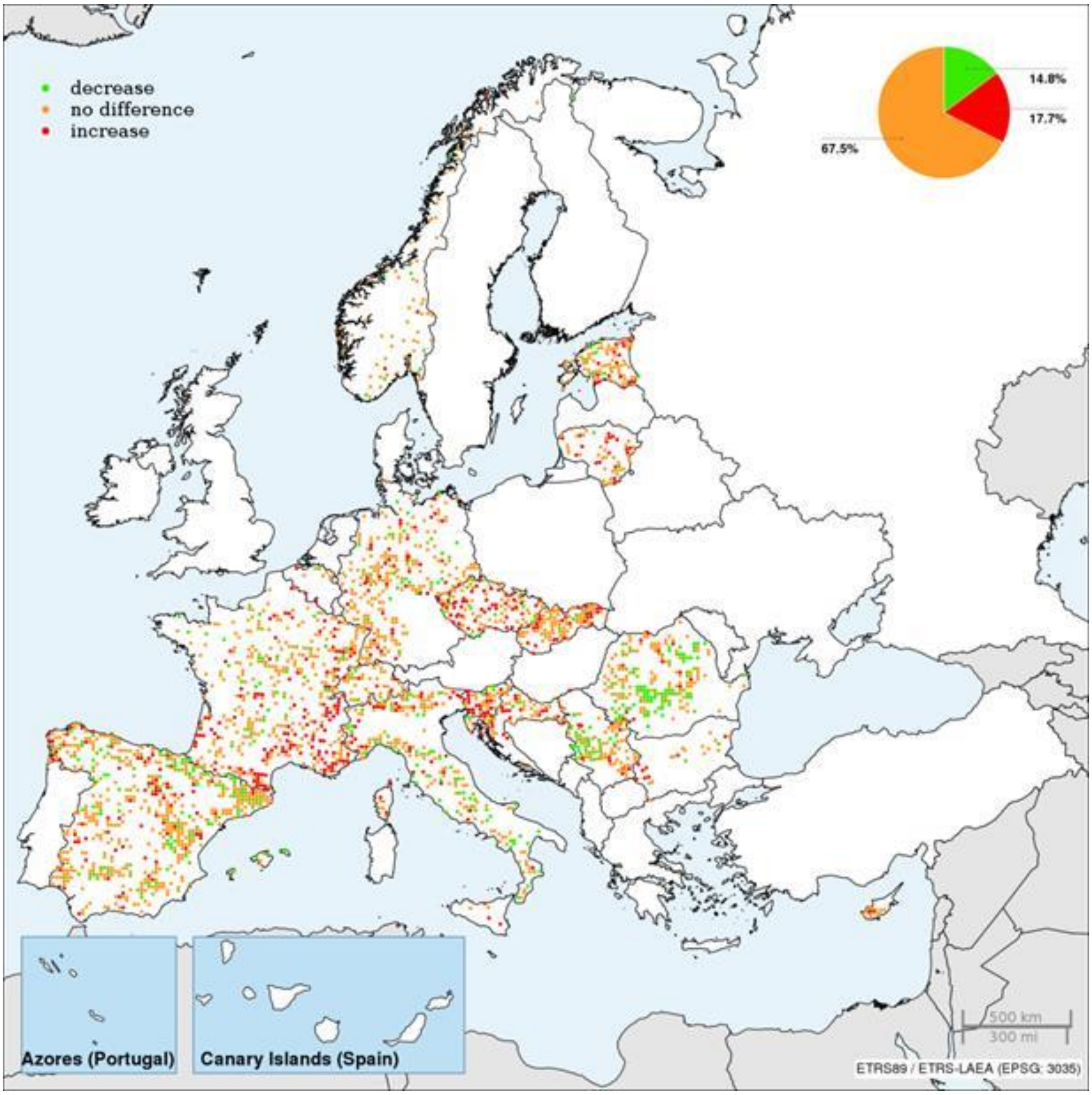
Annex I
Tree crown condition and damage causes – additional maps

Annex II
Results of the national crown condition surveys

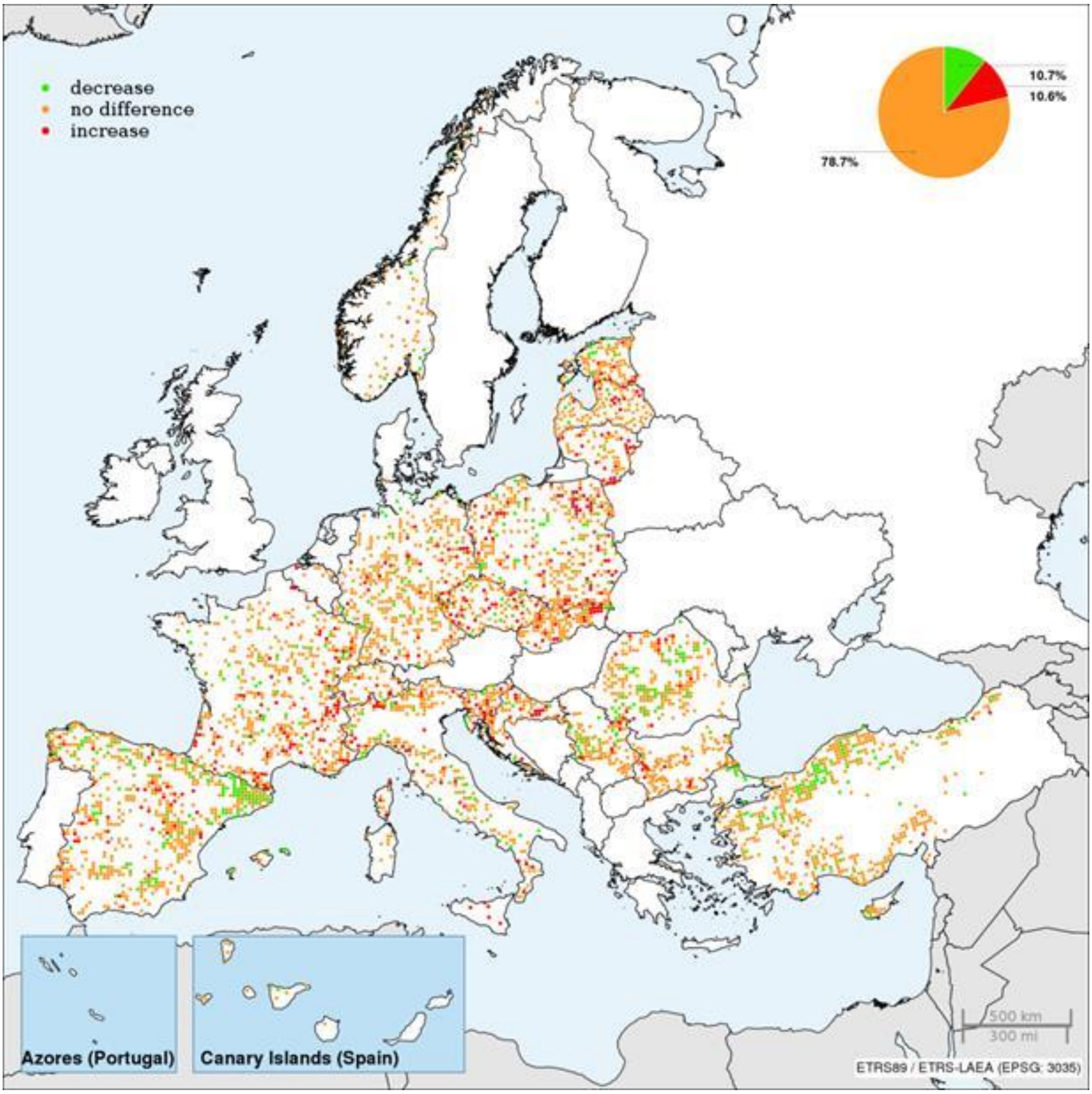
Annex III
Ozone concentration trends per country

Annex IV
Contacts

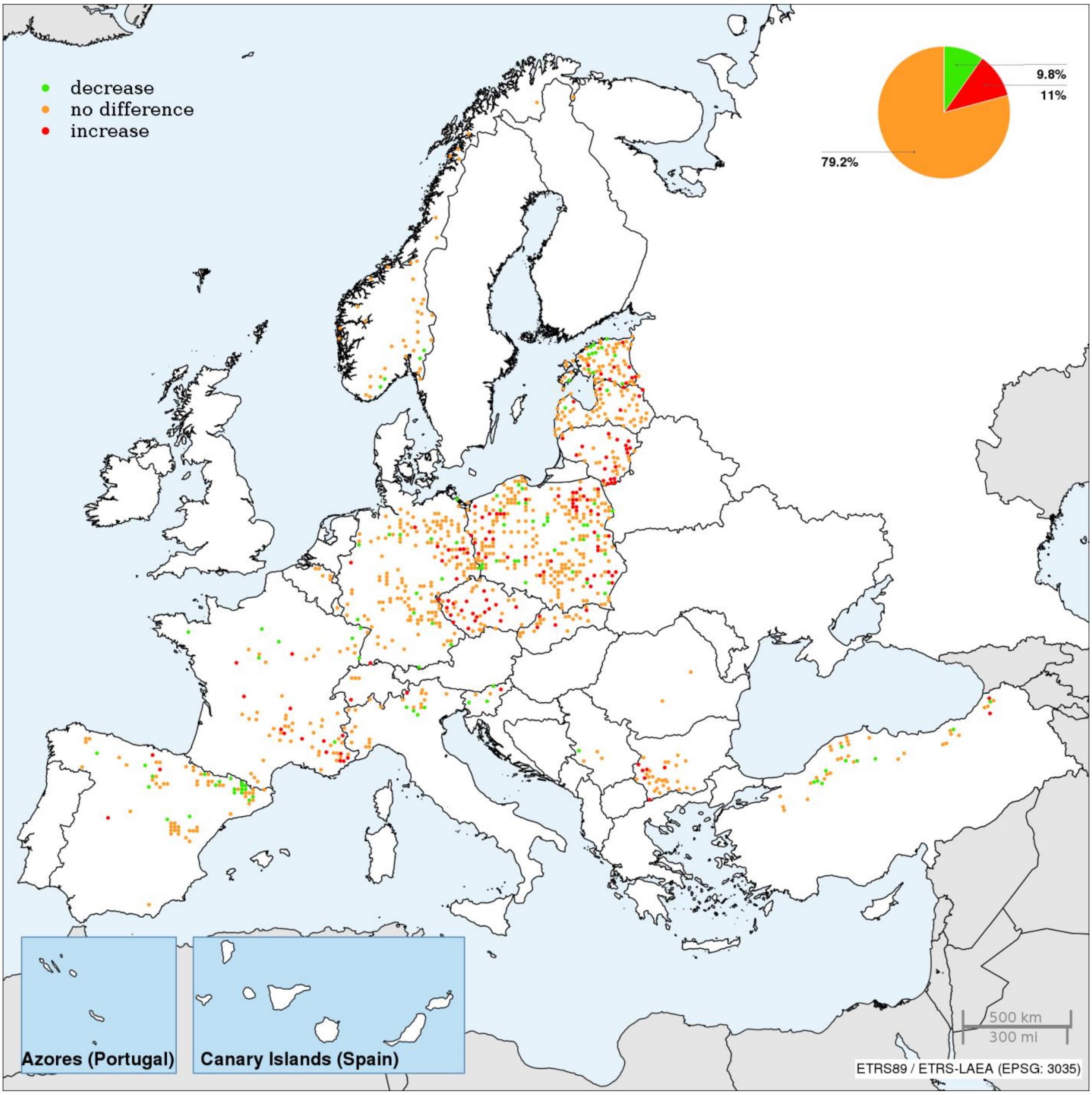
ANNEX I
TREE CROWN CONDITION AND DAMAGE CAUSES – ADDITIONAL MAPS



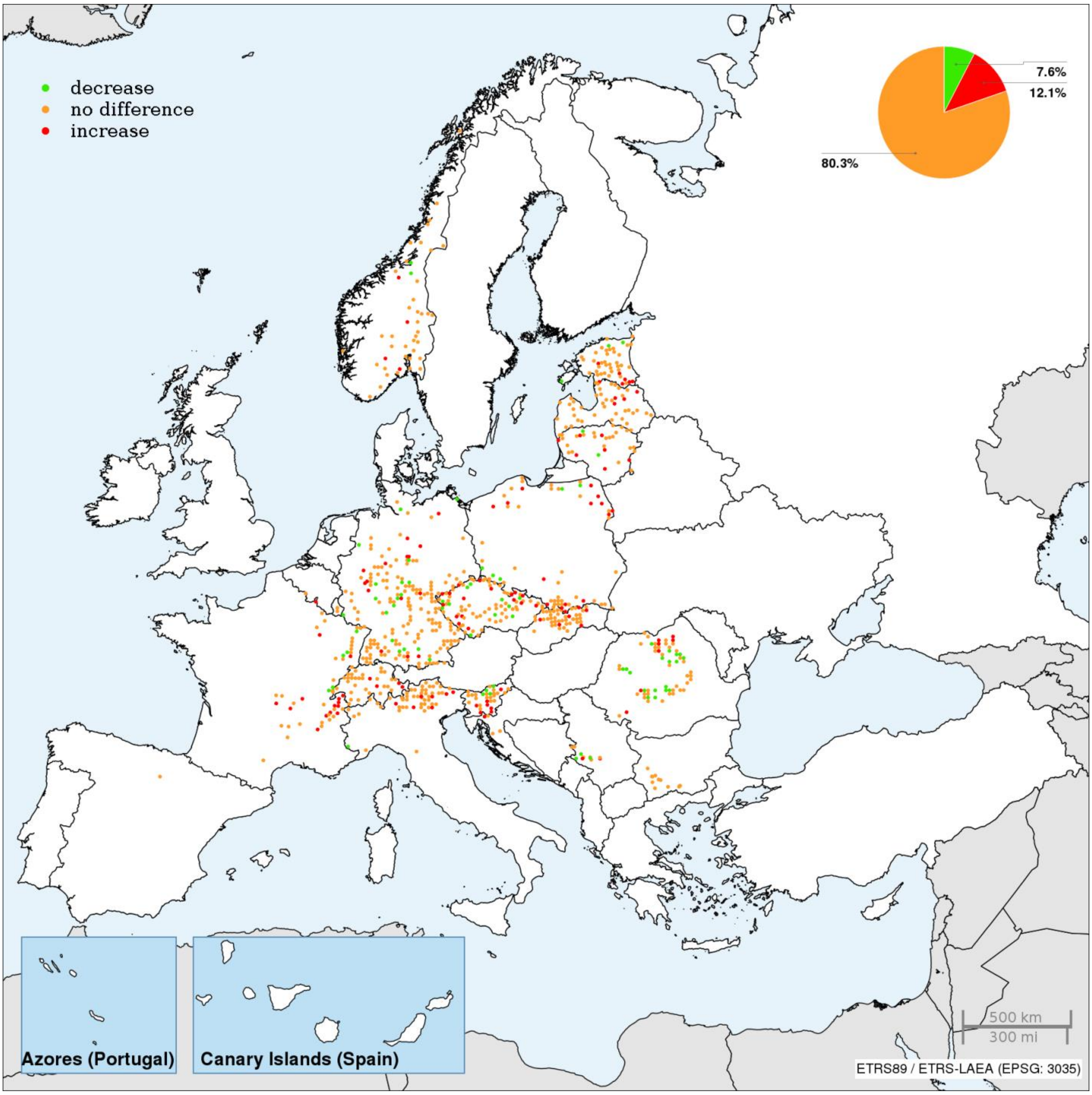
Annex I-1. Trends of mean plot defoliation (Mann-Kendall test) of all species between 2002 and 2014 with a minimum assessment length of 10 years.



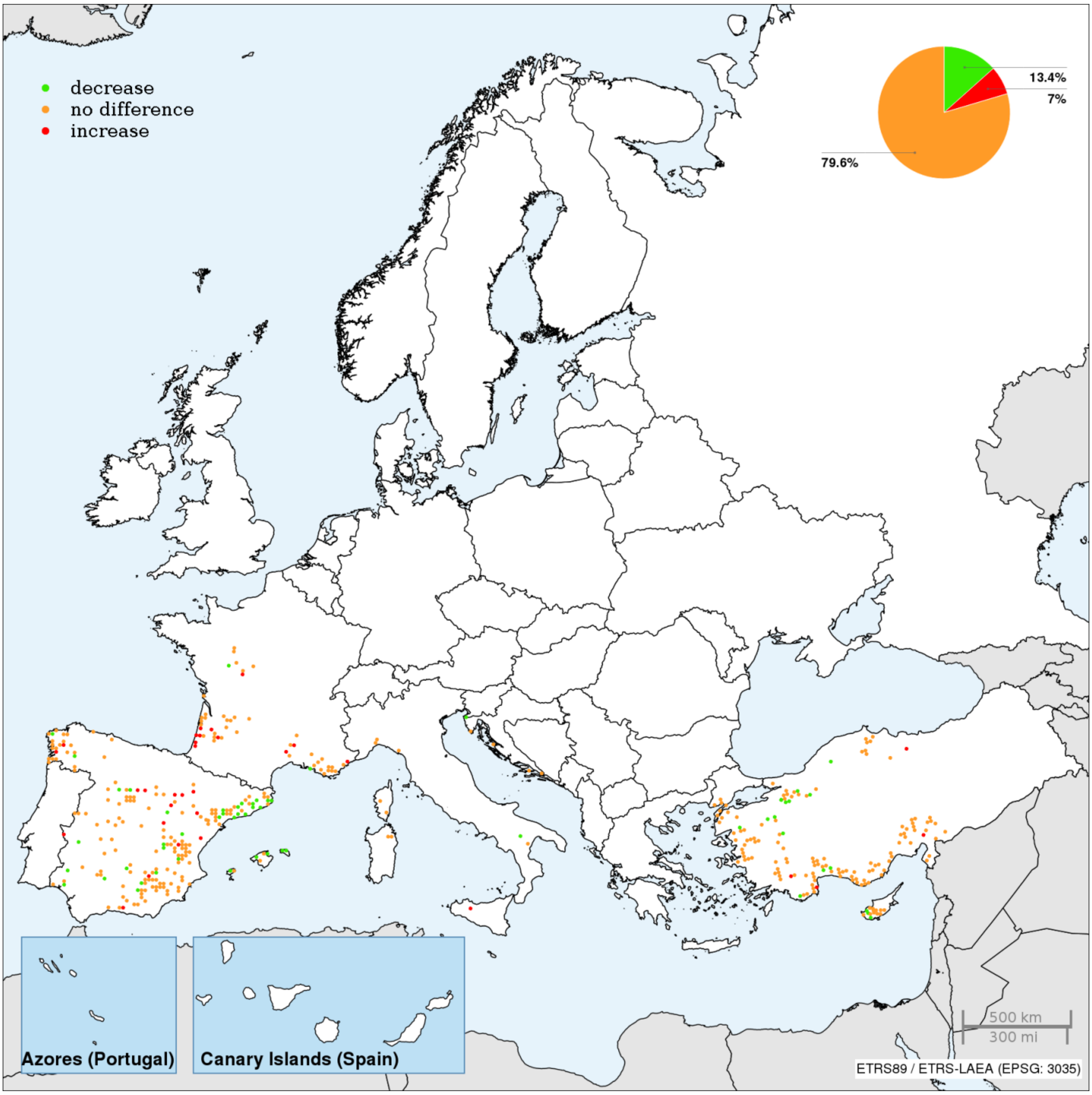
Annex I-2. Trends of mean plot defoliation (Mann-Kendall test) of all species between 2006 and 2014 with a minimum assessment length of 5 years.



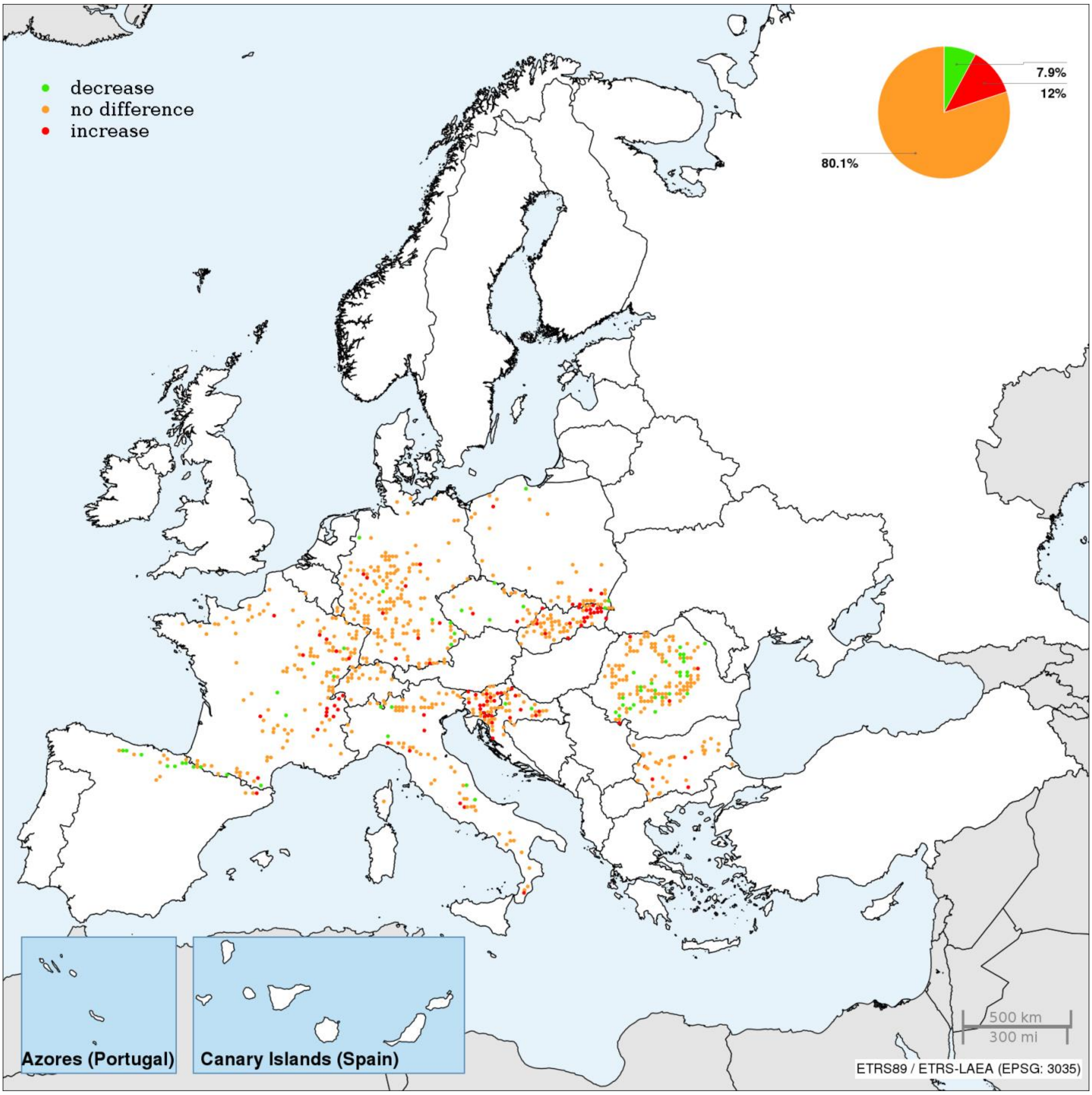
Annex I-3. Trends of mean plot defoliation (Mann-Kendall test) of Scots pine between 2006 and 2014 with a minimum assessment length of 5 years.



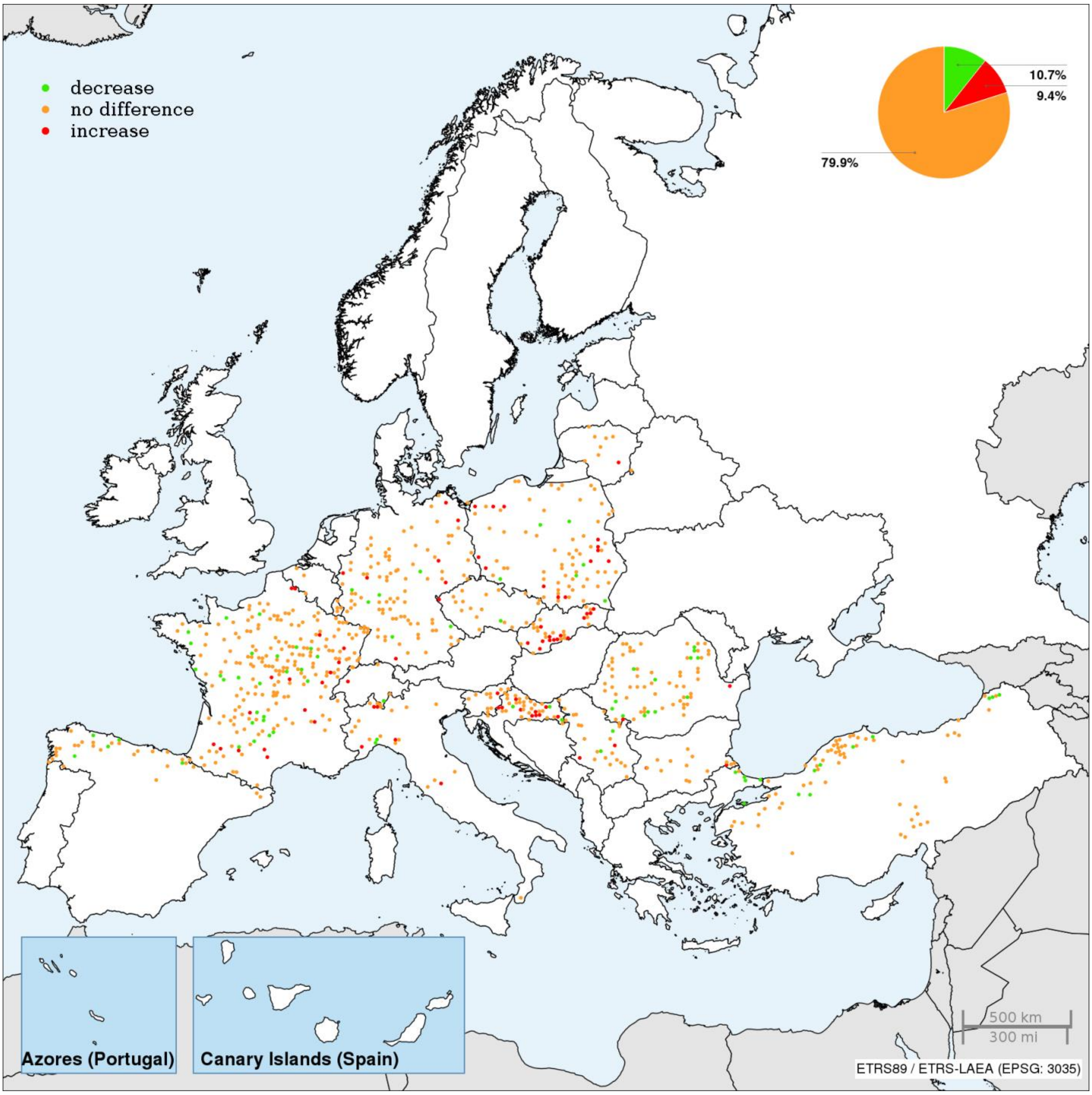
Annex I-4. Trends of mean plot defoliation (Mann-Kendall test) of Norway spruce between 2006 and 2014 with a minimum assessment length of 5 years.



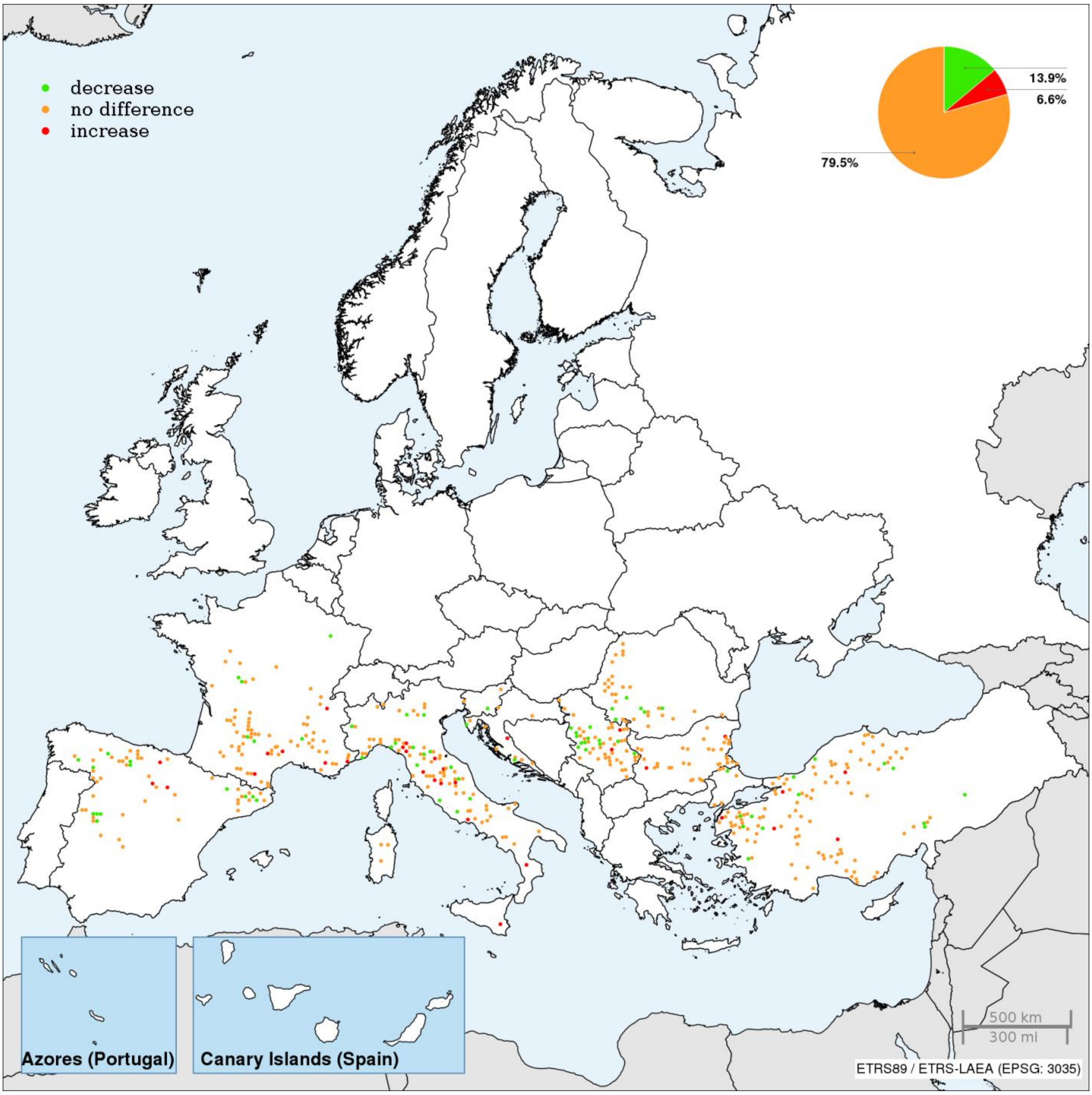
Annex I-5. Trends of mean plot defoliation (Mann-Kendall test) of Mediterranean lowland pines (*Pinus brutia*, *P. halepensis*, *P. pinaster*, *P. pinea*) between 2006 and 2014 with a minimum assessment length of 5 years.



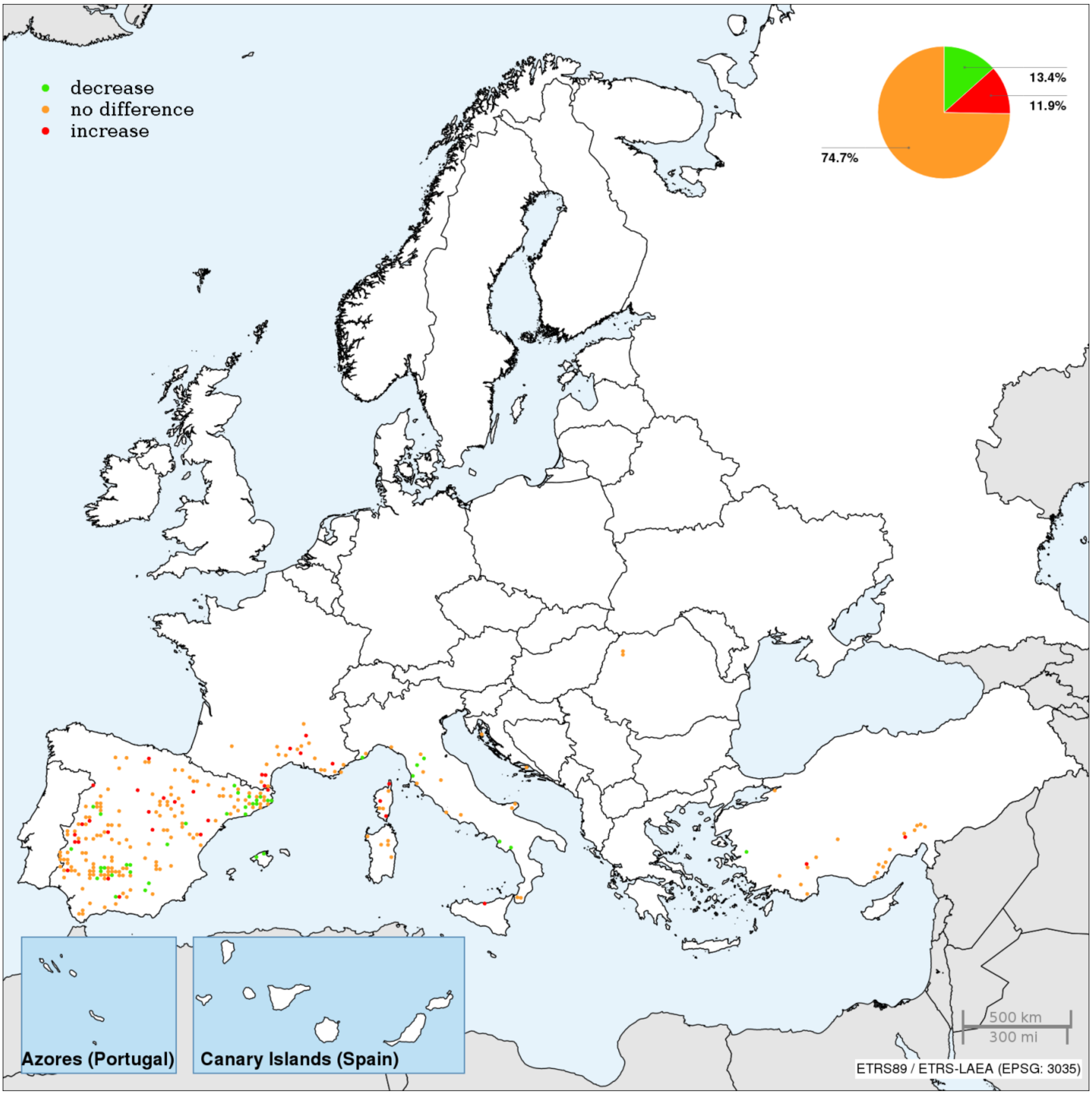
Annex I-6. Trends of mean plot defoliation (Mann-Kendall test) of common beech between 2006 and 2014 with a minimum assessment length of 5 years.



Annex I-7. Trends of mean plot defoliation (Mann-Kendall test) of deciduous temperate oaks (*Quercus robur* and *Q. petraea*) between 2006 and 2014 with a minimum assessment length of 5 years.



Annex I-8. Trends of mean plot defoliation (Mann-Kendall test) of deciduous (sub-) Mediterranean oaks (*Quercus cerris*, *Q. frainetto*, *Q. pubescens*, *Q. pyrenaica*) between 2006 and 2014 with a minimum assessment length of 5 years.



Annex I-9. Trends of mean plot defoliation (Mann-Kendall test) of evergreen oaks (*Quercus coccifera*, *Q. ilex*, *Q. rotundifolia*, *Q. suber*) between 2006 and 2014 with a minimum assessment length of 5 years.

ANNEX II
RESULTS OF THE NATIONAL CROWN CONDITION SURVEYS

Annex II-1 | Information on the monitoring design in the ICP Forests member states

Participating countries	Total area (1000 ha)	Forest area (1000 ha)	Coniferous forest (1000 ha)	Broadleaf forest (1000 ha)	Area surveyed (1000 ha)	Grid size (km x km)	No. of sample plots	No. of sample trees
Albania	No data available for 2014							
Andorra	46	17	15	2	17	4 x 4	11	264
Austria	No data available for 2014							
Belarus	No data available for 2014							
Belgium-Flanders	1 351	146	N/A	N/A	146	4 x 4	71	1 661
Belgium-Wallonia	1 684	554	223	256			42	373
Bulgaria	11 100	4 180	1 263	2 917	4 180		159	5 439
Croatia	5 654	2 061	321	1 740		16 x 16	103	2 472
Cyprus	925	297	171	N/A	137	16 x 16	15	361
Czech Republic	No data available for 2014							
Denmark	4 310	586	289	263			378	1 991
Estonia	4 510	2 253	1 115	1 138	2 253	16 x 16	96	2 329
Finland	No data available for 2014							
France	54 883	15 840	4 041	9 884	13 100		546	11 149
Germany	35 721	11 419	5 900	4 728	10 628	16 x 16	424	10 229
Greece	13 195	6 513	1 429	1 929	1 459		57	1 345
Hungary	No data available for 2014							
Ireland	No data available for 2014							
Italy	30 128	8 675	1 735	6 940		16 x 16	245	4 978
Latvia	6 459	3 162	1 453	1 710	3 162	8 x 8	116	1 743
Lithuania	6 530	2 177	1 152	903		4x4 / 16x16	1 028	6 306
Luxembourg	258	92	33	58	0.01	16 x 16	4	93
FYR of Macedonia	No data available for 2014							
Rep. of Moldova	3 384	400	7	366	374	2 x 2	611	12 379
Montenegro	No data available for 2014							
Netherlands	No data available for 2014							
Norway	32 376	12 000	6 800	5 200	12 000	3 x 3 / 9 x 9	1 744	9 647
Poland	31 268	9 164	6 382	2 782	9 164	8 x 8	2 013	40 258
Portugal	No data available for 2014							
Romania	23 839	6 233	1 873	4 360		16 x 16	241	5 784
Russian Fed.	No data available for 2014							
Serbia	8 836	2 360	179	2 181	1 868	16x16 / 4x4	130	2 943
Slovakia	No data available for 2014							
Slovenia	2 014	1 209	457	752	1 209	16 x 16	44	1 055
Spain	50 471	18 173	6 600	9 626		16 x 16	620	14 880
Sweden	40 729	28 068	14 637	1 239	17 204	varying	3 509	7 795
Switzerland	4 129	1 279	778	501			47	1 017
Turkey	77 846	21 537	13 158	8 379	9 057	16 x 16	531	12 338
Ukraine	60 350	9 400	2756	3 285	5 790	16 x 16	1 346	31 977
United Kingdom	No data available for 2014							
TOTAL	511 996	167 795	72 767	71 139			14 131	178 468

Annex II-2 | Tree defoliation of all species in 2014

Participating countries	Area surveyed (1000 ha)	No. of sample trees	0 none (%)	1 slight (%)	2 moderate (%)	3+4 severe and dead (%)	2+3+4 moderate to dead (%)
Albania	No data available for 2014						
Andorra	17	264	75.8	17.1	5.3	0.0	5.3
Austria	No data available for 2014						
Belarus	No data available for 2014						
Belgium-Flanders	146	1 661	9.0	69.9	18.3	2.8	21.1
Belgium-Wallonia		373	11.0	33.0	51.0	5.0	56.0
Bulgaria	4 180	5 439	27.4	46.6	21.7	4.3	26.0
Croatia		2 472	29.2	39.4	25.6	5.9	31.5
Cyprus	137	361	18.4	67.9	12.2	1.1	13.3
Czech Republic	No data available for 2014						
Denmark		1 991	71.1	21.9	5.7	1.3	7.0
Estonia	2 253	2 329	51.3	42.0	5.3	1.4	6.7
Finland	No data available for 2014						
France	13 100	11 149	22.3	34.9	37.8	5.0	42.8
Germany	10 628	10 229	32.7	41.1	24.6	1.6	26.2
Greece	1 459	1 345	45.9	29.3	18.4	6.4	24.8
Hungary	No data available for 2014						
Ireland	No data available for 2014						
Italy		4 978	29.4	39.8	25.6	5.2	30.8
Latvia	3 162	1 743	10.6	84.3	4.4	0.7	5.1
Lithuania		6 306	20.3	58.0	19.2	2.5	21.7
Luxembourg	No data available for 2014						
FYR of Macedonia	No data available for 2014						
Rep. of Moldova	374	12 379	43.0	37.1	19.0	0.9	19.9
Montenegro	No data available for 2014						
Netherlands	No data available for 2014						
Norway	12 000	9 647	48.1	36.0	13.4	2.5	15.9
Poland	9 164	40 258	11.6	69.6	17.6	1.3	18.9
Portugal	No data available for 2014						
Romania		5 784	54.4	32.2	10.6	2.9	13.5
Russian Federation	No data available for 2014						
Serbia	1 868	2 943	69.5	18.1	8.6	3.8	12.4
Slovakia	No data available for 2014						
Slovenia	1 209	1 055	16.8	44.9	30.9	7.4	38.3
Spain		14 880	21.7	63.4	11.4	3.5	14.9
Sweden	17 204	7 795	45.6	35.6	16.4	2.4	18.8
Switzerland		1 017	18.2	51.3	19.5	11.1	30.6
Turkey	9 057	12 338	39.4	49.6	9.8	1.2	11.0
Ukraine	5 790	31 977	65.6	28.3	5.7	0.3	6.0
United Kingdom	No data available for 2014						

Cyprus, Norway, Sweden: only conifers assessed.

Note that some differences in the level of defoliation between participating countries may be at least partly due to differences in standards used. This restriction, however, does not affect the reliability of the trends over time.

Annex II-3 | Tree defoliation of conifers in 2014

Participating countries	Coniferous Forest (1000 ha)	No. of sample trees	0 None (%)	1 Slight (%)	2 Moderate (%)	3+4 severe and dead (%)	2+3+4 moderate to dead (%)
Albania	No data available for 2014						
Andorra	15	259	77.2	17.4	5.4	0.0	5.4
Austria	No data available for 2014						
Belarus	No data available for 2014						
Belgium-Flanders	N/A	739	5.4	81.3	12.9	0.4	13.3
Belgium-Wallonia	223	194	7.0	34.0	55.0	4.0	59.0
Bulgaria	1 263	2 336	18.5	47.4	29.0	5.1	34.1
Croatia	321	384	23.2	27.1	38.5	11.2	49.7
Cyprus	171	360	18.8	67.9	12.2	1.1	13.3
Czech Republic	No data available for 2014						
Denmark	289	1 083	74.9	19.8	4.8	0.5	5.3
Estonia	1 115	2 047	48.3	44.8	5.4	1.5	6.9
Finland	No data available for 2014						
France	4 041	3 895	32.7	30.7	33.0	3.6	36.6
Germany	5 900	6 194	36.6	43.7	18.5	1.2	19.7
Greece	1 429	726	43.9	29.2	18.6	8.1	26.7
Hungary	No data available for 2014						
Ireland	No data available for 2014						
Italy	1 735	1 131	39.6	36.4	19.4	4.6	24.0
Latvia	1 454	1 336	10.6	84.6	4.3	0.5	4.8
Lithuania	1 152	3 714	19.8	59.1	19.5	1.6	21.1
Luxembourg	33	15	0.0	6.6	93.3	0.0	93.3
FYR of Macedonia	No data available for 2014						
Rep. of Moldova	8	34	64.7	5.9	29.4	0.0	29.4
Montenegro	No data available for 2014						
Netherlands	No data available for 2014						
Norway	6 800	9 647	48.1	36.0	13.4	2.5	15.9
Poland	6 382	26 048	9.5	73.3	16.1	1.1	17.2
Portugal	No data available for 2014						
Romania	1 873	1 119	52.5	33.8	11.0	2.7	13.7
Russian Fed.	No data available for 2014						
Serbia	179	336	74.1	11.3	8.6	6.0	14.6
Slovakia	No data available for 2014						
Slovenia	457	394	21.8	40.1	30.2	7.9	38.1
Spain	6 600	7 413	25.9	62.7	8.8	2.5	11.4
Sweden	14 637	7 795	45.6	35.6	16.4	2.4	18.8
Switzerland	778	725	14.8	53.5	23.5	8.2	31.7
Turkey	13 158	7 599	41.8	51.0	6.7	0.5	7.2
Ukraine	2 756	13 707	67.4	25.8	6.5	0.3	6.8
United Kingdom	No data available for 2014						

Note that some differences in the level of defoliation between participating countries may be at least partly due to differences in standards used. This restriction, however, does not affect the reliability of the trends over time.

Annex II-4 | Tree defoliation of broadleaves in 2014

Participating countries	Broadleaf forest (1000 ha)	No. of sample trees	0 None (%)	1 Slight (%)	2 Moderate (%)	3+4 severe and dead (%)	2+3+4 moderate to dead (%)
Albania	No data available for 2014						
Andorra	2	5	80.0	0.0	0.0	20.0	20.0
Austria	No data available for 2014						
Belarus	No data available for 2014						
Belgium-Flanders		922	11.9	60.8	22.5	4.8	27.3
Belgium-Wallonia	256	179	15.0	32.0	43.0	10.0	53.0
Bulgaria	2 917	3 103	34.0	46.0	16.3	3.7	20.0
Croatia	1 740	2 088	30.3	41.6	23.2	3.9	28.1
Cyprus	Only conifers assessed						
Czech Republic	No data available for 2014						
Denmark	263	908	66.5	24.5	6.8	2.2	9.0
Estonia	1 138	282	72.7	21.6	5.0	0.7	5.7
Finland	No data available for 2014						
France	9 884	7 254	16.8	37.2	40.4	5.7	46.1
Germany	4 728	4 035	26.6	37.3	34.1	2.0	36.1
Greece	1 929	619	49.4	33.9	13.6	3.1	16.7
Hungary	No data available for 2014						
Ireland	Only conifers assessed						
Italy	6 940	3 441	26.1	40.5	27.7	5.7	33.4
Latvia	1 710	407	10.6	83.3	4.9	1.2	6.1
Lithuania	903	2 592	21.0	56.5	18.8	3.7	22.5
Luxembourg	58	78	0.0	65.4	30.8	3.8	34.6
FYR of Macedonia	No data available for 2014						
Rep. of Moldova	367	12 345	42.9	37.2	19.0	0.9	19.9
Montenegro	No data available for 2014						
Netherlands	No data available for 2014						
Norway	Only conifers assessed						
Poland	2 782	14 210	15.4	62.8	20.2	1.7	21.9
Portugal	No data available for 2014						
Romania	4 360	4 665	62.1	24.9	8.9	4.1	13.0
Russian Fed.	No data available for 2014						
Serbia	2 181	2 607	68.9	19.0	8.6	3.5	12.1
Slovakia	No data available for 2014						
Slovenia	753	661	13.8	47.8	31.3	7.1	38.4
Spain	9 626	7 467	17.5	64.1	14.0	4.4	18.4
Sweden	Only conifers assessed						
Switzerland	501	292	25.4	46.7	11.0	17.0	28.0
Turkey	8 379	4 739	35.6	47.2	14.8	2.4	17.2
Ukraine	3 285	18 270	64.3	5.0	0.4	0.0	0.4
United Kingdom	No data available for 2014						

Note that some differences in the level of defoliation between participating countries may be at least partly due to differences in standards used. This restriction, however, does not affect the reliability of the trends over time.

Annex II-5 | Percentage of moderately to severely defoliated trees between 2004 and 2014 – All species

Participating countries	All species Defoliation classes 2–4											Change % points
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2013/14
Albania	12.2		11.1							21.0		**N/A**
Andorra	36.1		23.0	47.2	15.3	6.8	15.3	8.3	5.6	3.4	5.3	**+1.9**
Austria	13.1	14.8	15.0				14.2					**N/A**
Belarus	10.0	9.0	7.9	8.1	8.0	8.4	7.4	6.1				**N/A**
Belgium	19.4	19.9	17.9	16.4	14.5	20.2	22.1	23.5	28.2	27.6	27.5	**-0.1**
Bulgaria	39.7	35.0	37.4	29.7	31.9	21.1	23.8	21.6	32.3	33.5	26.0	**-7.5**
Croatia	25.2	27.1	24.9	25.1	23.9	26.3	27.9	25.2	28.5	29.1	31.5	**+2.4**
Cyprus	12.2	10.8	20.8	16.7	47.0	36.2	19.2	16.4	10.6	8.9	13.3	**+4.4**
Czech Republic	57.3	57.1	56.2	57.1	56.7	56.8	54.2	52.7	50.3	51.7		**N/A**
Denmark	11.8	9.4	7.6	6.1	9.1	5.5	9.3	10.0	7.3	4.9	7.0	**+2.1**
Estonia	5.3	5.4	6.2	6.8	9.0	7.2	8.1	8.1	7.8	8.0	6.7	**-1.3**
Finland	9.8	8.8	9.7	10.5	10.2	9.1	10.5	10.6	14.3			**N/A**
France	31.7	34.2	35.6	35.4	32.4	33.5	34.6	39.9	41.4	40.1	42.8	**+2.7**
Germany	31.4	28.5	27.9	24.8	25.7	26.5	23.2	28.0	24.6	22.7	26.2	**+3.5**
Greece		16.3				24.3	23.8				24.8	**N/A**
Hungary	21.5	21.0	19.2	20.7		18.4	21.8	18.9	20.2	22.4		**N/A**
Ireland	17.4	16.2	7.4	6.0	10.0	12.5	17.5		1.0			**N/A**
Italy	35.9	32.9	30.5	35.7	32.8	35.8	29.8	31.3	35.7	33.7	30.8	**-2.9**
Latvia	12.5	13.1	13.4	15.0	15.3	13.8	13.4	14.0	9.2	6.4	5.1	**-1.3**
Lithuania	13.9	11.0	12.0	12.3	19.6	17.7	21.3	15.4	24.5	19.7	21.7	**+2.0**
Luxembourg										33.2	34.6	**+1.4**
FYR of Macedonia				23.0								**N/A**
Rep. of Moldova	34.0	26.5	27.6	32.5	33.6	25.2	22.5	18.4	25.6		19.9	**N/A**
Montenegro										22.7		**N/A**
Netherlands	27.5	30.2	19.5			18.2	21.6					**N/A**
Norway	20.7	21.6	23.3	26.2	22.7	21.0	18.9	20.9	18.8	17.7	15.9	**-1.8**
Poland	34.6	30.7	20.1	20.2	18.0	17.7	20.7	24.0	23.4	18.8	18.9	**+0.1**
Portugal	16.6	24.3										**N/A**
Romania	11.7	8.1	8.6	23.2		18.9	17.8	13.9	13.9	13.6	13.5	**-0.1**
Russian Fed.						6.2	4.4	8.3				**N/A**
Serbia	14.3	16.4	11.3	15.4	11.5	10.3	10.8	7.6	10.3	14.7	12.4	**-2.3**
Slovakia	26.7	22.9	28.1	25.6	29.3	32.1	38.6	34.7	37.9	43.4		**N/A**
Slovenia	29.3	30.6	29.4	35.8	36.9	35.5	31.8	31.4	29.1	30.9	38.3	**+7.4**
Spain	15.0	21.3	21.5	17.6	15.6	17.7	14.6	11.8	17.5	16.6	14.9	**-1.7**
Sweden	16.5	18.4	19.4	17.9	17.3	15.1	19.2	18.9	15.9	19.9		**N/A**
Switzerland	29.1	28.1	22.6	22.4	19.0	18.3	22.2	30.9	31.3	26.0	30.6	**+4.6**
Turkey					24.6	18.7	16.8	13.6	12.4	10.2	11.0	**+0.8**
Ukraine	29.9	8.7	6.6	7.1	8.2	6.8	5.8	6.8	7.5	7.1	6.0	**-1.1**
United Kingdom	26.5	24.8	25.9	26.0			48.5					**N/A**

Note that some differences in the level of defoliation between participating countries may be at least partly due to differences in standards used. This restriction, however, does not affect the reliability of the trends over time.

Austria: from 2003 on results are based on the 16 x 16 km transnational grid net and must not be compared with previous years. *Poland*, *Belgium-Wallonia*: change of grid net since 2006 and 2010, resp. *Russian Federation:* north-western and Central European parts only. *Ukraine*: change of grid net in 2005. *Hungary, Romania*: comparisons not possible due to changing survey designs. *Norway*: new sampling design since 2013.

Annex II-6 | Percentage of moderately to severely defoliated trees between 2004 and 2014 – Conifers

Participating countries	Conifers Defoliation classes 2–4											Change % points
	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2013/14**
Albania	14.0		13.6							21.0		**N/A**
Andorra	36.1		23.0	47.2	15.3	6.8	15.3	8.3	5.6	3.1	5.4	**+2.3**
Austria	13.1	15.1	14.5				14.5					**N/A**
Belarus	8.9	8.4	7.5	8.1	8.1	8.3	7.7	5.8				**N/A**
Belgium	15.6	16.8	15.8	13.9	13.2	13.6	16.2	15.2	20.3	19.7	22.8	**+3.1**
Bulgaria	47.1	45.4	47.6	37.4	45.6	33.0	31.1	33.3	35.1	40.8	34.1	**-6.7**
Croatia	70.6	79.5	71.7	61.1	59.1	66.5	56.9	45.1	54.7	48.3	49.7	**+1.4**
Cyprus	12.2	10.8	20.8	16.7	46.9	36.2	19.2	16.4	10.6	8.9	13.3	**+4.4**
Czech Republic	62.6	62.7	62.3	62.9	62.8	63.1	60.1	58.9	56.9	59.2		**N/A**
Denmark	5.8	5.5	1.7	3.1	9.9	1.0	5.4	5.7	4.6	2.8	5.3	**+2.5**
Estonia	5.3	5.6	6.0	6.7	9.3	7.5	9.0	8.7	6.6	8.5	6.9	**-1.6**
Finland	10.1	9.2	9.6	10.4	10.1	9.9	10.6	11.7	14.6			**N/A**
France	18.6	20.8	23.6	24.1	25.1	26.8	27.4	31.9	32.2	33.7	36.6	**+2.9**
Germany	26.3	24.9	22.7	20.2	24.1	20.3	19.2	20.3	19.3	18.1	19.7	**+1.6**
Greece		15.0				26.3	23.7				26.7	**N/A**
Hungary	24.2	22.0	20.8	22.3		27.1	35.1	28.7	23.1	23.5		**N/A**
Ireland	17.4	16.2	7.4	6.2	10.0	12.5	17.5		1.0			**N/A**
Italy	21.7	22.8	19.5	22.7	24.0	31.6	29.1	32.2	31.8	24.2	24.0	**-0.2**
Latvia	11.9	13.2	15.2	16.2	16.7	14.8	15.0	16.0	7.9	6.9	4.8	**-2.1**
Lithuania	10.2	9.3	9.5	10.2	19.1	17.4	19.8	16.3	26.9	23.1	21.1	**-2.0**
Luxembourg										17.5	93.3	**+75.8***
FYR of Macedonia												**N/A**
Rep. of Moldova	35.5	38.0	38.6	34.3			33.3	32.1	44.3		29.4	**N/A**
Montenegro										22.6		**N/A**
Netherlands	17.2	17.9	15.3			14.1	18.9					**N/A**
Norway	16.7	19.7	20.2	23.0	19.2	17.9	16.4	17.3	16.1	17.7	15.9	**-1.8**
Poland	33.4	29.6	21.1	20.9	17.5	17.2	20.3	24.2	22.3	17.8	17.2	**-0.6**
Portugal	10.8	17.1										**N/A**
Romania	7.6	4.7	5.2	21.8		21.7	16.1	15.9	14.9	13.9	13.7	**-0.2**
Russian Fed.						7.3	5.1	10.6				**N/A**
Serbia	19.8	21.3	12.6	13.3	13.0	12.6	12.0	11.1	11.0	13.0	14.6	**+1.6**
Slovakia	36.2	35.3	42.4	37.5	41.1	42.7	46.8	46.6	43.5	43.3		**N/A**
Slovenia	37.4	33.8	32.1	36.0	40.7	38.8	37.8	33.6	31.3	31.3	38.1	**+6.8**
Spain	14.0	19.4	18.7	15.8	12.9	14.9	13.1	10.4	11.4	12.6	11.4	**-1.2**
Sweden	16.0	19.6	20.1	17.9	17.3	15.1	19.2	18.9	15.9	19.9	18.8	**-1.1**
Switzerland	27.4	28.2	22.5	20.7	18.7	18.8	20.9	31.5	30.6	23.3	31.7	**+8.4**
Turkey				8.1	16.2	16.0	14.5	11.6	9.9	6.9	7.2	**+0.3**
Ukraine	11.4	8.1	6.9	7.1	7.1	6.3	5.6	6.8	7.5	7.5	6.8	**-0.7**
United Kingdom	23.2	22.2	23.3	16.1			38.6					**N/A**

** In Luxembourg only 2.0% of the conifers assessed in 2013 were assessed in 2014.*

Note that some differences in the level of defoliation between participating countries may be at least partly due to differences in standards used. This restriction, however, does not affect the reliability of the trends over time.

Austria: from 2003 on results are based on the 16 x 16 km transnational grid net and must not be compared with previous years. *Poland, Belgium-Wallonia*: change of grid net since 2006 and 2010, resp. *Russian Federation:* north-western and Central European parts only. *Ukraine*: change of grid net in 2005. *Hungary, Romania*: comparisons not possible due to changing survey designs. *Norway*: new sampling design since 2013.

Annex II-7 | Percentage of moderately to severely defoliated trees between 2004 and 2014 – Broadleaves

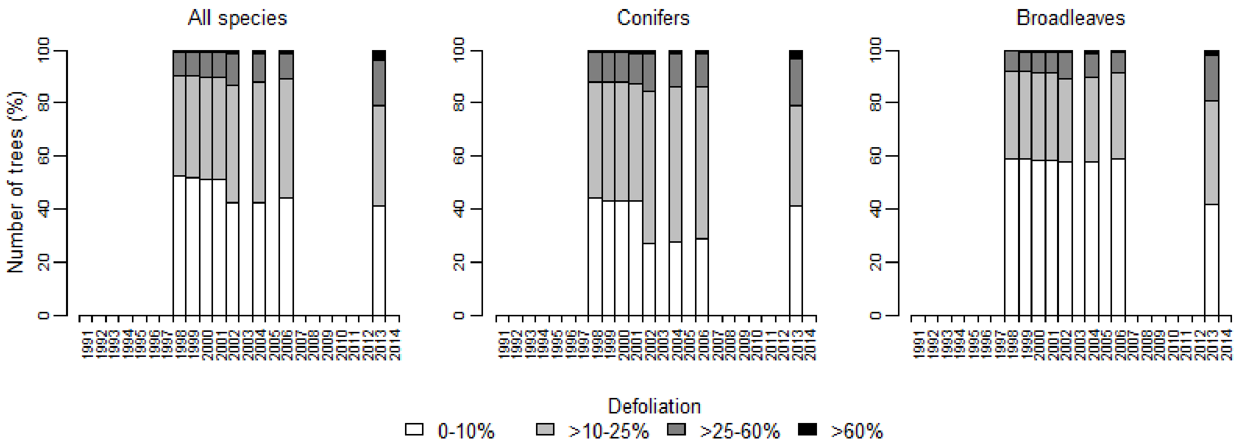
Participating countries	Broadleaves Defoliation classes 2–4											Change % points
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2013/14
Albania	10.3		8.5							19.0		**N/A**
Andorra										20.0	20.0	**0.0**
Austria	13.6	12.9	20.1				10.5					**N/A**
Belarus	12.9	10.6	8.9	8.2	7.6	8.7	6.9	6.4				**N/A**
Belgium	21.3	21.4	18.8	17.5	15.3	23.4	24.6	26.7	32.9	29.4	31.4	**+2.0**
Bulgaria	30.1	23.1	36.4	21.1	17.8	12.2	18.2	12.8	29.8	28.0	20.0	**-8.0**
Croatia	17.2	19.2	18.2	20.0	19.1	20.7	21.9	21.5	23.7	25.7	28.1	**+2.4**
Cyprus	Only conifers assessed											
Czech Republic	31.8	32.0	31.2	33.5	32.2	32.9	32.2	31.2	28.4	25.7		**N/A**
Denmark	19.1	14.4	14.8	10.3	8.0	10.0	12.1	12.8	10.9	7.9	9.0	**+1.1**
Estonia	5.3	3.4	8.6	7.6	3.4	3.5	2.5	3.0	14.9	5.3	5.7	**+0.4**
Finland	8.4	7.2	10.3	10.9	10.6	4.7	9.2	6.0	12.8			**N/A**
France	38.7	41.3	42.0	41.6	36.5	37.1	38.7	44.3	45.9	43.6	46.1	**+2.5**
Germany	41.5	35.8	37.2	32.8	28.4	36.1	29.4	38.0	32.5	29.8	36.1	**+6.3**
Greece		17.9				5.2	23.9				16.7	**N/A**
Hungary	21.0	20.9	19.0	20.6		17.1	19.7	17.3	19.9	22.3		**N/A**
Ireland												**N/A**
Italy	42.0	36.5	35.2	40.4	35.8	36.8	30.1	32.7	37.2	37.1	33.4	**-3.7**
Latvia	14.3	12.9	8.5	11.8	11.5	11.6	9.4	8.8	12.9	4.4	6.1	**+1.7**
Lithuania	21.8	15.4	16.6	17.7	20.3	18.4	23.7	13.8	21.0	14.7	22.5	**+7.8**
Luxembourg										42.4		**N/A**
FYR of Macedonia												**N/A**
Rep. of Moldova	33.9	26.4	27.6	32.5	33.6	25.2	22.4	18.4	25.6		19.9	**N/A**
Montenegro										22.8		**N/A**
Netherlands	46.9	53.1	26.2			25.6	26.6					**N/A**
Norway	33.2	27.6	33.2	36.3	33.8	31.0	26.8	32.3	27.3			**N/A**
Poland	38.7	34.1	18.0	18.9	19.1	18.5	21.5	23.5	25.5	20.7	21.9	**+1.2**
Portugal	19.0	27.0										**N/A**
Romania	13.0	9.3	9.9	23.5		18.3	18.0	13.4	13.6	13.6	13.0	**-0.6**
Russian Fed.						4.4	3.2	4.3				**N/A**
Serbia	13.5	15.7	11.0	15.7	11.3	9.9	10.7	7.2	10.2	14.9	12.1	**-2.8**
Slovakia	19.9	13.6	17.0	16.6	20.8	24.5	32.9	26.4	33.9	43.5	43.5	**0.0**
Slovenia	24.2	28.5	27.6	35.7	34.6	33.3	28.1	30.0	27.7	30.6	38.4	**+7.8**
Spain	16.1	23.3	24.4	19.5	18.4	20.7	16.1	13.2	23.6	20.7	18.4	**-2.3**
Sweden	8.3	9.2	10.8									**N/A**
Switzerland	32.8	27.9	22.6	26.1	19.6	17.4	25.2	29.6	33.3	31.5	28.0	**-3.5**
Turkey					38.3	23.4	21.2	17.2	16.8	15.7	17.2	**+1.5**
Ukraine	43.2	9.2	6.2	7.1	9.1	7.2	6.4	6.7	7.5	7.0	0.4	**-6.6**
United Kingdom	30.6	28.2	29.2	35.3			56.1					**N/A**

Note that some differences in the level of damage between participating countries may be at least partly due to differences in standards used. This restriction, however, does not affect the reliability of the trends over time.

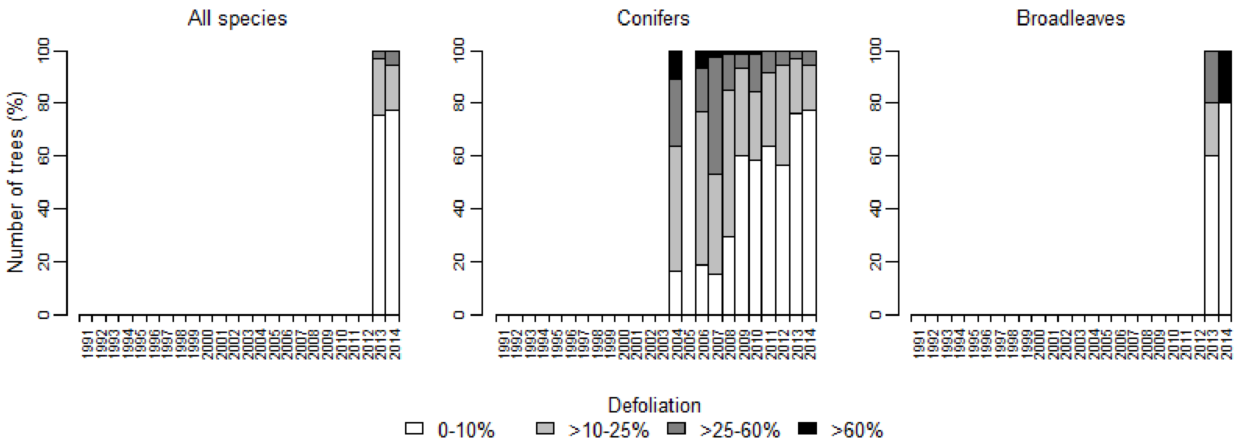
Austria: from 2003 on results are based on the 16 x 16 km transnational grid net and must not be compared with previous years. *Poland, Belgium-Wallonia*: change of grid net since 2006 and 2010, resp. *Russian Federation:* north-western and Central European parts only. *Ukraine*: change of grid net in 2005. *Hungary, Romania*: comparisons not possible due to changing survey designs. *Norway*: new sampling design since 2013.

Annex II-8 | Change of tree defoliation over time (1991–2014) per country

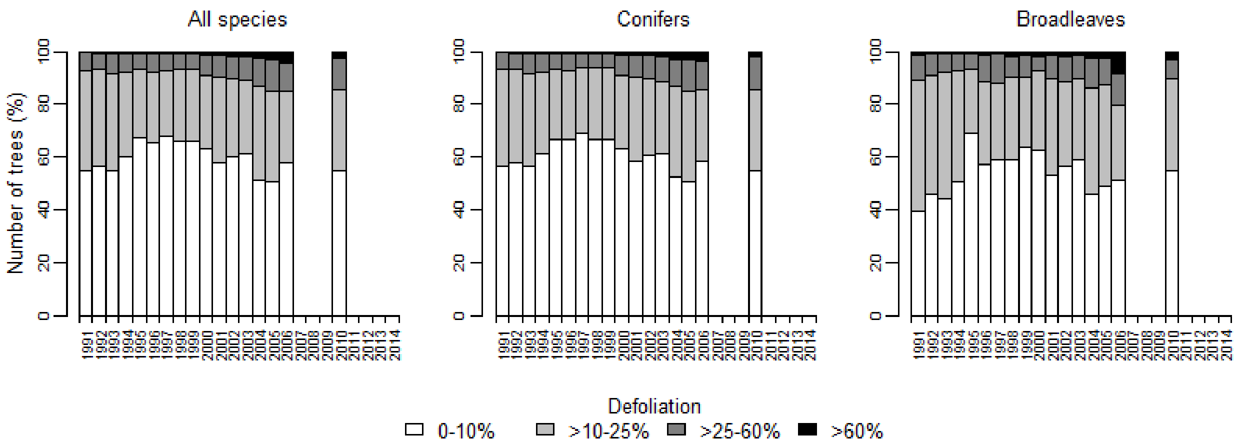
ALBANIA



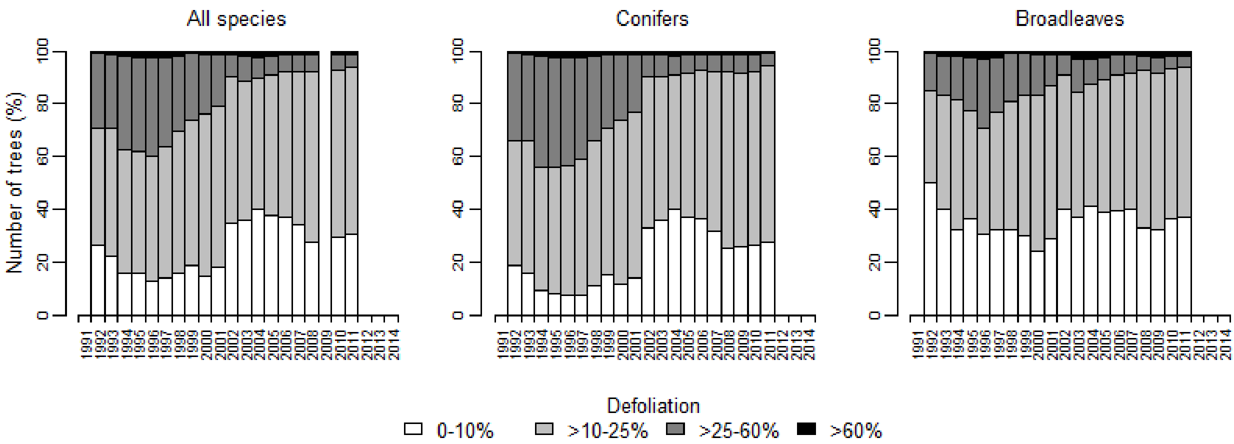
ANDORRA



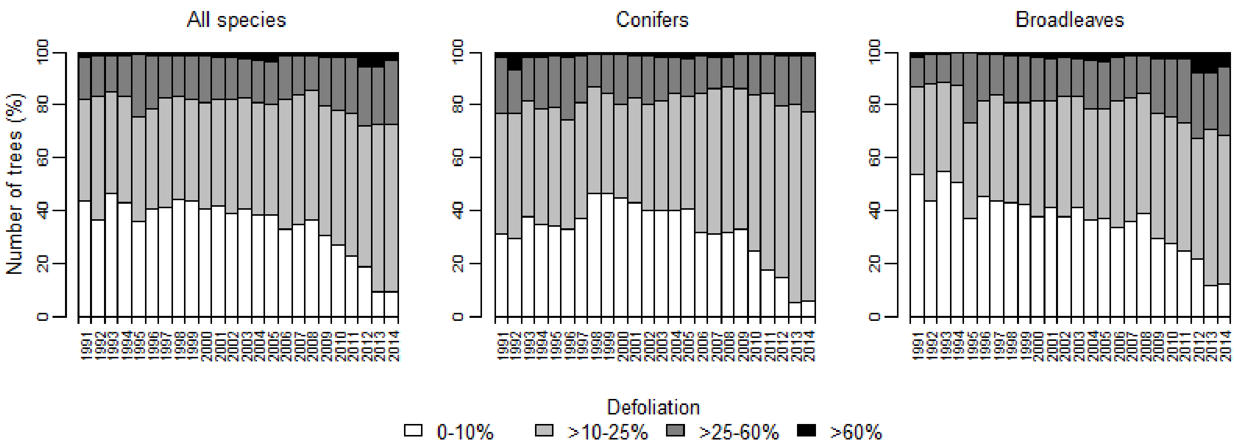
AUSTRIA



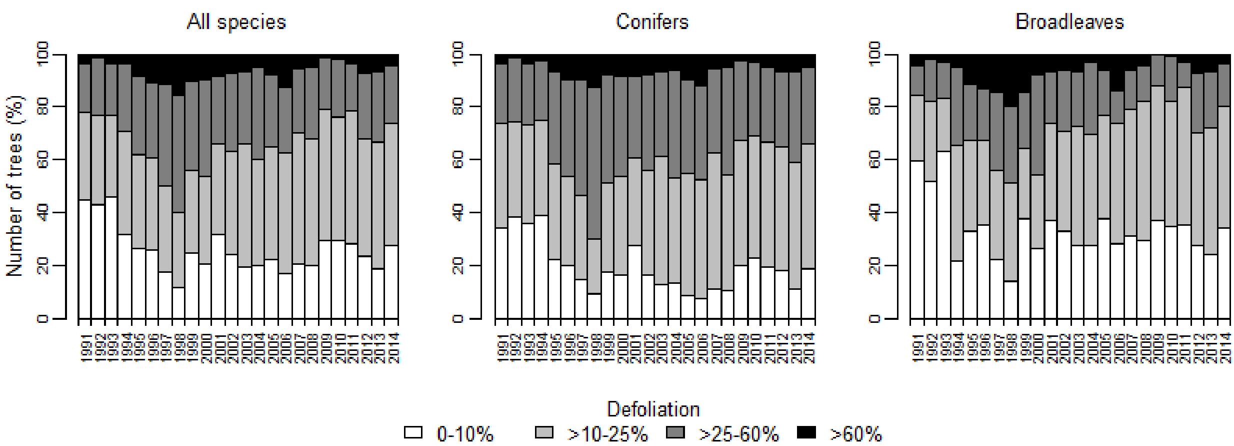
BELARUS



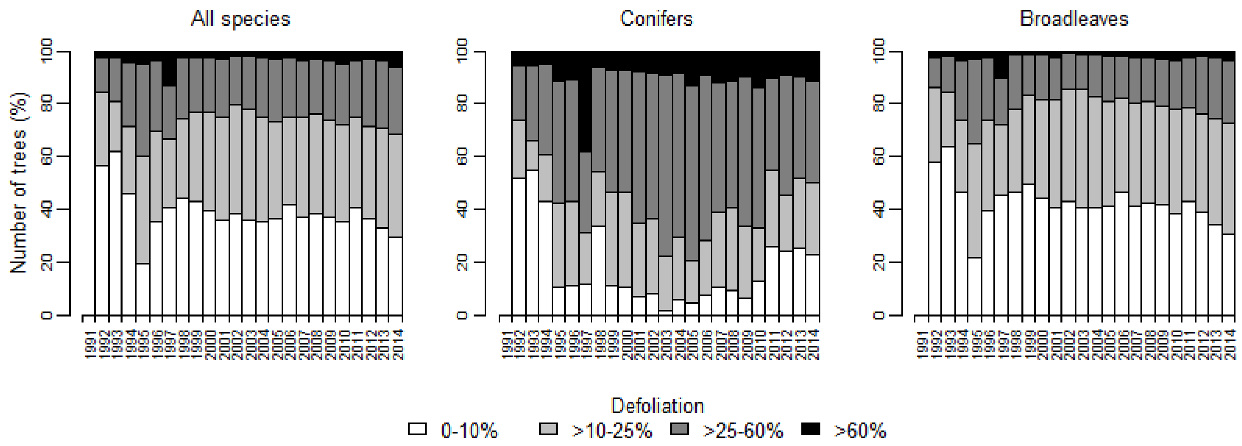
BELGIUM



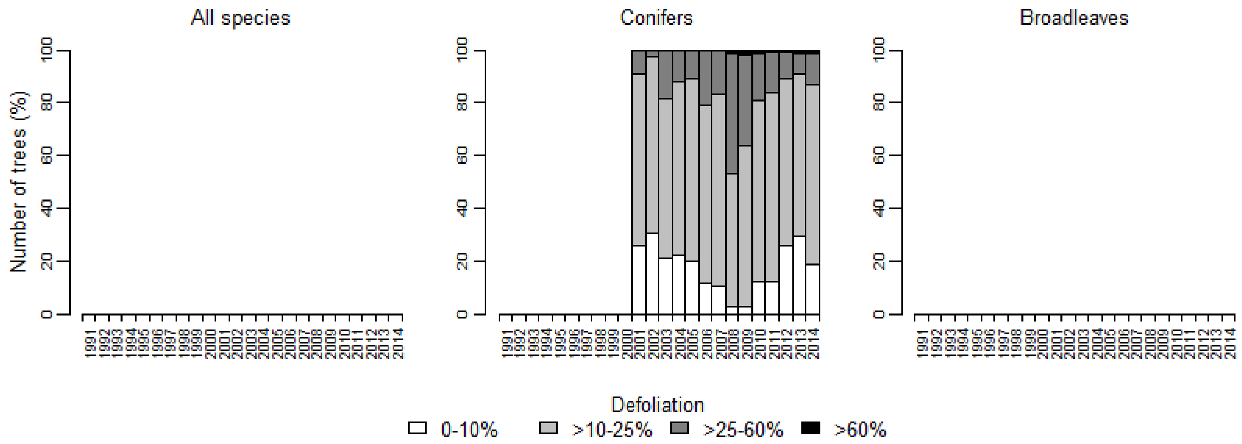
BULGARIA



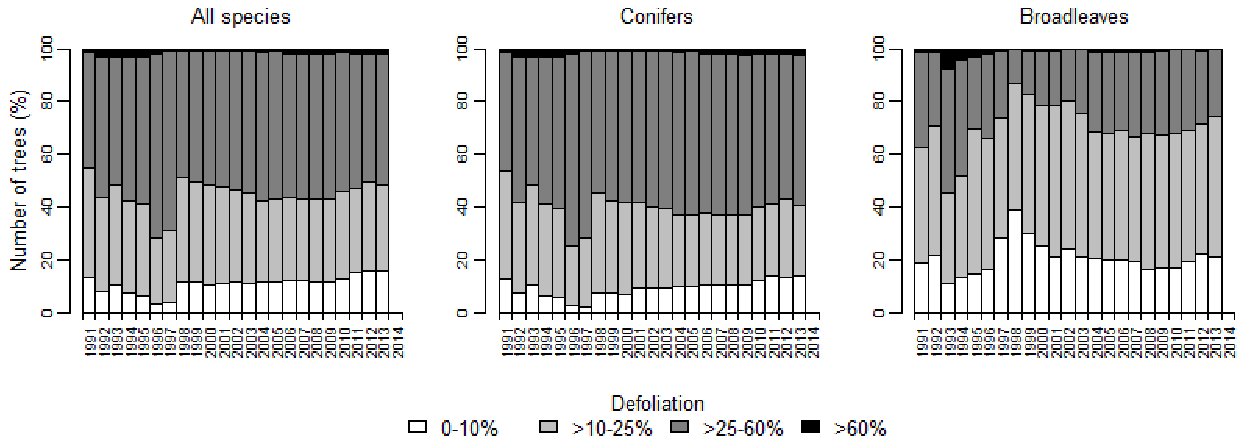
CROATIA



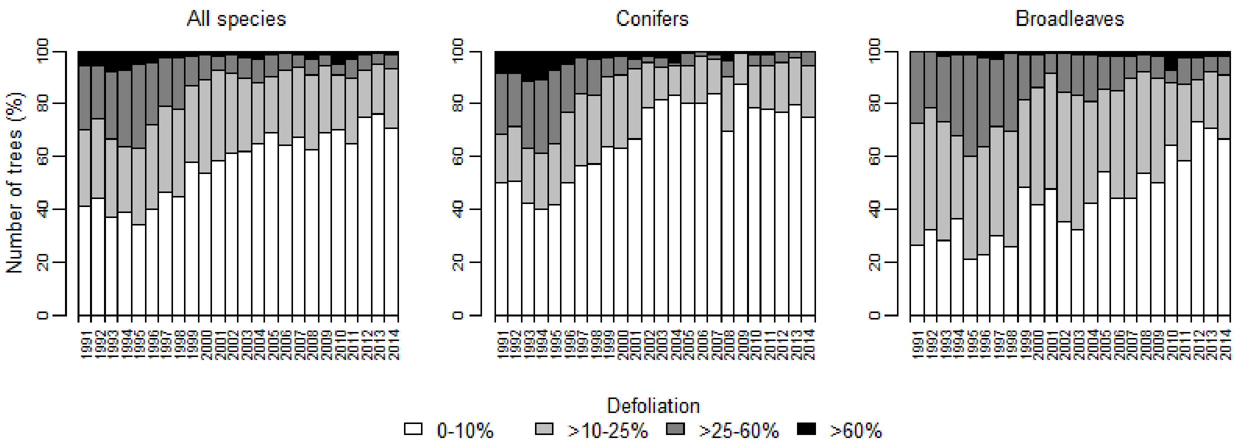
CYPRUS



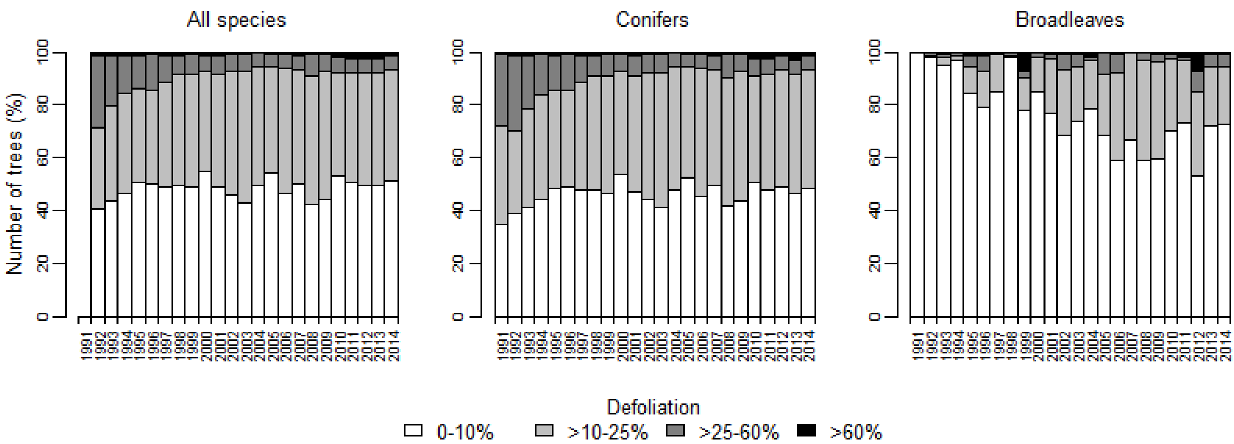
CZECH REPUBLIC



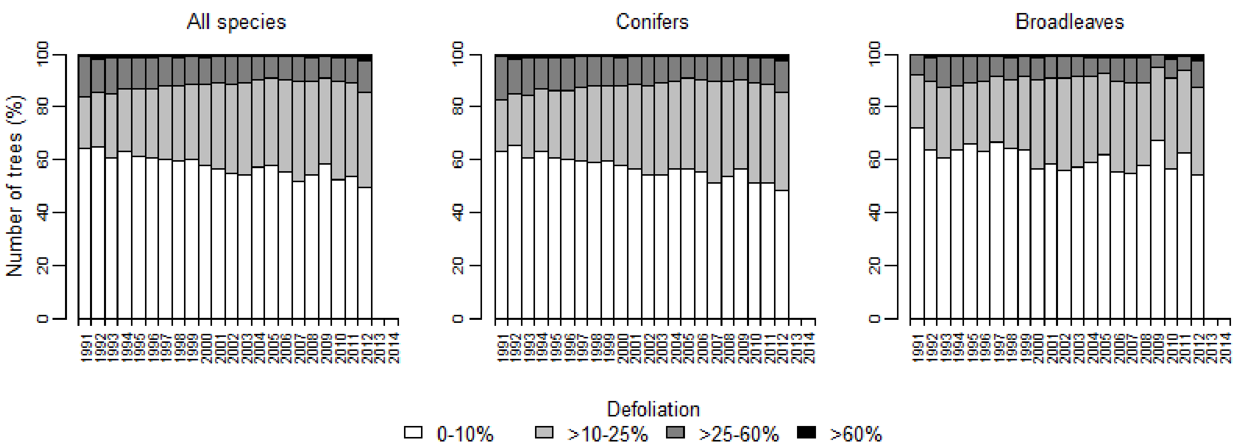
DENMARK



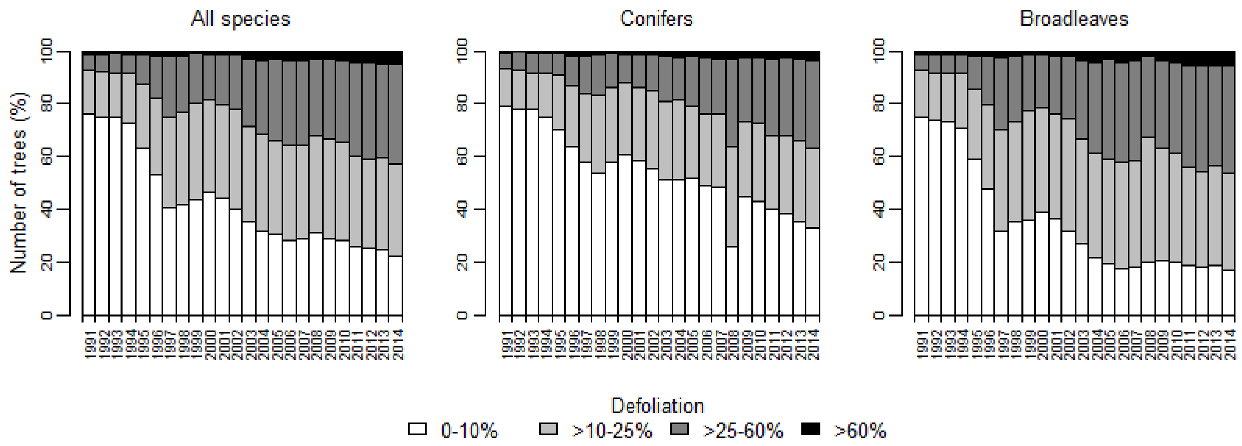
ESTONIA



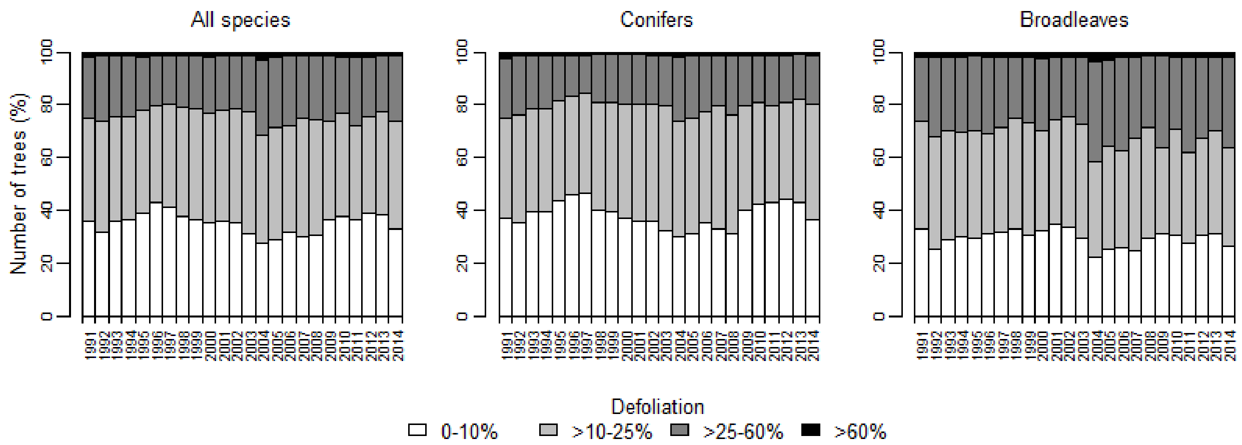
FINLAND



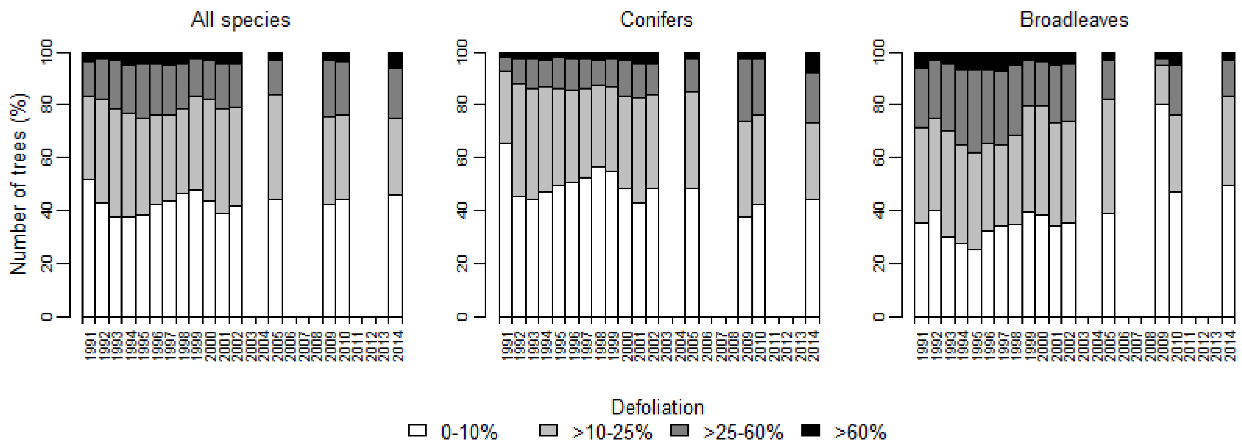
FRANCE



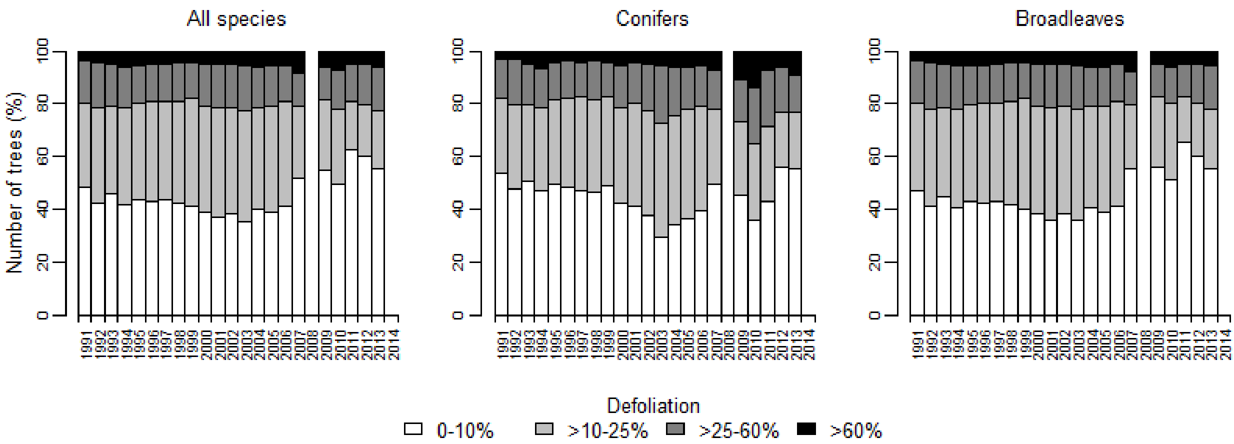
GERMANY



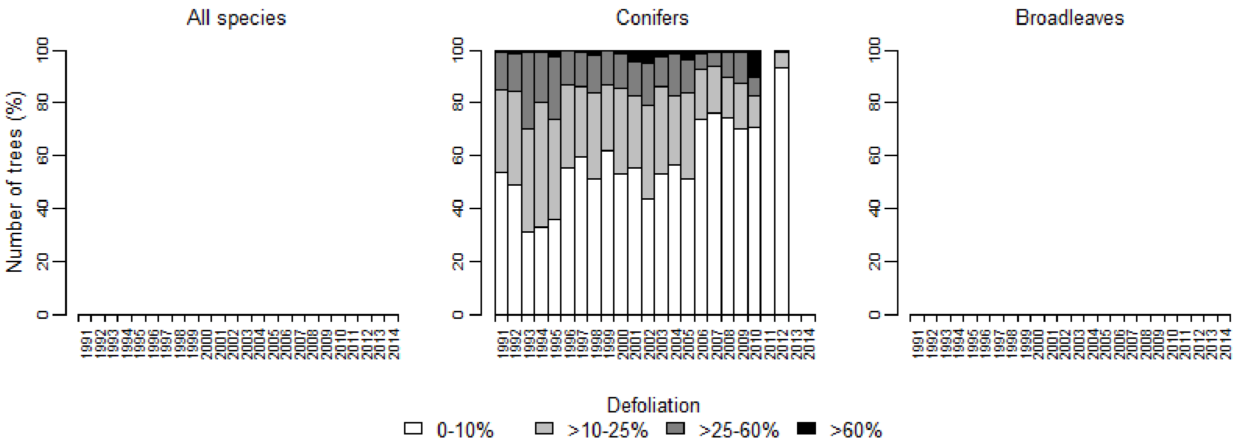
GREECE



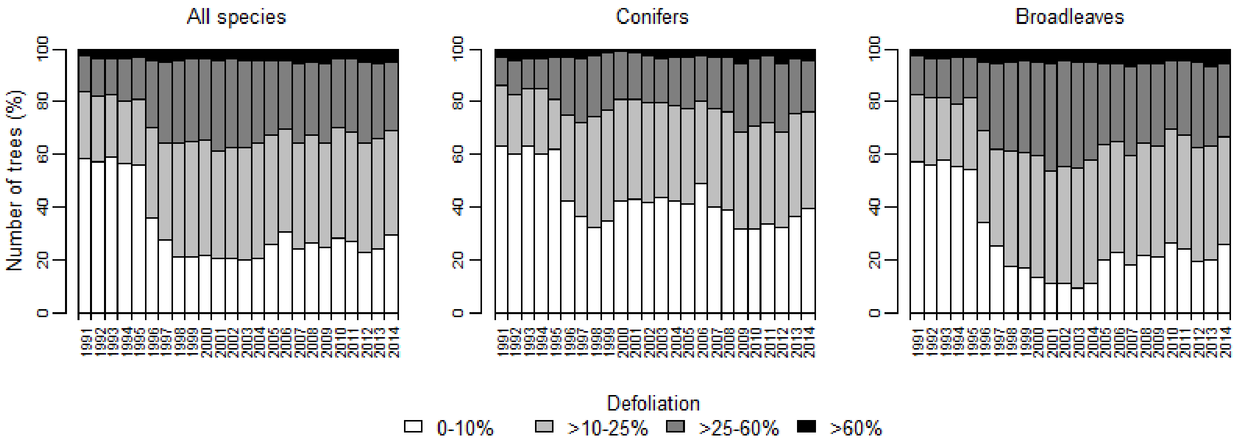
HUNGARY



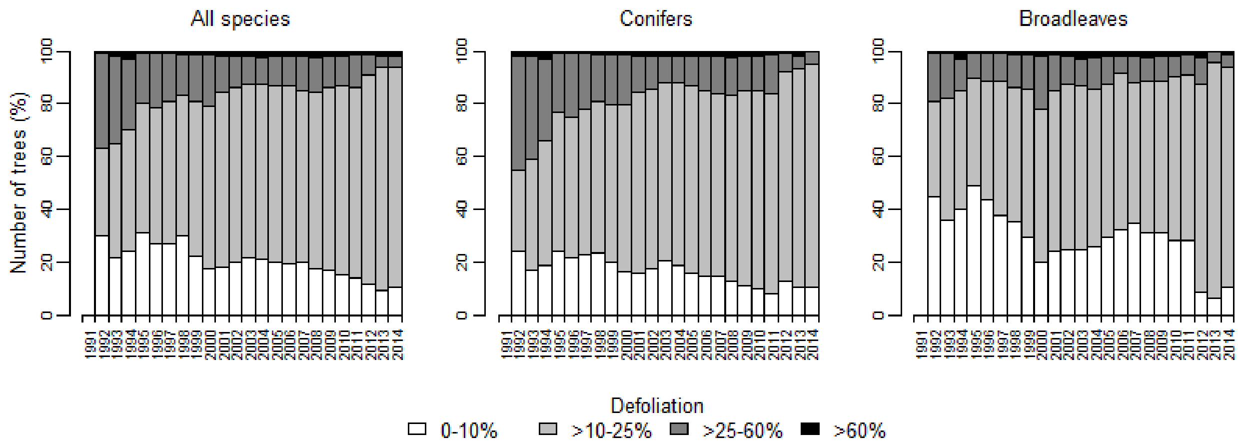
IRELAND



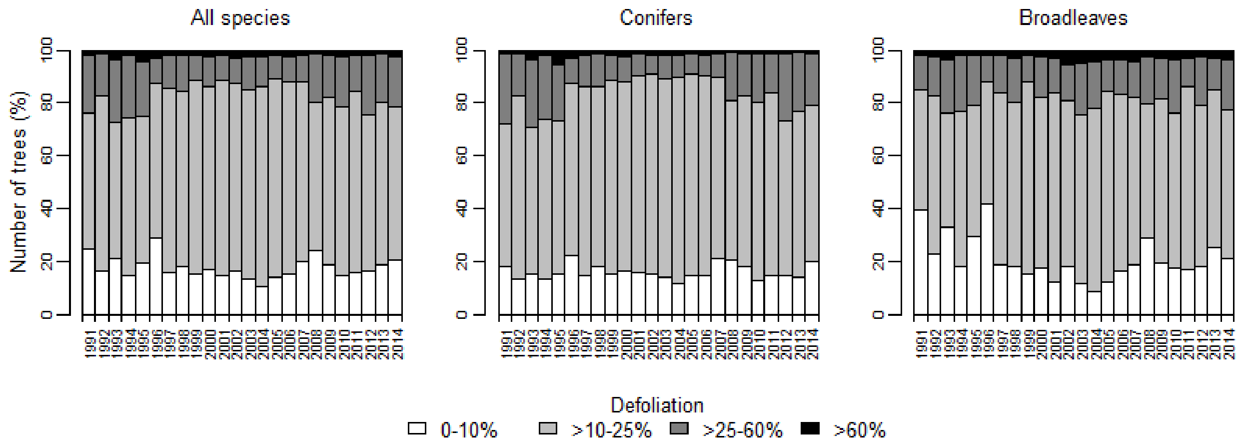
ITALY



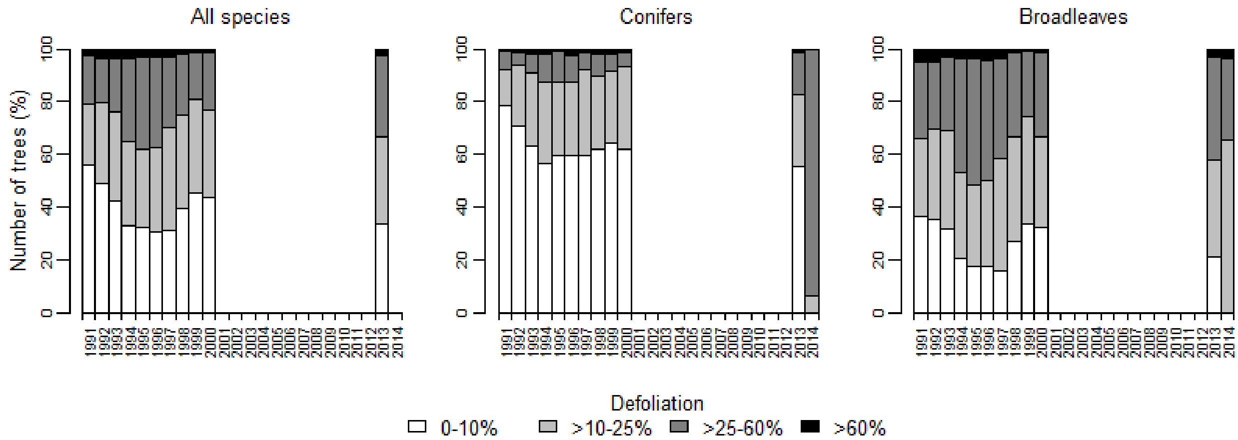
LATVIA



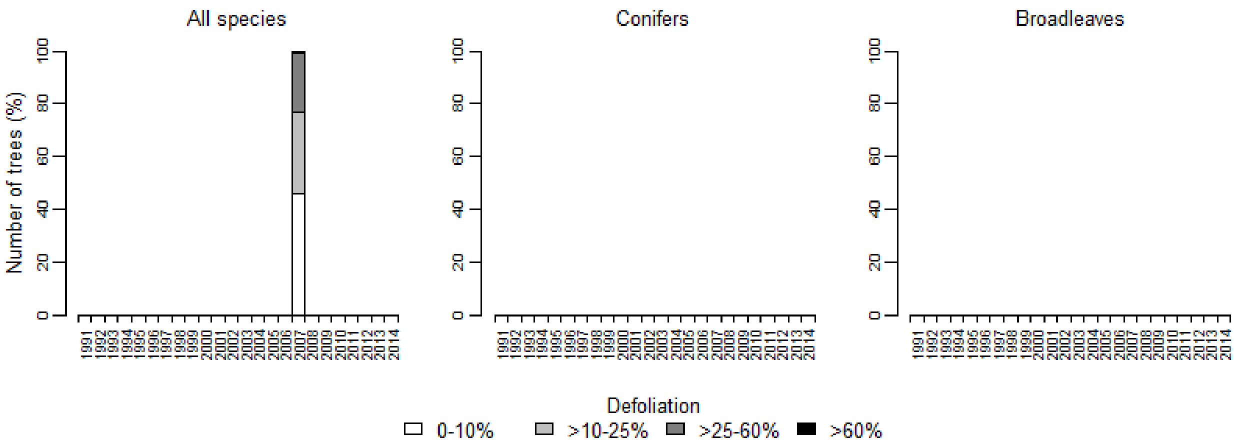
LITHUANIA



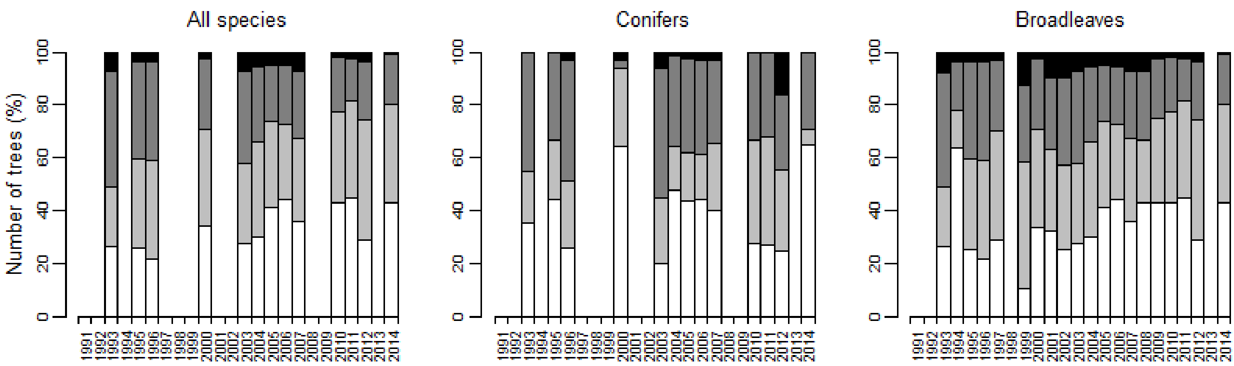
LUXEMBOURG



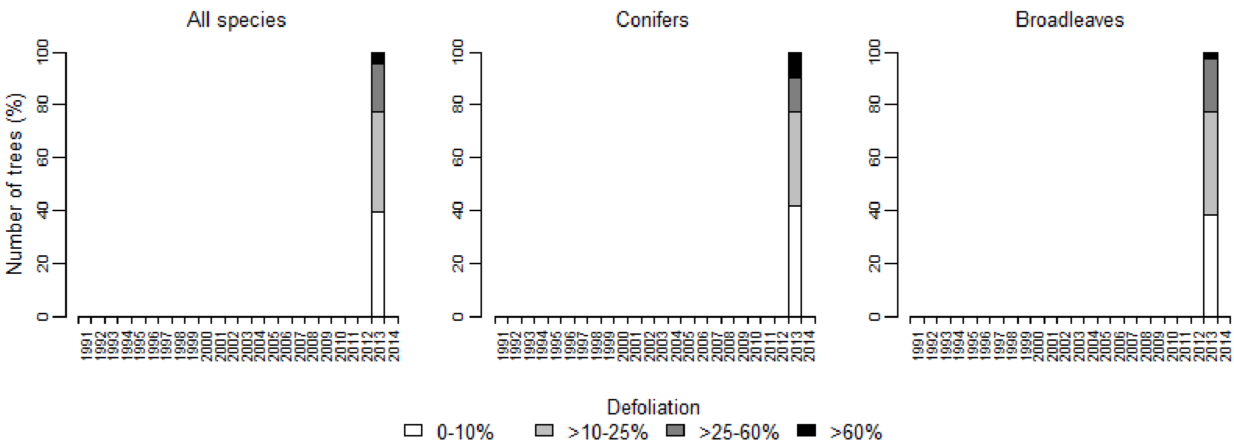
FYR OF MACEDONIA



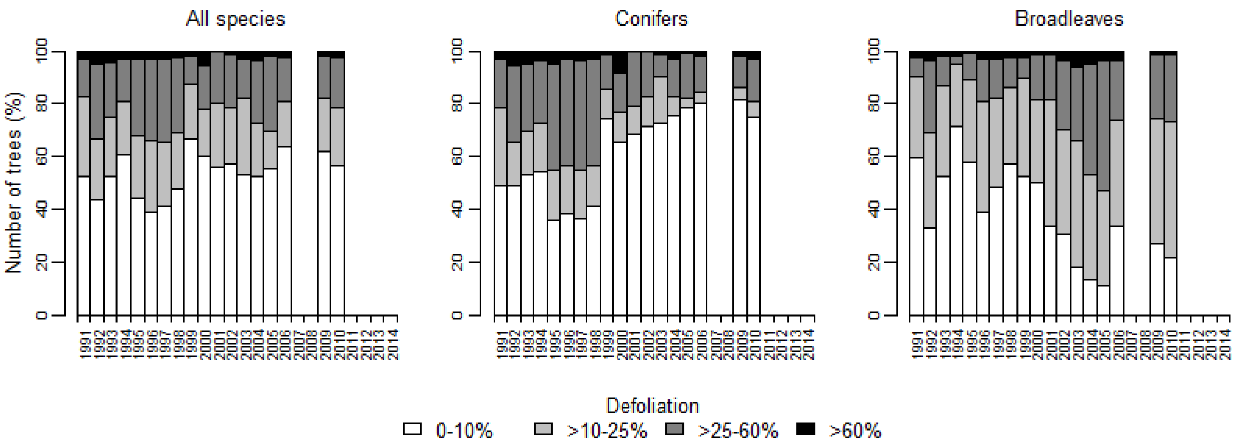
REPUBLIC OF MOLDOVA



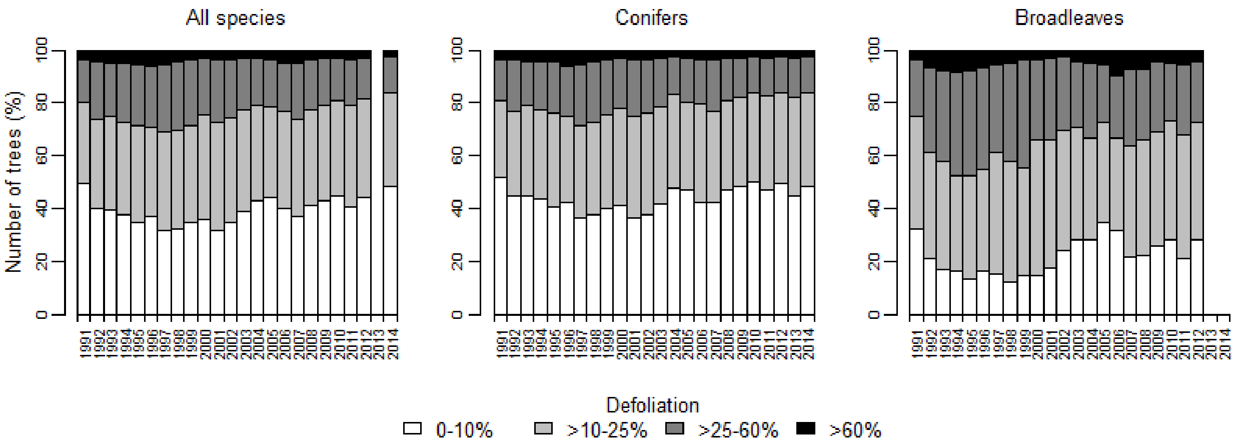
MONTENEGRO



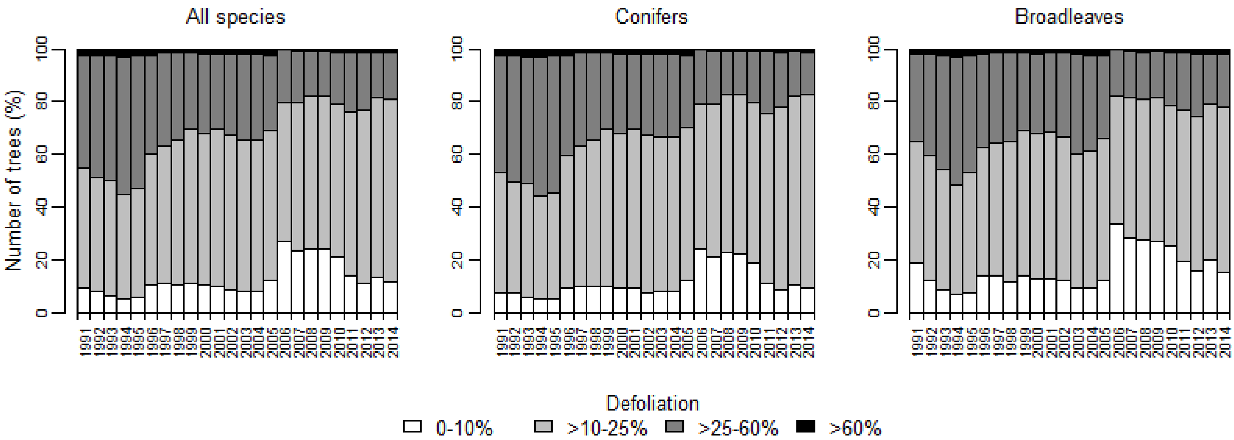
THE NETHERLANDS



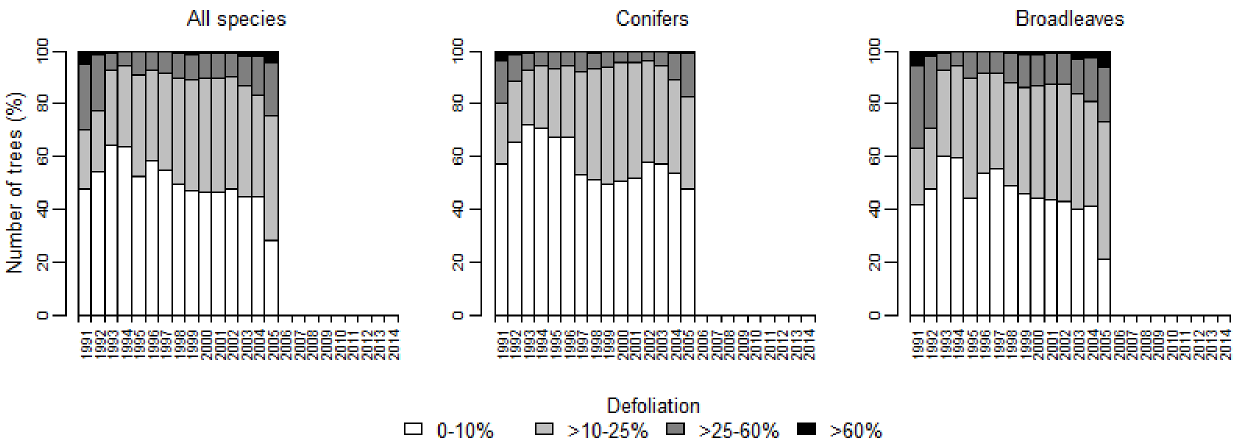
NORWAY



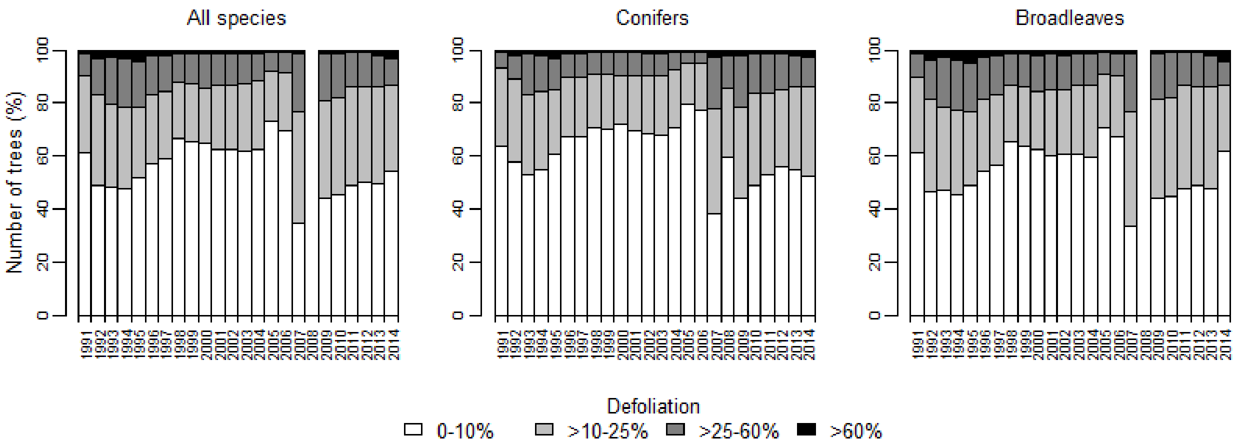
POLAND



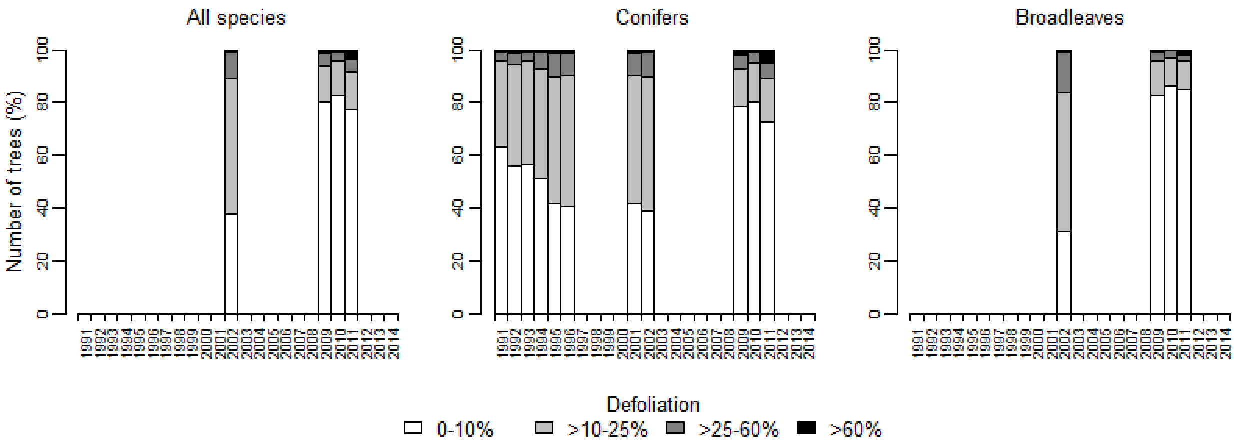
PORTUGAL



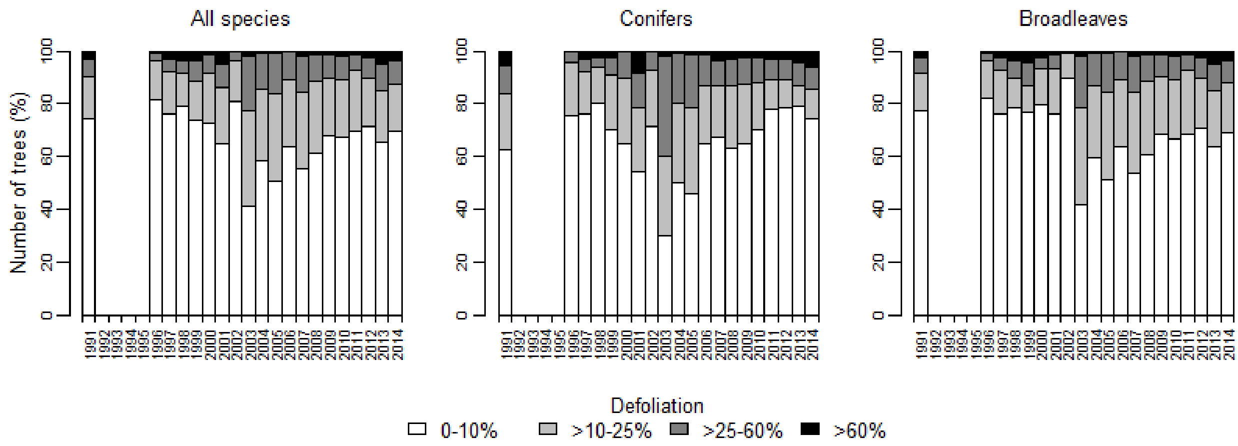
ROMANIA



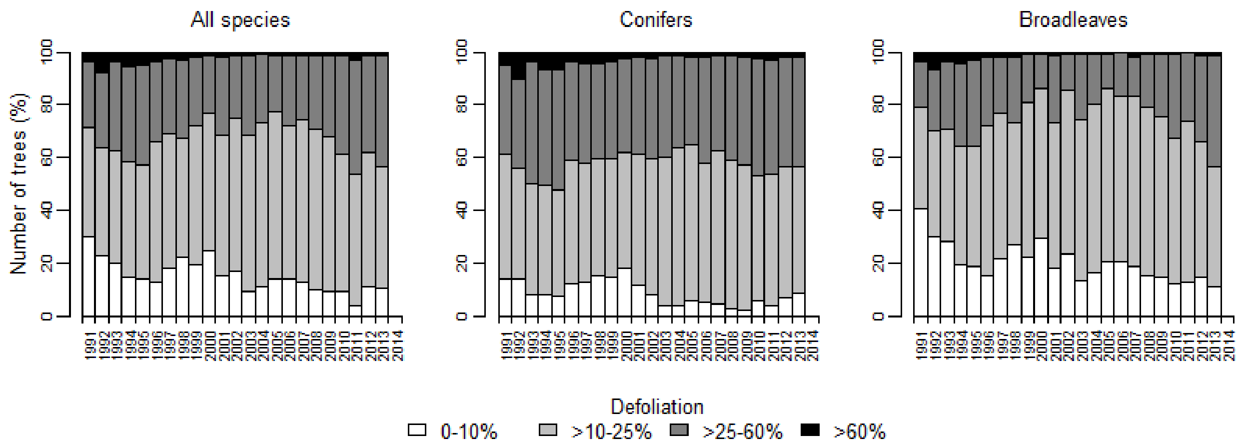
RUSSIAN FEDERATION



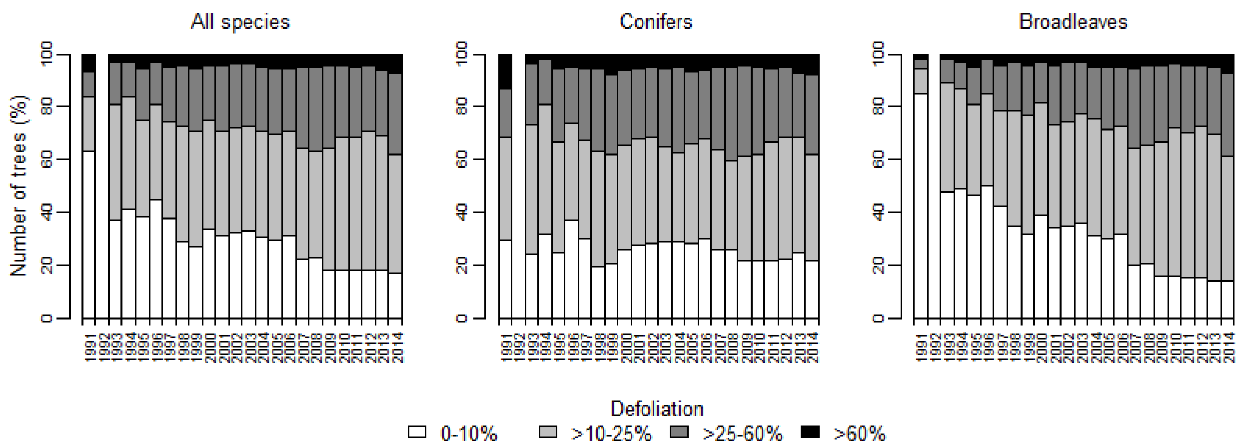
SERBIA



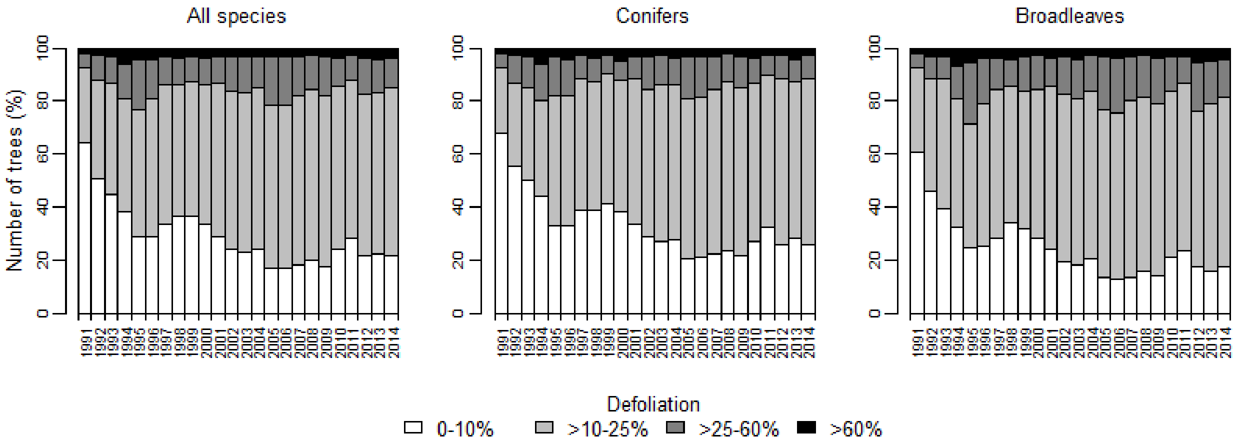
SLOVAKIA



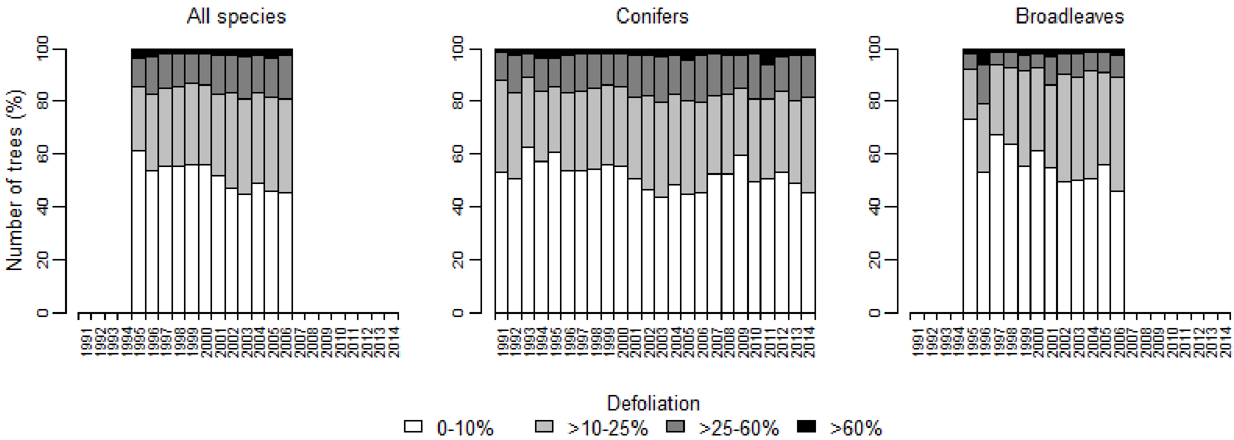
SLOVENIA



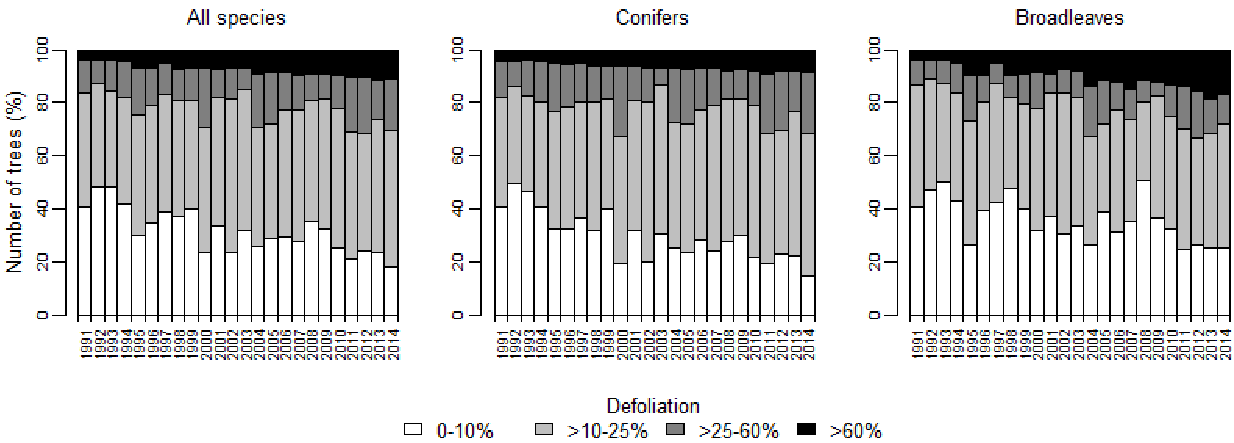
SPAIN



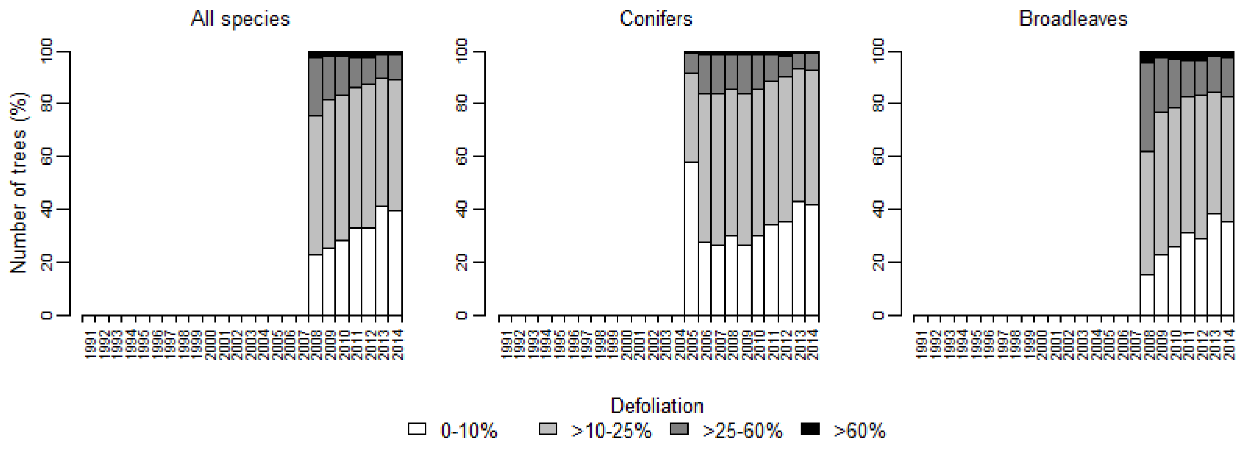
SWEDEN



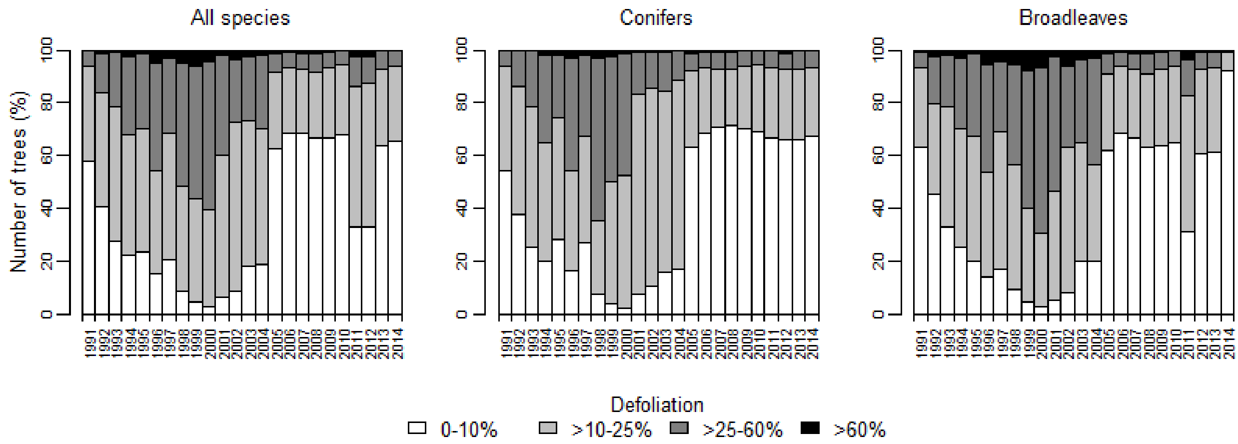
SWITZERLAND



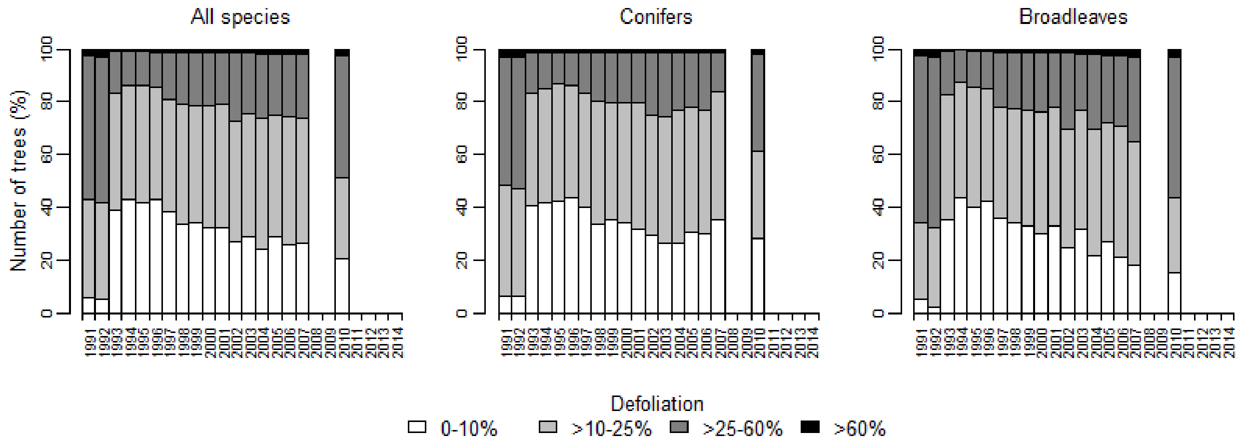
TURKEY



UKRAINE

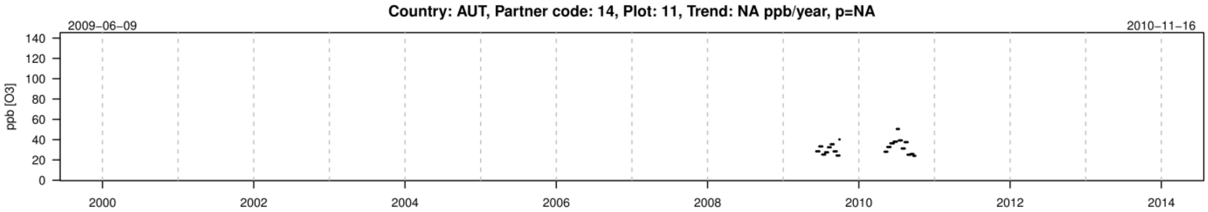


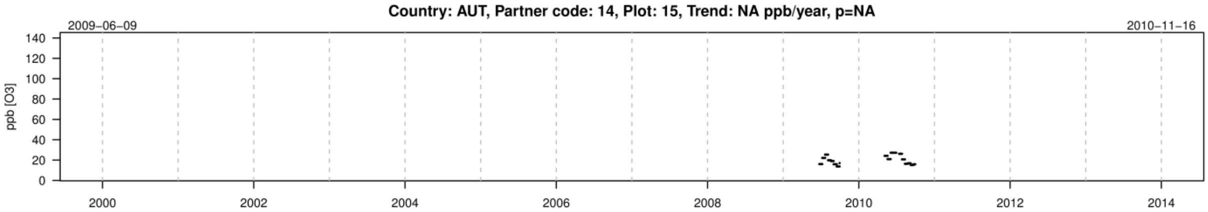
UNITED KINGDOM

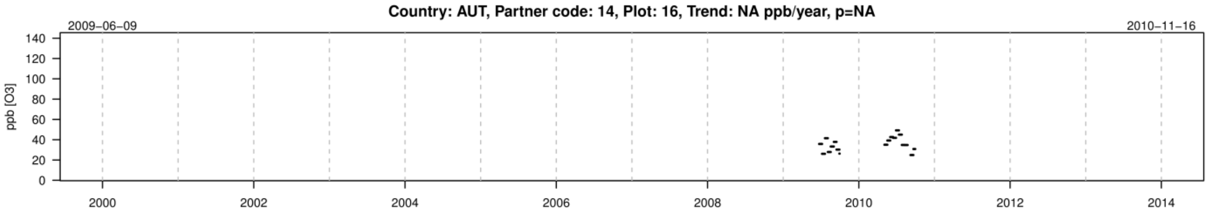


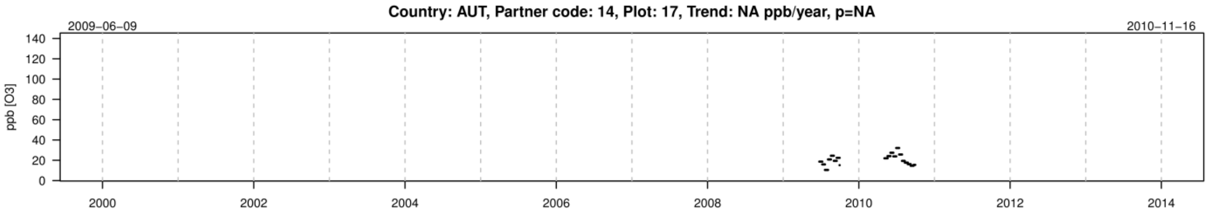
ANNEX III
OZONE CONCENTRATION TRENDS PER PLOT AND COUNTRY (2000-2013)

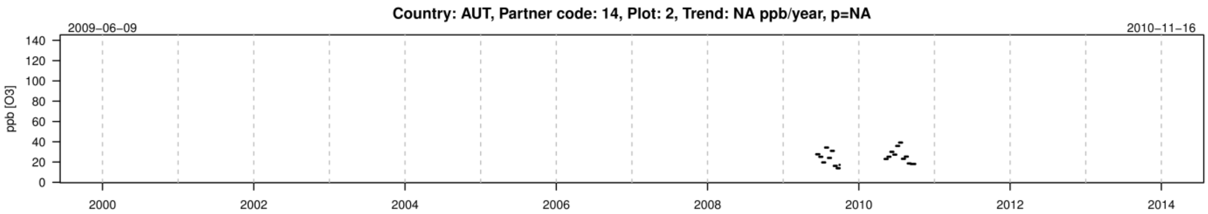
AUSTRIA

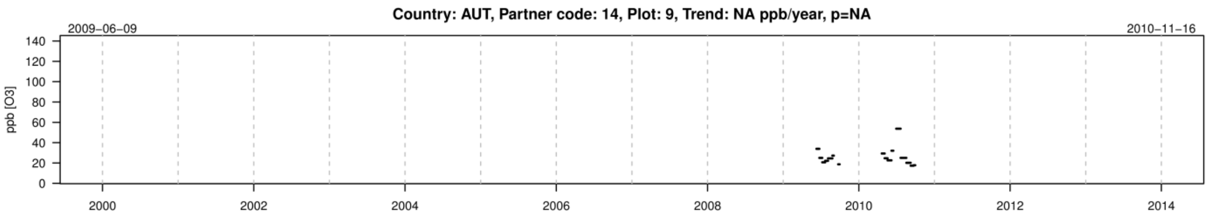




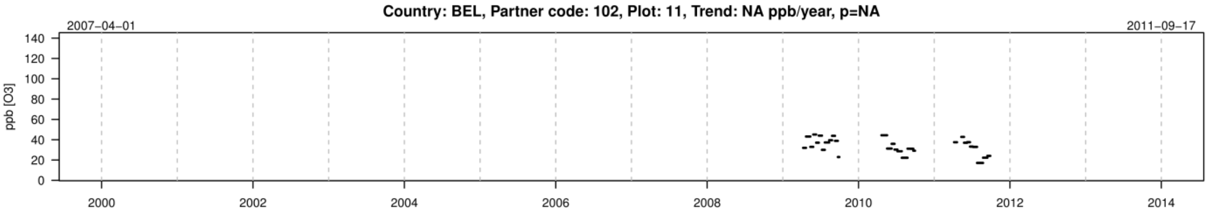


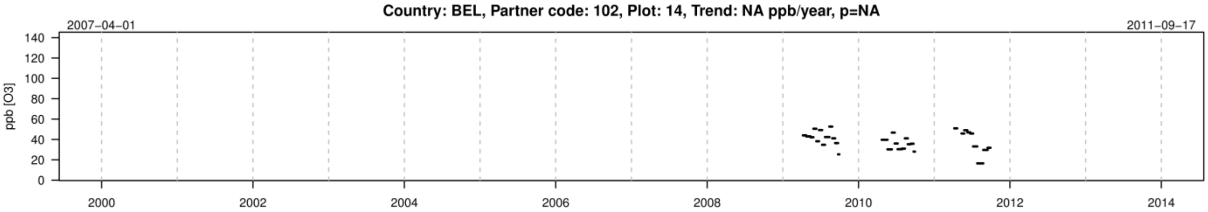


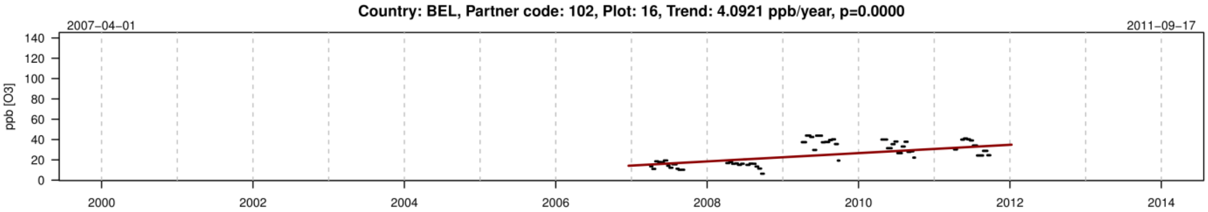


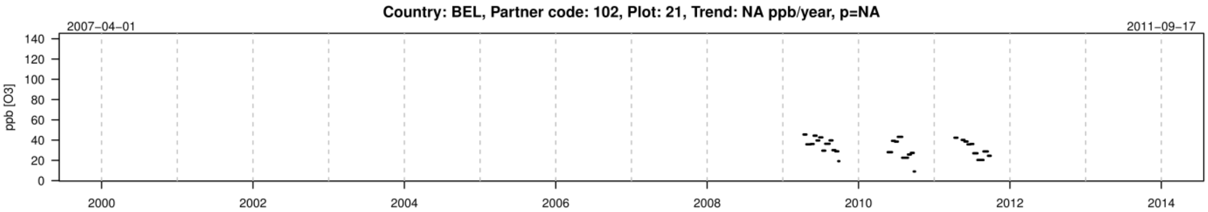


BELGIUM

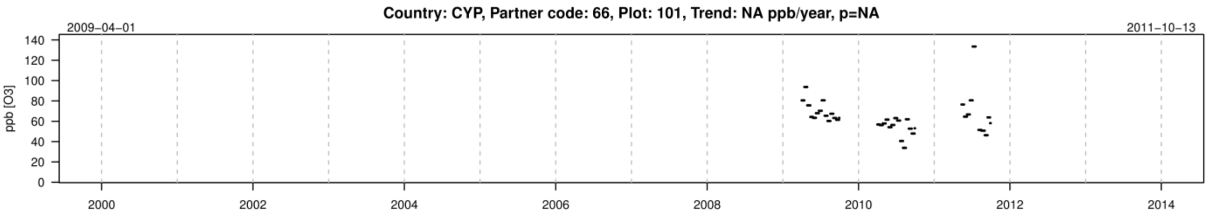


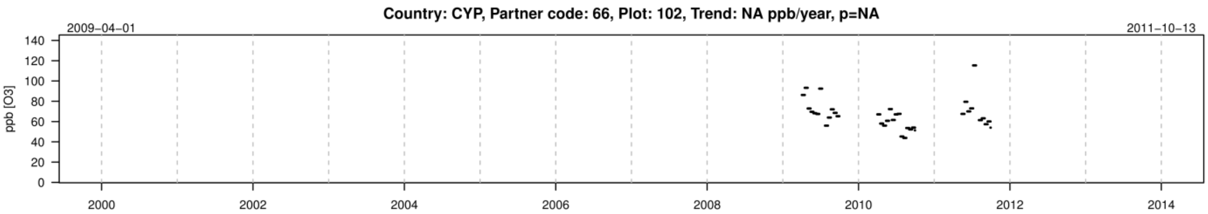




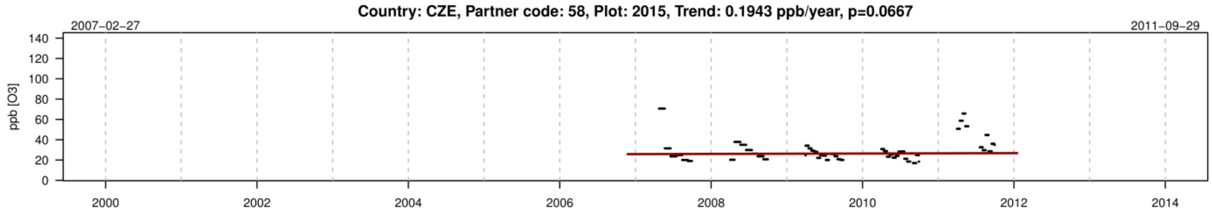


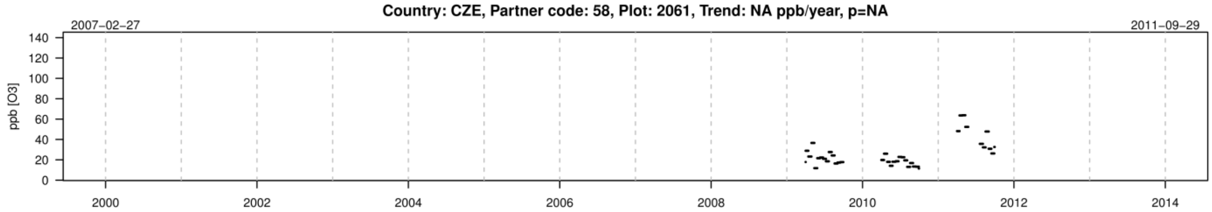
CYPRUS

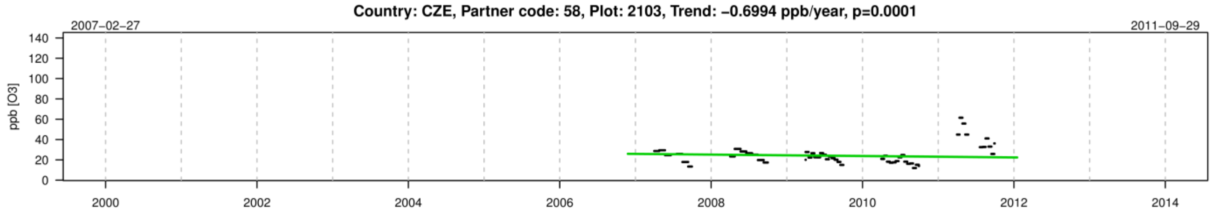


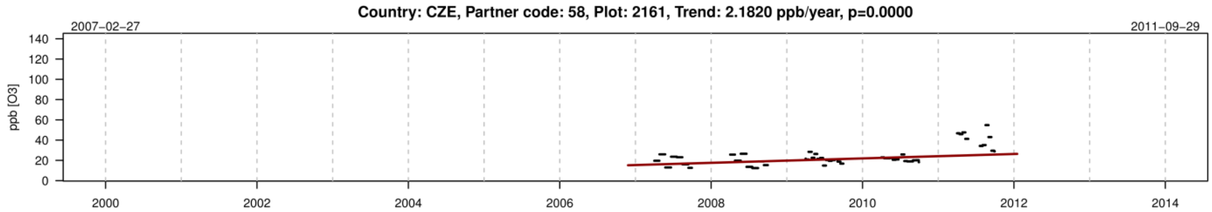


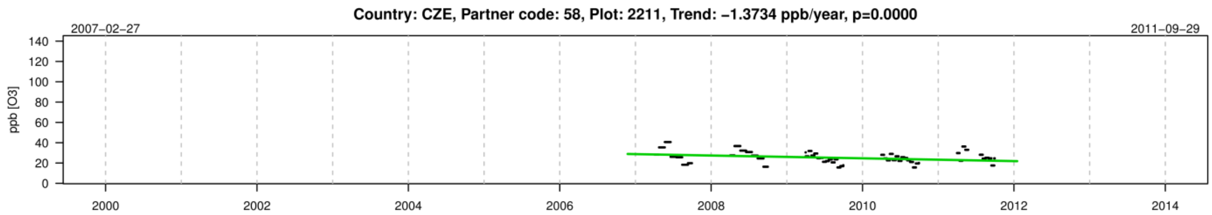
CZECH REPUBLIC

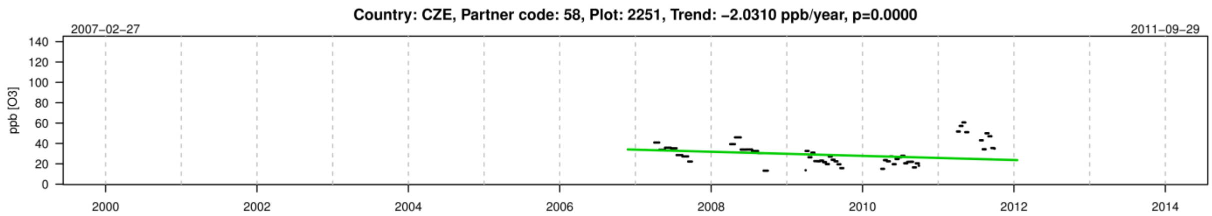


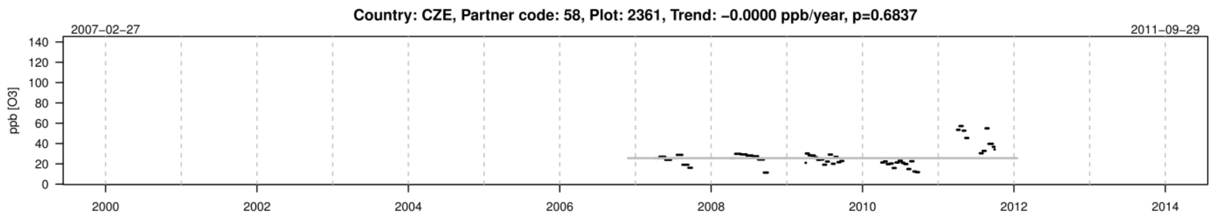


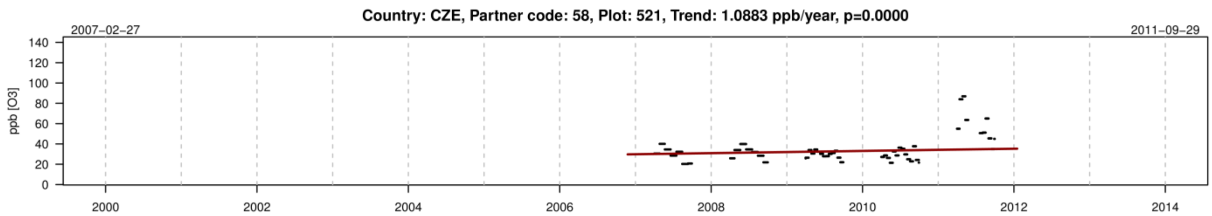


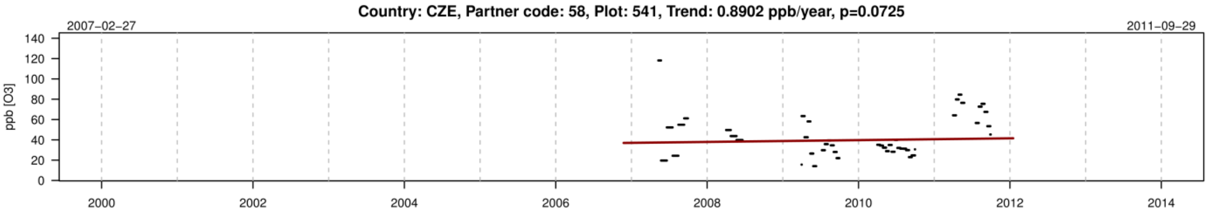




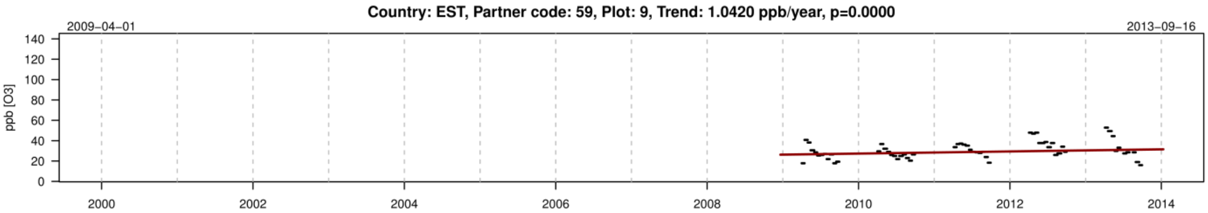




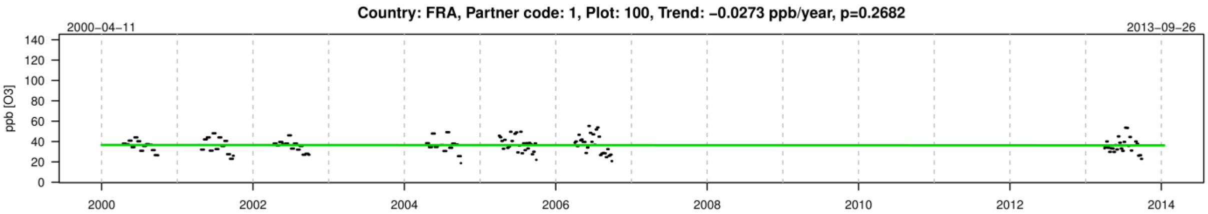


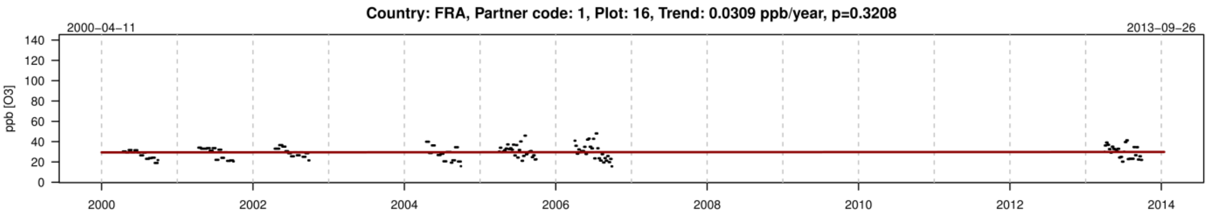


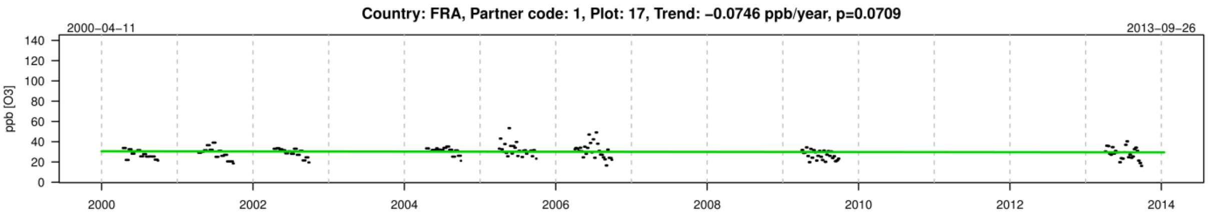
ESTONIA

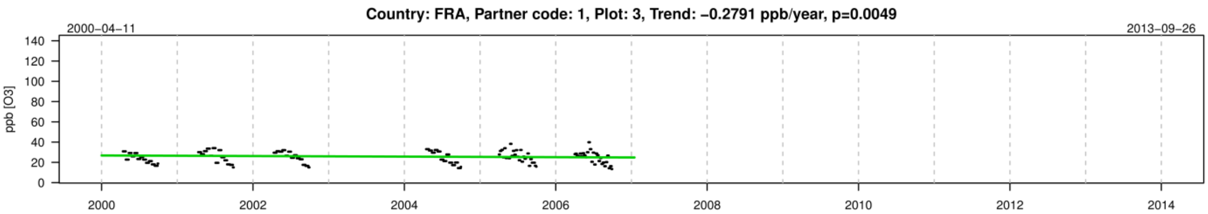


FRANCE









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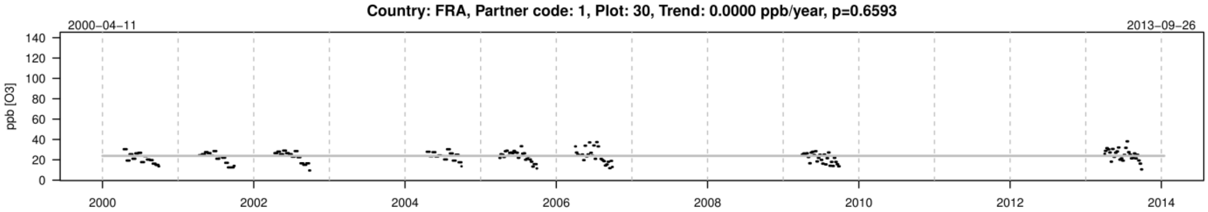

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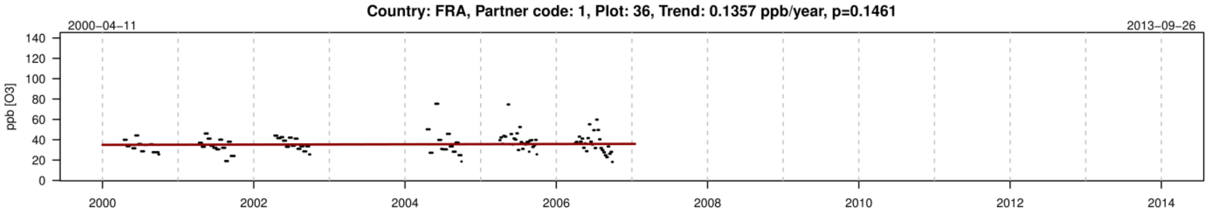
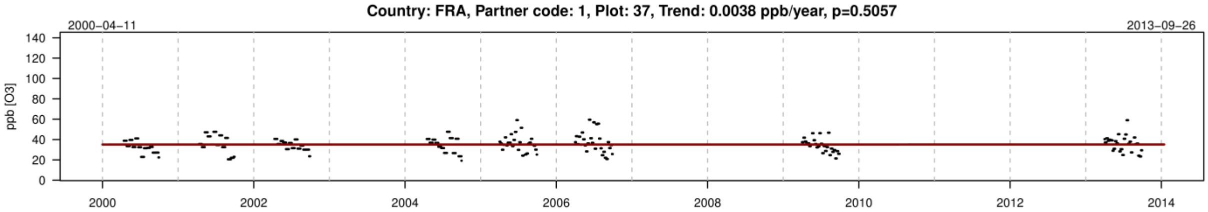
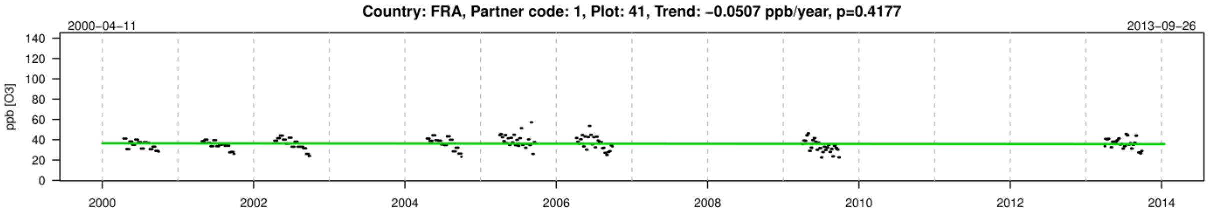


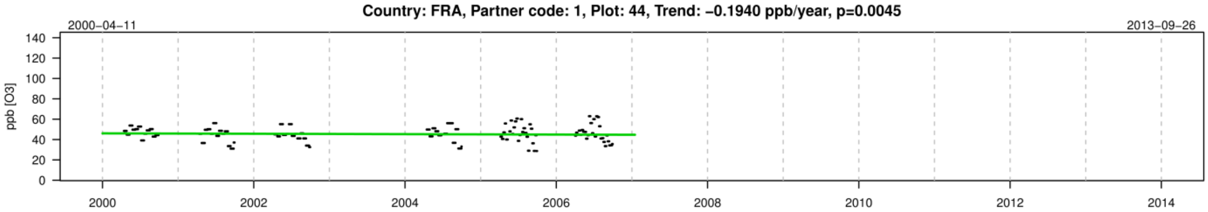
Country: FRA, Partner code: 1, Plot: 37, Trend: 0.0038 ppb/year, p=0.5057



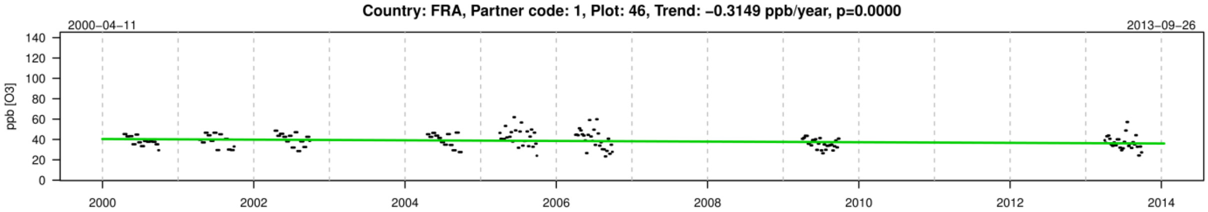
Country: FRA, Partner code: 1, Plot: 41, Trend: –0.0507 ppb/year, p=0.4177



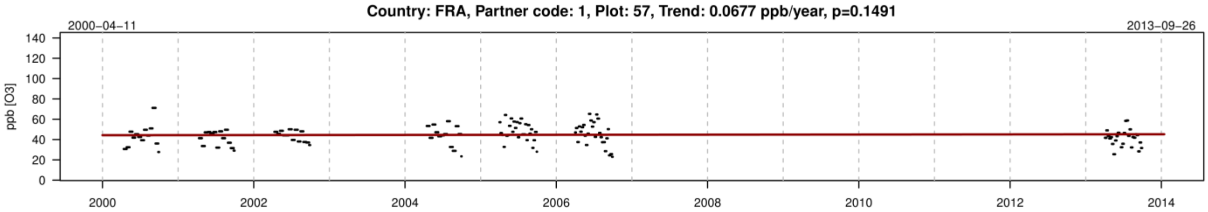
Country: FRA, Partner code: 1, Plot: 44, Trend: –0.1940 ppb/year, p=0.0045



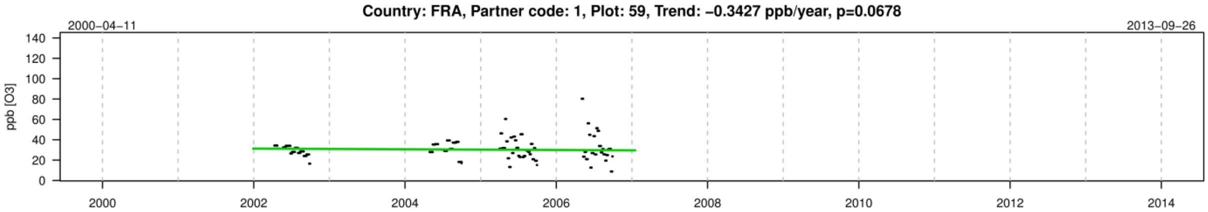
Country: FRA, Partner code: 1, Plot: 46, Trend: –0.3149 ppb/year, p=0.0000



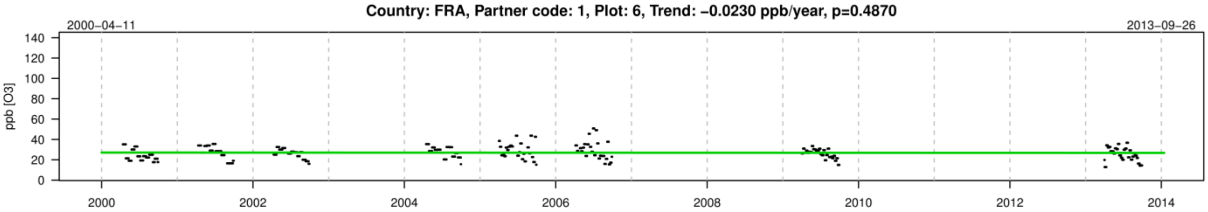
Country: FRA, Partner code: 1, Plot: 57, Trend: 0.0677 ppb/year, p=0.1491



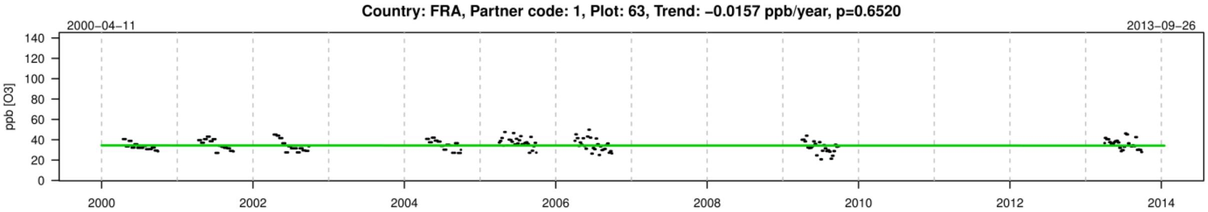
Country: FRA, Partner code: 1, Plot: 59, Trend: –0.3427 ppb/year, p=0.0678



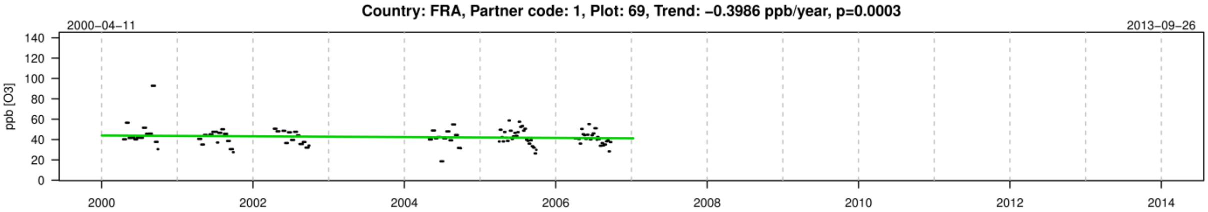
Country: FRA, Partner code: 1, Plot: 6, Trend: –0.0230 ppb/year, p=0.4870



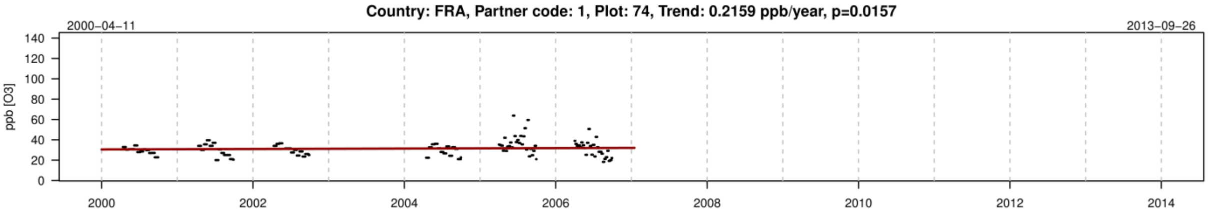
Country: FRA, Partner code: 1, Plot: 63, Trend: –0.0157 ppb/year, p=0.6520



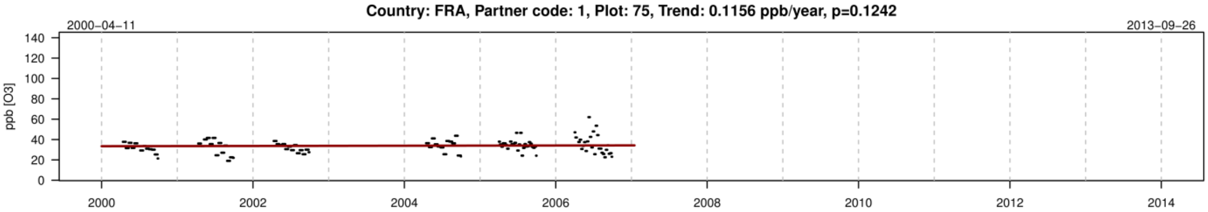
Country: FRA, Partner code: 1, Plot: 69, Trend: –0.3986 ppb/year, p=0.0003



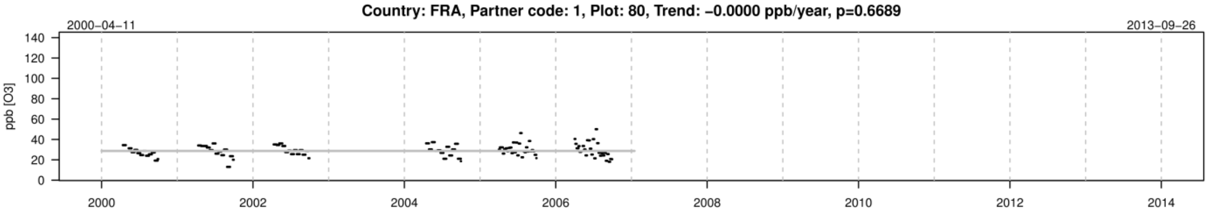
Country: FRA, Partner code: 1, Plot: 74, Trend: 0.2159 ppb/year, p=0.0157



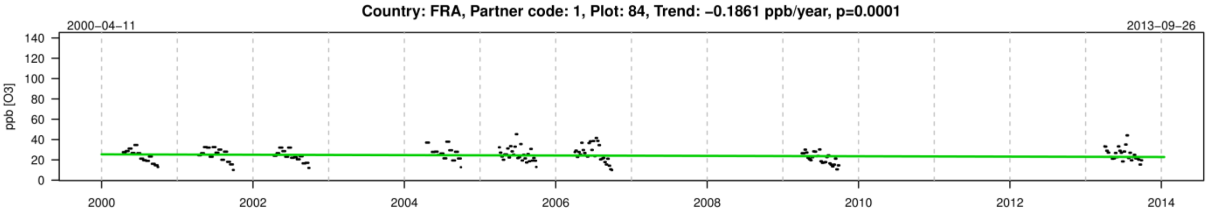
Country: FRA, Partner code: 1, Plot: 75, Trend: 0.1156 ppb/year, p=0.1242



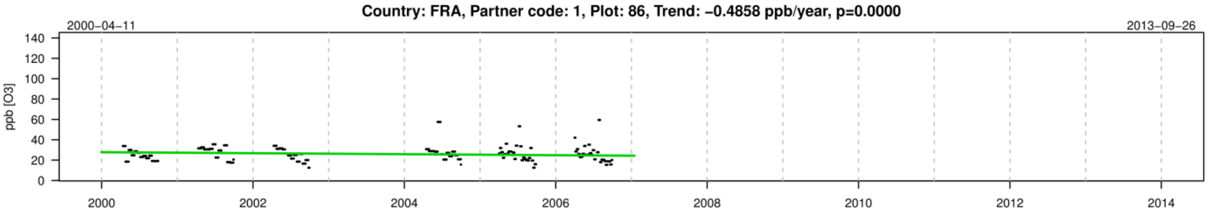
Country: FRA, Partner code: 1, Plot: 80, Trend: –0.0000 ppb/year, p=0.6689



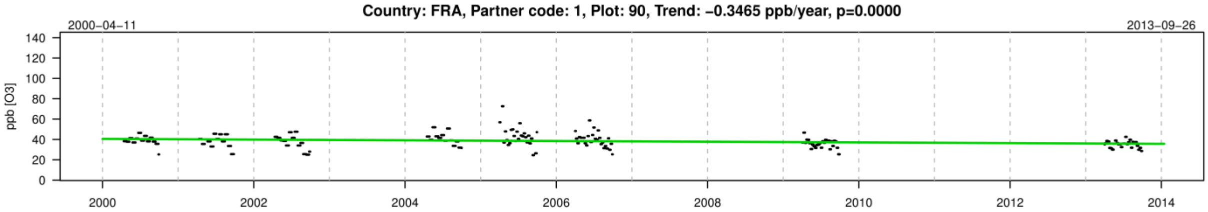
Country: FRA, Partner code: 1, Plot: 84, Trend: –0.1861 ppb/year, p=0.0001



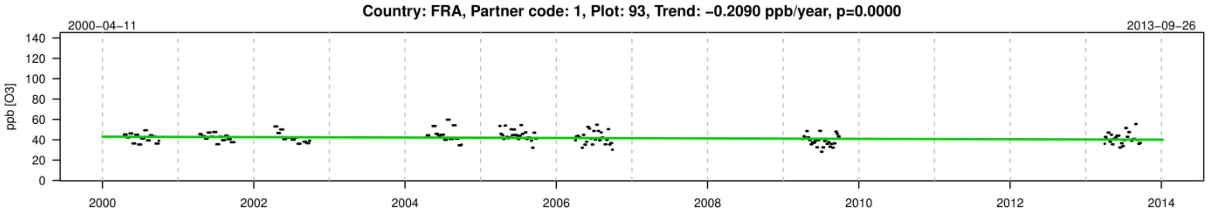
Country: FRA, Partner code: 1, Plot: 86, Trend: –0.4858 ppb/year, p=0.0000



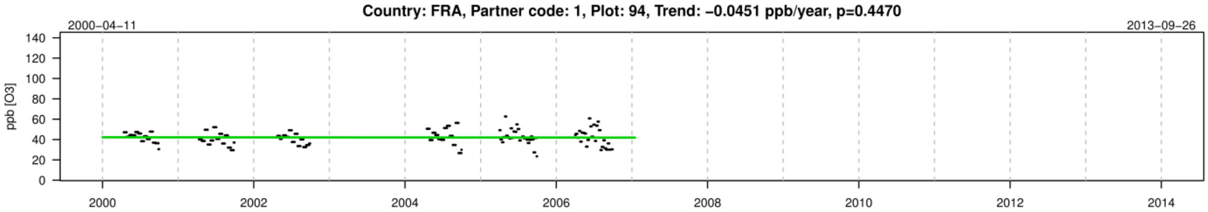
Country: FRA, Partner code: 1, Plot: 90, Trend: –0.3465 ppb/year, p=0.0000



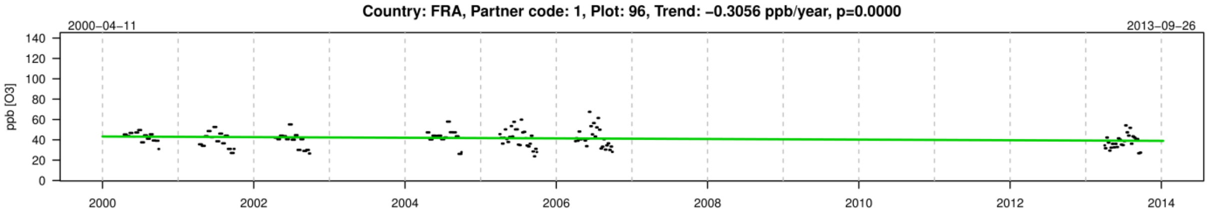
Country: FRA, Partner code: 1, Plot: 93, Trend: –0.2090 ppb/year, p=0.0000



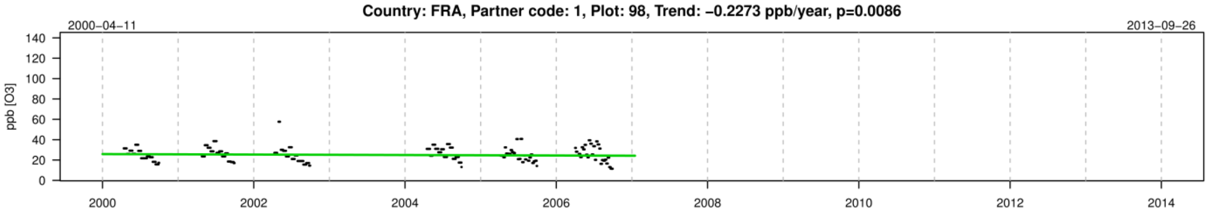
Country: FRA, Partner code: 1, Plot: 94, Trend: –0.0451 ppb/year, p=0.4470



Country: FRA, Partner code: 1, Plot: 96, Trend: –0.3056 ppb/year, p=0.0000

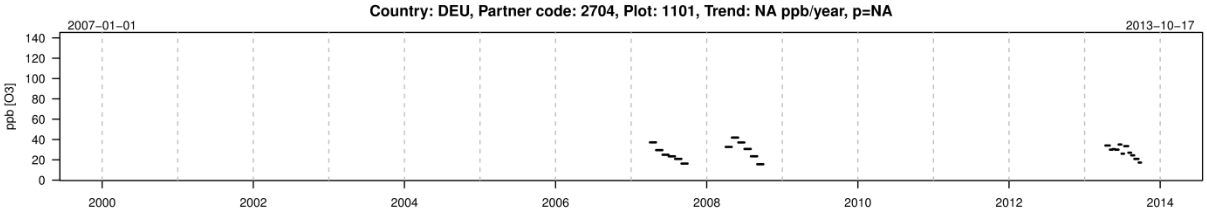


Country: FRA, Partner code: 1, Plot: 98, Trend: –0.2273 ppb/year, p=0.0086

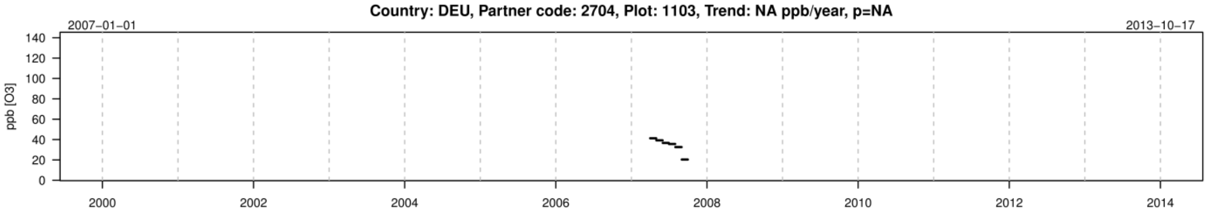


GERMANY

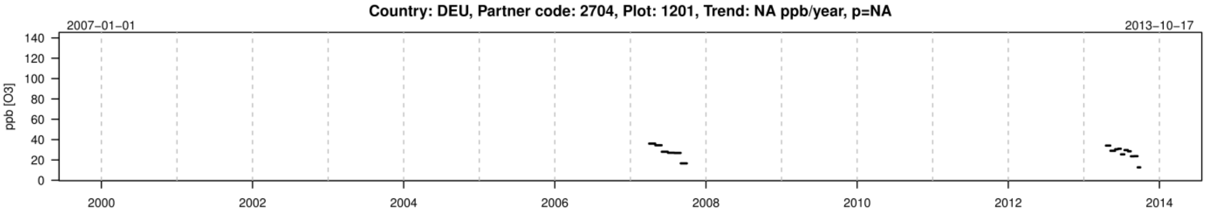
Country: DEU, Partner code: 2704, Plot: 1101, Trend: NA ppb/year, p=NA



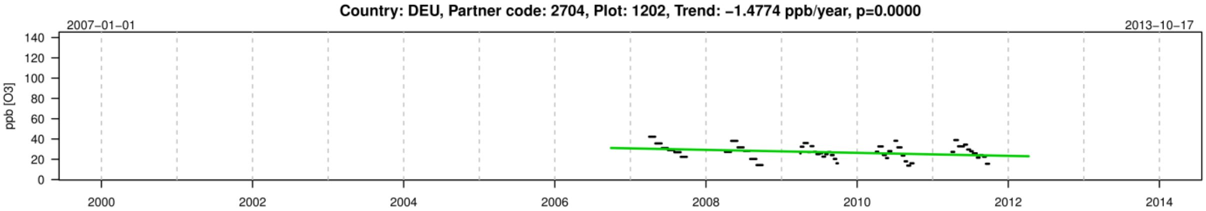
Country: DEU, Partner code: 2704, Plot: 1103, Trend: NA ppb/year, p=NA



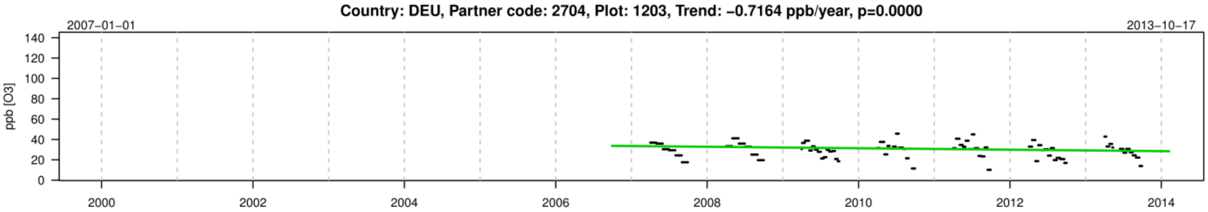
Country: DEU, Partner code: 2704, Plot: 1201, Trend: NA ppb/year, p=NA



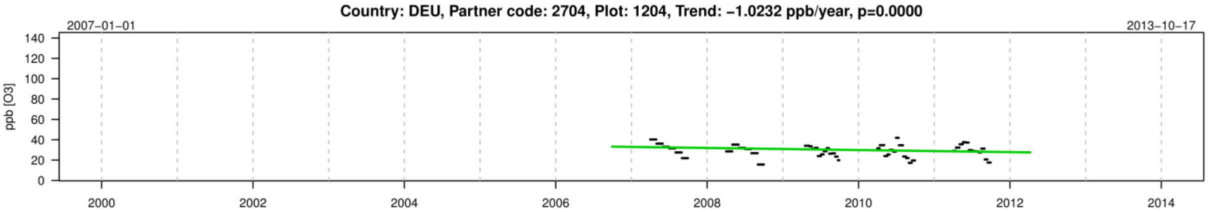
Country: DEU, Partner code: 2704, Plot: 1202, Trend: –1.4774 ppb/year, p=0.0000



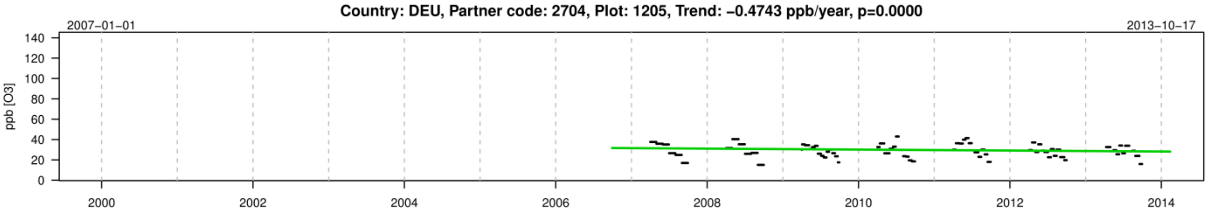
Country: DEU, Partner code: 2704, Plot: 1203, Trend: –0.7164 ppb/year, p=0.0000



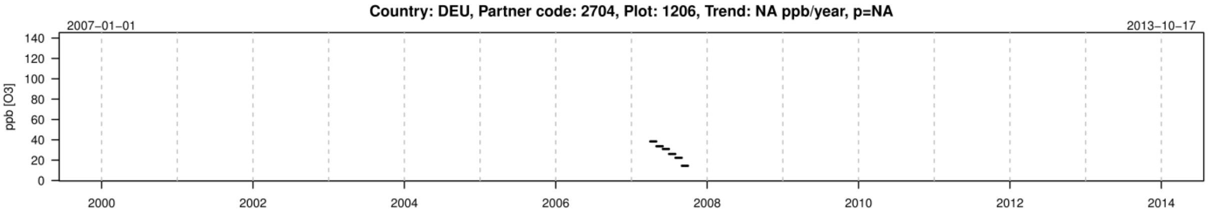
Country: DEU, Partner code: 2704, Plot: 1204, Trend: –1.0232 ppb/year, p=0.0000



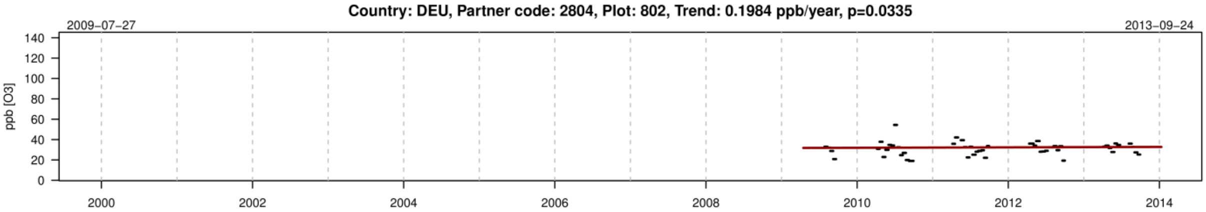
Country: DEU, Partner code: 2704, Plot: 1205, Trend: –0.4743 ppb/year, p=0.0000



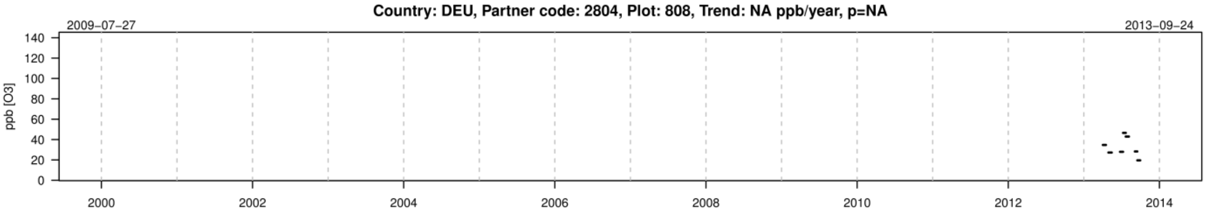
Country: DEU, Partner code: 2704, Plot: 1206, Trend: NA ppb/year, p=NA



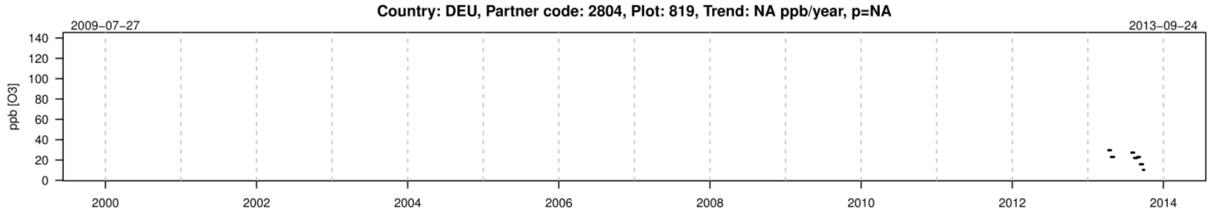
Country: DEU, Partner code: 2804, Plot: 802, Trend: 0.1984 ppb/year, p=0.0335



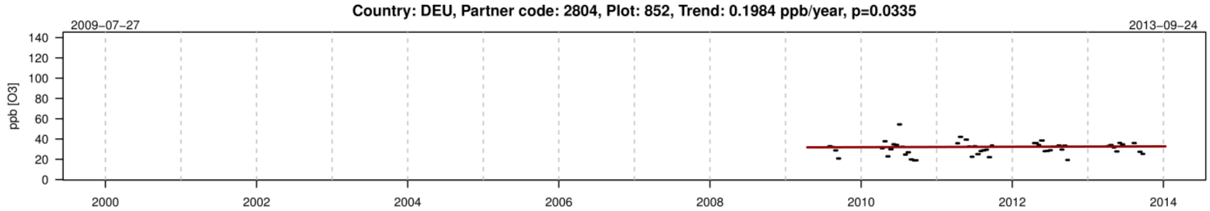
Country: DEU, Partner code: 2804, Plot: 808, Trend: NA ppb/year, p=NA



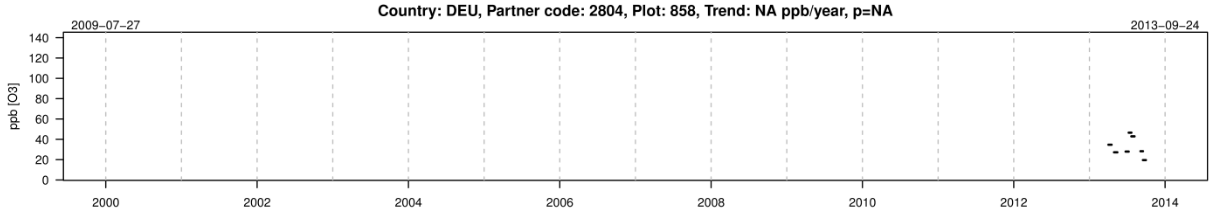
Country: DEU, Partner code: 2804, Plot: 819, Trend: NA ppb/year, p=NA



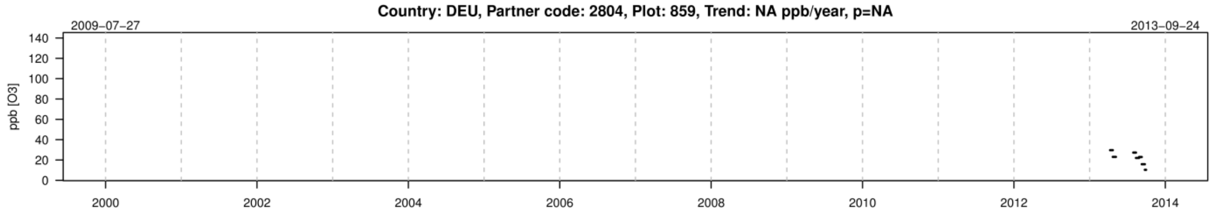
Country: DEU, Partner code: 2804, Plot: 852, Trend: 0.1984 ppb/year, p=0.0335



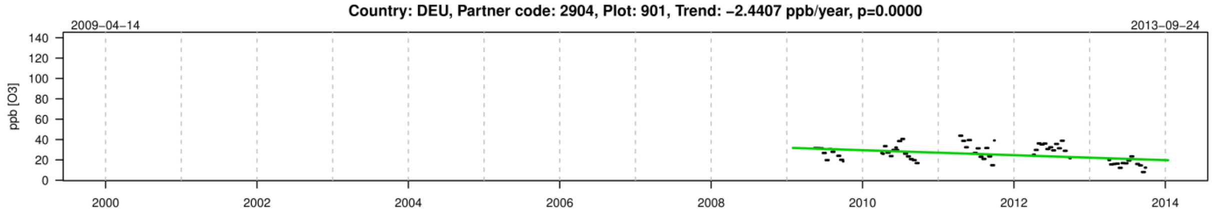
Country: DEU, Partner code: 2804, Plot: 858, Trend: NA ppb/year, p=NA



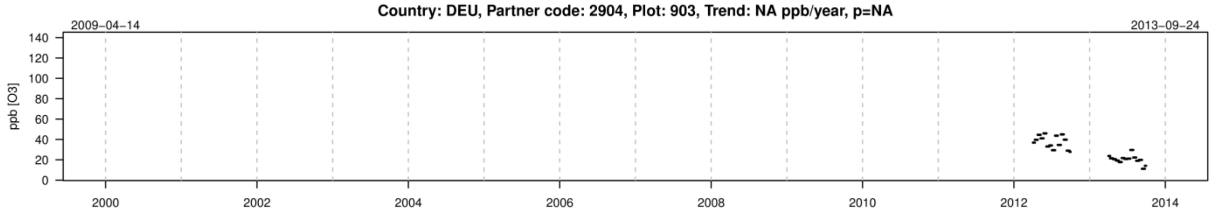
Country: DEU, Partner code: 2804, Plot: 859, Trend: NA ppb/year, p=NA



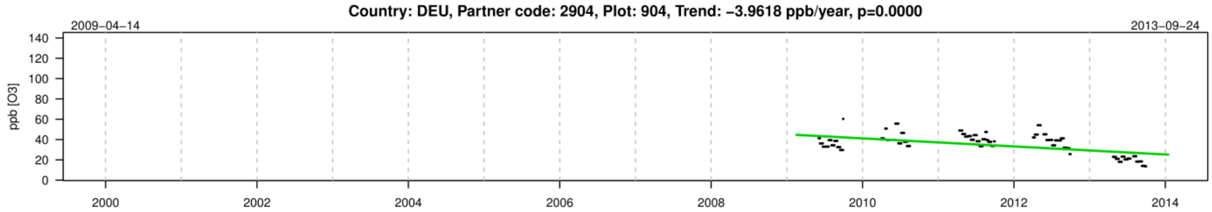
Country: DEU, Partner code: 2904, Plot: 901, Trend: –2.4407 ppb/year, p=0.0000



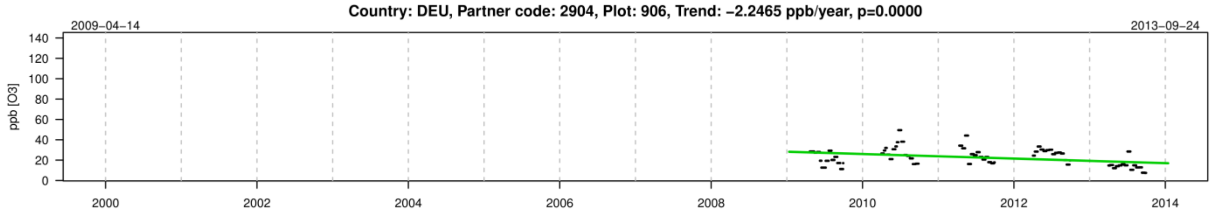
Country: DEU, Partner code: 2904, Plot: 903, Trend: NA ppb/year, p=NA



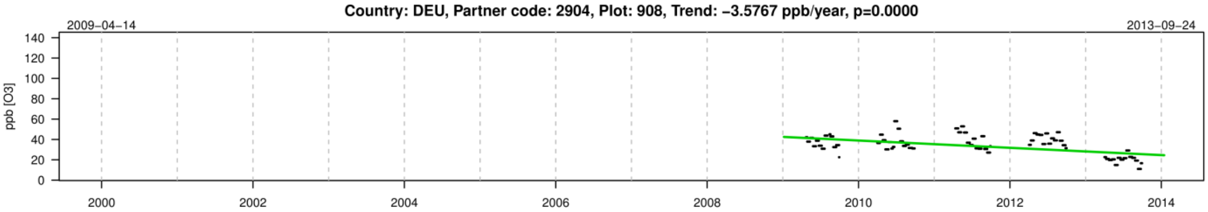
Country: DEU, Partner code: 2904, Plot: 904, Trend: –3.9618 ppb/year, p=0.0000



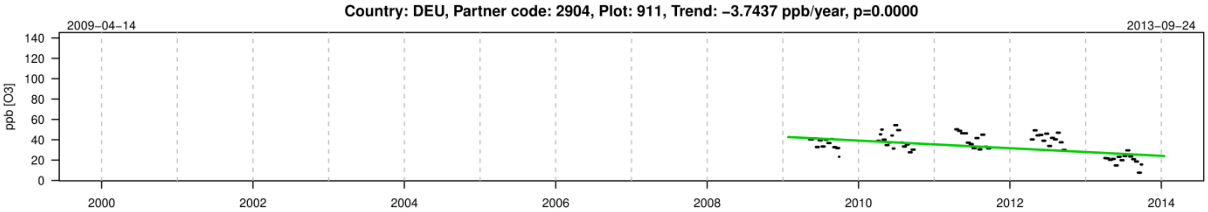
Country: DEU, Partner code: 2904, Plot: 906, Trend: –2.2465 ppb/year, p=0.0000



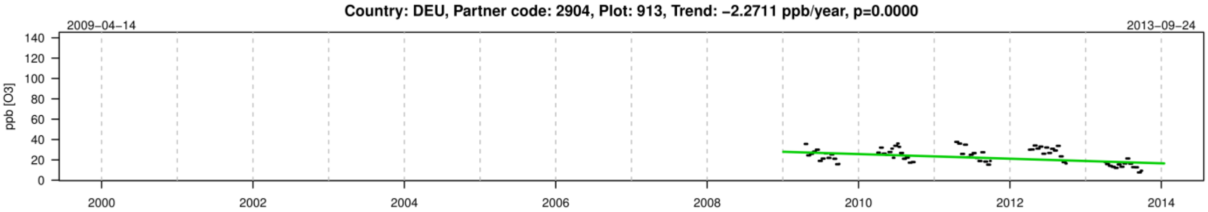
Country: DEU, Partner code: 2904, Plot: 908, Trend: −3.5767 ppb/year, p=0.0000



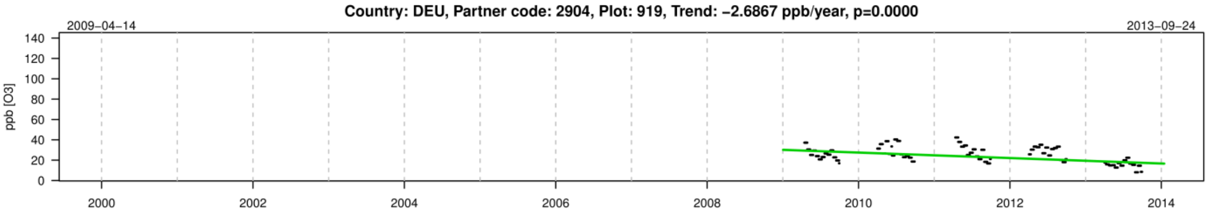
Country: DEU, Partner code: 2904, Plot: 911, Trend: −3.7437 ppb/year, p=0.0000



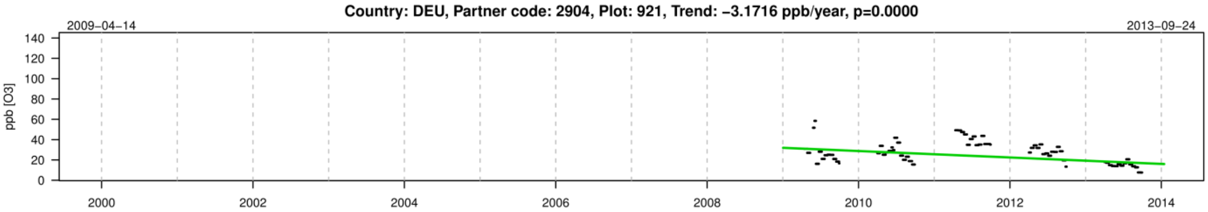
Country: DEU, Partner code: 2904, Plot: 913, Trend: −2.2711 ppb/year, p=0.0000



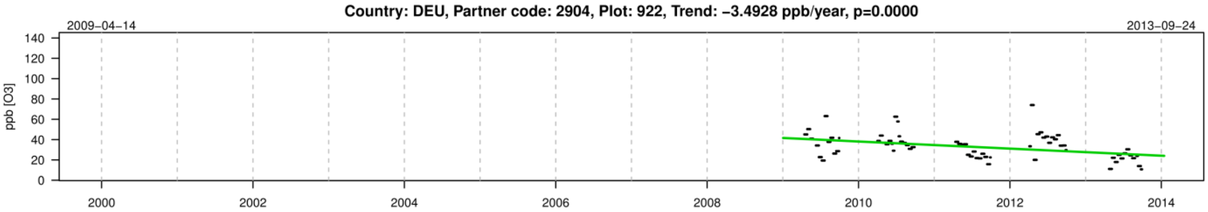
Country: DEU, Partner code: 2904, Plot: 919, Trend: −2.6867 ppb/year, p=0.0000



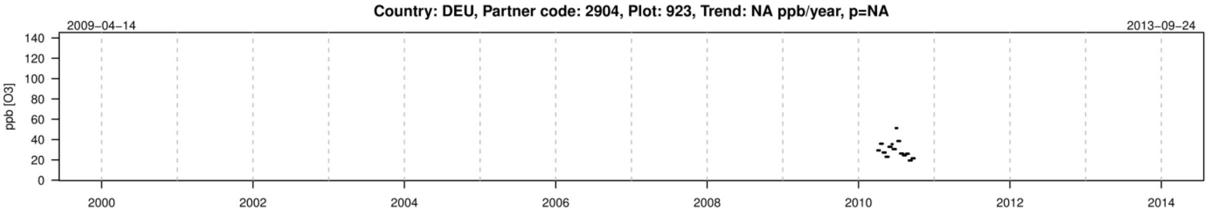
Country: DEU, Partner code: 2904, Plot: 921, Trend: −3.1716 ppb/year, p=0.0000

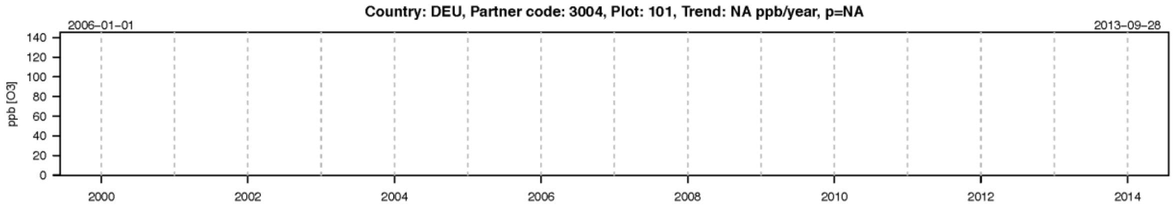


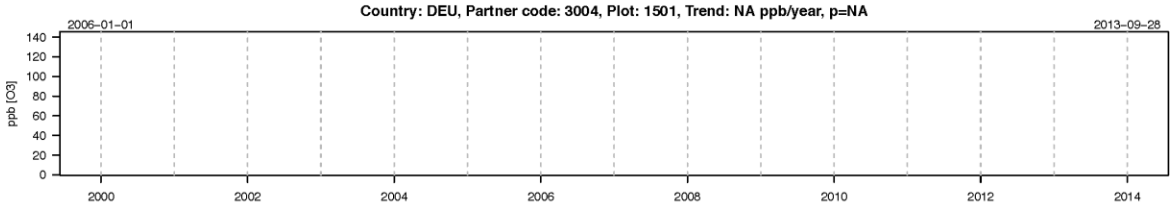
Country: DEU, Partner code: 2904, Plot: 922, Trend: −3.4928 ppb/year, p=0.0000



Country: DEU, Partner code: 2904, Plot: 923, Trend: NA ppb/year, p=NA




Country: DEU, Partner code: 3004, Plot: 101, Trend: NA ppb/year, p=NA
2006–01–01
2013–09–28
ppb [O3]
140 120 100 80 60 40 20 0
2000 2002 2004 2006 2008 2010 2012 2014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2013–09–28
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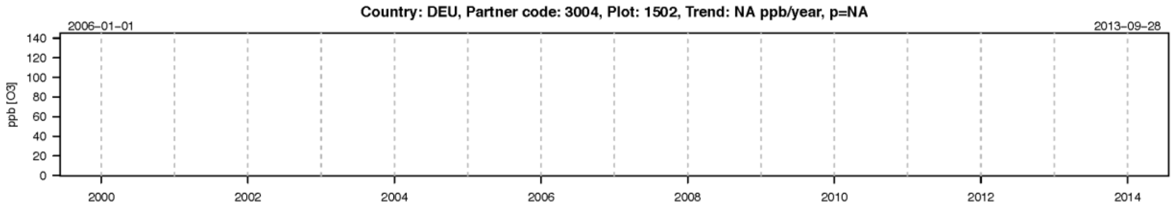
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2013–09–28
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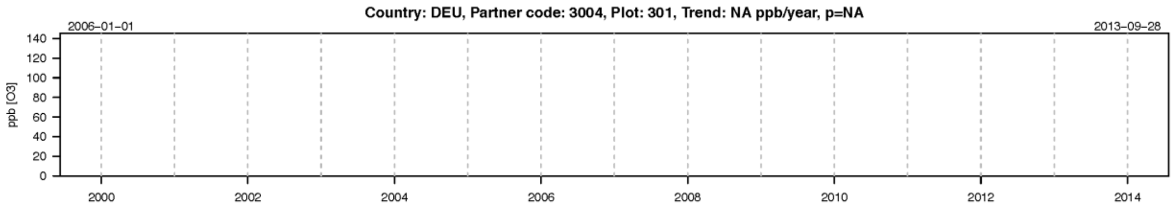
Country: DEU, Partner code: 3004, Plot: 301, Trend: NA ppb/year, p=NA
2006–01–01
2013–09–28
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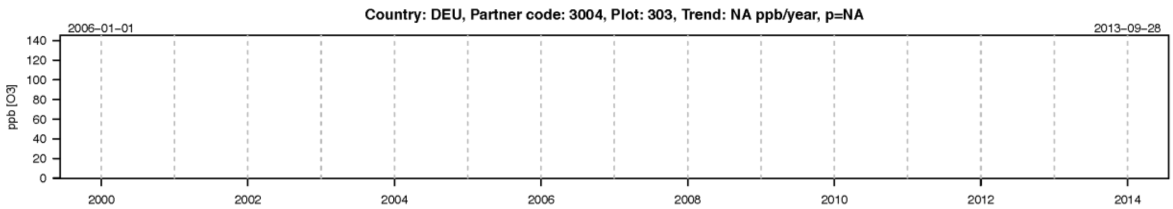
Country: DEU, Partner code: 3004, Plot: 303, Trend: NA ppb/year, p=NA
2006–01–01
2013–09–28
ppb [O3]
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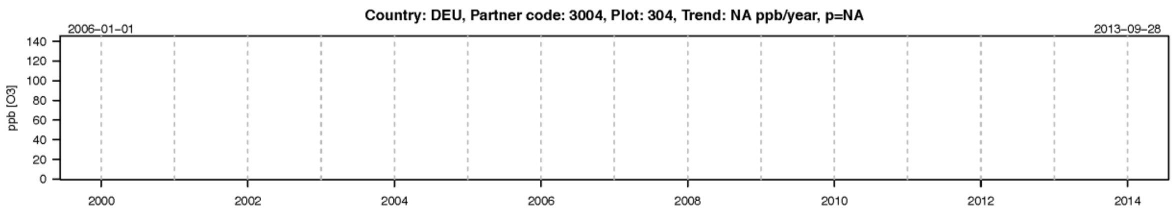
2000 2002 2004 2006 2008 2010 2012 2014


Country: DEU, Partner code: 3004, Plot: 304, Trend: NA ppb/year, p=NA
2006–01–01
2013–09–28
ppb [O3]
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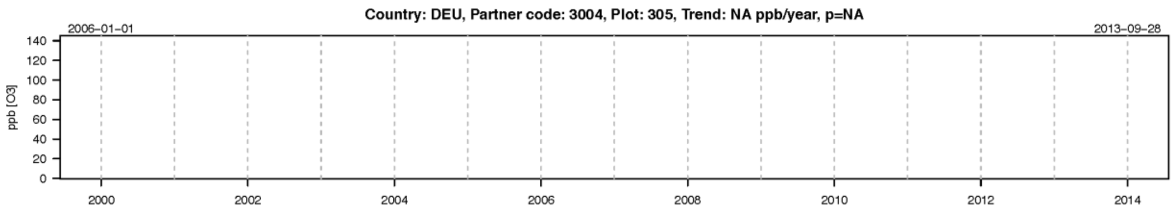
2000 2002 2004 2006 2008 2010 2012 2014


Country: DEU, Partner code: 3004, Plot: 305, Trend: NA ppb/year, p=NA
2006–01–01
2013–09–28
ppb [O3]
140 120 100 80 60 40 20 0
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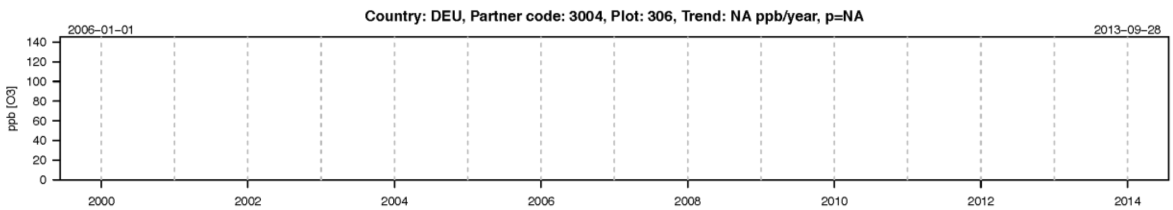
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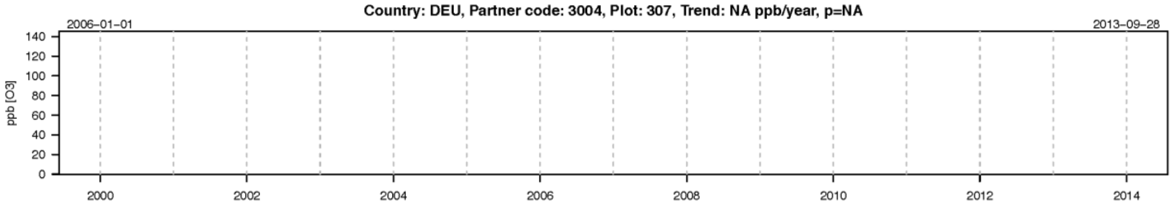
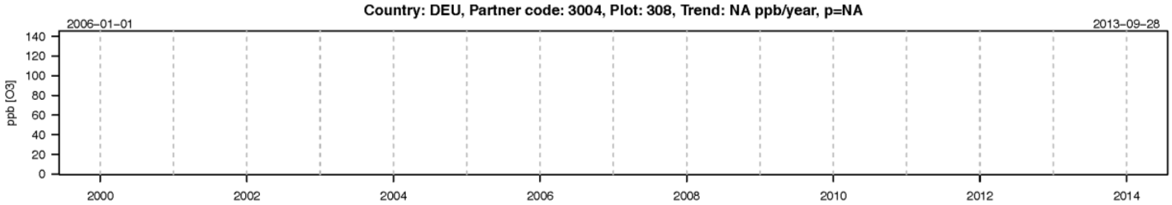
2006–01–01
2013–09–28
ppb [O3]
140 120 100 80 60 40 20 0
2000 2002 2004 2006 2008 2010 2012 2014

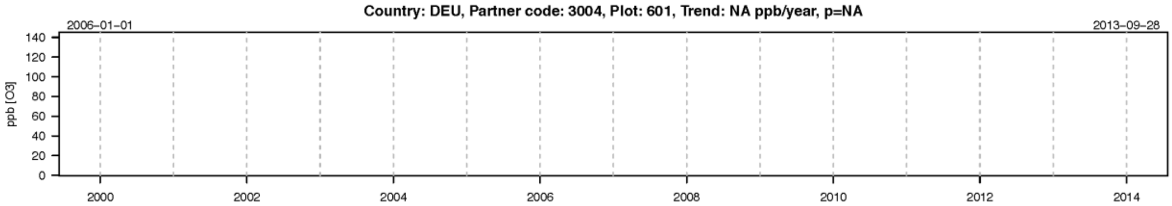
Country: DEU, Partner code: 3004, Plot: 307, Trend: NA ppb/year, p=NA



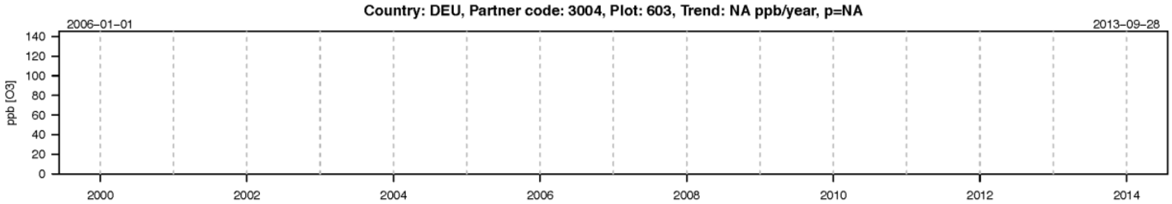
Country: DEU, Partner code: 3004, Plot: 308, Trend: NA ppb/year, p=NA



Country: DEU, Partner code: 3004, Plot: 601, Trend: NA ppb/year, p=NA



Country: DEU, Partner code: 3004, Plot: 603, Trend: NA ppb/year, p=NA



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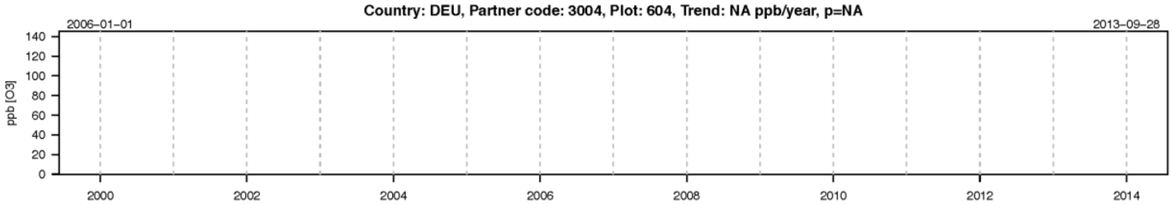

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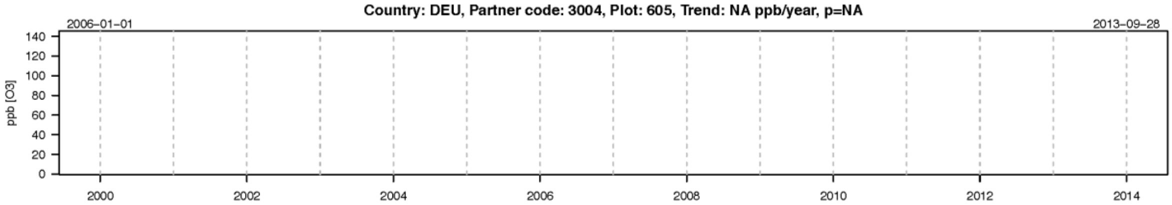

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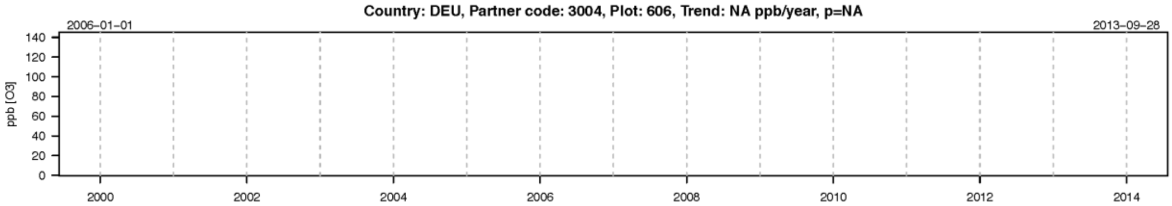

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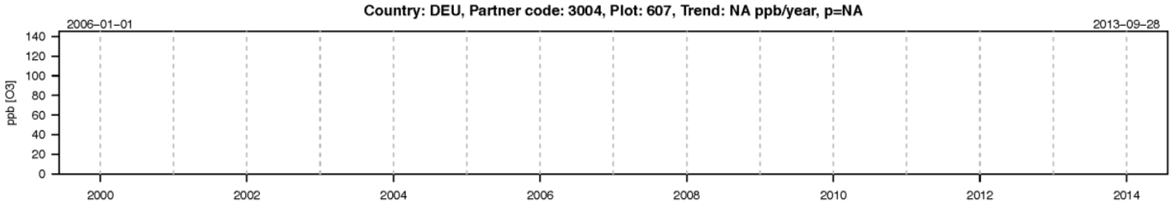

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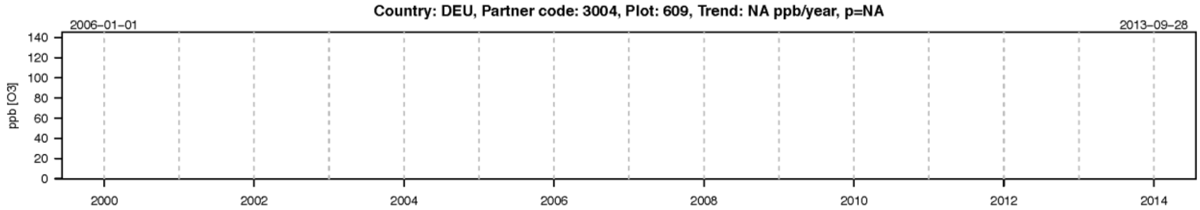

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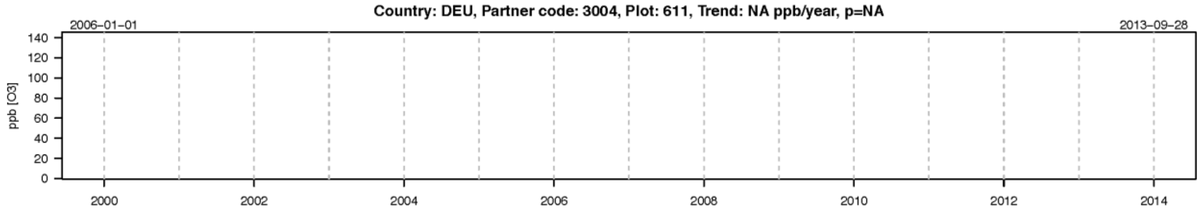
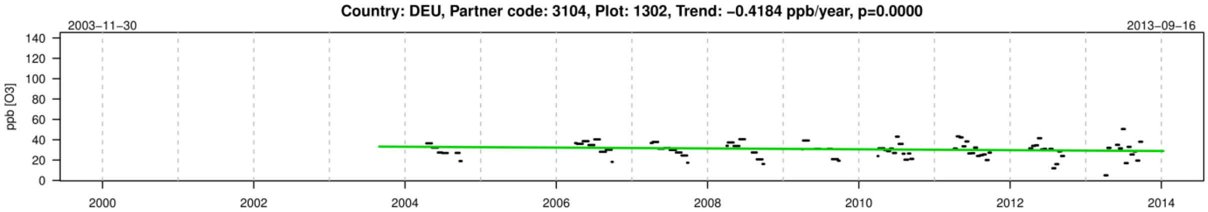


Country: DEU, Partner code: 3104, Plot: 1302, Trend: –0.4184 ppb/year, p=0.0000



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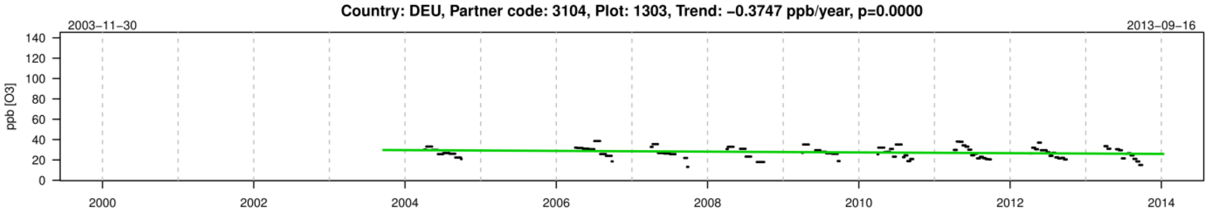

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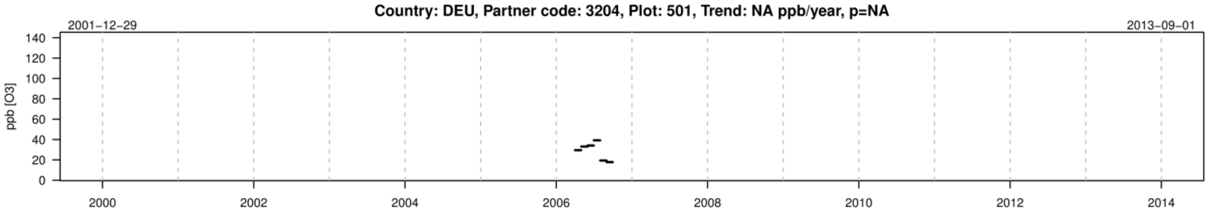
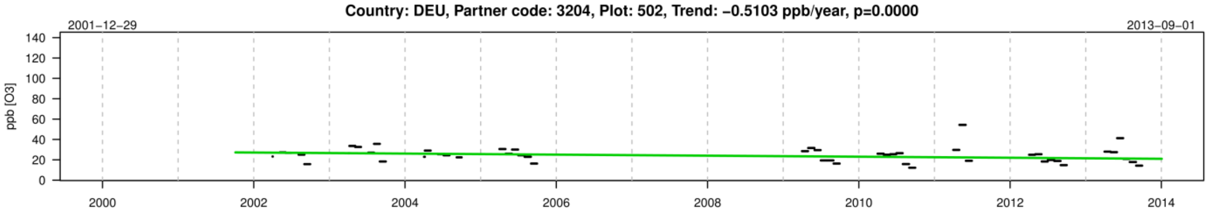


Country: DEU, Partner code: 3204, Plot: 502, Trend: –0.5103 ppb/year, p=0.0000



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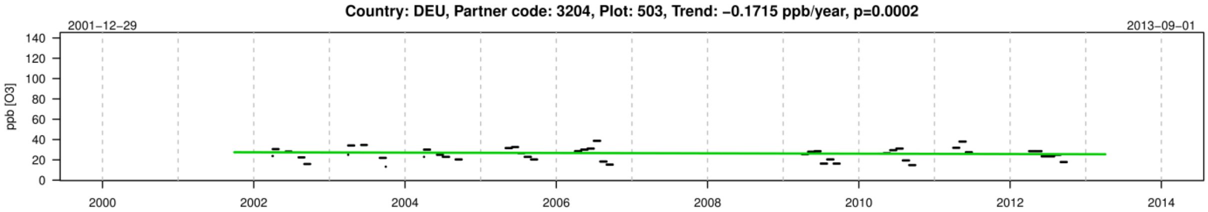

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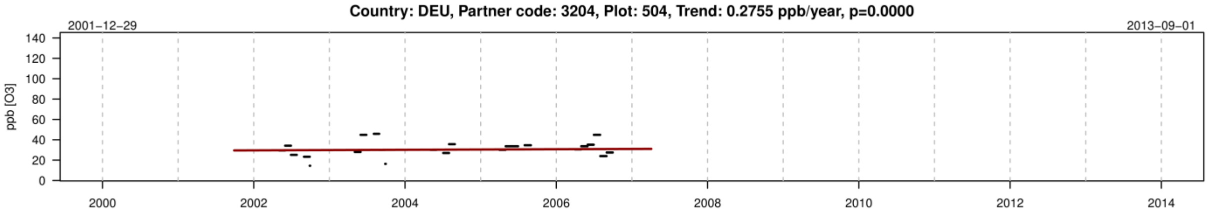
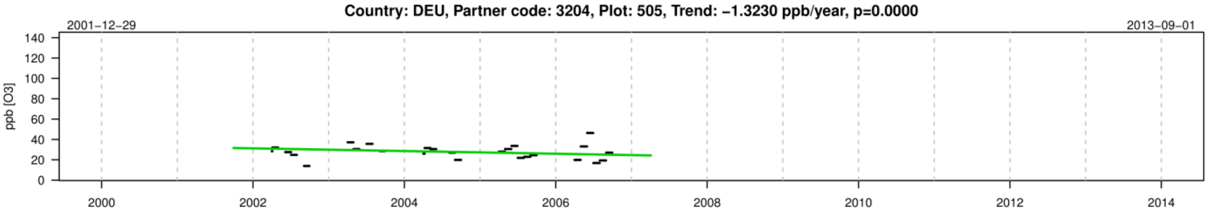
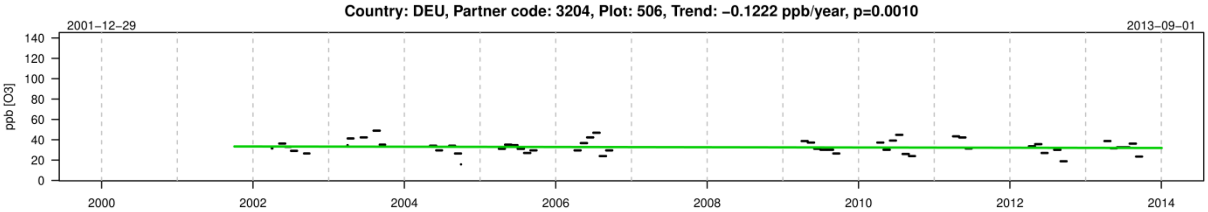


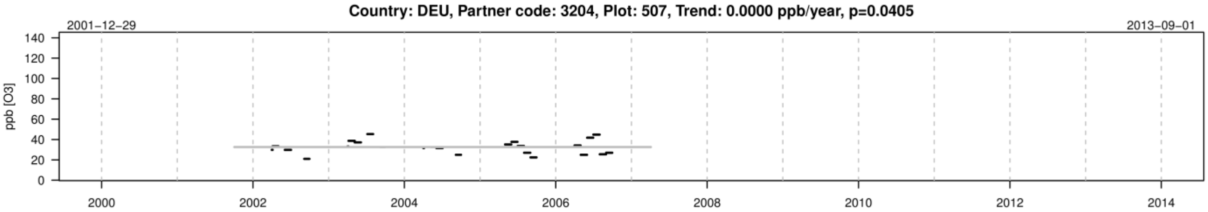
Country: DEU, Partner code: 3204, Plot: 505, Trend: –1.3230 ppb/year, p=0.0000



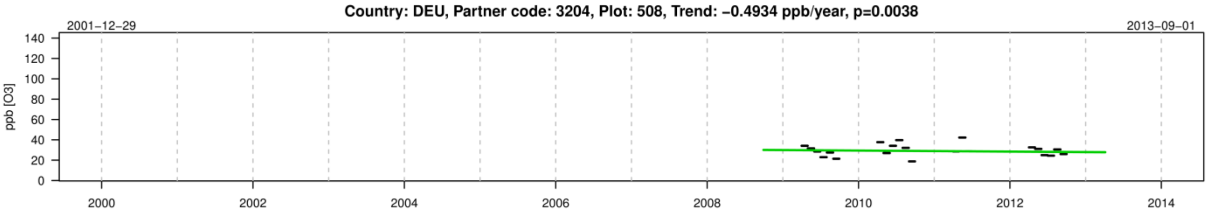
Country: DEU, Partner code: 3204, Plot: 506, Trend: –0.1222 ppb/year, p=0.0010



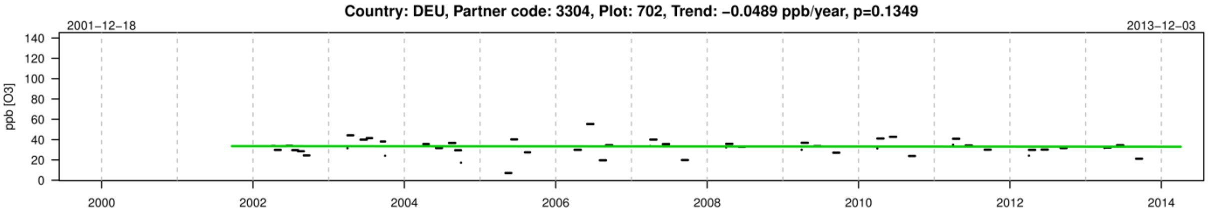
Country: DEU, Partner code: 3204, Plot: 507, Trend: 0.0000 ppb/year, p=0.0405



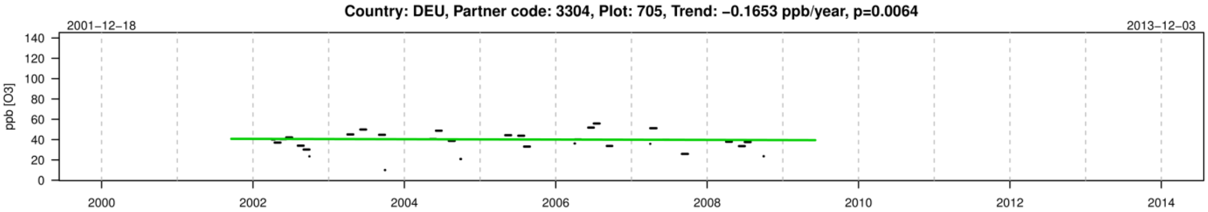
Country: DEU, Partner code: 3204, Plot: 508, Trend: –0.4934 ppb/year, p=0.0038



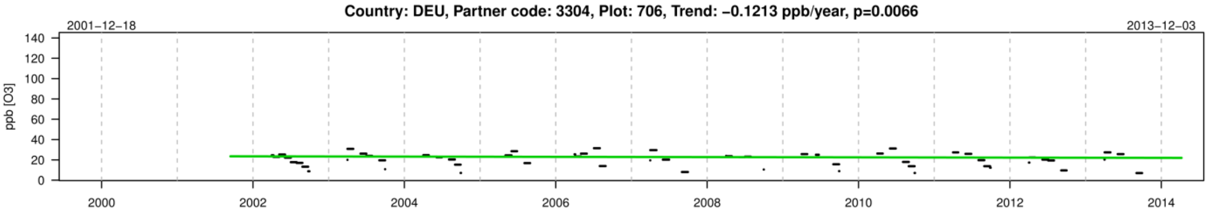
Country: DEU, Partner code: 3304, Plot: 702, Trend: –0.0489 ppb/year, p=0.1349



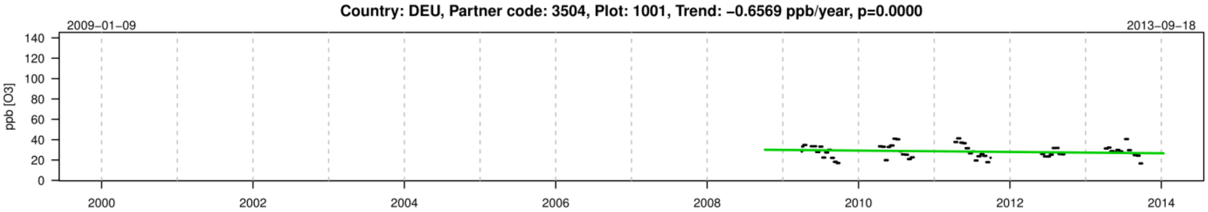
Country: DEU, Partner code: 3304, Plot: 705, Trend: –0.1653 ppb/year, p=0.0064



Country: DEU, Partner code: 3304, Plot: 706, Trend: –0.1213 ppb/year, p=0.0066



Country: DEU, Partner code: 3504, Plot: 1001, Trend: –0.6569 ppb/year, p=0.0000



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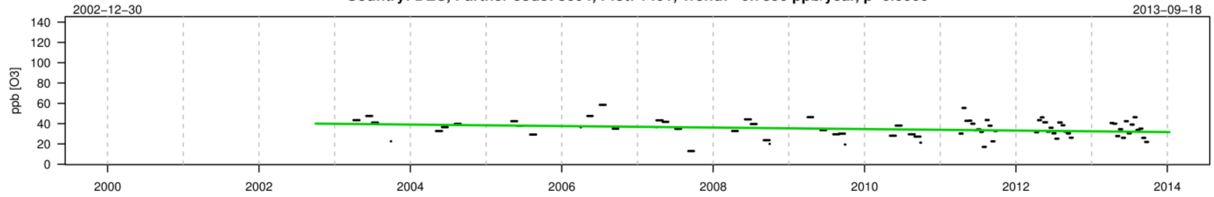

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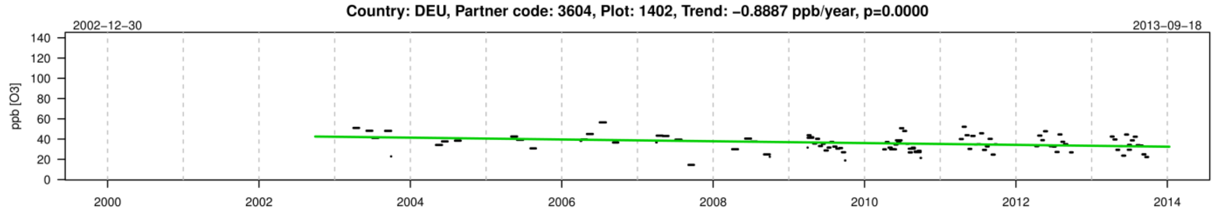

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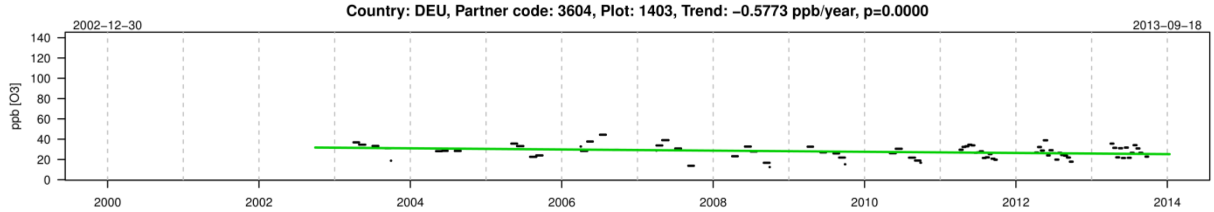

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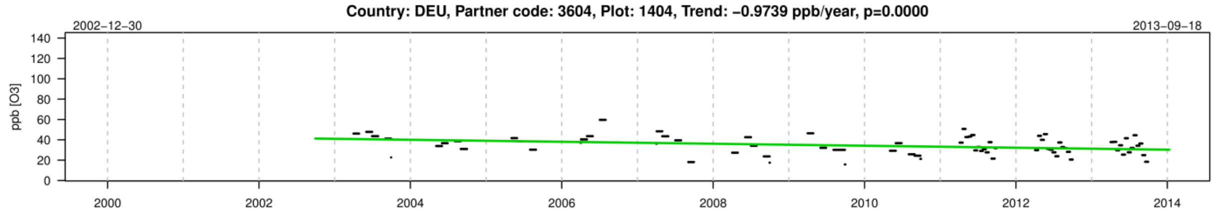

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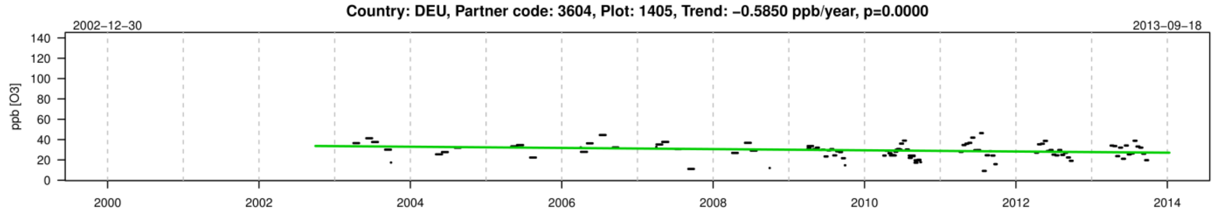

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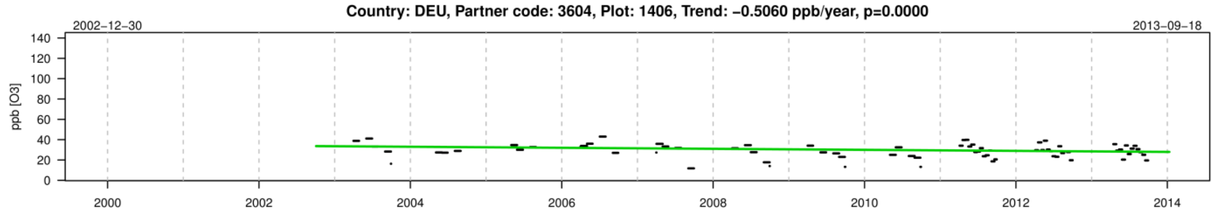

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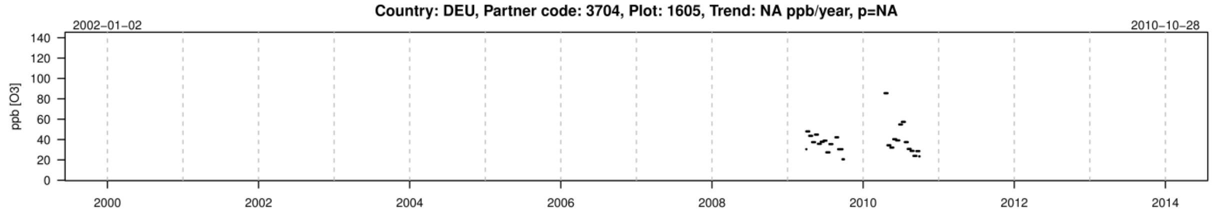
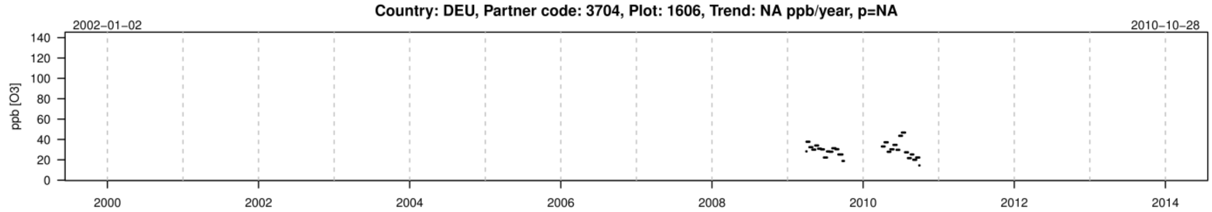
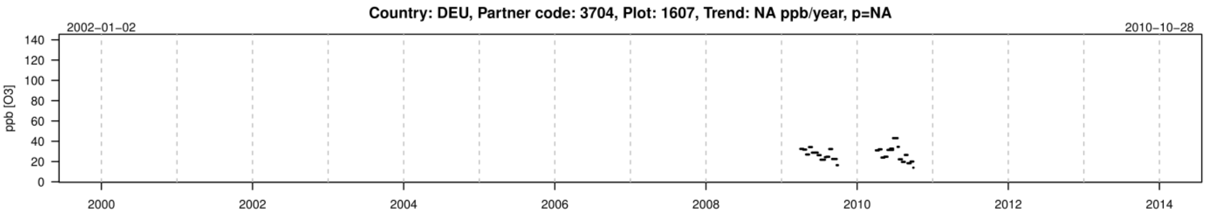
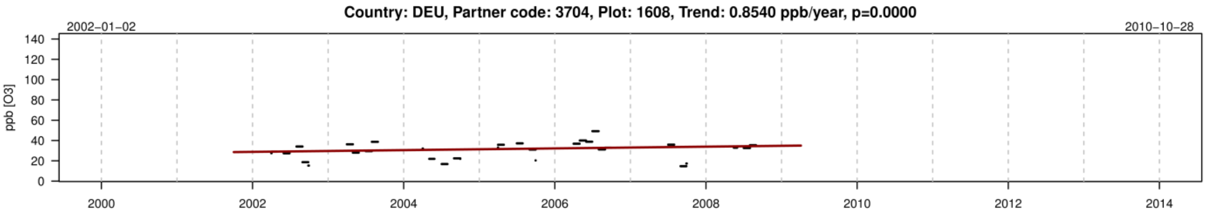


Country: DEU, Partner code: 3704, Plot: 1606, Trend: NA ppb/year, p=NA




Country: DEU, Partner code: 3704, Plot: 1607, Trend: NA ppb/year, p=NA
2002–01–02
2010–10–28
ppb [O3]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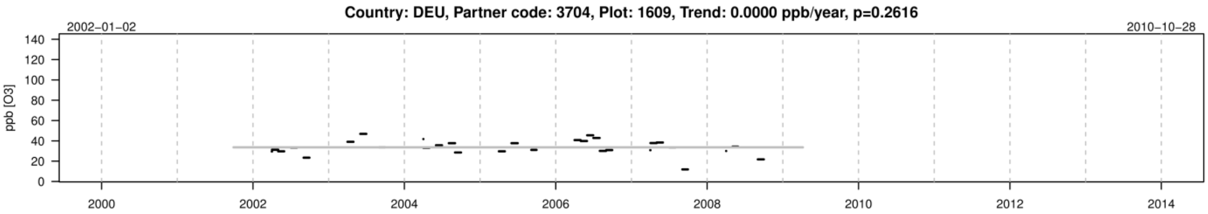
2002–01–02
2010–10–28
ppb [O3]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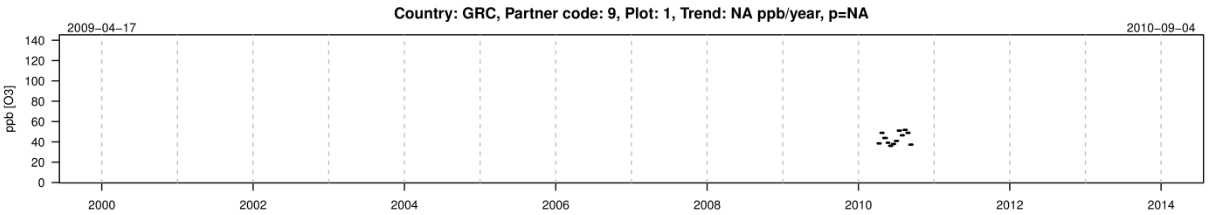
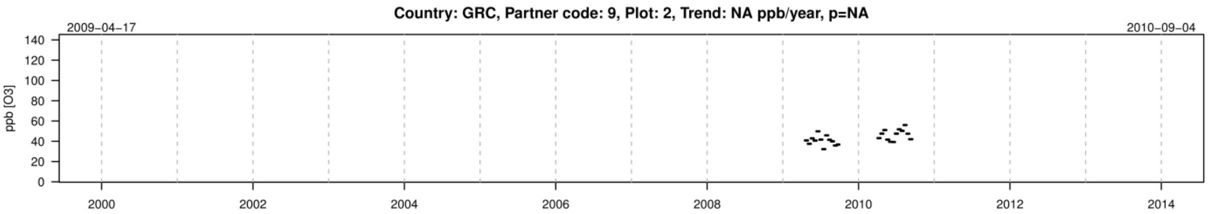
2002–01–02
2010–10–28
ppb [O3]

GREECE


Country: GRC, Partner code: 9, Plot: 1, Trend: NA ppb/year, p=NA
2009–04–17
2010–09–04
ppb [O3]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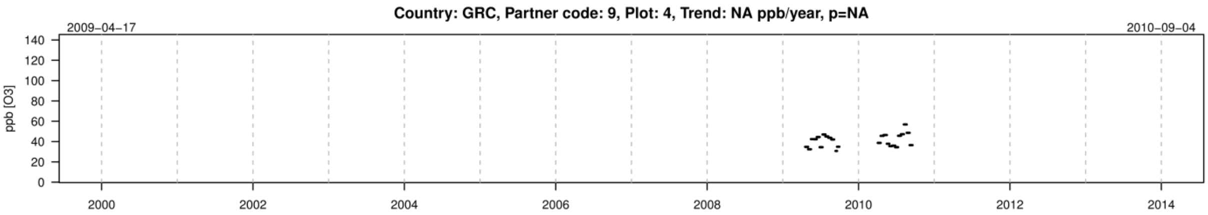
2009–04–17
2010–09–04
ppb [O3]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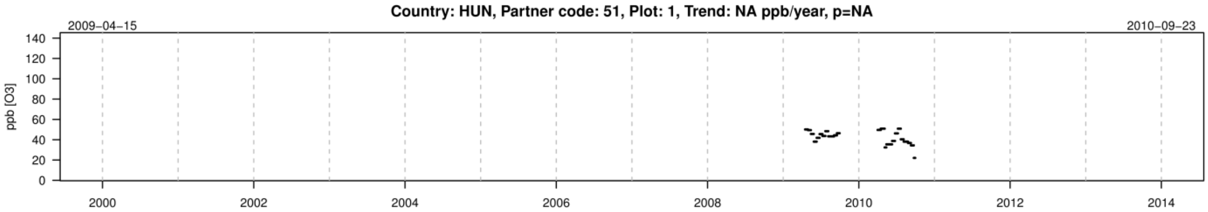
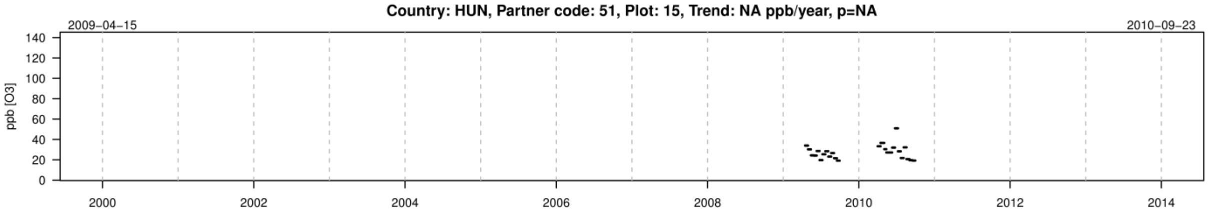
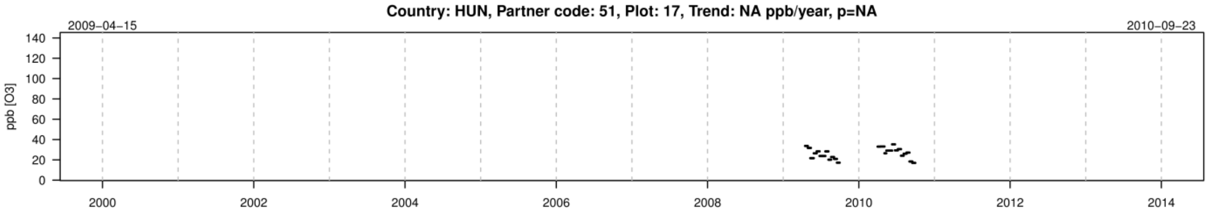
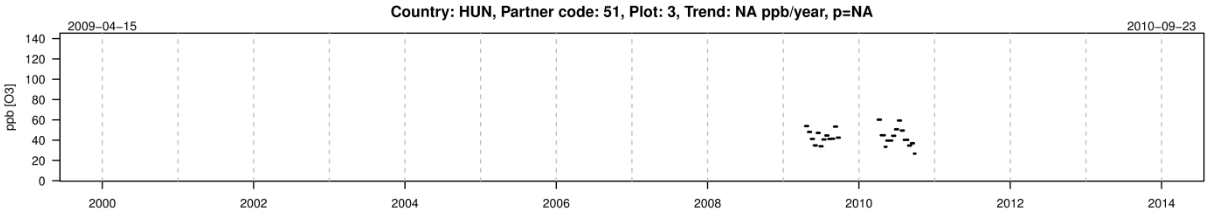
2009–04–17
2010–09–04
ppb [O3]

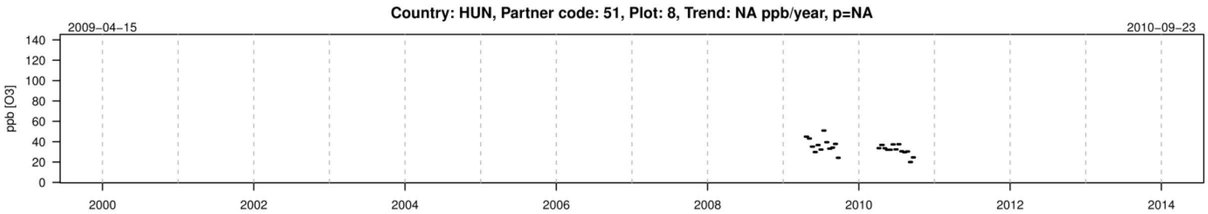
HUNGARY



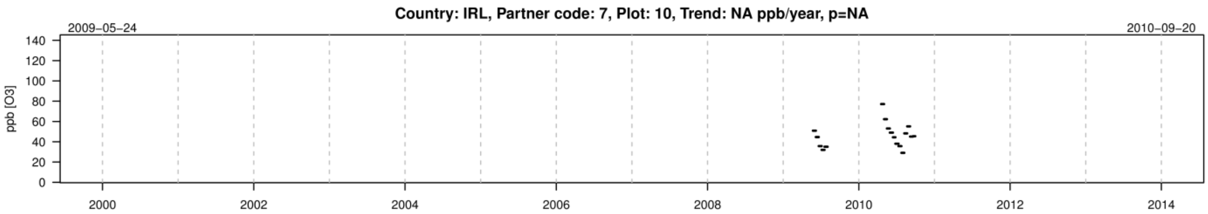


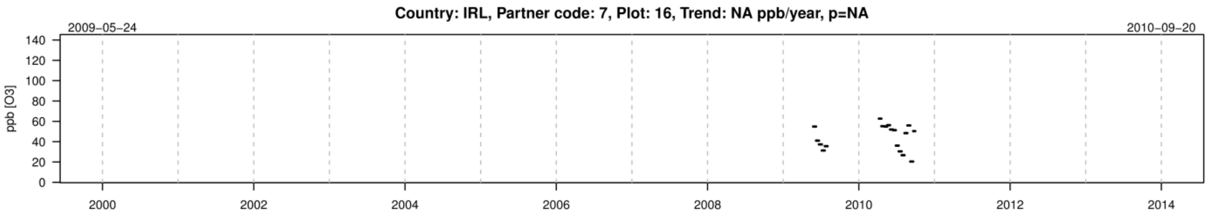




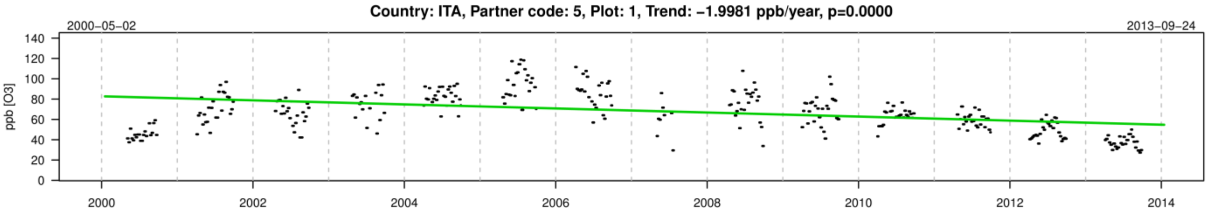


IRELAND





ITALY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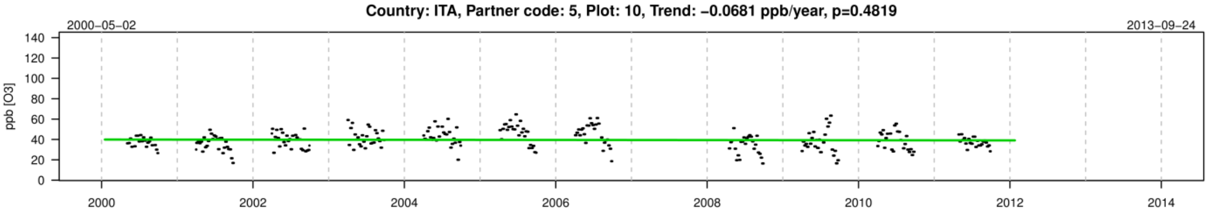
2000–05–02
2013–09–24
ppb [O3]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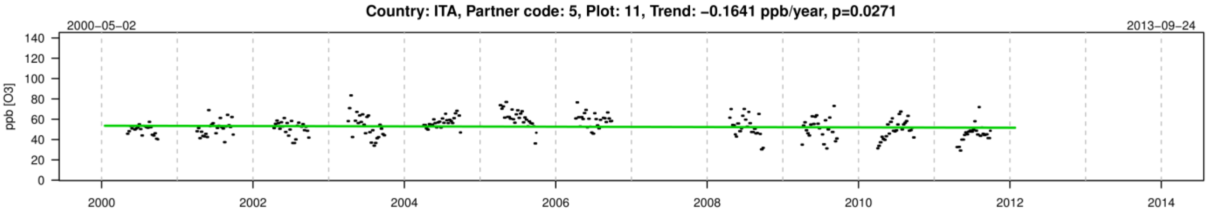
2000–05–02
2013–09–24
ppb [O3]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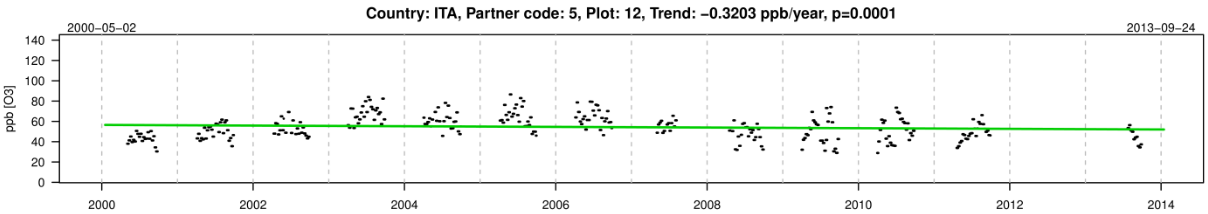
2000–05–02
2013–09–24
ppb [O3]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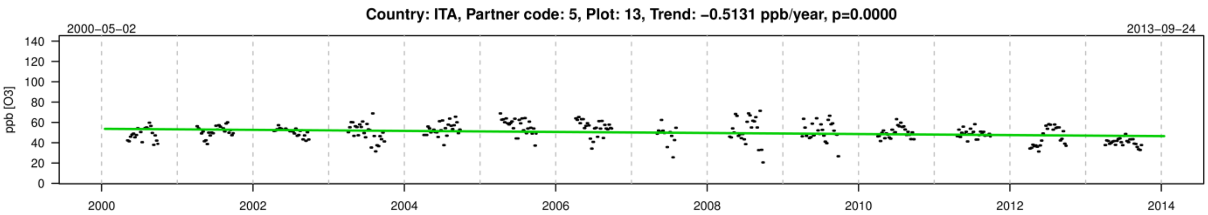
2000–05–02
2013–09–24
ppb [O3]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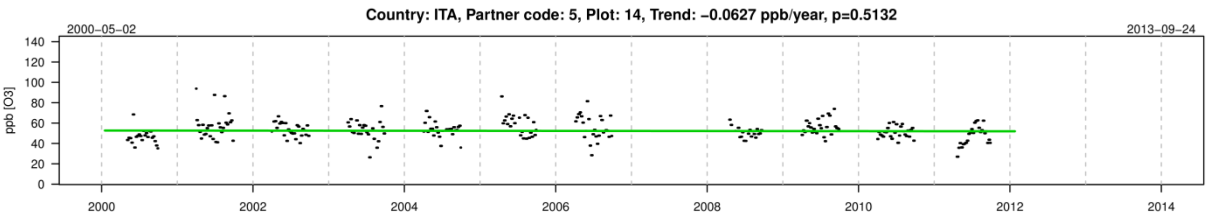
2000–05–02
2013–09–24
ppb [O3]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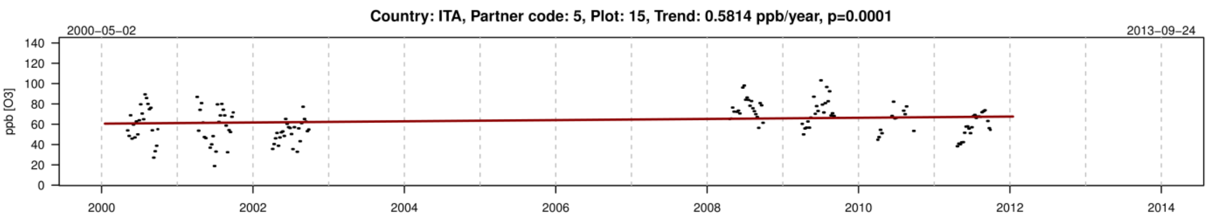
2000–05–02
2013–09–24
ppb [O3]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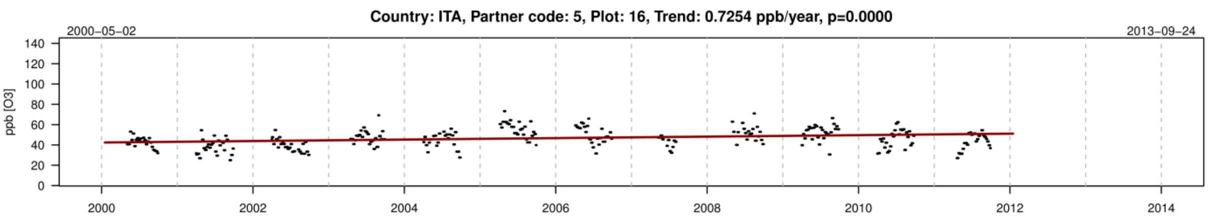
2000–05–02
2013–09–24
ppb [O3]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2000–05–02
2013–09–24
ppb [O3]

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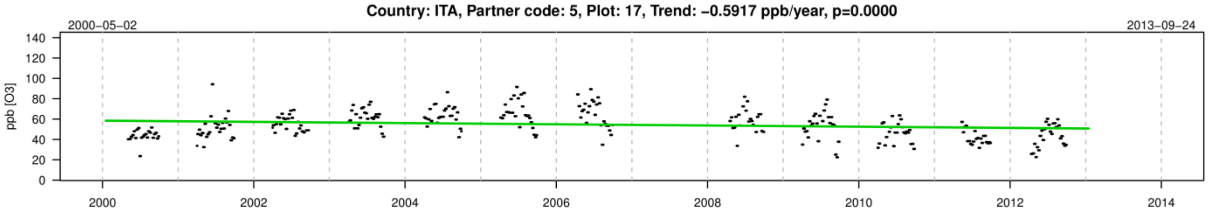

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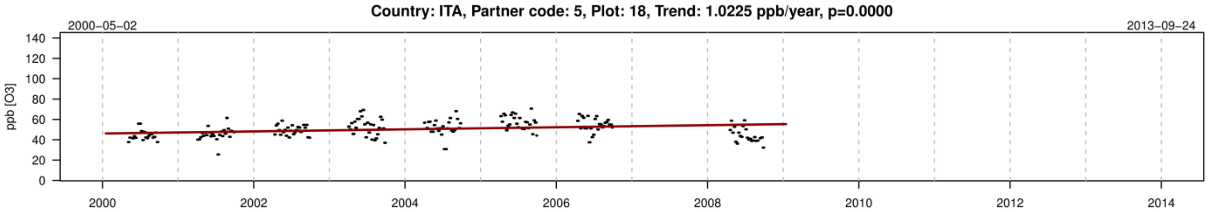

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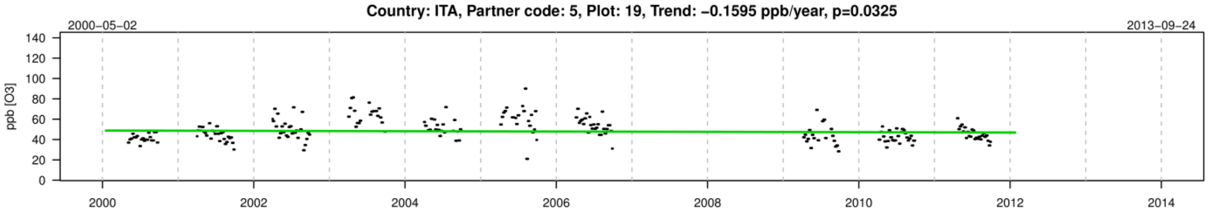

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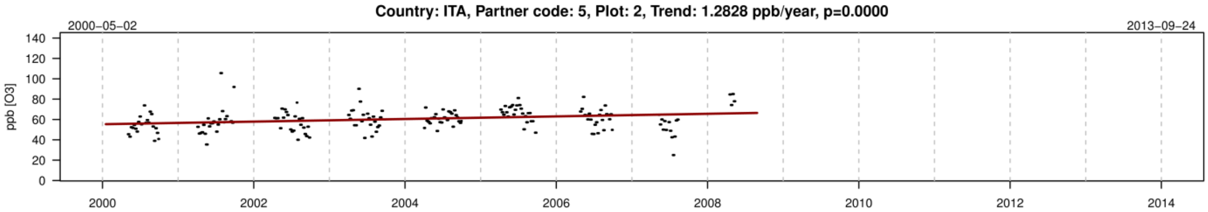

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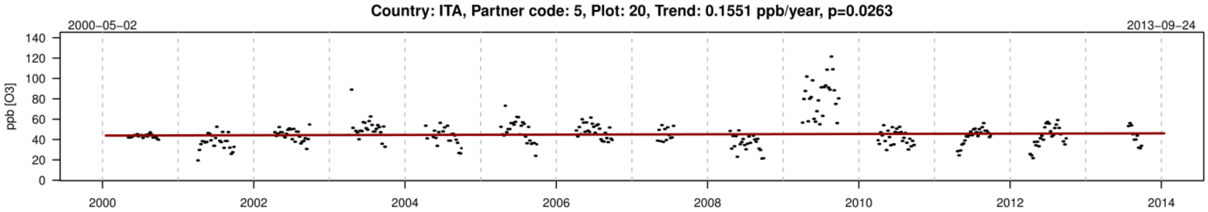

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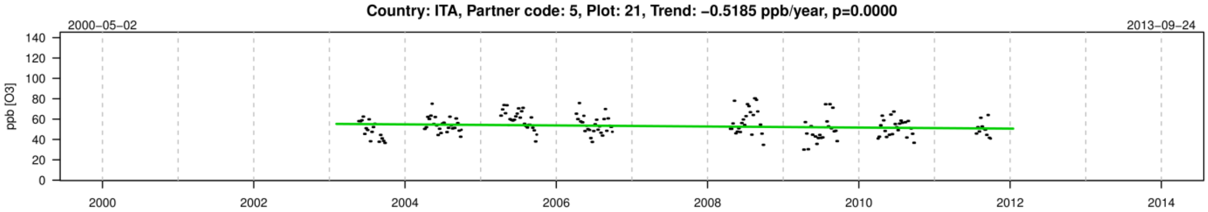

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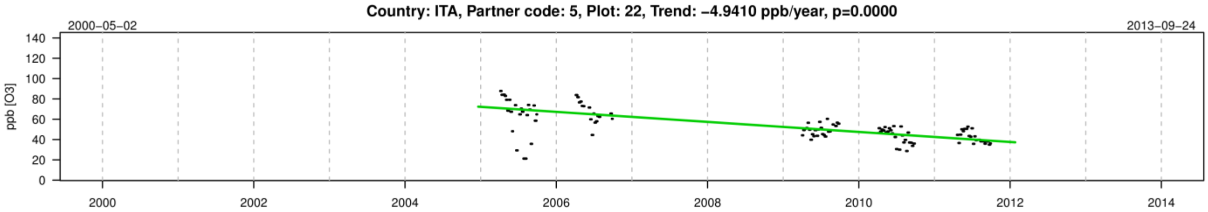
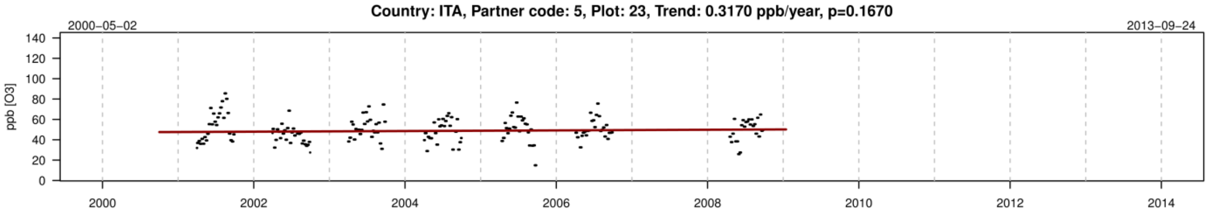
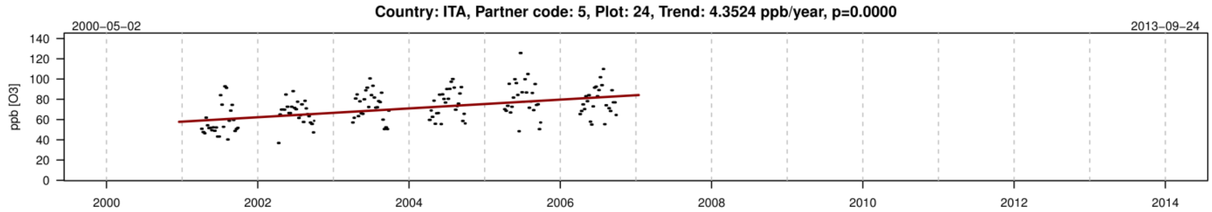
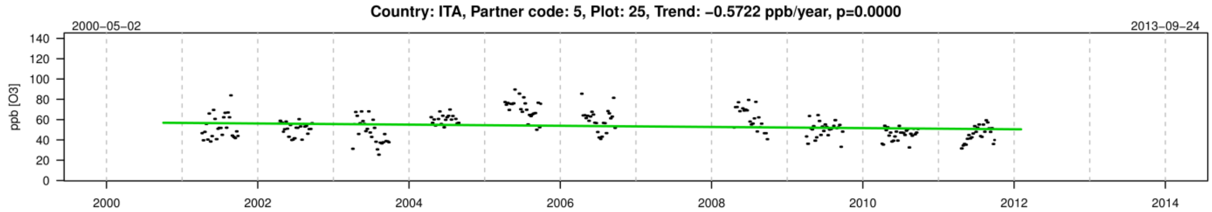
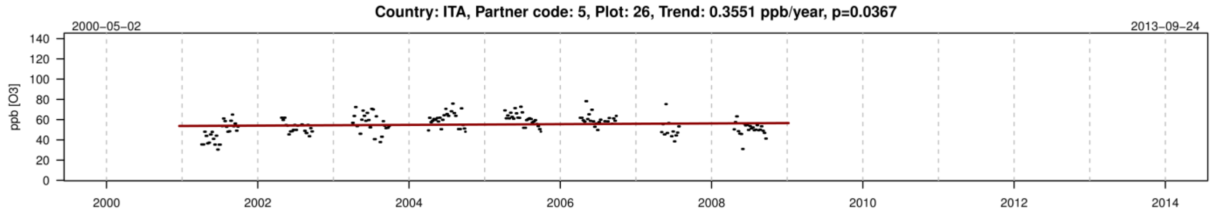


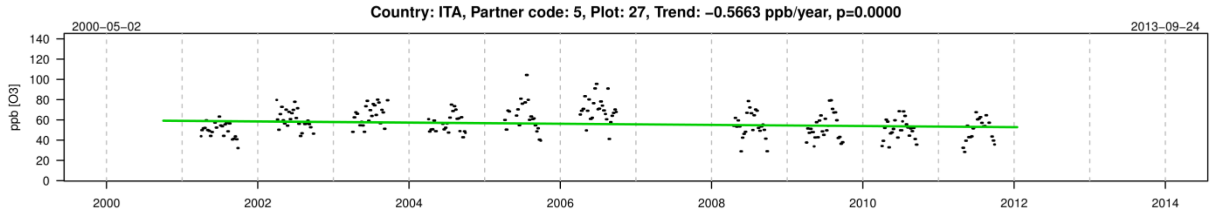
Country: ITA, Partner code: 5, Plot: 23, Trend: 0.3170 ppb/year, p=0.1670

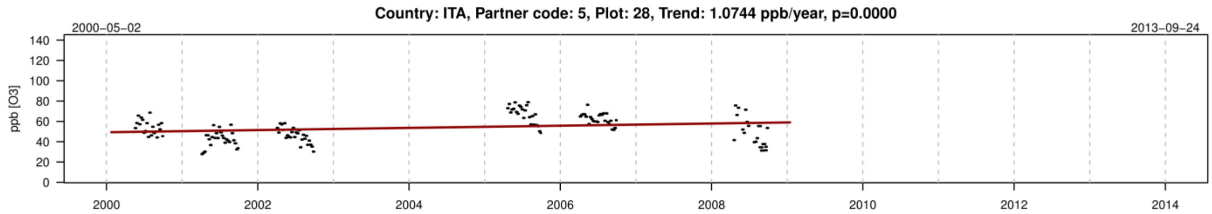


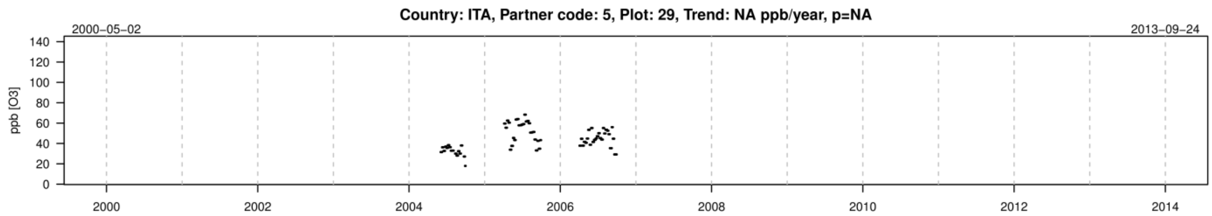

Country: ITA, Partner code: 5, Plot: 24, Trend: 4.3524 ppb/year, p=0.0000
2000–05–02
2013–09–24
ppb [O3]
0 20 40 60 80 100 120 140
2000 2002 2004 2006 2008 2010 2012 2014

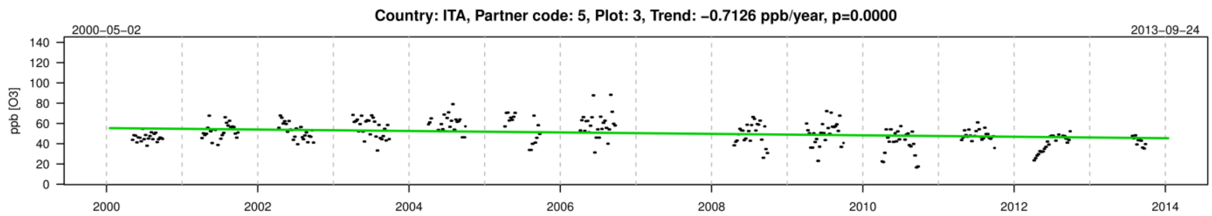

Country: ITA, Partner code: 5, Plot: 25, Trend: –0.5722 ppb/year, p=0.0000
2000–05–02
2013–09–24
ppb [O3]
0 20 40 60 80 100 120 140
2000 2002 2004 2006 2008 2010 2012 2014

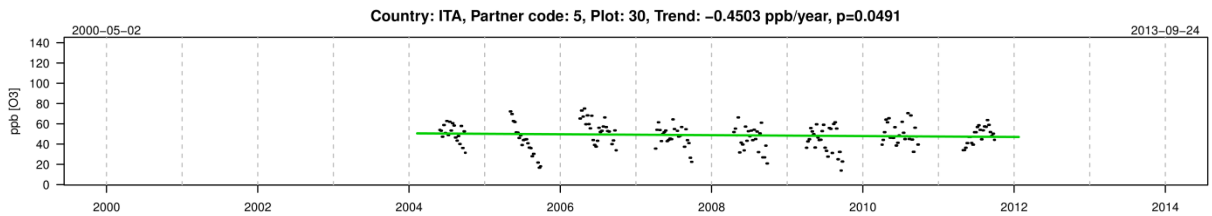

Country: ITA, Partner code: 5, Plot: 26, Trend: 0.3551 ppb/year, p=0.0367
2000–05–02
2013–09–24
ppb [O3]
0 20 40 60 80 100 120 140
2000 2002 2004 2006 2008 2010 2012 2014

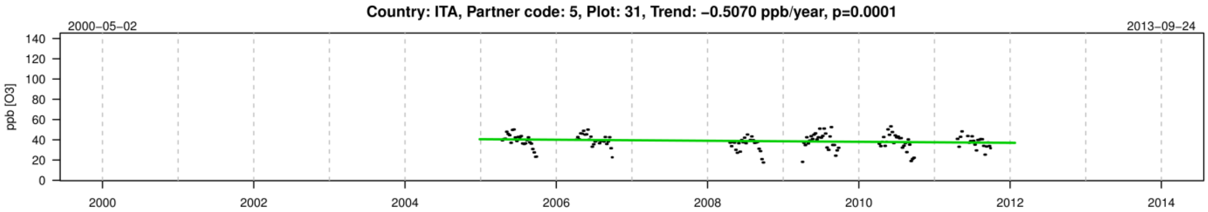

Country: ITA, Partner code: 5, Plot: 27, Trend: –0.5663 ppb/year, p=0.0000
2000–05–02
2013–09–24
ppb [O3]
0 20 40 60 80 100 120 140
2000 2002 2004 2006 2008 2010 2012 2014

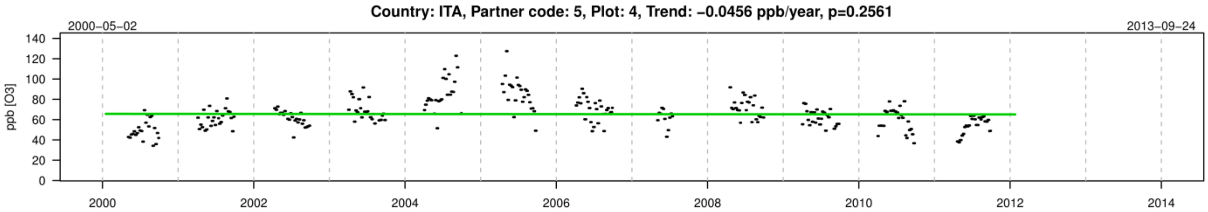

Country: ITA, Partner code: 5, Plot: 28, Trend: 1.0744 ppb/year, p=0.0000
2000–05–02
2013–09–24
ppb [O3]
0 20 40 60 80 100 120 140
2000 2002 2004 2006 2008 2010 2012 2014

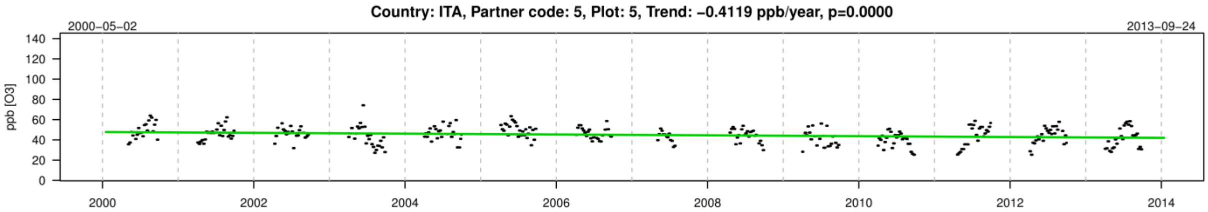

Country: ITA, Partner code: 5, Plot: 29, Trend: NA ppb/year, p=NA
2000–05–02
2013–09–24
ppb [O3]
0 20 40 60 80 100 120 140
2000 2002 2004 2006 2008 2010 2012 2014

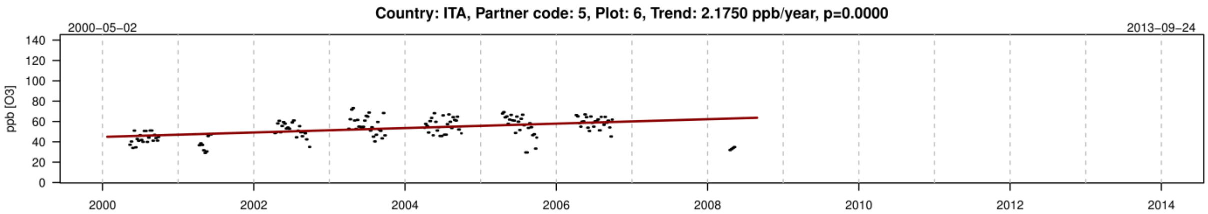

Country: ITA, Partner code: 5, Plot: 3, Trend: –0.7126 ppb/year, p=0.0000
2000–05–02
2013–09–24
ppb [O3]
0 20 40 60 80 100 120 140
2000 2002 2004 2006 2008 2010 2012 2014

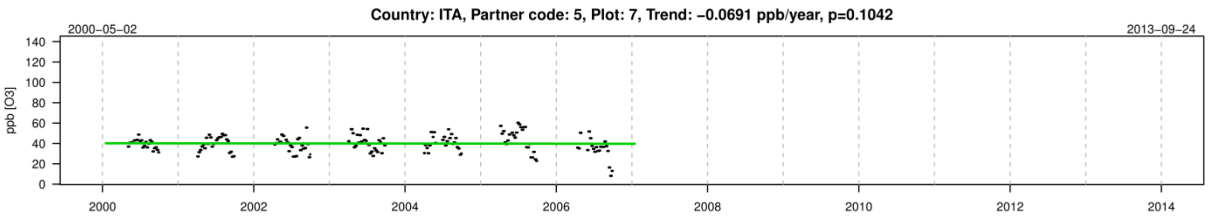

Country: ITA, Partner code: 5, Plot: 30, Trend: –0.4503 ppb/year, p=0.0491
2000–05–02
2013–09–24
ppb [O3]
0 20 40 60 80 100 120 140
2000 2002 2004 2006 2008 2010 2012 2014

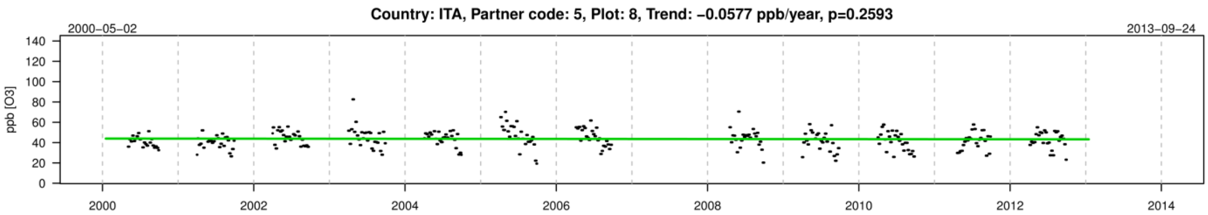

Country: ITA, Partner code: 5, Plot: 31, Trend: –0.5070 ppb/year, p=0.0001
2000–05–02
2013–09–24
ppb [O3]

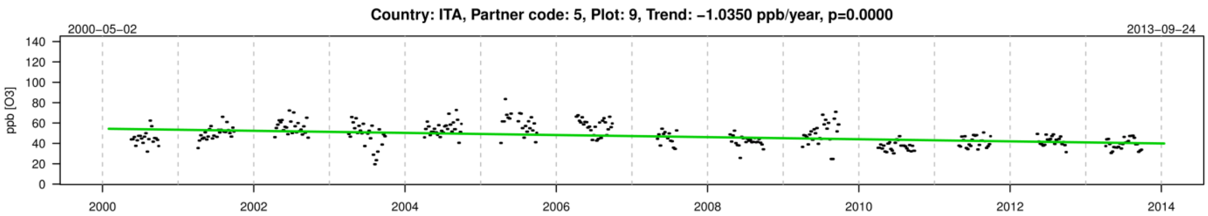

Country: ITA, Partner code: 5, Plot: 4, Trend: –0.0456 ppb/year, p=0.2561
2000–05–02
2013–09–24
ppb [O3]


Country: ITA, Partner code: 5, Plot: 5, Trend: –0.4119 ppb/year, p=0.0000
2000–05–02
2013–09–24
ppb [O3]

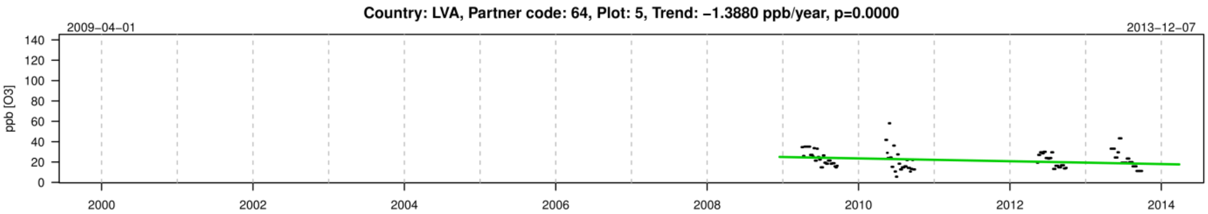

Country: ITA, Partner code: 5, Plot: 6, Trend: 2.1750 ppb/year, p=0.0000
2000–05–02
2013–09–24
ppb [O3]


Country: ITA, Partner code: 5, Plot: 7, Trend: –0.0691 ppb/year, p=0.1042
2000–05–02
2013–09–24
ppb [O3]

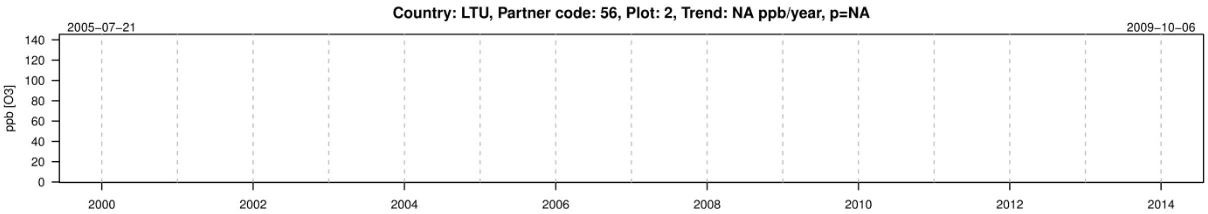

Country: ITA, Partner code: 5, Plot: 8, Trend: –0.0577 ppb/year, p=0.2593
2000–05–02
2013–09–24
ppb [O3]

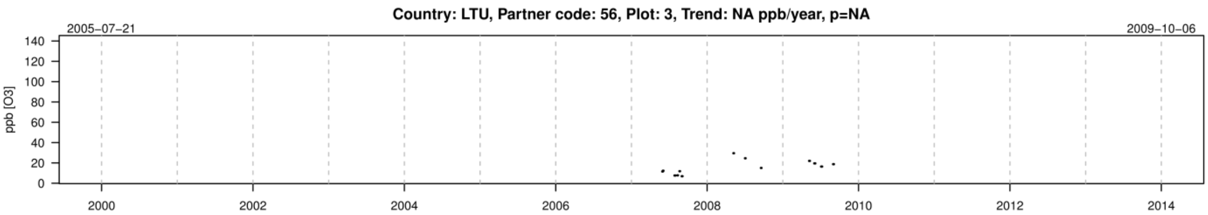

Country: ITA, Partner code: 5, Plot: 9, Trend: –1.0350 ppb/year, p=0.0000
2000–05–02
2013–09–24
ppb [O3]

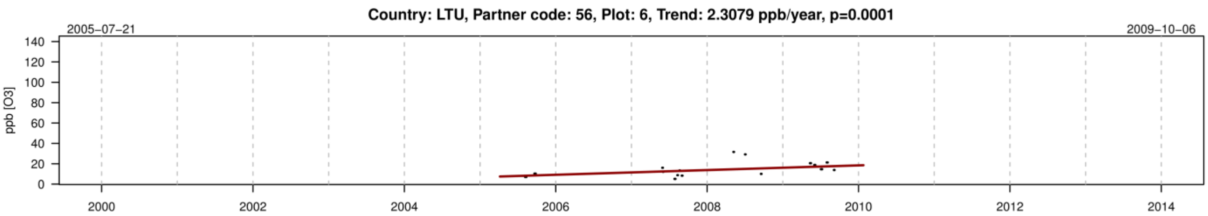
LATVIA



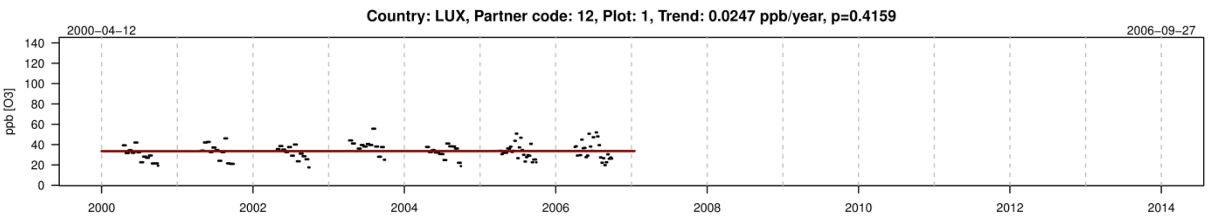
LITHUANIA

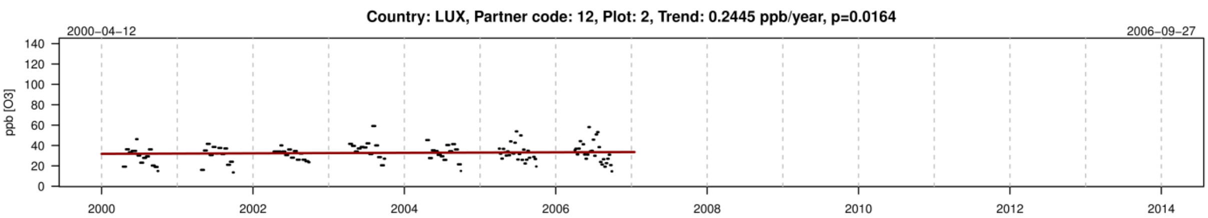




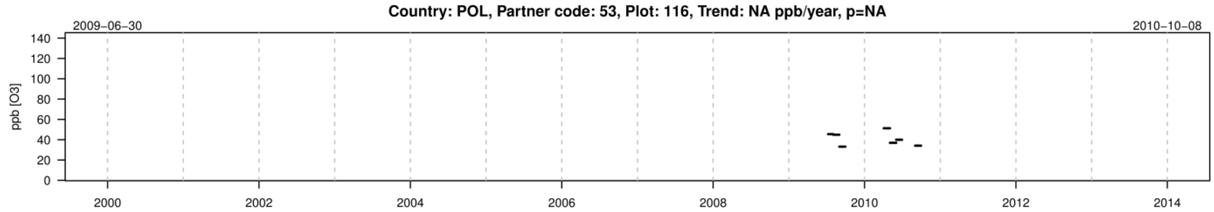


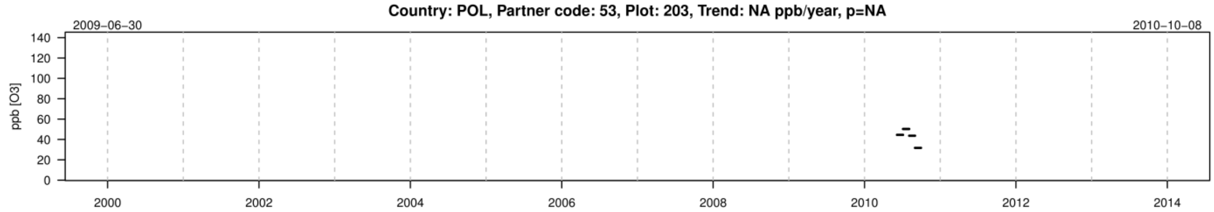
LUXEMBOURG

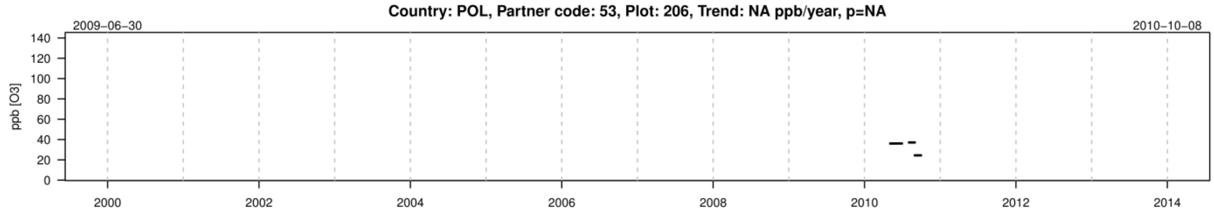


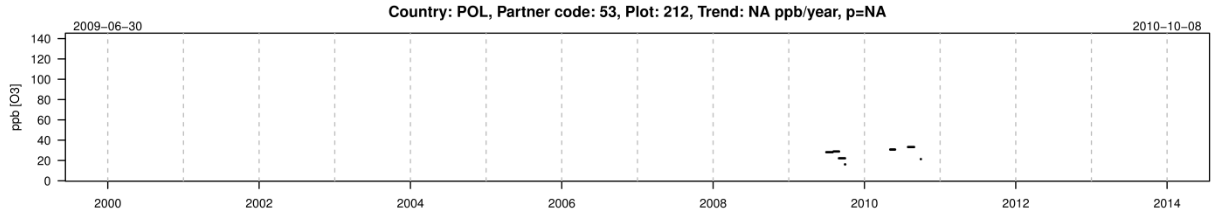


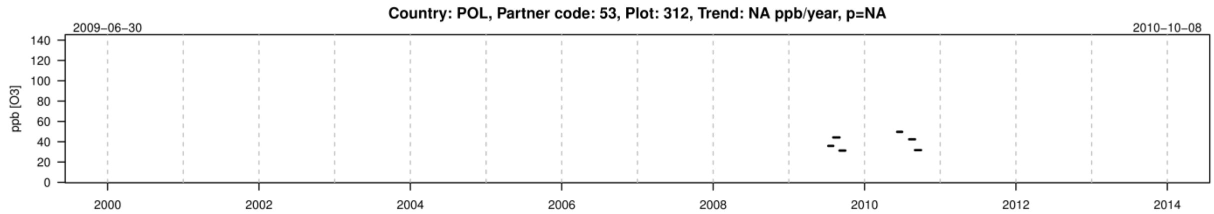
POLAND


Country: POL, Partner code: 53, Plot: 116, Trend: NA ppb/year, p=NA
2009–06–30
2010–10–08
ppb [O3]
0 20 40 60 80 100 120 140
2000 2002 2004 2006 2008 2010 2012 2014


Country: POL, Partner code: 53, Plot: 203, Trend: NA ppb/year, p=NA
2009–06–30
2010–10–08
ppb [O3]
0 20 40 60 80 100 120 140
2000 2002 2004 2006 2008 2010 2012 2014


Country: POL, Partner code: 53, Plot: 206, Trend: NA ppb/year, p=NA
2009–06–30
2010–10–08
ppb [O3]
0 20 40 60 80 100 120 140
2000 2002 2004 2006 2008 2010 2012 2014


Country: POL, Partner code: 53, Plot: 212, Trend: NA ppb/year, p=NA
2009–06–30
2010–10–08
ppb [O3]
0 20 40 60 80 100 120 140
2000 2002 2004 2006 2008 2010 2012 2014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2009–06–30
2010–10–08
ppb [O3]
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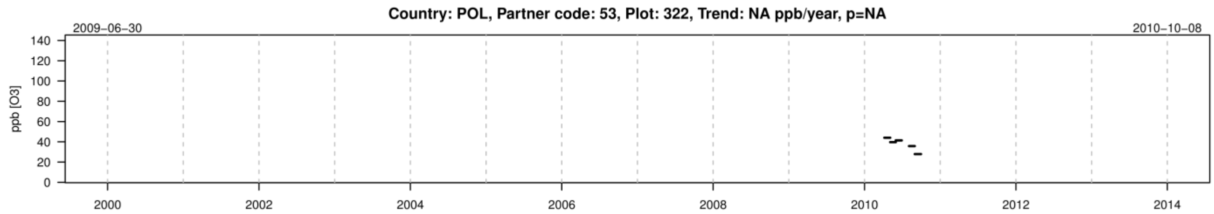
2000 2002 2004 2006 2008 2010 2012 2014


Country: POL, Partner code: 53, Plot: 322, Trend: NA ppb/year, p=NA
2009–06–30
2010–10–08
ppb [O3]
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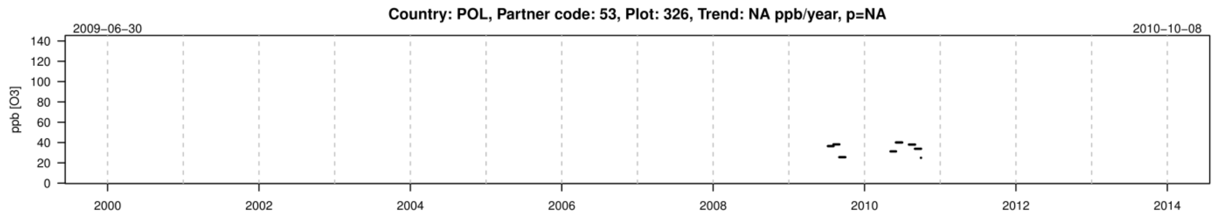
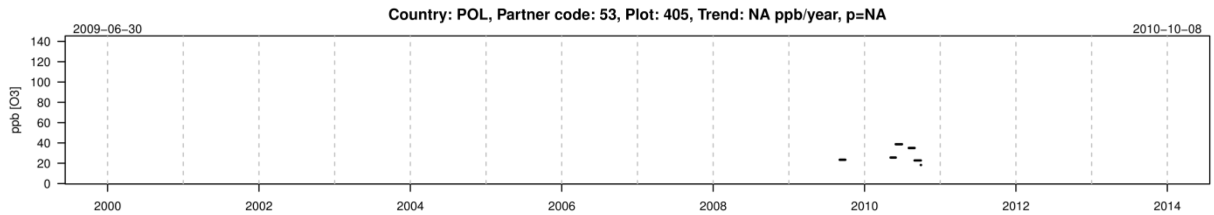
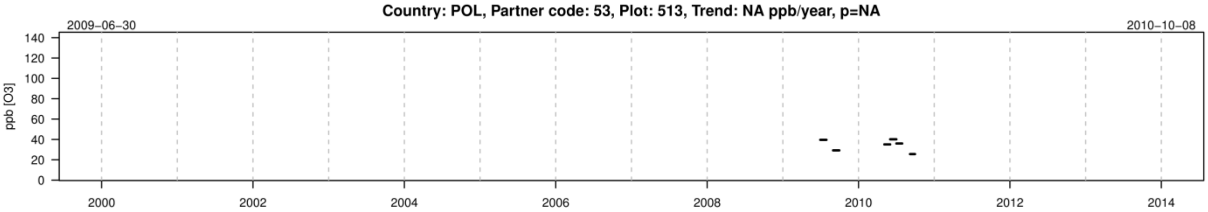
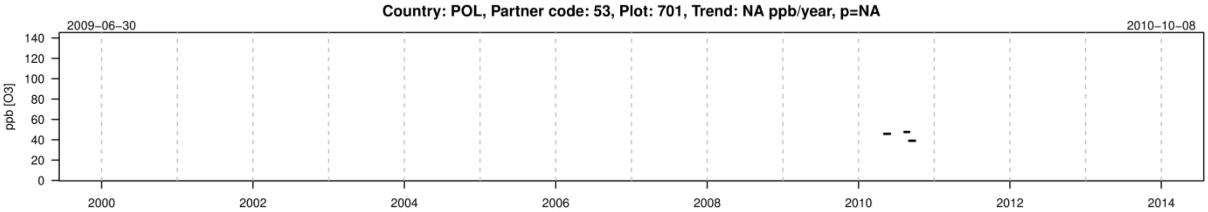
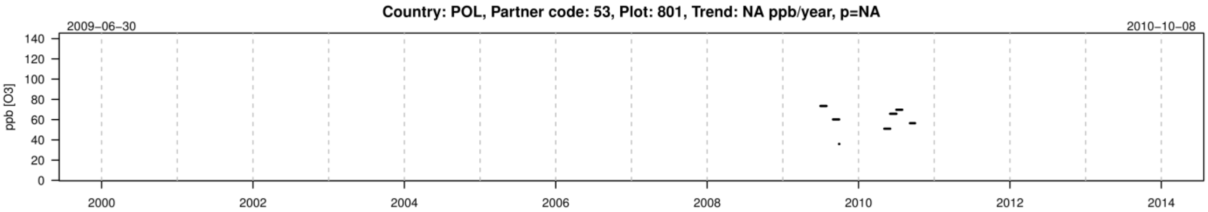
2000 2002 2004 2006 2008 2010 2012 2014


Country: POL, Partner code: 53, Plot: 326, Trend: NA ppb/year, p=NA
2009–06–30
2010–10–08
ppb [O3]
0 20 40 60 80 100 120 140
2000 2002 2004 2006 2008 2010 2012 2014


Country: POL, Partner code: 53, Plot: 405, Trend: NA ppb/year, p=NA
2009–06–30
2010–10–08
ppb [O3]
0 20 40 60 80 100 120 140
2000 2002 2004 2006 2008 2010 2012 2014


Country: POL, Partner code: 53, Plot: 513, Trend: NA ppb/year, p=NA
2009–06–30
2010–10–08
ppb [O3]


Country: POL, Partner code: 53, Plot: 701, Trend: NA ppb/year, p=NA
2009–06–30
2010–10–08
ppb [O3]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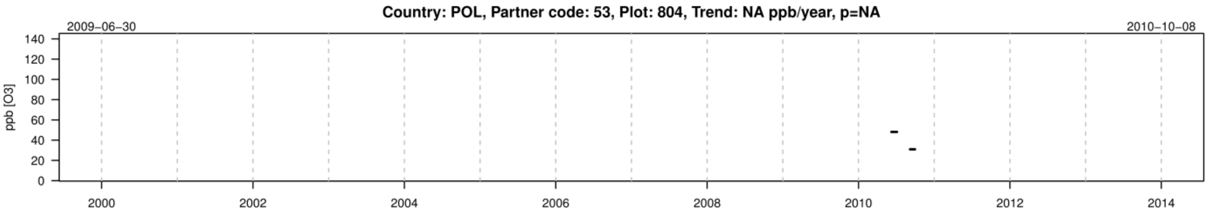
2009–06–30
2010–10–08
ppb [O3]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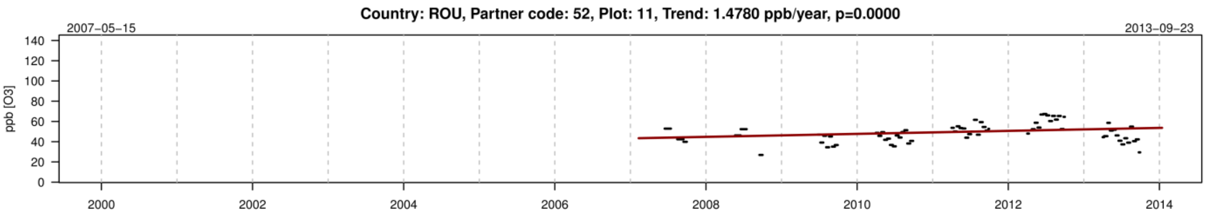
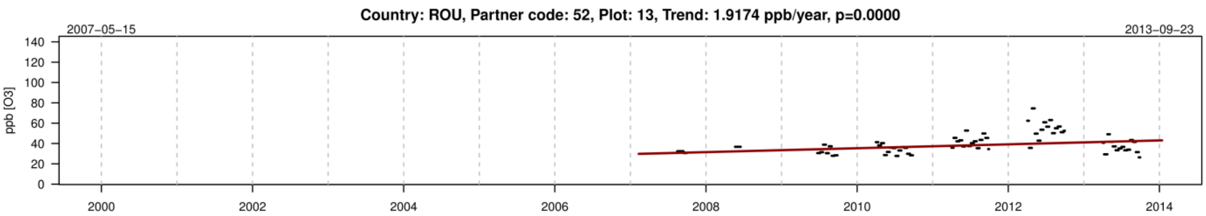
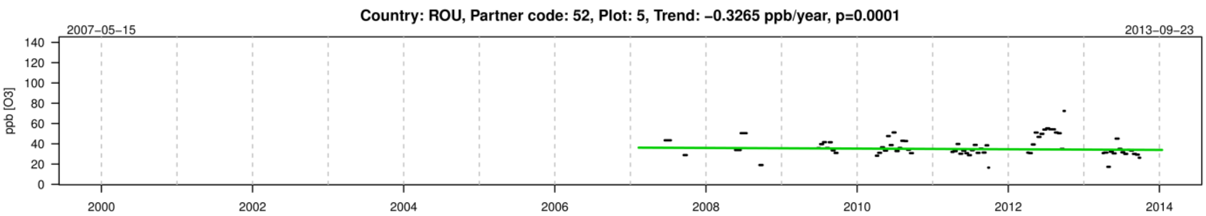
2009–06–30
2010–10–08
ppb [O3]

ROMANIA


Country: ROU, Partner code: 52, Plot: 11, Trend: 1.4780 ppb/year, p=0.0000
2007–05–15
2013–09–23
ppb [O3]


Country: ROU, Partner code: 52, Plot: 13, Trend: 1.9174 ppb/year, p=0.0000
2007–05–15
2013–09–23
ppb [O3]


Country: ROU, Partner code: 52, Plot: 5, Trend: –0.3265 ppb/year, p=0.0001
2007–05–15
2013–09–23
ppb [O3]

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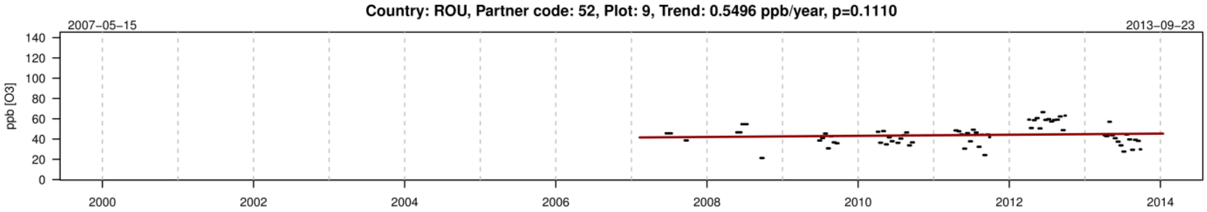
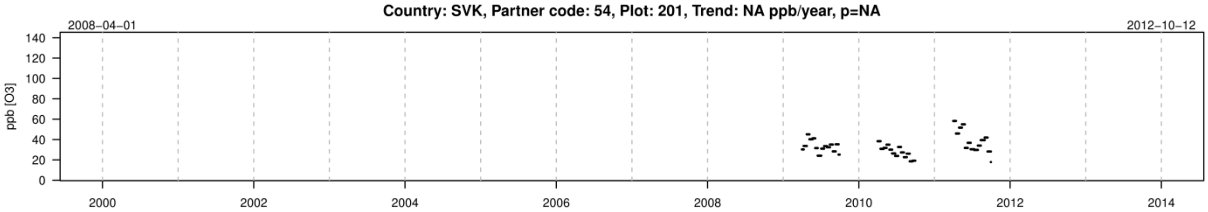
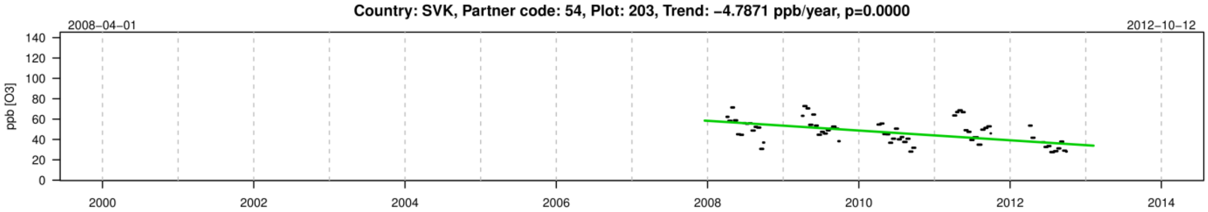


SLOVAKIA

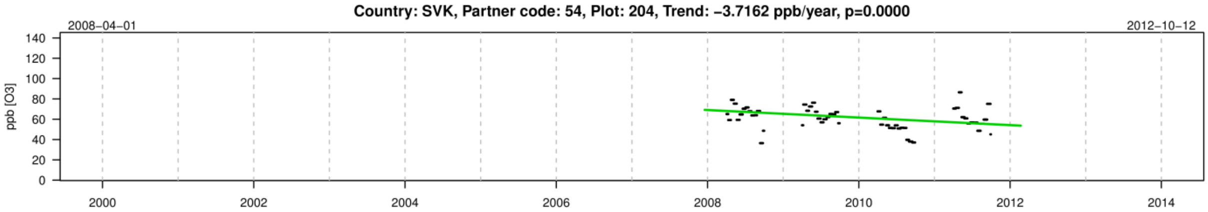
Country: SVK, Partner code: 54, Plot: 201, Trend: NA ppb/year, p=NA



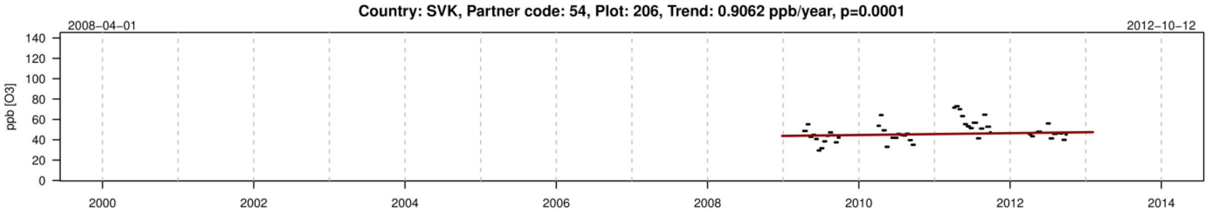
Country: SVK, Partner code: 54, Plot: 203, Trend: –4.7871 ppb/year, p=0.0000



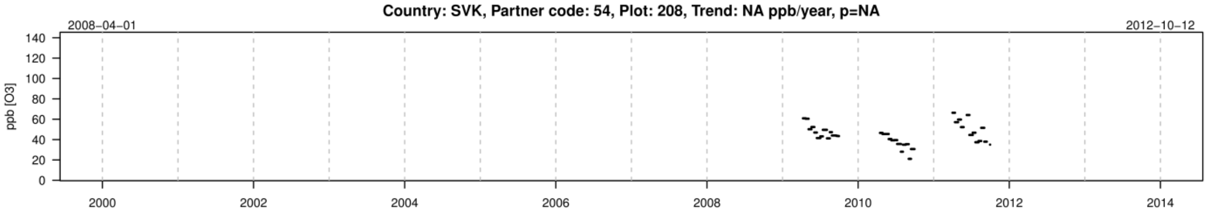
Country: SVK, Partner code: 54, Plot: 204, Trend: –3.7162 ppb/year, p=0.0000



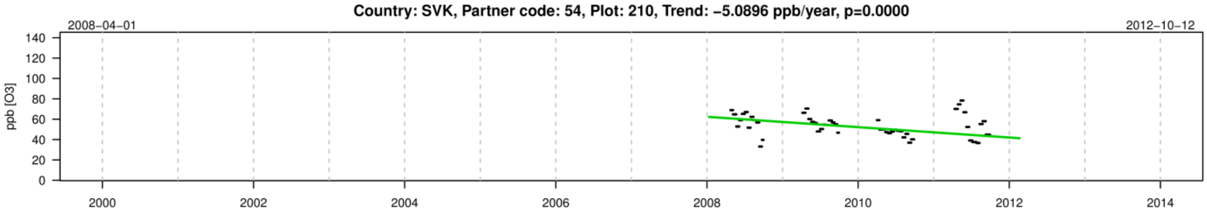
Country: SVK, Partner code: 54, Plot: 206, Trend: 0.9062 ppb/year, p=0.0001

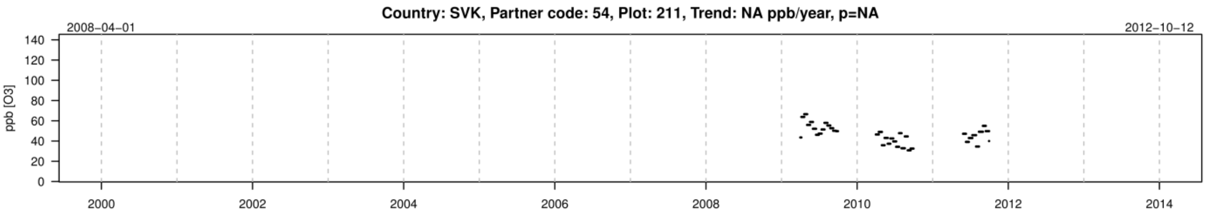


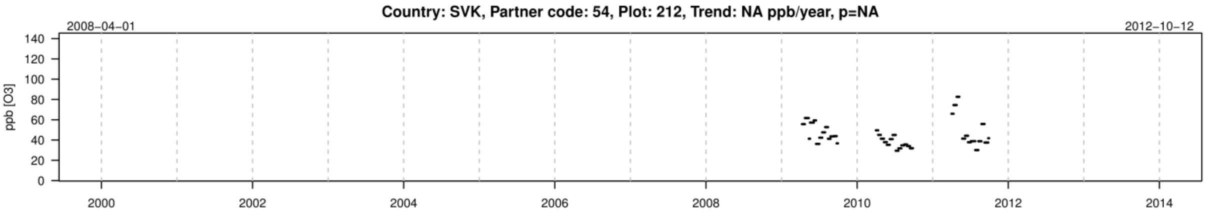
Country: SVK, Partner code: 54, Plot: 208, Trend: NA ppb/year, p=NA



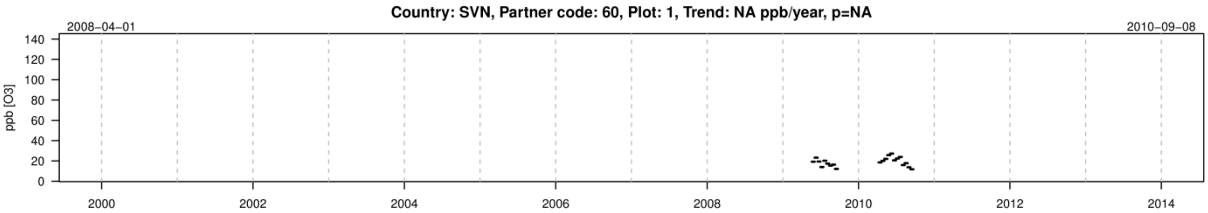
Country: SVK, Partner code: 54, Plot: 210, Trend: –5.0896 ppb/year, p=0.0000

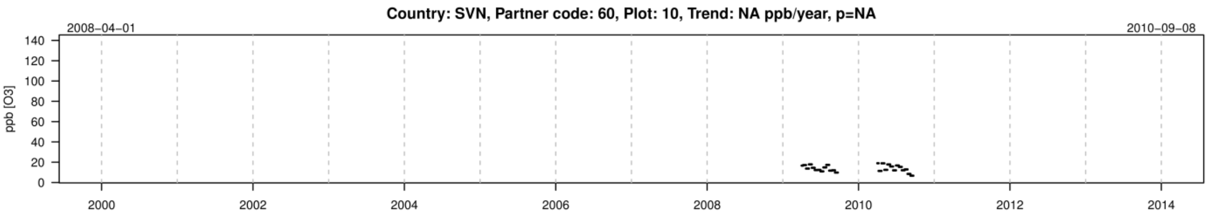


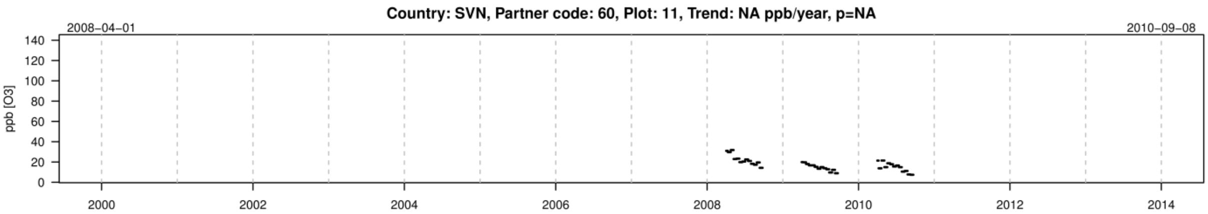

Country: SVK, Partner code: 54, Plot: 211, Trend: NA ppb/year, p=NA
2008−04−01
2012−10−12
ppb [O3]

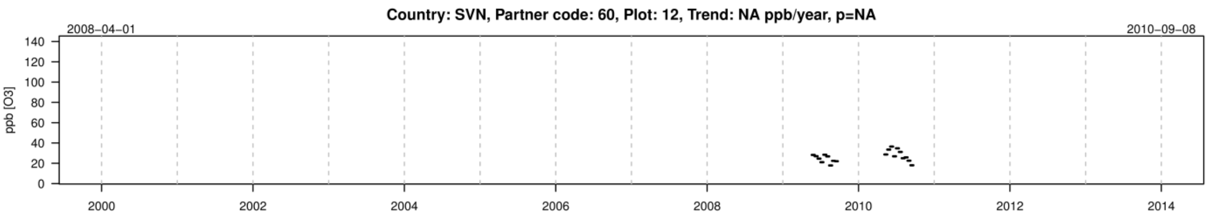

Country: SVK, Partner code: 54, Plot: 212, Trend: NA ppb/year, p=NA
2008−04−01
2012−10−12
ppb [O3]

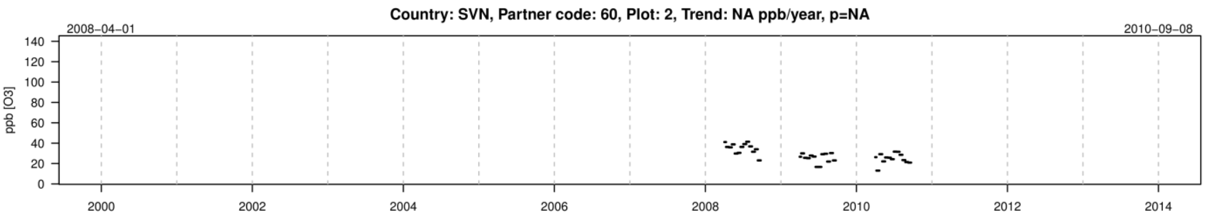
SLOVENIA

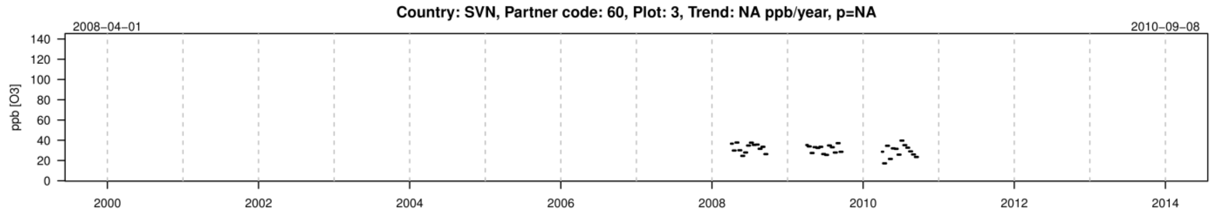

Country: SVN, Partner code: 60, Plot: 1, Trend: NA ppb/year, p=NA
2008−04−01
2010−09−08
ppb [O3]


Country: SVN, Partner code: 60, Plot: 10, Trend: NA ppb/year, p=NA
2008−04−01
2010−09−08
ppb [O3]


Country: SVN, Partner code: 60, Plot: 11, Trend: NA ppb/year, p=NA
2008−04−01
2010−09−08
ppb [O3]


Country: SVN, Partner code: 60, Plot: 12, Trend: NA ppb/year, p=NA
2008−04−01
2010−09−08
ppb [O3]


Country: SVN, Partner code: 60, Plot: 2, Trend: NA ppb/year, p=NA
2008−04−01
2010−09−08
ppb [O3]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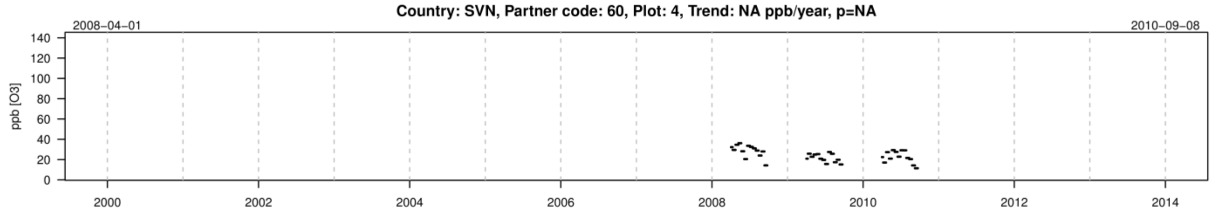
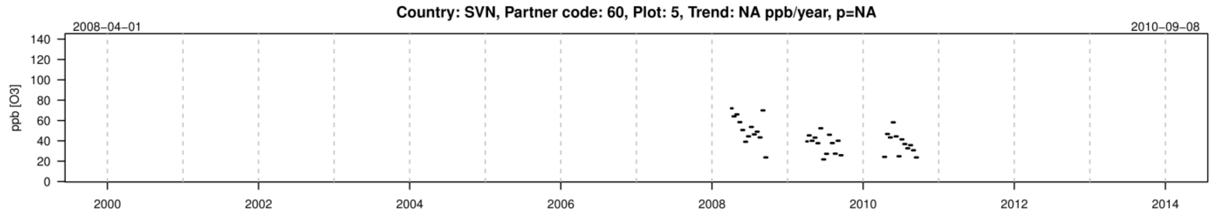
2008–04–01
2010–09–08
ppb [O3]


Country: SVN, Partner code: 60, Plot: 4, Trend: NA ppb/year, p=NA
2008–04–01
2010–09–08
ppb [O3]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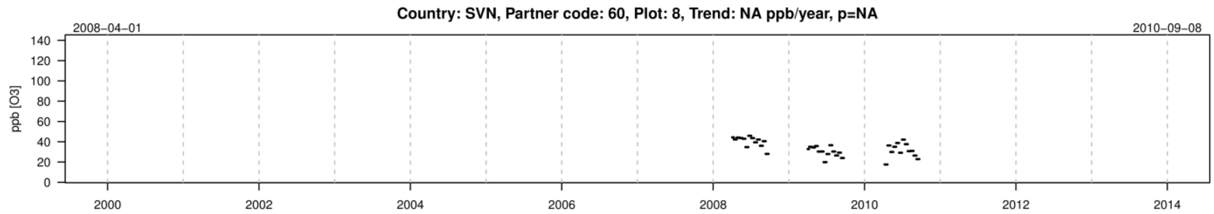
2008–04–01
2010–09–08
ppb [O3]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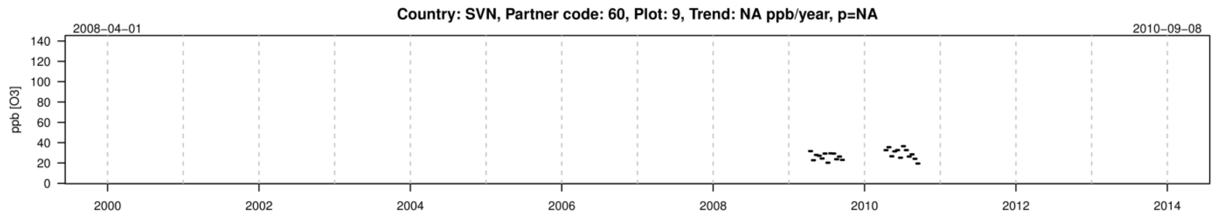
2008–04–01
2010–09–08
ppb [O3]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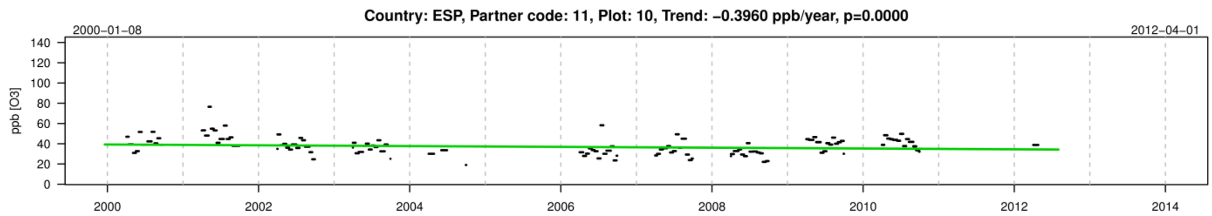
2008–04–01
2010–09–08
ppb [O3]

SPAIN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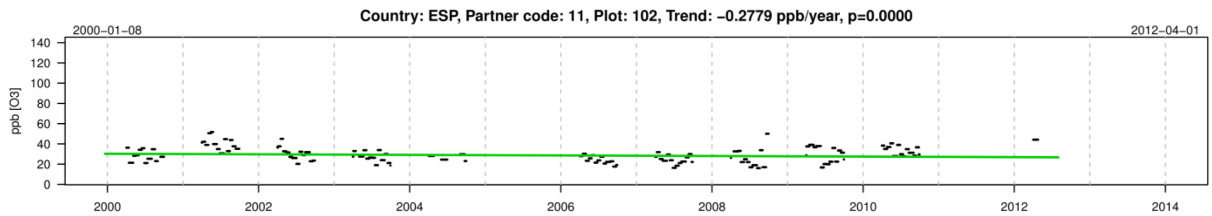
2000–01–08
2012–04–01
ppb [O3]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2000–01–08
2012–04–01
ppb [O3]

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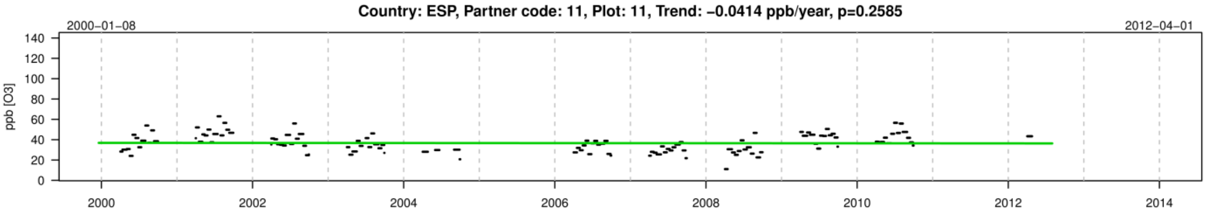

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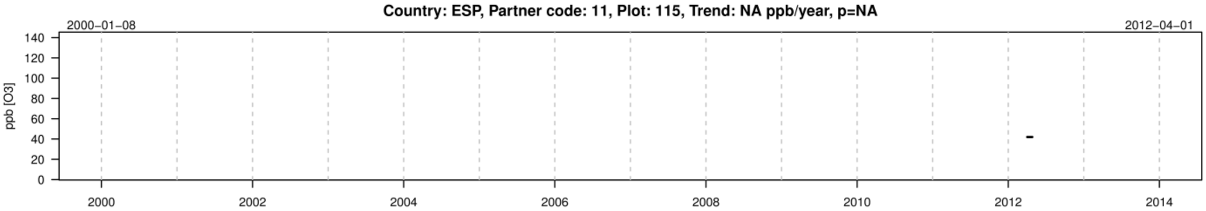

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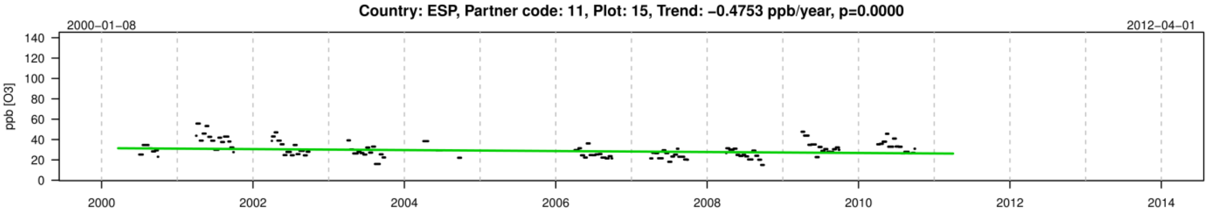

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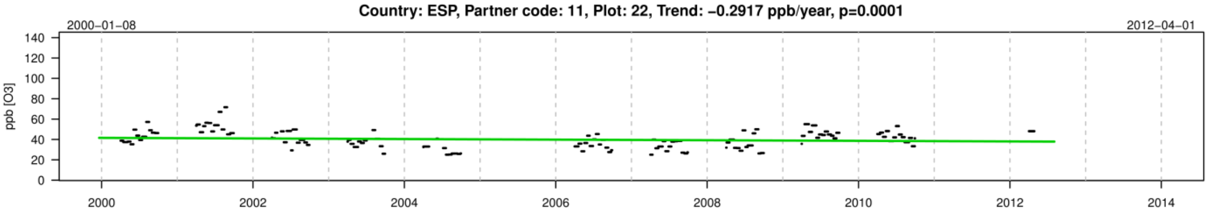

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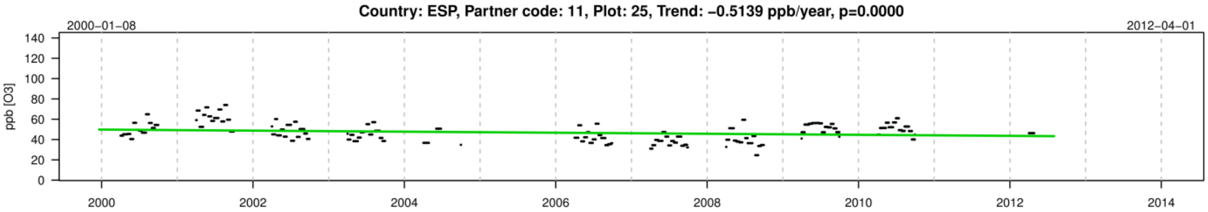

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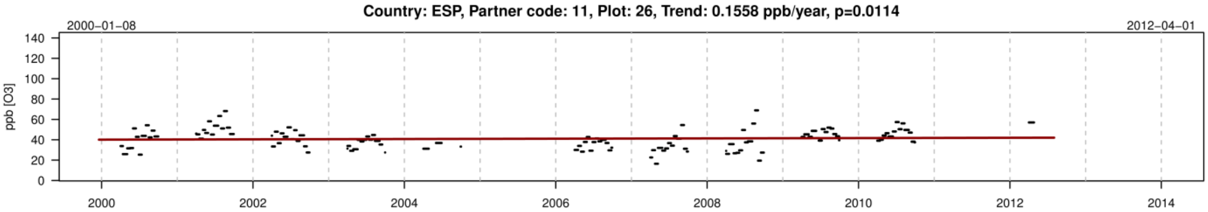

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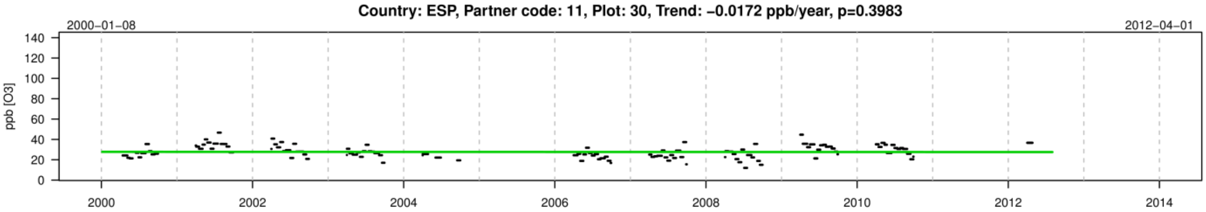

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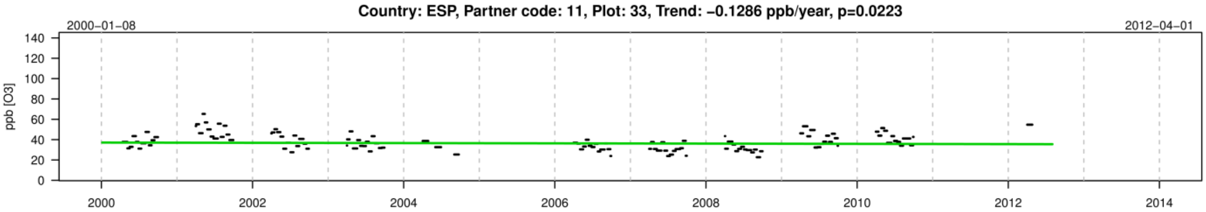
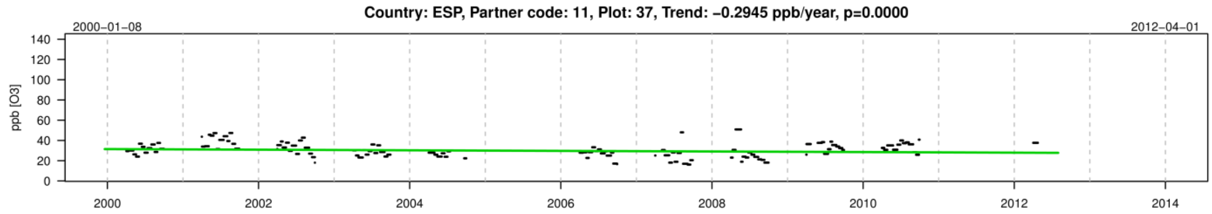
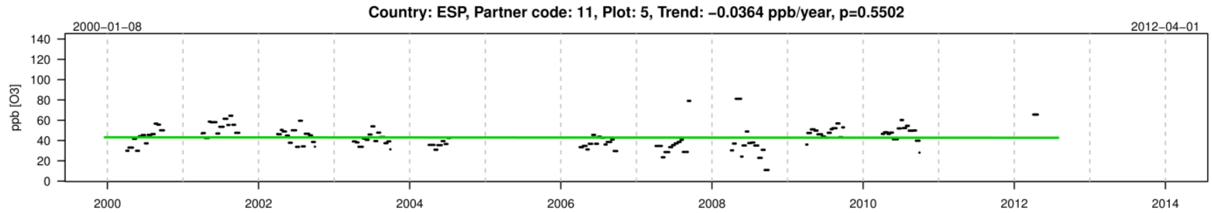
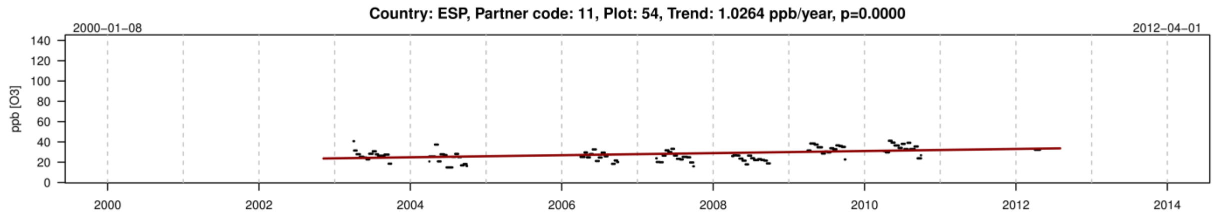
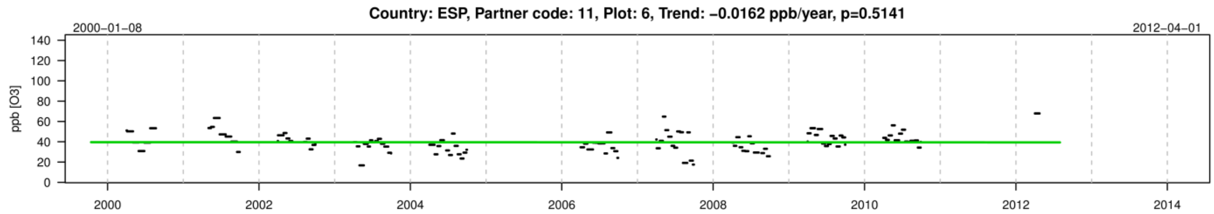


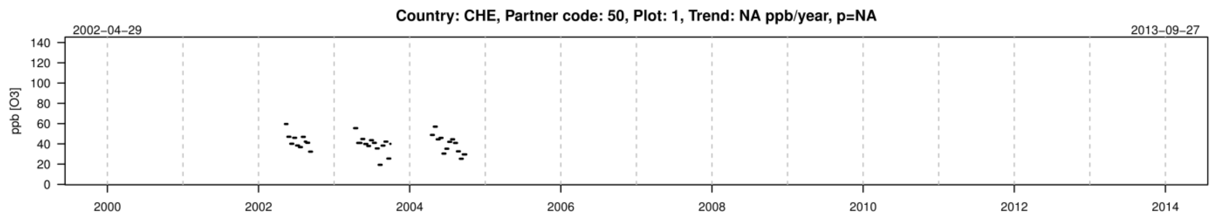


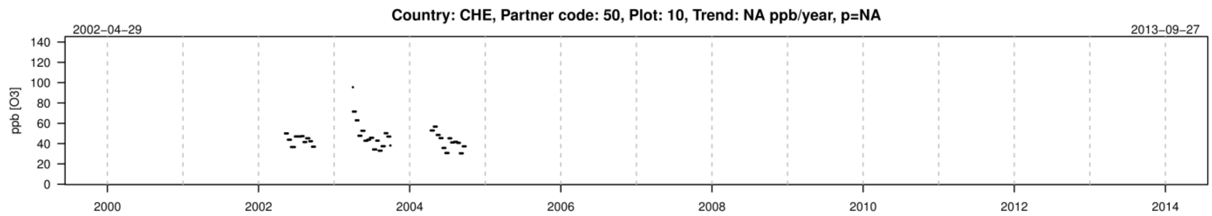


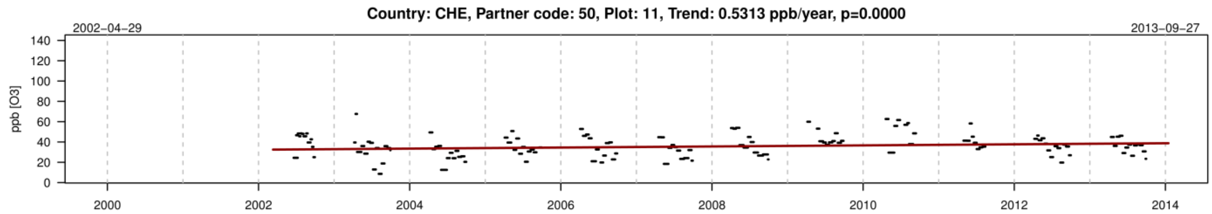




SWITZERLAND







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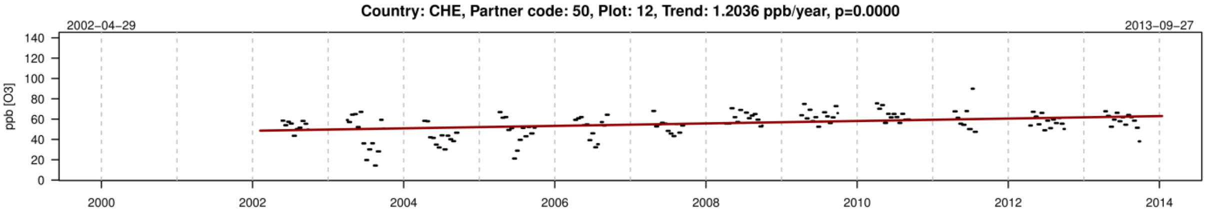

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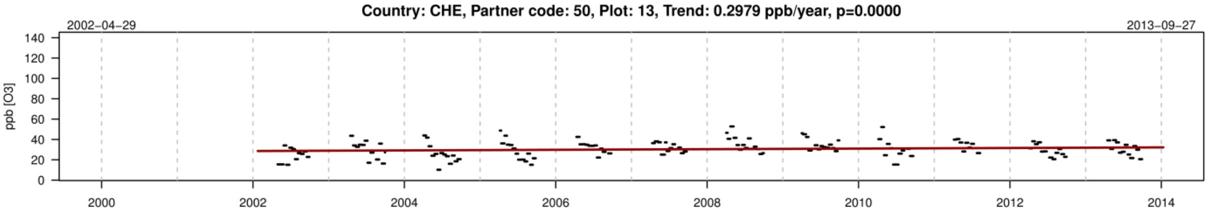

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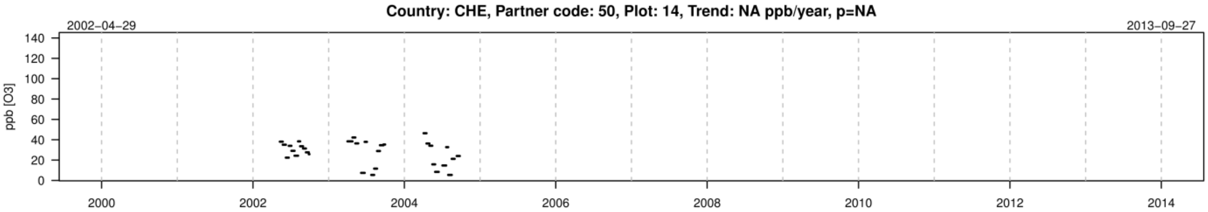

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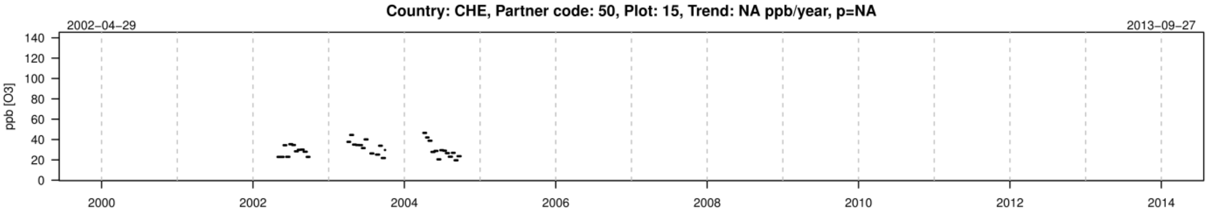

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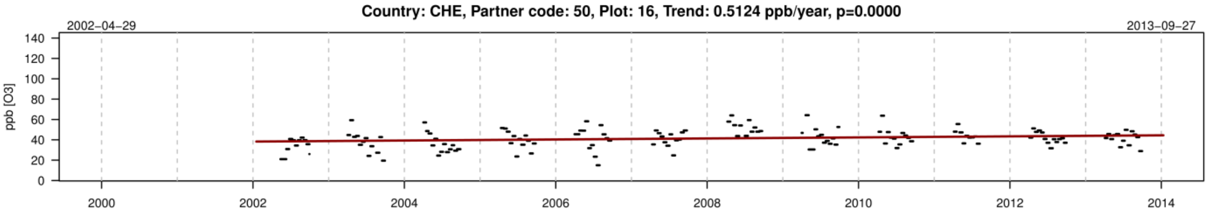

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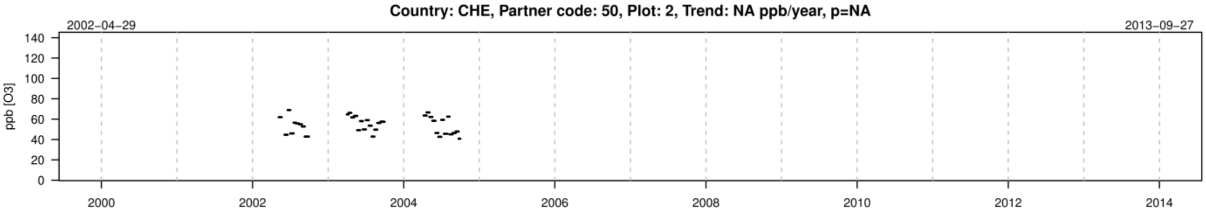

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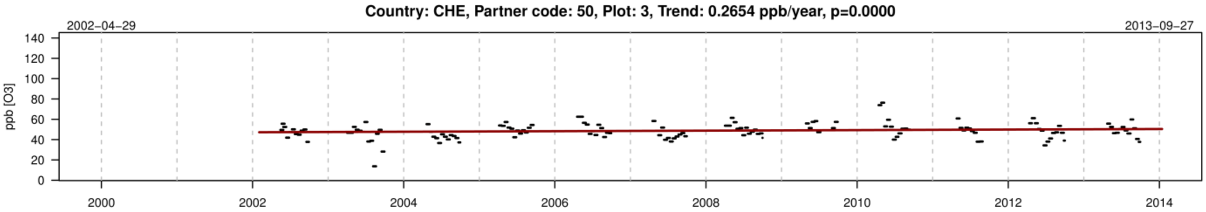

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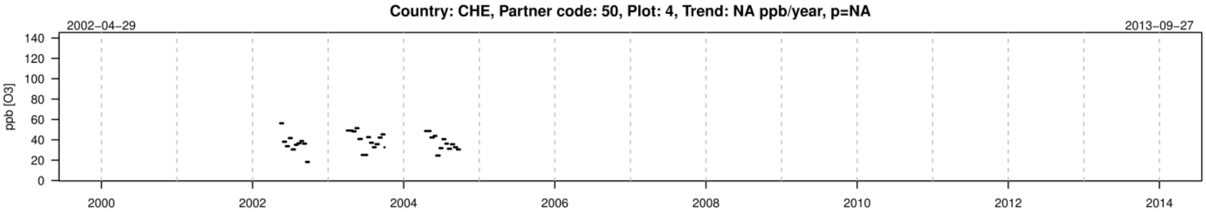
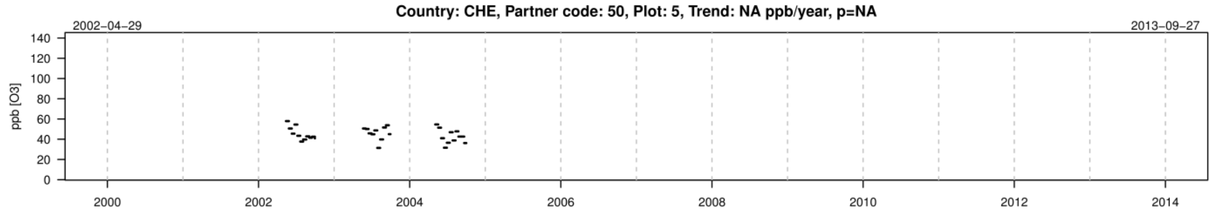
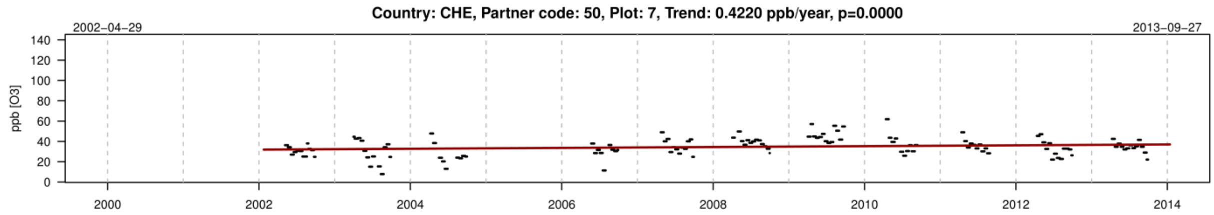
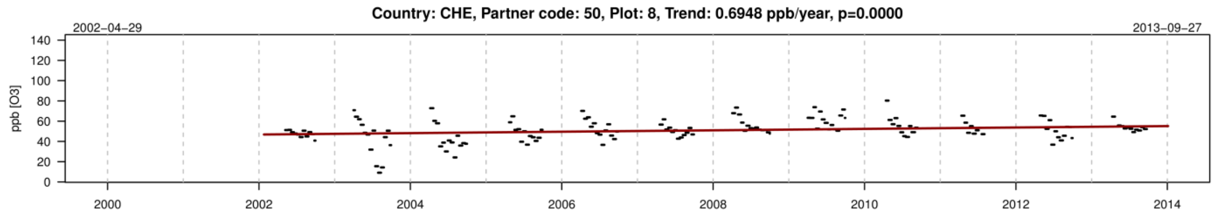
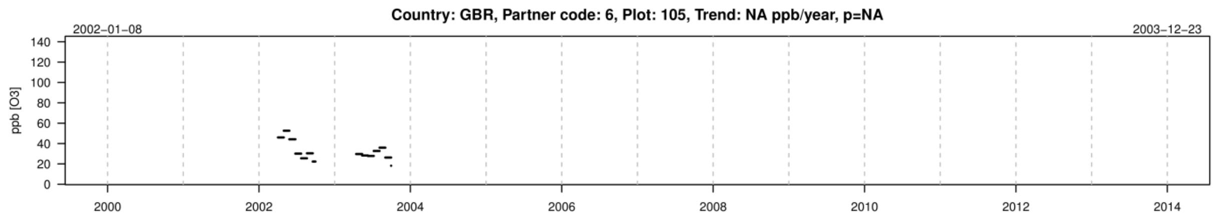


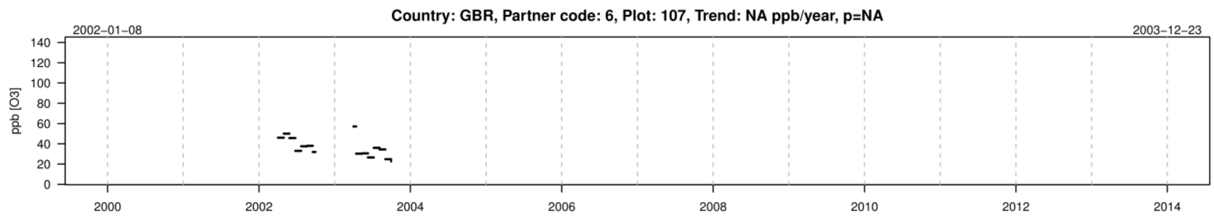


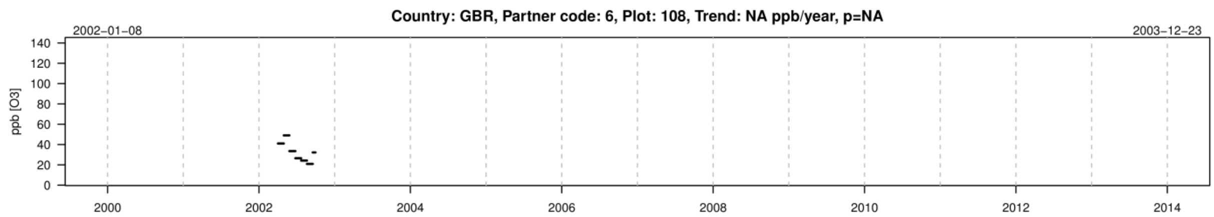


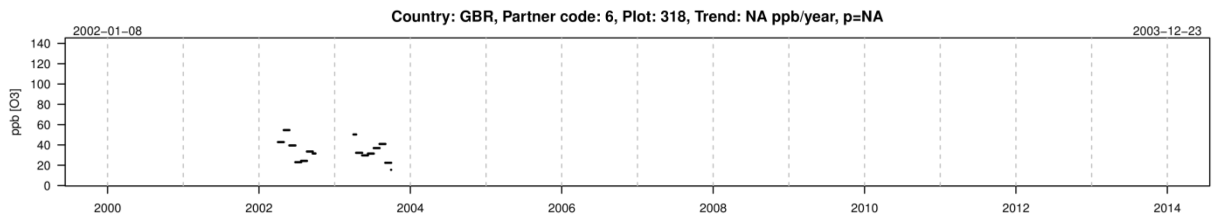


UNITED KINGDOM









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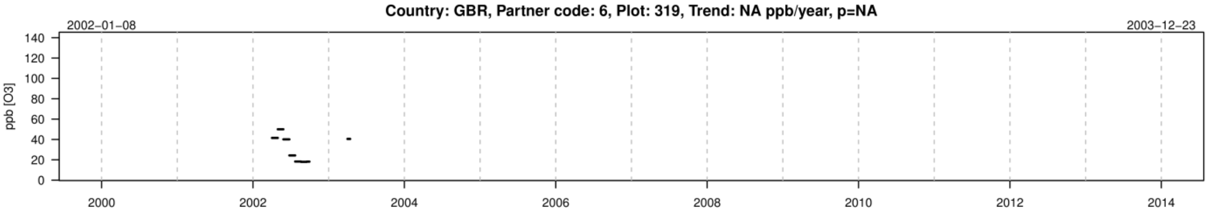

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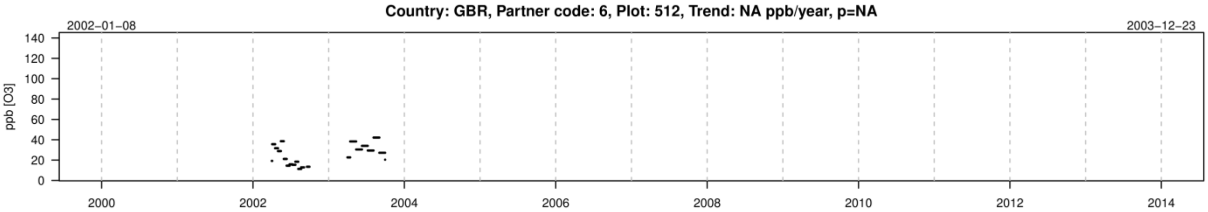

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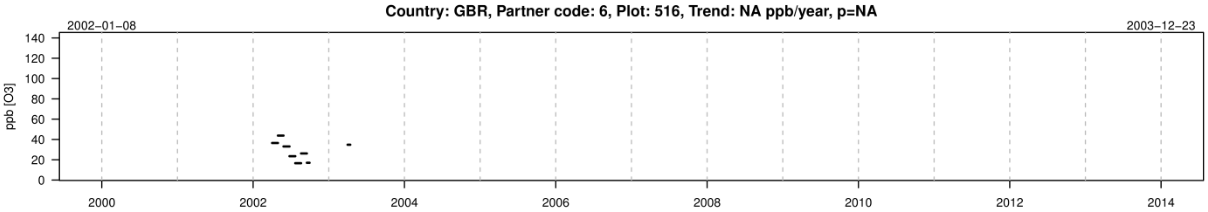

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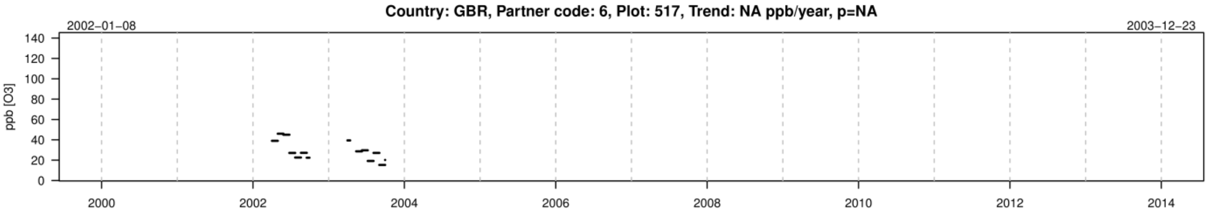

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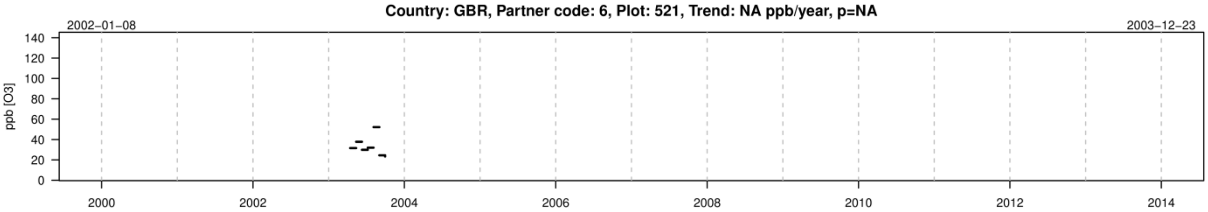

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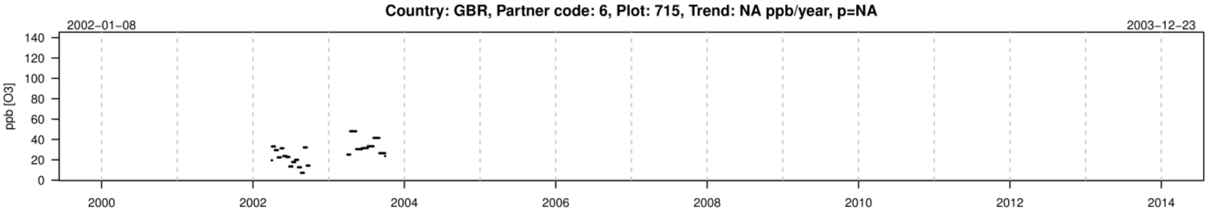

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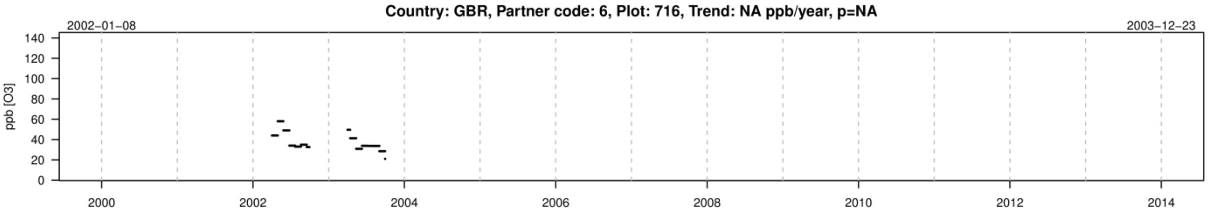

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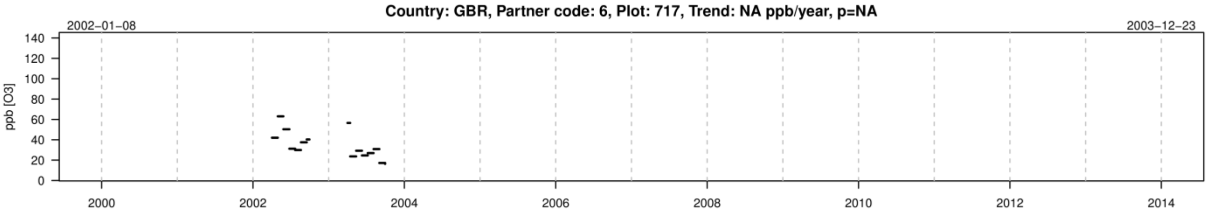

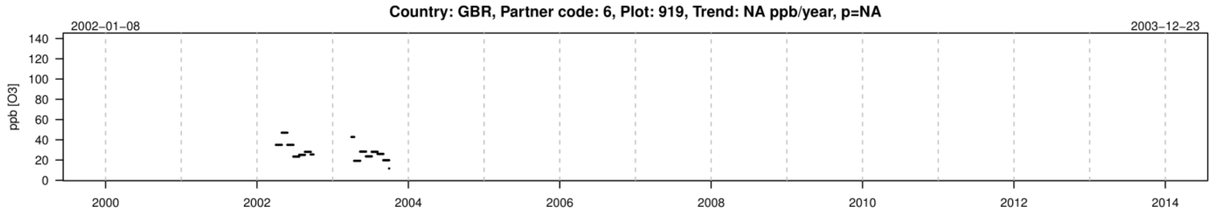
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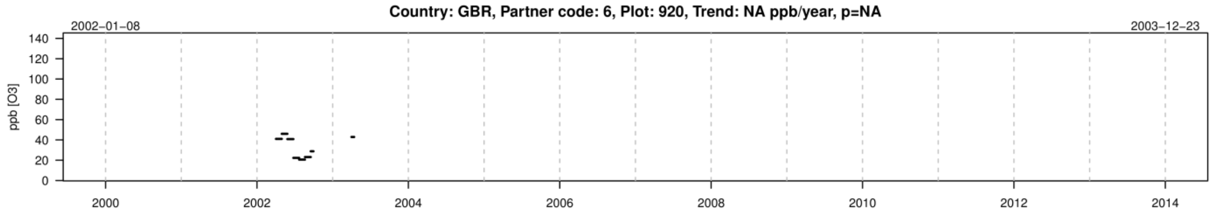
2002–01–08
2003–12–23
ppb [O3]
0
20
40
60
80
100
120
140
2000
2002
2004
2006
2008
2010
2012
2014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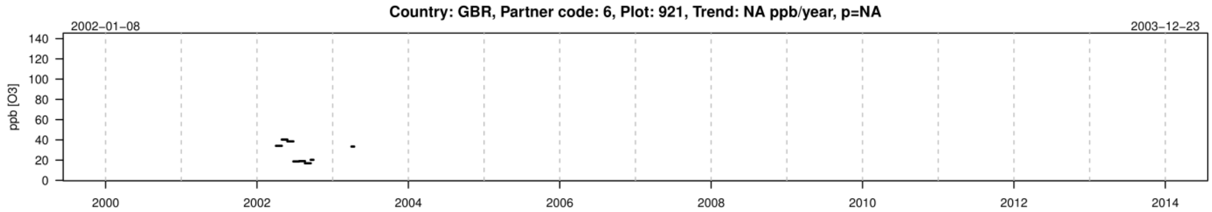
2002–01–08
2003–12–23
ppb [O3]
0
20
40
60
80
100
120
140
2000
2002
2004
2006
2008
2010
2012
2014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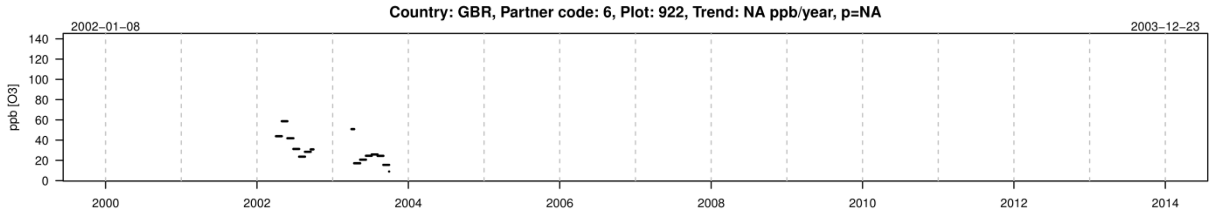
2002–01–08
2003–12–23
ppb [O3]
0
20
40
60
80
100
120
140
2000
2002
2004
2006
2008
2010
2012
2014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2002–01–08
2003–12–23
ppb [O3]
0
20
40
60
80
100
120
140
2000
2002
2004
2006
2008
2010
2012
2014

ANNEX IV – CONTACTS

Annex IV-1 | UNECE and ICP Forests

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ICP Forests Chair	Universität Hamburg, Zentrum Holzwirtschaft Leuschnerstr. 91 21031 Hamburg, GERMANY Phone: +49 40 739 62 101/Fax: +49 40 739 62 199 Email: michael.koehl@uni-hamburg.de Mr Michael Köhl, Chairman of ICP Forests
ICP Forests Programme Co-ordinating Centre (PCC)	Thünen Institute of Forest Ecosystems Alfred-Möller-Str. 1, Haus 41/42 16225 Eberswalde, GERMANY Phone: +49 3334 3820-338 /Fax: +49 3334 3820-354 Email: walter.seidling@ti.bund.de http://icp-forests.net Mr Walter Seidling, Head of PCC

Annex IV-2 | Expert panels, working groups, and other coordinating institutions

Expert Panel on Soil and Soil Solution

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Slovenian Forestry Institute (SFI)
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Phone: +386 1200 78 44
Email: tom.levanic@gozdis.si

Mr Vivian Kvist Johannsen, Co-chair
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Department of Geosciences and Natural Resource Management
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1958 Frederiksberg C, DENMARK
Phone: +453 53 316 99
Email: vkj@ign.ku.dk

Expert Panel on Deposition	Ms Karin Hansen, Chair Swedish Environmental Research Institute (IVL) Natural Resources & Environmental Research Effects Box 210 60 100 31 Stockholm, SWEDEN Phone: +46 859 85 64 25(direct) and +46 859 85 63 00 Fax: +46 859 85 63 90 Email: karin.hansen@ivl.se
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	Ms Elena Gottardini, Co-chair Fondazione Edmund Mach Via Mach 1 38010 San Michele all'Adige, ITALY Phone: +39 0461 615 362 Email: elena.gottardini@fmach.it
Expert Panel on Crown Condition Assessment and Damage Types	Mr Nenad Potočić, Chair Croatian Forest Research Institute (CFRI) Cvjetno naselje 41 10450 Jastrebarsko, CROATIA Phone: +385 162 73 027/Fax: +385 162 73 035 Email: nenadp@sumins.hr
	Mr Volkmar Timmermann, Co-chair Norwegian Forest and Landscape Institute (NFLI) P.O. Box 115 1431 Ås, NORWAY Phone: +476 49 49 192/Fax: +476 49 42 980 Email: volkmar.timmermann@skogoglandskap.no
Expert Panel on Biodiversity and Ground Vegetation Assessment	Mr Roberto Canullo, Chair Camerino University Dept. of Environmental Sciences Via Pontoni, 5 62032 Camerino, ITALY Phone: +39 0737 404 503/5 /Fax: +39 0737 404 508 Email: roberto.canullo@unicam.it

Expert Panel on Meteorology, Phenology and Leaf Area Index	Mr Stephan Raspe, Chair Bayerische Landesanstalt für Wald und Forstwirtschaft (LWF) Hans-Carl-von-Carlowitz-Platz 1 85354 Freising, GERMANY Phone: +49 81 61 71 49 21/Fax: +49 81 61 71-49 71 Email: Stephan.Raspe@lwf.bayern.de
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