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Forest Condition in Europe
2014 Technical Report of ICP Forests

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

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LRTAP
Long-range Transboundary Air Pollution

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

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Bundesforschungszentrum für Wald

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SUMMARY

This 2014 Technical Report provides descriptive statistics of the ICP Forests 2013 large-scale (Level I) and 2012 intensive (Level II) monitoring in 25 of the 42 ICP Forests member states, while considering the EEA European forest type classification. It also includes numerical results and national reports of the 2013 national crown condition surveys of 28 member states. Data analyses for this report focus on tree crown condition, including tree damage, and the spatial variation of open field (bulk) and throughfall deposition. The report also contains a description of the new “Aggregated Forest Soil Condition Database” (AFSCDB) of ICP Forests, which will foster integrated evaluations and process-based modelling in the future.

Crown condition is one of the most widely applied indicators of tree health and vigor in European forests. One of the variables used for assessing crown condition is foliage density, often referred to as defoliation, which is assessed as the percentage of needle/leaf loss in the crown compared to a reference tree with full foliage. The mean defoliation of 102,115 sample trees on 5672 transnational Level I plots in 25 participating countries in 2013 was 20.3%. Of all trees assessed in 2013 every fifth tree (20.5%) was scored as ‘damaged’, i.e. had a defoliation rate of more than 25%. In general, deciduous trees showed a slightly higher mean defoliation than conifers (23.1% and 20.0%, respectively), and oak species still seemed to be the most vulnerable of all the investigated species. Mediterranean evergreen oak species had the highest mean defoliation rate (25.4%), followed by deciduous temperate oak species (24.0%) and deciduous (sub-) Mediterranean oak species (21.8%). A mean defoliation rate of 21.0% was assessed for European beech (*Fagus sylvatica*). Coniferous species expressed lower defoliation rates, with Scots pine (*Pinus sylvestris*) reaching the lowest defoliation rate of all tree species with 18.2%, followed by Norway spruce (*Picea abies*) with 18.8% and Mediterranean lowland pine species with 20.0%.

These defoliation rates are, however, not directly comparable to those of previous reports because of changes in the annual participation of countries and ensuing fluctuations in the plot sample. In consequence, the temporal development of crown condition was calculated separately from the monitoring results for those countries that had submitted data every year without interruption since 1991, 1997, 2002, and 2006, respectively. The report also includes maps that depict species-related trends in mean defoliation on a European-wide scale.

Crown condition across Europe did not change significantly from 2012 to 2013. The spatial pattern of the changes in mean defoliation between those two years showed that on 77.5% of the plots no statistically significant differences in mean plot defoliation were detected. The share of plots with an increase in defoliation amounted to 13.4% and the share of plots with a decrease to 9.1%.

Evaluations of crown condition also comprise the assessment of tree damage caused by biotic and abiotic factors. In 2013, 40% of the trees included in the damage cause assessments showed some kind of tree damage. As in previous years, insects were the most frequent damage cause and had impaired more than every fourth (28%) of all damaged trees. Abiotic agents caused damage to 14% of the harmed trees and more than half of the symptoms were ascribed to drought (7%), which was also the second most frequent single damage cause.

The **Aggregated Forest Soil Condition Database (AFSCDB)** is a harmonised Level II soil database to better understand processes and changes in forest condition across Europe. It is part of the Forest Soil Condition Databases (FSCDB) of ICP Forests and contains the aggregated soil data of ICP Forests Level II plots of the second soil survey, i.e. soil data collected from 2003 until 2010 with co-funding under different projects. The importance and relevance of this dataset lies in (i) its wide geographical coverage across Europe, (ii) its harmonised methodology, and (iii) its ability to combine soil data with a high

number of other forest ecosystem surveys and long-term time series. Despite some limitations of the datasets resulting from analyses conducted by different national laboratories across Europe, this dataset reaches a degree and quality of harmonisation of forest soil data, which has so far not been realized by other international initiatives related to forest soil databases.

Measurements of bulk deposition in the open field and throughfall deposition within forest stands belong to the core activities of ICP Forests. These measurements constitute 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. The following **spatial variation of deposition in Europe** was found for $N\text{-}NH_4$, $N\text{-}NO_3$, $S\text{-}SO_4$, Ca, and Mg. Maps for the input of calcium and magnesium are depicted with and without sea salt corrections.

- Plots with the highest deposition of $N\text{-}NH_4$ are located in central Europe, plots with the lowest deposition in northern and southern Europe, France, and the Baltic states. The highest input with 19.2 kg ha^{-1} a^{-1} was found on an oak plot located in northwest Germany.
- Regarding the high and medium deposition fluxes, the spatial pattern for $N\text{-}NO_3$ is similar. A maximum value of 14.6 kg ha^{-1} a^{-1} was found in the Czech Republic.
- High industry-based deposition of $S\text{-}SO_4$ was observed on plots in Belgium and the ridges of the low mountain range extending from Germany to the Czech Republic, Slovakia and southern Poland, with the highest flux of about 19 kg ha^{-1} on a plot in the Czech Republic. High values were also found on all plots in Greece and on Cyprus, but contrary to individual plots located in the United Kingdom, Norway, and Denmark, their fluxes are not affected by seaborne deposition. The plots in France, Italy, Switzerland, Bulgaria, and most of the plots in Germany and northern Europe are characterized by low deposition.
- The highest values of calcium input were found on plots in the Mediterranean basin and in some regions of eastern Europe. The plots on Cyprus showed the highest fluxes of up to 52.8 kg ha^{-1} a^{-1}. Low calcium inputs prevail in central and northern Europe.
- The input of magnesium is clearly seaborne. A plot in Italy is the one with the highest input of sea salt corrected magnesium (6.6 kg ha^{-1} a^{-1}). High deposition was also found on plots in Hungary, Greece, and Cyprus where deposition originates most likely from dust sources.

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1 INTRODUCTION

Starting in the late 1970s, the condition of tree crowns in Central Europe was observed to rapidly deteriorate. These observations were originally ascribed mainly to air pollution and led to the establishment of the 'International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests' (ICP Forests) under the scope of the UNECE Convention on Long-range Transboundary Air Pollution (CLRTAP) in 1985. As of today, 42 countries in Europe and beyond participate in this programme.

Along with the other International Co-operative Programmes (ICPs) of the Working Group on Effects (WGE) under the LRTAP Convention, ICP Forests provides the Executive Body of CLRTAP with expert knowledge and significant research results of the effects of air pollution and other environmental factors on forest ecosystems. This information enables the Executive Body to develop and further amend legally binding protocols on international air pollution abatement policies. So far the Convention has been extended by eight specific protocols, the latest being the Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (Gothenburg Protocol) in its latest amended version from 2012.

Since 1986 the ICP Forests member states have established a systematic 16 x 16 km network of tree crown observation sites over large parts of Europe and even beyond — the basis of the extensive Level I monitoring. Starting in 1995, this network was complemented by an intensive monitoring network (Level II). While the aim of the Level I monitoring is to obtain representative estimates on tree condition across Europe, the Level II monitoring focuses on case studies of ecological interactions in distinct forest ecosystems. All investigations are conducted according to harmonized methods as laid down in the ICP Forests Manual. This manual guarantees the comparability of all data collected within ICP Forests and it is regularly updated by the members of the eight international ICP Forests Expert Panels.

Until 2006, the ICP Forests monitoring activities were performed in close co-operation with the European Commission based on the 'European Scheme on the Protection of Forests against Atmospheric Pollution' (EWG No 3528/86) and the 'Forest Focus' regulation (EC No 2152/2003). The co-operation with the EU was re-established between 2009 and 2011 with the project 'Further Development and Implementation of an EU-level Forest Monitoring System' (FutMon). Further co-operation with the EC especially in the field of data integration is sought.

The present 2014 Technical Report provides an overview of the monitoring system of ICP Forests (Chapter 2). It reports on the outcomes of the transnational crown condition survey of the year 2013 and compares them with the results of earlier years (Chapter 3). The report also presents the structure and contents of the 'Aggregated Forest Soil Condition Database' (AFSCDB) as an example for a harmonised soil database (Chapter 4). Deposition assessments are one of the core activities of the Level II monitoring; the 2012 results are presented in Chapter 5. In Chapter 6 the ICP Forests member countries report on their national crown condition surveys. The report concludes with an extensive Annex with additional maps, figures, and tables.

2 THE MONITORING SYSTEM OF ICP FORESTS

Walter Seidling[1]

2.1 Background

The deterioration in forest health in several areas of central and eastern Europe at the end of the 1970s caused some of the European states to establish a forest monitoring system in 1985 with the aim to collect and compile data on the condition of trees and to monitor their vigor. This was the start of the 'International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests' (ICP Forests) under the 'Working Group on Effects' (WGE) within the framework of the UNECE 'Convention on Long-range Transboundary Air Pollution' (Lorenz 1995). Within the WGE, several International Co-operative Programmes (ICPs) and a Task Force study the effects of air pollution on a wide range of eco- and geosystems (i.e. ICP Waters, ICP Integrated Monitoring, ICP Modelling and Mapping, ICP Vegetation), on technical materials (ICP Materials), and on human health (Task Force on Health). Together with the 'European Monitoring and Evaluation Programme' (EMEP) that focuses on the emission and dispersal of air pollutants, a comprehensive system to trace adverse air-transported substances from the source to the receptor is available.

At first, the aim of ICP Forests was primarily to collect and evaluate data on the impact of air pollution on forest trees. Soon, the need for more ecosystem-oriented approaches became apparent and, e.g. in addition to the assessment on crown defoliation large-scale data on soil condition (Vanmechelen et al. 1997) and on the nutritional status of foliage (Stefan et al. 1997) were collected on Level I plots and taken as a basis for integrated evaluations (de Vries et al. 2000). Since then a second survey on Level I plots on soil condition (De Vos & Cools 2011) and one on ground vegetation have been published within the BioSoil project under the Forest Focus Regulation (EC) No. 2152/2003

At the beginning of the 1990s it became obvious that many processes in forest ecosystems are very complex and cannot be adequately described with inferential statistics (cf. Müller-Edzards et al. 1997, De Vries et al. 2000). Continuous measurements of status and flux variables seemed to be necessary for a better understanding of forest ecosystems and their development. Some measurements such as those of soil solution or meteorological variables required elaborate techniques, but it was very difficult and laborious to continuously measure these variables with a consistent high quality. This led to the establishment of case studies on a subset of sites as part of the intensive (Level II) monitoring network in 1995 (De Vries et al. 2003). Only at those sites process-related data are collected continuously over time.

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 during all surveys. The transnational harmonisation of methods leads to comparable sampling practices across Europe and makes ICP Forests unique in global forest monitoring efforts. All methods are clearly described in the extensive ICP Forests Manual (ICP Forests 2010 and earlier versions of the manual), which has been developed over the years, and are presented by Ferretti & Fischer (2013) in a scientific context.

[1] For contact information, please refer to Annex III-4.

2.2 Large-scale forest monitoring (Level I)

The large-scale forest monitoring network consists of more than 7,500 plots across Europe on a 16 by 16 km grid (for an overview on Level I plots active in 2013, cf. Fig. 3-2). The final selection of plots lies in the responsibility of the member states. The overall density in each state is aimed at one plot per 256 km^2 forested area.

On the Level I plots crown condition surveys are performed annually according to the ICP Forests Manual (Eichhorn et al. 2010) and they are described in the annual Technical Reports of ICP Forests (e.g. Michel et al. 2014). In the early 1990s nutrient contents of tree foliage was additionally carried out on about 1,500 plots (Stefan et al. 1997) and a soil survey was conducted on approx. 3,500 of these plots (Vanmechelen 1997). Both the foliar and the soil survey were repeated in 2005/2006 on about 5,300 plots as part of the BioSoil Project under the EC Forest Focus Regulation (De Vos & Cools 2011) and ground vegetation was assessed on about 3,400 plots.

Since the FutMon project some member states have moved their Level I plots from their original position to locations coinciding with plots of their National Forest Inventories (NFI). This can cause constraints in time series analyses or longitudinal analyses as continuity of crown condition series may be interrupted. However, the information drawn from the NFI surveys may instead foster more biomass-oriented approaches (cf. Kovač et al. 2014).

2.3 Intensive forest ecosystem monitoring (Level II)

The intensive (Level II) monitoring follows an ecosystem-oriented approach (de Vries et al. 2003). This includes a multitude of investigations called surveys (ICP Forests 2010); of which not all are conducted on every plot in every year. This is reflected by Table 2-1 and Figure 2-1, which shows the variation in the number of plots in each survey between 2010 and 2012. In the foliar chemistry survey and even more in the soil condition survey constancy cannot be expected due to their multi-annual recording cycles. In other surveys a declining number of plots from 2010 to 2012 may be related to the end of the co-funding from the EC in 2011. However, in some cases like the phenology survey the number of observed plots has been constant or was even increasing.

Figure 2-1 gives an overview on the spatial distribution of Level II plots. The selection of Level II plots resides with the member states and they are installed in characteristic forest stands without any kind of general systematic concept. However, various statistical evaluations have shown that there is a comparatively good coverage of the main forest types in Europe. In many cases the principle of a 'found sample' sensu Overton et al. (1993) can be applied. Many of the recently published scientific papers on the results of the ICP Forests monitoring refer to data collected at Level II sites[2]. Scientific studies performed by third parties outside the ICP Forests community (e.g. Cox et al. 2010) additionally increase the value of the Level II plots.

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

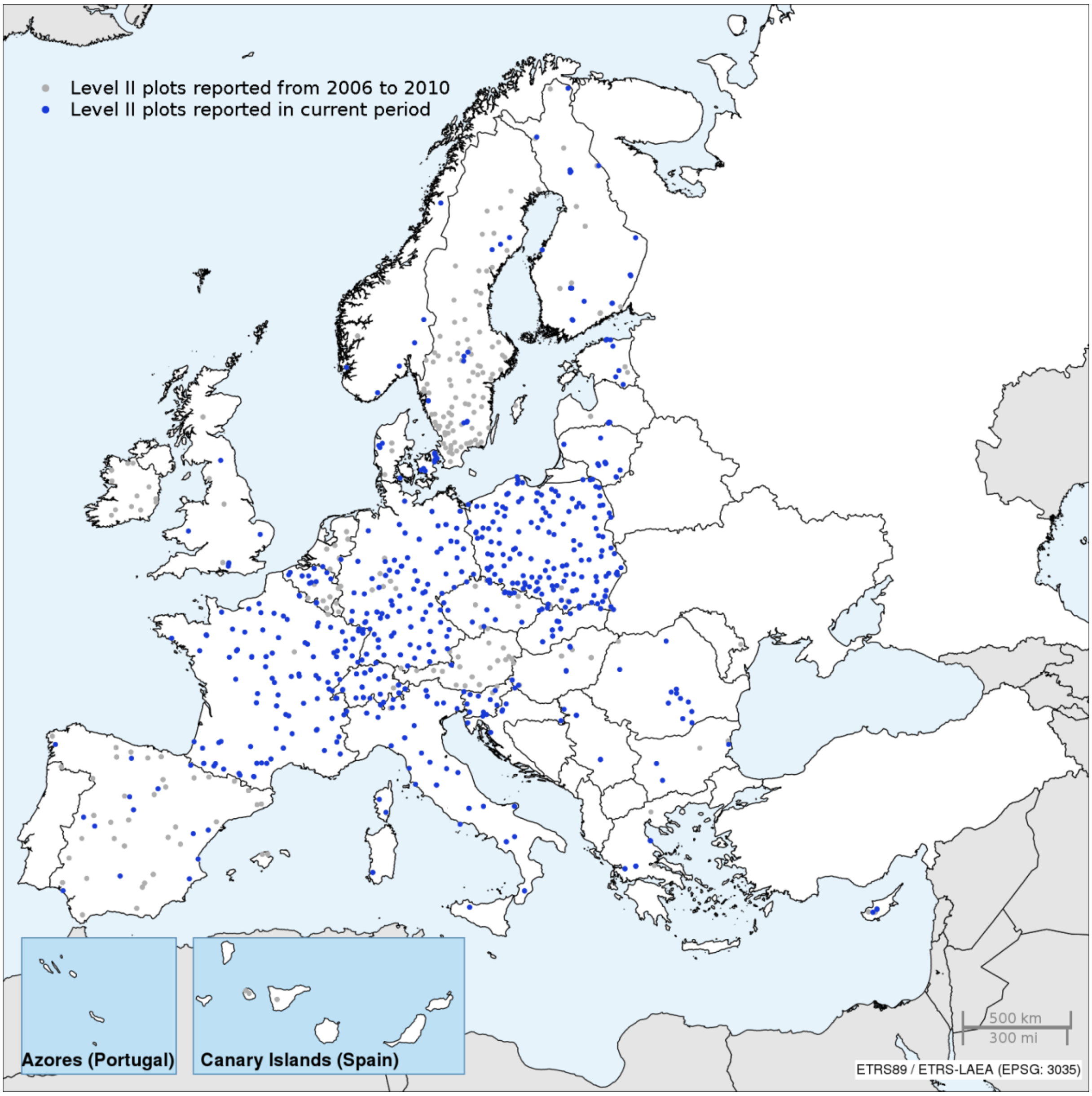

Figure 2-1: Distribution of Level II plots active in 2012 in comparison to Level II plots reported from 2006–2010

Table 2-1: Surveys and assessment frequencies 2010 to 2012 on Level II plots

Survey	Number of investigated plots in			Assessment frequency
Ambient air quality	159	125	103	Continuously
Crown condition	567	382	475	Annually
Deposition	313	293	208	Continuously
Foliar chemistry	113	172	68	Every two years
Ground vegetation	302	73	42	Every five years
Leaf area index	145	56	48	Occasionally (Annually)
Litterfall	174	179	132	Continuously
Meteorology	245	239	167	Continuously
Phenology	107	140	134	Several times per year
Ozone induced injury	126	95	59	Annually
Tree growth	101	61	108	Every five years
Soil condition	62	0	1	Every ten years
Soil solution chemistry	206	213	172	Continuously
Soil water	51	0	1	Once

2.4 References

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3 TREE CROWN CONDITION AND DAMAGE CAUSES

Nicole Wellbrock, Nadine Eickenscheidt, Henny Haelbich[3]

The following chapter is mainly based on the evaluation and presentation schemes already applied in the Technical Reports 2011 (Becher et al. 2012) and 2012 (Becher et al. 2014).

3.1 Large-scale tree crown condition

3.1.1 Methods of the 2013 survey

The annual transnational tree condition survey in 2013 was conducted on 5672 plots in 25 countries including 18 EU-Member States (Tab. 3-1). The assessment was carried out under national responsibilities according to harmonized methods laid down by Eichhorn et al. (2010). Prior to the evaluation all data were checked for consistency by the participating countries and submitted online to the Programme Co-ordinating Centre at the Thünen Institute of Forest Ecosystems in Eberswalde, Germany.

Table 3-1: Number of sample plots assessed for crown condition from 2001 to 2013 in countries with at least one Level I crown condition survey since 2001

Country	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Andorra	0	0	0	3	0	3	3	3	3	3	3	3	11
Austria	130	133	131	136	136	135	0	0	0	140	0	0	0
Belarus	408	407	406	406	403	398	400	400	410	411	417	0	373
Belgium	29	29	29	29	29	27	27	26	26	9	9	8	8
Bulgaria	108	98	105	103	102	97	104	98	159	159	159	159	0
Croatia	81	80	78	84	85	88	83	84	83	84	92	100	105
Cyprus	15	15	15	15	15	15	15	15	15	15	15	15	15
Czech Republic	139	140	140	140	138	136	132	136	133	132	136	135	0
Denmark	21	20	20	20	22	22	19	19	16	18	18	18	18
Estonia	89	92	93	92	92	92	93	92	92	97	98	97	96
Finland	454	457	453	594	605	606	593	475	886	932	717	785	0
France	519	518	515	511	509	498	506	508	500	532	544	553	550
Germany	446	447	447	451	451	423	420	423	412	411	410	415	417
Greece	92	91	0	0	87	0	0	0	97	98	0	0	0
Hungary	63	62	62	73	73	73	72	72	73	72	72	74	71
Ireland	20	20	19	19	18	21	30	31	32	29	0	20	0
Italy	265	258	247	255	238	251	238	236	252	253	253	245	248
Latvia	97	97	95	95	92	93	93	92	115	115	118	115	115
Lithuania	66	66	64	63	62	62	62	70	72	75	77	79	80
Luxembourg	0	4	4	4	4	4	4	4	0	0	0	0	4
Rep. of Moldova	10	0	0	0	0	0	0	0	0	0	0	0	0
Montenegro	0	0	0	0	0	0	0	0	0	49	49	49	49
Netherlands	11	11	11	11	11	11	0	0	11	11	0	0	0
Norway	408	414	411	442	460	463	476	481	487	491	496	496	618
Poland	431	433	433	433	432	376	458	453	376	376	376	369	364
Portugal	150	151	142	139	125	124	0	0	0	0	0	0	0

[3] For contact information, please refer to Annex III-4.

Country	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Romania	232	231	231	226	229	228	218	0	231	252	254	257	258
Russian Fed.	0	0	0	0	0	0	0	0	365	288	295	0	0
Serbia	0	0	103	130	129	127	125	123	130	130	130	130	130
Slovakia	110	110	108	108	108	107	107	108	108	108	109	108	108
Slovenia	41	39	41	42	44	45	44	44	44	44	44	44	44
Spain	620	620	620	620	620	620	620	620	620	620	620	620	620
Sweden	770	769	776	775	784	790	0	0	857	832	641	609	740
Switzerland	49	49	48	48	48	48	48	48	48	48	48	48	47
Turkey	0	0	0	0	0	0	43	396	560	554	563	578	583
United Kingdom	86	86	86	85	84	82	32	0	0	87	0	0	0
Total Europe	5960	5947	5933	6152	6235	6065	5065	5059	7213	7475	6763	6129	5672

3.1.2 Assessment parameters

The stand and site characteristics reported for the monitoring year 2013 are presented in Tab. 3-2. Data on altitude, aspect, and mean age were submitted for all plots by all countries (Tab. 3-3). Data on water availability and humus type were submitted for 86% and 74% of the plots, respectively. Besides defoliation, the tree related data reported were the numbers of trees, tree species, identified damage causes and date of observation (Tab. 3-2). The results of the forest damage cause assessments are presented in Chapter 3.3.

Table 3-2: Stand and site parameters given in the crown condition database

Registry and location	country	member state in which the plot is assessed [code number]
	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 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]
	identified damage cause	treewise observations concerning damage caused by game and grazing, insects, fungi, abiotic agents, direct action of man, fire, known local pollution, and other factors

Table 3-3: Number of plots assessed for crown condition and specific site parameters in 2013

Country	Number of plots assessed for crown condition	Number of plots with specific site parameter assessment				
		Water	Humus	Altitude	Aspect	Age
Andorra	11	11	3	11	11	11
Austria	0	0	0	0	0	0
Belarus	373	373	373	373	373	373
Belgium	8	8	8	8	8	8
Bulgaria	0	0	0	0	0	0
Croatia	105	105	105	105	105	105
Cyprus	15	15	15	15	15	15
Czech Republic	0	0	0	0	0	0
Denmark	18	18	18	18	18	18
Estonia	96	96	96	96	96	96
Finland	0	0	0	0	0	0
France	550	490	488	550	550	550
Germany	417	417	413	417	417	417
Greece	0	0	0	0	0	0
Hungary	71	71	39	71	71	71
Ireland	0	0	0	0	0	0
Italy	248	248	248	248	248	248
Latvia	115	115	0	115	115	115
Lithuania	80	80	80	80	80	80
Luxembourg	4	4	4	4	4	4
Montenegro	49	49	49	49	49	49
Netherlands	0	0	0	0	0	0
Norway	618	0	85	618	618	618
Poland	364	364	364	364	364	364
Portugal	0	0	0	0	0	0
Romania	258	258	258	258	258	258
Russian Federation	0	0	0	0	0	0
Serbia	130	130	40	130	130	130
Slovakia	108	0	108	108	108	108
Slovenia	44	44	44	44	44	44
Spain	620	620	620	620	620	620
Sweden	740	740	176	740	740	740
Switzerland	47	46	45	47	47	47
Turkey	583	566	542	583	583	583
United Kingdom	0	0	0	0	0	0
Total number of plots in Europe	5672	4868	4221	5672	5672	5672
Percentage of total number of plots		85.8	74.4	100.0	100.0	100.0

3.1.3 Plot design

On each sample plot, trees are selected according to national procedures. Predominant, dominant, and co-dominant trees (according to the system of KRAFT) of all species qualify as sample tree, provided that they have a minimum height of 60 cm and that they do not show significant mechanical damage. On 62.5% of the plots the sample tree number per plot ranged between 20 and 24 trees. On 21.6% of all plots less than 10 trees were observed (Fig. 3-1).

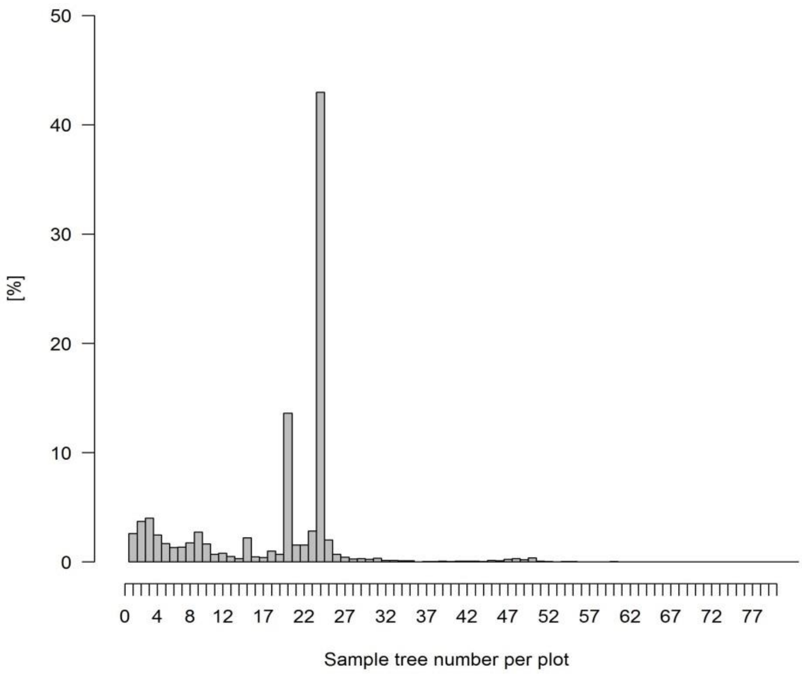


Figure 3-1: Percentage of sample tree number per plot

3.1.4 Species composition

In 2013, 54.9% of the plots were dominated by coniferous and 45.1% by broadleaved trees. The spatial distribution of coniferous-dominated and broadleaved-dominated plots is shown in Annex I-1.

Pinus sylvestris (20.5%) represented the most abundant tree species, followed by *Picea abies* (11.0%), *Fagus sylvatica* (9.1%), *Pinus nigra* and *Quercus robur* (both 4.3%), *Quercus ilex* (3.7%), *Quercus petraea* (3.6%), *Pinus brutia* (3.3%) and *Betula pendula* (3.2%). The number of tree species assessed on plots is presented in Annex I-2. In the following evaluation, some tree species were combined into species groups:

- **deciduous temperate oaks** (*Quercus petraea*, *Quercus robur*) accounting for 7.8% of the assessed trees
- **Mediterranean lowland pines** (*Pinus brutia*, *P. pinaster*, *P. halepensis*, *and P. pinea*) accounting for 8.1% of the assessed trees
- **deciduous (sub-) Mediterranean oaks** (*Quercus frainetto*, *Q. pubescens*, *Q. pyrenaica*, *and Q. cerris*) accounting for 6.3% of the assessed trees
- **evergreen oaks** (*Quercus coccifera, Q. ilex, Q. rotundifolia*, *and Q. suber*) accounting for 4.3% of the assessed trees.

3.1.5 European Forest Types

For certain analyses of defoliation, the Level I plots were stratified according to the European Forest Type (EFT) classification. The EFT system was developed in 2006 by the European Environment Agency (EEA) of the European Union in cooperation with experts from several European countries coordinated by the Italian Academy of Forest Sciences (EEA 2007). After improvements and refinements based on experts' knowledge and information gained from NFI plots, forest maps, and forest management plans, the classification of European forests into forest types became operational. The European Forest Type classification comprises 14 categories, each representing an ecologically distinct forest community dominated by specific assemblages of trees. The classification is conceived to categorize stocked forest land, with the help of classification keys mainly based on dominant tree species (Tab. 3-4). The spatial distribution of European Forest Types of assessed plots is shown in Figure 3-2.

Table 3-4: Description of the European Forest Types (EFT)

Forest type category	Main characteristics
1. Boreal forest	Extensive boreal, species-poor forests, dominated by *Picea abies* and *Pinus sylvestris*. Deciduous trees including birch (*Betula* spp.), aspen (*Populus tremula*), rowan (*Sorbus aucuparia*), and willow (*Salix* spp.) tend to occur as early colonisers.
2. Hemiboreal forest and nemoral coniferous and mixed broadleaved-coniferous forest	Latitudinal mixed forests located in between the boreal and nemoral (or temperate) forest zones with similar characteristics to EFT 1, but a slightly higher tree species diversity, also including temperate deciduous trees like *Tilia cordata*, *Fraxinus excelsior*, *Ulmus glabra*, and *Quercus robur*. Includes also: pure and mixed forests in the nemoral forest zone dominated by coniferous species native within the borders of individual FOREST EUROPE member states like *Pinus sylvestris*, pines of the *Pinus nigra* group, *Pinus pinaster*, *Picea abies*, *Abies alba.*
3. Alpine coniferous forest	High-altitude forest belts of central and southern European mountain ranges, covered by *Picea abies*, *Abies alba*, *Pinus sylvestris*, *Pinus nigra*, *Larix decidua*, *Pinus cembra*, and *Pinus mugo*. Includes also the mountain forests of the boreal region dominated by birch.
4. Acidophilous oak and oak-birch forest	Scattered occurrence associated with less fertile soils of the nemoral forest zone; the tree species composition is poor and dominated by acidophilous oaks (*Q. robur*, *Q. petraea*) and birch (*Betula pendula*).
5. Mesophytic deciduous forest	Related to medium rich soils of the nemoral forest zone; forest composition is mixed and made up of a relatively large number of broadleaved deciduous trees: *Carpinus betulus*, *Quercus petraea*, *Quercus robur*, *Fraxinus, Acer* and *Tilia cordata*.
6. Beech forest	Widely distributed lowland to submountainous beech forest. Beech (*Fagus sylvatica* and *F. orientalis* (Balkan)) dominate, locally important is *Betula pendula*.
7. Mountainous beech forest	Mixed broadleaved deciduous and coniferous vegetation belt in the main European mountain ranges. Species composition differs from EFT 6, including *Picea abies, Abies alba, Betula pendula*, and mesophytic deciduous tree species.
8. Thermophilous deciduous forest	Deciduous and semi-deciduous forests mainly of the Mediterranean region dominated by thermophilous species, mainly of *Quercus*. *Acer*, *Ostrya*, *Fraxinus*, *Carpinus* species are frequent as associated secondary trees. Includes also *Castanea sativa* dominated forests.
9. Broadleaved evergreen forest	Broadleaved evergreen forests of the Mediterranean and Macaronesian regions dominated by sclerophyllous or lauriphyllous trees, mainly *Quercus* species.

Forest type category	**Main characteristics**
10. Coniferous forests of the Mediterranean, Anatolian and Macaronesian regions	Varied group of coniferous forests in Mediterranean, Anatolian and Macaronesian regions, from the coast to high mountains. Dry and often poorly-developed soils limit tree growth. Several tree species of *Pinus*, *Abies*, and *Juniperus*, including a number of endemics.
11. Mire and swamp forest	Wetland forests on peaty soils widely distributed in the boreal region. Water and nutrient regimes determine the dominant tree species: *Pinus sylvestris*, *Picea abies*, or *Alnus glutinosa*.
12. Floodplain forest	Riparian and riverine species-rich forests characterised by different assemblages of species of *Alnus*, *Betula*, *Populus*, *Salix*, *Fraxinus*, and *Ulmus*.
13. Non riverine alder, birch, or aspen forest	Pioneer forests dominated by *Alnus*, *Betula*, or *Populus*.
14. Introduced tree species forests	Forests dominated by introduced trees of the above categories. Introduced tree species can be identified at regional (recommended) or national level.

3.1.6 Defoliation

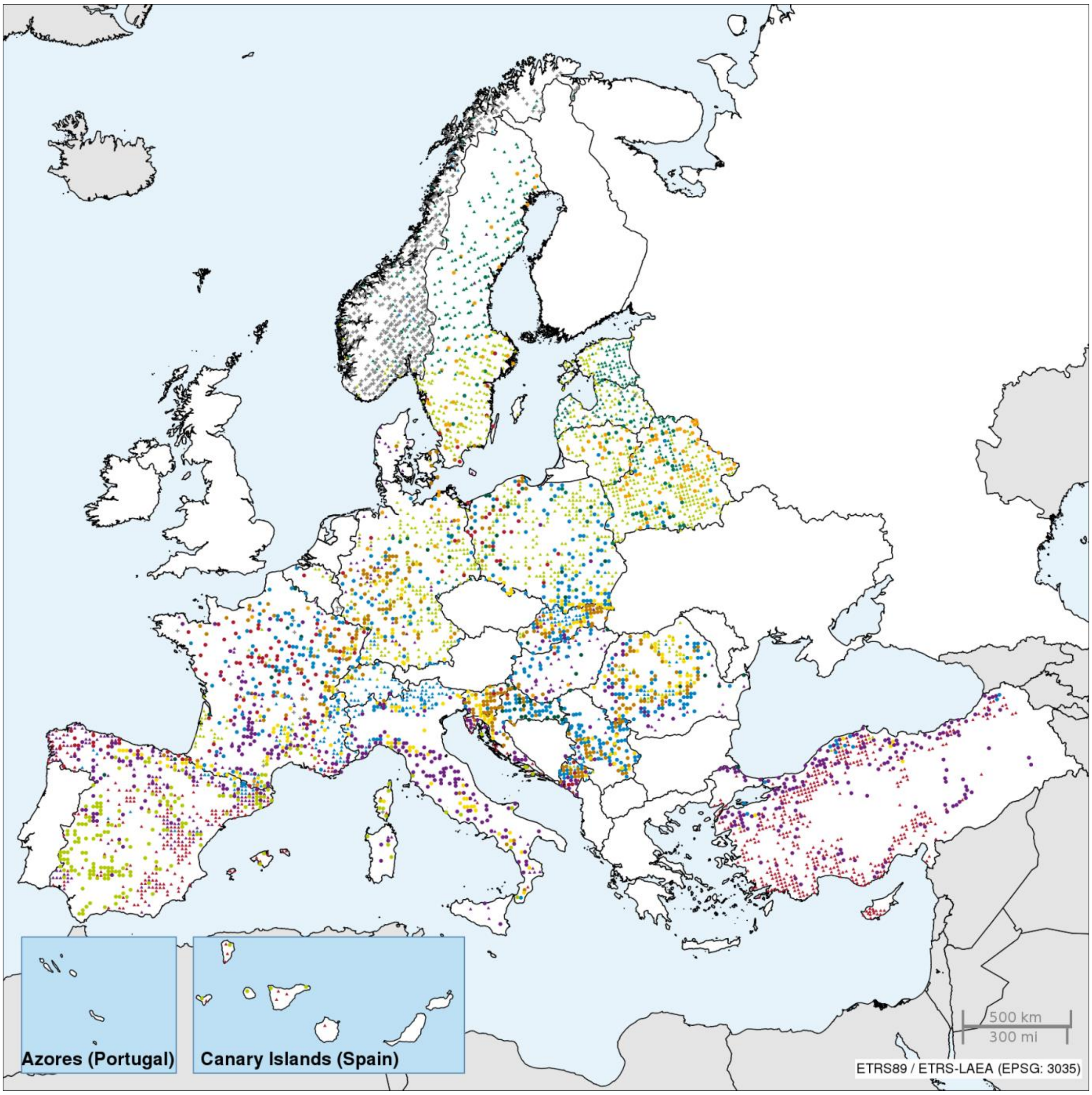
Scientific background of defoliation assessment and analysis

Crown condition, expressed in terms of defoliation, is influenced by a variety of anthropogenic and natural factors. Its variation is mainly the result of intrinsic factors, age, and site conditions. Moreover, defoliation may be caused by a number of biotic and abiotic stressors. Defoliation assessments attempt to quantify the reduction in foliage as an effect of stressors including air pollutants and not as an effect of long lasting site conditions. In order to compensate for site conditions local reference trees are used, defined as the most vigorous tree with full foliage that could grow at the particular site. Alternatively, absolute references are used, defined as the best possible tree of a genus or a species regardless of site conditions, tree age, etc. that is depicted on regionally applicable photos, e.g. photo guides.

Natural factors strongly influence crown condition. As also stated by many participating countries, air pollution is thought to interact with natural stressors as a predisposing or ac-companying factor, particularly in areas where deposition may exceed critical loads for acidification and/or nitrogen (Chappelka &Freer-Smith 1995, Cronan & Grigal 1995, Freer-Smith 1998, Posch et al. 2012).

As the true influence of site conditions and the share of tolerable defoliation cannot be quantified precisely, damaged trees cannot be distinguished from healthy ones only by means of a certain defoliation threshold. Consequently, the 25% threshold for defoliation does not necessarily identify trees damaged in a physiological sense. Some differences in the level of damage across national borders may be at least partly due to differences in the standards used. This restriction, however, does not affect the reliability of trends over time.

It has been suggested that the severity of forest damage has been underestimated as a result of the replacement of dead trees with living trees in the course of regular forest management activities. However, detailed statistical analyses of the results of six monitoring years have revealed that the number of dead trees has remained so small that their replacement has not influenced the results notably (Lorenz & Becher 1994).



- Boreal Forest
- Hemiboreal and nemoral coniferous and mixed broadleaved-coniferous forest
- Alpine coniferous forest
- Acidophilous oak and oakbirch forest
- Mesophytic deciduous forest
- Beech forest
- Mountainous beech forest
- Thermophilous deciduous forest
- Broadleaved evergreen forest
- Coniferous forests of the Mediterranean, Anatolian and Macaronesian regions
- Mire and swamp forest
- Floodplain forest
- Non-riverine alder, birch or aspen forest
- Introduced tree species forest
- Not yet classified

Figure 3-2: Spatial distribution of European Forest Types (2013)

Classification of defoliation data

The results of the evaluations of the crown condition data are presented in terms of mean plot defoliation or as the percentage of trees falling into 5%-defoliation steps. In previous presentations of survey results, partly the traditional classification of both defoliation and discolouration had been applied, although it is considered arbitrary by some countries. This classification (Tab. 3-5), however, is a practical convention as real physiological thresholds cannot be defined.

Table 3-5: Defoliation and discolouration classes according to UNECE and EU classification

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
Discolouration class	**Foliage discoloured**	**Degree of discolouration**
0	up to 10%	none
1	> 10–25%	slight
2	> 25–60%	moderate
3	> 60%	severe
4		dead

In order to discount background perturbations which are in general considered minor, a defoliation of >10–25% is considered as a warning stage, and a defoliation >25% is taken as a threshold for damage. For this reason, results are often only reported either in defoliation classes 0 and 1 (0–25% defoliation) or in classes 2, 3 and 4 (defoliation >25%).

Trees in classes 2, 3 and 4 are referred to as "damaged" as they represent trees with considerable defoliation. In the same way, the sample points are referred to as "damaged" if the mean defoliation of their trees (expressed as percentages) falls into class 2 or higher. Otherwise the sample point is considered as "undamaged".

Calculation of mean defoliation rates and trends

For all evaluations related to a particular tree species a criterion had to be set up to decide if a given plot represents this species or not. This criterion was that the number of trees of the particular species had to be three or more per plot (N ≥ 3). The mean plot defoliation for the particular species was then calculated as the mean defoliation of the trees of the species on that plot. The criterion was also used for other evaluations on plot level.

The development of defoliation (trend) was calculated assuming that the sample trees of each survey year reflect the influence of forest conditions. Studies carried out in the past years showed that the fluctuation of trees in a sample (due to the exclusion of dead and felled trees as well as inclusion of replacement trees) did not cause bias or other distortions of the results over the years. However, fluctuations due to the inclusion of new participating countries must be excluded, because forest condition among countries can deviate greatly. Several countries could also not be included in the time periods because of changes in their tree sample sizes, their assessment methods, or missing assessments in certain years. For this reason, trends in defoliation could only be calculated for defined sets of countries.

Defoliation trends for the periods 1991–2013 and 1997–2013 are presented in figures and in tables in chapter 3.2. Figures show the fluctuations of mean defoliation and shares of trees in defoliation classes over time. The maps depict trends in mean defoliation from 2002–2013 and from 2006–2013. Whereas all plots of the countries mentioned below are included for the two respective time periods in graphs, the maps of the trend analysis only represent plots within these countries that were included in all of the surveys. In the last years, plots were shifted within Austria, Finland, parts of Germany (Bavaria, Brandenburg), Greece, Latvia, Poland, Portugal, Romania, Sweden and the United Kingdom. These plots are not depicted in the maps but these country plots are included in the figures.

For the evaluation presented in figures, the following two time periods and the following countries were selected for tracing the trend in defoliation:

- **Period 1991–2013 ("long term period")**: Belgium, Denmark, France[4], Germany, Hungary, Italy, Latvia, Poland, Slovakia, Spain, Switzerland
- **Period 1997–2013 ("many countries")**: Belgium, Croatia, Denmark, Estonia, France, Germany, Hungary, Italy, Latvia, Lithuania, Norway, Poland, Slovakia, Slovenia, Spain, Switzerland.

The map of the spatial distribution shows only identical plots. To include as many countries as possible, two time periods (I and II) were mapped:

- **Period 2002–2013 ("short-term period I used to calculate the trend of the mean plot defoliation")**: Belgium, Croatia, Cyprus, Denmark, Estonia, France, Germany, Hungary, Italy, Lithuania, Norway, Slovakia, Slovenia, Spain, Switzerland
- **Period 2006–2013 ("short-term period II used to calculate the trend of the mean plot defoliation")**: Andorra, Belgium, Croatia, Cyprus, Denmark, Estonia, France, Germany, Hungary, Italy, Lithuania, Norway, Poland, Serbia, Slovakia, Slovenia, Spain, Switzerland.

On maps, the temporal trend of defoliation was expressed as the slope of a linear regression of mean defoliation against the observation year. It can be interpreted as the mean annual change in defoliation. These slopes were statistically tested and considered as 'significant' only if there was at least a 95% probability that they are different from zero.

Besides the temporal trend, also the change between 2012 and 2013 was calculated. In this case, changes in mean defoliation per plot were called 'significant' only if the significance at the 95% probability level was proven in a Student's t-test.

3.1.7 Weather condition in 2012 and 2013

In summer 2012, particularly south-eastern Europe but also parts of south-western and central Europe showed higher mean temperatures compared to the long-term mean (1961–1990). At the same time, little precipitation in comparison to the long-term mean was observed in south, south-eastern and partly eastern Europe. In autumn 2012, comparably high precipitation occurred in north Italy, Switzerland and Sweden. In February, May and June 2013, colder temperatures than in the long term were observed for central and south-western Europe. In northern, eastern and south-eastern Europe the deviation from the long-term mean was positive (warmer temperatures). In winter 2012/2013, the precipitation was comparably high in Sweden, but low in Norway. The temperature conditions changed during the summer (July). While south-western and central Europe had a warmer period than on average in the long term, eastern and south-eastern Europe were colder. In the early summer the precipitation was high in central Europe and occasionally in parts of south-eastern Europe. The information on weather was derived from 'wetteronline.de'[5] .

[4] Methodological changes in the first years of assessment

[5] http://www.wetteronline.de/rueckblick?gid=euro, assessed on 13.05.2014

3.2 Results of the transnational crown condition survey in 2013

3.2.1 Defoliation in 2013

On each sampling plot, sample trees were selected according to national procedures and assessed for defoliation. According to Tab. 3-6 the defoliation assessment was carried out on 106,730 trees in 25 countries in 2013. The figures in Tab. 3-6 are not necessarily identical with those published in the reports of the past years since in case of, for example, a restructuring of the national observation networks a resubmission of older data is possible.

Table 3-6: Number of sample trees from 2001 to 2013 according to the current database

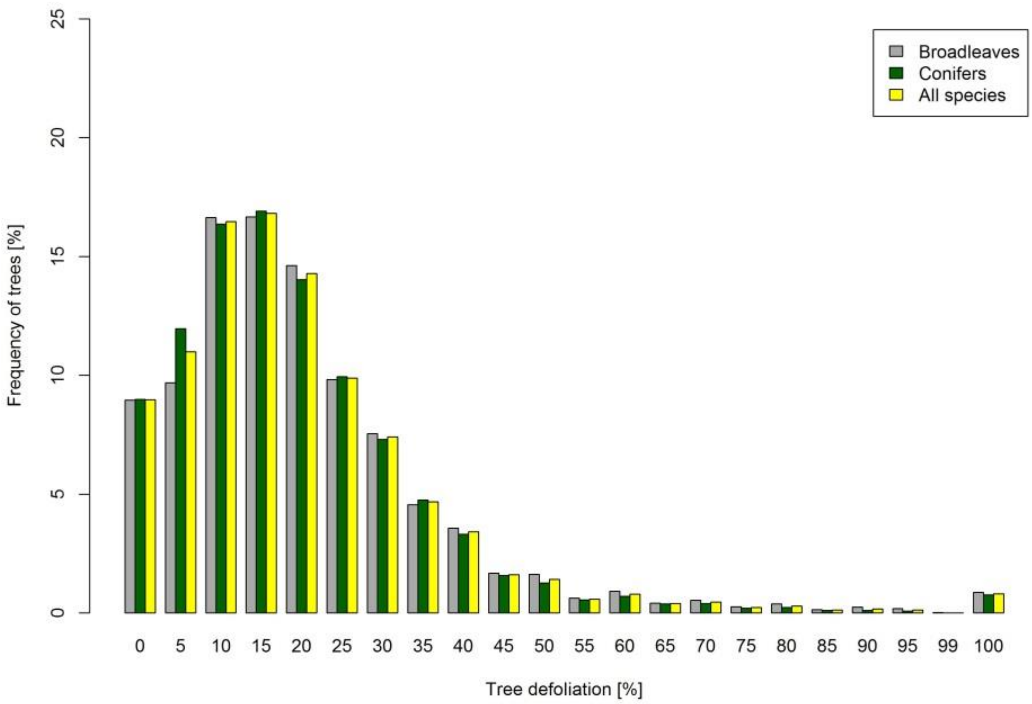
Country	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Andorra	0	0	0	72	0	74	72	72	73	72	72	72	264
Austria	3451	3503	3470	3586	3528	3425	0	0	0	3087	0	0	0
Belarus	9761	9723	9716	9682	9484	9373	9424	9438	9615	9617	9583	0	8709
Belgium	682	684	684	681	676	618	616	599	599	216	230	207	206
Bulgaria	4174	3720	3836	3629	3592	3510	3569	3304	5560	5569	5583	5608	0
Croatia	1941	1910	1869	2009	2046	2109	2013	2015	1991	1992	2208	2400	2520
Cyprus	360	360	360	360	361	360	360	360	362	360	360	360	360
Czech Republic	3475	3500	3500	3500	3450	3425	3300	3400	3325	3300	3400	3375	0
Denmark	504	480	480	480	528	527	442	452	384	408	432	411	420
Estonia	2136	2169	2228	2201	2167	2191	2209	2196	2202	2348	2372	2348	2329
Finland	8579	8593	8482	11210	11535	11489	11199	8812	7182	7946	4217	4676	0
France	10373	10355	10298	10219	10129	9950	10079	10138	9949	10584	11111	11268	11199
Germany	13478	13534	13572	13741	13630	10327	10241	10347	10088	10063	9635	9917	10335
Greece	2168	2144	0	0	2054	0	0	0	2289	2311	0	0	0
Hungary	1469	1446	1446	1710	1662	1674	1650	1661	1668	1626	1702	1655	1519
Ireland	420	424	403	400	382	445	646	694	717	641	0	489	0
Italy	7350	7165	6866	7109	6548	6936	6636	6579	6794	8338	8454	5507	5610
Latvia	2325	2340	2293	2290	2263	2242	2228	2184	1721	1721	1747	1740	1746
Lithuania	1597	1583	1560	1487	1512	1505	1507	1688	1734	1814	1846	1847	1907
Luxembourg	0	96	96	96	97	96	96	96	0	0	0	0	96
Rep. of Moldova	234	0	0	0	0	0	0	0	0	0	0	0	0
Montenegro	0	0	0	0	0	0	0	0	0	1176	1176	1176	1176
Netherlands	231	232	231	232	232	230	0	0	247	227	0	0	0
Norway	4304	4444	4547	5014	5319	5525	5824	6085	6014	6330	6463	6542	4977
Poland	8620	8660	8660	8560	8640	7520	9160	9036	7520	7482	7342	7404	7300
Portugal	4500	4530	4260	4170	3749	3719	0	0	0	0	0	0	0
Romania	5568	5544	5544	5424	5496	5472	5232	0	5448	5736	5808	5784	5656
Russian Fed.	0	0	0	0	0	0	0	0	11016	8958	9275	0	0
Serbia	0	0	2274	2915	2995	2902	2860	2788	2752	2786	2742	2782	2789
Slovakia	5054	5076	5116	5058	5033	4808	4910	4956	4944	4831	5218	4888	4769
Slovenia	984	936	983	1006	1056	1069	1056	1056	1056	1052	1057	1053	1061
Spain	14880	14880	14880	14880	14880	14880	14880	14880	14880	14880	14880	14880	14880
Sweden	11283	11278	11321	11255	11422	11186	0	0	2591	2742	2057	1991	2188
Switzerland	834	827	806	748	807	812	790	773	801	795	1105	1122	1047
Turkey	0	0	0	0	0	0	941	9291	13156	12974	13282	13603	13667
United Kingdom	2064	2064	2064	2040	2016	1968	768	0	0	1803	0	0	0
Total Europe	132799	132200	131845	135764	137289	130367	112708	112920	136678	143785	133357	113105	106730

Defoliation scores were available for 102,115 trees. Table 3-7 shows that the mean defoliation of all trees assessed in Europe was 20.3%. Because of differences in the composition of participating countries, the defoliation figures from 2013 are, however, not comparable to those from previous reports. Broadleaved trees showed a higher mean defoliation (22.2%) than conifers (18.5%). Regarding tree species and tree species groups, evergreen oaks and deciduous temperate oaks displayed the highest mean defoliation as well as the highest proportions of damaged trees (i.e. trees defoliated by >25%). In contrast, *Pinus sylvestris* and *Picea abies* showed the lowest mean defoliation whereas *Pinus sylvestris* and Mediterranean lowland pines had the highest share of undamaged trees. The largest share of trees (47.4%) showed mean defoliations ranging from 11% to 25%. Trees classified as dead trees only accounted for 1% of all trees.

Table 3-7: Percentages of trees in defoliation classes and their mean defoliation rates for different species and species groups

		Percentage of trees in defoliation class							Defoliation		No of
	Species group	0–10	>10–25	0–25	>25–60	>60	dead	>25	mean	median	trees
Total Europe	*Fagus sylvatica*	30.9	42.5	73.5	24.7	1.5	0.3	26.5	21.0	20	9540
	Deciduous temperate oak	23.8	43.8	67.6	29.3	2.5	0.6	32.4	24.0	20	8186
	Deciduous (sub-) Mediterranean oak	29.6	45.5	75.1	21.6	2.6	0.8	24.9	21.8	20	6525
	Evergreen oak	8.9	64.1	73.0	22.1	3.6	1.2	27.0	25.4	20	4620
	Broadleaves	29.4	45.0	74.4	21.7	2.8	1.1	25.6	22.2	20	48936
	Pinus sylvestris	31.7	55.2	86.9	11.5	0.9	0.7	13.1	18.2	15	21577
	Picea abies	39.5	38.4	77.9	19.8	1.7	0.5	22.1	18.8	15	11477
	Mediterranean lowland pines	23.7	62.9	86.6	10.8	1.1	1.6	13.4	20.0	15	8609
	Conifers	34.5	49.7	84.2	13.7	1.3	0.8	15.8	18.5	15	53179
	All species	32.1	47.4	79.5	17.5	2.0	1.0	20.5	20.3	15	102115

Figure 3-3: Relative frequency distribution of all trees assessed in 2013 in 5% defoliation steps



The map in Annex I-3 indicates a clustered occurrence of plots with high mean defoliation in central and southern Europe (mainly southern and south-eastern France and northern Italy). Clustered occurrence of lowest mean defoliation was found in south-eastern Norway and Denmark. The percentage of damaged trees per plot was relatively low in north-eastern Europe, south-eastern Norway, Cyprus and Turkey, whereas clusters of high shares of damaged trees were found in several regions of France (particularly in southern and south-eastern France and also on Corsica), northern Italy, Slovenia, Slovakia and central Germany (Annex I-4). For the 5% defoliation classes including dead trees (100% defoliation), a frequency distribution was calculated. Fig. 3-3 indicates that about 17% of all species were defoliated by 15%. More conifers than broadleaves fell in defoliation classes of up to 20% in 2013, whereas deciduous trees were more frequently represented in defoliation classes above 20%.

In addition to the evaluation according to tree species (groups), defoliation data were also evaluated according to the European Forest Types (Tab. 3-8). The highest mean defoliation rates were found in broadleaved evergreen forests (25.6%). High mean defoliation was also observed in mesophytic deciduous forests (22.2%) as well as in acidophilous oak and oak birch forests (22.6%), alpine forests (22.3%), and mountainous beech forests (22%). The highest shares of damaged trees were found in alpine forests (30.4%) and flood-plain forests (29.1%). Mean defoliation rates of most forest types varied between 17% and 22%. Apart from the rarely occurring mire and swamp forests, the healthiest trees in terms of mean defoliation were found in boreal forests with a mean defoliation of 17.3% and a percentage of healthy trees of 37% as well as in hemiboreal and nemoral coniferous and mixed broadleaved-coniferous forests with a mean defoliation of 17.8% and a share of healthy trees of 32.4%.

Table 3-8: Percentages of trees in defoliation classes and their mean defoliation rates for different European Forest Types (EFT)

Forest type		Percentage of trees in defoliation class							Defoliation		No. of
Code	Species type	0–10	>10–25	0–25	>25–60	>60	dead	>25	mean	median	trees
1	Boreal forest	37.0	52.7	89.7	8.2	1.2	0.9	10.3	17.3	15	4811
2	Hemiboreal and nemoral coniferous and mixed broadleaved-coniferous forest	32.4	54.1	86.6	12.3	0.7	0.5	13.4	17.8	15	19992
3	Alpine forest	31.8	37.9	69.6	27.3	2.4	0.6	30.4	22.3	20	6175
4	Acidophilous oak and oak birch forest	22.6	52.1	74.7	22.0	2.0	1.3	25.3	22.6	20	2495
5	Mesophytic deciduous forest	31.7	39.9	71.7	24.7	3.1	0.6	28.3	22.2	20	10068
6	Beech forest	34.0	40.6	74.6	23.3	1.7	0.4	25.4	20.3	20	8079
7	Mountainous beech forest	28.6	43.3	71.8	25.4	2.4	0.4	28.2	22.0	20	5467
8	Thermophilous deciduous forest	28.1	44.6	72.6	22.9	3.6	0.9	27.4	23.3	20	10704
9	Broadleaved evergreen forest	8.4	64.3	72.7	22.2	3.8	1.3	27.3	25.6	20	4615
10	Coniferous forests of the Mediterranean, Anatolian and Macaronesian regions	32.7	55.1	87.8	9.9	1.3	1.0	12.2	18.4	15	15099
11	Mire and swamp forest	29.5	57.5	87.0	11.1	1.6	0.2	13.0	18.7	15	1250
12	Floodplain forest	32.4	38.5	70.9	24.3	3.1	1.7	29.1	22.7	20	1260
13	Non-riverine alder, birch or aspen forest	39.9	49.6	89.6	9.1	0.9	0.4	10.4	16.6	15	2222
14	Introduced tree species forest	42.7	38.0	80.7	14.6	2.6	2.1	19.3	19.3	15	7016

In view of the species richness (126 species) recorded within the transnational forest monitoring only the most abundant species could be evaluated.

In Figures 3–4 to 3–10 mean plot defoliation for *Pinus sylvestris*, *Picea abies*, *Fagus sylvatica*, and the four species groups deciduous temperate oaks, deciduous (sub-) Mediterranean oaks, evergreen oaks, and Mediterranean lowland pines is mapped. The spatial distribution of these species and species groups is described in relation to Tab. 3-8.

The mean defoliation rate of *Pinus sylvestris* was the lowest (18.2%) of all species. 71.4% of the *Pinus sylvestris* plots had mean defoliation rates between >10% and 25%. The spatial distribution of the plots with healthy trees (0–10% defoliation) is concentrated in Norway and northern Germany. Plots with the highest clustered defoliation were found in southern and south-eastern France (Fig. 3-4).

The mean defoliation of *Picea abies* (18.8%) is comparable with that of *Pinus sylvestris.* Similar to *Pinus sylvestris* a cluster of healthy trees was observed in Norway ranging to Denmark. Plots with high mean defoliation, however, also frequently occurred in Norway and Sweden. 44.8% of all plots had mean defoliations between >10% and 25%. About one quarter of the plots showed mean defoliations of 10% and lower and another quarter displayed mean defoliations of >25% (Fig. 3-5).

The mean defoliation of Mediterranean lowland pines amounted to 20.0%; 78.4% of the plots showed mean defoliations between >10% and 25%. Several plots with a high mean defoliation of >40% were located in south-eastern France and northern Italy (Fig. 3-6).

Only relatively slightly damaged among broadleaves was *Fagus sylvatica* showing a mean defoliation of 21%. On half of the plots, the mean defoliation ranged between >10% and 25%, whereas on 30% of the plots a mean defoliation of >25% was found. Clustered occurrences of damaged *Fagus sylvatica* plots were observed in Germany, southern and eastern France, northern Italy, Slovenia and Slovakia (Fig. 3-7).

The mean defoliation rates of deciduous temperate oaks were comparably high with 24%. Half of the plots showed mean defoliations between >10% and 25% and about 40% of the plots were classified as damaged (defoliation >25%). A high number of damaged plots are located in Germany, France and Slovakia (Fig. 3-8). Only evergreen oaks (25.4%) were on average more affected than deciduous temperate oaks. About 35% of the evergreen oak plots were classified as damaged and only 2.4% as healthy. A cluster of damaged evergreen oak plots were observed in southern and south-eastern France including Corsica (Fig. 3-10).

A slightly lower number of defoliated trees was found in deciduous (sub-) Mediterranean oak plots (21.8%). 54.1% of the plots had mean defoliations between >10% and 25% and about 30% of the plots were classified as damaged. Similar to the evergreen oaks, a cluster of plots with high mean defoliations was observed in south-eastern France (Fig. 3-9).

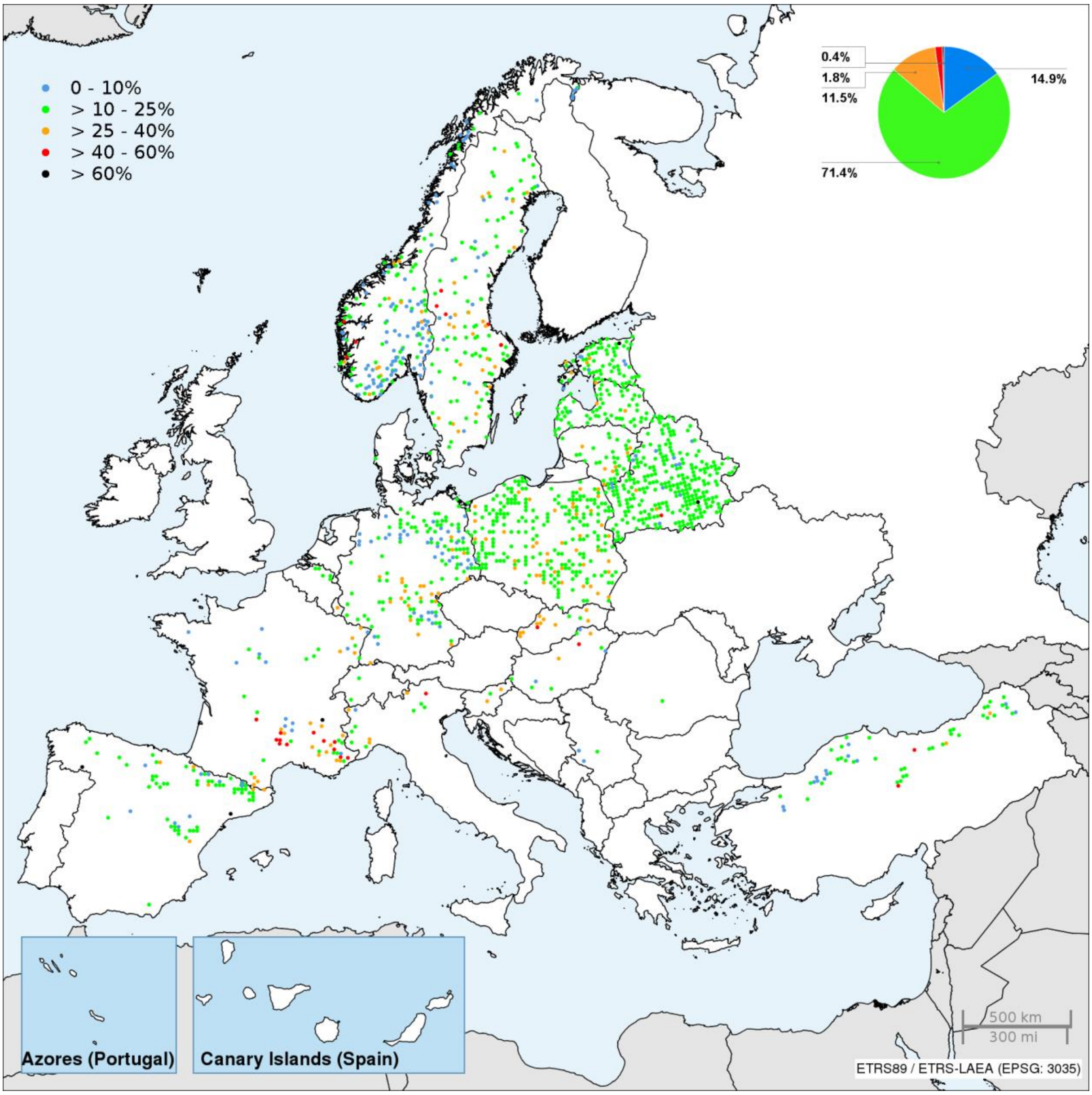


Figure 3-4: Mean plot defoliation of *Pinus sylvestris,* 2013

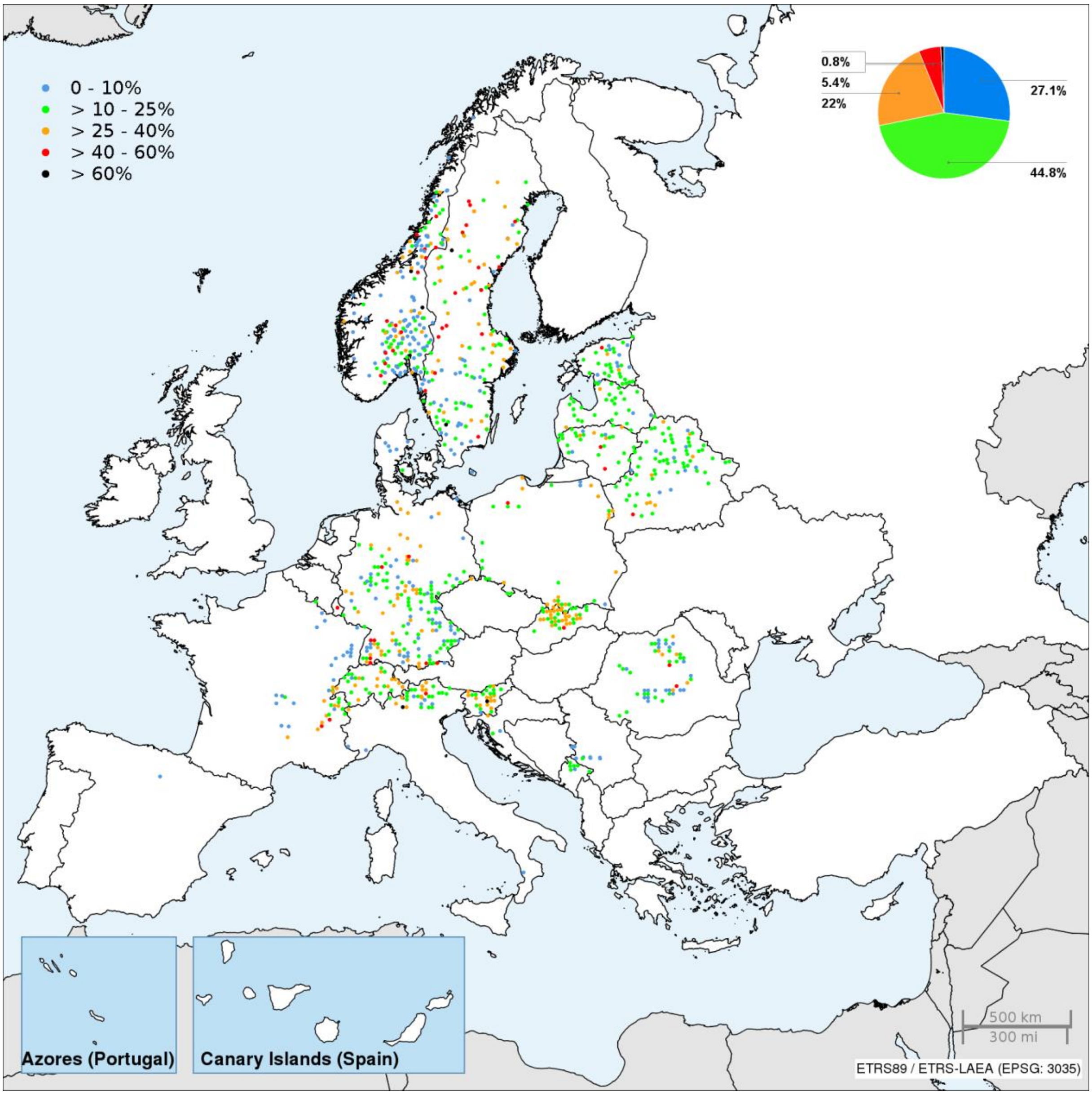


Figure 3-5: Mean plot defoliation of Picea abies, 2013

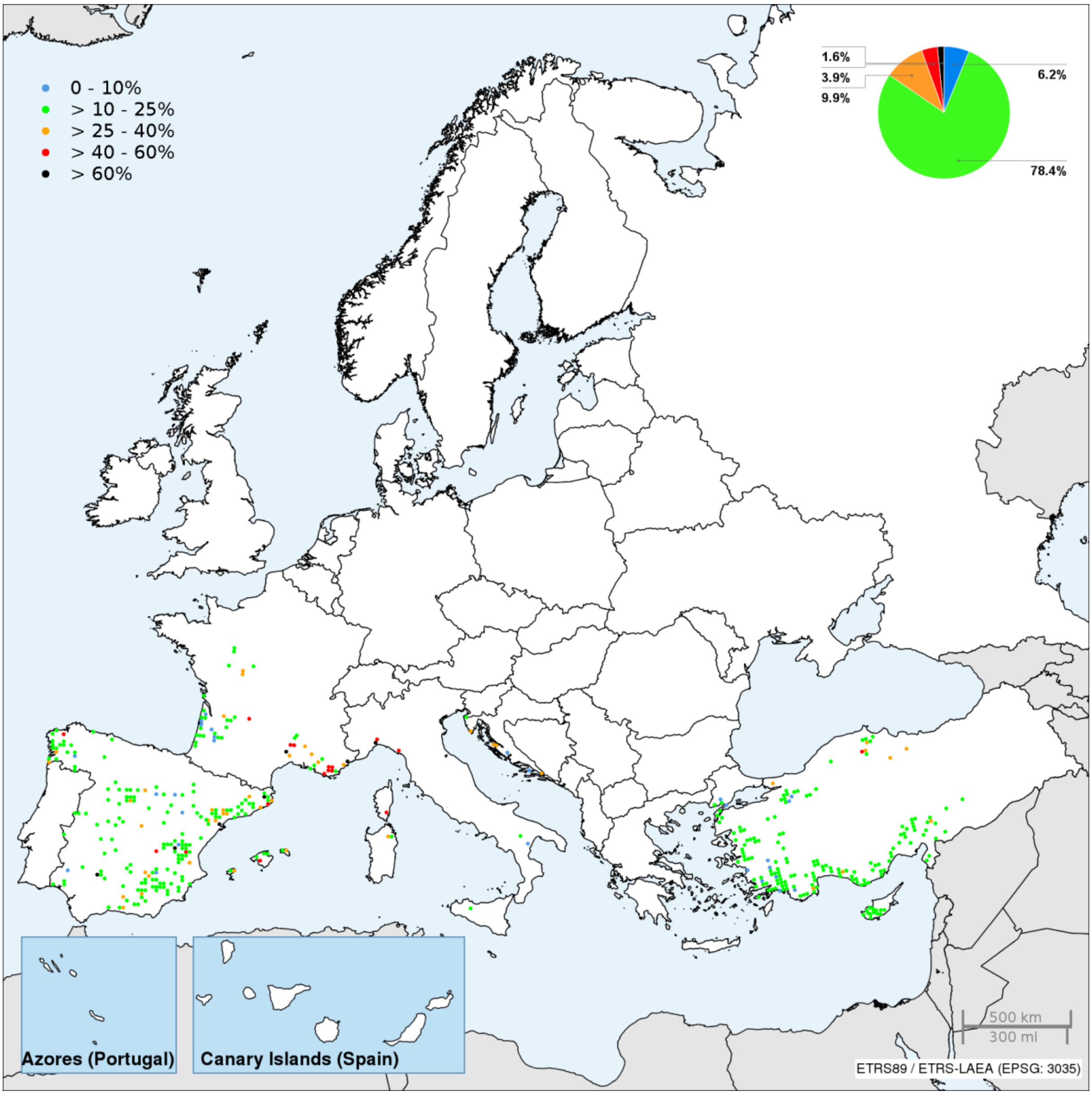


Figure 3-6: Mean plot defoliation of Mediterranean lowland pines (*Pinus brutia*, *Pinus halepensis*, *Pinus pinaster*, *Pinus pinea*), 2013

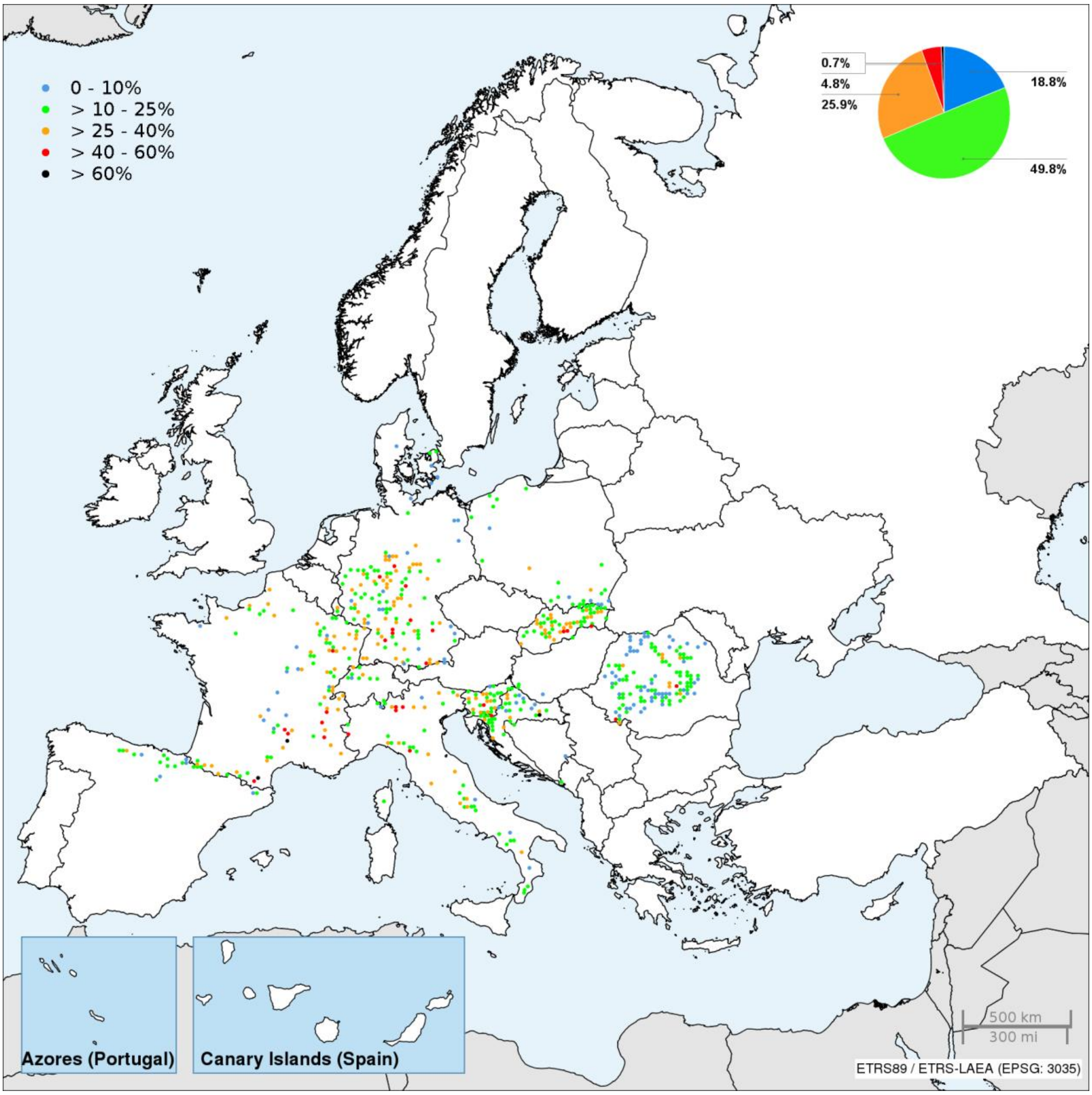


Figure 3-7: Mean plot defoliation of *Fagus sylvatica*, 2013

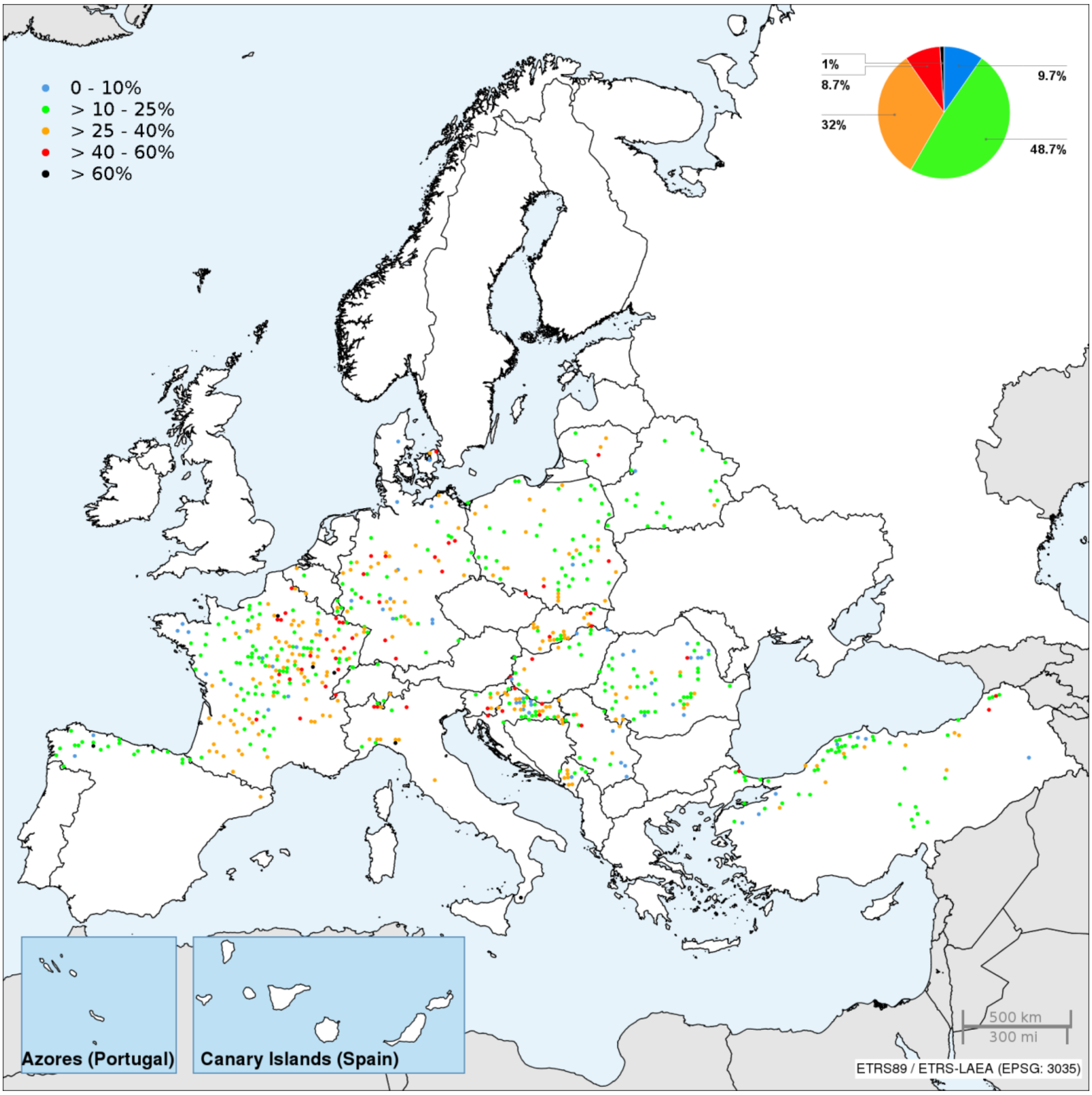


Figure 3-8: Mean plot defoliation of deciduous temperate oaks *(Quercus petraea and Quercus robur),* 2013

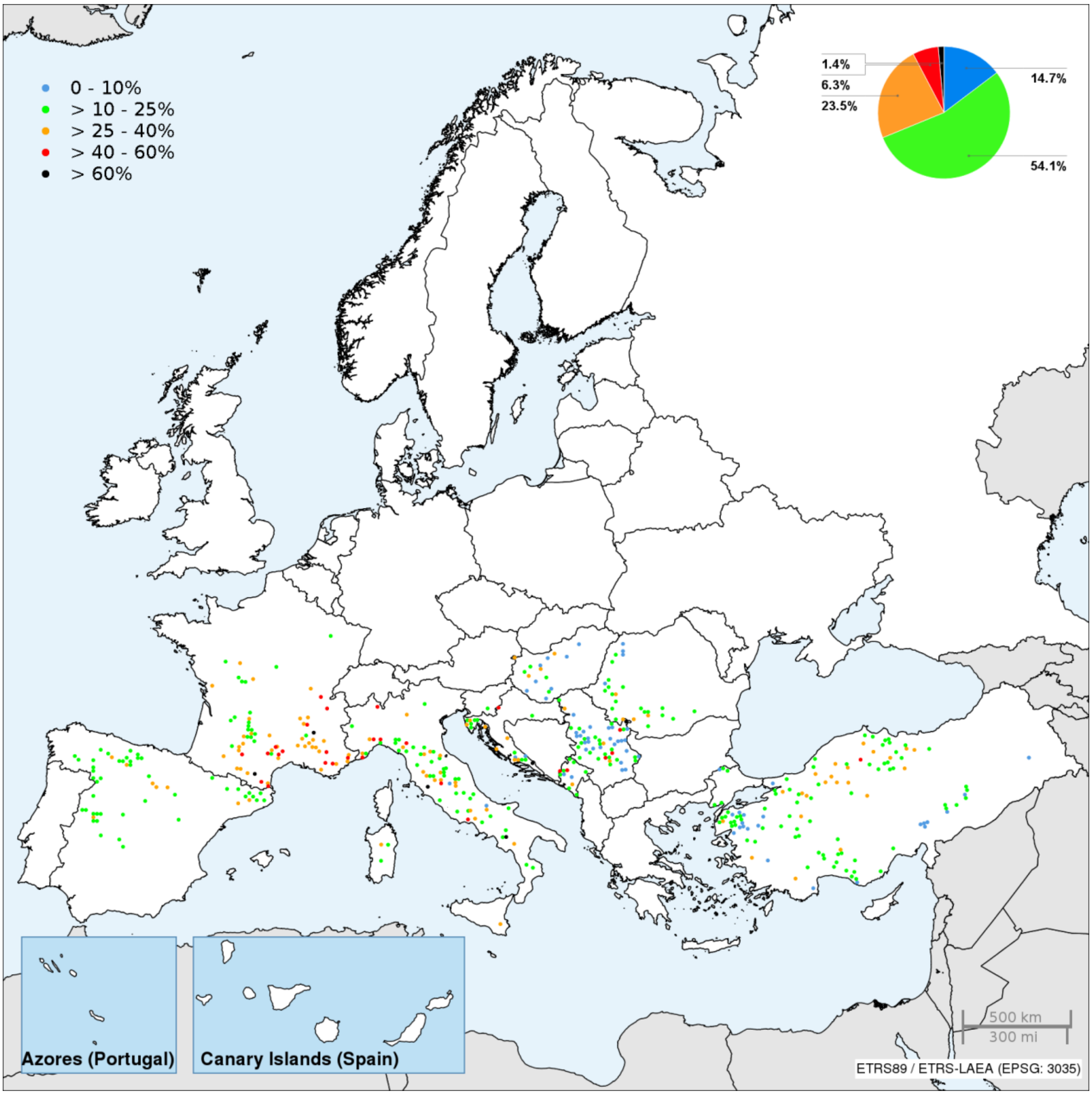


Figure 3-9: Mean plot defoliation of deciduous (sub-) Mediterranean oaks (*Quercus cerris*, *Quercus frainetto*, *Quercus pubescens*, *Quercus pyrenaica*), 2013

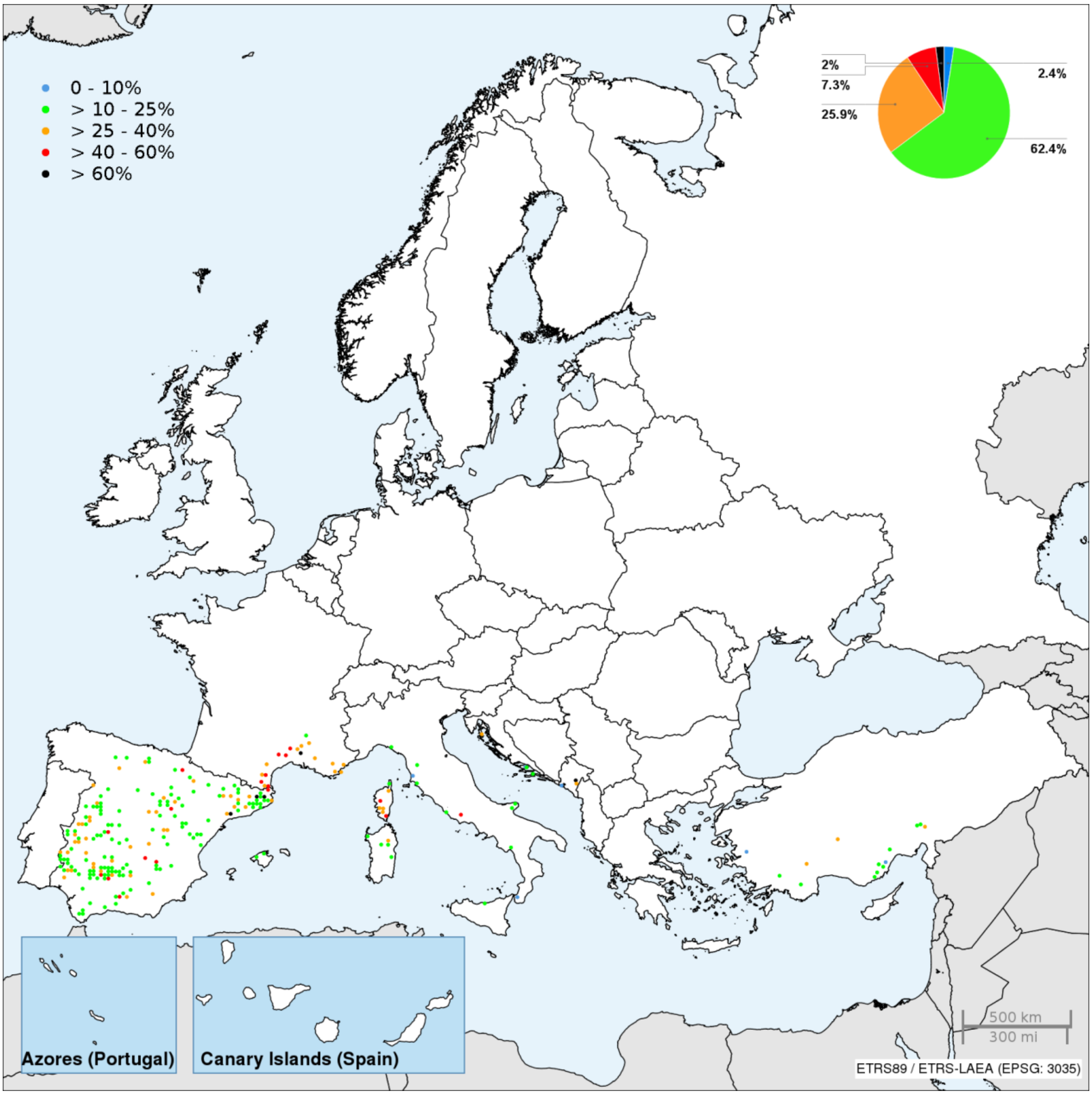


Figure 3-10: Mean plot defoliation of evergreen oak (*Quercus coccifera*, *Quercus ilex*, *Quercus rotundifolia*, *Quercus suber)*, 2013

3.2.2 Defoliation trends: time series

3.2.2.1 All species

For all species, the two time series showed very similar trends for mean defoliation which may have been caused by the fact that three quarter of the countries included in the shorter time series (1997–2013) were also included in the longer time series (1991–2013) (Fig. 3-11 and Fig. 3-12). An exception was *Fagus sylvatica* showing a higher proportion of 83% and *Picea abies* showing a lower proportion of 64%. The highest deviations between the two time series were found in *Picea abies.*

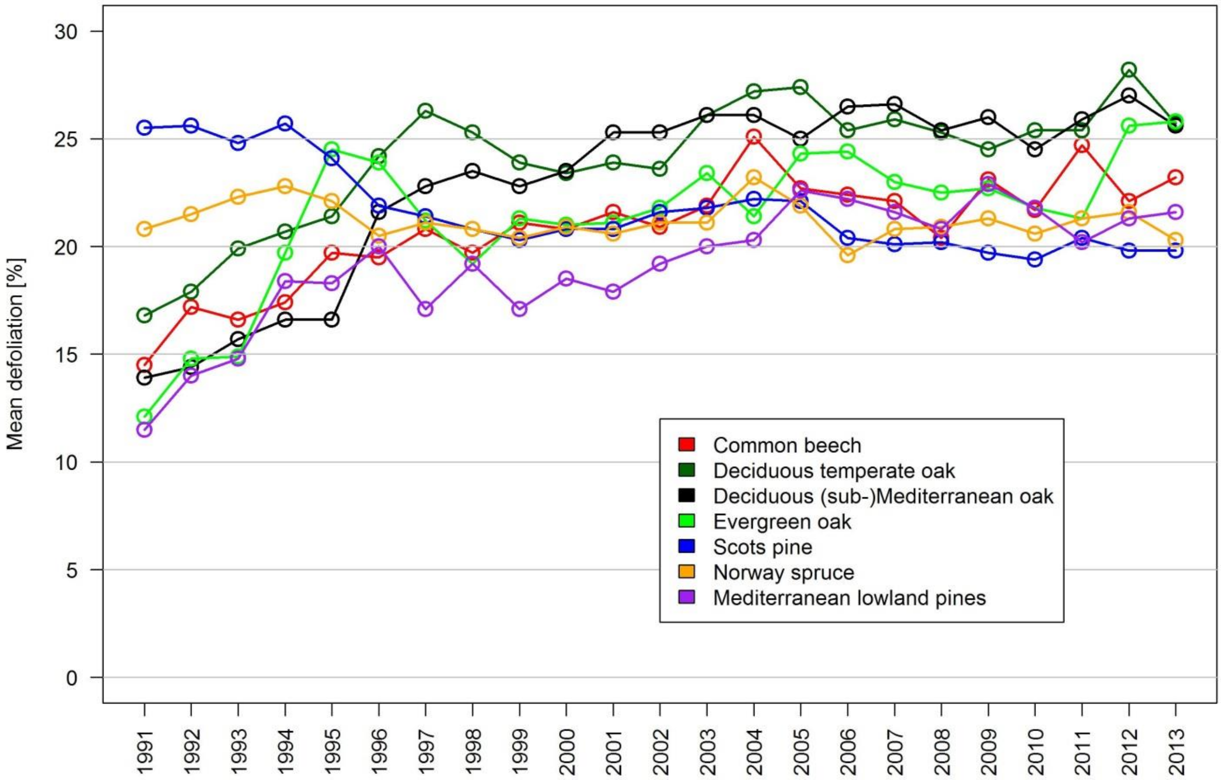


Figure 3-11: Mean defoliation of main species and species groups 1991–2013

Since 1991 mean defoliation of the evaluated tree species developed independently. With the exception of *Picea abies* and *Pinus sylvestris*, all tree species showed an increase in mean defoliation in the first years of the study until the mid-1990s. The mean defoliation of *Picea abies*, *Fagus sylvatica*, and the deciduous temperate oaks was most pronounced after the extremely dry and warm summer in 2003. In the last years broadleaves had in general the highest mean defoliation. Especially deciduous temperate as well as Mediterranean oaks had the highest mean defoliation rates of all species and species groups in the last decade. In contrast, *Pinus sylvestris* and *Picea abies* clearly showed the lowest mean defoliation rates during that time.

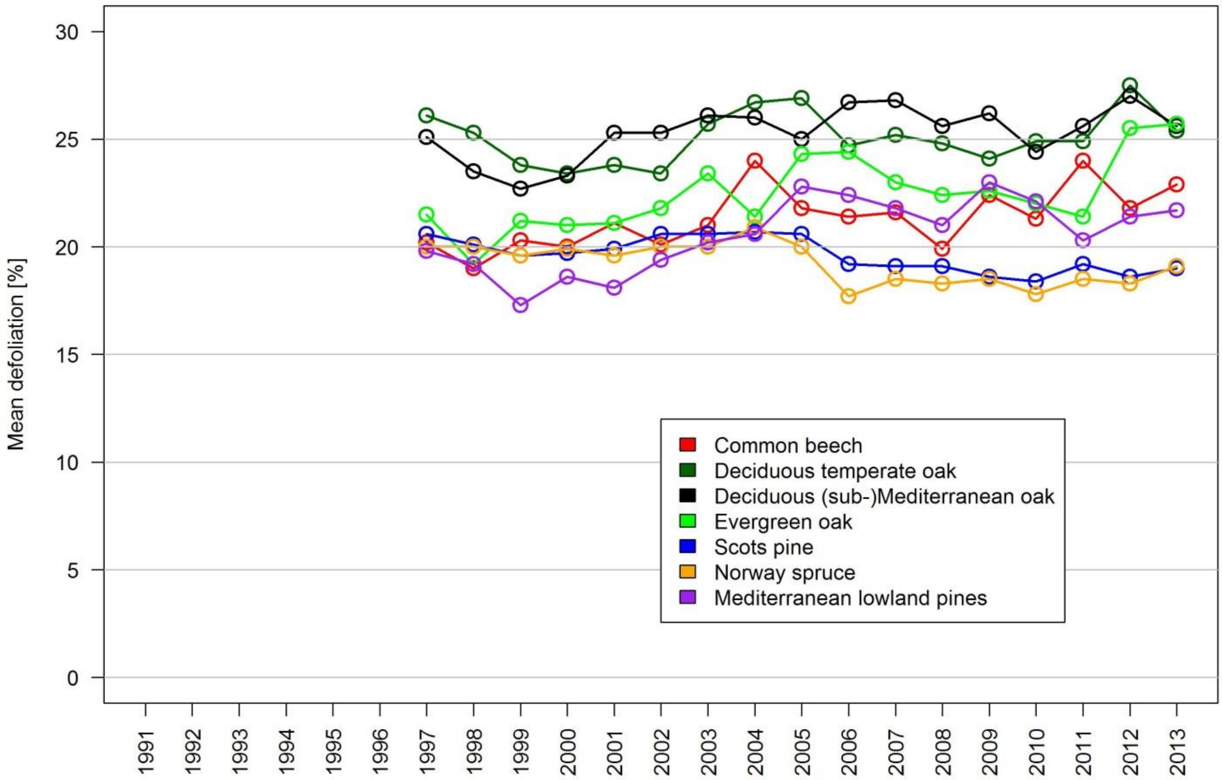


Figure 3-12: Mean defoliation of main species and species groups 1997–2013

Mean plot defoliation trends for all tree species for the two periods 2002–2013 and 2006–2013 are mapped in Fig. 3-13 and Annex I-5, respectively. In the period 2002–2013, the percentage of plots with increasing defoliation estimates (20.0%) was higher than the share of plots with decreasing defoliation estimates (12.9%). However, when regarding the period 2006–2013 a similar number of plots showed increasing and decreasing trends. Plots showing high defoliation rates were scattered across Europe in both periods. In the period 2002–2013 higher values were reported from the eastern edge of the Pyrenean Mountains ranging from southern and south-eastern France to northern Italy and Slovenia.

The spatial patterns of the changes in mean defoliation estimates across Europe in the years 2012 to 2013 is shown in Annex I-6. On 77.5% of the plots no statistically significant differences in mean plot defoliation were detected. The share of plots with an increase in defoliation amounted to 13.4% and the share of plots with a decrease to 9.1%. Plots with increasing and decreasing defoliation were scattered across Europe. A cluster of increasing defoliation rates was observed in Slovakia.

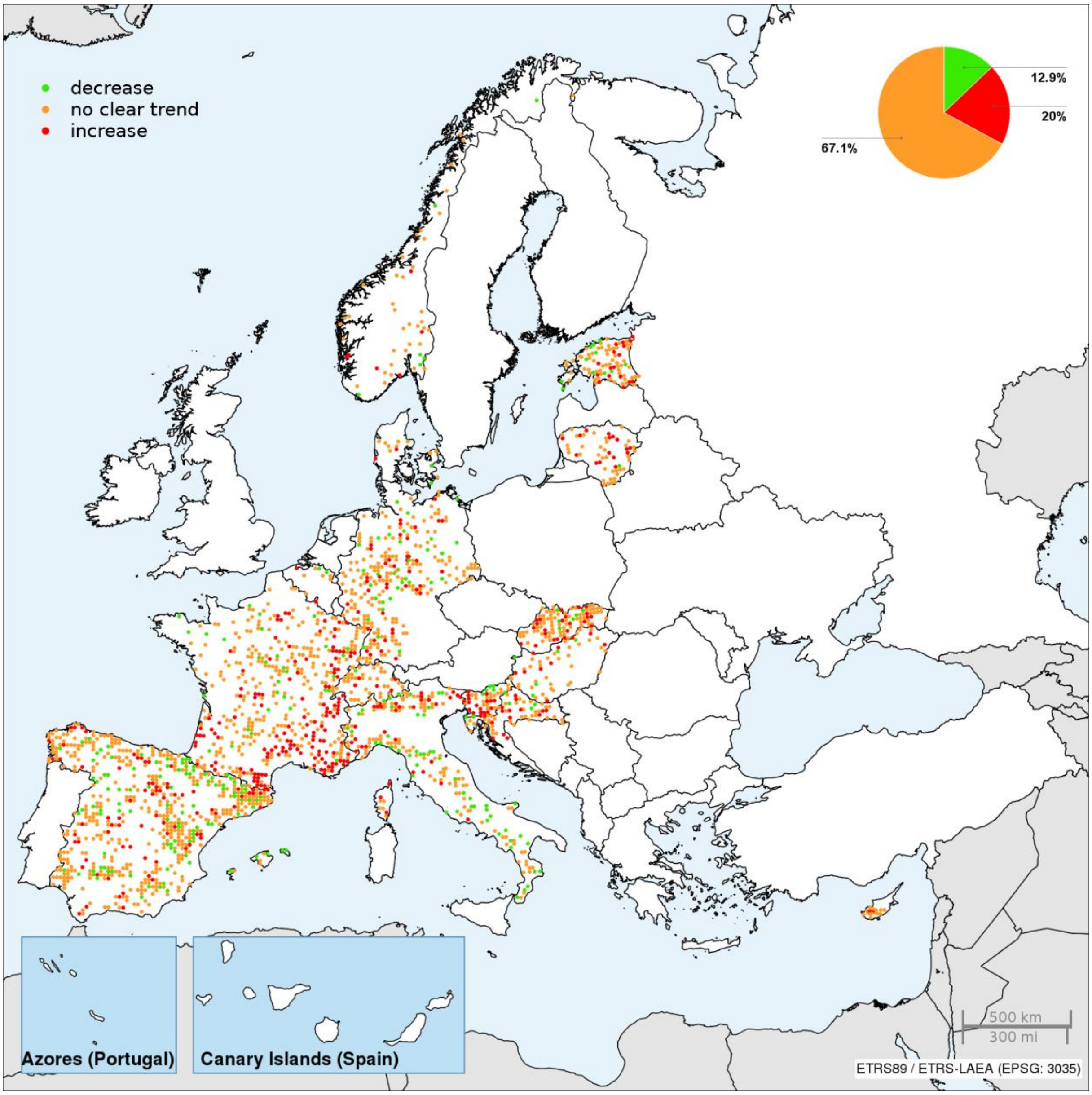


Figure 3-13: Trend of mean plot defoliation (slope of linear regression) of all species over the years 2002–2013

3.2.2.2 *Pinus sylvestris*

Pinus sylvestris is the most frequently assessed tree species in Europe. It covers most regions in Europe and occurs on Level I plots from northern Scandinavia to the Mediterranean region. When considering the respective time periods from 1991 and 1997 onwards, a decrease in the mean defoliation estimates was observed (Fig. 3-14). In recent years, hardly any change occurred. In both time periods, the percentage of healthy pines (0–10%) increased and the share of damaged trees (>25%) decreased (Tab. 3-9, Fig. 3-15).

Plots showing increasing defoliation rates were scattered across Europe (Fig. 3-16) with clusters in southern and south-eastern France and Lithuania. For most plots (67.9%) no trend was observed. The share of pines with decreasing defoliation (17.5%) exceeded those with increasing defoliation (14.6%).

Table 3-9: Share of *Pinus sylvestris* in different defoliation classes

	1991–2013				1997–2013			
	n trees	0–10%	>10–25%	>25%	n trees	0–10%	>10–25%	>25%
1991	14236	20.7	39.3	40.0				
1992	14244	20.4	39.4	40.2				
1993	14263	20.9	41.2	37.9				
1994	13672	19.4	39.8	40.8				
1995	13445	21.5	42.7	35.9				
1996	13473	24.4	48.6	27.0				
1997	13462	24.0	51.1	24.9	16759	26.4	51.0	22.6
1998	13957	24.9	52.0	23.1	17238	27.4	51.6	21.0
1999	14240	25.1	54.0	20.8	17517	27.4	53.7	18.9
2000	14188	23.7	55.0	21.3	17452	27.6	53.7	18.7
2001	14257	22.9	56.5	20.6	17535	26.2	55.4	18.4
2002	14138	20.7	57.3	22.0	17416	23.9	56.6	19.5
2003	14177	19.4	58.7	21.9	17504	22.9	57.9	19.2
2004	14216	19.2	57.5	23.3	17609	24.1	55.9	20.0
2005	14139	21.0	54.7	24.3	17596	26.0	53.1	20.9
2006	11424	25.2	54.6	20.2	14919	28.9	53.8	17.3
2007	12198	24.5	57.1	18.4	15703	28.5	55.1	16.4
2008	12122	23.6	58.0	18.4	15656	27.8	55.8	16.4
2009	10945	27.0	54.2	18.8	14492	30.9	52.6	16.4
2010	10906	28.4	54.1	17.5	14580	32.9	51.5	15.6
2011	10860	24.8	54.9	20.0	14548	29.7	52.4	17.4
2012	10868	24.1	57.8	17.8	14517	29.6	54.3	15.7
2013	10887	23.9	58.3	16.3	14213	28.6	55.4	14.9

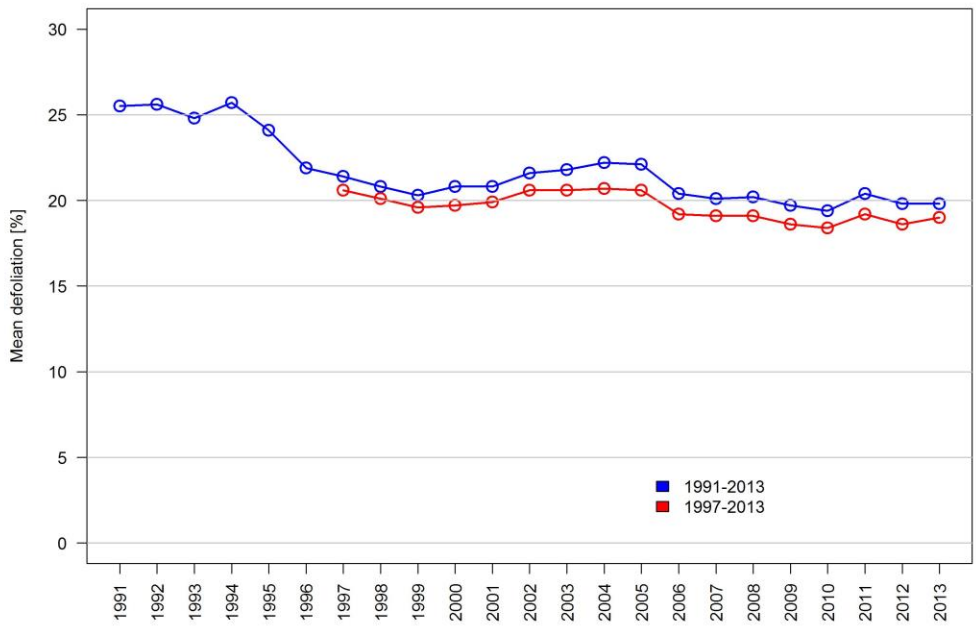


Figure 3-14: Mean defoliation of *Pinus sylvestris* in periods 1991–2013 and 1997–2013

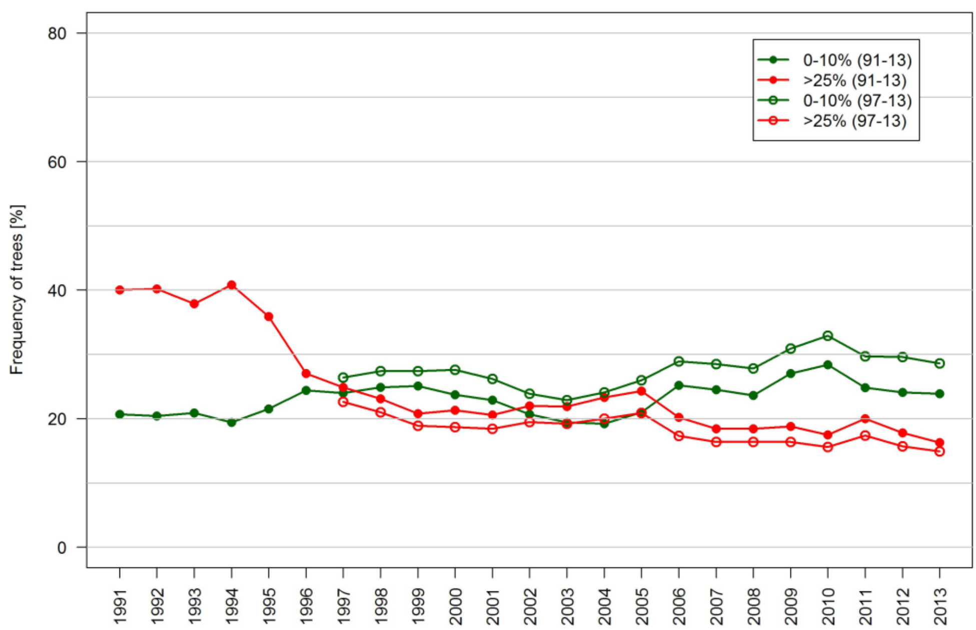


Figure 3-15: Share of *Pinus sylvestris* in defoliation classes 0–10% and >25% in periods 1991–2013 and 1997–2013

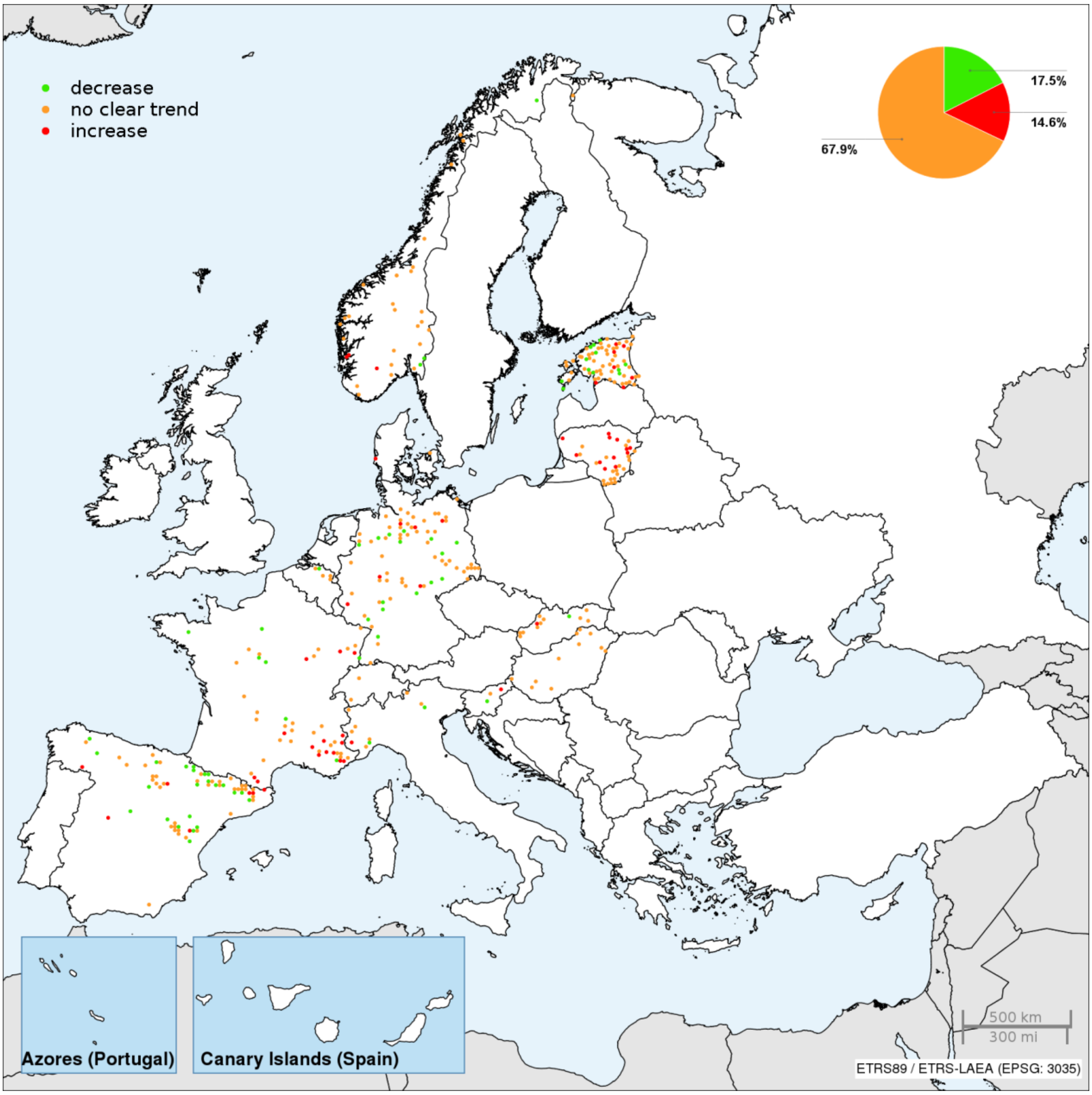


Figure 3-16: Trend of mean plot defoliation (slope of linear regression) of *Pinus sylvestris* in 2002–2013

3.2.2.3 *Picea abies*

Picea abies is the second most frequently observed species in the large-scale tree sample. Its area extends from Scandinavia to northern Italy.

The mean defoliation estimates of *Picea abies* slightly improved over both observation periods. Mean defoliation increased in 2004 which is often attributed to the extreme weather conditions in 2003. Until 2006 a recuperation phase was observed. Since then the level of the crown condition remained more or less stable (Fig. 3-17). In 2006 the proportion of healthy trees (0–10%) increased and stayed on this level whereas damaged trees showed an opposing trend (Tab. 3-10, Fig. 3-18).

Between 2002 and 2013 no clear trend was observed for 60.4% of the plots. In this time period a deterioration of crown condition occurred on 26.3% of the plots. The share of plots showing a positive trend in defoliation between 2002 and 2013 was 13.3% (Fig. 3-19). Plots with increasing and decreasing trends were scattered across Europe.

Table 3-10: Share of *Picea abies* in different defoliation classes

	1991–2013				1997–2013			
	n trees	0–10%	>10–25%	>25%	n trees	0–10%	>10–25%	>25%
1991	7603	33.7	36.6	29.7				
1992	7587	31.1	38.2	30.7				
1993	7544	31.7	36.2	32.1				
1994	7670	31.8	34.9	33.3				
1995	7815	34.9	33.4	31.6				
1996	7830	36.8	35.7	27.5				
1997	7669	33.0	38.2	28.8	10350	37.4	36.2	26.4
1998	8924	33.2	38.4	28.4	11591	36.8	36.5	26.7
1999	9019	34.1	38.9	27.0	11684	37.9	37.1	25.0
2000	9196	32.3	40.4	27.4	11810	36.3	38.6	25.1
2001	8924	31.1	42.3	26.5	11601	36.0	39.4	24.6
2002	8968	30.0	42.3	27.7	11681	35.2	39.6	25.2
2003	9034	28.8	44.2	27.0	11816	34.5	40.8	24.7
2004	8975	25.7	40.5	33.8	11845	33.7	37.2	29.1
2005	8643	26.9	43.2	29.9	11622	34.9	38.8	26.3
2006	6702	36.0	38.5	25.5	9779	43.7	34.6	21.7
2007	6356	31.1	41.6	27.3	9654	41.1	35.8	23.1
2008	6331	31.2	40.8	28.0	9816	41.7	34.9	23.5
2009	6383	29.8	40.8	29.0	9876	40.9	34.9	23.9
2010	6517	33.3	38.4	27.7	10148	44.4	32.5	22.8
2011	6778	30.7	36.9	28.1	10459	41.4	32.2	22.9
2012	6337	30.1	38.0	28.9	10092	42.4	32.4	22.8
2013	6355	30.1	40.5	25.5	8674	36.4	37.8	22.9

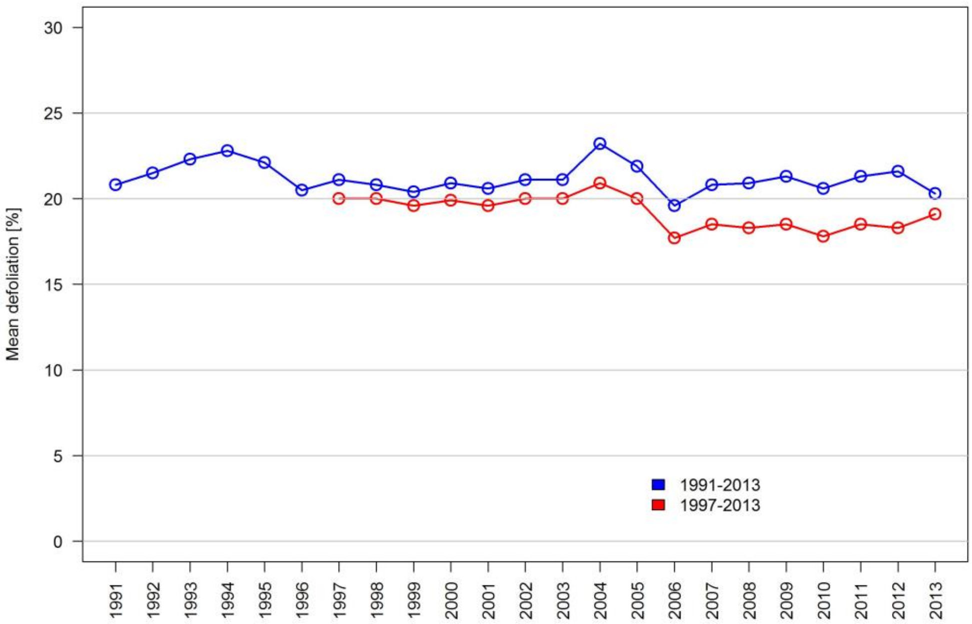


Figure 3-17: Mean defoliation of *Picea abies* in periods 1991–2013 and 1997–2013

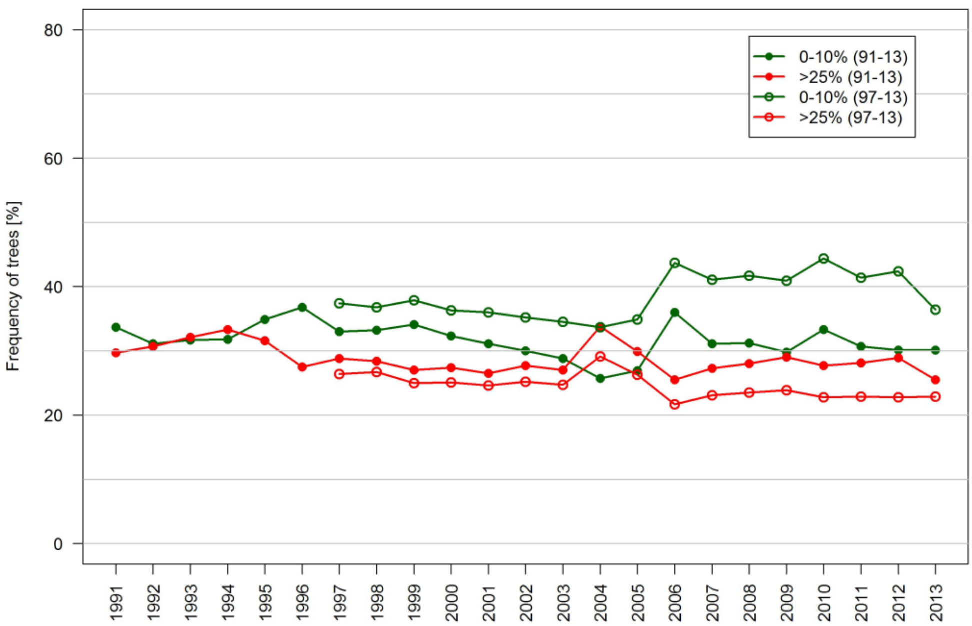


Figure 3-18: Share of *Picea abies* in defoliation classes 0–10% and >25% in periods 1991–2013 and 1997–2013

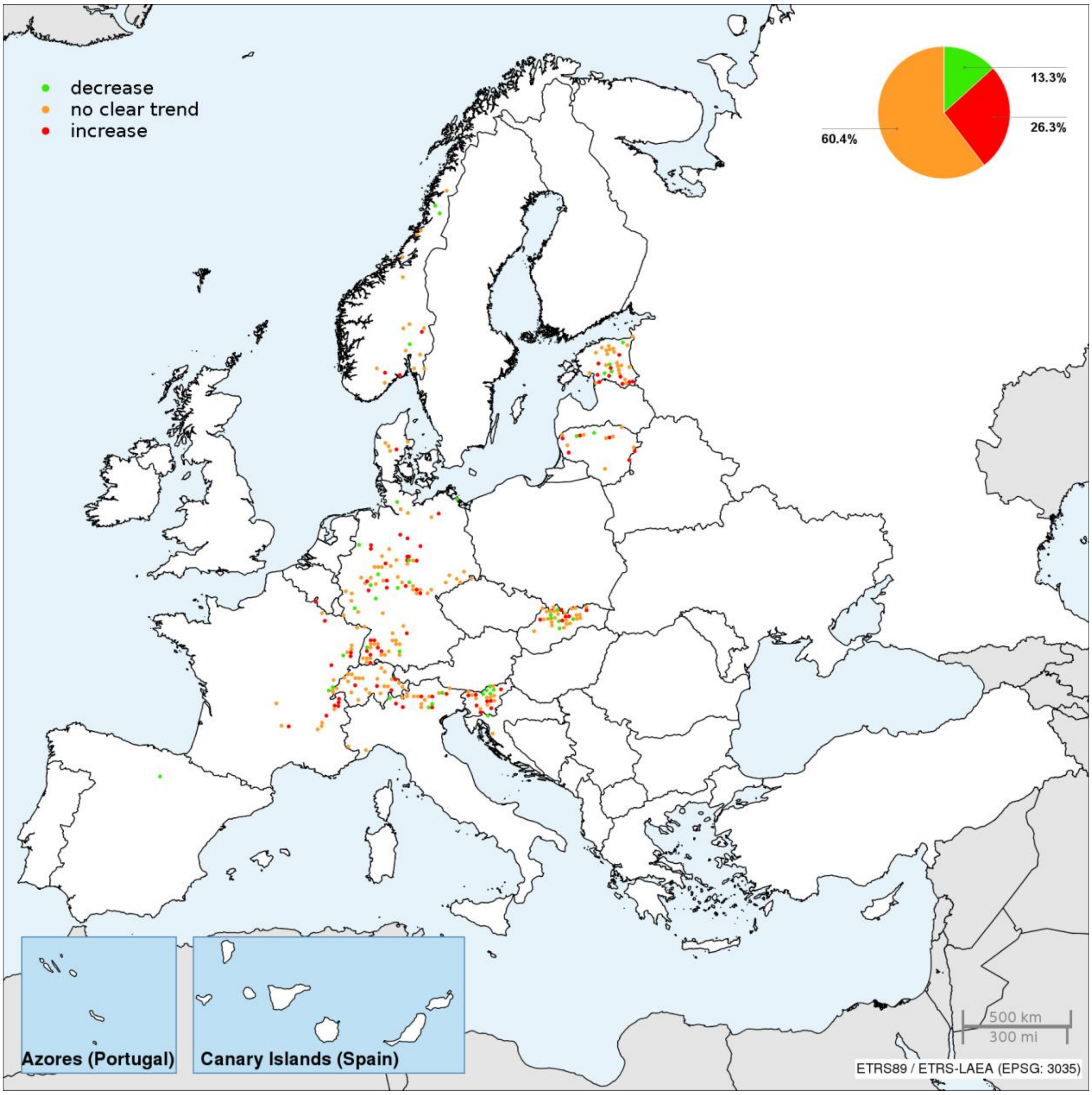


Figure 3-19: Trend of mean plot defoliation (slope of linear regression) of *Picea abies* in 2002–2013

3.2.2.4 Mediterranean lowland pines

Three pine species belong to the group of Mediterranean lowland pines: *P. pinaster*, *P. halepensis* and *P. pinea*. These tree species are characterized by a pronounced and continuous increase in mean defoliation since 1991 (Fig. 3-20). This is also evident from the decline in healthy trees. Their share dropped from about 73.1% in 1991 to 20.1% in 2013 (Tab. 3-11, Fig. 3-21). The lowest share of undamaged trees (18.2%) was recorded in 2009. A peak was identified in 2011. In contrast to the share of healthy trees, the share of damaged trees rose but less pronounced than the share of healthy trees declined.

The share of plots showing deterioration (18.6%) exceeded the share of plots on which the mean defoliation decreased between 2002 and 2013 (11.7%). The plots with worsened tree condition are mainly located in the south of France along the Mediterranean coast as well as along the Atlantic coast (Fig. 3-22).

Table 3-11: Share of Mediterranean lowland pines in different defoliation classes

	1991–2013				1997–2013			
	n trees	**0–10%**	**>10–25%**	**>25%**	**n trees**	**0–10%**	**>10–25%**	**>25%**
1991	3737	73.1	20.8	6.1				
1992	3845	64.1	24.3	11.7				
1993	3871	60.5	27.0	12.5				
1994	3782	50.4	32.8	16.8				
1995	3804	39.2	43.9	16.9				
1996	3796	36.7	45.3	17.9				
1997	3751	40.3	48.3	11.4	3926	38.5	46.4	15.1
1998	3807	37.2	47.3	15.6	3920	37.6	46.5	16.0
1999	5177	40.9	47.6	11.6	5289	40.1	47.6	12.3
2000	5255	39.2	48.5	12.3	5344	38.7	48.5	12.8
2001	5264	34.1	54.4	11.5	5353	33.6	54.2	12.3
2002	5259	29.6	55.7	14.6	5324	29.3	55.5	15.2
2003	5194	27.4	56.5	16.1	5259	27.1	56.1	16.8
2004	5214	28.7	55.2	16.1	5327	28.2	54.6	17.2
2005	5178	20.8	56.0	23.2	5269	20.5	55.3	24.2
2006	5179	21.3	56.6	22.0	5268	21.1	55.9	23.1
2007	5217	22.9	57.1	20.0	5282	22.7	56.7	20.6
2008	5223	21.3	60.5	18.2	5288	21.1	60.2	18.8
2009	5081	18.2	61.0	20.8	5146	18.0	60.5	21.6
2010	5059	23.2	58.7	18.0	5124	23.1	58.3	18.7
2011	5062	27.9	55.9	16.2	5223	28.1	55.4	16.4
2012	4956	19.2	63.7	17.1	5117	19.6	62.4	17.8
2013	4943	20.1	62.8	16.7	5104	20.7	61.7	17.3

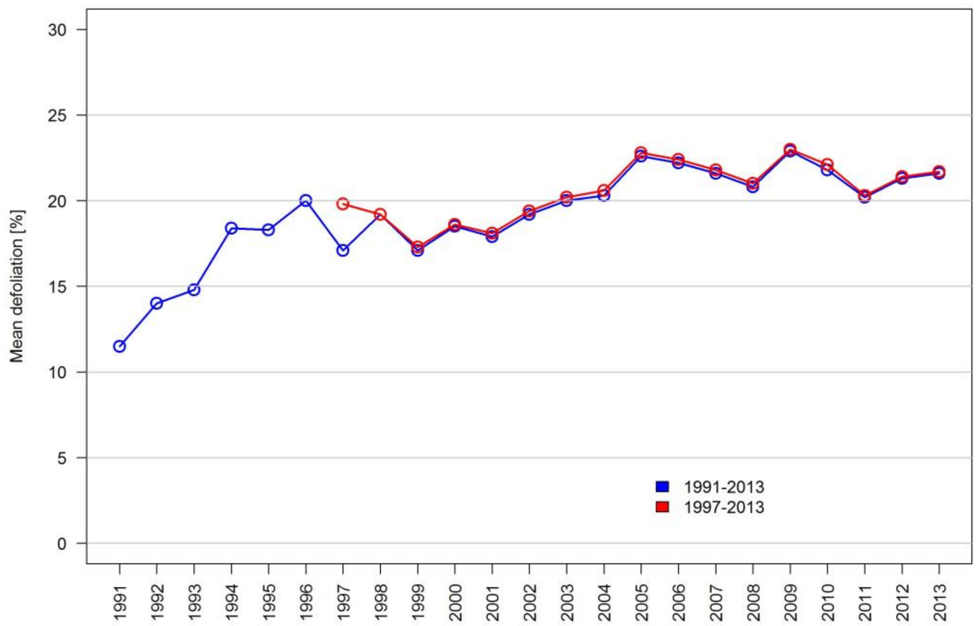


Figure 3-20: Mean defoliation of Mediterranean lowland pines in the periods 1991–2013 and 1997–2013

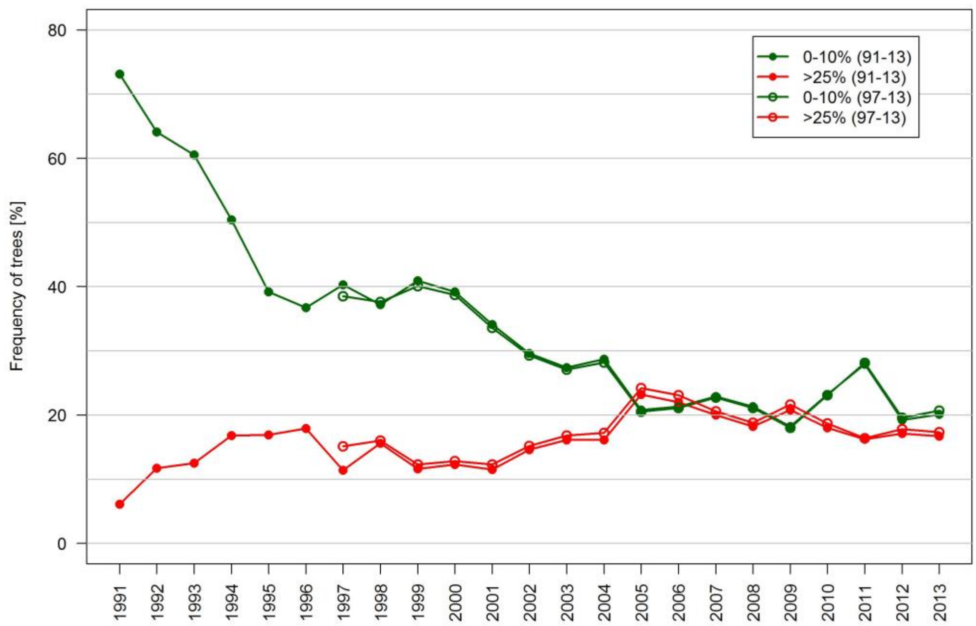


Figure 3-21: Share of Mediterranean lowland pines in defoliation classes 0–10% and >25% in periods 1991–2013 and 1997–2013

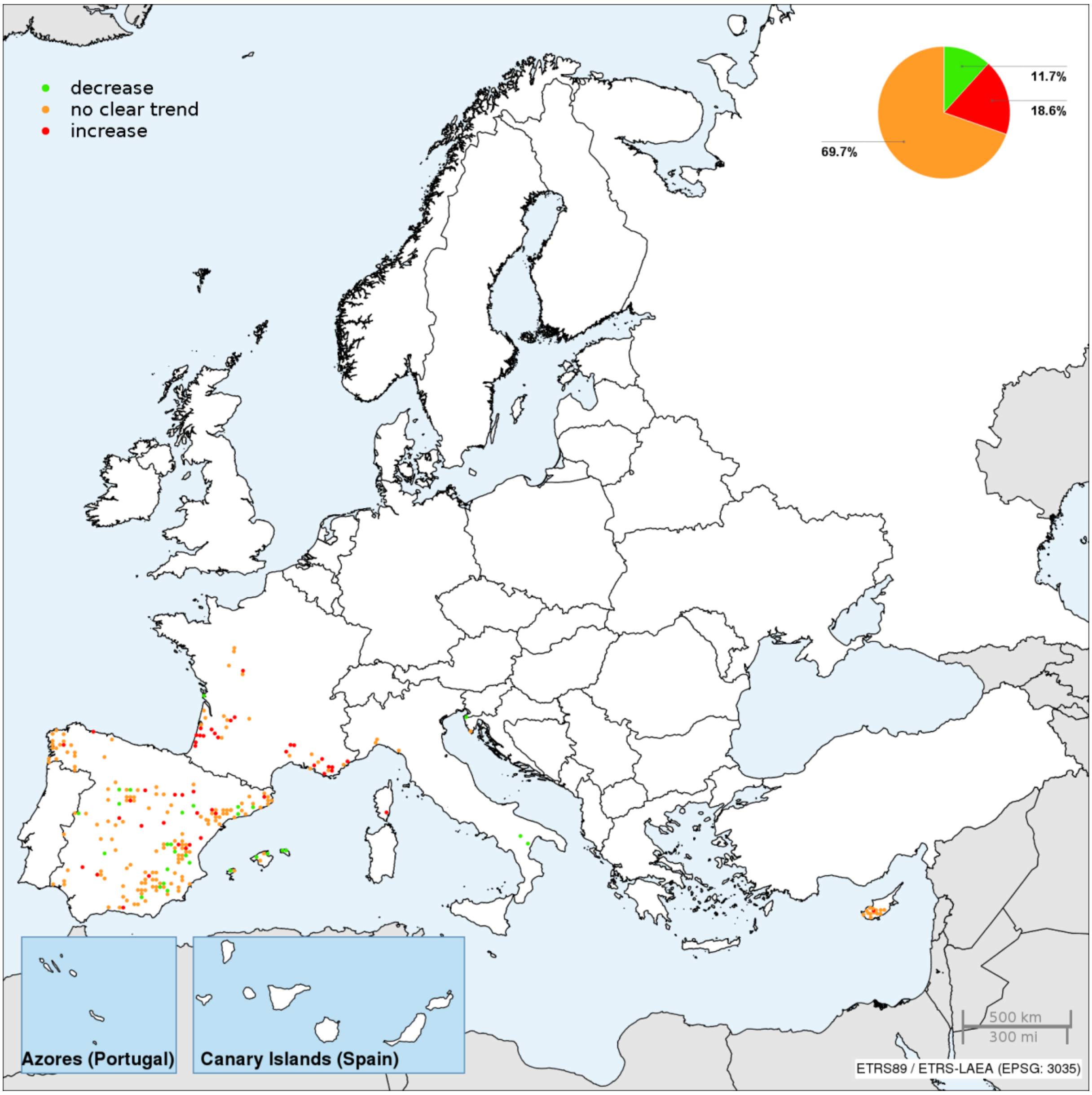


Figure 3-22: Trend of mean plot defoliation (slope of linear regression) of Mediterranean lowland pines in 2002–2013

3.2.2.5 *Fagus sylvatica*

Fagus sylvatica is the most frequently observed deciduous tree species on Level I plots. The area of its occurrence ranges from southern Scandinavia to Sicily and from the northern coast of Spain to Bulgaria.

Since the beginning of the study mean defoliation of this tree species increased slightly. The highest mean defoliation was recorded in the year 2004 often linked to the hot and dry summer of 2003 in central Europe (Fig. 3-23). Between 1991 and 2004 the percentage of healthy trees (0–10%) diminished from 50.9% to 17.6% whereas the percentage of damaged trees increased from 15.6% to 35.1% (Tab. 3-12, Fig. 3-24). After 2004 defoliation values of common beech alternated from year to year. The increases in 2009 and 2011 were ascribed to widespread exceptionally high fructification incidences. In 2013, 23.1% of the trees were classified as healthy and 31.3% as damaged.

In the period from 2002 to 2013, the share of plots with decreasing defoliation (9.4%) was lower than that with increasing defoliation (23.0%) (Fig. 3-25). Clusters of plots with high defoliations were observed in Slovenia, Croatia, southern and eastern France, and Slovakia.

Table 3-12: Share of *Fagus sylvatica* in different defoliation classes

	1991–2013				1997–2013			
	n trees	0–10%	>10–25%	>25%	n trees	0–10%	>10–25%	>25%
1991	6046	50.9	33.5	15.6				
1992	5941	43.8	35.2	20.9				
1993	6079	45.4	34.7	19.9				
1994	5993	42.2	36.5	21.3				
1995	6176	35.3	38.3	26.3				
1996	6156	33.0	45.4	21.6				
1997	6003	29.0	47.0	24.0	6827	32.3	44.7	23.0
1998	6310	32.2	45.5	22.3	7159	35.3	43.9	20.8
1999	6886	25.5	49.7	24.8	7780	29.0	47.9	23.1
2000	6922	29.2	46.7	24.1	7830	32.2	45.4	22.3
2001	6977	25.2	47.7	27.1	7887	27.9	46.3	25.8
2002	6956	25.8	50.4	23.8	7836	29.1	48.8	22.1
2003	6923	23.2	50.2	26.7	7820	26.5	48.9	24.6
2004	7008	17.6	47.3	35.1	7882	20.9	46.8	32.3
2005	7072	23.4	47.7	28.9	7972	26.0	47.2	26.9
2006	6545	25.8	44.7	29.6	7469	28.3	44.4	27.3
2007	6701	22.5	50.6	26.8	7600	24.4	50.0	25.5
2008	6697	28.6	49.1	22.3	7647	30.2	48.3	21.5
2009	6548	24.3	43.8	31.8	7476	26.1	43.9	29.9
2010	6866	25.9	47.6	26.4	7813	26.5	48.1	25.3
2011	6998	21.3	41.8	34.7	7926	22.9	42.1	33.1
2012	6515	26.1	43.9	28.1	7473	26.7	44.7	26.9
2013	6495	23.1	42.7	31.3	7461	23.4	43.8	30.1

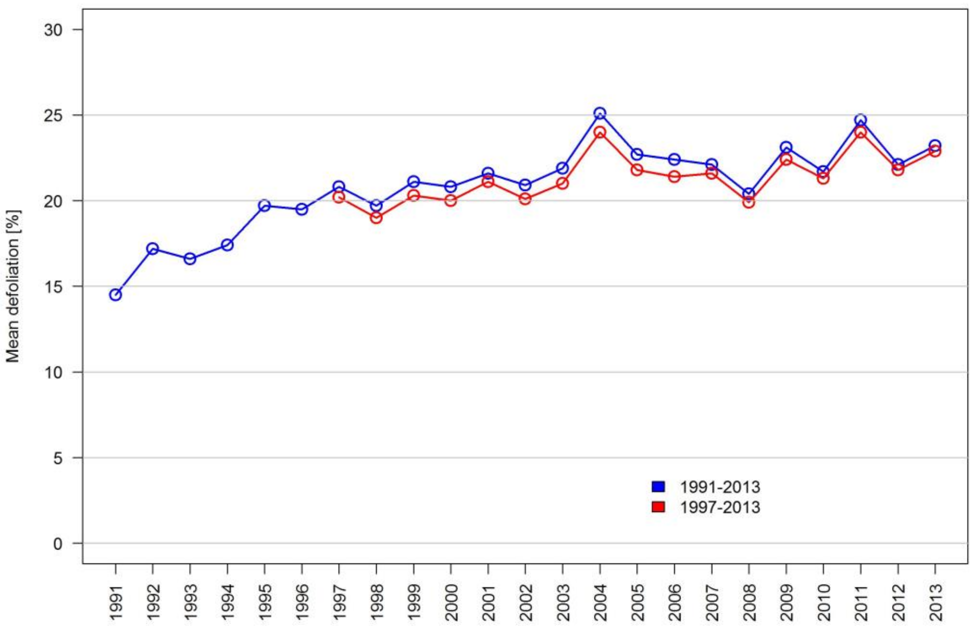


Figure 3-23: Mean defoliation of *Fagus sylvatica* in periods 1991–2013 and 1997–2013

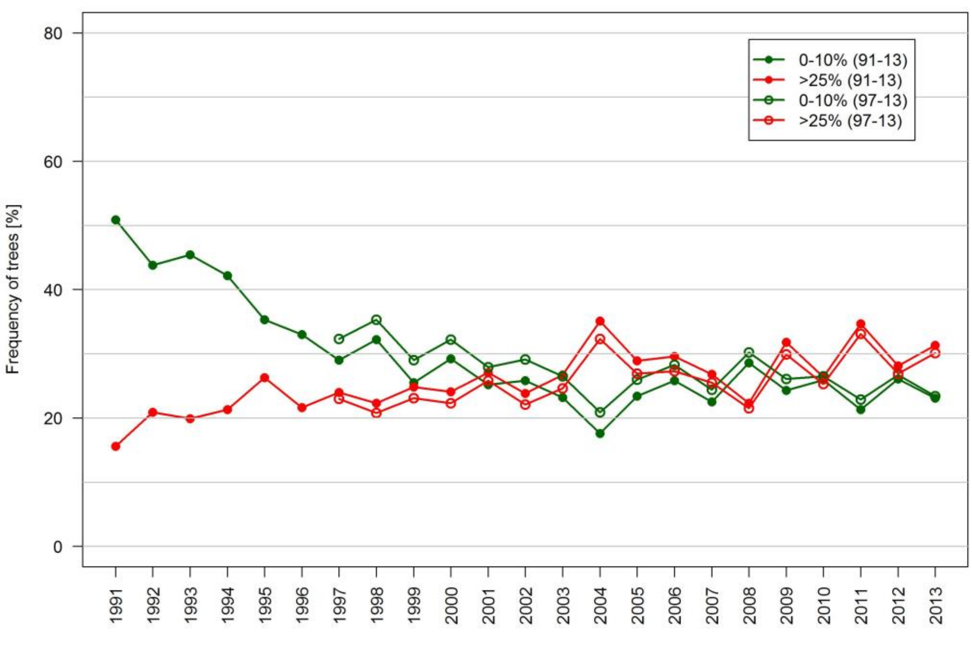


Figure 3-24: Share of *Fagus sylvatica* in defoliation classes 0–10% and >25% in periods 1991–2013 and 1997–2013

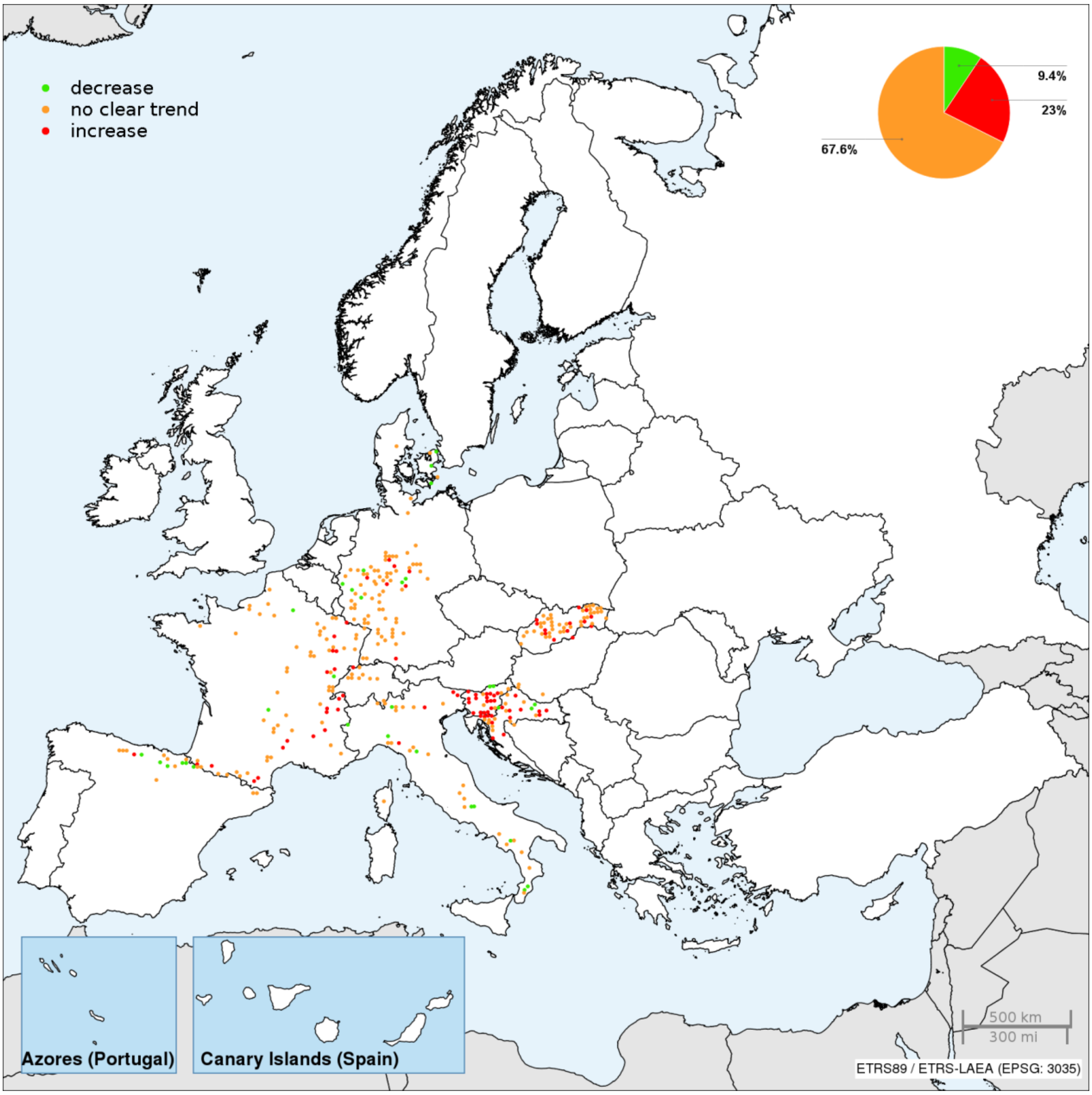


Figure 3-25: Trend of mean plot defoliation (slope of linear regression) of *Fagus sylvatica* in 2002–2013

3.2.2.6 Deciduous temperate oaks

The group of deciduous temperate oaks includes *Quercus robur* and *Q. petraea* occurring throughout central Europe.

Temporal development of these tree species is characterized by an increase in defoliation from 1991 to 1997 followed by a period when defoliation values fluctuated with no clear trend. Besides 1997, peaks were observed in 2004, 2005, and 2012 (Fig. 3-26). The share of healthy trees decreased notably from 1991 (48.5%) to 1997 (16.4%) and stayed on a similar level until 2013 (17.9%) while the share of damaged trees displayed the opposing trend (Tab. 3-13, Fig. 3-27).

No clear linear trend was found on 72.9% of the plots in the time period 2002–2013 (Fig. 3-28). An increase in mean defoliation was observed on 18% of the plots and a decrease on only 9.1% of the plots. A cluster of plots showing a decreasing trend of mean defoliation occurred in central France. Plots with increasing defoliation were found across all countries.

Table 3-13: Share of deciduous temperate oaks in different defoliation classes

	1991–2013				1997–2013			
	n trees	0–10%	>10–25%	>25%	n trees	0–10%	>10–25%	>25%
1991	5058	48.5	31.2	20.4				
1992	4997	43.4	34.9	21.7				
1993	4959	38.3	34.4	27.3				
1994	4994	36.9	33.4	29.6				
1995	5088	34.0	36.1	29.9				
1996	5072	25.2	39.4	35.4				
1997	5083	16.4	42.9	40.7	5601	16.9	42.9	40.3
1998	5225	19.5	42.4	38.0	5802	19.6	42.3	38.1
1999	5285	19.6	48.2	32.2	5909	20.1	47.8	32.0
2000	5324	20.6	48.5	30.9	5912	20.9	48.2	30.9
2001	5319	18.4	49.6	32.0	5912	19.1	49.5	31.4
2002	5337	17.9	50.9	31.2	5932	18.6	51.0	30.4
2003	5344	14.2	47.1	38.7	5938	15.2	47.6	37.2
2004	5456	14.7	44.8	40.5	6066	15.9	45.1	39.0
2005	5460	13.4	43.7	42.9	6111	14.9	43.6	41.5
2006	4935	17.0	46.0	36.9	5582	19.5	45.3	35.3
2007	5027	15.7	47.5	36.8	5676	18.1	46.6	35.3
2008	5197	16.1	48.3	35.6	5876	17.9	47.5	34.5
2009	5138	18.3	47.0	34.7	5802	20.0	46.3	33.8
2010	5201	16.3	48.1	35.5	5834	18.3	46.9	34.7
2011	5364	17.2	47.0	34.9	6034	19.2	45.8	34.3
2012	5288	12.9	41.9	44.3	6010	15.4	41.1	42.8
2013	5353	17.9	43.0	36.9	6076	19.5	41.9	36.5

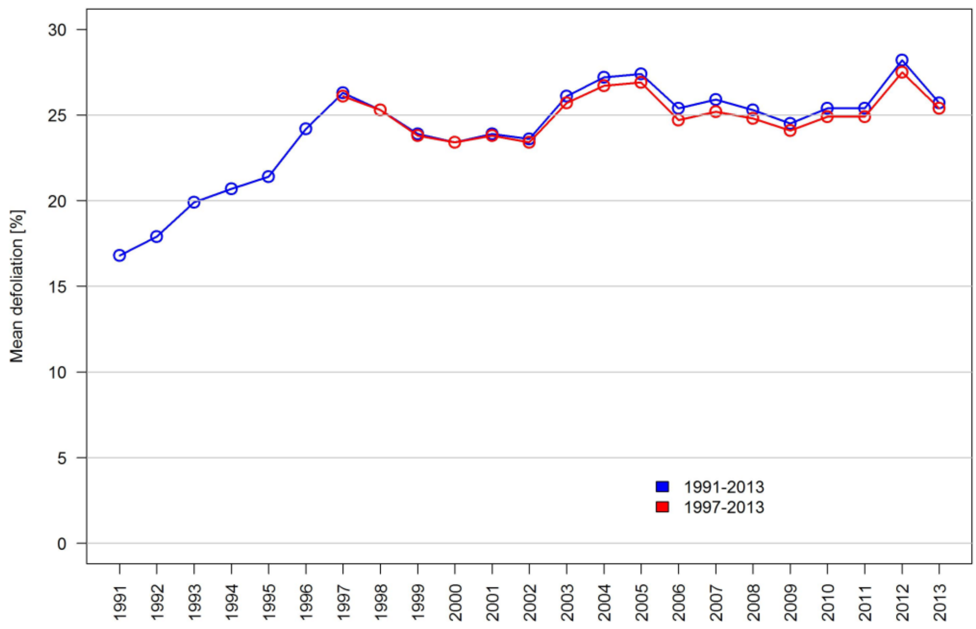


Figure 3-26: Mean defoliation of deciduous temperate oaks in periods 1991–2013 and 1997–2013

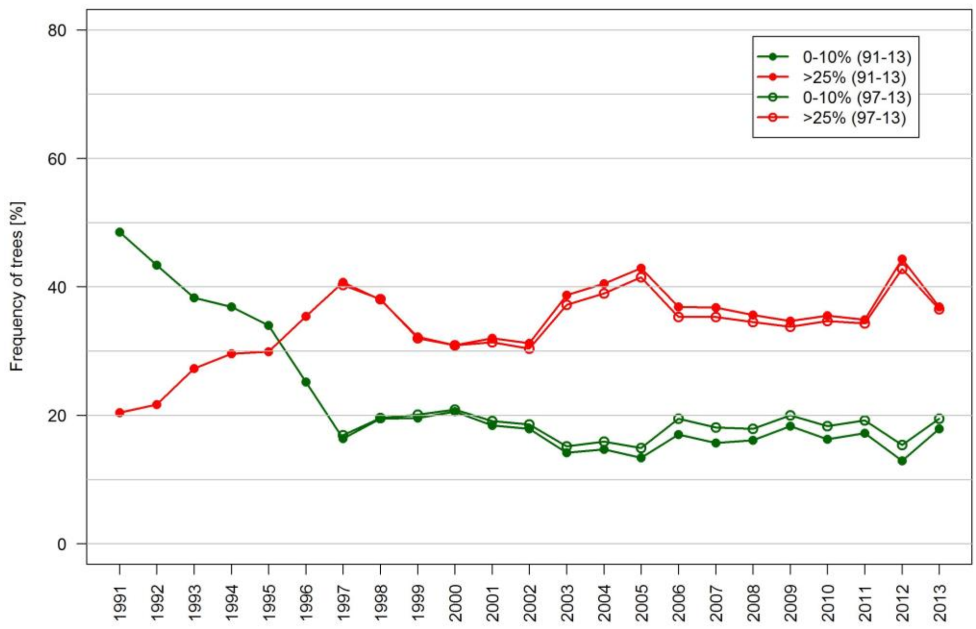


Figure 3-27: Share of deciduous temperate oaks in defoliation classes 0–10% and >25% in periods 1991–2013 and 1997–2013

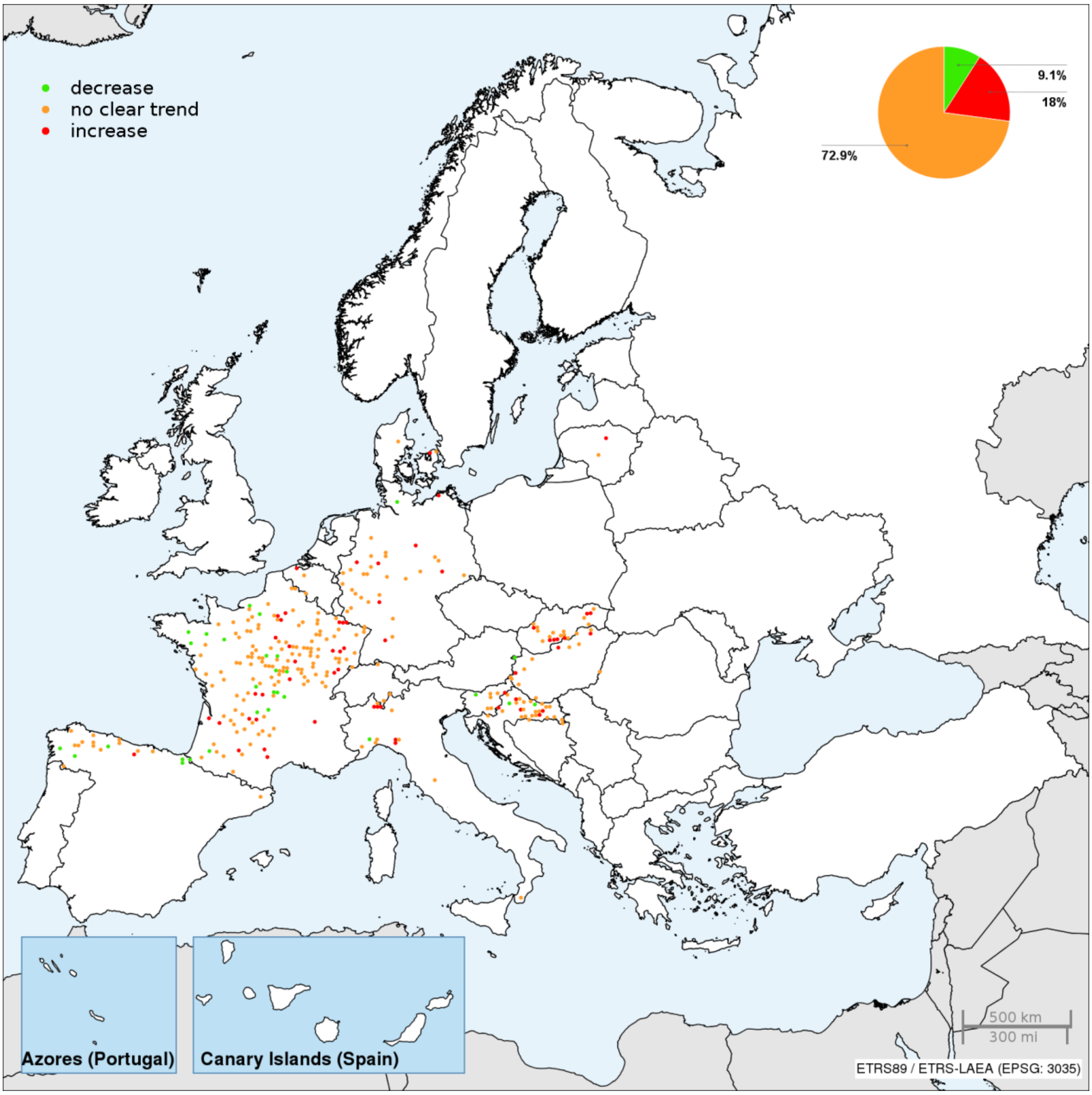


Figure 3-28: Trend of mean plot defoliation (slope of linear regression) of deciduous temperate oak species in 2002–2013

3.2.2.7 Deciduous (sub-) Mediterranean oaks

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

Mean defoliation of these oaks deteriorated dramatically until 2001 (Fig. 3-29) while in the following years no clear trend was observed. Consequently, the share of healthy trees notably decreased from 57.3% in 1991 to 16.6% in 2003 and levelled off in the following years (Tab. 3-14, Fig. 3-30. In 2013, 15.3% of the trees were classified as healthy but 30.9% as damaged.

The spatial distribution showed an increase in defoliation on 23.6% of all plots distributed over southern Europe (Fig. 3-31). However, a cluster occurred ranging from northern Spain to southern and south-eastern France. Decreasing defoliation rates of the four oak species were identified on 16.3% plots. These plots were mainly found in Italy and north-western Spain.

Table 3-14: Share of deciduous (sub-) Mediterranean oaks in different defoliation classes

	1991–2013				1997–2013			
	n trees	0–10%	>10–25%	>25%	n trees	0–10%	>10–25%	>25%
1991	3057	57.3	30.5	12.3				
1992	3102	54.2	32.9	12.9				
1993	3096	53.0	31.7	15.3				
1994	3062	49.3	33.0	17.7				
1995	3112	47.3	35.0	17.7				
1996	3159	30.4	43.7	25.9				
1997	2997	26.9	42.6	30.5	3248	25.4	41.4	33.2
1998	3030	26.0	41.8	32.2	3288	26.0	41.7	32.3
1999	3623	24.7	46.3	29.0	3813	25.0	46.2	28.8
2000	3591	22.4	46.9	30.7	3786	22.5	47.2	30.3
2001	3632	20.2	45.0	34.9	3822	20.1	45.2	34.7
2002	3545	18.2	46.1	35.7	3711	17.7	46.7	35.5
2003	3462	16.6	46.3	37.1	3625	16.1	47.0	36.9
2004	3569	16.2	48.9	34.9	3753	16.4	49.0	34.7
2005	3527	18.4	48.8	32.8	3711	18.4	48.6	33.1
2006	3530	17.4	46.3	36.2	3732	17.6	45.5	36.9
2007	3533	14.9	49.4	35.7	3740	15.1	48.4	36.5
2008	3553	16.1	50.3	33.6	3725	16.1	49.4	34.5
2009	3558	16.2	50.1	33.7	3753	16.1	49.4	34.5
2010	3914	19.3	48.9	31.8	4090	19.7	48.6	31.7
2011	4028	17.9	45.6	33.7	4261	18.5	45.4	33.4
2012	3280	15.0	44.5	35.8	3525	15.1	44.0	36.5
2013	3293	15.3	48.5	30.9	3636	15.6	48.0	31.5

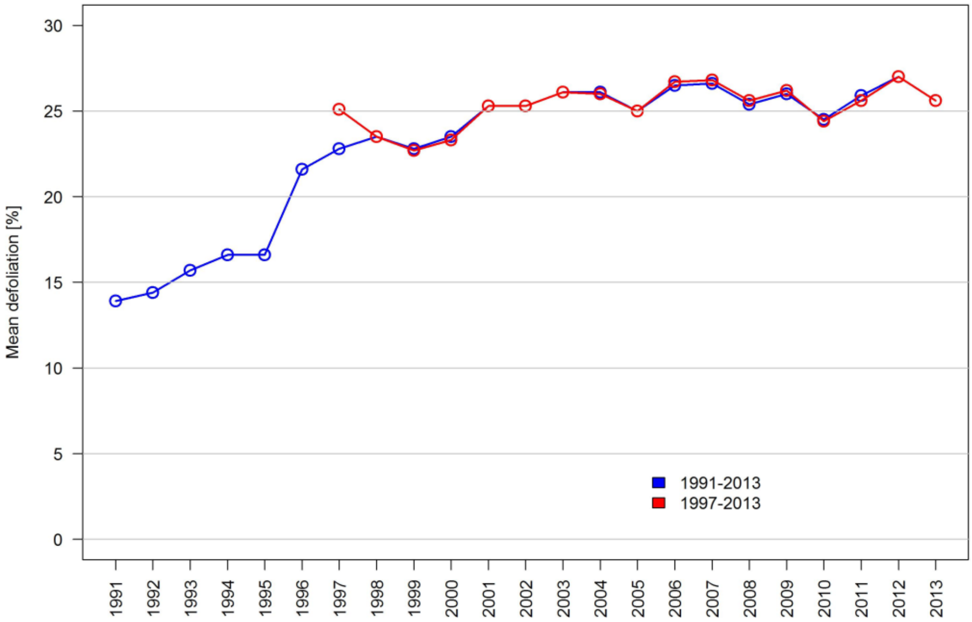


Figure 3-29: Mean defoliation of deciduous (sub-) Mediterranean oaks in periods 1991–2013 and 1997–2013

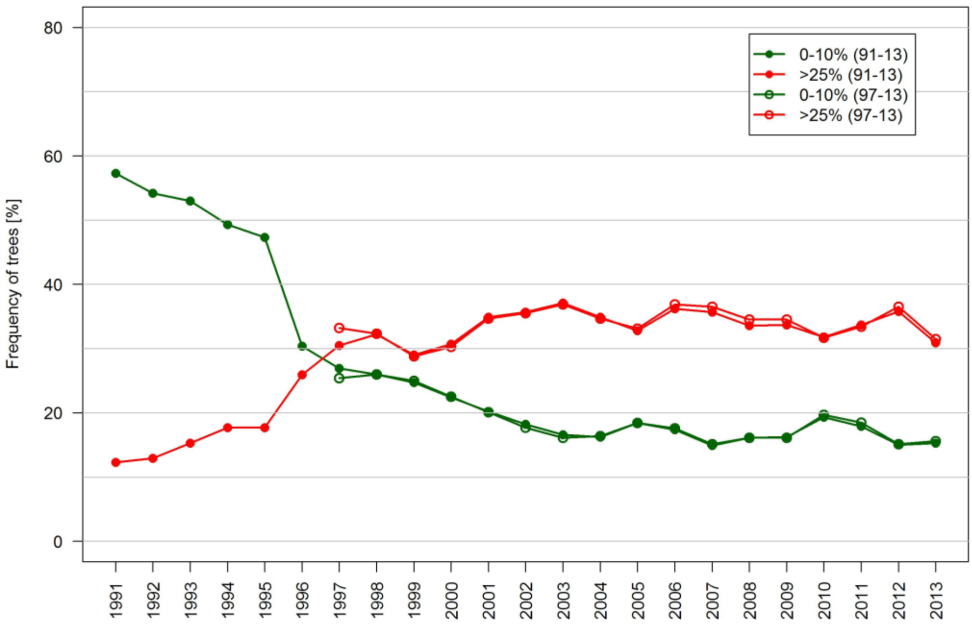


Figure 3-30: Share of deciduous (sub-) Mediterranean oaks in defoliation classes 0–10% and >25% in periods 1991–2013 and 1997–2013

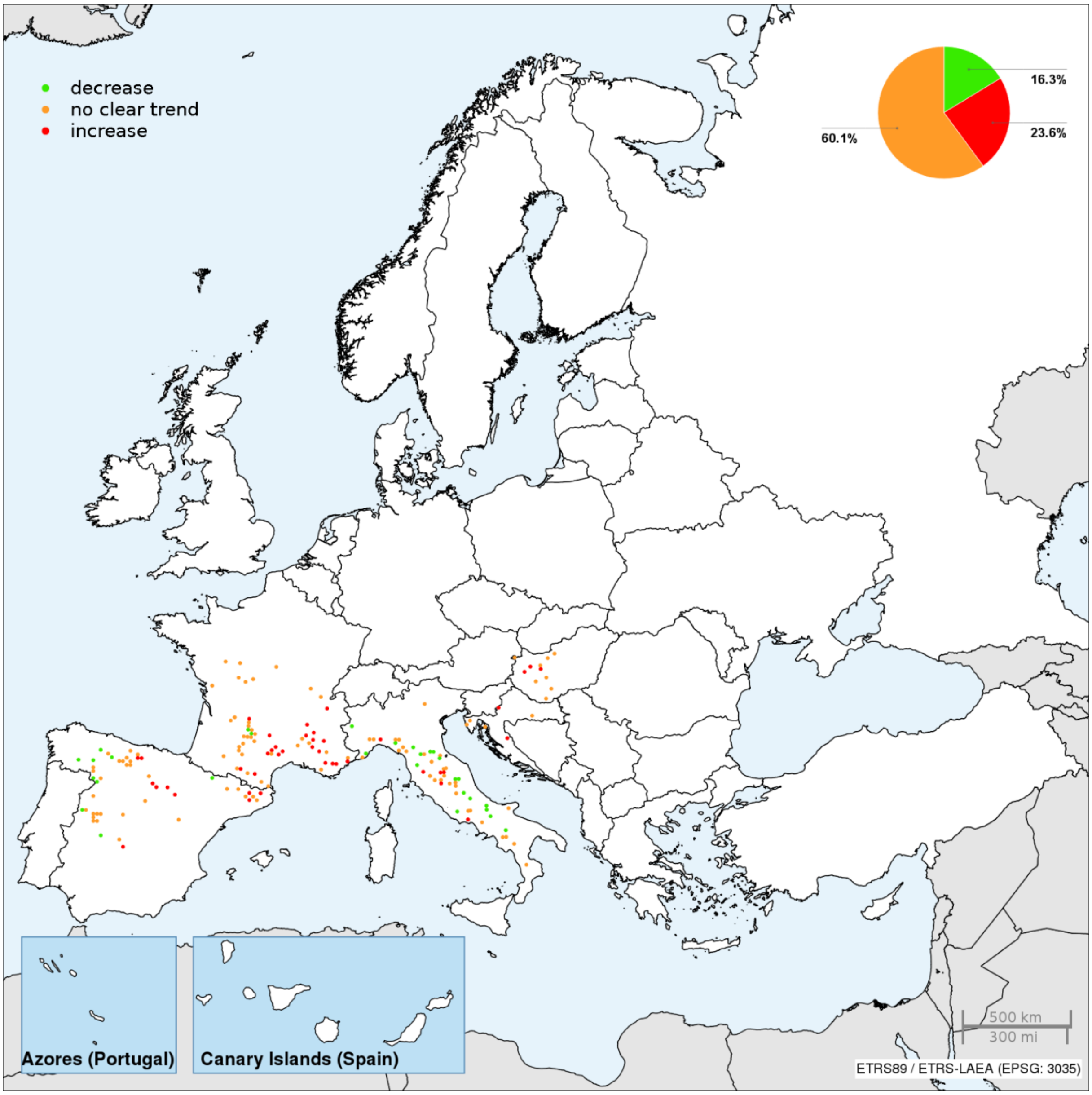


Figure 3-31: Trend of mean plot defoliation (slope of linear regression) of deciduous (sub-) Mediterranean oaks in 2002–2013

3.2.2.8 Evergreen oaks

The group of evergreen oaks includes *Quercus coccifera*, *Q. ilex*, *Q. rotundifolia*, and *Q. suber*. The results presented in Tab. 3-15 are similar in both time periods because the composition of plots only marginally differed.

In the early 1990s, at the beginning of the study, the mean defoliation of evergreen oaks was less than 15%, which corresponded to a high percentage of healthy trees (59.7% in 1991) (Figure 3-32, Figure 3-33). Until 1995 defoliation strongly increased up to 25% and the share of healthy trees decreased. Mean defoliation estimates slightly declined after 1995, stayed on a relatively constant level from 1999 to 2011, and then notably increased over 25% in 2012. The share of damaged trees (> 25%) also showed three peaks: in 1995 (32.5%), in 2005 (27.9%) and in 2012 (30.1%). In 2013 the share of damaged trees was still high with 27.6% and only 7.4% of the trees were classified as healthy.

The majority of plots with evergreen oaks were located in Spain with a few in southern France and along the western coast of Italy. The share of evergreen oaks with deteriorating trends between 2002 and 2013 was 14.0% whereas the percentage of plots with increasing trends was 19.3% (Figure 3-34). An increase in mean defoliation was detected all over Spain and in southern France.

Table 3-15: Share of evergreen oaks in different defoliation classes

	1991–2013				1997–2013			
	n trees	0–10%	>10–25%	>25%	n trees	0–10%	>10–25%	>25%
1991	3187	59.7	36.1	4.3				
1992	3325	47.2	44.5	8.3				
1993	3278	41.5	51.0	7.5				
1994	3253	31.3	52.6	16.1				
1995	3293	18.9	48.6	32.5				
1996	3272	17.8	53.6	28.5				
1997	3274	22.1	58.2	19.7	3322	21.9	57.8	20.3
1998	3232	28.5	56.1	15.5	3256	28.3	56.2	15.5
1999	4194	21.6	57.0	21.4	4218	21.6	57.2	21.3
2000	4268	19.1	60.5	20.4	4292	19.0	60.3	20.7
2001	4284	19.8	62.7	17.5	4308	19.7	62.8	17.4
2002	4268	16.1	62.8	21.0	4292	16.1	63.0	20.9
2003	4175	14.0	62.3	23.6	4199	13.9	62.5	23.5
2004	4240	17.7	63.4	18.9	4288	17.5	63.8	18.7
2005	4189	9.7	62.4	27.9	4237	9.7	62.4	27.9
2006	4195	8.7	64.1	27.3	4243	8.6	64.0	27.4
2007	4283	10.0	67.5	22.4	4331	10.3	67.4	22.4
2008	4302	11.6	67.3	21.1	4326	11.9	67.1	21.0
2009	4312	10.9	67.1	22.0	4336	11.3	66.8	21.9
2010	4410	17.1	62.5	20.4	4458	17.2	62.1	20.7
2011	4446	19.6	62.1	18.0	4518	19.8	61.7	18.3
2012	4293	9.2	60.3	30.1	4380	9.9	59.6	30.1
2013	4309	7.4	64.7	27.6	4396	8.1	64.2	27.4

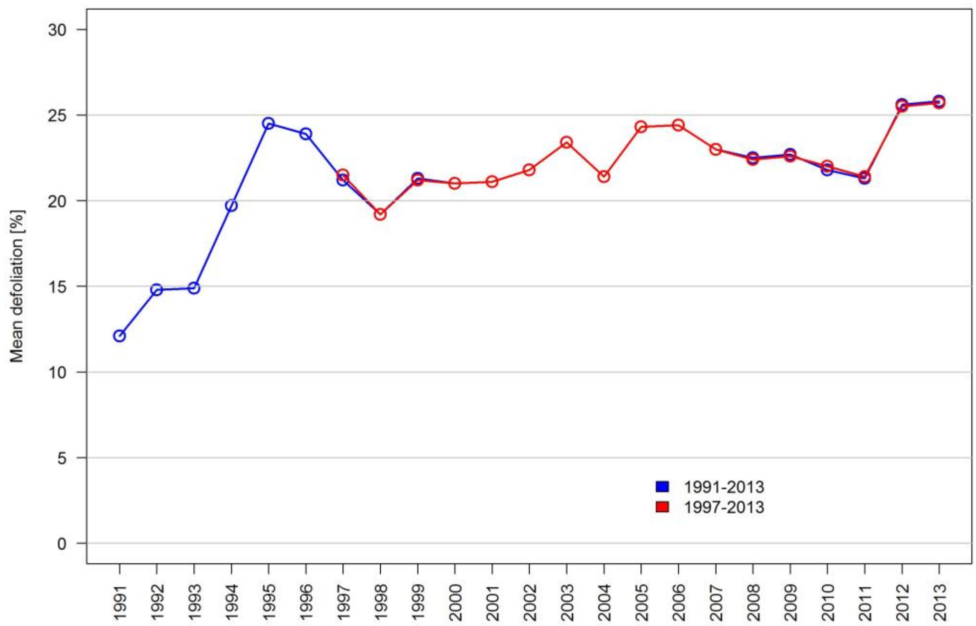


Figure 3-32: Mean defoliation of evergreen oaks in periods 1991–2013 and 1997–2013

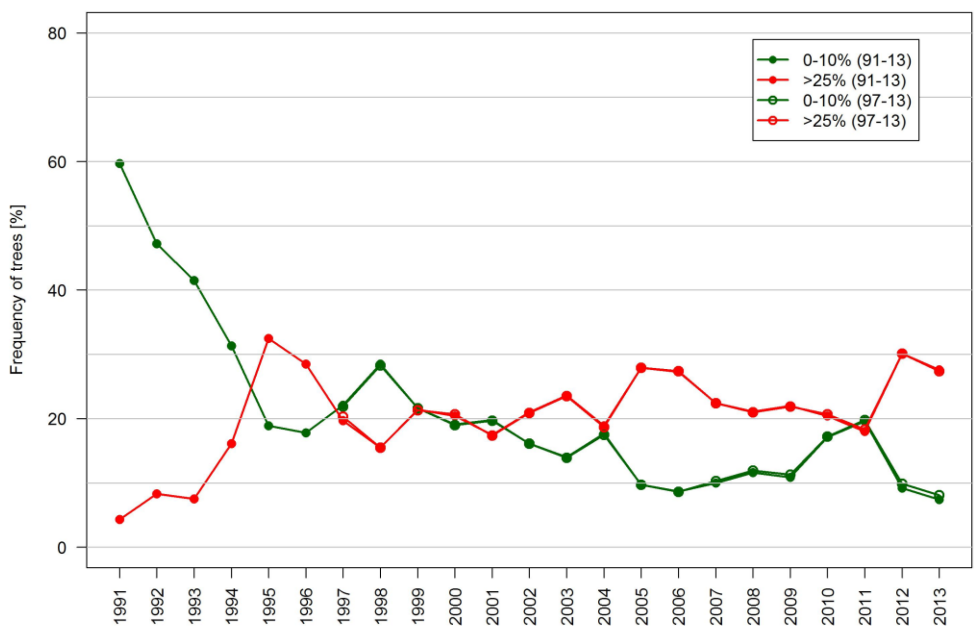


Figure 3-33: Share of evergreen oaks in defoliation classes 0–10% and >25% in periods 1991–2013 and 1997–2013

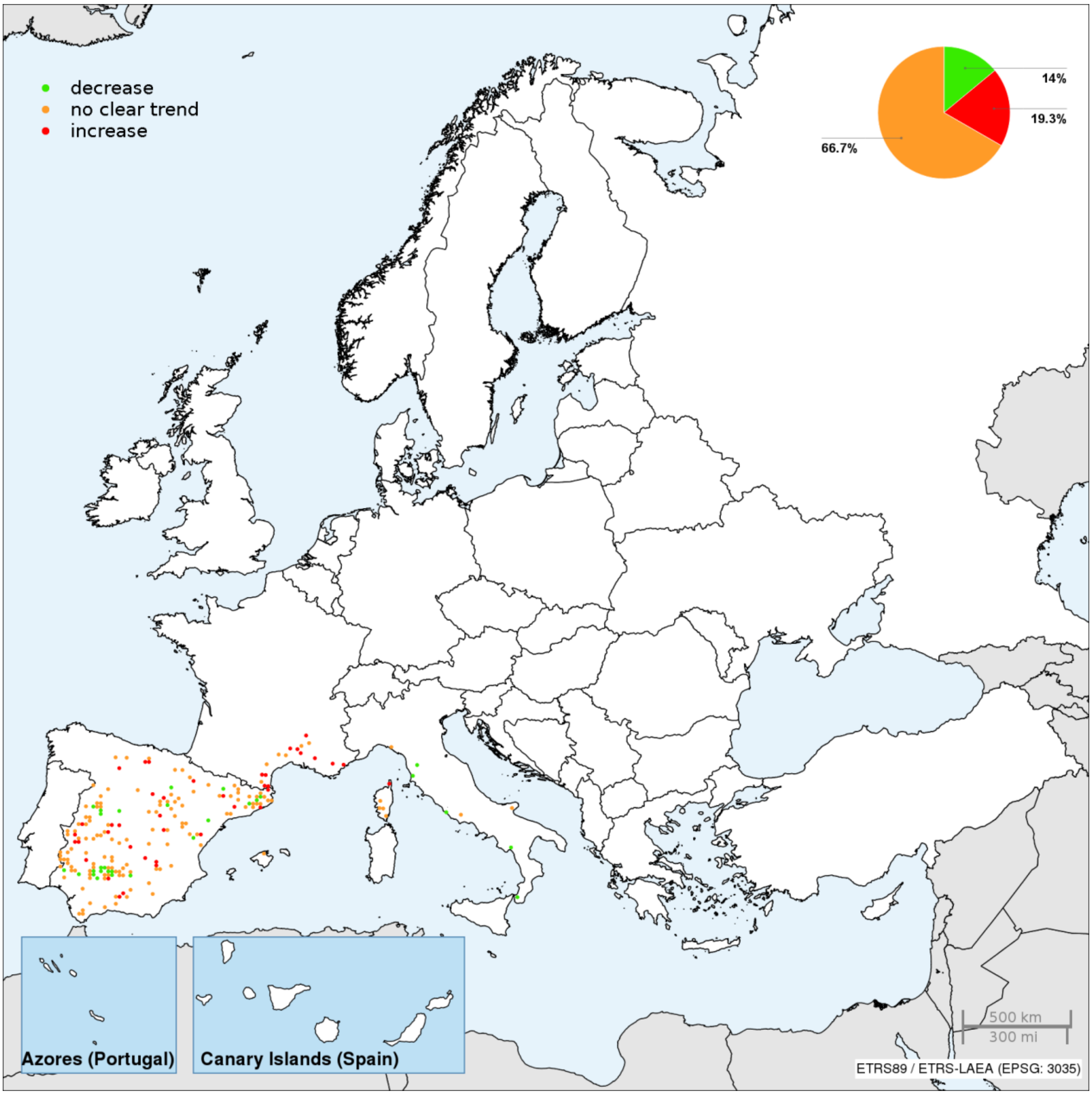


Figure 3-34: Trend of mean plot defoliation (slope of linear regression) of evergreen oaks in 2002–2013

3.3 Damage cause assessment

Crown condition is the most widely applied indicator for forest health and vitality in Europe. In order to interpret crown condition estimates accurately, it is necessary to also assess tree parameters that have an influence on tree vitality such as damage caused by biotic and abiotic factors. Through the assessment of damage and their influence on crown condition, it is possible to draw conclusions on cause-and-effect mechanisms. Since 2005, tree crowns on Level I plots have been examined based on an amended set of methods for damage assessment, which allows to obtain more information on injury symptoms, causes of damage, and the extent of an injury.

The aim of the damage cause assessment is to collect as much information as possible on the causal background of tree damage in order to enable a differential diagnosis and to better interpret the unspecific parameter ‘defoliation’.

3.3.1 Background of the survey in 2013

The assessment of damage causes is part of the visual assessment of crown condition, and all trees included in the crown condition sample (Level I plots) are regularly assessed for damage causes. In 2013, damage causes were assessed on 5527 plots in 24 different countries across Europe (Fig. 3-35, Tab. 3-16). A total of 122,760 damage causes were recorded. As a particular tree may be affected by more than one damage agent the total number of trees assessed for damage was 101,713.

Table 3-16: Number of sample plots assessed for damage causes

Country	2005	2006	2007	2008	2009	2010	2011	2012	2013
Andorra	0	3	3	3	3	3	3	3	11
Austria	136	135	0	0	0	135	0	0	0
Belgium	21	27	26	25	23	9	9	8	8
Belarus	403	398	339	320	330	328	324	0	373
Bulgaria	96	96	100	54	134	148	159	159	0
Croatia	33	32	0	0	0	0	0	0	0
Cyprus	15	15	15	15	15	15	15	15	15
Czech Republic	138	0	40	35	38	43	55	135	0
Denmark	0	0	0	0	16	17	18	18	18
Estonia	85	81	64	76	92	97	98	97	96
Finland	605	606	518	423	886	932	717	784	0
France	464	498	450	459	459	489	282	553	550
Germany	208	235	255	238	412	389	404	415	416
Greece	79	0	0	0	97	98	0	0	0
Hungary	73	73	0	0	73	71	71	74	68
Ireland	17	15	0	31	32	29	0	20	0
Italy	236	250	238	235	251	253	253	245	247
Latvia	65	93	93	92	77	81	115	115	115
Lithuania	48	50	49	54	63	69	71	77	79
Luxembourg	4	4	2	4	0	0	0	0	4
Montenegro	0	0	0	0	0	49	49	49	49
Netherlands	9	11	0	0	11	11	0	0	0
Norway	460	463	476	481	487	491	240	496	616
Poland	432	354	430	433	376	374	367	369	364
Portugal	88	6	0	0	0	0	0	0	0
Romania	66	61	157	0	227	239	242	241	236
Russian Fed.	0	0	0	0	336	279	283	0	0
Serbia	62	74	53	35	94	88	119	0	121

Country	2005	2006	2007	2008	2009	2010	2011	2012	2013
Slovakia	108	107	107	103	108	108	0	108	107
Slovenia	33	23	0	0	44	44	44	44	44
Spain	620	620	620	620	590	582	567	620	620
Sweden	784	748	0	0	857	370	640	609	740
Switzerland	20	19	18	23	31	31	33	46	47
Turkey	0	0	1	212	386	408	407	578	583
United Kingdom	84	82	0	0	0	70	0	0	0
Total Europe	5492	5179	4054	3972	6548	6350	5585	5878	5527

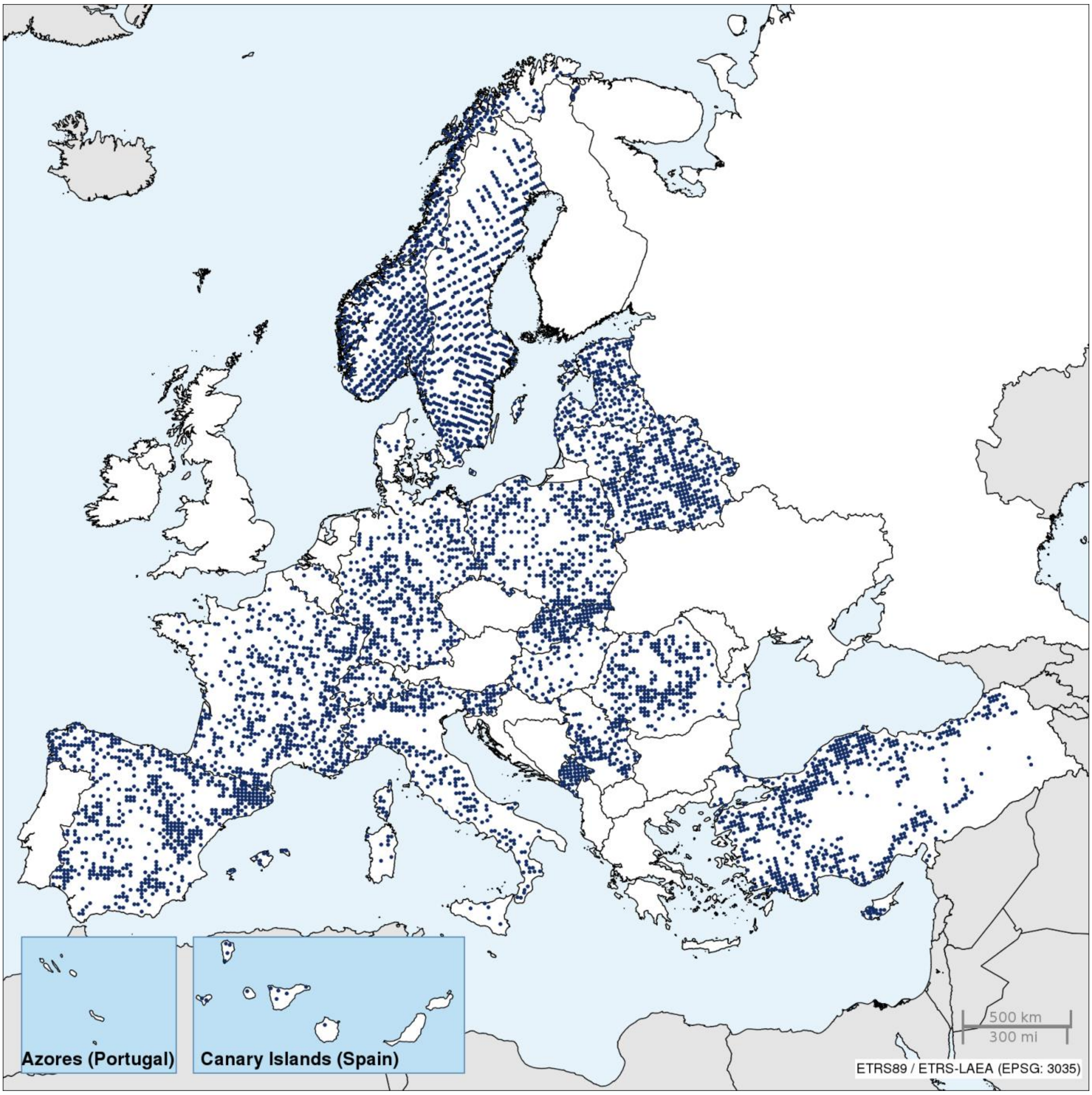


Figure 3-35: Plots with damage cause assessment in 2013

3.3.2 Assessment parameters

The damage assessment of trees is based on the ICP Forests Manual and includes three stages: symptom description, determination of causes, and quantification of the symptoms. Several damage symptoms can be described for each tree. The symptom description focuses on important factors that may have an influence on crown condition.

Table 3-17: Affected parts of a tree

Affected part	**Specification of affected part**	**Location in crown**
Leaves/needles	Current needle year Older needles Needles of all ages Broadleaves (incl. evergreen spec.)	Upper crown Lower crown Patches Total crown
Branches, shoots & buds	Current year shoots Twigs (diameter < 2 cm) Branches diameter 2 – < 10 cm Branches diameter ≥ 10 cm Varying size Top leader shoot Buds	Upper crown Lower crown Patches Total crown
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	
Dead tree	*see below*	
No symptoms on any part of tree	*see below*	
No assessment	*see below*	

Symptoms

Symptom description aims at describing visible damage causes for single trees. The description indicates affected parts of the assessed trees and the symptom type observed. Symptom description focuses on important factors that may have an influence on crown condition.

Three main categories are distinguished and indicate the affected part of a tree: (a) leaves/needles, (b) branches, shoots, & buds, and (c) stem & collar. For each affected tree area, further specification is required (Tab. 3-17). Symptoms are grouped into broad categories like wounds, deformations, necrosis etc. This allows a detailed description of the occurring symptoms.

Extent

The damage extent is classified in eight classes (Tab. 3-18). In trees with multiple types of damage (and thus multiple extent classes), all extent values are evaluated.

Causal agents

For each symptom description a causal agent must be determined which is crucial for the study of the cause-and-effect mechanisms. Causal agents are grouped into nine categories (Tab. 3-19). In each category a more detailed description is possible through a hierarchical coding system. In 2013, agent groups were identified for 40,516 trees (Tab. 3-20).

Table 3-18: Damage extent classes

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

Table 3-19: Main categories of causal agents

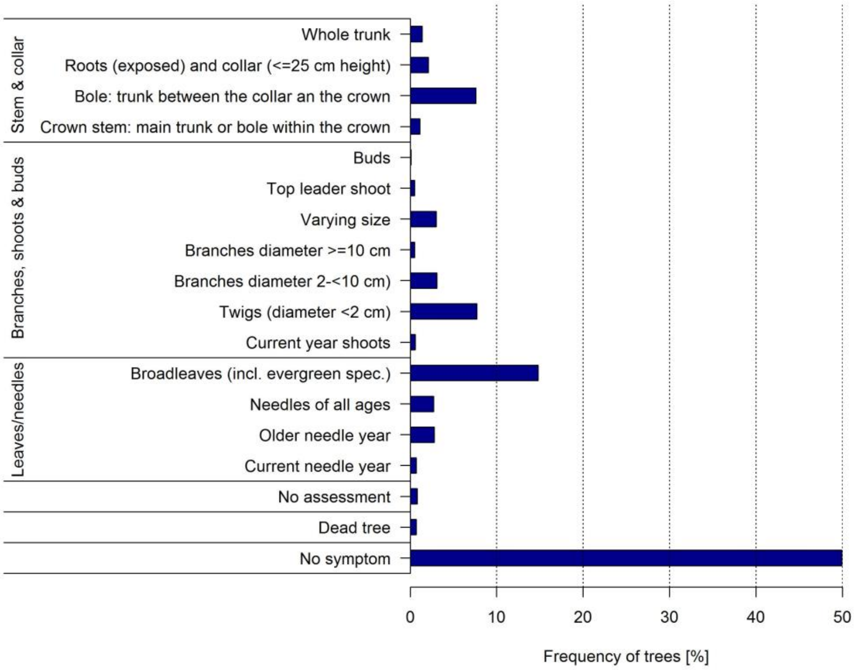
Agent group
Game and grazing
Insects
Fungi
Abiotic agents
Direct action of men
Fire
Atmospheric pollutants
Other factors
(Investigated but) unidentified

Table 3-20: Number of damaged sample trees with at least one defined agent group. In this overview trees with more than one agent group are only counted once.

Country	2005	2006	2007	2008	2009	2010	2011	2012	2013
Andorra	0	7	7	8	8	8	8	8	13
Austria	607	747	0	0	0	982	0	0	0
Belarus	1827	1628	1770	1393	1271	1276	1183	0	1072
Belgium	239	450	408	455	451	193	177	185	188
Bulgaria	1283	1231	1155	469	2563	2762	2461	3163	0
Croatia	257	256	0	0	0	0	0	0	0
Cyprus	255	248	234	321	341	310	268	320	323
Czech Republic	59	0	144	110	134	170	326	193	0
Denmark	0	0	0	0	86	94	88	75	11
Estonia	1013	1007	732	830	897	2068	1695	1616	1624
Finland	4261	4274	3278	2959	2310	2137	1204	1289	0
France	5385	6101	6259	5951	6107	6607	1943	5350	4597
Germany	2146	2216	2471	2000	2363	2115	2704	2754	2523
Greece	1023	0	0	0	2071	1983	0	0	0
Hungary	957	928	0	0	1225	1231	1281	1082	1358
Ireland	198	143	0	211	283	171	0	29	0
Italy	5346	5274	5232	5148	5468	6541	6592	4250	4043
Latvia	507	456	403	398	243	266	326	257	338
Lithuania	139	146	140	159	235	326	336	366	422
Luxembourg	70	41	6	20	0	0	0	0	44
Montenegro	0	0	0	0	0	626	653	757	662
Netherlands	111	0	0	0	75	86	0	0	0
Norway	792	973	1053	975	779	817	1000	691	925
Poland	3734	4215	4869	5102	4165	4179	4202	4030	4058
Portugal	1693	97	0	0	0	0	0	0	0
Romania	585	565	0	0	1623	1890	1240	1133	1086
Russian Fed.	0	0	0	0	3723	3475	3283	0	0
Serbia	856	1167	503	188	838	941	282	0	406
Slovakia	690	4229	3894	3907	4312	4211	0	4092	4027
Slovenia	312	185	0	0	765	799	778	780	767
Spain	9452	9150	8925	8168	8781	7620	6532	8130	7740
Sweden	7653	3829	0	0	506	543	311	320	340
Switzerland	100	71	76	74	79	105	110	323	215
Turkey	0	0	17	2120	3487	3681	3469	2470	3734
United Kingdom	1806	1619	0	0	0	1243	0	0	0
Total Europe	53356	51253	41576	40977	55189	59456	42452	43663	40516

3.3.3 Results in 2013

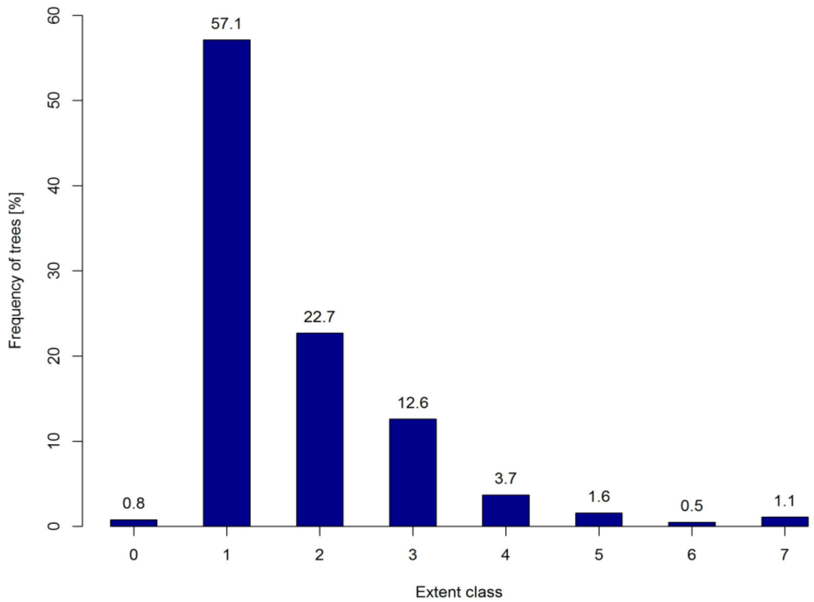
3.3.3.1 Affected parts in 2013



In 2013, the most frequently affected parts of trees were leaves (only broadleaves; 14.8% of the recorded affected parts), followed by twigs (7.7%) and the bole (7.6%) (Fig. 3-36). In trees with multiple types of damage (and thus possibly multiple affected parts), all affected parts were evaluated.

Figure 3-36: Frequency of affected parts of trees. Several affected parts were considered in cases where multiple damage causes occurred on different parts of one tree.

3.3.3.2 Extent in 2013



In total, 57.1% of all damage assessed on trees have been assigned an extent class of 1 (1–10%). Nearly one quarter of all damage assessed on trees (22.7%) had an extent class of 2 (11–20%) and 12.6% had an extent class of 3 (21–40%). Higher classes rarely occurred (Fig. 3-37).

Figure 3-37: Share of trees with recorded damage extent class in 2013. In trees with multiple types of damage, all extent values were evaluated.

3.3.3.3 Agent groups

The distribution of agent groups in 2013 showed that 14,905 trees displayed symptoms caused by insects (Fig. 3-38) corresponding to 28% of the records (Tab. 3-21). More than half of the insect-caused symptoms were attributed to defoliators, which also represented the most frequent damage cause observed (15% of all damaged trees). Boring and mining insects each accounted for one sixth of the insect-caused symptoms. Significantly fewer trees, namely 7,102, displayed damage caused by abiotic agents, corresponding to 14% of the trees. More than half of the symptoms caused by abiotic agents were ascribed to drought, which also was the second frequent damage cause observed (7% of all damaged trees). In 6,059 trees (12%) symptoms caused by fungi were found with decay and root rot as well as canker being the most common. 61,197 trees showed no sign of damage, corresponding to 60% of all trees that were assessed for damage causes. It should be mentioned that the agent group 'atmospheric pollutants' only includes direct and visible symptoms. Indirect effects via long-term input of acidifying and/or eutrophying substances are not included in this group.

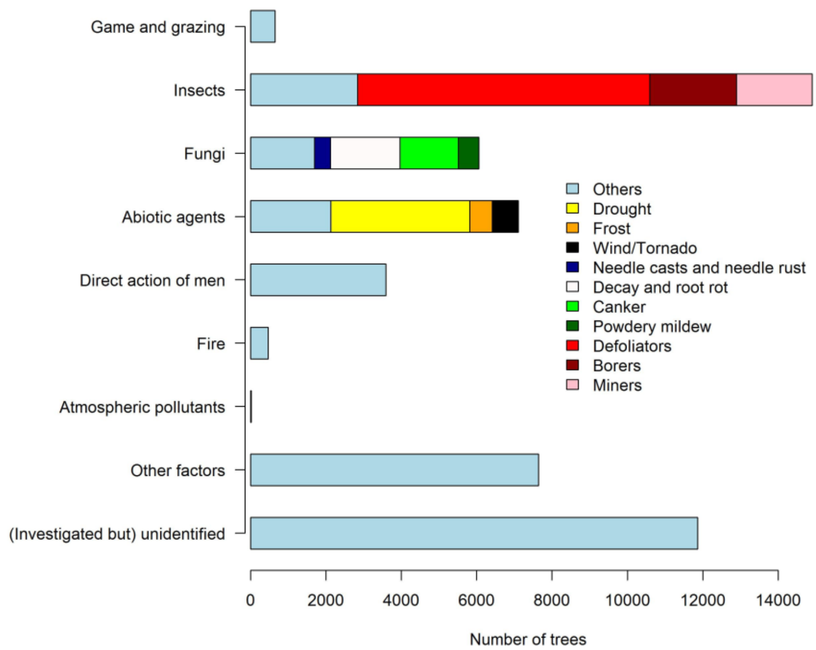


Figure 3-38: Frequency of agent groups. Each agent group was only counted once per tree.

Table 3-21: Damage by agent group and country in percent for the year 2013. 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	0	8	31	31	0	0	0	0	31
Belarus	1	10	39	8	23	1	2	10	6
Belgium	0	8	31	6	7	0	0	1	47
Croatia	No assessment of agent groups in 2013								
Cyprus	3	81	0	9	0	0	0	6	0
Denmark	9	0	36	0	0	0	0	0	55
Estonia	2	5	29	5	9	0	0	3	47
France	0	35	14	15	2	0	0	3	30
Germany	4	49	10	6	10	0	0	9	12
Hungary	0	27	14	10	10	1	0	7	32
Italy	1	31	6	5	0	0	0	6	51
Latvia	23	10	19	13	32	0	0	1	2
Lithuania	6	9	16	24	16	0	0	6	22
Luxembourg	0	32	2	0	0	0	0	0	66
Montenegro	0	47	9	13	6	9	0	1	15
Norway	2	21	12	11	1	0	0	0	52
Poland	1	21	8	6	7	0	0	26	32
Romania	5	52	8	14	7	0	0	15	0
Serbia	0	64	15	8	7	0	0	1	5
Slovakia	1	19	11	6	14	0	0	49	0
Slovenia	1	24	13	7	9	0	0	5	42
Spain	1	28	11	37	5	3	0	13	2
Sweden	6	1	13	14	20	0	0	1	45
Switzerland	0	51	8	18	1	0	0	7	15
Turkey	0	38	5	7	4	0	0	11	34
Total Europe	1	28	12	14	7	1	0	15	23

[1] Visible symptoms of direct atmospheric pollution impact only

The occurrence of agent groups differed among species types. Damage symptoms recorded for *Fagus sylvatica*, deciduous temperate oaks, and deciduous (sub-) Mediterranean oaks were mainly attributed to insects (42%, 39%, and 40% of all damaged trees, respectively). Mining insects (23% of all damaged trees) and defoliators (14% of all damaged trees) were responsible for most of the insect-caused damage in *Fagus sylvatica*, defoliators (23% of all damaged trees) in deciduous temperate oaks, and defoliators (22%) and borers (13%) in deciduous Mediterranean oaks. In deciduous temperate oaks an additional 16% of the symptoms were caused by fungi (9% of all damaged trees displayed powdery mildew). Evergreen oaks and Mediterranean lowland pines primarily showed symptoms caused by abiotic agents (47% and 30% of all damaged trees). Most of this damage were caused by drought (45% of all damaged evergreen oaks and 25% of all damaged Mediterranean lowland pines). Evergreen oaks and Mediterranean lowland pines also displayed high occurrences of insect-caused symptoms (25% and 28%). Most of these symptoms were ascribed to borers (13% of all damaged trees) in evergreen oaks and to defoliators (15%) in Mediterranean lowland pines. In *Pinus sylvestis* damage was caused mainly by other factors (25%), followed by fungi (17%), and direct action of men (10%). Canker (9% of all damaged trees) was the main fungi-caused damage in *Pinus sylvestris*. Direct action of men (19% of all damaged trees) and other factors (18%) were mainly responsible for damage symptoms in *Picea abies*. The four main identified damage causes for each tree species group are presented in Tab. 3-22.

Table 3-22: Four main identified damage causes and percentage of all damaged trees given for different tree species (groups)

		First	Second	Third	Fourth
Pinus sylvestris	damage cause	competition	canker	*Viscum album*	borers
	% of trees	10	9	7	4
Picea abies	damage cause	other factors	silvicultural operations or forest harvesting	Cervidae	mechanical/vehicle damage
	% of trees	9	8	5	4
Mediterranean lowland pine	damage cause	drought	defoliators	sucking insects	*Viscum album*
	% of trees	25	15	8	6
Fagus sylvatica	damage cause	miners	defoliators	other factors	insects (n.s.)
	% of trees	23	14	13	7
Deciduous temperate oak	damage cause	defoliators	powdery mildew	insects (n.s.)	borers
	% of trees	23	9	8	7
Deciduous Mediterranean oak	damage cause	defoliators	borers	insects (n.s.)	drought
	% of trees	22	13	6	4
Evergreen oak	damage cause	drought	borers	defoliators	decay and root rot
	% of trees	45	13	9	7

Note: n.s. not specified

The evaluation of damage causes according to European Forest Types (EFT) revealed four groups with similar damage causes and three EFT that could not be categorized according to these groups. In one group only insects played a role and made up 36–38% of all damage observed (mountainous beech forests, thermophilous deciduous forests, mires, and swamps forest). In another group insects (29–38%) as well as fungi (14–23%) were of importance (acidophilous oak and oakbirch forests, mesophytic deciduous forests, floodplain forests, non-riverine alder, birch, or aspen forests). For broadleaved evergreen forest and coniferous forests of the Mediterranean, Anatolian and Macaronesian regions abiotic agents (23–50%; mainly drought) played a role in addition to insects (25–30%). Besides insects (27–38%) other factors made up a great proportion of damage (20–24%) in the introduced tree species forests and beech forests. In alpine forests other factors (27%), direct action of men (15%), and abiotic agents (14%; mainly snow/ice) were the main causes for damage. In boreal forests fungi (22%; mainly canker) followed by direct action of men (14%; mainly mechanical/vehicle damage) were important. Several damage causes were observed in hemiboreal and nemoral coniferous and mixed broadleaved-coniferous forests: other factors (21%; mainly competition), fungi (15%; mainly canker), insects (14%; mainly defoliators) and direct action of men (12%; mainly mechanical/vehicle damage).

Agent Group ‘Game and grazing’

In 2013, only minor damage from ‘game and grazing’ was observed on the assessed trees throughout Europe. Tab. 3-21 displays that only 1.2% of damage recorded was caused by this agent group. It has, however, to be taken into account that only trees in KRAFT classes 1–3 are regularly assessed for damage types and browsing whereas in the herb and shrub layer no assessment was carried out. In 2013, 70% of all affected plots showed a share of damaged trees of 25% or lower (Fig. 3-39). A high share of trees per plot damaged by ‘game and grazing’ was mainly recorded in Latvia and central Germany.

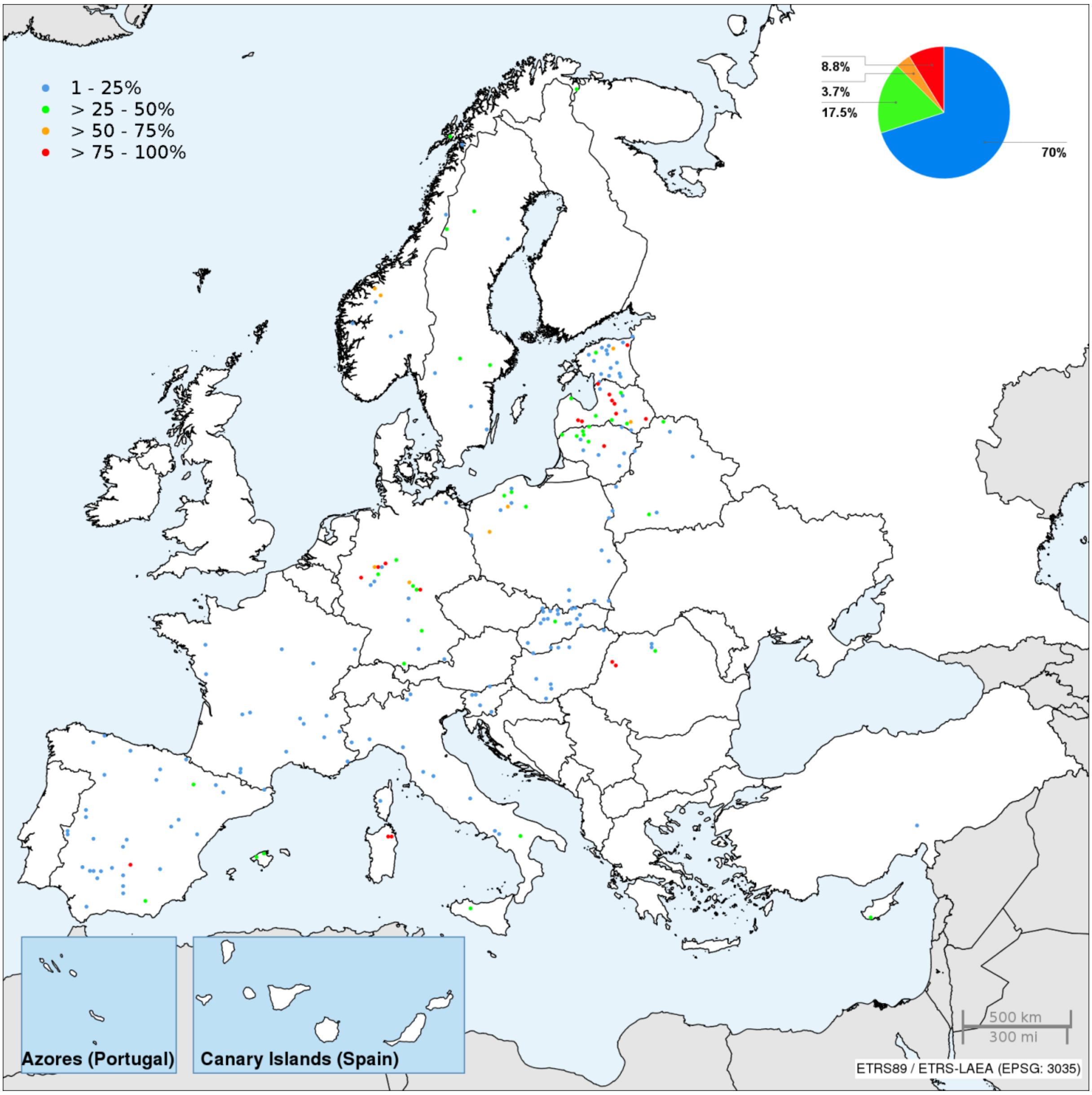


Figure 3-39: Share of trees per plot with recorded agent group ‘game and grazing’, 2013

Agent Group 'Insects'

'Insects' were the most frequently detected agent group (28.5% of damage) in 2013 (Tab. 3-21). Damage caused by insects were observed in different intensities throughout Europe. On 44.1% of all affected plots between 25% and 75% of the trees were damaged by insects. Plots with more than 75% of the trees affected accounted for 25.2% of all plots. One cluster ranged from Germany and France to northern Spain. Other clusters were found in eastern and south-eastern Europe (Romania, Serbia, Montenegro, Turkey, and Cyprus) and in northern Norway. A cluster of plots with <25% of the trees damaged by insects ranged from Slovenia, Hungary and Slovakia to eastern Poland (Fig 3-40).

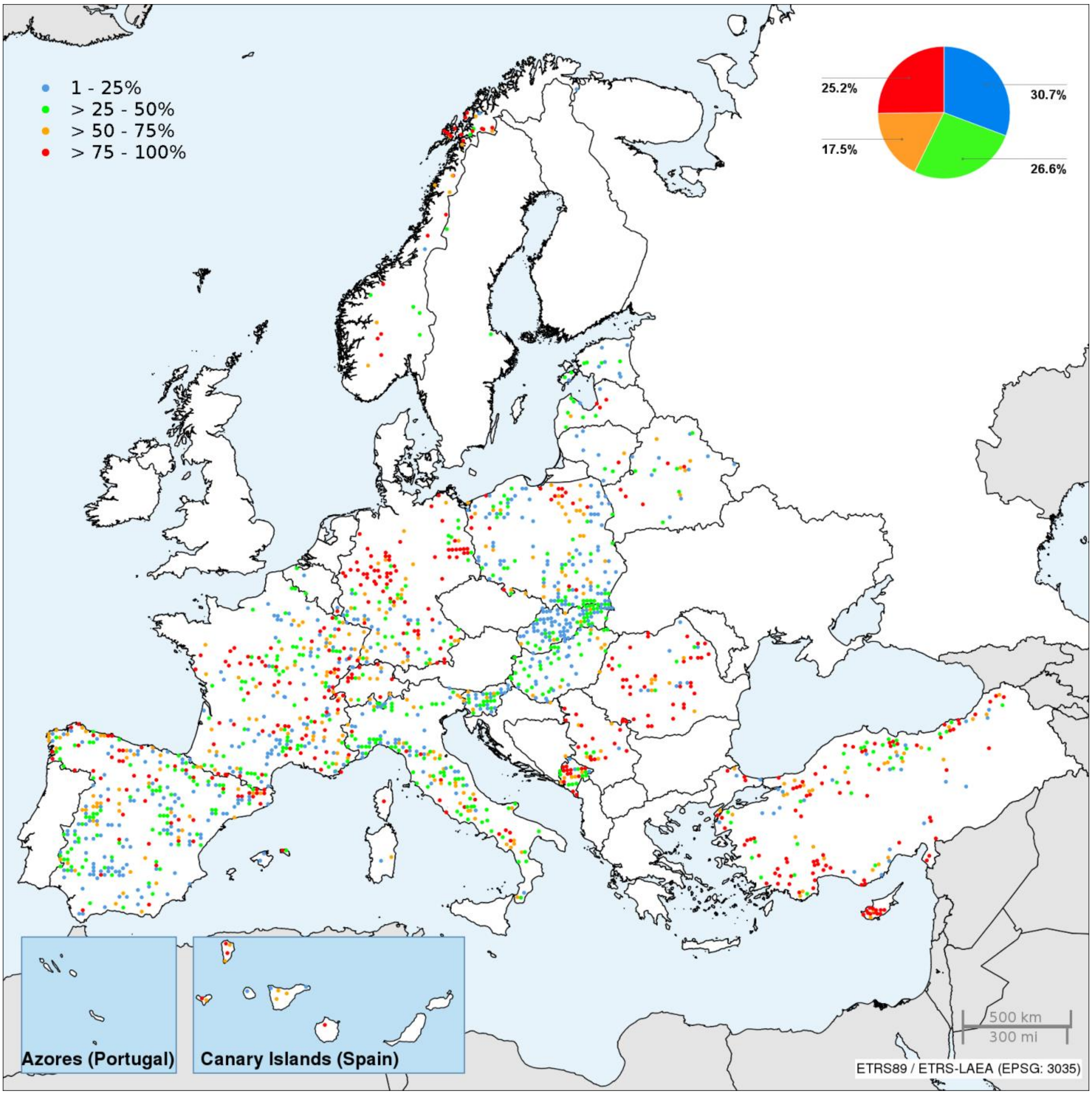


Figure 3-40: Share of trees per plot with recorded agent group 'insects', 2013

Agent Group 'Fungi'

A total of 11.6% of all damage was included in the agent group 'fungi' (Tab. 3-21). Most affected plots (55.9%) showed only a small share of damaged trees. On 12% of all affected plots, between 50 and 75% of the trees showed damage caused by fungi, and on 8.2% of all plots more than 75% of the trees were damaged. A particularly high share of trees per plot damaged by fungi was found in Norway, Estonia, Belarus, Serbia and southern France (Fig. 3-41).

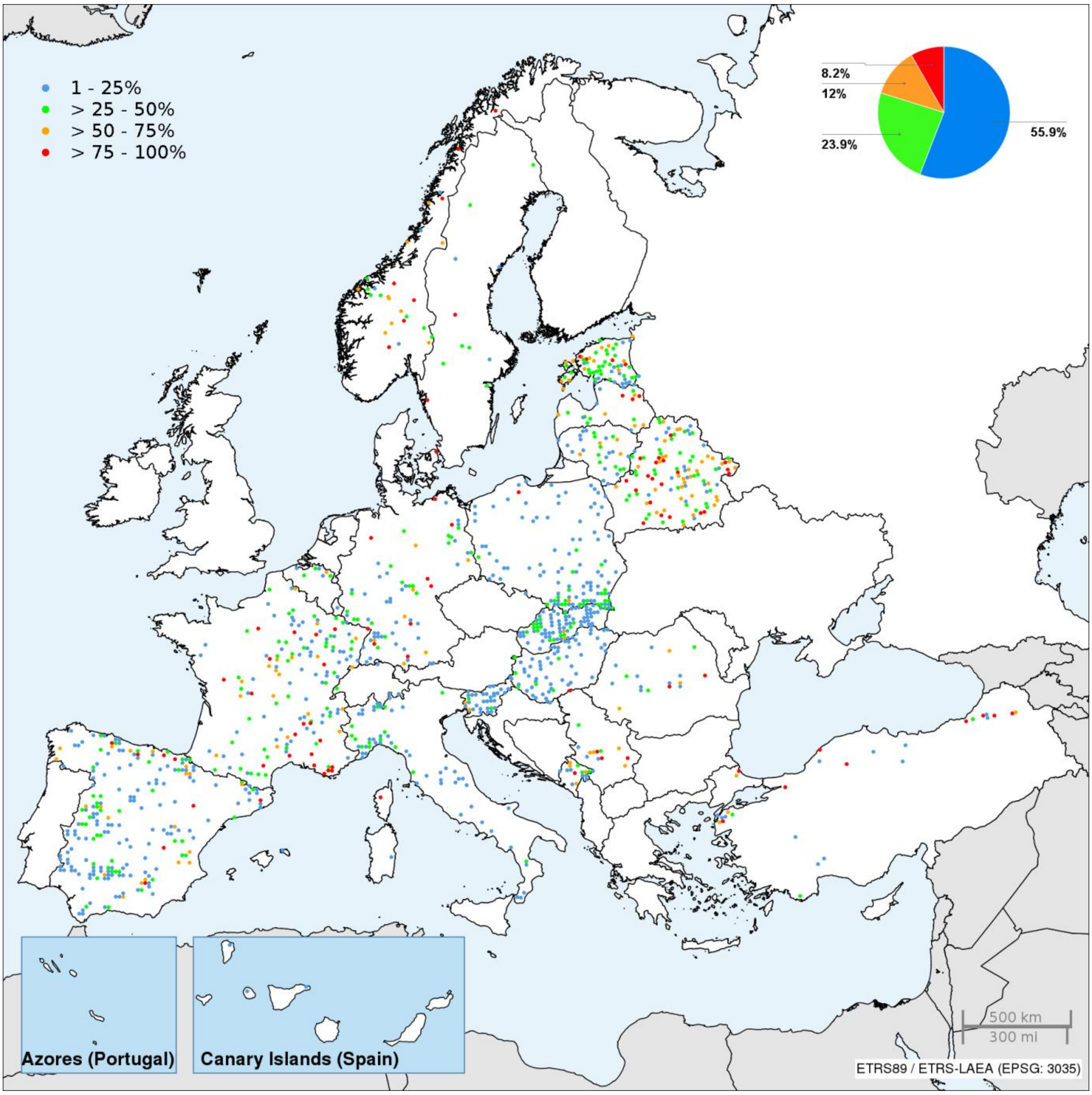


Figure 3-41: Share of trees per plot with recorded agent group 'fungi', 2013

Agent Group 'Abiotic agents'

In 2013, the mean share of trees with damage caused by 'abiotic agents' amounted to 13.6% (Tab. 3-21). The most frequent cause was drought followed by wind and frost. 51.4% of all affected plots showed a small share of damaged trees. Plots with a higher share of damaged trees were mainly found in the Mediterranean areas of Europe (Spain and southern France). A cluster of plots with severe damage occurred at the eastern edge of the Pyrenean Mountains (Fig. 3-42).

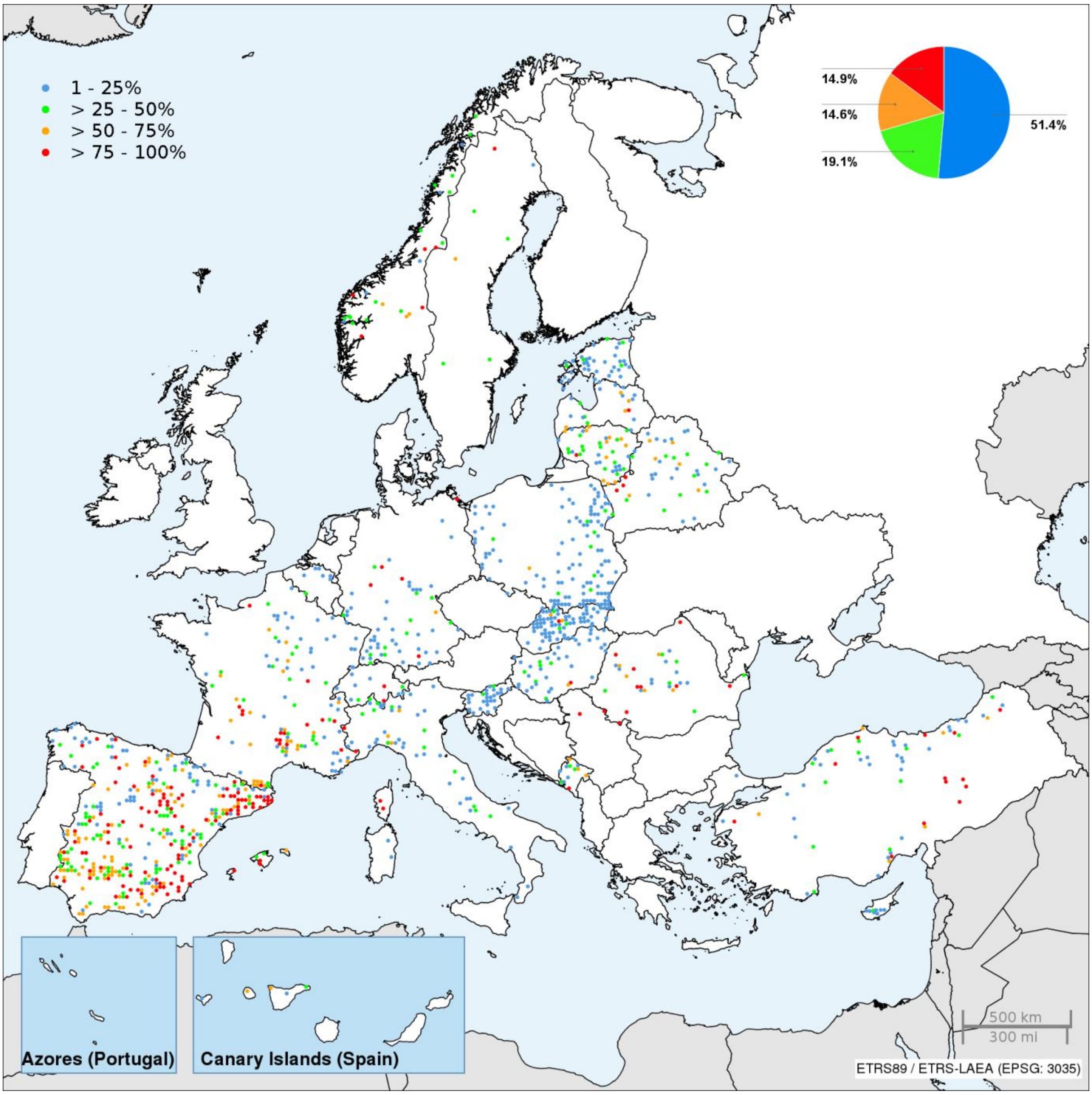


Figure 3-42: Share of trees per plot with recorded agent group 'abiotic agents', 2013

Agent Group 'Direct action of men'

The agent group 'direct action of men' includes improper silvicultural treatment, soil compaction, mechanical injuries caused by skidding, and others. This agent group was recorded on 6.9% of all damaged trees in 2013 (Tab. 3-21). For the majority of plots (62.4%) the share of trees damaged by 'direct action of men' was 25% and lower (Fig. 3-43).

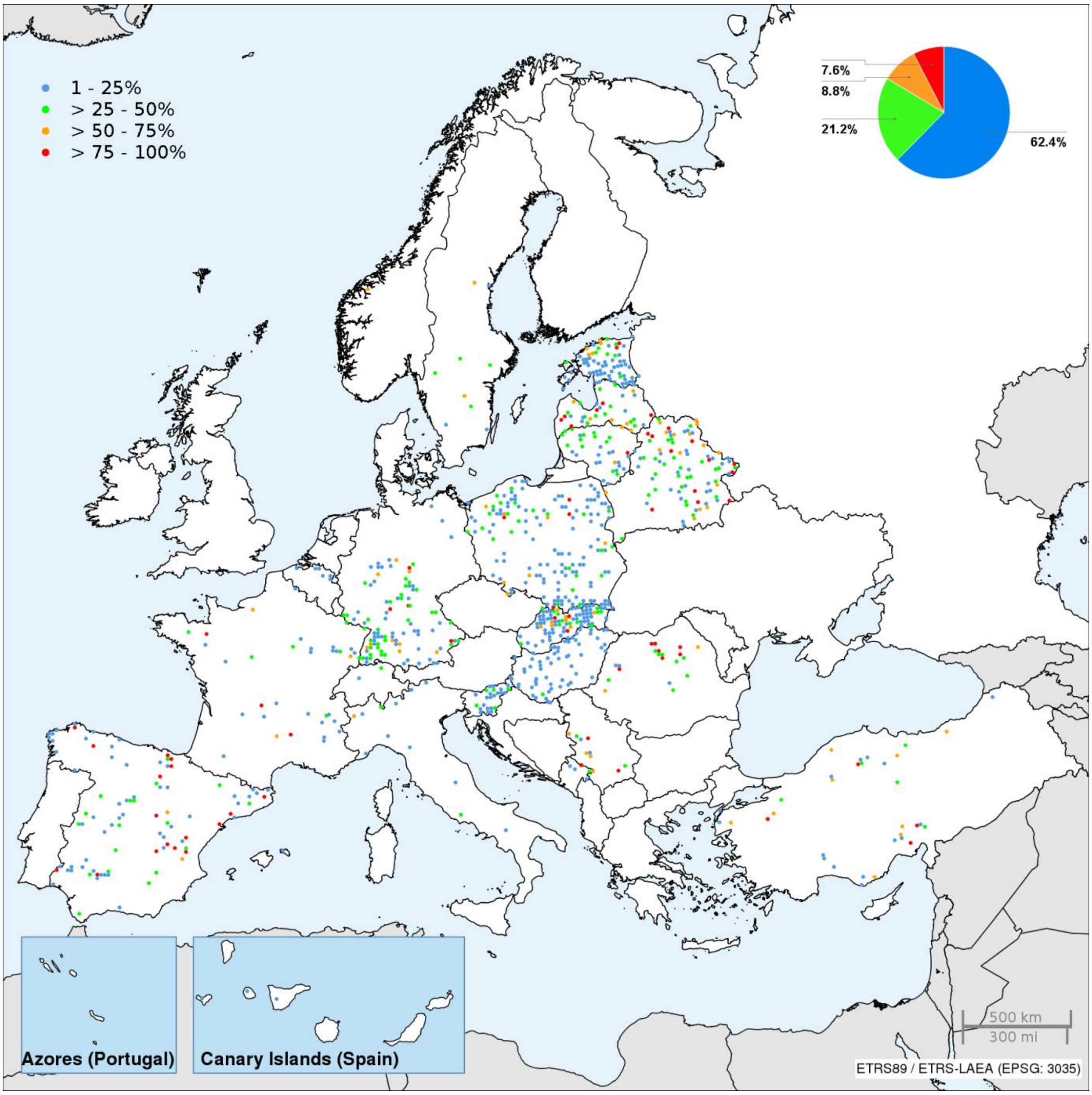


Figure 3-43: Share of trees per plot with recorded agent group 'direct action of men', 2013

Agent Group ‘Fire’

The percentage of plots influenced by the agent group ‘fire’ was low (0.9%) (Tab. 3-21). The spatial distribution showed a focus of fire-affected plots in southern and eastern Europe. Damage caused by fire was frequently recorded in Spain but usually less than half of the trees of one plot were damaged. In comparison, in Montenegro, where fire also played a significant role, >75% of the trees per plot were affected by fire (Fig. 3-44).

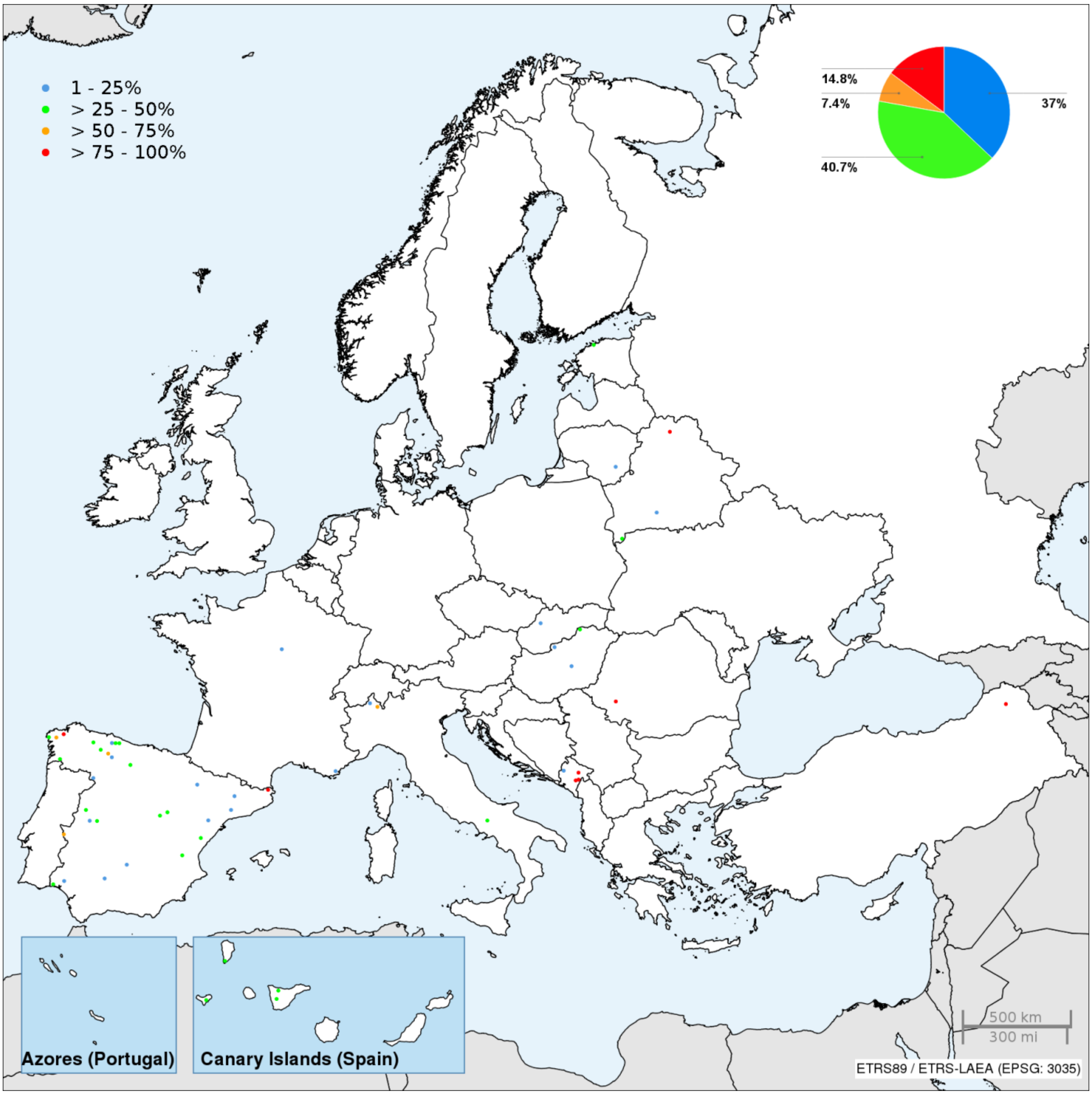


Figure 3-44: Share of trees per plot with recorded agent group ‘fire’, 2013

Conclusions

The annual transnational tree condition survey was conducted on 5,672 plots in 25 participating countries including 18 EU-Member States. The assessment was carried out under national responsibilities according to harmonized methods laid down by ICP Forests. In the present study, defoliation data as well as damage cause data were examined. The evaluation is based on 102,115 trees with a defoliation score, for most of which (101,713 trees) damage causes were additionally specified. The number of tree species amounted to 126. The most abundant tree species was *Pinus sylvestris* (20.5%) followed by *Picea abies* (11%), *Fagus sylvatica* (9.1%), *Pinus nigra*, and *Quercus robur* (both 4.3%), *Quercus ilex* (3.7%), *Quercus petraea* (3.6%), *Pinus brutia* (3.3%), and *Betula pendula* (3.2%). The evaluation was based on seven tree species groups and furthermore on 14 European Forest Types in order to take into account the extended geographical scope of the surveys. 54.9% of the investigated plots were dominated by coniferous trees and 45.1% by broadleaved trees. The share of plots dominated by coniferous trees was lower compared to previous years, which was mainly attributed to changes in the country composition considered (e.g. absence of data of Finland in 2013). The comparison of mean defoliation of different years is not meaningful due to the differences in country composition.

The mean defoliation of all trees assessed in Europe in 2013 was 20.3%. Broadleaved trees showed a higher mean defoliation (23.1%) as compared to conifers (20.0%). The largest share of plots (61%) were plots with mean defoliation ranging from >10% to 25%. A cluster of plots with high mean defoliations (>40%) occurred ranging from southern and south-eastern France to northern Italy. This part of the Mediterranean coast had already previously been recognized as a hot spot with specifically high rates of defoliation in several species groups. Plot mean defoliations of >40% were further frequently observed in Norway and Sweden. Slovakia, Slovenia, Germany and France showed a comparably high share of plots with mean defoliations of >25% to 40%, as well. Clusters of plots with low mean defoliation (0–10%) were found (a) ranging from southern Norway and Denmark to northern Germany and (b) in Serbia, eastern Hungary and Romania.

Regarding all species groups, the mean defoliation of *Pinus sylvestris* was the lowest with 18.2% followed by *Picea abies* with 18.8%. The spatial distribution of the plots with healthy pine trees (0–10% defoliation) was located in southern Norway and northern Germany. Similarly, healthy spruce trees were mainly observed in southern Norway and Denmark. For *Pinus sylvestris*, the small share of plots with mean defoliations >40% (0.4% of the pine plots) were predominantly found in south-eastern France whereas for *Picea abies*, plots with mean defoliation >40% mainly occurred in Norway and Sweden. The mean defoliation of the Mediterranean lowland pines amounted to 20% and about 80% of the plots showed mean defoliations between >10% and 25%. *Fagus sylvatica* displayed the lowest mean defoliation among the broadleaved species groups (21%). A clustered occurrence of plots with damaged trees (defoliation >25%) ranged from south-eastern and north-eastern France to Germany and was further observed in Slovakia. The mean defoliation of deciduous temperate oaks was comparably high (24%). About 40% of the plots showed mean defoliations >25% and these plots were predominantly distributed in central Europe. Deciduous (sub-) Mediterranean oaks were slightly lower defoliated (21.8%) than the temperate oaks. Plots with high mean defoliations were observed in southern and south-eastern France as well as in northern Italy. Evergreen oaks represented the species group with the highest mean defoliation (25.4%). Again, a cluster of severely damaged trees occurred in southern France including Corsica.

The European Forest Types ‘broadleaved evergreen forest’ displayed the highest mean defoliation with 25.6% whereas ‘non-riverine alder, birch or aspen forest’ had the lowest mean defoliation with 16.6%.

The temporal trends of mean defoliation from 1991 to 2013 differed among the tree species groups. With the exception of *Pinus sylvestris* and *Picea abies*, all tree species groups showed a sharp increase in mean defoliation in the first years of the assessment until the mid-1990s. The increase was followed by fluctuations on a comparably high level of defoliation, which was especially true for the three species groups comprising oaks. In contrast, a (slight) decrease in mean defoliation was observed for *Pinus sylvestris* and *Picea abies* that levelled off during the last decade. Peak values of defoliation could mainly be ascribed to the extremely dry and warm summer in 2003. The share of plots with statistically significantly increasing defoliation (20.0%) was higher than the share of plots with decreasing defoliation (12.9%) when regarding the period 2002–2013. However, when regarding the period 2006–2013 similar shares of plots showed increasing and decreasing trends. Plots showing deterioration were scattered across Europe (both periods), but when regarding the period 2002–2013 their shares were particularly high at the eastern edge of the Pyrenean Mountains ranging from southern and south-eastern France to northern Italy and Slovenia. The present study demonstrates that development of tree health and vitality in terms of crown condition still requires further attention.

Defoliation reflects a variety of natural and human induced environmental influences. Weather, site conditions, tree age and deposition (nitrogen, sulphur) have been acknowledged as important factors affecting defoliation. However, the weight of the individual factors affecting crown condition may differ, depending on site and other environmental factors. Thus, in 2005 the damage cause assessment was additionally introduced on Level I plots. In 2013, approx. 60% of the trees showed no sign of damage. Symptoms caused by the agent group ‘insects’ represented the most frequent damage cause assessed (14,905 trees corresponding to 28% of all trees with observed damage). More than half of the insect-caused symptoms were attributed to defoliators, which also presented the most frequent damage cause observed (15% of all damaged trees). Boring and mining insects each accounted for one sixth of the insect-caused symptoms. Significantly fewer trees (14%) displayed damage caused by abiotic agents. More than half of the symptoms caused by abiotic agents were ascribed to drought, which also was the second frequent damage cause observed (7% of all damaged trees). In 12% of the damaged trees symptoms caused by fungi were found with decay and root rot as well as canker being the most common. The occurrence of agent groups differed among species groups as well as among European Forest Types. Defoliation and forest damage are two of the four quantitative indicators of the criterion 2 "Maintenance of Forest Ecosystem Health and Vitality" of Forest Europe (formerly "The Ministerial Conference on the Protection of Forests in Europe" - MCPFE). The ICP Forests database offers the only transnational, harmonized and plot based information system for such information in Europe. The descriptive evaluations need to be continued and integrated evaluations with other datasets on weather and site conditions are needed as insects and fungi might also reflect changes in environmental conditions.

The continuation of the time series and the further implementation of related quality assurance measures like field intercomparison courses and quality checks in the database are of importance to ensure an early warning system for tree health and vitality in the future and to provide the basis for further integrated statistical evaluations which need to be supported by research projects.

3.4 National surveys and reports

National surveys are conducted in many countries in addition to the transnational surveys. The national surveys in most cases rely on denser national grids and aim at the documentation of forest condition and its development in the respective country. Since 1986, densities of national grids with resolutions between 1 × 1 km and 32 × 32 km have been applied due to differences in the size of forest area, in the structure of forests and in forest policies.

Results of crown condition assessments on the national grids are presented in Chapter 6 and Annex II. Comparisons between the national surveys of different countries should be made with great care because of differences in species composition, site conditions, and methods applied.

3.5 References

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4 A HARMONISED LEVEL II SOIL DATABASE TO UNDERSTAND PROCESSES AND CHANGES IN FOREST CONDITION AT THE EUROPEAN LEVEL

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4.1 Abstract

On 274 ICP Forests intensive monitoring plots (Level II), soil profiles have been described in the field and samples analysed by national laboratories using harmonised reference methods. Analytical data were cross-checked, validated, compiled and aggregated in the “Aggregated Forest Soil Condition Database” (AFSCDB). The quality of the chemical and physical laboratory analyses has been controlled by interlaboratory comparisons. The data were aggregated by fixed depth layers (0–10 cm, 10–20 cm, 20–40 cm and 40–80 cm), including forest floor, mineral and peat layers. There is a good overlap with the surveys on crown condition, foliar chemistry, deposition analyses, meteorology, soil solution chemistry, soil water content and growth conducted since the nineties on the same intensive monitoring plots. The importance and relevance of this dataset lays in i) its wide geographical coverage across Europe, ii) its harmonised methodology, and iii) its ability to combine soil data with a high number of other forest ecosystem surveys and long term time series.

4.2 Introduction

On a number of selected permanent observation plots spread across Europe, ICP Forests aims at gaining a better understanding of the cause-effect relationships between the condition of forest ecosystems and anthropogenic and natural stress factors (in particular air pollution) by means of intensive monitoring (Lorenz & Fischer 2013). The soil plays an important role in forest ecosystem research, such as in input-output budget modelling (Ranger & Turpault 1999) or critical load calculations which take into account a high number of chemical and physical soil characteristics (Augustin et al. 2005; De Vries et al. 2007). Soil data are also essential to calibrate and validate models that predict future impacts (Reinds et al. 2008, Jochheim et al. 2009, Mol Dijkstra et al. 2009). In 1993, the European Commission (Commission Regulation 993R0926 1993) decided to conduct a first forest soil condition survey on nearly 800 ICP Forests intensive monitoring plots across Europe, the so called Level II plots. Although a large number of plots were included, the dataset was not fully harmonised. Neither much attention was given to physical soil variables - such as bulk density, content of coarse fragments or soil water retention characteristics (De Vries et al. 1998). In the meantime the focus of environmental forest research broadened from air pollution to climate change effects, increasing the need for physical soil data. During the EC Forest Focus BioSoil demonstration project and the Life+ FutMon programme, the opportunity was provided to the network to include a number of the ICP Forests intensive monitoring plots in the large-scale forest soil inventory (on the so called Level I plots) following the methods as outlined in the ICP Forests manual on sampling and analysis of soil (Cools & De Vos 2013).

Several researchers defined the need for harmonised environmental databases at the European level (Köhl et al. 2000), forest databases (Clarke et al. 2011, Danielewska et al. 2013), soil monitoring data (Morvan et al. 2008) and particularly forest soil databases (De Vries et al. 2007). The latter

[1] For contact information, please refer to Annex III-4.

recommended a more in-depth analysis, based on more input-output budgets of N to further investigate the possible role of the C:N ratio of the soil on the N dynamics. In 2007, De Vries et al. (2007) conducted a study on 121 Level II plots combining the deposition, meteo and soil solution datasets though no measured meteorological data were employed. Soil nutrient stocks were calculated based on estimated soil content and bulk densities.

The objectives of this first version of the **A**ggregated **F**orest **S**oil **C**ondition **D**ata**B**ase", **L**evel **II**, **2**nd survey, version **1** (**AFSCDB.LII.2.1**) are to provide:

- Descriptive and explanatory soil variables sustaining forest ecosystem monitoring
- Aggregated forest soil data to one (mean) value for each variable per plot per fixed depth layer (0–10 cm, 10–20 cm, 20–40 cm and 40–80 cm, OL and OFH layer)
- Derived soil variables as base saturation, sum of basic cations, sum of acid cations, cation exchange capacity and C:N ratios.

4.3 Materials and methods

4.3.1 Data sources

The described database is part of the Forest Soil Condition Databases (FSCDB) of ICP Forests. It contains the aggregated soil data of European ICP Forests Level II plots of the second soil survey, this means soil data collected from 2003 till 2010. The data of the first soil survey, that took place in the nineties on nearly 800 plots, are not contained in this database. The decision to assemble the soil data from 2003 onwards was led by the major revision of the measured soil variables, the sampling and laboratory methods in 2003 (ICP Forests soil manual 2003).

The data originate from different projects. Between 2003 and 2006 (duration of the Forest Focus regulation) the full ICP Forests Level II database was managed by the Institute for Environment and Sustainability of the Joint Research Centre of the European Commission. At that time soil data on only a few plots were submitted to the database. At the end of the Forest Focus period, a large-scale forest soil survey was set up as a demonstration project, called 'BioSoil' (sampling mainly in 2006 and 2007). A subset of 127 ICP Forests Level II plots was investigated within the framework of this project. During the EU Life+ FutMon project (2009–2011), the participating countries had the opportunity to collect soil information on the remaining intensive monitoring plots not already assessed during the BioSoil survey.

All sampling and analyses was done following the ICP Forests manual part on Sampling and Analysis of Soil of 2006 (FSCC, 2006). After the compilation of the data from the different data sources, detailed quality checks were carried out. FSCC contacted the data providers (national focal centres of the countries) for correction and/or provision of additional information.

Since 1989, the Expert Panel on Soil and Soil Solution controls the quality of soil data collection within the ICP Forests programme. The manual on sampling and analysis of soil lists for each of the soil variables the required reference method, which is usually compliant with ISO (International Organisation of Standardization) methods (Cools & De Vos 2013). In addition, interlaboratory comparisons were organised on a regular basis. Prior to the soil inventory in 2006, field training courses on soil profile description and classification were organised.

4.3.2 Structure of the database

The core of the AFSCDB.LII.2.1. database consists of five datasets: the PLS, PRF, PFH, SOM and LQA datasets. The PLS or 'General **PL**ot information on **S**oil' dataset describes the location and a number of environmental variables of the plot. One record in the dataset corresponds to one observation plot (Table 4-1).

Table 4-1. The variables contained in the 'General plot information' (PLS) dataset showing field name, format and description of the variables

Field name	Type	Description
CODECOUNTRY	Numeric	ICP Forests country code
CODEPLOT	Numeric	Plot number
PLOTID	Text	Combination of CODECOUNTRY and CODEPLOT (unique)
DATESAMPLING	Date/time	Date of sampling
LAT	Numeric	Latitude of the plot in geographical coordinates (degrees, sexagesimal minutes, sexagesimal seconds), datum = WGS84, no projection (+/- DDMMSS)
LONG	Numeric	Longitude of the plot in geographical coordinates (degrees, sexagesimal minutes, sexagesimal seconds), datum = WGS84, no projection (+/- DDMMSS)
LATDDMMSS	Text	Same as above though written with + and - sign, degrees, minutes and seconds are separated by a dot (+/- DD.MM.SS)
LONGDDMMSS	Text	Same as above though written with + and - sign, degrees, minutes and seconds are separated by a dot (+/- DD.MM.SS)
DDLAT	Numeric	Latitude of the plot in decimal degrees, datum = WGS84
DDLONG	Numeric	Longitude of the plot in decimal degrees, datum = WGS84
ETRS89X	Numeric	Longitude of the plot in European Terrestrial Reference System 1989 LAEA
ETRS89Y	Numeric	Latitude of the plot in European Terrestrial Reference System 1989 LAEA
CODEELEV	Numeric	Altitude in 50 metre classes (from 1 till 51)
CODEWATER	Numeric	Code referring to the water availability for trees
CODEHUMUS	Numeric	Code referring to the humus type
DATASOURCE	Text	FORESTFOCUS/BIOSOIL/FUTMON/ADDITIONAL
OBSERVATION	Text	Any other observation at the plot level

The PRF or 'Soil **PR**o**F**ile information' dataset describes the soil type (soil classification according to IUSS WRB Working Group 2006), parent material, information on groundwater table and rooting limiting layers of each soil profile. More than one profile could have been described on one observation plot (Table 4-2).

Table 4-2. The variables contained in the 'Soil profile information' (PRF) dataset showing field name, unit, format and description of the variables

Field name	Unit	Type	Description
SURVEYYEAR			Year of the profile description (is normally the same as in PFH file)
CODECOUNTRY		Numeric	ICP Forests country code
CODEPLOT		Numeric	Identification number of the plot
PLOTID		Text	Combination of CODECOUNTRY and CODEPLOT

Field name	Unit	Type	Description
CODEPROF		Text	Identification of the profile pit
DATEDESCR	YYYY-MM-DD	Date	Date of description of the soil profile
RSG		Text	World Reference Base, Reference Soil Group (WRB 2006) of the plot
QUAL1		Text	First adjective describing the reference soil group
SPEC1		Text	Specifier for the adjective 1
…		…	…
QUAL6		Text	Sixth adjective describing the reference soil group
SPEC6		Text	Specifier for the adjective 6
DIAG1		Text	Code of 1st diagnostic horizon, property or material
DDIAG1	cm	Numeric	Depth of appearance of first diagnostic horizon, property or material
…		…	…
DIAG10		Text	Code of 10th diagnostic horizon, property or material
DDIAG10	cm	Numeric	Depth of appearance of 10th diagnostic horizon, property or material
WRBPUB		Text	Reference to WRB version (IUSS Working Group WRB 2006, 2007)
PMAT1		Numeric	Code for the dominant parent material of the plot (Lambert et al. 2003)
PMAT2		Numeric	Code for a second parent material (Lambert et al. 2003)
HGWL		Numeric	Mean highest groundwater depth (in depth classes)
LGWL		Numeric	Mean lowest groundwater depth (in depth classes)
TWT		Numeric	Type of water table (0 = no water table; 1 = perched; 2 = permanent)
ROOT	cm	Numeric	Root depth of the soil profile
ROCK	cm	Numeric	Rock depth of the soil profile
OBSTACLE	cm	Numeric	Obstacle depth of the soil profile
DEPTHSTOCK	cm	Numeric	Depth to be used for stock calculation (maximum 1 m)
OBSERVATION		Text	Any other observation about the soil profile

The PFH or '**P**ro**F**ile **H**orizon description' dataset contains the descriptions of the genetic horizons. On 95% of the profiles between 3 and 12 horizons were described following international reference guidelines (FAO 2006) (Table 4-3).

Table 4-3. The variables and amount of information contained in the 'Description of the soil profile horizons' (PFH) dataset showing field name description, units of the variables and % of horizons with this information

Field name	Unit	Description	% horizons with data
SURVEYYEAR		Year that the samples of the soil horizons were analysed	100
CODECOUNTRY		ICP Forests country code	100
CODEPLOT		Identification number of the plot	100
PLOTID		Combination of CODECOUNTRY and CODEPLOT	100
CODEPROF		Identification number of the profile	100
CODEHOR		Identification number of the horizon	100
DATEANAL	YYYY-MM-DD	Date of the laboratory analysis	100
HORDISC		Number to indicate a discontinuity in the horizon designation	9
HORMAST		Symbol of the master part of the horizon designation	100
HORSUBORD		Symbol of the subordinate characteristics of the horizon designation	40
HORVERT		Order number of the vertical subdivision in the horizon designation	30

Field name	Unit	Description	% horizons with data
HORTOP	cm	The upper limit of the horizon depth	99
HORBOT	cm	The lower limit of the horizon depth	96
HORDISTINC		Code of horizon distinction	22
HORTOPO		Code of horizon topography	21
STRUCT		Type of the soil structure	58
COLOURM		Moist colour of the soil matrix (Munsell soil colour charts)	69
COLOURD		Dry colour of the soil matrix (Munsell soil colour charts)	33
TEXCLASS		Horizon textural class (USDA)	56
CLAY	%	Particle size fraction corresponding to clay percentage of fine earth (0–2 µm fraction)	51
SILT	%	Particle size fraction corresponding to silt (2–63 µm fraction)	50
SAND	%	Particle size fraction corresponding to sand (63–2000 µm fraction)	51
CFCODE		Code of volume class of coarse fragments (stones and gravel with a diameter > 2 mm)	64
CFMASS	Mass %	Mass % of coarse fragments (stones and gravel with a diameter > 2 mm)	13
OC	%	Organic carbon content	71
TON	%	Total nitrogen content	68
CARBONATES	%	Total calcium carbonate ($CaCO_3$) content	24
PH		pH value of the soil horizon	74
EC	dS m^{-1}	Electrical conductivity of the horizon	9
ESP	%	Exchangeable sodium percentage of the horizon (expressed as % of CEC)	4
EXCHCA	$cmol_+ kg^{-1}$	Exchangeable calcium of the horizon	58
EXCHMG	$cmol_+ kg^{-1}$	Exchangeable magnesium of the horizon	58
EXCHK	$cmol_+ kg^{-1}$	Exchangeable potassium of the horizon	58
EXCHNA	$cmol_+ kg^{-1}$	Exchangeable sodium of the horizon	58
EXCHACID	$cmol_+ kg^{-1}$	Exchangeable acidity of the horizon	1
EXCHAL	$cmol_+ kg^{-1}$	Exchangeable aluminium of the horizon	4
EXCHFE	$cmol_+ kg^{-1}$	Exchangeable iron of the horizon	4
EXCHMN	$cmol_+ kg^{-1}$	Exchangeable manganese of the horizon	4
FREEH	$cmol_+ kg^{-1}$	Free H+ of the horizon	4
CEC	$cmol_+ kg^{-1}$	Cation exchange capacity (CEC) of the horizon	64
BS	%	Base saturation of the horizon [(exchangeable Ca+Mg+K+Na)/CEC * 100]	64
CODEPOROS		Class of total porosity	43
POROSITY	Vol %	Total porosity of the horizon	8
BD	g cm^{-3}	Measured bulk density of the horizon	30
BDEST	g cm^{-3}	Estimated bulk density of fine earth if no measured bulk density exists	25
ROOTSVERYFINE		Abundance class of very fine roots	12
ROOTSFINE		Abundance class of fine roots	21
ROOTSMEDIUM		Abundance class of medium roots	12
ROOTSCOARSE		Abundance class of coarse roots	13
REACAL	mg kg^{-1}	Acid ammonium oxalate extractable aluminium content of the horizon	4
REACFE	mg kg^{-1}	Acid ammonium oxalate extractable iron content of the horizon	4
OBSERVATION		Observation about the horizon	27

The dataset SOM 'Sampling and analysis of **SO**il at fixed depths' contains 1404 records with laboratory analyses performed on the composite samples taken at fixed depths (Table 4-4 and Table 4-5). The median number of sampling points per plot was 24, consisting of 3 replicates per layer consisting each of 8 subsamples. Data availability is best for the upper 10 cm of the soil profile and is decreasing with increasing depth.

Table 4-4. The number and type of soil layers contained in the dataset with the 'Sampling and analysis at fixed depths' (SOM) information

Depth of the layer	Mean thickness (cm)	Code of layer	N° plots	Code of layer	N° plots	Total N° plots
Variable	1.7 [0.5; 4]*	OL	190			
Variable	4.1 [1; 13]*	OFH	244			
0–10 cm	10	M01	254	H01	6	260
10–20 cm	10	M12	253	H12	6	259
20–40 cm	20	M24	241	H24	5	246
40–80 cm	40	M48	204	H48	1	205
Total N° records						1404

*95% range

Table 4-5. The variables contained in the 'Sampling and analysis at fixed depths' (SOM) dataset showing field name, unit, format and description of the variables

Field name	Unit	Decimals	Type	Description
SURVEYYEAR			Numeric	Year of the laboratory analysis
CODECOUNTRY			Numeric	ICP Forests country code
CODEPLOT			Numeric	Identification number of the plot
PLOTID			Text	Combination of CODECOUNTRY and CODEPLOT
CODELAYER			Text	The code of the layer
REPETITION			Numeric	Order number of composite sample
LAYTOP	cm	0	Numeric	The upper limit of the layer depth
LAYBOT	cm	0	Numeric	The lower limit of the layer depth
SUBSAMPLES			Numeric	Number of subsamples used in the composite
DATEANAL			Date	Date of laboratory analysis
MOISTURE	%	1	Numeric	Moisture content of air dried sample vs. oven dried sample
CLAY	g $100g^{-1}$	1	Numeric	Mass fraction of clay (0 - 2 µm)
SILT	g $100g^{-1}$	1	Numeric	Mass fraction of silt (2 - 63 µm)
SAND	g $100g^{-1}$	1	Numeric	Mass fraction of sand (63 - 2000 ųm)
TEXCLASS			Numeric	USDA texture class
BD	kg m^{-3}	0	Numeric	Mean bulk density of fine earth
BDEST	kg m^{-3}	0	Numeric	Estimated bulk density of the fine earth
CFMASS	g $100g^{-1}$	0	Numeric	Mass of coarse fragments (> 2 mm)
CFVOL	Vol %	0	Numeric	Volume of coarse fragments (> 2 mm)
ORGLAY	kg m^{-2}	2	Numeric	Total dry weight of the organic layer
PHCACL2		1	Numeric	pH measured in calcium chloride $CaCl_2$
PHH2O		1	Numeric	pH measured in water
OC	g kg^{-1}	1	Numeric	Organic carbon content
TON	g kg^{-1}	1	Numeric	Total nitrogen content
CN		1	Numeric	C:N ratio = [OC]/[TON]
CARBONATES	g kg^{-1}	0	Numeric	Carbonate content
EXCHACID	$cmol_+ kg^{-1}$	2	Numeric	Total exchangeable acidity
EXCHAL	$cmol_+ kg^{-1}$	2	Numeric	Exchangeable Al
EXCHCA	$cmol_+ kg^{-1}$	2	Numeric	Exchangeable Ca

Field name	Unit	Decimals	Type	Description
EXCHFE	$cmol_+ kg^{-1}$	2	Numeric	Exchangeable Fe
EXCHK	$cmol_+ kg^{-1}$	2	Numeric	Exchangeable K
EXCHMG	$cmol_+ kg^{-1}$	2	Numeric	Exchangeable Mg
EXCHMN	$cmol_+ kg^{-1}$	2	Numeric	Exchangeable Mn
EXCHNA	$cmol_+ kg^{-1}$	2	Numeric	Exchangeable Na
FREEH	$cmol_+ kg^{-1}$	2	Numeric	Free H^+ acidity
BCE	$cmol_+ kg^{-1}$	2	Numeric	Sum of basic cations (Ca, K, Mg, Na)
ACE	$cmol_+ kg^{-1}$	2	Numeric	Sum of acid cations (Al, Fe, Mn and Free H+)
CEC	$cmol_+ kg^{-1}$	2	Numeric	Sum of [BCE] and [ACE]
BS	%	1	Numeric	[BCE]/[CEC] * 100
EXTRAL	$mg\ kg^{-1}$	1	Numeric	Aqua regia extractable Al
EXTRCA	$mg\ kg^{-1}$	1	Numeric	Aqua regia extractable Ca
EXTRCD	$mg\ kg^{-1}$	2	Numeric	Aqua regia extractable Cd
EXTRCR	$mg\ kg^{-1}$	1	Numeric	Aqua regia extractable Cr
EXTRCU	$mg\ kg^{-1}$	1	Numeric	Aqua regia extractable Cu
EXTRFE	$mg\ kg^{-1}$	1	Numeric	Aqua regia extractable Fe
EXTRHG	$mg\ kg^{-1}$	3	Numeric	Aqua regia extractable Hg
EXTRK	$mg\ kg^{-1}$	1	Numeric	Aqua regia extractable K
EXTRMG	$mg\ kg^{-1}$	1	Numeric	Aqua regia extractable Mg
EXTRMN	$mg\ kg^{-1}$	1	Numeric	Aqua regia extractable Mn
EXTRNA	$mg\ kg^{-1}$	1	Numeric	Aqua regia extractable Na
EXTRNI	$mg\ kg^{-1}$	1	Numeric	Aqua regia extractable Ni
EXTRP	$mg\ kg^{-1}$	1	Numeric	Aqua regia extractable P
EXTRPB	$mg\ kg^{-1}$	1	Numeric	Aqua regia extractable Pb
EXTRS	$mg\ kg^{-1}$	1	Numeric	Aqua regia extractable S
EXTRZN	$mg\ kg^{-1}$	1	Numeric	Aqua regia extractable Zn
TOTAL	$mg\ kg^{-1}$	1	Numeric	Total Al content
TOTCA	$mg\ kg^{-1}$	1	Numeric	Total Ca content
TOTFE	$mg\ kg^{-1}$	1	Numeric	Total Fe content
TOTK	$mg\ kg^{-1}$	1	Numeric	Total K content
TOTMG	$mg\ kg^{-1}$	1	Numeric	Total Mg content
TOTMN	$mg\ kg^{-1}$	1	Numeric	Total Mn content
TOTNA	$mg\ kg^{-1}$	1	Numeric	Total Na content
REACAL	$mg\ kg^{-1}$	1	Numeric	Acid oxalate extractable Al
REACFE	$mg\ kg^{-1}$	1	Numeric	Acid oxalate extractable Fe
OBSERVATION			Text	

All analytical results have been recalculated to obtain one mean value per plot for each variable. The data availability (Table 4-6) is best for the soil variable pH-$CaCl_2$, organic carbon and total nitrogen. The database contains a number of derived soil variables such as the C:N ratio, the sum of the basic (BCE) and acid exchangeable cations (ACE), the base saturation (BS) and the cation exchange capacity (CEC). In order to allow calculations with small concentrations below the limit of quantification (LOQ), they have been replaced by half the value of the median LOQ of all labs participating in the FSCC Interlaboratory Comparisons.

Table 4-6. Number of aggregated data for the concerning variables and layers (OL, OFH, M01, M12, M24, M48, H01, H12, H24 and H48) available on the 274 Level II plots contained in the AFSCDB.LII.2.1. Total elemental analyses are not included in this overview as it maximally concerned 6% of the plots.

	Forest floor		Fixed depth					Forest floor		Fixed depth			
Layer/ Variable	OL	OFH	M01	M12	M24	M48	Layer/ Variable	OL	OFH	M01	M12	M24	M48
CLAY			188	190	219	168	BCE	30	227	246	245	243	185
SILT			188	190	219	168	ACE	26	216	242	241	239	182
SAND			188	190	219	168	CEC	30	227	246	245	243	185
BD			195	184	172	143	BS	30	227	246	245	243	185
BDEST			27	29	29	28	EXTRAL	124	183	203	161	157	116
CFMASS			67	62	62	24	EXTRCA	134	229	224	202	196	143
CFVOL			188	186	171	172	EXTRCD	132	218	228	158	156	122
ORGLAY	183	224					EXTRCR	120	191	204	158	157	116
PHCACL2	59	243	259	259	245	188	EXTRCU	133	230	246	173	169	127
PHH2O	47	211	223	218	216	161	EXTRFE	131	203	222	169	166	124
OC	130	242	260	259	244	187	EXTRHG	39	49	58	38	36	36
TON	128	242	260	259	244	187	EXTRK	134	230	224	202	196	143
CN	128	242	259	256	229	160	EXTRMG	134	230	224	202	196	143
EXCHACID	25	213	237	235	233	174	EXTRMN	133	230	225	203	198	145
CARBONATES	4	24	34	36	37	33	EXTRNA	107	178	196	148	146	104
EXCHAL	26	212	242	241	238	181	EXTRNI	121	193	207	161	160	119
EXCHCA	30	227	246	245	243	186	EXTRP	134	230	224	203	198	145
EXCHFE	26	212	242	241	239	182	EXTRPB	133	230	246	172	169	127
EXCHK	30	227	247	246	244	188	EXTRS	123	172	191	152	150	106
EXCHMG	30	227	247	246	244	188	EXTRZN	133	230	246	171	167	125
EXCHMN	30	223	247	246	244	188	REACAL	26	71	166	165	166	125
EXCHNA	30	227	247	246	244	188	REACFE	26	71	166	165	166	125
FREEH	27	218	243	242	239	182							

4.3.3 Quality assurance and quality control

Data submitted from the survey year 2009 onwards are accompanied by information on quality assurance and quality control. The laboratory methods are provided by a detailed coding system. Information on the within laboratory quality program is provided together with information of the performance of the laboratory for the concerning soil analytical variable in the FSCC ring tests (Table 4-7).

Table 4-7. The variables contained in the 'Quality assurance and quality control' (LQA) dataset showing field name, unit, format and description of the variables

Field name	Type	Description
SURVEYYEAR	Numeric	Year of the laboratory analysis
CODECOUNTRY	Numeric	ICP Forests country code
CODEPLOT	Numeric	Observation plot number (maximum 9999)
PLOTID	Text	Combination of CODECOUNTRY and CODEPLOT
STARTDATE	Date	Start date
ENDDATE	Date	End date
SOILVAR	Text	Code of soil variable
DIGEXTR	Numeric	Digestion/Extraction method (pretreatment)
SIEVING	Numeric	Sieving/milling method
REMOVAL	Numeric	Code removal compounds
DETERM	Numeric	Determination method (see reference list)
LOQ	Numeric	Quantification limit (unit of parameter)
CCMEAN	Numeric	Mean of control chart
CCCV	Numeric	Relative standard deviation [%]
RT	Numeric	Participated at ring test (yes = 1, no = 0)
RTID	Text	ICP Forests Ring Test Number
LABID	Numeric	ID of laboratory (e.g. H45, B78, etc.)
PERC	Numeric	Percentage [%] of results of ring test within tolerable limits for each ring test
REQUAL	Logical	Requalification information (yes = 1, no = 0)
REQUALPERC	Numeric	Percentage [%] of results of ring test within tolerable limits for each ring test in requalification
OBSERVATION	Text	Other observations (free text)

4.4 Results

Below we outline, rather than analyse in depth, a few variables of the AFSCDB and suggest research questions that could be explored using these data.

4.4.1 General plot information

The most important information in the 'general plot information' (PLS) dataset is the geographical location of the 274 plots (Figure 4-1) in 24 European countries. Although ICP Forests is a pan-European network, only soil data from EU member states and Switzerland are presently included in the database. Missing EU countries are Portugal, the Netherlands and Luxembourg (+ missing region = Wallonia in Belgium). The reason is that most of the recent soil inventories were co-financed by the EC DG ENV though only for those EU member states that participated in the related projects.

The plots in the AFSCDB extend from 34° 55' in the South (Cyprus) to 69° 44' in the North (Finland) and from -9° 33' in the west (Ireland) to 33° 03' in the east (Cyprus). Fifty percent of the plots are located between 46.6° and 54° northern latitude and fifty percent are located between 8.6° and 22.04° eastern longitude indicating that the soil data availability is the most dense in central Europe (Belgium, Germany, Czech republic, Slovakia, Austria, Switzerland and Slovenia).

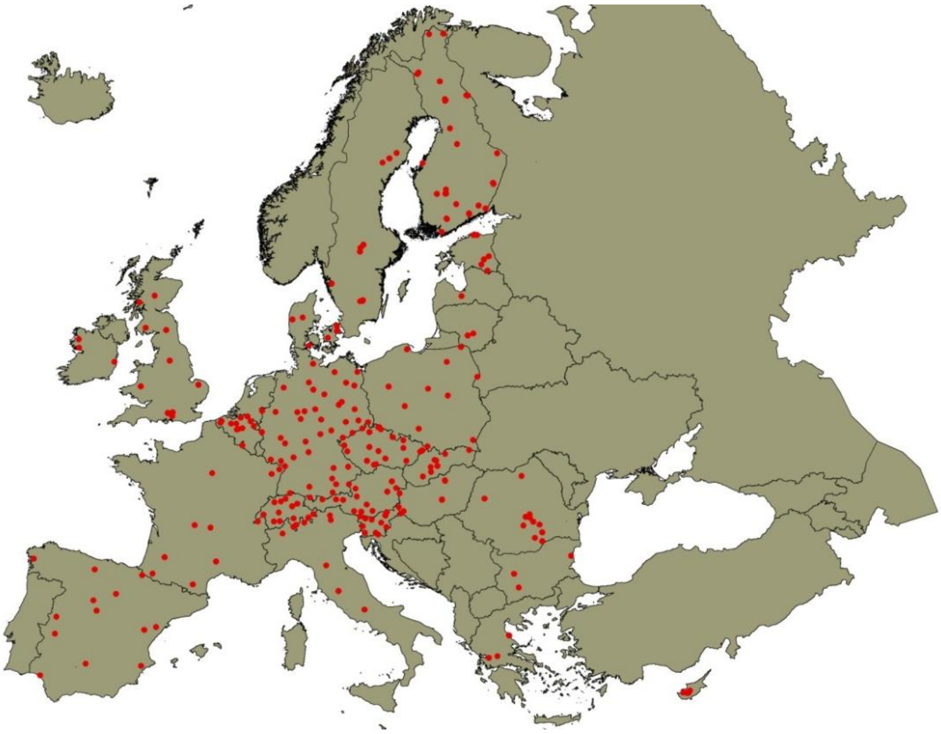

Figure 4-1. **Geographical distribution of the 274 plots contained in the PLS dataset of the AFSCDB.LII.2.1. database**

The altitude of the 274 plots ranges from class 1 (0–50 m) till class 39 (1901–1950 m), one Swiss plot in the Alps. The sampling dates for the general plot information go back to 1990 as a number of countries made the profile description and classification at the time of the plot installation. The analysis of the composite samples was however done between 1999 and 2011.

The database also provides an estimate on the water availability status related to the requirements of the forest stand. The water availability is estimated to be sufficient on 160 plots (58%), excessive on 24 plots (8.6%) and insufficient on 35 plots (13%). The information is missing for 55 of the 274 plots (20%).

The humus type on nearly 30% of the plots is Moder. It is followed in importance by Mor and Mull. Note however, that the humus type is missing on nearly 23% of the plots (**Table** 4-8**. The distribution of the humus types in the PLS dataset of the AFSCDB.LII.2.1 database**).

Table 4-8. The distribution of the humus types in the PLS dataset of the AFSCDB.LII.2.1 database

Humus type	***N° plots***	***% plots***
Mull	49	17.9
Moder	81	29.6
Mor	70	25.5
Amphi (or Amphihumus)	2	0.7
Anmoor	3	1.1
Histomor	7	2.6
Missing values (NA)	62	22.6
Total	274	100.0

4.4.2 Soil profile information

The PRF dataset contains soil profile information on 300 profiles located on 269 plots. On five plots described above, the PRF data are missing (3 German plots, 2 Slovenian plots). On the French plots and on a number of Slovenian and Danish plots, more than one profile per plot was described and reported. For all profiles, the reference soil group (according to WRB 2006) is available while a first qualifier is available for 275 profiles (92%) and a second qualifier for 62% of the profiles.

The distribution of the reference soil groups (according to WRB 2006) within the AFSCDB is roughly as follows: one fifth are Podzols, one fifth are Cambisols and one fifth are Arenosols. There are about 10% Luvisols, 5% Gleysols and 5% Regosols. Next in row are the Umbrisols (3.5%) and the stony Leptosols (2.8%), followed by the Alisols (2.1%), Stagnosols (2.1%) and Histosols (1.8%). The remaining 6% of the plots are spread among nine different reference soil groups each with a coverage between 0.4 and 1.1% (Figure 4-2).

The dominant parent material is available for 91% of the plots (Table 4-9) where we see a relative high percentage of unconsolidated glacial deposits (Lambert et al. 2003) which can be explained by the relative high number of Finnish, Polish and Estonian Level II plots.

Table 4-9. The distribution of the parent material classes in the PLS dataset of the AFSCDB.LII.2.1 database

Parent material class	% plots
Consolidated-clastic-sedimentary rocks	10.6
Sedimentary rocks (chemically precipitated, evaporated, or organogenic or biogenic in origin)	5.8
Igneous rocks	12.4
Metamorphic rocks	9.1
Unconsolidated deposits (alluvium, weathering residuum and slope deposits)	12.4
Unconsolidated glacial deposits, glacial drift	30.7
Eolian deposits	8.0
Organic materials	1.8
No information	9.1
Total	100.0

4.4.3 Soil horizon information

The PFH dataset contains the horizon descriptions of 303 profile pits described on 255 plots. In five countries the profile descriptions date from the first soil inventory of the 1990s. All the chemical analyses on the genetic horizon samples were optional to report. Table 3 shows in the last column the data availability for a selected number of variables contained with the soil horizon information dataset.

4.4.4 Sampling and analysis of composite samples taken at fixed depths

Analytical soil data is available on 260 plots for the 0–10 cm layer, but the information is decreasing with increasing soil depth till 205 (79% of the) plots in the 40–80 cm layer (Table 4-4). One obvious reason is that when the soil is stony, the depth of the loose soil which can be sampled by an auger is limited. Though the decrease of information with increasing soil depth is also due to sampling differences between the countries. For example, one country did not report analytical soil data below a depth of 40 cm which was indeed not required if this was already reported in the first inventory (Cools & De Vos

2013). Other countries did not sample the OL layer, which was another layer that was not mandatory to sample. There were 6 plots with peat layers (one in Sweden, four in Finland, one in Ireland).

After data aggregation, general statistics, such as mean and median values, along with the ranges, could be computed for all soil layers and layers of interest. Table 4-10 illustrates the general statistics of the soil analytical variables in the 0–10 cm mineral topsoil layer. The mean bulk density of the fine earth in the 0–10 cm layer is situated around 1000 kg m^{-3}. The mean pH-$CaCl_2$ is 4.0 and is on average 0.6 pH units lower than the pH-H_2O. The mean organic carbon concentration of 253 Level II intensive monitoring plots is 49 g kg^{-1}, the mean total nitrogen content 2.8 kg kg^{-1} while the mean C:N ratio is 19. Carbonates have only been measured in calcareous soils and are available for 12% of the considered plots. The cation exchange capacity is on average 11 $cmol_+kg^{-1}$ and is dominated by the basic cation calcium. 95% of the base saturation values range between 5 and 100%. The semi-total analyses by the aqua regia extract show that Al and Fe are by far the most dominant elements.

Loam is the most frequently measured textural class in the topsoil (0–10 and 10–20 cm) while it is sandy loam in the 20–40 cm and 40–80 cm layers.

The overlay of the 274 plots with the other surveys conducted in the forest monitoring programme show a good overlap with the mandatory surveys of crown condition (at least once a year), foliage analyses (at least every other year), growth increment (at least every 5 years) and deposition (continuous) (Table 4-11). A total of 155 plots have data available on both soil and soil solution. On 178 of the concerning plots a previous soil inventory took place in the period 1990–1999. The limited overlap is rather due to the fact that while a number of countries started monitoring after 1999, other countries changed the selection of their monitoring plots over the years.

Table 4-10. Descriptive statistics (number of data entries (n), mean, median, 95% range) for each of the measured variables on the upper layer (0–10 cm) of the mineral soil on the 274 Level II plots contained in the AFSCDB.LII.2.1. The total analyses of Al, Ca, Fe, K, Mg and Na were only available on 16 plots and are not shown in this table.

Statistic	n	Mean	Median	P2.5	P97.5
CLAY	188	16.6	15.2	1.0	46.9
SILT	188	34.5	35.5	3.4	71.9
SAND	188	48.9	47.2	2.9	96.1
BD	194	968	1004	436	1404
BDEST	27	1024	1050	779	1232
CFMASS	66	10	7	0	39
CFVOL	188	10	4	0	52
PHCACL2	253	4.0	3.7	2.9	6.9
PHH2O	218	4.6	4.4	3.6	6.7
OC	254	48.8	36.7	9.9	149.1
TON	254	2.8	2.1	0.3	9.4
CN	253	19.1	18.4	8.5	33.9
CARBONATES	34	65	11	1	569
EXCHACID	231	4.18	3.26	0.05	13.67
EXCHAL	236	3.12	1.95	0.01	12.26
EXCHCA	240	5.50	0.72	0.05	37.34
EXCHFE	236	0.19	0.09	0.01	1.11
EXCHK	241	0.20	0.15	0.03	0.68
EXCHMG	241	0.97	0.26	0.02	5.99
EXCHMN	241	0.16	0.06	0.01	0.98
EXCHNA	241	0.09	0.04	0.01	0.52
FREEH	237	0.86	0.47	0.05	3.63
BCE	240	6.77	1.20	0.14	41.76
ACE	236	4.33	3.11	0.15	13.56
CEC	240	11.05	7.11	1.57	46.28
BS	240	37.0	18.9	4.9	99.7
EXTRAL	198	14232.1	11065.6	1316.7	41009.8
EXTRCA	218	3763.6	838.8	38.1	15044.1
EXTRCD	222	0.32	0.25	0.02	1.60
EXTRCR	199	22.5	15.3	1.4	98.5
EXTRCU	240	10.8	6.7	0.7	42.7
EXTRFE	216	16542.2	13476.9	1064.8	44117.8
EXTRHG	58	0.177	0.106	0.015	0.699
EXTRK	218	1574.6	1165.4	158.4	5240.3
EXTRMG	218	2927.4	1818.4	90.4	12872.4
EXTRMN	219	445.1	214.5	8.4	1946.1
EXTRNA	191	143.8	88.5	12.5	610.7
EXTRNI	201	12.2	5.7	0.5	52.5
EXTRP	218	427.2	384.0	58.6	1274.5
EXTRPB	240	35.7	28.2	4.0	110.5
EXTRS	186	330.9	242.3	49.9	1134.8
EXTRZN	240	49.1	34.0	2.1	168.1
REACAL	165	2369.1	1650.9	210.9	6323.2
REACFE	165	3853.8	3127.1	332.7	11774.8

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Crown Condition	6	20	8	10	37	128	156	173	179	172	169	191	142	163	205	183	202	223	184	242	242
Sampling &Analysis of Needles and Leaves		2	4	12	20	129	69	132	47	166	35	182	69	129	37	192	30	160	59	201	78
Sampling & Analysis of Deposition		4	5	17	19	53	120	146	145	152	156	158	138	173	170	187	200	201	194	209	221
Assessment of Growth and Increment		16	9	16	45	58	63	34	10	81	83	11	11	18	87	92	20	20	22	159	50
Meteorological Measurements		2	3	3	4	12	43	69	77	98	103	99	92	100	111	111	130	134	129	178	176
Soil Solution Collection & Analysis		2	8	6	7	17	47	65	81	90	88	95	82	105	115	110	127	131	122	152	155
Assessment of Ground Vegetation						19	46	17	77	67	52	66	34	77	49	55	59	40	6	145	84
Monitoring of Air Quality										1	21	21	56	55	57	40	64	77	87	144	137
Sampling & Analysis of Litterfall													23	30	37	52	51	81	61	144	155
Phenological Observations													16	25	37	41	46	43	46	91	114
Assessment of Ozone Injury													30	32	29	21	24	33	31	93	90
Leaf Area Index (LAI) & Radiation Measurements																				95	133
Ground Vegetation Biomass & Nutrients Analyses																				89	74
Soil water content (part of meteorological survey)						1														46	49

Table 4-11. Number of plots with coinciding aggregated soil data in the AFSCDB.II.2.1 and forest ecosystem monitoring data series till 2010

4.5 Discussion

4.5.1 Strengths of the database

Compared to the database based on the first soil inventory, more essential soil variables, assessed and analysed according to harmonised methods are included in the AFSCDB. The database includes measured bulk density and estimated (sometimes measured) stoniness data on a volume basis allowing a reliable calculation of nutrient stocks both of the mineral soil and the forest floor.

Another importance and relevance of this dataset lays in the fact that a substantial number of surveys are combined — for a long term — on the same plots. The correspondence with crown condition, foliage, deposition, meteorological and soil solution surveys is relatively good both in terms of length of time series and in number of common plots. Note that the foliage survey is conducted every other year but not necessarily in the same years throughout Europe. When the foliage survey data of 2009 and 2010 are combined, there are 237 plots in common with the AFSCDB.

Having the aggregated soil information at hand, it will help us to relate the site conditions (e.g. soil type) and the stress factors by correlative studies. Trend analysis in long-term monitoring is looking for explanatory variables which can possibly be found in soil condition data assessed in a harmonised way across Europe. The soil also plays a role in input-output budget modelling (e.g. basic cations originating from soil weathering). Critical load calculations take into account a high number of chemical and physical soil characteristics. Soil data are also necessary to validate models and to initialise models that predict future impacts. The results obtained on Level II can be upscaled to the systematic soil inventory on Level I, whereas Level I models can be validated on the Level II dataset holding more data for explaining the model uncertainties.

4.5.2 Limitations of the database

The comparison of the statistics of the AFSCBD.LII.2.1 with the data contained in the Forest Soil Condition Database at Level I from the second soil survey (De Vos & Cools 2011) tells us that the AFSCDB is not representative for the WRB forest soil types across Europe (Figure 4-2).

On Level II, the stony soils (Leptosols), the young undeveloped soils (Regosols) and the peat soils (Histosols) seem to be underrepresented while the well-developed soils with texture B horizon (Luvisols), the Podzols and the sandy Arenosols might be overrepresented. This can probably be explained by the criteria which were used for the selection of the intensive Level II plots. Leptosols and Histosols are typically located in remote areas (mountains, swamps) which are not easily accessible and by consequence, not ideal to be included in an intensive monitoring programme. The over-representation of Arenosols and Podzols might lay in the fact that these sandy soils are often characterised by a poor buffer capacity and consequently a high vulnerability for soil acidification is expected.

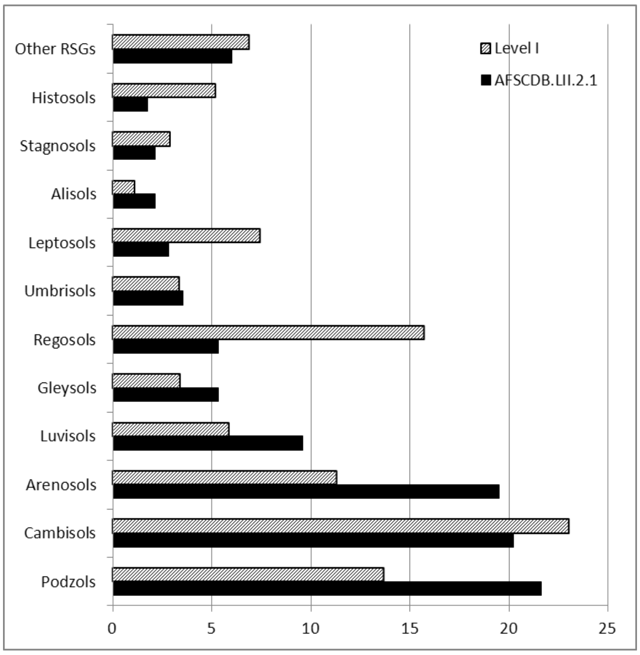

Figure 4-2. Relative distribution of the WRB reference soil groups in the AFSCDB.LII.2.1. database compared to the Forest Soil Condition database on Level I

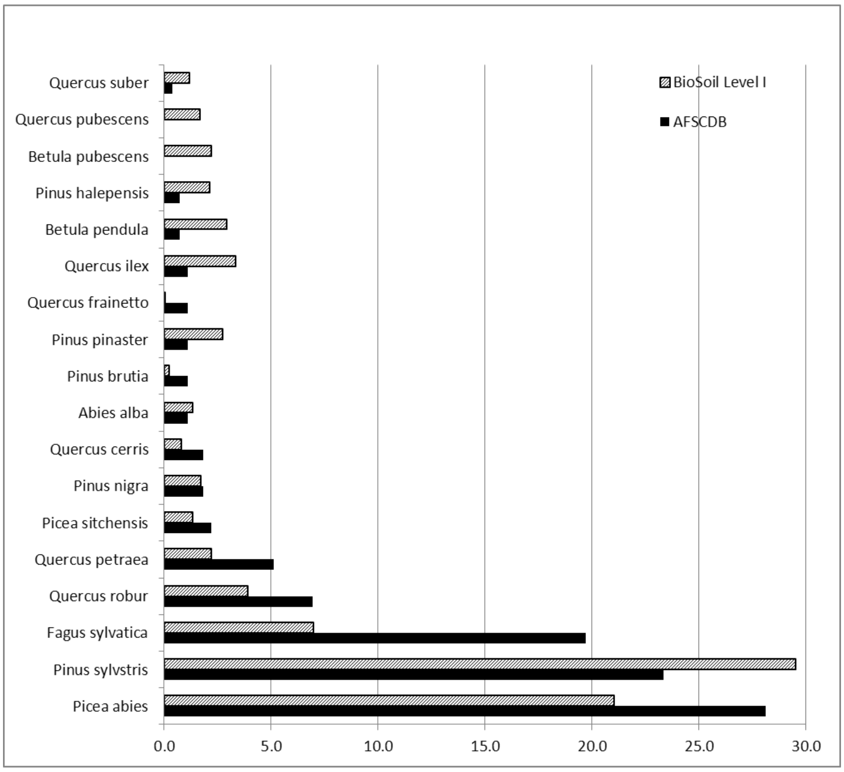

Figure 4-3. Relative distribution of the main tree species in the AFSCDB.LII.2.1. database compared to the Forest Soil Condition database on Level I

Similar as for soil types, the distribution of the main tree species in the aggregated forest soil condition database is not representative for the distribution of main tree species across Europe (Figure 4-3). In the AFSCDB *Picea abies* is the main tree species on 28.1% of the plots followed by *Pinus sylvestris* on 23.4% of the plots. In the BioSoil survey on the Level I grid of ICP Forests (De Vos & Cools 2011) the most dominant main tree species was *Pinus sylvestris* (29.5%) followed by *Picea abies* (21.0%). The third most important tree species was *Fagus sylvatica* though in the AFSCDB beech seems to be overrepresented (19.7% versus 7%). While *Betula pubescens* and *Betula pendula* are important main tree species on more than 5% of the Level I plots, *Betula pendula* is the main tree species on only two plots in the AFSCDB while *Betula pubescens* is completely absent. Also *Quercus pubescens* is not present at all in the AFSCDB.

Here also, the most important reasons are the selection criteria used at the installation of the intensive monitoring network (Annex I of Regulation EC N° 1091/94). The plots had been located in such a way that the more important forest tree species and more widespread growing conditions in the respective country were represented. The plots had to be easily accessible at all times and with limited restrictions for sampling and observations. So remote areas (such as boreal marshes and swamps) were consequently underrepresented. The plots and the buffer zone surrounding the plot had to be as uniform as possible regarding, e.g. species or species mixture, tree age, size, soil and slope.

Despite the limitations of the datasets resulting from analyses conducted by different national laboratories across Europe (Cools et al. 2004), we believe that this dataset reaches a degree and quality of harmonisation of forest soil data which has so far not been reached by other international initiatives related to forest soil databases. Too often the quality and comparability of analytical laboratory data is taken for granted or users are forced to ignore the quality aspects as no information on the quality for the data is provided. We hope that by using this aggregated soil database the errors, which are probably still present, could be traced by the users and reported to the ICP Forests database managers in order to fix these errors and prepare updates of this database at regular time intervals.

4.5.3 Future developments of the database

This paper described the first version of the AFSCDB Level II. This version included survey data till 2010. The next update will include the soil data submission for the survey year 2011 plus it will allow to include corrected and missing data. Furthermore the modelled soil moisture retention data recorded during the meteorological survey of the FutMon project on a selection of intensive monitoring plots will be included as well. Further, there will be the possibility to include stock calculations and information on the variability (standard deviations for most on the parameters on most of the plots).

4.6 Acknowledgements

We wish to acknowledge the ICP Forests National Focal Centres of Austria, Belgium, Bulgaria, Czech Republic, Cyprus, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Poland, Romania, Slovenia, Slovakia, Spain, Sweden, Switzerland and the United Kingdom for making the soil survey data available to the Programme Coordinating Centre of ICP Forests and to the Forest Soil Coordinating Centre for analysis and evaluation at the European level. We thank all participants of the Expert Panel on Soil and Soil Solution for their active discussions and contributions in setting up the survey, the methods, and the quality control of the data.

Financial support for the data collection was granted by the European Commission through Commission Regulation (EEC) No. 926/93, the European Commission Forest Focus Regulation (EC) No. 2152/2003, and the Life+ co-financing instrument of DG Environment funding the project "Further Development and Implementation of an EU-level Forest Monitoring System (FutMon)”.

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5 SPATIAL VARIATION OF DEPOSITION IN EUROPE

Uwe Fischer and Walter Seidling[7]

5.1 Introduction

The measurement of atmospheric deposition of acidifying, buffering and eutrophying compounds to forests is one of the core activities within the intensive part (Level II) of the ICP Forests monitoring. This activity includes deposition sampling in the open field (bulk deposition) and under forest canopies (throughfall), the latter in beech stands often complemented by the sampling of stemflow. In some cases wet-only deposition is additionally sampled in the open field. These measurements constitute an important source of knowledge on the deposition of the amount and type of anthropogenic or naturally emitted substances after they have been transported over more or less long distances by air.

In excess, a long-term input of all these substances can affect whole ecosystems (e.g. de Vries et al. 2014), while more sensible compartments of ecosystems, 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. This chapter documents the most recent measurements of throughfall and — if available — stemflow deposition on ICP Forests 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, is measured mainly by passive samplers in an extra survey of ambient air quality and is not included here.

5.2 Methods

Deposition measurements according to the ICP Forests Manual (Clarke et al. 2010) for the year 2012 were available for 223 plots across Europe. Throughfall 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 — if available — was included for beech stands, which plays a significant role in overall flux calculations. Only plots with a temporal coverage of at least 315 days per year were used. For the calculation of element fluxes, missing values of up to 45 days per year were accepted. Plots with extreme outliers in annual deposition rates were tested by quality checks (ion charge balance and conductivity check, Clarke et al. 2010). If in one of these checks a threshold value was exceeded by more than 70%, the respective plot was excluded from the analysis.

As sulphate, calcium and magnesium are important constituents of sea salt, the deposition of these elements on coastal areas may originate from sea salt rather than from anthropogenic sources. To ensure the comparability between plots, sea salt corrections (ICP Modelling and Mapping 2004) were conducted according to:

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

[7] For contact information, please refer to Annex III-4.

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

5.3 Results and Discussion

NH_4-N deposition is presented in Figure 5-1; central Europe is characterised by the highest fluxes with fewer occurrences of high fluxes on plots in Poland, Belgium, and northern Italy. The highest input with 19.2 kg ha^{-1} a^{-1} is determined on an oak plot located in northwest Germany. The lowest deposition is found in northern and southern Europe, France, and in the Baltic states.

Regarding the high and medium deposition fluxes, the spatial pattern of NO_3-N is similar (Figure 5-2). However, the highest range is also assessed on plots in Denmark, Latvia, and Cyprus. In south-eastern Europe and in France N deposition derived from nitrate seems to be generally higher than N input derived from ammonium. The maximum value of 14.6 kg ha^{-1} a^{-1} is found in the Czech Republic.

Deposition of SO_4-S is shown in Figure 5-3a and 5-3b. High deposition is observed on plots in Belgium and the ridges of the low mountain range extending from Germany to the Czech Republic, Slovakia, and southern Poland, with the highest flux of 18.8 kg ha^{-1} a^{-1} on a plot in the Czech Republic. High values are also found on plots in Hungary, Greece and Cyprus, but contrary to individual plots located in the United Kingdom, Norway, and Denmark, their fluxes are not largely affected by seaborne deposition. After sea salt correction all plots in northern Europe and the United Kingdom are with one exception in the lowest range (Figure 5-3b). The plots in France, Italy, Switzerland, Bulgaria, and most of the plots in Germany and northern Europe are characterized by low deposition.

Calcium is an important element neutralizing acidifying inputs primarily derived from SO_2- and NO_y-emissions. The highest values of calcium inputs (Figure 5-4a) are found on plots in the Mediterranean basin and in some regions of eastern Europe. The plots on Cyprus show the highest fluxes of up to 52.8 kg ha^{-1} a^{-1}. Low calcium inputs prevail in central and northern Europe. Only few cases have been determined with obviously decreasing input after sea salt correction (Norway, Denmark, United Kingdom, Figure 5-4b).

At first sight, magnesium shows a similar pattern to that of calcium for central and southern Europe (Figure 5-5a). However, the highest range is also found in states of northern Europe and the United Kingdom. The input of this element is clearly seaborne. For example, the input on a coastal plot in Norway is reduced to below 1.5 kg ha^{-1} a^{-1} after sea salt correction (Figure 5-5b) compared to 16.9 kg ha^{-1} a^{-1} without sea salt correction. This is also valid for all of the plots located in France and Belgium, and with one exception in Italy and Switzerland, respectively. The plot in Italy is the one with the highest input of sea salt corrected magnesium (6.6 kg ha^{-1} a^{-1}). High deposition is also found on plots in Hungary, Greece, and Cyprus. There, deposition originates most likely from dust sources.

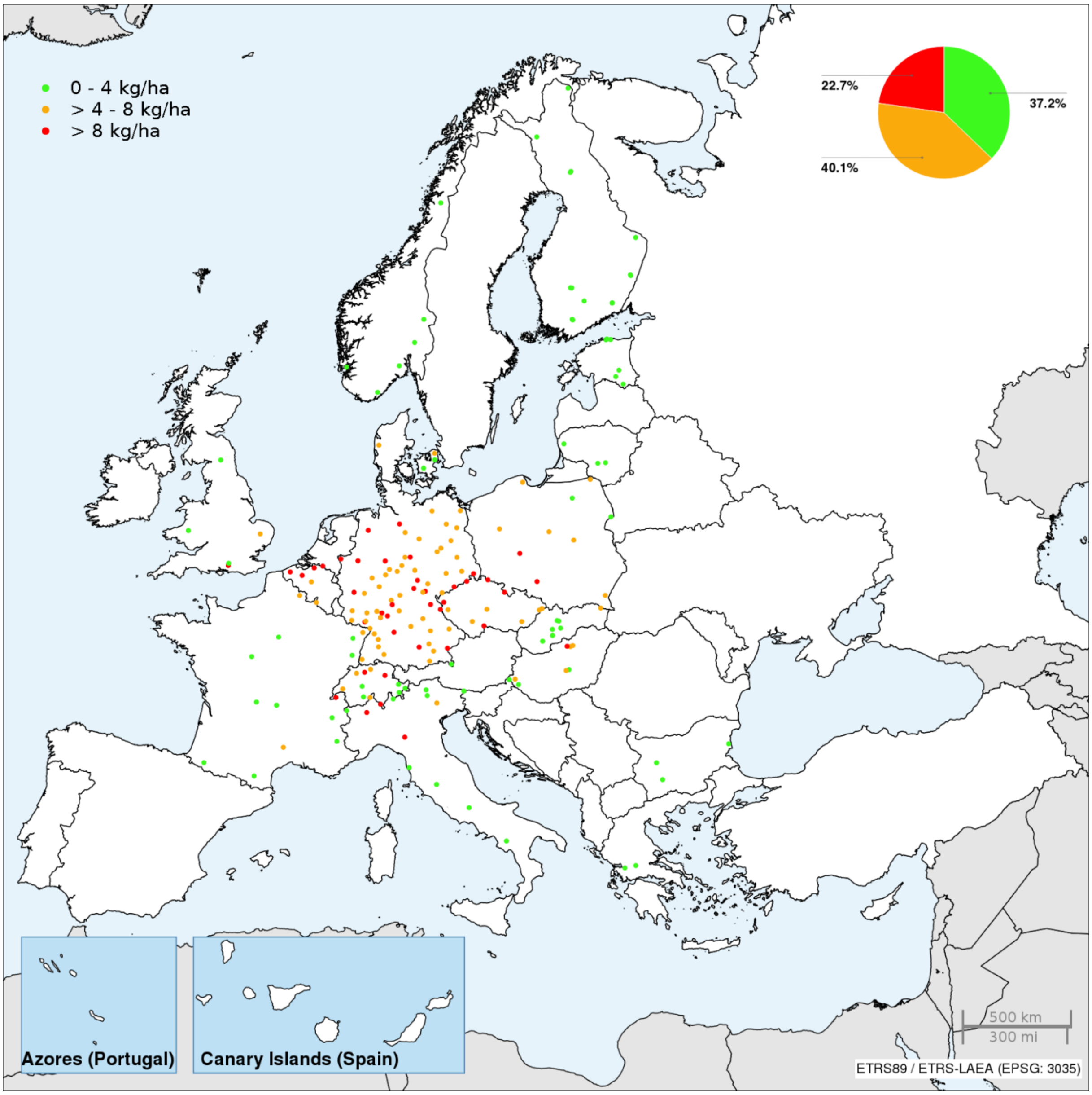

Figure 5-1: Throughfall (and stemflow if measured) deposition of ammonium nitrogen (N-NH_4) in European forests in 2012

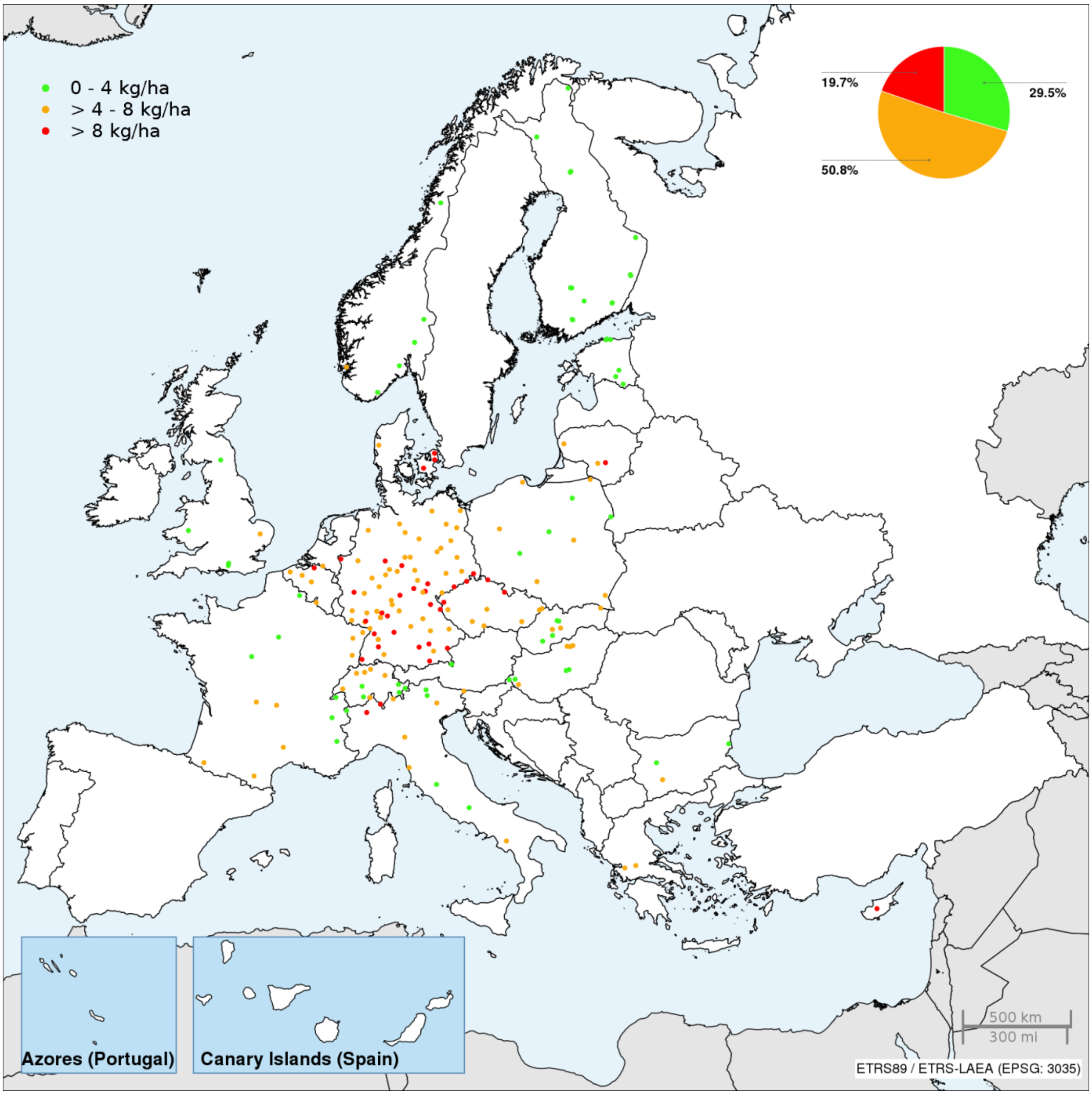

Figure 5-2: Throughfall (and stemflow if measured) deposition of nitrate nitrogen (N-NO_3) in European forests in 2012

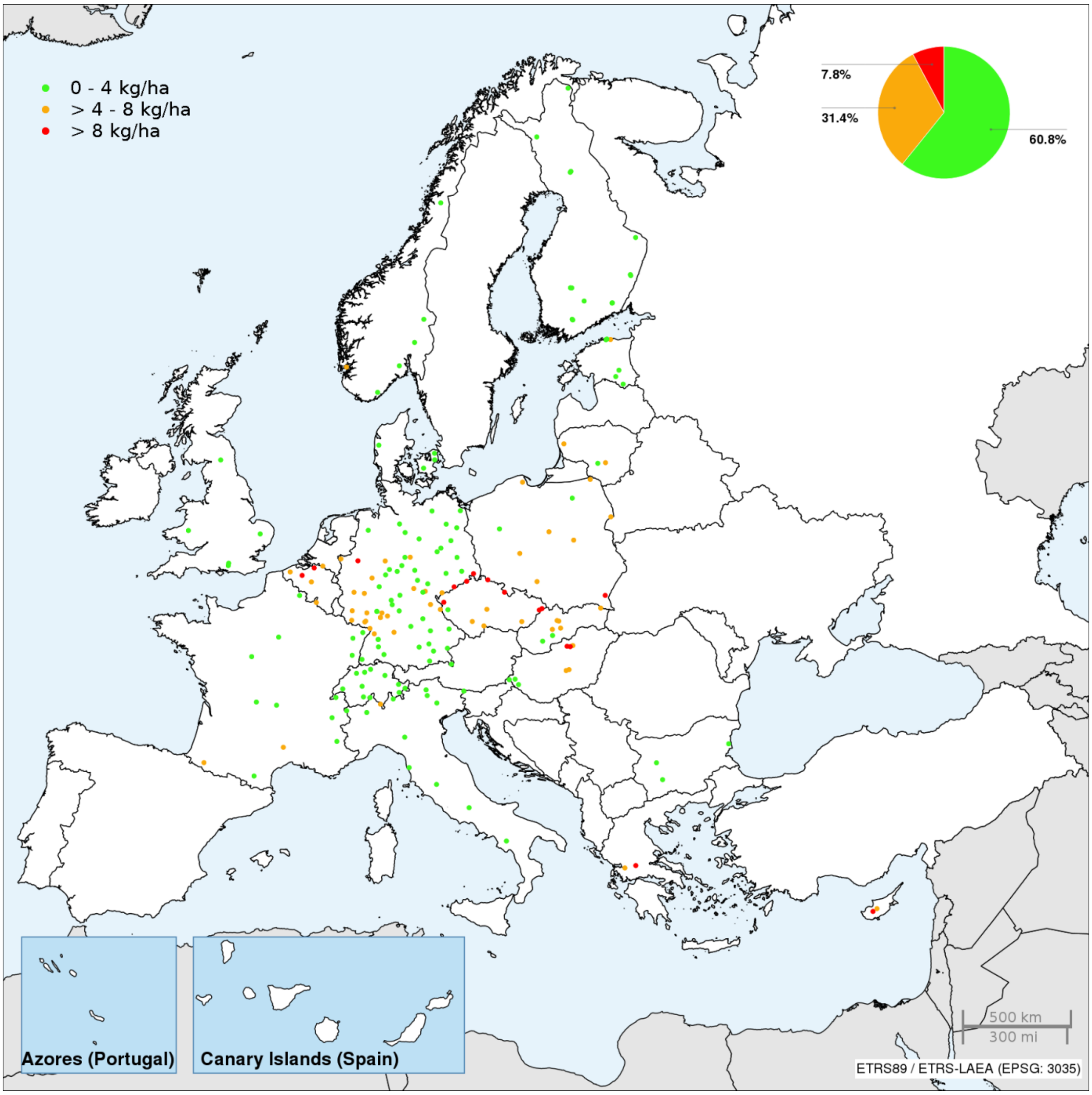

Figure 5-3a: Throughfall (and stemflow if measured) deposition of sulphate sulphur (S-SO_4) in European forests in 2012 without sea salt correction

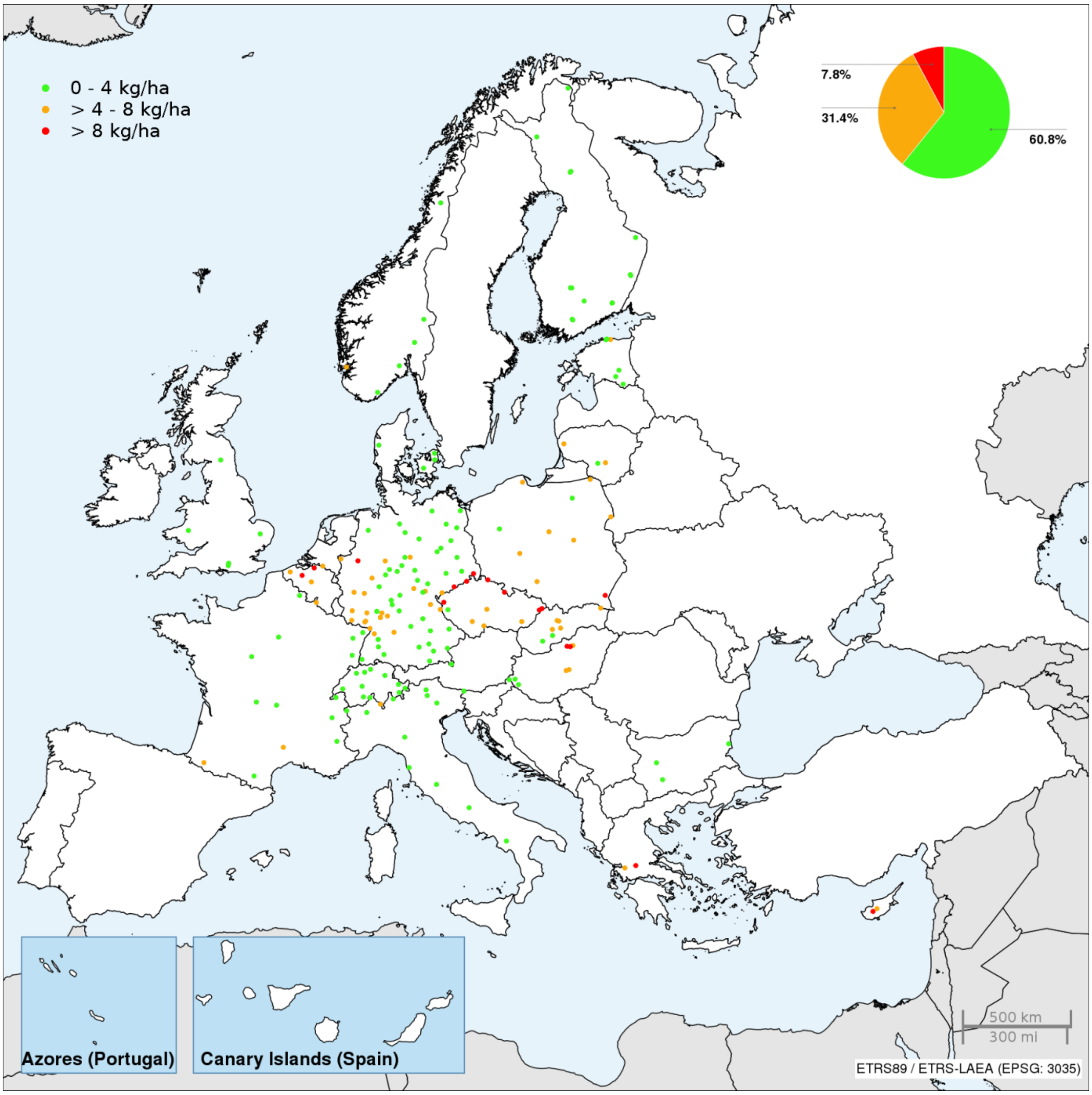

Figure 5-3b: Sea salt corrected throughfall (and stemflow if measured) deposition of sulphate sulphur (S-SO_4) in European forests in 2012

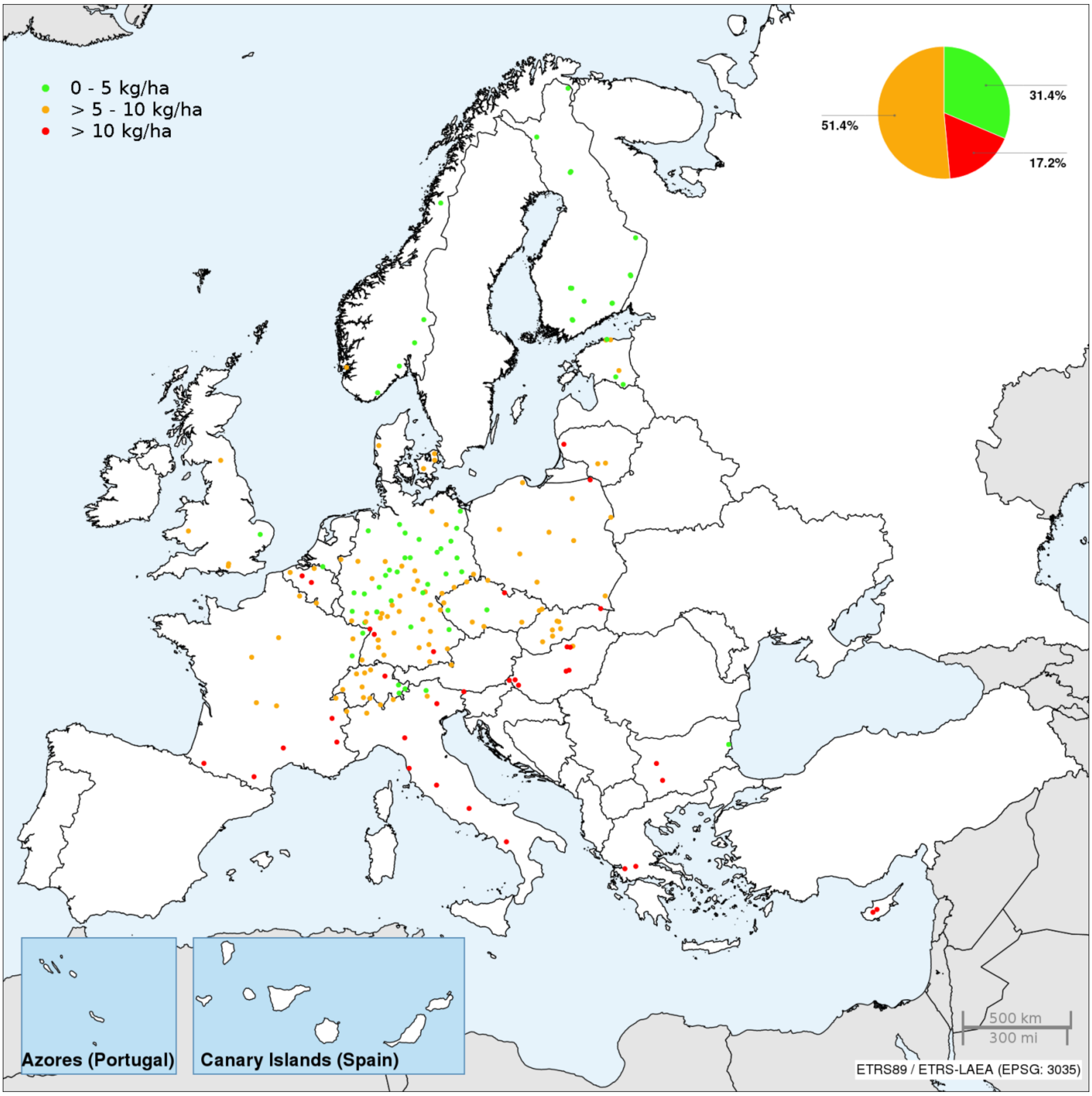

Figure 5-4a: Throughfall (and stemflow if measured) deposition of calcium in European forests in 2012 without sea salt correction

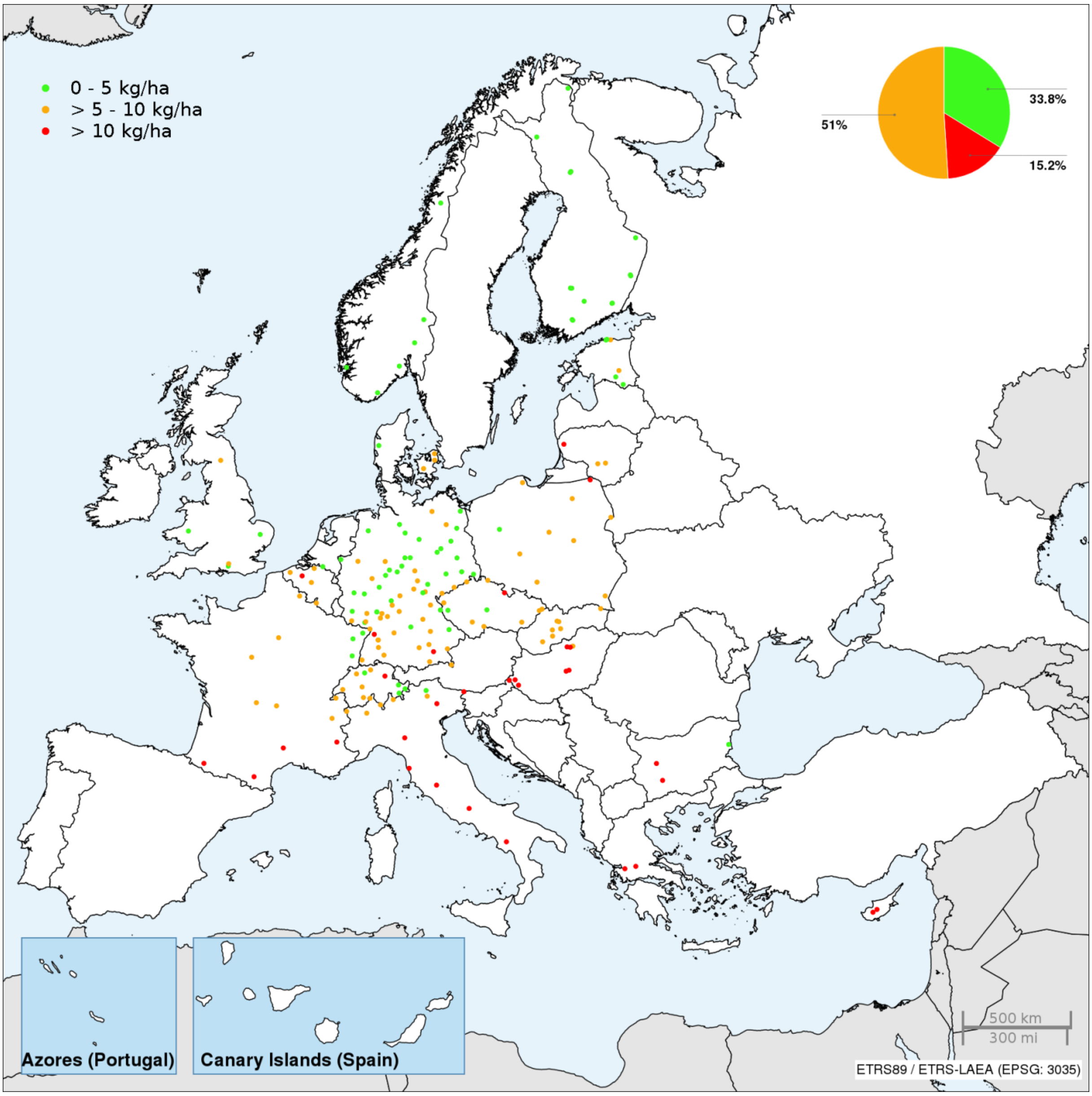

Figure 5-4b: Sea salt corrected throughfall (and stemflow if measured) deposition of calcium in European forests in 2012

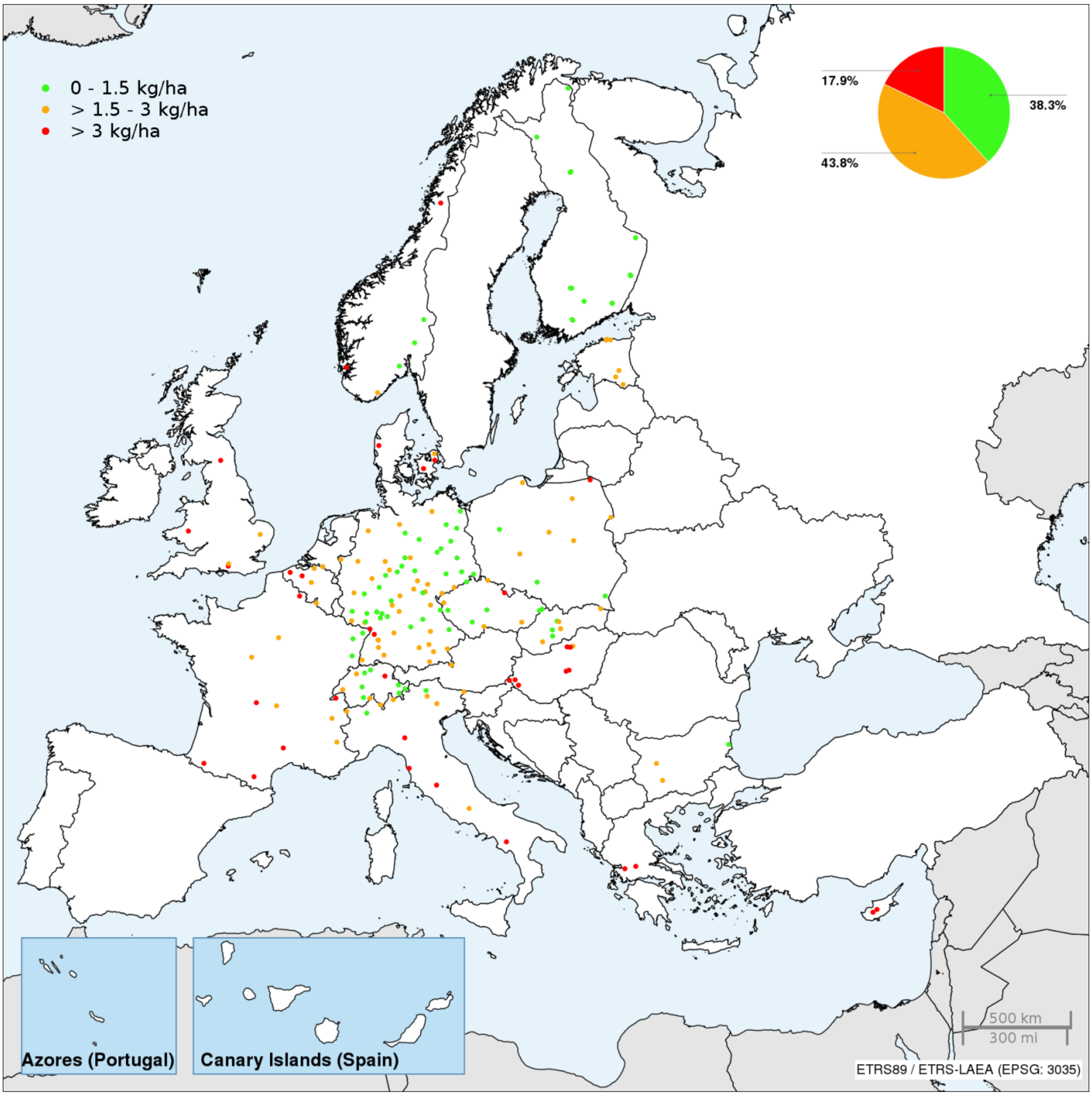

Figure 5-5a: Throughfall (and stemflow if measured) deposition of magnesium in European forests in 2012 without sea salt correction.

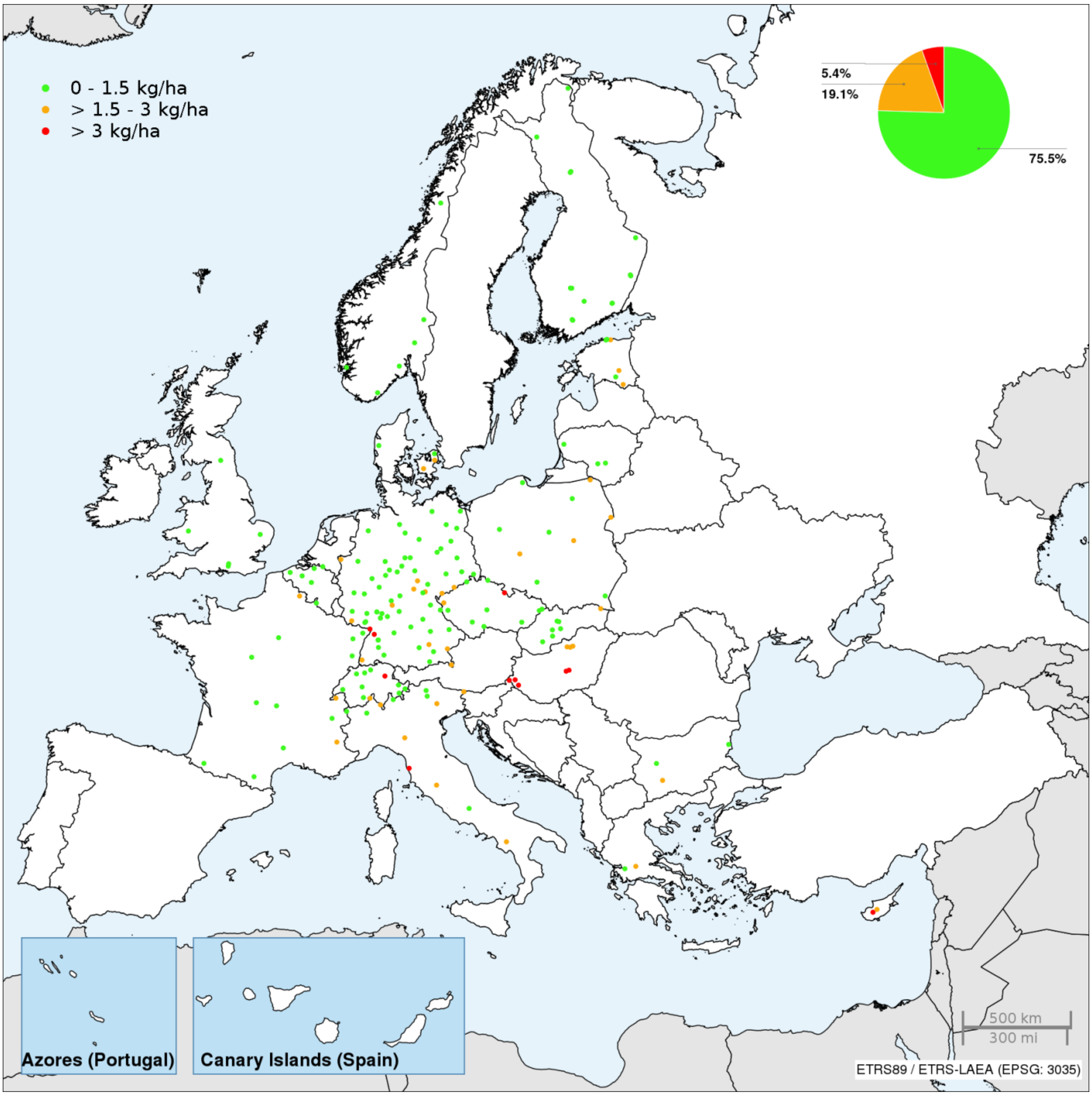

Figure 5-5b: Sea salt corrected throughfall (and stemflow if measured) deposition of magnesium in European forests in 2012

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6 NATIONAL REPORTS

6.1 Introduction

Twenty-eight countries have submitted numerical results of their 2013 national crown condition surveys. All but one have included 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.

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 forest conditions in Chapter 3 (Level I). It is, therefore, not possible to directly compare the results of the national surveys of individual countries in this chapter. Missing values in the tables and figures in Annex II-1 to II-8 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 in this chapter, please refer to Table 3-5.

6.2 Albania

Tree defoliation has been monitored as indicator for forest tree health and forest vitality. Forest trees' leaves always react to various factors, including climate conditions and extreme weather, as well as sequestration or tree exposure levels to fungus disease. During the years 1997–2002 in Albania, the National Observing-Signalization Network at the Forestry Service was established with 296 experimental plots distributed in the entire country to study the degree to which forests of the main forest tree species are affected by insects and diseases (Figure 6-1). After the closing of the Pastures and Forestry Research Institute (IPPK Alb.), the Forestry Department at the Environmental and Forest Agency (AMP Alb.) continued the monitoring of forests with a reduced methodology due to financial impediments. Of course, the estimation of the defoliation represents an early warning system and it provides valuable feedback of forest ecosystem responses to change. The trees which entirely keep their leaves or needles are assessed as having 0% leaf downfall and are considered healthy, those with 25–50% downfall or leaf loss are classified as moderately damaged trees and those which reach 91–100% indicate completely dead trees. This aspect of the sanitary situation of the forest trees in Albania is not going to be monitored regularly by a questionnaire inspection to observe the trees' crown situation, depending on implemented structures of the field experts. That is why the data are a little bit limited in proportion with its own forest ecosystem extension.

Relating to the five year period 2005–2010, the data are collected from permanent experimental plots installed in 12 Albanian districts in equal proportion of the weight of the main species' area determined according to the forest stands' composition (Figure 6-1). Timing tendencies of the defoliation and needles of the main forestry trees species have been calculated for the monitored plots in 12 districts of the country. The observed changes during the vegetation period indicate a healthy situation in Albania, not or only very little affected were some of the main conifer species such as *Pinus nigra*, *Pinus halepensis*, *Pinus pinea* as well as *Cupressus sempervirens* and in particular *Platanus orientalis* — from the broadleaved trees. The latter indicates distinctions regarding the damage degree beyond the aggravation situation, in various districts like Tepelena, Gjirokastra, and Përmet, because the plane tree as a species, due to unknown causes in this five years was observed to show the total drying of the woods in quite some habitats (in small plots) alongside the Vjosa stream and rarely in Shkumbini river ponds. During the period 2000–2010, the percentage of the defoliation from the tree crowns indicates a healthy and vital situation of Albanian forest ecosystems. The monitoring of the defoliation degree of leaves and needles in the tree crowns, according to the three classes *slightly damaged, moderately, or heavily damaged*, indicates maximum levels of 9% heavily damaged trees in the Dibra district and 6.9% in the Kukësi district, meanwhile the average of the defoliation degree on country level is estimated to be 1.3%, an estimation which was monitored during the year 2010.

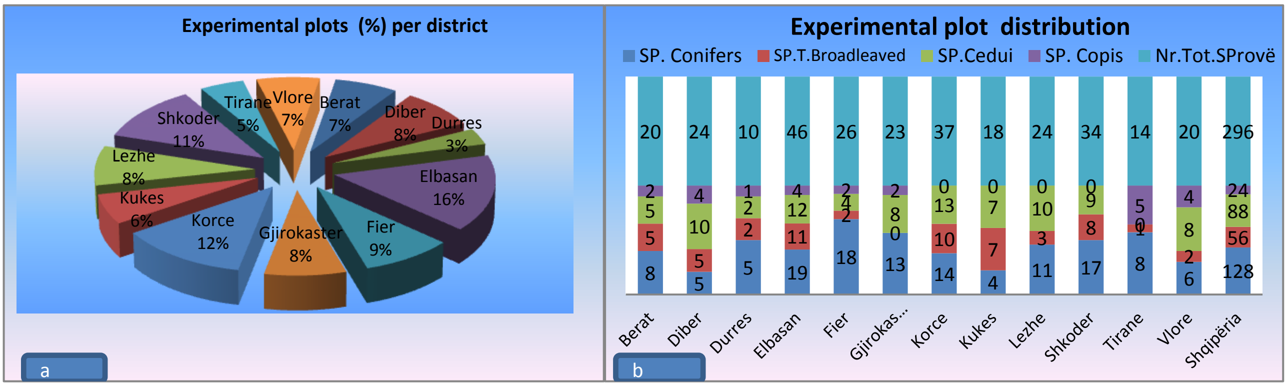


Figure 6-1. Distribution of experimental plots per district and species groups

Trends and explanations regarding the defoliation show that there is no decrease in the percentage of monitored plots during the last 10 years. The observed instability cannot be taken into consideration to indicate a deterioration of the forest trees' canopy situation. These tree reactions derive from the impact of drought and lack of water and aerial humidity, which cause the assessed defoliation. Beetle attacks and fungus disease are altered with a vulnerability decrease caused by sequestration loads, weather conditions, and other anthropogenic factors, and indicate how much these trends are connected. High levels observed in defoliation might indicate that there is a reduced potential to face negative environmental impacts.

6.3 Andorra

The assessment of crown condition in Andorra in 2013 was conducted on 11 plots of the transnational ICP Forests grid. Three plots have been assessed since 2004 and eight new plots were added in 2012 in order to intensify the sampling network. As in previous years, the three old plots included 72 trees: 42 *Pinus sylvestris* and 30 *Pinus uncinata*. The eight new plots were composed of 192 trees: 76 *Pinus sylvestris*, 108 *Pinus uncinata*, 5 *Betula pendula* and 3 *Abies alba* trees.

Results for 2013 in the already existing plots showed an improving tendency in forest condition, as registered since 2009, with just a slow decrease in 2012. For both pine species, most of the trees were classified in defoliation and discolouration classes 0 and 1. In 2013 compared to 2012, the amount of pine trees decreased from class 1 to class 0, which is the most important development. In the new plots, results for 2013 showed an acceptable forest condition. For all species, the results showed that most of the trees were classified in defoliation and discolouration classes 0 and 1. Results for both new and old plots can be considered compatible; the trees were classified mostly as not damaged (80.3%) and slightly damaged (15.2%) according to the combined assessment.

Related to defoliation, in the already existing plots an increase in not defoliated trees (56.9% in 2012 from 77.8% in 2013) was registered, and a decrease in slightly defoliated trees (37.5% in 2012 from 18.1% in 2013) and moderately defoliated trees (5.6% in 2012 from 4.2% in 2013). In the new plots, most of the trees were not defoliated (values ranged from 60% to 100%). *Betula pendula* presented a relatively high value in the moderately defoliated class (20%), although the significance of this result is low due to the reduced number of individuals of birch surveyed, all in the same plot. There were no trees registered in the severe defoliation class in any of the plots.

The results for discolouration showed for the already existing plots a very important increase in the not discoloured class (13.9% in 2012 from 56.9% in 2013), an important decrease in the slight discoloured class (77.8% in 2012 from 40.3% in 2013), and a less important decrease in the moderate discoloured class (8.3% in 2012 from 2.8% in 2013). Severe discolouration was not reported. In the new plots, the results showed that the totality of trees was classified as discolouration classes 0 and 1 with the exception of birch trees which follow a different distribution with 40% of trees in the moderate and severe discolouration classes. As noticed for defoliation, the significance of this result is low due to the reduced number of individuals of birch surveyed.

Favourable climatic conditions in 2013 with high precipitation during the vegetative period could explain the improvement of discolouration and defoliation conditions in the already existing plots and the good forest condition observed in the new plots. In 2013, the assessment of damage causes showed in the already existing plots, as in previous surveys, that the main causal agent was the fungus *Cronartium flaccidum* which affected 5.6% of the sampled trees, distributed in two plots. The assessment of damage causes in the new plots showed many causal agents, like wind, snow, rots and lightning scars, which affected overall 3.1% of the sampled trees.

6.4 Belgium

Belgium/Flanders

The Level I survey was conducted on 71 plots of the regional 4 x 4 km grid. Of a total of 1722 sample trees 56.5% were broadleaves. The main species are *Quercus robur*, *Q. rubra, Fagus sylvatica, Populus* sp., *Pinus sylvestris* and *P. nigra* subsp. *laricio*. A sample with 'other broadleaves' consists of different species like *Alnus glutinosa*, *Castanea sativa*, *Quercus petraea*, *Fraxinus excelsior*, *Betula pendula* and *Acer pseudoplatanus*.

20.8% of the trees were in defoliation classes 2–4 and the mean defoliation of the sample trees was 24.6%. 8.5% of the trees were in defoliation class 0. 25.5% of the broadleaves and 14.7% of the conifers were moderately to severely defoliated.

Defoliation was high in *Pinus nigra*, *Q. robur* and *Populus* sp. The share of damaged trees amounted to 34.8% in *P. nigra*, 30.2% in *Q. robur* and 25.0% in *Populus* sp.

The mortality rate was 2.4%. This high figure is due to one *Alnus glutinosa* plot, where 30 trees died due to *Phytophthora alni* infection and very wet site conditions. The high defoliation level in this dense plot influenced the whole survey. 33.6% of trees in the category 'other broadleaves' were classified as being damaged.

Q. rubra showed the lowest level of defoliation, with 4.3% of the trees in defoliation classes 2–4. The defoliation level of *Fagus sylvatica* and *Pinus sylvestris* was also lower than the average, with 6.7% and 8.4% of the trees showing more than 25% defoliation.

Crown condition improved compared to 2012. The share of damaged trees decreased by 3.3 percentage points and the mean defoliation by 0.4 percentage points. Only the 'other broadleaves' showed a higher share of moderate to severely defoliated trees and a significant increase in defoliation.

Symptoms of pests and diseases were observed less frequently. The share of trees with more than 10% defoliation caused by insects decreased from 11.2% in 2012 to 7.3%.

The share of trees with more than 10% discolouration of the leaf area decreased from 16.1% to 8%. Damage by fungal infections like *Microsphaera alphitoides* on *Quercus robur*, *Melampsora* sp. on *Populus* and *Scirhia pini* on *Pinus* sp. was less intensive than in 2012 and the first symptoms of infections like *Melampsora* sp. were observed later in the vegetation season than in the previous year.

Spring was cold but weather conditions were normal during summer. Mechanical damage was observed in several plots and 0.2% of the trees were removed after storm. 1.8% of the trees were cut in thinning operations.

Belgium/Wallonia

The survey in 2013 concerned 409 trees on 40 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 these 3 last years.

Since 2010 spruces show stable defoliation with a mean around 40%. After undergoing severe damage in the early 2000s (Scolytidae and drought), beech show a decrease in mean defoliation value to reach 33% in 2013. Oaks had the maximum defoliation in 2012 (50%). This could be explained by massive attacks of defoliating insects and oïdium in 2011 and 2012 (which also influenced the observation of trees and perhaps brought bias). However, in 2013 this unusual rate decreased to reach 25% of mean defoliation for sessile oaks and 35% for English oaks.

6.5 Croatia

In the forest condition survey in 2013, there was an increase in the number of plots in comparison with year 2012. One hundred and five sample plots (2520 trees) on the 16 x 16 km grid network were included in the survey after the completion of the field inspection of non-active plots.

The mean annual temperature in Croatia in 2013 was higher than normal, but also the precipitation was normal to very high.

The percentage of trees of all species within classes 2–4 in 2013 (29.1%) was higher than in 2012 (28.5%), and highest in the last ten years. The percentage of broadleaves in classes 2–4 (25.7%) was also highest in the last ten years of survey. For conifers, the percentage of trees in classes 2–4 was 48.3%, a significant decrease from year 2012 (54.7%). There were 385 conifer trees and 2135 broadleaves in the sample.

Pinus nigra, with 61.6% trees in the classes 2-4, along with *Abies alba* (59.6%), remain our most defoliated tree species.

With broadleaved trees, the deterioration of crown condition was most prominent with pedunculate oak. The percentage of *Quercus robur* trees in classes 2–4 was fairly constant at around 25–30% until the year 2000. Afterwards it decreased to values below 20% (15.4% in 2003, 18.5% in 2004). In 2005 a slight increase was recorded with 22.1%, followed by 22.2% in 2008, 22.8% in 2009, 26.0% in 2010, 22.3% in 2011, and 27.8% in year 2012. This year we recorded 30.5% of moderately to severely defoliated oak trees.

Fagus sylvatica remains one of the tree species with lowest defoliation with 17.2% trees in the defoliation class 2–4. In the last ten years of monitoring, this percentage varied from 5.1% in 2003 to

13.8% in year 2011. Although the defoliation of common beech is relatively low, it is also constantly on the rise.

6.6 Cyprus

The annual assessment of crown condition was conducted on 15 Level I plots during the period July–September 2013. The assessment covered the main forest ecosystems of Cyprus and a total of 360 trees (*Pinus brutia, Pinus nigra* and *Cedrus brevifolia)* were assessed. Defoliation, discolouration and the damaging agents were recorded.

A comparison of the results of the conducted survey with those of the previous year (2012) does not show significant differences among the four categories on all species. From the total number of trees assessed (360 trees), 29.7% of them were not defoliated, 61.4% were slightly defoliated, 7.8% were moderately defoliated, and 1.1% were severely defoliated.

A comparison with the results of the previous year, the 2013 results show an increase of 3.9% in class 0 (not defoliated). A decrease of 2.2% in class 1 (moderately defoliated) and a decrease of 2.2% in class 2 (severely defoliated) have been observed. A slight increase of 0.6% has been observed in class 3 and no dead trees have been recorded (class 4, dead). The slight improvement of crown in 2013 is mainly due to the sufficient rainfall of the period 2008–2012.

In the case of *Pinus brutia*, 32% of the sample trees showed no defoliation, 58% were slightly defoliated, 9.3% were moderately defoliated and 0.7% were severely defoliated. For *Pinus nigra*, 11.1% of the sample trees showed no defoliation, 88.9% showed slight defoliation. For *Cedrus brevifolia*, 29.2% of the sample trees showed no defoliation, 62.5% were slightly defoliated and and 8.3% were severely defoliated. No dead trees have been observed.

From the total number of trees assessed (360 trees), 100% of them were not discoloured.

From the total number of sample trees surveyed, 73.1% showed signs of insect attacks and 8.3% showed signs of attacks by "*other agents*, *T8*" (lichens, dead branches and rat attacks). Also 8.9% showed signs of both factors (insect attacks and other agent). From the total number of trees that showed signs of insect attacks (82.0%), for 68.4% it was signs of insect attacks from the previous year.

The major abiotic factors causing defoliation in some plots during 2013 were the combination of the climatic with the edaphic conditions which resulted to secondary attacks by *Leucaspis* spp. and defoliator insects to half of the trees.

6.7 Czech Republic

In 2013, compared to the last year results, a slight increase of the total defoliation in older stands (60+) was observed, characterized by the decrease of percentage in the 0 and 1 class of defoliation and increase in class 2. This change was observed in most of the species assessed (*Picea abies, Abies alba* and *Larix decidua*). Development of the total defoliation of the younger conifers (stands up to 59 years) shows really moderate improvement in 2013. It characterizes an increase of trees in class 0, compared to class 1. This change was observed with most of the species, with the exclusion of fir (*Abies alba*), where, in contrary, a deterioration of its state was observed with significant decrease in class 0 and increase in class 1.

In the broadleaves of the older age category (60+), a moderate decrease of defoliation in class 2 and simultaneous increase in class 1 was observed. Mostly oak was in deal (*Quercus* sp.), with defoliation in class 1 increasing from 32.6% in 2012 to 40.3% in 2013 and decreasing in class 2. In younger broadleaves (up to 59 years) no major changes in defoliation were observed. Some changes were observed among individual species — the main tree species (*Quercus* sp., *Fagus sylvatica*) have shown a significant defoliation increase, most of the other species could be characterized with a defoliation decrease.

Younger conifers (up to 59 years) show lower defoliation than younger broadleaves, in the long term perspective. In older stands (60+) this ratio is opposite, older conifers are with a significantly higher defoliation than older broadleaves. Pine in both age categories is of higher defoliation.

Average monthly temperatures in the period March–September 2013, compared to the long term averages, have varied most in March (+3.2° deviation) and July (+2.5°). Average precipitation amounts were mostly higher in this period, with the exclusion of July (43% of normal). The unfavourable ratio of temperature and precipitation amounts in July could have had a bad impact on the health state of spruce stands in higher elevations.

Emission development of the main pollutants (solid matter, SO_2, NO_X, CO, VOC, NH_3) did not show any significant changes in the last ten years. Total emission of most of the substances is decreasing gradually, emission of solid matter and NH_3 shows a constant state.

6.8 Denmark

The Danish forest condition monitoring in 2013 was carried out via the National Forest Inventory (NFI) including the remaining Level I and II plots. Monitoring showed that most tree species had satisfactory health status. However, in autumn 2013 two major storms caused major wind throw and crown breakage in both broadleaves and conifers. As the summer of 2013 was conducive for population increase of the bark beetle *Ips typographus*, problems may arise in 2014, depending on local weather conditions. A casualty of the storms was one of the oldest remaining Level II plots in Denmark (Ulborg).

As in previous years *Fraxinus excelsior* showed extensive dieback due to the invasive pathogen *Hymenoscyphus pseudoalbidus*. Average defoliation was 27% for all monitored ash trees, and 36% of the trees had at least 30% defoliation. However, these data do not completely reflect the situation, because many diseased ash stands are clear cut. This is reflected in timber statistics, where the amount of ash harvested has risen significantly after 2010.

Picea abies stayed at a low average defoliation of 5%, and the health situation for Norway spruce in Denmark is still excellent based on monitored stands. Other conifers such as *Picea sitchensis* and *Pinus* sp. had a slightly higher defoliation at 7% and 10% respectively, but the health of conifers in general can be considered satisfactory. The warm and dry July 2013 has led to expectations of an expansion of *Dendroctonus micans* on sandy soils, which may impact Sitka spruce.

Firs (*Abies* sp.) do not occur in high numbers in Danish forests, except for Christmas trees and stands for greenery production, mainly *A. nordmanniana* and *A. procera*. Two new threats have emerged in recent years, a fungus (*Neonectria neomacrospora*) causing extensive damage since 2011, and a bark beetle (*Cryphalus piceae*) which was first recorded as significant pest on noble fir in 2013. Both may also become a problem for forest species such as *A. alba* and *A. grandis*.

The average defoliation score of *Fagus sylvatica* and *Quercus* (*robur* and *petraea*) decreased to 7% and 15% respectively. For oak this improvement reflected the fact that the attacks by defoliators such as

Operophtera brumata observed last year, was not widespread in 2013. On the other hand reports of dead and dying oaks, especially on soils with drainage problems, has increased in recent years.

Based on defoliation assessments on NFI plots and Level I & II, the results of the crown condition survey in 2013 showed that 80% of all coniferous trees and 71% of all deciduous trees were undamaged. 17% of all conifers and 21% of all deciduous trees showed warning signs of damage. The mean defoliation of all conifers was 6% in 2012, and the share of damaged trees was less than 3%. Mean defoliation of all broadleaves was 10%, and 8% of the trees were damaged, which is an improvement since 2012.

6.9 Estonia

Forest condition in Estonia has been systematically monitored since 1988. In 2013 altogether 2329 trees, thereby 1465 Scots pines (*Pinus sylvestris*), 582 Norway *spruces (Picea abies*) *and* 227 Silver birches (*Betula pendula*), were examined on Level I permanent sample plots from July to October.

The total share of not defoliated trees, 49.5%, was by 0.1% higher as in 2012 and 1.3% lower as in 2011. The percentage of trees in classes 2 to 4, moderately defoliated to dead, was 8.0 in 2013. Whereas the percentage of conifers in classes 2 to 4, moderately to dead, was 8.4 in 2012.

In Estonia the most defoliated conifer species has traditionally been Scots pine, the share of not defoliated trees (defoliation class 0) was 43.1% in 2013, while the percentage of pines in classes 2 to 4, moderately defoliated to dead, was 8.8 in 2013. Some increase of defoliation of Norway spruce occurred, the share of not defoliated trees (defoliation class 0) was 54.6% in 2013.

The percentage of broadleaves in classes 2 to 4, moderately to dead, was 3.0 in 2011, 15.0 in 2012 and again smaller – 5.3 in 2013. Thus a serious change in crown conditions as compared to 2012 happened. The share of not defoliated birches was 74% in 2011, 59% in 2012 and 73.6% in 2013.

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. Winter moth was the main reason of increased birch defoliation in 2012.

In 2013 4.6% of the trees had some kind of insect damage and 30.9% of the trees had identifiable symptoms of disease (in 2012 accordingly 8.2% and 28.3%). Pine shoot blight was the most significant reason of biotic damage of Scots pine. Norway spruces mostly suffered due to root rot and moose damage.

6.10 France

In 2013, the forest damage monitoring in the French part of the systematic European network comprised 11 262 trees on 563 plots.

The climatic conditions of the year were favourable to the forest vegetation due to a rainy and chilly spring.

Nevertheless, these good climatic conditions did not seem to have a clear impact on the level of defoliation insofar as, for most species, the rate of less defoliated trees (class 0) decrease so as the moderately defoliated trees (class 2), which benefits the slightly defoliated trees (class 1). *Quercus pubescens* and evergreen oak, species which are frequent in the South East of France, still had the worst crown condition of all monitored species in 2013.

Death of sampled trees stayed at a relatively low level. The number of discoloured trees was still low except for poplars, 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).

6.11 Germany

In 2013 forest condition slightly improved compared to the previous year. This applies to all tree species but Scots pine. However, defoliation of the latter has always been less than that of other tree species since the 90ies. Beech trees continued to recover as already observed in the previous year. Oaks show a significant improvement in crown condition, while still remaining the tree species with the highest rates of defoliation.

Averages for all tree species show that 23% (2012: 25%) of the forest area was assessed as damaged, i.e. recorded with more than 25% of crown defoliation (damage classes 2 to 4); 39% (2012: 36%) were in the warning stage, and 38% (2012: 39%) showed no defoliation. The mean crown defoliation decreased from 19.2 to 18.8%.

Spruce (*Picea abies*): the percentage of damage classes 2 to 4 is 24%, compared to 27% in the previous year; 38% (2012: 35%) of the trees were in the warning stage. The share of trees without defoliation remained unchanged at 38%. Mean crown defoliation decreased from 19.3 to 18.8%.

Scots Pine (*Pinus sylvestris*): the share of damage classes 2 to 4 was 11%, unchanged in comparison to 2012; 42% (2012: 39%) were in the warning stage; 47% (2012: 50%) showed no defoliation. The mean crown defoliation increased from 14.5% to 15.1% but still remains below other tree species.

Beech (*Fagus sylvatica*): beech continued to recover, however, not at the same rate as between 2011 and 2012. The share of damage classes 2 to 4 further decreased from 38% in 2012 to 35% in 2013; 42% (2012: 40%) were classified in the warning stage. The share of trees without defoliation remained nearly unchanged, 23% compared to 22% in 2012. Mean crown defoliation decreased from 24.3% to 23.7%.

Oaks (*Quercus petraea, Q. robur*): the share of damaged trees decreased from 50% to 42%. The share of trees in the warning stage was 39% (2012: 33%). 19% (2012: 17%) of the oaks showed no defoliation. Mean crown defoliation was 27.0% compared to 29.4% in 2012.

Oaks remain the most defoliated tree species in our forests. Damage caused by defoliators, namely the caterpillars of a number of moth species, play an important role, additionally second shoots are often affected by mildew.

6.12 Hungary

The forest condition survey — based on the 16 x 16 km grid — in 2013 included 1,800 sample trees on 78 permanent plots in Hungary (three of them are temporarily unstocked). The assessments were carried out between 15th July and 15th August. 88.7% of all assessed trees were broadleaves (as in 2012), 11.3% were conifers.

The overall health condition of the Hungarian forests compared to the previous year got worse but it is still better than in 2010. The share of trees without visible damage symptoms decreased from 60% to 55.6%, the mean defoliation level of all species was 17.6%, and this is 0.4% higher than in 2012.

The percentage of all trees within ICP defoliation classes 2–4 (moderately damaged, severely damaged and dead) in 2013 (22.4%) is higher than in 2012 (20.2%). This means that 2013 is the worst year since 2010. In Hungary the dead trees remain in the sample till they are standing, but the newly (in the surveyed year) died trees can be separated. The rate of trees died in 2013 was 0.9% of all trees that is almost the same as in the previous year. The number of all dead trees increased slightly, but the tendency is constant over the long period.

Apart from the very rare species (with a rate of less than 3%), in the classes 2–4 the tree species suffering most damage are *Quercus robur* (32.5%), *Robinia pseudoacacia* (30.2%) and *Fagus sylvatica* (29.3%), (the percentages show the rate of sample trees belonging to category 2–4). *Populus* x *euramericana* 'Pannónia' (1.1%) and *Alnus glutinosa* (6.7%) had the lowest defoliation rates in classes 2–4. Defoliation rates by species generally show considerable year to year variation in these categories.

Discolouration can rarely be observed in the Hungarian forests, 94.9% of living sample trees did not show any discoloration. This is a less than 1% decrease compared to the previous year's value.

According to the classification defined in the ICP manual on crown condition the damage caused by defoliating insects had the highest rate, 26.5% of all the damage. This damage occurred particularly on the following species: *Quercus petraea* (40.2%), *Quercus robur* (36.3%), and other soft wood (42.7%). The mean damage values of these trees were 7.3%, 9.5%, and 7.2% respectively. The tree species suffering the highest damage level was *Carpinus betulus* (14.6%) but only the 28.5% of the trees were affected.

The rate of assessed damage caused by fungi was 13.3%. Fungal damage was mostly assessed on the stem and root (wet rot causing fungus) (69.7%) and on needles and leaves (10.2%). The mean damage value was 19.9%.

11.2% of the assessed damage was abiotic, this is similar to the previous year. The general intensity was 15.4%. Within the abiotic damage most important identifiable causes were drought (52%), frost (24.9%) and wind (20.7%), while the other causes were unimportant.

6.13 Italy

The survey of Level I in 2013 took into consideration the condition of the crown by 5092 selected trees in 248 plots belonging to the EU network 16 x 16 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 trees (75.7%) are included in the classes 1 to 4; 33.8% are included in the classes 2 to 4.

By analysing the sample for groups of species, conifers and broadleaves, it appears that conifers have a transparency of less than deciduous foliage: 36.6% of conifers and 19.9% of broadleaves are without any defoliation (class 0). The conifers falling in the defoliation classes 2 to 4 are 24.2% in respect to the 37.1% of broadleaves.

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 31.7% and 30.0%, respectively, of trees in the classes 2 to 4, *Pinus sylvestris* has 23.9% and *Pinus nigra* has 19.9% of trees in the classes 2 to 4, but in the best condition is *Larix decidua* with 14.0%.

Among the old conifers (≥60 years) the species appearing to be of worse quality of foliage are *Pinus nigra* (40.0%), *Picea abies* (28.9%), *Abies alba* (28.6%), and *Larix decidua* with 14.3% of trees in the classes 2 to 4, while *Pinus cembra* (1.8%) is a conifer in better condition.

Among the young broadleaves (<60 years), *Castanea sativa*, *Quercus pubescens*, and *Ostrya carpinifolia* have 82.5%, 46.0%, and 32.6%, respectively, of trees in the classes 2 to 4, while others have a frequency range between 19.7% and 27.1% in classes 2 to 4 distributed in different species: *Quercus cerris* (19.7%) and *Fagus sylvatica* (27.1%).

Among the old broadleaves (≥60 years) in the classes 2 to 4, *Castanea sativa* has 93.9%, *Quercus pubescens* 53.3%, *Ostrya carpinifolia* 53.7%, and *Fagus sylvatica* 23.3%. *Quercus ilex* with 12.9% has the lowest level of defoliation of trees in the classes 2 to 4.

Starting from 2005, a new methodology for a deeper assessment of damage factors (biotic and abiotic) was introduced. The main results are summarized below.

Most of the observed symptoms were attributed to insects (23.5%), subdivided into defoliators (17.2%) and galls (2.6%), followed by symptoms attributed to fungi (4.3%), the most significant being attributable to “dieback and canker fungi” (3.1%). Of those assigned to abiotic agents the most significant are “hail” (1.0%).

6.14 Latvia

The forest condition survey 2012 in Latvia was carried out on two plot sets — on 88 ICP Level I plots on the transnational grid 16 x 16 km and on 115 NFI plots, 203 plots in total. The national report of 2012 is based on data from both datasets.

In total, defoliation of 3879 trees was assessed, of which 75% were conifers and 25% broadleaves. Of all tree species, 11.8% were not defoliated, 79% were slightly defoliated and 9.2% moderately defoliated to dead. Comparing to 2011, the proportion of not defoliated trees has decreased by 2%, the proportion of moderately defoliated to dead trees has decreased by almost 5% but the proportion of slightly defoliated trees has increased by almost 7%. Unlike the previous year, when the proportion of trees in defoliation classes 2–4 remained to be about 5–7% higher for conifers than for broadleaves, this year the proportion of trees in defoliation classes 2–4 was higher for broadleaves. It is important to mention that 293 trees were excluded from survey this year and replaced by new ones, the main reason for replacement being nonconformity with the requirements for crown assessment (e.g. heavy crown breaks or trees no longer in KRAFT classes 1, 2 or 3).

Mean defoliation of *Pinus sylvestris* was 19.7% (22.4% in 2011). The share of moderately damaged to dead trees constituted 8.4% (16.4% in 2011). Mean defoliation of *Picea abies* was 16.8% (20.7% in 2011). The share of moderately damaged to dead trees for spruce constituted 6.4%. The considerable decrease in the defoliation level for *Pinus sylvestris* and *Picea abies* can most likely be attributed to the change of the dataset used for national reporting and to the exclusion of a large number of damaged and suppressed trees from the survey. The mean defoliation level of *Betula* spp. was 20.8% (18.0% in 2011), showing a slight increase of the defoliation level. The share of trees in defoliation classes 2–4 increased to 12.6% compared to 8.3% in 2011. The mean defoliation level for *Populus tremula* was 21.1%. The worst crown condition of all assessed tree species remained for *Fraxinus excelsior* with a mean defoliation of 28.3% (31.8% in 2011) but these results were based on a very small number of assessed trees.

Visible damage symptoms were observed to a similar extent than in the previous year – 12.6% of the assessed trees (12.2% in 2011). Most frequently recorded damage was caused by direct action of men (34.2% of all cases), insects (23.0%), animals (21.2%), fungi (11.7%), and abiotic factors (7.6%). Other damage causes were recorded for 0.6% of all cases and unknown cause for 1.6% of all cases. The distribution of damage causes was considerably different than last year when damage by abiotic factors constituted 21.3% of all cases, by direct action of man 17.7% and by fungi 15.1%. The proportion of insect damage has increased considerably since last year. Differences in the distribution of damage causes are most likely induced by the change of dataset and expected maximum of outbreak of *Lymantria monacha* that started in the vicinity of Riga city in 2011. The greatest share of trees with damage symptoms was recorded for *Populus tremula* (19%) and the smallest for *Betula* spp. (10.5%).

6.15 Lithuania

In 2013, the forest condition survey was carried out on 1089 sample plots from which 80 plots were on the transnational Level I grid and 1009 plots on the National Forest Inventory grid. In total 6749 sample trees representing 18 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 decreased to 21.6% (22.6% in 2012). 18.5% of all sample trees were not defoliated (class 0), 61.8% were slightly defoliated and 19.7% were assessed as moderately defoliated, severely defoliated and dead (defoliation classes 2–4).

Mean defoliation of conifers slightly decreased to 22.4% (23.0% in 2012) and for broadleaves to 20.4% (22.1% in 2012).

Pinus sylvestris is a dominant tree species in Lithuanian forests and composes about 40% of all sample trees yearly. Mean defoliation of *Pinus sylvestris* was 22.8% (22.8% in 2012) 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 15.7% (17.1% in 2012) and the proportion of trees in defoliation classes 2–4 was only 4.1% (3.6% in 2012).

Condition of *Fraxinus excelsior* remained the worst between all observed tree species. This tree species had the highest defoliation since year 2000. Mean defoliation significantly decreased to 32.4% (39.0% in 2012). The share of trees in defoliation classes 2–4 decreased to 44.6% (55.7% in 2012).

22.6% of all sample trees had some kind of identifiable damage symptoms. The most frequent damage was caused by abiotic agents (about 7.0%) in the period of 2010–2013. 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* (43.6%), *Populus tremula* (35.1%), and *Alnus incana* (32.8%), the least for *Alnus glutinosa* (13.1%).

In general, mean defoliation of all tree species has varied inconsiderably from 1997 to 2013 and the condition of Lithuanian forests can be defined as relatively stable.

6.16 Luxembourg

In 2013 the forest condition survey was based on a 4 x 4 km grid, which included 1200 sample trees on 51 permanent plots.

On average over all tree species, 33.1% of the forest was showing no defoliation, 33.2% was assessed as damaged (classes 2-4), and 33.1% was in the warning stage.

In 2013, 17.5% of conifers were in defoliation classes 2-4, 26.9% were slightly defoliated, and 55.7% were not defoliated. For broadleaves 42.4% were assessed as damaged (classes 2-4), 36.7% were slightly defoliated, and 21.0% showed no signs of defoliation.

6.17 Republic of Moldova

In the spring of 2013 there was a dry period with high temperatures not typical for this time period. After a short dry period with high temperatures favorable climatic conditions were established for the growth and development of trees and shrubs, which lasted throughout the growing season. This led to the stabilization of the general sanitary condition of plantations, so the number of trees in defoliation class 2–4 decreased by 0.7%, and an increase in the number of trees without signs of injury by 2.9% was recorded, accounting for 32.0%.

According to this year's data in almost all species, both deciduous and coniferous trees, a decrease in the percentage of trees in the 2–4 defoliation class was observed. In oak stands, this indicator is 22%, which is 3% less than last year. In conifers the same tendency was recorded and trees in the 2–4 defoliation class make up 41.4%, which is 2.9% less than in the previous year. In the black locust plantation the number of trees in the 2–4 defoliation class decreased by 3.4% and makes up 40.0%. In ash plantations this indicator remained at the level of the previous year and is 26.9%.

6.18 Montenegro

In 2013 the condition of the forest species on 49 sample plots was assessed. The assessment of defoliation was done as well as damage monitoring caused by biotic and abiotic factors on a total of 1176 trees.

From the total analyzed species most common is Beech (*Fagus moesiaca*) with 300 trees (25.5%), followed by Turkey oak (*Quercus cerris*) with 113 trees (9.6%), Manna Ash (*Fraxinus ornus*) 106 trees (9.0%), Spruce (*Picea abies*) 102 trees (9.0%), Fir (*Abies alba*) 100 trees (8.5%), Hornbeam (*Carpinus betulus*) 90 trees (7.7%), sessile oak (Quercus petraea) 87 trees (7.4%), Austrian pine (*Pinus nigra*) 70 trees (6.0%) etc.

The condition of defoliation of the broadleaf species which are most represented on the sample plots in Montenegro was assessed. Oriental Hornbeam (*Carpinus orientalis*) proved to be the most resistance species, since on 75% trees on all of the sample plots no sign of defoliation was found, in Hornbeam (*Carpinus betulus*) it was 60%. Good condition was also found at Manna Ash (*Fraxinus ornus*), Turkey oak (*Quercus cerris*) and Beech (*Fagus moesiaca*).

Defoliation (fragmentation or needle falling out) on conifer trees, to the least extent in 2013 was presented on Austrian pine. Good condition was found at spruce. In regard of desiccation, fir is more sensitive.

The most frequent causes of damage are the insects and the fungi which caused the damage on 25% of the trees.

6.19 Norway

In 2013, a new monitoring approach was introduced in Norway with five year revision intervals on all plots, following the rotation of the National Forest Inventory (NFI). Thus, each year one fifth of the NFI plots are monitored. 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 design produces good estimates of average national crown condition, however estimates of regional crown condition are probably less accurate. In 2013, the mean defoliation for *Picea abies* was 17.5%, and 14.5% for *Pinus sylvestris*. 2013 was the second year with a decrease in defoliation for pine. However, for spruce the increase in defoliation was considerable from 14.7% in 2012 to 17.5% in 2013, resulting in the highest defoliation for spruce since 2007.

Of all the coniferous trees, 44.8% were rated not defoliated in 2013, which is a decrease of about 5%-points compared to the year before. Only 42.4% of the *Pinus sylvestris* trees were rated as not defoliated which is an increase of 2%-points. 47.0% of all Norway spruce trees were not defoliated, a decrease of 10%-points compared to the year before. For other classes of defoliated trees, the opposite trend was observed.

In crown discolouration we observed 9.9% discoloured trees for *Picea abies*, a decrease of about 1%-point from 2012. For *Pinus sylvestris*, 4.9% of the assessed trees were discoloured, an increase of about 2%-points from the year before.

The mean mortality rate for all species was 0.2% in 2013. The mortality rate was 0.2% and 0.1% for spruce and pine, respectively. The mortality rates have been at the same level the last 4 years.

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 2013 had both higher temperatures and more precipitation than normal. The summer temperature was 1.1 ºC higher than normal as an average for the country. However, the summer precipitation was also higher with about 120% of the normal, and for June the precipitation was about 160%. In Southeast Norway the June precipitation, which is very crucial to avoid drought in spruce, was even higher and one of the wettest June months observed during the last 100 years. However, July was opposite with precipitation less than 50% of normal and temperature about 2 ºC higher than normal in this region of Norway. The July climate is also important for drought in spruce in Southeast Norway. There are of course large climatic variations between regions in Norway, ranging from 58 to 71 ºN.

6.20 Poland

In 2013 the forest condition survey was carried out on 1982 plots. Forest condition (all species total) improved as compared to the previous year. 13.7% (11.3% in 2012) of all sample trees were without any symptoms of defoliation, indicating an increase by 2.4 percentage points compared to 2012. The proportion of defoliated trees (classes 2–4) decreased by 4.6 percentage points to an actual level of

18.8% of all trees. The share of trees defoliated by more than 25% decreased by 4.5 percentage points for conifers and by 4.8 percentage points for broadleaves.

10.4% of conifers were not suffering from defoliation. For 17.8% of the conifers defoliation of more than 25% (classes 2–4) was observed. With regard to the three main coniferous species *Abies alba* remained the species with the lowest defoliation (19.1% trees in class 0, 15.9% trees in classes 2–4), and indicated a slight improvement compared to the previous year. A share of 19.2% (21.8% in 2012) of fir trees up to 59 years old and 15.1% (18.3% in 2012) of fir trees 60 years old and older was in defoliation classes 2–4. *Pinus sylvestris* is characterized by a lower share of trees in class 0 (9.2%), as well as in classes 2–4 (17.0%). *Picea abies* is characterized by a higher share of trees in class 0 (18.6%), as well as in classes 2–4 (27.0%). *Pinus sylvestris* and *Picea abies* indicated a slight improvement compared to the previous year.

19.9% of the assessed broadleaved trees were not defoliated. The proportion of trees with more than 25% defoliation (classes 2–4) amounted to 20.7%. As in the previous survey the highest defoliation amongst broadleaved trees was observed in *Quercus* spp. and indicated improvement in younger stands. In 2013 a share of 21.6% (28.3% in 2012) of oak trees up to 59 years old and 42.2% (42.9% in 2012) of oak trees 60 years old and older was in defoliation classes 2–4. *Fagus sylvatica* remained the broadleaved species with the lowest defoliation, and indicated a slight improvement in older stands. A share of 9.8% (10.2% in 2012) of beech trees up to 59 years old and 6.3% (9.2% in 2012) of beech trees 60 years old and older was in defoliation classes 2–4.

In 2013, discolouration (classes 1–4) was observed on 1.1% of the conifers and 2.2% of the broadleaves.

6.21 Romania

In the year 2013, the assessment of crown condition of the Level I network in Romania was carried out on the 16 x 16 km transnational grid net during 15^{th} of July and 15^{th} of September. The total number of sample trees was 5784, which were assessed on 241 permanent plots. From the total number of trees, 1103 were conifers and 4681 broadleaves. Trees on the missing plots were harvested during the last years or unreachable due to natural hazards.

For all species, 49.4% of the trees were rated as healthy, 37.0% as slightly defoliated, 11.8% as moderately defoliated, 1.1% as severely defoliated and 0.7% were dead. The percentage of damaged trees (defoliation classes 2–4) was 13.6%.

For conifers, 13.9% 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 11.0% (defoliation classes 2–4), whereas *Abies alba* had 22.9%. For broadleaves 13.6% 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 (10.5%), with special mentioning of *Tillia* sp. (4.6%) as tributary species, followed by *Carpinus betulus* (12.2%). The most affected broadleaves were the *Quercus* sp. (16.2%).

Compared to last year, the overall share of damaged trees (classes 2–4) decreased by only a marginal 0.3 percentage points, mainly due to conifers (-1.0 percentage points), along with an uncertain recovering trend of the more numerous broadleaves (-0.1 percentage points). Forest health status was mainly influenced by the relatively good weather conditions during the spring, seemingly contrasting with the succeeding prolonged droughty summer and autumn seasons.

Concerning the assessment of biotic and abiotic damage factors, most of the observed symptoms (90%) were attributed to broadleaves species, especially to defoliator insects (48%), fungi (11.7%), and abiotic factors (e.g. heat stress and frost) (15%).

6.22 Serbia

In Serbia, ICP plots were established on a 16 x 16 km grid consisting of 103 sampling plots and on an additional 4 x 4 grid, including new 27 plots, all together the number of plots is 130 (not including the assessments of AP Kosovo and Metohija). Observations on Level I plots were performed according to the ICP Forests Manual of Methods. The actual monitoring has been performed on 117 plots in the year 2013 due to the clear cutting of a few spots.

During 2013, the researchers of the NFC Serbia - Institute of Forestry with collaborators from other institutions in Serbia, have worked all sampling points and 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 2794 trees, of which 338 were conifer trees and a considerably higher number, i.e. 2456, was broadleaf trees. The conifer tree species are: *Abies alba*, number of trees and percentage of individual tree species 69 (20.4%), *Picea abies* 146 (43.2%), *Pinus nigra* 67 (19.8%), *Pinus sylvestris* 56 (16.6%); and the most represented broadleaf tree species are: *Carpinus betulus*, number of trees and percentage of individual tree species 117 (4.8%), *Fagus moesiaca* 833 (33.9%), *Quercus cerris* 516 (21.0%), *Quercus frainetto* 368 (15.0%), *Quercus petraea* 161 (6.5 %) and other species 461 (18.8%).

The results of the available data processing and the assessment of the degree of defoliation of individual conifer and broadleaf species (%) are: *Abies alba* (None 92.8, Slight 1.4, Moderate 4.4, Severe 1.4 and Dead 0.0); *Picea abies* (None 90.4, Slight 6.2, Moderate 2.0, Severe 1.4, Dead 0.0); *Pinus nigra* (None 35.8, Slight 17.9, Moderate 34.3, Severe 10.5, Dead 1.5); *Pinus sylvestris* (None 83.9, Slight 8.9, Moderate 0.0, Severe 7.2, Dead 0.0).

The degree of defoliation calculated for all conifer trees is as follows: no defoliation 79.0% trees, slight defoliation 8.0% trees, moderate 8.6% trees, severe defoliation 4.1% trees and dead 0.3% trees.

Individual tree species defoliation (%) are: *Carpinus betulus* (None 74.4, Slight 8.5, Moderate 7.7, Severe 8.5, Dead 0.9); *Fagus moesiaca* (None 69.0, Slight 18.9, Moderate 8.6, Severe 2.9, Dead 0,6); *Quercus cerris* (None 56.0, Slight 29.2, Moderate 10.5, Severe 3.7, Dead 0.6); *Quercus frainetto* (None 73.1, Slight 14.1, Moderate 8.4, Severe 4.1, Dead 0.3); *Quercus petraea* (None 50.9, Slight 31.7, Moderate 13.1, Severe 3.1, Dead 1.2) and the rest (None 58.1, Slight 21.7, Moderate 13.0, Severe 4.8, Dead 2.4).

Degree of defoliation calculated for all broadleaf species is as follows: no defoliation 63.9% trees, slight defoliation 21.2% trees, moderate 10.1%, severe defoliation 3.9% trees and dead 0.9% 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 the vitality score caused by the effect of adverse agents (climate stress, insect pests, pathogenic fungi). It may only be a temporary phase of natural variability of crown density.

6.23 Slovakia

The 2013 national crown condition survey was carried out on 108 Level I plots in the 16 x 16 km grid net. The assessments covered 4684 trees, 3835 of which were being assessed as dominant or co-dominant trees according to KRAFT. Of the 3835 assessed trees, 43.4% were damaged (defoliation classes 2–4). The respective figures were 43.3% for conifers and 43.5% for broadleaved trees. Compared to the year 2012, the share of trees defoliated more than 25% increased by 5.5 percent points. Mean defoliation for all tree species together was 26.5%, with 26.7% for conifers and 26.3% for broadleaved trees. Results show that crown condition in Slovakia is worse than mean crown condition of all European monitoring plots.

Compared to the 2012 survey, considerable worsening of average defoliation was observed for *Fagus sylvatica* and *Carpinus betulus.* The most severe damaged has been observed in *Robinia pseudacacia, Pinus sylvestris* and *Quercus petraea*.

From the beginning of the forest condition monitoring in 1987 until 1996 results show significant decrease in defoliation and visible forest damage. Since 1996, the mean defoliation (22–26%) has been relatively stable. The recorded fluctuation of defoliation depends mostly on meteorological conditions.

As a part of the crown condition survey, damage types were assessed. 86.7% of all sampling trees (4684) had some kind of damage symptoms. 22.4% of the trees had an intensity of damage of more than 20%, 64.3% of trees were only slightly damaged (intensity of the damage less than 20%). The most frequent damage causes were competition of trees (33.3%), insects (31.1%) and anthropogenic damage (21.5%).

6.24 Slovenia

In 2013 the Slovenian national forest health inventory was carried out on 44 systematically arranged sample plots (grid 16 x 16 km). The assessment encompassed 1056 trees, 396 coniferous and 660 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).

The mean defoliation of all tree species was estimated to be 25.9%. Compared to the 2012 survey, the situation deteriorated for 1% (mean defoliation in 2012 was 24.9%). In the year 2013 mean defoliation for coniferous trees was 25.3% (in the year 2012 it was 24.6%) and for broadleaves 26.2% (year before 25.1%).

In 2013 the share of trees with more than 25% of defoliation (damaged trees) reached 30.9%. In comparison to the results of 2012, when the share of trees with more than 25% of unexplained defoliation was 29.0%, the value increased by 1.9%.

Especially significant is the change of damaged trees for broadleaves where the share of damaged trees increased from 23.0% in 2012 to 28.5% in 2013, while the share of damaged conifers decreased from 37.0% in 2012 to 34.3% in 2013.

In the year 2012 conifers were more damaged than broadleaves. But in the year 2013 the proportion has changed and broadleaves are more damaged then conifers.

In general, the mean defoliation of all tree species has slightly increased since 1991. In comparison to the year 2010 the mean defoliation deteriorated in the year 2011, improved in 2012 by 0.5%, but decreased again in the year 2013.

6.25 Spain

Results obtained in the 2013 inventory show a slight improvement in the general health condition of trees when compared to the previous year. In 2013, a percentage of 83.4% of the surveyed trees looked healthy (compared to 82.5% in the previous year).

A percentage of 14.2% of the trees were included in defoliation classes “2” and “3”, indicating defoliation levels higher than 25% whereas in 2012 this percentage was 15.9%. The number of damaged trees has clearly decreased whereas the number of dead ones increases remarkably until reaching a percentage of 2.4%, showing different trends between broadleaves (percentage increases clearly reaching 3.1%) and conifers (percentage decreases to 1.7%).

The improvement is more noticeable in broadleaves with a percentage of 79.4% of healthy trees (76.5% in the previous year). In the case of conifers the percentage of healthy trees decreases, though slightly (87.4% this year and 88.5% in 2012).

The mortality of trees (2.4% of the total sample) are due to felling operations like sanitary cuts and forest harvesting processes as well as to decline processes related to isolated hydric shortages.

Concerning other possible damaging agents, there is an overall decrease in damage recorded. Damage due to drought has decreased, although the old ones still can be noticed in the field. The records from other abiotic damaging agents such as wind and snow descend as well. Regarding damage caused by biotic agents, the populations of the pine processionary moth decrease, as well as the importance of leaf feeders in holm oak and others such as *Agelastica alni*, *Aglaope infausta*, *Gonipterus scutellatus* and *Rhynchaenus fagi*. Concerning borers, the populations of conifer bark beetles and *Cerambyx* spp. remain stable. As regards to fungi, there is a general decrease in the impact of *Sirococcus conigenus* and concerning parasitic phanerogams, records of *Viscum album* and *Arceuthobium oxycedri* remain at the same levels as in the previous years. On the other hand, it looks like damage related to the “Seca” syndrome is increasing.

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.

6.26 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, 7749 trees on 3484 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% of the total sample, are remeasured every 5th year.

The proportion of trees with more than 25% defoliation is for Norway spruce 26.3% and for Scots pine 14.3%. The previously observed increase in defoliation for both Scots pine and Norway spruce in southern Sweden has ceased. In central and northern Sweden defoliation in Scots pine increased during 2013. Increased defoliation on Norway spruce is also seen in northern Sweden. There are some large temporal changes seen in defoliation levels at the regional level, however, the majority of changes during recent years are minor.

In autumn 2013 Sweden was struck by several storms. The first storms hit southern Sweden followed by two severe storms in northern Sweden. The two storms in northern Sweden caused the most damage and in total ca 11.5 million m³ forests were felled. These storm fellings were predominately Scots pine but areas of Norway spruce were also felled. One such area of storm damage with Norway spruce was in an area which had previously been exposed to an outbreak of bark beetles. The damage caused by bark beetles was followed-up in a TFDI and the results from the inventory show that presently there is only a small volume of living Norway spruce trees that are subjected to an attack by European spruce barkbeetle *(Ips typographus)*. However, as the number of bark beetles increases so does the risk for damage in older spruce forests. It is likely that a large volume of wind-felled trees will be left in the forests following the storms. The primary choice for the bark beetle population during 2014 will be to utilize these new wind-felled trees. This will, in the short-term, lead to less damage on growing trees, however if the population growth rate is consistent with previous storms then the bark beetle population in the spring of 2015 can be expected to be 30 times higher than before the storms. This 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. Still, 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*.

6.27 Switzerland

In 2013, the defoliation decreased compared to 2012. The proportion of "significantly damaged trees" between 30% and 95% NBV (unexplained defoliation subtracting the known causes such as insect damage, or frost damage) decreased from 31.4% in 2012 to 25.0% in 2013. This percentage is only slightly above 23.8%, the long-term average of the last twenty years. The recovery took place mainly in the category of "moderately damaged" trees. Their proportion decreased from 21.2% in 2012 to 14.5% in 2013. The last increase of the proportion of trees with a defoliation above 25% began in 2009 with 17.8% and reached a maximum of 31.4% in 2012. All species with the exception of ash have recovered.

After the significant increase in defoliation seen until the mid 90s, no clear long-term trend is visible since about 2000. The heavy increase and the subsequent recovery coincide mainly 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.

The increase in defoliation from 2009 to 2012 cannot be explained completely by climatic events, even if the dry periods in spring and late summer of 2011 and the heavy snowfall in autumn 2012 played an important role. Insects have to be considered as well as driving forces of the defoliation: the more insect damage that has been identified, the greater the defoliation. This relationship is mainly visible in the deciduous trees, where the beech leaf miner (*Rhynchaenus fagi)* is likely to have the greatest influence. The seed years of 2009 and 2011 also affected the crown density. The reduction of insect, climate and fungal damage is correlated with the improvement in the crown condition in 2013.

The ash dieback that started in Switzerland in 2008 caused, after a short relief in 2012, another increase in defoliation in 2013. A third of the ash trees are now severely affected.

6.28 Turkey

With the monitoring studies conducted on a grid of 16 x 16 km, crown condition of 13553 trees in 585 sample plots has been evaluated in 2013. Average needle/leaf loss ratio of all evaluated trees is 16.6%. The proportion of healthy trees (class 0–1) is 89.8% and the remaining 10.2% had a needle/leaf loss of greater than 25%. Annual average needle/leaf loss declined slightly in comparison to the previous year. The downward trend in needle/leaf loss ıs still present based on the evaluation of data from the last six years.

The average defoliation ratio is 18.8% in broadleaved species. Major broadleaved tree species with highest defoliation ratios are *Alnus glutinosa* (29.6%), *Quercus pubescens* (28.0%), *Castanea sativa* (26.0%) and *Quercus petraea* (22.5%). The same species were also among the highly defoliated species in 2012. Among the less common broadleaved species, *Corylus avellana, Ulmus glabra, Salix alba, Prunus avium, Populus nigra, Ostrya carpinifolia, Juglans regia* and *Fraxinus angustifolia* have an average defoliation ratio of over 25%. Overall, 84.3% of broadleaved species showed no or slight defoliation (class 0–1) while 15.7% of them had a defoliation ratio of more than 25% (class 2–4).

Average defoliation of coniferous species is 15.3%. 93.1% of all evaluated coniferous trees have needle loss of less than 25% (class 0–1), and the remaining 9.9% of them have over 25% defoliation (class 2–4). Junipers (*Juniperus foetidissima, J. excelsa, J. oxycedrus, J. communis*) are among the highly defoliated species with defoliation ratios between 13.7 and 17.8%. Among the pine species, defoliation ratios of *Pinus brutia*, *P*. *sylvestris* and *P. nigra* are 17.5%, 15.8% and 13.3%, respectively. In addition, the highest defoliation among the conifers was observed in *P. pinaster*, which is a less common species and was represented by only 14 sample trees.

Thaumetopoea spp., *Tortrix viridana, Rhynchaenus fagi, Lophodermium pinastri and Ips sexdentatus* are among the major biotic causes of damage. The number of trees affected by *Thaumetopoea* spp. has increased approximately three fold in comparison to the previous year. In contrast, the number of trees affected by *Lymantria dispar* has been reduced gradually over the last four years and was almost 75% in the present year in comparison to 2012. As usual, mistletoe (*Viscum alba*) is also among the common biotic agents.

In terms of geographical regions, needle/leaf loss appears to be higher in the Central and Eastern Blacksea Regions, Central Anatolia which is dominated by semiarid and continental climate. Conversely, the health status of the forests in the Marmara Region is getting better in comparison to the previous years.

6.29 Ukraine

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. Maintaining a national database of forest monitoring is carried out by experts of URIFFM.

In 2013, 35203 sample trees were assessed on 1487 permanent forest monitoring plots in all 25 administrative regions of Ukraine. Mean defoliation of conifers was 11.4% and of broadleaved trees was 12.0%.

Generally the tree crown condition is satisfactory: the part of healthy (not defoliated) trees amounts to 63.4%. There are no sufficient changes in crown condition in 2013 compared to the previous year. For the total sample the percentage of healthy trees slightly increased (63.4 against 63.1%), and at the same time, the share of slightly to moderately defoliated trees decreased from 36.9% to 36.6%. The part of "damaged trees" (with defoliation over 25%) includes 7.2% of sample trees.

For broadleaves the part of healthy trees is 61.6%, and respectively the part of defoliated trees is 38.4%, from those the part of damaged trees (with defoliation over 25%) is 7.0%. Compared to the previous year the part of defoliated broadleaved trees decreased by 0.8% in 2013. For conifers the part of healthy trees is 66.0% and the part of damaged trees (with defoliation more then 25%) amounts to 7.5%.

For the sample of common sample trees (CSTs) (31201 trees) mean defoliation remained at the same level – 11.8%.

The lowest average defoliation have *Pinus sylvestris* trees (10.7%), middle values have *Quercus robur* and *Fraxinus excelsior* – 12%, *Fagus sylvatica* – 12.6%, and the highest average defoliation have trees of *Picea abies* (14.3%).

ANNEX

Annex I:
Maps of the transnational evaluations

Annex II:
Results from national reports

Annex III:
Contacts

ANNEX I: MAPS OF THE TRANSNATIONAL EVALUATIONS

Annex I-1: Broadleaves and conifers

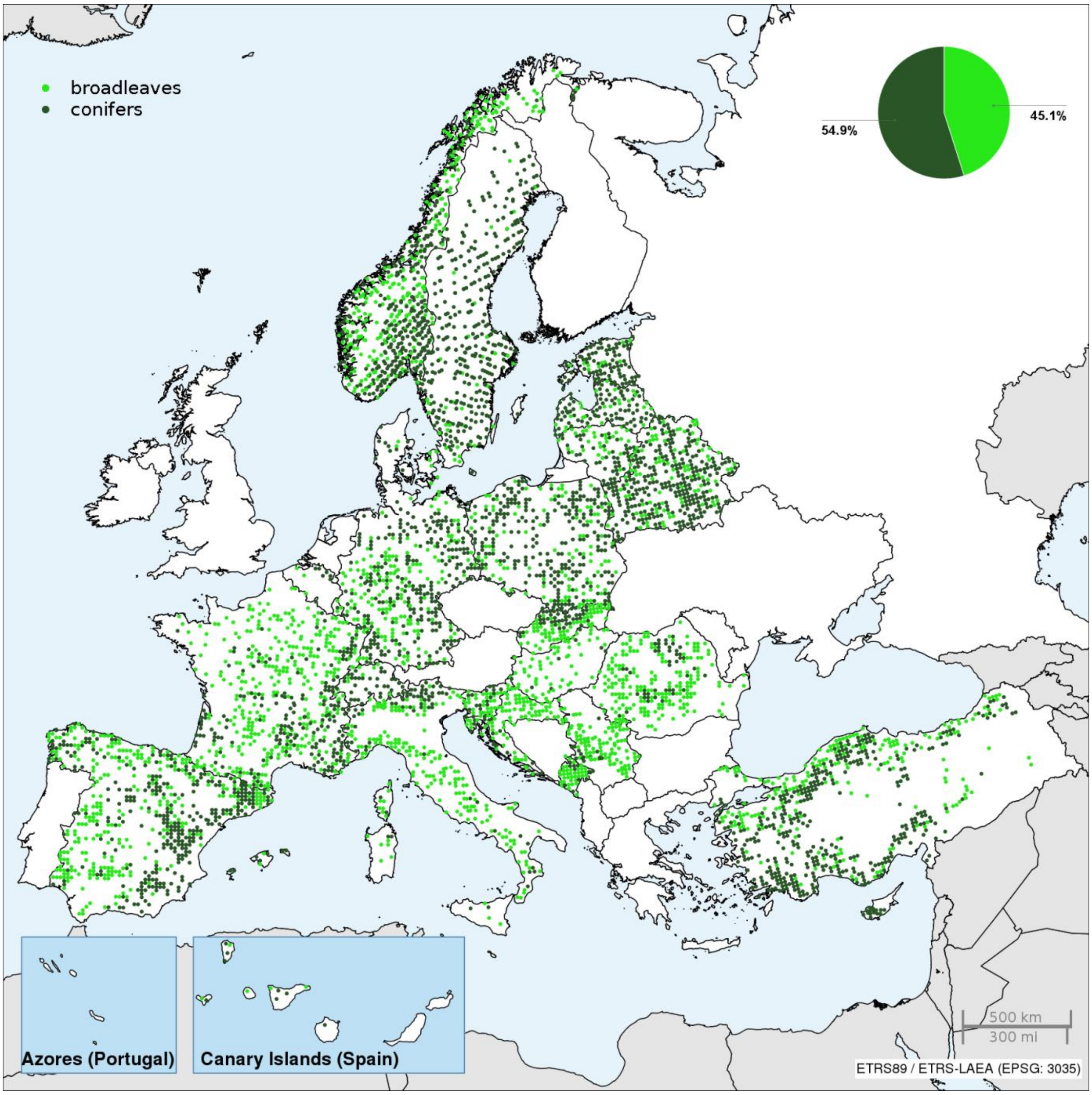


Figure Annex I-1: Shares of broadleaves and conifers assessed on Level I plots in 2013

Annex I-2: Number of tree species per plot (Forest Europe classification) (2013)

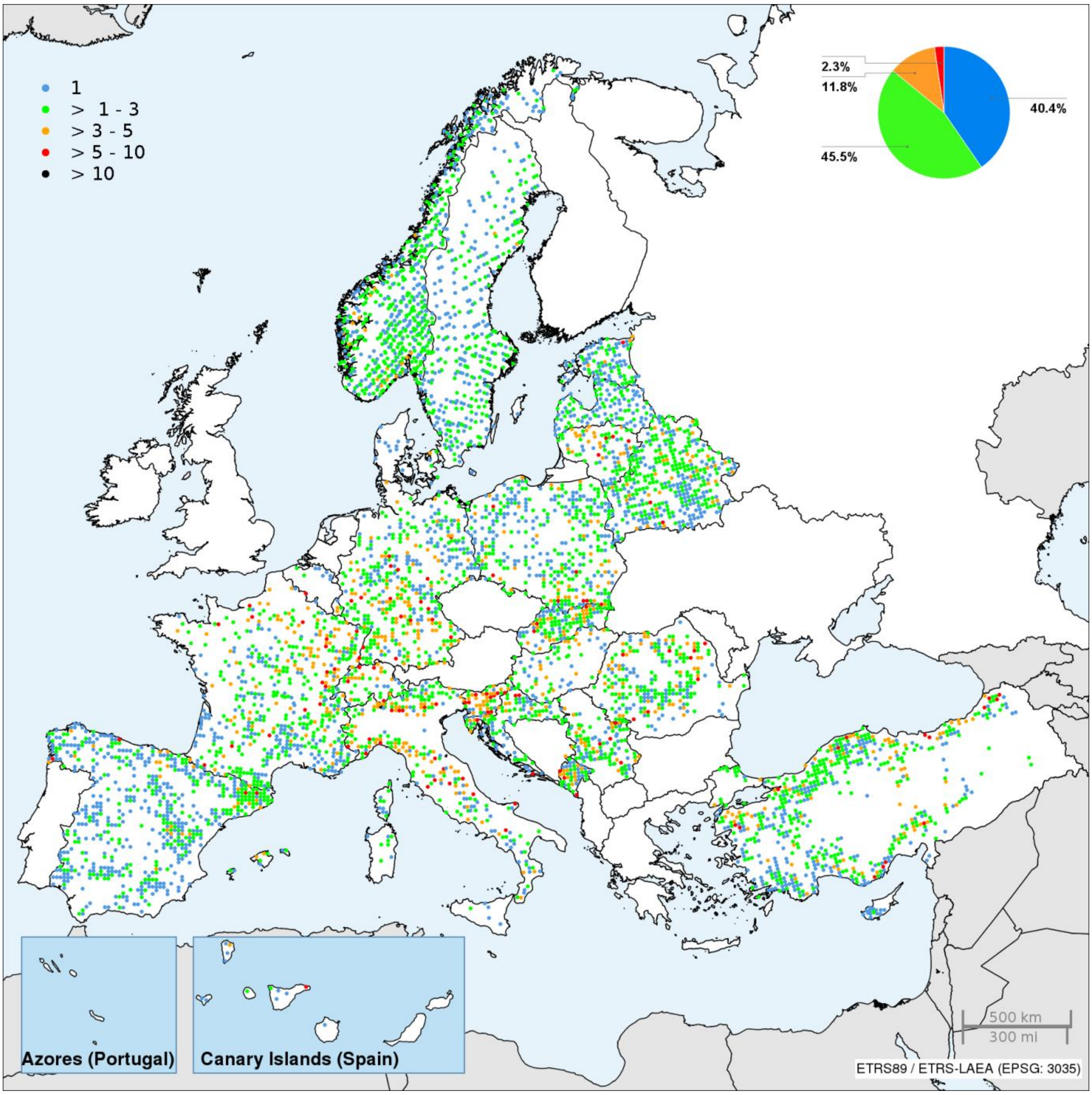


Figure Annex I-2: Number of tree species assessed on Level I plots in 2013

Annex I-3: Mean plot defoliation of all species (2013)

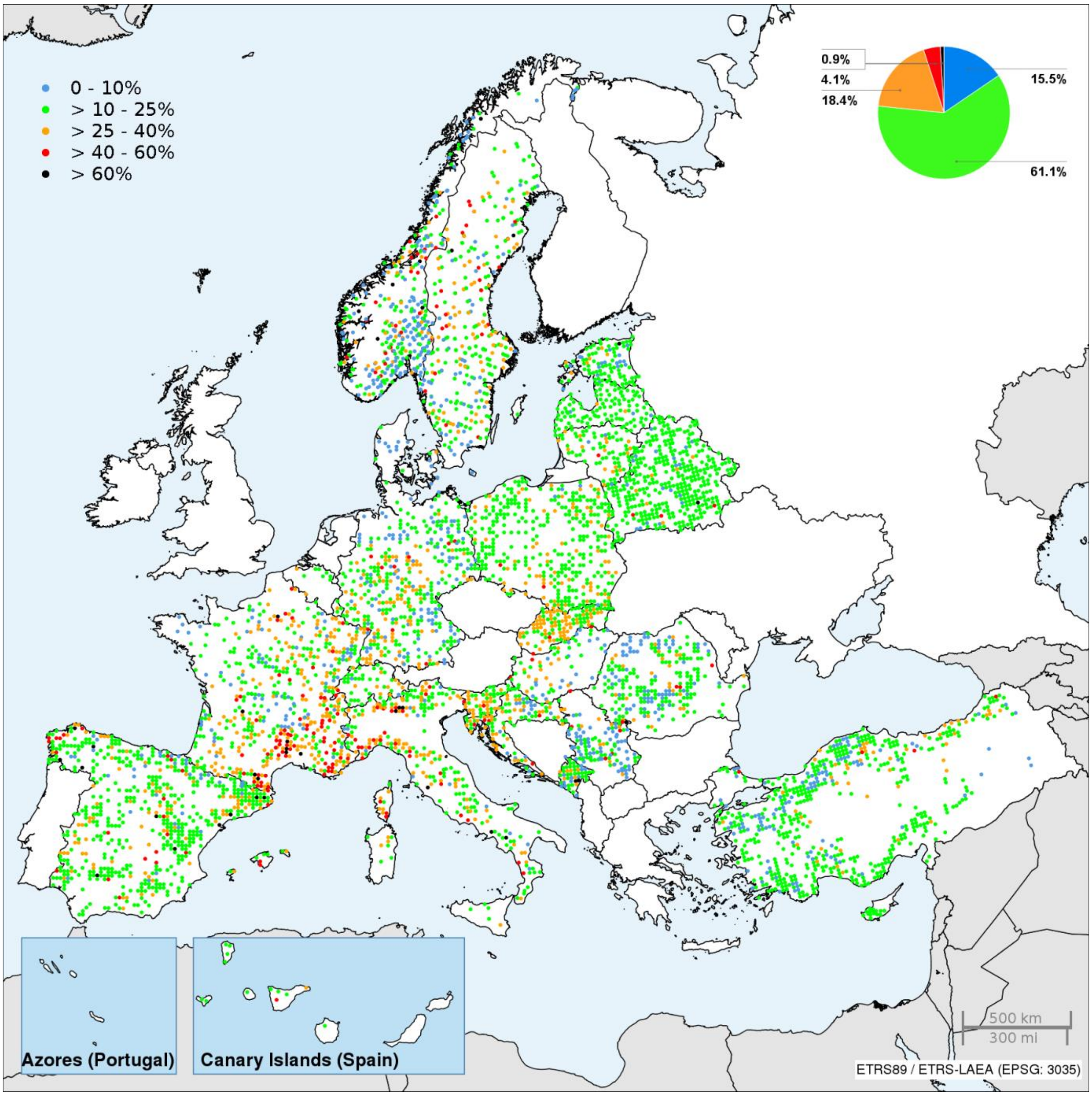


Figure Annex I-3: Mean plot defoliation of all species (2013)

Annex I-4: Percentage of trees damaged (2013)

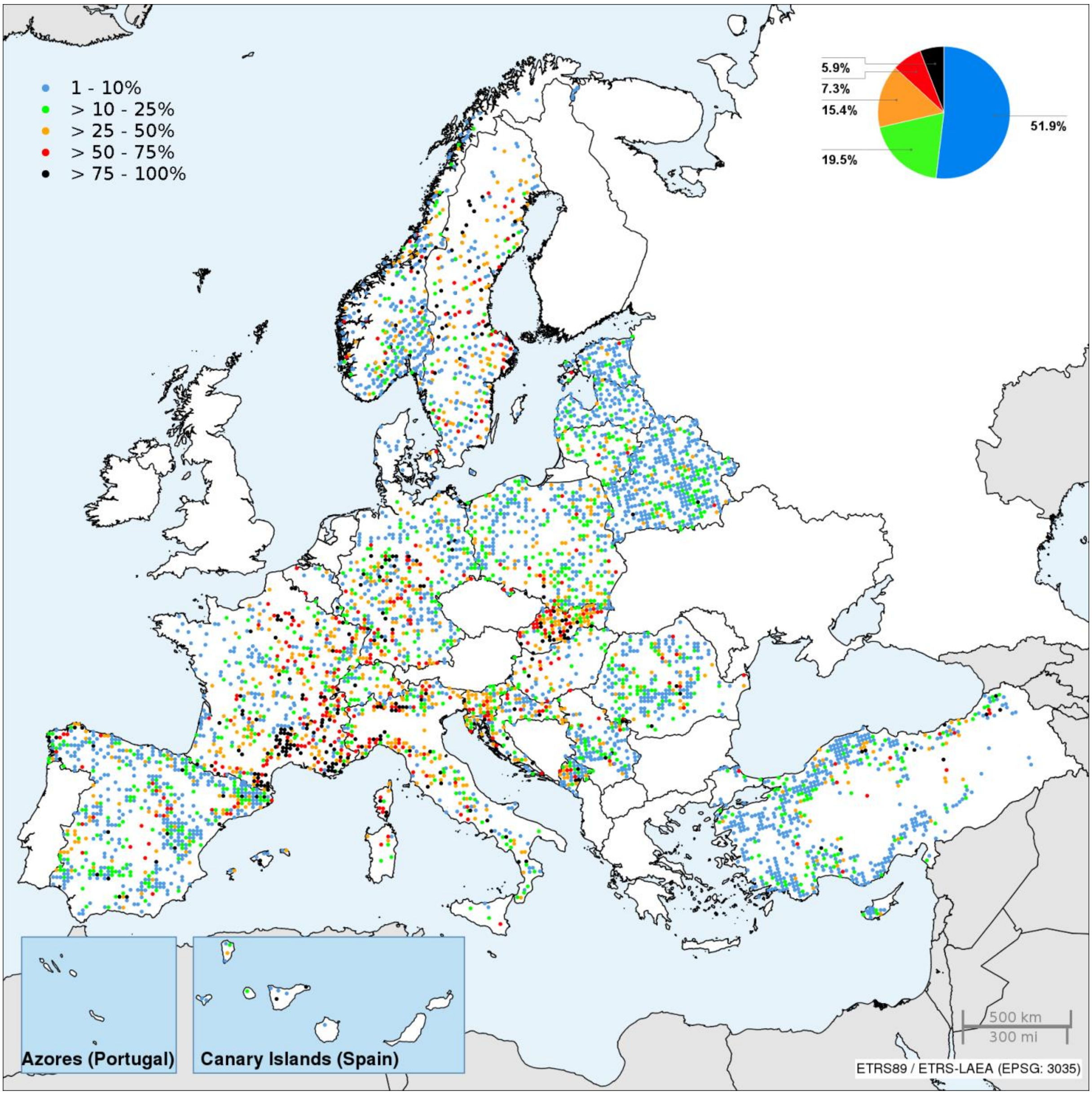


Figure Annex I-4: Percentage of trees assessed as damaged (defoliation >25%) on Level I plots (2013)

Annex I-5: Development of mean plot defoliation (2006–2013)

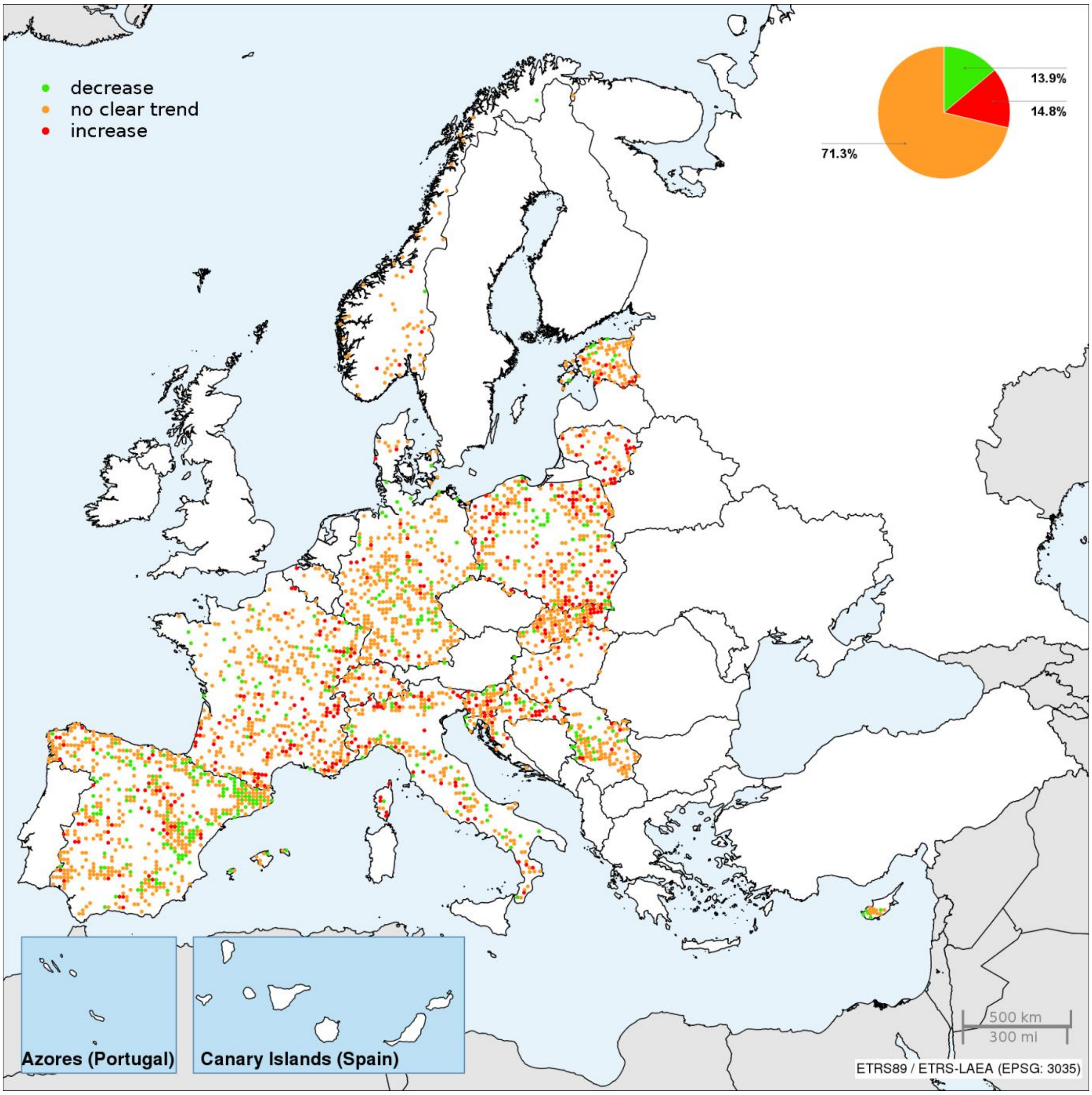


Figure Annex I-5: Trend of mean plot defoliation (slope of linear regression) of all species over the years 2006–2013.

Annex I-6: Changes in mean plot defoliation (2012–2013)

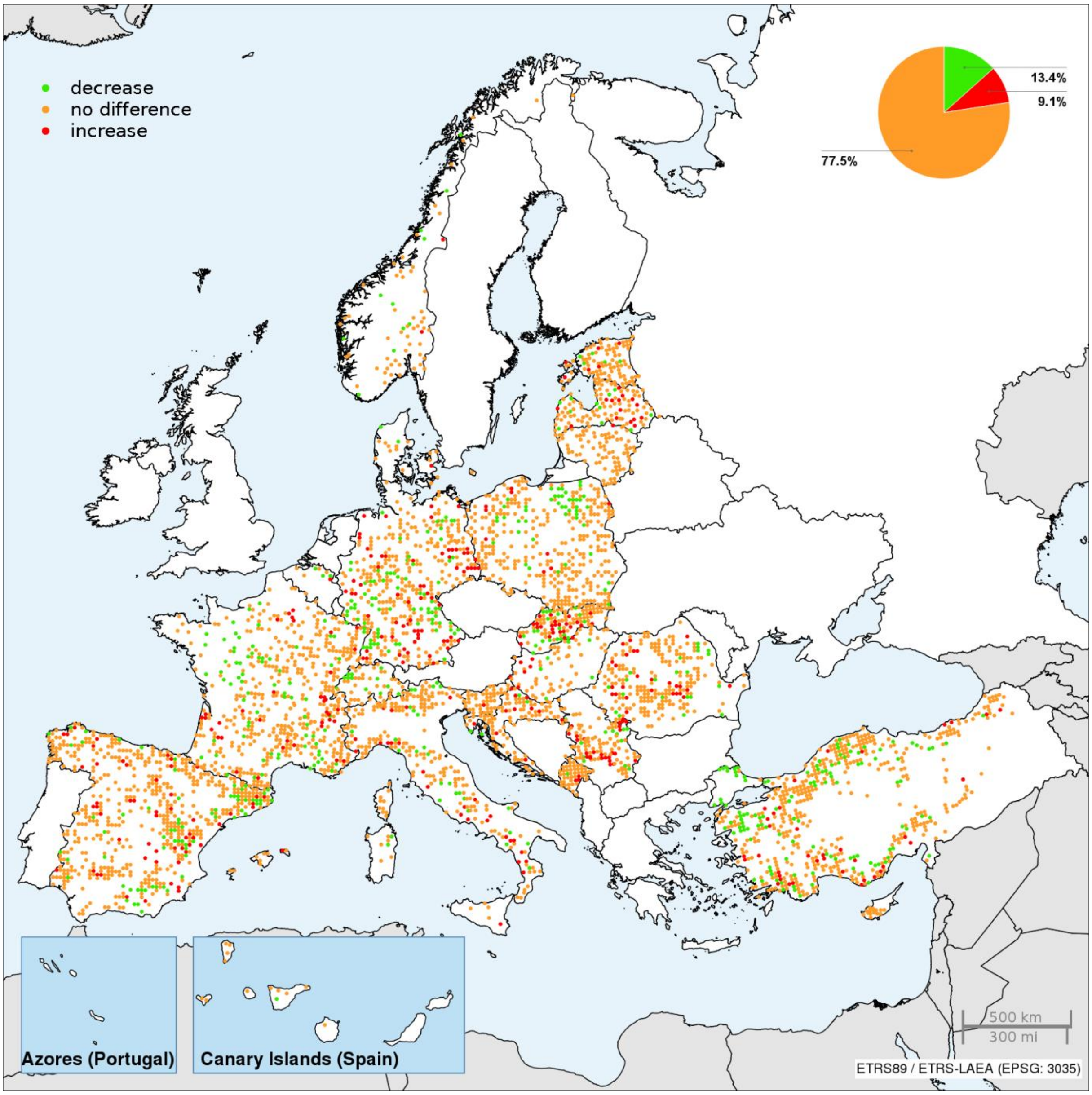


Figure Annex I-6: Changes in mean defoliation of all trees assessed per Level I plot from 2012 to 2013 (Student's t-test)

ANNEX II: RESULTS FROM NATIONAL REPORTS

Annex II-1: Forests and surveys in European countries (2013)

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	2875	1237	180	601			184	1380
Andorra	47	18	15	2	18	16 x 16	11	264
Austria	no data available for 2013							
Belarus	no data available for 2013							
Belgium	3036	700				4^2 / 8^2	111	2131
Bulgaria	no data available for 2013							
Croatia	5654	2061	321	1740		16 x 16	105	2520
Cyprus	925	298	172	0	138	16 x 16	15	360
Czech Republic	7886	2647	2014	633	2647	8 x 8/16 x 16	135	5309
Denmark	4310	586	289	263		7 x 7/16 x 16	325	1940
Estonia	4510	2234	1099	1135	2234	16 x 16	96	2329
Finland	no data available for 2013							
France	54883	15840	4041	9884	13100		550	11234
Germany	35702	11076	6490	3857	10347	16 x 16	417	10041
Greece	no data available for 2013							
Hungary	9300	1934	216	1718	1934	16 x 16	78	1800
Ireland	no data available for 2013							
Italy	30128	8675	1735	6940		16 x 16	248	5092
Latvia	6459	3162	1454	1711	3162	8 x 8	115	1746
Liechtenstein	no data available for 2013							
Lithuania	6530	2174	1153	902		4 x 4/16 x 16	1089	6749
Luxembourg	259	91	27	59	86	4 x 4	51	1200
FYR of Macedonia	no data available for 2013							
Rep. of Moldova	no data available for 2013							
Montenegro	1381	827	510	159			49	1176
Netherlands	no data available for 2013							
Norway	32376	12000	6800	5200	12000	3 x 3 / 9 x 9	1745	9343
Poland	31268	9143	6398	2746	9143	16 x 16	1982	39640
Portugal	no data available for 2013							
Romania	23839	6233	1873	4360		16 x 16	241	5784
Russian Fed.	no data available for 2013							
Serbia	8836	2360	179	2181	1868	16 x 16/4 x 4	130	2794
Slovakia	4901	1961	815	1069	1961	16 x 16	108	3835
Slovenia	2014	1210	457	753	1210	16 x 16	44	1056
Spain	50471	18173	6600	9626		16 x 16	620	14880
Sweden	40729	28068	14605	1236	17135	varying	3484	7513
Switzerland	4129	1279	778	501		16 x 16	47	1061
Turkey	77846	21537	13158	8379	9057	16 x 16	583	13553
Ukraine	60350	9400	2756	3285	6033	16 x 16	1487	35203
United Kingdom	no data available for 2013							
TOTAL	510643	164924	74136	68939	92073	varying	14050	189933

Annex II-2: Percent of trees of all species by defoliation classes and class aggregates (2013)

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		1380	41.0	38.0	17.0	4.0	21.0
Andorra	17.7	264	75.8	20.8	3.4	0.0	3.4
Austria	no data available						
Belarus	no data available						
Belgium		2131	9.4	63.1	21.9	5.6	27.6
Bulgaria	no data available						
Croatia		2520	32.9	38.0	25.3	3.8	29.1
Cyprus	137.8	360	29.7	61.4	7.8	1.1	8.9
Czech Republic	2647	5309	15.7	32.6	49.7	2.0	51.7
Denmark		1940	76.2	18.9	4.0	0.9	4.9
Estonia	2234	2329	49.5	42.4	5.3	2.7	8.0
Finland	no data available						
France	13100	11234	24.4	35.4	35.4	4.7	40.1
Germany	10347	10041	38.4	38.9	21.3	1.4	22.7
Greece	no data available						
Hungary	1934	1800	55.6	22.0	16.5	5.9	22.4
Ireland	no data available						
Italy		5092	24.3	42.0	27.9	5.8	33.7
Latvia	3162.3	1746	9.6	84.1	4.6	1.8	6.4
Liechtenstein	no data available						
Lithuania		6749	18.5	61.8	18.1	1.6	19.7
Luxembourg	86	1200	33.8	33.1	30.6	2.6	33.2
FYR of Macedonia	no data available						
Rep. of Moldova	no data available						
Montenegro		1176	39.3	38.0	18.5	4.3	22.7
Netherlands	no data available						
Norway	12000	9343	44.8	37.5	14.3	3.4	17.7
Poland	9143	39640	13.7	67.5	17.5	1.3	18.8
Portugal	no data available						
Romania		5784	49.4	37.0	11.8	1.8	13.6
Russian Federation	no data available						
Serbia	1868	2794	65.7	19.6	9.9	4.8	14.7
Slovakia	1961	3835	10.3	46.3	41.9	1.5	43.4
Slovenia	1209.9	1056	18.1	51.0	25.0	5.9	30.9
Spain		14880	22.2	61.2	12.1	4.6	16.6
Sweden	17135	7513	48.7	31.4	17.1	2.8	19.9
Switzerland		1061	23.4	50.6	14.7	11.3	26.0
Turkey	9057	13553	41.2	48.6	9.0	1.2	10.2
Ukraine	6033	35203	63.4	29.4	6.6	0.5	7.1
United Kingdom	no data available						

Cyprus, Norway, Sweden: only conifers assessed.

Note that some differences in the level of damage across national borders 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: Percent of conifers by defoliation classes and class aggregates (2013)

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	180	960	41.0	38.0	18.0	3.0	21.0
Andorra	15	259	76.1	20.8	3.1	0.0	3.1
Austria	no data available						
Belarus	no data available						
Belgium		825	5.3	75.0	18.3	1.5	19.7
Bulgaria	no data available						
Croatia	321	385	25.5	26.2	38.7	9.6	48.3
Cyprus	172	360	29.7	61.4	7.8	1.1	8.9
Czech Republic	2014	4107	14.2	26.6	56.6	2.6	59.2
Denmark	289	1132	79.9	17.3	2.5	0.3	2.8
Estonia	1099		46.4	45.1	5.4	3.1	8.5
Finland	no data available						
France	4041	3911	35.3	31.0	30.8	2.9	33.7
Germany	6490	6108	42.9	39.0	17.1	1.0	18.1
Greece	no data available						
Hungary	216	204	55.4	21.1	14.7	8.8	23.5
Ireland	no data available						
Italy	1735	1332	36.6	39.2	20.7	3.5	24.2
Latvia	1454	1360	10.5	82.6	4.7	2.2	6.9
Liechtenstein	no data available						
Lithuania	1153	4090	13.9	63.0	22.3	0.8	23.1
Luxembourg	27	442	55.7	26.9	16.1	1.4	17.5
FYR of Macedonia	no data available						
Rep. of Moldova	no data available						
Montenegro	510	288	42.0	35.4	12.9	9.7	22.6
Netherlands	no data available						
Norway	6800	9343	44.8	37.5	14.3	3.4	17.7
Poland	6398	25878	10.4	71.8	16.7	1.1	17.8
Portugal	no data available						
Romania	1873	1103	55.1	31.0	11.7	2.2	13.9
Russian Fed.	no data available						
Serbia	179	338	79.0	8.0	8.6	4.4	13.0
Slovakia	815	1553	8.9	47.8	41.6	1.7	43.3
Slovenia	457	396	24.8	43.9	24.2	7.1	31.3
Spain	6600	7435	28.2	59.2	8.4	4.2	12.6
Sweden	14605	7749	48.7	31.4	17.1	2.8	19.9
Switzerland	755	813	22.5	54.2	15.6	7.7	23.3
Turkey	13158	8538	42.9	50.2	6.4	0.6	6.9
Ukraine	2756	14828	66.0	26.5	7.1	0.4	7.5
United Kingdom	no data available						

Note that some differences in the level of damage across national borders 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: Percent of broadleaves by defoliation classes and class aggregates (2013)

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	600.6	420	42.0	39.0	17.0	2.0	19.0
Andorra	2	5	60.0	20.0	20.0	0.0	20.0
Austria	no data available						
Belarus	no data available						
Belgium		1139	11.6	59.1	21.4	8.0	29.4
Bulgaria	no data available						
Croatia	1740	2135	34.2	40.1	22.9	2.8	25.7
Cyprus	only conifers assessed						
Czech Republic	633	1202	20.9	53.4	25.5	0.2	25.7
Denmark	263	808	70.9	21.2	6.2	1.7	7.9
Estonia	1135		72.0	22.7	4.6	0.7	5.3
Finland	no data available						
France	9884	7323	18.6	37.8	37.9	5.7	43.6
Germany	3857	3933	31.4	38.8	27.8	2.0	29.8
Greece	no data available						
Hungary	1718	1596	55.6	22.1	16.8	5.5	22.3
Ireland	no data available						
Italy	6940	3760	19.9	43.0	30.5	6.6	37.1
Latvia	1711	386	6.2	89.4	4.1	0.3	4.4
Liechtenstein	no data available						
Lithuania	902	2659	25.5	59.8	11.8	2.9	14.7
Luxembourg	59	758	21.0	36.7	39.1	3.3	42.4
FYR of Macedonia	no data available						
Rep. of Moldova	only conifers assessed						
Montenegro	159	888	38.4	38.9	20.3	2.5	22.8
Netherlands	no data available						
Norway	only conifers assessed						
Poland	2746	13762	20.0	59.4	18.9	1.8	20.7
Portugal	no data available						
Romania	4360	4681	48.0	38.4	11.7	1.9	13.6
Russian Fed.	no data available						
Serbia	2181	2459	63.9	21.2	10.1	4.8	14.9
Slovakia	1069	2282	11.3	45.2	42.1	1.4	43.5
Slovenia	753	660	14.1	55.3	25.5	5.2	30.6
Spain	9626	7445	16.1	63.2	15.7	4.9	20.7
Sweden	only conifers assessed						
Switzerland	501	306	25.4	43.2	12.8	18.7	31.5
Turkey	8379	5015	38.6	45.8	13.5	2.2	15.7
Ukraine	3285	20375	61.6	31.4	6.3	0.7	7.0
United Kingdom	no data available						

Note that some differences in the level of damage across national borders 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: Percent of damaged trees of all species (2002–2013)

Participating Countries	All species Defoliation classes 2–4												Change % points 2012/13
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	
Albania	13.1		12.2		11.1							21.0	
Andorra			36.1		23	47.2	15.3	6.8	15.3	8.3	5.6	3.4	-2.2
Austria	10.2	11.1	13.1	14.8	15				14.2				
Belarus	9.5	11.3	10	9	7.9	8.1	8	8.4	7.4	6.1			
Belgium	17.8	17.3	19.4	19.9	17.9	16.4	14.5	20.2	22.1	23.5	28.2	27.6	-0.6
Bulgaria	37.1	33.7	39.7	35	37.4	29.7	31.9	21.1	23.8	21.6	32.3		
Croatia	20.6	22	25.2	27.1	24.9	25.1	23.9	26.3	27.9	25.2	28.5	29.1	0.6
Cyprus	2.8	18.4	12.2	10.8	20.8	16.7	47	36.2	19.2	16.4	10.6	8.9	-1.7
Czech Republic	53.4	54.4	57.3	57.1	56.2	57.1	56.7	56.8	54.2	52.7	50.3	51.7	1.4
Denmark	8.7	10.2	11.8	9.4	7.6	6.1	9.1	5.5	9.3	10	7.3	4.9	-2.4
Estonia	7.6	7.6	5.3	5.4	6.2	6.8	9	7.2	8.1	8.1	7.8	8.0	0.2
Finland	11.5	10.7	9.8	8.8	9.7	10.5	10.2	9.1	10.5	10.6	14.3		
France	21.9	28.4	31.7	34.2	35.6	35.4	32.4	33.5	34.6	39.9	41.4	40.1	-1.3
Germany	21.4	22.5	31.4	28.5	27.9	24.8	25.7	26.5	23.2	28	24.6	22.7	-1.9
Greece	20.9			16.3				24.3	23.8				
Hungary	21.2	22.5	21.5	21	19.2	20.7		18.4	21.8	18.9	20.2	22.4	2.2
Ireland	20.7	13.9	17.4	16.2	7.4	6	10	12.5	17.5		1		
Italy	37.3	37.6	35.9	32.9	30.5	35.7	32.8	35.8	29.8	31.3	35.7	33.7	-2.0
Latvia	13.8	12.5	12.5	13.1	13.4	15	15.3	13.8	13.4	14	9.2	6.4	-2.8
Liechtenstein													
Lithuania	12.8	14.7	13.9	11	12	12.3	19.6	17.7	21.3	15.4	24.5	19.7	-4.8
Luxembourg												33.2	
FYR of Macedonia						23							
Rep. of Moldova	42.5	42.4	34	26.5	27.6	32.5	33.6	25.2	22.5	18.4	25.6		
Montenegro												22.7	
Netherlands	21.7	18	27.5	30.2	19.5			18.2	21.6				
Norway	25.5	22.9	20.7	21.6	23.3	26.2	22.7	21	18.9	20.9	18.8	17.7	-1.1
Poland	32.7	34.7	34.6	30.7	20.1	20.2	18	17.7	20.7	24	23.4	18.8	-4.6
Portugal	9.6	13	16.6	24.3									
Romania	13.5	12.6	11.7	8.1	8.6	23.2		18.9	17.8	13.9	13.9	13.6	-0.3
Russian Fed.	10.9							6.2	4.4	8.3			
Serbia	3.9	22.8	14.3	16.4	11.3	15.4	11.5	10.3	10.8	7.6	10.3	14.7	4.4
Slovakia	24.8	31.4	26.7	22.9	28.1	25.6	29.3	32.1	38.6	34.7	37.9	43.4	5.5
Slovenia	28.1	27.5	29.3	30.6	29.4	35.8	36.9	35.5	31.8	31.4	29.1	30.9	1.8
Spain	16.4	16.6	15	21.3	21.5	17.6	15.6	17.7	14.6	11.8	17.5	16.6	-0.9
Sweden	16.8	19.2	16.5	18.4	19.4	17.9	17.3	15.1	19.2	18.9	15.9	19.9	4.0
Switzerland	18.6	14.9	29.1	28.1	22.6	22.4	19	18.3	22.2	30.9	31.3	26.0	-5.3
Turkey							24.6	18.7	16.8	13.6	12.4	10.2	-2.2
Ukraine	27.7	27	29.9	8.7	6.6	7.1	8.2	6.8	5.8	6.8	7.5	7.1	-0.4
U.K.	27.3	24.7	26.5	24.8	25.9	26			48.5				

Note that some differences in the level of damage across national borders 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*: Change of grid net since 2006. *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.

Annex II-6: Percent of damaged conifers (2002–2013)

Participating countries	Conifers Defoliation classes 2–4												Change % points 2012/13
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	
Albania	15.5		14		13.6							21.0	
Andorra			36.1		23	47.2	15.3	6.8	15.3	8.3	5.6	3.1	-2.5
Austria	10.1	11.2	13.1	15.1	14.5				14.5				
Belarus	9.7	9.5	8.9	8.4	7.5	8.1	8.1	8.3	7.7	5.8			
Belgium	19.7	18.6	15.6	16.8	15.8	13.9	13.2	13.6	16.2	15.2	20.3	19.7	-0.6
Bulgaria	44	38.4	47.1	45.4	47.6	37.4	45.6	33	31.1	33.3	35.1		
Croatia	63.5	77.4	70.6	79.5	71.7	61.1	59.1	66.5	56.9	45.1	54.7	48.3	-6.4
Cyprus	2.8	18.4	12.2	10.8	20.8	16.7	46.9	36.2	19.2	16.4	10.6	8.9	-1.7
Czech Republic	60.1	60.7	62.6	62.7	62.3	62.9	62.8	63.1	60.1	58.9	56.9	59.2	2.3
Denmark	4.5	6.1	5.8	5.5	1.7	3.1	9.9	1	5.4	5.7	4.6	2.8	-1.8
Estonia	7.9	7.7	5.3	5.6	6	6.7	9.3	7.5	9	8.7	6.6	8.5	1.9
Finland	11.9	11.1	10.1	9.2	9.6	10.4	10.1	9.9	10.6	11.7	14.6		
France	15.2	18.9	18.6	20.8	23.6	24.1	25.1	26.8	27.4	31.9	32.2	33.7	1.5
Germany	19.8	20.1	26.3	24.9	22.7	20.2	24.1	20.3	19.2	20.3	19.3	18.1	-1.2
Greece	16.1			15				26.3	23.7				
Hungary	22.8	27.6	24.2	22	20.8	22.3		27.1	35.1	28.7	23.1	23.5	0.4
Ireland	20.7	13.9	17.4	16.2	7.4	6.2	10	12.5	17.5		1		
Italy	20.5	20.4	21.7	22.8	19.5	22.7	24	31.6	29.1	32.2	31.8	24.2	-7.6
Latvia	14.3	12.2	11.9	13.2	15.2	16.2	16.7	14.8	15	16	7.9	6.9	-1.0
Liechtenstein													
Lithuania	9.3	10.7	10.2	9.3	9.5	10.2	19.1	17.4	19.8	16.3	26.9	23.1	-3.8
Luxembourg												17.5	
FYR of Macedonia													
Rep. of Moldova		55.4	35.5	38	38.6	34.3			33.3	32.1	44.3		
Montenegro												22.6	
Netherlands	17.5	9.4	17.2	17.9	15.3			14.1	18.9				
Norway	24.1	21.2	16.7	19.7	20.2	23	19.2	17.9	16.4	17.3	16.1	17.7	1.6
Poland	32.5	33.2	33.4	29.6	21.1	20.9	17.5	17.2	20.3	24.2	22.3	17.8	-4.5
Portugal	3.6	5.3	10.8	17.1									
Romania	9.9	9.8	7.6	4.7	5.2	21.8		21.7	16.1	15.9	14.9	13.9	-1.0
Russian Fed.	10							7.3	5.1	10.6			
Serbia	7.3	39.6	19.8	21.3	12.6	13.3	13	12.6	12	11.1	11	13.0	2.0
Slovakia	40.4	39.7	36.2	35.3	42.4	37.5	41.1	42.7	46.8	46.6	43.5	43.3	-0.2
Slovenia	31.4	35.3	37.4	33.8	32.1	36	40.7	38.8	37.8	33.6	31.3	31.3	0.0
Spain	15.6	14.1	14	19.4	18.7	15.8	12.9	14.9	13.1	10.4	11.4	12.6	1.2
Sweden	17.7	20.4	16	19.6	20.1	17.9	17.3	15.1	19.2	18.9	15.9	19.9	4.0
Switzerland	19.9	13.3	27.4	28.2	22.5	20.7	18.7	18.8	20.9	31.5	30.6	23.3	-7.3
Turkey						8.1	16.2	16	14.5	11.6	9.9	6.9	-3.0
Ukraine	14.6	15.4	11.4	8.1	6.9	7.1	7.1	6.3	5.6	6.8	7.5	7.5	0.0
United Kingdom	25.1	25.8	23.2	22.2	23.3	16.1			38.6				

Note that some differences in the level of damage across national borders 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*: Change of grid net since 2006. *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.

Annex II-7: Percent of damaged broadleaves (2002–2013)

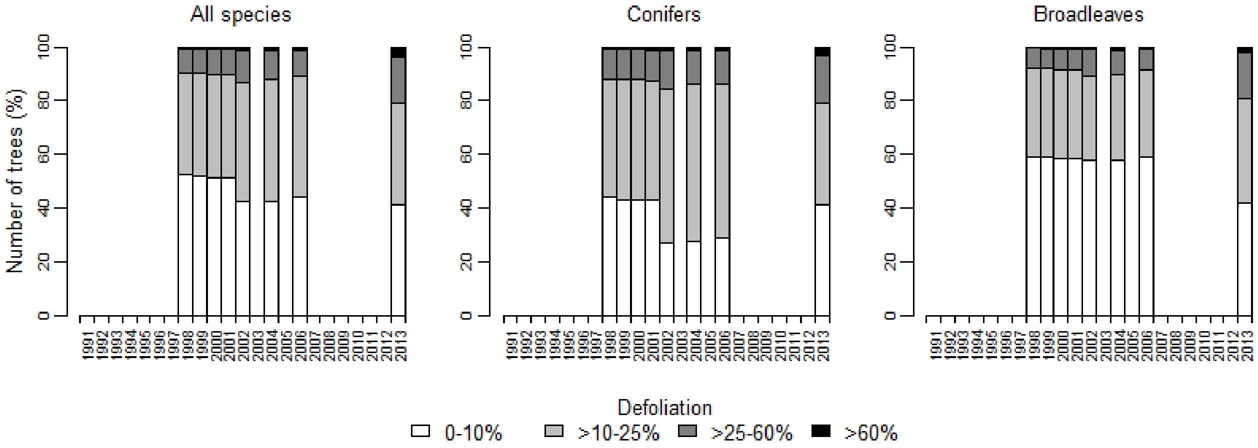
Participating countries	Broadleaves Defoliation classes 2–4												Change % points 2012/13
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	
Albania	10.7		10.3		8.5							19.0	
Andorra												20.0	
Austria	11.3	10.2	13.6	12.9	20.1				10.5				
Belarus	9	15.8	12.9	10.6	8.9	8.2	7.6	8.7	6.9	6.4			
Belgium	17	16.6	21.3	21.4	18.8	17.5	15.3	23.4	24.6	26.7	32.9	29.4	-3.5
Bulgaria	29	27.2	30.1	23.1	36.4	21.1	17.8	12.2	18.2	12.8	29.8		
Croatia	14.4	14.3	17.2	19.2	18.2	20	19.1	20.7	21.9	21.5	23.7	25.7	2.0
Cyprus	only conifers assessed												
Czech Republic	19.9	24.4	31.8	32	31.2	33.5	32.2	32.9	32.2	31.2	28.4	25.7	-2.7
Denmark	15.4	16.6	19.1	14.4	14.8	10.3	8	10	12.1	12.8	10.9	7.9	-3.0
Estonia	2.7	6.7	5.3	3.4	8.6	7.6	3.4	3.5	2.5	3	14.9	5.3	-9.6
Finland	8.8	8.3	8.4	7.2	10.3	10.9	10.6	4.7	9.2	6	12.8		
France	25.5	33.5	38.7	41.3	42	41.6	36.5	37.1	38.7	44.3	45.9	43.6	-2.3
Germany	24.7	27.3	41.5	35.8	37.2	32.8	28.4	36.1	29.4	38	32.5	29.8	-2.7
Greece	26.5			17.9				5.2	23.9				
Hungary	20.8	22	21	20.9	19	20.6		17.1	19.7	17.3	19.9	22.3	2.4
Ireland													
Italy	44.6	45	42	36.5	35.2	40.4	35.8	36.8	30.1	32.7	37.2	37.1	-0.1
Latvia	12.8	13.5	14.3	12.9	8.5	11.8	11.5	11.6	9.4	8.8	12.9	4.4	-8.5
Liechtenstein													
Lithuania	19	24.6	21.8	15.4	16.6	17.7	20.3	18.4	23.7	13.8	21	14.7	-6.3
Luxembourg												42.4	
FYR of Macedonia	no data available												
Rep. of Moldova	42.5	42.3	33.9	26.4	27.6	32.5	33.6	25.2	22.4	18.4	25.6		
Montenegro												22.8	
Netherlands	29.6	33.7	46.9	53.1	26.2			25.6	26.6				
Norway	30.4	29	33.2	27.6	33.2	36.3	33.8	31	26.8	32.3	27.3		
Poland	33.1	39.6	38.7	34.1	18	18.9	19.1	18.5	21.5	23.5	25.5	20.7	-4.8
Portugal	12.6	16.2	19	27									
Romania	14.8	13.3	13	9.3	9.9	23.5		18.3	18	13.4	13.6	13.6	0.0
Russian Fed.	16							4.4	3.2	4.3			
Serbia	0.6	21.5	13.5	15.7	11	15.7	11.3	9.9	10.7	7.2	10.2	14.9	4.7
Slovakia	14.5	25.6	19.9	13.6	17	16.6	20.8	24.5	32.9	26.4	33.9	43.5	9.6
Slovenia	25.9	22.6	24.2	28.5	27.6	35.7	34.6	33.3	28.1	30	27.7	30.6	2.9
Spain	17.3	19.1	16.1	23.3	24.4	19.5	18.4	20.7	16.1	13.2	23.6	20.7	-3.0
Sweden	9.6	11.1	8.3	9.2	10.8								
Switzerland	16	18.1	32.8	27.9	22.6	26.1	19.6	17.4	25.2	29.6	33.3	31.5	-1.8
Turkey							38.3	23.4	21.2	17.2	16.8	15.7	-1.1
Ukraine	36.7	35.3	43.2	9.2	6.2	7.1	9.1	7.2	6.4	6.7	7.5	7.0	-0.5
United Kingdom	30.3	23.2	30.6	28.2	29.2	35.3			56.1				

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

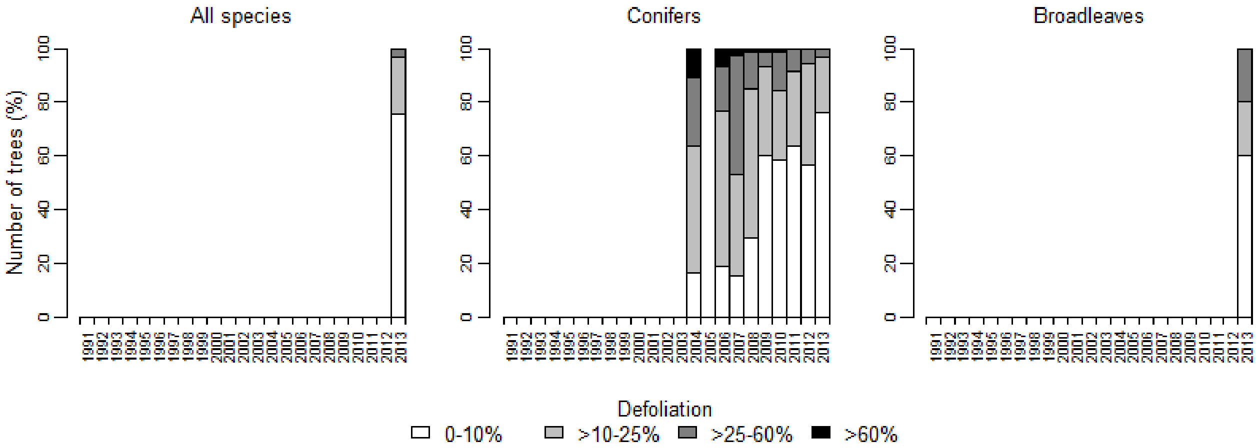
Austria: from 2003 on results are based on the 16 x 16 km transnational grid net and must not be compared with previous years. *Poland*: Change of grid net since 2006. *Russian Federation:* North-western and Central European parts only. *Ukraine*: Change of grid net in 2005. *Hungary, Romania*: Comparisons not possible due to changing survey designs.

Annex II-8: Changes in defoliation (1991–2013)

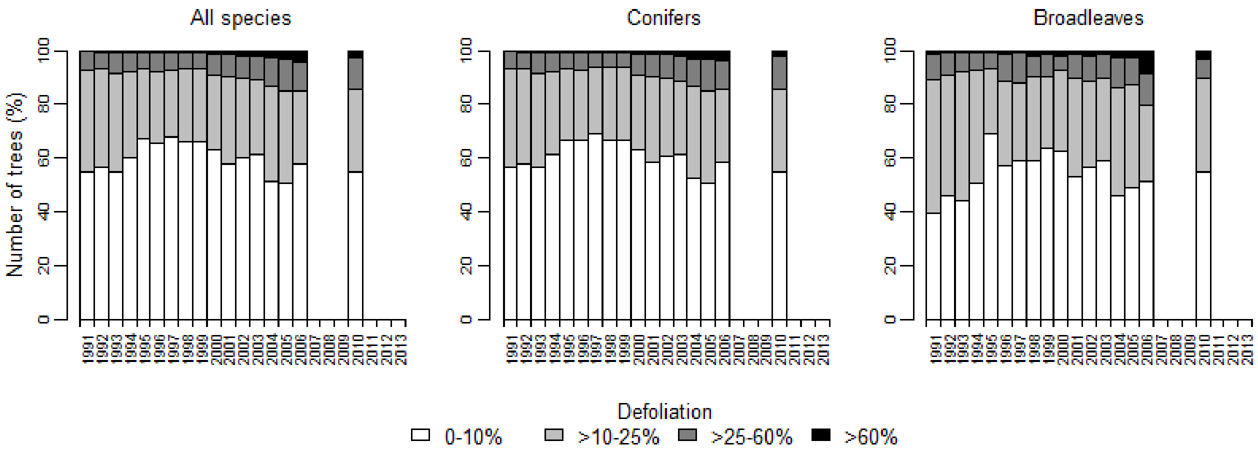
ALBANIA



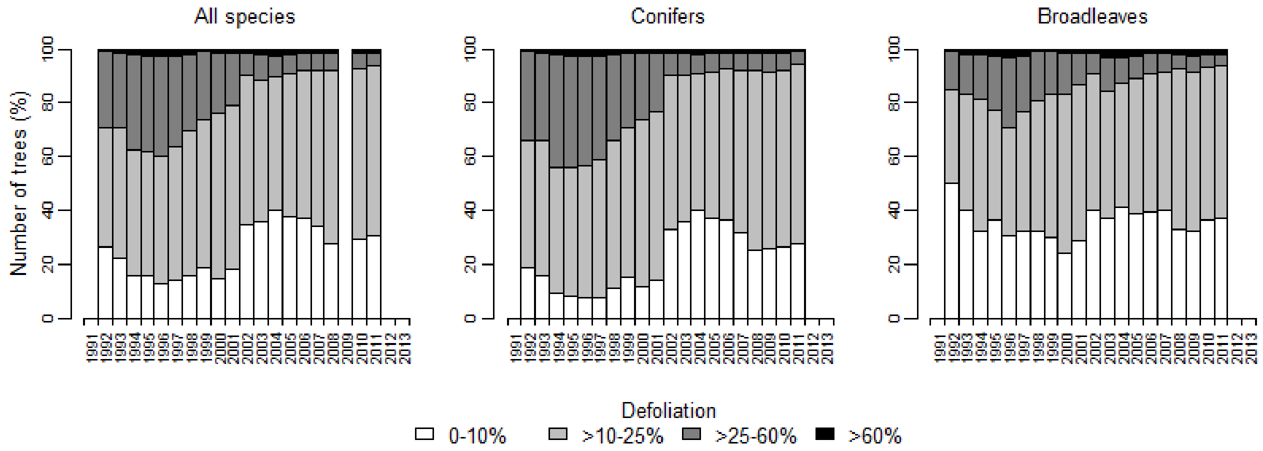
ANDORRA



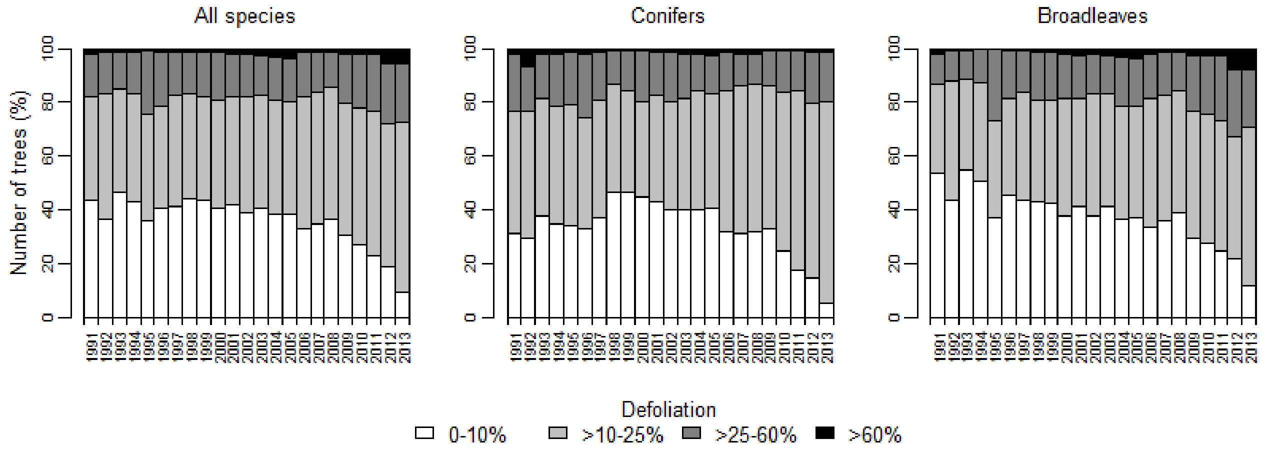
AUSTRIA



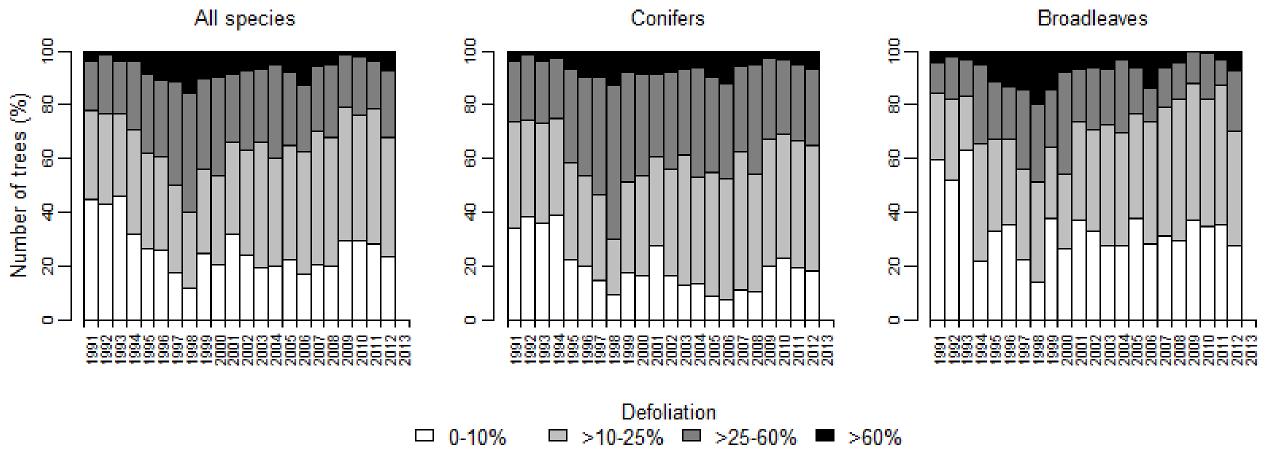
BELARUS



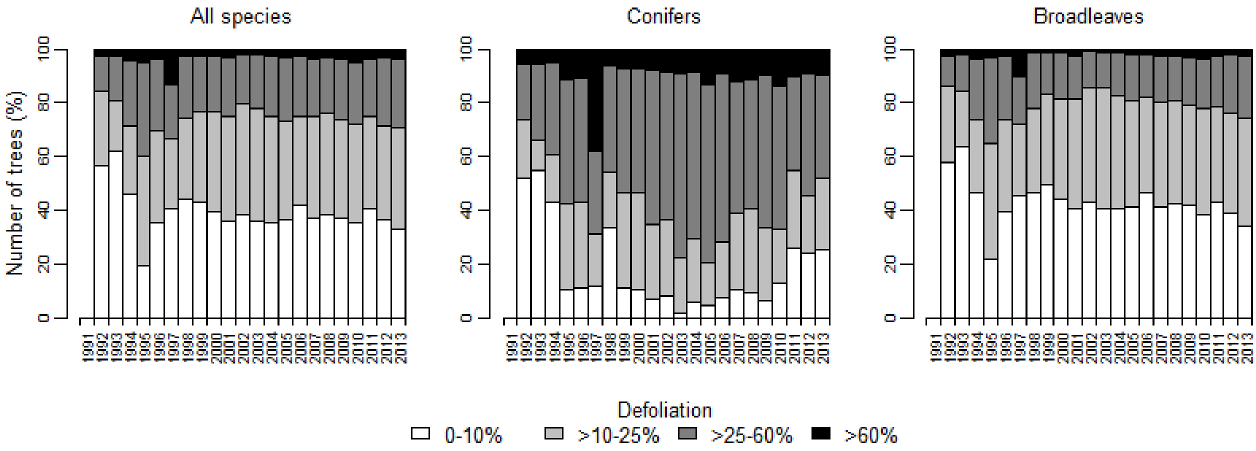
BELGIUM



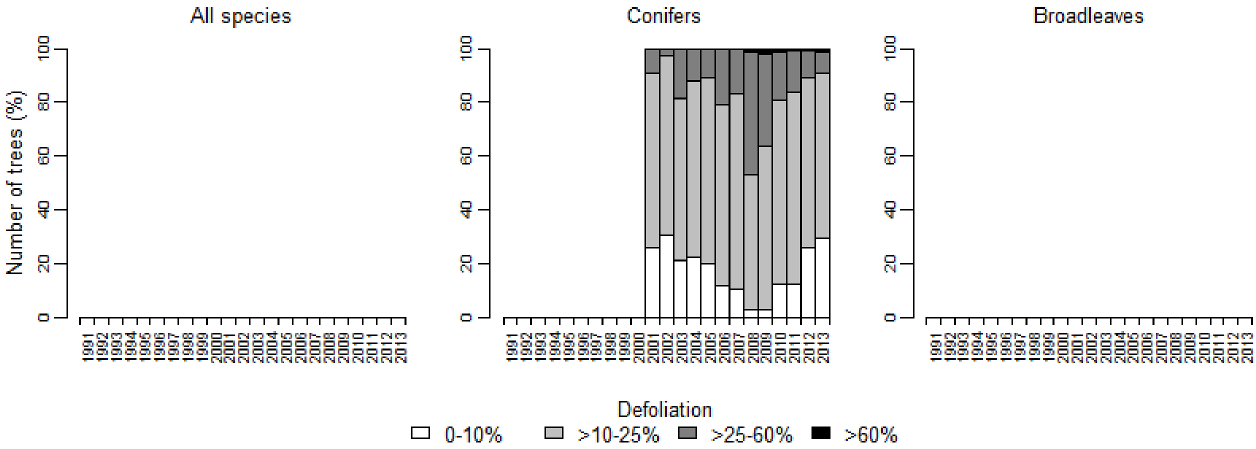
BULGARIA



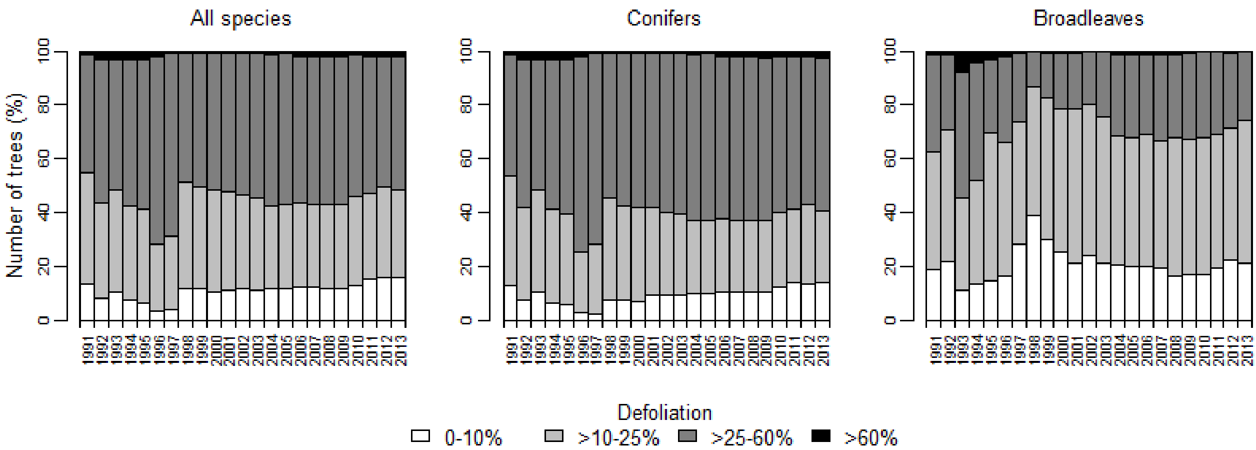
CROATIA



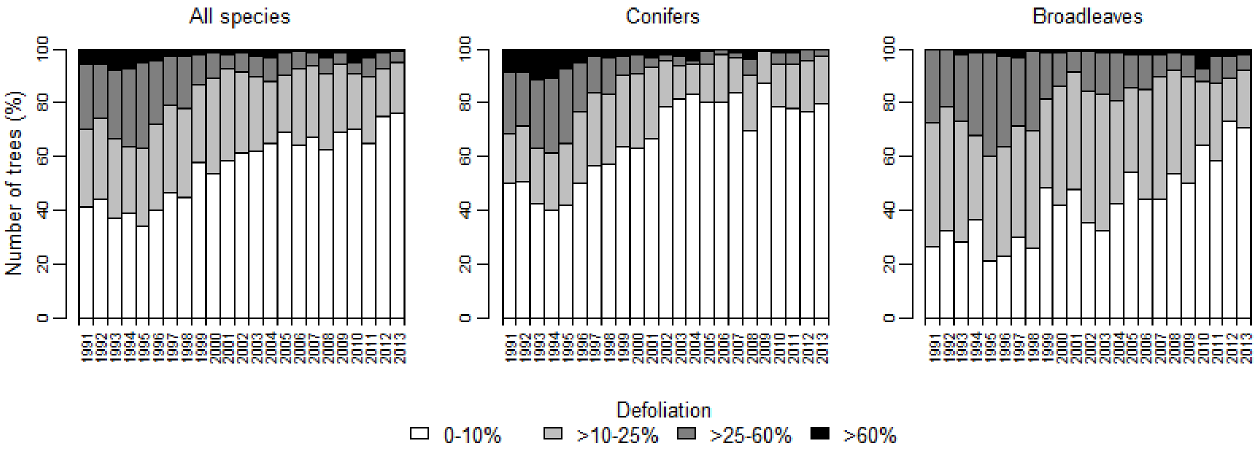
CYPRUS



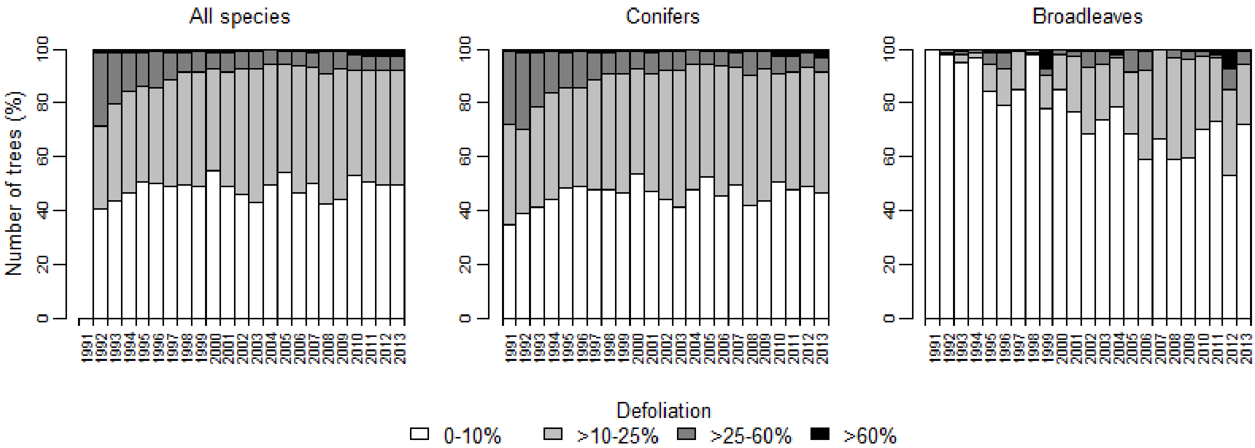
CZECH REPUBLIC



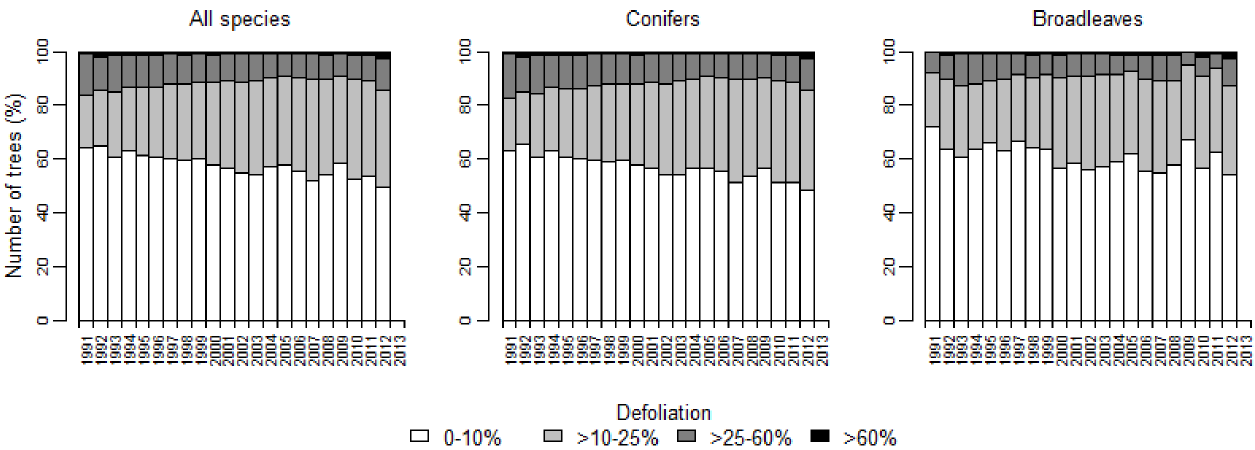
DENMARK



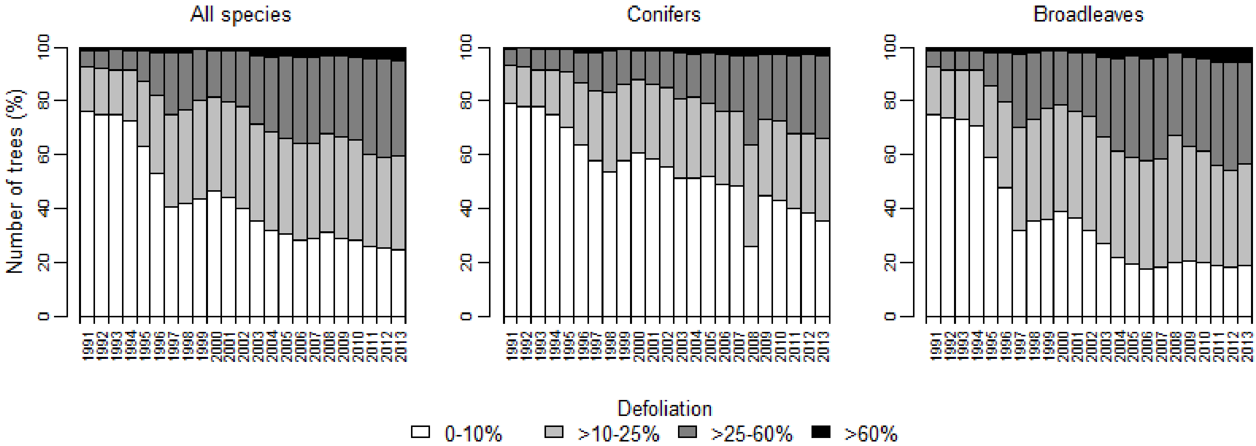
ESTONIA



FINLAND



FRANCE



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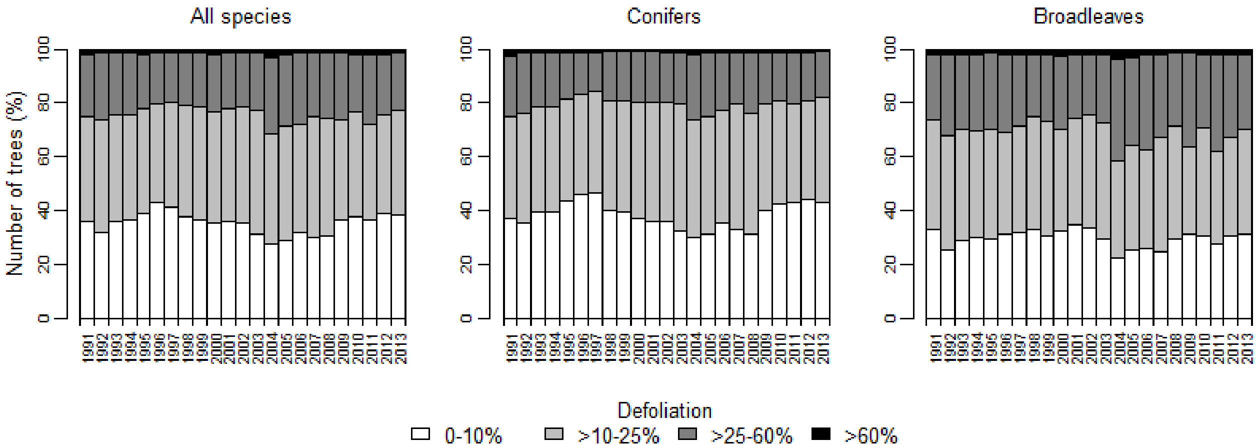

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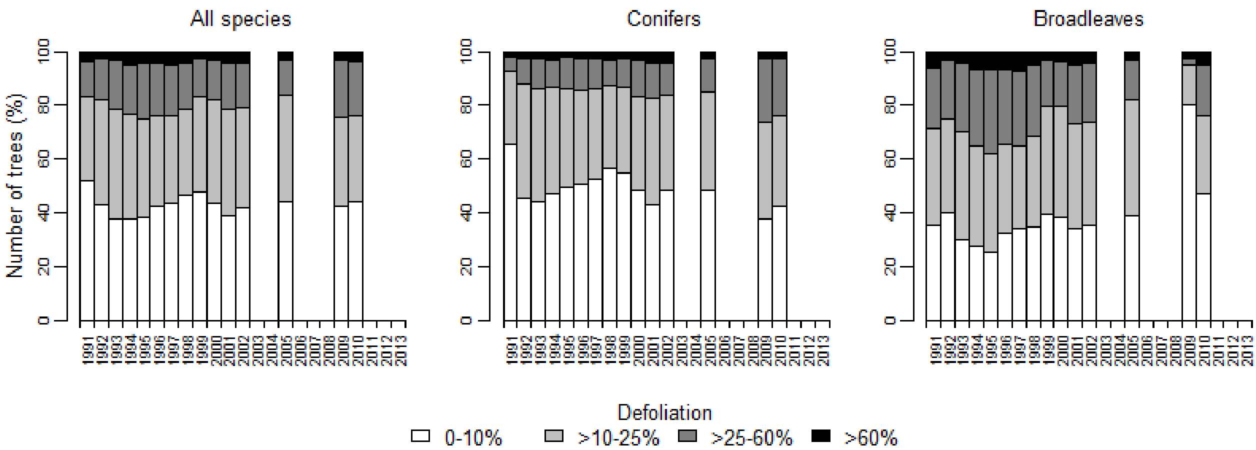
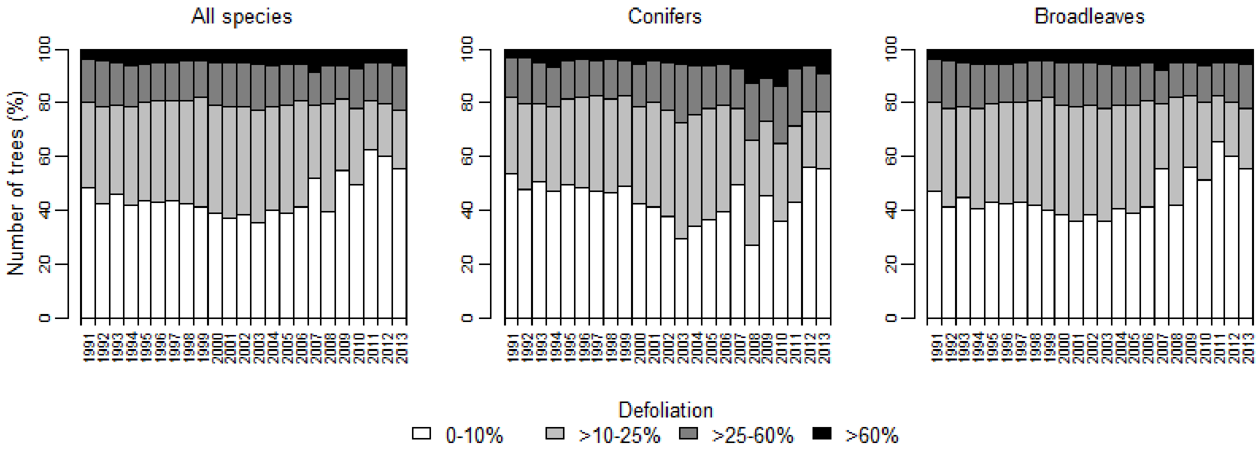
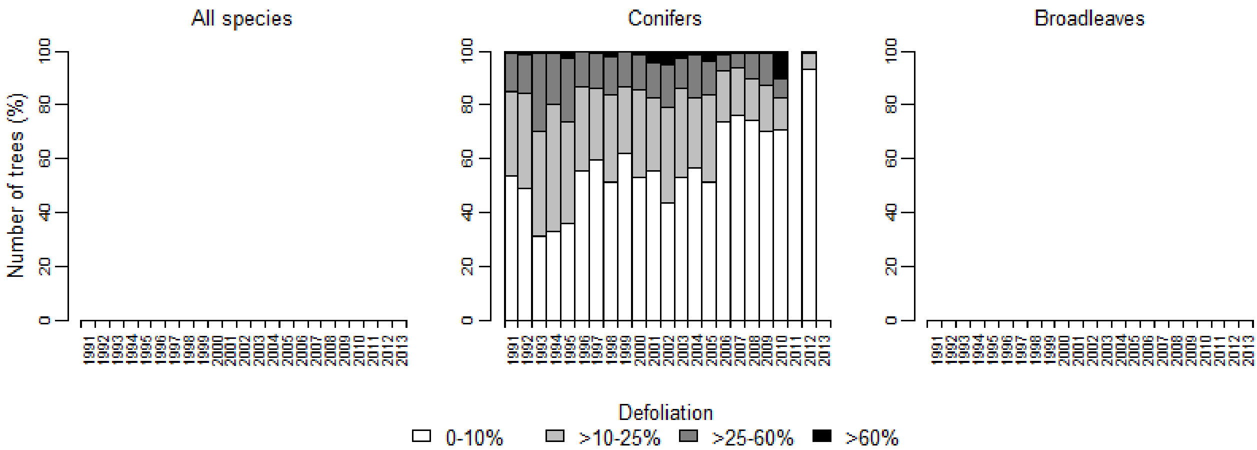


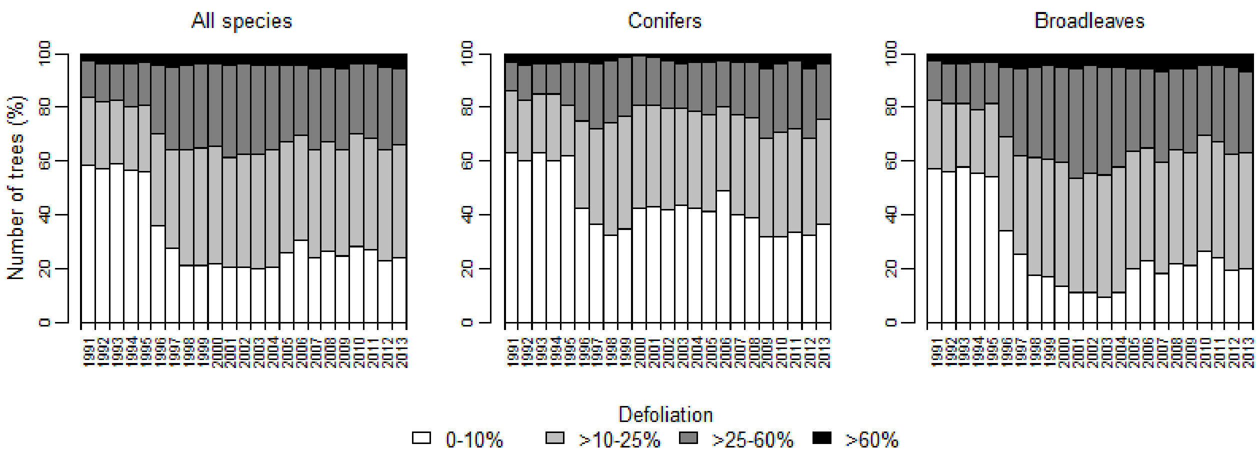
HUNGARY



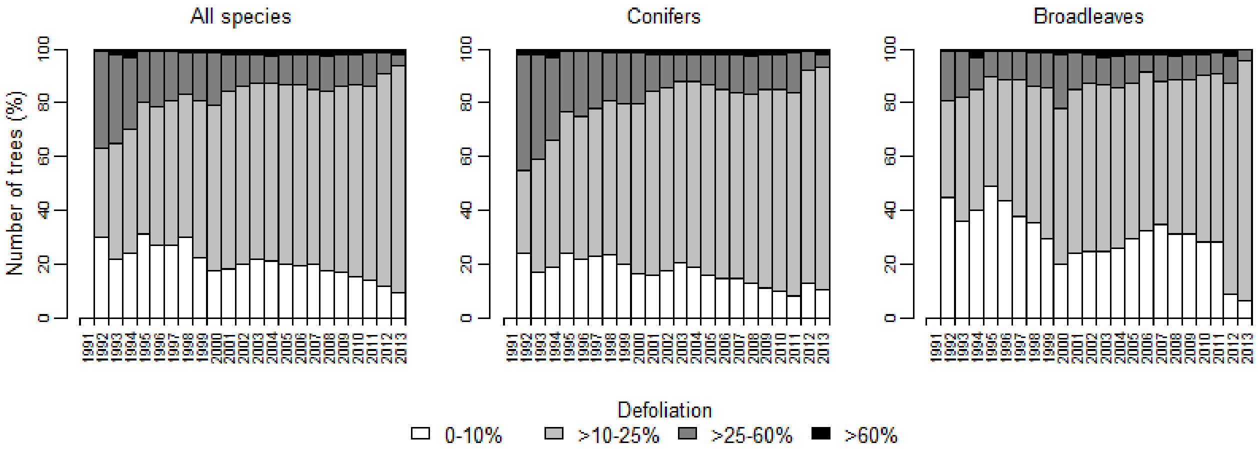
IRELAND



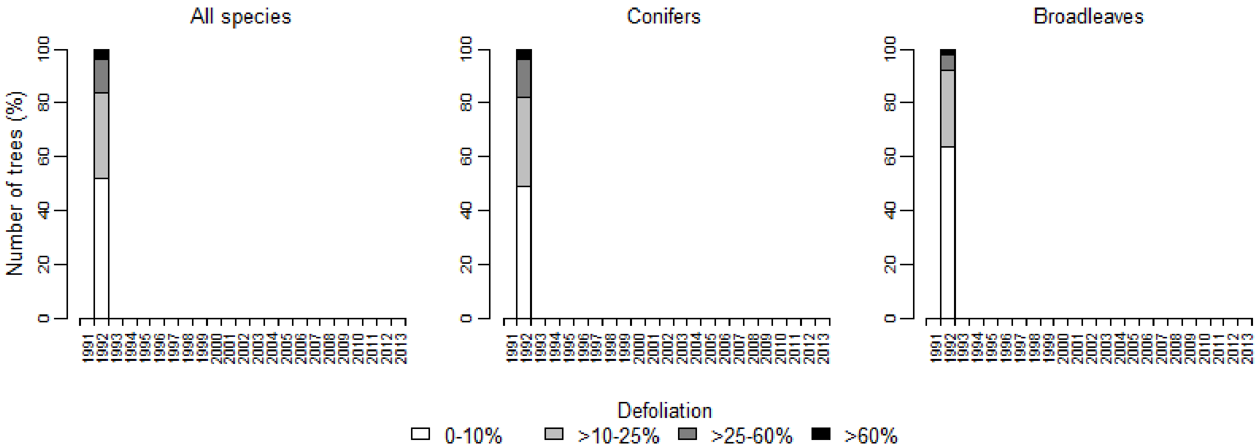
ITALY



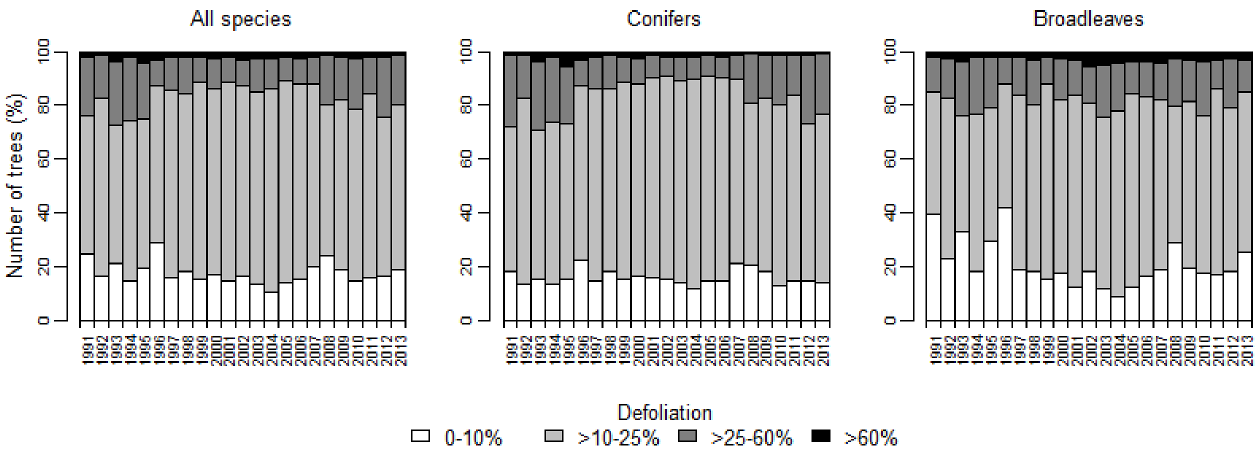
LATVIA



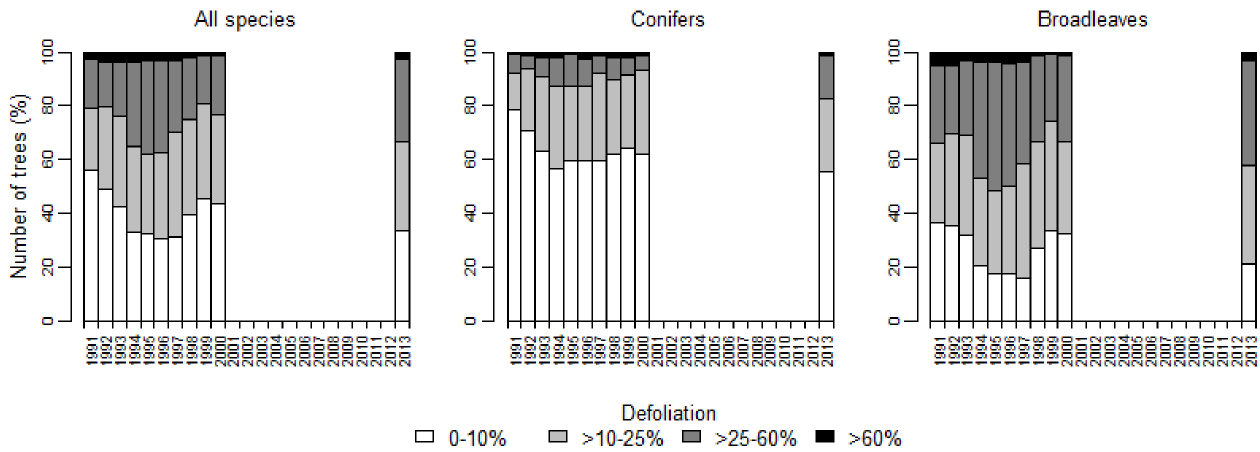
LIECHTENSTEIN



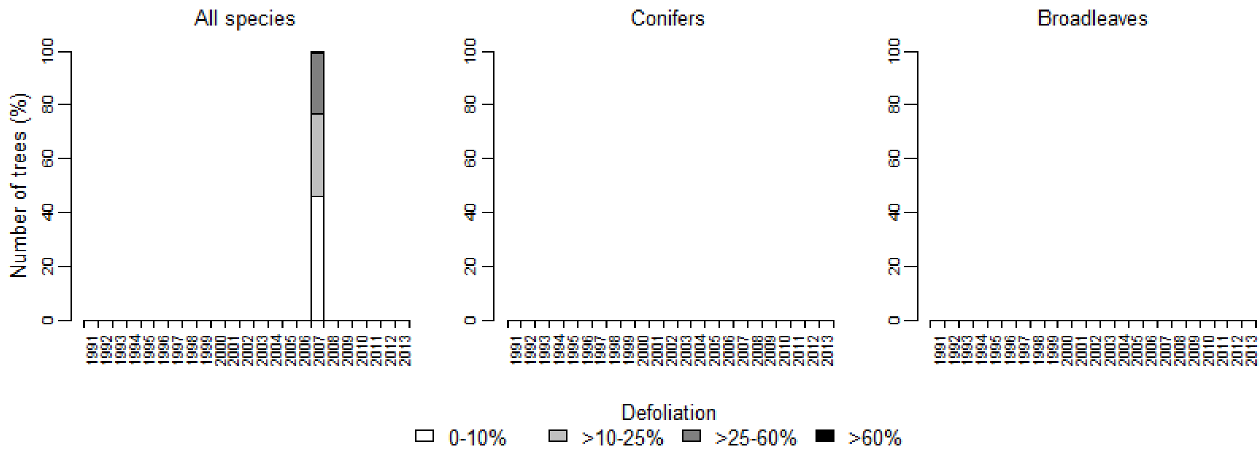
LITHUANIA



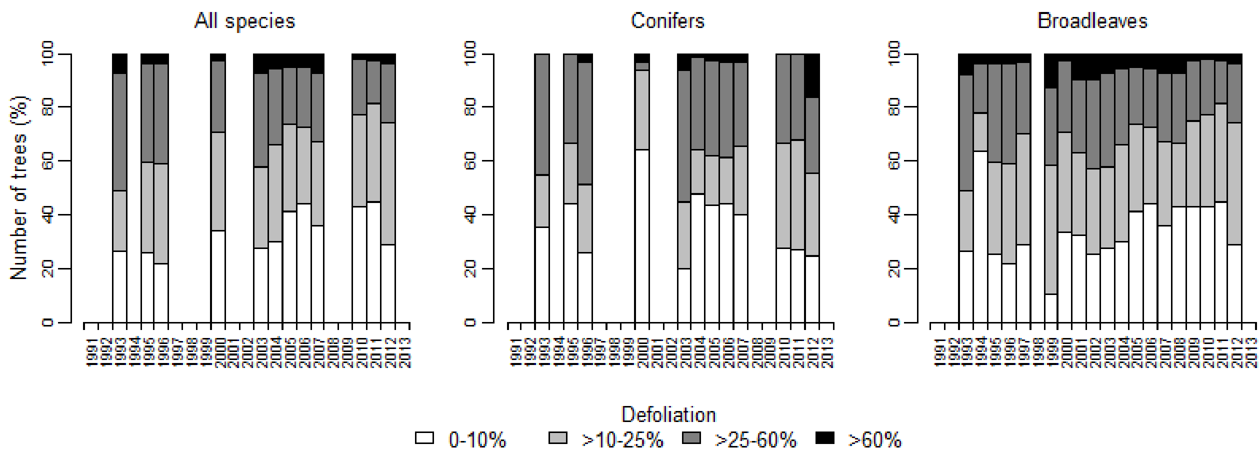
LUXEMBOURG



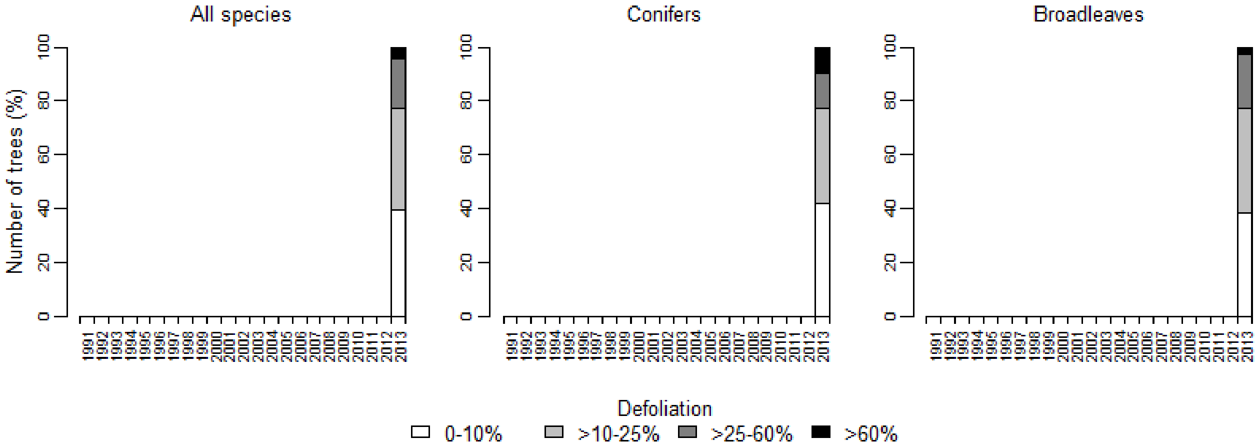
FYR OF MACEDONIA



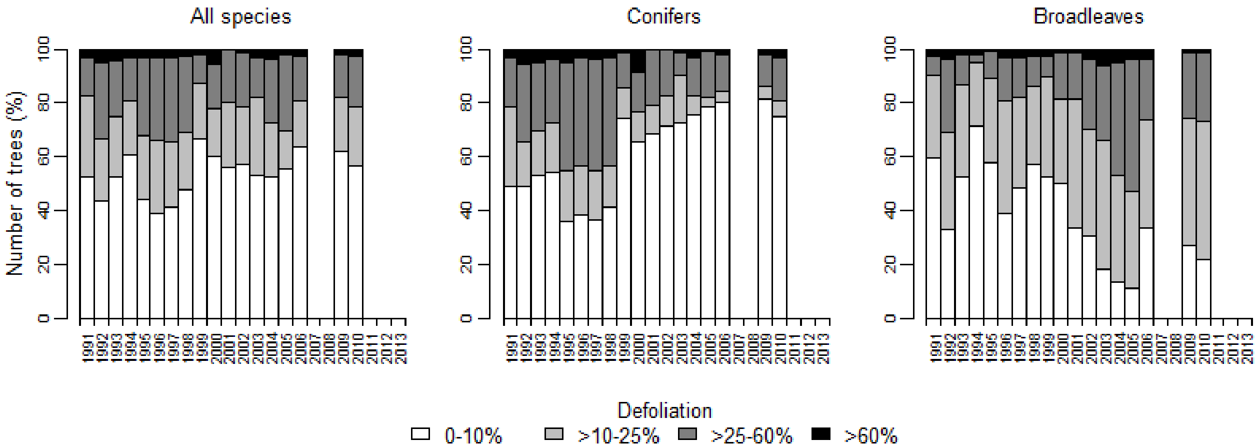
REPUBLIC OF MOLDOVA



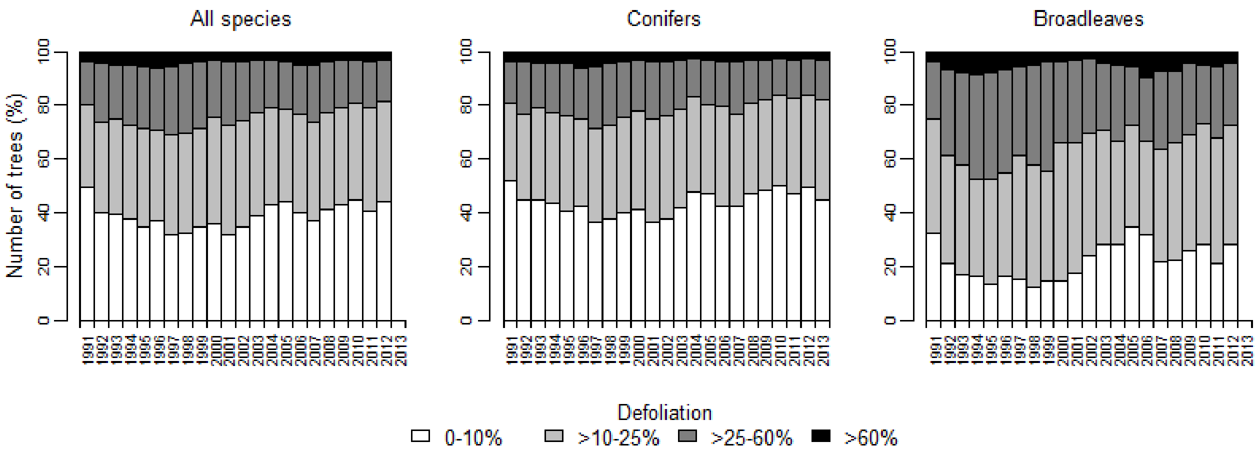
MONTENEGRO



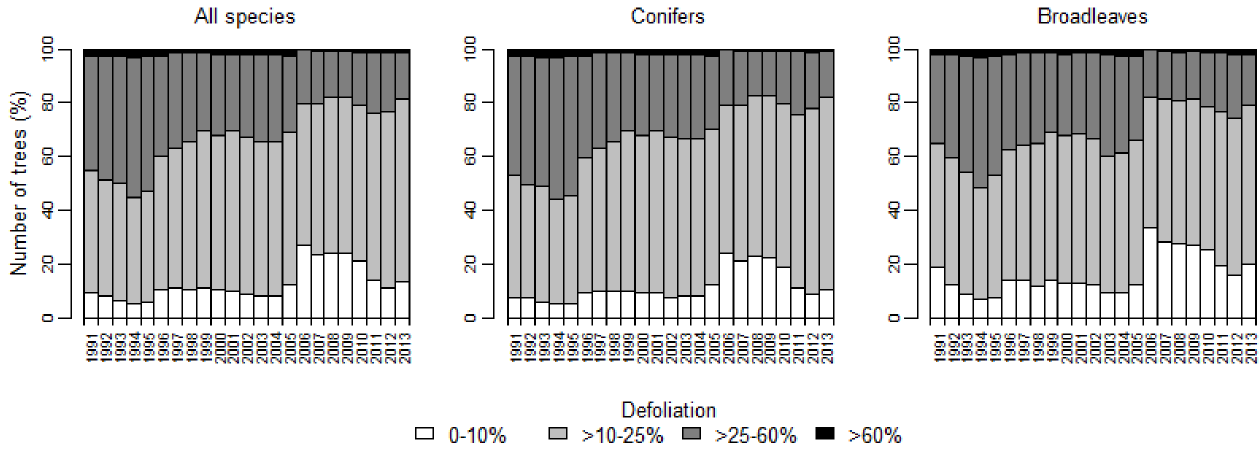
THE NETHERLANDS



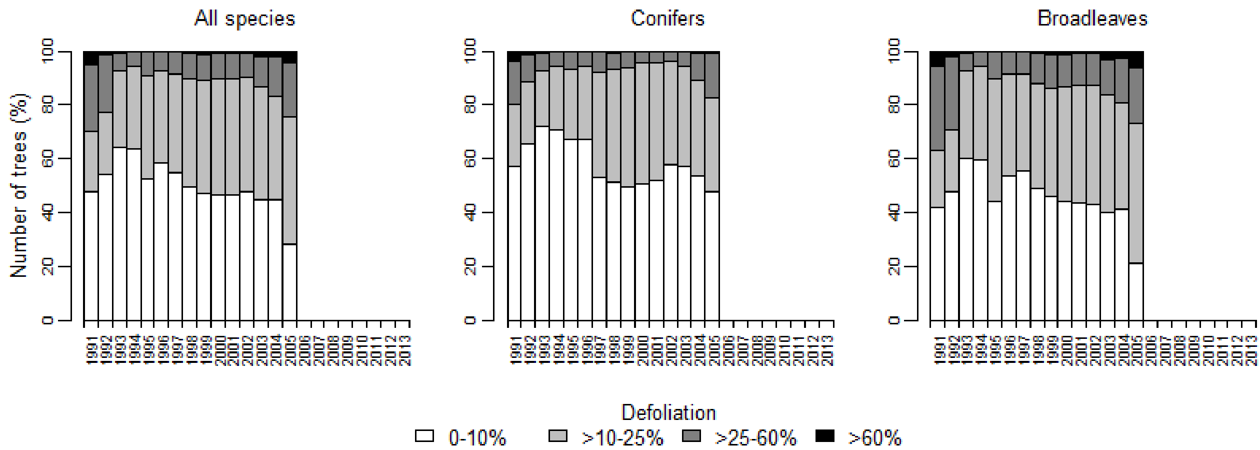
NORWAY



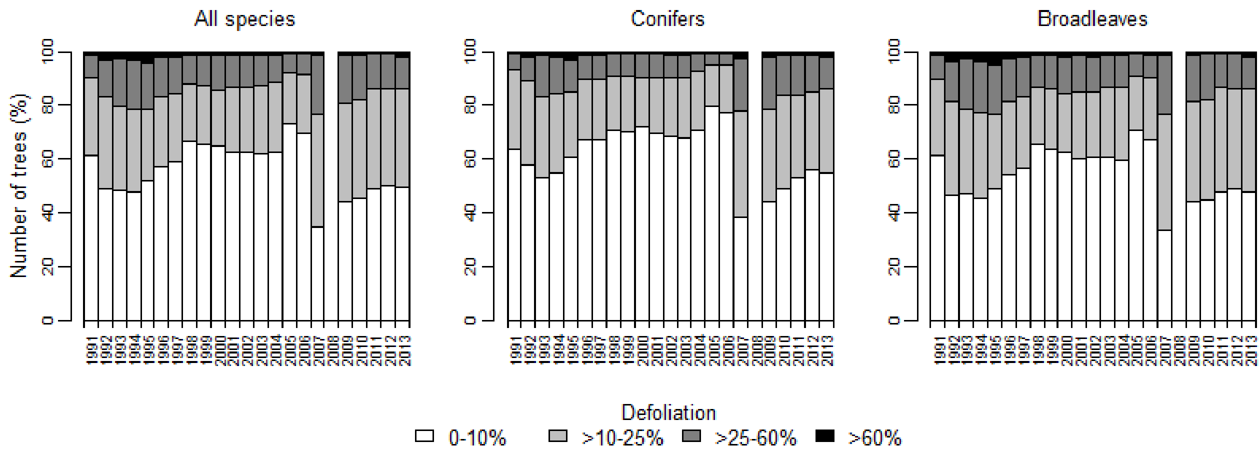
POLAND



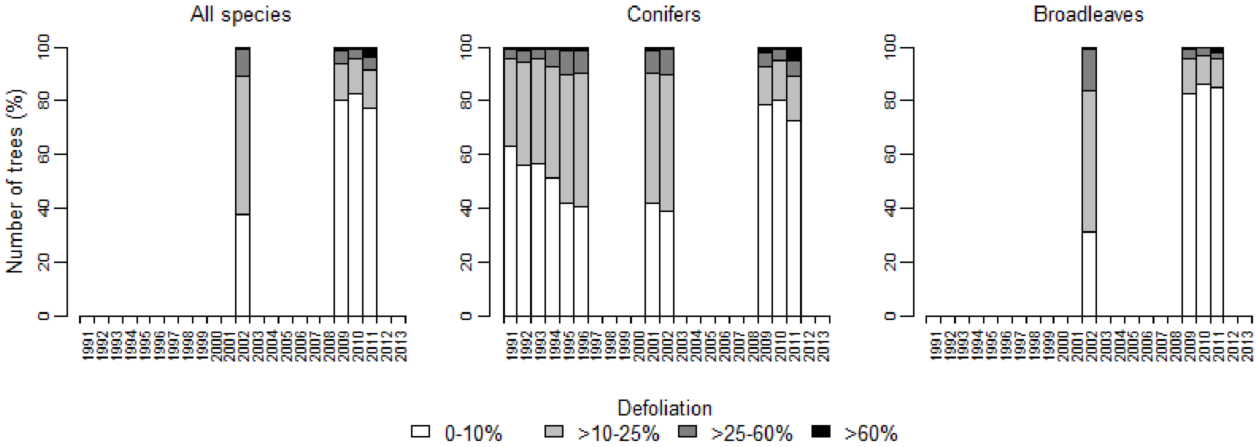
PORTUGAL



ROMANIA



RUSSIAN FEDERATION



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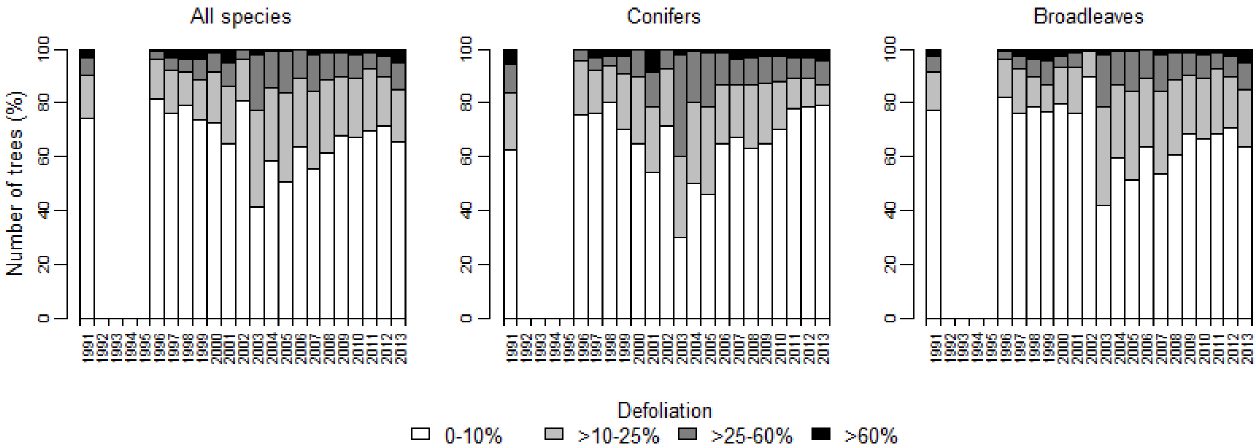

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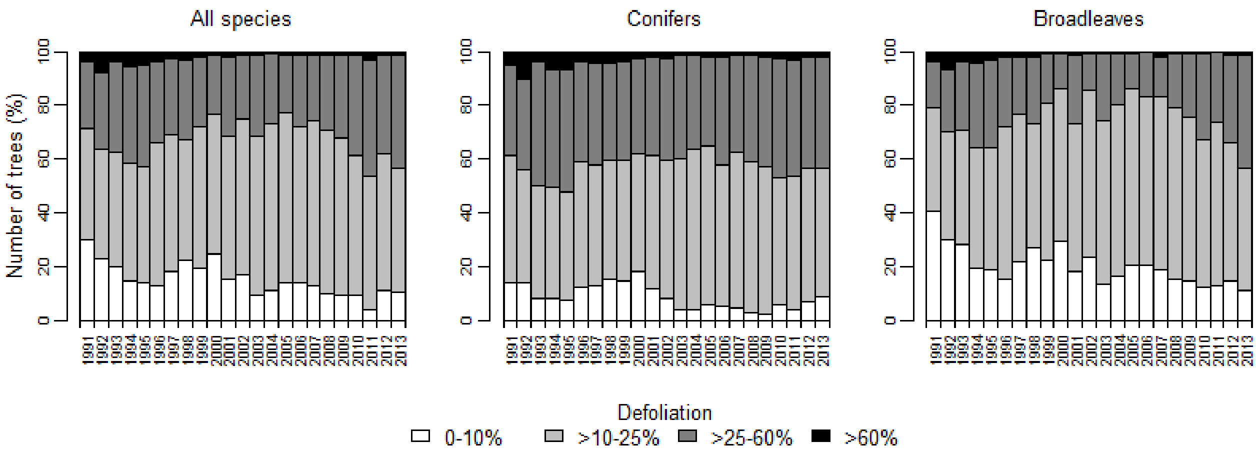

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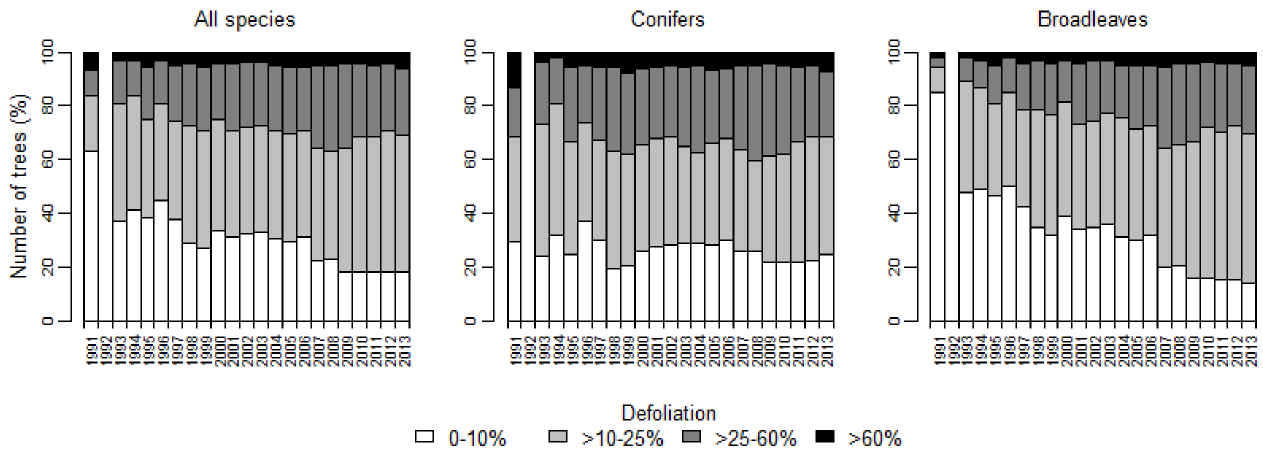
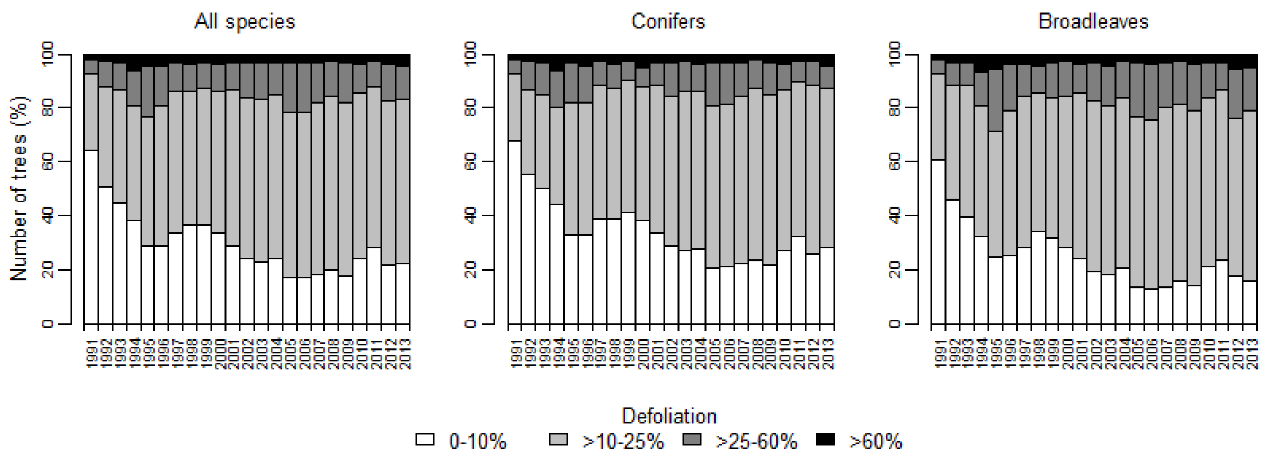
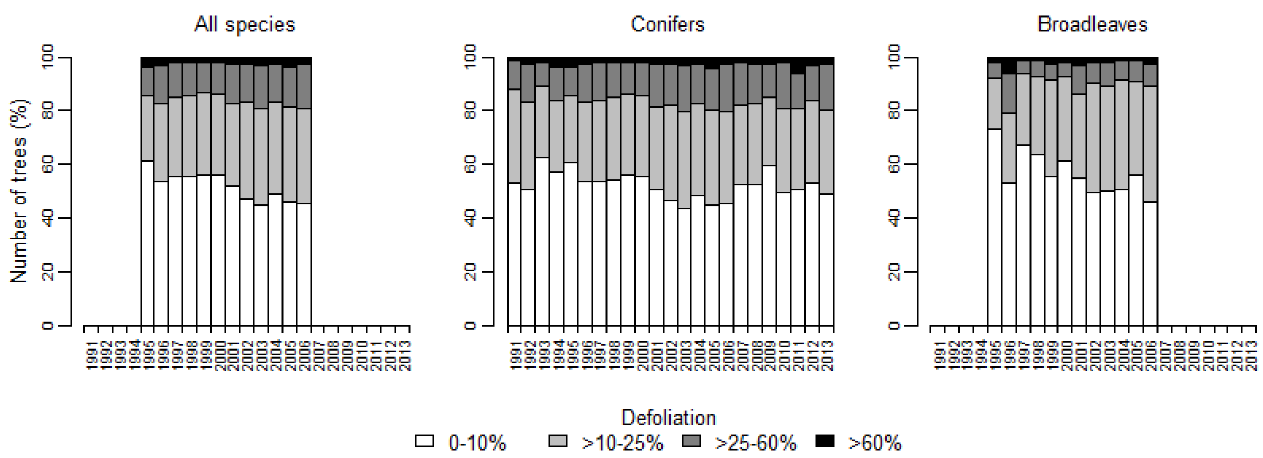


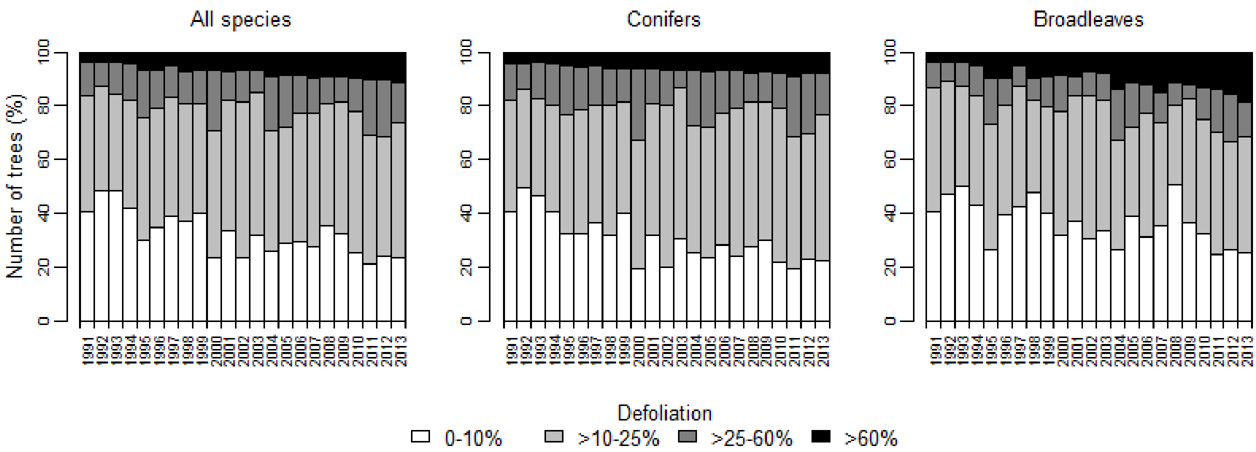
SPAIN



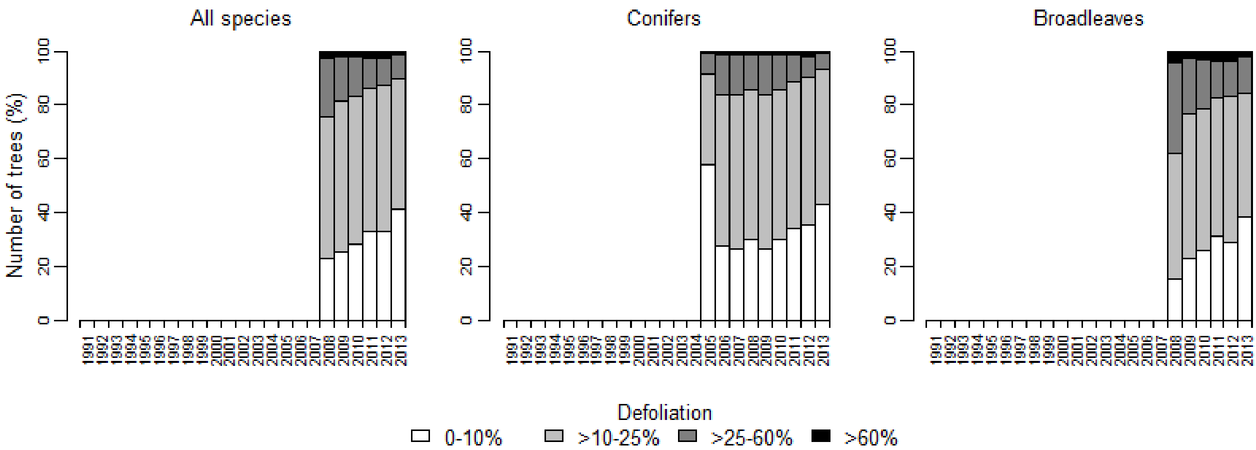
SWEDEN



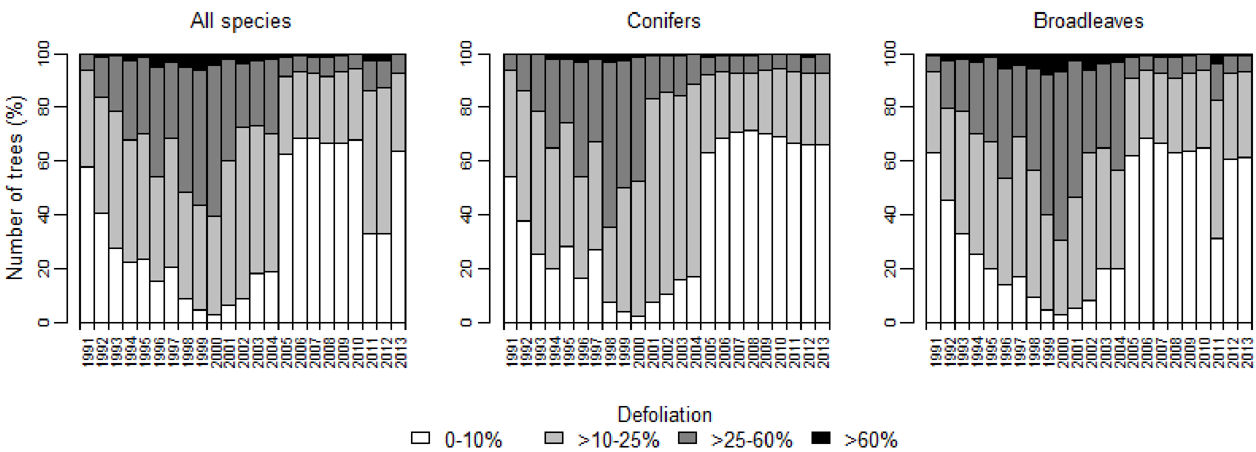
SWITZERLAND



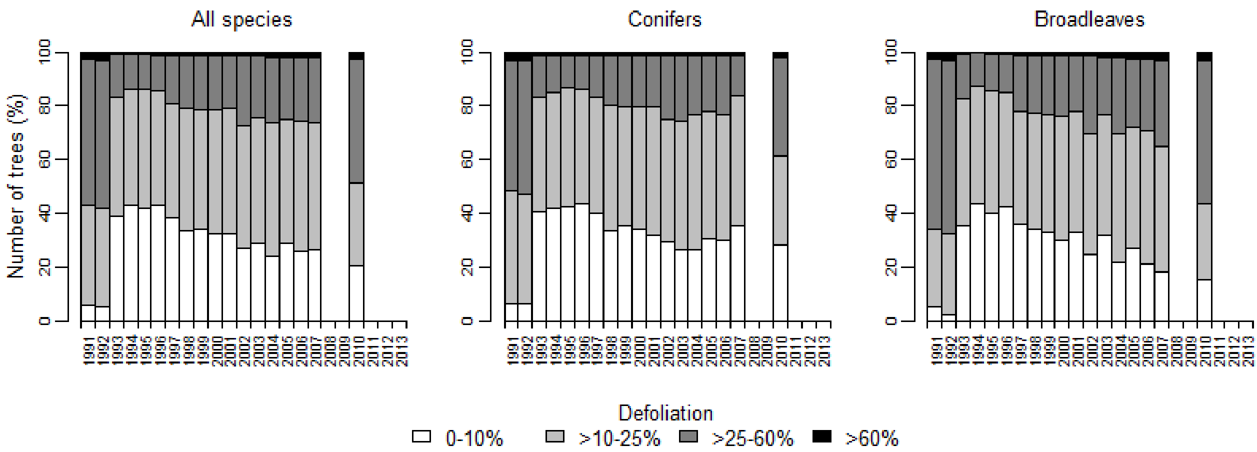
TURKEY



UKRAINE



UNITED KINGDOM



ANNEX III: CONTACTS

Annex III-1: UNECE and ICP Forests

UNECE	United Nations Economic Commission for Europe LRTAP Convention Secretariat Palais des Nations, 8-14, avenue de la Paix 1211 Geneva 10, SWITZERLAND Phone: +41 22 917 23 58/Fax: +41 22 917 06 21 Email: krzysztof.olendrzynski@unece.org Mr Krzysztof Olendrzynski
ICP Forests Lead Country	Federal Ministry of Food and Agriculture - Ref. 535 Postfach 14 02 70 53107 Bonn, GERMANY Phone: +49 228 99 529-41 30/Fax: +49 228-99 529 42 62 Email: sigrid.strich@bmel.bund.de, 535@bmel.bund.de Ms Sigrid Strich
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 Coordinating Centre (PCC)	Thünen Institute of Forest Ecosystems Alfred-Möller-Str. 1 16225 Eberswalde, GERMANY Phone: +49 3334 3820-338 /Fax: +49 3334 3820-354 Email: walter.seidling@ti.bund.de Internet: www.icp-forests.net Mr Walter Seidling, Head of PCC

Annex III-2: Expert Panels, Working Groups, and other coordinating institutions

Expert Panel on Soil and Soil Solution	Research Institute for Nature and Forest (INBO) Environment & Climate Unit Gaverstraat 4 9500 Geraardsbergen, BELGIUM Mr Bruno De Vos, Chair Phone: +32 54 43 71 20/Fax: +32 54 43 61 60 Email: bruno.devos@inbo.be
	Research Institute for Nature and Forest (INBO) Gaverstraat 4 9500 Geraardsbergen, BELGIUM Ms Nathalie Cools, Co-chair Phone: + 32 54 43 61 75/Fax: +32 54 43 61 60 Email: nathalie.cools@inbo.be
	Finnish Forest Research Institute (Metla) PL 18 01301 Vantaa, FINLAND Ms Tiina Nieminen, Co-chair Phone: +358 10 211 5457/Fax: +358 10 211 2103 Email: tiina.nieminen@metla.fi
Expert Panel on Foliar Analysis and Litterfall	Finnish Forest Research Institute (Metla) Northern Unit PO Box 16, Eteläranta 55 96301, Rovaniemi, FINLAND Mr Pasi Rautio, Chair Phone: +358 50 391 4045/Fax: +358 10 211 4401 Email: pasi.rautio@metla.fi
	Finnish Forest Research Institute (Metla) PL 18 01301 Vantaa, FINLAND Ms Liisa Ukonmaanaho, Co-chair Litterfall Phone: +358 10 211 5115/Fax: +358 10 211 2103 Email: liisa.Ukonmaanaho@metla.fi
Expert Panel on Forest Growth	Slovenian Forestry Institute (SFI) Večna pot 2 1000 Ljubljana, SLOVENIA Mr Tom Levanič, Chair Phone: +386 1 200 78 44 Email: tom.levanic@gozdis.si
	University of Copenhagen Department of Geosciences and Natural Resource Management Rolighedsvej 23 1958 Frederiksberg C, DENMARK Mr Vivian Kvist Johannsen, Co-chair Phone: +453 53 316 99 Email: vkj@ign.ku.dk

Expert Panel on Deposition Measurements	Swedish Environmental Research Institute (IVL) Natural Resources & Environmental Research Effects Box 210 60 100 31 Stockholm, SWEDEN Ms Karin Hansen, Chair Expert Panel Deposition 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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