Forest Condition in Europe

The 2020 Assessment

Online Supplementary Material

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

Contact

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

Recommended citation

Michel A, Prescher A-K, Schwärzel K, editors (2020) Forest Condition in Europe: The 2020 Assessment. ICP Forests Technical Report under the UNECE Convention on Long-range Transboundary Air Pollution (Air Convention). Online supplementary material, 59 p. Eberswalde: Thünen Institute. Available at http://icp-forests.net/page/icp-forests-technical-report

United Nations Economic Commission for Europe (UNECE)
Convention on Long-range Transboundary Air Pollution (Air Convention)
International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests)

http://icp-forests.net

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

CONTENTS

S1 TREE CROWN CONDITION AND DAMAGE CAUSES – ADDITIONAL TABLES AND MAPS

S1-1 Mean plot defoliation of main tree species in 2019

Table S1-1: Percentage of plots with mean plot defoliation in defoliation classes 0-3 (class 2 subdivided) for the main species or species groups and the number of plots in each group in 2019. Dead trees are not included.

Main species or species groups	Class 0 0-10%	Class 1 >10-25%	Class 2-1 >25-40%	Class 2-2 >40-60%	Class 3 >60%	No. of plots
Scots pine (*Pinus sylvestris*)	15.3	63.1	16.4	4.5	0.7	1 222
Norway spruce (*Picea abies*)	24.0	42.7	26.0	6.5	0.7	949
Austrian pine (*Pinus nigra*)	11.9	60.4	15.4	10.5	1.8	285
Mediterranean lowland pines	3.8	67.6	22.7	5.0	0.9	423
Common beech (*Fagus sylvatica*)	20.9	44.9	22.7	10.4	1.1	722
Deciduous temperate oaks	6.5	40.3	39.1	13.2	0.9	650
Dec. (sub-) Mediterranean oaks	16.1	49.0	26.6	7.9	0.4	469
Evergreen oaks	1.6	46.1	39.2	11.4	1.6	245

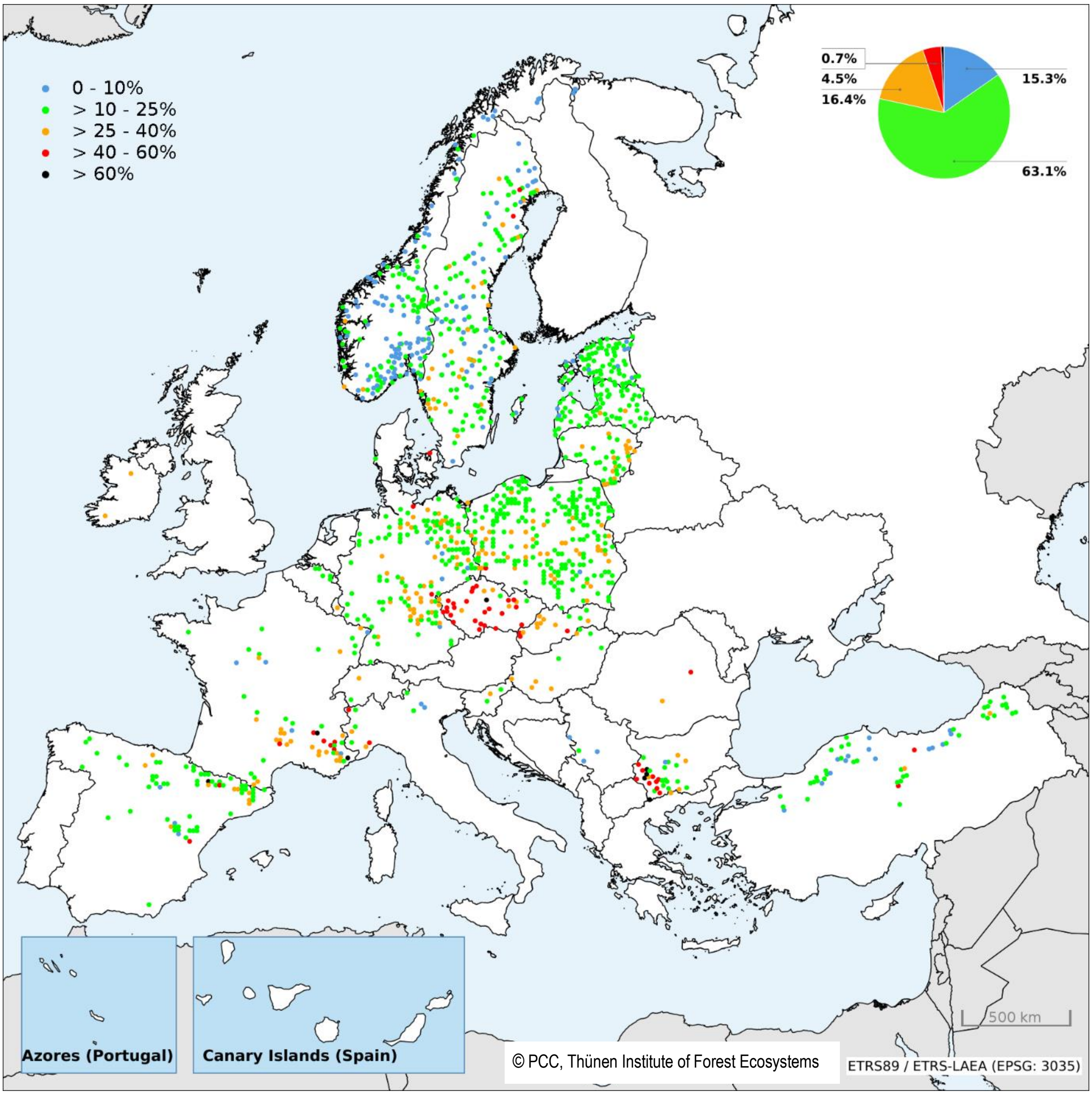


Figure S1-1: Mean plot defoliation of Scots pine (*Pinus sylvestris*) in 2019. Dead trees are not included. The legend (top left) indicates the degree of defoliation (defoliation class) ranging from none (blue), slight (green), moderate (orange and red), to severe (black). The percentages refer to the needle/leaf loss in the crown compared to a reference tree. The pie chart (top right) indicates the percentage of plots per defoliation class.

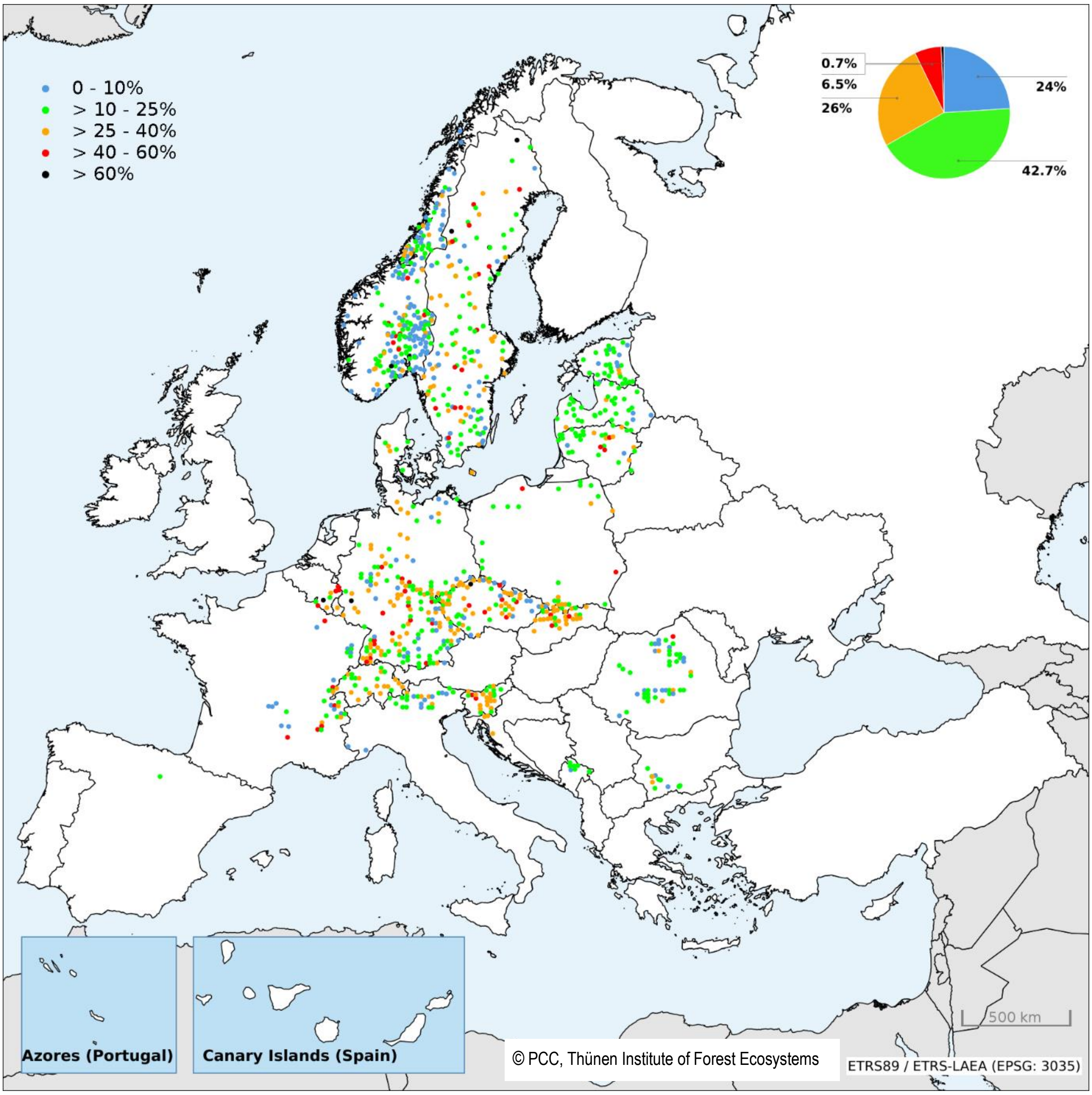


Figure S1-2: Mean plot defoliation of Norway spruce (*Picea abies*) in 2019. Dead trees are not included. The legend (top left) indicates the degree of defoliation (defoliation class) ranging from none (blue), slight (green), moderate (orange and red), to severe (black). The percentages refer to the needle/leaf loss in the crown compared to a reference tree. The pie chart (top right) indicates the percentage of plots per defoliation class.

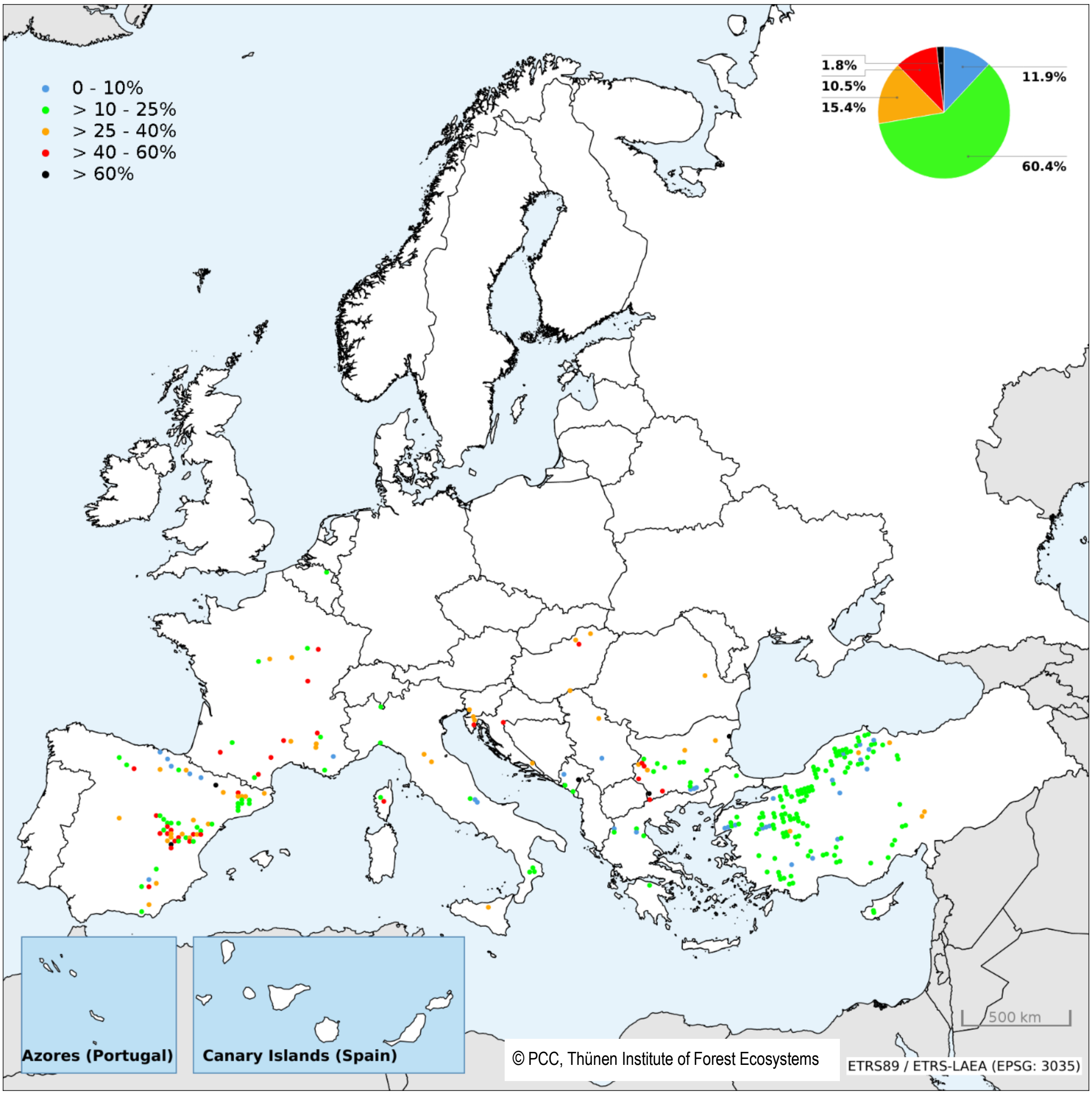


Figure S1-3: Mean plot defoliation of Austrian pine (*Pinus nigra*) in 2019. Dead trees are not included. The legend (top left) indicates the degree of defoliation (defoliation class) ranging from none (blue), slight (green), moderate (orange and red), to severe (black). The percentages refer to the needle/leaf loss in the crown compared to a reference tree. The pie chart (top right) indicates the percentage of plots per defoliation class.

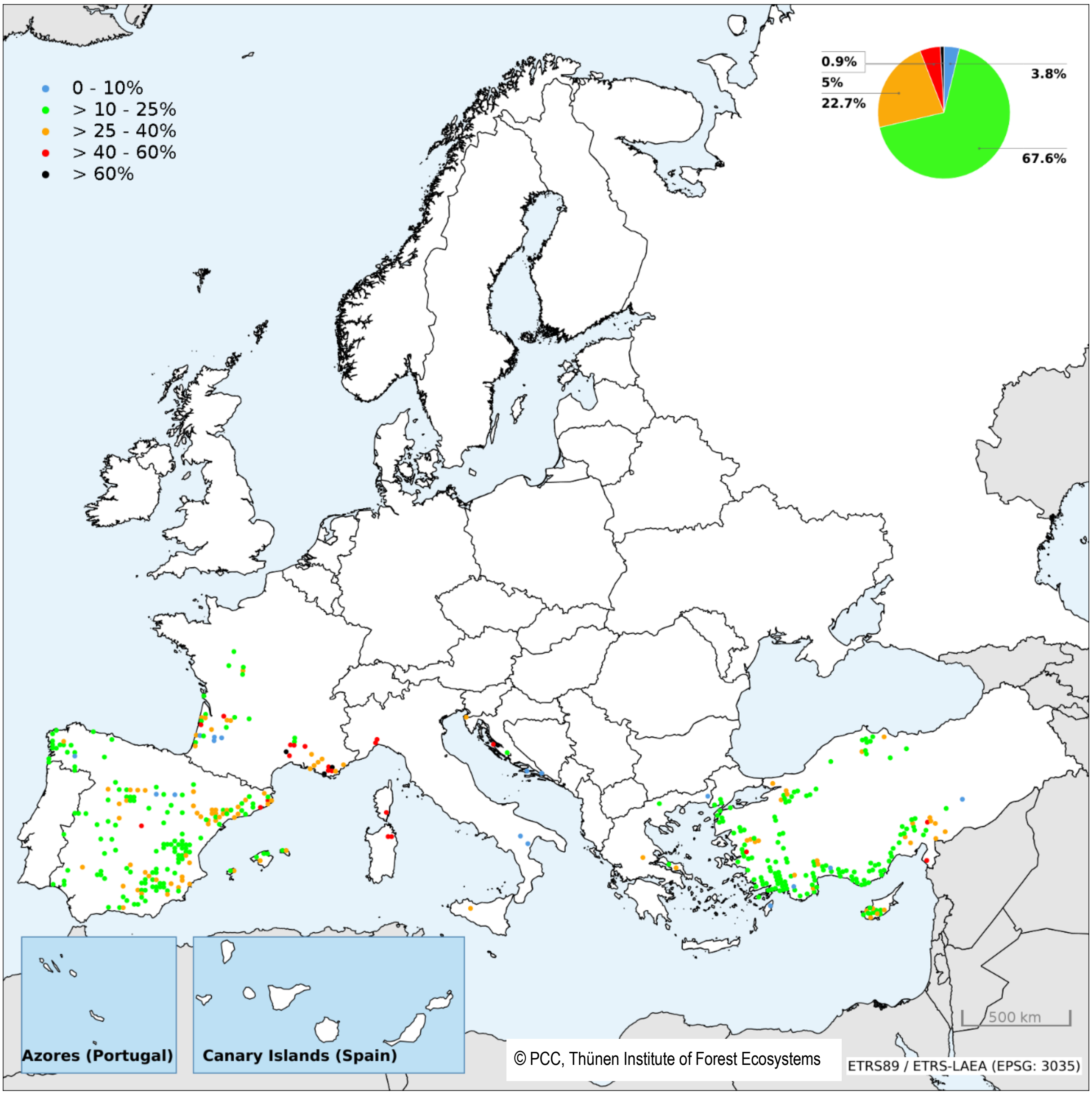


Figure S1-4: Mean plot defoliation of Mediterranean lowland pines (*Pinus halepensis, P. pinaster, P. pinea, P. brutia*) in 2019. Dead trees are not included. The legend (top left) indicates the degree of defoliation (defoliation class) ranging from none (blue), slight (green), moderate (orange and red), to severe (black). The percentages refer to the needle/leaf loss in the crown compared to a reference tree. The pie chart (top right) indicates the percentage of plots per defoliation class.

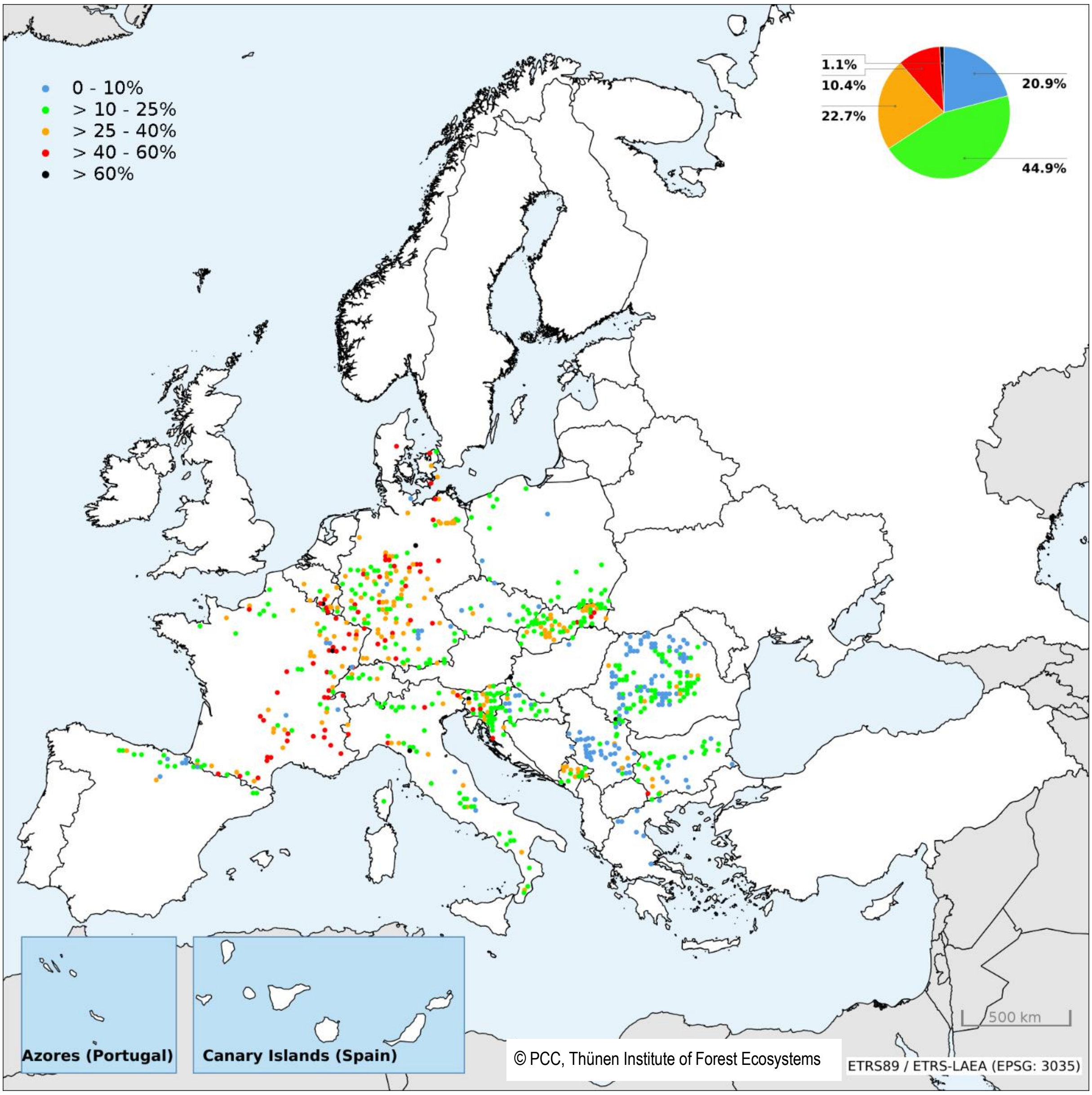


Figure S1-5: Mean plot defoliation of common beech (*Fagus sylvatica*) in 2019. Dead trees are not included. The legend (top left) indicates the degree of defoliation (defoliation class) ranging from none (blue), slight (green), moderate (orange and red), to severe (black). The percentages refer to the needle/leaf loss in the crown compared to a reference tree. The pie chart (top right) indicates the percentage of plots per defoliation class.

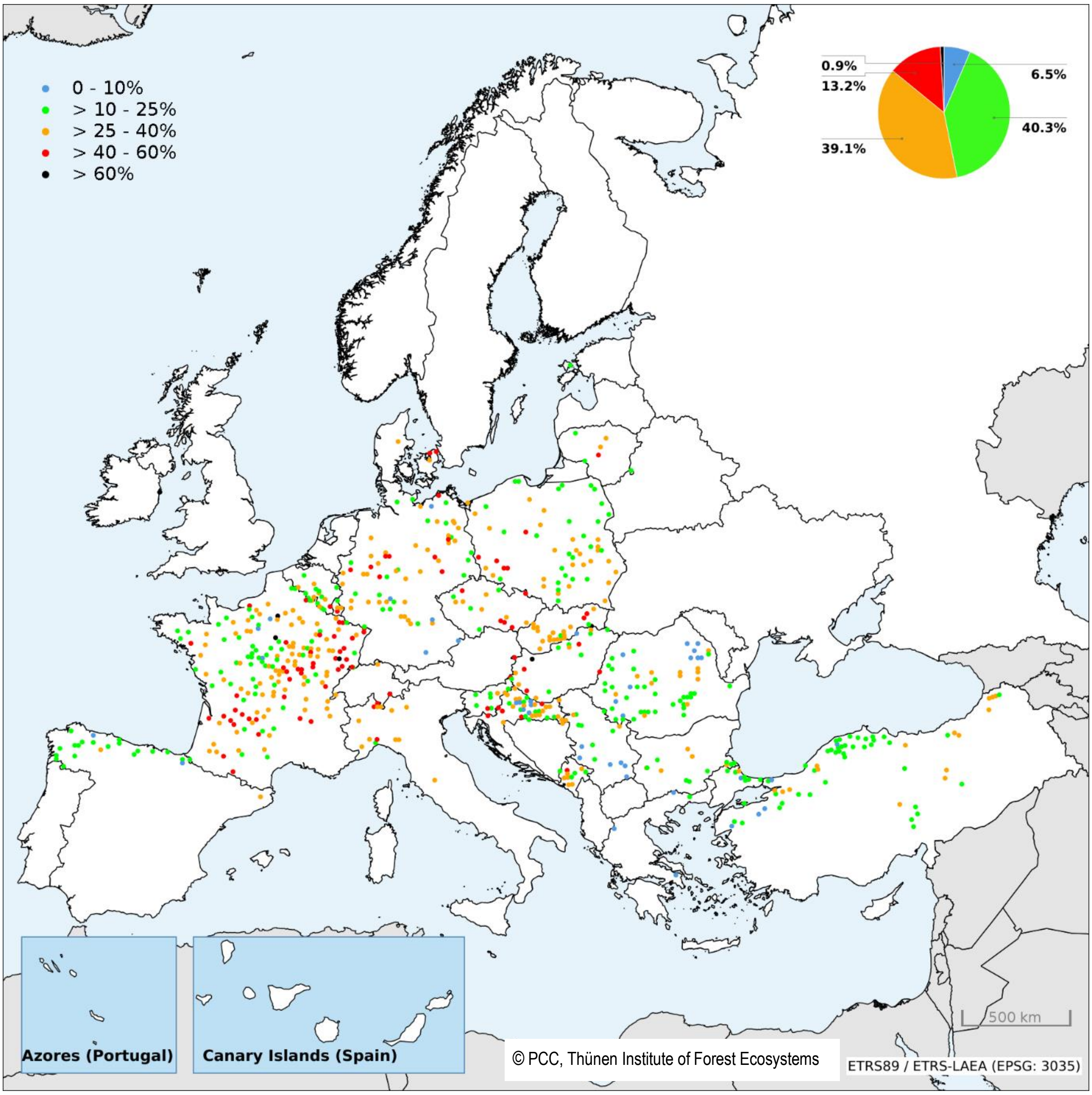


Figure S1-6: Mean plot defoliation of deciduous temperate oaks (*Quercus robur and Q. petraea*) in 2019. Dead trees are not included. The legend (top left) indicates the degree of defoliation (defoliation class) ranging from none (blue), slight (green), moderate (orange and red), to severe (black). The percentages refer to the needle/leaf loss in the crown compared to a reference tree. The pie chart (top right) indicates the percentage of plots per defoliation class.

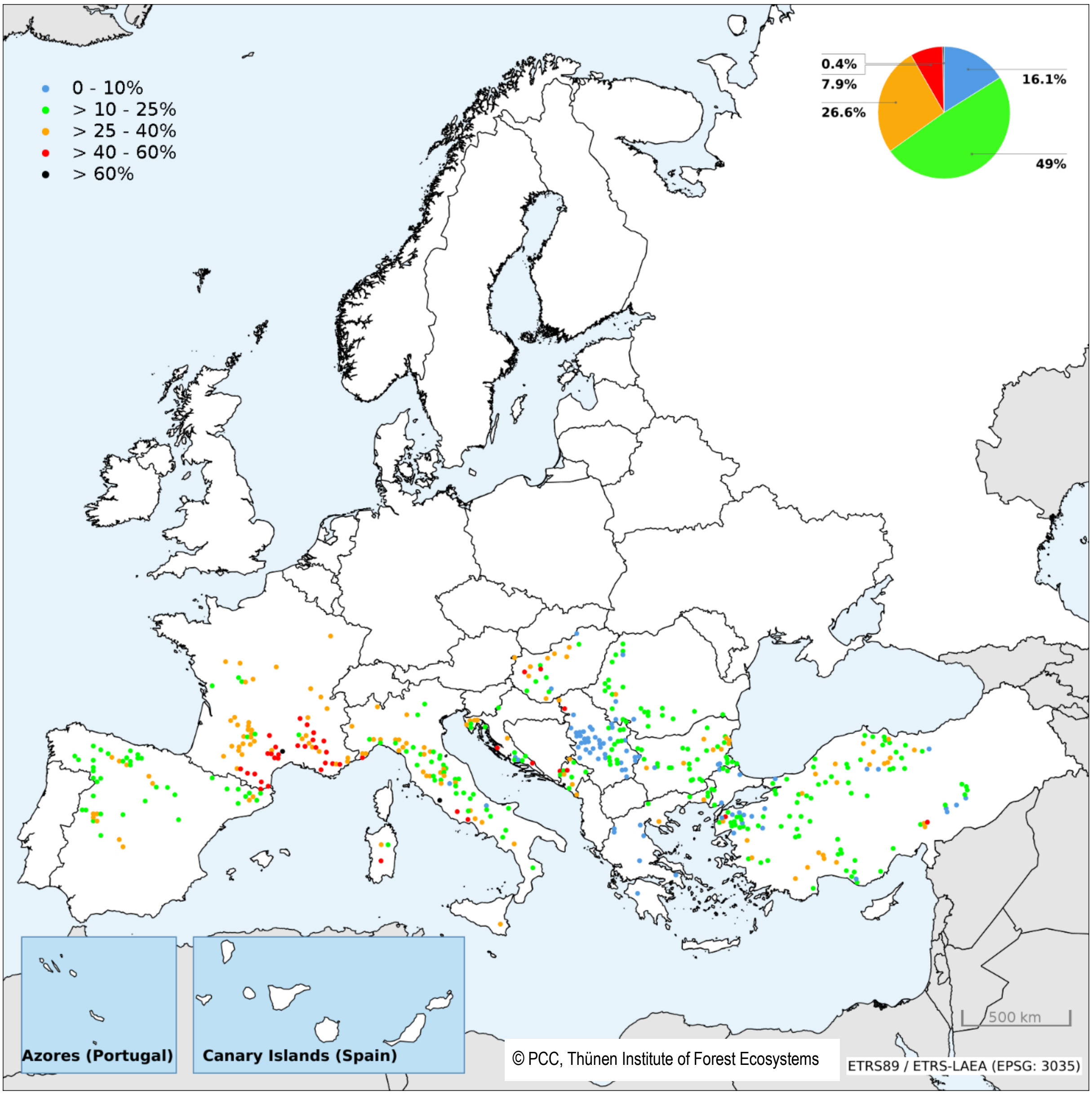


Figure S1-7: Mean plot defoliation of deciduous (sub-) Mediterranean oaks (*Quercus cerris, Q. frainetto, Q. pubescens, Q. pyrenaica*) in 2019. Dead trees are not included. The legend (top left) indicates the degree of defoliation (defoliation class) ranging from none (blue), slight (green), moderate (orange and red), to severe (black). The percentages refer to the needle/leaf loss in the crown compared to a reference tree. The pie chart (top right) indicates the percentage of plots per defoliation class.

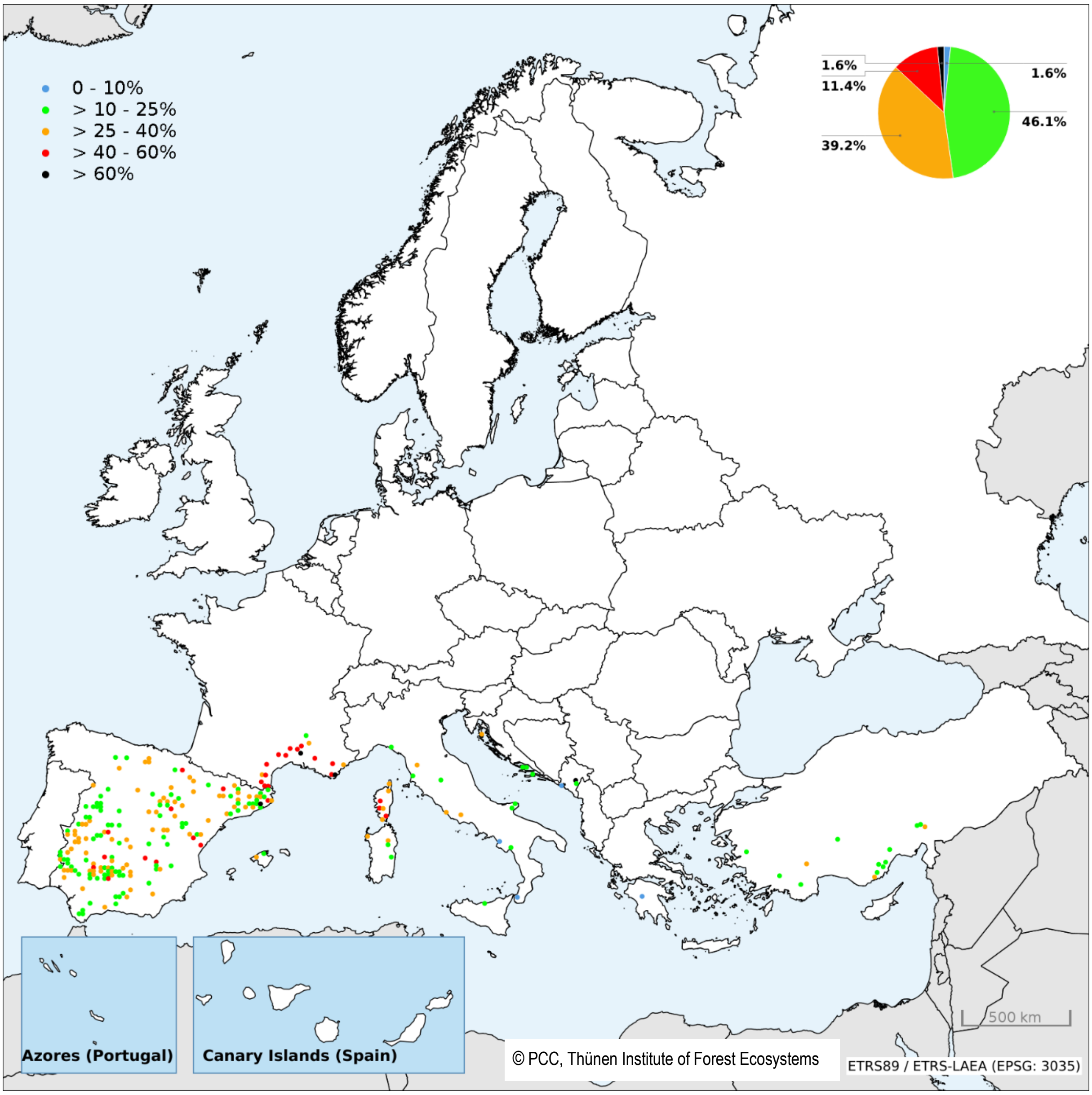


Figure S1-8: Mean plot defoliation of evergreen oaks (*Quercus coccifera, Q. ilex, Q. rotundifolia, Q. suber*) in 2019. Dead trees are not included. The legend (top left) indicates the degree of defoliation (defoliation class) ranging from none (blue), slight (green), moderate (orange and red), to severe (black). The percentages refer to the needle/leaf loss in the crown compared to a reference tree. The pie chart (top right) indicates the percentage of plots per defoliation class.

S1-2 Trends in mean plot defoliation of the main tree species 2011–2019

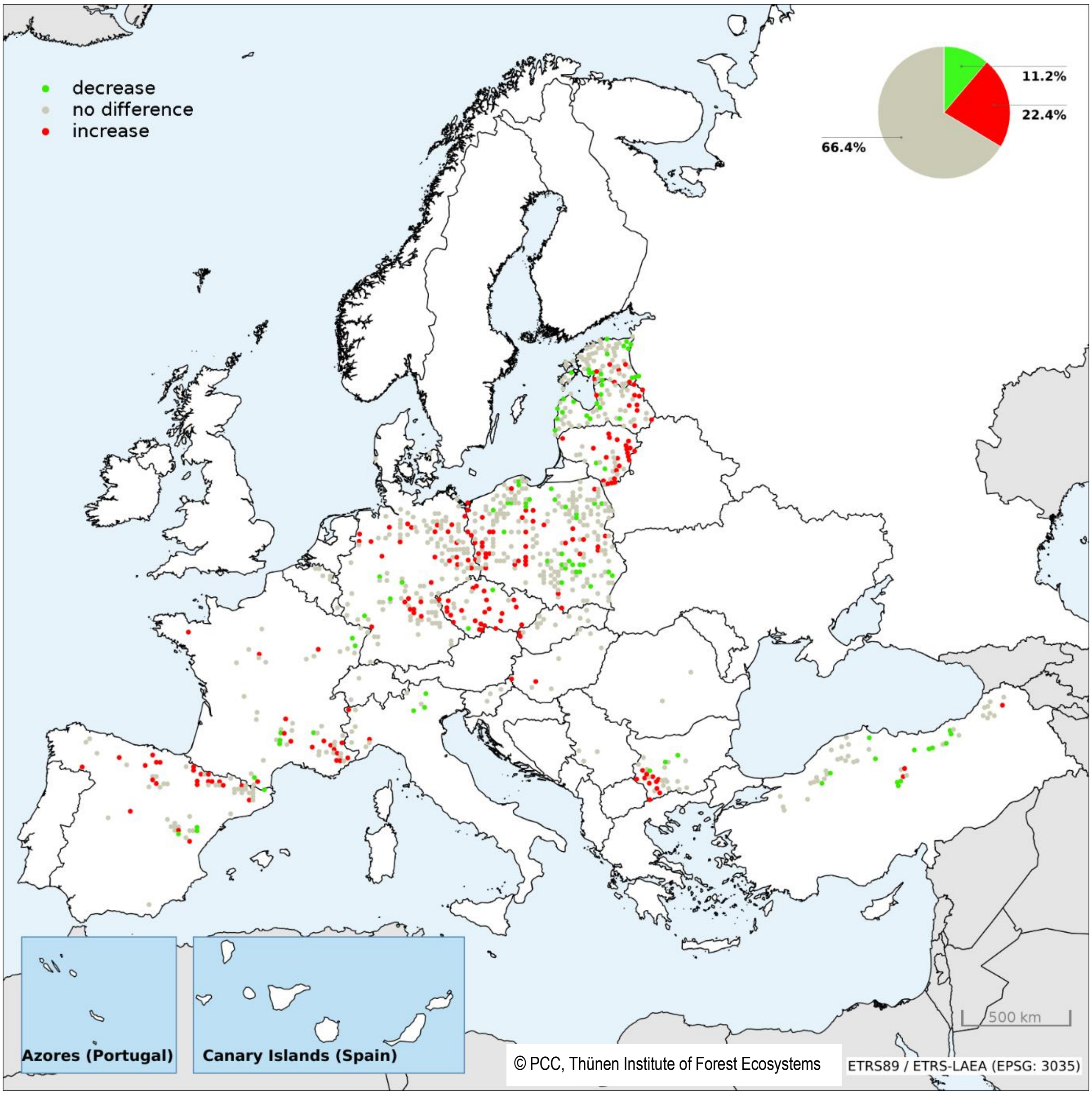


Figure S1-9: Trends in mean plot defoliation of Scots pine (*Pinus sylvestris*) between 2011 and 2019. Plots were included if assessments were available for at least 80% of the period. The legend (top left) indicates whether mean plot defoliation overall decreased, stayed the same or increased within the given period. The pie chart (top right) indicates the respective percentage of plots per trend direction.

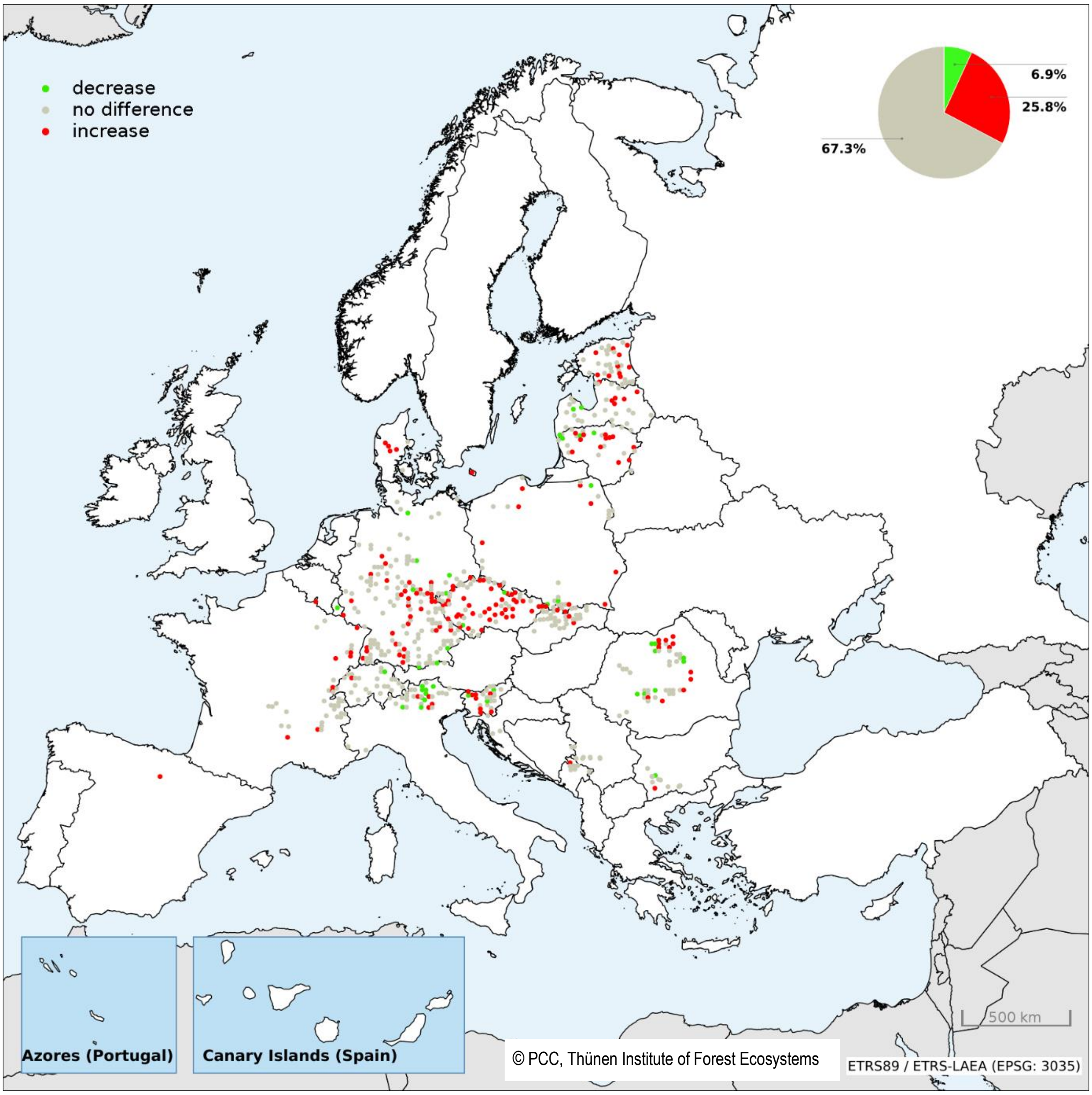


Figure S1-10: Trends in mean plot defoliation of Norway spruce (*Picea abies*) between 2011 and 2019. Plots were included if assessments were available for at least 80% of the period. The legend (top left) indicates whether mean plot defoliation overall decreased, stayed the same or increased within the given period. The pie chart (top right) indicates the respective percentage of plots per trend direction.

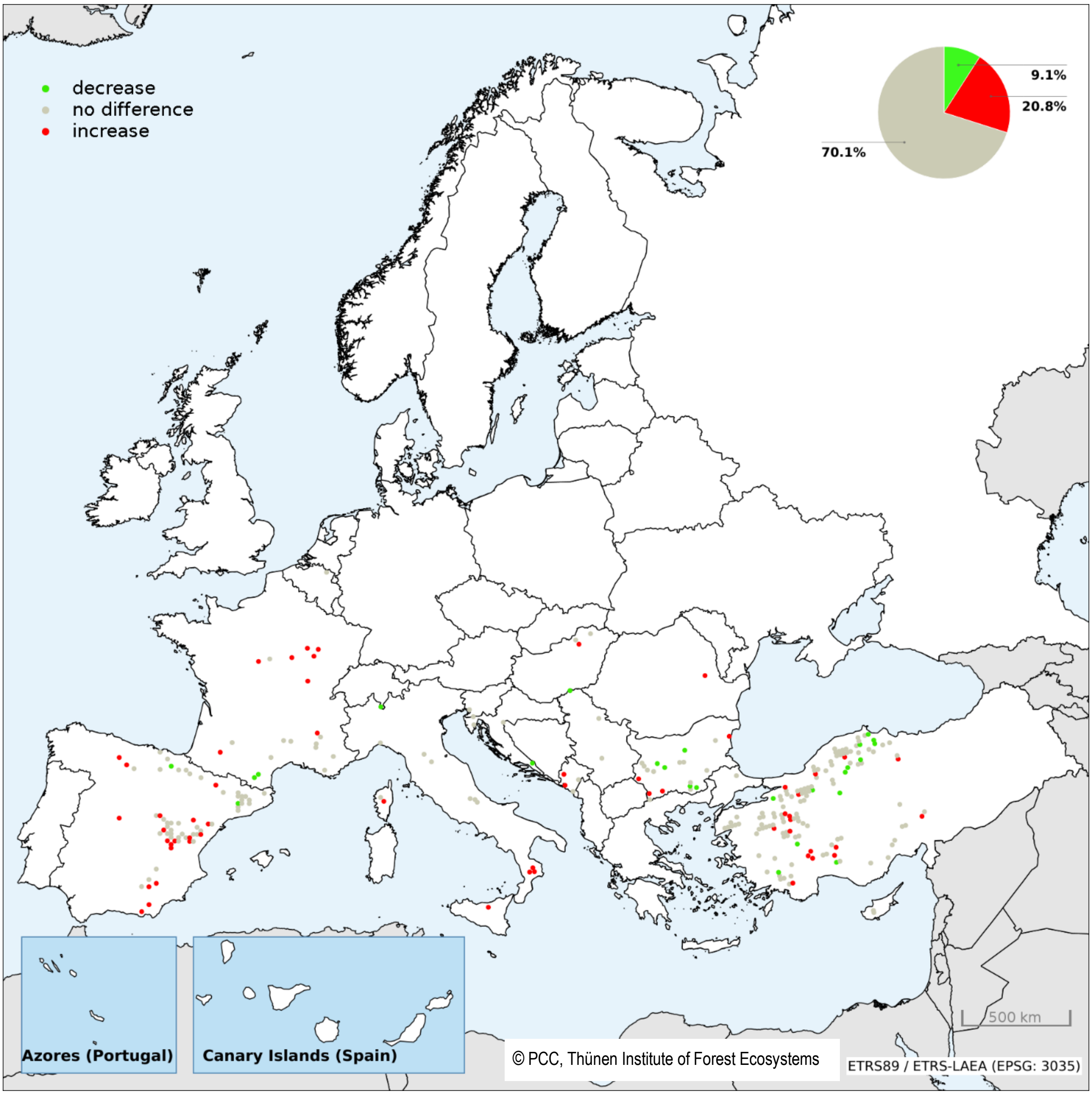


Figure S1-11: Trends in mean plot defoliation of Austrian pine (*Pinus nigra*) between 2011 and 2019. Plots were included if assessments were available for at least 80% of the period. The legend (top left) indicates whether mean plot defoliation overall decreased, stayed the same or increased within the given period. The pie chart (top right) indicates the respective percentage of plots per trend direction.

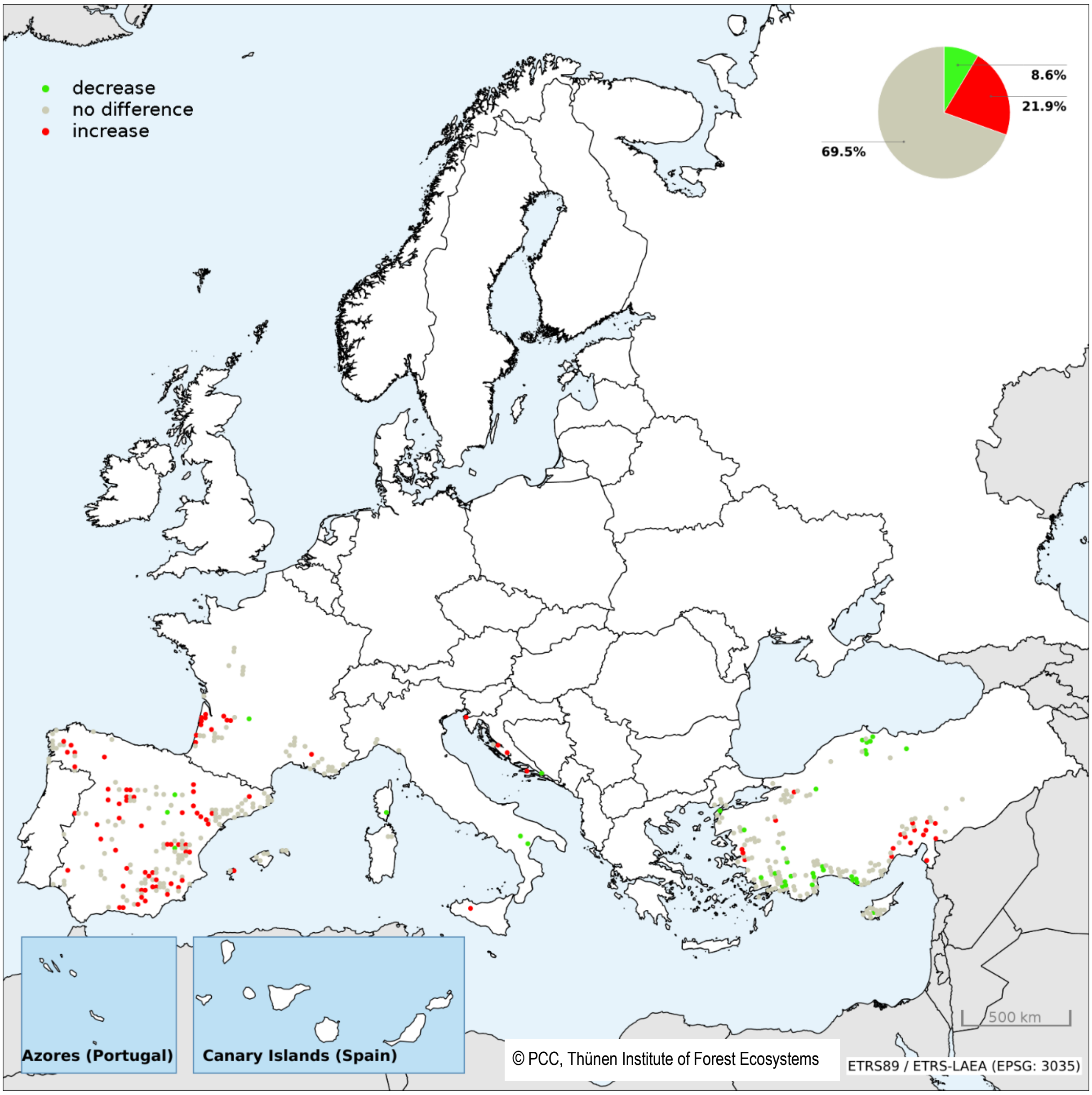


Figure S1-12: Trends in mean plot defoliation of Mediterranean lowland pines (*Pinus brutia, P. halepensis, P. pinaster, P. pinea*) between 2011 and 2019. Plots were included if assessments were available for at least 80% of the period. The legend (top left) indicates whether mean plot defoliation overall decreased, stayed the same or increased within the given period. The pie chart (top right) indicates the respective percentage of plots per trend direction.

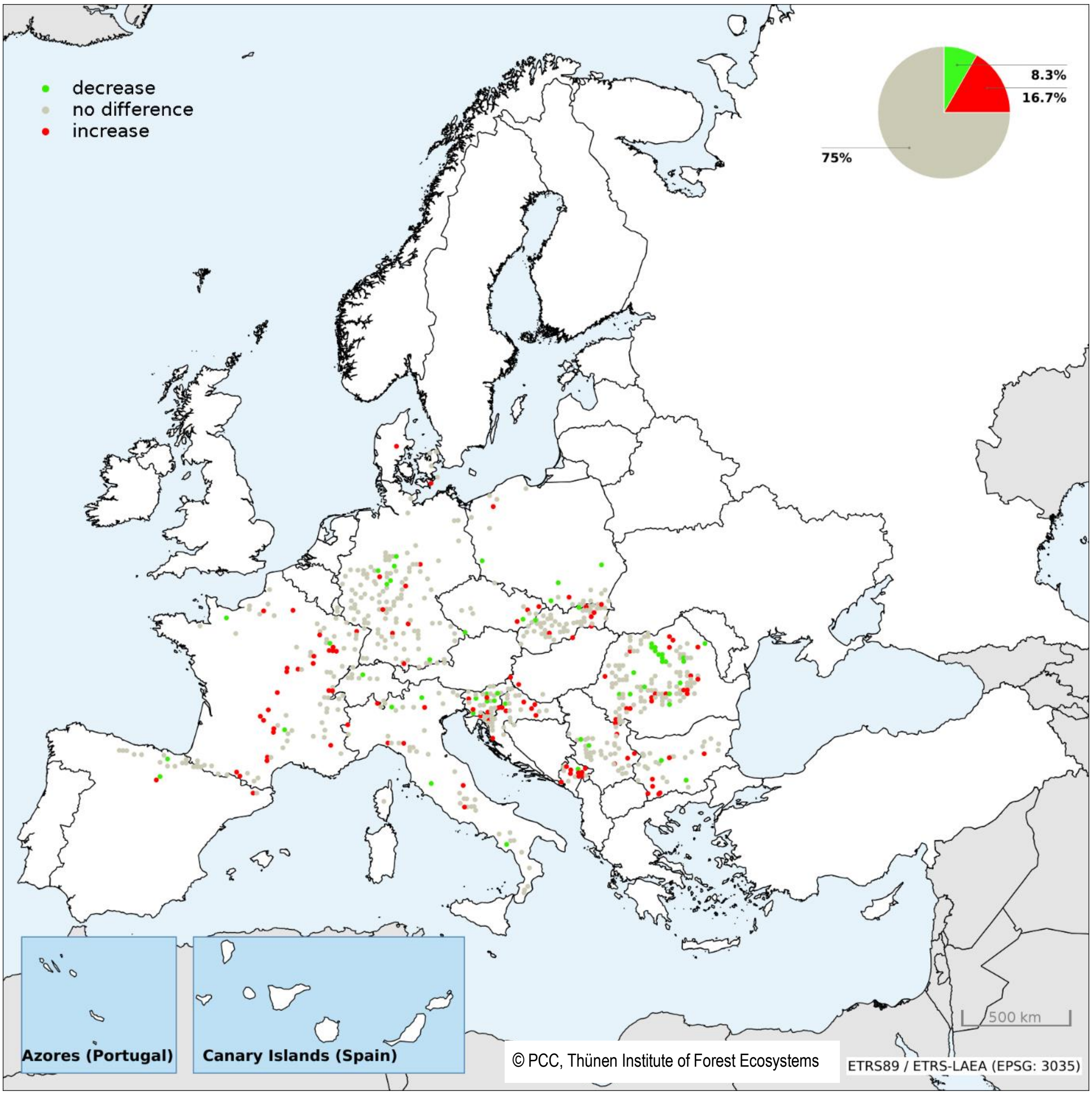


Figure S1-13: Trends in mean plot defoliation of common beech (*Fagus sylvatica*) between 2011 and 2019. Plots were included if assessments were available for at least 80% of the period. The legend (top left) indicates whether mean plot defoliation overall decreased, stayed the same or increased within the given period. The pie chart (top right) indicates the respective percentage of plots per trend direction.

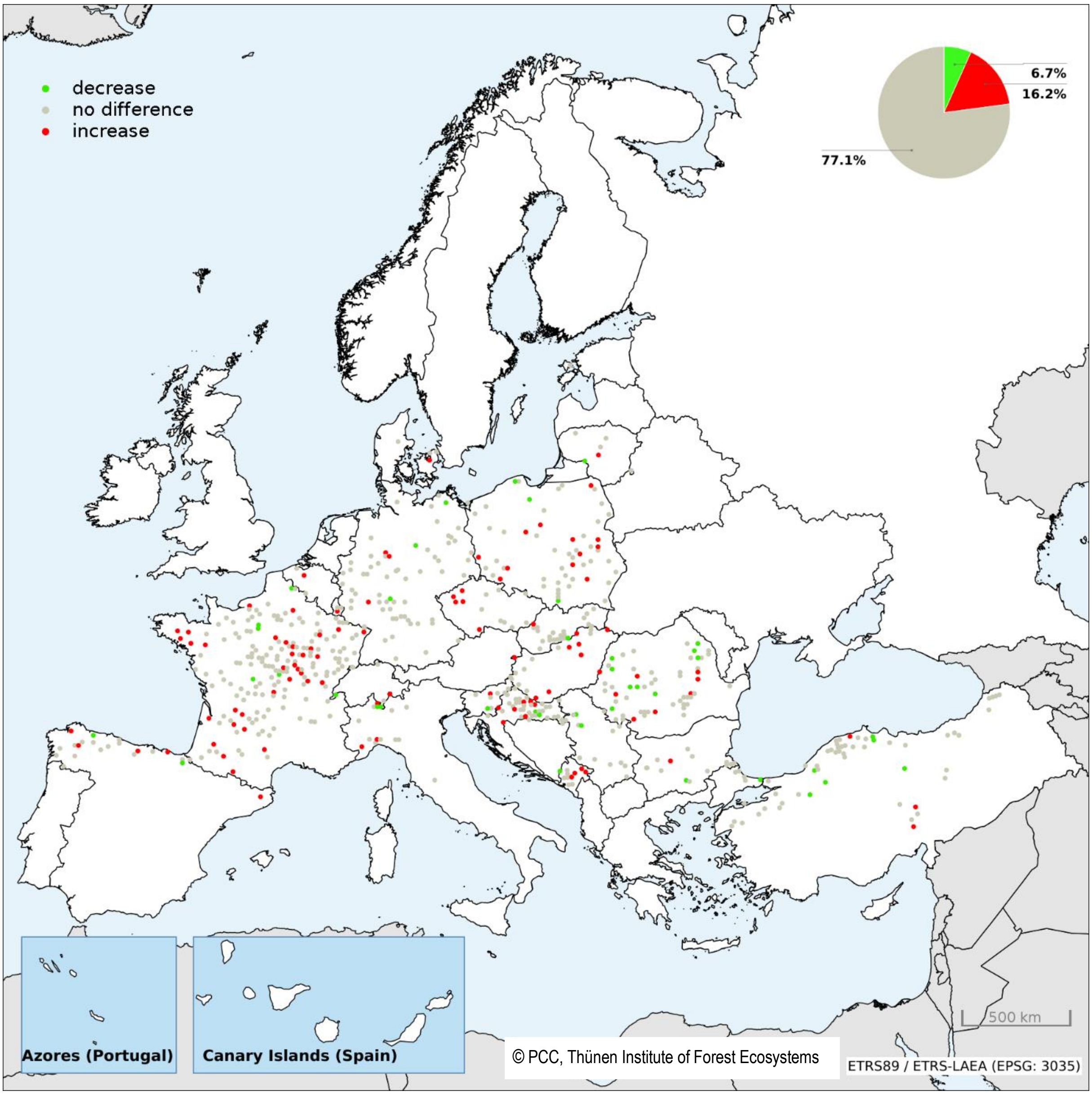


Figure S1-14: Trends in mean plot defoliation of deciduous temperate oaks (*Quercus robur* and *Q. petraea*) between 2011 and 2019. Plots were included if assessments were available for at least 80% of the period. The legend (top left) indicates whether mean plot defoliation overall decreased, stayed the same or increased within the given period. The pie chart (top right) indicates the respective percentage of plots per trend direction.

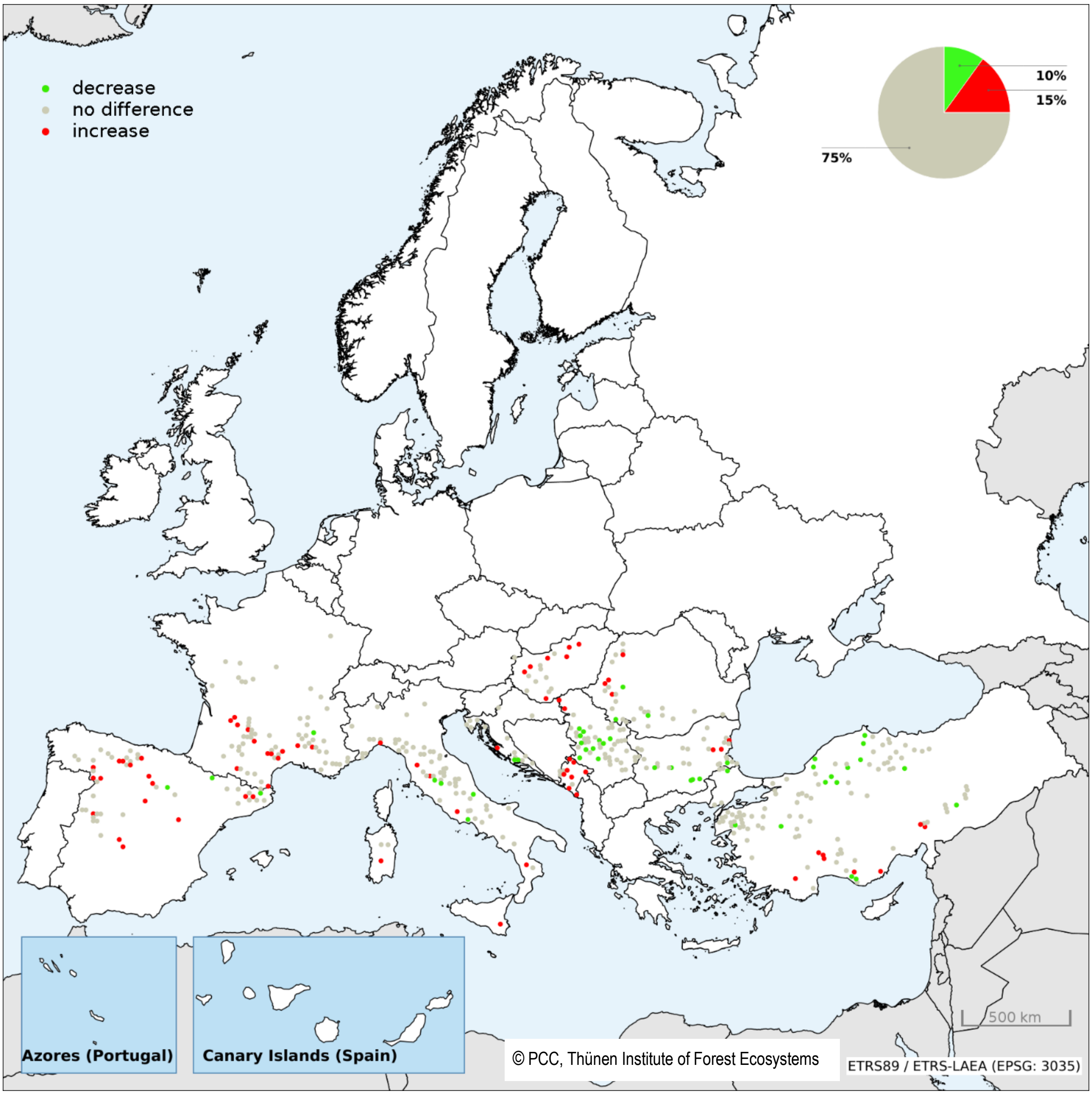


Figure S1-15: Trends in mean plot defoliation of deciduous (sub-) Mediterranean oaks (*Quercus cerris, Q. frainetto, Q. pubescens, Q. pyrenaica*) between 2011 and 2019. Plots were included if assessments were available for at least 80% of the period. The legend (top left) indicates whether mean plot defoliation overall decreased, stayed the same or increased within the given period. The pie chart (top right) indicates the respective percentage of plots per trend direction.

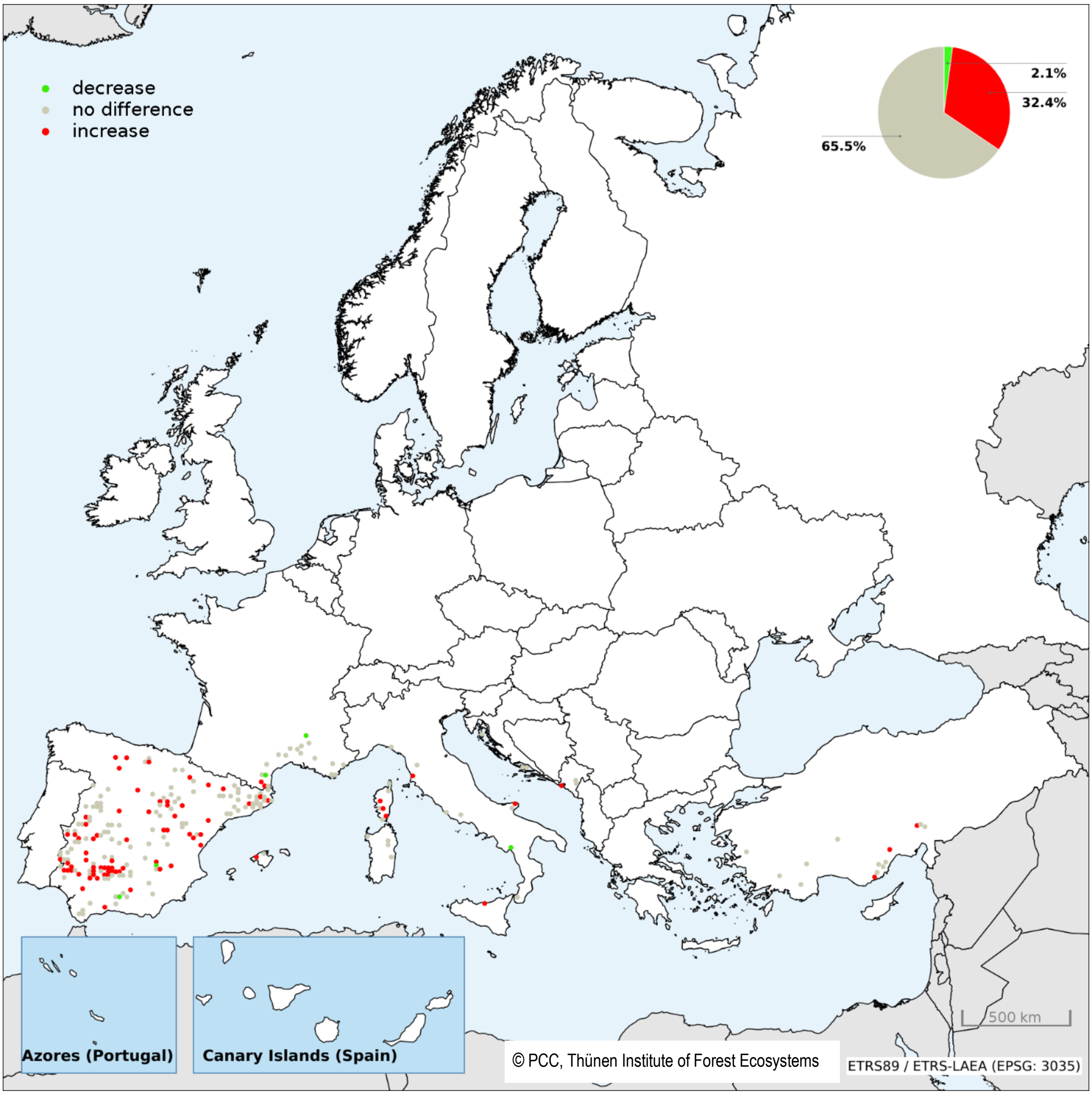


Figure S1-16: Trends in mean plot defoliation of evergreen oaks (*Quercus coccifera, Q ilex, Q. rotundifolia, Q. suber*) between 2011 and 2019. Plots were included if assessments were available for at least 80% of the period. The legend (top left) indicates whether mean plot defoliation overall decreased, stayed the same or increased within the given period. The pie chart (top right) indicates the respective percentage of plots per trend direction.

S1-3 Damage from various damaging agent groups reported in 2019

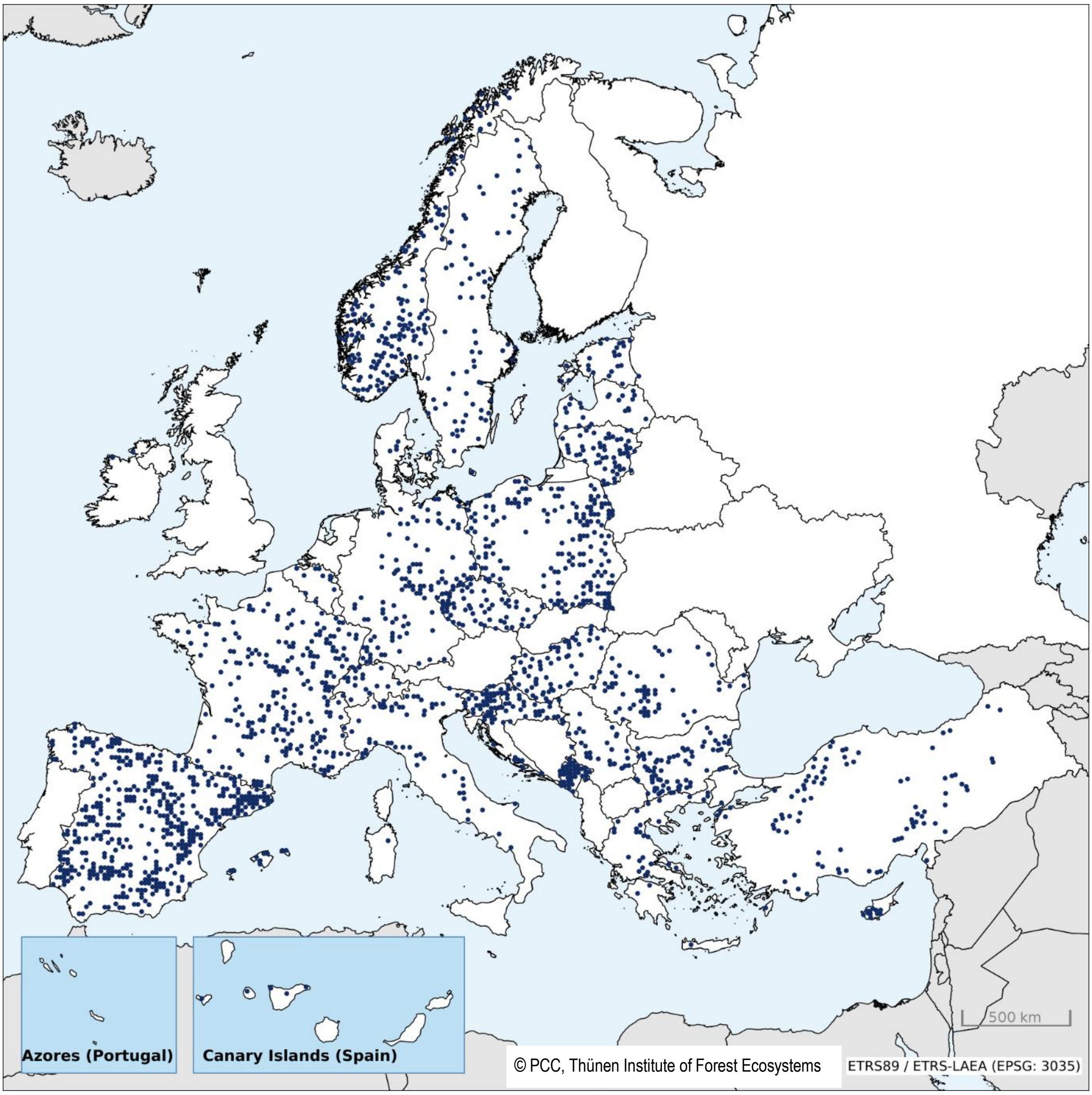


Figure S1-17: Damage from agent group Abiotic factors reported in 2019. Both fresh and old damage is shown.

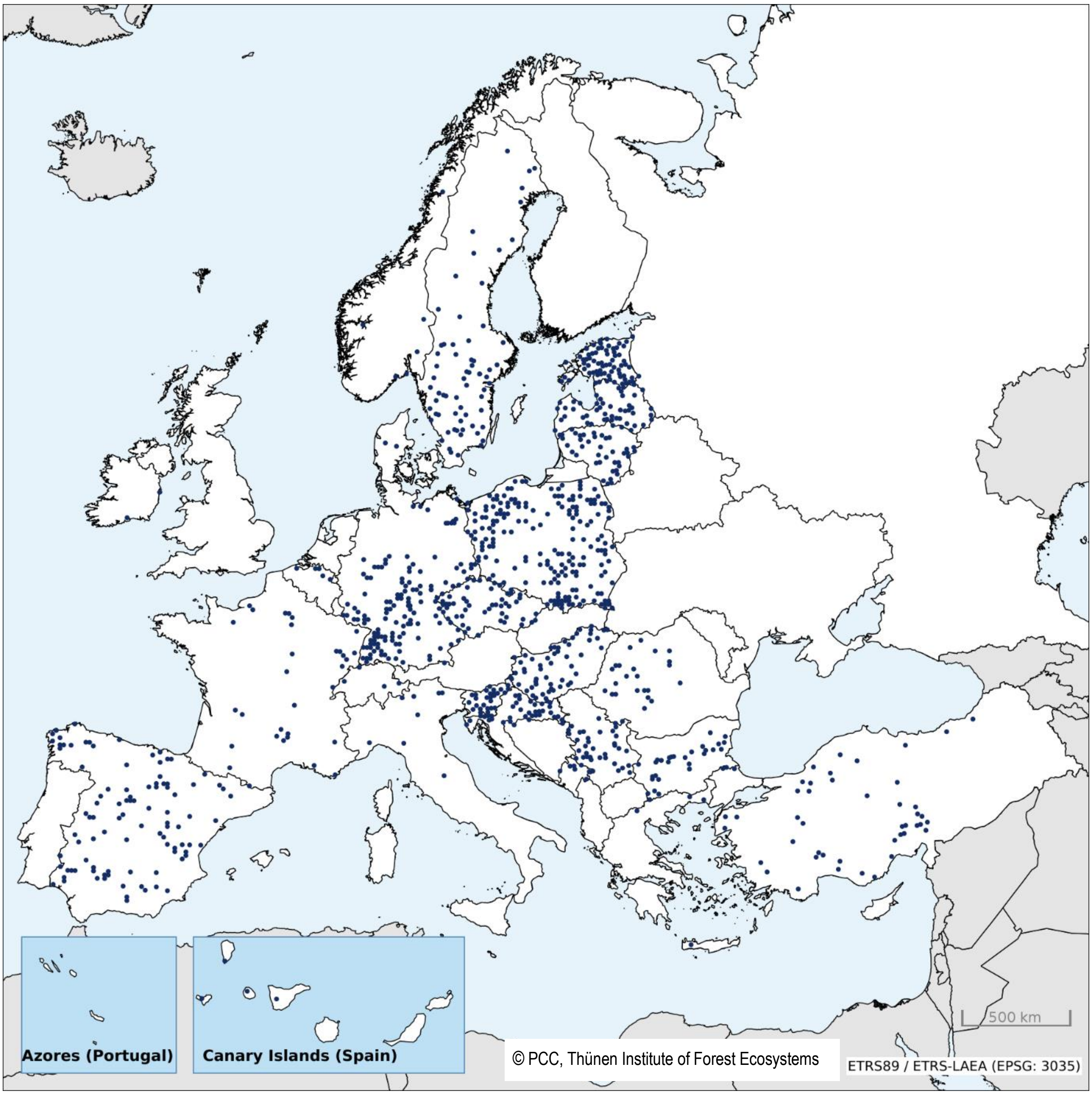


Figure S1-18: Damage from agent group Direct action of man reported in 2019. Both fresh and old damage is shown.

Figure S1-19: Damage from agent group Fire reported in 2019. Both fresh and old damage is shown.

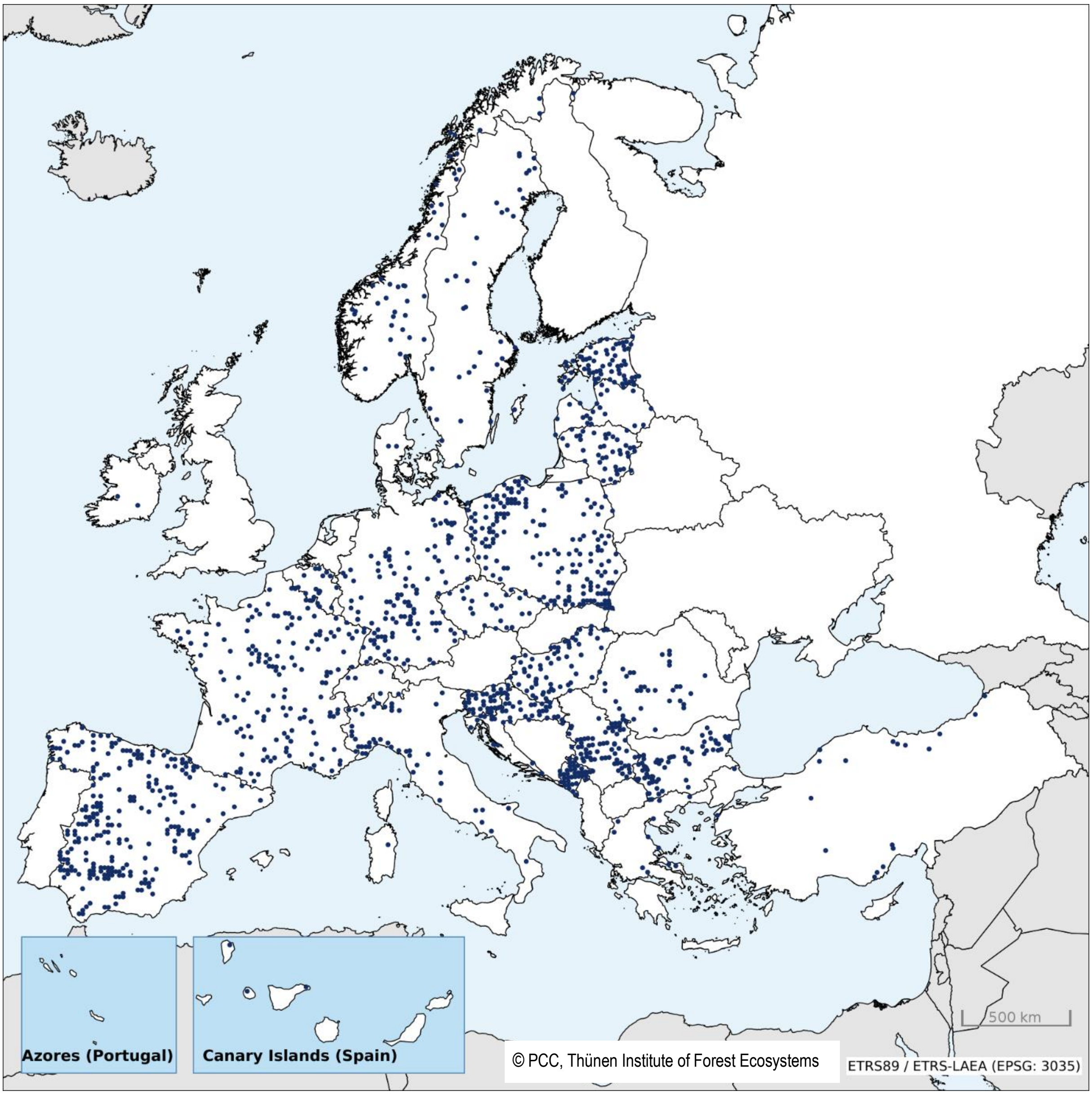


Figure S1-20: Damage from agent group Fungi reported in 2019. Both fresh and old damage is shown.

Figure S1-21: Damage from agent group Game and grazing reported in 2019. Both fresh and old damage is shown.

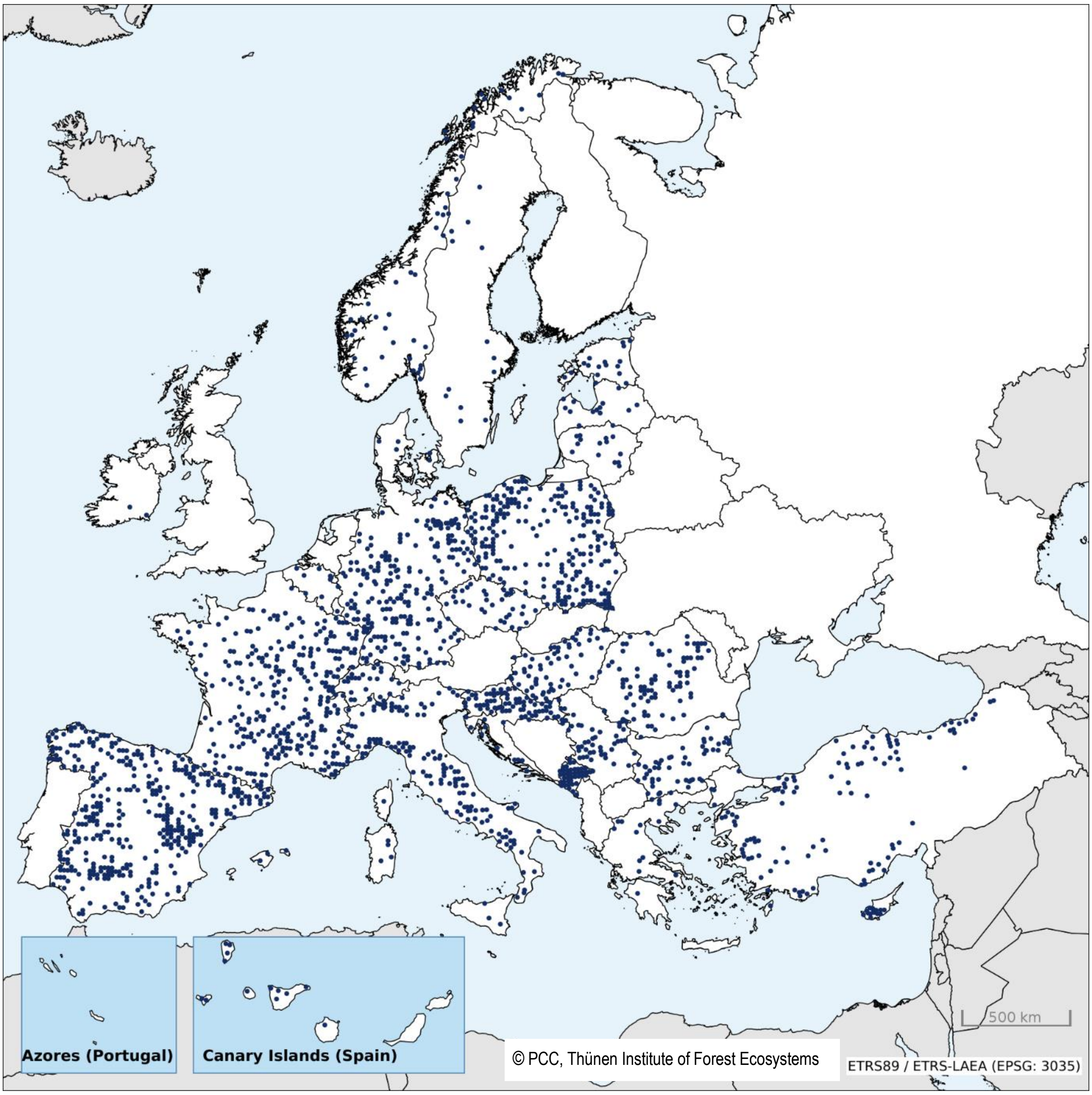


Figure S1-22: Damage from agent group Insects reported in 2019. Both fresh and old damage is shown.

S2 RESULTS OF THE NATIONAL CROWN CONDITION SURVEYS

S2-1 Tree defoliation (%) in different defoliation classes from national crown condition surveys in 2019

Participating country	No. of sample trees	Defoliation classes 0 none (%)	1 slight (%)	2 moderate (%)	3 severe (%)	4 dead (%)	2-4 mod.-dead (%)
Belgium-Flanders							
Broadleaves	816	9.7	63.5	22.2	2.9	1.7	26.8
Conifers	658	7.1	75.3	16.7	0.3	0.6	17.6
All trees	1474	8.5	68.8	19.7	1.7	1.2	22.7
Belgium-Wallonia							
Broadleaves	194	14.4	41.2	36.1	8.3	0.0	44.3
Conifers	178	1.1	6.7	71.9	20.2	0.0	92.1
All trees	372	8.1	24.7	53.2	14.0	0.0	67.2
Bulgaria							
Broadleaves	3170	36.8	42.9	17.0	1.7	1.5	20.3
Conifers	2421	29.2	25.4	31.1	10.5	3.8	45.4
All trees	5591	33.5	35.3	23.1	5.5	2.5	31.2
Croatia							
Broadleaves	1990	34.0	39.7	23.0	2.8	0.7	26.4
Conifers	338	19.8	26.6	39.6	13.6	0.3	53.6
All trees	2328	31.9	37.8	25.4	4.3	0.6	30.3
Cyprus							
Broadleaves	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Conifers	365	14.8	55.6	26.0	2.2	1.4	29.6
All trees	365	14.8	55.6	26.0	2.2	1.4	29.6
Czechia							
Broadleaves	1175	18.4	44.1	32.6	3.8	1.1	37.5
Conifers	3363	11.3	24.4	54.9	7.8	1.7	64.3
All trees	4538	13.2	29.5	49.1	6.7	1.5	57.4
Denmark							
Broadleaves	1023	21.0	33.0	44.0	2.0	0.0	46.0
Conifers	1353	38.0	40.0	20.0	2.0	0.0	22.0
All trees	2376	30.7	37.0	30.3	2.0	0.0	32.3
Estonia							
Broadleaves	274	53.3	41.7	4.3	0.0	0.7	5.1
Conifers	2012	49.4	44.9	5.5	0.0	0.3	5.8
All trees	2286	49.8	44.5	5.4	0.0	0.3	5.7
France							
Broadleaves	6942	9.8	28.0	52.0	9.7	0.5	62.2
Conifers	3726	28.2	29.8	37.2	4.3	0.5	42.0
All trees	10668	16.2	28.6	46.8	7.8	0.5	55.1

Participating country	No. of sample trees	Defoliation classes 0 none (%)	1 slight (%)	2 moderate (%)	3 severe (%)	4 dead (%)	2-4 mod.-dead (%)
Germany							
Broadleaves	4238	19.1	37.3	38.1	4.6	0.9	43.6
Conifers	5890	23.5	45.3	28.9	1.3	1.0	31.2
All trees	10128	21.7	42.0	32.8	2.7	1.0	36.4
Greece							
Broadleaves	641	70.2	14.4	11.7	2.5	1.3	15.5
Conifers	414	41.3	30.0	25.1	2.9	0.7	28.7
All trees	1055	58.9	20.5	17.0	2.7	1.0	20.7
Hungary							
Broadleaves	1693	31.4	34.3	25.9	7.0	1.4	34.3
Conifers	176	33.0	23.9	30.7	8.0	4.6	43.2
All trees	1869	31.6	33.3	26.3	7.1	1.7	35.1
Italy							
Broadleaves	4166	21.9	42.1	31.6	3.4	1.1	36.0
Conifers	931	34.2	37.0	25.2	2.5	1.1	28.8
All trees	4482	22.1	38.6	31.9	5.0	2.1	39.0
Latvia							
Broadleaves	458	5.2	86.7	7.6	0.0	0.4	8.1
Conifers	1274	13.5	82.0	3.9	0.2	0.6	4.6
All trees	1732	11.3	83.2	4.9	0.1	0.5	5.5
Lithuania							
Broadleaves	2247	19.6	65.2	13.2	0.7	1.3	15.2
Conifers	3709	13.6	64.7	20.4	0.8	0.5	21.7
All trees	5956	15.9	64.9	17.7	0.7	0.8	19.2
Luxembourg							
Broadleaves	782	6.0	36.6	51.8	4.7	0.9	57.4
Conifers	394	34.2	30.3	24.8	0.5	10.2	35.5
All trees	1176	15.4	34.5	42.7	3.3	4.0	50.1
Norway							
Broadleaves	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Conifers	10563	46.2	37.3	13.8	2.3	0.3	16.5
All trees	10563	46.2	37.3	13.8	2.3	0.3	16.5
Poland							
Broadleaves	15224	11.6	64.5	21.1	2.0	0.8	23.9
Conifers	25616	6.3	74.2	18.0	1.0	0.6	19.6
All trees	40840	8.3	70.6	19.1	1.4	0.7	21.2
Rep. of Moldova							
Broadleaves	16676	35.2	36.8	24.2	1.0	2.7	28.0
Conifers	47	48.9	31.9	2.1	0.0	17.1	19.2
All trees	62	62.9	24.2	9.7	0.0	3.2	12.9

Participating country	No. of sample trees	Defoliation classes 0 none (%)	1 slight (%)	2 moderate (%)	3 severe (%)	4 dead (%)	2-4 mod.-dead (%)
Romania							
Broadleaves	4732	54.9	34.0	9.4	1.2	0.5	11.2
Conifers	989	57.8	28.5	11.9	1.2	0.5	13.7
All trees	5721	55.4	33.0	9.9	1.2	0.5	11.6
Serbia							
Broadleaves	2634	78.6	12.7	6.7	1.8	0.2	8.7
Conifers	356	78.9	11.3	6.5	3.4	0.0	9.8
All trees	2990	78.6	12.5	6.7	2.0	0.2	8.9
Slovakia							
Broadleaves	2287	8.7	56.5	32.7	1.8	0.3	34.8
Conifers	1425	6.2	48.5	40.4	3.6	1.3	45.3
All trees	3712	7.7	53.4	35.7	2.5	0.7	38.8
Slovenia							
Broadleaves	700	16.4	48.4	27.4	7.1	0.6	35.1
Conifers	356	22.2	35.1	35.7	5.1	2.0	42.7
All trees	1056	18.4	43.9	30.2	6.4	1.0	37.7
Spain							
Broadleaves	7512	16.3	56.6	22.3	3.2	1.5	27.0
Conifers	7368	14.9	58.4	20.1	3.0	3.6	26.7
All trees	14880	15.6	57.5	21.3	3.1	2.5	26.9
Sweden							
Broadleaves	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Conifers	7795	51.2	31.7	14.3	2.3	0.5	17.1
All trees	7795	51.2	31.7	14.3	2.3	0.5	17.1
Switzerland							
Broadleaves	272	15.3	51.5	16.9	2.9	13.4	33.2
Conifers	732	14.8	51.6	26.0	0.5	7.1	33.6
All trees	1004	15.0	51.6	23.5	1.1	8.8	33.5
Turkey							
Broadleaves	5315	40.6	46.3	11.9	1.2	0.1	13.1
Conifers	8423	34.0	54.5	10.7	0.6	0.2	11.4
All trees	13738	36.6	51.4	11.2	0.8	0.2	12.1

S2-2 Percentage of moderately to severely defoliated trees (defoliation classes 2–4) between 2010 and 2019 – All species

Participating countries	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Change % points 2018/19
Albania				21.0							**N/A**
Andorra	15.3	8.3	5.6	3.4	5.3	4.5	3.4	7.0	5.6		**N/A**
Austria	14.2										**N/A**
Belarus	7.4	6.1									**N/A**
Belgium	22.1	23.5	28.2	27.6	27.5	26.4	26.1	26.6	27.7	31.6	**+3.9**
Bulgaria	23.8	21.6	32.3	33.5	26.0	26.2	29.9	27.7	31.9	31.2	**-0.7**
Croatia	27.9	25.2	28.5	29.1	31.5	29.7	28.5	25.6	30.8	30.3	**-0.5**
Cyprus	19.2	16.4	10.6	8.9	13.3	12.5	35.0	23.6	33.5	29.6	**-3.9**
Czechia	54.2	52.7	50.3	51.7		52.0	54.3	53.6	56.4	57.4	**+1.0**
Denmark	9.3	10.0	7.3	4.9	7.0	8.7	14.8	12.9	21.4	32.3	**+10.9**
Estonia	8.1	8.1	7.8	8.0	6.7	6.7	6.4	5.2	8.5	5.7	**-2.8**
Finland	10.5	10.6	14.3								**N/A**
France	34.6	39.9	41.4	40.1	42.8	43.4	48.6	48.8	52.2	55.1	**+2.9**
Germany	23.2	28.0	24.6	22.7	26.2	23.8	28.0	22.7	28.7	36.4	**+7.7**
Greece	23.8				24.8	20.2		20.2	18.4	20.7	**+2.3**
Hungary	21.8	18.9	20.2	22.4	24.2	24.0	34.6	41.0	47.3	35.1	**-12.2**
Ireland	17.5		1.0								**N/A**
Italy	29.8	31.3	35.7	33.7	30.8	29.8	34.7	39.0	39.0	36.0	**-3.0**
Latvia	13.4	14.0	9.2	6.4	5.1	4.4	5.7	5.3	5.1	5.5	**+0.4**
Lithuania	21.3	15.4	24.5	19.7	21.7	23.8	21.0	21.1	18.5	19.2	**+0.7**
Luxembourg				33.2		32.6	38.2	30.3	31.3	50.1	**+18.8**
Montenegro				22.7		25.4	27.3	26.6	33.6		**N/A**
Netherlands	21.6										
Norway	18.9	20.9	18.8	17.7	15.9	16.5	15.5	19.0	15.5	16.5	**+1.0**
Poland	20.7	24.0	23.4	18.8	18.9	16.7	19.5	20.2	18.6	21.2	**+2.6**
Rep. of Moldova	22.5	18.4	25.6		19.9	26.1	26.5	28.7		28.0	**N/A**
Romania	17.8	13.9	13.9	13.6	13.5	13.1	13.4	14.5	14.8	11.6	**-3.2**
Russian Fed.	4.4	8.3									**N/A**
Serbia	10.8	7.6	10.3	14.7	12.4	10.7	11.3	11.8	11.9	8.9	**-3.0**
Slovakia	38.6	34.7	37.9	43.4		34.5	40.3	32.6	42.7	38.8	**-3.9**
Slovenia	31.8	31.4	29.1	30.9	38.3	37.8	33.9	37.0	36.0	37.7	**+1.7**
Spain	14.6	11.8	17.5	16.6	14.9		21.9	27.8	22.7	26.9	**+4.2**
Sweden	19.2	18.9	15.9	19.9		19.8	16.4	18.2	17.6	17.1	**-0.5**
Switzerland	22.2	30.9	31.3	26.0	30.6	24.8	25.2	33.7	23.5	33.5	**+10.0**
Turkey	16.8	13.6	12.4	10.2	11.0	9.5	9.8	8.8	10.5	12.1	**+1.6**
Ukraine	5.8	6.8	7.5	7.1	6.0	7.1					**N/A**
United Kingdom	48.5										**N/A**

Please note that some differences in the level of defoliation between participating countries may be at least partly due to differences in standards used. This restriction, however, does not affect the reliability of the trends over time. In some countries there has been a change in the monitoring design at different points in time.

S2-3 Percentage of moderately to severely defoliated trees (defoliation classes 2–4) between 2010 and 2019 – Conifers

Participating countries	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Change % points 2018/19
Albania				21.0							**N/A**
Andorra	15.3	8.3	5.6	3.1	5.4	4.3	3.5	7.1	5.6		**N/A**
Austria	14.5										**N/A**
Belarus	7.7	5.8									**N/A**
Belgium	16.2	15.2	20.3	19.7	22.8	27.9	24.6	26.8	27.7	33.2	**+5.5**
Bulgaria	31.1	33.3	35.1	40.8	34.1	40.1	39.9	37.0	45.0	45.4	**+0.4**
Croatia	56.9	45.1	54.7	48.3	49.7	56.0	51.0	35.0	47.0	53.6	**+6.6**
Cyprus	19.2	16.4	10.6	8.9	13.3	12.5	35.0	23.6	33.5	29.6	**-3.9**
Czechia	60.1	58.9	56.9	59.2		57.8	60.3	60.3	63.0	64.3	**+1.3**
Denmark	5.4	5.7	4.6	2.8	5.3	7.4	11.3	11.8	15.2	22.0	**+6.8**
Estonia	9.0	8.7	6.6	8.5	6.9	6.5	6.7	5.5	9.3	5.8	**-3.5**
Finland	10.6	11.7	14.6								**N/A**
France	27.4	31.9	32.2	33.7	36.6	38.0	39.3	38.8	40.0	42.0	**+2.0**
Germany	19.2	20.3	19.3	18.1	19.7	20.3	22.3	19.5	22.8	31.2	**+8.4**
Greece	23.7				26.7	27.2		32.1	26.2	28.7	**+2.5**
Hungary	35.1	28.7	23.1	23.5	30.7	46.5	52.8	44.9	52.3	43.2	**-9.1**
Ireland	17.5		1.0								**N/A**
Italy	29.1	32.2	31.8	24.2	24.0	22.6	19.6	21.8	28.1	28.8	**+0.7**
Latvia	15.0	16.0	7.9	6.9	4.8	4.4	4.9	5.3	3.9	4.6	**+0.7**
Lithuania	19.8	16.3	26.9	23.1	21.1	25.0	21.7	23.5	21.1	21.7	**+0.6**
Luxembourg				17.5	93.3	18.7	17.4	17.7	16.2	35.5	**+19.3**
Montenegro				22.6		26.1	28.1	23.6	30.9		**N/A**
Netherlands	18.9										**N/A**
Norway	16.4	17.3	16.1	17.7	15.9	16.5	15.5	19.0	15.5	16.5	**+1.0**
Poland	20.3	24.2	22.3	17.8	17.2	15.7	17.1	18.4	17.2	19.6	**+2.4**
Rep. of Moldova	33.3	32.1	44.3		29.4		21.6	19.6		19.2	**N/A**
Romania	16.1	15.9	14.9	13.9	13.7	8.0	10.4	10.7	10.3	13.7	**+3.4**
Russian Fed.	5.1	10.6									**N/A**
Serbia	12.0	11.1	11.0	13.0	14.6	14.5	13.5	12.0	10.2	9.8	**-0.4**
Slovakia	46.8	46.6	43.5	43.3		49.4	45.6	41.6	49.7	45.3	**-4.4**
Slovenia	37.8	33.6	31.3	31.3	38.1	41.0	38.6	40.6	40.3	42.7	**+2.4**
Spain	13.1	10.4	11.4	12.6	11.4		20.9	26.2	23.1	26.7	**+3.6**
Sweden	19.2	18.9	15.9	19.9	18.8	19.8	16.4	18.2	17.6	17.1	**-0.5**
Switzerland	20.9	31.5	30.6	23.3	31.7	24.0	24.9	33.4	22.1	33.6	**+11.5**
Turkey	14.5	11.6	9.9	6.9	7.2	8.6	9.1	8.2	10.2	11.4	**+1.2**
Ukraine	5.6	6.8	7.5	7.5	6.8	7.9					**N/A**
United Kingdom	38.6										**N/A**

Please note that some differences in the level of defoliation between participating countries may be at least partly due to differences in standards used. This restriction, however, does not affect the reliability of the trends over time. In some countries there has been a change in the monitoring design at different points in time.

S2-4 Percentage of moderately to severely defoliated trees (defoliation classes 2–4) between 2010 and 2019 – Broadleaves

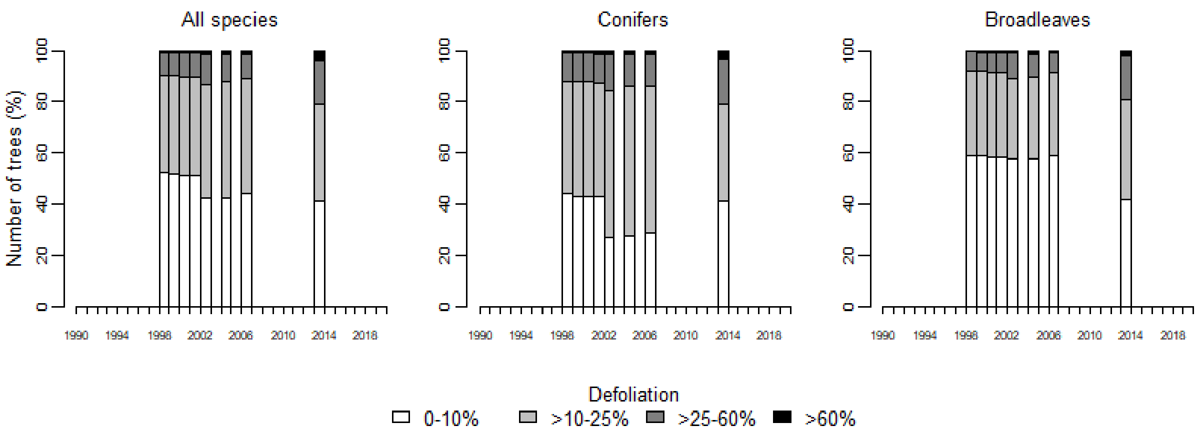
Participating country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Change points 2018/19
Albania				19.0							**N/A**
Andorra				20.0	20.0	16.7	0.0	0.0	0.0		**N/A**
Austria	10.5										**N/A**
Belarus	6.9	6.4									**N/A**
Belgium	24.6	26.7	32.9	29.4	31.4	25.1	27.4	26.2	27.7	30.3	**+2.6**
Bulgaria	18.2	12.8	29.8	28.0	20.0	15.6	22.3	20.5	21.8	20.3	**-1.5**
Croatia	21.9	21.5	23.7	25.7	28.1	25.3	24.7	24.0	27.8	26.4	**-1.4**
Cyprus							N/A	N/A	N/A	N/A	**N/A**
Czechia	32.2	31.2	28.4	25.7		32.7	34.7	31.6	35.6	37.5	**+1.9**
Denmark	12.1	12.8	10.9	7.9	9.0	10.8	19.7	14.4	30.0	46.0	**+16.0**
Estonia	2.5	3.0	14.9	5.3	5.7	8.0	5.2	3.3	4.1	5.1	**+1.0**
Finland	9.2	6.0	12.8								**N/A**
France	38.7	44.3	45.9	43.6	46.1	47.0	53.5	54.2	58.8	62.2	**+3.4**
Germany	29.4	38.0	32.5	29.8	36.1	29.0	35.7	27.5	37.1	43.6	**+6.5**
Greece	23.9				16.7	11.3		14.6	14.4	15.5	**+1.1**
Hungary	19.7	17.3	19.9	22.3	23.3	21.4	32.5	40.6	46.8	34.3	**-12.5**
Ireland											**N/A**
Italy	30.1	32.7	37.2	37.1	33.4	32.1	39.5	45.0	43.4	38.1	**-5.3**
Latvia	9.4	8.8	12.9	4.4	6.1	4.2	8.3	5.2	8.8	8.1	**-0.7**
Lithuania	23.7	13.8	21.0	14.7	22.5	21.9	20.0	17.8	14.2	15.2	**+1.0**
Luxembourg				42.4	34.6	40.3	49.0	37.2	39.7	57.4	**+17.7**
Montenegro				22.8		25.2	27.1	27.6	34.8		**N/A**
Netherlands	26.6										**N/A**
Norway	26.8	32.3	27.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**N/A**
Poland	21.5	23.5	25.5	20.7	21.9	18.4	24.0	23.3	21.1	23.9	**+2.8**
Rep. of Moldova	22.4	18.4	25.6		19.9	26.1	26.5	28.7	N/A	28.0	**N/A**
Romania	18.0	13.4	13.6	13.6	13.0	13.9	14.2	15.3	15.8	11.2	**-4.6**
Russian Fed.	3.2	4.3									**N/A**
Serbia	10.7	7.2	10.2	14.9	12.1	10.1	11.0	11.8	12.1	8.7	**-3.4**
Slovakia	32.9	26.4	33.9	43.5	43.5	24.3	36.5	26.7	38.4	34.8	**-3.6**
Slovenia	28.1	30.0	27.7	30.6	38.4	35.9	31.1	35.1	33.7	35.1	**+1.4**
Spain	16.1	13.2	23.6	20.7	18.4		22.7	29.3	22.4	27.0	**+4.6**
Sweden								N/A	N/A	N/A	**N/A**
Switzerland	25.2	29.6	33.3	31.5	28.0	26.4	25.9	34.7	26.6	33.2	**+6.6**
Turkey	21.2	17.2	16.8	15.7	17.2	10.8	11.0	9.8	11.0	13.1	**+2.1**
Ukraine	6.4	6.7	7.5	7.0	5.5	6.3					**N/A**
United Kingdom	56.1										**N/A**

Please note that some differences in the level of defoliation between participating countries may be at least partly due to differences in standards used. This restriction, however, does not affect the reliability of the trends over time. In some countries there has been a change in the monitoring design at different points in time.

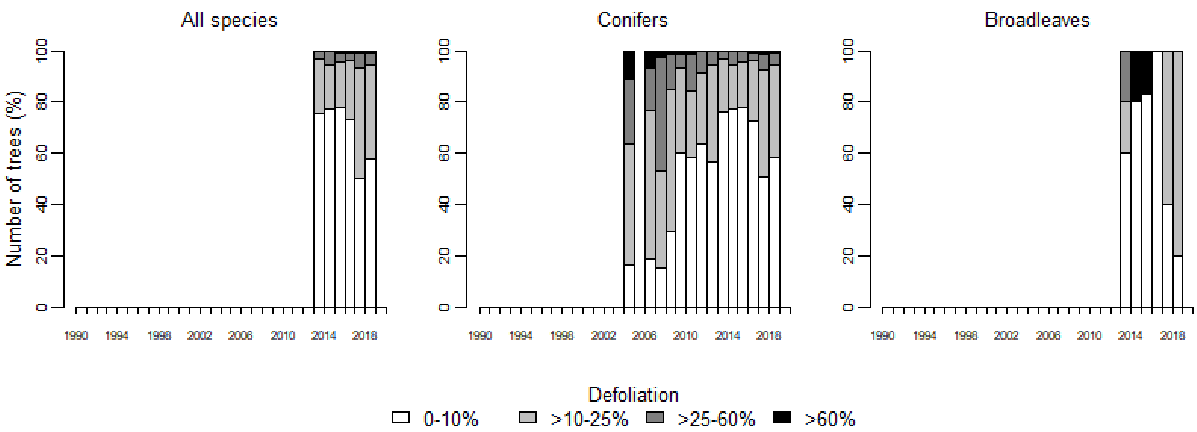
S2-5 Change of tree defoliation over time (1990–2019) per country

Please note that some countries have changed their monitoring design at different points in time which may explain sudden strong increases or decreases in the number of trees per defoliation category in the figures below. For detailed information, please contact the respective NFCs. Their contact information is given in the Annex of the 2020 Technical Report[1].

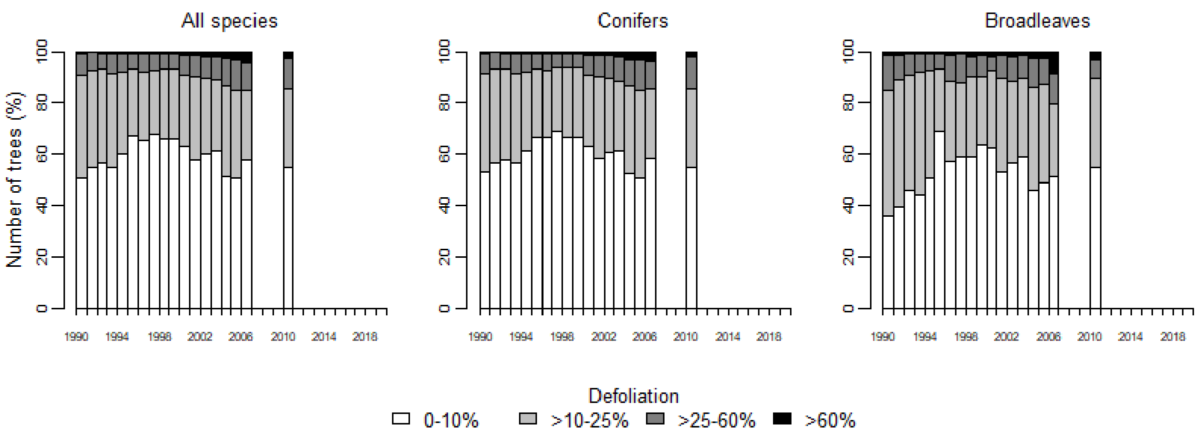
ALBANIA



ANDORRA

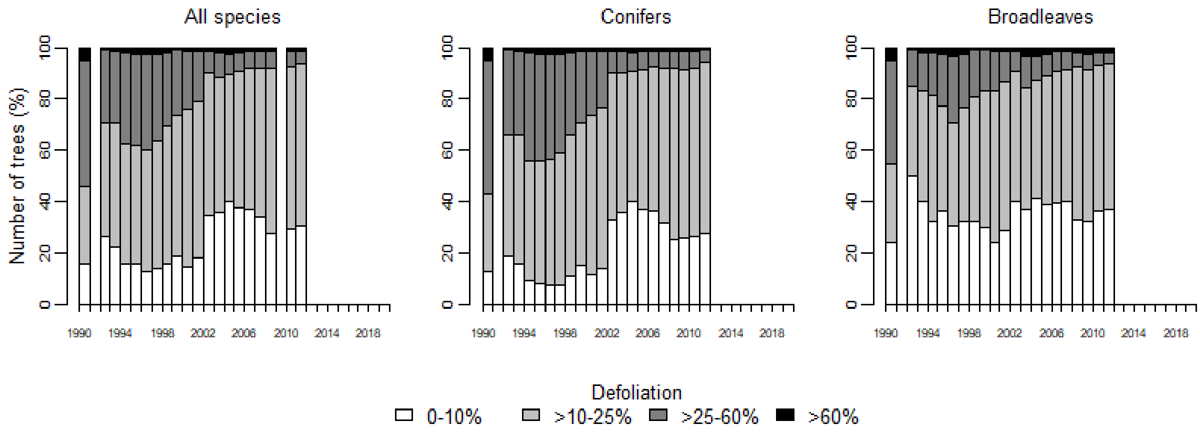


AUSTRIA

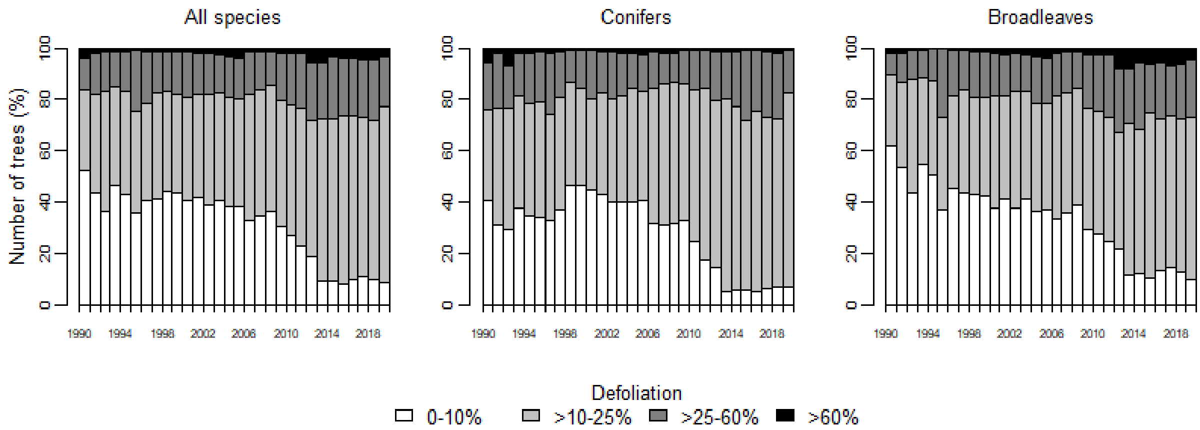


[1] http://icp-forests.net/page/icp-forests-technical-report

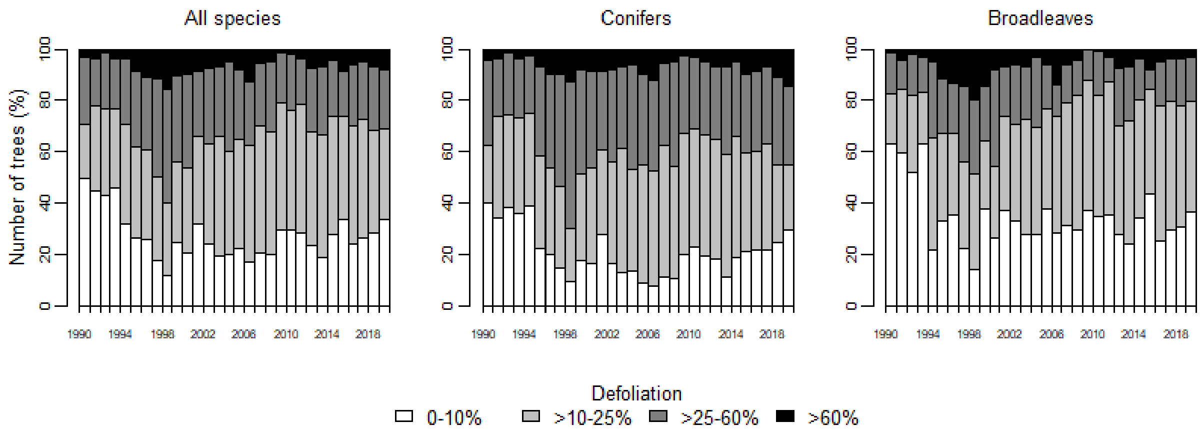
BELARUS



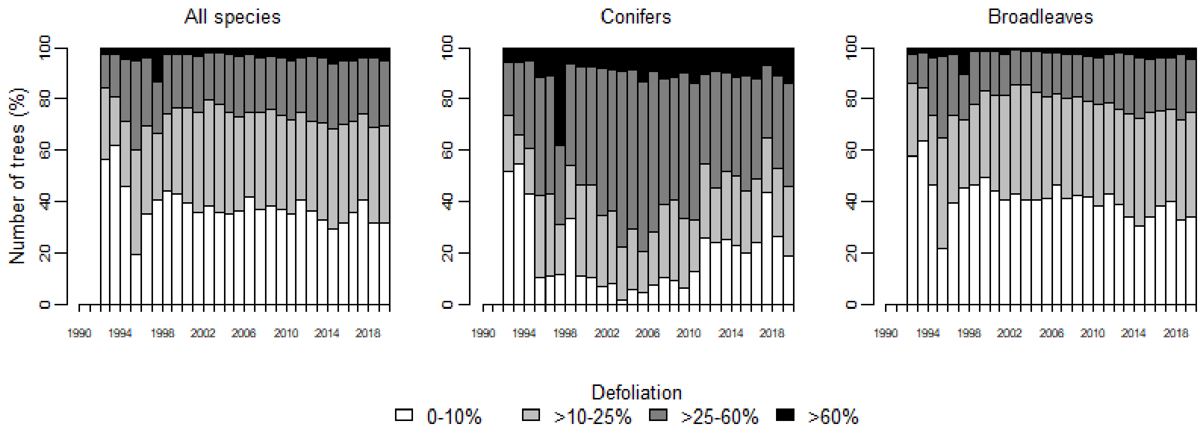
BELGIUM



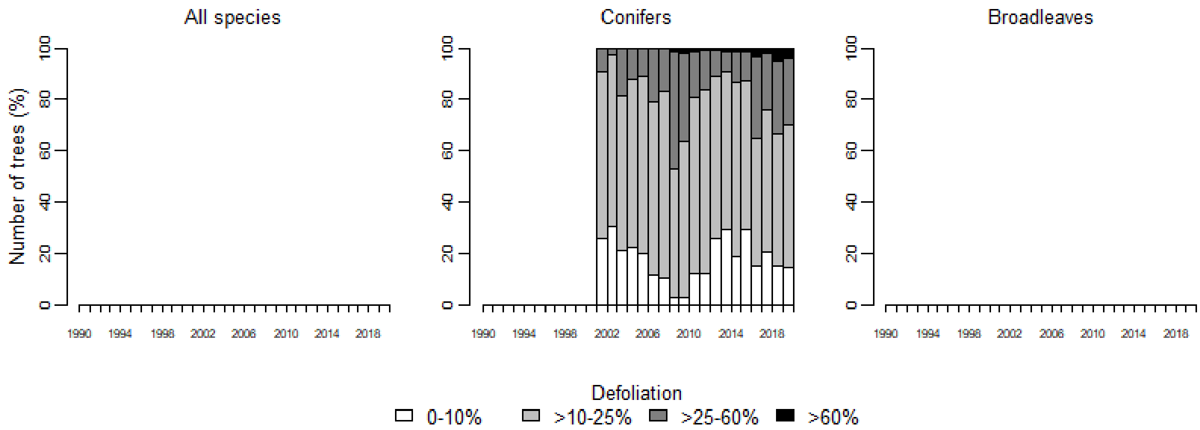
BULGARIA



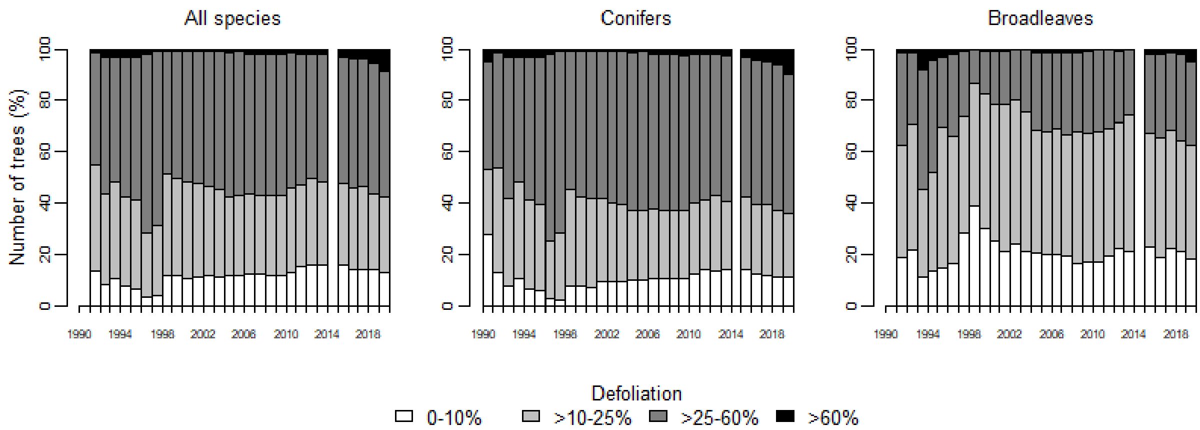
CROATIA



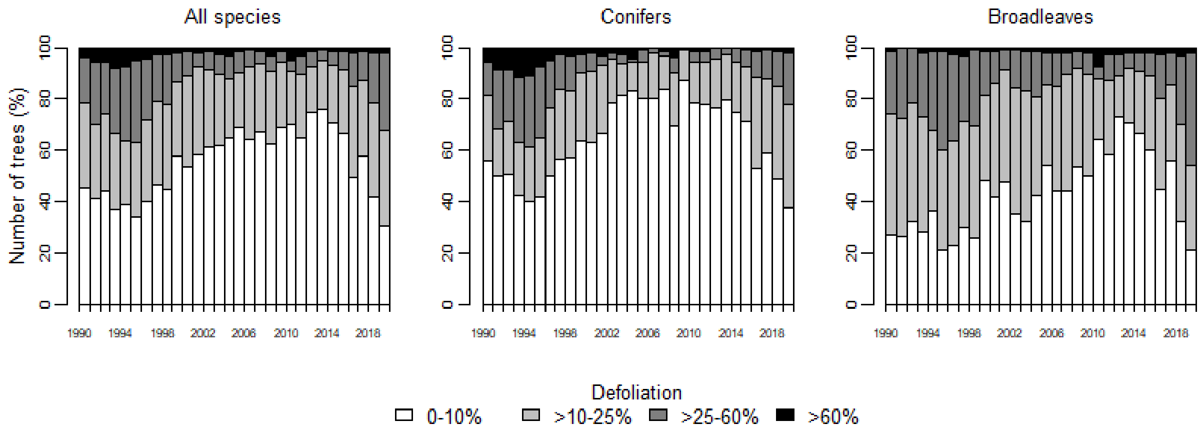
CYPRUS



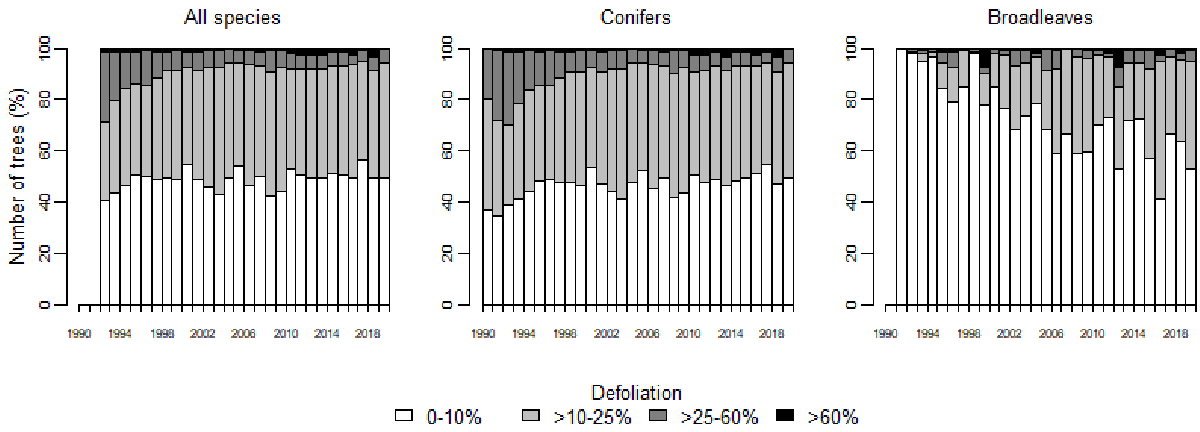
CZECHIA



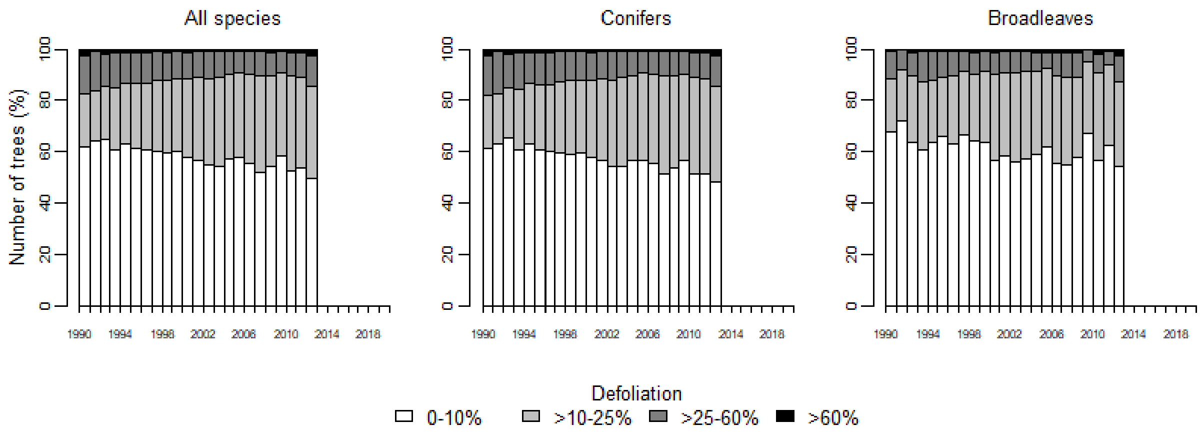
DENMARK



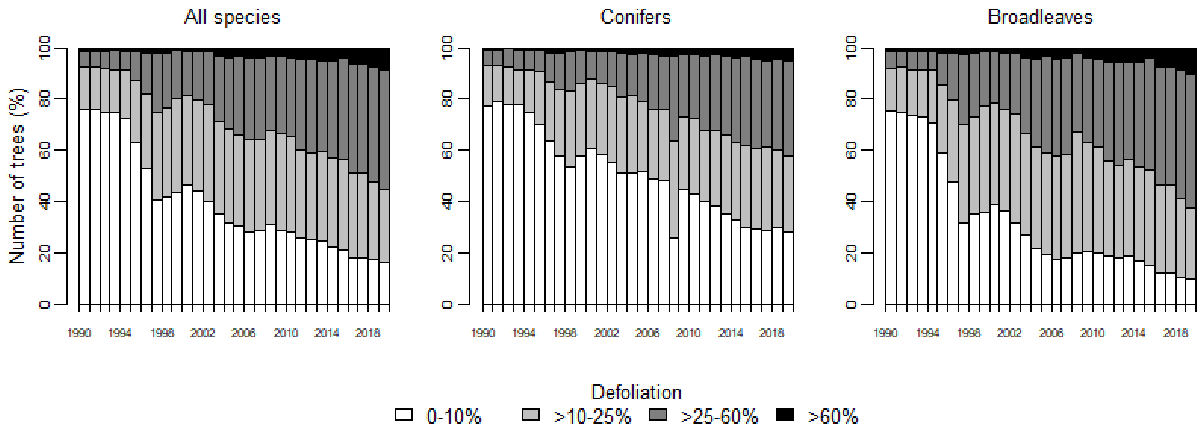
ESTONIA



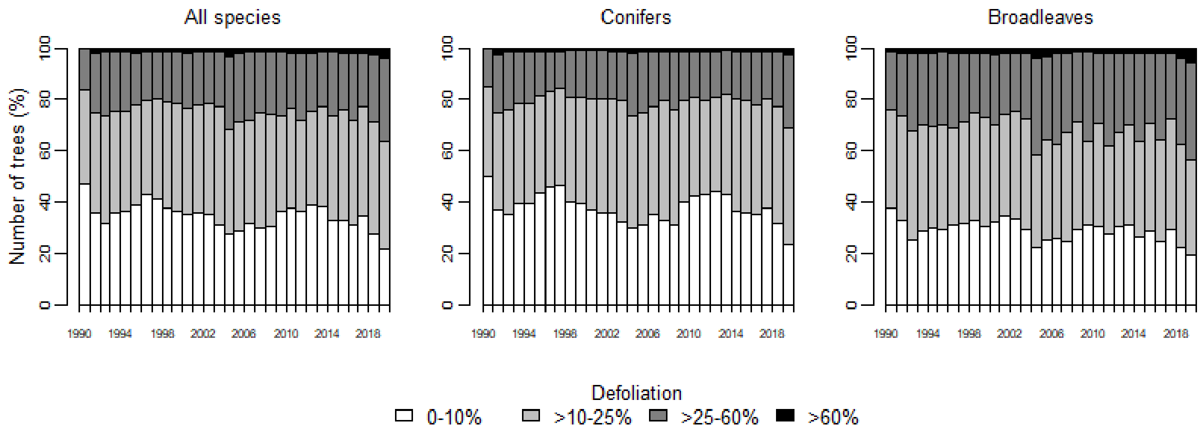
FINLAND



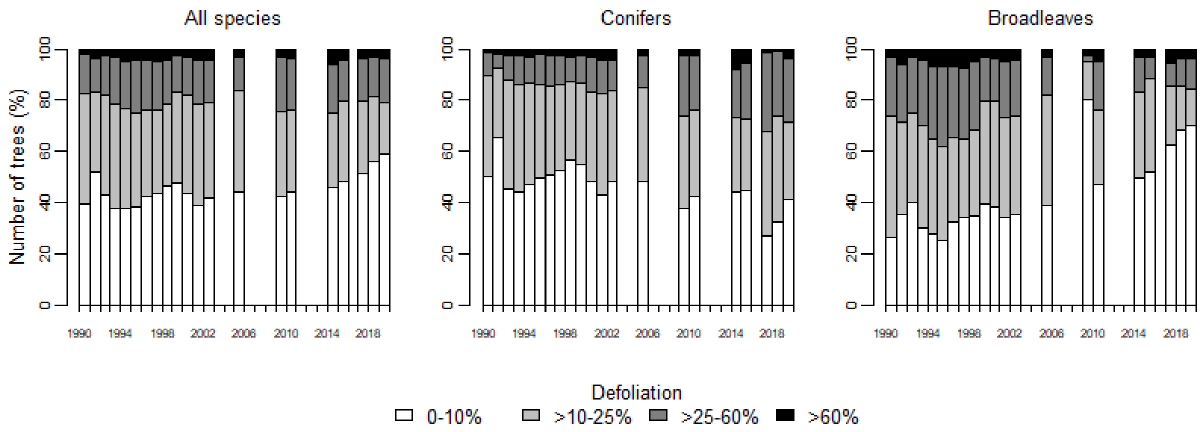
FRANCE



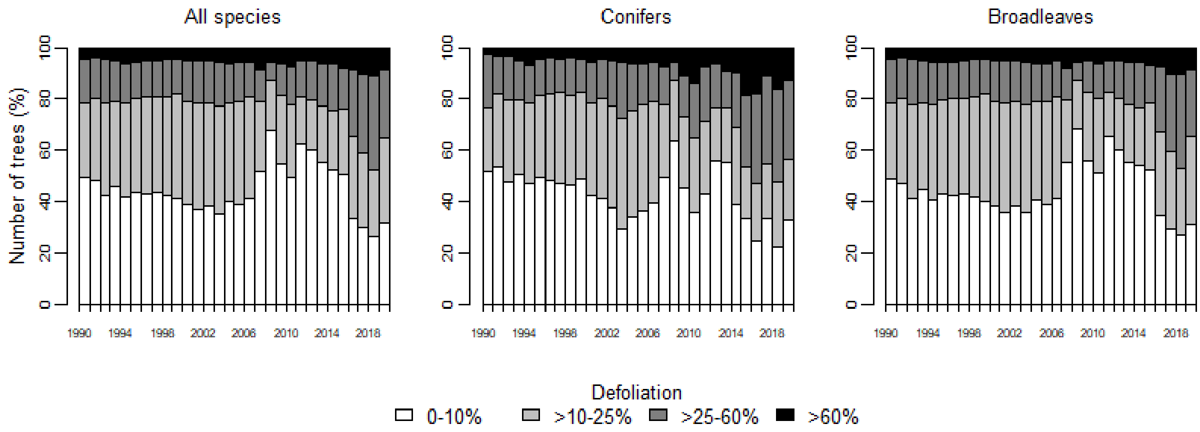
GERMANY



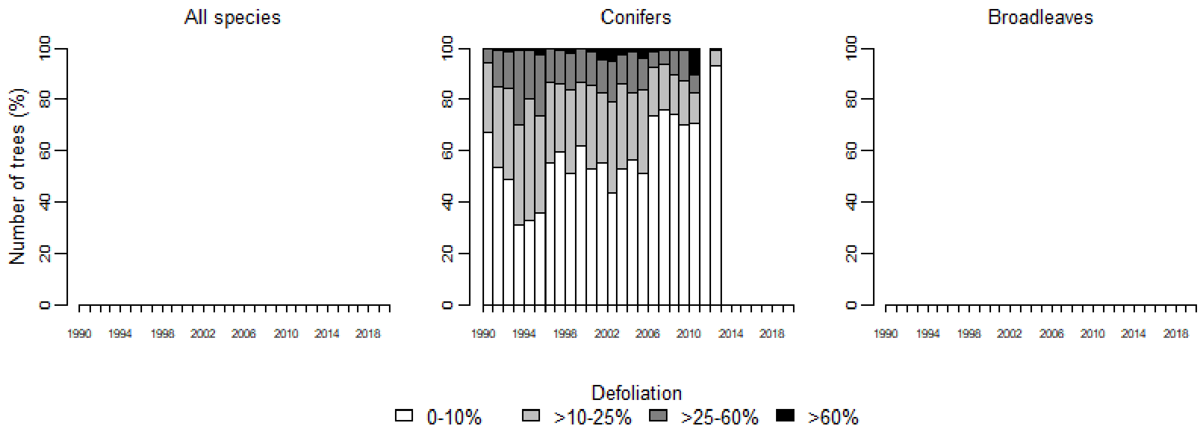
GREECE



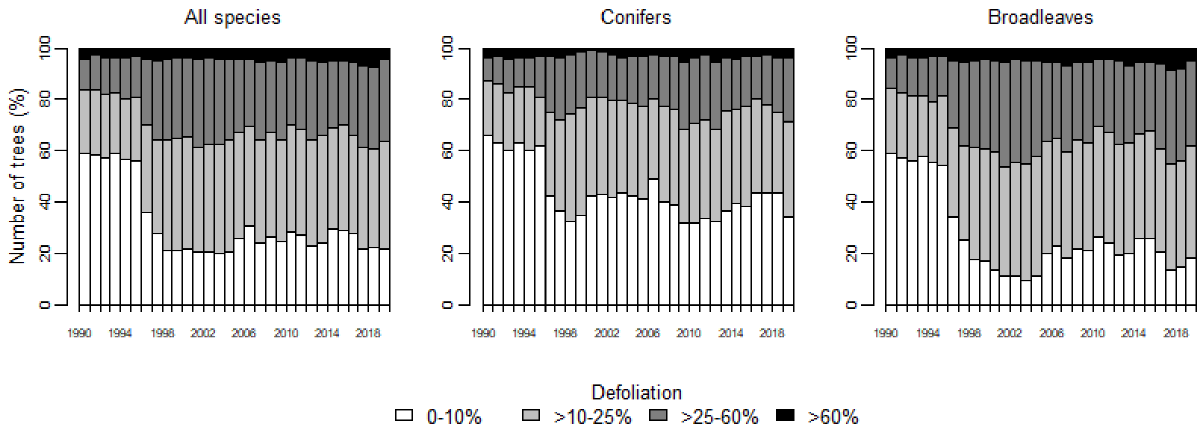
HUNGARY



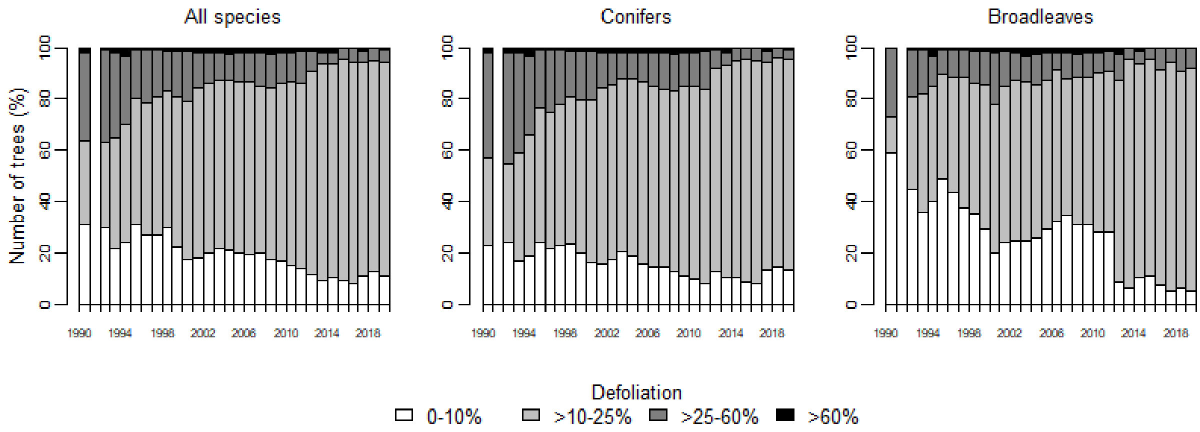
IRELAND



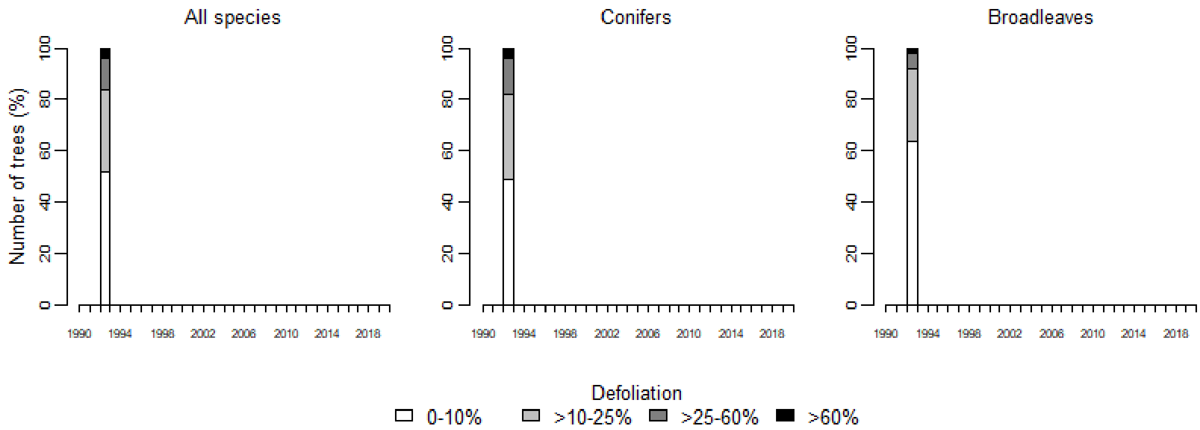
ITALY



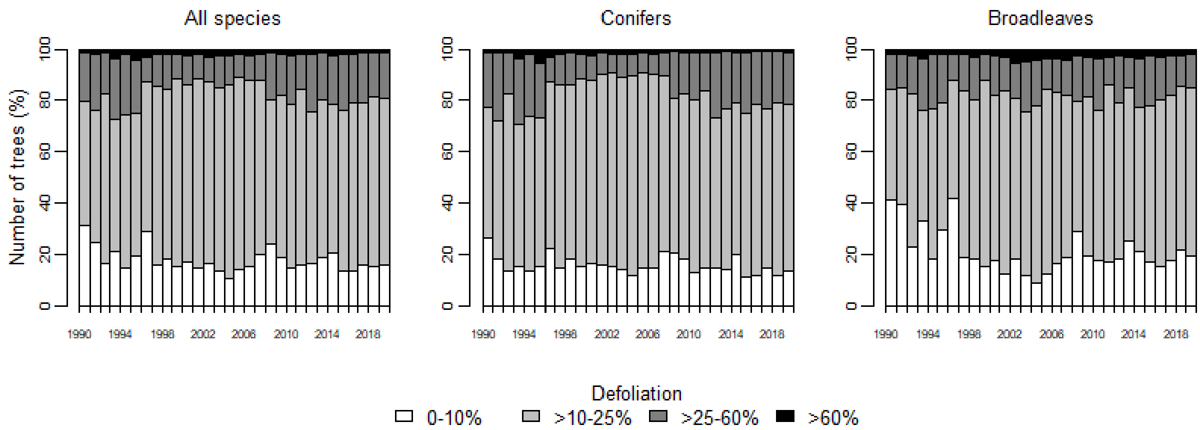
LATVIA



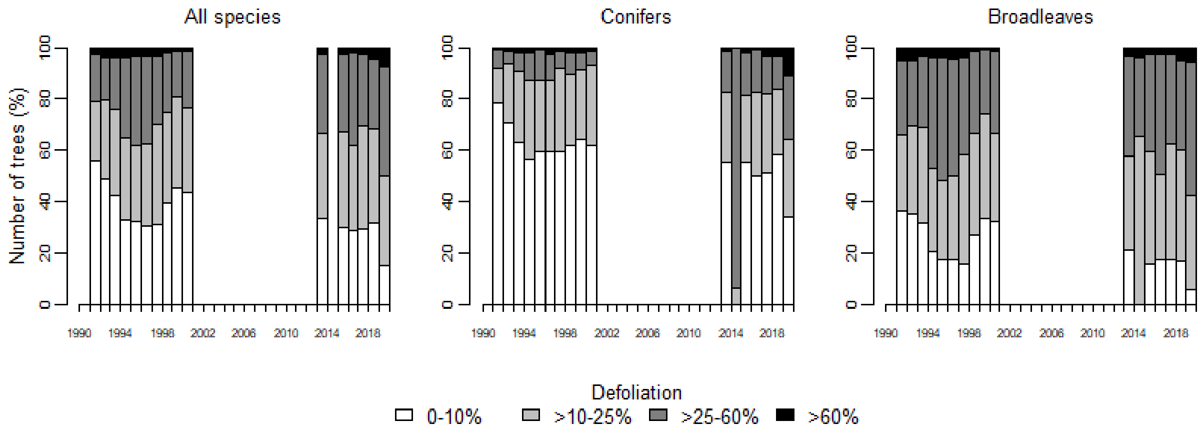
LIECHTENSTEIN



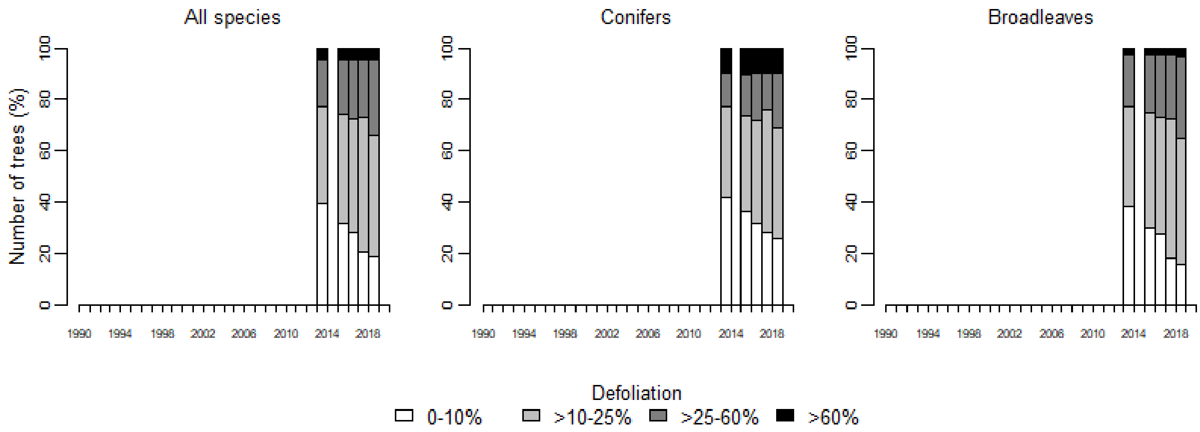
LITHUANIA



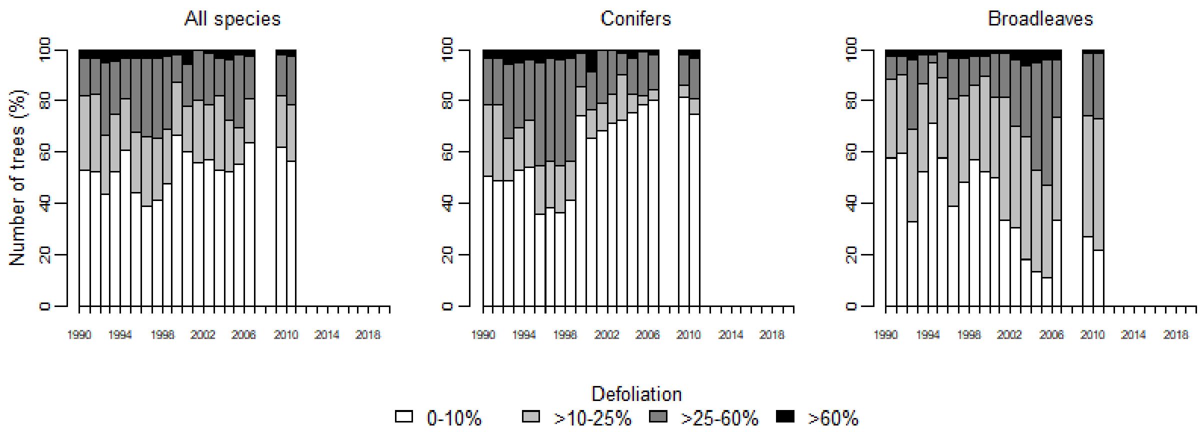
LUXEMBOURG



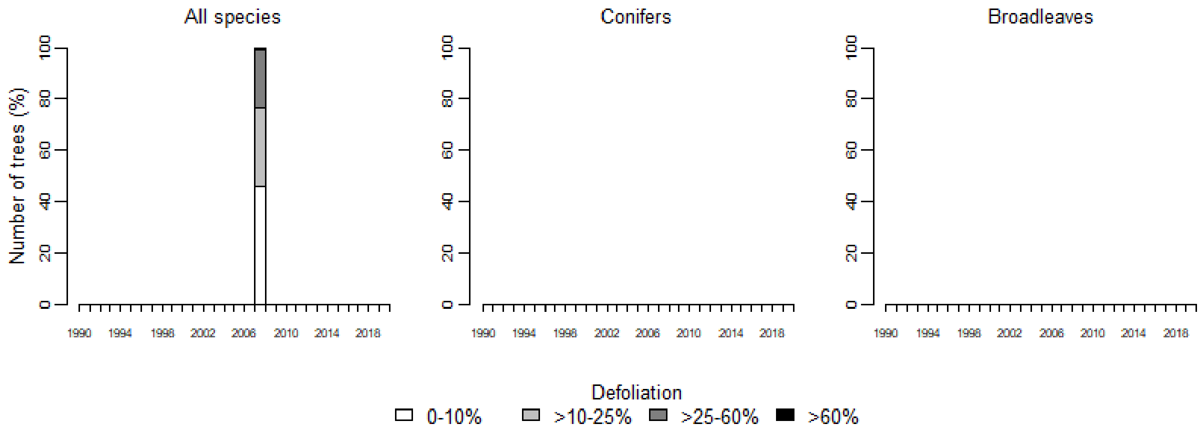
MONTENEGRO



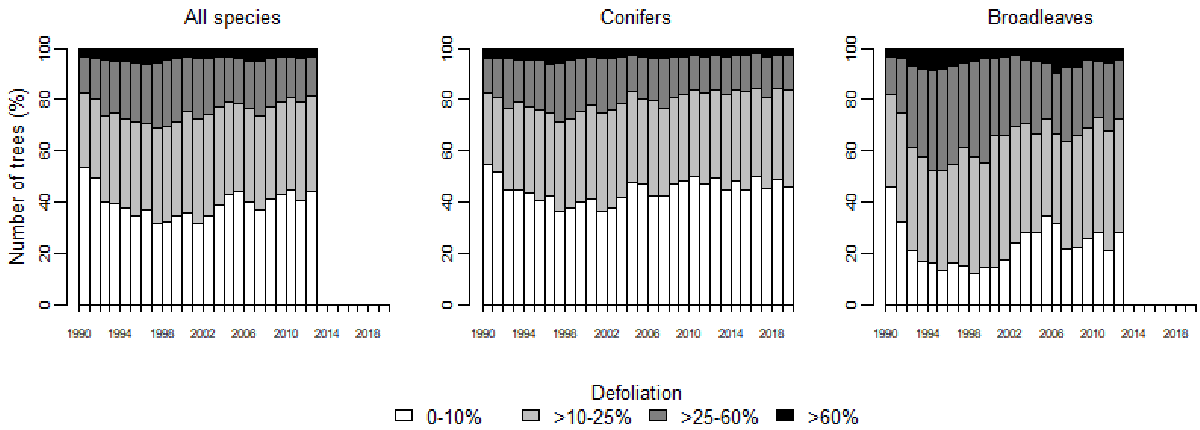
NETHERLANDS



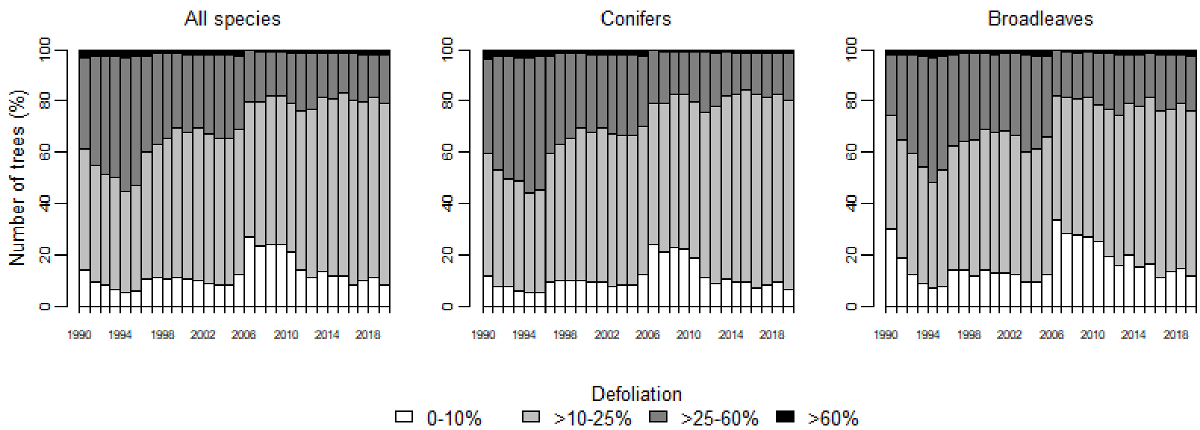
NORTH MACEDONIA



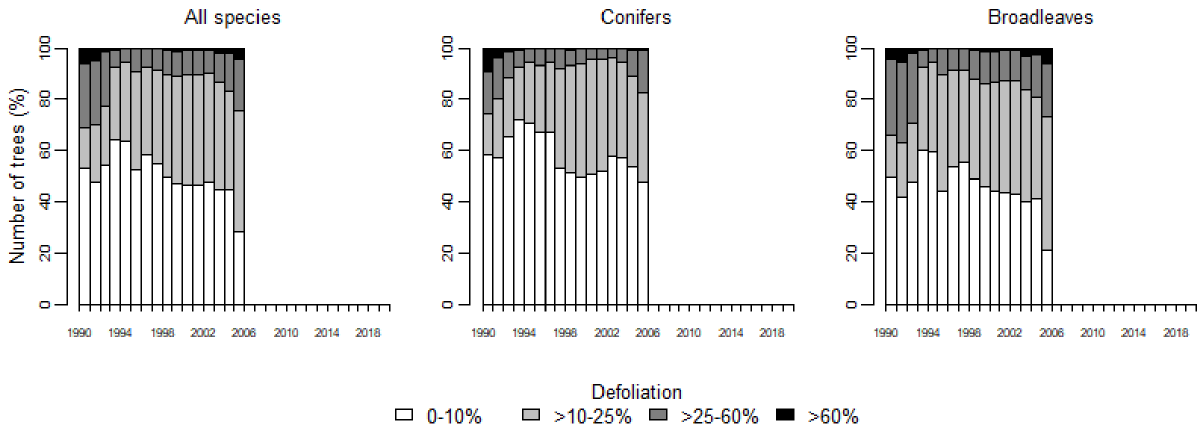
NORWAY



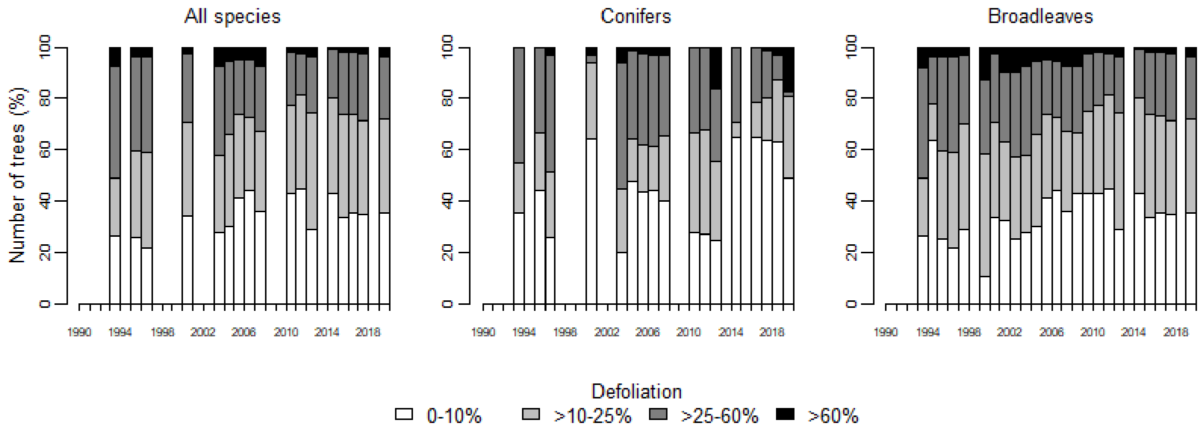
POLAND



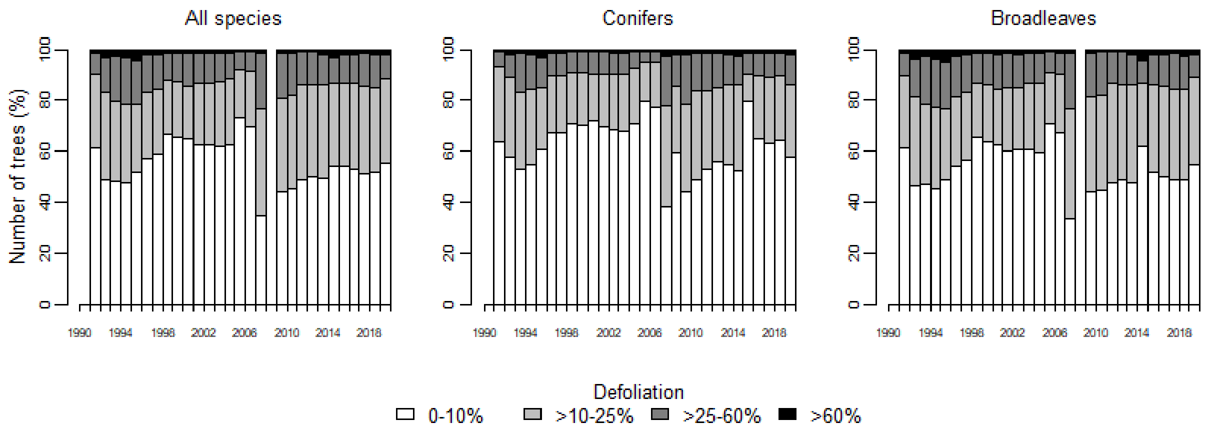
PORTUGAL



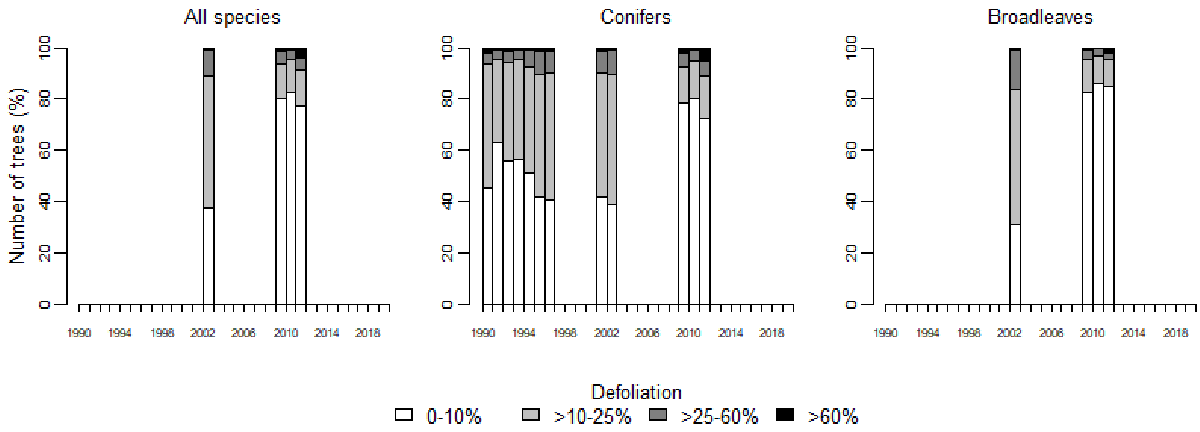
REPUBLIC OF MOLDOVA



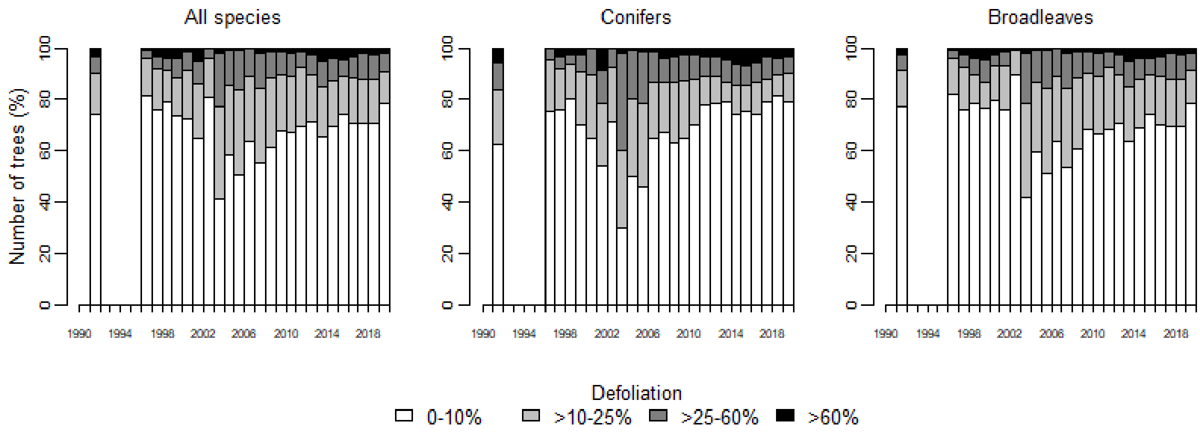
ROMANIA



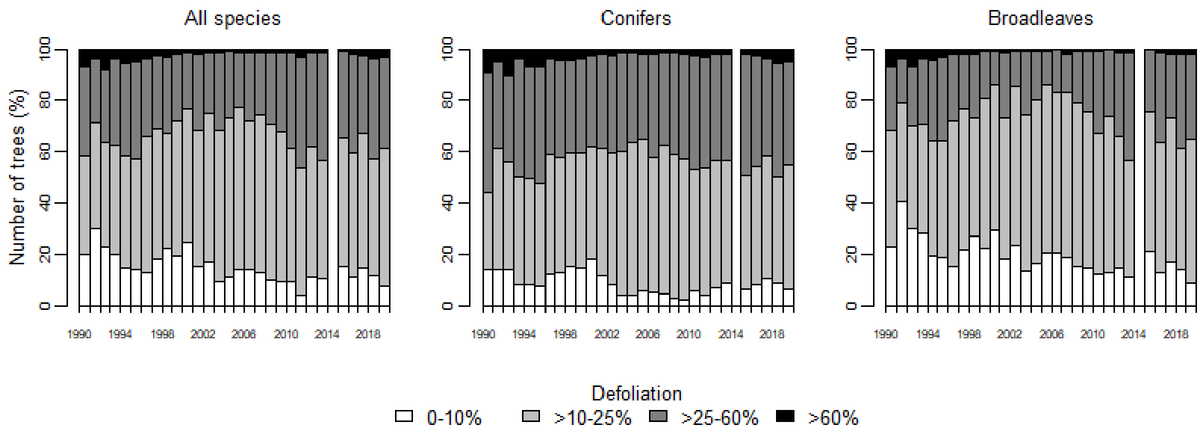
RUSSIAN FEDERATION



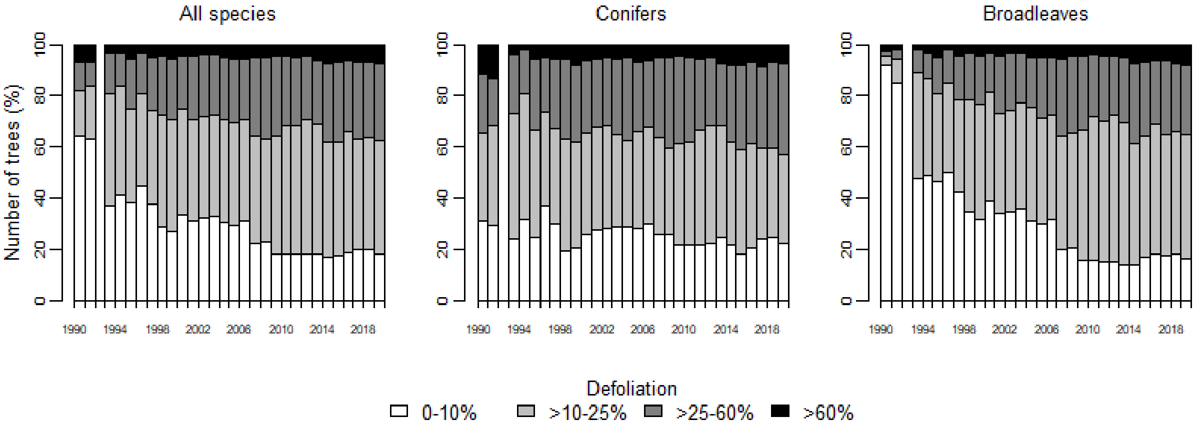
SERBIA



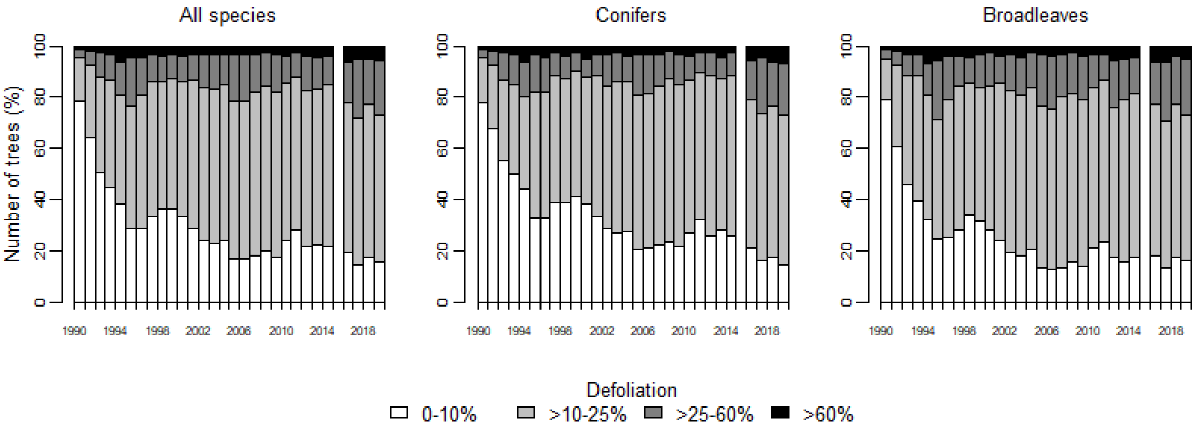
SLOVAKIA



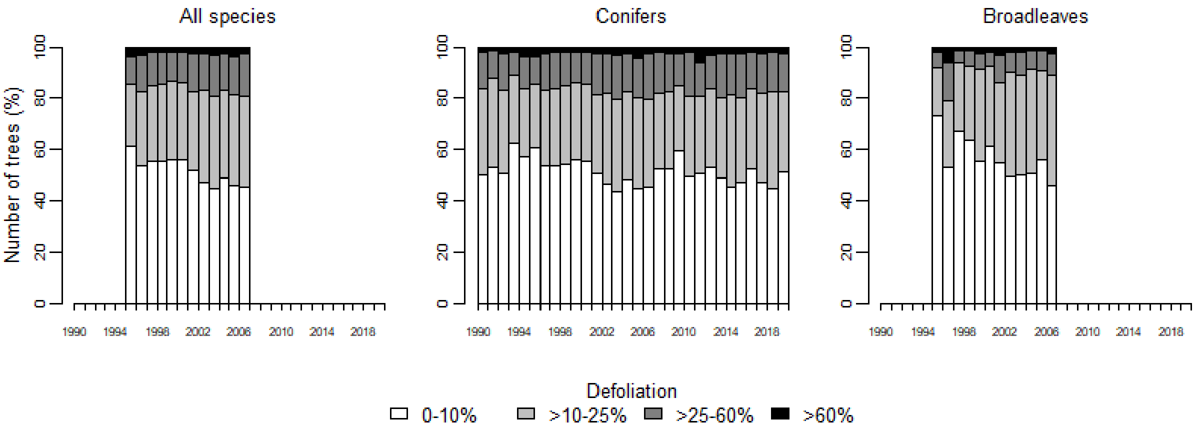
SLOVENIA



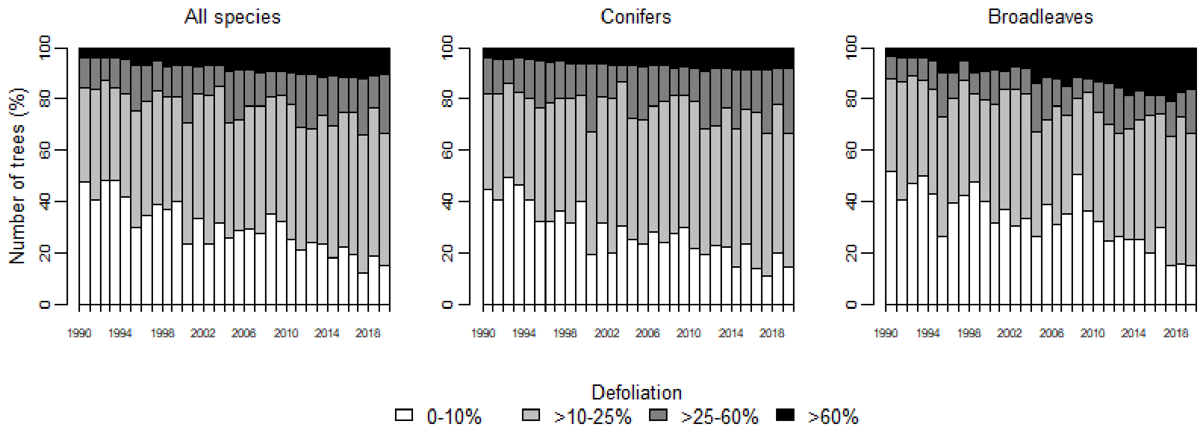
SPAIN



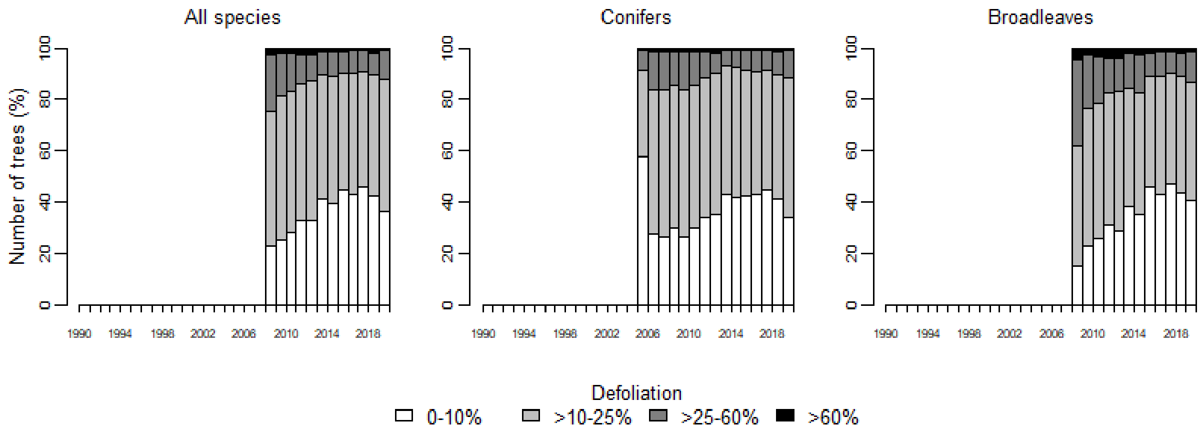
SWEDEN



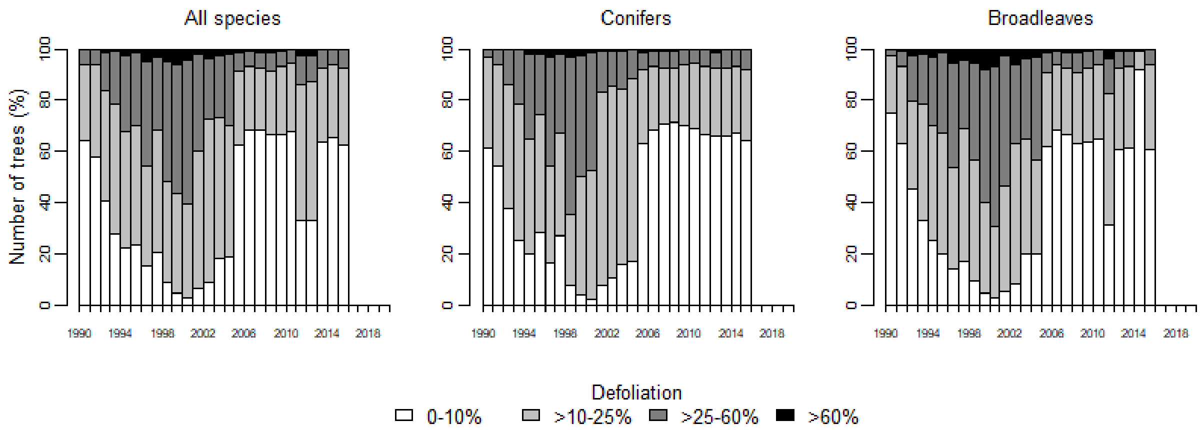
SWITZERLAND



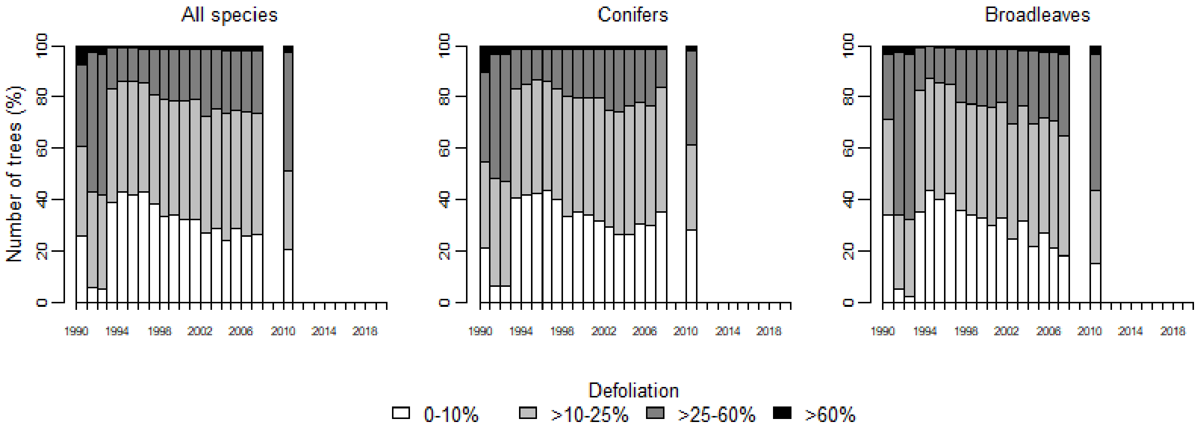
TURKEY



UKRAINE



UNITED KINGDOM



S3 RESULTS OF THE ONLINE QUESTIONNAIRE ON ADDRESSING CHALLENGES ASSOCIATED WITH LONG-TERM FOREST ECOSYSTEM MONITORING

Question 1

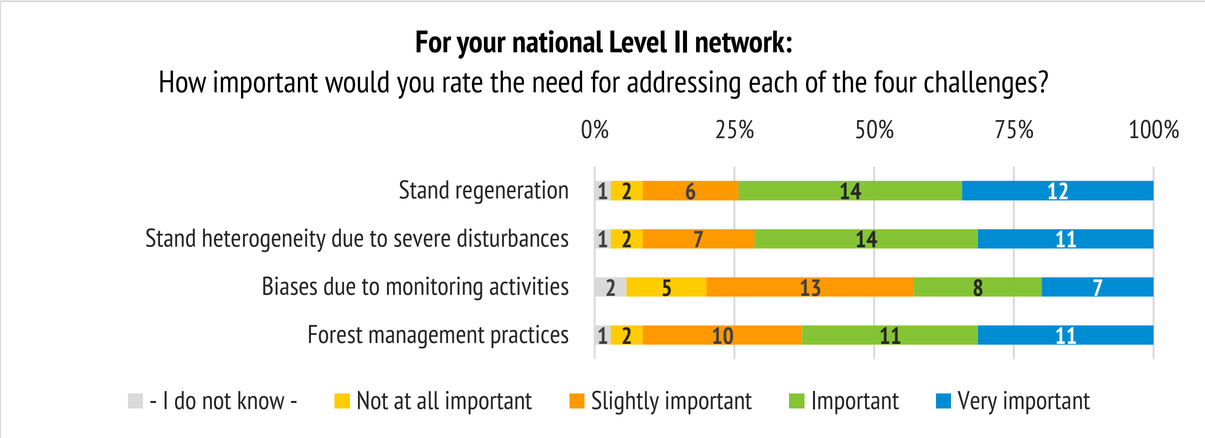


Figure S3-1: Importance of four challenges associated with long-term forest ecosystem monitoring at national level

Question 2

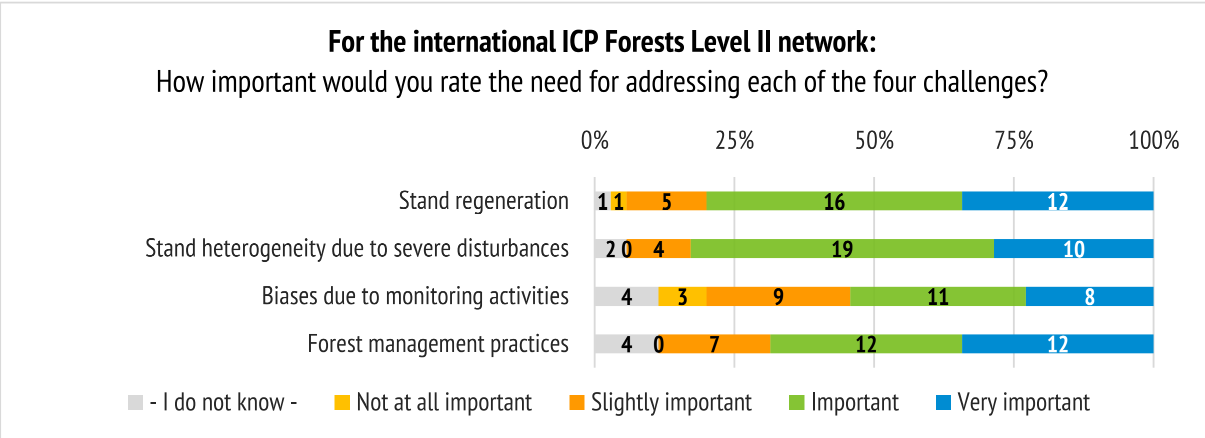


Figure S3-2: Importance of four challenges associated with long-term forest ecosystem monitoring at international level

Question 3

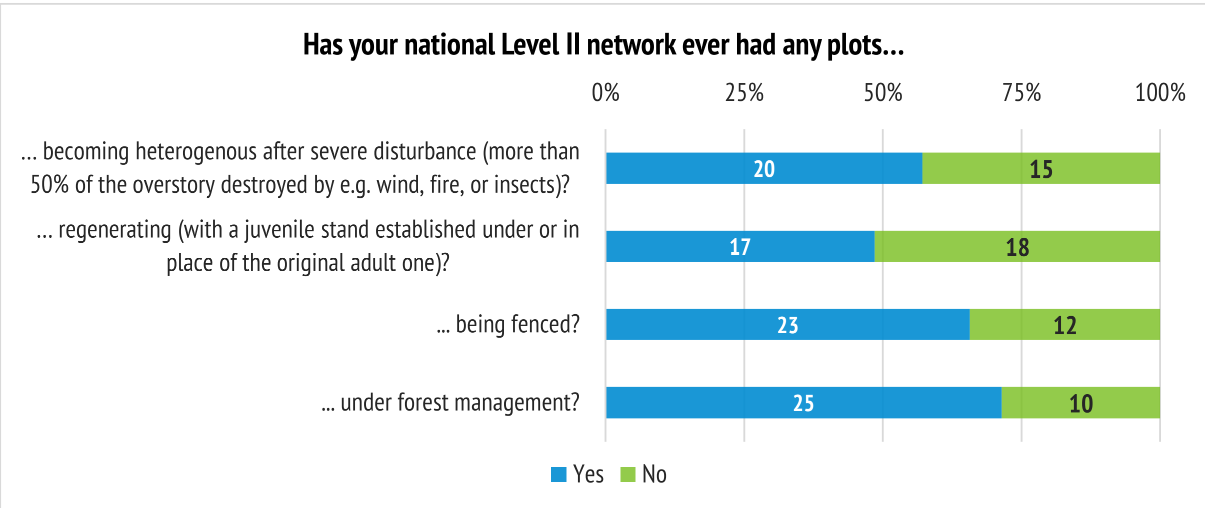


Figure S3-3: Level II plot management and experience with challenges

Question 4

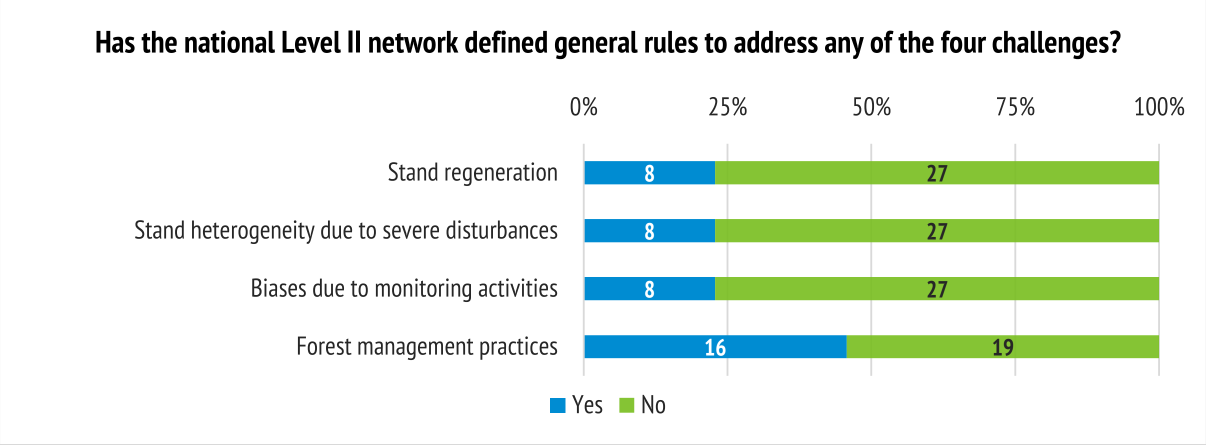


Figure S3-4: Recent applications of general rules to address the four challenges?

Comments to Question 4 (slightly edited, country names removed):

- Stand regeneration (following clearfell): relocate to nearby plot. Short forest generations has meant we have done this twice already at one location. Disturbances (wind): withdraw from damaged area. Felling within a few years leads to new stand generation. Biases (site staff foot-fall): remove and avoid path infrastructure: use way-of-ease pathways on raw forest floor, and minimal total-exclusion areas using loose branches (loose branches arranged to block access over soil-water samplers; minimise use of stakes. Record management where it occurs, or exclude all management: only suitable for mature stands. No long-term ideal approach at plot scale. Experience suggests the solutions are a nested design of multiple plots within a larger monitored (Level III or IM) catchment; not achieved, but this is one hope.
- Bund-Länder-AG zur Umsetzung der Verordnung über Erhebungen zum forstlichen Umweltmonitoring (ForUmV-AG) (2016): Forstliches Umweltmonitoring in Deutschland: Durchführungskonzept Forstliches Umweltmonitoring. Bundesministerium für Ernährung und Landwirtschaft (BMEL) (ed.), 40 pp.
- From the very beginning of the Programme it was agreed that the plots should be managed in the same way as the surrounding stand. The aim was to monitor ecosystem processes in managed forests. Regarding the other types of "disturbances" we started the discussion only recently and did not yet develop rules.
- Stand regeneration and stand heterogeneity: since storm damages in 1999, 8 Level II plots have been under complete regeneration and 6 other ones have become very heterogeneous (large clearings). It was first decided to keep monitoring them at the same location and to adapt protocols as far as possible for this. But nevertheless, they cannot be monitored as in detail and as representatively as plots installed under homogeneous adult stand as initially required for Level II. And since most of the plots are under managed regular high forest, many more ones will be concerned by this problem when they will turn to regeneration stage within the next few decades. So, in order to keep the national Level II network consistent and powerful, the rules will probably change so that to replace plots under regeneration or very heterogeneous stand by some new plots with homogeneous adult stands in some other locations (either close by or in some other ecological context of interest). But the precise locations of the former plots should be documented as precisely as possible to keep the possibility to monitor them again in the future or to make them valuable for some other research purposes. Forest management practices: growth inventories are performed before and after each planned cutting, to document them and to allow cut trees to be deduced from growth calculation."
- Those problems are not relevant for this country.
- With regard to stand regeneration we are talking about clearfell and replanting in commercial conifer plantations. All Level II plots in this country are subjected to standard management practices. In all cases the national strategy would be to carry on monitoring after either natural or man-made interventions.
- Deposition data from these plots are not protected forest (under forest management) and some plots are fenced.
- The plots have been fenced so as to function properly. The wild boars can destroy everything without fencing.

- Due to disturbances caused by stand regenerating processes, in 2010 the sampling site from one field station was changed (nearby the old sample plot) by taking into consideration the location in relation to the station for automatic monitoring of the atmospheric pollutants and meteorological indices, plot for collection of depositions in the open field, tree species and density.
- Not managed forests (nature reserves): no interventions. Managed forests: standard management in buffer zone, management allowed in stand of monitoring plot but without damage of samplers and installed equipment, in fact usually no management.
- General rule – is substitution of plot after tree losses over 50% (after cutting, disturbance, etc). On biases due to monitoring activities – minimization of disturbance, without fencing. Business as usual (forest management) at all monitoring plots.
- All our plots are exempt from management since 2014.
- Regarding forest management, the aim was to make the Level II plots as realistic as possible e.g. in the case of the forest type Norway spruce plantations the forest plot is managed as Norway spruce plantations are typically managed in this country, and the other way around regarding the case of unmanaged forest (set aside as forest reserve) where forest management is abandoned.
- Contract with landowner says, 10 years no forest management to establish a baseline, hereafter usual management by land owner. However, more and more of the Level II plots are becoming part of forest reserves.
- The general rule is: "management should be the same as in the surrounding forest". However, the presence of a fence often leads to delay thinning operation or decrease of their frequency.
- ICP Forests Manual, Working Concept of German Env. Monitoring (BMEL 2016), national guidelines for periodical regeneration inventories at the plots.
- We do not have any "general" rules. In our current situation we have one Level II plot partly disturbed (<30% of the area), but due to increasing bark beetle calamity there is high probability of increased disturbances on several Level II plots in the close future (next 5 years). We have increasing importance of understory at two plots (natural regeneration of the stand), which makes plots more heterogenous - it is unequal - but up to now not influencing deposition samplers and other measurements. Our plots are in mature (> 80 years) managed forest. In such age there are no more management activities (so they were not important so far), but the age of regular planned cuttings is approaching in a few years up to a few decades. In two cases we are at the edge of stands which were recently cut and regenerated which also brings some bias. (In total we have seven highly equipped plots).
- After stand regeneration or severe disturbances, the new plot, which meets the same requirements, has to be established in a new place taking into account the possibility of long-term observation (has to be quite a young stand).
- In case of a thinning, we always try to measure the diameter and height of all felled trees and we try to collect stem discs (although sometimes this fails when we are not timely informed).

Question 5

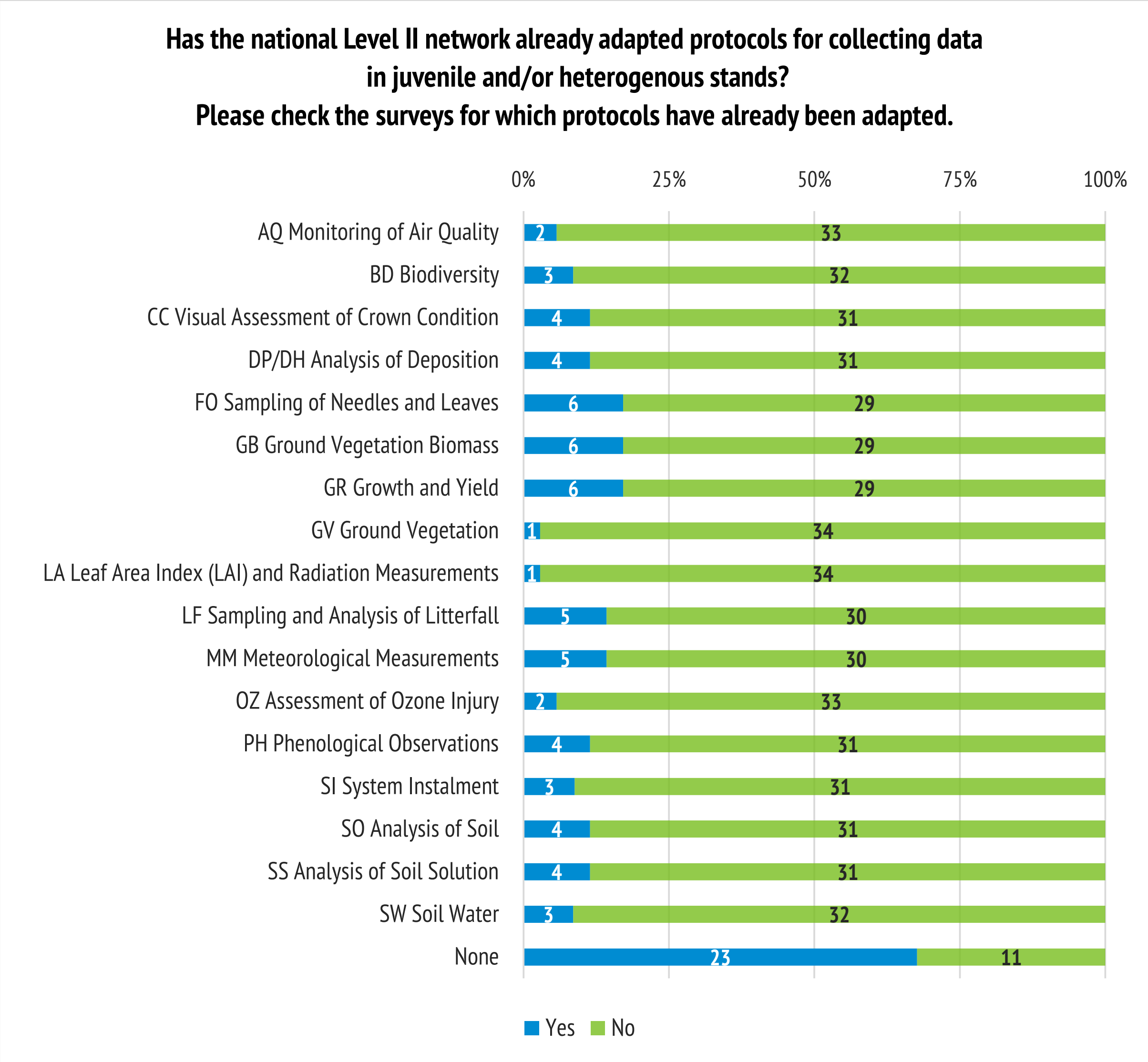


Figure S3-5: Recent adjustments to survey protocols for collecting data in juvenile and/or heterogenous stands

Question 6

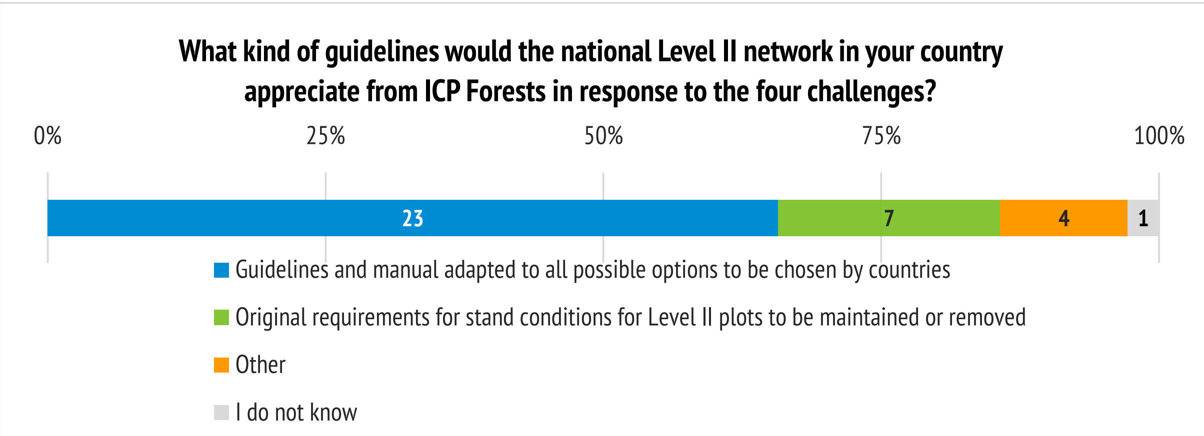


Figure S3-6: Requested guidelines on future national Level II plot management addressing the four challenges

Comments to Question 6 (slightly edited, country names removed):

Comments for "Guidelines and manual adapted to all possible options to be chosen by countries"

- Principles are needed, so countries can apply principles to select from options. The issue of scale, noting that a plot is a meaningful unit only at one scale, must be addressed. Larger-area processes, such as hydrology, disturbance, and management, must be accommodated.
- ICP Forests manuals are in use.
- Ideally, the same strategical orientations should be defined for all the Level II plots. But since the selection, the design and the way to handle the Level II plots have been up to countries, and since monitoring relies on national funding, such strategical choices will finally be made by countries according to their interest and possibilities, and will probably not be the same from one country to another. So at least ICP Forests should provide guidelines adapted to all possible options.
- Standardised systems for carrying out current monitoring requirements in juvenile crops. Above all it is essential that where countries are monitoring in juvenile crops, protocols are standardised to enable comparisons/analysis of the data set.
- Account should be taken of the regional particularities in the application of methodology.
- It is a difficult question, as ICP Forests' strength is the comparability between countries and plots, which points in the directions of all following the same set of rules. On the other hand, there may be a very specific and sound reason for not following general rules for a specific national plot.
- Preferably both, a recommendation for the requirements, i.e. the preferred decisions on management and relocation of plots to be taken, and guidelines for the adaptation of the manuals for measuring.
- In some cases, we would like to stay at the same plot, monitor the regeneration period and growth of young stands. But because all of our plots are relatively close to planned cutting age, we will probably shift most of them to some adult stand in the vicinity. If we want to keep harmonized programme, we have to have some international guidelines.
- Guidelines could be helpful to make a decision on how to deal with a certain situation, although it will be difficult to generalize.

  When making guidelines it is important to bear in mind that monitoring activities/number of plots/financing/forest management practices vary from country to country.

Comments for "Original requirements for stand conditions for Level II plots to be maintained or removed"

- International guidelines are not necessary but always helpful.

Comments for "Other"

- In our opinion the choice of plots must be based on the representativity of forest ecosystems in the various countries.
- Common guidelines for monitoring of seedling/sapling stages in general would be useful. On the other hand, guidelines for establishing substitute plots are also needed.
- "Optional recommendations (at least) would be satisfactory. But in case of "core plots" of extraordinary importance from the point of view of the international grid of plots, also obligatory guidelines may be accepted.
- I do not modify the original requirements, but there should be a guideline for the possible options with the advantages and disadvantages.

Question 7

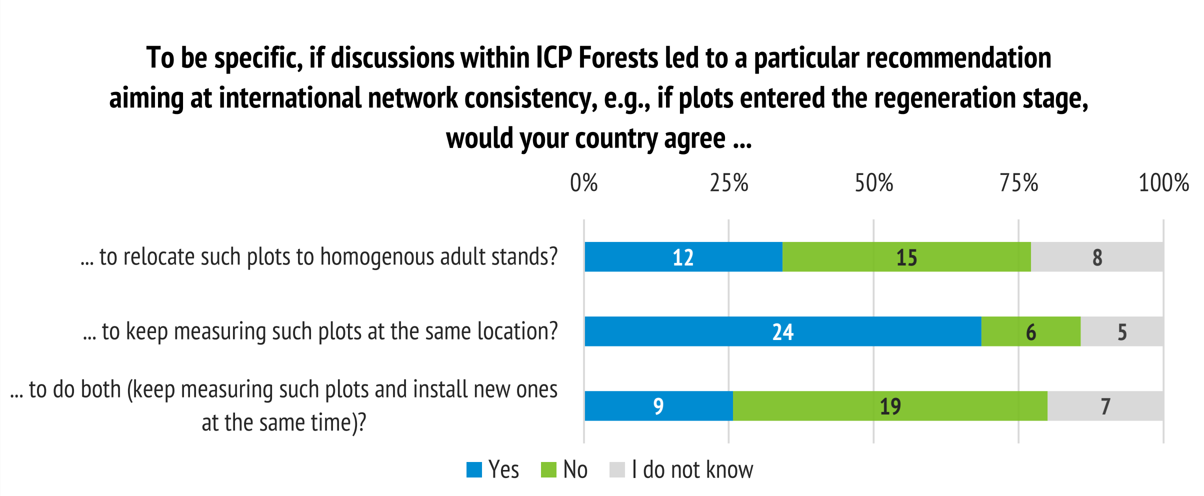


Figure S3-7: Potential acceptance of ICP Forests guidelines after stand disturbance and regeneration on Level II plots)

Comments to Question 7 (slightly edited, country names removed):

- Only the third option makes sense, in the long term. However, such up-scaling implies a big increase in funding. There is a disjoin between acceptance of these options by NFCs as technically suitable, and any possibility of national funding to facilitate that.
- Probably, the regenerating phase may be documented by observing an additional nearby plot with similar structure as the old one for some years in parallel. In the exchange of views that we had so far in our national working group, we agreed that all of the mentioned options should be taken into account. The third option is interesting from a scientific point of view but due to limited resources could never be implemented on all plots. We agreed that we should choose the first and the second option in a coordinated balanced way. On a few plots and for some measurements, it might be possible to implement Option 3.
- Financial limitations would prevent us from establishing further plots. As we are interested in the effects of a 2nd rotation it is unlikely we would relocate a plot, and establishing a further plot is not possible within current funding.
- It depends on the plots. These actions have already been implemented at different locations within our network.
- We have continued monitoring on two clearcut Level II plots. So far, relocation of the plots has not occurred. "To do both" is a tempting option, but is hardly financially possible.
- Relocation, only if a homogeneous adult stand is available near the air quality and meteorological parameters measurement facilities.
- To do both is not feasible (mainly due to budgetary reason).
- Keeping the measurement in the same location would lead to a long break in the data, and the data would not be comparable with the old dataset for years. We could not do parallel monitoring on regeneration plots and newly established plots due to financial reasons.
- Again, this is a difficult question, for some of the reasons mentioned above in Question 6, but also the local politics and budget may force us to depart from general rules. E.g. we may be forced to substitute a wind felled mature Norway spruce plantation with another mature Norway spruce plantation since this type of forest covers a large percentage of our forested area, hence current knowledge of these forests is in demand.
- In the exchange of views that we had so far in our national working group, we agreed that all of the mentioned options should be taken into account. The third option is interesting from a scientific point of view but due to limited resources could never be implemented on all plots. We agreed that we should choose the first and the second option in a coordinated balanced way. On a few plots and for some measurements, it might be possible to implement Option 3.
- The question of keeping plots, relocating plots or both have not been systematically discussed within our country network. So far plots were kept, but activities were in some cases partly reduced. Hence, we could also have checked 'I do not know'.

- The third option should probably be rejected if all the surveys must be achieved on both plots. However, if the monitoring of the "disturbed" plot is limited to some surveys, it might be accepted.
- To do both might be possible within the same stand of a plot for a distinct time frame and parameter. To relocate plots (in changing environment) and starting a new time-series might be an option only on a rare sample, as far as national or international demand exists.
- As we stated above, we would like to keep both possibilities. The third one, unfortunately, will lead to increased costs which will not be acceptable for us, unless there will be some source of international co-funding.
- To do both is the best option but might be hard due to restrictions of financial and personnel demand.
- Not adult stand (explanation in answer to Question 4.
- We would prefer to continue monitoring at the same location, regarding the value of the collected long time series.
- In our country, we only have three Level II plots left. It would take several decades with regeneration before many of the monitoring surveys could be re-started. In the case of final felling of a stand/plot, this is normally done as clear-cut, leaving nothing left to monitor. For these reasons, the only acceptable possibility will be to move the plot to a (preferably) nearby locality.

Question 8

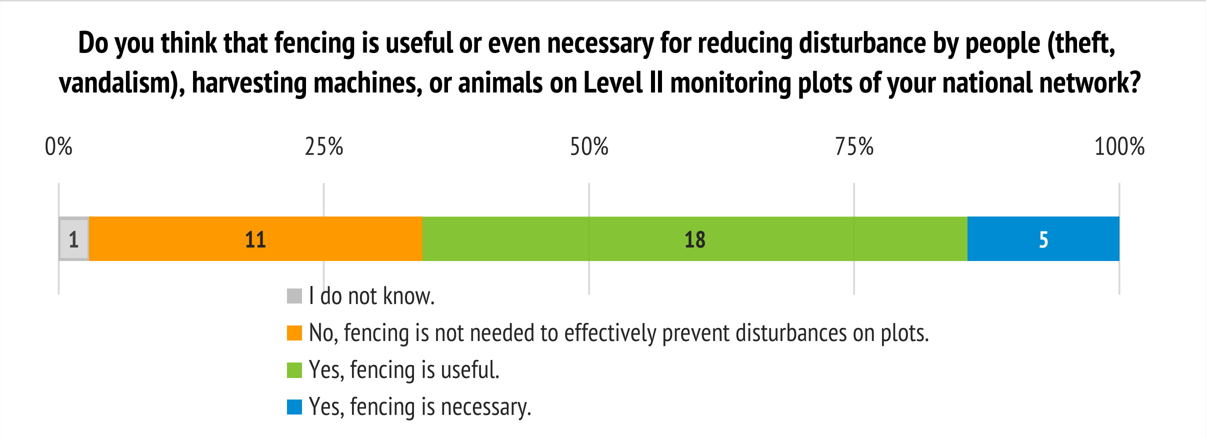


Figure S3-8: Rating the importance of fencing Level II plots

Comments to Question 8 (slightly edited, country names removed):

<u>Comments related to answer "Yes"</u>

- In our network, most plots are fenced, but some are not. In general, fencing seems necessary for core plots and useful for standard plots.
- Most of the plots in our country are fenced.
- Fencing may not be necessary everywhere, but it has proved useful to prevent disturbances by people in several cases when devices installed outside were disturbed or stolen. It also efficiently prevents ungulates from coming into plots but this has rather been a problem since it has caused biases at least on the dynamics of the ground vegetation inside in comparison to relevés made outside fences (Boulanger et al., 2018).
- Only in the instrumented area.
- We have an intense problem with wild boars in all plots.
- Fencing proved to be very useful for protecting installations for collecting atmospheric deposits and soil solutions.
- We have one fenced plot, effect on regeneration is visible (eliminated damage by animals). All open field subplots are fenced to minimise the vandalism.

- This depends on the plot (the presence of game or people in the area).
- In our federal state only some plots are fenced, e.g. we fenced those which are next to a highly frequented hiking trail.
- But not everywhere.
- Whether fencing is needed depends on local factors (number of people visiting the area, value of equipment, etc.). We have two of our five plots fenced and where experience learned that this is really necessary, while in the other locations there is no need for fencing.
- Our plots are not fenced - only the area containing soil solution equipment is fenced to avoid damage by game and cattle. This partly fencing, on the other hand, is absolutely necessary in some plots.
- Necessary, primarily for reducing the game effects. It is an option not to fence the whole plot.

Comments related to answer "No"

- Better to have no fencing, unless the plot is a focus of activity.
- On one plot, there is a loose fence (one wire) on one side of a plot towards a highly frequented path. However, the plot is openly accessible for animals from the backsides. Disturbance by people was very seldom so far.
- We have only minor problems with vandalism. In our view the plot should be managed according to the "standard" rules, which is complicated by fencing. In our experience at least in some plots there is a quite different ground vegetation cover and also water relation comparing to forests nearby, if the plot is fenced.
- In this country's conditions.

Question 9+10

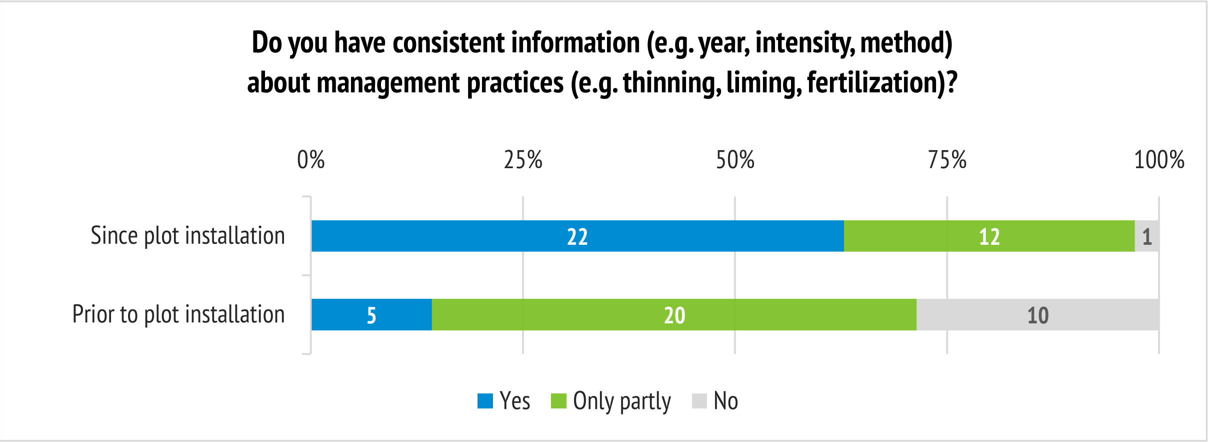


Figure S3-9: Availability of long-term information on management history of Level II plots

Comments to Questions 9+10 (slightly edited, country names removed):

Comments about information available since plot installation.

- No explicit record, but it could be recreated.
- Information on natural disturbances (windthrow, biotic damage) is only partly available.
- The länder might have much more Information than what is included in the national and international database.
- Growth inventories have been performed before and after planned cuttings since the installation of the Level II plots. Storm damages have also been documented with date and intensity (not in terms of impact on stand basal area but at least in terms of number of fallen trees within the plot area).
- Management practices are not performed since plots were established.

- In general, there is complete information, but there may be information gaps, especially in the first years of the historical series.
- Management practices (e.g. thinning, liming, fertilization) have not been applied since plot installation.
- Data is available on the level of the management unit, but not for the plot itself (e.g. volume of wood thinned out on the plot).
- On several plots there were cutting activities in the neighbouring area and just to the border of the plot, e.g. in today's buffer zone. There is very little information on these management activities (e.g. only date, side of plot).
- Thinning operations had to be registered in the database, but this was not systematically done. No liming /fertilization occurred.
- Yes, we have permanent contact and good collaboration with the local forest administrations.
- At stand level and even at plot level by data.
- As we stated above, our plots are in mature forests which are not thinned any more. There was also no liming or fertilization. We try to keep information about individual trees which were removed due to e.g. windthrow or snowbreak but must admit that the information is incomplete.
- There has not been conducted any forest management in our Level II plots after monitoring started. Areas around/close to the plots, on the other hand, have been subjected to forest management (mostly final felling).
- On our Level II plots only the sanitary fellings were done.

Comments about information available prior to plot installation

- Management history for one plot; studies on long-term ecosystem development on another.
- Information on thinning activities is less detailed, if ever available.
- Information was collected from historical forest management documents at the location of every Level II plots. But the completeness and quality of this information are quite heterogeneous from one plot to another. In addition, such information is related to the forest management unit in which a plot is located and not to its specific area (so that we cannot know how far some reported cutting actually impacted this area before the plot was installed).
- Some information exists about previous rotations and/or land use history.
- Information is available on request.
- Data is available on the level of the management unit, but not for the plot itself (e.g. volume of wood thinned out on the plot).
- There is information on forest management activities available for the whole land patch (Waldabteilung, several hectares) within which the plot is located available at the Forest Services. However, there it is not specified, where within the patch it took place, i.e. if the plot was included or not.
- It is accessible from forest management data.
- It might be possible to get information like this from the forest owners/management companies, but that would require some extra work.
- Theoretically. It has not been tested.

Question 11

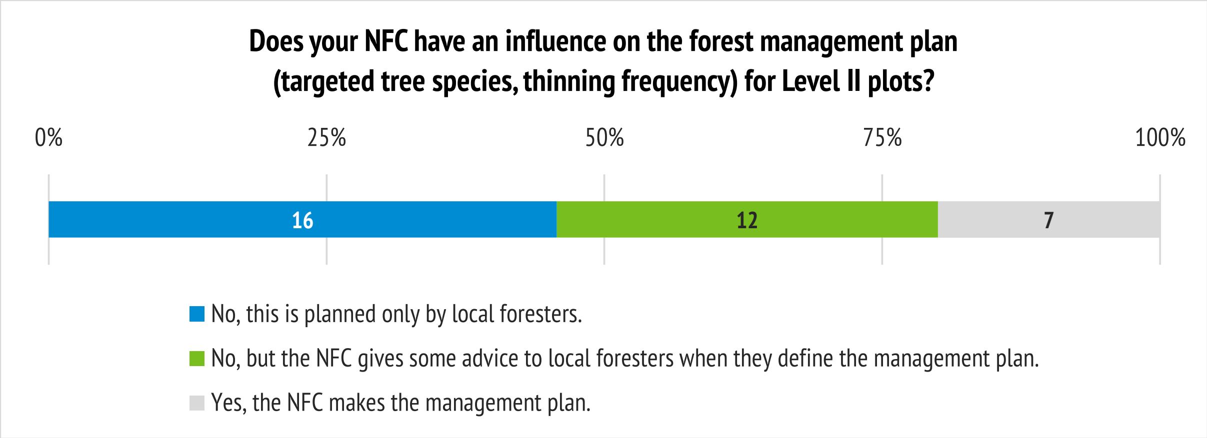


Figure S3-10: Influence on forest management plan on Level II plots

Comments to Question 11 (slightly edited, country names removed):

- Weaker links to forest managers, who have withdrawn from active participation in this research.
- The management plan is developed by the NFC in consultation and agreement with the local foresters. Sometimes, the management plan is restricted by nature protection rules depending on the protection status.
- Management is planned and co-ordinated at länder level.
- Local management is applied but the NFC is advised of any management.
- No, this is planned only by local foresters.
- The local foresters are aware of the NFC's will that the Level II plots are out of management due to fencing.
- As a person responsible for the implementation of the forest ecosystem monitoring programme, I take part in the adoption of the forest management plans.
- Since 2014 removal of dead trees is practised in the buffer zone only, there is no management on the plots.
- Except the agreement on no management in the first 10 years. However, local foresters and land owners would - to a certain degree - probably be open for suggestions of NFC in several cases.
- This is planned by local foresters, but they are open to specific demands (e.g., trees to be marked, path for the machines, ...).
- Same measurements at plot and stand level are mandatory, regional management concepts are intended, destruction of devices is restricted; activities are under control.
- No, but we are in most cases in contact with the local foresters.
- We have already thinned three of in total eight plots in close co-operation with the local foresters.
- There has not been conducted any forest management in our Level II plots after monitoring started. Sometimes we are informed about planned activities next to our plots, sometimes not.
- If NFC is equal to Forestry Directorate.

Question 12

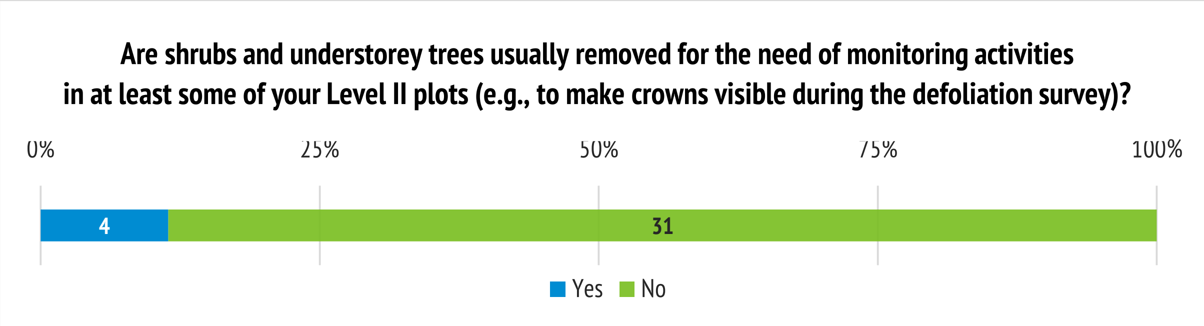


Figure S3-11: Shrub and understorey tree removal for the need of monitoring activities on Level II plots

Comments to Question 12 (slightly edited, country names removed):

Comments related to answer "Yes"

- Some understorey trees (as few as possible) can be removed if the crowns of the sample trees are not anymore visible enough for crown condition or phenology surveys or for foliar sampling (with a shotgun).
- Understory is removed periodically from within our oak plot according to established historic management practices in order to maintain a management baseline.
- In all plots there is always the need to clear the low vegetation in order for the meteorological stations to function properly.
- Above the deposition subplots to keep the sampling manageable.

Comments related to answer "No"

- Only exceptionally, if access to specific sensors/sampling points is precluded by understory vegetation.
- Usually - not, but if necessary - yes.
- We had to remove some understorey trees in the buffer zone to be able to take foliage samples from overstory trees (sampling by shotgun).
- In the the exceptional case: to reinstall or install probes/sensors.
- In the subplot of the Level II plot where intensive monitoring is carried out (DB, LF, SS, GV) walking access pathways are defined. There obstacles (e.g. laying stems) may be cut and put aside to prevent researchers from deviating and walking e.g. on permanent vegetation plots.
- But it will probably be useful in some plot in the near future...
- Shrubs might be removed if they directly influence/disturb any measurements.

Question 13

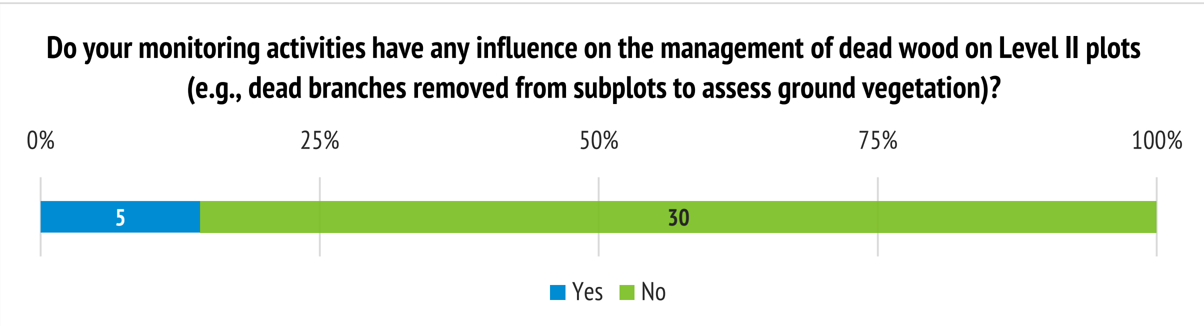


Figure S3-12: Influence of monitoring activities on dead wood management on Level II plots

Comments to Question 13 (slightly edited, country names removed):

Comments related to answer "Yes"

- Small-scale redistribution of fine deadwood to modify access. Sub-plot disturbance avoided.
- After cuttings, if dead branches have been piled on subplots to assess ground vegetation, they are removed. Also, to avoid soil compaction on subplots for soil sampling and subplots for ground vegetation surveys, harvesting machines keep outside the plots if possible, so that whole trees may have sometimes been winched to be further logged and the residues left outside plot area.
- Dead branches of larger diameter are removed if they fall on the fence or samplers.
- Crowns are removed after thinning from the plots for ground vegetation survey. However, individual branches that fall are not removed.
- Only if sampling or assessing would be strongly hampered.

Comments related to answer "No"

- Removing understory or dead wood might occur in particular cases, e.g. if coarse dead wood dropped on the fence or on measuring devices. Please refer to the länder answers.
- No, they have not any influence.
- In the subplot of the Level II plot where intensive monitoring is carried out (DB, LF, SS, GV) walking access pathways are defined. There obstacles (e.g. laying stems) may be removed to prevent researchers from deviating and walking e.g. on permanent vegetation plots.
- Safety reasons are respected.
- Dead wood might be removed if they directly influence/disturb any measurements.
- All dead wood (broken branches, tops and fallen stems) are normally left wherever they have fallen (also on vegetation plots), but the local observers who collect soil water and throughfall samples sometimes remove dead wood from the tracks.

Question 14 – Any general comment about this questionnaire or further suggestions to address the identified practical challenges?

Comments to Question 14 (slightly edited, country names removed, only technical answers shown):

- With short rotations of about 40 years, plot regeneration has been faced multiple times in the Level II network. The guiding principle has been to see "forest" as a mature closed-canopy vegetation, leading to plot replacement in each case. An ideal would be to rotate plots, or continuously monitor through all development stages at a set of plots, located within a larger landscape unit such as a catchment. Three Level II plots of different stages, within an IM/"Level III" catchment, would be suitable. A move beyond plot monitoring to representative and stratified observations would be another approach, again nested within a larger functional ecosystem unit.
- It is better to change the location of the plots after cuts, fires ... since Level II is a set of plots focused on forest ecosystems. It is necessary to promote regeneration in high mountain pine stands, rather than the fixed location of plots (otherwise, scrub monitoring may be carried out in the future instead of forest monitoring), especially taking into account the low number of Level II plots in our country. For example, the hypothetical cut of one specific plot may be faced:
  - by maintaining regeneration monitoring: there is no information on mature trees, and there would be a risk of regeneration
  - by moving the plot within the same pine stand: the monitoring of the species will keep on.
- Presently no data are reported on Level II only within ICP IM. Some data from the monitoring program are reported. The national monitoring programmes are currently under external revision. Therefore, the answers given here, on number of plots etc. might be modified during 2019-2020.
- Forest management and damage are important issues for the European scale monitoring.

- We think that any changes in the Manual should be done with the maximum preservation of the adopted methodological approaches for samplings and assessments in the Level II sample plots.
- Harmonized approach is needed. We should distinguish between:
  - guidelines what to do (in case of forest disturbance or cut)
  - additional data to be reported at plot level.
- We believe that this questionnaire and the four identified practical challenges are useful for the future monitoring activity in the Level II plots.
- Due to changes in forestry there is an increasing problem to find homogenous forest stands of 50 by 50 meters with a convenient buffer zone. The increasing variability of forests will be another challenge for the close future. The idea of a European gradient of highly harmonized core plots in the most representative (managed) forest ecosystems would be nice, but it is hardly to be realized without any co-financing.
- With regard to the future, we are already facing critical issues in some Level II areas due to biotic and abiotic damage (related above all to climate change) since last year.