Guidance note on site selection

Support to Member States regarding the monitoring of effects of air pollution on ecosystems according to
Article 9(1) of the NEC Directive (Directive (EU) 2016/2284)

Ruta Landgrebe
Aaron Best
Felicity Hayes
Ulf Stein
Graham Harker
Hannes Schritt
Laurens Duin
Samantha Deacon

14 February 2022

FINAL

Ecologic Institute

Contact

Aaron Best
Senior Fellow
Ecologic Institute
Pfalzburger Straße 43/44
10717 Berlin

E-Mail: aaron.best@ecologic.eu

Ecologic Institute: Science and policy for a sustainable world

Ecologic Institute is an independent, academic think tank for environmental research and policy analysis. Since our founding in 1995, Ecologic Institute has been dedicated to improving environmental policy, sustainable development and policy practice. Through findings and ideas Ecologic Institute helps to mainstream environmental issues into other policy areas. Strengthening the European and international dimensions in research, education and environmental policy discourses is a key priority. Ecologic Institute has offices in Berlin and Brussels.

Today more than 100 employees work for Ecologic Institute. Our colleagues come from over 25 countries. Offering diverse expertise and skills, our experts cover the entire spectrum of environmental policy, sustainable development and socio-ecological research in inter- and transdisciplinary projects. Our staff researches, supports and evaluates national, European and international political processes and brings together actors from science, politics and practice. The results are in-depth analyses and practical recommendations. In cooperation with leading American and German universities, the Institute is also active in education.

Ecologic Institute is a private, non-profit institution financed through its project work. Funding partners include the European Commission, the European Parliament, the German Federal Ministry for the Environment, the German Federal Ministry of Education and Research, the German Federal Environment Agency and various foundations.

Ecologic Institute is a member of the Ecological Research Network (Ecornet).

Ecologic Institute is a registered charity. Donations are tax deductible.

Further information: www.ecologic.eu

Specific Contract No 07/0201/2020/837661/SFRA/ENV.C3 concluded with the European Commission Framework Contract No EEA/ACC/18/001/LOT 2 concluded with the European Environment Agency and the European Commission

Contents

List of Figures

List of Tables

List of Boxes

1 Purpose of this guidance

This Guidance Note on Site Selection provides advice for harmonising and enhancing the networks for monitoring air pollution impacts on ecosystem, under Directive (EU) 2016/2284, Article 9 (the NEC Directive). This Guidance Note on Site Selection aims to facilitate adequate and efficient technical implementation of the legal obligation in Article 9 of the NEC Directive to ensure that the monitoring of negative impacts of air pollution upon ecosystems is based on a network of sites that is representative of Member States' freshwater, natural and semi-natural habitats and forest ecosystem types, taking a cost-effective and risk-based approach.

The guidance on how sites are selected is voluntary for the Member States to apply in accordance with their own circumstances. It is intended to help Member States meet their reporting requirements and improve monitoring in future reporting cycles. The use of this guidance should contribute to building a representative network of ecosystem monitoring sites at EU level.

This guidance builds on already existing guidance and on reporting tools previously developed to fulfil the requirements of Article 9 of the NEC Directive. It uses the lessons learnt during the first NEC Directive ecosystem reporting round (in 2018 and 2019) and is aimed at remediating the shortcomings identified then. The document is also informed by Member State and expert feedback. This includes feedback collected in an October 2021 workshop on the suitability and feasibility of the site selection approach to fulfil the legal requirements of the NEC Directive, Article 9. It can be used for setting up a new monitoring network or expanding/improving an existing network so as to identify the most appropriate locations to undertake monitoring.

This Guidance Note on Site Selection is a component of the reporting toolbox, which also includes the reporting template.

Annex 1 contains a collection of the most relevant information related to site selection from the documents and information sources most relevant to the NEC Directive.

2 Structure of this guidance

The approach described in this document follows the legal requirements of the NEC Directive. The document also provides additional recommendations that can help Member States improve their monitoring beyond the legal requirements (e.g. cost-efficiency considerations).

The Guidance Note is divided into two main parts, covering terrestrial and freshwater ecosystems respectively. The document provides both general instructions that apply widely for site selection across ecosystem types, as well as additional instructions specific to different ecosystem types.

The terrestrial ecosystem types to be monitored are:

- **Forests and Woodlands** (this type of ecosystem belongs to the group of natural and semi-natural habitats);
- **Grasslands, Heathland and Shrub, and Wetlands** (these three types of ecosystems pertain to the group of (non-forest) natural and semi-natural habitats); and
- **Cropland** (as this type of ecosystem is a managed system it has the most significant deviations from the general instructions)

The freshwater ecosystem types to be monitored are:

- **Rivers and Lakes**.

This guidance describes how differing levels of monitoring intensity can be developed when building an ecosystem monitoring network. The guidance and reporting template refer to Level 1 and Level 2 monitoring sites as well as core and non-core parameters. The reporting template and the text in this guidance also mention monitoring sites under other programmes (i.e. Water Framework Directive, Habitats Directive, AAQ Directive).

The Level 1 and Level 2 terminology relates to the intensity of monitoring at the sites, with Level 2 sites having more parameters measured than Level 1 (see Section 3.3.4 for the details on two-level monitoring and core vs. non-core parameters).

3 Site selection – terrestrial ecosystems

The site selection guidance builds on **three criteria: (1) representativeness, (2) risk-based approach, and (3) cost-effectiveness.**

3.1 Representativeness of the monitoring network

This section describes two approaches to site selection that can be used either alone or together. A grid-based approach is the preferred approach assuming that the resources are available to fulfil the criteria. In applying the principles in this guidance, national experts can exercise their best judgement in line with available resources. This could include bringing the principles of each approach together in a blended site-selection strategy.

Approach 1: Grid-based approach

The monitoring network should be based on EMEP grids to define a minimum number of sites (see Figure 1 and Figure 2). When deciding on the density of sites, a density of one monitoring site per 150 km x 150 km grid is a recommended minimum. A density of one site per 50 km x 50 km grid would be aspirational where funds permit. **Member States should select at least one site for each ecosystem type in a grid square.** The size of the ecosystem does not matter as long as it is large enough to be monitored adequately, i.e. to make measurements and take samples over a long period of time (e.g. 50 years) without affecting the integrity of the ecosystem. For example, it is impossible to take lots of soil cores away from a small field or wetland area without destroying the habitat.

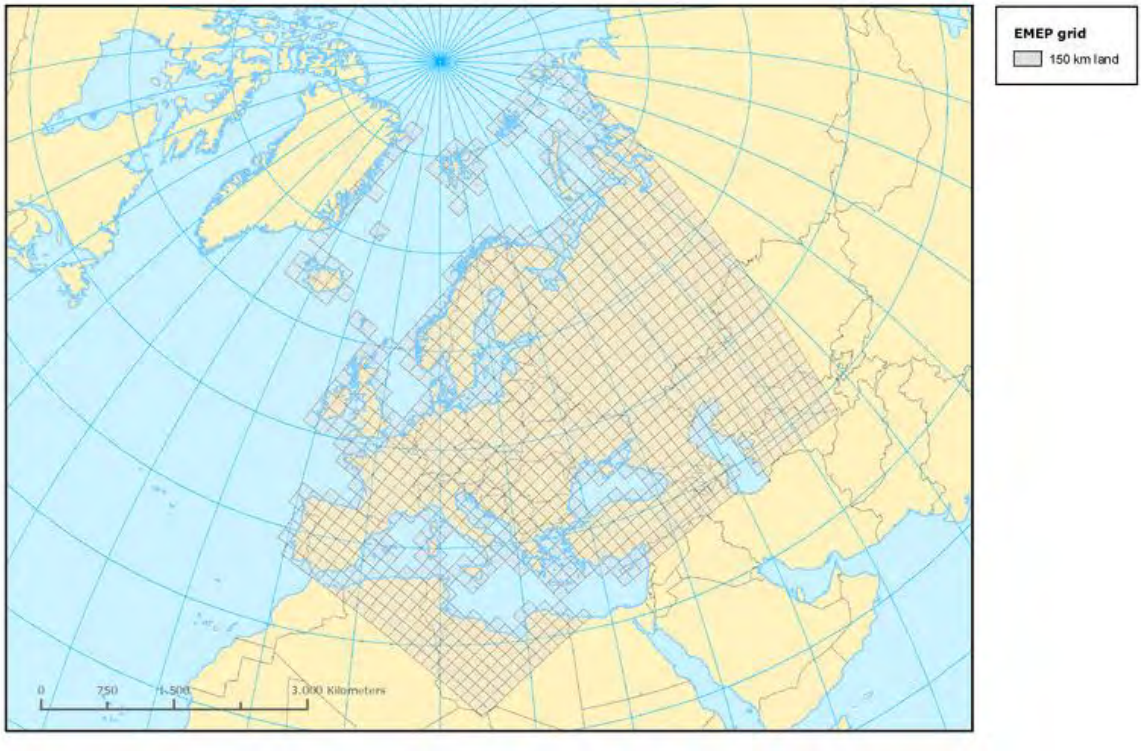
For EMEP grids covering more than one country, the country with more than 50% of the grid in its territory should establish a monitoring site. This recommendation is however not suitable for some small countries, where it would result in under representative monitoring of their territory. In such cases, small countries should prioritise representative monitoring.

When applying the grid-based site selection for ecosystems, this should be done at EUNIS level 1 (e.g. there should be one grassland site per grid square). For any ecosystem type, if locations with sensitive species or habitats exists within the grid square, one of these locations should be selected for a monitoring site. EUNIS Levels 2 or 3 can be used to select the sensitive habitats.

An application of the spatial grid over the entire territory of the country is scientifically the best option (see box below). In line with their particular environmental conditions and budgetary contexts, Member States could selectively adjust the grid sizes used as a means of ensuring that the method remains affordable while not losing on its benefits.

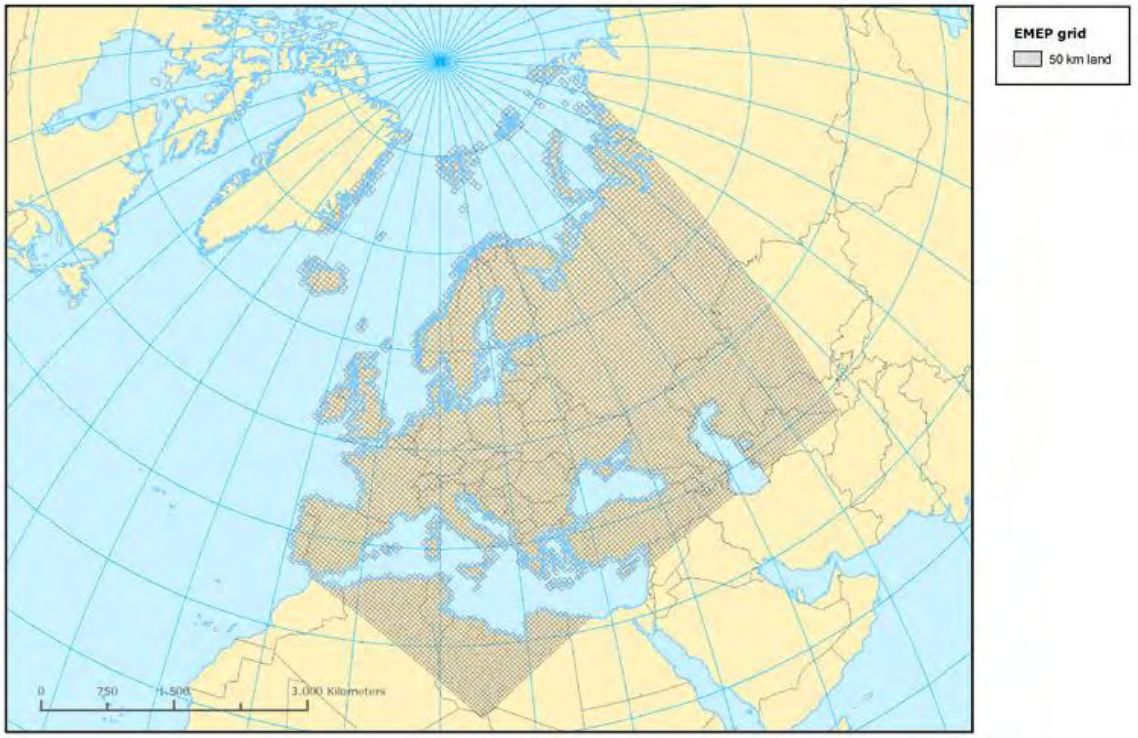
Justification for selecting the grid-based approach: Observations at individual points that are organised in regular grids are a common scientifically approved approach to assess impacts across pollution gradients and describe the distribution and status of geographical phenomena (e.g. vegetation, soils). They can be used to take systematic samples and to analyse the interrelationships between human pressures (e.g. air pollution) and the environment. They would cover the regional differences, the most important natural environmental and spatial conditions found in a Member State (e.g. gradients, including key climatological parameters like precipitation and temperature, hydrological parameters and soil alkalinity). The individual points do not reflect administrative or ecological boundaries and may be used for spatial aggregations and interpolations. Its key strength is that it is normally easier to implement than simple random sampling while offering good representativeness.

Figure 1. EEA reprojected EMEP grid (150*150 km2 land) for analyses on air emissions covering Europe



Source: EEA (2009a)

Figure 2. EEA reprojected EMEP grid (50*50 km2 land) for analyses on air emissions covering Europe



Source: EEA (2009b)

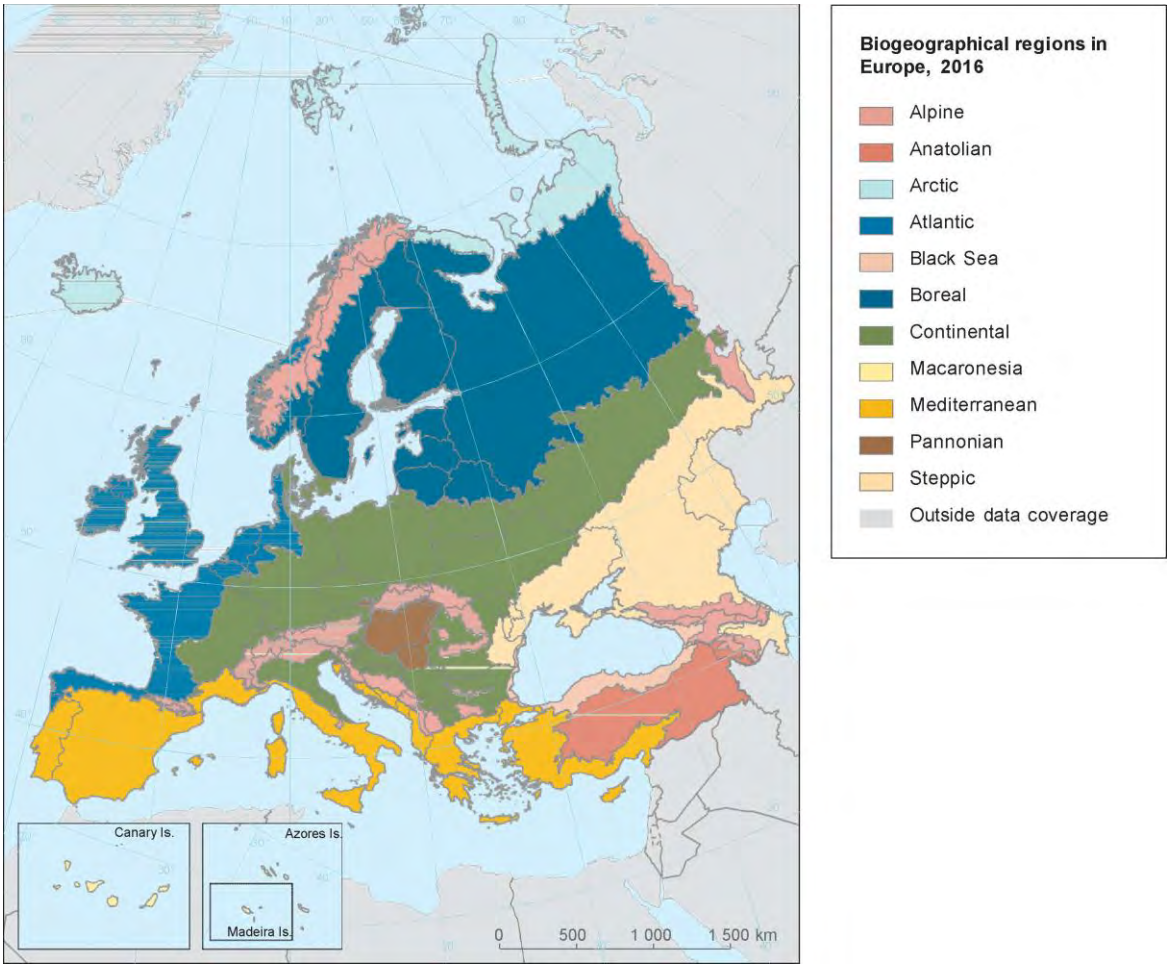
Approach 2: Approach based on biogeographical regions and pollution levels

If using a grid-based approach is not feasible for establishing a suitable network of monitoring sites, a more targeted site-selection approach based on a consideration of ecosystems in biogeographical regions and the ecosystems' exposure to air pollution levels is recommended. **Member States should select at least one site for each ecosystem type found within a biogeographic region.** Selected sites should represent the range of pollution pressures across the Member State and should cover all biogeographic regions present in the Member State. It is strongly recommended to monitor all ecosystem types relevant to the NEC Directive[1] and present in each Member State. The number of monitoring sites per ecosystem type should increase with the size of the MAES ecosystem type area. However, it does not need to be fully proportional. For sensitive ecosystems and cases where particular ecosystems are prevalent in only a few Member States (rather than across the whole EU region), the density of monitoring of those ecosystems in the relevant Member States should be greater than the average density of monitoring sites within those Member State. This would ensure that greater emphasis is given to rare and/or sensitive ecosystems.

The following figure provides a map of biogeographical regions in Europe.

[1] Please see Section 2 for the list of relevant ecosystem types.

Figure 3. Map of biogeographical regions in Europe



Source: EEA (2016). Link: https://www.eea.europa.eu/data-and-maps/data/biogeographical-regions-europe-3

The following box provides an overview of how the biogeographical regions relevant to the NEC Directive are distributed in the EU-27.

Biogeographical regions relevant to the NEC Directive: Alpine, Atlantic, Boreal, Continental, Mediterranean, Pannonian, and Steppic.

Number of biogeographical regions per Member State	Member States and corresponding biogeographical regions
4 biogeographical regions each	Romania (Alpine, Continental, Pannonian, Steppic) France (Alpine, Atlantic, Continental, Mediterranean)
3 biogeographical regions each	Croatia (Alpine, Continental, Mediterranean) Germany (Alpine, Atlantic, Continental) Italy (Alpine, Continental, Mediterranean) Spain (Alpine, Atlantic, Mediterranean) Sweden (Alpine, Boreal, Continental)
2 biogeographical regions each	Austria (Alpine, Continental) Belgium (Atlantic, Continental) Bulgaria (Alpine, Continental) Czechia (Continental, Pannonian) Denmark (Atlantic, Continental) Finland (Alpine, Boreal) Poland (Alpine, Continental) Portugal (Atlantic, Mediterranean) Slovakia (Alpine, Pannonian) Slovenia (Alpine, Continental)
1 biogeographical region each	Cyprus (Mediterranean) Estonia (Boreal) Greece (Mediterranean) Hungary (Pannonian) Ireland (Atlantic) Latvia (Boreal) Lithuania (Boreal) Luxembourg (Continental) Malta (Mediterranean) Netherlands (Atlantic)

Sources for a Member States to find relevant information: A Member State could use the 'land cover and change statistics 2000-2018) (EEA, 2019), which includes land cover maps https://www.eea.europa.eu/data-and-maps/dashboards/land-cover-and-change-statistics. This interactive EEA data viewer on land cover allows for continuous comparability. A Member State can also use the national land cover data.

The following box shows the share of each Member States' total territory that is covered by those MAES ecosystem types relevant for the NEC Directive.

Relevant MAES ecosystem types: six major categories of ecosystem types are relevant for the NEC Directive for the EU-27: Grasslands, Cropland, Forests and Woodlands, Heathland and Shrub, Wetlands, and Rivers and Lakes.

MAES (%) for EU-27 (The MAES initiative: Mapping and Assessment of Ecosystems and their Services)

	Cropland	Grassland	Heathland and shrub	Inland wetlands	Rivers and lakes	Woodland and forest	Marine inlets and transitional waters	Sparsely vegetated land	Urban	Total
Total	**43,23**	**9,04**	**1,03**	**0,27**	**0,94**	**32,88**	0,50	1,57	4,83	**100,00**
Austria	23,50	15,71	2,34	0,25	0,86	44,35	0,00	7,06	5,94	100,00
Belgium	45,46	11,50	0,52	0,27	0,54	20,52	0,23	0,04	20,91	100,00
Bulgaria	48,12	7,18	0,21	0,09	0,88	38,20	0,02	0,48	4,82	100,00
Croatia	34,75	9,45	1,94	0,34	0,99	47,38	0,02	1,30	3,83	100,00
Cyprus	47,43	2,84	16,92	0,05	0,25	20,57	0,21	2,22	9,50	100,00
Czechia	46,35	10,73	0,03	0,14	0,74	35,30	0,00	0,01	6,71	100,00
Denmark	70,91	2,16	1,14	1,19	0,94	11,93	3,22	0,25	8,26	100,00
Estonia	24,82	7,46	0,22	4,74	4,58	55,74	0,04	0,10	2,29	100,00
Finland	8,28	0,07	2,08	6,28	9,44	71,82	0,04	0,59	1,41	100,00
France	43,23	17,61	1,88	0,16	0,65	27,98	0,78	1,71	6,00	100,00
Germany	38,71	18,25	0,26	0,32	1,15	30,48	1,37	0,10	9,37	100,00
Greece	37,75	8,47	17,98	0,18	0,94	28,21	0,47	2,72	3,29	100,00
Hungary	57,24	9,93	0,00	0,93	1,91	23,48	0,00	0,03	6,48	100,00
Ireland	12,39	54,97	1,76	13,91	1,69	10,29	1,18	1,35	2,46	100,00
Italy	50,45	3,90	3,85	0,06	0,74	29,65	0,49	5,29	5,56	100,00
Latvia	29,72	9,93	0,00	2,52	2,02	53,63	0,00	0,10	2,08	100,00
Lithuania	51,49	6,97	0,04	0,87	1,97	34,58	0,59	0,06	3,43	100,00
Luxembourg	36,91	15,64	0,00	0,02	0,35	36,51	0,00	0,00	10,57	100,00
Malta	51,70	0,00	15,24	0,00	0,00	0,65	0,09	2,43	29,90	100,00
Netherlands	34,76	26,26	1,03	1,23	8,02	8,02	6,55	0,38	13,75	100,00
Poland	49,70	9,04	0,02	0,36	1,52	32,88	0,24	0,05	6,21	100,00
Portugal	44,35	3,83	7,72	0,07	0,94	36,65	0,88	1,50	4,07	100,00
Romania	45,77	13,41	0,29	1,22	1,40	31,87	0,33	0,14	5,57	100,00
Slovakia	41,62	6,03	0,31	0,08	0,67	44,97	0,00	0,24	6,08	100,00
Slovenia	28,97	6,24	0,97	0,13	0,42	58,36	0,04	1,35	3,52	100,00
Spain	45,52	9,07	13,11	0,04	0,64	26,43	0,25	2,25	2,70	100,00
Sweden	8,25	1,02	6,13	6,69	8,19	65,60	0,09	2,50	1,53	100,00

	Cropland	Grassland	Heathland and shrub	Inland wetlands	Rivers and lakes	Woodland and forest	Marine inlets and transitional waters	Sparsely vegetated land	Urban	Total
Low	8,2	-	-	-	-	0,7	-	-	1,4	100,0
High	70,9	55,0	18,0	13,9	9,4	71,8	6,5	7,1	29,9	100,0
25% Q1	15,7	13,7	4,5	3,5	2,4	17,8	1,6	1,8	7,1	-
50% Q2	31,3	27,5	9,0	7,0	4,7	35,6	3,3	3,5	14,2	-
75% Q3	47,0	41,2	13,5	10,4	7,1	53,4	4,9	5,3	21,4	-
100% Q4	62,7	55,0	18,0	13,9	9,4	71,2	6,5	7,1	28,5	-

Source: Based on the 'land cover and change statistics 2000-2018) (EEA, 2019), https://www.eea.europa.eu/data-and-maps/dashboards/land-cover-and-change-statistics

Source for a Member State to find relevant information:

A Member State could use the 'land cover and change statistics 2000-2018 (EEA, 2019), https://www.eea.europa.eu/data-and-maps/dashboards/land-cover-and-change-statistics. This interactive EEA data viewer on land cover and land cover change statistics allows continuous comparability. A Member State can also use the national land cover data.

An explanation on how the Mapping Europe's ecosystems is done, https://www.eea.europa.eu/themes/biodiversity/mapping-europes-ecosystems

Maps of areas showing the distribution of ecosystems can be useful when selecting monitoring sites, see https://www.eea.europa.eu/themes/biodiversity/mapping-europes-ecosystems

3.2 Risk-based approach applied to a representative monitoring network

The NEC Directive does not provide a formal definition of risk-based approach. In developing this guidance, the relevant risks to consider can be found in the following areas, which are each considered to be at higher risk of air pollution impacts:

- **Areas with high pollution pressure** - areas with deposition rates of acidifying and/or eutrophying substances and/or concentration levels of ozone where critical loads (eutrophication, acidification) and critical levels (ozone) are already exceeded (the exceedance of the critical load and flux based critical level takes into account the pollution pressure and the sensitivity of the ecosystem); and
- **Sensitive areas** - areas with representative/sensitive habitats and/or species in each ecosystem type.

Acidification due to sulphur emissions is likely to be less prevalent than eutrophication or acidification due to nitrogen emissions as sources of nitrogen pollution are more abundant (i.e. including road traffic and agricultural emissions).

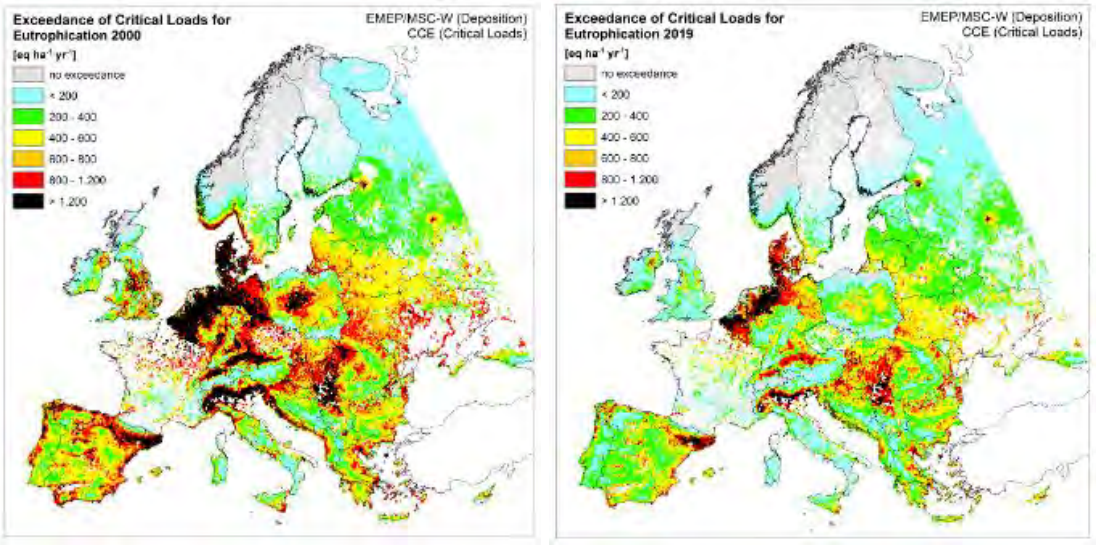
In order to monitor these areas effectively, an approach that also incorporates available background sites (including pristine areas) is presented below. Where a pollution pressure is hardly present in a Member State, monitoring of its impact indicators is not suggested (impact is unlikely to be detectable where the pollution pressure is absent). However, all core parameters should be monitored at the background sites.

3.2.1 Selecting sites in areas with air pollution pressure

Where resources are limited, the priority is to have more sites in heavily polluted areas and a minimum of one site in pristine/cleaner areas. It is preferable to monitor where effects are likely to be present. Background sites with low deposition rates or ambient air concentration values are, however, valuable for long-term comparisons.

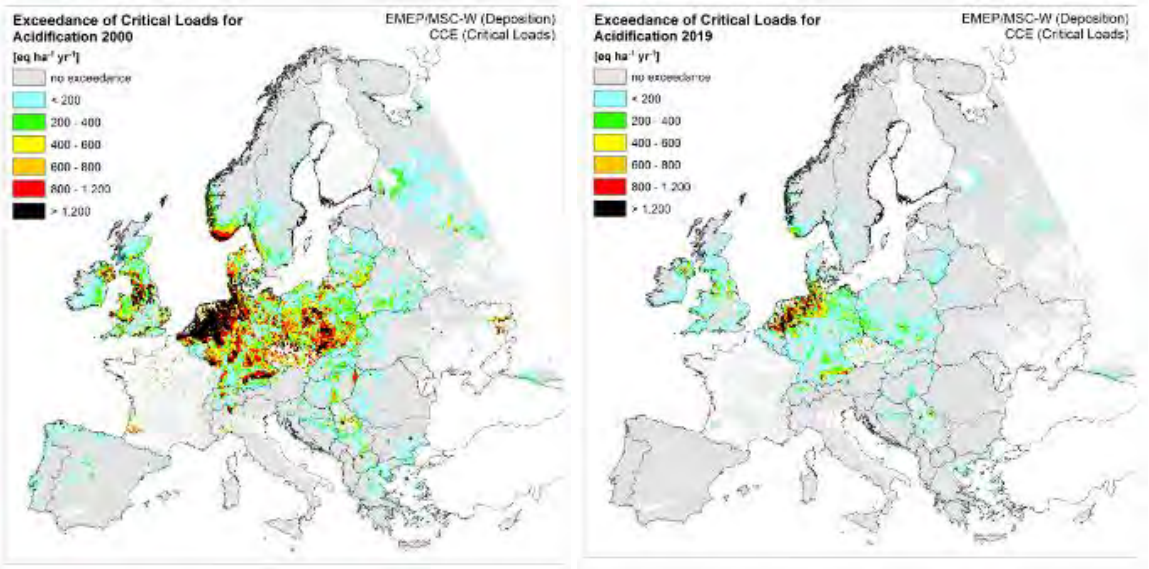
The locations of the monitoring sites should be selected in a way that ensures the site is sensitive to the pressure in question and to allow the impacts of aerial deposition from other pressures to be distinguished. The impacts should be readily identifiable. Member States should look for sites with exceedance of critical loads, which shows the risk of impacts. The following figure shows the exposure of ecosystems in Europe to eutrophication.

Figure 4. Exceedance of critical load for eutrophication for the years 2000 and 2019



Source: Norwegian Meteorological Institute (2021).

Figure 5. Exceedance of critical load for acidification for the years 2000 and 2019



Source: Norwegian Meteorological Institute (2021).

Whilst pollution pressures are likely to diminish over time due to the effects of the NEC Directive and other policies to reduce emissions, reducing the number of monitoring sites due to reducing pressures is not recommended, as it is very important to monitor the recovery of the ecosystem to evaluate the effectiveness of the pollution reductions measures.

The following box provides more detailed information on critical levels and loads and where pollution effects are most likely.

More info: Ecosystems most sensitive to air pollution effects will have the lowest critical levels and loads and the impacts will be highest in those locations where the critical levels and loads are most exceeded. These locations are likely to be those where the impacts of air pollution are most discernible. High nature value areas could be one of the options for locating such a site.

Monitoring where air pollution effects are most likely to be discernible is not specifically related to the proximity to a specific pollutant source but rather related to either locations where pollution pressure is high or where habitats and/or species sensitive to acidification, eutrophication or ozone effects are present. For instance, wet deposition depends on rainfall patterns rather than local pollution sources and the only other pollution sources would be direct emissions to land or water. The obvious source of nitrogen concentrations in cropland soil is fertiliser application rather than air pollution deposition, which is why cropland sites only consider ozone damage, which is discernible from other pollution pressure sources.

Background sites with low deposition rates or ambient air concentration values could provide a valuable long-term comparison to the more polluted sites. Member States should place them in pristine areas or far from direct human disturbance. Protected areas are good candidates for such sites and the AAQ Directive provides guidance for siting **background** monitoring sites away from the direct influence of pollution sources (thus, the AAQ background site guidance could be useful for identifying suitable monitoring locations for NECD ecosystem monitoring). Pristine areas are arguably more vulnerable to change, as other more polluted sites might have changed already. It is relevant to incorporate background sites into the ecosystem monitoring network for all terrestrial and freshwater ecosystems apart from cropland. If the situation allows, it is recommended to set a minimum of one background site per ecosystem as a counterpart to representative sensitive habitats in more polluted areas where air pollution effects are likely to be present.

The following box provides information sources that Member States may find useful for identifying sites using a risk-based approach.

Sources for Member States to find relevant information:

For areas with high air pollution levels: data are available from the Air Convention Meteorological Synthesizing Centre - West (MSC-W) under EMEP (https://www.emep.int/mscw/index.html).

For background sites: Natura 2000 areas set in line with the Habitats Directive, nationally designated areas, other protected sites; background sites set in line with the AAQ Directive. The AAQ Directive provides criteria for the location of monitoring sites to avoid measurements being undertaken in locations directly impacted by local pollutant emission sources. Where possible, monitoring sites should avoid the direct influence of local pollution sources.

Maps of areas showing exceedance of critical loads (https://www.eea.europa.eu/data-and-maps/figures/exceedance-of-critical-loads-of) or the exposure of Europe's ecosystems to acidification, eutrophication and ozone (for ozone, https://www.eea.europa.eu/data-and-maps/indicators/exposure-of-ecosystems-to-acidification-15/assessment) can be useful when selecting monitoring sites. For ozone, the link provides data in terms of AOT40; if exceedance data in terms of PODy are available then these should be used to refine the location of ozone sensitive areas.

Additional information on critical loads for eutrophication and acidification is available from the Air Convention Coordination Centre for Effects (CCE), including revisions for 2022: https://www.umweltbundesamt.de/en/Coordination_Centre_for_Effects

3.2.2 Selecting sites in areas with sensitive habitats and/or species

A Member State should choose the location of monitoring sites according to how sensitive habitats and/or reference species are to air pollution. The ecosystem monitoring networks should represent typical habitats and/or reference species that are sensitive to air pollution, i.e. those with the lowest critical levels/loads and predicted impacts that are readily identifiable via measurement or observation. It will likely be the case that implementation of this principle will be only partially doable, as for several habitat types and reference species types it is not yet known if they are sensitive or not.

Member States should use the EUNIS habitats to Level 3 when selecting sites. The EUNIS classification scheme is hierarchical and covers all of Europe. Relationships between EUNIS habitats and other habitat classifications are available from the EUNIS website (see Maes et al. 2013 for linkages between MAES ecosystem typology the Corine Land Cover level classes and EUNIS Habitat classes).[2] In particular, all habitats of the EU Habitats Directive are cross-referenced to EUNIS habitats. Sites can be classified based on samples of between 1 m^2 and 100 m^2. Reference species can be attributed to respective EUNIS classes which are requested in the reporting template. Natura 2000 sites designated for the protection of Annex I habitats[3] could be considered as a priority for selection. High nature value areas could be one of the options to locate such a site. The presence of invasive exotics species should be avoided if they significantly modify the physico-chemical or biological characteristics of the habitat.

More info: The identification of ozone-sensitive communities is only partially developed. A database identifying ozone-sensitive communities contains good representation from those within EUNIS code E (Grasslands), with Heathlands, scrub and tundra (EUNIS code F, henceforth described as ‘‘Heathlands’’) and Mires, Bogs and Fens (EUNIS code D), having the next highest representation (EEA Website; EEA 2021). Less than five communities within the database were representatives of Coastal habitats (EUNIS Code B), Inland unvegetated or sparsely vegetated habitats (EUNIS Code H) and Regularly or recently cultivated agricultural, horticultural and domestic habitats (EUNIS Code I, henceforth described as ‘‘Cultivated land’’).” Furthermore, a representative ozone-sensitive species list is in development by the ICP Vegetation and will be published in 2021. By way of example, it may include ozone-sensitive species representing trees, wildflowers and grasses.

It is important to note that some habitats are poorly represented in the relevant literature (Mills et al. 2006, page 740; ICP Vegetation 2017, page 39). The Manual on Modelling and Mapping states that relative sensitivities have been derived for around 100 species which accounts for about 2% of (semi-)natural vegetation species, excluding forests: “The (semi-)natural vegetation type includes all vegetation not planted by humans, excluding forests, but influenced deliberately or inadvertently by human actions (Di Gregorio & Jansen, 2000). This vegetation type is the most florally diverse of those considered –– there are 4000+ species of (semi-)natural vegetation in Europe – making the generalisations needed for setting critical levels difficult. Although response functions and relative sensitivities have been derived for >100 species (Hayes et al. 2007; Bergmann et al. 2015), at least 98% of (semi-)natural species remain untested” (ICP Vegetation 2017, page 39). The information on responses of vegetation to SO_2 has not been updated for a very long time (more than 20+ years). Therefore, there is little available information on the identification of SO_2-sensitive communities. For example, the Manual on Modelling and Mapping (ICP Vegetation 2017, page 5, Table III.1: ‘Critical levels for SO_2 (µg m-3) by vegetation category’ refers only to the broad vegetation groups, practically representing ecosystem types (i.e. Cyanobacterial lichens, Forest ecosystems, (Semi-)natural,

[2] European Environment Agency (European Topic Centre on Biological Diversity) associated a more detailed description of species and habitat types under EUNIS classification with MAES ecosystems typology, that is based on CORINE land cover data and introduces a spatial dimension. This allows the use of data resulting from reporting on species and habitat types for building statistics, indicators and maps on the ecosystem level (EEA 2017; Roscher et al. 2015).

[3] Annex I of the Habitats Directive covers natural habitat types of community interest whose conservation requires the designation of special areas of conservation.

and Agricultural crops). Critical loads of acidity are available, which comprise acidifying S and N for soils. The acidity critical loads data were last revised in 2004 in UK and sensitive habitats include acid grassland, calcareous grasslands, dwarf shrub heath, bog, montane, coniferous woodland and deciduous woodland, although not all habitats have been comprehensively tested for their sensitivity (Hall 2018; Hall et al. 2018). The European critical loads have been updated in 2017 and recently in 2021 (CCE Status Report 2017; CCE Status Report 2021 (not published)).

Another approach in relation to selecting/defining acidification/acid sensitive areas is taken by Spain. The definition of acid sensitive areas in Spain are determined by the type of lithology in each corresponding basin and in line with the exceedances of critical loads of acidification (CCE Status Report 2017). Therefore, in Spain, the areas potentially sensitive to acidification are found mainly in the western area, and in the mountain areas of crystalline lithology in the north-east (Pyrenees), in small basins in the centre/north-east (Iberian Range) and in the south-east (Sierra Nevada and coastal basins). The rest of the country is covered with damping lithology (for example, calcareous, evaporite, sedimentary mixture).

When assessing the nitrogen-sensitivity of communities[4] of plant species, there are different amounts of information for the different community types, which means that for some ecosystems there is high confidence about the sensitivity to nitrogen deposition, but less confidence for others. In many cases the changes observed in response to increased nitrogen deposition include changes in species composition and increased N leaching. When mosses and lichens are present, these can decline sharply with N deposition. 'Grasslands and tall forb habitats', 'heathland, scrub and tundra habitats', 'mire, bog and fen habitats' and 'coastal habitats' all contain communities sensitive to N deposition (Bobbink et al. 2010). In Bobbink et al. (2010) there is a list of empirical critical loads of N for natural and semi-natural ecosystems (structured following EUNIS classification) that can be used to identify nitrogen sensitive ecosystems. An update to empirical critical loads is due to be published in 2022 by the CCE (Task Force on Modelling and Mapping).

The following box provides sources where Member States can obtain relevant information on areas with sensitive habitats and/or species.

Sources for Member States to find relevant information:

The Member States should look for information on what sensitive habitats are found in their territories and the relevant abundance of these, so that they could have a good idea about what is representative, and what is more rare. An example of where this information can be found is the harmonised land cover map, where vegetation types are identified by their EUNIS Code (EEA Website, http://eunis.eea.europa.eu/). The map dataset contains information down to EUNIS level 3 for specific habitat types and has been compiled by the Stockholm Environment Institute from existing digital and paper sources including the European Environment Agency (EEA) Corine Land Cover 2000, SEI Land European Cover Map (2002 Revision), FAO Soil Map of the World, EEA European Biogeographical regions (2005). Alternatively, information is available from the most recent Corine land-cover map (https://land.copernicus.eu/pan-european/corine-land-cover/clc2018).

For the selection of sites according to known sensitive species, the Interpretation Manuals could be used. The Interpretation Manual of European Union Habitats - EUR28 (2013) aims to help clear any ambiguities in the interpretation of the Annex 1 of the Habitats Directive by developing common definition for all habitat types. Alternatively the habitat descriptions could be used as in the Interpretation Manual of the habitats listed in Resolution No. 4 (1996) listing endangered natural habitats requiring specific conservation measures (2019). The EUNIS habitat classification gives example species and typical species for each habitat.

[4] A community is a group of different species that share a habitat.

3.3 Cost-effective approach applied to a representative monitoring network

In developing this guidance, the following approaches are considered as providing cost effectiveness: 1) coordination with other EU monitoring programmes (incl. the Ambient Air Quality Directive (AAQ Directive), the Water Framework Directive and the Habitats Directive), and where appropriate, making use of data collected under those programmes; 2) if appropriate, coordinating with the Air Convention monitoring, and making use of data reported to the ICPs; 3) if appropriate, coordinating with the EU and national research infrastructures, such as eLTER at the EU level and national research institutions, and making use of data; 4) applying a tiered (two level) approach at NEC Directive sites, wherein some sites monitor fewer parameters; and 5) reactivation of currently inactive sites.

3.3.1 Coordination with other EU monitoring programmes

The purposes of the various EU monitoring frameworks are quite different, which leads to the complexity of harmonising monitoring efforts in compliance with the various EU directives. Member States have developed different monitoring programmes or have adapted previously existing monitoring schemes to include relevant aspects of, for instance, the Habitats Directive, which, due to the heterogeneity of approaches may complicate a harmonised approach for directly using data for the NEC Directive reporting.

However, the Habitat Directive and AAQ Directive do monitor air pollution relevant pressures and parameters with direct and indirect relevance for the NEC Directive.

For building and/or refining the NEC Directive monitoring network, Member States could therefore consider the relevant information on ecosystems' conservation status according to the Habitats Directive, aiming to select representative, permanent monitoring sites. The Habitats Directive has a sophisticated and well-developed monitoring network with sites both within and outside protected areas.

The AAQ Directive sites in or near urban areas should not be used for NEC Directive Article 9 purposes. However, in order to benefit from monitoring being undertaken via other frameworks, AAQ Directive **background** sites could be used for NEC Directive ecosystem impacts reporting purposes (pollutant concentration parameters) as AAQ Directive background sites should be sufficiently remote from local pollutant sources so as not to be influenced by them (see References, Box 8).

To use AAQ Directive pollution concentration monitored data in lieu of monitoring the parameters again at a NEC Directive ecosystem impact monitoring site, the two monitoring sites should be in locations with similar pollution levels. The pollution levels are influenced by the proximity to local pollution sources, site elevation and local climatic conditions such as rainfall patterns. These factors mean that the two monitoring sites are likely to be relatively close together, i.e. within 5°km of each other. This will help ensure that the monitored ecosystem impacts relate to the monitored air pollution levels.

Note on data collection: In line with the principle of cost effectiveness, the data already obtained under other EU monitoring programmes can be included in the NEC Directive ecosystem monitoring reporting, provided that the parameters definitions and units for the collected data match the NEC Directive parameters and units. Undertaking additional data collection for NEC Directive parameters at the monitoring sites of other EU monitoring programmes could be considered as a possibility where found

useful for resource efficiency, or as part of an integrated monitoring approach. This could save labour costs for sampling and partly also for analysis.

3.3.2 Coordination with other monitoring programmes – the Air Convention monitoring

The ICPs under the Air Convention largely align with monitoring requirements under the NEC Directive, which is why they formed the basis of the suggested parameters under Annex V of the NEC Directive (please note that not all Member States participate in the ICPs). The Member States participating in the ICPs monitoring frameworks can leverage the work done in this context to the extent it is compatible with the ecosystem monitoring requirements under the NEC Directive.

The ICP monitoring methodology is likely the best way to achieve a higher level of standardisation and comparability, since the ICP protocols (ICP Forests in particular) are already applied and a majority of the NEC Directive reporting sites belong to the ICP monitoring network, as the first reporting cycle showed, especially for some Member States.

ICP Vegetation does not define fixed plots for ozone injury and other general vegetation assessments at a systematic country level. Plots are generally located near to the participating universities and institutes. Similarly, for sampling mosses for nitrogen, metals and other pollutants, the locations and densities of the plots sampled is determined by each participating country. There is guidance that there should ideally be at least one sample per 50 km x 50 km grid-square for moss (ICP Vegetation, 2020).

ICP Integrated Monitoring, which monitors both terrestrial and freshwater ecosystems, works on a water catchment basis. It carries out simultaneous measurement of physical, chemical and biological properties of an ecosystem over time (long-term perspective) and across compartments at the same location (cross-media flux approach). It usually uses one intensive monitoring site per ecosystem type in a small catchment. If a site meets the criteria mentioned above for site selection, it can be used. However, the network design should not consist entirely of all proximate sites from a few catchments, as this will bias the representativeness for the whole country (nugget effect)[5].

3.3.3 EU and national research infrastructures

There are also research institutions that can contribute to the Member States' ecosystem monitoring under the NEC Directive. In addition to providing data, national research institutions can provide expertise for specific ecosystem monitoring questions. However, research projects may have limited continuity of data and a narrow focus, limiting its ability to provide representative ecosystem monitoring of use to Member States for the monitoring under the NEC Directive.

The long-term ecological research infrastructure of eLTER, which is being implemented by the EU and almost all EU-27 Member States, could be a promising contributor. It is linked to existing monitoring sites and a potentially cost-effective approach (for further information, see https://elter-ri.eu/). The site provides a catalogue (https://deims.org/) that could be useful for countries in selecting sites as well as a map indicating intensively equipped sites (https://deims.org/map/).

[5] The nugget effect is a function of the clustering of certain attributes (e.g. like clustering of particular minerals in a nugget). This clustering effect can cause biases in data (overestimation if the clustered attributes are sampled; underestimation if the cluster is missed in the sampling).

3.3.4 A tiered (two level) approach

This guidance and the reporting template refer to two levels of monitoring with different monitoring sites for each level:

- Level 1 sites, spatially broader but with less parameters measured;
- Level 2 sites, with more intensive and in-depth monitoring, with more parameters measured.

This approach is similar to the one of ICP Forests and ICP Integrated Monitoring, and can be used as a cost-effective way of balancing breadth and depth in monitoring. Please note that he Level 1 terminology used in this guidance does not refer to the specific Level I sites existing under other monitoring frameworks (e.g. ICP Forests Level I sites).

Types of parameters

- **Core parameters -** Core parameters are those parameters most important to collect (includes the Level 1 subset of core parameters).
- **Non-core parameters -** Non-core parameters provide **extra 'depth'**, i.e. they provide additional scientific data but are generally more time consuming or more expensive to collect data on.

Types of sites

- **Level 1 sites –** Level 1 sites conduct the minimum recommended monitoring covering the subset of core parameters that are easier to collect data on). Level 1 sites provide spatially broader (but less intensive) monitoring than Level 2 sites. Level 1 sites could be upgraded to Level 2 in the future, supporting a step-wise approach to increased monitoring.
- **Level 2 sites –** Level 2 sites conduct the recommended monitoring covering core parameters and potentially non-core parameters.
- **Monitoring sites under other programmes -** Additional sites from other monitoring programmes can provide supplementary information (any parameter type available: core or non-core). Note: urban locations are normally not advisable to use for the NEC Directive Article 9 monitoring purposes.

Table 1 provides a schematic overview of the parameter coverage of Level 1 and Level 2 sites.

Table 1. NEC Directive monitoring sites – monitoring levels

	Level 1 sites	Level 2 sites	
Core parameters *Most important to monitor*	✓	✓	Subset of core parameters easier to monitor
	✓	✓	
	✓	✓	
	✓	✓	
		✓	
		✓	
		✓	
		✓	
Non-core *Provide additional scientific depth*		✓	Generally more time consuming or expensive to monitor
		✓	
		✓	
		✓	
		✓	

3.3.5 Reactivation of currently inactive sites

For a cost-effective approach, reusing currently inactive sites might be promising. Member States usually have inactive sites with information on the suitability/surrounding of a site in that area and partly still existing technical equipment that might make it possible to reactivate those sites cost-effectively. Nevertheless, it should be verified whether the inactive sites comply with the representativeness requirement and the risk-based approach. In addition, they should have a good accessibility. Another aspect to be taken into account is the continuation of a site use in the case of vegetation loss (e.g. forest fires – becoming temporarily inactive) or in the case of land use change.

3.4 Specific considerations for specific terrestrial ecosystem types

3.4.1 Forests and woodlands

The recommended site selection approach for forests and woodlands builds on the general terrestrial ecosystem guidance above. This subsection lists the differences to the general site selection approach.

For the NEC Directive purposes, the definition of the ecosystems is the one provided under the MAES classification: “Woodland and forest are areas dominated by woody vegetation of various age or they have succession climax vegetation types on most of the area supporting many ecosystem services” (MAES et al. 2013).

Representativeness of the monitoring network

The general guidance for terrestrial ecosystems describes two approaches to ensuring representativeness: 1) a grid-based approach; and 2) an approach based on biogeographical regions and pollution levels. For ecosystem monitoring of forests and woodlands, Member

States could choose either of these approaches. In addition, following the recommendations of ICP Forests regarding specific criteria for site selection could be useful. Specifically, the criteria from ICP Forests Manual "Part II Basic design principles" are relevant for forests and woodlands site selection under the NEC Directive. Box 1 provides these ICP Forests criteria.

Box 1. Specific criteria for site selection – ICP Forests

Section 4. Location of measurement and sampling, Sub-section 4.1.2.5 Level II buffer zone (page 7):

The buffer zone is an area surrounding the Level II plots designated to ensure plot protection against direct influence of nearby paths, roads and disturbances. The size and shape of the buffer zone depends on local conditions. However, it must be large enough to protect the plot from direct disturbances and – at the same time – still be characterized by the same plot conditions in terms of aspects, slope, canopy cover and soil condition.

Section 4. Location of measurement and sampling, Sub-section 4.2.2.2 Selection of sites (page 10):

Plots are selected on a preferential basis taking into account:

1: Ecological and logistic issues: The situation shall be as homogeneous as possible (regarding e.g. tree species, stand type and site conditions within the plot). However, the more homogeneous the plot, the higher is the chance its homogeneity will decrease with time as result of different factors (Palmer 1993). Plots should be accessible to allow routine operations;

2. The importance of forest ecosystems within a country: One important selection criterion is that the Level II plots in a country should be located in such way that the most important forest species and most widespread growing conditions in the country are represented. In order to facilitate data analyses; it is advisable to give priority to replicates within the same forest ecosystem type, rather than spreading plots over a huge variety of forest types;

3. The existence of data series and the importance of their continuation: Whenever possible, plots should be selected which have been monitored during the last years. The great advantage of existing data on air quality and meteorological parameters from nearby stations should be taken into consideration whenever establishing Level II plots.

Source: The ICP Forests Manual. Part II Basic design principles for the ICP Forests monitoring networks (versions 2016). Available at https://www.icp-forests.org/pdf/manual/2016/ICP_Manual_2017_01_part02.pdf

Risk-based approach applied to a representative monitoring network

For forest ecosystems, Member States should follow the general terrestrial ecosystem guidance regarding the selection of sites in areas of air pollution pressures as well as the selection of sites in areas with sensitive species to acidification, eutrophication and ozone effects.

Cost-effectiveness approach applied to a representative monitoring network

Coordination with other monitoring programmes – the Air Convention ICPs

Of the Air Convention ICPs, ICP Forests is the relevant programme for the forest and woodlands ecosystem. The ICP Forests monitoring methodology—both site selection and data collection on parameters—is a good option to achieve a higher level of standardisation and comparability. In the proposed revised NEC Directive reporting template for ecosystem monitoring, ICP Forests protocols are recommended to be used for nearly all the terrestrial parameters. For this reason, submission of data already collected at ICP Forests sites is a cost-effective option for Member States for their NEC Directive ecosystem monitoring.

A tiered (multi-level) approach

ICP Forests uses two monitoring intensity levels: large-scale Level I monitoring and intensive Level II monitoring. This approach is in line with the two-level approach outlined in the general terrestrial ecosystem guidance above. For monitoring forests and woodland ecosystems under the NEC Directive, ICP Forests Level I and Level II sites existing in Member States are recommended as the basis for selecting Level 1 and Level 2 terrestrial sites.

Application of site-selection guidance in forest ecosystems – illustrative examples

The following two figures provide illustrative examples of site selection using the grid-based approach (Figure 6) and approach based on biogeographical regions and pollution levels (Figure 7), respectively.

Figure 6. Grid-based approach in forest ecosystems (illustrative example)

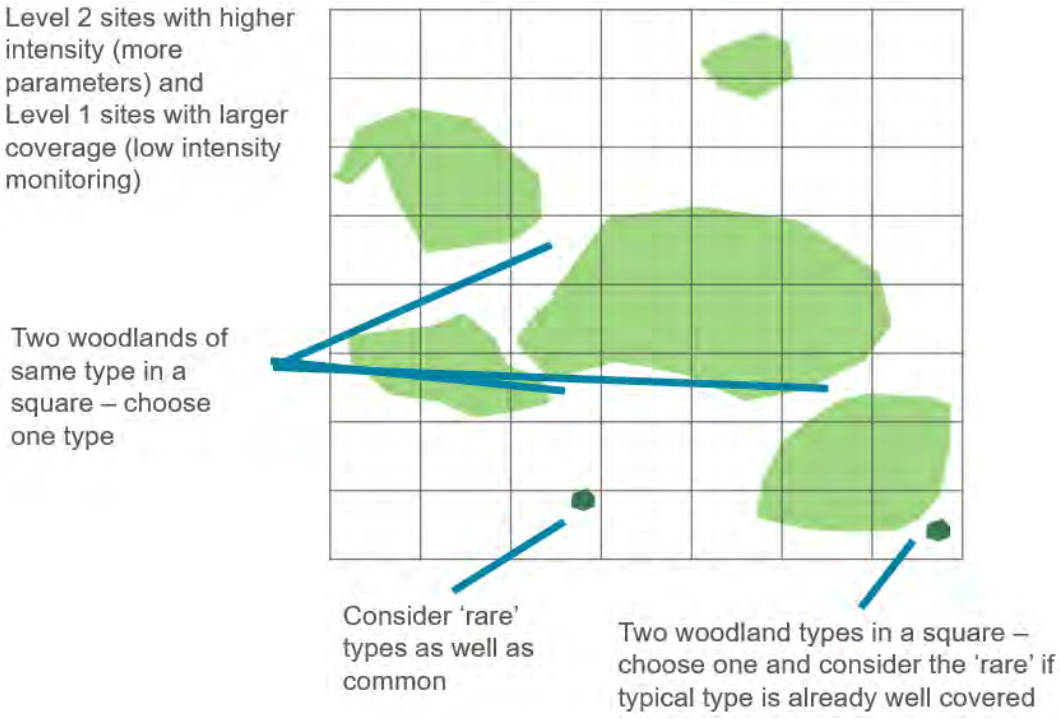
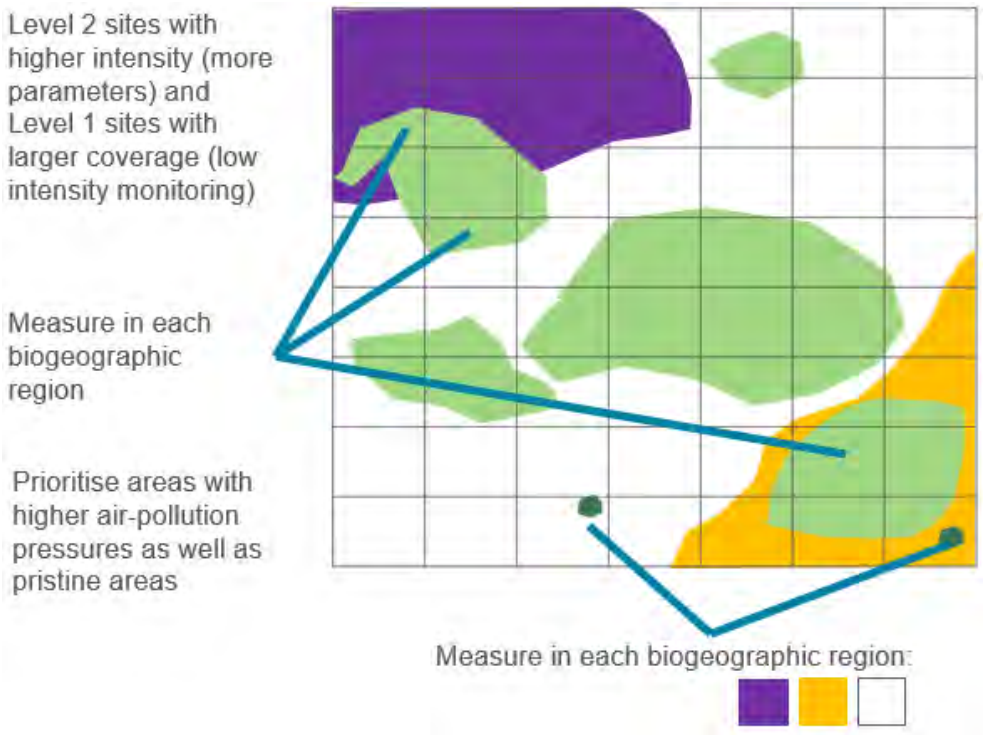


Figure 7. Approach based on biogeographical regions and pollution levels in forest ecosystems (illustrative example)



3.4.2 Grasslands, heathland and shrub, and wetlands

The recommended site selection approach for grasslands, heathland and shrub, and wetlands builds on the terrestrial ecosystem guidance above. This subsection lists the differences to the general site selection approach.

For the NEC Directive purposes, the definition of the ecosystems is the one provided under the MAES classification:

- "Grassland covers areas dominated by grassy vegetation (including tall forbs, mosses and lichens) of two kinds – managed pastures and (semi-)natural (extensively managed) grasslands."
- "Heathland and shrub are areas with vegetation dominated by shrubs or dwarf shrubs. They are mostly secondary ecosystems with unfavourable natural conditions. They include moors, heathland and sclerophyllous vegetation."
- "Inland wetlands are predominantly water-logged specific plant and animal communities supporting water regulation and peat-related processes. This class includes natural or modified mires, bogs and fens, as well as peat extraction sites" (MAES et al. 2013).

Representativeness of the monitoring network

The general guidance for terrestrial ecosystems describes two approaches to ensuring representativeness: 1) a grid-based approach; and 2) an approach based on biogeographical regions and pollution levels. For ecosystem monitoring of grasslands, heathland and shrub, and wetlands, Member States could choose either of these approaches. **In addition, it is recommended that Member States use the adapted recommendations of ICP Forests, as**

described below, regarding specific criteria for site selection for the group of (non-forest) natural and semi-natural habitats.

For ozone - The available ICP Vegetation ozone manuals focus mainly on surveys of ozone injury on crops, but do not establish site selection design. **Using the guidance of ICP Vegetation regarding selection of ozone sensitive crops is recommended.**

Recommendations of ICP Forests adapted to grasslands, heathland and shrub, and wetlands ecosystems

ICP Forests offers a suitable basis for grasslands, heathland and shrub, and wetlands site selection for ecosystem monitoring under the NEC Directive. The ICP Forests guidelines are relevant because they are the result of many years experience of ecosystem monitoring. They provide a minimum level of harmonisation, which aids data comparability and interpretation. The monitoring was designed to give periodic overviews of forest health, with intensive monitoring plots established to perform integrative studies and to investigate potential drivers of change. It is appropriate to adapt the forest ecosystem site selection methodology for other vegetation, taking into account the differences in vegetation height, species composition and spatial diversity. In addition to guidance of monitoring ozone injury in forest sites, the ICP Forests Manual Part VIII Assessment of ozone injury (versions 2020, see the box below for references) offers specific **criteria for the establishment of the 'Light Exposed Sampling Site'.** These criteria, although aimed at non-forested areas aligned to ICP Forests sites, **cover the following points that ensure that the forest does not have an influence** and which can be aligned to the grasslands, heathland and shrub, and wetlands needs. In addition, guidance on general site selection is useful (The ICP Forests Manual. Part II Basic design principles for the ICP Forests monitoring networks (versions 2016)). The relevant points and principles are:

a) Identify a suitable area of grasslands, heathland and shrub, and wetlands with homogenous plant growth and without direct influence of nearby paths, roads and disturbances. Trees might be present in the ecosystem, but the site should distinctly belong to grasslands, heathland and shrub, and wetlands ecosystems and not to 'forest'.

b) Ensure that the site is located at least 500 metres away from the forest. The purpose of this is to ensure that the forest does not have a large influence on the vegetation to be monitored. NB: for heathland and wetland, there may be patches of such vegetation located less than 500 metres from forest.

c) Ensure that the plot conditions are similar across the sampling site in terms of aspect, slope, vegetation characteristics (i.e. height) and soil condition.

d) Select a minimum of five sampling quadrats of 1 x 1 m randomly, were vegetation is recorded representative for the different habitat types (to link to EUNIS classification) or in order to assess the presence and absence of ozone visible injury on the respective species.

e) If ozone monitoring already occurs at a grasslands, heathland and shrub, or wetlands site: identify an area within 500 metres radius of this ozone monitoring location. NB: this approach is relevant only if the ozone monitoring occurs over vegetation with similar characteristics (i.e. height) to the vegetation that is proposed to be monitored, and within the identified radius. Ozone monitoring sites located under the tree canopy in a <u>forest</u> are <u>not</u> relevant for positioning non-ozone monitoring sites in a grasslands, heathland and shrub, or wetland.

The above points are based on ICP Forests criteria for the 'Light Exposed Sampling Site' sites and ICP Forests Manual "Part II Basic design principles", please see the annex for the relevant excerpts.

The following box provides sources where Member States can obtain relevant information on site selection which could be aligned for the grasslands, heathland and shrub, and wetlands ecosystem needs.

ICP Forests manuals:

The ICP Forests Manual. Part II Basic design principles for the ICP Forests monitoring networks (versions 2017). Available at https://www.icp-forests.org/pdf/manual/2016/ICP_Manual_2017_01_part02.pdf

The ICP Forests Manual. Part VIII Assessment of ozone injury (versions 2020). Available at https://storage.ning.com/topology/rest/1.0/file/get/8951994869?profile=original

ICP Integrated Monitoring recently developed the „IM light" concept which could prove helpful to many countries (ICP IM Light 2021). It targets non-forest ecosystem monitoring and adopts a tiered approach to simplify the monitoring with three levels of monitoring intensity. While the Level 3 uses the current ICP IM monitoring strategy and manual, the Level 2 and Level 1 focus on other ecosystem types than forests. Level 2 uses seven larger measurement groups with monthly resolution; and Level 1 uses three larger measurement groups with annual resolution. All three levels measure chemical parameters, water budget and biological parameters.

Risk-based approach applied to a representative monitoring network

Selecting sites in areas with high air pollution

Regarding acidification and eutrophication of grasslands, heathland and shrub, and wetlands ecosystem monitoring, Member States should follow the terrestrial ecosystem guidance (see Section 3.2.1).

As regards ozone, information on how to calculate and map the potential ozone uptake by (semi-)natural vegetation (pertaining to the temperate perennial grasslands and the Mediterranean annual pastures) and tree species (Beech and birch, Norway spruce, Deciduous oaks and Evergreens) in different biogeographic regions is available from Chapter 3 of the Mapping Manual (ICP Vegetation, 2017). This manual also provides information on how to determine exceedance of species-specific critical levels or vegetation-type critical levels of ozone for the (semi-)natural vegetation and tree species.

Selecting sites in areas with sensitive habitats and species

Regarding acidification and eutrophication, Member States should select the areas for grasslands, heathland and shrub, and wetlands based on the general terrestrial ecosystem guidance. Regarding ozone, following the recommendations of ICP Vegetation regarding selection of ozone sensitive plant species could be useful. The available ICP Vegetation ozone manuals (ICP Vegetation 2017 and 2018) focus mainly on surveys of ozone injury on grassland species, small trees/shrubs or heathland which are known to be ozone sensitive in terms of visible injury (ICP Vegetation 2018) and forest trees and (semi-)natural vegetation (ICP Vegetation 2017). ICP Vegetation 2018 suggests to choose, when possible, from the list below, with photographs of distinctive ozone-injury symptoms for these species that can be found on the ICP Vegetation smartphone app as well as on the ICP Vegetation webpage (https://icpvegetation.ceh.ac.uk/get-involved/ozone-injury).

Shrubs

- Hawthorn (*Crataegus monogyna*); Honeysuckle (*Lonicera implexa*) and Wayfaring tree (*Viburnum lantana*).

Grassland

- Clovers: White clover (*Trifolium repens*) and Red clover (*Trifolium pratense*).
- Other grassland herbs: Ribwort plantain (*Plantago lanceolata*); Brown knapweed (*Centaurea jacea*) and Black knapweed (*Centaurea nigra*).

Heathland

- Mediterranean macchia: Strawberry tree (*Arbutus unedo*); Myrtle (*Myrtus communis*); Mastic tree (*Pistacia lentiscus*) and Turpentine tree (*Pistacia terebinthus*).

Wetlands (APIS Website)

- Common cottongrass (*Eriophorum anugustifolium*) shows ozone-induced visible leaf-injury (Mortensen 1994; Hayes et al. 2006); Peat mosses (*Sphagnum -angustifolium*, *-magellanicum* and *-papillsum*) have ozone damage manifesting as decreased chloroplast area within cells of the capitulum (Rinnan et al. 2004).

Member States can use these vegetation species as a guide to select which species to monitor in different ecosystems.

The following box provides sources where Member States can obtain relevant information on ozone sensitive vegetation.

ICP Vegetation ozone manuals:

ICP Vegetation (2017). Chapter 3. Mapping critical levels for vegetation. Available at https://icpvegetation.ceh.ac.uk/get-involved/manuals/mapping-manual

ICP Vegetation (2018). Recording the presence/absence of ozone injury on Sensitive Ozone Species ('SOS') using the ICP Vegetation smart-phone App. Monitoring Protocol. Available at https://icpvegetation.ceh.ac.uk/sites/default/files/ICPVegetation_OzoneGardensandAppprotocol_2018_Final.pdf

3.4.3 Croplands

The recommended site selection approach for cropland builds on the general terrestrial ecosystem guidance above. This subsection lists the differences to the general site selection approach.

For the NEC Directive purposes, the definition of croplands is the one provided under the MAES classification: "Cropland is the main food production area including both intensively managed ecosystems and multifunctional areas supporting many semi- and natural species along with food production (lower intensity management). It includes regularly or recently cultivated agricultural, horticultural and domestic habitats and agro-ecosystems with significant coverage of natural vegetation (agricultural mosaics)" (MAES et al. 2013).

The Corine Land Cover dataset is important for mapping terrestrial and freshwater ecosystems as well as land use types. Table 2 shows the correspondence between the MAES ecosystem

typology, the Corine Land Cover level classes and EUNIS Habitat classes (based on MAES et al. 2013).[6]

Table 2. Correspondence between MAES ecosystem type and other land cover classification classes (Corine Land Cover (CLC) classes and EUNIS habitat classes)

MAES Ecosystem type	EUNIS Habitat classes Level 1	EUNIS Habitat classes Level 2	CLC Level 1	CLC Level 2	Corine Land Cover (CLC) classes Level 3
Cropland	I Regularly or recently cultivated agricultural, horticultural and domestic habitats	I1 Arable land and market gardens I2 Cultivated areas of gardens and parks	Agricultural areas	2.1.Arable land	2.1.1.Non-irrigated arable land 2.1.2.Permanently irrigated land 2.1.3.Rice fields
				2.2. Permanent crops	2.2.1.Vineyards 2.2.2.Fruit trees and berry plantations 2.2.3.Olive groves
				2.4. Heterogeneous agricultural areas	2.4.1.Annual crops associated with permanent crops 2.4.2.Complex cultivation patterns 2.4.3.Land principally occupied by agriculture, with significant areas of natural vegetation 2.4.4.Agro-forestry areas

Representativeness of the monitoring network

The general guidance for terrestrial ecosystems describes two approaches to ensuring representativeness: 1) a grid-based approach; and 2) an approach based on biogeographical regions and pollution levels.

For croplands ecosystem monitoring, Member States could choose either of these approaches, in accordance with their own circumstances, but they should monitor only impact of ozone on croplands. For croplands, increased nutrient load by fertilisation generally exceeds that from air pollution, therefore the impact of eutrophication and acidification on crops is excluded from monitoring. **In addition, it is recommended that Member States use the following adapted recommendations of ICP Forests regarding specific criteria for site selection for croplands**.

The available ICP Vegetation ozone manuals focus mainly on surveys of ozone injury on crops, but do not establish site selection design. **Recommendations of ICP Vegetation regarding selection of ozone sensitive crops are recommended for use.**

[6] See more explanation in section 3.2.2 Selecting sites in areas with sensitive habitats and/or species.

Recommendations of ICP Forests adapted to croplands

ICP Forests offers a suitable basis for cropland site selection for ecosystem monitoring under the NEC Directive. In addition to guidance of monitoring ozone injury in forest sites, the ICP Forests Manual Part VIII Assessment of ozone injury (versions 2020) offers specific criteria for the establishment of the 'Light Exposed Sampling Site'. These criteria, although aimed at non-forested areas aligned to ICP Forests sites, cover the following points that ensure that the forest does not have an influence and which can be adapted for croplands. In addition, guidance on general site selection is useful (The ICP Forests Manual. Part II Basic design principles for the ICP Forests monitoring networks (versions 2016)). The relevant points and principles are:

a) Ensure that the site is located at least 500 metres away from the forest.

b) Identify a suitable area of cropland with homogenous plant growth and without direct influence of nearby paths, roads and disturbances.

c) Ensure that the plot conditions are similar across the sampling site in terms of aspect, slope, vegetation characteristics and soil condition.

d) Select minimum of five sampling quadrats of 1 x 1 m randomly in order to assess the presence and absence of ozone visible injury on the respective species.

The above points are based on ICP Forests criteria for the 'Light Exposed Sampling Site' sites and ICP Forests Manual "Part II Basic design principles", please see the annex for the relevant excerpts.

For their cropland site selection under the NEC Directive, use of these ICP Forests criteria by Member States is recommended.

The following box provides sources where Member States can obtain relevant information on site selection which could be aligned for the croplands needs.

ICP Forests manuals:

The ICP Forests Manual. Part II Basic design principles for the ICP Forests monitoring networks (versions 2016). Available at https://www.icp-forests.org/pdf/manual/2016/ICP_Manual_2017_01_part02.pdf

The ICP Forests Manual. Part VIII Assessment of ozone injury (versions 2020). Available at https://storage.ning.com/topology/rest/1.0/file/get/8951994869?profile=original

Risk-based approach applied to a representative monitoring network

Selecting sites in areas with air pollution pressure

In case of croplands monitoring, Member States should follow the terrestrial ecosystem guidance on this point, but only for ozone (see Section 3.2.1).

For cropland ecosystems, nutrient load by air pollution is less relevant compared to fertilisation and other measures, therefore, the impact of eutrophication and acidification on crops is excluded from monitoring. However, many crops are sensitive to ozone pollution and the ozone induced leaf injury symptoms can be more distinctive than on many native species, which justifies monitoring of cropland ecosystems.

The highest ozone concentrations are typically in the Mediterranean areas of Europe, and generally lower in the northern part of Europe. While the southern part of Europe is affected by significantly high ozone concentrations during the entire course of the growing season, the northern part might however have spring peaks that occur mostly in the early part of the growing

season (e.g. northern Scandinavia) (Manninen et al. 2009 in Mills and Harmens 2011). However, risk to vegetation from ozone is related to the uptake of ozone through the stomata. This means that risk can also be high when low to moderate ozone concentrations coincide with climatic and other conditions favourable for ozone uptake. The potential for ozone uptake into the crop plants should be considered when using a risk-based approach. Crops that are irrigated are particularly at risk as the high soil moisture can mean that the stomata are open and allow ozone uptake. Information on how to calculate and map the potential ozone uptake by various crops and in different biogeographic regions is available from Chapter 3 of the Mapping Manual (ICP Vegetation, 2017). This manual also provides information on how to determine exceedance of species-specific critical levels of ozone for the crops wheat, potato and tomato.

Selecting sites in areas with sensitive crops

Member States should select the areas for cropland ecosystems based on the crop species that (1) are sensitive to ozone, and (2) has significant economic value in their territories.

For annual and permanent croplands, if locations with crops sensitive to ozone exist in an area being considered for locating a monitoring site, the ozone-sensitive crop locations should be selected for a monitoring site.

For annual cropland, slightly different sites could be used each year due to the rotational nature of agricultural production, but the site monitored should be as close as possible to the previous site (e.g. within 1 km).

From the agricultural production perspective, the southern part of Europe growths a much larger number and variety of crops than other parts of the EU. In addition to cereals that are typical for the northern part of Europe, horticultural crops and irrigated crops should be considered in the southern part of Europe when selecting the crops for ecosystem monitoring when they show sensitivity to ozone.

Using recommendations of ICP Vegetation regarding selection of ozone sensitive crops

Recommendations of ICP Vegetation regarding selection of ozone sensitive crops are useful for NECD monitoring. Member States should select annual and permanent crops on level > 3 of Corine Land Cover class to carry out a monitoring of ozone damage on croplands. Annual crops would be preferable as there is more evidence of ozone impacts (particularly the occurrence of ozone specific visible leaf injury) than for permanent/ perennial crops. The crops should represent ozone sensitive varieties of crops typical for food production in a biogeographical region/Member State, including both intensively managed cropland ecosystems and those with a lower intensity management.

The available ICP Vegetation ozone manuals focus mainly on surveys of ozone injury on crops. ICP Vegetation 2018 suggests to choose when possible from the crops listed below, which are known to be ozone sensitive in terms of visible injury, with photographs of distinctive ozone-injury symptoms for these species that can be found on the ICP Vegetation smartphone app as well as on the ICP Vegetation webpage (https://icpvegetation.ceh.ac.uk/get-involved/ozone-injury).

- Agricultural cereal: Common wheat (*Triticum aestivum*); Durum wheat (*Triticum durum*); Finger millet (*Eleusine coracana*); Pearl millet (*Pennisetum glaucum*); Rice (*Oryzia sativa*) and Maize (*Zea mays*).

- Agricultural non-cereal: Soybean (*Glycine max*); Onion (*Allium cepa*); Alfalfa (*Medicago sativa*); Potato (*Solanum tuberosum*); Peas (*Pisum sativum*); French bean (*Phaseolus vulgaris*) and Common bean (*Phaseolus vulgaris*).
- Fruit crops: Tomato (*Lycopersicon esculentum*); Grape (*Vitis vinifera*); Watermelon (*Citrullus lanatus*); Muskmelon (*Cucumis melo*); Courgette (*Cucurbita pepo*) and Aubergine (*Solanum melongena*).
- Leaf salad crops: Lettuce (*Lactuca sativa*); Spinach (*Spinacia oleracea*); Chicory (*Cichorium intybus*) and Swiss chard (*Beta vulgaris*).
- Cooking herbs: Parsley (*Petroselinum crispum*) and Coriander (Coriandrum sativum).

Crops might be sensitive to ozone in terms of reduced yield quantity and/or quality, reduced root growth, decreased seed production, as well as reduced resilience to other pressures such as drought or pest infections. The majority of crops react to elevated ozone concentrations with reductions in yield, but the significance of the effect varies between crop species and cultivars (Mills and Harmens 2011). However, this information on sensitivity is not available for all crop species, and it is not easy to detect reductions in yield due to ozone in field conditions. Table 3 shows different tolerance of crops yield to ozone (sensitivity is decreasing by descending list), which can also be used as a guide to select which crops to monitor. Note that this list is slightly different to that listed above, because some crops show reductions in yield without showing distinctive ozone-injury symptoms.

Table 3. Grouping of crops by sensitivity of yield to ozone

Sensitive	Moderately sensitive	Tolerant
Peas and beans (including peanut)	Alfalfa	Strawberry
Sweet potato	Water melon	Oat
Orange	Tomato	Broccoli
Onion	Olive	
Turnip	Field mustard	
Plum	Sugar beet	
Lettuce	Oilseed rape	
Wheat	Maize	
Soybean	Rice	
	Potato	
	Barley	
	Grape	

Source: Mills and Harmens (2011), Table 1.

Member States can find a comprehensive list of sensitive annual and permanent crops in Section 4.3 Variation in ozone sensitivity between crops, Table 4.2 in Mills and Harmens (2011).

For annual crops, Member States should consider ozone exposure over all or part of a single growing season. For biennial or perennial crops, Member States should be aware of potential carry-over effects and/or the effects of cumulative exposure to ozone over several growing seasons. The tree crops, i.e. olive, orange, grape and plum, are those best studied to date. For example, the Grape (*Vitis vinifera cv Welschriesling*) showed increased sensitivity to ozone in the third consecutive year of exposure (Mills and Harmens 2011).

The following box provides sources where Member States can obtain relevant information on ozone sensitive crops.

ICP Vegetation ozone manuals:

ICP Vegetation (2020). 'Seeing is Believing' Ozone injury on *Phaseolus vulgaris* (common bean). Bean Biomonitoring Protocol. Available at https://icpvegetation.ceh.ac.uk/sites/default/files/ICP%20Vegetation_Phaseolus%20vulgaris%20protocol%202020.pdf

ICP Vegetation (2018). Recording the presence/absence of ozone injury on Sensitive Ozone Species ('SOS') using the ICP Vegetation smart-phone App. Monitoring Protocol. Available at https://icpvegetation.ceh.ac.uk/sites/default/files/ICPVegetation_OzoneGardensandAppprotocol_2018_Final.pdf

ICP Vegetation (2017). Chapter 3. Mapping critical levels for vegetation. Available at https://icpvegetation.ceh.ac.uk/get-involved/manuals/mapping-manual

Mills, G., Harmens, H. (2011). Ozone pollution: a hidden threat to food security. https://icpvegetation.ceh.ac.uk/sites/default/files/Ozone%20Pollution%20-%20A%20hidden%20threat%20to%20food%20security.pdf

4 Site selection – freshwater ecosystems

The recommended site selection approach builds on **three criteria: (1) representativeness, (2) risk-based, and (3) cost-effectiveness.**

Please note: For the avoidance of repetition, this freshwater ecosystem guidance refers to portions of the terrestrial ecosystem guidance.

4.1 Representativeness of the monitoring network

The terrestrial ecosystem guidance describes two approaches to ensuring representativeness: 1) a grid-based approach; and 2) an approach based on biogeographical regions and pollution levels (see Section 3). In contrast to the approach for terrestrial ecosystem, for freshwater ecosystems, the grid-based approach is replaced with a typology-based approach.

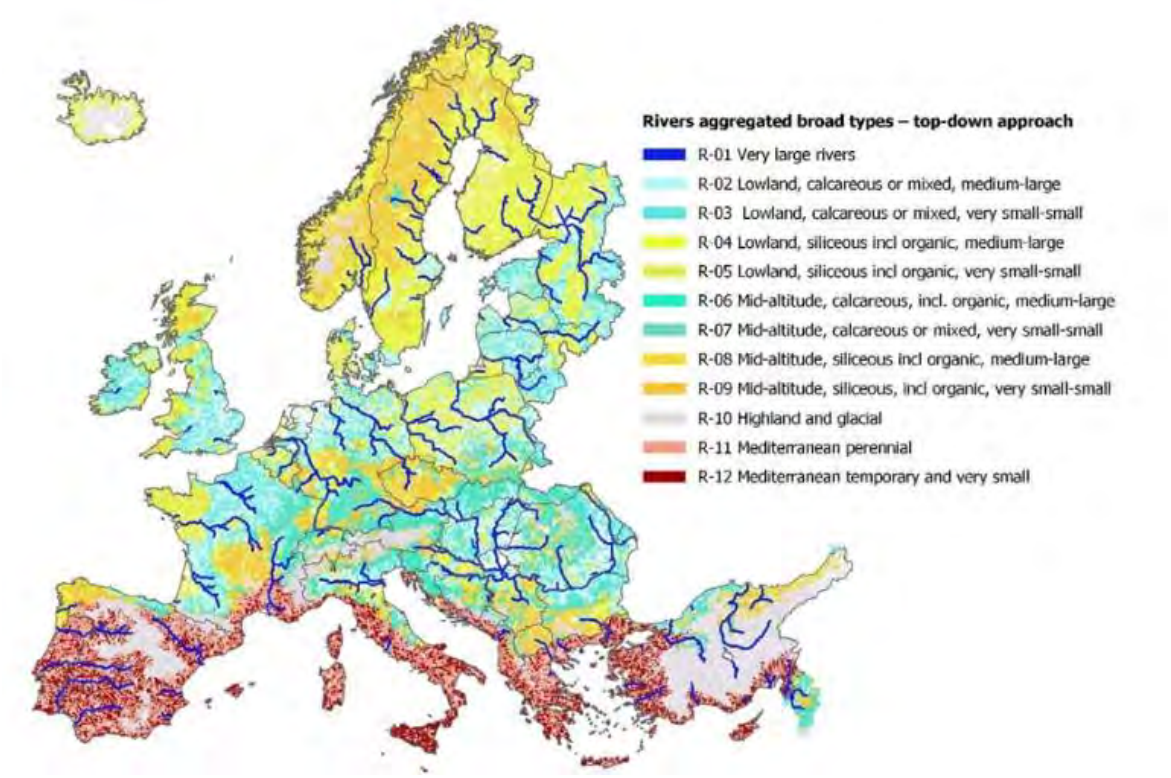
Justification: For freshwater ecosystems, different river and lake types can be determined. The lake and river typologies much better represent the longitudinal and altitudinal characteristics of aquatic systems, and thus, link better to the concept of representativeness of monitoring sites. These river and lake types are amongst other aspects, defined by their chemical-physical characteristics, which corresponds to their sensitivity to air pollution. For example, lowland siliceous lakes are much more sensitive to acidification than lowland calcareous lakes.

For freshwater ecosystem monitoring, Member States should choose an approach based either on 1) **rivers and lakes typology**, or 2) on **biogeographical regions and pollution levels**. In addition, it is recommended to follow the ICP Waters guidance regarding specific criteria for freshwater site selection.

Approach 1: Typology-based approach

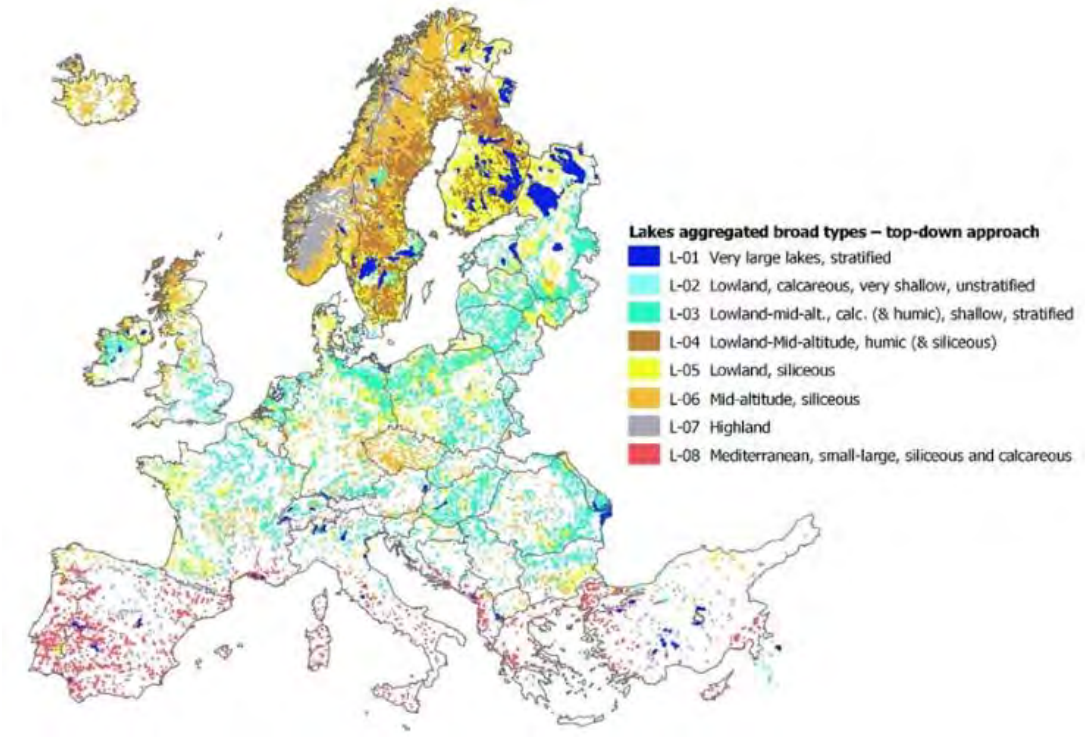
Lyche et al. (2019) introduced an approach to cluster the >1000 national river types and >400 national lake types of the Water Framework Directive to 20 broad river types and 15 broad lake types for Europe (see Figure 8 and Figure 9).

Figure 8. Broad river types in Europe characterized by altitude, size and geology ("Top-down approach")



Source: Lyche et al. (2019).

Figure 9: Broad lake types in Europe characterized by altitude, size, geology and mean depth ("Top-down approach")



Source: Lyche et al. (2019).

The typology-based broad types could be used selecting sites for monitoring of freshwater ecosystems. **A Member State should establish at least one monitoring site in each broad river basin and lake type in its territory.** European Environment Agency provides an overview of relevant broad types in the EU and Member States (EEA tableau).

An application of the typology-based approach is the best option for being representative (see box above). In line with their particular geographical conditions and budgetary contexts, Member States could selectively use their national typologies to further refine the broad type concept for their territory.

Approach 2: Approach based on biogeographical regions and pollution levels

Typically, medium-large rivers and lakes are often already affected by nutrient and acid inputs not related to air pollution. For this type of rivers and lakes it will be difficult to find suitable monitoring sites. Thus, if using a typology-based approach is not feasible to establish a network of monitoring sites, a more targeted site-selection approach based on a consideration of biogeographical regions and the ecosystems' exposure to air pollution levels is recommended. **At a minimum, Member States should select at least one freshwater monitoring site per biogeographical region**, and this site should be able to generate useful monitoring data regarding air pollution impacts on the freshwater ecosystem being monitored. In cases where biogeographic regions contain both rivers and lakes, selecting at least one river site and one lake site is preferable. Ideally, the number of monitoring sites is proportional to the size of a biogeographical area covered in a Member State and selected sites should represent the range of pollution pressures across the Member State. Note that even within the same river and lake

types, the species composition may vary among biogeographical regions. It is therefore important to ensure distribution of monitoring across biogeographical regions.

Please see the terrestrial monitoring guidance for a list of biogeographical regions in each Member State (Section 3.1)

Recommendations of ICP Waters regarding specific criteria for freshwater site selection

Given the similarity in intent for ecosystem monitoring between ICP Waters work and the NEC Directive, ICP Waters offers a suitable basis for freshwater site selection for ecosystem monitoring also under the NEC Directive.

The ICP Waters Manual offer specific criteria for site selection, which covers the following points:

a) Sites should not have impacts from local pollution sources*

b) Sites susceptible to air pollution are preferable

c) Protected areas are valuable for long-term data collection

d) Sites should offer both chemical and biological monitoring

e) A high sampling frequency and sustainability of monitoring should be prioritised over the number of sites

f) Reference sites offering long time series enhance the network

g) Forestry activities should have no major impact on water quality

*Note: in case no potential monitoring site in a Member State fulfils criterium a), Member States should select sites that have the least impact from local pollution sources and that have the best prospects to fulfil this criterium in the future.

For the full ICP Waters explanation of these criteria, please see Box 2.

Box 2. Specific criteria for site selection – ICP Waters Manual 2010

a) The ICP Waters monitoring network should consist, as much as possible, of sites that do not have impacts from local pollution sources (e.g. domestic sewage, industrial waste water, agriculture etc.). ICP Waters is established to monitor effects of long-range transboundary air pollution on surface waters, and a pronounced influence from local sources of pollution in the catchment may lead to misinterpretation of chemical and biological data. Sites should be chosen that represent the diversity of the region (chemically, biologically and geographically);

b) In regions where surface waters exhibit a wide range of acid-sensitivity, the sites should be chosen among the most susceptible to air pollution and with no strong lithological contribution. The aim of the site selection should be to focus primarily on sites that are likely to change in response to air pollution, and secondarily to represent the region as a whole (where possible);

c) Confidence in the future protection of the site from changes in local influences. Very valuable long-term records may be lost due to significant local changes. Areas such as national parks and nature reserves are often well protected from changes and should be considered for sampling sites;

d) Sites should provide the opportunity for both chemical and biological monitoring;

e) A larger number of sites increases the possibilities to make trend tests at a regional scale, but a high sampling frequency should be prioritised to the number of sites. The number of sites should also be balanced against the ability to support the monitoring on a sustainable and long-term basis.

f) As reference sites, sensitive sites in low deposition areas can be used. In high deposition regions, reference sites for acidifications can be selected from sites with moderate buffering capacity, where biological impact from acidification is not found. Sites with long time series of data are preferable if the other main criteria are met.

g) When forestry is performed in the catchment area, the size of the catchment should be large enough in relation to the scale of the forestry activities so that single measures such as clear-cuts will have no major impact on the water quality.

Source: Excerpt from ICP Waters Manual 2010, p. 15

ICP Waters also provides specific site-selection guidance regarding lakes and rivers. This guidance (reproduced fully in Box 3) can also usefully be followed by Member States selecting freshwater sites for ecosystem monitoring under the NEC Directive.

Box 3. Site-selection guidance for lakes and rivers – ICP Waters Manual 2010

Lakes

Drainage lakes (i.e. with an outlet) are best suited for monitoring. Lakes with a moderate water renewal period, approximately one year or less are preferable. Lakes with very long residence times react slowly to changes in deposition of air pollutants and are not good candidates for detecting trends for decade timescales. Lakes should preferably be selected in the headwater part of the catchment, without a larger lake upstream.

Rivers

A small river or brook is preferable. In general, small catchments react more rapidly than large ones to changes in deposition of airborne pollution. However, the site should be large enough to sustain a permanent flow throughout the year. The presence of upstream lakes should be minimal.

In regions with a large number of lakes, two types of river stations can be identified. One type with a large influence of lakes within the catchment which are representative for the region, and one type with a minimum of lake influence which better shows the response of deposition and climate on stream ecology.

Source: Excerpt from ICP Waters Manual 2010, p. 16

4.2 Risk-based approach applied to a representative monitoring network

Member States should follow the terrestrial ecosystem guidance for selecting sites in areas with high air pollution (see Section 3.2.1), while noting that ozone damages are not relevant for freshwater ecosystem monitoring.

4.3 Cost-effective approach applied to a representative monitoring network

4.3.1 Coordination with other EU monitoring programmes

Annex 5 of the Water Framework Directive distinguishes surveillance, operational and investigative monitoring programmes. Among these, the surveillance monitoring sites and to some extent also the investigative monitoring sites of surface water are those of most relevance for site selection under the NEC Directive.

The monitoring network of the Water Framework Directive was not designed specifically to analyse the impacts of air pollution on aquatic ecosystems. Nevertheless, there are a number of Water Framework Directive monitoring sites and some portion of these may fulfil the site-selection criteria for monitoring freshwater ecosystem impacts of air pollution. Sampling sites that were used to define the Water Framework Directive reference conditions can be presumed to be pristine and, thus, represent a promising search backdrop for NEC monitoring site selection.

Member States are encouraged to review their list of existing Water Framework Directive monitoring sites and assess whether they meet the selection criteria (see Section 4.1). An additional verification step for sites meeting the criteria would be an assessment of whether the existing data collection is suitable for the freshwater ecosystem monitoring objectives of the NEC Directive (see reporting template for a list of parameters and protocols). After these two steps, and in case there are suitable sites with suitable parameters, Member States should determine whether it is useful to add additional parameters to comply with the freshwater ecosystem monitoring objectives of the NEC Directive, or to establish new sites meeting the NEC Directive selection criteria.

4.3.2 Coordination with other monitoring programmes – the Air Convention ICPs

Of the Air Convention ICPs, ICP Waters is the relevant programme for the freshwater ecosystem. The ICP Waters monitoring methodology—both site selection and data collection on parameters—is a good option to achieve a higher level of standardisation and comparability. In the proposed revised NEC Directive reporting template for ecosystem monitoring, ICP Waters protocols are recommended to be used for nearly all the freshwater chemical parameters. For this reason, submission of data already collected at ICP Waters sites is a cost-effective option for Member States for their NEC Directive ecosystem monitoring.

4.3.3 A tiered (multi-level) approach

In contrast to the case for the terrestrial ecosystem types, ICP Waters prioritises a higher frequency of sampling over the number of sites. ICP Waters focuses on frequently sampled sites for water chemistry. For further details on the tiered design of the ICP Waters monitoring programme see Box 4. Note: the way ICP Waters defines Level I and Level II sites differs from the Level 1 and Level 2 definitions used in the terrestrial ecosystem site-selection guidance in this document, which are based on the number of parameters and the relative costs of their collection.

Implementing a multi-level approach can be considered by all Member States as part of creating a representative network taking risks and costs into consideration. It should certainly be considered by those countries already implementing this approach in ICP Waters.

Box 4. Design of the ICP Waters Monitoring Programme

The hierarchy of national monitoring programmes is thus reflected in the hierarchy of the ICP Waters programme to deal with:

- Level I: Data from small catchments, monthly or seasonal sampling.
- Level II: Relatively large number of sites with minimum annual sampling frequency.
- Level III: Regional surveys. Sampling of many sites one time in several years.

ICP Waters focuses on Level I, and deals with water chemical data from catchments with a sampling frequency from weekly to seasonal. With the less frequent sampling, the biological aspects become more important as they accumulate the effects of changing water quality in the previous period. Also monitoring of sediments will provide possibilities for a coherent and comprehensive picture of the impact of long-range transboundary air pollution on the freshwater ecosystems.

The Level II and III data are important in particular to illustrate the regional picture of acidification situation and to evaluate the representativeness of the more intensively monitored catchments.

Source: Excerpt from ICP Waters Manual 2010, p. 10

4.3.4 Reactivation of inactive sites

This approach is not considered the most appropriate for freshwaters ecosystem monitoring. Indeed, considering the very large number of monitoring sites already established throughout Europe under the Water Framework Directive and ICP Waters, it is more appropriate to use the existing and active monitoring sites as long as they comply with the site selection criteria for ecosystem monitoring outlined in this guidance. This is especially true when high financial resources would be needed to reactivate inactive sites. However, where inactive sites fulfil site selection criteria and active sites are not considered as appropriate and/or are insufficient, reusing inactive sites might be considered as a cost-effective approach, especially where past data collected at the site is compatible with the current parameter set as a way of establishing longer-term trends.

5 References

Essential references

The NEC Directive: European Commission (2016). Office Journal of the European Union. Directive on the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC. Available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2016.344.01.0001.01.ENG&toc=OJ:L:2016:344:TOC

The NEC Directive is the legal basis for the Member States' reporting requirement. The first deadline for reporting was 1 July 2019.

The Commission Guidance Notice on ecosystem monitoring (2019): European Commission (2019). Communication from the Commission – Commission Notice on ecosystem monitoring under Article 9 and Annex V of Directive (EU) 2016/2284 of the European Parliament and of the Council on the reduction of national emissions of certain atmospheric pollutants (NEC Directive). Published 11 March 2019. Available at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:C:2019:092:FULL&from=EN

The Commission Guidance Notice on ecosystem monitoring (2019) provides detailed guidance to Member States on how to report ecosystem monitoring sites and their collected data, including recommended priority setting of pollutants, ecosystems, impacts and indicators.

The NEC Directive ecosystem website: European Commission (2019). Reduction of National Emissions – Guidance on ecosystem monitoring. Available at: http://ec.europa.eu/environment/air/reduction/ecosysmonitoring.htm

The NEC ecosystem website is an information hub regarding ecosystem monitoring under the NEC Directive.

Reporting template: European Commission (2018). Template NEC Directive Article 10 paragraph 4 (a). Available at: http://ec.europa.eu/environment/air/pdf/template%20NEC%20Article%209%20location%20and%20indicators%20for%2001%20July%202018%20final.xlsx

The reporting template provides a structured and recommended way for Member States to report both mandatory and suggested reporting information. Member States are not required to use the template. Note that this template is being updated for the 2022-23 reporting.

Template guidance: EEA / European Commission (2018). Technical specifications for NEC Article 10 (4a) data requirement on location of the monitoring sites and the associated indicators. Version 17 May 2018. Available at: http://ec.europa.eu/environment/air/pdf/Technical%20Specifications%20NEC%20Article%209%20location%20and%20indicators%20final.docx

The template guidance was provided in 2018 in the context of the first reporting requirement (reporting of monitoring sites) but includes elements relevant to the 2019 reporting also. This guidance applied to the template that was recommended to use for the 2018-19 reporting.

Reportnet: Reportnet – Eionet (2019). European Environment Information and Observation Network. Available at: https://www.eionet.europa.eu/reportnet

Report on Monitoring Sites (2019): WUR (Wageningen Environmental Research). (2019). First Analysis of Ecosystem Monitoring as Required under Article 9 of the NEC Directive. Final report. Reference: 3417/B2017/EEA; Framework Contract EEA/NSS/17/002/Lot 1 July. Available at: https://ec.europa.eu/environment/air/pdf/reduction_reports/Final%20report%20ecosystem%20monitoring%20network%20Nov2019.pdf

This report analyses information provided by Member States in July 2018 in compliance with Article 10(a) of the NEC Directive regarding their respective ecosystem monitoring networks and the indicators and monitoring protocols they intended to use.

Report on Monitoring Data (2020): Best, A., Landgrebe, R., Stein, U., Schritt, H., Duin, L (2020) Analysis of Ecosystem Monitoring Data under Article 9 of Directive(EU)2016/2284: Comprehensive Assessment. Available at https://ec.europa.eu/environment/air/pdf/reduction_reports/NECD-ecosystem-monitoring_2020-07-31-FINAL-REPORT.pdf

A report on monitoring data submitted by Member States in 2019, their analysis and the baseline for future reporting.

The Air Convention: UNECE Convention on Long-Range Transboundary Air Pollution, https://www.unece.org/env/lrtap/welcome.html.html

EU legislation (the underlined title is used in the text)

The National Emission reduction Commitments Directive/The NEC Directive (Directive (EU) 2016/2284): Directive (EU) 2016/2284 of the European Parliament and of the Council of 14 December 2016 on the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2016.344.01.0001.01.ENG&toc=OJ:L:2016:344:TOC

The Ambient Air Quality Directive/The AAQ Directive (Directive 2008/50/EC): Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe, https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1486474738782&uri=CELEX:02008L0050-20150918

The Habitats Directive (Council Directive 92/43/EEC): Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31992L0043

The Water Framework Directive (Directive 2000/60/EC): Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32000L0060

Data source

CCE Status Report (2017). CCE Status Reports. Coordination Centre for Effects (CCE). Available at https://www.umweltbundesamt.de/en/cce-status-reports

EEA Website. EUNIS, the European Nature Information System. Available at https://eunis.eea.europa.eu/

EEA (2021). EUNIS habitat classification. Data. Available at https://www.eea.europa.eu/data-and-maps/data/eunis-habitat-classification-1

EEA (2019). Land cover and change statistics 2000-2018. Available at https://www.eea.europa.eu/data-and-maps/dashboards/land-cover-and-change-statistics

EEA (2017). Linkages of species and habitat types to MAES ecosystems. Data. Available at https://www.eea.europa.eu/data-and-maps/data/linkages-of-species-and-habitat

EEA (2016) Biogeographical regions. Available at https://www.eea.europa.eu/data-and-maps/data/biogeographical-regions-europe-3

EEA (2009a). EEA reprojected EMEP grid (150*150 km^2 land) for analyses on air emissions covering Europe. Available at https://www.eea.europa.eu/data-and-maps/figures/eea-reprojected-emep-grid/emep_150_land.eps

EEA (2009b). EEA reprojected EMEP grid (50*50 km^2 land) for analyses on air emissions covering Europe. Available at https://www.eea.europa.eu/data-and-maps/figures/eea-reprojected-emep-grid/emep_50_land.eps

EEA tableau. Surface water bodies: Broad types. Available at https://tableau.discomap.eea.europa.eu/t/Wateronline/views/WISE_SOW_BroadType/SWB_BroadType_Europe_G?:embed=y&:showShareOptions=true&:display_count=no&:showVizHome=no

ICP Manuals

The manuals and knowledge base of the UNECE Air Convention ICPs (International Cooperative Programmes). The Air Convention was negotiated under the auspice of UNECE (United Nations Economic Commission for Europe). Article 9 of the NEC Directive states that the Air Convention methodologies may be used when collecting and reporting ecosystem-monitoring data.

ICP Forests Manual (2017). Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests. Part II Basic Design Principles for the ICP Forests Monitoring Networks. Section on design principles and site selection. Available at https://www.icp-forests.org/pdf/manual/2016/ICP_Manual_2017_01_part02.pdf (http://icp-forests.net/page/icp-forests-manual)

ICP IM Manual (1998). Manual for Integrated Monitoring. Section 3 Site selection. Available at https://helda.helsinki.fi/handle/10138/242414 (https://www.syke.fi/en-US/Research__Development/Nature/Monitoring/Integrated_Monitoring/Manual_for_Integrated_Monitoring)

ICP IM Light (2021). Extended ICP Integrated Monitoring strategy – An extended monitoring strategy for Integrated Monitoring under the Convention of Long-Range Transboundary Air Pollution. Salar Valinia, David Elustondo, Thomas Dirnböck, Jussi Vuorenmaa, Jesper Bak, Markus Erhard, Martin Forsius, Ulf Grandin & Maria Holmgren. Available at https://www.syke.fi/download/noname/%7B9597D97B-E6E9-4BF5-945D-75108AE951F0%7D/169785

ICP Vegetation (2020). Monitoring of atmospheric deposition of heavy metals, nitrogen and pops in Europe using bryophytes. Monitoring Manual 2020 survey. International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops. Available at https://icpvegetation.ceh.ac.uk/sites/default/files/ICP%20Vegetation%20moss%20monitoring%20manual%202020.pdf

ICP Vegetation (2020a). 'Seeing is Believing' – Ozone injury on Phaseolus vulgaris (common bean). Bean Biomonitoring Protocol. Available at https://icpvegetation.ceh.ac.uk/sites/default/files/ICP%20Vegetation_Phaseolus%20vulgaris%20protocol%202020.pdf

ICP Vegetation (2018). Recording the presence/absence of ozone injury on Sensitive Ozone Species ('SOS') using the ICP Vegetation smart-phone App. Monitoring Protocol. Available at https://icpvegetation.ceh.ac.uk/sites/default/files/ICPVegetation_OzoneGardensandAppprotocol_2018_Final.pdf

ICP Vegetation (2017). Manual on modelling and mapping critical loads & levels. Chapter 3. Mapping Critical Levels for Vegetation. Available at https://icpvegetation.ceh.ac.uk/sites/default/files/FinalnewChapter3v4Oct2017_000.pdf

ICP Waters Manual (2010). ICP Waters Report 105/2010. ICP Waters Programme Manual 2010. Available at https://drive.google.com/file/d/0B_DU7Rk3lFWYQmwzZEZCSnh2VEk/view?resourcekey=0-qV3yQS4dzDj3O4YqQPBpJQ (http://www.icp-waters.no/publications/#icpwmanual)

Works cited

APIS Website. Ozone: Bogs, wetland and heath. APIS, Air Pollution Information System. Available at http://www.apis.ac.uk/ozone-bogs-wetland-and-heath

Arle et al. (2016). Monitoring of Surface Waters in Germany under the Water Framework Directive—A Review of Approaches, Methods and Results. May 2016, Water 8(6):217. DOI: 10.3390/w8060217, License CC BY 4.0.

Bergmann, E., Bender, J., Weigel, H.-J., (2015). Assessment of the impacts of ozone on biodiversity in terrestrial ecosystems: Literature review and analysis of methods and uncertainties in current risk assessment approaches. Part II: Literature review of the current state of knowledge on the impact of ozone on biodiversity in terrestrial ecosystems. Umwelt Bundesamt TEXTE 71/2015, Dessau-Roßlau, Germany. ISSN 1862-4804.

Bobbink, R.; Hicks, K.; Galloway, J.; Spranger, T.; Alkemade, R.; Ashmore, M.; Bustamante, M.; Cinderby, S.; Davidson, E.; Dentener, F.; Emmett, B.; Erisman, J.-W.; Fenn, M.; Gilliam, F.; Nordin, A.; Pardo, L.; de Vries, W.. (2010). Global assessment of nitrogen deposition effects on terrestrial plant diversity: a synthesis. Ecological Applications, 20 (1). 30-59. 10.1890/08- 1140.1

EC Guidance document Nr. 7. European Commission Common Implementation Strategy for the Water Framework Directive (2000/60/EC). Guidance document No. 7.

Ellwanger G, Runge S, Wagner M, Ackermann W, Neukirchen M, Frederking W, Müller C, Ssymank A, Sukopp U (2018). Current status of habitat monitoring in the European Union according to Article 17 of the Habitats Directive, with an emphasis on habitat structure and functions and on Germany. Nature Conservation 29: 57–78. https://doi.org/10.3897/natureconservation.29.27273

Hall, J. (2018). Critical loads of acidity and nutrient nitrogen for UK habitats. Available at https://doi.org/10.5285/299e2779-0787-46bb-9482-03ad474eae27

Hall, J., Rowe, E., Smith, R., Dore, T., Banin, L.F., Levy, P. and Sawicka, K. (2018). Trends Report 2018: Trends in critical load and critical level exceedances in the UK. Report to Defra under Contract AQ0843, CEH Project: NEC05708. Available at https://uk-air.defra.gov.uk/assets/documents/reports/cat09/1905230854_Trends_Report_2018.pdf

Hayes, F., Jones, M.L.M., Mills, G. & Ashmore, M., (2007). Meta-analysis of the relative sensitivity of semi-natural vegetation species to ozone. Environmental Pollution 146, 754-762.

Hayes, F., Mills, G., Williams, P., Harmens, H., Buker, P. (2006) Impacts of summer ozone exposure on the growth and overwintering of UK upland vegetation. Atmospheric Environment 40 4088-4097

Interpretation Manual of European Union Habitats - EUR28 (2013). Available at https://ec.europa.eu/environment/nature/legislation/habitatsdirective/docs/Int_Manual_EU28.pdf

Interpretation manual of the habitats listed in Resolution No. 4 (1996) listing endangered natural habitats requiring specific conservation measures (2019). Available at https://rm.coe.int/interpretation-manual-of-the-habitats-listed-in-resolution-no-4-1996-/168098c68c

Kelleghan, D. B., Hayes, E.T., Everard, M., Curran, T.P. (2019). Mapping ammonia risk on sensitive habitats in Ireland, Science of The Total Environment, 649, 1580–1589. doi: 10.1016/j.scitotenv.2018.08.424

Lyche Solheim, A., Globevnik, L., Austnes, K., Kristensen, P., Jannicke Moe, S., Persson, J., Phillips, G., Poikane, S., van de Bund, W., Birk, S. (2019). A new broad typology for rivers and lakes in Europe: Development and application for large-scale environmental assessments, Science of The Total Environment (697). Available at https://doi.org/10.1016/j.scitotenv.2019.134043

Maes J, Teller A, Erhard M, Liquete C, Braat L, Berry P, Egoh B, Puydarrieux P, Fiorina C, Santos F, Paracchini ML, Keune H, Wittmer H, Hauck J, Fiala I, Verburg PH, Condé S, Schägner JP, San Miguel J, Estreguil C, Ostermann O, Barredo JI, Pereira HM, Stott A, Laporte V, Meiner A, Olah B, Royo Gelabert E, Spyropoulou R, Petersen JE, Maguire C, Zal N, Achilleos E, Rubin A, Ledoux L, Brown C, Raes C, Jacobs S, Vandewalle M, Connor D, Bidoglio G (2013). Mapping and Assessment of Ecosystems and their Services. An analytical framework for ecosystem assessments under action 5 of the EU biodiversity strategy to 2020. Publications office of the European Union, Luxembourg. https://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/pdf/MAESWorkingPaper2013.pdf

Manninen, S., Huttunen, S., Tømmervik, H. et al. (2009). Northern plants and ozone. Ambio 38: 406-412. in Mills and Harmens 2011.

Metzger, M.J., Bunce, R.G.H, Jongman, R.H.G, Mücher, C.A., Watkins, J.W. (2005). A climatic stratification of the environment of Europe. Global Ecology and Biogeography 14: 549-563. DOI link: http://dx.doi.org/10.1111/j.1466-822x.2005.00190.x

Mills, G. and Harmens, H. (2011) Ozone pollution: a hidden threat to food security. Available at https://icpvegetation.ceh.ac.uk/sites/default/files/Ozone%20Pollution%20-%20A%20hidden%20threat%20to%20food%20security.pdf

Mills, G., Hayes, F., Jones, M.L.M., and Cinderby, S. (2006). Identifying ozone-sensitive communities of (semi-)natural vegetation suitable for mapping exceedance of critical levels. Environmental Pollution 146 (2007) 736e743. Available at https://www.sciencedirect.com/science/article/abs/pii/S0269749106002739?via%3Dihub

Mortensen, L. (1994). The Influence of Carbon Dioxide or Ozone Concentration on Growth and Assimilate Partitioning in Seedlings of Nine Conifers. Acta Agriculturae Scandinavica, Section B — Soil & Plant Science 44 157-163

Norwegian Meteorological Institute (2021). EMEP Status Report 1/2021. Transboundary particulate matter, photo-oxidants, acidifying and eutrophying components. Available at https://emep.int/publ/reports/2021/EMEP_Status_Report_1_2021.pdf

Rinnan, R. and Holopainen, T. (2004). Ozone effects on the ultrastructure of peatland plants: Sphagnum mosses, Vaccinium oxycoccus, Andromeda polifolia and Eriophorum vaginatum. Annals of Botany 94 623-634

Roscher, S., Condé, S., Bailly Maitre, J. (2015). Final database on linkages between species/habitat-types and broad ecosystems. ETC/BD report to the EEA. Available at https://www.eea.europa.eu/data-and-maps/data/linkages-of-species-and-habitat/further-documentation/final-database-on-links-between/at_download/file

Wilkins, K., Aherne, J., and Bleasdale, A. (2016). Vegetation community change points suggest that critical loads of nutrient nitrogen may be too high, Atmospheric Environment. Pergamon, 146, 324–331. doi: 10.1016/j.atmosenv.2016.07.016

Annex 1. Site selection – excerpts from and analysis of supporting documents

Annex 1 provides a collection of excerpts and analyses related to site selection approaches from the documents and information sources most relevant to the NEC Directive (Box 5 to Box 11).

Note: bold emphasis has been added to the elements most relevant for shaping the site selection approach in the guidance note

Box 5. The NEC Directive, excerpt of Article 9

Article 9 Monitoring air pollution impacts

1. Member States **shall** ensure the monitoring of negative impacts of air pollution upon ecosystems based on **a network of monitoring sites that is representative of their freshwater, natural and semi-natural habitats and forest ecosystem types, taking a cost-effective and risk-based approach**.

To that end, Member States **shall coordinate with other monitoring programmes** established pursuant to Union legislation including Directive 2008/50/EC, Directive 2000/60/EC of the European Parliament and of the Council (1) and Council Directive 92/43/EEC (2) and, if appropriate, the Air Convention and, **where appropriate, make use of data collected under those programmes**.

In order to comply with the requirements of this Article, Member States may use the optional monitoring indicators listed in Annex V.

2. The methodologies laid down in the Air Convention and its Manuals for the International Cooperative Programmes may be used when collecting and reporting the information listed in Annex V.

3. The Commission is empowered to adopt delegated acts in accordance with Article 16 to amend this Directive with regard to the adaptation of Annex V to technical and scientific progress and to developments within the framework of the Air Convention.

Source: Excerpt of Article 9(1) of the NEC Directive (Directive (EU) 2016/2284). Emphasis (**bold**) added.

Box 6. The Commission Guidance Notice on ecosystem monitoring (2019), excerpt on 'representativeness'

3.2. Ecosystem types

Article 9(1) of the NEC Directive requires that Member States conduct monitoring on the basis of: 'a network of monitoring sites that is representative of their freshwater, natural and semi-natural habitats and forest ecosystem types, taking a cost-effective and risk-based approach'.

There is a large number of ecosystem types distributed throughout Europe with a significant variation in the number of ecosystem types per Member State. While **the network coverage must be representative of the ecosystems existing in their territories**, Member States **should take a cost-effective and risk-based approach** as provided in Article 9(1) of the NEC Directive **when choosing the number and locations of the sites and the kind of indicators monitored**.

A starting point for identifying a representative number of ecosystems and their habitats to be monitored is the number of biogeographical regions in each Member State. The latest classification of the EU's biogeographical regions comprises eleven areas (Alpine, Anatolian, Arctic, Atlantic, Black Sea, Boreal, Continental, Macaronesian, Mediterranean, Pannonian and Steppic) . . . .

Ideally, at least one monitoring site should be established for each ecosystem type in a biogeographical region.

Within each biogeographical region, the main ecosystems and habitats of interest can be classified according to the MAES (13) and EUNIS (14) classifications. The proportion of area covered by each MAES ecosystem type varies substantially . . . within a country and in the EU as a whole, and there is also substantial variation between countries.

Some ecosystem types under the MAES classification are clearly not relevant for the NEC Directive purposes (principally urban ecosystems and most of sparsely or unvegetated land). As regards cropland, nutrient load by air pollution is less relevant compared to fertilisation and other measures, however the fact that crops are sensitive to ozone justifies monitoring.

On that basis, six major categories of ecosystems are relevant for the NEC Directive: Grasslands, Cropland, Forests and Woodlands, Heathland and Shrub, Wetlands, and Rivers and Lakes. . . . These MAES categories can be easily linked with EUNIS habitat classes (Level 1 and 2) and Corine Land Cover (15) classes (Level 3) at the respective level of available information from the general Level 1 to the more detailed Level 3 or higher. Specific ecosystems and habitats of special interest or high importance and value can be integrated into the monitoring scheme, linking them to these categories.

Source: Excerpt of Section 3.2. Ecosystem types in the Commission Guidance Notice on ecosystem monitoring (2019). Emphasis (**bold**) added.

Box 7. The Commission Guidance Notice on ecosystem monitoring (2019), excerpt on site selection, number and density

3.3. Site selection, number and density

Given the variety of conditions as regards air pollution load and the biological, chemical and physical characteristics of each ecosystem type across the EU, this section focuses on providing **qualitative criteria for site selection** that are **relevant for each type of ecosystem**. These criteria should be the basis for selecting sites and determining their **number and density** to ensure a **sufficient and consistent** monitoring network **specific to the situation of the individual Member States**. It should be kept in mind that **the selection of sites is a multi-criteria process** which may vary between Member States.

Where possible the sites chosen should satisfy the following **principles**:

— the site should be **typical for the ecosystem type** to be monitored;

— the site should be such that the impacts of **aerial deposition can be distinguished from other pressures**;

— the site should **be sensitive to the pressure in question**, such that if there are any impacts they would be readily identifiable.

Maps of areas sensitive to particular impacts can be useful when selecting monitoring sites.

Biodiversity should be another selection criterion for monitoring sites to address the cause-effect relationships of pollution on biodiversity. While not every site has to be necessarily of high biodiversity value, **the network as a whole should ensure an adequate representation of sites that are minimally disturbed by management and preferably rich in species**, which may for example be found in Natura 2000 areas, nationally designated areas (CDDA) or other protected sites.

Overall, the required **number and density of sites** are dependent on the sensitivity of the ecosystems, the ecosystem types affected, the number of different ecosystem types occurring in the different biogeographical regions (see section 3.2 above), and the intensity of the air pollution pressures. The national network should be such as to allow for analysis of spatial gradients and understanding of cause-effect relationships and should provide data for mapping and modelling of critical loads, and levels and exceedances. It is more important to have sites in several regions than to have several sites in each region. More pristine areas need fewer sites when no major changes are anticipated in those regions, but they should not be omitted.

With regard to **natural environmental conditions**, the most important gradients found in the Member States should be covered by the network. Key climatological parameters (precipitation, temperature), hydrological parameters and soil alkalinity (e.g. pH) gradients should vary systematically. This information

is partly inherent **in the respective biogeographical regions** (see section 3.2) and can be further specified with maps with more detailed classification of environmental strata (e.g. Metzger et al. 2005).

With regard to **air pollution parameters**, each Member State should at least cover areas with high deposition levels of acidifying and eutrophying substances (on a national scale) and high concentration levels of ozone. For long-term comparisons, reference sites at low deposition/concentration values should also be selected. The use of existing maps of critical load/level exceedance for site selection is recommended.

With regard to ecosystem types, each Member State should select sites according to their representativeness within its territory . . . . Additionally, Annex I of the Habitat Directive (92/43/EEC) can be used for selecting habitats according to their relevance.

Taking into account the distribution of sensitive ecosystems and the resources needed for taking the necessary measurements to assess air pollution impacts, **a tiered approach** may be appropriate, with **wide-ranging monitoring** of a relatively simple parameter set (Level I) reinforced by more targeted and **in-depth monitoring** of a smaller set of more sophisticated parameters (Level II). For some ecosystems, it may be appropriate to use a minimum density of sites for Level I-type monitoring (for instance Level I monitoring under the ICP Forests uses a network based on a 16 × 16 km grid). Where appropriate, such level distinction is made in the recommendations below on parameters and monitoring frequency.

Source: Excerpt of Section 3.3. Site selection, number and density in the Commission Guidance Notice on ecosystem monitoring (2019). Emphasis (**bold**) added.

Box 8. Site selection requirements from other EU legislation (excerpts and analysis as indicated)

This box covers three directives:

- **The Ambient Air Quality Directive]**
- **The Habitats Directive**
- **The Water Framework Directive**

The Ambient Air Quality Directive – excerpts on site selection

The upper and lower assessment thresholds specified in Section A of Annex II shall apply to sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter (PM_{10} and $PM_{2,5}$), lead, benzene and carbon monoxide.

SO_2 upper threshold 12 µg/m^3; SO_2 lower threshold 8 µg/m^3

NO_x upper threshold 24 µg/m^3; NO_x lower threshold 19.5 µg/m^3

In all zones and agglomerations where the level of pollutants referred to in paragraph 1 exceeds the upper assessment threshold established for those pollutants, fixed measurements shall be used to assess the ambient air quality. Those fixed measurements may be supplemented by modelling techniques and/or indicative measurements to provide adequate information on the spatial distribution of the ambient air quality.

In all zones and agglomerations where the level of pollutants referred to in paragraph 1 is below the upper assessment threshold established for those pollutants, a combination of fixed measurements and modelling techniques and/or indicative measurements may be used to assess the ambient air quality.

In all zones and agglomerations where the level of pollutants referred to in paragraph 1 is below the lower assessment threshold established for those pollutants, modelling techniques or objective-estimation techniques or both shall be sufficient for the assessment of the ambient air quality.

In addition to the assessments referred to in paragraphs 2, 3 and 4, **measurements shall be made, at rural background locations away from significant sources of air pollution**, for the purposes of providing, as a minimum, information on the total mass concentration and the chemical speciation

concentrations of fine particulate matter ($PM_{2,5}$) on an annual average basis and shall be conducted using the following criteria:

(a) one sampling point shall be installed every 100 000 km^2;

(b) each Member State shall set up **at least one measuring station** or may, **by agreement with adjoining Member States, set up one or several common measuring stations**, covering the relevant neighbouring zones, **to achieve the necessary spatial resolution**;

(c) **where appropriate, monitoring shall be coordinated** with the monitoring strategy and measurement programme of the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP);

(d) Sections A and C of Annex I shall apply in relation to the data quality objectives for mass concentration measurements of particulate matter and Annex IV shall apply in its entirety.

Member States shall inform the Commission of the measurement methods used in the measurement of the chemical composition of fine particulate matter ($PM_{2,5}$).

Sampling points targeted at the protection of vegetation and natural ecosystems shall be sited more than 20 km away from agglomerations or more than 5 km away from other built-up areas, industrial installations or motorways or major roads with traffic counts of more than 50 000 vehicles per day, which means that a sampling point must be sited in such a way that the air sampled is representative of air quality in a surrounding area of at least 1 000 km^2. A Member State may provide for a sampling point to be sited at a lesser distance or to be representative of air quality in a less extended area, taking account of geographical conditions or of the opportunities to protect particularly vulnerable areas.

The main objectives of such measurements (*at rural background locations irrespective of concentration*) are to ensure that adequate information is made available on levels in the background. This information is essential to judge the enhanced levels in more polluted areas (such as urban background, industry-related locations, traffic-related locations), assess the possible contribution from long-range transport of air pollutants, support source apportionment analysis and for the understanding of specific pollutants such as particulate matter. It is also essential to support the use of modelling.

Measurement of $PM_{2,5}$ must include at least the total mass concentration and concentrations of appropriate compounds to characterise its chemical composition. At least the list of chemical species given below shall be included.

SO_4^{2-} Na^+ NH_4^+ Ca_2^+ elemental carbon (EC) NO_3^- K^+ Cl^- Mg^{2+} organic carbon (OC)

Minimum number of sampling points for fixed measurements to assess compliance with critical levels for the protection of vegetation in zones other than agglomerations If maximum concentrations exceed the upper assessment threshold - 1 station every 20 000 km^2. If maximum concentrations are between upper and lower assessment threshold - 1 station every 40 000 km^2

Criteria for classifying and locating sampling points for assessments of ozone concentrations:–

Suburban locations: to assess the exposure of the population and vegetation located in the outskirts of the agglomeration, where the highest ozone levels, to which the population and vegetation are likely to be directly or indirectly exposed occur, representative of tens of km^2, where population, sensitive crops or natural ecosystems located in the outer fringe of an agglomeration are exposed to high ozone levels;

Rural locations: to assess the exposure of population, crops and natural ecosystems to sub-regional scale ozone concentrations, representative of some hundreds of km^2, stations can be located in small settlements and/or areas with natural ecosystems, forests or crops; representative for ozone away from the influence of immediate local emissions such as industrial installations and roads;

Rural background locations: to assess the exposure of crops and natural ecosystems to regional- scale ozone concentrations as well as exposure of the population, Regional/ national/continental levels (1 000 to 10 000 km^2), station located in areas with lower population density, e.g. with natural ecosystems, forests, at a distance of at least 20 km from urban and industrial areas and away from local emissions; avoid locations which are subject to locally enhanced formation of ground-near inversion conditions, also summits of higher mountains; coastal sites with pronounced diurnal wind cycles of local character are not recommended.

Ozone target value for the protection of vegetation; May to July, AOT40 (calculated from 1 h values) 18 000 µg/m^3·h averaged over five years. Ozone long term objective: AOT40 (calculated from 1 h values) 6 000 µg/m^3·h

Note: The Manual on modelling and mapping (ICP Vegetation, 2017) indicated slightly different values for the current critical levels for vegetation than the AAQ Directive. Critical levels in the Manual are based on 3

months (crops) or 6 months (perennial vegetation – trees and grasslands); AOT40 has been retained (but isn't the preferred metric), with units ppm.h.

Source: AAQ Directive (Directive 2008/50/EC)

The Habitats Directive – analysis of site selection requirements

Article 11 of the Habitats Directive requires a system to be set up for the surveillance of the conservation status of the natural habitat types of Community Interest (as listed in Annex I) and animal and plant species of Community Interest (as listed in Annex II, IV and V). Consequently this provision is not restricted to Natura 2000 sites and **data need to be collected both inside and outside the Natura 2000 network to achieve a full appreciation of conservation status of listed habitats and species at the level of biogeographic regions**. These data form an important part of the information to be collated for the National Report to the EU.

Member States have developed different monitoring programmes or have adapted previously existing monitoring schemes to include relevant aspects of the Habitats Directive. Independent monitoring programmes specially developed for Article 11 monitoring exist merely in a few countries (Germany, Denmark, Latvia, as well as the Czech Republic). Austria is currently developing Article 11 monitoring (Ellwanger et al. 2018).

Source: Analysis of relevant text from the Habitats Directive (Council Directive 92/43/EEC) and other indicated sources.

The Water Framework Directive – analysis of site selection requirements

The Water Framework Directive covers surface water (i.e. inland waters, transitional waters and coastal waters) and groundwater. This also includes wetlands, which are subsumed under the term "Groundwater Dependent Terrestrial Ecosystems".

Annexes II and V of the Water Framework Directive required the Member States to elaborate comprehensive assessment and monitoring plans by 22 December 2006. Annex V of the Water Framework Directive specifies in depth the minimum requirements of the monitoring itself. Applicable monitoring programs had to be produced.

The Water Framework Directive distinguishes surveillance, operational or investigative monitoring programmes. Among those the surveillance monitoring and to some extent also the operational monitoring of the surface water and groundwater bodies are those of most relevance for the implementation of the NEC Directive. Both monitoring programmes inhabit distinct objectives.

The **selection of the monitoring** sites for the Water Framework Directive is based on estimates with respect to the representativeness of a monitoring site for the specific water body. The term "representativeness" is not quantitatively defined directly by the Water Framework Directive.

Following criteria are relevant for the selection of sites monitoring (Arle et al. 2016):

- How many monitoring sites are necessary to obtain reliable assessment results for each water body?
- Where to place monitoring sites to be sure that they really are representative of an entire water body?
- What assessment uncertainties can be expected and to what extent will they appear?
- In how far does the natural variability of biocenoses influence the assessment results?
- Going beyond the minimum requirements of the Water Framework Directive, should the number of monitoring sites and the frequency of measurement be adjusted to the predominant pressure?

More specifications on the Monitoring programmes are given in the EC Guidance document Nr. 7. **Surveillance monitoring** focuses among other on: (1) The assessment of long term changes in natural conditions within a river basin or sub-basin of a river basin district; and (2): The assessment of long term

changes resulting from widespread anthropogenic activity (the Water Framework Directive, Annex V.1.3.1).

Minimum monitoring frequencies for surveillance monitoring are outlined in Annex V of the Water Framework Directive. Surveillance monitoring has to be undertaken for at least a period of one year during the period of a river basin management planning for parameters indicative of all biological, hydromorphological and general physico-chemical quality elements. The relevant quality elements monitored for each type of water are given in Annex V.1.1.

Furthermore, it is the Water Framework Directive requires that "frequencies shall be chosen so as to achieve an acceptable level of confidence and precision" and that "monitoring frequencies shall be selected which take account of variability in parameters resulting from both natural and anthropogenic pressures. The times at which monitoring is undertaken shall be selected so as to minimise the impact of seasonal variation on the results".

In contrast, the **operational monitoring** aims to assess the status of those bodies identified as being at risk of failing to meet their environmental objectives (the Water Framework Directive, Annex V.1.3.1). It is also used to control whether measures have been successfully implemented.

For operational monitoring, Member States are required to monitor for those biological and hydromorphological quality elements most sensitive to the pressures to which the body or bodies are subject. Additionally, the use of non-biological indicators for estimating the condition of a biological quality element may complement the use of biological indicators but it cannot replace it. The minimum requirements for monitoring frequencies differ from the surveillance monitoring.

Source: Analysis of the Water Framework Directive (2000/60/EC) and other sources cited in the text.

Box 9. The relevant ICPs (excerpts and analysis as indicated)

ICP Forests – analysis of site selection requirements

Although developed based on generally agreed principles, the ICP Forests monitoring network originates from national initiatives, and consequently these reflect the design concepts of the individual participating countries. The Level I network is often a subsample of National Forest Inventories. Similarly the Level II network has varying plot designs across Europe. However, the Level I network is designed to be large-scale and representative across the UNECE region and most commonly the sites (plots) are circular and defined by the centre and the radius. The guidance is that the number of plots should equal the forest area of the country (in km^2) divided by 256, although for small countries and/or infrequent forest types then denser sampling should be considered. Countries can use different designs for setting up the network e.g. random sampling, systematic sampling, stratified random sampling and in many cases there can be harmonisation to utilise existing networks. There is guidance for Level II plots, although the selection is within the responsibility of the individual country. The Level II plots should be as homogeneous as possible (e.g. for site conditions within the plot). Plot size should be a minimum of 0.25 ha.

Section 4. Location of measurement and sampling, Sub-section 4.1.2.5 Level II buffer zone (page 7):

The buffer zone is an area surrounding the Level II plots designated to ensure plot protection against direct influence of nearby paths, roads and disturbances. The size and shape of the buffer zone depends on local conditions. However, it must be large enough to protect the plot from direct disturbances and – at the same time – still be characterized by the same plot conditions in terms of aspects, slope, canopy cover and soil condition.

Section 4. Location of measurement and sampling, Sub-section 4.2.2.2 Selection of sites (page 10):

Plots are selected on a preferential basis taking into account:

1: Ecological and logistic issues: The situation shall be as homogeneous as possible (regarding e.g. tree species, stand type and site conditions within the plot). However, the more homogeneous the plot, the

higher is the chance its homogeneity will decrease with time as result of different factors (Palmer 1993). Plots should be accessible to allow routine operations;

2. The importance of forest ecosystems within a country: One important selection criterion is that the Level II plots in a country should be located in such way that the most important forest species and most widespread growing conditions in the country are represented. In order to facilitate data analyses; it is advisable to give priority to replicates within the same forest ecosystem type, rather than spreading plots over a huge variety of forest types;

3. The existence of data series and the importance of their continuation: Whenever possible, plots should be selected which have been monitored during the last years. The great advantage of existing data on air quality and meteorological parameters from nearby stations should be taken into consideration whenever establishing Level II plots.

Source: Analysis of ICP Forests Manual (2017).

Specific criteria for site selection – ICP Forests

Annex I – Procedure for the establishment of a Level II 'Light Exposed Sampling Site' (LESS) (page 16):

For the establishment of the LESS, the following procedure is to be applied:

1. Identify an area (A) (500 m radius) centered around the Level II open-field monitoring station (meteorological tower and/or deposition devices) where passive O3 samplers are installed (M) (Figure A-1a).

2. Identify all the light exposed forest edges within A (Figure A-1a).

3. From those, choose the forest edge closest to M (Figure A-1b).

4. Determine the start point and measure the length of the selected forest edge and virtually identify a 1 m width area along them. You now have an x m long and 1 m width transect (Figure A-1b).

5. Calculate how many possible 2 x 1 m non-overlapping quadrates fit into the selected forest edge area by dividing the x m long transect by 2. The 2 m long edge of the rectangular quadrate lies along (parallel) the forest edge. The total number of non-overlapping quadrates is our target population.

6. Select your sampling quadrates randomly.

7. At the end, you will obtain a list of n codes. Each code is a 2 x 1 m quadrate within the LESS; the codes will give you the distance of the beginning of each quadrate from the beginning of the previously determined start of the forest edge. Now you are ready for the field to install the LESS (Figure A-1d).

Source: ICP Forests Manual Part VIII Assessment of ozone injury (version 2020)

Specific criteria for site selection – ICP Forests

Source: ICP Forests Manual Part II Basic design principles for the ICP Forests monitoring networks (version 2017)

ICP Vegetation – analysis of site selection requirements

There is no common manual that provides a design for site selection for different forms of terrestrial vegetation and considers the three air pollution impacts. The manual on measuring atmospheric deposition of nitrogen in moss provides site selection guidance for this group of species (ICP Vegetation 2020). The monitoring protocol on monitoring sensitive ozone species ('SOS') using the smart-phone App focuses on the method to detect the ozone injury on ozone sensitive species for crops, trees, grassland, and heathland (ICP Vegetation 2018 and 2021a). It does not provide site selection guidance.

ICP Vegetation does not define fixed plots for ozone injury and other general vegetation assessments at a systematic country level. Plots are generally located near to the participating Universities and Institutes. Similarly, for sampling mosses for nitrogen, metals and other pollutants, the locations and densities of the

plots sampled is determined by each participating country. There is a recommendation that there should ideally be at least one sample per 50 km x 50 km grid-square (ICP Vegetation, 2020).

ICP Vegetation (2020), page 5: “Number of sampling sites. Similar to previous surveys each country should aim to collect at least 1.5 moss samples/1000 km2. If this is not feasible, a sampling density of at least two moss sample sites per ‘old’ EMEP1 grid (50 km x 50 km) is recommended. It is recommended to make an even and objective distribution of the samples whenever possible, and to have a more dense sampling regime in areas where steep gradients in the deposition of heavy metals can be foreseen. To aid the analysis of temporal trends in the concentration of heavy metals in mosses, it is recommended to collect samples from the same sites as in the previous surveys.”

Source: Analysis of ICP Vegetation (2020). Site selection starts at ‘Sampling Programme’, page 5. ICP Vegetation 2018 and 2021a).

Critical levels for grasslands and pastures – ICP Vegetation (2017)

Section III.3.5.4 (Semi-)natural vegetation choice of representative species and ecosystems

Critical levels have been established for:

1. Temperate perennial grasslands found in Boreal, Atlantic and Continental biogeographical regions of Europe that are dominated by grasses and forbs and have little or no tree cover, and may be grazed. The majority of vegetation species are perennials, but annual species may also be present. Parameterisations and critical levels for temperate perennial grasslands may also be applicable for Pannonian and Steppic regions, but this has not been tested yet and stronger soil water limitations might be expected.

2. Mediterranean annual pastures that are dominated by annual plants (grasses and forbs, including legumes). They include Dehesa annual pastures and other grazed annual pastures found in the Mediterranean region of Europe.

Source: Excerpted from ICP Vegetation (2017)

ICP Waters – <u>analysis</u> of site selection requirements

The ICP Waters monitoring network also has a tiered approach to its sites, as does the ICP Forests and ICP IM, but based on monitoring frequency. These also include data from (1.) small catchments with monthly or seasonal sampling; (2.) a relatively large number of sites with minimum annual sampling frequency; and (3.) regional surveys of many sites sampled one time in several years. The focus on ICP Waters analysis is the frequently sampled sites based on water chemical data, but for the less frequently monitored sites the biological aspects become more important as these accumulate the effects of changing water quality in the previous period.

Site selection is the responsibility of the national focal centres, with guidance to cover different regions, and to have sampling sites reflecting the characteristics of the region – particularly in regards to the relative importance of rivers and streams vs lakes. Sites with impacts from local pollution sources should be avoided, and consideration should be given to acid-sensitivity of the surface water and sites that are likely to change in response to air pollution. Due to the value of long-term records, well protected areas such as national parks and nature reserves are recommended, and where forestry is performed in the catchment area, the size of the catchment should be large enough that single measures such as clear-cuts will not have a major impact on the water quality. For ICP Waters a high sampling frequency should be prioritised over the number of sites. Drainage lakes (with an outlet) are preferred and should ideally have a renewal period of one year or less. For rivers, a small river or brook is preferable, and small catchments react more rapidly to change. Ideally the site should be large enough to sustain a permanent flow throughout the year.

Source: Analysis of ICP Waters Manual (2010). Site selection information on pages 15-17.

ICP Integrated monitoring (IM) - analysis (including excerpt) of site selection requirements

A central aim of integrated monitoring is to establish the relationships between chemical, physical and biological parameters. This is best achieved by carrying out the subprogrammes as close to each other as possible within the main habitat type(s) at the site.

Excerpt:

“Monitoring should preferably take place in hydrologically well defined small catchments, where the interaction between all the subprogrammes can be used at the catchment scale. Where such catchments cannot be found other defined areas are acceptable provided input-output budgets can be made.

The following selection criteria should be met:

1. The site must allow for input-output measurements. Input measurements mean that deposition is measured at the site. Output measurements mean that the drainage water flux can be quantified and its chemistry analysed.
2. The site should be hydrologically well definable and as geologically homogeneous as possible.
3. The site should not be less than a few tens of hectares and no more than a few square kilometres (range 10-1000 ha) and preferably buffered by a zone of similar land use.
4. The ideal site is one in which there are no ongoing management activities. Otherwise, land use within the area should be controllable. This normally means that the area is protected in some way. If management activities take place they must be well documented.
5. The site should be typical for the region.
6. It is desirable that other scientific research related to environmental assessment/modelling is carried out at or close to the site.
7. The closest significant point pollution source should be > 50 km away. Where the background level of pollutants is high, the distance to the pollution source can be less, but the distance should be greater when the background level is low.”

The following countries have continued data submission to the ICP IM data base during the period 2016–2020: Austria, Belarus, the Czech Republic, Estonia, Finland, Germany, Ireland, Italy, Lithuania, Norway, Poland, the Russian Federation, Spain, Sweden, and Switzerland. The number of sites with on-going data submission for at least part of the data years 2015–2019 is 48 from fifteen countries. Sites from Canada, Latvia and United Kingdom only contain older data.

Source: Analysis of ICP IM Manual (1998). Site selection in Section 3.

ICP IM Light - analysis of site selection requirements

The ICP IM are currently moving towards a tiered approach. The different ecosystem components are monitored simultaneously within a small catchment or other hydrologically well-defined area (recommended 10-1000 ha). Although the previous focus of ICP IM was process-based research with detailed monitoring of relatively few catchments (typically 1-10 per ECE country), recently a method for establishing ‘ICP IM Light’ sites is proposed. At the tier 1 type of these sites, fewer parameters can be recorded, and on a less frequent basis. This gives the ability to more Parties to launch ICP IM sites; they can then gradually advance the density of monitoring to a higher ICP IM tier. Sites must, as a minimum, allow for input-output measurements, and should be as geologically homogeneous as possible, and preferably buffered by a zone of similar land use. It is desirable that other scientific research related to environmental assessment/modelling is carried out at or close to the site. Ideally the site should have no ongoing management activities, and the site should be typical for the region. The closest point pollution source should be >50 km away.

Source: Analysis of ICP IM Light (2021)

Box 10. Report on Monitoring Sites (2019), analysis (including excerpts) on conclusions and recommendations related to site selection, number and density

Report on Monitoring Sites (2019) proposes a stepwise approach, using Greece as a case study example

Step 1: Mapping of monitoring sites under the NEC Directive, the Habitats Directive, the Water Framework Directive and the AAQ Directive

In the first step of this process the aim is to record the number and location of monitoring sites under the NEC Directive, the Habitats Directive, the Water Framework Directive and the AAQ Directive.

Excerpt:

"During the establishment of the NEC Directive monitoring network, Member States were required to have taken into consideration all relevant information on ecosystems' conservation status under the Habitats Directive and ecological status under the Water Framework Directive aiming to select representative, permanent monitoring sites. Ecosystems in unfavourable conservation status under the Habitats Directive or in below good ecological status under the Water Framework Directive are likely to be less resilient, regarding their capability to withstand additional negative impacts (including air pollution), than ecosystems in favourable conservation status or in good ecological quality accordingly. One viable option could therefore be to select the NEC Directive sites out of the Habitats Directive and the Water Framework Directive monitoring sites (with unfavourable conservation status or in below good ecological quality respectively), where parameters and pressures related directly or indirectly to air pollution have been recorded simultaneously".

"'Direct pressures and parameters' are considered to be the ones that are recorded during the implementation of the required the Habitats Directive and the Water Framework Directive monitoring processes and which have direct relevance to NEC Directive key indicators (e.g. air-born pollutants, physical-chemical conditions). 'Indirect pressures and parameters' are considered to be the ones that have the potential to result in further ecosystem deterioration when taken as acting in synergy with air pollution impacts (e.g. eutrophication, acidification, roads, motorways, and urbanisation). Thus, in sites with these direct and indirect pressures and parameters NEC Directive monitoring could clearly be implemented with the likelihood of obtaining meaningful and relevant results and outcomes".

"It could therefore be interesting for Member States to consider monitoring sites from these directives to be included in the NEC Directive monitoring network (and, where appropriate, vice versa), especially for Member States which have: (1) established only a (very) limited number of NEC Directive monitoring sites in relation to the area of the Member State; (2) located their NEC Directive monitoring sites in only a limited number of MAES-ecosystem types; (3) established many NEC Directive monitoring plots, but only monitor a limited number of key-parameters."

Step 2: Identification of monitoring sites per MAES-ecosystem type

Excerpt:

"It is one of the key-requirements under the NEC Directive that the monitoring network should be representative for the ecosystems of the Member States. (Note: the MAES ecosystem types do not correspond to the majority of habitat and ecosystem classifications used at national level, so we should not expect a completely even distribution of the monitoring sites; although it should be noted that work is on-going in order to identify 'crosswalks' between different classifications)".

"The AAQ Directive plots are normally located in urban or peri-urban areas, which include urban ecosystem types such as urban forests, parks or other green areas. Though these are not ecosystems that are included within the MAES-ecosystem types them), these plots can still be useful, in order to assess dispersal of air pollutants to neighbouring ecosystems of relevance in relation to the NEC Directive Article 9 monitoring."

Step 3: Identification of monitoring sites in relation to ecosystem conservation status and pressures from air pollution

Excerpt:

"In this step, monitoring sites (plots) located within ecosystems in unfavourable conservation status under the Habitats Directive or which are recorded as being below good ecological quality under the Water Framework Directive could be considered for inclusion within the NEC Directive monitoring network (preparing a map). ".

"In addition, (preparing a map of) the monitoring sites that have: 1) recorded pressures which are directly related to air pollution (e.g. air-pollutants); and/or 2) indirect pressures which act in synergy with the effects on ecosystems delivered by air pollution (e.g. roads, motorways)".

"The sites which correspond to both … could be considered for inclusion within the NEC Directive monitoring network."

Step 4. Identification of monitoring sites in relation to the spatial distribution across Greece

Excerpt:

"Further identification of monitoring plots has been carried out by taking into account their spatial distribution across Greece. The 10x10 km EEA Reference Grid has been used as the spatial reference unit. The following criteria have been applied:

- At least one monitoring site per MAES ecosystem type in each 10x10 km EEA reference grid cell;
- When islands/islets are present within the same cell, the previous rule (of at least one monitoring site per MAES ecosystem type in each 10x10 km EEA reference grid cell) is followed for the area of each island."

"It should be noted that the indicators and parameters actually already monitored at the current sites under the Habitats Directive, the Water Framework Directive and the AAQ Directive sites are not examined under this initiative and the actual scope for synergy can therefore not be fully assessed."

Source: Report on Monitoring Sites (2019)

Box 11. Report on Monitoring Data (2020), excerpt on recommendations related to site selection, number and density

Compliance with the ecosystem representativeness requirements

Recommendations:

R6. To accompany their provision of monitoring data, EU Member States should be provided with a standardised means to: 1) explain how their submission of monitoring data fulfils their NEC Directive obligations regarding representativeness of their ecosystem types; and 2) explain or justify **how the representativeness of sensitive habitats and ecosystem types complies with the principles of a risk-based approach and cost-effectiveness. A supplementary report template** could be provided with a specified word limit and defined fields covering representativeness, risk-based approach (e.g. sensitive habitats), and cost-effectiveness.

R7. While the NEC Directive requires the site network to be representative of ecosystem types, it does not explicitly require the monitoring data provided to be representative. In any future revision of the legislation, the representativeness requirement should be extended to include the monitoring data; this would increase the quality and relevance of ecosystem monitoring.

R8. Monitoring sites should always report which MAES ecosystem types they cover, which is currently not being done, even for some of the active sites. To ensure that Member States provide consistent data in their reporting, Member States should be provided with standardised guidance for the level of detail expected regarding the ecosystem categories.

R9. Member States should revisit the representation of ecosystem types within each biogeographical region and consider to what degree it would be possible to ensure each ecosystem type therein contains at least one active monitoring site that continuously reports indicators at the recommended frequency listed in Annex V of the NEC Directive.

Biogeographical regions

Recommendations:

R23. EU Member States should review the distribution of their monitoring sites to ensure that monitoring covers their different biogeographical regions and the ecosystem types within them.

R24. When considering the placement of monitoring sites and the intensity of data collection at these sites, Member States should consider the following issues**: biogeographical representation, ecosystem**

type, level of air-pollution pressures, vulnerability of ecosystems to air pollution and conservation status of the habitats. Specifically, an above-average density of monitoring sites should be placed: 1) in areas of high sulphur and nitrogen deposition as well as in areas with high ozone concentrations; 2) in ecosystems vulnerable to these substances; and 3) at sites with unfavourable conservation status (according to the Habitats Directive) or in below 'good' ecological quality (according to the Water Framework Directive). However, monitoring should not exclusively target areas of high vulnerability to air pollution due to the need for background monitoring in areas less affected by air pollution.

Spatial analysis

Recommendations:

R25. Future development of the monitoring network should consider **the spatial distribution of the active monitoring sites, especially in those regions facing elevated levels of atmospheric nitrogen, sulphur and ozone pollution and larger areas of vulnerable ecosystems, especially those sensitive to atmospheric pollution** (e.g. grasslands and heathlands appearing on nutrient-poor soils, wetlands with a high dependence on rainwater and a very low nutrient status and lakes on lime-poor bedrock).

Integrated assessment

Recommendations:

R26. **Minimum monitoring requirement**: At least one continuous monitoring site should be established for each ecosystem type in a biogeographical region in each EU Member State. This is also suggested by the Commission Guidance Notice on ecosystem monitoring (2019) (Source: NEC Directive Article 9(1) first paragraph and the Commission Guidance Notice on ecosystem monitoring (2019), page 5). Such an approach would be compatible with the reporting under the Habitats Directive (Article 17), which requires one report per biogeographical region, per EU Member State.

R27. **Differentiated monitoring levels**: As is done in the ICP Forests, ICP Integrated Monitoring and the ICP Waters, which use two- to three-level hierarchies, levels of monitoring intensity can be differentiated by spatial coverage, comprehensiveness and frequency of sampling. Level I monitoring could provide wider-scale monitoring with lower intensity, while Level II monitoring could have higher-intensity monitoring at a smaller number of sites that focusses on specific issues of concern, such as air pollution sensitive ecosystems.

R29. The representativeness of the active monitoring network should be developed to fill in the gaps identified in the first round of NEC Directive site reporting (July 2018) and reporting of NEC Directive monitoring data (July 2019).

R30. Building on **the stepwise approach** developed in WUR (2019), the following method of ensuring a representative core network of active monitoring sites with consistent long-term monitoring under the NEC Directive for each Member State is put forward for consideration.

- Step 1: Map monitoring sites under the NEC Directive, Habitats Directive, Water framework Directive, the Ambient Air Quality Directives and national forest inventories;
- Step 2: Identify monitoring sites per biogeographical region and MAES-ecosystem type;
- Step 3: Identify monitoring sites in relation to a) habitat conservation status and water quality status; and b) pressures from air pollution;
- Step 4: Identify monitoring sites in relation to c) protected areas versus non-protected areas and d) sensitive ecosystem types in each Member State;
- Step 5. Identify monitoring sites in relation to e) the spatial distribution across each Member State.
- Step 6. Combining the considerations in the previous steps, each Member State should select at least three monitoring sites from each MAES-ecosystem type in each biogeographical region for large-scale Level I monitoring of at least a set of key variables that are reported consistently in the NEC Directive reporting cycles. A variety of sites with different conservation and protection statuses, as well a good spatial distribution should be included if possible. In those cases where a particular ecosystem type covers large areas of a Member State, additional monitoring sites are needed.

• Step 7: Consistent with a risk-based approach, intensive Level II monitoring sites should be established for long-term monitoring focused on specific issues of concern (e.g. sensitive ecosystems and areas of higher pollution pressure) and reported consistently in the NEC Directive reporting cycles.

Annex G. Summary of comments made by ecosystem experts

In June 2020, at a meeting organised by the European Commission of an ecosystem experts' subgroup of the NEC Directive expert group, the authors of this report presented draft versions of their main conclusions and recommendations. Experts were invited to discuss and comment on the material and provide written comments following the meeting. The following text provides a synthesis overview of the main comments received, grouped by category and topic. Not every individual point raised by the experts is summarised here. This summary of the comments received does not represent the opinions of all the experts, some of whom did not provide comments.

Site selection and intensity of monitoring

Reactivation of sites - There was mixed support for the issue of reactivating past sites, with some supporting the idea as a means of establishing historical trends. Other experts raised concern regarding the expense and funding issues.

Representativeness - Regarding the representativeness of the monitoring network, experts raised the need for more precisely defining what the term "representativeness" means. In addition, some suggested that the process for gradually achieving a more representative monitoring system should be discussed and defined.

Other site issues - There was quite a bit of support in the comments for the idea of a "core network" of sites that uses a risk-based approach and considers cost effectiveness. Whether a site is part of an ICP network was raised as an important consideration for including it in ecosystem monitoring under the NEC Directive. Physical access to sites was raised as an issue (e.g. some sites of interest are on private land).

Tiered monitoring - The experts who commented seemed to generally favour the idea of using a tiered approach to monitoring. The benefit of Level II monitoring sites for validating the results of Level I monitoring was mentioned.

Source: Excerpt from report on Monitoring Data (2020)

Ecologic Institute

www.ecologic.eu

FB: /Ecologic.Institute

Twitter: /EcologicBerlin