Report No. 498

Indicators of Air Pollution Effects in Ecosystems for Monitoring under the EU National Emission Reduction Commitments Directive

Authors: Thomas Cummins, Lorna Marcham and Keelan McHugh

Lead organisation: University College Dublin

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Rialtas na hÉireann
Government of Ireland

Environmental Protection Agency

The EPA is responsible for protecting and improving the environment as a valuable asset for the people of Ireland. We are committed to protecting people and the environment from the harmful effects of radiation and pollution.

The work of the EPA can be divided into three main areas:

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1. Office of Environmental Sustainability
2. Office of Environmental Enforcement
3. Office of Evidence and Assessment
4. Office of Radiation Protection and Environmental Monitoring
5. Office of Communications and Corporate Services

The EPA is assisted by advisory committees who meet regularly to discuss issues of concern and provide advice to the Board.

epa Research

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What did this research aim to address?

The NEC Indicators project aimed to review those indicators used to detect effects of air pollution in sensitive ecosystems such as bogs and semi-natural grasslands. Air pollutants of concern for sensitive ecosystems are ammonia, the main source of which is agriculture, and ozone, which is formed following chemical reactions with other air pollutants, including emissions from industrial and transport activities. The priority effects considered were change in characteristic plant communities with nitrogen inputs, and the risk of direct harm to vegetation from ozone exposure.

What did this research find?

The research found that ozone concentrations are highest near the Atlantic coast of Ireland, and decrease inland, due to deposition onto foliage. They further decrease in urban areas, through reaction with nitrogen dioxide from traffic. Ozone concentrations were assessed using metrics based on concentration and on plant susceptibility through opening of leaf stomatal pores. With open pores, typical of high humidity levels in Ireland, ozone has more access to sensitive leaf cells and can do damage.

Plant communities were studied through an extensive survey of plots. Community change responses to nitrogen deposition level were assessed, using the Threshold Indicator Taxa Analysis (TITAN) method, which identifies the N input where most plant species change abundance, either decreasing or increasing with N input. Overall, the indications are that the plant community changes even at quite low N inputs.

How can the research findings be used?

Findings from this research can be used to review and, where appropriate, modify monitoring methods that are being implemented in the National Ecosystems Monitoring Network. Recommendations include analysing foliar nutrient ratios; matching ammonia monitoring with ozone samplers; developing a soil solid survey compatible with the forthcoming EU Soil Monitoring Law; initiating soil pore water monitoring; and developing data-checking structures within a new data platform, while also having regard to the National Emission reduction Commitments Directive requirement that monitoring is representative, cost-effective and risk based. Further development of structures and communication within the monitoring community is encouraged.

Project code: 2019-CCRP-LS-3

EPA RESEARCH PROGRAMME 2021–2030

Indicators of Air Pollution Effects in Ecosystems for Monitoring under the EU National Emission Reduction Commitments Directive

(2019-CCRP-LS-3)

EPA Research Report

Prepared for the Environmental Protection Agency

by

University College Dublin

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ACKNOWLEDGEMENTS

This report is published as part of the EPA Research Programme 2014–2020. The EPA Research Programme is a Government of Ireland initiative funded by the Department of Climate, Energy and the Environment. It is administered by the Environmental Protection Agency, which has the statutory function of co-ordinating and promoting environmental research. This project was wholly funded by the EPA.

The authors would like to acknowledge the members of the project steering committee, namely Brendan Wall (Environmental Protection Agency), Eoin Riordan (Department of Climate, Energy and the Environment) and Damian McFerran (National Museums Northern Ireland), plus the consistent support of Karen Roche (Project Manager on behalf of EPA Research). We also thank the original and revised project team, namely Julian Aherne (Trent University, Peterborough, Ontario), Andy Bleasdale (Department of Housing, Local Government and Heritage), Luke Heffernan (Department of Agriculture, Food and the Marine), Shane Flanagan (Department of Agriculture, Food and the Marine) and Svitlana Sytnyk (Dnipro State Agrarian and Economic University and Universität Bielefeld).

Many landowners, contractors and research supporters provided access to land, data and information of importance to the project, for all of which we are grateful.

EPA RESEARCH PROGRAMME 2021–2030

Published by the Environmental Protection Agency, Ireland

ISBN: 978-1-80009-318-8 November 2025

Price: Free Online version

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Executive Summary

Ecosystem monitoring in Europe has been operating for over four decades, based on commitments under the Air Convention, in a set of international cooperative programmes linking the impacts of air pollution in ecosystems to emissions of eutrophying and acidifying substances. Directive (EU) 2016/2284, informally the National Emission reduction Commitments Directive (NECD), requires EU Member States to each operate a network of ecosystem monitoring sites in freshwaters and in terrestrial natural, semi-natural and forest habitats. The directive provides a structured, statutory basis for work previously carried out under the Air Convention. This network is to assess the negative effects of air pollution and is required to be designed to be representative, risk-based and cost-effective. Monitoring methods used under the Air Convention have been identified as suitable for this work. Ireland has established a network under the NECD, titled the National Ecosystems Monitoring Network (NEMN), with a network design manual for its current and future development, and has made two of the required 4-yearly data submissions to the European Environment Agency/European Commission.

The NEC Indicators project on indicators of air pollution effects in ecosystems for monitoring under the EU NECD, funded by Ireland's EPA from 2020 to 2024, has been designed to (1) improve the suite of indicators of air pollution impacts on terrestrial ecosystems in Ireland, referring to acidification and eutrophication effects; (2) develop a basis and rationale for ozone assessment and monitoring; (3) document the impacts of air pollution on biodiversity; and (4) support the development of researchers specialising in this topic and national research capacity.

Assessment of ozone concentrations and their spatial and seasonal variation and long-term trends was undertaken from existing instrumented stations. Additional passive-sampler monitoring contributed short-term data. Relatively high ozone concentrations were recorded in western coastal areas, with decreases inland and further decreases in urban areas. Deposition on vegetation is suggested as the process causing the decreases in concentration from coast to inland and in urban areas, and destruction by reaction with nitrogen dioxide is also suggested. Metrics for vegetation exposure to ozone were compared, with the indicator PODy (physiological ozone dose above a detoxification threshold *y*) suggesting high exposure in humid regions where leaf stomata are frequently open. Modelling of PODy against sensitive species shows exceedance of suggested damage thresholds. Spatial modelling of ozone concentrations against candidate land cover and land use metrics yields a model R^2 of 68%, reinforcing the observation of a strong oceanic–coastal signal in the spatial variation, expressed in the exposure metric PODy.

Surveys of vegetation composition in plots, as part of and in addition to NEMN activity, were undertaken in sensitive semi-natural grassland, wet heath and peatland habitats. Analysis of community change points by habitat in relation to modelled nitrogen deposition, using Threshold Indicator Taxa Analysis (TITAN), indicates where maximal species change points can be aggregated to indicate a community change point, relative to nitrogen deposition. Although this analysis does not identify a damage condition, it is a means of gaining insights into, and quantitative indicators for, plant community change under loading of reactive nitrogen from atmospheric deposition.

Moss sampling in support of identifying nitrogen deposition effects compared tissue nitrogen contents across moss species, and an index was used to calibrate values between species. Further exploratory sampling of plantain (*Plantago lanceolata*) gave an independent check, supporting the use of moss species tissue sampling, while highlighting difficulties in interpreting site-level effects from deposition modelling at 5 km resolution.

Monitoring capacity was developed during the NEC Indicators project through two PhD studies and during stakeholder interactions related to the NEMN and through links to Air Convention monitoring. A new module, AESC40690 Ecosystem Monitoring, has been developed at University College Dublin in response to the NEC Indicators project, which also incorporates

knowledge from prior monitoring in Ireland and Europe under the Air Convention.

Initial analysis by the European Commission of data submitted by Member States, including Ireland, finds that a high level of heterogeneity in submissions makes meaningful comparisons impossible. Furthermore, the requirement to link emissions to ecosystems effects cannot be fulfilled at the EU scale using existing submitted data. This does not rule out country-level objectives to relate emissions to effects.

Recommendations for further NEMN development include analysing foliar nutrient ratios; matching current ammonia monitoring with passive ozone monitoring; developing a soil solid survey, compatible with the forthcoming EU Soil Monitoring Law; supplementing bulk precipitation with throughfall and soil pore water monitoring; and developing data-checking structures within a new data platform. Further development of structures and communication within the monitoring community is encouraged.

1 Ecosystem Monitoring in Ireland

1.1 Existing Ecosystem Monitoring in Europe under the Air Convention

Under the Air Convention (United Nations Economic Commission for Europe Convention on Long-range Transboundary Air Pollution), ecosystems have been monitored for air pollution pressures, processes and effects across a large European network of thousands of plots over four decades. Monitoring is justified by signatory states' commitments under the Air Convention, and under a set of eight protocols therein.

Large and continuing datasets from monitoring of terrestrial and freshwater ecosystems are collected under the Air Convention. Strict data submission processes result in high, documented data quality, supported by extensive laboratory quality controls, international intercomparisons in laboratory and field, conference series, expert panels, mapping and modelling by specialists, and data-sharing policies.

Air Convention monitoring as part of a set of international cooperative programmes (ICPs) has linked ecosystem health to emissions and provided the basis for political action to reduce especially sulphur emissions from large combustion plants, a major environmental success story. As an example of legacy data available from Air Convention monitoring, data on nutrient concentrations (and hence ratios) in foliage can be used to indicate forest condition related to increased deposition of reactive nitrogen species in precipitation and other contributions to atmospheric deposition.

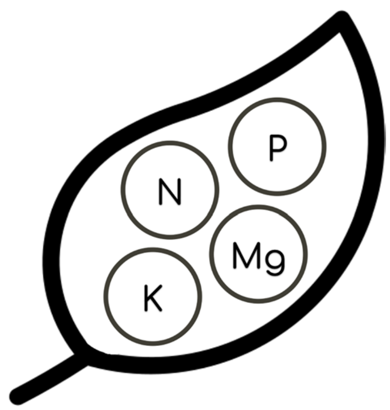
1.2 The National Emission Reduction Commitments Directive Requirement for Ecosystem Monitoring

The National Emission reduction Commitments Directive ((EU) 2016/2284; NECD) introduced the first mandatory requirement for EU Member States to continuously monitor the state of ecosystems where negative effects of air pollution may occur at a network of nominated sites. Monitoring is to be representative of freshwaters and sensitive terrestrial natural and semi-natural ecosystems and forests, and must be risk-based and cost-effective.

Member State monitoring networks, overseen by the European Commission, should be progressively developed towards 2027. A strict 4-year cycle of identifying sites and indicators (2018, 2022, 2026) is followed with data submission by 1 July the following year (2019, 2023, 2027).

The NECD draws explicit attention to the Air Convention monitoring, identifying its approaches and manuals of methods as suitable for NECD ecosystem monitoring.

Ireland established its National Ecosystems Monitoring Network (NEMN) to satisfy the NECD requirement for ecosystem monitoring (Figure 1.1), informed by an initial design report on site selection aiming to make the network representative, risk-based and cost-effective (Kelleghan *et al.*, 2021).



Foliar nutrient ratios

These ratios can be used to indicate plant nutrient status by comparing them with reference ranges.

Historical forest monitoring under the Air Convention has provided data on forest foliage nutrient contents, from which nutrient ratios can be assessed as indicators of ecosystem nutrient status.

While the methodology is well established for forest foliage, research on the methodology is needed for other types of vegetation.

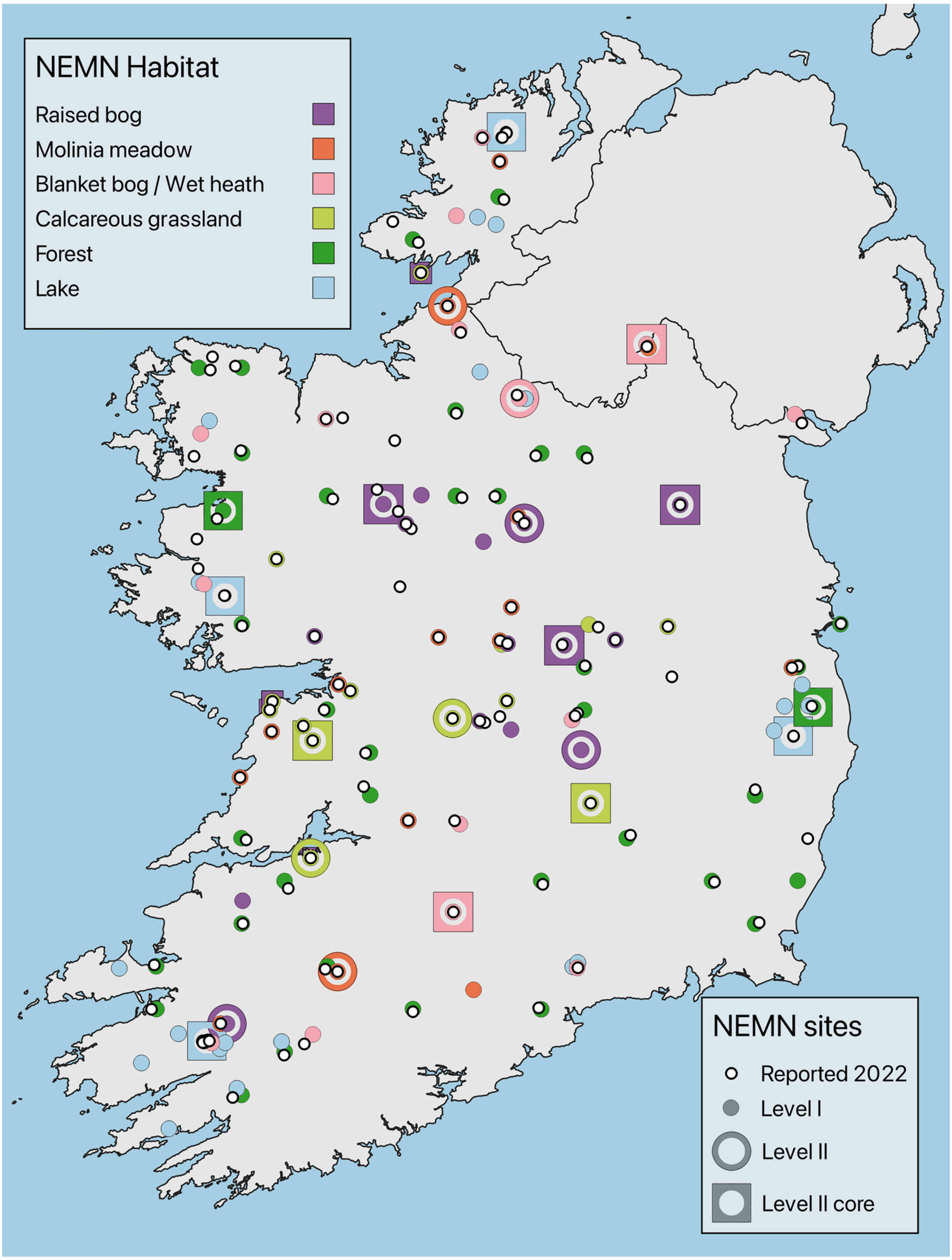


Figure 1.1. Sites in the National Ecosystems Monitoring Network as proposed during design (from Kelleghan *et al*. 2021; large symbols by habitat) and as submitted during 2022 reporting (from EEA, 2022; smaller dots).

Monitoring data from the NEMN, including data captured under Water Framework Directive and Habitats Directive monitoring, plus legacy Air Convention monitoring data, were submitted to the Commission in the 2019 and 2023 NECD data submissions.

1.3 NEC Indicators Project Objectives

This report addresses the level of Member State competence established in the NECD for selecting indicators of ecosystem impacts from air pollution. The directive suggests a set of indicators but expressly delegates the responsibility for their selection to Member States.

The NEC Indicators project set out to (1) improve the suite of indicators of air pollution impacts on terrestrial ecosystems in Ireland, referring to acidification and eutrophication effects; (2) develop a basis and rationale for ozone assessment and monitoring; (3) document the impacts of air pollution on biodiversity; and (4) support the development of researchers specialising in this topic and national research capacity.

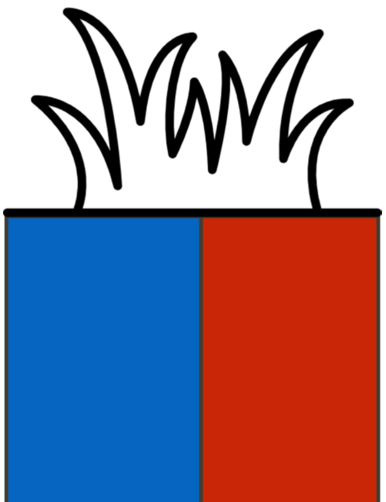
2 Indicators of Air Pollution in Terrestrial Ecosystems

A suite of indicators of negative air pollution impacts on terrestrial ecosystems for use by EU Member States in NECD monitoring is provided in Annex V of the directive. The ecosystem components or sampling matrices needed to establish indicators by monitoring are discussed below.

For terrestrial ecosystems, Annex V, referring to Article 9 of the NECD, provides a list of indicators and supporting indicators, which are available for Member States to identify as their selected indicators for the 4-yearly reporting.

Not all of the indicator statements are fully clear, leaving a lot of flexibility for Member States, but also risking ambiguity that may lead to difficulty in comparison across regions. For example, the two biodiversity indicators do not set a constraining scope, such as vascular plants, but leave the methodology used for the evaluation of biodiversity loss wide open, thereby allowing for molecular techniques, among others.

Indicator statements on temporal control are also ambiguous. For evaluating soil acidity from the soil solid matrix, sampling periodically at 10-year intervals is suggested (Table 2.1). For soil acidity mentioning ions, however, it is likely that soil pore water is being referred to, with samplers to be continuously exposed in non-destructive sampling of the soil liquid phase and aggregate annual reporting. The indicator “nitrate leaching” would also require continuous sampling of the soil solution and a whole-soil evaluation of the water and solutes entering and exiting the soil on an annual basis.

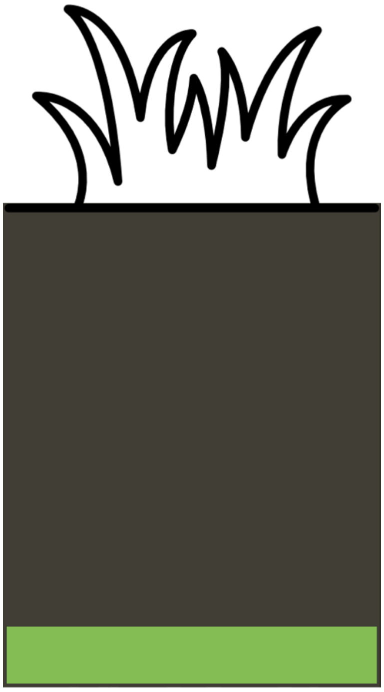


Ratio of non-acid to aluminium ions

The ratio of non-acid to aluminium ions in the soil solid phase (BC:Al) is an indicator of soil acidity status and is supported by the indicators pH and concentrations of sulphate, nitrate, non-acid cations and aluminium in soil solution.

Soil solid measurements at decadal intervals are intended to show long-term changes in BC/Al, and two such surveys have been undertaken for forests under the Air Convention. While these forest plots do not correspond to the NEMN forest plots, they are drawn from the same National Forest Inventory grid, and the sites originally sampled could be revisited. Archived soil samples could also contribute to this work.

Continuing long-term reduction in sulphur emissions from large combustion plants has led to the recovery of soils from induced soil acidification in unlimed terrestrial ecosystems. Continued monitoring is required to quantify the loss of non-acid cations as a result of intensified hydrology under climate change, increased removal of harvest residues, or changes in acidifying emissions.

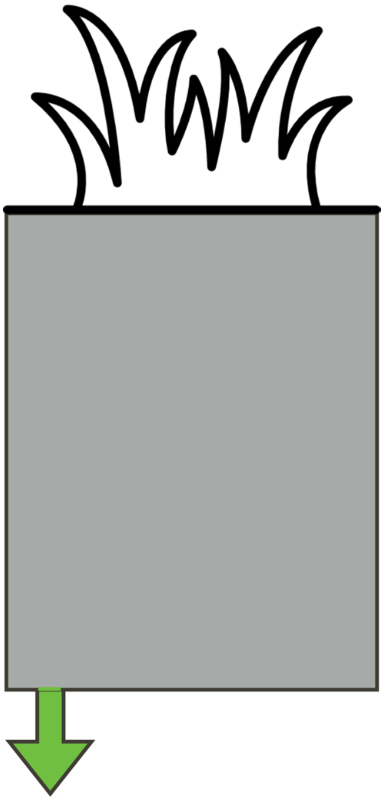


Soil carbon–nitrogen ratio

Soil carbon–nitrogen (C:N) ratio is a key global variable used in soil management, which depends on all forms of land management in which vegetation is manipulated. In semi-natural ecosystems, nitrogen deposition in excess of the needs of biodiverse plant communities is reflected in increased nitrogen concentrations. The C:N ratio only indicates this change in the context of stable carbon content. The potential for carbon accumulation, or carbon loss through decomposition, means that the C:N ratio must be related to controlling variables to be meaningful.

The C:N ratio is measurable in solid soil samples, including topsoil and soil at greater depths, and across mineral and organic soil types.

Within the NEMN monitoring, the C:N ratio is measured through 0–10 cm topsoil sampling in vegetation survey plots.



Nitrate leaching

Soil nutrient loss, expressed in the indicator nitrate leaching, reflects nitrogen levels surplus to the uptake by organisms in a terrestrial ecosystem.

Measuring nitrate leaching requires continuous sampling of the soil solution in and below the soil levels occupied by plant roots. Nitrate concentration can be measured in these samples and annual mean concentrations compared. Water flow also needs to be measured, requiring initial characterisation of the hydrological properties of the soil mass in situ plus continuous monitoring of soil moisture levels.

Nitrate leaching has been measured in agricultural ecosystems, of concern for the quality of municipal water supplies, and under the Air Convention in forest plots that are now incorporated in the NEMN.

Table 2.1. Indicators identified in NECD Annex V "for monitoring air pollution impacts referred to in Article 9"[a]

Annex V section	Negative impact	Key indicator	Supporting indicators	Time[b]	Component or matrix
(b)(i)	Soil acidity	Soil acidity, BCexch, Alexch		10 years	Soil solid
(b)(i)	Soil acidity		pH, SO_4, NO_3, BC, Al	1 year	Soil solution
(b)(ii)	Soil nutrient loss	Nitrate leaching		1 year	Whole soil
(b)(iii)	Nitrogen status	C:N ratio	Total N	10 years	Soil solid
(b)(iv)	Nitrogen balance[c]	N:P, N:K, N:Mg ratios		4 years	Foliage
(b)	Biodiversity loss	Not stated			Ecosystem
(c)(i)	Ozone damage to vegetation growth	Vegetation growth and foliar damage		1 year	Vegetation
(c)(i)	Ozone damage to vegetation growth		C flux	1 year	Ecosystem
(c)(ii)	Ozone damage to vegetation growth	Exceedance of flux-based critical levels		1 year	Vegetation
(c)	Ozone damage to biodiversity	Not stated			Ecosystem

These indicators apply to all monitored terrestrial ecosystems, representing natural, semi-natural and forest ecosystems. The entries in the final column, "Component or matrix", are offered as interpretations of the terms used in Annex V to identify operational targets for monitoring.

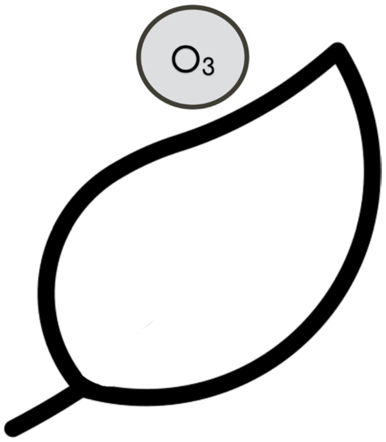
[a]Article 9 does not specify impacts but establishes a scope of "negative impacts". Impacts are listed only in Annex V.

[b]"10 years" indicates sampling at decadal intervals; "1 year" indicates annual reporting from continuously exposed samplers or sensors, whether observed periodically or continuously, and allowing possible seasonal constraints on sampling (e.g. growing season only or no-freeze periods only).

[c]Annex V(b) gives "nitrogen status and balance", suggesting either soil or ecosystem level, but Annex V(b)(iv) narrows this to "nutrient balance in foliage", without specifying whether this refers to forest trees or to other vegetation and habitat types.

K, potassium; Mg, magnesium; NO_3, nitrate; P, phosphorus; SO_4, sulphate.

3 Ozone Assessment and Monitoring in Ireland



Ozone

Ozone is a secondary reactive gas in the atmosphere formed by the light-dependent reaction of emitted precursor gases nitrogen dioxide and volatile organic compounds in ambient air, an allotrope of oxygen with the chemical symbol O_3.

Ecosystem effects occur through ozone entering stomata and causing damage to leaf cells, leading to loss of photosynthetic area.

Ozone is measured at stations in Ireland's airquality.ie network. High spatial variability also requires ozone measurement using passive samplers where foliar symptoms are observed. Landscape modelling can account for this, where supported by a sufficient network of passive-sampling monitoring locations.

Atmospheric total-column ozone protects life on Earth by absorbing high-energy electromagnetic cosmic radiation, while lower atmosphere tropospheric ozone at higher concentrations is an oxidant that is potentially harmful to human and ecosystem health. Ozone enters plants through the leaf stomata (Figure 3.1).

3.1 Distribution and Long-term Trends in Ozone Concentration in Ireland

Tropospheric ozone is highly variable over space and time, reflecting local production and destruction as well as addition and loss through regional and long-range transport. Ozone concentrations at 11 stations in Ireland and their long-term trends (at seven to nine sites) were evaluated (McHugh *et al*., 2023b). The station characteristics are described in Table 3.1.

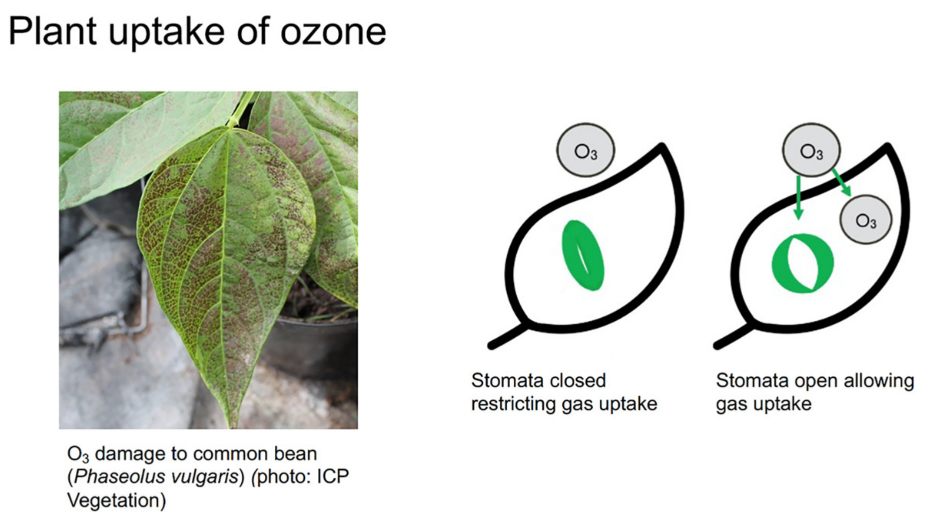


Figure 3.1. Damage symptoms (left) in a leaf exposed to ozone (source: ICP Vegetation). Ozone enters the leaf intercellular space through stomata when open (right).

Table 3.1. Names and characteristics of stations where ozone concentration measurements meet the minimum data threshold of 5 years (2015–2019)

Station name	ID	Landcover	Network	Altitude (m)	Latitude	Longitude	Year observations started
Belfast	BFT	Urban	AURN	8	54.5996	–5.9288	1992
Castlebar	CBR	Suburban	EPA	39	53.8511	–9.3003	2010
Clonskeagh	CSK	Suburban	EPA	25	53.3118	–6.2353	2009
Cork	CSL	Urban	EPA	10	51.8785	–8.4651	2015
Emo	EMO	Rural	EPA	20	53.1076	–7.1983	2004
Kilkitt	KKT	Rural	EPA	170	54.0661	–6.8831	1995
Lough Navar	LNV	Rural	AURN	130	54.4395	–7.9003	1987
Mace Head	MHD	Atlantic	EPA	8	53.3253	–9.9036	1987
Rathmines	RTM	Urban	EPA	25	53.3320	–6.2672	2002
Seville Lodge	SVL	Suburban	EPA	50	52.6383	–7.2676	2012
Valentia	VAL	Atlantic	EPA	10	51.9385	–10.2401	2001

The measurement networks are the EPA in Ireland and the UK Automatic Urban and Rural Network (AURN).
Source: McHugh *et al*. (2023b), reproduced under the terms and conditions of the Creative Commons Attribution CC BY 4.0 licence (https://creativecommons.org/licenses/by/4.0/).

Ozone concentrations (2015–2019) varied spatially, with the highest annual mean concentrations along the Atlantic west coast (69–75 μg/m^3), and the lowest in urban centres (39–43 μg/m^3). The ranges are shown in Figure 3.2. Ozone concentrations followed a daily pattern, with morning and evening maxima, and a seasonal pattern, with spring and winter maxima and a summer–autumn minimum.

Significant long-term (2005–2019) increasing annual ozone concentrations were observed at two rural stations (e.g. Emo in Figure 3.3). During the decade 2010–2019, significant annual increases were observed at four out of nine stations.

Observed site- and season-specific increasing trends in ozone concentrations are likely to reflect regional changes in the sources of precursor gas emissions. Despite reported decreases in peak concentrations in the marine boundary layer in northern mid-latitudes in recent decades (Yan *et al*., 2018), ozone concentrations at some sites in Ireland have increased significantly, primarily observed as changes in winter concentrations. There were no significant decreasing trends at any site or in any season.

Figure 3.2 suggests relatively higher ozone concentrations in coastal regions, which decrease inland, and further decrease over urban land cover. This supports the theory suggesting that ozone is removed from the lower atmosphere when deposited on vegetation surfaces and further destroyed in areas where nitrogen dioxide emissions occur, including urban areas. The coastal effect was tested by plotting ozone concentration against wind direction and speed, as shown in Figure 3.4.

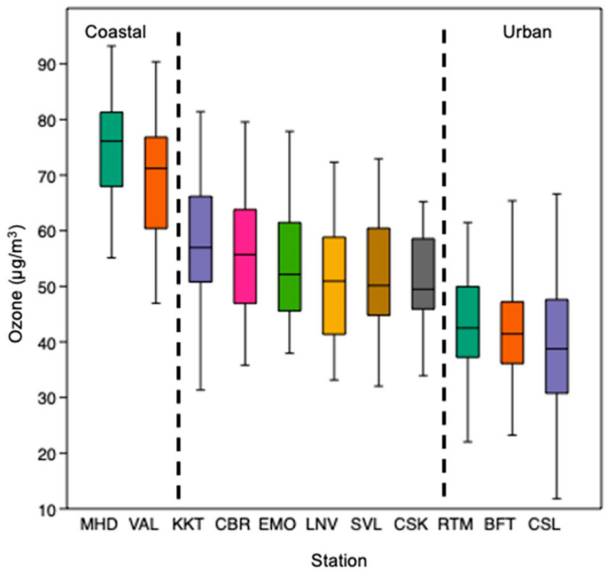


Figure 3.2. Monthly mean ozone concentration ranges (μg/m^3) for 2015–2019. The medians, 95th, 75th, 50th, 25th, and 5th percentiles, ordered from highest to lowest median, are presented. Station codes are given in Table 3.1. Source: Published as figure 2 in McHugh *et al*. (2023b), reproduced under the terms and conditions of the Creative Commons Attribution CC BY 4.0 licence (https://creativecommons.org/licenses/by/4.0/).

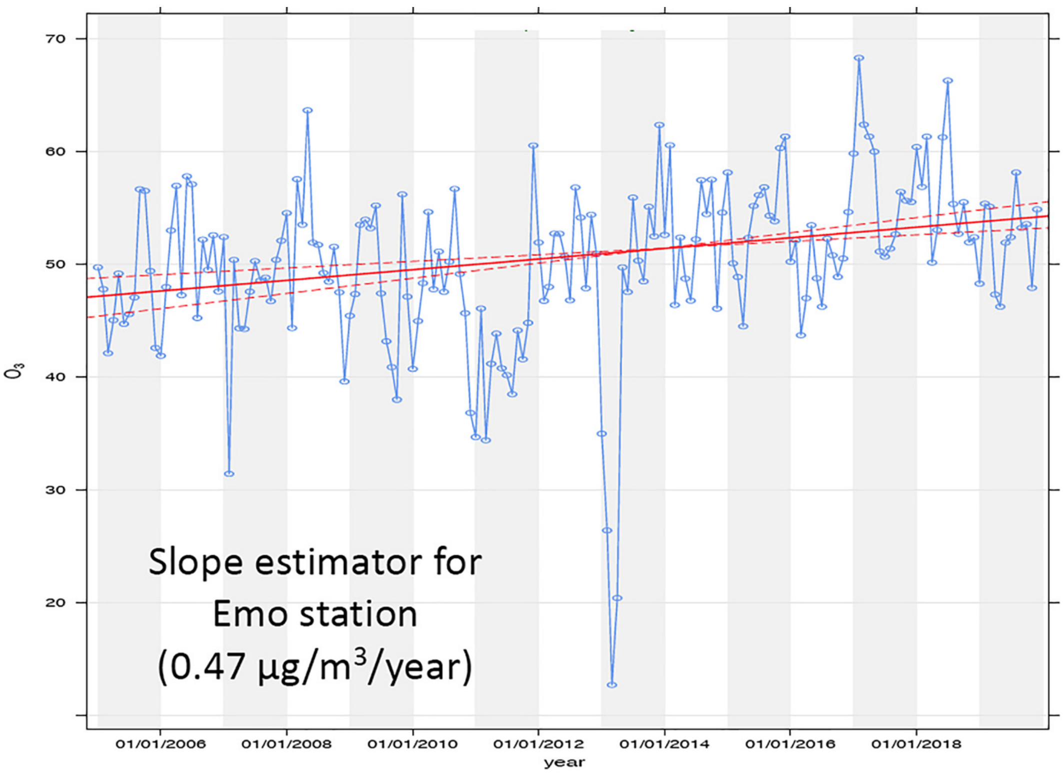


Figure 3.3. Ozone concentrations (µg/m³) and Theil–Sen slope estimator of long-term trend (0.47 µg/m³/year) at rural station Emo, with a Mann–Kendall test showing a significant long-term increasing trend over 2005–2019. Lough Navar also showed a significant increasing trend (0.47 µg/m³/year). Source: Reproduced from McHugh *et al.* (2021).

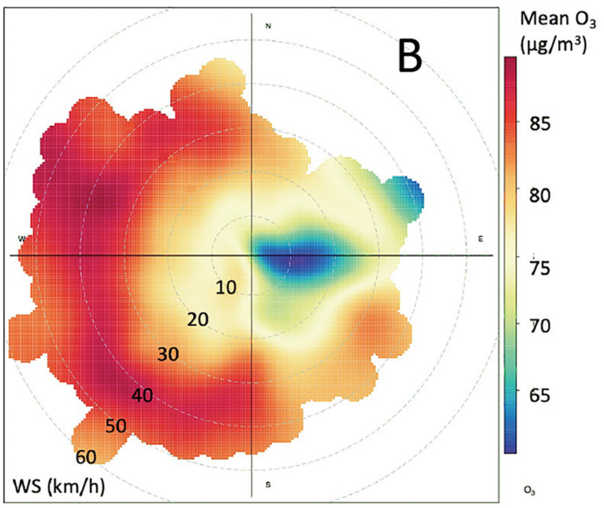


Figure 3.4. Polar plot showing the concentration of ozone with wind direction and speed (WS) at the west coast station Mace Head. Radial directions are the direction from which air is arriving, radial distance of plotted points is the wind speed for that observation, and the colours show ozone concentrations for each measurement.

Figure 3.4 supports the observation of higher ozone concentration ranges at coastal stations. It demonstrates an association of higher ozone concentration with air masses of oceanic origins and with higher wind speeds; low wind speeds and easterly winds give lower ozone concentrations. Considering Figures 3.2 and 3.4 together, the conclusion is that higher ozone concentrations in Ireland arise from oceanic transport of ozone, assumed to be from continental sources beyond the ocean, which decrease inland and further decrease in urban areas. While ozone production in Ireland may be an important source of atmospheric ozone, both now and in the future or during specific weather conditions, the dominant source currently is imported ozone from transoceanic continental sources.

The conclusions from the two coastal sites on the Atlantic coast would be strengthened if measurements from non-urban east coast sites were available. This would provide additional evidence to support the proposed dominance of transcontinental sources of ozone. Assuming that it is the dominant source, it highlights the importance of addressing precursor emissions at regional and global levels. It also highlights the importance of engaging with large emitters at international meetings as part of the EU when considering the Air Convention and the United Nations Framework Convention on Climate Change.

3.2 Phytotoxic Ozone Dose, PODy

The two main approaches to assessing ozone exposure in plants are (1) the amount of time ozone concentration exceeds a threshold, and (2) the time that inner leaf cells are physiologically exposed, above a critical natural detoxification level. The following two metrics have different theoretical regional distributions and have been tested for conditions within Ireland (Figure 3.5): AOT40 (accumulated ozone exposure above a threshold concentration (40 ppb) in ambient air) and PODy (phytotoxic ozone dose above a threshold concentration *y*).

Ozone risk to forests, crops and semi-natural vegetation in Ireland was assessed by modelling the PODy risk metric based on local ozone and meteorological data during 2005–2021 at eight sites, using the model package DO3E (Emberson *et al*., 2000, 2007; Büker *et al*., 2015). Long-term trends in PODy were compared with trends in AOT40 (setting stomatal conductance to > 0) using a Mann–Kendall trend test. The outcomes were published in McHugh *et al*. (2024), and Figure 3.6 shows an example.

The main conclusions of this study are that PODy predicts a higher risk to vegetation than the AOT40 metric; Atlantic coastal areas had higher predicted risks than rural and suburban areas; and significant increases in PODy have occurred at rural sites for grasses and forbs since 2005.

3.3 Land Use Regression of Ozone Concentrations

Air quality monitoring stations are limited spatially to large urban centres; accordingly, accurate prediction of pollutant concentrations outside cities is important for protecting human and plant health. Land use regression has been successfully used for modelling air pollutant concentrations by establishing a relationship between observed concentrations and candidate landscape features representing sources and sinks. A land use regression model was developed that explained 68% of the variance in average summer ozone concentrations in Ireland. Ozone was measured at 14 active and 20 passive monitoring sites; air concentrations varied spatially, with the highest ozone levels measured in rural upland (64.5 μg/m^3) and Atlantic coastal (50.2–60.5 μg/m^3) sites and the lowest generally in urban centres (38.9–45.7 μg/m^3) (Figure 3.7). A total of 74 land use predictor variables were tested, and their inclusion in the model was based on their impact on the coefficient of determination (R^2). The final model included variables linked primarily to deposition processes, rather than emission of

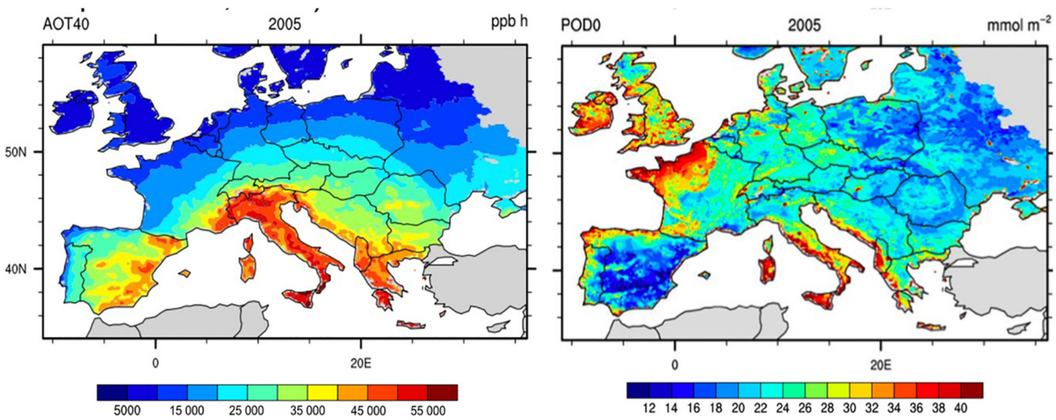


Figure 3.5. Regional distributions of ozone exposure metrics AOT40 (left) and POD0 (right), suggesting different outcomes in the Atlantic regions of western Europe. Source: Reproduced from Anav *et al.* (2016) with permission from Wiley.

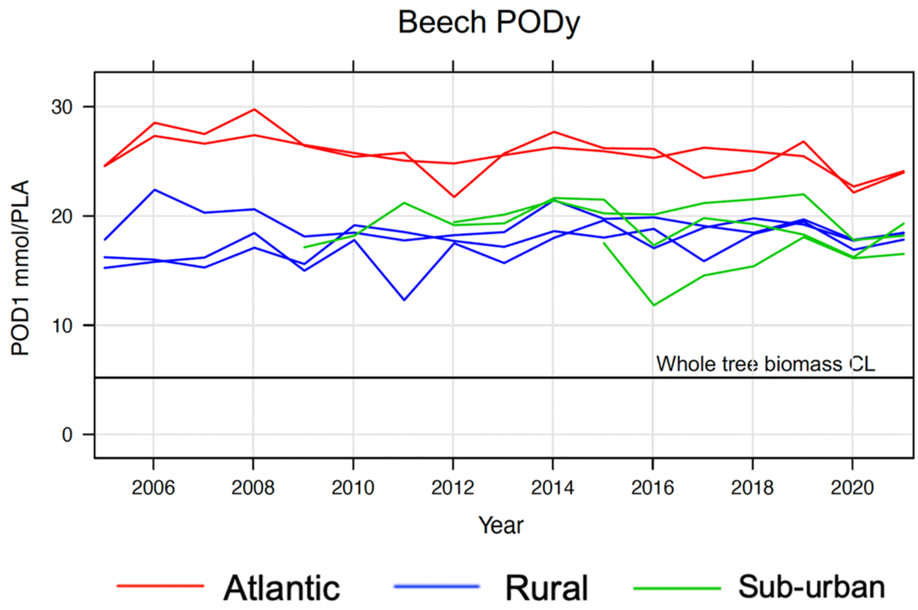


Figure 3.6. Long-term series for POD1 in target species European beech for the response in terms of whole-tree biomass. All sites indicated exceedance of the whole-tree biomass critical load (CL). Source: Reproduced from McHugh *et al*. (2024), under the terms and conditions of the Creative Commons Attribution CC BY 4.0 licence (https://creativecommons.org/licenses/by/4.0/).

precursors, and included "forest woodland and scrub area" and "distance to coast". The meteorological variable "rain" and a speculative indicator "distance to EPA integrated pollution control facilities" were also included in the final model. Our results demonstrate the potential effectiveness of land use regression modelling in predicting (although not explaining) ozone concentrations at a scale relevant for ecosystem protection.

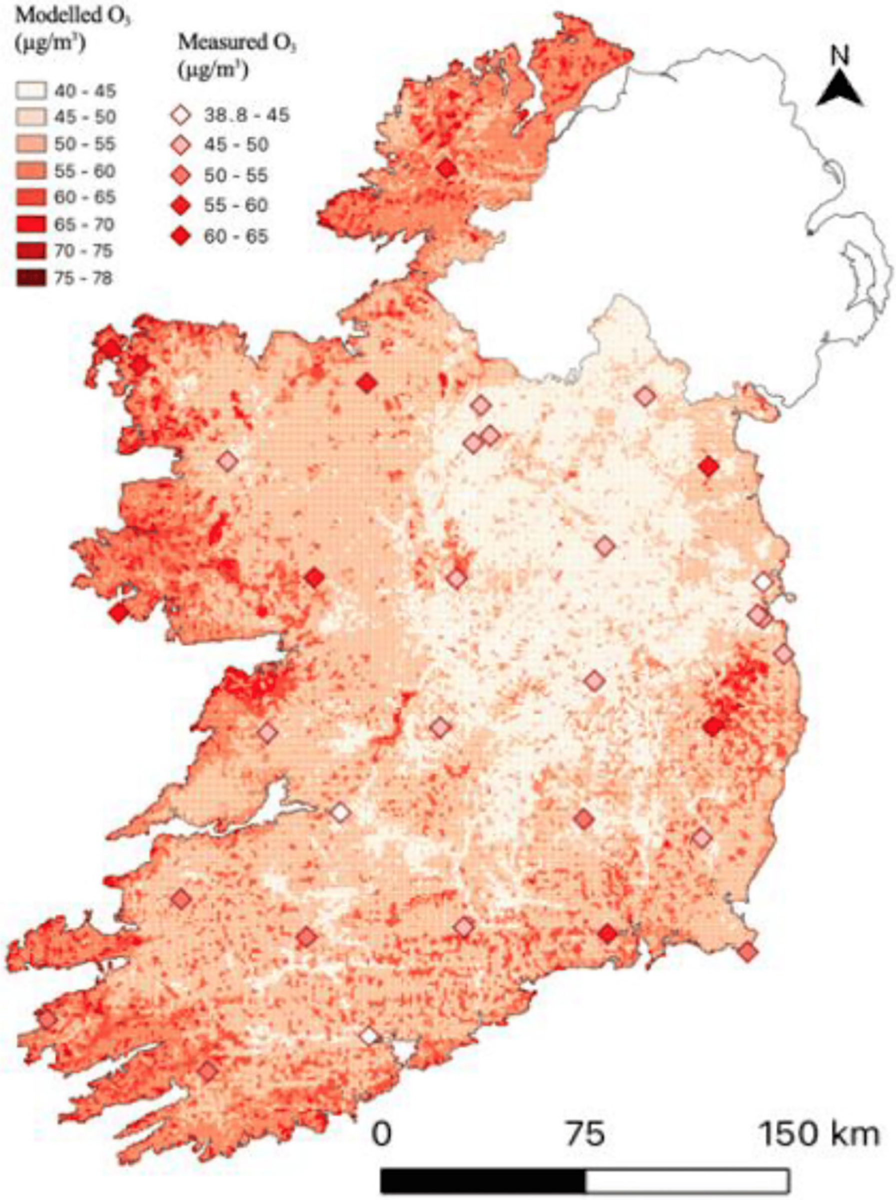


Figure 3.7. Modelled 1 km × 1 km and measured mean summer ozone (O_3) concentrations in Ireland. Diamonds represent the measured concentration at each active and passive study site. Source: Reproduced from McHugh *et al.* (2023a), under the terms and conditions of the Creative Commons Attribution CC BY 4.0 licence (https://creativecommons.org/licenses/by/4.0/).

4 Effects of Nitrogen Deposition on Biodiversity

Plant community composition

Community composition is monitored at multiple permanent sample plots at terrestrial NEMN sites. Sampling sites are spread across a gradient of nitrogen deposition values, while also trying to account for other variation, especially rainfall. Vascular plants and bryophyte species are recorded at intervals of 4–6 years.

Changes in the occurrence and frequency of species are combined to identify how the plant community changes across a nitrogen deposition gradient and at what levels of deposition the greatest change occurs. Specific measurements are identified that indicate more complex changes.

Now well established in the NEMN, aligned with Habitats Directive monitoring, Ireland has a network for monitoring plant community changes in some habitats, which can be expanded to new habitats in future.

4.1 Monitoring Biodiversity and Change

The biodiversity and vegetation effects of atmospheric reactive nitrogen deposition were studied by three main survey types. Firstly, plant species abundance was recorded in plots in five bog and semi-natural grassland habitats across the nitrogen deposition gradient. Some of these plots were surveyed as part of National Parks and Wildlife Service Habitats Directive monitoring, with minor additions to also satisfy the requirements of NEMN monitoring. Further sampling was done solely for NEC Indicators research. Secondly, moss and vascular plant tissue was collected and analysed for tissue nitrogen concentration. Some of this sampling was integrated with the ICP Vegetation[1] European Moss Survey and some with the NEMN monitoring, and some was undertaken solely for this research. Thirdly, satellite imagery was used to look for changes in the reflection of red and near-infrared light in grasslands exposed to a gradient of nitrogen deposition. This used botanical data from earlier Habitats Directive monitoring, alongside freely available satellite imagery, and will be reported by Marcham (forthcoming).

4.2 Measuring Vegetation Change Using TITAN

In nutrient-poor habitats such as species-rich grasslands and bogs, deposition of ammonia, and other forms of reactive nitrogen, can cause changes in vegetation composition, leading to a decline in the number of species, particularly species more specialised to a particular habitat (Bobbink *et al.*, 2022). By adding nitrogen, deposition allows generalist species with competitive traits to grow faster and larger, thus overshadowing the specialist species with resource-conservative traits (Hautier *et al.*, 2009), which grow slowly and remain small (Hodgson *et al.*, 2014). Ammonia, or substances released by the acidifying effects of nitrogen deposition on soil, can also damage plants, with some species more

1 ICP Vegetation is an international cooperative programme investigating the effect of air pollution on natural vegetation and crops, under the Air Convention.

susceptible than others. Such changes sometimes occur abruptly along a gradual environmental gradient (Huggett, 2005), which has been demonstrated in Irish grasslands and bogs on a nitrogen deposition gradient (Wilkins *et al*., 2016).

Cover of all plant species was recorded in 2 m × 2 m plots in five habitats. Modelled total nitrogen deposition (MET Norway, 2022) was extracted for each plot, averaged over the 3 years prior to survey.

Threshold Indicator Taxa Analysis (TITAN) (Baker and King, 2010; Baker *et al*., 2020) was used to find change points for individual species and the whole community and to identify species useful for indicating change in the whole community. The outputs from TITAN for one habitat across the surveys undertaken, calcareous grassland, are graphically presented in Figure 4.1.

TITAN shows promise as a tool for identifying points of greatest change in vegetation and for identifying

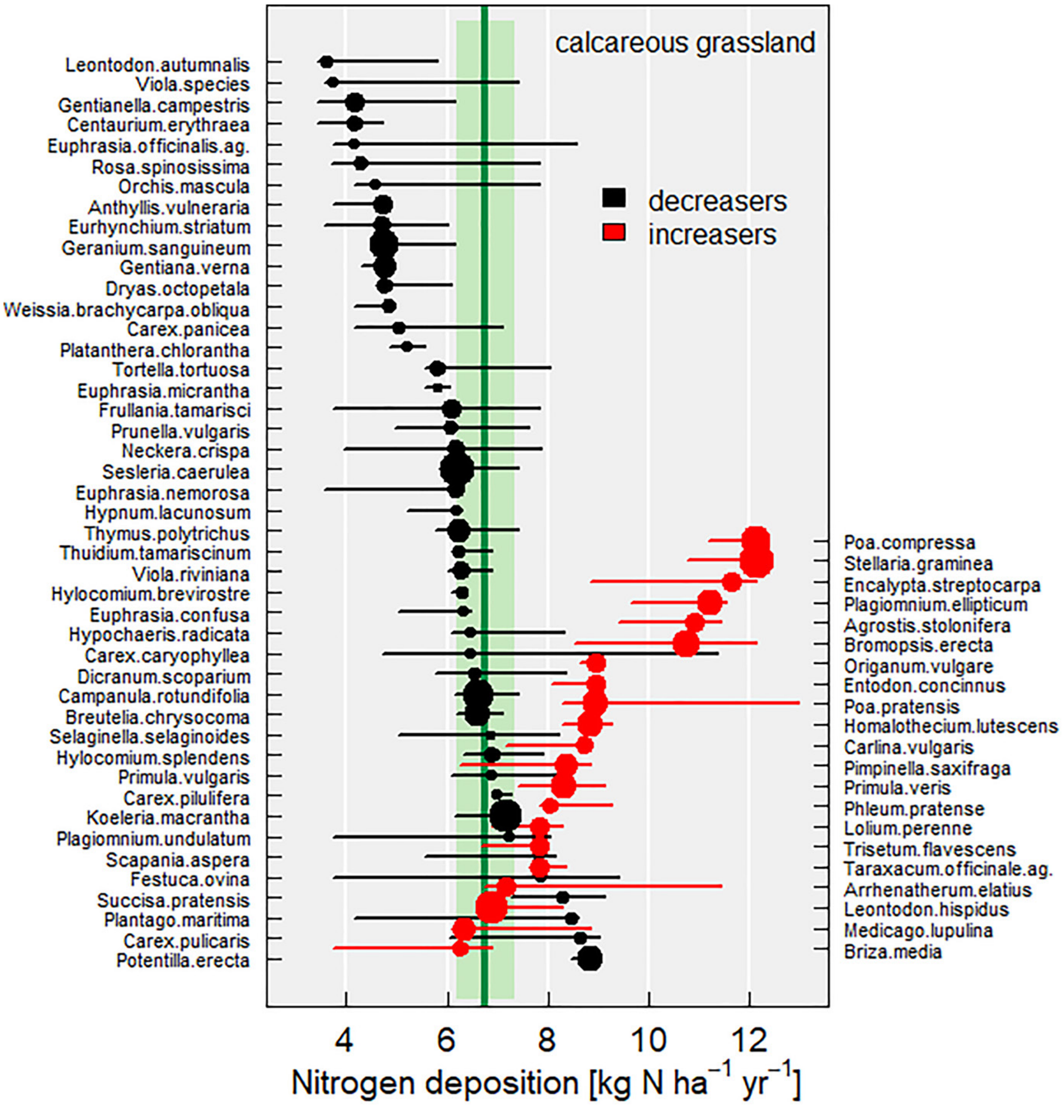


Figure 4.1. TITAN output showing species change points (dots) and community change point (green line) in calcareous grassland habitat (Habitats Directive Annex I habitat 6210) across the nitrogen deposition gradient in Ireland. Species shown in black decline with increasing nitrogen concentration, with the greatest change at the dot. Species shown in red increase with increasing nitrogen concentration. Species with larger dots have greater reliability as indicators and horizontal bars convey uncertainty in the change point position. The vertical green line is the community change point, calculated as the point on the deposition gradient with the greatest sum of individual qualifying decreasing change points. Source: Reproduced from Marcham and Cummins (2023).

species or trait indicators of such change. However, further investigation of the data is required alongside TITAN, as several caveats and limitations are recognised among practitioners.

TITAN can only consider one environmental variable at a time, but several variables are likely to be influencing the plant community at the same time. TITAN has been shown to produce incorrect change points in certain scenarios (Cuffney and Qian, 2013), and although those scenarios are not based on typical biological data they may occur sometimes. In addition, species that both increase and decrease within the dataset are missed but do represent ecosystem impacts. Other analyses are required alongside TITAN to check for such problems, but so far a systematic procedure has not been established. Accordingly, TITAN may form part of a future assessment approach, but its use requires further controls than are currently available.

TITAN change points have been used in setting critical loads (Aherne *et al.*, 2021), taking the change point as the point at which harm is caused to the ecosystem. This interpretation requires some caution to assess the biological significance of the change, as TITAN simply reports the points of greatest change within the dataset, even if the change is small.

Lastly, while TITAN is designed to identify points of greatest change, the nature of gradual changes across the whole gradient is also important for understanding ecosystem impacts.

4.3 Moss Tissue Nitrogen Content

Mosses accumulate nitrogen in their tissues, so tissue nitrogen concentration is used as an indicator of air pollution pressure (Frontasyeva *et al.*, 2020). In order to co-locate moss tissue collection with habitat monitoring plots, a wider pool of moss species than previously tested is required. This became apparent during initial surveys for the NEMN. Nitrogen deposition increases foliar nitrogen levels in some vascular plant species, mediated through soil processes. This can influence plant health and herbivores but also could be tested for use as an early indicator of more slowly emerging vegetation changes.

Moss tissue was collected at 291 plots across a deposition gradient in Ireland, including 20 plots where more than one species was sampled. For the ICP Vegetation European Moss Survey, moss was collected from a subset of plots sampled in 2015, which were designed to be distributed across map grid squares, with their exact locations chosen for the availability of one moss species, *Hylocomium splendens* (Figure 4.2). Other surveys collected moss at plots chosen for specific habitats and covering a range of nitrogen deposition concentrations and so collected whichever suitable species was available.

Tissue nitrogen concentration differed significantly among moss species. Figure 4.3 shows the ranges and differences, plus a normalising approach, the Moss Enrichment Index (MEI) (Rowe *et al.*, 2017), calculated to calibrate values between moss species:

$$\text{MEI} = \frac{\%N_{observed} - \%N_{minimum}}{\%N_{maximum} - \%N_{minimum}}$$

By several measures, the use of the MEI was not successful in removing the effect of species in this study, which is likely to be because the MEI is calculated from a small range of tissue nitrogen values. A solution is proposed in which external reference values are used to calculate the MEI, but this will require international research to sample

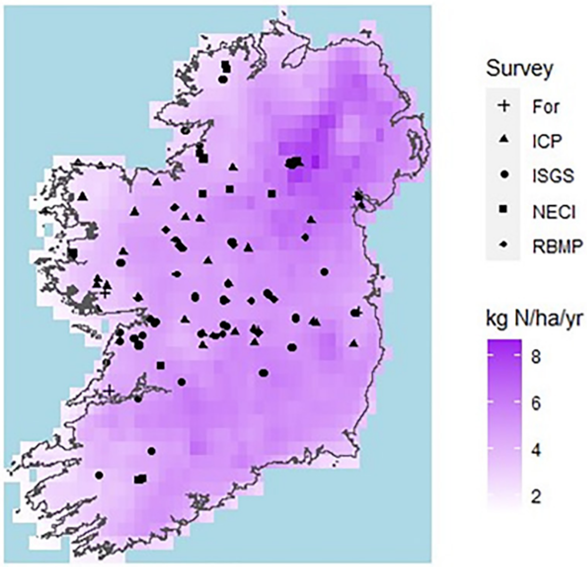


Figure 4.2. Moss sampling sites in Ireland for 2021 and 2022 surveys and EMEP MSC-W modelled nitrogen deposition as an average value across the 3 years before sampling. For, ICP Forests survey; ICP, ICP Vegetation European Moss Survey, ISGS, Irish Semi-natural Grasslands Survey; NECI, NEC Indicators project; RBMP, Raised Bog Monitoring Project.

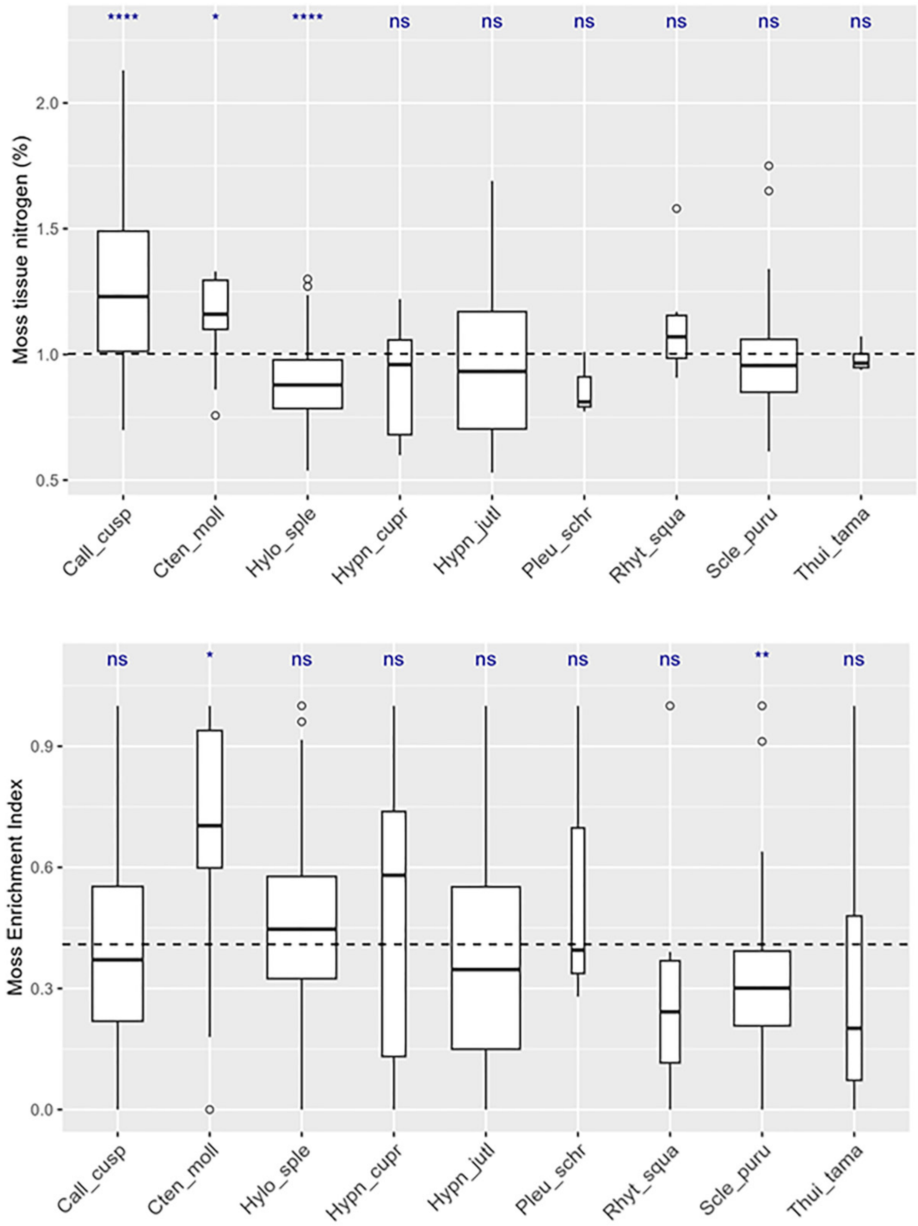


Figure 4.3. Moss tissue nitrogen concentration (top) and Moss Enrichment Index (bottom), ordered by moss species. Box widths are proportional to the number of samples available for that species. Boxes represent the interquartile range (IQR) and whiskers are to 1.5 × IQR. The difference from the overall mean (dashed line) is indicated at the 5% significance level following analysis of variance. Call_cusp, *Calliergonella cuspidata*; Cten_moll, *Ctenidium molluscum*; Hylo_sple, *Hylocomium splendens*; Hypn_cupr, *Hypnum cupressiforme*; Hypn_jutl, *Hypnum jutlandicum*; Pleu_schr, *Pleurozium schreberi*; Rhyt_squa, *Rhytidiadelphus squarrosus*; Scle_puru, *Scleropodium purum*; Thui_tama, *Thuidium tamariscinum*.

each moss species at a greater range of measured deposition. This would perhaps best be combined with work to further coordinate monitoring capacity internationally, so that the method ultimately selected can then be applied.

Vascular plant leaves were collected at 86 of the semi-natural grassland plots. At each plot, one sample was collected of only *Plantago lanceolata* and one of a representative mixture of the species present. Vascular plant C:N was better predicted by moss C:N ratio than

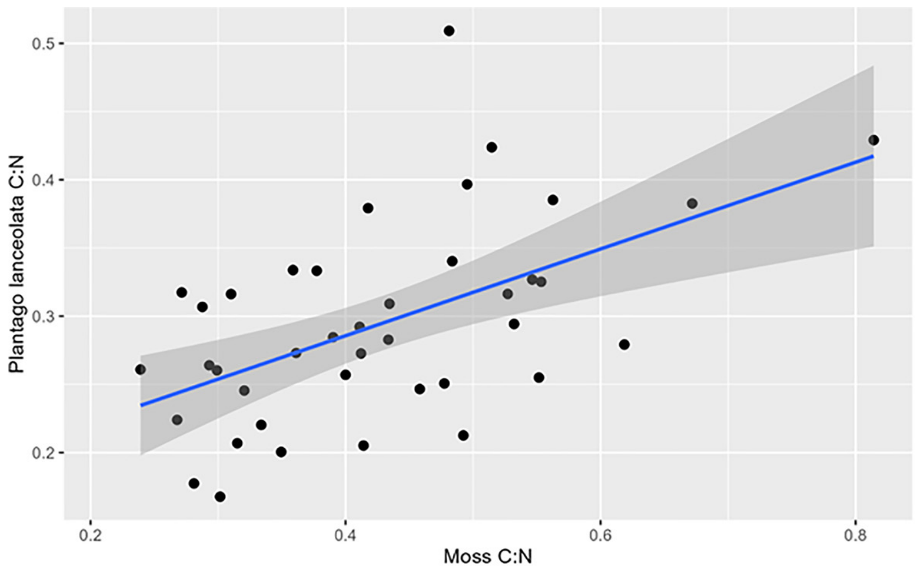


Figure 4.4. C:N ratios from samples of moss and a selected vascular plant, *Plantago lanceolata*, collected at the same grassland plots. The blue line is drawn from a simple linear regression and the shading shows the 95% confidence interval. Graph from Marcham (forthcoming).

by modelled nitrogen deposition value (Figure 4.4), which could be partly due to a disparity between deposition modelled for 5 km squares and local conditions in plots of 50 m radius. This suggests that moss tissue nitrogen concentration has an important role in understanding the nitrogen deposition pressure on ecosystems, alongside modelling and instrumented air quality measurements.

5 Capacity for Ecosystem Monitoring

The NEC Indicators project has supported the development of two researchers undertaking PhD studies specialising in air pollution effects in ecosystems. A new module, AESC40690 Ecosystem Monitoring, at University College Dublin has been developed in response to the NEC Indicators project, also incorporating knowledge from prior monitoring carried out under the Air Convention in Ireland and Europe.

State capacity for ecosystem monitoring within the NEMN is increasing incrementally and has drawn on the NEC Indicators project through the project steering committee, publication outputs and participation in the NEMN Stakeholder Forum.

Botanical surveys conducted as part of the NEC Indicators research have contributed to the NEMN data submission for blanket bog and wet heath habitats and identified potential locations for continued monitoring. At raised bog and grassland sites, NEMN plots were mainly co-located with previous habitat monitoring plots, while in the upland habitats, which are often very large sites with habitat mosaics, new monitoring capacity comes from establishing new plots.

The analysis of NEMN data as part of the NEC Indicators research, and the combination of these datasets with data from other sources, has helped to highlight some important considerations in data management. This has helped to inform recommendations for NEMN data handling at all stages.

Capacity for monitoring within the NEMN remains limited compared with the level of activity envisaged in the NEMN design report (Kelleghan *et al*., 2021). As reported at the National Air Event 2024 (English, 2024), in addition to vegetation recording from plots across terrestrial habitats, installed and operating monitoring consists of the following:

- monthly passive sampling of ammonia and nitrogen dioxide at 12 sites;
- annual soil and moss sampling at six forest sites;
- forest crown condition monitoring at 35 sites (not submitted under the NECD).

Further developments planned within the reporting cycle to 2027 are as follows:

- installation of bulk deposition monitoring;
- extension of passive trace gas monitoring to reach a total of 18 sites.

The future development of the NEMN reflects the necessarily incremental approach recommended.

A review by the European Commission Directorate-General for Environment of core parameters from Ireland's data submissions shows most categories reliant on legacy data to 2017 or with only limited or entirely absent monitoring (Williamson *et al*., 2024, pp. 75–76). The authors stated that data across the EU Member States' NECD submissions were "too heterogenous ... to allow a meaningful comparison", and that "no Member State could reliably construct a full causal chain from emissions to impacts".

Several difficulties arise from the data submission and hosting approach and from the lack of a public-facing interface or observatory for NECD ecosystem monitoring data. The development of a spatial interface and data interrogation capability would allow at least Member State teams to review each other's submissions. A community suggestion envisages an observatory combining data from NECD monitoring, Habitats Directive monitoring, and further external integration with European Monitoring and Evaluation Programme and Air Convention monitoring under several ICPs (ICP Forests, ICP Vegetation, ICP Waters, ICP Modelling and Mapping, ICP Integrated Monitoring).

6 National Ecosystems Monitoring Network Recommendations

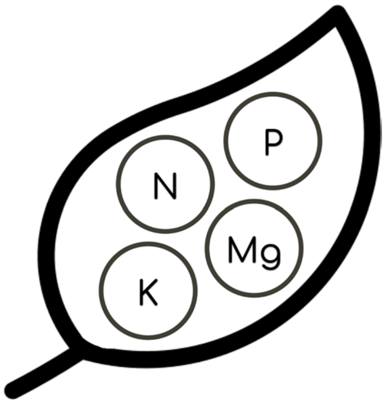
Recommendations for further development of the design of the NEMN have been proposed frequently during the NEC Indicators project work, through contact with NEMN stakeholders and informally over the years the work took place. Feedback from the project steering committee was sought to draw up an initial list, following which a reduced set of recommendations is proposed here.

At the EU level, a procedure for checking data on submission was recommended by the NEC Indicators team and is also recommended by Williamson *et al.* (2023). This emerging issue seems to reflect a gap in NECD monitoring that could draw more closely on existing methods: in ICP Forests, to give one related example, highly automated checking is undertaken, with multi-step submission qualification, preventing simple avoidable errors in submission formatting. Beyond this example, the expertise and systems developed over four decades of monitoring by the ICPs under the Air Convention could further inform and contribute to NECD monitoring development.

Across the six key indicators identified in the NECD (the six categories here), NEC Indicators research proposes high-level recommendations for continued monitoring and for new monitoring required to measure indicators of air pollution effects in terrestrial ecosystems within Ireland's NEMN. These recommendations include significant additional sampling matrices (soil solid, soil liquid, tree growth) and broad additional areas of investigation (foliar nutrients, soil acidity, soil nitrate leaching). Several of these recommendations are in addition to and assume urgent establishment of continuous bulk-precipitation deposition monitoring with annual reporting, and further timely development of continuous forest throughfall deposition monitoring in the next NECD cycle from 2027, a full decade after the last throughfall deposition monitoring exercise under the Air Convention.

This study supports the further development of Ireland's NEMN, established under the NECD. Continuous monitoring of atmospheric deposition of nitrogen and other substances, growing season ambient atmospheric ozone monitoring, and further surveys of soil solid (10- to 15-year cycle), and supplementing of bulk precipitation with throughfall and soil pore water monitoring (continuous) are required to better understand the effects of air pollution on sensitive ecosystems.

A final suggestion, discussed during early planning for the establishment of the NEMN, and frequently mentioned in the years since, is to establish at least one "super-site", or possibly a named "level 3 site", ideally based around a catchment or other hydrological unit and in which a wide range of monitoring approaches are represented. This would provide a context for education, training and outreach, give a primary reference for Ireland, form a platform for one-off or exploratory projects and surveys, potentially allow some field-scale experimentation, and overall encourage investment in monitoring and intellectual development.

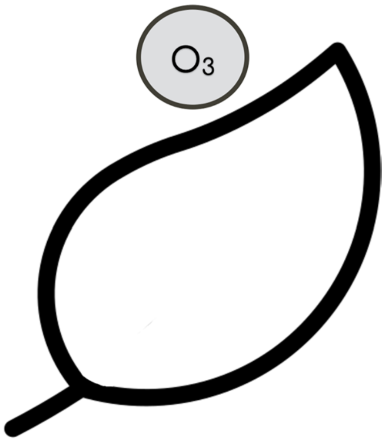


Foliar nutrients

Use historical foliar analysis from ICP Forests to review foliar nutrient ratios in forest foliage.

Initiate foliar analysis and assessment of foliar nutrient ratios on all NEMN terrestrial surveys, considering methods developed by Lorna Marcham (Marcham, forthcoming) (4- to 6-year intervals)

Further develop use of moss tissue nitrogen concentration for indicating nitrogen deposition pressure on ecosystems, alongside modelling and instrumented air quality measurements (4- to 6-year cycle).



Ozone effects

Establish passive monitoring of ozone (during growing season) at level 2 ecosystem monitoring plots, terrestrial and aquatic, alongside ammonia monitoring, using a risk-based approach following ozone assessments made by Keelan McHugh (McHugh, 2024) in the next iteration of monitoring from 2027.

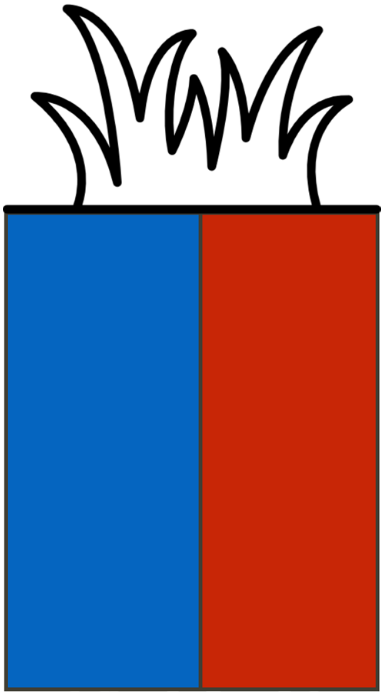
Develop capability in ozone symptom recognition, and develop vegetation monitoring, following the recommendation of the ICP Forests Expert Panel on Ozone Symptoms (annually). Recommend ozone symptoms are monitored during cereal crop monitoring by the Department of Agriculture, Food and the Marine.

Develop modelling capability for routine assessment of PODy (every 4 years).

Vegetation change

Continue the integration of NEMN plot monitoring with Habitats Directive monitoring as established following the NEMN design report (4- to 6-year cycle).

Establish forest tree growth measurement on level 2 forest plots (every 5 years), and tree stem diameter measurement on level 1 plots (annually).

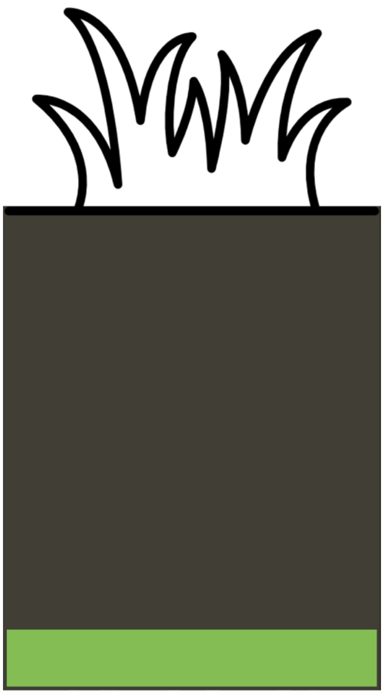


Soil acidity

Design and implement a soil solid survey (to be carried out at 10- 15-year intervals), drawing on past surveys under ICP Forests, and where possible planning for integration with the proposed EU Soil Monitoring Law.

Design and establish soil pore water monitoring (continuous) at qualifying instrumented terrestrial plots, based on risk of acidification using critical load concepts and representing acid-sensitive ecosystems.

Undertake throughfall monitoring in forest habitats.

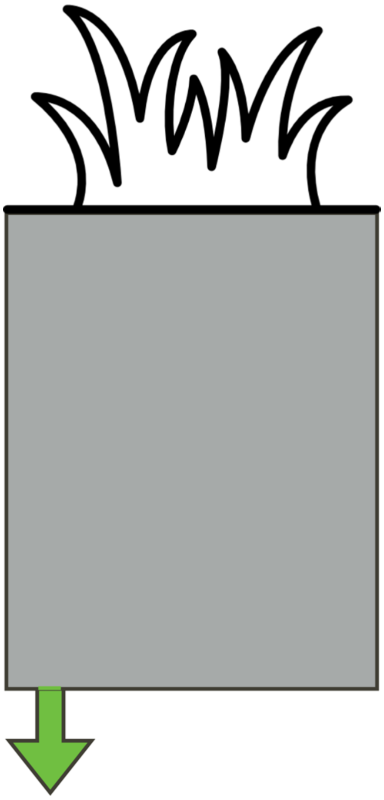


Soil C:N ratio

Continue topsoil sampling associated with botanical surveys at NEMN plots (4- to 6-year cycle).

Integrate soil sampling for C:N ratio monitoring with soil solid survey (10- to 15-year intervals) and, where possible, in compatibility with surveys undertaken under the proposed Soil Monitoring Law.

Use more measurements of soil carbon from the National Forest Inventory for NEMN monitoring.



Soil nitrate leaching

Design and establish soil pore water monitoring (continuous) at qualifying instrumented terrestrial plots, representing nitrate-sensitive hydrological systems.

Develop a set of measurements (continuous) for parameterising unsaturated soil water flow at soil water monitoring locations.

Supplement bulk-precipitation collection with throughfall monitoring in forest habitats, to allow quantification of water and solutes entering the soil.

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Abbreviations and Glossary

AOT40	An indicator of ozone stress in plants, accumulated ozone exposure above a threshold concentration, 40 ppb ozone in ambient air.
EMEP MSC-W	The chemical transport model developed at Meteorological Synthesizing Centre – West, Norwegian Meteorological Institute, part of the Co-operative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP), under the UNECE Convention on Long-range Transboundary Air Pollution (the Air Convention).
EPA	Ireland’s Environmental Protection Agency.
ICP	International cooperative programme, of which there are several under the Air Convention, namely ICP Forests, ICP Vegetation, ICP Modelling and Mapping, and ICP Integrated Monitoring.
MEI	Moss Enrichment Index.
NECD	Directive (EU) 2016/2284/EU, previously known informally as the National Emission Ceilings Directive and now as the National Emission reduction Commitments Directive. Note the use of the lowercase “r”, allowing continued use of the established abbreviation “NECD”, and also emphasising “Commitments”.
NEMN	National Ecosystems Monitoring Network, Ireland’s response to NECD Article 9 and Annex V commitments to monitor the harmful effects of air pollution in ecosystems. The NEMN is operated by Ireland’s EPA.
PODy	An indicator of ozone stress in a specified group of plants: phytotoxic ozone dose above a threshold concentration *y*. Varying the value of *y* gives rise to POD1, POD3, POD6, and so on.
TITAN	Threshold Indicator Taxa Analysis, a method for relating plant community composition and change to a stressor such as nitrogen deposition and identifying change points on the stress axis.

An Ghníomhaireacht Um Chaomhnú Comhshaoil

Tá an GCC freagrach as an gcomhshaol a chosaint agus a fheabhsú, mar shócmhainn luachmhar do mhuintir na hÉireann. Táimid tiomanta do dhaoine agus don chomhshaol a chosaint ar thionchar díobhálach na radaíochta agus an truaillithe.

Is féidir obair na Gníomhaireachta a roinnt ina trí phríomhréimse:

Rialáil: Rialáil agus córais chomhlíonta comhshaoil éifeachtacha a chur i bhfeidhm, chun dea-thorthaí comhshaoil a bhaint amach agus díriú orthu siúd nach mbíonn ag cloí leo.

Eolas: Sonraí, eolas agus measúnú ardchaighdeáin, spriocdhírithe agus tráthúil a chur ar fáil i leith an chomhshaoil chun bonn eolais a chur faoin gcinnteoireacht.

Abhcóideacht: Ag obair le daoine eile ar son timpeallachta glaine, táirgiúla agus dea-chosanta agus ar son cleachtas inbhuanaithe i dtaobh an chomhshaoil.

I measc ár gcuid freagrachtaí tá:

Ceadúnú

> Gníomhaíochtaí tionscail, dramhaíola agus stórála peitril ar scála mór;
> Sceitheadh fuíolluisce uirbigh;
> Úsáid shrianta agus scaoileadh rialaithe Orgánach Géinmhodhnaithe;
> Foinsí radaíochta ianúcháin;
> Astaíochtaí gás ceaptha teasa ó thionscal agus ón eitlíocht trí Scéim an AE um Thrádáil Astaíochtaí.

Forfheidhmiú Náisiúnta i leith Cúrsaí Comhshaoil

> Iniúchadh agus cigireacht ar shaoráidí a bhfuil ceadúnas acu ón GCC;
> Cur i bhfeidhm an dea-chleachtais a stiúradh i ngníomhaíochtaí agus i saoráidí rialáilte;
> Maoirseacht a dhéanamh ar fhreagrachtaí an údaráis áitiúil as cosaint an chomhshaoil;
> Caighdeán an uisce óil phoiblí a rialáil agus údaruithe um sceitheadh fuíolluisce uirbigh a fhorfheidhmiú
> Caighdeán an uisce óil phoiblí agus phríobháidigh a mheasúnú agus tuairisciú air;
> Comhordú a dhéanamh ar líonra d'eagraíochtaí seirbhíse poiblí chun tacú le gníomhú i gcoinne coireachta comhshaoil;
> An dlí a chur orthu siúd a bhriseann dlí an chomhshaoil agus a dhéanann dochar don chomhshaol.

Bainistíocht Dramhaíola agus Ceimiceáin sa Chomhshaol

> Rialacháin dramhaíola a chur i bhfeidhm agus a fhorfheidhmiú lena n-áirítear saincheisteanna forfheidhmithe náisiúnta;
> Staitisticí dramhaíola náisiúnta a ullmhú agus a fhoilsiú chomh maith leis an bPlean Náisiúnta um Bainistíocht Dramhaíola Guaisí;
> An Clár Náisiúnta um Chosc Dramhaíola a fhorbairt agus a chur i bhfeidhm;
> Reachtaíocht ar rialú ceimiceán sa timpeallacht a chur i bhfeidhm agus tuairisciú ar an reachtaíocht sin.

Bainistíocht Uisce

> Plé le struchtúir náisiúnta agus réigiúnacha rialachais agus oibriúcháin chun an Chreat-treoir Uisce a chur i bhfeidhm;
> Monatóireacht, measúnú agus tuairisciú a dhéanamh ar chaighdeán aibhneacha, lochanna, uiscí idirchreasa agus cósta, uiscí snámha agus screamhuisce chomh maith le tomhas ar leibhéil uisce agus sreabhadh abhann.

Eolaíocht Aeráide & Athrú Aeráide

> Fardail agus réamh-mheastacháin a fhoilsiú um astaíochtaí gás ceaptha teasa na hÉireann;
> Rúnaíocht a chur ar fáil don Chomhairle Chomhairleach ar Athrú Aeráide agus tacaíocht a thabhairt don Idirphlé Náisiúnta ar Ghníomhú ar son na hAeráide;
> Tacú le gníomhaíochtaí forbartha Náisiúnta, AE agus NA um Eolaíocht agus Beartas Aeráide.

Monatóireacht & Measúnú ar an gComhshaol

> Córais náisiúnta um monatóireacht an chomhshaoil a cheapadh agus a chur i bhfeidhm: teicneolaíocht, bainistíocht sonraí, anailís agus réamhaisnéisiú;
> Tuairiscí ar Staid Thimpeallacht na hÉireann agus ar Tháscairí a chur ar fáil;
> Monatóireacht a dhéanamh ar chaighdeán an aeir agus Treoir an AE i leith Aeir Ghlain don Eoraip a chur i bhfeidhm chomh maith leis an gCoinbhinsiún ar Aerthruailliú Fadraoin Trasteorann, agus an Treoir i leith na Teorann Náisiúnta Astaíochtaí;
> Maoirseacht a dhéanamh ar chur i bhfeidhm na Treorach i leith Torainn Timpeallachta;
> Measúnú a dhéanamh ar thionchar pleananna agus clár beartaithe ar chomhshaol na hÉireann.

Taighde agus Forbairt Comhshaoil

> Comhordú a dhéanamh ar ghníomhaíochtaí taighde comhshaoil agus iad a mhaoiniú chun brú a aithint, bonn eolais a chur faoin mbeartas agus réitigh a chur ar fáil;
> Comhoibriú le gníomhaíocht náisiúnta agus AE um thaighde comhshaoil.

Cosaint Raideolaíoch

> Monatóireacht a dhéanamh ar leibhéil radaíochta agus nochtadh an phobail do radaíocht ianúcháin agus do réimsí leictreamaighnéadacha a mheas;
> Cabhrú le pleananna náisiúnta a fhorbairt le haghaidh éigeandálaí ag eascairt as taismí núicléacha;
> Monatóireacht a dhéanamh ar fhorbairtí thar lear a bhaineann le saoráidí núicléacha agus leis an tsábháilteacht raideolaíochta;
> Sainseirbhísí um chosaint ar an radaíocht a sholáthar, nó maoirsiú a dhéanamh ar sholáthar na seirbhísí sin.

Treoir, Ardú Feasachta agus Faisnéis Inrochtana

> Tuairisciú, comhairle agus treoir neamhspleách, fianaise-bhunaithe a chur ar fáil don Rialtas, don tionscal agus don phobal ar ábhair maidir le cosaint comhshaoil agus raideolaíoch;
> An nasc idir sláinte agus folláine, an geilleagar agus timpeallacht ghlan a chur chun cinn;
> Feasacht comhshaoil a chur chun cinn lena n-áirítear tacú le hiompraíocht um éifeachtúlacht acmhainní agus aistriú aeráide;
> Tástáil radóin a chur chun cinn i dtithe agus in ionaid oibre agus feabhsúchán a mholadh áit is gá.

Comhpháirtíocht agus Líonrú

> Oibriú le gníomhaireachtaí idirnáisiúnta agus náisiúnta, údaráis réigiúnacha agus áitiúla, eagraíochtaí neamhrialtais, comhlachtaí ionadaíocha agus ranna rialtais chun cosaint chomhshaoil agus raideolaíoch a chur ar fáil, chomh maith le taighde, comhordú agus cinnteoireacht bunaithe ar an eolaíocht.

Bainistíocht agus struchtúr na Gníomhaireachta um Chaomhnú Comhshaoil

Tá an GCC á bainistiú ag Bord lánaimseartha, ar a bhfuil Ard-Stiúrthóir agus cúigear Stiúrthóir. Déantar an obair ar fud cúig cinn d'Oifigí:

1. An Oifig um Inbhunaitheacht i leith Cúrsaí Comhshaoil
2. An Oifig Forfheidhmithe i leith Cúrsaí Comhshaoil
3. An Oifig um Fhianaise agus Measúnú
4. An Oifig um Chosaint ar Radaíocht agus Monatóireacht Comhshaoil
5. An Oifig Cumarsáide agus Seirbhísí Corparáideacha

Tugann coistí comhairleacha cabhair don Ghníomhaireacht agus tagann siad le chéile go rialta le plé a dhéanamh ar ábhair imní agus le comhairle a chur ar an mBord.

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