Extended ICP Integrated Monitoring strategy

An extended monitoring strategy for Integrated Monitoring under the Convention of Long-Range Transboundary Air Pollution

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SUMMARY

ICP Integrated Monitoring[1] has decided to develop its monitoring strategy to include other ecosystem types than forests and to allow a simplified monitoring at differing levels of intensity. The extended monitoring strategy aims at monitoring current and future effects of air pollution on ecosystems across the UNECE area.

The extended monitoring program has been developed with three levels of monitoring in ecosystem types other than forests such as grasslands, heathlands, wetlands or coastal habitats:

- **Level 1**: Full ICP IM site. High frequency measurements and catchment based, as stated in the ICP IM Manual.
- **Level 2**: Plot scale with element budgets. Alowing less frequent measurements.
- **Level 3**: Plot scale without element budgets. Aiming for annual measurements, but accepting other temporal resolution, of soil and vegetation. Plant list and abundance, soil and foliage chemistry.

We argue that the extended ICP IM monitoring programme will ensure that other ecosystems that are not part of the monitoring of the Air Convention today are monitored with proper methods that provide consistent monitoring within the UNECE area. The extended ICP IM monitoring programme is designed in a way that allows parties to be part of the ICP IM monitoring programme based on their own prerequisites with less intensive monitoring campaigns compared with the full ICP IM monitoring.

[1] https://www.slu.se/en/Collaborative-Centres-and-Projects/integrated-monitoring/

TABLE OF CONTENTS

1 INTRODUCTION 5
1.1 International Cooperative Programme Integrated Monitoring 5
2 EXTENDED ICP IM MONITORING STRATEGY 6
2.1 Aim and scope of the extended monitoring strategy 6
2.2 Ecosystem types 6
2.3 Levels of monitoring in the extended ICP IM strategy 7
2.4 Chemical parameters and water budget 8
2.5 Biological parameters and strategy 9
3 FORMALITIES 10
4 CONCLUSIONS 10
5 REFERENCES 11
APPENDIX 1 12

1 INTRODUCTION

The work on the Convention of Long-range Transboundary Air Pollution (Air Convention) started in 1979 with the issue of acidification. The first protocol came into force in 1983 and since then many elements and protocols have been implemented to abate substances harmful to ecosystems and human health. To develop the necessary international co-operation in the research on and the monitoring of pollutant effects, the Working Group on Effects (WGE) was established under the Convention in 1980 and held its first meeting in 1981.

The Working Group on Effects provides information on the degree and geographic extent of the impacts of major air pollutants, such as sulphur and nitrogen oxides, ozone, volatile organic compounds, persistent organic pollutants, heavy metals, particulate matter including black carbon, and ammonia on human health and the environment.

Its six International Cooperative Programmes (ICPs) on Forests, Waters, Materials, Vegetation, Integrated Monitoring and Modelling and Mapping and the Task Force on Health identify the most endangered areas, ecosystems and other receptors by considering damage to human health, terrestrial and aquatic ecosystems and materials. An important part of this work is long-term monitoring. The work is underpinned by scientific research on dose-response, critical loads and levels and damage evaluation. The work within ICP IM falls under the CLRTAP convention with support from Parties to the convention and National Focal Points (contact persons) within the Parties of the Convention.

1.1 International Cooperative Programme Integrated Monitoring

Investigations of air pollutants acting on particular receptors have shown that an integrated approach is needed to properly understand the mechanisms of damage and the resulting effects. Thus, the impacts of acid deposition may take place in the soil, but effects are more likely to be seen in vegetation growing in the soil or in the water draining from the system. Further, while biological impacts are of prime concern, it is the chemical processes and the physical parameters in the various parts of the ecosystem that determine its suitability for biota.

The objective of the International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems (ICP Integrated Monitoring)[2] is to monitor the state of ecosystems (catchments/plots), their changes, the effects of air pollutants including interactions with climate change from a long-term perspective, and to develop and validate models for the simulation of ecosystem responses.

Integrated monitoring of ecosystems involves simultaneous physical, chemical and biological measurements over time of different ecosystem compartments at the same location. In practice, monitoring is divided into a number of compartmental sub-programmes linked by the use of the same parameters (cross-media flux approach) and/or stations (cause-effect approach).

The data collected are used for local and cross-site empirical studies as well as to calibrate and test models that can then be used to estimate responses to actual or predicted ecosystem changes under a variety of biogeophysical conditions and pollution scenarios.

ICP IM has a comprehensive monitoring network within the Air Convention and WGE, which focuses on unmanaged forest ecosystems within the UNECE region. The initial focus of the monitoring programme was on understanding movement of pollutants in a whole catchment approach with a focus on acidification. This has evolved to include improved understanding of movements and effects of air pollution linked to metal deposition and nitrogen. In later years, the effects of air pollution and climate change on biodiversity were increasingly investigated.

[2] https://www.slu.se/en/Collaborative-Centres-and-Projects/integrated-monitoring/

2 EXTENDED ICP IM MONITORING STRATEGY

At the task force meeting in 2020, the programme centre and the chairs announced that work would start on developing an extended monitoring strategy for ICP IM to be more inclusive by allowing for different levels of monitoring intensity. The rationale behind this development is:

I. It has come to our attention that establishing new ICP IM sites is difficult due to the large cost of starting and operating the monitoring programs
II. There is a request from the Air Convention to add other ecosystem types than forests in the monitoring strategies.
III. For ICP IM to expand its monitoring to more sites, a simplified monitoring of other ecosystem types is needed and desirable
IV. There is a high demand from the EU directive on National Emission Ceiling (NECD) to harmonize ecosystem monitoring towards other ecosystem types than forests.

With the above-mentioned rationales, the chairs and Programme Centre set up a working group (WG) of members of ICP IM and with support the EU - Commission and EEA to develop an extended monitoring strategy under ICP IM.

2.1 Aim and scope of the extended monitoring strategy

The aim of the WG is to develop an extended monitoring strategy for ICP IM that:

i) *is simplified compared to the current ICP IM monitoring manual;*
ii) *integrates monitoring with other ICPs under the WGE;*
iii) *reflects and integrates todays and possible future environmental issues;*
iv) *allows monitoring in more ecosystem types than today and higher number of sites;*
v) *promotes high international cooperation with other initiatives such as the EU-NECD, eLTER, LIFE Watch and others.*

2.2 Ecosystem types

The WG has decided to move forward with the Mapping and Assessment of Ecosystems and their Services (MAES)[3] in defining *other ecosystem types* relevant to air pollution. This is a standardized system within many of the relevant ecosystem classifications and will cover many other regions as well. The initial idea of using MAES does not exclude other ecosystem types that are present within the UNECE region. Here we have also focused on the larger headings of ecosystem types, this will be more comprehensive during the process of this work.

3 https://data.europa.eu/doi/10.2760/757183

Table 1. suggested *other ecosystem* types to be included in the extended ICP IM monitoring program for level 2 and 3.

Grassland	E **Grasslands** and land dominated by forbs, mosses or lichens	E1 Dry grasslands
		E2 Mesic grasslands
		E3 Seasonally wet and wet grasslands
		E4 Alpine and subalpine grasslands
		E5 Woodland fringes, clearings and tall forb stands
		E6 Inland salt steppes
		E7 Sparsely wooded grasslands
Heathland and shrub	F **Heathland**, scrub and tundra	F1 Tundra
		F2 Arctic, alpine and subalpine scrub
		F3 Temperate and mediterraneo-montane scrub
		F4 Temperate shrub heathland
		F5 Maquis, arborescent matorral and thermo- Mediterranean brushes
		F6 Garrigue
		F7 Spiny Mediterranean heaths
		F8 Thermo-Atlantic xerophytic scrub
		F9 Riverine and fen shrubs
		FA Hedgerows
		FB Shrub plantations
Attributed to sparsely vegetated land	B **Coastal** habitats	B1 Coastal dunes and sandy shores
		B2 Coastal shingle
		B3 Rock, cliffs, ledges and shores, including supralittoral
Wetlands	D **Mires**, bogs and fens	D1 Raised and blanked bogs
		D2 Valley mires, poor fens and transition mires
		D3 Aapa, palsa and polygon mires
		D4 Base-rich fens and calcareolus spring mires
		D5 Sedge and reedbeds, normally without free-standing water
		D6 Inland saline and brackish marshes and reedbeds

Source: Maes et al., 2013

2.3 Levels of monitoring in the extended ICP IM strategy

The working group has identified three levels for the ICP IM monitoring strategy. The numeric level description is aligned to eLTER levels to simplify the external communication. Specific parameters are identified in Appendix 1 but a brief overview is given here. It is again important to state that Level 2 and 3 are not focused on forested ecosystems. For new forested sites at any level, we refer to the IM manual or any of the ICP Forests[1] or eLTER manuals[2]. The extended ICP IM monitoring program focuses on other ecosystem types such as heathlands, wetlands and sand dunes, and the methodology is throughout the levels the same as identified in the ICP IM manual.

The three levels identified are:

- **Level 1**: Full ICP IM site. High frequency measurements and catchment based, as stated in the ICP IM Manual.
- **Level 2**: Plot scale with element budgets. Alowing less frequent measurements.
- **Level 3**: Plot scale without element budgets. Aiming for annual measurements, but accepting other temporal resolution, of soil and vegetation. Plant list and abundance, soil and foliage chemistry.

[1] http://icp-forests.net/
[2] https://elter-ri.eu/standard-observations-spheres

2.3.1 Level 1: Full ICP IM site

No changes to the current ICP IM monitoring strategy and manual.

2.3.2 Level 2 ICP IM monitoring

At ICP IM level 2 monitoring we suggest adopting monthly measurements on plot scale with enough parameters to be able to calculate element budgets. The focus is on other ecosystem types than forests (see table 1). For calculations of budgets, we suggest that seven larger groups of measurements are done with monthly resolution as the lowest frequency of monitoring:

Table 2: measurements of level 2 monitoring

Measurement group	Comments
Soil chemistry	Some parameters will be measured once or every five years
Soil water chemistry	Monthly sampling
Foliage chemistry	Yearly or every five years
Precipitation chemistry	Monthly
Meteorology	Can be taken from a nearby station
Vegetation cover and species structure	Every 3 to 5 years, with equal intervals
Dry deposition	Monthly monitoring

The specific parameters that are included in the measurements are presented in Appendix I.

2.3.3 Level 3 ICP IM monitoring

At ICP IM level 3 monitoring, we suggest adopting annual (at least) measurements on plot scale with enough relevant parameters to assess the state of the environment. Like level 2, level 3 will focus on other ecosystem types than forests (table 1). We suggest monitoring within three larger groups:

Table 3: measurements of level 1 monitoring

Measurement group	Comments
Soil chemistry	Some parameters will be measured annually or every five years
Foliage chemistry	Yearly or every five years
Vegetation cover and species structure	Every 3 to 5 years, with equal intervals

2.4 Chemical parameters and water budget

To determine input-output budgets of substances (the chemical parameters) at the monitoring plots it is necessary to estimate the leaching fluxes of the plots. Leaching flux is calculated for any substance by multiplying its concentration in soil solution with the soil water flux estimated at the same depth and time interval. To calculate annual means from periodic soil solution concentrations, estimated water fluxes can also be used as weighting factors (ICP Forests 2016). Models are used to estimate the soil water fluxes in cases when the fluxes have not been measured directly. Meteorological data are used as input for models and calculations to derive soil water fluxes. Estimates of the soil water recharge needed for output calculations can also be estimated using the chloride mass-balance method (e.g. Allison and Hughes 1983, Vuorenmaa et al. 2020).

Numerous hydrological models are available for soil leaching flux calculations. Here we provide some examples:

- BIOME-BGC (Thornton et al. 2002) is an ecosystem process model for calculating water, carbon and nitrogen budgets for vegetation, soil and litter compartments of terrestrial biomes. The model requires daily input values of temperature (T), precipitation (P), radiation (R), humidity (H), and wind speed (W).

- MetHyd is a pre-processor for hydro-meteorological data of VSD+ to calculate daily evapotranspiration, soil moisture, precipitation surplus and parameters related to N processes (Bonten et al. 2016). MetHyd reads daily data on temperature (T), precipitation (P) and radiation (R), or, alternatively, derives daily inputs from monthly data. MetHyd input includes information on soil properties such as bulk density, the content of clay, sand and organic C. Also soil hydraulic properties (soil water content at saturation, field capacity, wilting point and at hydraulic tension of -1 bar) can be given as input to MetHyd or can be derived in MetHyd from given soil properties.

- WATBAL (Starr 1999, Teutschbein 2008) is single layer capacity type model for water balance of forest stands (plot) with freely draining soils, which requires daily or monthly input values of temperature (T), precipitation (P), and radiation (R).

2.5 Biological parameters and strategy

The main aim of biological monitoring in Extended IM is the detection of air pollution effects of nitrogen on vascular plant, bryophyte, and lichen species composition and abundance and respective trends indicating eutrophication. The data recording should allow calculation of the most common metrics (Rowe et al. 2017). The current ICP IM manual subprogram Vegetation Cover (VG) describes such a method and can also be used for Level 2 and 3, although adaptations are needed in non-forest habitats. We note that it should be made mandatory in all Levels of the ICP IM program and the post 2010 reporting scheme should be used. The size of the vegetation plot and the number of subplots where vegetation is recorded should be representative for the different habitat types in a Level 3 catchment, and for the habitat type found in the Level 1 and 2 plot where all other parameters are monitored. The number must not be less than 5 vegetation subplots per habitat type. The size of the monitoring plots and subplots should preferably match the patchiness and heterogeneity of the vegetation community being monitored, i.e. with too small subplots there may only be one species per subplot. Their location should be a stratified random placement, i.e. the monitored area should be divided into homogeneous subareas and the monitoring subplots should be equally distributed among the subareas with a random distribution within each subarea, but without overlap and avoiding locally deviating substrates, e.g. bedrock, water courses, dense shrubs etc. The plot and subplot locations should be permanently marked and mapped for re-inventories of the same plots.

As in the subprogram VG, all vascular plants, bryophytes and lichens should be recorded together with their cover values, differentiated in layers. The cover of each layer should also be recorded. The monitoring should be repeated every 3rd to 5th year, but with equal intervals at each monitoring site.

3 FORMALITIES

Countries that already have active Level 1 site(s) should include new Level 2 and Level 3 sites in their IM organisation.

Countries that are not actively involved in ICP IM and want to join at any of the three levels of ambition, should assign a national focal point (NFP) who represents the country and its IM monitoring sites at the annual Task Force meetings. The NPF will have one vote in all decisions taken by voting. The NFP is also responsible for submitting data from the country to the IM database, in accordance with the IM manual.

New countries that join IM will be asked to sign an agreement to make data submitted to the central IM database publically available under a CC BY (Creative Commons by-attribution) licence.

4 CONCLUSIONS

The extended monitoring program presented for ICP IM will develop the program and allows ICP IM to be important in addressing air pollution effects on ecosystems across the UNECE region. The development of the monitoring program is in line with the CLRTAP long-term strategy and can serve multiple purposes for other relevant international conventions or directives.

The extended ICP IM monitoring program will allow for monitoring of ecosystem types other than forests, lakes or rivers that are sensitive to air pollution and at the same time give flexibility in the intensity of the monitoring parties want to undertake. The extended monitoring program will have three levels of monitoring intensity and is accompanied by manuals that allow for coherent and reproducible monitoring.

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APPENDIX 1

Extended ICP IM level 2 monitoring parameters:

Sub-programme	SubprogName	Parameter	ParamName
SC	Soil chemistry	AC_EXC	Exchangeable acidity, ICP Forests method
SC	Soil chemistry	ACE	Acid cations exchangeable, ICP Forests
SC	Soil chemistry	ACI_ET	Exchangeable titrable acidity (H+Al)
SC	Soil chemistry	AL	Aluminium
SC	Soil chemistry	BASA	Base saturation
SC	Soil chemistry	BCE	Base cations exchangeable, ICP Forests
SC	Soil chemistry	BDEN	Bulk density (<2mm)
SC	Soil chemistry	C/N	C/N
SC	Soil chemistry	C_ORG	Organic carbon, ICP Forests method
SC	Soil chemistry	CA	Calcium
SC	Soil chemistry	CEC_E	Cation exchange capacity effective (Ca+Mg+K+Na+ACI_ET)
SC	Soil chemistry	COND	Conductivity
SC	Soil chemistry	CU	Copper
SC	Soil chemistry	DW_SAMP	Sample weight (dry)
SC	Soil chemistry	FE	Iron
SC	Soil chemistry	K	Potassium
SC	Soil chemistry	MG	Magnesium
SC	Soil chemistry	MN	Manganese
SC	Soil chemistry	NA	Sodium
SC	Soil chemistry	NTOT	Total nitrogen
SC	Soil chemistry	ORGLAY	Organic layer, ICP Forests parameter
SC	Soil chemistry	PH	pH
SC	Soil chemistry	PSA_CLAY	Particle size analysis, % clay
SC	Soil chemistry	PSA_SAND	Particle size analysis, % sand
SC	Soil chemistry	PSA_SILT	Particle size analysis, % silt
SC	Soil chemistry	PTOT	Total phosphorous
SC	Soil chemistry	SCONT	Stone content (>2 mm)
SC	Soil chemistry	STOT	Total sulphur
SC	Soil chemistry	TC	Total carbon
SC	Soil chemistry	TOC	Total organic carbon
SC	Soil chemistry	VOL_SAMP	Volume of sample
SC	Soil chemistry	ZN	Zinc
SW	Soil water chemistry	AL	Aluminium
SW	Soil water chemistry	ALK	Alkalinity
SW	Soil water chemistry	CA	Calcium
SW	Soil water chemistry	CL	Chloride
SW	Soil water chemistry	COND	Conductivity
SW	Soil water chemistry	DOC	Dissolved organic carbon
SW	Soil water chemistry	K	Potassium
SW	Soil water chemistry	MG	Magnesium
SW	Soil water chemistry	NA	Sodium
SW	Soil water chemistry	NH4N	Ammonium as nitrogen
SW	Soil water chemistry	NO3N	Nitrate as nitrogen
SW	Soil water chemistry	NTOT	Total nitrogen
SW	Soil water chemistry	PH	pH
SW	Soil water chemistry	PTOT	Total phosphorous
SW	Soil water chemistry	SO4S	Sulphate as sulphur
FC	Foliage chemistry	CA	Calcium
FC	Foliage chemistry	K	Potassium
FC	Foliage chemistry	MG	Magnesium
FC	Foliage chemistry	MN	Manganese
FC	Foliage chemistry	NTOT	Total nitrogen
FC	Foliage chemistry	PTOT	Total phosphorous

FC	Foliage chemistry	STOT	Total sulphur
FC	Foliage chemistry	TOC	Total organic carbon
FC	Foliage chemistry	RE_T	Oven dry sample weight of 1000 needles, or 100 leaves
PC	Precipitation chemistry	CA	Calcium
PC	Precipitation chemistry	DOC	Dissolved organic carbon
PC	Precipitation chemistry	K	Potassium
PC	Precipitation chemistry	MG	Magnesium
PC	Precipitation chemistry	NA	Sodium
PC	Precipitation chemistry	NH4N	Ammonium as nitrogen
PC	Precipitation chemistry	CL	Chloride
PC	Precipitation chemistry	NO3N	Nitrate as nitrogen
PC	Precipitation chemistry	NTOT	Total nitrogen
PC	Precipitation chemistry	PH	pH
PC	Precipitation chemistry	PTOT	Total phosphorous
PC	Precipitation chemistry	PREC_MET	Precipitation amount measured from the deposition collector used for metal analysis
PC	Precipitation chemistry	PREC	Precipitation
PC	Precipitation chemistry	SO4S	Sulphate as sulphur
AM	Meteorology	TEMP	Temperature
AM	Meteorology	SOL_G	Global radiation
VG	Vegetation structure and species cover	COVE_B	Cover of layer/species in bottom layer
VG	Vegetation structure and species cover	COVE_F	Cover of layer/species in field layer
Vg	Vegetation structure and species cover	COVE_S	Cover of layer/species in shrub layer
VG	Vegetation structure and species cover	COVE_T	Cover of layer/species in tree layer
AC	Dry deposition		Ammonia
AC	Dry deposition		Sulfur
AC	Dry deposition		Nitrogen

Extended ICP IM level 3 monitoring parameters

Subprogramme	SubprogName	Parameter	ParamName
SC	Soil chemistry	AC_EXC	Exchangeable acidity, ICP Forests method
SC	Soil chemistry	ACE	Acid cations exchangeable, ICP Forests
SC	Soil chemistry	ACI_ET	Exchangeable titrable acidity (H+Al)
SC	Soil chemistry	AL	Aluminium
SC	Soil chemistry	BASA	Base saturation
SC	Soil chemistry	BCE	Base cations exchangeable, ICP Forests
SC	Soil chemistry	BDEN	Bulk density (<2mm)
SC	Soil chemistry	C/N	C/N
SC	Soil chemistry	C_ORG	Organic carbon, ICP Forests method
SC	Soil chemistry	CA	Calcium
SC	Soil chemistry	CEC_E	Cation exchange capacity effective (Ca+Mg+K+Na+ACI_ET)
SC	Soil chemistry	COND	Conductivity
SC	Soil chemistry	CU	Copper
SC	Soil chemistry	DW_SAM	Sample weight (dry)
SC	Soil chemistry	FE	Iron
SC	Soil chemistry	K	Potassium
SC	Soil chemistry	MG	Magnesium
SC	Soil chemistry	MN	Manganese
SC	Soil chemistry	NA	Sodium
SC	Soil chemistry	NTOT	Total nitrogen
SC	Soil chemistry	ORGLAY	Organic layer, ICP Forests
SC	Soil chemistry	PH	pH
SC	Soil chemistry	PSA_CLAY	Particle size analysis, % clay
SC	Soil chemistry	PSA_SAND	Particle size analysis, % sand
SC	Soil chemistry	PSA_SILT	Particle size analysis, % silt
SC	Soil chemistry	PTOT	Total phosphorous
SC	Soil chemistry	SCONT	Stone content (>2 mm)
SC	Soil chemistry	STOT	Total sulphur
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SC	Soil chemistry	TOC	Total organic carbon
SC	Soil chemistry	VOL_SAMP	Volume of sample
SC	Soil chemistry	ZN	Zinc
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FC	Foliage chemistry	K	Potassium
FC	Foliage chemistry	MG	Magnesium
FC	Foliage chemistry	MN	Manganese
FC	Foliage chemistry	NTOT	Total nitrogen
FC	Foliage chemistry	PTOT	Total phosphorous
FC	Foliage chemistry	STOT	Total sulphur
FC	Foliage chemistry	TOC	Total organic carbon
FC	Foliage chemistry	RE_T	Oven dry sample weight of 1000 needles, or 100 leaves
VS	Vegetation structure and species cover	COVE_B	Cover of layer/species in bottom layer
VS	Vegetation structure and species cover	COVE_F	Cover of layer/species in field layer
VS	Vegetation structure and species cover	COVE_S	Cover of layer/species in shrub layer
VS	Vegetation structure and species cover	COVE_T	Cover of layer/species in tree layer