



Federal Ministry  
of Food  
and Agriculture



**UNECE**

Convention on Long-range  
Transboundary Air Pollution



## On the Pulse of European Forests

40 years of Pan-European Forest Monitoring:  
From Air Pollution to Climate Change

ICP Forests 40<sup>th</sup> Anniversary Report under the UNECE Convention  
on Long-range Transboundary Air Pollution (Air Convention)

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



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**PART 4**

The future:  
ICP Forests as a  
multifunctional, pan-  
European monitoring  
infrastructure

**ICP Forests: towards the next 40 years**

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Four decades after the inception of ICP Forests, monitoring is now firmly established as an essential scientific approach to inform forest policy and management, and the demand for harmonized approaches has even increased (Bontemps et al., 2021; Breidenbach et al., 2025; European Commission, 2023; Ferretti, 2021; Ferretti et al., 2024b; ITMN, Senf et al., 2025). Confronted with evolving priorities and challenging political, environmental and societal conditions, ICP Forests should now envision its future. There are several authors providing suggestions on do's and don'ts of monitoring programs (e.g. Legg and Nagy, 2006; Lindenmayer and Likens, 2009; Lovett et al., 2007; Parr et al., 2001; Percy and Ferretti, 2004; Spellerberg, 1994; Vos et al., 2011). Here, however, we intent offering a broader framework for a long-term perspective based on what we have learned after 40 years of international co-operative forest monitoring.

**Five important lessons**

**Lesson 1: Forests are complex ecosystems; their condition and dynamics are driven by several factors whose effects vary in time, space, and intensity.** To capture this complexity, monitoring needs to be comprehensive (portfolio of measurements), reliable (statistically sound, quality assured), flexible (to adapt), reactive, and proactive. The latter involves actively observing and detecting effects before they escalate into significant challenges.

**Lesson 2: Priorities (scientific, political) have changed and will continue to change.** The history of ICP Forests demonstrates how scientific and political priorities can evolve. The monitoring design of ICP Forests was able to accommodate new priorities (e.g. loss of biodiversity and climate change). Priorities, however, will continue to evolve, and ICP Forests needs to stay tuned to address future grand challenges.

**Lesson 3: Technological evolution opens perspectives.** Since ICP Forests was launched, technology has progressed at an unprecedented pace in all fields (e.g. close-range and remote sensing tools, x-omics, computational power, modeling, ...). This development can pave the way for optimizing and enhancing forest monitoring (e.g. Ferretti et al., 2024a) and needs to be taken into account in future activities.



**Lesson 4: Ground-based monitoring remains essential.** Complexity, changing priorities, and rapid technological evolution render ground-based monitoring programs even more crucial for (i) covering specific measurement needs and targets (e.g. forest health diagnosis, mycorrhiza, soil properties, below-canopy processes) otherwise difficult to satisfy and/or reach; (ii) understanding ecosystem properties and ecological processes; (iii) providing harmonized and comparable platforms for evolving measurement targets, approaches and techniques; and (iv) validating remotely sensed data and model outputs.

**Lesson 5: ICP Forests remains a valid model for international forest monitoring, but needs support.** At a time when changes in forest condition are often triggered by factors (e.g. those related to climate change) that are of regional to global nature and effects, ICP Forests' pioneering experience with transboundary air pollution is of outstanding value. ICP Forests was conceived in view of its international dimension, and monitoring design, expertise and governance has proven robust and effective over four decades. The international framework within the UNECE Air Convention, the long-term co-operation with the European Commission and the continuous support (political and institutional, financial, scientific, and technical) from various actors at national and international levels were essential to ICP Forests, and should be strengthened in the future.



## Towards the next 40 years

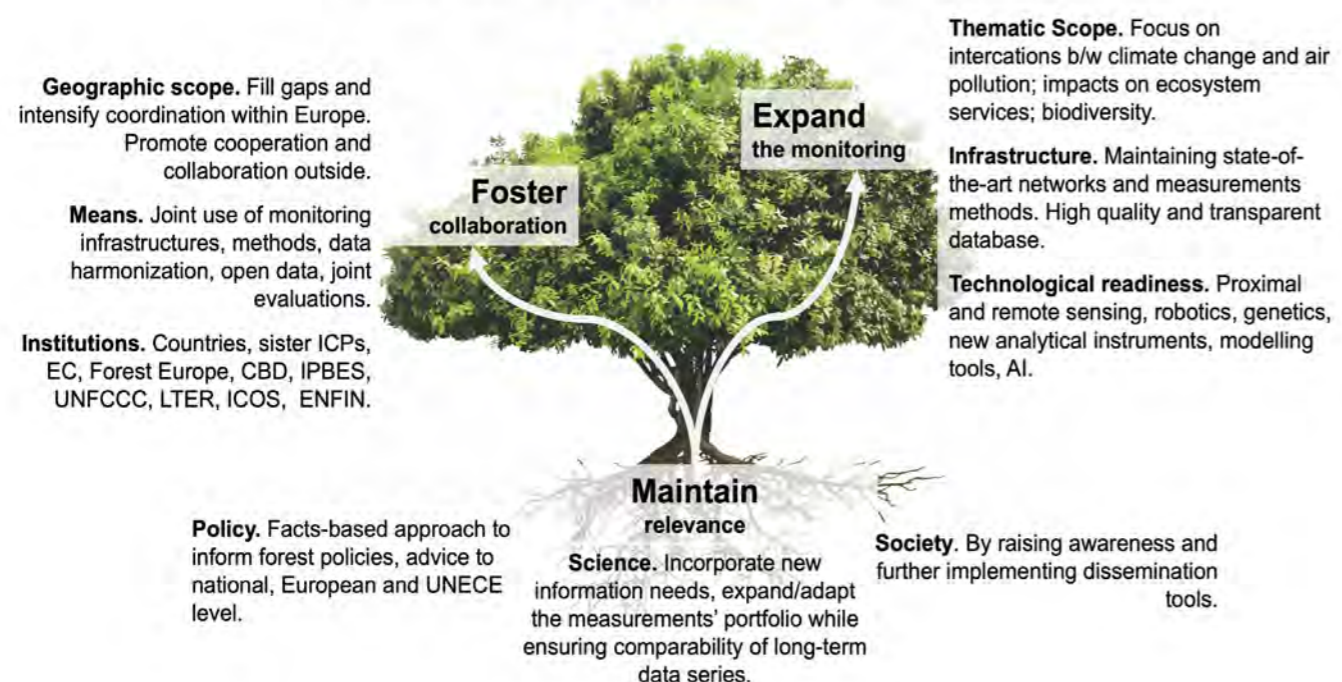
It is impossible to foresee what will happen in the next decades. Rather, it is feasible to identify key actions that will support the development of ICP Forests over a large range of possible scenarios. Besides the lessons learned, these actions are grounded on a firm belief: ICP Forests will continue advocating for a sustainable, co-operative, internationally harmonized forest monitoring system to respond to global challenges. ICP Forests' strategy for the future can consider including three main categories of actions.

**Maintain.** Staying relevant at political, scientific and societal levels is indispensable to secure support for monitoring activities and represent a permanent long-term goal of ICP Forests. It implies being able to provide state-of-the-art answers to policy, science, and society. In this context, securing ICP Forests' relevance within the scope of the Working Group of Effects of the UNECE Air Convention is a priority.

**Foster.** Fostering collaboration remains key to addressing gaps in the European coverage and to expanding harmonized monitoring in other parts of the UNECE region and beyond. This can be achieved by fostering co-ordination with institutions at national and European level, and through the joint use of infrastructures, methods, and data.

**Expand.** Expanding the monitoring needs (i) broadening the thematic scope and (ii) updating the monitoring infrastructures to maintain technological readiness and the ability to address new information requirements. Further developing ICP Forests' themes (e.g. climate change and its interactions with air pollution), methods (e.g. continuous updating an expanded portfolio of measurements), technology (e.g. proximal and remote sensing, robotics, genetics, modelling, AI-related tools) and FAIRness of its data and data products should be a continuous activity.

### Main actions for the future of ICP Forests



Main actions for the future development of ICP Forests. Fostering collaboration and expanding monitoring activities are rooted in the ability to maintain relevance at political, scientific, and societal level (© M Ferretti).





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