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Conference Abstract

Restoration as a Process, Not a Product: Why Monitoring Defines Success

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Abstract

Ecosystem restoration has become a central priority of environmental policy, reflecting the urgent need to reverse biodiversity loss, address land degradation, strengthen climate resilience, and secure the long-term provision of ecosystem services. However, despite increasing political commitments and investments in restoration, a fundamental challenge remains: how can restoration success be reliably defined, measured, and demonstrated over time? Restoration initiatives are frequently evaluated through implementation-oriented indicators, such as the area restored, number of trees planted, or completion of planned interventions, rather than through evidence of ecological recovery. Such approaches risk treating restoration as a final product instead of recognising it as a dynamic, long-term ecological process (Gann et al. 2019).

This keynote argues that monitoring is not merely a supporting activity of ecosystem restoration but an essential mechanism for defining its objectives, evaluating its effectiveness, and guiding adaptive management. Restoration success cannot be determined solely by the implementation of management measures (Suppl. material 1). It must be demonstrated through measurable changes in ecosystem condition, structure, functions, biodiversity, resilience, and capacity to sustain ecosystem services under changing environmental conditions (Gann et al. 2019, Lindenmayer and Likens 2009).

From an ecological perspective, restoration involves complex interactions among vegetation, soils, hydrological processes, biological communities, and environmental drivers. These interactions operate at different spatial and temporal scales, often

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producing nonlinear responses, delayed recovery, and trajectories that do not necessarily converge towards historical reference conditions. Climate change further complicates restoration planning by modifying disturbance regimes, species distributions, soil processes, and ecosystem functioning. Consequently, restoration objectives should be based on a realistic understanding of ecosystem dynamics, ecological thresholds, environmental pressures, and the potential for recovery under both current and future conditions (Holl and Aide 2011, Gann et al. 2019).

Particular attention is given to forest ecosystems, where restoration outcomes depend on processes extending far beyond vegetation establishment. Soil organic carbon dynamics, nutrient cycling, soil biodiversity, water regulation, natural regeneration, structural complexity, and habitat connectivity are fundamental dimensions of ecosystem recovery. Soil properties and processes are especially important because they influence ecosystem productivity, resistance to disturbance, and long-term resilience, while frequently responding more slowly than aboveground vegetation. Monitoring frameworks that neglect belowground processes may therefore provide an incomplete assessment of restoration effectiveness.

A process-oriented restoration framework requires the integration of baseline assessments, reference conditions, measurable ecological indicators, repeated observations, and clearly defined criteria for evaluating recovery trajectories. Long-term ecological monitoring provides the temporal evidence needed to distinguish short-term responses to restoration interventions from persistent improvements in ecosystem condition. It also allows the identification of unexpected changes, emerging pressures, and potential trade-offs among biodiversity conservation, carbon sequestration, ecosystem productivity, and other ecosystem services (Lindenmayer and Likens 2009).

The lecture highlights the importance of established long-term observation systems, particularly the Long-Term Ecosystem Research network (LTER) and the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests). These initiatives provide valuable experience in harmonised methodologies, repeated field measurements, environmental data integration, and assessing ecosystem responses to multiple pressures. Their contribution extends beyond documenting environmental change: they provide scientific evidence for interpreting restoration trajectories, identifying drivers of ecosystem degradation, and evaluating whether management interventions generate sustained ecological improvements.

An additional challenge concerns the translation of ecological monitoring results into operational indicators and policy-relevant assessments. European initiatives such as Mapping and Assessment of Ecosystems and their Services (MAES) and the System of Environmental-Economic Accounting - Ecosystem Accounting (SEEA-EA) provide conceptual and methodological opportunities to connect ecosystem condition, ecosystem services, and the societal benefits of restoration. Integrating these frameworks with field-based ecological observations, spatial information, and long-term monitoring can strengthen the scientific basis for restoration prioritisation, evaluation, and reporting.

Within the evolving European policy framework, particularly Regulation (EU) 2024/1991 on nature restoration, monitoring assumes an increasingly strategic role (European Parliament and Council, 2024). Effective implementation requires moving beyond assessments of restoration activities towards transparent, scientifically robust evaluations of ecological outcomes. This implies developing harmonised but ecosystem-specific indicators, appropriate monitoring frequencies, spatially representative sampling designs, and mechanisms to translate monitoring results into management decisions.

The keynote proposes a conceptual transition from activity-based restoration reporting to evidence-based evaluation of ecological recovery, structured around five interconnected elements:

1. understanding ecosystem condition and degradation drivers before intervention;
2. defining realistic and measurable restoration objectives;
3. selecting indicators that reflect ecosystem structure, functions, and resilience;
4. establishing integrated and sufficiently long-term monitoring; and
5. using monitoring evidence to adapt restoration strategies in response to observed ecosystem trajectories and changing environmental conditions (Gann et al. 2019, Lindenmayer and Likens 2009).

Ultimately, ecosystem restoration should not be understood as a discrete intervention with a predetermined endpoint, but as a sustained commitment to facilitating ecological recovery and maintaining ecosystem functionality. Monitoring transforms restoration from an assumption of improvement into a testable, evidence-based process. Its value lies not only in demonstrating whether restoration measures have been implemented successfully, but also in revealing whether ecosystems are genuinely recovering, why certain interventions succeed or fail, and how management can respond to emerging challenges.

Restoration is what we do. Ecological recovery is what we must demonstrate. Monitoring provides the evidence that connects the two.

Keywords

Ecosystem restoration, long-term ecological monitoring, ecological recovery, forest ecosystems, soil processes, ecosystem resilience, adaptive management, ecosystem condition, LTER, ICP Forests

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Conflicts of interest

The authors have declared that no competing interests exist.

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Supplementary material

Suppl. material 1: Presentation

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