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Conference Abstract

Towards an integrated ecosystem monitoring framework at the LTER Parangalitsa site

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Abstract

Introduction

Long-term ecosystem research increasingly relies on the integration and harmonization of complementary environmental observations to improve our understanding of ecosystem functioning and responses to environmental change (Mollenhauer et al. 2018, Zacharias et al. 2026). Extended time series provide an essential temporal perspective for detecting ecosystem responses to environmental change and understanding interactions among multiple environmental drivers (Jones and Driscoll 2022).

Long-term observations at the site provide information on climatic conditions and key components of forest ecosystem status and functioning. However, these datasets originate from different monitoring programs, periods and methodological frameworks, which limits their direct integration and the assessment of interactions among atmospheric, soil and vegetation processes. The harmonization of existing long-term records with newly established observations therefore represents an important step towards a more comprehensive ecosystem-level monitoring framework.

The aim of this work is to present the ongoing development of an integrated monitoring framework at the LTER Parangalitsa site, combining historical and long-term datasets with newly introduced measurements of complementary ecosystem variables. The framework is intended to improve the capacity to assess ecosystem responses to

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environmental change and to support future integrated analyses of this old-growth mountain forest ecosystem.

Materials and methods

The LTER Parangalitsa site, located within the old-growth Norway spruce forests of the Parangalitsa Biosphere Reserve (Rila Mountains, Bulgaria), represents a long-term forest monitoring and research site within the ICP Forests, LTER-Bulgaria and eLTER networks.

The monitoring programme combines historical and contemporary observations covering multiple ecosystem compartments. Meteorological records dating back to 1980 are complemented by long-term environmental monitoring conducted within the ICP Forests programme, in which the site has participated since 1990. Soil monitoring follows established ICP Forests methodological guidelines and includes periodic assessments of soil physical and chemical properties, such as soil organic carbon, total nitrogen, soil acidity, bulk density, texture and nutrient status. Together, these datasets provide a basis for investigating long-term ecosystem dynamics under natural, unmanaged forest conditions.

The ongoing expansion of the monitoring programme is guided by the eLTER Standard Observations framework, aiming to progressively cover relevant ecosystem variables and improve methodological harmonization across monitoring components. As part of this development, Leaf Area Index (LAI) measurements were initiated in 2026 to characterize canopy structure and seasonal dynamics, while litterfall monitoring provides information on aboveground organic matter inputs. Continuous monitoring of shallow subsurface water has also been established using a multiparameter EXO1 sonde installed in a dedicated 2-m-deep monitoring well. The recorded parameters include temperature, pH, dissolved oxygen, oxidation-reduction potential, salinity and total dissolved solids.

Together, these complementary observations establish a foundation for linking climatic variability, canopy dynamics, soil processes and subsurface hydrological conditions within an integrated ecosystem monitoring framework.

Results and discussion

The compilation of historical and contemporary monitoring records reveals substantial differences in the temporal coverage and frequency of ecosystem observations at the LTER Parangalitsa site (Table 1). Meteorological records extend back to 1979, while soil observations have been available since the early 1990s. Periodic assessments of forest floor properties and aboveground biomass provide additional information on forest ecosystem characteristics. More recently, the monitoring programme has expanded to include automated measurements, molecular biodiversity observations and additional hydrological and vegetation-related variables.

Table 1.

Overview of ecosystem monitoring components and their temporal coverage at the LTER Parangalitsa site in relation to eLTER Standard Observations.

Ecosystem compartment	**Monitoring component / eLTER Standard Observation**	**Monitoring period / first records**
Geosphere	Soil inventory (SOGEO_001)	1990
Geosphere	Soil chemical and physical properties (SOGEO_003)	1991
Geosphere	Forest floor properties / organic layer	From 2000, at five-year intervals
Hydrosphere	Groundwater chemical/physical properties (SOHYD_006)	2026
Hydrosphere	Soil water content and temperature (SOHYD_168)	Since 2021 at meteorological stations; under-canopy monitoring added in 2026.
Hydrosphere	Snow (SOHYD_012)	Planned – sensor installation scheduled for November 2026 (SOMMER)
Biosphere	Deadwood inventory	Initiated in 2026; planned five-year assessment intervals
Biosphere	eDNA Soil (SOBIO_022)	2024 – SOILBON
Atmosphere	Meteorological data (SOATM_027)	Historical records from 1979; new monitoring equipment installed in 2021
Atmosphere	Radiation (SOATM_028)	2021
Atmosphere	Forests – Litterfall (SOATM_092)	2026
Atmosphere	Forest – Aboveground biomass (SOATM_023)	From 2000, at five-year intervals
Atmosphere	Forest – LAI (SOATM_025)	2026
Atmosphere	Atmospheric deposition in precipitation (SOATM_103)	ICP Forests Level II monitoring (EEA); starting year 2025*[1]
Atmosphere	Dry deposition of N-components (SOATM_108)	ICP Forests Level II monitoring (EEA); starting year 2025*[1]

The compiled datasets cover multiple ecosystem compartments but differ considerably in temporal continuity, sampling frequency and methodological approaches. Historical observations provide a valuable long-term perspective, whereas recently introduced measurements extend the range of ecosystem variables being monitored. Their integration will require careful consideration of methodological compatibility and temporal resolution. The ongoing development of the monitoring programme, guided by the eLTER Standard Observations framework, provides a basis for improving data harmonization and supporting future integrated assessments of ecosystem dynamics.

Conclusions

The LTER Parangalitsa site provides a valuable basis for integrated ecosystem monitoring through the combination of historical records, established long-term observations and newly introduced measurements. The progressive alignment of these

monitoring components with the eLTER Standard Observations framework is expected to improve data comparability and strengthen the capacity for cross-compartment analyses. This developing framework will support future assessments of long-term ecosystem dynamics and responses to environmental change in old-growth mountain forests.

Keywords

ecosystem monitoring, old-growth forest, ICP Forests, climate observations, soil monitoring

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Conflicts of interest

The authors have declared that no competing interests exist.

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Endnotes

*1 Atmospheric deposition data are provided by the Bulgarian Executive Environment Agency (EEA) within the ICP Forests Level II monitoring programme.