ARPHA Conference Abstracts 8: e151596
doi: 10.3897/aca.8.e151596

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Conference Abstract

Developing a FAIR-Compliant Metadata Template for Digital Twins of Ecosystems: Insights from the LTER-LIFE Project

Parinaz Rashidi‡, W. Daniel Kissling‡

‡ University of Amsterdam, Amsterdam, Netherlands

Corresponding author: Parinaz Rashidi (p.rashidi@uva.nl)

Received: 27 Feb 2025 | Published: 28 May 2025

Citation: Rashidi P, Kissling WD (2025) Developing a FAIR-Compliant Metadata Template for Digital Twins of Ecosystems: Insights from the LTER-LIFE Project. ARPHA Conference Abstracts 8: e151596. https://doi.org/10.3897/aca.8.e151596

Abstract

Understanding and predicting the impact of environmental changes and external pressures on ecosystems is a critical challenge in ecology. The LTER-LIFE project, funded by the Dutch Research Council (NWO), addresses this challenge by advancing data-driven modeling and simulation through the development of Digital Twins of ecosystems. This initiative develops an integrated infrastructure, including a Virtual Research Environment (VRE) and associated services like catalogues and repositories, which provide findable, accessible, interoperable, and reusable (FAIR) data, models, and tools. These components enable the creation of customized virtual laboratories to build Digital Twins of two iconic Dutch ecosystems: the LTSER Veluwe, a forest-rich ridge of hills with woodlands, heath, some small lakes and Europe's largest sand drifts, and the LTSER Dutch Wadden Sea Area, a large, temperate, relatively flat coastal wetland environment, with tidal channels, sea-grass meadows, mudflats, salt marshes, estuaries, beaches and dunes. The development of Digital Twins for ecosystems depends on the seamless integration and harmonization of diverse data sources, making it essential to ensure that data is as FAIR as possible, along with semantic mapping and crosswalk techniques to enable machine-actionable metadata. Our primary goal is to define the LTER-LIFE metadata schema and develop a dynamic inventory of diverse biotic and abiotic datasets while ensuring their metadata adheres to FAIR principles to support

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complex analyses, modeling, and simulations. This includes applying established (meta)data standards, aligning heterogeneous metadata with data models, incorporating standardized terms, controlled vocabularies, and ontologies, identifying thresholds for rich metadata based on feedback from the community and FAIR-Aware recommendations, establishing a common minimum set of metadata fields, and creating a specialized metadata template tailored to capturing FAIR data for Digital Twins of ecosystems. We employed the cross-walking method, leveraging insights from three projects —Ponderful, FAIR-EuMon, and FAIRsFAIR— selected for their shared focus on advancing FAIR principles and developing Digital Twins. This approach allowed us to define relevant metadata standards, encompassing both general and domain-specific fields. To refine and finalize the proposed metadata fields for the LTER-LIFE project, we conducted a half-day expert workshop involving data owners, data scientists, data stewards, ecologists, and researchers. The CEDAR repository model, an open-source platform for creating metadata templates in JSON format, which can be enriched with JSON-LD for enhanced machine-readability, was utilized to implement the LTER-LIFE metadata schema. Integration with BioPortal's semantic artefacts and alignment with eLTER vocabularies (EnvThes) further enriched the schema with ontology-based concepts and domain-specific terminologies. The resulting template enables the implementation of the LTER-LIFE metadata schema as a CEDAR template. By adhering to the FAIR principles, the proposed framework enhances data accessibility, integration, and scalability, supporting terrestrial and marine ecosystem research. This effort lays the groundwork for sustainable and impactful Digital Twins applications, driving biodiversity and ecosystem science progress in an increasingly dynamic and interconnected world.

Keywords

minimum metadata, FAIR, schema, Virtual Research Environment, LTSER Veluwe Netherlands, Dutch Wadden Sea, CEDAR

Presenting author

Parinaz Rashidi

Presented at

ORAL

Funding program

National Roadmap for Large-Scale Research Facilities from the Dutch Research Council (NWO) (grant number 2023/ENW/01403565)

Grant title

LTER-LIFE: a research infrastructure to develop Digital Twins of ecosystems in a changing world

Conflicts of interest

The authors have declared that no competing interests exist.