Data Cubes and Living Earth in Landshift: Building Interoperable Earth Observation Infrastructures for Scalable Environmental Monitoring

The increasing availability of Earth Observation (EO) data has substantially improved opportunities for monitoring environmental change and supporting evidence-based land management. However, the growing volume and diversity of EO datasets continue to create challenges related to interoperability, data management, and operational use (Giuliani et al., 2019; Dhu et al., 2019). Although cloud-based infrastructures have expanded analytical capabilities, environmental monitoring systems often remain fragmented across platforms and institutions, limiting transparency, flexibility, and the integration of heterogeneous datasets into coherent analytical workflows. Furthermore, increasing demands for policy-relevant environmental intelligence require approaches that support collaboration between scientific communities, institutions, and regional stakeholders while maintaining transparent, reproducible, and sustainable data infrastructures (Planque et al., 2026). Within Landshift, these challenges are being addressed through the development of a Data Ecosystem based on interoperable Earth Observation Data Cubes and standardized analytical environments. The proposed approach focuses on deploying modular and containerized infrastructures that can be consistently replicated across multiple regional contexts while remaining adaptable to local requirements. The infrastructures are designed to support the integration of Analysis Ready Data (ARD), collaborative geospatial workflows, and environmental datasets across multiple Living Spaces while promoting efficient and scalable data management strategies.

As part of Landshift, the activities focus on establishing a Data Ecosystem across the five Landshift Living Spaces (LSs), namely Occitanie (FR), Basilicata (IT), Macedonia–Thrace (GR), Kyiv (UA), and Mazovia (PL). The developed solution builds on the Open Data Cube (ODC) technology, which provides the underlying architecture for organizing and analysing large EO datasets in a structured, analysis-ready format (Killough et al., 2018; Lewis et al., 2017). To support the deployment across heterogeneous regional environments, the system adopts a modular and containerized approach inspired by the Cube-in-a-Box concept (ODC, 2025), which has been adapted and extended to address Landshift requirements. This implementation has enabled harmonized deployment across multiple sites while preserving flexibility for local configurations, datasets, and computational resources, resulting in interoperable environments with reproducible and scalable analytical capabilities.

A key target of the implementation is the integration of heterogeneous EO datasets into a common analytical framework. The initial deployment incorporates core ARD, including Sentinel-1 and Sentinel-2 imagery, Landsat collections, digital elevation models, and various environmental descriptors such as canopy cover, leaf type, crop type, and urban density. These datasets are structured using standardized metadata and indexing procedures to support efficient retrieval and consistent spatio-temporal querying. To improve scalability and optimize storage requirements, where possible, datasets are indexed using lightweight URI references (e.g., href links) rather than duplicating complete data archives within local infrastructures. This approach facilitates efficient access to large EO archives while supporting interoperability and reducing infrastructure overhead. The system is designed as an extensible framework, allowing the progressive integration of additional environmental, climatic, socio-economic, and land cover datasets generated throughout the project.

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LANDSHIFT

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To support usability and collaborative work, the infrastructure includes a web-based interface for dataset discovery and interactive analytical environments for geospatial processing. Metadata exploration tools enable users to examine dataset availability, spatial footprints, and temporal coverage, with dataset discovery interfaces designed to support standards such as the SpatioTemporal Asset Catalog (STAC). Notebook-based environments support reproducible geospatial analyses. These environments provide preconfigured computing resources, shared workspaces, and the possibility to develop and execute tailored workflows, supporting both individual analyses and collaborative development of reusable analytical pipelines.

A central component of the system is its integration with the Living Earth framework. The Living Earth approach, developed as an EO-optimized implementation of the FAO Land Cover Classification System (LCCS) version 2, provides a structured and hierarchical method for deriving consistent land cover information from EO data (Owers et al., 2021). The framework improves semantic consistency while remaining flexible to varying data availability and EO-derived environmental descriptors. Within Landshift, this framework has been implemented as an automated workflow to generate annual land cover products at 10 m spatial resolution for the period 2018-2025 across all LSs. These outputs demonstrate the operational feasibility and transferability of the approach while providing a baseline for subsequent analyses of land cover dynamics and Land Use, Land-Use Change and Forestry (LULUCF) assessments, including under various environmental and land-use scenarios.

Overall, the implementation has demonstrated that interoperable environmental monitoring infrastructures can be deployed across multiple regional contexts while maintaining methodological consistency. The resulting ecosystem provides a shared analytical environment that supports reproducible research, cross-site comparability, and future integration of modelling and policy-relevant applications. The combination of ODC-based architectures, modular system design, and the Living Earth framework establishes a robust foundation for scalable environmental monitoring.

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