

The role of Water-Oriented Living Labs (WoLLs) and Research Infrastructures (RIs) in European water resources resilience - A case study in a Greek island

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1 INTRODUCTION & SCOPE OF WORK

The effects of climate change -such as water scarcity and extreme events- along with pollution, economic and humanitarian crises, and other anthropogenic activities, are accelerating and continue to act as pressing challenges to securing sufficient and high-quality water globally, despite significant efforts undertaken to counteract them. In this context, an urgent need has arisen to elevate knowledge and solutions to a new level in order to proactively adopt a more holistic way of thinking and approach to water-related issues (European Partnership Water4All Water Security for the Planet, 2022). Under these circumstances, the European Union has already implemented effective strategies and water policy directives, such as the EU Green Deal (European Commission, 2019), the Water Framework Directive (Directive 2000/60/EC, 2000), and the EU Water Resilience Strategy (European Commission, 2025), to help its Member States adapt to the new reality and mitigate the effects of climate change that drive extreme water pressures.

In this context, the Water4All Partnership initiative (European Partnership Water4All Water Security for the planet, n.d.-b) was created in response to the need to improve Research and Innovation (R&I) in order to tackle urgent issues in the water sector. Under the activities of the Partnership, innovative water initiatives that integrate science, policy, and end-users within the R&D+I water sector are seen as new instruments that could accelerate the transition toward a green, resilient, and competitive Europe. Thus, Water-Oriented Living Labs (WoLLs) and Research Infrastructures & Observatories (RIs/Obs) are increasingly recognised as key enabling mechanisms for strengthening resilience and accelerating innovation uptake in the European water sector. More specifically, WoLLs are collaborative ecosystems that support community innovation in a multi-participatory context and provide a practical environment and methodology to identify, validate, and refine innovative solutions in real-world settings, leading to faster market uptake. In parallel, according to the European definition of RIs (European Commission, n.d.), they are facilities, resources, and services used by research communities to conduct research and foster innovation in their fields. Their added value is highlighted by the growing importance and need for interoperable water data and service provision, given that the effective implementation of water-related frameworks is not possible without the necessary data and services to predict, prevent, or adapt to extreme events such as droughts, floods, and pollution. Thus, the current paper presents the role of WoLLs and RIs/Obs in strengthening European water resources resilience under the framework of the Water4All Partnership. More specifically, the work described highlights the importance of WoLLs for the R&I sector, accompanied by an advanced case study on a Greek island and the contribution of an online RIs/Obs platform developed to enhance collaboration among providers and between providers and end-users of water-related RIs/Obs, while improving accessibility to their data and services, as well as a needs and gaps analysis of the RI sector.

2 METHODOLOGY

Under the Water4All umbrella of activities, different methodologies for enhancing the implementation of European water directives are being applied. Our team's work focuses on the alignment of WoLLs with water resources resilience and the effective mapping of water-related RIs/Obs in an online repository, achieving relevance to European policies, interoperability, and alignment with FAIR data principles and Open Science.

The methodology used for the identification and promotion of WoLLs supports Water4All in enabling long-term water security for all and in promoting systemic transformations by supporting the demonstration and market uptake of innovative solutions across the entire water research and innovation pipeline. In parallel, the methodology used to enhance the RIs/Obs sector -by integrating their information into a comprehensive and comparable online database, including a thorough analysis of the needs and gaps identified by their administrators- supports evidence-based decision-making and digital water innovation under Horizon Europe principles. It also promotes metadata harmonization and interoperability, enabling cross-border and cross-domain collaboration.

Water-Oriented Living Labs (WoLLs) represent collaborative innovation ecosystems where researchers, public authorities, utilities and local communities jointly develop and validate water-related solutions under real-world conditions. The Living Lab approach promotes open innovation through stakeholder participation, co-creation processes and experimentation in operational environments (Hossain et al., 2019). Within the Water4All framework, the WoLL methodology focuses on three main components: (i) identification and mapping of suitable demonstration sites, (ii) stakeholder engagement and co-design of innovative solutions, and (iii) monitoring and evaluation of the tested technologies and management approaches. Through these steps, WoLLs enable the testing of innovative water solutions while integrating technical, environmental and socio-economic considerations (Steen & van Bueren, 2017). By facilitating collaboration between research and practice, Water4All supports the validation and potential replication of innovative water solutions across different European contexts. In parallel, workshops, seminars, networking activities, and collaborative actions organised under Water4All and Water Europe frameworks support the exchange of experiences, methodologies, and best practices among WoLLs, while helping participating initiatives better identify stakeholder needs, improve interaction with local actors and authorities, and enhance the scalability and replication potential of innovative solutions

Furthermore, under the Water4All initiative, during Phase 1 of the project, an initial mapping initiative of European water-related RIs/Obs was conducted to facilitate access to these infrastructures, as well as to enable the sharing and use of large-scale and long-term environmental data. During Phase 2 of the project, further insights into the RI landscape are being gained through the development and dissemination of a questionnaire and a survey to RIs/Obs administrators, in combination with a literature review. More specifically, the questionnaire was developed with the aim of collecting additional information from RIs/Obs owners to be included in the online repository, enhancing its added value to the water sector by integrating harmonized metadata and services. The questionnaire was disseminated to more than 150 RIs/Obs administrators across Europe with the aim of collecting detailed information, such as: RI Full Name, RI Acronym, Description, Institution/Coordinating Institution, Country/Coordinating Country, Other Partners, Current Status (Active, Under Development, Inactive, Other), Location, Website, Contact Person/Email, RI Type (Single-Site RI, Distributed RI, Knowledge-Based RI, e-Infrastructure), Level of Access, Cost of Access, Keywords, Water4All Keywords, and Links with Other RIs. Until now, 73 answers have been received. Based on the questionnaire replies, the established links between RIs/Obs are being studied not only to support evolving collaborations and future cooperation, but also to strengthen the science-policy-providers-end-users interface, thereby maximizing their contribution to the R&D+I sector. To gain deeper insights into the RIs/Obs landscape, a survey primarily focused on the needs, gaps, and proposed solutions identified by RIs/Obs administrators was developed and disseminated. The questions were mainly focused on the most critical needs and challenges they face, particularly those related to funding issues and existing policies, as well as the solutions they propose to help address these challenges. To date, 62 responses have been received and thoroughly assessed.

Through this process, and in combination with the literature review, the RIs/Obs web platform (European Partnership Water4All Water Security for the planet, n.d.-a) is being continually updated and upgraded, that provide important water data and information to researchers, policymakers, and stakeholders worldwide, and acting as the foundation for a stable collaboration scheme among data and service providers and between providers and end-users. The list of RIs & Obs, along with their provided data and services in the repository, is UpToDate, taking into consideration the needs of the RIs/Obs community, including both administrators and end-users. Interoperability requirements are also considered, maintaining the possibility of potential API integration in future upgrades. RIs/Obs are further categorized

according to their level of maturity in structured networking and their significance for international research, with the ultimate goal of proposing an effective collaboration scheme among them and between providers and end-users.

3 RESEARCH OUTCOMES

Within the framework of the Water4All Partnership and Water Europe initiatives, significant efforts have been dedicated to the mapping, networking, and strengthening of WoLLs across Europe. More specifically, the development of the Water4All Atlas of Water-Oriented Living Labs represents one of the first coordinated attempts to systematically map and categorize European WoLLs, supporting the creation of a collaborative network of water-related innovation ecosystems. The current Atlas includes more than 28 WoLL research settings across Europe, covering different technological, environmental, and governance contexts. (Water4All, 2024). A major benefit of the WoLL approach is that it brings together research institutions, local authorities, utilities, and community members. This collaboration makes it easier to share knowledge and makes new water solutions more practical and relevant. WoLLs also collect real-life data and offer useful insights, helping people make better decisions and build stronger, more adaptable water management systems (Evans et al., 2015).

A representative example of the WoLL approach is the Antissa Wastewater Treatment Plant Living Lab located on the island of Lesbos, Greece. Initially developed under the HYDROUSA project (HYDROUSA demo sites, 2020), the Living Lab has remained fully operational through successive European initiatives, serving as a full-scale testing site where new wastewater treatment and circular water management solutions can be tried out in a Mediterranean island setting. The facility combines decentralized treatment, reclaimed water reuse, environmental monitoring, and stakeholder engagement activities, while generating long-term operational data for research and policy-oriented applications. This Living Lab shows how WoLLs can help validate and demonstrate new solutions, which strengthens water resilience in vulnerable areas.

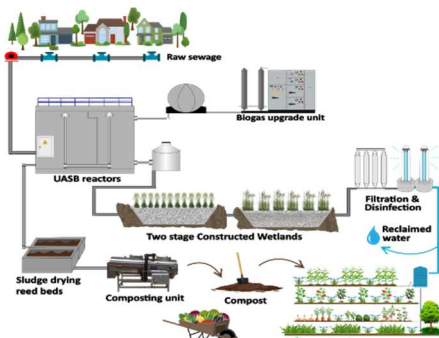


Figure 1: Flow chart of Antissa WoLL

European water RIs/Obs are essential for water R&I but remain fragmented. The current analysis highlighted the limited visibility of RIs/Obs and the difficulty of accessing their data and services. This situation leaves the RI sector behind the scenes and creates barriers to transnational access to data and services. Persistent problems in the RIs/Obs sector -such as conflicting national and European RI strategies, inadequate integration of RI services into policy and decision-making frameworks, bureaucratic constraints in public governance, and a lack of incentives for stakeholder engagement and innovation adoption- have a significant impact on the evolution of water resilience R&I capacity in Europe, slowing its growth. In this context, mapping the European water-related RI landscape represents the first step toward

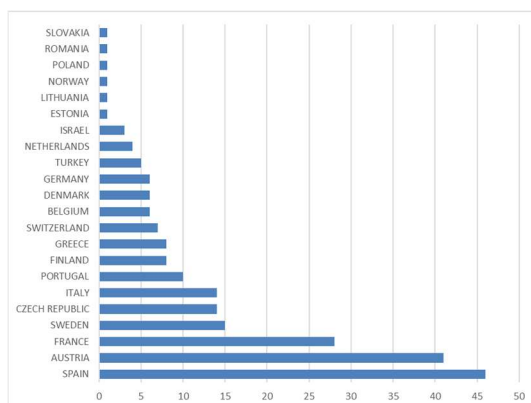


Figure 2: Geographical coverage of the RIs/Obs platform

assessing possible gaps and identifying synergies among existing structures. It is a prerequisite when aiming to make such RIs/Obs accessible to the widest possible audience and to facilitate interaction among different actors and stakeholders. The Water4All RIs/Obs platform currently includes 227 entries from across Europe and beyond, and continues to expand, upgrade, and evolve. This wide coverage strengthens the platform's role as a major European reference point for freshwater-related RIs/Obs, providing opportunities for cooperation beyond EU borders. An informed and updated mapping of existing RIs/Obs

can raise awareness of what already exists and enhances a more comprehensive approach to water-related issues. One of the main objectives of this mapping is to facilitate access to water-related RIs/Obs, as well as the sharing and accessibility of large-scale and long-term environmental data, ultimately contributing to enhanced water resilience.

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