Review of the challenges and opportunities for digital solutions and applications targeting different approaches, regions of Europe, and sectors of water use for information sharing

GOVAQUA Deliverable 5.1

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Contents

List of Abbreviations

Abbreviation	Explanation
CaBA	Catchment Based Approach
EA	Environment Agency
EEA	European Environment Agency
EC	European Commission
EU	European Union
GRDC	Global Runoff Data Centre
IWRM	Integrated water resources management
OECD	Organisation for Economic Co-operation and Development
PPSR	Public Participation in Scientific Research
RBMP	River Basin Management Plan
SDG	Sustainable Development Goals
TWEDM	Thames Water Event Duration Monitoring
WFD	Water Framework Directive
WP	Work Package
WWF	World Wide Fund

Executive Summary

The **GOVAQUA project aims to identify, assess, develop, and validate innovations in water governance** to support and accelerate a transition towards sustainable and equitable water use in Europe. The project covers systemic development needs for this transition, focusing on four key areas of governance innovations: legislation and regulation (WP2), participation and collaboration (WP3), economics and finance (WP4), and digital solutions for information sharing (WP5). **Within Work Package 5 (WP5) ”Digital solutions for information sharing”, we worked collaboratively with the other thematic work packages (WP2-4) to review over 200 digital tools for information sharing in the context of water governance and created an inventory**. Due to the large number of digital tools supporting water governance, this inventory is not exhaustive. Our aims were threefold:

- **To capture the diversity of tools and techniques** used for sharing information on various aspects of water governance (legal, finance and participation) at different scales.
- **To encompass both global tools and national/catchment-level ones** from various countries across Europe.
- **To reflect the multi-sectorial nature of water governance**, ensuring the inclusion of perspectives and inputs from diverse sectors.

The inventory includes tools in English, Spanish, Dutch, Finnish, German, and French, reflecting the focus countries of the GOVAQUA project. With respect to GOVAQUA's key areas, amongst these tools: 132 support legal aspects, 63 support citizen science and 31 support financial aspects of water governance. The comparatively low number of tools focusing on financial aspects of water governance is likely due to the limited accessibility of such tools or data to the public.

To assess digital tools in the context of water governance, **a user-friendly and intuitive digital solution assessment framework was designed** to systematically evaluate their effectiveness. This flexible assessment framework **supports both qualitative and quantitative assessments** and is designed to address the multifaceted challenges of water governance. **The framework consists of four main criteria, each targeting a specific governance dimension to ensure clarity and focus.** Together, these criteria form a comprehensive evaluation framework that reflects the interconnected nature of governance principles. They are further detailed into sub-criteria that can be tailored to suit specific applications. The main criteria are:

1. Transparency and Accountability: This criterion focused on adherence to FAIR principles to ensure transparency and accountability in governance practices.
2. Serving the Purpose of Water Governance: This criterion evaluated how well the tool aligns with water governance principles, such as cross-sectoral or integrated water resources management (IWRM), public participation (e.g., citizen science initiatives), and the effective application of government policies, including those outlined in the GOVAQUA project.
3. Contextual information: This criterion assessed the adequacy of the information provided regarding the purpose of the tool, its history (if relevant) and its use.
4. Inclusivity: This criterion considered factors such as gender equality, language accessibility, and target audience diversity to ensure inclusivity in tool design and implementation.

Each criterion was further broken down into sub-criteria that can be tailored to suit specific applications, resulting in a total of 18 sub-criteria. To support a quantitative assessment, a system of scores and weights

was designed. The score, ranging from 2 to 5 levels with specific scores assigned to each level, represents the quantitative assessment of each individual criterion and remains fixed regardless of the purpose of the assessment. The weight reflects the qualitative assessments, representing the importance or relevance of each criterion within the assessment framework. Weights are adapted based on the specific assessment purpose, typically ranging from 1 to 5.

This digital tool assessment framework is intended to help a diverse range of users, including web developers, regulators, academics, and water industry stakeholders; whether at the inception stage of designing a digital tool for supporting governance or assessing an existing digital tool. This digital tool assessment framework provided the basis to implement components of the assessment framework developed within WP1, that are relevant to digital solutions.

The digital solution assessment tool was applied to a sub-selection of digital tools from the inventory. This sub-selection was established in consultation with project partners and the representatives from the six GOVAQUA Living Labs. In total 20 digital tools, spanning a range of languages (English, French, Finnish and Spanish), spatial scales, key areas and tool types, such as web platform, data repository and interactive map. **The selected tools were then systematically evaluated using the assessment tool, allowing for the identification of strengths and weaknesses**, and thus constituting a set of case studies from which to select potential "good practice".

A collaborative approach was employed for the evaluation, involving partners from various linguistic backgrounds to enhance inclusivity. Detailed guidance was provided to ensure consistent scoring, with results visualized in a heatmap for intuitive comparison. The analysis revealed significant insights into each tool's strengths and weaknesses across the main criteria.

The findings highlight the critical role that digital solutions can play in enhancing water governance. Despite intrinsic challenges related to the fragmentation of water governance, data accessibility and oppeness are key to transparency and accountability. The **adoption of common principles** such as the FAIR principles and standard practices such as the use of Digital Object Identifier (DOI), the sharing of data via API (Application programming interface) are key enablers.

Digital tools for information sharing often fail to fully align with the purposes of water governance due to the multifaceted aspects of water governance. However, this can be achieved by displaying whenever possible **multi-dimensional datasets** that support environmental monitoring, regulatory compliance, and decision-making**.**

The lack of contextual information can be detrimental in particular to provide information related to the purpose of the tool or its potential usability. Such aspects can be remediated by adhering to the **open data standard** and providing **a range of user support tool** (eg. tutorial videos, frequently asked questions page or a reliable help guide).

Regarding inclusivity, the tools reviewed highlight that this is an area where many challenges remain. There is a clear need to break down language barriers by providing **multi-lingual options** and thus expand outreach within culturally diverse stakeholder communities whether it is at the local level or at the broader scale. Furthermore, the **use of simplified interfaces, graphical displays, and versatile data formats**, as well as complex ones, enables accessibility for members of the community with less expertise/knowledge and thus fosters inclusivity.

It is clear that **challenges remain, particularly regarding data quality and usability, open data standards, and multi-stakeholder engagement**. By addressing these challenges, the GOVAQUA project aims to promote more sustainable and equitable water governance practices.

The digital tools assessment tool developed within WP5 will be further applied as part of Task 5.3 where two innovative tools will be designed and implemented for bringing multi-stakeholder data together to improve water governance. The findings in this report will provide the building blocks to validate good practices in innovative water governance and to support the co-creation of contextualized transition pathways that align with broader policy aims via engagement with the Living Labs (WP6).

1. Introduction

Improving the sustainable use of water at local, basin, and national levels is a central goal of key policy frameworks, including the European Water Framework Directive (WFD), the European Green Deal (EGD), and the United Nations Sustainable Development Goals (SDGs). These policies call for transformative changes in water management practices to ensure a more sustainable future. Innovations and adoption of existing best practices in water governance are essential for accelerating this transition.

The primary objective of the GOVAQUA project is to identify, assess, develop, and validate innovative water governance approaches that support and foster the transition to sustainable and equitable water use in Europe. Through extensive examination of water governance innovations, the project aims are to assess their adaptability and provide valuable knowledge, tools, and guidelines to adopt sustainable water utilisation across various sectors. The focus is on accelerating the transition to sustainable water management and governance by identifying key innovations in approaches, models, and instruments.

The project covers systemic development needs for this transition focusing on four key areas: (1) legislation and regulation, (2) multi-stakeholder participation and collaboration, (3) economics and finance, and (4) digital solutions for information sharing. Good practices related to these key areas will be systematically reviewed, analyzed, and compared. Furthermore, they will be co-developed, assessed, and validated with key stakeholders in 6 living labs located in river basins, sub-basins, or catchments in France, Finland, Spain, the UK, and Romania, as well as transnationally between Finland and Sweden.

The overall structure of the project to support its implementation is shown in Figure 1.

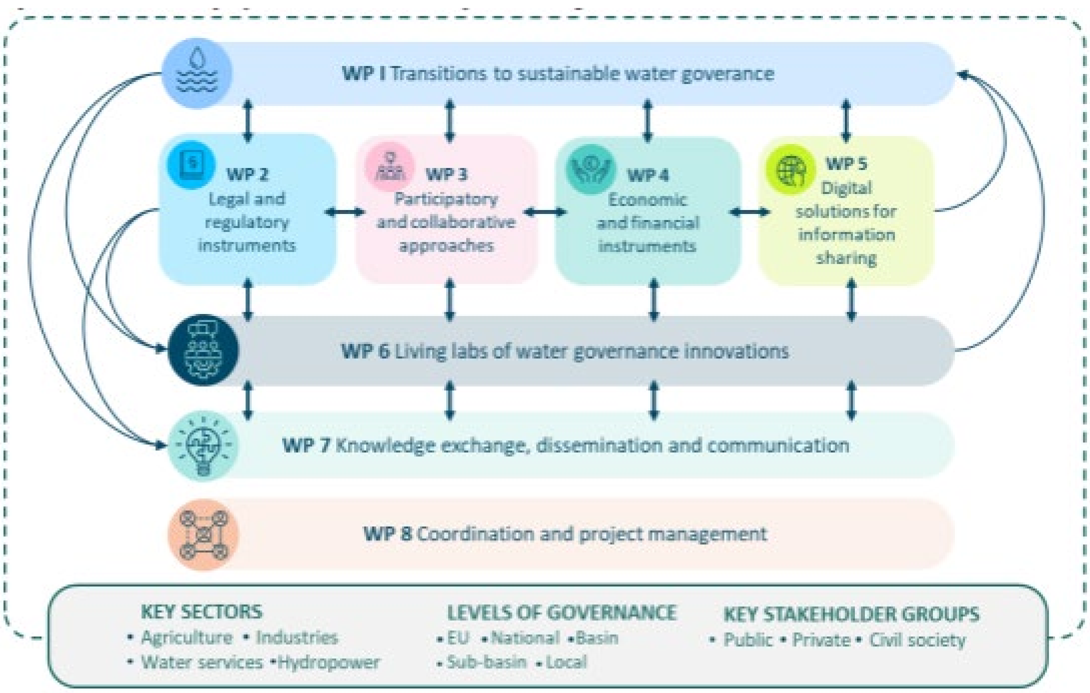

Figure 1. GOVAQUA project structure.

Within this report, we focus on the work undertaken as part of **work package (WP5) on "Digital solutions for information sharing".** The objective of WP5 is to aid **delivery of innovative digital tools for sharing information and know-how in water governance** The specific objectives of WP5 are to:

- **Identify the current digital solutions** at a range of scales to enable the use/uptake/ deployment of different types of information required to support sustainable WG. Such information may include environmental observations, financial data and tools, and legislative requirements. (**Task 5.1**). The digital solutions identified will include tools from the legal and regulatory theme (WP2), participatory approaches such as citizen science (WP3) and tools related to economic and financial aspects of water governance (WP4).
- **Review and assess digital tools** (Task 5.1) **and data sharing** (Task 5.2) between organisations and multiple stakeholders. The tools reviewed will cut across the thematic WPS (2-4). The digital tool assessment framework will be used to inform relevant parts of the assessment framework developed in WP1.
- **Develop two examplar innovative tools** (Task 5.3) for bringing multistakeholder data together to improve WG. These two new tools will be applied and assessed within two Living Labs (WP6) to demonstrate the potential for data and digital solutions to underpin new governance models, and will build on learning from the reviews of existing digital solutions
- **Provide recommendations** on enhancing the use of digital for transition to sustainable and equitable water use in Europe (Task 5.4).

The approach adopted within WP5 feeds directly into the GOVAQUA methodological approach as illustrated in Figure 2.

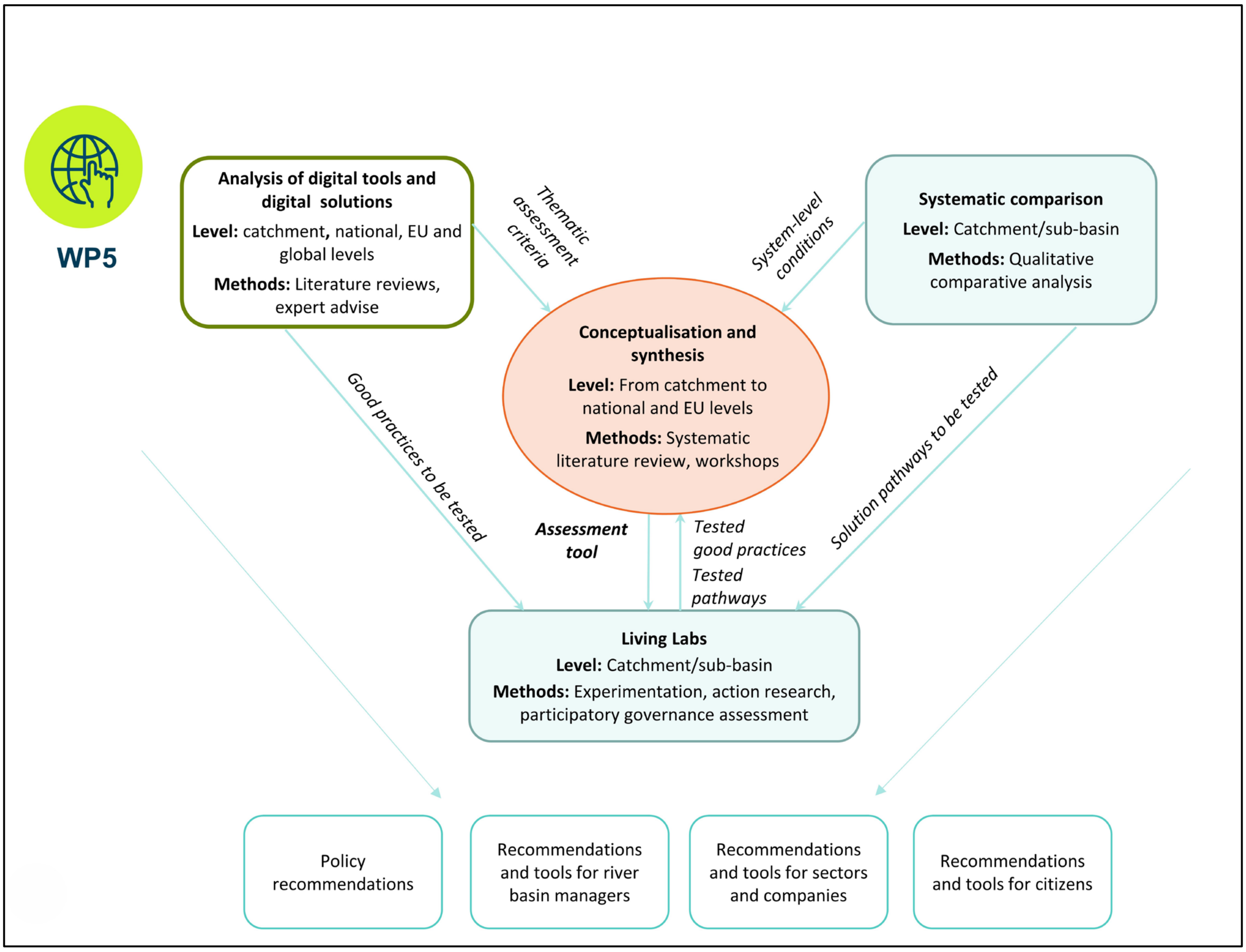

Figure 2. Positioning of the WP5 and this report in the overall framework of the GOVAQUA project.

1.1. Objective and content of this report

The main aim of this report was **to identify, review and assess digital tools and data to support information sharing at multiple levels** in water governance. It **presents an inventory of digital tools for sharing information in water governance and an assessment framework to evaluate these tools' effectiveness** in supporting sustainable water management practices.

The review was based on a structured process, and an assessment framework was developed to assess digital tools (and associated data) that help support water governance. An inventory of available digital tools and techniques was compiled, showcasing their use in sharing information across various aspects of water governance at different scales. This inventory includes global tools as well as those from various European countries, while capturing the multi-sectoral nature of water governance. The key areas covered include instruments and approaches in legislation and regulation, multi-stakeholder participation and collaboration and economics and finance, that GOVAQUA is focussing on.

The report is organised into five chapters. Chapter 1 provides a brief overview of the GOVAQUA project and introduces the content of this report. Chapter 2 details the method applied to compile the inventory of digital tools for sharing information for water governance. Chapter 3 provides an overview of the design of the Digital Solution Assessment Framework, which is then described in detail in Chapter 4. The final Chapter 5 sets out the challenges and opportunities identified based on the detailed review of available digital tools and their evaluation using the assessment framework and provides our conclusions.

2. Inventory of digital tools for sharing information and know-how in water governance

To understand how digital tools for information sharing can support water governance, an inventory of relevant digital tools was compiled using systematic mapping approach and through collaborative efforts. This inventory aims to capture a diverse array of tools, such as datahubs, frameworks, data portals, data standards, webtools and models that support water governance. While not exhaustive—due to the existence of hundreds of tools—it includes a selection of European and other international digital tools, spanning spatial scales from local catchment to European-wide and global applications. To represent the complexities and differences in water governance across Europe including the GOVAQUA living labs, the inventory includes tools in English, Dutch, Spanish, French, Finnish and German.

2.1 Systematic mapping and collaboration

A systematic mapping approach to canvas digital tools supporting water governance was developed initially in English and then reproduced in most languages (English, Dutch, Spanish, Finnish, French, German) available within the consortium. Searches for the tools were conducted using different combinations of keywords relevant to the GOVAQUA project across various search engines such as Google and Scopus. The Scopus search guide[1]served as a reference for constructing these searches.

[1] schema.elsevier.com/dtds/document/bkapi/search/SCOPUSSearchTips.htm

The searches were reproduced in the various languages available amongst the consortium's partners. A detailed guidance document (Appendix 1) was distributed to all partners to provide support and foster consistency across this activity. There is a plethora of digital tools available to support water governance, some of which might not be captured by the searches the team produced, despite their best efforts. Thus, to ensure that most relevant tools were included in the inventory, partners were also asked to add tools relevant to either the Living Labs (WP6) or the thematics included in the project (WP1-5) that were not identified via the searches.

The keywords used to do the searches in English and the tools obtained from the searches are provided as example in Appendix 2. Based on these searches, a list of relevant tools was compiled and subsequently classified according to the key aspects of the GOVAQUA project, including 'Legal and Regulatory Aspects' (WP2), 'Enhancing Participation' (WP3), and 'Economics and Financing' (WP4).

The results of the searches were recorded in an Excel spreadsheet, along with a brief description completed from publicly available information as detailed in Table 1.

Table 1 Fields describing the digital tools included in the inventory.

Title of column	Description
Use case	Name of the digital tool
Type	Type of the tool, includes datahubs, frameworks, data portals, data standards, webtools and models
Link	Weblinks to access the digital tool
Description	Brief description of the use case explaining water governance, its spatial scale etc.
Finance	Flag (yes/no) indicating whether the tool tackles financial and economic aspects of water governance
Legislation	Flag (yes/no) indicating whether the tool tackles legal and regulatory aspects of water governance
Participation	Flag (yes/no) indicating whether the tool supports citizen science and multi-stakeholder collaboration
Comments	Brief comment about the tool regarding its specific relevance to WPs, case studies or Living Labs

2.2 The inventory

The compiled inventory, titled "WP5_use_case_examples (V1).xlsx" includes 220 digital tools supporting water governance. Although the inventory is only a large sample of the multitude of tools available for supporting water governance, it will serve as the foundation for selecting case studies in the remaining activities of WP5 and understand how they can support water governance. While not comprehensive, this inventory highlights the diversity of tools and techniques used to share information on various aspects of water governance.

Some of the notable types of tools in the inventory include the following, chosen based on their relevance, accessibility, and proven utility in water management and governance:

- **Data Hubs**: These include the Catchment Based Approach (CaBA)[2] Data Hub, which supports collaborative water management at the catchment level by providing data on river quality, flood risk, and habitat quality; the **Environment Agency (EA) Data Services Platform**[3], which offers real-time

[2] https://data.catchmentbasedapproach.org/

[3] https://environment.data.gov.uk/catchment-planning/

environmental data for effective monitoring and management; and the **European Environment Agency (EEA) Waterbase**[4], a comprehensive database on Europe's water resources that aids in assessing water quality and compliance with EU directives.

- **Frameworks:** Tools like the OECD Water Governance Self-assessment Tool[5] help countries evaluate and improve their water governance practices.
- **Data Portals**: Examples include the Thames Water EDM Map[6], which tracks storm overflow durations, and **Blue Earth Data**[7], which provides satellite-based environmental data.
- **Data Standards:** The PPSR-Core[8] ensures interoperability of citizen science data, facilitating data sharing and collaboration.
- **Web Tools: The CASTWATER ONLINE TOOL**[9] promotes sustainable water use in tourism, offering practical solutions for managing water resources in this sector. WWF Water Risk Filter[10] provides organizations with an online platform to assess and manage water-related risks in their operations, helping businesses make informed decisions regarding water stewardship.
- **Models:** Tools such as the **WaterGAP**[11] Global Hydrology Model and the WEAP[12] (Water Evaluation and Planning) System are essential for simulating water systems and supporting integrated water resources planning.

The inventory consists of tools in English, Spanish, Dutch, Finnish, German, and French. With respect to GOVAQUA's key areas, there are 132 tools identified as supporting legal aspects, 63 supporting citizen science and 31 supporting financial aspects of water governance. There are fewer financial tools which is the combination of a range of factors including the fragmentation of financial arrangements between the public and the private sector. It is worth noting that sometimes although the data is available it is not always accessible/understandable to all stakeholders (De Stefano et al., 2016). Despite low numbers in financial tools, the most relevant tools tackling financial and economic aspects of water governance were included in the case study selection (Section 4.3).

Additionally, several datasets, models, and web tools included in the list may not be explicitly categorized as "legislative" in their descriptions but could nonetheless support legislation and governance efforts. For example, the Global Runoff Data Centre (GRDC) offers comprehensive hydrological data on river discharge and related parameters, which is widely applied in policy-making and governance.

It is worth noting that only one tool related to environmental flows (E-flows) was identified: the Spanish tool SAIH del Guadalquivir. This may be because E-flows are often addressed through methodologies rather than models, usually documented in water resources management plans. Given its relevance, as it connects directly to WP2—where E-flows were examined as part of national water policy frameworks in six studied countries, addressing implementation challenges—this tool was considered in further analyses within this report to reinforce the linkage between WP2 and the focus areas of WP5.

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[4] https://www.eea.europa.eu/en/datahub
[5] https://www.oecd.org/content/dam/oecd/en/topics/policy-sub-issues/water-governance/oecd_water-governance-indicator-framework_en.pdf
[6] https://www.thameswater.co.uk/edm-map
[7] https://blueearthdata.org/data
[8] https://core.citizenscience.org/docs/
[9] https://www.castwater-tool.ceid.upatras.gr/?lang=en
[10] https://riskfilter.org/water/home
[11] https://zenodo.org/records/6902111
[12] https://www.sei.org/projects/weap-water-evaluation-planning-system/

To analyse some of these tools and assess them, it is important to develop a suitable framework that will support this task and act as guidance for future tool development.

3. Design of the digital tool assessment framework

Building on the comprehensive inventory of digital tools cataloged in Section 2.2, this section outlines the design of the digital tool assessment framework developed within the GOVAQUA project. As the landscape of water governance evolves towards digital transformation to support information transparency, the need for an effective assessment criteria for digital tools becomes paramount.

3.1. Objectives of the framework

The primary objective of the digital tool assessment framework was to scrutinise a sub-selection of tools available in the inventory and assess their practical applications to support water governance. This framework also serves as a guide to inform the development of digital tools tailored to address the evolving needs of water governance.

To achieve these objectives, the framework was developed through a conceptual literature review to analyse the performance and impact of selected tools in the inventory, with a special emphasis on their potential to support a sustainability transition in water governance. Thus, several aspects that underpin a water resources system understanding, were considered while designing the framework, including:

- **Data/information** required to support water governance.
- **Capacity to share information** from various disciplines including legislation, finance, water policy and environmental science.
- **Capacity to integrate different type of data** (*in-situ* and remote sensing, observed and modelled, public and private) including citizen science data.
- **Accessibility of information** to a wide range of stakeholder including water users (domestic/agricultural/industrial/recreational purposes), water managers and regulators (including water pricing), and scientists.

The proposed framework needed to build on existing knowledge of GOVAQUA team members, thus, we have conducted literature reviews and further discussed the content of the framework with the WPs 2-4 to ensure the resulting framework is robust and fit for purpose.

3.2. Literature review

This chapter provides an overview of existing data management principles, policy documents, data standards and frameworks we have reviewed, aiming to identify relevant dimensions, criteria, and indicators for assessing digital tools and solutions. These elements are intended for inclusion in the assessment framework criteria. The approach we adopted mirrors the literature review process employed by WP1 for the GOVAQUA Assessment Tool (Deliverable 1.3). In this chapter, we outline the reviewed approaches, describing their conceptual foundations while critically examining the suitability and limitations of the dimensions, criteria, and indicators they use. Our focus was particularly on the conceptual and methodological aspects relevant to the GOVAQUA digital solution assessment tool.

3.2.1. Data management principles

In developing our assessment framework for evaluating digital tools in water governance, we referred to several key data management principles that enhance collaboration and information sharing. These principles provide essential guidelines for effective data stewardship:

The ***FAIR principles***—Findable, Accessible, Interoperable, and Reusable—provide a framework for effective scientific data management (Wilkinson et al., 2016). They extend beyond data to encompass algorithms, tools, and workflows, ensuring that water-related data is accessible and interoperable for all stakeholders.

The ***TRUST Principles***—Transparency, Responsibility, User focus, Sustainability, and Technology—are vital for managing digital repositories effectively (Lin et al., 2020). These principles promote reliability and long-term accessibility, fostering transparency and accountability in information sharing, which are crucial for informed decision-making.

The ***CARE principles***—Collective benefit, Authority to control, Responsibility, and Ethics—are designed to complement the FAIR principles and focus on indigenous data governance. They focus on collective ownership, ethical practices, and community involvement, addressing power imbalances and ensuring marginalized voices are included.

The ***OCAP principles***—Ownership, Control, Access, and Possession— developed by the First Nations Information Governance Centre, assert that First Nations communities should own and control their data. These principles reinforce their rights and sovereignty in data management, ensuring cultural protocols are respected.

Recognizing that these principles share overlapping elements and differ in their relevance to digital solutions for water governance, we integrated only the most applicable aspects into our framework. The FAIR principles were considered in their entirety, as they align strongly with the needs for data discoverability, usability, and interoperability—key aspects for managing water-related digital data. Transparency was established as one of the main criteria, encompassing FAIR principles due to their shared emphasis on openness and accessibility. Similarly, aspects of ownership and authority to control from the CARE and OCAP principles were integrated into a broader criterion for trustworthiness to reflect their focus on ethical practices and accountability.

3.2.2. Policy documents and reports

A series of influential policy documents and reports have helped inform our approach, these include:

Recommendation of the Council on OECD Legal Instruments Enhancing Access to and Sharing of Data
To provide valuable guidance for policymakers in the field of data governance, the OECD has developed multiple legal instruments including recommendations for enhancing access to and sharing of data *(OECD, 2023)*. This offers extensive guidance and best practices on critical aspects such as data openness,

transparency, stakeholder engagement, intellectual property rights and pricing. The document proves to be highly valuable in offering effective guidance for policymakers, making it an excellent resource for data governance.

Digitalisation in the water sector recommendations for policy developments at the EU Level
The document primarily provides general recommendations on the technological, social, and environmental aspects of digitalisation (EREA, 2022). This document was reviewed, as it is one of the important documents related to the main objective of the task, which is digitalisation in the water sector. It emphasises the need to concentrate digitalisation efforts on high-demand areas within the water sector, standardising digital tools through active engagement with relevant organisations, enhancing public involvement, implementation of nexus approaches, and the significance of user-friendly digital tools. The report recommends conducting further research to understand the new challenges and effects associated with adopting computationally expensive and energy-intensive digital solutions. Considering the review and assessment criteria, this report may not be particularly relevant.

3.2.3. Data standards

PPSR Core- Public Participation in Scientific Research

PPSR Core (PPSRCore, 2021) is a set of global, transdisciplinary data and metadata standards for Public Participation in Scientific Research (Citizen Science). As such it is a readily useable, widely adopted, and simple approach to capturing citizen science information. The PPSR-core documentation provides clear guidelines regarding capturing standardized monitoring scheme metadata to support sharing of information about citizen science programmes, which is highly relevant to the work of WP5 and GOVAQUA. According to the documentation, the dataset-level metadata should encompass various components, such as the title and description of the dataset, graphical elements associated with the dataset, the method or survey protocol employed, the temporal range covered by the dataset, the dataset's licensing and ownership information, the quality assurance methods implemented throughout the data collection process (pre, during, and post-recording), data access methods, constraints and biases impacting data usage, and a data management plan. It supports several existing catalogues of citizen science schemes.

3.2.4. Frameworks and tools

OECD Water Governance Indicator Framework

The OECD Water Governance Indicator Framework consists of 12 principles distributed across three dimensions: efficiency, effectiveness, and trust and engagement (OECD, 2015). It evaluates water governance through policy frameworks (what), institutions (who), and instruments (how), with each principle assessed by three specific indicators. The framework includes a methodology with three phases—preparation, diagnosis, and action—and provides a self-assessment toolkit for each principle (OECD, 2018). Although the framework is practical and requires minimal adaptation for practitioners, it has some limitations for GOVAQUA. It does not fully address the systemic transitions necessary for sustainable and equitable water use and primarily focuses on governmental roles, potentially overlooking broader, non-governmental aspects. Additionally, while the framework is suitable for local, basin, or national levels, its use at non-national levels has been limited (Akhmouch et al., 2018; Martín Velasco et al., 2023).

STEER Conceptual Framework

The STEER (Erhöhung der STEuerungskompetenz zur ERreichung der Ziele eines integrierten Wassermanagements) Conceptual Framework (Pahl-Wostl et al 2020) is designed to provide a deeper understanding of how the characteristics of governance and management systems influence their performance, and how these relationships are impacted by surrounding social and environmental conditions. The framework emphasizes the importance of effective coordination, collaboration, social learning, and conflict resolution. It examines the broad and lasting effects of governance outcomes on societal, environmental, and economic conditions, which can be both direct and indirect, as well as intentional and unintentional. Indicators for measuring these impacts may be tailored to specific water governance goals, such as improving water quality, or aligned with universal standards, such as sustainability principles related to water security. The framework utilises the concept of action situations, a core element of the Institutional Analysis and Development (IAD) framework introduced by Elinor Ostrom in 2005. STEER expands on this concept to describe various governance functions associated with planning and implementation processes. Each action situation is categorised into phases: planning, which involves strategic and operational planning and establishing procedures; implementation, which refers to the execution of policies and capacity building for operational activities; and ecosystem services interactions, which include direct activities impacting resources and ecosystem services.

MICS: Measuring the impact of citizen science

The MICS project (MICS, 2020) enables the evaluation of a citizen-science project's impact using scores and indicators in various domains. For instance, when measuring the impact of citizen science on governance, two indicators, namely policy and sustainable development goals, are considered. To assess these indicators, users are required to answer multiple questions, and the scores for each indicator are determined by adding up the weights assigned to the selected answer options. Based on these weights and the recommended threshold scores, the tools are categorised into different domains. The suitability of such an approach was investigated for the assessment of Digital Tools within activities of WP5.

3.3. Assessment criteria

During the literature review detailed in Section 3.2, approximately 40 key points, keywords, or criteria were identified as critical to understanding the effectiveness of water governance tools. These points were carefully analyzed and grouped based on thematic similarities, resulting in the development of four main criteria to serve as the foundation of the assessment framework.

Building on this comprehensive review and drawing insights from frameworks of other GOVAQUA WP, such as the WP4 assessment framework (D4.1), an initial framework structure was developed. To maintain consistency across related work packages, a similar approach was adopted.

The framework structure consists of a set of main assessment criteria, each refined into specific sub-criteria to enable a thorough and systematic evaluation. Assessment criteria serve as the standards used to evaluate the performance, effectiveness, and suitability of various tools within the water governance system. These criteria allow for systematic evaluation of how well each tool functions to achieve its objectives and address core challenges. Sub-criteria break down each main criterion into specific aspects or dimensions that contribute to the overall assessment, offering a more nuanced approach to evaluating the tools' utility and alignment with water governance goals.

A detailed description of these criteria and their practical application is provided in Section 4, where each criterion is explored in depth to facilitate consistent and accurate evaluation.

4. Framework and the assessment tool

This section outlines the structured process involved in developing a comprehensive framework to evaluate the effectiveness of digital tools in water governance. The process consists of three main components:

- Designing the Assessment framework
- Developing the Assessment Tool
- Testing the Assessment Tool

The assessment framework has been designed by identifying the main assessment criteria, refining the relevant sub-criteria, and establishing a scoring method on scores and weights. Unlike existing frameworks such as those by the OECD, which often emphasize dimensions and indicators, this framework deliberately simplifies the approach while maintaining robustness.

By focusing on clearly defined and weighted criteria, the framework offers a comprehensive yet practical method for evaluating digital tools. The use of scores and weights ensures a structured and quantifiable evaluation process, effectively serving the purpose that dimensions and indicators might fulfill in other methodologies.An Excel-based assessment tool was created to facilitate the application of the framework, providing users with a practical method to assess digital tools and identify best practices in water governance.

The assessment tool was then tested through case study applications, which demonstrated its utility within the GOVAQUA project.

4.1. Assessment framework

1.1.1. Defining the main criteria and sub-criteria

Four key criteria were identified (as explained in Section 3.3) for the assessment framework to evaluate the effectiveness of water governance tools. The focus of each criterion is as follows:

- **Transparency and accountability (A1)**: This criterion focuses on adherence to FAIR principles to ensure transparency and accountability in governance practices.
- **Alignment with Water Governance Goals (A2)**: This criterion evaluates how well the tool aligns with water governance principles, including those outlined in the GOVAQUA project.
- **Contextual Information (A3)**: This criterion assesses the comprehensiveness and relevance of the webtool's content, including its aim, description, and information provided.
- **Inclusivity (A4)**: This criterion considers factors such as gender equality, language accessibility, and target audience diversity to ensure inclusivity in tool design and implementation.

Each criterion is further broken down into several sub-criteria, resulting in a total of 18 sub-criteria: 5 for A1, 4 for A2, 7 for A3, and 2 for A4, as depicted in Figure 3.

The assessment framework was designed to be flexible, supporting both qualitative and quantitative assessments. It allows for the tailoring of main criteria and relevant sub-criteria to suit specific applications. Additionally, some sub-criteria can be excluded if they do not align with the context or objectives of the assessment.

1.1.2. Establishing the scoring method

To support a quantitative assessment, a system of scores and weights was designed. The score represents the quantitative assessment of each individual criterion and remains fixed regardless of the purpose of the assessment. On the other hand, the weight reflects the importance or relevance of each criterion within the assessment framework and is driven by the purpose of the assessment.

Each sub-criterion has a unique scoring scale, ranging from 2 to 5 levels, with specific scores assigned to each level. These scales were established through GOVAQUA team discussions to incorporate diverse perspectives. For example, the sub-criterion S1 (Figure 3), which evaluates the presence of detailed background or initiative data, has four levels: standardized metadata (score 3), complete information (score 2), partial information (score 1), and no information (score 0).

This final score is the weighted total for S5, based on the individual subsection scores.

4.1.2.1. Weights and their application

Weights are adapted based on the specific assessment purpose, typically ranging from 1 to 5, allowing flexible emphasis on each criterion's significance. For instance, sub-criterion S1, when used to evaluate tools based on data content (as in Task 5.1), is assigned a weight of 3 to reflect its importance in that context.

Some sub-criteria contain additional subsections. For example, the sub-criteria S5 (whether it supports the reuse of data) includes: S5.1- Whether it supports the reuse of data & S5.2- Whether it provides simple or clear data licensing. Each subsection (S5.1 and S5.2) is scored as either 1 (Yes) or 0 (No). To calculate the total score for S5, first sum the scores for S5.1 and S5.2, then multiply this sum by the assigned weight for S5. For instance, if both S5.1 and S5.2 score "Yes" (1), the calculation would be:

Total Score for S5= $(1+1)\times4=8$

Although this framework was initially developed to assess digital tools, its structured approach—using assessment criteria, sub-criteria, scoring scales, scores, and weights—makes it versatile and applicable to a range of water governance practices.

The concept of weights in particular, provides users means to adapt the framework to their needs. **Transparency and Accountability** should be assigned higher priority (thus greater weight) for repositories of information such as data portals. These tools are designed to provide open access to datasets that support water-related decision-making. Ensuring that data is accurate, openly accessible, and accompanied by metadata is essential to building trust and enhancing decision-making processes.

For risk analysis tools, **Alignment with Water Governance Goals** should be given greater weights. These tools are intended to evaluate and communicate risks related to water scarcity, quality, or governance issues. Their effectiveness relies on analytical rigor and policy relevance, directly supporting decision-makers in achieving governance objectives such as sustainability, equity, and resilience.

In the case of decision-support systems, both **Alignment with Water Governance Goals** and **Contextual Information** should be prioritized. These systems integrate data, models, and user inputs to support policy and operational decisions, requiring strong alignment with governance objectives and the inclusion of localized, sector-specific information to ensure their relevance and utility.

For stakeholder engagement platforms, **Inclusivity** should be assigned the highest priority. These platforms are designed to facilitate dialogue and enhance collaboration among stakeholders, making it critical to ensure diverse representation and equitable access for meaningful participation in water governance.

4.2. Assessment Tool

To facilitate effective utilisation of the assessment framework without the need for extensive training, a straightforward Excel tool (Assessment tool.xlsx) was developed. This tool serves as a user-friendly interface for assessing the various digital tools within the water governance system. It can be used to assess the effectiveness of different tools and identify good practices, for example, in Task 5.1 and Task 5.2, and it can also be used at the design stages of a digital tool for information sharing, as in Task 5.3. The tool is aimed at a range of users including web developers, regulators, academics and water industries (e.g. water companies and hydropower industries).

This tool is organised into three worksheets, each serving a specific purpose:

- **Instructions:** This is a metadata worksheet. It serves as a comprehensive repository of all necessary details on the assessment criteria, sub-criteria, scores, and weights. Additionally, it includes supporting instructions and comments intended to assist users throughout the assessment process. These instructions or comments may encompass notes and web links to provide users with additional context or guidance as they navigate the assessment criteria.
- **User Input**: This worksheet is designed to enable direct user interaction. Here, the user inserts scores for each tool based on their evaluation against the specified criteria and sub-criteria.
- **Assessment Results:** In this worksheet, the total score for each tool is calculated based on the user-inputted scores and the assigned weights for each task.

Assessment criteria		Sub criteria	Score levels and scores	Weight (1 -5 scale)
Transparency and accountability	S1	Whether the data have a detailed background or initiative?	Standardised Metadata – 3; All the information- 2; Some of the information -1; None - 0	3
	S2	Whether it supports Findable data?	With DOI/ data repository – 1; Otherwise - 0	4
	S3	Whether it supports Accessible data? S3.1. Whether it is downloadable via API	With API – 2; With API partially-1; Without API - 0	4
		S3.2. Whether it is downloadable via CSV	Yes – 1 ; No - 0	4
	S4	Whether it meets/supports interoperable data ? S4.1. Whether the method/survey protocol used is mentioned?	Yes – 1 ; Partially – 0.5; No - 0	4
		S4.2. Whether it has a consistent data format across datasets?	Yes – 1 ; No - 0	4
	S5	Whether it supports the Reuse of data S5.1. Is it findable, accessible, interoperable? S5.2. Whether it supports simple or clear data licensing?	Yes – 1 ; No - 0	4
Alignment with Water Governance Goals	S6	Whether it supports public participation S6.1. Whether there is possibility of citizen science data? S6.2. Whether there is any mechanism of reporting for users?	Yes – 1 ; No - 0	3
	S7	Whether it has a clear GDPR and data privacy notice?	Yes – 1 ; No - 0	4
	S8	Whether it supports cross-sectoral water governance?	Yes – 1 ; No - 0	3
	S9	Whether the tool supports understanding or application of policies?	Yes – 1 ; No - 0	5
Contextual information	S10	Whether the webpage has detailed background or initiative?	All the information- 2; Some of the information -1; None - 0	3
	S11	Whether the data have trustworthiness with proper quality control and data custodian?	Yes – 1 ; No - 0	5
	S12	Whether it provides or supports open data?	Open data in whatever format – 1; Structured data (e.g., Excel) – 2; Non-proprietary open format (e.g., CSV) -3; URIs to denote things- 4; link data to other data to provide context- 5	3
	S13	Whether it is free to use or even at least with minimal cost?	Yes – 1 ; No - 0	4
	S14	Whether the start date is mentioned?	With start date – 1; Without start date - 0	2
	S15	Are they still active?	Not active -0; Still active but less than 5 years data -1; Still active and more than 5 years data -2	3
	S16	Whether there is different means of user guidance/support?	More than one- 2; Only one- 1; None- 0	3
Inclusivity	S17	Whether it supports inclusivity? S17.1. Gender equality	Yes – 1 ; No - 0	3
		S17.2. Language	Multiple languages including English- 4; Multiple languages but not English -3; Only English -2; Only other languange-1	3
	S18	Who are the target audiences (Practitioners, regulators, academics, local people, etc?)	One – 1; More than one -2	2

Figure 3 Digital tool Assessment framework: the weights are only presented as an illustration of how the framework may be used. The reported weights are those used within Task5.1 focussing on the data content of a digital tool for information sharing.

4.3. Case study application of assessment tool

4.3.1 Case study selection process

A set of case studies was selected from the extensive inventory (presented in Section 2.2). The aim of the case studies is to dive deeper into selected digital tools and identify successful approaches for sharing information across multi-disciplinary stakeholder to support sustainable water governance

Whilst selecting these, the aim was to ensure a comprehensive representation of the multifaceted aspects of water governance encompassed within the GOVAQUA project. To achieve this, each partner participating in the WP was tasked with selecting 5-10 tools that they deemed most relevant to the project's objectives and scope. This subset of digital tools will be used as good practice for use within Tasks 5.1 and 5.2 and for use within WP1.

The selection process was guided by various considerations to encompass diverse perspectives and functionalities. One consideration included covering a range of spatial scales, including basin/regional, national, and European levels. Additionally, the selection aimed to incorporate a variety of data display techniques, spanning tabular formats, graphics, storylines, and videos. Moreover, the selection process was conducted to include the key GOVAQUA areas, such as water-related financial aspects and citizen science and thematic pressures on Europe’s water resources relevant to the project, such as water quality (WP6 LL4) and e-flows (WP2). Table 2 presents an overview of the 20 selected case studies.

Table 2. Brief overview of the selected case studies

Tool/Project with the weblink	Scale	Description of the tool	How is it being used to support water governance
WWF Water Risk Filter https://riskfilter.org/water/home	Global	Part of WWF (World Wide Fund for Nature) Risk Filter Suite, this tool is designed to assist companies and financial institutions in identifying and managing nature-related risks with a focus on biodiversity and water risks, and support sustainable decisions and resilience.	Designed to be used as corporate and portfolio-level screening tools to help identify risks and prioritise corporate action for enhancing business resilience and contributing to a sustainable future. These tools are not designed for local-level assessments at singular site-level.
Copernicus Interactive Climate Atlas (C3S Atlas) https://atlas.climate.copernicus.eu/atlas	Global	This is a web application from the Copernicus Climate Change Service for the discoverability and exploration of a wide range of climate data, many of the datasets are directly related to understanding and managing water resources.	Widely used as the authoritative source of EU level datasets relevant to water management and governance.
FreshWaterWatch https://cos4cloud-eosc.eu/citizen-science-innovation/cos4cloud-citizen-	Global	This is a global citizen science tool for water quality observations as part of the Cos4Env initiative, which is an online platform integrating environmental monitoring data (water/air quality) from citizen observatories with large datasets, though there is a spatial data gap.	An initiative to collect and share citizen science data, to help monitor the quality of freshwater ecosystems globally and thus leverage information to promote sustainable water governance.

observatories/freshwater-watch/			
GEMStat GEMStat - The global water quality database	Global	This is a web application that provides data on global inland water quality trends. Part of the GEMS/Water Programme of the United Nations Environment Programme (UNEP), it is hosted by the GEMS/Water Data Centre (GWDC) in Koblenz, Germany.	A central repository of freshwater quality observations, searchable by station, country, and catchment.
State of Bathing Waters State of bathing waters 2024	European	This is an interactive map showing locations and quality of bathing waters in 27 EU Member States, Albania, and Switzerland, with data from 2023 and previous seasons. The data displayed includes quality status, microbiological parameters, and classifications.	A central dashboard of bathing water quality presented at the member state level.
CaBA Data Hub CaBA Data Explorer | Catchment Based Approach Data Hub	National (UK)	This is the data hub for the Catchment Based Approach initiative in the UK, it supports collaborative water management with 106 river catchment partnerships and over 200 spatial data layers related to land and water management.	A UK curated catalogue of data and applications to support catchment management.
The Riverfly Partnership https://www.riverflies.org/	National (UK)	A network of organisations supporting citizens to collect data on riverflies to help understand the health of rivers.	A quality-controlled dataset on key indicators of river health that is used by the Environment Agency and water utilities to help understand river health.
Sispea https://www.services.eaufrance.fr/	National (France)	This platform provides access to data on public water and sanitation services, including management methods, service pricing, yield, water quality, and claims ratios. Users can also perform geolocation searches to find information specific to their locality.	An annual report on water and sanitation services.
Économie Eau France https://economie.eaufrance.fr/propos-deconomie-eaufrance	National (France)	This is a public information service on water and aquatic environment economics in France. The platform provides access to data, key figures, publications, methodologies, and general information on water pricing, expenditures, environmental values, economic analysis, and decision-making in water management.	Provides economic information on water resources and their use in France.

HERTTA-information system https://www.syke.fi/fi-FI/Avoin_tieto/Ymparistotietojarjestelmat	National (Finland)	This is a web-based platform for open datasets offering access to environmental management information, including data on water resources, surface and groundwater conditions, biological species, environmental load, land use, and geospatial materials.	Supporting a range of actors with data on water resources.
PISARA-platform Pisara | Modern water management	National (Finland)	This is a data-gathering service and internal tool for administration, where all River Basin Management Plans (RBMP) and Program of Measures information is collected. This platform ensures data consistency across the nation, supporting standardised and reliable environmental management practices.	A broad collection of datasets related to Finland's water resources.
Water Restorator's Map Service https://syke.maps.arcgis.com/apps/MapSeries/index.html?appid=513a13e3fb324bbc9c9e8be616909b26	National (Finland)	Provides guidance on planning and implementing watercourse renovations, along with details on renovation measures and monitoring practices.	Helping the restoration of water bodies.
WATERINFO.fi https://www.vesi.fi/en/	National (Finland)	This is a web portal that provides comprehensive information on Finland's water resources, including water situation and water level.	Provides regional and national snapshots on the water situation in Finland i.e. how much water is available.
Riverbed Information System https://ckan.ymparisto.fi/dataset/uomatietojarjestelma	National (Finland)	This is a national database containing physiographic and hierarchical data on rivers with catchment areas over 10 km², as well as smaller, hydrologically significant rivers.	Serves as a basis for defining boarders between water areas which is important when planning water protection measures for WFD.
Lake-Sea Wiki https://www.jarviwiki.fi/wiki/Etusivu	National (Finland)	This is an online platform developed through collaboration between authorities and citizens, providing data on all lakes (over one hectare) and coastal marine areas. Users can access tools to maintain observation spots and contribute their own insights and observations about local waters.	Aiding the sharing of data and understanding of lakes.
Thames Water Event Duration	Regional (UK)	This is an innovative tool developed by Thames Water to monitor active storm	Central source of data on sewer discharges to water bodies.

Monitoring (TW EDM) https://www.thameswater.co.uk/edm-map		discharges and performance of sewer/treatment works, helping improve river health and environmental sustainability. The tool was originally designed to respond to river pollution campaigners and later on to comply to the Environment Act.	
Pang Valley Flood Forum https://www.floodalleviation.uk/dashboard/stw/	Regional (UK)	Local initiative proving a range of information to help address flood risk in the Pang Valley area.	Proving a range of datasets and related resources to help reduce flood risk.
WyeViz (Wye Alliance Citizen Science Dashboard) https:/WyeVizWyeAllianceCitizenScienced	Regional (UK)	This is a citizen science dashboard for monitoring the Wye River in England, it provides real-time data on water quality and health of the river system.	Provides access to citizen science water quality data.
Utah Water Watch (UWW) CitSci.org	Regional (USA)	This is a citizen science project for water quality monitoring in Utah, it aims to increase awareness and promote stewardship of water resources through public involvement.	Provides access to citizen science water quality data.
SAIH del Guadalquivir S.A.I.H. del Guadalquivir	Regional (Spain)	The Automatic Hydrological Information System of the Guadalquivir Basin is designed to provide real-time data on climate and hydrological variables including E-flows that are critical for water management.	Provides real-time information on river flows across the catchment.

The selected tools were then subjected to detailed evaluation using the developed assessment tool. This evaluation process allowed for a systematic examination of each tool's performance and suitability within the context of the GOVAQUA project objectives. The strengths, weaknesses, and overall effectiveness of the selected tools through the assessment tool are explained in the next section.

4.3.2 Evaluation of case studies with the assessment tool

The case study analyses of the assessment tool was carried out using a collaborative approach that actively involved various partners across the consortium. This approach allowed the inclusion of tools from different languages, enhancing the assessment’s inclusivity and relevance across diverse regions. Partners contributed by scoring the tools in the User Input section (Section 4.2), providing valuable, real-world perspectives and practical insights from those who might use or be affected by these tools.

To ensure accurate and consistent scoring, each partner received detailed guidance (Appendix 3) along with an online demonstration (working sessions, one-to-one and group meetings) of the assessment tool. This demonstration explained the tool's features and scoring criteria, ensuring a standardised evaluation process and reducing the likelihood of scoring discrepancies. This preparation empowered partners to confidently engage with the tool, thereby improving the quality of the feedback and the reliability of the results.

Based on partner scores and assigned weights from Task 5.1, total scores were calculated for each tool. These scores covered four key criteria: Transparency and Accountability, Alignment with Water Governance Goals, Contextual Information, and Inclusivity (Section 4.1). To allow comparison, raw scores were converted to percentages due to differing maximum scores. This quantitative approach provided a structured overview of each tool's performance across the evaluated dimensions.

The results of this analysis were visualized in a heatmap (Figure 4), which facilitated an intuitive comparison of the tools' strengths and weaknesses. In this heatmap, color intensity represents performance: darker green indicates higher scores, and lighter colour indicates lower scores. This visualization allow stakeholders to quickly identify areas where each tool excels or may need improvement, aiding in decision-making and future planning.

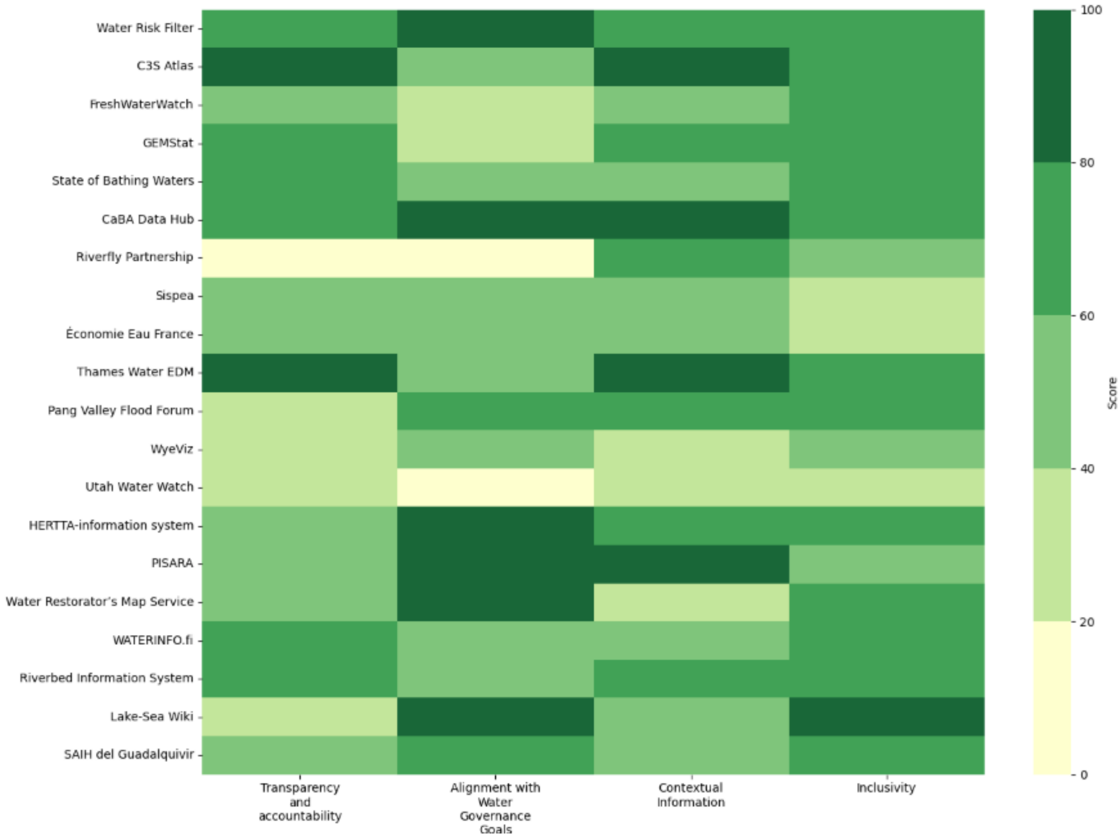

Figure 4 Effectiveness of different digital tools to support water governance based on GOVAQUA digital solution assessment framework

Key Observations from the analysis by criterion are as follows:

1. ***Transparency and Accountability:***

The Copernicus Interactive Climate Atlas (C3S Atlas) and Thames Water Event Duration Monitoring (TWEDM) stand out in Transparency and Accountability, with a score above 80%. This high score suggests that the tool provides open access to extensive datasets along with clear and detailed documentation. Such transparency allows stakeholders to understand the data's origins, methodologies, and limitations, contributing to its trustworthiness and reliability. Although the C3S Atlas primarily focuses on climate data rather than water governance specifically, its data management practices—including rigorous documentation, structured metadata, and open access—can serve as an exemplary model for water governance tools. The practices used by C3S Atlas highlight the importance of transparency in data accessibility and usability, and other tools in the water governance domain could benefit from adopting similar standards.

Lake-Sea Wiki, despite scoring well in other areas, does not perform as highly in transparency and accountability due to its lack of a Digital Object Identifier (DOI, a unique identifier for resources on the internet), data repository, an Application Programming Interface (API, interface for sharing data across and within organisations), and downloadable CSV of data. Similarly, Riverfly Partnership scored low, with scores below 20% in this criterion.

2. *Alignment with Water Governance Goals:*

Lake-Sea Wiki, World Wide Fund for Nature (WWF) Water Risk Filter, Catchment Based Approach (CaBA) data hub, HERTTA-information system, PISARA-platform and Water Restorator's Map Service scored highly here, likely due to the alignment of these tools with water governance goals. They provide detailed, multi-dimensional datasets that support regulatory compliance, environmental monitoring, and decision-making.

Tools like the Utah Water Watch, and Riverfly Partnership score lower, less than 20%. The Utah Water Watch and Riverfly Partnership tools are citizen science projects primarily focused on water quality monitoring, which, while valuable, limits their scope for broader governance applications. These projects scored lower due to limited information on GDPR compliance and privacy policies, which are essential for transparency in data handling. Furthermore, their emphasis on specific water quality parameters restricts their ability to support cross-sectoral water governance goals, as they lack the comprehensive data needed for a holistic view. Although TWEDM scores well in other categories (>75%), its performance is slightly lower in areas related to long-term governance and planning (50%). As an event-monitoring tool, TWEDM relies primarily on sensor data to provide real-time updates, such as alerts for stormwater discharges. While effective for immediate monitoring, this real-time focus limits its capacity to contribute to broader governance needs. TWEDM's narrower scope hinders its utility in areas such as policy development, compliance monitoring, and long-term trend analysis, which requires a more extensive, longitudinal data foundation.

3. *Contextual Information:*

Most of the tools perform well, with the C3S Atlas, CaBA Data Hub, TWEDM, and PISARA platform performing exceptionally well, each scoring above 80% in this category. These tools are free to use, have been active for a long time, and achieved high ratings according to the five-star open data scoring system. Additionally, they are supported by multiple types of user guidance such as video tutorial, FAQ and Help button, therefore targeting a wider-audience with a range of experience.

However, some tools scored lower for example WyeViz, Utah Water Watch, and Water Restorator's Map Service received scores below 40%, partly because their inception dates were unclear. Although WyeViz offers citizen science data with an option to download, the data did not download as expected and, therefore, does not fully comply with the five-star open data scoring system.

4. *Inclusivity:*

Most of the tools, especially "Lake-Sea Wiki," scored highly in inclusivity, suggesting they are accessible to a diverse range of users through user-friendly interfaces, multilingual support, or inclusive design (e.g. simple data formats such as pdfs and documents and displays such as graphs). These features ensure that various stakeholders—such as community members, researchers, and policymakers—can access and utilize the data effectively.

Sispea, Économie Eau France, and Utah Water Watch scored lower in this category, each receiving less than 40%. These lower scores are due to certain limitations: Sispea and Économie Eau France are available only in French, making them less accessible to non-French-speaking users. Although Utah Water Watch explicitly supports citizen science, its relevance for other practitioners, such as academics or researchers, is unclear.

CaBA Data Hub and Water Risk Filter consistently score well across most criteria, likely due to their robust datasets, clear transparency policies, inclusive design, and alignment with governance objectives. In contrast, Utah Water Watch and WyeViz consistently scored low in most criteria, where both are citizen science projects.

5. Challenges and opportunities identified for digital solutions and applications

Based on a detailed review of available digital tools and their evaluation using the assessment framework, the main findings on challenges of existing tools and opportunities identified are demonstrated in this chapter. These insights illustrate how digital tools for information sharing can enhance water management practices and facilitate informed decision-making. Fundamentally, digit tools need to support the needs of individuals, groups, and organisations involved in decision making related to improving water governance.

1. ***Transparency and Accountability:***

Data accessibility and openness remain significant challenges for many tools. For instance, Riverfly Partnership and Lake-Sea Wiki lack critical features like Digital Object Identifiers (DOIs), APIs, or downloadable data formats (e.g., CSVs). The lack of such information and accessibility technologies hinders transparency and stakeholders' ability to verify data origins and methodologies. Additionally, as observed in Riverfly Partnership, **gaps in documentation and metadata** reduce trust and the capacity to evaluate data reliability effectively. These factors inherently reduce the potential usage of the data amongst stakeholders and limits its potential support to water management.

Adopting open standards can significantly enhance transparency and accountability. Tools like the C3S Atlas exemplify best practices through rigorous documentation, structured metadata, and open access policies. Similarly, platforms such as CaBA Data Hub, which offer APIs and downloadable datasets, enable data reuse and foster accountability across sectors.

2. ***Alignment with Water Governance Goals:***

Digital tools often **fail to align fully with the multifaceted objectives of water governance**. Narrowly focused tools, such as Utah Water Watch and Riverfly Partnership, emphasize water quality monitoring but lack the breadth to support broader governance objectives like regulatory compliance, cross-sectoral planning, or policy development. Additionally, while tools like TWEDM are effective for real-time monitoring, they fall **short in offering longitudinal data needed for long-term governance and planning**, highlighting a gap in their strategic applicability.

Opportunities exist to enhance the alignment of digital tools with water governance objectives. Tools like the CaBA Data Hub and Water Risk Filter already demonstrate this by **offering multi-dimensional datasets** that support environmental monitoring, regulatory compliance, and decision-making**. Expanding the scope and quality of data** in tools like Utah Water Watch can bridge citizen science with broader governance goals.

3. Contextual Information:

Challenges in providing sufficient contextual information persist across several platforms. Tools like WyeViz score poorly due to **unclear operational timelines and limited user guidance**, which undermine their usability. Furthermore, **non-compliance with open data standards**, such as the five-star open data scoring system, creates barriers for stakeholders who require seamless data integration for effective decision-making.

Thus, improving user guidance can enhance the contextual information provided by digital tools. Platforms like the PISARA platform and TWEDM excel in **offering robust support, including video tutorials, FAQs, and help options, which improve user experience and accessibility**. Additionally, adopting the five-star open data scoring system, as demonstrated by tools like the C3S Atlas, can further enhance usability and trust.

4. Inclusivity:

Inclusivity remains a challenge for digital tools that **lack multilingual support** or are designed for specific user groups. For example, Sispea and Économie Eau France cater primarily to French-speaking audiences, limiting accessibility for a broader demographic. Similarly, some tools focus only on one aspect, for eg. Utah Water Watch focus on citizen science, restricts its relevance to researchers and policymakers. These limitations reduce stakeholder engagement and hinder effective collaboration among diverse user groups.

Expanding language options would make them accessible to a global audience. Additionally, s**implified interfaces, graphical displays, and versatile data formats** (e.g., PDFs, graphs) can help diverse stakeholders, such as community members and policymakers, to use data effectively. **Training initiatives and resources**, as seen in the C3S Atlas, can further empower users from varied backgrounds to leverage digital tools effectively.

6. Conclusions and recommendations

Digitalization has become increasingly common in the water sector. However, there is a significant knowledge gap specifically in digitalization targeted at water governance. Addressing this gap is crucial for advancing effective water governance in the digital age. It requires a shift in focus towards developing innovative digital solutions that facilitate data and information exchange among stakeholders, streamline decision-making processes, and promote more sustainable and equitable water governance practices. Engaging local communities, water users, companies, and other relevant organizations in policy development, implementation, and monitoring is vital for achieving inclusive and responsive governance practices.

This report underscores the pivotal role of digital solutions for information sharing in advancing water governance practices. The GOVAQUA project, with its overarching objective of fostering sustainable and equitable water use, has meticulously explored and assessed a wide array of digital tools aimed at enhancing information sharing and know-how in water governance.

Through systematic mapping and collaboration with other thematic WPs (2-4), an extensive inventory of over 200 digital tools has been compiled, covering various aspects of water governance across different regions and sectors. This inventory serves as a valuable resource for identifying both challenges and opportunities in the realm of digital solutions for water governance. Constructing this inventory highlighted the lack of information sharing relating to financial and economic aspects of water governance. This is partly mostly due to the fragmentation of water across the public and the private domain.

The development of a digital solution assessment framework and tool has enabled the systematic evaluation of these digital tools, highlighting their strengths, weaknesses, and overall suitability for supporting sustainable water governance practices. This digital assessment framework provided vital information to address digital solutions in the assessment framework developped as part of WP1. Challenges such as data openness, accessibility, and quality have been identified, highlighting the need for further innovation and collaboration in this domain.

Despite these challenges, significant opportunities emerge for leveraging digital solutions to drive transformative change in water governance. Stakeholder participation can be enhanced, open data initiatives can be promoted, and transparency can be improved through the effective utilization of digital tools. Moreover, the simplicity and accessibility of these tools hold promise for promoting their widespread adoption and use.

Moving forward, it is necessary to consider these opportunities and address the identified challenges to realize the full potential of digital solutions to support information sharing and thus in advancing water governance objectives. Based on the identified case studies, a set of good practices will be identified, reported and assessed within Living Labs (WP6) to demonstrate the potential for data and digital solutions to underpin new governance models.

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Appendices

Appendix 1: Guidelines to prepare the inventory of digital solutions

1. **What are we expecting?**

   Aim: Initial Task identified as part of Task 5.1 and 5.2 is to create an ***Inventory (long list) of digital solutions (web-based platforms, software, models, databases and data catalogues) supporting water governance*** WP5_use_case_examples (V1).xlsx .

   - Ensure the inventory includes the tools you are aware of.
   - Search for the digital tools available in your own language, translate and amend the inventory of digital solutions.
     - Similar approach used to search in English, with improvements where possible.

     The aim is to cover all languages available in the consortium. Depending on your expertise, you can also undertake a search focussed on one of the following themes: 'Legal and regulatory aspects' (WP2), 'Enhancing participation' (WP3), 'Economics and Financing' (WP4).

   - Keep a record of both the 'DigitalSolutionsInventory' and 'Queries' used.
   - Queries outputs to be returned by all partners by End of June.

2. **Description of the WP5_use_case_examples (V1).xlsx document**

   This document comprises two worksheets: Queries and DigitalSolutionsInventory, for recording the searches and the outputs of the searches, respectively.
   The columns are self-explanatory.

   - The 'DigitalSolutionsInventory' worksheet contains the following fields: 'Use case', 'Type', 'Link', 'Short description', 'Finance', 'Legislation', 'Participation' and 'Comments'
     - Use case: Name of the digital tool (eg. OECD Water Governance Self-assessment Tool).
     - Type: Type of the tool, includes webtool, dataset and model.
     - Link: Weblinks to access the digital tool.
     - Short description: Brief description of the use case including the parameters supporting water governance and its spatial resolution.
     - Finance, Legislation, Participation: set to yes or no accordingly.
     - Comments: Brief comment about the tool regarding their support to the work packages.
   - The 'Queries' worksheet have 'Searches' column to provide the used search engines, 'Keywords' to mention the combinations of keywords used to do the searches and the 'Tools' column to fill the digital tools found in each of the searches.

3. **Brief description of searches undertaken in English**
   - Searches for the tools were made using different combinations of keywords which is given in the 'Queries' worksheet.
   - 'Short description' column of the 'DigitalSolutionsInventory' worksheet has been filled based on the information available in the 'About' page of the websites of each tool.

- Comments' column of the 'DigitalSolutionsInventory' worksheet has been filled by exploring each website for the type of data/model, whether it is open access, whether it is downloadable, whether it needs a registration etc.

4. Supporting instructions to undertake the searches

- Please feel free to use any search engines - Google, Scopus, Google scholar etc. Scopus search guide is available at schema.elsevier.com/dtds/document/bkapi/search/SCOPUSSearchTips.htm
  Note that as we are looking for the actual tools academic papers may not be the most relevant outputs
- Use operators, braces ({}), double quotations or wildcards to produce more relevant results. Few examples are shown below:
  - water AND governance AND map: Finds the results that contains all of the terms water, governance, map.
  - water AND governance AND map OR tool: Finds the results that contains the terms water, governance, and either map or tool
  - "water governance" AND map: Finds the results for the terms water and governance together and for the term map.
  - water AND govern* : Finds the results that contains the term water and all words beginning with "govern", such search will include words such as governance and governing.

Appendix 2: Keywords used to do the searches in English and the tools obtained from the searches

Searches	Keywords	Tools
		STEER Diagnostic Water Governance Tool
Scopus	"water governance" AND online tool	CASTWATER online Tool
		The OECD Water Governance Indicator Framework
Google	water AND governance AND "digital tool"	WaPOR
		SSWM Toolbox
Google	sustainable AND water AND management AND tool	WEAP
Google	water AND governance AND map OR tool	GWP map
Google	water AND "interactive maps" AND Europe	European Water Framework Directive (WFD) Database
		Global Surface Water Explorer
		Water360
		Global Groundwater Information System (GGIS)
		GWP map
		European Water Framework Directive (WFD) Database
Google	water AND "interactive maps" AND global	Global Surface Water Explorer tool
		Integrated Water Resources Management (IWRM) ToolBox
		Dynamic Water Resources Assessment Tool (DWAT)
Google	"Water resource management" AND sustainability AND tools	Cap-Net
		Aqueduct
Google	"Water resources data" AND "global map"	Global Surface Water Explorer
		environment.data.gov.uk
Google	"catchment management" AND water AND UK AND tools	CABA data hub and data package
Google	water AND "digital solution" AND Europe	digital-water.city
Google	map AND discharge AND UK	Thames Water EDM map
		HydroSHEDS database
		Global Hydrological Model
		Global Runoff Data Centre (GRDC)
Google	hydrology AND database AND global	PCR-GLOBWB
Google	"water resource" AND model AND global	WaterGAP Global Hydrology Model
Google	water AND "information system"	Water Information System for Europe (WISE)
Google	water AND global AND IT	GWI WaterData
Google	"water equity" AND tools	Water & Equity Mapping Tools
Google		Water Resources Charging Mapping Tool
Google	"water availability" AND tools	Water Availability Tool for Environmental Resources (WATER-KY)
Google	"water governance" AND "citizen science" AND tools	CABA data hub and data package
		CABA data hub and data package
Google	"water governance" AND participation AND tools	STEER Diagnostic Water Governance Tool

Appendix 3: Guidelines for the assessment of inventory of digital solutions

1. Introduction / Purpose of this document

The main aim of Work Package (WP) 5, titled "Digital Solutions for Information Sharing," is to develop new and effective digital tools for sharing information in water governance. This involves examining various digital solutions used at different levels to understand how they can be applied to important information such as environmental observations, financial data, and legal requirements to support sustainable water governance. The focus is also on demonstrating how these digital tools and accessible data can bring together different people involved in water governance to address problems collaboratively. The initial step in this process involved creating an inventory of digital solutions, including 220 case studies, that assist in water governance. To refine this inventory, an initial set of assessment criteria was developed by reviewing existing frameworks and related documents, and the evaluation results were documented in Milestone Report 15.

Moving on to the next steps, Tasks 5.1 and 5.2 involve creating a shortlist of use cases from the initial tool list using the selected assessment categories. A scoring system, based on the framework developed in Milestone Report 15, has been designed using scores and weights. Scores were initially assigned to each assessment category, followed by assigning weights on a 1-5 scale for Task 5.1 and 5.2 based on their relevance to each task. Initial threshold scores and weights were set for this exercise, and detailed information is available in the Assessment Criteria.xlsx file.

Due to the volume of Digital Tools included in the original inventory, an initial shortlisting will be required as it is not possible to assess all tools in the list. This selection will prioritize 5 to 10 commonly used and pertinent water governance tools, such as those supporting financial aspects, citizen science, E-flows, and varying spatial scales (global, regional, etc.). Relevant digital tools will be assessed using this system and a further short listing will be produced as a result of the assessment process.

Assessment outputs to be returned by all partners by 1st of March.

2. Description of the Assessment Tool for the purposes of Task5.1 and 5.2:

The design of the assessment framework was based on the outcomes of Milestone Report 15.

A system of scores and weight was derived and captured in and Excel Work Book Assessment tool. Score is the qualitative assessment of each individual criteria. The scoring is fixed regardless of the purpose of the assessment. Within the context of this exercise the score remains unchanged across Task 5.1 and Task 5.2. Weight is to rate importance/relevance of each criteria as part of the assessment framework. Depending on the purpose of the assessment the weight will vary. Weighting for Task5.1 and Task5.2 are examples of how the framework may be used for specific purpose.

Assessment tool consists of four worksheets: Instruction, User input, Assessment results Task 5.1, and Assessment results Task 5.2, respectively.

- 'Instruction' worksheet is just for information and doesn't need any user input. The threshold scores and weights are available in this worksheet, which includes the following fields: 'Assessment Category,' 'Sub-criteria,' 'Scores,' 'Weight for Task 5.1,' 'Weight for Task 5.2,' and 'Supporting instructions/Comments if any.'

- Assessment Category: The four main assessment categories identified from the literature review.
- Sub criteria: Sub criterias identified within each main categories
- Score: Threshold scores identified for each sub-criteria
- Weight for Task 5.1: Weight identified for each sub-criteria based on its relevance to Task 5.1
- Weight for Task 5.2: Weight identified for each sub-criteria based on tis relevance to Task 5.2
- Supporting instructions/Comments if any: Notes to support or assist the assessment process.

- The 'User input' worksheet which requires user input and is for filling in the scores identified for each tool.
    - Change the column names with the names of the tools identified, and hyperlink with the webpage.
    - The 'Assessment results Task 5.1' worksheet automatically fills with the weights identified for Task 5.1 assessment criteria for each tool. No user input required.
    - Column names automatically change with the names of the tools as changes are made in the 'Scores' worksheet.
    - The final row (Row 25) calculates the total score based on the filled-in scores and weight for each tool.

- The 'Assessment results Task 5.2' is similar to 'Assessment results Task 5.1,' but assesses the relevance of the tool for Task 5.2. No user input required.

2.1 Initial selection of digital tools from the inventory (longlist):

Due to time and budget constraints specific to each partner and initial subset of digital tools must be made from the inventory.

To ensure that this selection reflects the multifaceted aspects of the GOVAQUA project, each partner involved in the work package will undertake the selection of 5-10 tools. They will then process these selected cases through the assessment tool.

During the selection process, it is important to ensure that the tools selected cover a variety of spatial scales (eg. basin/regional, national, European), use a range of data display techniques (eg. tabular format, graphics, storylines, videos, …) and exhibit differences in web page content (eg. water quality, floods, e-flows, water related financial tools, …)

As an example, UKCEH tested the tool on a selection of tools relevant to Thames water:

- WyeViz

and some pertinent tools for citizen science in the UK:

- CitSci