WP1 - Policy, Stakeholder and Service Analysis

D1.4 Report with end-user needs and requirements

Project Identification	
Project Full Title	Water scenarios for Copernicus Exploitation
Project Acronym	Water-ForCE
Grant Agreement	101004186
Starting date	01.01.2021
Duration	36 months

Document Identification	
Deliverable number	D1.4
Deliverable Title	Report with end-user needs and requirements
Type of Deliverable	Report
Dissemination Level	Public (PU)
Work Package	WP1
Leading Partner	ICCS

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History of Changes

Date	Version	Comments
09.11.2021	V0.1	Initial ToC
06.12.2021	V1.0	First version
20.12.2021	V1.1	Synthesis and refinement of user needs
14.01.2022	V1.2	Integration of new feedback
19.01.2022	V1.3	Comments solving and reviewing
02.02.2022	V1.4	Comments solving and reviewing stage 2
08.02.2022	V1.5	Further additions and reviewing
15.02.2022	V1.6	Consolidated version
10.04.2023	V1.7	Consolidation of the review suggestions: Updated Chapter 4 and Table 5 to include the TRL – maturity level

List of Acronyms

AGRI	Directorate-General Agriculture and Rural Development
C3S	Copernicus Climate Change Service
CAP	Common Agricultural Policy
CLMS	Copernicus Land Monitoring Service
DEFIS	Directorate-General Defence Industry and Space
EARSC	European Association of Remote Sensing Companies
EEA	European Environment Agency
EMSA	European Maritime Safety Agency
ENVI	Directorate-General Environment
EO	Earth Observation
ESA	European Space Agency

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EU	European Union
JRC	Joint Research Centre
MARE	Directorate-General Maritime Affairs and Fisheries
OECD	Organisation for Economic Co-operation and Development
SDG	Sustainable Development Goal
PwC	PricewaterhouseCooper
RTD	Directorate-General Research and Innovation
TEU	Treaty on the European Union
TFEU	Treaty on the Functioning of the European Union
UN	United Nations
Water-ForCE	Water scenarios for Copernicus Exploitation
WP	Work Package

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1 Introduction

1.1 Project & work package introduction

The **Horizon 2020** project **Water-ForCE** (Water scenarios for Copernicus Exploitation) is developing a Roadmap to better integrate the entire water cycle within the **Copernicus services**, thereby addressing needs and requirements from the user community, the current disconnection between remote sensing / in-situ observations and upgrade of the modelling algorithms. The clarity in terms of the needs and expectations of both public and private sectors from the core Copernicus Program and the wider research and business innovation opportunities will be delivered. The Roadmap will then also advise on a strategy to ensure effective uptake of water-related services by end-users and further support the implementation of relevant directives and policies.

The Water-ForCE consortium is led by the University of Tartu (Estonia) and consists of 20 organizations from all over Europe. It will bring together experts on water quality and quantity, in policy, research, engineering, and service sectors. Through close collaborations with these communities, Water-ForCE will among others:

- **Analyze EU and international policies** to identify where the Copernicus services can improve monitoring programs and how the Copernicus data can be more effectively used in developing and delivering the next versions of EU legislations.
- **Specify the technical requirements** for future Copernicus missions in order to make them more suitable for inland and coastal water remote sensing (e.g. adding new spectral bands on Sentinel-2E and onward, improved spatial resolution, hyperspectral sensors).
- **Optimize future exploitation** of Copernicus Services for inland water monitoring, management, legislation implementation, service provision and research & development through enlarged service portfolio and optimized delivery of water related products and services.

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The project is divided into eight work packages (WP), each of them focusing on a specific problem and/or target of the Copernicus service (see Figure 1). The project started 1 January 2021 with a duration of three years.

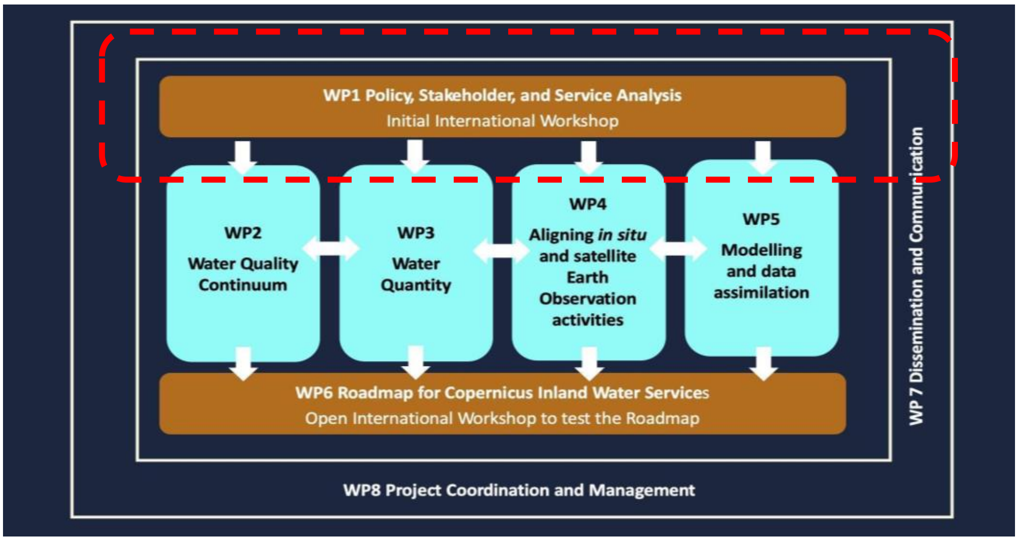

Figure 1 - Organizational structure of the different work packages in the Water-ForCE project

This report delivers the result of Task 1.4 (T1.4): End-user needs and requirements identification (Deliverable 1.4 - **D1.4**). This report is strongly related and complements the objectives and scope of the deliverables: **D1.5** Business opportunities & **D1.6** Satellite EO, SDGs and climate indicators.

1.2 WP1 overall aim and expected impact

The overall aim of WP1 is to identify key users within the different public domains and business sectors and evaluate whether operational services can meet policy goals. The expected impact is increased coverage of EU policies clearly identifying which and how the project would like to address them.

WP1 has six tasks and two milestones, as shown in the table below. The tasks and milestones are closely linked and together provide input to WPs 2-6.

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Table 1: overview of WP1 tasks and deliverables

Task	Deliverable
T1.1 Value chain and stakeholder identification	D1.1 List of stakeholders (M7)
T1.2 Public domain and business sector identification	D1.2 Report with assessment of domain-specific and sectoral policies and legislation (M10)
T1.3 Links between mission-service-application	D1.3 Report with analysis of links within Copernicus programme and between Copernicus programme and domain / sector policies (M14)
T1.4 End-user needs and requirements identification	**D1.4 Report with end-user needs and requirements (M14)**
T1.5 Innovation need and opportunities	D1.5 Report with analysis of business opportunities, validated by industry (M14)
T1.6 Contribution towards societal challenges, missions and SDGs	D1.6 Report on links and gaps between satellite EO and water related SDGs and climate indicators (M14)
MS1	WP1 Participants workshop (M4)
MS2	Input to the Roadmap (WP6)

This report is the deliverable for Task 1.4.

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1.3 Objectives T1.4

The report aims to provide an overview of needs and requirements of different users in the inland and coastal water domain, as emerged from stakeholders' and end users' engagement processes. Activities under this task build on the analysis of the value chain and of relevant stakeholders (taking place within T1.1) as well as on identification of relevant policies and strategies affecting public domains and business sectors relevant to the inland water cycle (T1.2). The outcomes of the "Workshop WP1 - Stakeholder Input on the Evolution of Copernicus Water Services" are also taken into account for the formulation of the D1.4 deliverable.

1.4 Terminology

In this chapter the terminology used in the report is presented to facilitate the reading.

- **Focus groups**: Users are grouped based on their "active sector" categorization or main thematic area of interest. The following chapter describes the logic with which the different focus groups were created.
- **User story:** A user story is a representation of a user need or requirement written in one or two sentences using the user's common language. The user stories typically follow a simple template:

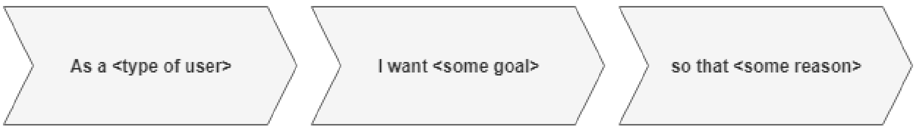

Figure 2 - User stories' steps

A User story is a short description of what the user will do when they use a specific software/tool/service.

These are examples of user stories:

- As a traveler I want to check in for a flight, so I can fly to my destination.
- As a business owner, I want to create an invoice so that I can bill a customer.

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Within the scope of this deliverable and taking into account the goal of the project a user story describes how the user exploits or wish to use earth observation data for inland water quality/quantity processes.

- **End user:** This deliverable follows the terminology of "end users" as expressed in PwC, Copernicus market report, Issue 2, 2019 [9] & Main Trends & Challenges in the Space. Sector (2nd Edition) by PwC [7]. More specifically, an end user can be part of the wider base of businesses, institutional players, consumers, industries, governments, nonprofit organizations for which EO-derived products are an input, but whose core activity is not centered on EO and require ready to use data and products from Copernicus. End users can be non-experts in EO, and therefore typically rely on intermediate users to have access to the relevant input information and products for their activity.
- **User needs and requirements:** User needs and requirements describe any function, constraint, specification, observation, wish list, service or other property that must be provided to satisfy the current and future user needs. They can also relate to potential existing gaps between users' aims and their current situation, which is reflected by user difficulties and opportunities, as well as the context of use, which comprises the intended users' attributes, current tasks, and environment. [1] User requirements are created from the perspective of the user. Any function, constraint, or other property that must be given to meet the user's needs is referred to as a user need. [2]

[1] Kujala, Sari et al. "Bridging the Gap between User Needs and User Requirements." (2001).

[2] Abbott, R. J. An Integrated Approach to Software Development. Wiley, New York, 1986.

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1.5 Method

By analyzing the deliverables D1.1 "List of stakeholders", D1.2 "Public domain and business sector identification" as well as the outcomes of the WP1 workshop a co-design methodology has been selected in order to ensure that the users are actively participating in the definition of the user needs and requirements. Furthermore, the outcomes and workshops' results from the activities carried out in D2.2 "Review document, gap analysis and recommendations on Copernicus products related to water quality" and D3.1 "An international working group with water quantity remote sensing specialists and water resources experts" were also taken into account.

The users and stakeholders were grouped into 8 different focus groups/personas according to their active sector and application domain, which are stored in the Customer relationship management (CRM) platform (HubSpot) and also described in Figure 3 of the current deliverable and Figure 3b of D1.1. The aim was to co-develop application-related user stories [3] for all the respective domains. For each application, a structured focus group was created by inviting stakeholders and end-users with different levels of EO expertise, involvement in different aquatic systems as well as different role (e.g. Advisor, Researched, Regulator, etc.). The detailed archiving of the stakeholders in the HubSpot facilitated the proper classification and grouping of the stakeholders. The following steps were carried out:

1) Enumeration of **user heterogeneity** and **formulation of the focus groups** based on their "active sector" categorization. 9 different groups correlated to inland water quality/quantity applications were created;
2) **Analysis and extraction of user needs** from the work and workshops realized in WP1 (MS1), WP2 (MS3), WP3 (MS5) and WP4 (MS7).

[3] *A user story is a representation of a requirement written in one or two sentences using the user's common language. E.g. As a traveler I want to check in for a flight, so I can fly to my destination.*

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3) **User consultations** through co-design & structured group interviews with end users from two mayor EuroGEO [4] communities, e-shape [5] and EIFFEL [6] in order to structure **specific user stories** for the thematic areas/applications.
4) Dissemination of a **structured questionnaire** to end-users and stakeholders, which allowed the collection of additional feedback with respect to their needs and requirements. A gap analysis to the D1.1 was performed in order to identify users and stakeholders, where more info was required;
5) **Desk study and analysis of published reports & market research**: the following sources were considered as the primary source of information and were analyzed for the formulation of this deliverable:
    a. Main Trends & Challenges in the Space Sector – 2nd Edition, 2020, PwC [7];
    b. Earth Observations in Support of Global Water Quality, International Ocean Colour Coordinating Group (IOCCG) [8];
    c. PwC, Copernicus market report, Issue 2, 2019 [9];
    d. COMMISSION STAFF WORKING DOCUMENT: Expression of User Needs for the Copernicus Programme, 2021 [10];

[4] https://ec.europa.eu/info/research-and-innovation/knowledge-publications-tools-and-data/knowledge-centres-and-data-portals/eurogeo/about-eurogeo_en

[5] https://e-shape.eu/

[6] https://www.eiffel4climate.eu/

[7] https://www.pwc.fr/fr/assets/files/pdf/2020/12/en-france-pwc-main-trends-and-challenges-in-the-space-sector.pdf

[8] https://repository.oceanbestpractices.org/handle/11329/535

[9] https://www.copernicus.eu/sites/default/files/201902/PwC_Copernicus_Market_Report_2019_PDF_version.pdf

[10] https://knowledge4policy.ec.europa.eu/publication/commission-staff-working-document-expression-user-needs-copernicus-programme_en

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e. SeBS - "Showcasing the benefits brought by the usage of Sentinels data to society, environment and economy" reports[11].

f. DANISH USES OF COPERNICUS [12]

g. Analysis of repositories of user stories related to the identified applications domains from eurisy [13], nereus [14] and eo4geo surveys [15].

h. Analysis and extraction of user requirements and needs related to inland water quality/quantity from NextSpace EC Study [16, 17].

6) Finalization and synthesis of the user needs and requirements by combining the questionnaire results, the user stories, the online focus groups and the desk research.

[11] https://earsc.org/sebs/

[12] https://www.copernicus.eu/sites/default/files/2021-01/Copernicus_ENG_digital.pdf

[13] https://www.eurisy.eu/stories/

[14] http://www.nereus-regions.eu/copernicus4regions/publication/

[15] http://www.eo4geo.eu/surveys/

[16] https://www.copernicus.eu/sites/default/files/2020-01/Nextspace_database_for_observation_requirements.xlsx

[17] https://www.copernicus.eu/sites/default/files/202001/Nextspace_database_for_user_requirements.xlsx

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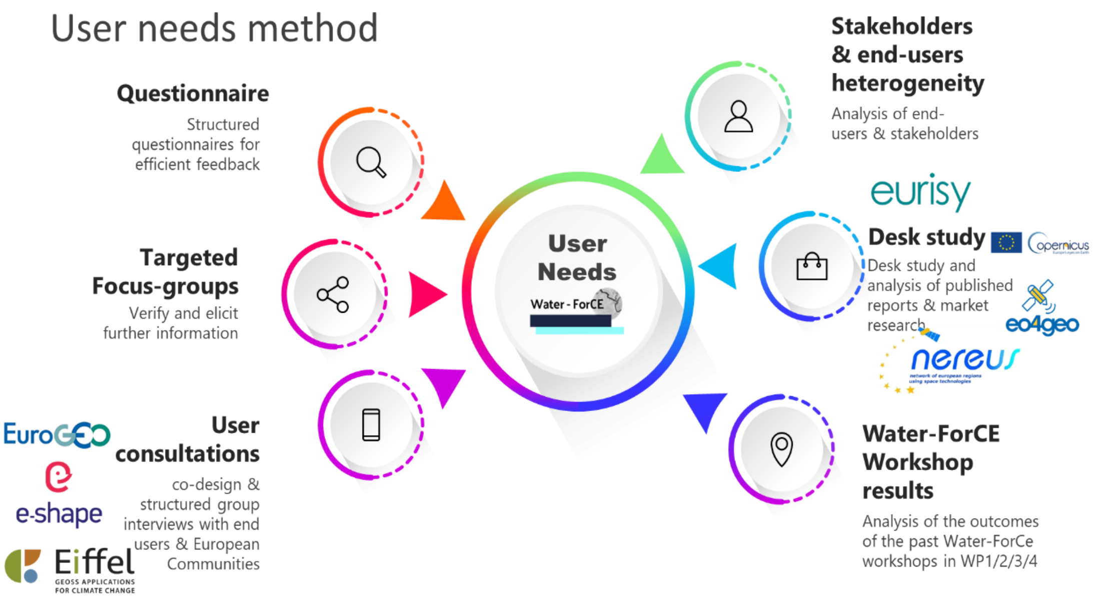

Figure 3 - Formulation of the user needs and requirements based on multiple input.

As described above, the consortium reached two major EuroGEO communities: e-shape and EIFFEL, as well as DIONE project network and performed co-design & structured group interviews in order to structure specific user stories for the thematic areas/applications. The user stories were then analyzed and user needs and requirements were extracted from the descriptive scenarios. The involvement of these communities, representing needs of more than 100 relevant end users, was facilitated through the involvement of ICCS, which is also leading the EIFFEL project and also participating to the GEOSS Infrastructure Development Task Team (GIDTT) [18].

[18] https://ec.europa.eu/jrc/communities/en/community/eovalue/page/geoss-infrastructure-development-task-team-gidtt-and-european-role

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Table 2: User consultations for the creation of user stories and extraction of user needs & requirements

Community/User group	**Key End Users**	**User consultation date**
Water-ForCE WP3&5 workshop for use of Remote Sensing for monitoring and modelling the water cycle	> 30 participants from various organizations such as: ● CLS ● CREAF ● ICRA ● IRTA ● Romanian Waters ● UNESCO-IHP ● IIASA ● IHE-Delft ● SAVBA ● EGR ● ICRA ● FORIM ● STUBA ● CLS ● University of Natural Resources & Life Sciences, Vienna (BOKU) - Institute for Hydrology and Water Management (HyWa) ● TerraSigna	● 15/03/2021 (online)

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Community/User group	Key End Users	User consultation date
Water-ForCE Workshop WP1- Stakeholder Input	> 60 participants from various organizations such as [19]: ● Confederación Hidrográfica del Ebro ● FAO of the UN ● Water Directorate, Ministry for the Ecological Transition and the Demographic Challenge, Spain ● Ministry of the Environment of Estonia ● Middle East Technical University Institute of Marine Sciences ● Scottish Water ● GMV	● 20/04/2021 (online)
Water-ForCE WP2&4 Expert Workshop	Around 50 participants on each of the 3 days from various organizations such as: ● NETLAKE ● SAFER ● Cary Institute ● LTER ● GEO AQUAWATCH ● DLR-CCVS ● NIGLAS	● 17/05/2021, 18/05/2021, 20/05/2021 (online)

[19] *Full list of participants is described in deliverables D1.1 & D1.2*

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Community/User group	Key End Users	User consultation date
	• CSIRO • DLR • University of Twente, ITC	
e-shape	• SMHI operational water resources analysis and forecasting services with key stakeholders • Swedish Agency for Marine and Water Management (SWAM) • Swedish Geological Survey (SGU) • Global Flood Partnership • Policy makers for Green Funds	• 07/12/2021 (online) • 10/12/2021 (online)
Eiffel GEOSS APPLICATIONS FOR CLIMATE CHANGE	• Noord-Brabant Province, Netherlands • National Paying Agency, Lithuania • Port Authority of the Balearic Islands (BPA) • Region of Attica, Greece • Finnish Environment Institute - SYKE	• 11/11/2021 with Port Authority of the Balearic Islands (online) • 16/11/2021 with Finnish Environment Institute - SYKE (online)

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Community/User group	Key End Users	User consultation date
		• 18/11/2021 with Noord-Brabant Province, Netherlands and National Paying Agency, Lithuania (online) • 19/11/2021 with Region of Attica, Greece (online)
DIONE	• National Paying Agency of Cyprus • Agricultural Ministry Officials	• 14/01/2022 (online)
Complementary users	• DRAXIS (Private Company) • Romanian Waters National Administration - Mures River Basin Administration • Dept. of Industry, Energy and Natural Resources of the Prefecture of Attica, Greece • Environment Agency Austria	• 4/1/2022 (online) • 11-12/01/2022 (online)

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Community/User group	Key End Users	User consultation date
	• United States Environmental Protection Agency • Rijkswaterstaat, Directorate-General for Public Works and Water Management, Netherlands • Ministerio de Transportes, Movilidad y Agenda Urbana, Spain • Confederación Hidrográfica del Ebro, Spain • Vewin national association of water companies in the Netherlands	

The co-design workshops were realized in the form of brainstorming discussions & structured interviews. User-stories were created in parallel either along the discussion or were sent at a later stage through a filled form. Acknowledging the fact that the end users may not have technical skills and familiarity with Earth Observation data/services/algorithms, a simple descriptive template was chosen to structure the user stories. The template, which was used follows below:

Table 3: Random example of a user story

As a / an	I want to ...	So that ...
Water manager Regional Authority & Municipality	Monitor extreme flood events	Identify water retention in flooding periods and use in drought
	Monitor water drought	To define new plans of actions

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As a / an	I want to ...	So that ...
Land user (farmer)	Monitor water droughts by (agricultural) use	To work with land owners / farmers
	Measure soil carbon sequestration from water change view	To have a more integrated view of the water and soil carbon effect
	To be able to have better flood forecasts	To get a better idea of extreme events on the overall and measures system (real time)

A full presentation of the user stories can be found in Annex 1: User Stories. The analysis of the users' input can be found in the following section.

2 Analysis of Focus Groups' & Users' Needs and Requirements

The users were analyzed according to their active sectors and thematic areas of interest. From this analysis, 9 different focus groups were created, consisting of people with similar goals, motivations and behaviors, but in parallel with different roles in order to achieve a higher heterogeneity. The defined focus groups are also in line with the identified public domains/business sectors presented in D1.2 and are covering a great spectrum of applications exploiting inland water quality/quantity services and products.

A brief presentation of the applications and focus groups' characteristics is presented below.

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Table 4: Thematic/application-based personas

#	Focus Group /Application	Short Information
1	**Drinking water management**  	Access to clean drinking water is a major concern and will have high priority in the future. Sewage discharge and inland navigation are putting more strain on rivers. Lakes, reservoirs, and rivers must be assessed and reported on by government agencies and the water business. Such large-scale project necessitates frequent spatial mapping and cannot be accomplished just through on-site water monitoring. In that case the synergetic use of satellite earth observation data is of paramount importance to assist on the proper drinking water management.
2	**Aquaculture/fisheries** 	Aquaculture (e.g. fish, oysters, seaweed) has a direct effect on the water environment. Remote sensing is used for location planning in order to minimize their impact and monitor how much they pollute. For example, increased testing of aquaculture stocks can reduce the levels of toxins in food destined for human

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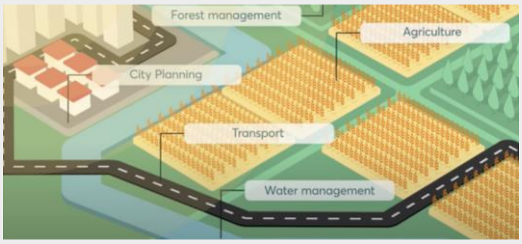
		consumption. Jellyfish blooms can also be monitored through ocean analysis, which can affect tourism in coastal environments, and have implications for healthcare provision.
3	**Agriculture** 	Monitoring the inland and coastal water quality/quantity is enabling water savings through better irrigation management in agriculture.
4	**Urban water management** 	Inland water monitoring services can assist water managers, which work in subjects like water allocation, flood management, hydropower generation and management of the industrial water use. Such services and products can assist on the better formulation of strategies to mitigate the effects of climate change.

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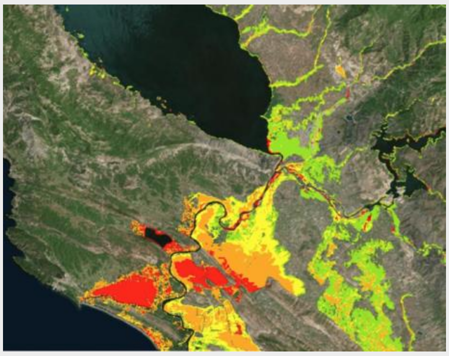
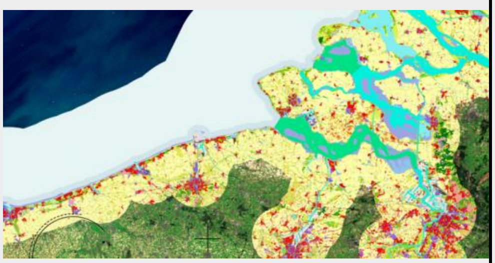
5	**River basin management** 	River Basin Management includes all aspects of Hydrology, Ecology, Environmental Management, Flood Plains and Wetlands. Riverine systems are coming under increasing pressure due to anthropological and natural causes. Prominent amongst the problems affecting them is water quantity and quality, which requires the development of improved methods for better river management.
6	**Hazards/Emergencies** 	Provision of high quality information and services can assist on the better preparation of the national emergency activities. Better monitoring and emergency response activities (e.g. for oil spills, accidents, pollution, etc.) as well as more efficient decision-making tools can benefit from earth observation data.
7	**Coastal zone management** 	Coastal area monitoring includes a broad range of interlinked challenges between urban and land areas and marine basins. Indeed, natural marine and environmental factors such as waves, winds, tides, storms, currents,

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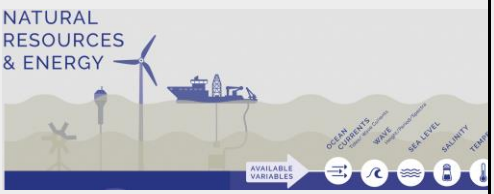
		etc. have an impact on coastal land areas. In addition, human factors such as coastal urbanisation and economic activities are also included in the list of drivers contributing to subsidence and coastal erosion.
8	**Biodiversity** 	Water bodies such as lakes, lagoons and reservoirs provide a range of ecosystem services including fresh drinking water, recreation, transport and fishing. In order for these activities to be carried out safely – and without disrupting the biodiversity of local ecosystems – these water bodies need to be regularly monitored and preserved.
9	**Energy** 	Satellite data and services can support applications such as solar and wind energy production forecasting, renewable energy site selection, biomass monitoring or water level monitoring ensuring efficient exploitation of renewable energies.

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3 User needs and requirements analysis

3.1 Drinking water management

State of play

In the European Union, drinking water accounts for roughly 18% of total fresh water abstractions. Water is a vital environmental, social, and economic sector since it is processed and delivered by about 70,000 utilities. Safe drinking water is a prerequisite for protecting public health and all human activity and unfortunately at least 1.8 billion people [20] globally use a source of drinking water that is contaminated. However, water industry groups, suppliers, and municipalities are facing new challenges in terms of **drinking water quality** control as a result of **climate change** and **agricultural** expansion.

Drinking water quality assurance has been one of the most difficult responsibilities for water management organizations in recent years. The intensification of agriculture, in particular, has an impact on the water quality of both **ground** and **surface** water. Better fertilization frequently accompanies increased agricultural efficiency, resulting in **nutrient leaching and a higher nitrate concentration in groundwater**. Furthermore, the number of extreme weather occurrences, such as regional torrential rains or long-term droughts, has increased and worsened the problem as a result of climate change.

As a result, water management organizations must deal with contaminant inputs into ground and surface water more frequently. Improved water monitoring programs, as well as initiatives to prevent drinking water pollution, are critical for ecologically friendly water resource management.

Applications/Products examples:

- Adjustment of the treatment processes at water plant level;
- Improve drinking water quality in water utilities;

[20] https://www.unoosa.org/res/oosadoc/data/documents/2018/stspace/stspace71_0_html/st_space_71E.pdf

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- Trace elements in groundwater and its impact on drinking water;
- Optimization of the use of resources;
- Quality assessment of raw drinking water;
- Alignment with the Drinking Water Directive.

Satellite missions:

- Sentinel 2
- Sentinel 3
- MODIS
- PROBA-V
- Landsat-8

End Users Examples:

- Suppliers of drinking water
- Water supply and sewerage companies
- Water resources companies
- Water associations
- Water treatment plants and reservoirs
- Research and academic institutions

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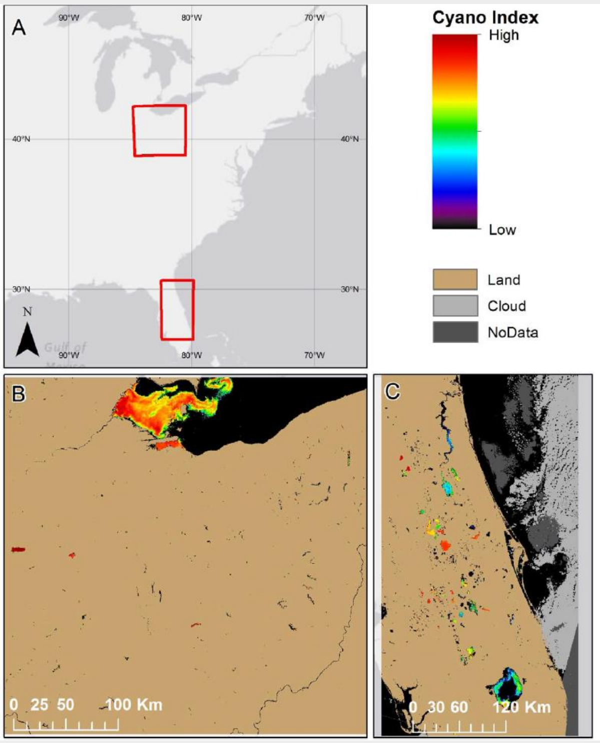

Figure 4 - Cyanobacterial harmful algal blooms abundances in drinking water sources in Florida and Ohio [21]

Policy context

The main policy drivers in European level for the drinking water quantity and quality are the followings:

- The EU **Water Framework Directive** provides protection of aquatic ecology, drinking water resources, and bathing water across EU member states.

- The **Drinking Water Directive** concerns the quality of water intended for human consumption. Its objective is to protect human health from adverse effects of any

[21] https://www.sciencedirect.com/science/article/pii/S1470160X17302194

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contamination of water intended for human consumption by ensuring that it is wholesome and clean.

Emerging needs/requirements related to drinking water management

- Cyanobacterial harmful algal blooms;
- Frequency of algal bloom occurrence;
- Dissolved organic carbon (DOC) and Colored dissolved organic matter (CDOM) concentrations;
- Water temperature changes;
- Turbidity changes;
- Nitrate concentration;
- Phosphorus concentration;
- Organic matter concentrations;
- Chlorophyll concentrations;
- water level changes.

3.2 Aquaculture/fisheries

State of play

Seafood has an important role in the human diet, both in Europe and around the world, as a rich and healthful source of protein. Approximately 20% of the world's population gets at least 20% of their animal protein from fish. As the population grows, more fish will be required, putting more strain on fisheries productivity. Because sea-based fishing of many species has already exceeded sustainable levels, the only way to meet this demand is to expand aquaculture. Effective and long-term management of aquaculture sites, on the other hand, is difficult and necessitates constant monitoring of local circumstances. This is not only to detect any possible threats to fish stocks, but also to guarantee that production practices do not degrade ecosystems or harm public health by leaking waste products, foods, chemicals, or parasites, for example.

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A wide range of satellite-based products and services can help with aquaculture practice planning and management. These include **identifying and tracking potential aquaculture site dangers such as changes in sea-surface temperature and ocean color, algal blooms, jellyfish invasions, and the intrusion of water masses with differing temperatures or oxygen concentrations**. Changes in sea grass beds, coral reefs, mangrove forests, erosion, and deposition on intertidal mud flats can all be detected using satellite data in the proximity of aquaculture operations. The collection of statistical data on local conditions can aid in the optimal **selection of new aquaculture sites**. Simultaneously, local models can aid in the **prediction of disease and other contaminants spread from aquaculture facilities**. When a region is threatened by algal blooms or other dangerous events, this helps optimize cage relocation.

Copernicus satellite-derived data and services are assisting the marine aquaculture sector in unlocking its growth potential in a sustainable way. Copernicus maintains a large collection of real-time ocean observations and biogeochemical ocean forecasts to help fisheries, sustainable best practices, fisheries regulation, and fish stock planning activities. Such products are frequently used, and recent statistics on program usage show that consumer demand is increasing rapidly.

Applications/Products examples:

- Bio-geochemistry analysis and forecast for global and regional seas
- Geophysical parameters including sea-surface temperature and ocean currents

Satellite missions:

- All-weather capability of C-band SAR data from Sentinel-1
- High-spatial resolution optical images from Sentinel-2
- Sentinel 3: Images from the Ocean Land Colour Instrument and Sea Land Surface Temperature Radiometer

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End Users Examples:

- Aquafarmers
- Relevant associations
- Public/private control and inspection authorities for food security
- Research and academic institutions

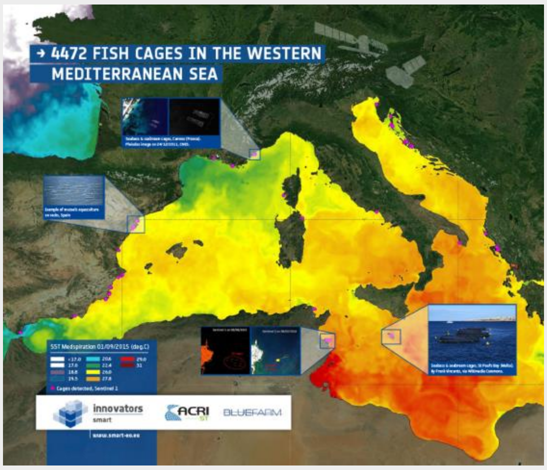

Figure 5 - Images from the Sentinel-1A satellite are being used to monitor aquaculture in the Mediterranean [22]

[22] https://www.esa.int/Applications/Observing_the_Earth/Sentinel-1_counts_fish

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Policy context

The Common Fisheries Policy Regulation (CFP) [23] has defined a set of harmonized provisions [24] to manage the EU fleet and their fishing activities to keep fish stocks at healthy levels, and for conserving fish stocks to ensure the sustainability of fisheries in EU waters and the EU fleet globally.

The EU CFP established fishing quotas per exploited species and regional fishing effort limits to safeguard the sustainability of fisheries and aquaculture in the waters around the continent. Internationally, similar processes are negotiated as well, particularly through Regional Fisheries Management Organizations (RFMOs), of which the EU is a member. In parallel, fisheries control is managed at national level, at sea or when landing, by public authorities and controlled at European level by the European Fisheries Control Agency (EFCA).

To provide proper administration and control of fishing and aquaculture activities, access to accurate and verified data and parameters is critical.

Emerging needs/requirements related to aquaculture/fisheries

- Fish-shoals mapping, benthic algae mapping and bathymetry;
- Aquaculture and fishery structures inventory and monitoring;
- Determine favorable coastal conditions (e.g., planktons, temperature) in order to best plan annual or seasonal fishing activity;

[23] Regulation (EU) No 1380/2013 of the European Parliament and of the Council of 11 December 2013 on the Common Fisheries Policy, amending Council Regulations (EC) No 1954/2003 and (EC) No 1224/2009 and repealing Council Regulations (EC) No 2371/2002 and (EC) No 639/2004 and Council Decision 2004/585/EC, OJ L 354, 28.12.2013, p. 22–61.

[24] European Commission, The new Common Fisheries Policy: Sustainability in depth, Factsheet, 2015, https://ec.europa.eu/fisheries/sites/fisheries/files/docs/body/2015-cfp-management_en.pdf.

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- Monitoring and controlling fishing activity and production at coastal areas, including detecting and deterring unregulated and illegal fishing, mapping and control of aquaculture sites; Information on low-pressure fishing grounds and suitable aquaculture farm sites while staying within protective limits and regulations;
- Monitoring information on coastal water health and conditions influencing stocks and production e.g. harmful algae blooms, plankton-to-fish links, oil, land chemical pollutants, atmospheric inputs of nutrients
- Near-real-time data is required to advise fishers away from active nursery or protected species habitat.
- Time series and forecasts are also useful for planning activities and establishing environmental scenarios for fish stock assessments that are based on modeling.
- Water quality and biogeochemistry variables linked to: pollutants, eutrophication, productivity of oceanic fronts, algae species differentiation with toxicity information, distribution of nutrients and functional types of plankton, plankton biomass, phenology, suspended sediments, as well as environmental parameters such as seabed habitats, river discharges, winds, and waves.

3.3 Agriculture

State of play

Agriculture is a vital part of the world economy, and it is continually evolving as a result of the introduction and development of different techniques, particularly in the face of a changing environment. Agriculture will face a number of serious challenges in the next years, including rising global population, the threat of climate change, and escalating competition for increasingly precious land, water, and energy resources.

Through the existing land use/land change products portfolio, the Copernicus programme serves the agriculture sector, for example, for farm management, smart

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farming, crop dynamics, irrigation, seasonal mapping of yields and cultures, or subsidy controls (both for farmers and for policy aims), food security, etc. With high-resolution layers of information on grassland, wetness, and woody characteristics, Copernicus aids in assessing agricultural land use and trends, crop conditions, and yield estimates. Many products, including but not limited to **fraction of green vegetation cover, vegetation productivity, leaf area index, land dry matter, and climate indicators such as soil moisture, temperature, humidity, and precipitation**, are also recommended for vegetation monitoring.

Applications/Products examples:

- Copernicus Land Monitoring Service (CLMS) Land Cover
- Normalised Difference Vegetation Index (NDVI),
- Leaf Area Index (LAI),
- Fraction of Absorbed Photosynthetically Active Radiation (FAPAR)
- Fraction of Green Vegetation Cover (FCOVER)
- Surface Soil Moisture
- Dry Matter Productivity
- Evapotranspiration and crop water productivity (eg WaPOR FAO Water Productivity)

Satellite missions:

- Open data (Sentinels, Landsat, MODIS, Copernicus contributing missions) for low and medium resolution data
- Sentinel-2
- Sentinel-1 (complementary source)
- Proba-V
- Copernicus contributing missions: SPOT, Rapid eye, Worldview

End Users Examples:

- Farmers

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- Agricultural cooperatives
- Paying Agencies/Public authorities (national, regional)
- Public authorities for food security
- Decision makers
- Research and academic institutions.

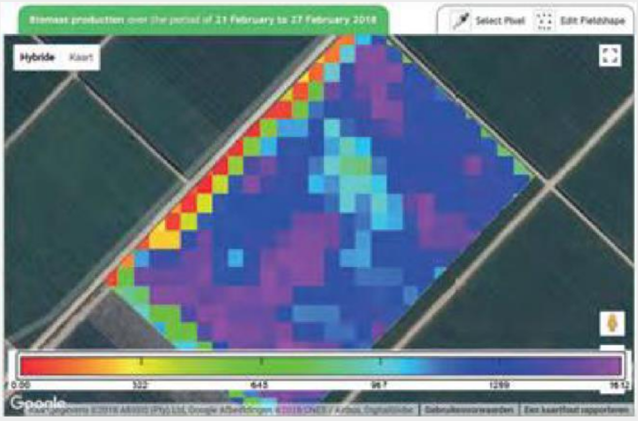

Figure 6 - Variation in crop growth [25]

Policy context

The core policy for the agriculture domain is the Common Agricultural Policy Regulation (CAP) [26], which has as a goal to: a) increase agricultural productivity, b) ensure a fair standard, c) stabilize markets, d) assure the availability of supplies and e) ensure that supplies reach consumers at reasonable prices.

Land use, including agriculture, land cover and crop type maps, land take, crop conditions, soil moisture, high nature value farmland, and landscape fragmentation are all essential

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[25] https://www.copernicus.eu/sites/default/files/2018-10/copernicus4regions.pdf

[26] Regulation (EU) No 1306/2013 of the European Parliament and of the Council of 17 December 2013 on the financing, management and monitoring of the common agricultural policy and repealing Council Regulations (EEC) No 352/78, (EC) No 165/94, (EC) No 2799/98, (EC) No 814/2000, (EC) No 1290/2005 and (EC) No 485/2008, OJ L 347, 20.12.2013, p. 549–607.

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land monitoring factors that COPERNICUS data and services can give in the context of the CAP. Satellite tracking of land parcels is already in use in a number of nations, and it is assisting Paying Agencies by reducing the number of on-the-spot checks required.

Emerging needs/requirements related to agriculture

- Large coverage, at regional or sub-regional scale, and high-spatial resolution appropriate to observe smallest parcels size;
- Water availability and soil moisture should be combined with yield production;
- Evapotranspiration is also needed for irrigation management and planning;
- Optimization of water resources in compliance with the CAP and the WFD;
- Weekly, possibly to daily, products;
- Spatial resolution for 5-10m to 1-2m;
- Water stress is an important parameter;
- Inland water features such as ditches and culverts are needed;
- State of rivulets, streams and small water bodies;
- Monitoring and detection of irrigated areas at regional/national scale;
- Wetness indicators to help identify the level of irrigation needed;
- Identify lack of water, or if there is an increase in algae in the water, which could indicate fertilizer pollution;

3.4 Urban water management

State of play

Surface water, groundwater, potable water, sewage, drainage, stormwater, flood risk, wetlands, streams, and estuaries in urban settings are all examples of urban water management activities. Water quality, storm water management, flood control, environmental health, and related ecosystem issues have all been impacted as a result of the growing population and urbanization. Earth Observation data and geographic

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information systems (GIS) techniques provide products and services, which assist in the resolution of a wide range of water management concerns in metropolitan environments.

In areas with limited networks and where information on hydrologic conditions is unavailable, satellite remote sensing is frequently a vital source of data. Most water cycle components, limited elements of water quality (e.g., **turbidity, chlorophyll and other phytoplankton pigments, dissolved organic content, temperature, and salinity**), and vegetation distributions and health are all retrievable. Some concerns/limitations are observed about data quality, resolution (both temporal and spatial), sampling, legacy, and latency.

In parallel, the quantity and quality of raw water used for producing drinking water is changing due to the ongoing changes in the climate and high levels of pollutants. Examples of water quality parameters relevant to water treatment plants and drinking water are **water temperature, pH, turbidity, ammonium, nitrate, nitrite, phosphorus, organic matter, carbon compounds, COD (chemical oxygen demand), Coli-bacteria, cyanobacteria, algal toxins and chlorophyll**.

Applications/Products examples:

- Design of flood control systems;
- Design of wastewater treatment systems;
- Design of irrigation systems;
- Design of water supply systems;
- Water supply operations;
- Early warning systems for droughts;
- Early warning systems for floods;
- Water-related health (i.e. pollution, water quality);
- Drinking water quality and quantity.

Satellite missions:

- Landsat 8

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- AVHRR
- ASTER
- MODIS
- Sentinel-1
- Sentinel-2

End Users Examples:

- Water resources management offices
- Environmental agencies
- National or local government authorities
- Water companies
- Energy companies
- Institutional/water research centers
- Research and academic institutions

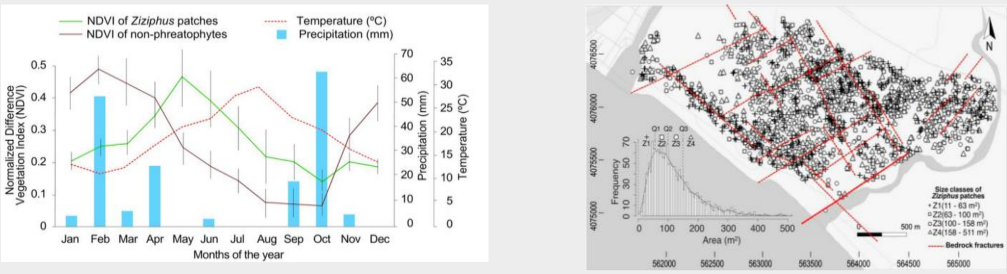

Figure 7 - Sentinel-2 analysis in order to identify groundwater dependent ecosystems in an urban environment [27]

Policy context

- EU Water Framework Directive
- Groundwater Directive 2006/118/EC
- Urban Waste Water Treatment Directive 91/271/EEC

[27] https://sentinels.copernicus.eu/web/success-stories/-/copernicus-sentinel-2-helps-to-identify-groundwater-dependent-ecosystems

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- Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks
- Directive 2000/60/EC – framework for Community action in the field of water policy

Emerging needs/requirements related to urban water management

- Drinking water quality and quantity;
- Dissolved organic carbon (DOC) and Colored dissolved organic matter (CDOM) quantities;
- Long-term records of precipitation and streamflow;
- Mapping of groundwater and surface water quantity;
- Real-time precipitation and evapotranspiration;
- Recent data on water levels;
- Recent data on soil moisture;
- Crop water needs;
- Forecasts in crucial parameters such as precipitation;

3.5 River basin management

State of play

River basins are the natural unit of area for water resource management. At the river basin scale, ensuring sustainable water management is becoming increasingly difficult due to increased water demand, climate change, and land use changes. Various sectors, such as agriculture, industry, drinking water supply, power generation, and nature, require different amounts of water. To achieve this, basin-scale planning for water distribution and prioritizing of water needs under strained situations must be established.

The main task of river basin management is to keep track of the basin's water supply and demand. Water availability is determined by the hydrology and ecology of the basin, as

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well as weather and climate. Monitoring the quantity and quality of water in a river basin is critical for efficient and effective management.

Applications/Products examples:

- Identification and delineation of watersheds;
- Delineation of stream channels;
- Terrain and slope characteristics;
- Soil and vegetation properties;
- Mapping of lakes and reservoirs;
- Mapping of groundwater storages;
- Water flow;
- Land use/land cover maps
- Evapotranspiration estimations
- Mapping of droughts/floods

Satellite missions:

- Sentinel-1
- Sentinel-2
- Sentinel-3
- Landsat 7,8
- MODIS: Terra & Aqua
- SMOS/SMAP
- Proba-V

End Users Examples:

- Relevant ministries
- River basin authorities
- Prefectures
- Hydrological institutes
- Research and academic institutions

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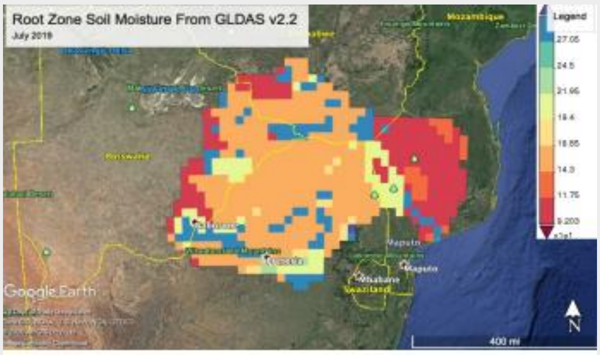

Figure 8 - Water Budget Estimation using Global data [28]

Policy context

- Commission Regulation (EC) No 414/2007 [29];
- Directive 2005/44/EC [30];
- EU Water Framework Directive (WFD)

Emerging needs/requirements related to river basin management

- Information about water demand in various scales;
- Modeling of water budget;
- Precipitation;
- Evaporation and Transpiration;
- Soil characteristics, soil moisture;
- Surface and Groundwater Storage;
- Runoff and inflows;
- Near-real-time and daily information;
- River gauges' measurements;

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[28] https://giovanni.gsfc.nasa.gov/giovanni/

[29] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32007R0414

[30] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32005L0044

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- Higher level biogeochemical products (like primary production);
- Water quality parameters, for example: temperature, chlorophyll-a, algae blooms, turbidity/suspended solids;
- Water quantity parameters (storage/water level/flow) for water bodies.

3.6 Hazards/Emergencies

State of play

Emergencies and hazards are handled by the Copernicus Emergency Management Service (CEMS), which is a key component of Copernicus, the EU Earth Observation program. It assists in all phases of the disaster management cycle by providing flood and forest fire warnings and risk assessments, as well as geospatial information obtained from satellite photos on the effect of natural and man-made disasters around the world (before, during or after a crisis). Since April 2012, CEMS' two mapping services (Rapid Mapping, and Risk and Recovery Mapping) have been producing deliverables.

Various activations have been realized for inland water bodies (i.e. rivers, lakes, dams & reservoirs) like:

- https://emergency.copernicus.eu/mapping/list-of-components/EMSN091
- https://emergency.copernicus.eu/mapping/list-of-components/EMSN054
- https://emergency.copernicus.eu/mapping/list-of-components/EMSR438
- https://emergency.copernicus.eu/mapping/list-of-components/EMSN066

Such activations are related either to a flooding event, where the damages are delineated and assessed or are related to a subsidence event.

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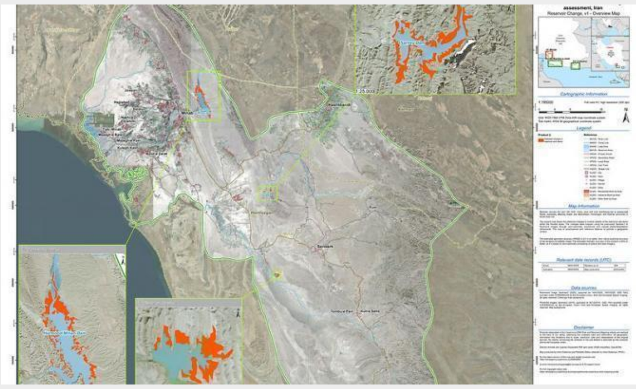

Figure 9 - Reservoir and dam change detection from the EMSN066 activation

Applications/Products examples:

- Flooded areas delineation
- Damage assessment on relative infrastructure
- Changes in water levels
- Water dynamics
- Coastal erosion

Satellite missions:

- Sentinel-1
- Sentinel-2
- Copernicus contributing missions: Worldview, Pleiades

End Users Examples:

- Related Ministries
- Public authorities
- Weather services;
- Development Banks
- Insurance companies
- Research and academic institutions

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Policy context

The European Commission is in charge of CEMS (joint coordination between the Directorate Generals GROW, ECHO, JRC). The Emergency Response Coordination Centre (ERCC) of DG ECHO in Brussels coordinates all activation requests.

With the Council decision on emergency support, the EU civil protection mechanism updated in 2019, humanitarian aid legislation and the creation of a dedicated corps in 2014, the Floods Directive, the EU forest strategy, the EU action on droughts and the creation of the European drought observatory, and the EU solidarity fund, the European Union has established various mechanisms to assist Member States in preventing, preparing for, and better combating natural risks.

Emerging needs/requirements related to hazards and emergencies

- Early warning systems for floods and in particular for coastal floods;
- Industrial pressure on inland water bodies;
- Total water storage in dams & reservoirs;
- Real time weather conditions to anticipate floods in mayor rivers, especially on border areas;
- Water quality and water levels (quantity) not only on major lakes, but also in smaller reservoirs and rivers at much finer scale (catchment scale);
- Nutrient pollution alert systems;
- Flood prevention and flood risk management;
- Drought related products: forecasting, prevention and management;
- Capacity development.

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3.7 Coastal zone management

State of play

Coastal regions are important areas for human activities such as tourism, economic activity, fisheries, offshore operations, industrial port areas, and city development. These are also areas that could be exposed to a variety of hazards, including storm surges, flooding, erosion, and climate change-related effects such as sea level rise. Natural systems (e.g. marshes, beaches, and dunes) that ordinarily operate as a buffer between the inland water and the land can be harmed by coastal development, resulting in a conflict between protecting socio-economic activity and maintaining the ecological functioning of coastal zones in Europe.

Applications/Products examples:

- Monitoring shoreline and prevention of coastal erosion
- Renewable energies development and operations
- Bathymetry, habitat mapping, and sedimentation
- Land Cover/Land Use of inland water bodies

Satellite missions:

- Sentinel-1
- Sentinel-2
- Sentinel-3
- Proba-V

End Users Examples:

- International organizations
- NGOs
- National agencies
- Environmental agencies

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- Industry
- Research and academic institutions

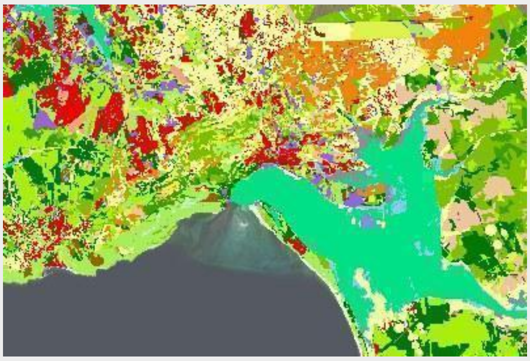

Figure 10 - Coastal Zone hotspot thematic mapping by EEA [31]

Policy context

The corresponding policy related to coastal zone management is implemented through existing directives like: the Marine Strategy Framework Directive, Maritime Spatial Planning Directive, the Water Framework Directive89, and the common fisheries policy.

Emerging needs/requirements related to coastal zone management

- Higher level biogeochemical products (like primary production)
- Higher spatial resolution and more accurate water quality resolution water quality products
- Benthic habitat and bathymetry maps
- Weather forecasts;
- Large waves forecasts and mapping;
- High resolution models;
- Better anticipation of coastal erosion;
- Improved awareness of the existence of monitoring techniques to survey coastal areas.

[31] https://land.copernicus.eu/local/coastal-zones

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3.8 Biodiversity

State of play

Public administrations and agencies in charge of protected areas, such as freshwater systems and inland water bodies, are primarily responsible for monitoring biodiversity status and taking action at the national and regional levels. The Group of Earth Observation (GEO) addresses strategic biodiversity status monitoring at the international level in order to build a uniform approach for evaluation.

Currently, Copernicus portfolio and services don't include any direct information products or data on live ecosystems that address biodiversity. However, there exist tools that can be used to characterize and monitor biotope-related environmental conditions and landscapes. Such products are land use and land change mapping in Natura 2000 sites, as well as information on inland and coastal waters habitats.

Applications/Products examples:

The Copernicus Climate Change Service (C3S) [32] provides operational climate indicators that assess the impact of temperature, rainfall, and other atmospheric, terrestrial or oceanic variables on:

- habitat suitability
- species distribution
- species fitness and reproduction
- ecosystem services

Satellite missions:

- Sentinel-1
- Sentinel-2
- Copernicus contributing missions

[32] https://climate.copernicus.eu/biodiversity

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- Sentinel-5P

End Users Examples:

- Centers for Research and Conservation
- NGOs
- National institutes
- National Parks
- Natural resource management offices
- Research and academic institutions

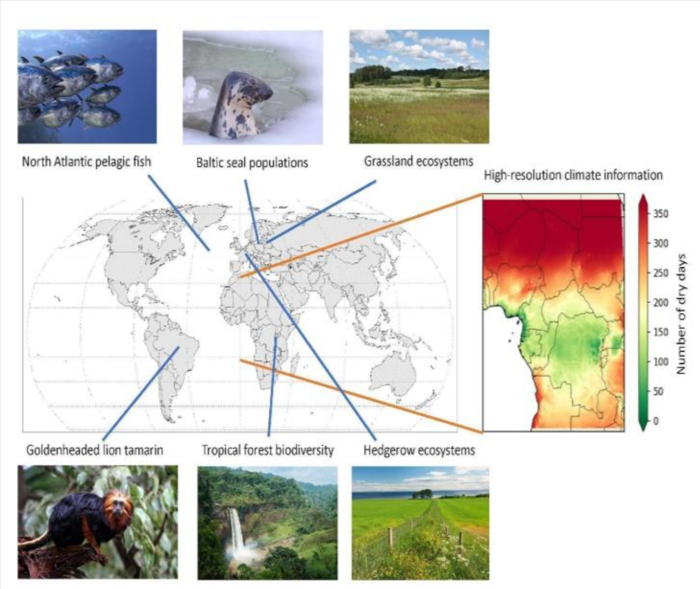

Figure 11 - Different case studies to provide information on biodiversity applications

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Policy context

In terms of policy the Biodiversity Strategy to 2020 [33] and the Biodiversity Strategy to 2030 [34] are describing and presenting a framework, which can be supplemented by Earth Observation product and services for targets like:

- implementation of Birds and Habitats Directives[35];
- deployment of green infrastructures;
- ensure the sustainable use of fisheries;
- support a green recovery.

Emerging needs/requirements related to inland water quality/quantity

- Modelling of socioecological systems;
- Habitat extent;
- Condition assessment and monitoring;
- Monitoring of inland and coastal water biodiversity;
- Aquatic species distribution;
- Analysis of anthropogenic pressures;
- Various temporal & spatial resolutions;
- Monitoring of water acidity and PH indicator.

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[33] Communication from the Commission to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions Our life insurance, our natural capital: an EU biodiversity strategy to 2020, COM/2011/0244 final

[34] https://ec.europa.eu/environment/strategy/biodiversity-strategy-2030_en#the-business-case-for-biodiversity

[35] European Commission, Directorate-General for Environment, The EU Birds and Habitats Directives For nature and people in Europe, March 2018, available at https://publications.europa.eu/en/publication-detail/-/publication/7230759d-f136-44ae-9715-1eacc26a11af.

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3.9 Energy

State of play

Earth Observation data and services can support energy planning activities and especially those related to the inland water bodies. Such information is provided by Copernicus satellites, which is particularly important to energy suppliers for optimizing **hydroelectric power production, managing dam levels, and determining electricity rates**. Snow cover, moisture, and the commencement of melting are all monitored by satellites. This data is used to **forecast future water reservoir levels and model daily inflow conditions** in the catchment area.

Authorities and energy suppliers are improving the production planning and reduce the number of costly field campaigns by seeing and analyzing this data as maps and diagrams. Given that hydropower is one of the renewable energies that will gradually replace nuclear and fossil energy in the future, this knowledge will become even more critical. In order to plan their production, hydropower producers need information on inflow to hydropower reservoirs. Many elements of the process involve inflow projections and scenarios, such as daily short-term production planning, optimization, price forecasting, and long-term investment planning.

Applications/Products examples:

- Data from CAMS, e.g. Aerosol analysis, ozone, water vapor, etc.
- Data from CLMS, e.g. Land cover, land use change, etc.
- C3S data (ERA5 reanalysis)
- Site selection for new plants
- Production forecasting
- Monitoring of plant's efficiency
- Risk management

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Satellite missions:

- Sentinel-1
- Sentinel-2
- National missions (NOAA, JAXA)
- MODIS Data
- ENVISAT
- Landsat OLI-TIRS

End Users Examples:

- Relevant Ministries
- Private energy companies
- Environmental agencies
- Public authorities
- Insurance companies
- Companies working on renewable energies
- Research and academic institutions

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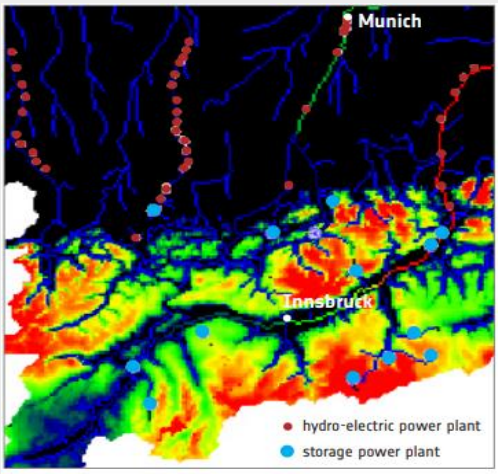

Figure 12 - Stored water and inflow conditions in the Alpine Upper Danube region [36]

Policy context

- Directive 2012/27/EU on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC.
- A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy, COM/2015/080
- Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018 on the Governance of the Energy Union and Climate Action, amending Regulations (EC) No 663/2009 and (EC) No 715/2009 of the European Parliament and of the Council, Directives 94/22/EC, 98/70/EC, 2009/31/EC, 2009/73/EC, 2010/31/EU, 2012/27/EU and 2013/30/EU.

Emerging needs/requirements related to inland water quality/quantity

- Information about inflow to hydropower reservoirs;

[36] Koch, Franziska & Prasch, Monika & Bach, Heike & Mauser, Wolfram & Appel, Florian & Weber, Markus. (2011). How Will Hydroelectric Power Generation Develop under Climate Change Scenarios? A Case Study in the Upper Danube Basin. Energies. 4. 1508-1541. 10.3390/en4101508.

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- Daily/weekly/monthly inflow forecasts and scenarios;
- Monitoring of water recharge to reservoirs;
- Integration of climate variables;
- Precipitation.

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4 Synthesis of user needs and requirements.

Having performed the different user consultations and the supplementary desk research it can be considered that the different user needs and requirements for the inland water quality/quantity services & products are converging and aligning. The following table presents a synthesis of the collected user needs and requirements grouped by the application area and also by their subject: a) Evolving needs: New Products/Services, b) Policy, c) Sensor Requirements and Capabilities and d) Best Practices.

Table 5: Synthesis of user needs and requirements

User Needs/ Requirements	General	Drinking water management	Aquaculture/ Fisheries	Agriculture	Urban water management	River basin management	Hazards/ Emergencies	Coastal zone management	Biodiversity	Energy	Relation to Water-ForCE WPs	Technology Readiness Level (TRL) [37]
Evolving needs: New Products/Services												
Regular information on rivers dynamics and especially on river runoff, interfaces with seas/oceans and overall hydrological dynamics	X					X					2, 3, 4, 5	7

[37] TRL (Technology Readiness Level) is a metric that is commonly used to evaluate the maturity of a technology and its readiness for implementation. In this specific context it is being used as a complementary metric to measure the feasibility of a user requirement, specifically the technical feasibility, to reach operationally the market in line with the core COPERNICUS services requirements. It ranges from TRL 1, representing the basic principles of the technology, to TRL 9, which signifies that the requirement is fully developed, tested, and operational as a core COPERNICUS service. The TRL scale will help assess the technical feasibility and maturity of each product or service in the context of the project, as well as indicate the potential readiness for market uptake by matching the user need/requirement to products/services already operational, available at research level, under development or not yet developed. The TRLs provided here are subject to variation depending on the scale of implementation and represent an average across cases. A specific method or algorithm may perform well at a smaller scale, but its TRL could decrease when applied at larger scales due to inherent differences and challenges. As such, please consider these TRLs as indicative of the average performance across various scales and applications.

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Water quality and water levels (quantity) not only on major lakes, but also in smaller reservoirs and rivers at much finer scale (catchment scale)	X	X	X		X	X			X		2, 3, 4	6
Monitoring service for the drinking water quantity and quality. Parameters such as: • Cyanobacterial harmful algal blooms; • Frequency of algal bloom occurrence;		X			X	X					2, 3, 4	6
Frequent mapping of CDOM (Colored dissolved organic matter) / DOC (Dissolved organic carbon) products to assist on		X		X	X						2, 3, 4	5

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drinking water quality monitoring												
Information to monitor ground-water and aquifers		X		X	X	X					3, 4	6
Service for evapotranspiration process (observations & forecasts)				X		X	X				4, 5	5
Soil moisture/soil water balance (observations & forecasts)				X		X	X				3, 4, 5	6
Hydrological models to calculate hydrological fluxes for small streams or entire river basins in connection with sea					X	X	X	X		X	3, 5	6

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Water-related forecasts and water-related climate records	X					X					2, 3, 4, 5	7
Better resolution of the algal community structure and plant biomass.		X	X	X		X			X		2, 4	5
Inclusion of microbial, nutrient, toxin, algal and metal indicators, and plastic pollution indicators		X	X			X	X	X	X		2, 4	4
Services dedicated to coastal areas								X			2, 3, 4, 5	7
Monitoring of fast growing water plants and algae			X			X	X	X	X		2, 4	5
Dedicated services for water level, altimetry, bathymetry					X	X	X	X			3, 4	6

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Risk-related indices to water systems: congestion, fishing jetties, flow speed, overgrowth, subsidence, sedimentation			X		X	X	X	X			2, 5	4
Discrimination of permanent and temporary water bodies		X		X	X	X			X		3	6
Monitoring of illegal activities				X		X					2, 3	5
Floods and droughts forecasting and monitoring. Near ”real-time” forecasts.	X						X				3, 4, 5	7
Detection of soil salinization		X		X							4	5

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Basin-scale high resolution surface models and topography data						X					3, 5	6
Forecast models and provision of early warning for food production and sustainable agriculture				X					X		3, 5	6
Detect leakage from the supply network		X			X					X	3, 4	5
Monitoring of drinking water quality in reservoirs		X			X						2, 4	6
Coupling groundwater level monitoring to land use change		X		X	X	X				X	3, 4, 5	4
Modelling changes in topography and sediment discharge						X	X				3, 5	6
Watershed modelling, hydrological and hydrodynamic modelling					X	X	X	X	X	X	3, 5	7

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Detection of micro-plastics		X			X	X		X	X		2, 4	3
Sea Surface Temperature in Coastal and Inland Water						X		X			2, 3, 4	7
Inland waterways, canals, ditches, culverts				X	X	X					3, 4	6
Chlorophyll-a concentration in lakes and inland waters in general	X		X		X	X			X		2, 4	7
Detection of Dissolved Organic Matter			X	X	X	X		X	X		2, 4	5

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Policy												
More products are needed for the implementation of the Water Framework Directive on natural water retention measures	X	X				X					2, 3, 4	4
Legislation should be adapted in country-level to include Earth Observation derived water quality products	X					X					2, 3, 4	3
Data quality and specific metrics	X	X									2, 4	3

[38] For the following items, the TRL levels are not directly applicable since they are more related to policy and regulatory aspects rather than specific technology development. However, a relative maturity level (1-5) considering the current state of the technologies and the integration of Earth Observation data into legislation and policies is provided.

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should be included in directives													
Copernicus data can be validated by in situ measurements, for example to simplify reporting required by the Water Framework Directive	X					X						4	5
Need of international practices/standards for monitoring and evaluation. Guidelines in policy do not specify how to incorporate earth observation data to the legislations	X	X										All	3

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Sensor Requirements and Capabilities												
Time resolution yearly and seasonal maps based on daily to weekly information				X							2, 3	7
Spatial resolution 5-20 m pixel resolution to go for 1 ha minimum mapping unit				X							2, 3	7
Spatial resolution 1-5 m		X			X	X	X	X		X	3	6
Integration of radar data and services	X			X	X	X	X				3	7
Increased resolution (sub 1m) in order to identify smaller inland water bodies and provide information on		X			X	X	X				3, 5	5

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hydromorphology of rivers												
Ideal inland and near-coastal water quality sensor for general use and covering the needs of most of the applications: • Imaging spectrometer with 5 to 8 nm spectral bands from 340 to 1000 nm, and a minimum of three SWIR bands • Spatial resolution: 5-10 m ground sampling distance (GSD). • Revisit frequency should be as high as possible: daily	X										2, 3, 4	6

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in reservoirs/dams, weekly on lakes/rivers, monthly on coastal												
Integration of spectroradiometers in the existing infrastructures					X	X					2, 3, 4	6
Wider collection of hyperspectral radiometry					X			X			2, 3	7
Hyperspectral data for water quality, algal blooms, and shallow water	X					X					2, 4	7

User Needs/ Requirements	General	Drinking water management	Aquaculture / Fisheries	Agriculture	Urban water management	River basin management	Hazards/ Emergencies	Coastal zone management	Biodiversity	Energy	Relation to Water-ForCE WPs	Maturity
Best Practices												
More information on the hydrological processes, which can be fulfilled by	X					X					3, 5	5

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Earth Observation data												
Need for a centralized data portal / service catalogue	X					X					All	5
Dedicated trainings (for data, products, basic tools) so the organizations can process satellite data internally	X					X	X				All	5
Provision of cost-effective services from the private sector	X										All	3
Provision of services for the non-expert audience (3rd level of information)	X										All	3
Standardization in algorithms, calibration, validation is needed	X										All	2

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Better and more complete metadata, especially for the quality measures (validation, accuracy, uncertainties, etc)	X										All	
Definition of practices to integrate and correlate satellite and in situ data with models.	X										All	3
Coupling models, satellite EO and in situ data	X					X	X				All	3
Need for understanding the trade-offs of different satellite sensor platforms and other methodology	X										All	4
Using citizen scientists and crowd sourcing activities to collect	X				X		X				2, 4	3

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and provide water quality data												
Water quality database with metadata and quality-controlled data	X					X					2, 4	5

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Annex 1: User Stories/High Level Scenarios

As a / an (Actor)	I want to ...	So that ...
Port Environmental Manager	Be able to collect and analyse environmental data	Be able to show real-time data in the pilot
	Receive automatic environmental alerts with enough foresight: 24, 48 or even 72 hours	Undertake actions for the mitigation of port activities in the environment thanks to these alerts
	Monitoring pollution. Detect peaks and sources. Back-trajectory	Be able to detect sources of contamination.
	Traffic control in areas close to the port	See how this congestion affects pollution in the port
	Monitor and detect pollution episodes	Could carry out inspections on the possible actors to confirm the results and establish the corresponding actions: • Sanctions • Promotion of corrective measures Manage or send customised alerts to trigger the relevant actions according to the established environmental protocol, if any, or define specific actions: • Email to responsible people

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As a / an (Actor)	I want to ...	So that ...
		• Notifications in other applications
Port Operations Manager	Vessel monitoring. Analyse whether it is possible to link the origin of a pollution episode to a specific vessel	Be able to know the main features of the vessel. I could establish mitigation / corrective measures to that vessel or to the port management. For instance: to change fuel type once the vessel is 2 miles away from the coast, to change the fuel during berthing or to decrease the maximum speed allowed inside the port
	Monitoring regular lines. Detecting if there are pollution patterns to a specific time frame (diurnal, weekly, seasonal).	Be able to monitor the line and obtain different KPIs on it. Providing recommendations to avoid saturations, thus avoiding pollution episodes
	Prediction, optimisation and replanning. Perform berth assignments based on the experience gained, both in terms of the vessel's emissions and the vehicles on board	Undertake actions for mitigation of port activities. Have an allocation advice tool to help mitigate the pollution generated so that as few people as possible are affected. This will allow identifying if there are vessels and/or berths that should change their propulsion system (fuel) to

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As a / an (Actor)	I want to …	So that …
		reduce their impact on the city in terms of investment required
Water manager	Monitor extreme flood events	Identify water retention in flooding periods and use in drought
	Monitor water drought	To define new plans of actions
	Monitor water droughts by (agricultural) use	To work with land owners / farmers
Regional Authority & Municipality	Measure soil carbon sequestration from water change view	To have a more integrated view of the water and soil carbon effect
Land user (farmer)	To be able to have better flood forecasts	To get a better idea of extreme events on the overall and measures system (real time)
		Comparing modelling effects with real time data
	To have knowledge of the water needs	To monitor in real time the demand side of water (agriculture)
Agricultural Policy Maker	To have information about biodiversity enhancement, CO_2 and carbon sequestration	To monitor crop rotation; to see yearly changes in area, per parcel.
		To monitor crop diversification, to plant and declare in the same area.
	To monitor changes in water resources	To be prepared for water problems / advance warnings

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As a / an (Actor)	I want to ...	So that ...
Water professional at regional authority	To monitor soils sulphating / water quality issues due to severe rain / drainage	To be prepared for different water use
	Water use type - irrigation	To adjust the water management to future water uses and climate conditions
Regional authority	To detect illegal water abstraction and control river basin management plans	To implement the Water Framework Directive
	To have water quality measures on small reservoirs	To monitor the water user
	To have information on the river runoffs	To understand interactions between inland waters and sea.
Hydro-meteorological administration	Information of evapotranspiration process and the soil moisture/soil water balance	To optimize agriculture processes
	Information on hydrological processes	To ensure best water use practices related to irrigation monitoring and forecasting
	New accurate and timely information on the cryosphere like snow depth, wet snow, snow melt.	To address water use and changes in water and cryosphere resources
Agency in charge of agriculture	Yearly and seasonal maps based on daily to weekly information	To have information of the use of water in agriculture for the production of indicators required by the CAP proposal

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As a / an (Actor)	I want to ...	So that ...
Farmer	Forecasts about precipitation and rainfall events	To find the optimal timing of crop sowing.
	Have information about the drainage of the soil and affected areas	To optimize the production and understand the impact to the agricultural soil
	To know when and how much to irrigate	To derive optimal water use
Environmental Protection Agency	Multitemporal mapping of wet areas	To support climate adaptation, agricultural and land use planning, environmental management, infrastructure planning and financial investments.
	Observations and forecasts for water level data that does not require complex modelling.	To assess flood extent for emergency services.
Coastal Authority	Data and information with high temporal and spatial resolution.	To monitor the dynamic changes of coasts short- and long-term basis.
	Prediction of changes in the coasts	To deal with the variability and trends of the coastal areas
	High-resolution bathymetric data near the shoreline	To manage and plan construction of marine structures
Policy maker	Accurate and high-resolution mapping of wetland ecosystems	To monitor and guide efforts to preserve and restore wetlands in terms of wetland extent and biodiversity status.

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As a / an (Actor)	I want to …	So that …
Water Authority	Updated daily and weekly view of the remote infrastructure	To monitor remotely the status of the water infrastructure and facilities (i.e. dams and reservoirs)
		To monitor large areas and relocate time and workforce in other tasks
Aquafarmer	Information on environmental parameters such as water temperature, sea-level rise, water eutrophication	Identify the optimal time to harvest, sell products and optimize the production sites.
Responsible for water resources in Province level	Maps and data of the canals, rivers and waterways	To develop efficient flood plan
	Near real time flood areas	
Lake authority	Monitor of cyanobacteria and related toxins	Evaluate the consequences in lake ecosystems
River basin authority	Multitemporal information about water and soil	To implement the basin plan
	Monitoring of subsidence and landslides in river banks	Identify areas in risk
National authority	Integration of the current traditional methods and sensors to satellite observations	Monitor water quality remotely in large areas according to the EU Water Framework Directive (WFD)
	Information about flood and erosion risk	To evaluate potential investments for infrastructure to battle flood events

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As a / an (Actor)	I want to ...	So that ...
Water network manager	Forecasting models for water flows and water quality	To better inform the local water suppliers for changes in the water quantity and quality
Hydrological modeler	Be able to map the hydrological stations on the model river network	The station data can be used for calibration and verification of the model
	Identify water bodies	The modelled river network and reservoirs can be verified
Environmental scientist	Be able to ingrate and correlate multi sensor solutions (i.e. bathymetric and aerial data) with information from different satellite sensors	To better evaluate water levels in flooding events.
Ecologist	Have clear international practices/standards for monitoring and evaluation of earth observation indices	To facilitate the monitoring of pre & post environmental crises in freshwater systems
Research scientist in water quality changes	To have cross-calibrated models from different sensors	To have a well-managed plan for multitemporal mismatches.

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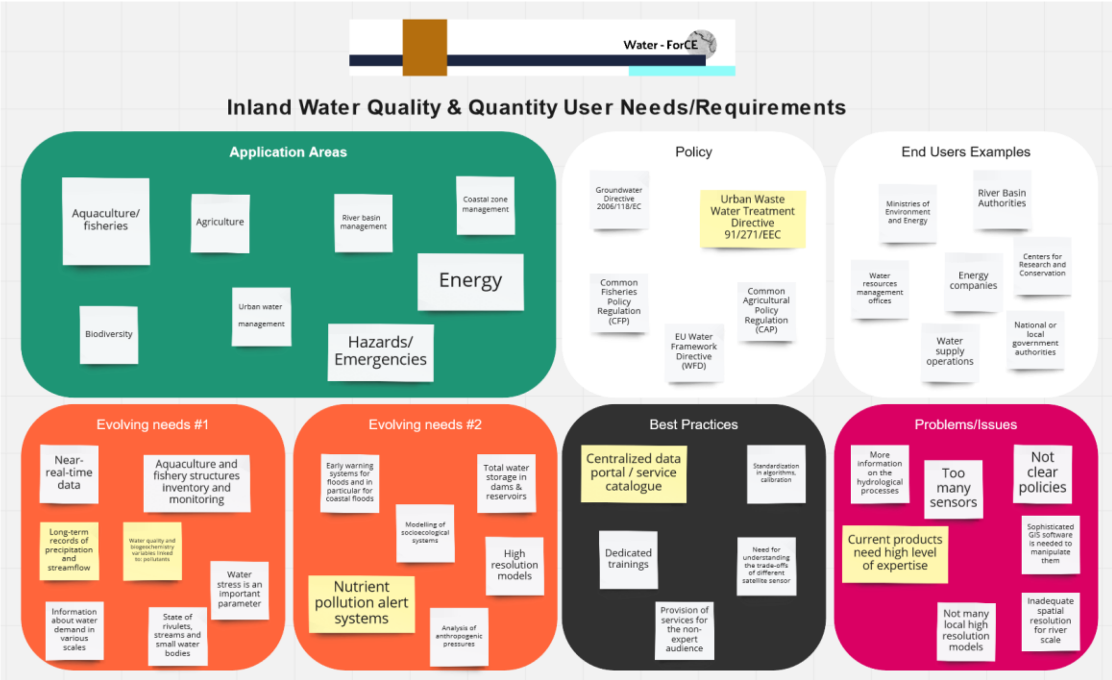

Figure 13 - Miro board example for the collection of user needs/requirements [39]

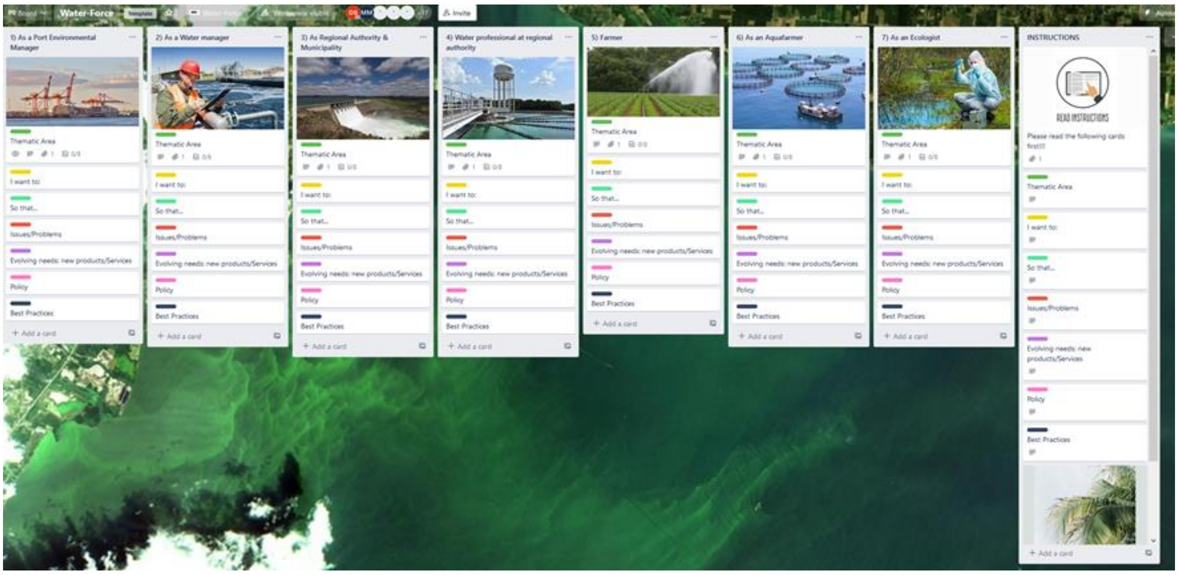

Figure 14 - Trello example for the co-design and creation of user stories [40]

[39] https://miro.com/app/board/uXjVOYxVYqg=/

[40] https://trello.com/b/jUFOPFh6/water-force

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