D1.2- Report on CENTAUR use cases and Indexes definition

Deliverable #:	**D1.2**
WP#:	**WP1**
WP Leader:	**European Union Satellite Centre (SatCen)**
Task Leader:	**UNI/SERTIT** (Task 1.3)
Revision Date:	30.11.2023
Submission Date:	30.11.2023
Document Type:	Report
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Version:	1.0
Dissemination Level:	Public (PU)

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This document is issued within the frame and for the purpose of the CENTAUR project. This project has received funding from the European Union's HORIZON-CL4-2021-SPACE-01 - Strategic Autonomy in Developing, Deploying and Using Global Space-based Infrastructures, Services, Application and Data *Framework Programme under Grant Agreement No. 101082720. The opinions expressed and arguments employed herein do not necessarily reflect the official views of the European Commission.*

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History of Changes

Date	Version	Author	Change Description
08/08/2023	0.1	UNI/SERTIT	Initial version with ToC
30/11/2023	1.0	CENTAUR Consortium	First version of the document

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1 EXECUTIVE SUMMARY

The present document corresponds to deliverable *D1.2 - Report on CENTAUR use cases and Indexes definition* of the CENTAUR project. It falls under Work Package *WP1 – Analysis of requirements and use cases definition*, in particular under Task *T1.3 – Cross cutting analysis, use cases and Synthetic Indexes definition*.

Herein, the document describes:

- Design of composite indexes – The definition and design of advanced composite indexes, in response to end-user needs. They allow for an operational monitoring of climate and meteorological-driven crisis events, namely Urban Floods (UF) and Water and Food Security (WFS).
- End-user needs evaluation – An assessment delineating the correspondence between the proposed development plan and the specific needs of end-users, articulated in terms of their prioritization and temporal expectations.
- Conceptual models for UF and WFS – The conceptual models for both UF and WFS tracks, which describe the anticipated data services, and how they will be combined to yield composite indicators and indexes for global monitoring, alert triggering and event-driven monitoring.
- Use case selection – The rationale behind the selection of use cases for both UF and WFS tracks. This entails a consideration of multiple factors, such as end-user feedback, contextual relevance, and the availability of relevant data. Additional insight is also provided on CENTAUR's dynamic ability to shift focus between cold and hot cases based on emerging crises.
- Holistic cross-cutting analysis – A demonstration of CENTAUR's adaptive capacity, agility and real-world applicability, by integrating UF and WFS concerns into a single and comprehensive demonstrator.

First of all, the information provided in this document will be the basis for work package *WP2 – Thematic product engineering*. Using the conceptual models described herein, we will design the workflow for computing composite indexes. Additionally, this deliverable will underpin *WP4 – Climate change crisis and natural disaster demonstrators*. The use cases identified in this document will be crucial for establishing operational demonstrators in that phase.

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2 INTRODUCTION

2.1 PROJECT DESCRIPTION

Climate change is a fact and its impact on human lives and security is continuously growing. The EU understood the importance and consequences of climate change a long time ago, adopting ambitious legislation in different policy areas. The Green Deal recognises that tackling climate change and striving for climate neutrality should be placed at the centre of societal and economic transformation.

Over the last 50 years, more than 11,000 reported disasters related to extreme weather and climate conditions have caused over 2 million deaths and US$ 3.64 trillion in losses. The number of disasters has multiplied by a factor of five during that period, mainly driven by climate and more weather extremes[1]. In particular, the last twenty years have seen the number of major floods more than double, from 1,389 to 3,254, while the incidence of storms grew from 1,457 to 2,034[2]. Floods and storms were the most prevalent events and floods are the most common type of disaster worldwide, accounting for 44 % of total events registered in the last twenty years. A global temperature increase of the global climate is estimated to boost the frequency of potentially high impact natural hazard events across the world. This could render current national and local strategies for disaster risk reduction and climate change adaptation obsolete in many countries. In total, between 2000 and 2019, there were 3,068 disaster events in Asia, 1,756 events in the Americas and 1,192 events in Africa.

Climate change is increasingly acknowledged within the EU's integrated approach to security. The related environmental degradation is recognized as a threat multiplier and an aggravating factor for political instability with serious implications for peace and security across the globe[3]. Nowadays, climate change is already causing people to migrate, and while migration should not be directly labelled as a security problem, implicitly the link with pressures on society and increased competition for resources are often made[4]. People living in places affected by violent conflict are particularly vulnerable to climate change and it is agreed that some of the factors that increase the risk of violent conflict are sensitive to climate change[5]. This way, it is estimated that 95 % of new displacements by conflicts in 2020 happened in countries that have high or very high vulnerability to climate change[6]. From 2008 to 2016, this represents over 20 million people per year that have been forced to migrate due to climate change effects[7].

Within Copernicus Security and Emergency Services evolution, the objective of CENTAUR is to respond to societal challenges deriving from climate change threats by developing and demonstrating new service components for the Copernicus Emergency Management Service (CEMS, or EMS) and Copernicus Security Service - Support to EU External Action service (CSS-SEA, or SEA), aiming to:

[1] World Meteorological Organization (2021). WMO atlas of mortality and economic losses from weather, climate and water extremes (1970–2019).
[2] UNDRR report: The human cost of disasters: an overview of the last 20 years (2000-2019).
[3] Meyer, C., Vantaggiato, F. P., & Youngs, R. (2021). Preparing the CSDP for the new security environment created by climate change. European Union.
[4] Schaik, L., Bakker, T. (2017). Climate-migration-security: Policy Brief Making the most of a contested relationship. Planetary Security.
[5] W.N., J.M. Pulhin, J. Barnett, G.D. Dabelko, G.K. Hovelsrud, M. Levy, Ú. Oswald Spring, and C.H. Vogel (2014). Human security. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 755-791.
[6] University of Notre Dame. (n.d.). Country index // Notre Dame Global Adaptation Initiative // University of Notre Dame. Notre Dame Global Adaptation Initiative. Retrieved January 23, 2022, from https://gain.nd.edu/our-work/country-index/.
[7] WEF (2020). *The Global Risks Report 2020*, Insight Report 15th Edition. World Economic Forum, Geneva Switzerland, p. 102. https://www.weforum.org/reports/the-global-risks-report-2020.

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1. Improve situational awareness and preparedness around climate change and its impact on complex emergencies and multi-dimensional (security) crises;
2. Anticipate the occurrence and possible knock-on effects of crisis events, in particular those triggered by climatic extremes, thus contributing to resilience and effective adaptation.

In the emergency domain, CENTAUR will address the flood-related threats to population, assets and infrastructures in urban areas. In the security domain, CENTAUR will address water & food insecurity. The two work streams will be connected via a cross-cutting component focusing on exposure and vulnerability to climate change, as well as resilience and societal capacity for managing environmental risks and social conflict. Across work streams, indicators and models will be validated by different methods.

CENTAUR will integrate data coming from multiple heterogeneous sources, with a specific focus on those generated by other Copernicus services, and, in particular, those of the Climate Change Service. It will combine these with meteorological data, socio-economic data, and data coming from new sensors (e.g., traditional and social media). Thus, it will enhance current capacities to produce composite risk indexes and to perform multi-criteria analyses in the emergency and security domains.

2.2 SCOPE OF THE DOCUMENT

This document is produced under **WP1 - Analysis of requirements and use cases definition** that has the objective to provide user requirements and indications, and to lay the groundwork for subsequent activities in CENTAUR. It relates to Task T1.3, which is divided into **3 main phases**.

The first phase concentrates on **designing advanced composite monitoring, forecasting and crisis indexes**. It is a continuation of the efforts made under Deliverable D1.1, as well as Tasks 1.1 and 1.2 of the CENTAUR project, where the base indicators and indexes were outlined. Through **conceptual models**, Task 1.3 and D1.2 showcase the interplay between indicators, as well as their combination into higher order indexes. The goal of this step is to lay the groundwork for WP2, which will focus on fully fleshing out the indicators and indexes that the proposed system depends on.

The second phase is focused on the **definition of use cases**, aligning them with the needs of Copernicus EMS and SEA end-users. These use cases encompass a range of scenarios, including areas within and outside Europe, where urban flooding or food and water security challenges are either ongoing, have occurred in the past or are expected to unfold during the project's lifetime. This phase involves confirming and, if necessary, adjusting use cases based on stakeholders' experiences and ensuring active engagement with local and regional authorities. Furthermore, detailed design and preparation of selected case studies in collaboration with users are integral to test CENTAUR's innovative outcomes, in preparation for WP4. This results in a dichotomy between **cold cases**, designed for calibrating the system, and **hot cases**, used for testing the system in a pre-operational environment. Additionally, the project identifies at least one **multi-disciplinary case** study that encompasses both Copernicus EMS and SEA aspects.

Finally, the third phase involves conducting a **cross-cutting analysis** of the urban flood and water & food security tracks. This step is structured around a combined analysis of state-of-the-art knowledge, identified gaps, and proposed indicators. The cross-cutting analysis serves as the bridge between the two tracks within CENTAUR. Its role is to uncover **synergies**, enhance the understanding of **complex interactions**, and propose **integrated solutions** that address the shared challenges faced by both domains. Ultimately, this analysis aims to **maximize the effectiveness** of CENTAUR's systems in improving resilience and preparedness for urban flood and climate security events.

To cover the above objectives, the document has been structured into the following chapters:

- Chapter 1: Executive summary.

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- Chapter 2: Introduction, including scope of the document, definitions, abbreviations, acronyms and reference documents.
- Chapter 3: Definition and design of advanced composite indexes.
- Chapter 4: Definition of use cases.
- Chapter 5: Cross-cutting analysis.
- Chapter 6: Conclusions.

2.3 DEFINITION, ABBREVIATIONS AND ACRONYMS

Table 1: Table with abbreviations and acronyms.

Acronym	Description
ACLED	Armed Conflict Location and Event Data Project
AdBPo	Po Basin Authority
AEMET	Agencia Estatal de Meteorología
AGEA	Agenzia Regionale Piemontese per le Erogazioni in Agricoltura
AI	Artificial Intelligence
AOI	Area Of Interest
API	Application Programming Interface
AR	Accessibility Requirements
ARPA	Agenzia Regionale per la Protezione Ambientale
CCM	Copernicus Contributing Missions
CCR	Caisse Centrale de Réassurance
CEMS, EMS	Copernicus Emergency Mapping Service
CENTAUR	Copernicus ENhanced Tools for Anticipative response to climate change in the emergency and secURity domain
CHE	Confederación Hidrográfica del Ebro
CLC	Corine Land Cover
CNES	Centre National d'Etudes Spatiales
CNIG	Centro Nacional de Información Geográfica
CSS-SEA, SEA	Copernicus Service in Support to EU External Action
DHS	Demographic and Health Surveys
DIEM	Data In Emergency Monitoring
DLR	Deutsches Zentrum für Luft- und Raumfahrt

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Acronym	Description
DP	Data/indicators integration, management and Processing requirements
DTM	Digital Terrain Model
EEAS	EU Situation Room
EFAS	European Flood Awareness System
ENSO	El Niño Southern Oscillation
EO	Earth Observation
EOG	Earth Observation Group
EU	European Union
EU	European Union
FAO	Food and Agriculture Organisation
FAO DIEM	FAO Data in Emergencies Hub
FAO WaPOR	Water Productivity Open-access portal
FEWS NET	Famine Early Warning Systems Network
GADM	Global Administrative Areas
GHSL	Global Human Settlement Layer
GR	General Requirements
GUI	Graphic User Interface
HR	High Resolution
HTML	HyperText Markup Language
ICPDR	International Commission for the Protection of the Danube River
ID	Indicator
IDMC	Internal Displacement Monitoring Centre
IDP	Internally Displaced People
InSAR	Interferometric Synthetic Aperture Radar
INSEE	Institut National de la Statistique et des Etudes Economiques
IOM	International Organization for Migration
IOM DTM	IOM Displacement Tracking Matrix
IR	Interoperability Requirements
JRC	Joint Research Center

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Acronym	Description
KOFGI	KOF Globalisation Index
LiDAR	Light Detection And Ranging
MASE	Italian Ministry of the Environment and Energy Security
MHFP	Ministerio de Hacienda y Función Pública
MITECO	Ministerio para la Transición Ecológica y el Reto Demográfico
ML	Machine Learning
MODIS	Moderate-Resolution Imaging Spectroradiometer
NAO	North Atlantic Oscillation
NASA	National Aeronautics and Space Administration
NASA GRACE	Gravity Recovery and Climate Experiment
OGC	Open Geospatial Consortium
OR	Operational Requirements
OSM	OpenStreetMap
PDF	Portable Document Format
PoliTO	Polytechnic University of Turin
PR	Platform Requirements
REDIAM	Red de Información Ambiental de Andalucía Environmental information
REST	Representational State Transfer
RGE	Référentiel à Grande Echelle
RM	Rapid Mapping
RRM	Risk and Recovery Mapping
SAIH Ebro	Sistema Automático de Información Hidrológica de la Cuenca Hidrográfica del Ebro
SAR	Synthetic Aperture Radar
SatCen	European Union Satellite Centre
SE	Socio-Economic
sFTP	SSH File Transfer Protocol
SMAP	Soil Moisture Active Passive
SSH	Secure Shell

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Acronym	Description
TR	Training Requirements
UF	Urban Floods
UN	United Nations
UNOSAT	United Nations Satellite Centre
URR	User Requirement Review
VHR	Very High Resolution
WDI	World Development Indicators
WFS	*Depending on the context* Water & Food Security Web Feature Service
WMS	Web Map Service
WP	Work Package

2.4 APPLICABLE AND REFERENCE DOCUMENTS

Table 2. Applicable and reference documents.

ID	Document name
[RD01]	Copernicus Emergency Management Service – Rapid Mapping and Risk & Recovery: https://emergency.copernicus.eu/
[RD02]	Copernicus Service in Support to EU External Action: https://sea.security.copernicus.eu/
[RD03]	D1.1 – Report on Urban Flood and Water & Food security indicators
[RD04]	D2.1 – Catalogue of CENTAUR data and related specifications
[RD05]	D2.2 – Urban flood and Water & Food Insecurity Design

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3 DEFINITION AND DESIGN OF ADVANCED COMPOSITE INDEXES

3.1 IMPROVING UPON THE STATE OF THE ART IN COPERNICUS EMS AND SEA

Within the domains of Copernicus EMS ([RD01]) and SEA ([RD02]), significant progress has been made in harnessing EO data for disaster management. However distinct gaps remain, especially for urban flood mapping and climate security, that underscore the need for novel integrated approaches. With an increase in climate-related crises, techniques that can effectively bridge these domains are also invaluable, as they could help better understand the complex interplay between floods, urban areas, as well as between droughts, food and water security, fragility, and displacement.

Deliverable *D1.1 - Report on Urban Flood and Water & Food security indicators* ([RD03]) already provides a thorough review of gaps identified within Copernicus EMS and SEA's portfolios, as well as end-user needs[8]. This section focuses on how CENTAUR is addressing those in relation to the proposed indicators, composite indexes and systems.

3.1.1 Review of user expectations and operational requirements

Regardless of thematic specificities, both UF and WFS tracks hold similar high-level **user expectations**. The developed solutions should be comprehensive, scalable and adaptable. Once configured and calibrated with reference data, these solutions should be replicable as well.

Key expectations include:

a. **Early warning system and alerts:** A robust early warning system is required. It must be capable of issuing timely alerts in response to impending crisis events, drawing from a combination of various indicators to detect anomalies. Such a system can offer actionable insights to authorities and communities, allows for targeted anticipatory measures, and enhances Copernicus EMS and SEA's capabilities for pre-tasking satellite imagery and other data collection processes.
b. **Integration of various data sets:** The collation of heterogeneous data is a missing part in the majority of early warning frameworks. Earth observation data should be complemented with non-geographic data, such as socio-economic data or traditional and social media markers, to better detect anomalies and crises.
c. **Precision of input data:** One of the limiting factors in the existing crisis portfolios is the spatiotemporal resolution of input data. Novel data with enhanced precision (both spatially and temporally), as well as covering relevant dimensions of exposure and vulnerability, are expected to improve the quality of delivered products.
d. **Novel methodologies for an improved management of risks:** The integration of novel data sets requires to develop new processing techniques. Leveraging machine learning and predictive models should help

[8] End-user needs were defined as per a two-step process. First, SatCen defined a list of potential use cases for the CENTAUR project, and solicited several units of the EEAS to provide feedback on climate security issues. Second, a questionnaire was tailored to collect end-user information and needs, as well as their understanding of climate security, existing methods and tools, and their limitations. The targeted groups were either users or potential users of the Copernicus EMS and SEA services, including EEAS, EC JRC, CCR, UN Environment Programme, German Federal Foreign Office, Wav-e, ICPDR, REDIAM, General Directorate of Civil Protection, Helpcode and the Danish Refugee Council.

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process heterogeneous data, provide timely forecasts, outline major trends, minimize delivery times and improve thematic accuracy.

e. **Geoportal for online access to information:** The need for a user-friendly geoportal that offers online access to a wealth of information related to UF and WFS is expressed. Such a platform should serve as a centralized application for accessing data, tools and services, facilitating informed and evidence-based decision-making.

f. **Pre-operational products and services**, validated with a suite of **demonstrators**, and distributed as part of Copernicus EMS and SEA's catalogues.

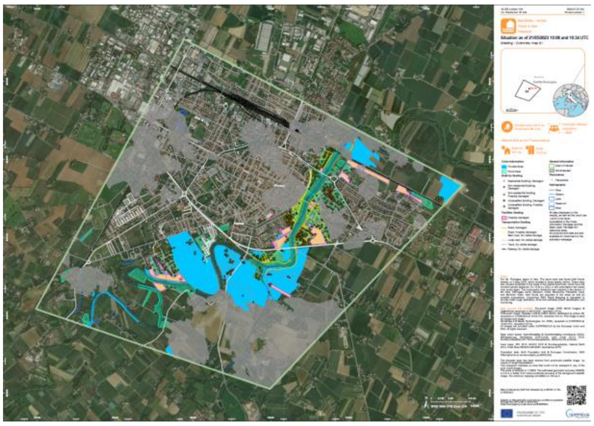
The present deliverable emphasizes points (a), (d), and (f). The subsequent sub-sections delve into the specifics of each point both for the UF and WFS tracks. Moreover, they suggest how to fill gaps that were identified within the existing Copernicus EMS and SEA's portfolios, as well as in the literature. The solutions suggested in this document leverage data sets described in deliverable *D2.1 – Catalogue of CENTAUR data and related specifications* ([RD04]), which answers points (b) and (c). Finally, point (e) is part of *WP3 – Service deployment*.

3.1.2 Composite indexes to address gaps in urban flood mapping

In the context of the UF track of CENTAUR, the following categories of gaps have been identified:

- **Earth observation constraints:** Optical sensors struggle to capture images through clouds, but they typically offer clearer information on the extent and impact of floods. In contrast, SAR sensors are favoured for flood mapping because they can see through cloud cover in favourable atmospheric conditions. However, their use can be challenging because of their unique radiometric, geometric, and orbital characteristics.
- **Data integration challenges:** Limited joint use of SAR and optical data to bridge each other's weaknesses, as well as with other information sources, like media data. This hinders comprehensive event delineation.
- **Resolution and geometry mismatch**: The under-exploitation of VHR satellite data and DTMs, which are better suited for the usual dense urban environments, results in an inaccurate delineation of the event. Urban areas are usually entirely omitted on flood maps derived from automated techniques.
- **Weather data constraints**: Weather data with insufficient spatial and temporal resolution can lead to challenges in identifying precipitation peaks accurately, resulting in underestimated flood extents.

Figure 1: Example of flood product provided by Copernicus EMS (EMSR664, AOI04).Flood delineation is available outside of settlements, but could not be extracted or digitized inside urban areas due to their geometry and other properties.



So far, these challenges have resulted in either biased or missing products in Copernicus EMS' portfolio. In particular, flooded areas in settlements are often omitted, due to satellite sensor limitations (Figure 1). The lack of higher spatial resolution data also hinders hydraulic modelling and the computation of flood depth.

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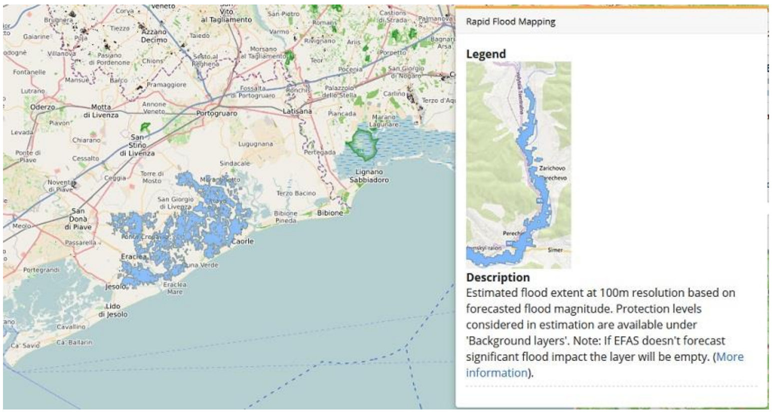
On a broader scale, these shortcomings lead to imprecise flood maps, with a 100 m spatial resolution for European countries (Figure 2) and a much coarser 1 km resolution for countries elsewhere.

Figure 2: Example of a flood product provided by EFAS at 100 m resolution in Italy.[9]



In response to these challenges and in alignment with the expectations of end-users, CENTAUR has developed two significant composite indexes: the early warning forecast index and the flood impact index. These indexes represent a concerted effort to improve the accuracy, precision, and comprehensiveness of urban flood mapping, addressing the identified gaps while harnessing the strengths of various data sources and technologies.

3.1.3 Composite indexes to answer gaps in water and food security

In the context of the WFS track of CENTAUR, the following categories of gaps have been identified:

- **Enhanced data timeliness and accessibility**: Climate security management within the water and food security track requires more up-to-date data to assess the impact of climate change on various dimensions of human security. Furthermore, there is currently a significant gap in the availability of systems that can systematically and automatically collect, prepare, and integrate up-to-date geospatial data, both at the local and regional levels, to address climate-related crises.
- **Comprehensive early warning and alert systems**: Addressing the needs of water and food security stakeholders, it is crucial to recognize the importance of an early warning system that can alert users when predefined triggers and drivers for crises, especially climate-related ones, are met. The existing landscape lacks a comprehensive system that proactively monitors climate security implications, performs risk assessments, offers early warning capabilities, and provides foresight capabilities for various climate security events.
- **Integrated approach to tackle climate security**: Climate security management goes beyond the assessment of climate impacts on food and water resources; it also includes understanding how these factors relate to broader security concerns and potential conflicts. This results in a need for tools and services that can assess food security as a precursor to conflict and provide support to local administration in urban planning and climate change adaptation.

In the context of WFS, CENTAUR aims to provide tools and services that proactively monitor climate security challenges, offer early warning systems, assess the impact of climate change on water availability and crop production, and study the relationship with civil security. The project aims to bridge this gap by developing an integrated system that not only identifies climate security threats but also offers tools for scenario analysis (i.e., "what if" scenarios) and proactive monitoring of migration and displacement, which are often linked to climate-induced crises (Figure 3).

[9] Products generated by EFAS are available on the EFAS viewer: https://www.efas.eu/efas_frontend/#/home

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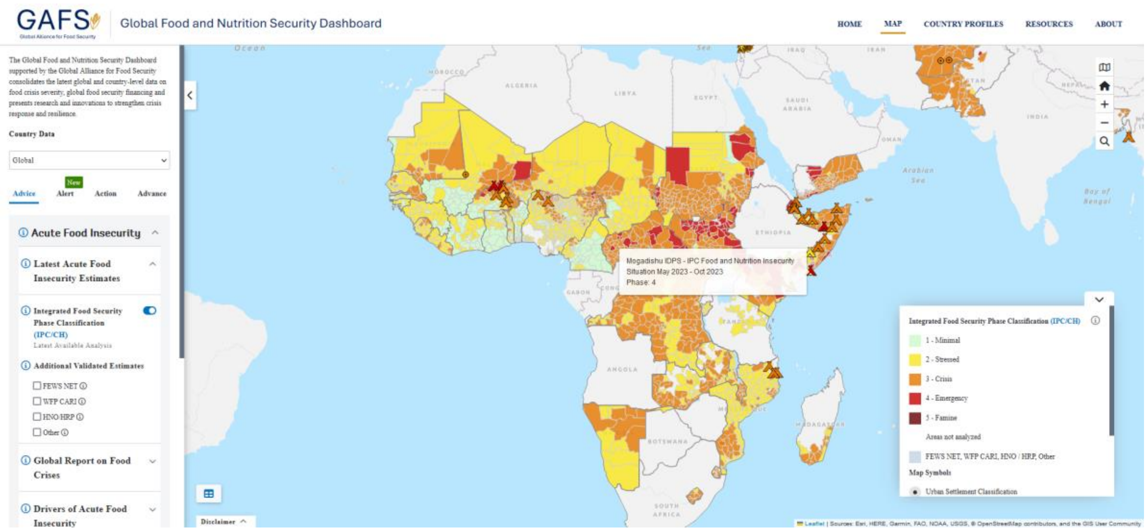
Figure 3: Example of the Global Food and Nutrition Security dashboard.[10]



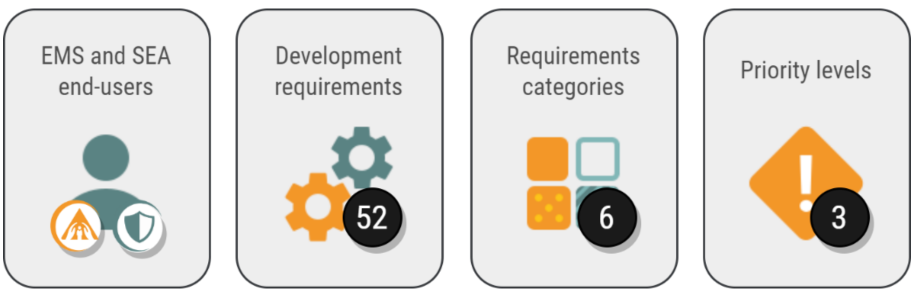
To address this comprehensive approach for WFS, data is integrated into high-level tools and platforms, including a risk monitor, an IDP situation monitor, and a dashboard with data viewing capabilities. These tools and platforms are expected to bridge the gap between climate security, food and water security, and broader conflict prevention efforts.

3.2 USER REQUIREMENTS AND DEVELOPMENT PRIORITIES

This section elaborates on the **user requirements** presented in Chapter 4 of D1.1 ([RD03]), especially by including information on the **priority of developments** within the framework of the project. It results from the analysis of user requirement questionnaires, in relation to the requirements of systems and tools that are being developed as part of CENTAUR (Figure 4).

Development priority provides information about the timeframe for developing a system or tool. In total, 3 levels have been considered. **Short-term** prioritization (Table 3) indicates that the requirement is to be implemented in 2024. **Medium-term** prioritization (Table 4) pushes this target to the end of the project. Finally, **long-term** prioritization (Table 5) corresponds to requirements that will not be actively developed within the 3-year life cycle of CENTAUR, saving them for future projects or subsequent developments within Copernicus EMS and SEA directly.

Figure 4: User requirements and development priorities in numbers.



[10] https://www.gafs.info/map/?state=Advice&country=Global&indicator=overall_phase_proj

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Requirement tables are structured as follows:

- **Requirement category**: Each requirement belongs to one of 6 categories, which include “General”, “Accessibility”, “Operational”, “Data/Indicators integration, management and processing”, “Interoperability” and “Training”.
- **Code**: Unique identifier.
- **Requirement name**: Name of the user requirement.
- **Description**: Description of the user requirement.

Particular attention has been placed on **functional requirements**, which qualitatively describe the functions or tasks performed by CENTAUR’s systems and tools. Requirements that cover the quantitative overview, such as performance requirements, are not the focus of this deliverable and will be further described in the system design documentation.

Table 3: Short-term priority developments.

SHORT-TERM PRIORITY DEVELOPMENTS			
Requirement category	Code	Requirement name	Description
Accessibility	AR-01	Access regulation	• Regulate access by providing identity and access management based on access control policies, roles, permissions, and attributes. This should include “admin” and “super admin” roles for batch updates/bulk user addition.
Data/indicators integration, management, and processing	DP-01	Big data	• The system shall give the capacity of ingesting and exploiting large amount of data (big data). • In order to save disk space, non-required intermediate products or imagery input data should be automatically removed after a certain period of time.
Data/indicators integration, management, and processing	DP-02	Satellite imagery access	• The platform shall provide access to the CENTAUR services online satellite imagery services, optical and SAR.
Data/indicators integration, management, and processing	DP-03	Multisource data	• The system shall provide systematic access to data, background information and time series. • The following list of data sources must be managed and offered to the user by the platform (preliminary list, more can be added in accordance to the developed services and system needs): o EO data. o Non-EO data collected systematically (e.g., climate, socio-economic, crowdsourcing, and media data). o Products from other Copernicus services (e.g., Climate Change Service, Atmosphere Service, and Land Monitoring Service).

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SHORT-TERM PRIORITY DEVELOPMENTS			
Requirement category	Code	Requirement name	Description
Data/indicators integration, management, and processing	DP-04	Metadata	• All products, services and datasets stored and managed by the system shall include its metadata. • Metadata may be compliant with INSPIRE requirements. • Whenever possible, the process of collecting and completing the metadata should be automatized.
Data/indicators integration, management, and processing	DP-05	Catalogue	• The system shall integrate a product/service/datasets catalogue to explore, browse and access all the different products/services/datasets available and managed by the platform. • The catalogue shall list external datasets, product and services produced by the system itself and other ancillary and complementary data (e.g., AOIs, thematic layers). • It shall allow to apply personalized filters and queries to restrict the results subsets.
Data/indicators integration, management, and processing	DP-06	Asynchronous jobs	• The platform must be able to process synchronous requests for the execution of simple functions over limited amount of data and asynchronous requests for the executing long-running processes.
Data/indicators integration, management, and processing	DP-08	Model development and simulation	• The system shall allow the development and customization of simulation models that represent the dynamics of the water and food insecurity system. • The platform should offer an interface to define model parameters, relationships, and scenarios.
General	GR-01	Security	• The early-warning platform must ensure the security of the monitored data. • The system shall provide encryption mechanisms to protect data in transit and at rest. • It must adhere to industry-standard security practices, such as vulnerability assessments, penetration testing, and regular security updates.
General	GR-02	Reliability	• The platform should be highly reliable, ensuring continuous operation and minimizing downtime. • It should include fault tolerance and failover mechanisms to mitigate the impact of hardware or software failures. • The system should be designed to handle concurrent user access and support high availability.
General	GR-03	Ethics	• Technical and organizational measures shall be implemented in the system for ensuring that personal data protection and privacy issues are considered.

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SHORT-TERM PRIORITY DEVELOPMENTS			
Requirement category	Code	Requirement name	Description
Interoperability	IR-04	Information consumption	• The system should be prepared to consume and display third-party geospatial web services and data (e.g., Sentinel imagery, other Copernicus issued products).
Operational	OR-03	Catalogue of datasets	A catalogue of datasets on urban floods and water and food insecurity covering the following domains: • *Urban Flooding* o Real time data about flood extent during events. o Use of SAR and optical data for flood extent. o Flood model in blind urban areas. o Improved damage assessment based on climate, exposure and ground truth (media markers). • *Water and Food Security* o Near-real time and projected geospatial data. o Water and food availability. o Crop production monitoring. o Social, economic, political and security data. o Mobility and migration. o Population distribution and evolution. o Changes in land use. o Climate, meteorological and weather data. o Other biophysical parameters. o Pastoralism, transhumance, etc. o Multi-hazard.

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SHORT-TERM PRIORITY DEVELOPMENTS			
Requirement category	Code	Requirement name	Description
Platform	PR-01	Graphic user interface	The CENTAUR solution shall have intuitive and user-friendly graphical user interfaces (GUI), ensuring the best level of usability and user experience, and guaranteeing a good customization with respect to user needs. As a general indication, GUIs shall be in line with the following characteristics: • Simplicity (e.g., screen complexity, progressive disclosure). • Aesthetically pleasing (e.g., contrast between elements, use colours and graphics appropriately and customized to the user/group). • Clarity – visual, conceptual, language (e.g., visual elements, words and text, forms filling). • Easy to understand. • Consistency. • Efficiency (e.g., minimize eye and hand movements via proper screen layout, number of clicks and paths for each task). • Compatibility (user characteristics respect to the task and job to be done). • Forgiveness, recovery (e.g., tolerate errors and allow commands to be abolished or reversed, warnings). • Predictability (e.g., user should be able to anticipate natural progression in the task, user should know all the time where they are, what is the next step, how to go back, how to abort). • Configurability (e.g., allow personalization and configuration of settings). • Familiarity (e.g., follow a common style for each technical area). • Responsiveness. • Whenever possible, the use of frameworks and standards, incorporating best practices, last trends, and features for building a rich and modern user interface is recommended.
Platform	PR-02	Cloud architecture	• The CENTAUR solution must be based on a cloud architecture to help manage and process large amounts of data more efficiently, to provide easy access to users and service delivery, facilitate integration and provide reliability and robustness for handling large volumes of data.

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SHORT-TERM PRIORITY DEVELOPMENTS			
Requirement category	Code	Requirement name	Description
Platform	PR-03	Geoviewer component	• The CENTAUR solution should integrate a navigation panel to easily explore, navigate and display the Areas of Interest, Indexes and Indicators and different datasets available and selected by the user (e.g., from drop down lists). • The geoviewer GUI shall allow to display, navigate, zoom in/out, pan or overlay spatial data sets or layers, measure areas and distances, transparency control, print and display legend information. • Users should be able to select base maps of different type (e.g., satellite imagery, dark, light).
Platform	PR-04	Graphs and statistical visualization	• The platform shall facilitate the display of historical series of data, trends or statistical analysis to identify anomalies. • The visualization should be customizable and include different interactive charts and graphs (e.g., lines, bars, KPIs).
Platform	PR-05	Datasets visualization	• All different types of information and derived products shall be displayed with adapted semiology to be configured. Metadata information should be easily accessible.
Platform	PR-08	Single access point	• The CENTAUR platform should have a single access point and get an overview of the complete service catalogue when landing in the homepage.
Platform	PR-11	Language	• All the GUI and documentation must at least be available in English.

Table 4: Medium-term priority developments.

MEDIUM-TERM PRIORITY DEVELOPMENTS			
Requirement category	Code	Requirement Name	Requirement and development description
Accessibility	AR-02	User authentication	• Integrate authentication with the OpenID Connect identity provider of SatCen (Identity Server).
Data/indicators integration, management, and processing	DP-07	Tools and AI algorithms	• The platform shall integrate tools and AI trained algorithms to automatically process and interpret large-scale data.
Data/indicators integration, management, and processing	DP-09	Orchestration of processing chains	• The system shall be capable of automatically executing in a pre-defined, ordered and consecutive or parallelized manner concurrent EO processing chains. • Processing chains should be able to be launched automatically each time new input data (e.g., satellite imagery) is available.

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MEDIUM-TERM PRIORITY DEVELOPMENTS			
Requirement category	Code	Requirement Name	Requirement and development description
General	GR-05	Notifications	• The user must be notified through a notification inbox and by email when a relevant event occurs, like new alerts of the early-warning system or availability of a specific data requested by the user.
General	GR-07	Licensing	• For those services/products/data provided subject to certain agreements or licenses (e.g., ESA license, Copernicus copyright, etc.), the corresponding copyright clauses must be displayed.
Interoperability	IR-01	Data delivery: online platform or web service	• The data provided by the service should be made available to the user by either a web service or an on-line platform.
Interoperability	IR-02	Information delivery	• The CENTAUR solution shall support the dissemination of information in form of services to be easily ingested by other existing systems/workflows, with standard interfaces: o sFTP. o OGC Web Services (WFS, WMS…). o RESTful services. o APIs.
Operational	OR-01	Risk assessment and early-warning system	• The solution should mainly consist in an early-warning system based on more precise meteorological data and a combination of several biophysical and socio-economic inputs to alerting the user when pre-defined triggers or anomalies driving for crisis are met. • The system shall be able to generate, display and send-user selected/configured alerts automatically. • The system should provide intelligent alerting mechanisms (e.g., group related events, double check mechanisms) to reduce false positives.
Operational	OR-02	Urban flood mapping	• Increase of the accuracy of urban flood mapping (>75%) using SAR and InSAR processing combined with urban flood modelling. • To implement an application in an operational, automated (unsupervised) mode in diverse global environments, for characterizing river overflow and pluvial runoff floods in urban areas by processing SAR and optical imagery at high resolution (10, 20 meters) and Very High Resolution (less than 1 meter). • Provide information on urban flood extent and impacts on population and assets in areas where standard SAR-based flood mapping is not technically feasible.

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MEDIUM-TERM PRIORITY DEVELOPMENTS			
Requirement category	Code	Requirement Name	Requirement and development description
Operational	OR-04	Simulation and predictive analysis	• The system shall incorporate predictive analytics techniques to forecast future trends on climate security events. • It should utilize historical data, statistical methods, and machine learning algorithms to generate accurate predictions. • It should allow users to experiment with different forecasting models and algorithms to identify the most effective approach and launch "what if" analysis.
Operational	OR-05	Improved situational awareness	• Situational Awareness Portal providing continuous monitoring (with a predefined cadence) of Climate Security Risk Indicators and Indexes. The final aim is to support the decision-making process. • Better understanding of the underlying mechanisms related to climate change and conflict at regional level (e.g., ADMIN1, ADMIN2). • Tools and services for support to local administration in urban planning and climate change adaptation. • Innovative ways of analysing the links between climate change, environmental degradation, conflict and displacement.
Operational	OR-07	Improved CEMS pre-tasking	• CEMS pre-tasking success (75%), in terms of number of pre-tasking alert, timeliness and improvement in the definition of the AOI for crisis-time satellite acquisitions. • To contribute/enhance the CEMS global flood monitoring product, by developing Urban Flood Indicators, urban flood mapping, assessing urban flood impacts on population and assets, etc.
Operational	OR-08	CEMS products and services	CENTAUR must supply the products and services based on the following characteristics: • *Capabilities:* o Real time data about flood extent during events. o Use of SAR data for flood extent. o Flood model in urban and forested areas. o Flood assessment and climatic aspects. • *Regions for flood:* o Mozambique (Cabo Delgado, Maputo and Manica). o Ebro Basin (Navarra). o German Floods (Danube River). o Piemonte, Italy.

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MEDIUM-TERM PRIORITY DEVELOPMENTS			
Requirement category	Code	Requirement Name	Requirement and development description

Operational	OR-09	CSS-SEA products and services	CENTAUR must supply the products and services based on the following characteristics:
			• *Capabilities:*
			  o Risk Assessment and Early-Warning System for Water and Food Insecurity-related crises.
			  o Foresight capabilities.
			  o Access to catalogue of datasets for enriching service production and incorporate a climate security perspective.
			• *Regions covered by Water and Food Insecurity use cases:*
			  o Somalia.
			  o Mozambique.
			  o Mali.

Operational	OR-10	Maturity level	• The CENTAUR solution must be validated and demonstrated up to the pre-operational level.
Platform	PR-06	Alerts and thresholds configuration and management	• Alerts shall be generated automatically without requiring user intervention (push notifications). By clicking on the alert, the user will access context information and metrics about the alert. • The system should provide a user-friendly interface to customize alerting services. • User should be able to easily specify, edit and manage thresholds for different metrics, indicators or indexes. • User should have the flexibility to set absolute values or percentage-based thresholds, depending on the indicator/index being monitored.
Platform	PR-07	Web access	• The web interface shall support the following browsers: Internet Explorer 9, 10 and 11, Edge, Firefox and Chrome (in their latest version available).
Platform	PR-09	Display	• CENTAUR system should be prepared to be accessed mainly through computers and should be designed for an average resolution of Computer Monitors (21' – 24').
Platform	PR-13	Search tools	• The platform may include filtering tools to conduct very specific searches (e.g., by date, by, country, by theme, by product type) tools.
Platform	PR-14	Download data	• The platform may include easily accessible and user-friendly download tools.
Platform	PR-15	Configurable AOIs	• The system shall allow to an administration user drawing, saving, editing, removing and storing personalized Areas of Interest (AOI) that will serve to launch specific analysis.

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MEDIUM-TERM PRIORITY DEVELOPMENTS			
Requirement category	Code	Requirement Name	Requirement and development description
Platform	PR-16	Personal area component	• The platform should contain a personal area allowing the user to set its personal preferences (e.g., modify email address; enable or disable email notifications; configure alerts etc.).
Training	TR-01	Training	• Support training processes through the organization of different workshops where the users will be able to learn the capabilities of the CENTAUR solution.
Training	TR-02	Helpdesk section	• A helpdesk section should be available to the users, in HTML format, accessible through the user profile and serving as the user manual of the application.

Table 5: Long-term priority developments.

LONG-TERM PRIORITY DEVELOPMENTS			
Requirement category	Code	Requirement Name	Requirement and development description
Accessibility	AR-03	Data access restrictions	• Ensure that the data are accessible only to those authorized to have access, in a secure way.
Data/indicators integration, management, and processing	DP-10	Efficiency and reactivity	• The system should implement Near Real Time data processing to minimize delay from event occurrence to alert notification. • Efficient data handling capabilities should be implemented to accommodate large volumes of data from various sources.
General	GR-04	Scalability	• The system should be scalable to able to handle increasing data volumes. • The system should be prepared to be extended to other similar regions such as Burkina Faso, Niger, Central African Republic, Kenia, Sudan, South of Tuscany, Yemen, Ethiopia, South of Tuscany and Danube River Basin.
General	GR-06	Information	• The platform could include access to information communities, such as open slack community, for having a more dynamic notification feed.
Interoperability	IR-03	Geospatial data format	• In case the user has to download/receive the data, to ensure interoperability of geospatial data and enable its integration with other existing systems, the geo-referenced maps, vector and raster data and satellite imagery should be produced and delivered in standard formats: tif, jp2, gdb, shp, kml, geojson, etc.

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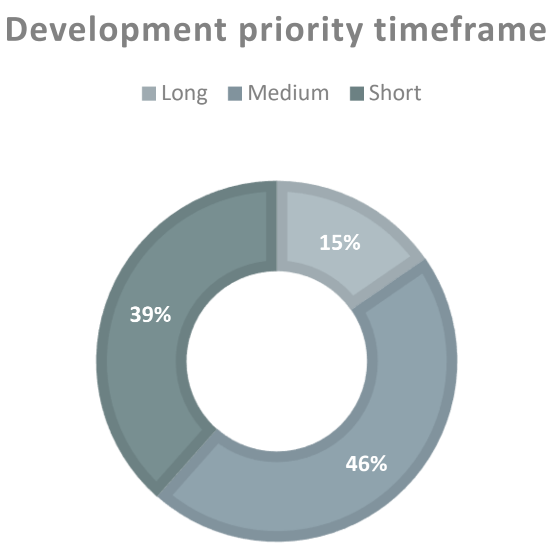
LONG-TERM PRIORITY DEVELOPMENTS			
Requirement category	Code	Requirement Name	Requirement and development description
Operational	OR-06	Improved existing indicators	• Improvement of other more traditional map quality indicators owing to a more integrated and accurate input information and to more effective AI/ML modelling (thematic accuracy, speed of delivery, resolution, etc.).
Platform	PR-10	Responsiveness	• The platform should be developed following responsive design principles, prepared to be accessed from different devices and screen resolutions (tablets, laptops, large screens and any other platform).
Platform	PR-12	Other languages	• All the GUI and documentation could be available in other European languages.

In total, 52 development priorities have been identified (Figure 5). The majority of these priorities are concentrated in the medium-term category, accounting for 46% of the total. Short-term priorities closely follow, representing 39% of the identified needs. This distribution suggests that 44 end-user needs are anticipated to be addressed by the end of the project in November 2025. Consequently, 8 needs are categorized as long-term objectives, which are meant to be tackled post-project.

Figure 5: Development priority timeframe of end-user needs for the CENTAUR project.



The majority of short-term developments fall into the DP and PR categories (Figure 6), which correspond to “Data/indicators integration, management and processing” and “Platform” respectively. For the medium-term development priorities, the OR and PR categories, denoting "Operational" and "Data/indicators integration, management, and processing," are expected to be the primary areas of focus. Long-term priorities exhibit a more balanced distribution across all categories.

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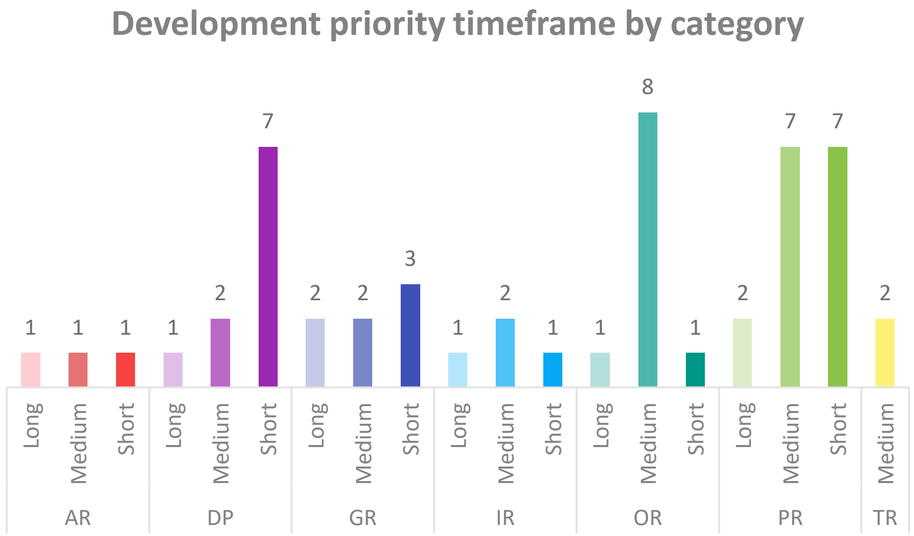
Figure 6: Development priority timeframe of end-user needs for the CENTAUR project, by category.

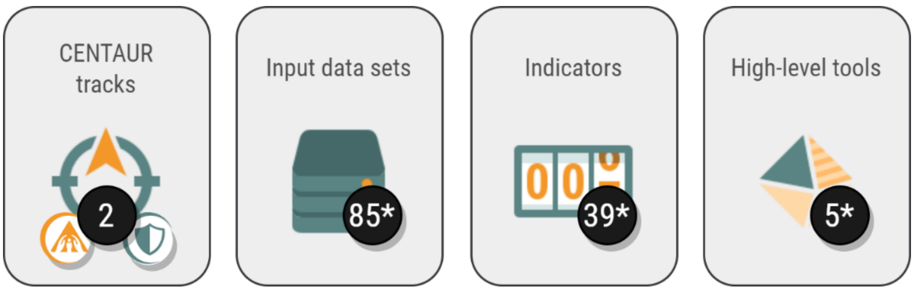


It is noteworthy that the "Training" (TR) category lacks both short and long-term development priorities, as these are anticipated to be addressed in 2025. The DP category is mostly comprised of short-term developments, that will span WP2 (Thematic product engineering) for the most part. With a majority of short to medium-term developments, the PR category is expected to be undertaken in WP3 (Service deployment). Finally, almost all developments for the OR category fall into the medium-term bracket, as they are anticipated to be addressed during WP4 (Climate change crisis and natural disaster demonstrators) and WP5 (Analysis of the integration in the operational set-up of Copernicus EMS and SEA, impact and further exploitation).

3.3 CONCEPTUAL MODELS AND METHODOLOGICAL APPROACHES

This section presents two conceptual models of how CENTAUR will integrate and combine input data into higher order indicators and composite indexes, respectively for its **Urban Floods** and **Water & Food Security** tracks (Figure 7). Furthermore, it suggests methods to be used for the computation of said indicators and indexes. Additional details are available in *D2.2 – Urban Flood and Water & Food Insecurity Design* ([RD05]).

Figure 7: CENTAUR tracks and conceptual models in numbers. * indicates the number is liable to change during the project, due to unforeseen circumstances (e.g., additional input data required for validation, indicator not computed due to complexity in data collection, creation of a new index, etc.).



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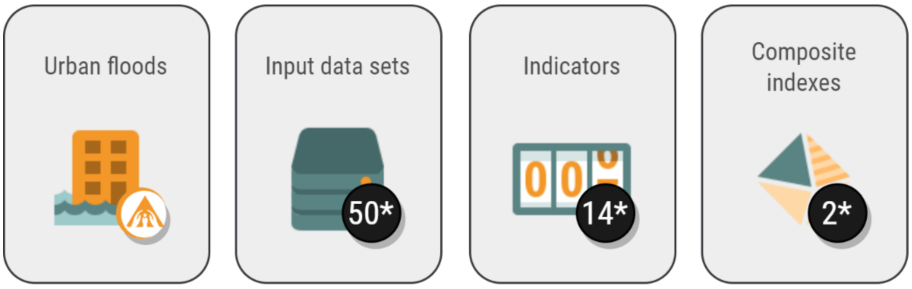
3.3.1 Urban flood indexes

CENTAUR's UF track focuses on developing applications for early warning and impact analysis around flood-related risk in urban settlements. In this context, an **early warning forecast index** and a **flood impact index** (Figure 8) are being developed.

Figure 8: The UF track and its conceptual model in numbers. * indicates the number is liable to change during the project, due to unforeseen circumstances (e.g., additional input data required for validation, indicator not computed due to complexity in data collection, creation of a new index, etc.). Moreover, some input data sets are shared with the WFS track.



The methodological approach for the UF track is leveraged by a **dual-mode monitoring system**. As its first component, the system runs **a continuous global monitoring** to detect potentially hazardous events. **Alerts** are triggered at pre-defined thresholds that launch an **event-driven monitoring** at the scale of the area of interest (AOI). Both modes depend on custom indicators and composite indexes described in the following sub-sections, and whose hierarchy and interactions are shown in Figure 9. The model considers several indicators of exposure and vulnerability to urban flood hazards, as well as of the severity of impacts. This includes data on settlement patterns, rainfall, and other environmental factors. Given that CENTAUR emphasizes macro and medium scales, some processes were not captured or only represented in a simplified way with the set of proposed indicators.

The conceptual model primarily focuses on input data, indicators, and indexes as key components for urban flood detection, monitoring and forecasting. Moreover, it does not necessarily show how we assume these components

UF-ID-1 captures historical rainfall events, allowing to establish a benchmark for typical rainfall patterns in a given urban area, against which extreme events can be identified. UF-ID-1 further provides a measure of the severity of rainfall events, expressed in return periods (i.e., high return periods signal rainfall events that are so far beyond the historical norm that they are expected to occur only on rare occasions, or 'once in many years'). **UF-ID-2** uses these historical records, combined with current and forecasted weather data, to predict urban rainfall intensities, expressed as return period categories. Using return periods provided by UF-ID-1 and UF-ID-2, extreme events can easily be identified, which facilitates the development of a useful and actionable early-warning forecast index. **UF-ID-3** expands on the prior two indicators by integrating various ancillary data to produce high-resolution urban inundation probability and depth maps.

The aim is to use high-resolution ancillary data, provided by regional or national institutions, whenever possible, to predict the local impact of a precipitation event as accurately as possible. However, data sets such as elevation layers are not always available at high resolution, due to pricing notably. Thus, global coverage data sets with coarser resolutions are also considered as part of the design process. Restrictions on data availability depending on the desired scale will be mentioned in later sections of this report, on a per use case basis. Nonetheless, by accounting for more variables, UF-ID-3 identifies urban areas most susceptible to flooding at high resolution, ideally at 10 meters or less. Even though state-of-the-art global meteorological forecasts are produced at much coarser resolution, from 25 and up to 9 km, the prediction of return levels of precipitation and their probabilities help bridge the scale gap between meteorological forecasts and high-resolution inundation modelling, and constitutes a major novelty achieved within CENTAUR. Furthermore, frequent updates of the forecast (i.e., every 6 hours) facilitate continuous updates of UF-ID-2 and the associated predictions.

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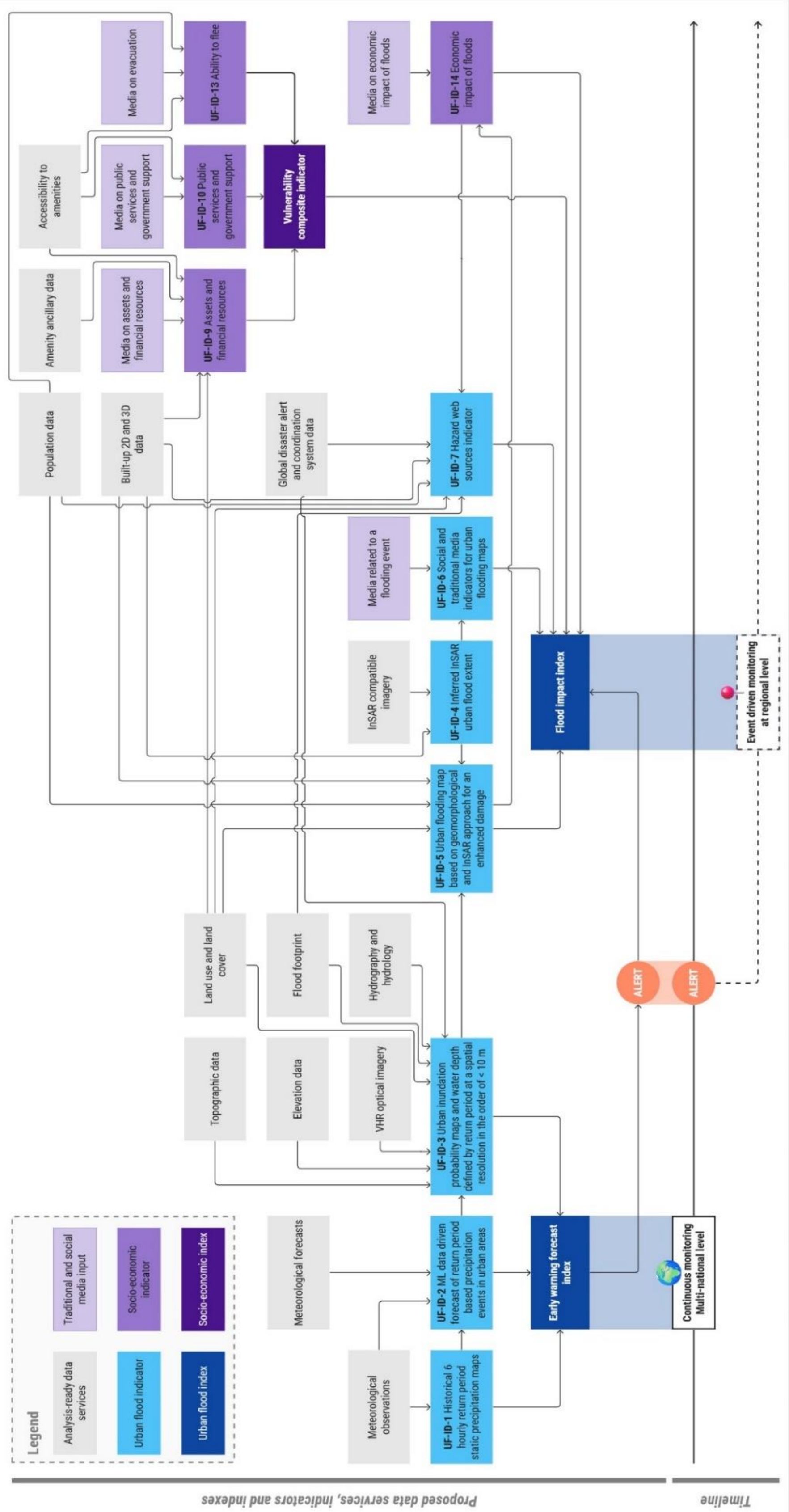

Figure 9: Conceptual model for the urban flood track.

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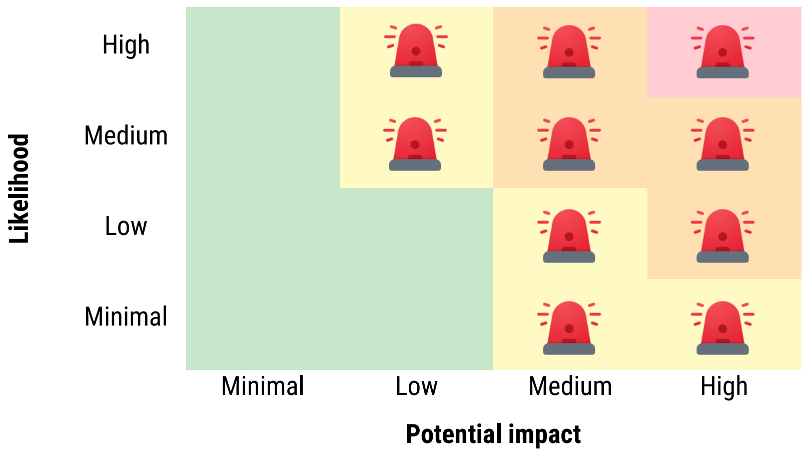
Early warning forecast index

The **urban flood early-warning forecast index**, which initiates event-driven monitoring at the regional or local scale, relies on a specific risk definition (Figure 3). It takes into account two crucial aspects of risk, the likelihood of a flood and its potential impact. This approach, widely employed in forecasting for anticipatory action[11], allows for the identification of situations with a low probability of causing significant harm, and scenarios where low-level impacts have a high chance of occurrence. These considerations are graphically depicted on a **risk matrix** (Figure 10), which employs a colour gradient (ranging from green to red) to categorize predictions based on the intersection of likelihood and potential impact.

In this context, the methodology has been adapted to primarily focus on assessing the severity and extent of potential floods. However, it can also offer an initial estimation of **potential impact** by incorporating exposure and vulnerability indicators. On the provided risk matrix, the "likelihood" axis corresponds to UF-ID-2 and provides an estimate of the probability of an extreme event occurring within the next 48 hours. This **likelihood** is expressed in terms of return periods of precipitation, categorized as minimal, low, medium, or high, based on historical event records, informed by UF-ID-1. Meanwhile, the "potential impact" axis assesses the expected severity of precipitation events on the ground, as determined by UF-ID-3.

Figure 10: Risk matrix based on hazard likelihood and potential impact.



A **warning** is activated as soon as the likelihood of extreme precipitation reaches a medium level, even if the potential impact is assessed as low (indicating a high probability of occurrence with limited harm potential). Conversely, a warning is triggered when the potential impact is estimated to be at least medium, regardless of the precipitation event's likelihood (implying a low probability but the potential for significant harm).

In its basic configuration, the assessment of potential impact relies solely on the probability of areas being inundated. In an enhanced version, refining the estimation of potential impact becomes possible by integrating exposure and vulnerability factors into the warning levels.

[11] Feyen, L., Dankers, R., Bódis, K., Salamon, P., & Barredo, J. I. (2012). Fluvial flood risk in Europe in present and future climates. Climatic Change, 112(1), 47–62. https://doi.org/10.1007/s10584-011-0339-7

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This advancement aligns the early warning forecast index more closely with the risk framework outlined by the IPCC[12] and provides a preliminary evaluation of the risk associated with the predicted event. Leveraging high-resolution ancillary data indicators, such as population and land cover data, enables the estimation of the number of affected households, individuals, and potential damage to critical infrastructure. This enhancement holds the potential to further improve the early-warning index, ideally within the CENTAUR project's timeframe.

Flood impact assessment (event-driven mode)

The early warning forecast index plays a crucial role in identifying areas at risk, warranting a more comprehensive high-resolution analysis. This leads into the system's second mode, the **event-driven mode**, which operates in response to a detected crisis. Evaluating the impact of a flood typically entails the consideration of various variables and parameters associated with observed and potential flood damage in a particular region. Although the exact methodology may vary based on the area of interest and the available data, it generally encompasses the following key steps:

1. **Data Collection**: Gather relevant data, including topographic information, rainfall data, hydrological data, and data related to the location's proximity to water bodies.
2. **Defining the Area of Interest (AOI)**: Determine the geographic area under consideration. This area can vary in size, from a small watershed to an entire region.
3. **Hydrological Analysis**: Use hydrological models to estimate peak river discharge and the flow of water into the AOI, often considering historical rainfall and runoff data.
4. **Hydraulic Analysis**: Use hydraulic models to simulate how water would flow and inundate the study area under various flood scenarios. This analysis considers factors such as flow velocity and depth.
5. **Vulnerability Assessment**: Assess the vulnerability of people, assets, and critical infrastructures within the AOI. This may include variables such as building types, population density and emergency response capabilities.
6. **Defining relevant parameters**: Define specific parameters to characterize the potential impact of flood events. These parameters can include flood depth, flood velocity, flood duration and more.
7. **Weighting Factors**: Assign weights to different risk parameters based on their relative importance in the flood hazard assessment. For example, flood depth might be given more weight than flood velocity.
8. **Index Calculation**: Combine the various parameters and their assigned weights into a formula or model to estimate (potential) impacts from flood for each location within the AOI.
9. **Mapping the Index**: Map the estimated impacts across the AOI to identify more or less severely affected locations. Resulting maps can be visualized within a geographic information system (GIS).

This approach is informed by eight indicators that describe ongoing or past events[13] and their impact.

UF-ID-4 is responsible for generating urban flood maps using radar satellite data, which is generally unaffected by atmospheric conditions. **UF-ID-5** then combines data from UF-ID-3 and **UF-ID-4**, along with other ancillary data sources, to provide a comprehensive assessment of the event's extent and impact.

UF-ID-7 plays a critical role in understanding the crisis from a managerial and planning perspective. It accomplishes this by aggregating diverse datasets, including information on population, land cover, and vulnerable areas. Both

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[12] Reisinger, A., Howden, M., & Vera, C. (n.d.). Guidance for IPCC authors. https://www.ipcc.ch/site/assets/uploads/2021/02/Risk-guidance-FINAL_15Feb2021.pdf

[13] Even though the event-driven phase is designed to monitor on-going floods, the proposed workflow can be deployed to analyse the impact of past events. This feature will be leveraged for cold case demonstrators in WP4, but can also provide information on short events such as flash floods, where the monitoring frequency might be inadequate.

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UF-ID-5 and UF-ID-7 leverage **socio-economic data** and data extracted from **traditional and social media markers**. For example, UF-ID-5 is refined using media indicators of flood depths and other pertinent location-specific details, as highlighted in **UF-ID-6**.

UF-ID-9, **UF-ID-10**, and **UF-ID-13** contribute valuable insights into the vulnerability of urban populations and areas. These components focus on various aspects, including amenities, economic assets, and evacuation capacities.

Lastly, **UF-ID-14** serves to estimate the potential economic consequences of floods. It draws information from UF-ID-3, UF-ID-5, and available media markers to provide a comprehensive assessment of the economic impact associated with the flooding event.

Flood hazard index

The **flood hazard index** plays a critical role in consolidating essential information derived from indicators computed during the event-driven mode. In order to combine indicators into a high-order index, two strategies have been considered, namely weighting and discretization into classes. Even though these strategies will be addressed in WP2, this deliverable lays the general idea. Once data collection is completed under Task 1.3, all the building blocks will be available in WP2 to **initialize weights and thresholds** for discretization, informed by scientific literature primarily. The **execution of demonstrators** under WP4 will help calibrate those, either in a per use case fashion, or in a more general manner to attain a generic system.

First, the definition of a **weighting system** is a reflection of the varying significance of each indicator in shaping the overall impact assessment. The final goal is to create an index that faithfully captures the distinct characteristics and vulnerabilities of the specific area being evaluated.

Some of the key considerations when assigning weights include:

1. **Relevance**: Assess how strongly each indicator relates to flood hazard. Indicators that have a more direct and significant impact on flood risk should be assigned higher weights.
2. **Reliability**: Consider the quality and availability of data associated with each indicator. Indicators with reliable and complete data should be given more weight.
3. **Historical Significance**: Evaluate whether certain indicators have played a substantial role in past flood events in the area. If so, these indicators may warrant higher weights.
4. **Stakeholder Input**: Involve relevant stakeholders, including local authorities, community members, and experts, to gather input on the perceived importance of each indicator.
5. **Scientific Analysis**: Utilize scientific analyses and modelling techniques to determine the potential impact of each indicator on flood hazard.

Second, in addition to weights, **discretizing** or **classifying** indicator values is also expected to prove useful for assessing hazard at a glance, as well as combining different indicators in a comprehensive manner. For example, the classification of indicators involved in the estimation of flood impact could follow an ordinal scale, ranging from 0 to 3, as follows:

- 0 → No hazard.
- 1 → Low level of hazard.
- 2 → Medium level of hazard.
- 3 → High level of hazard.

The **preliminary classification** envisioned for the different UF indicators is as follows:

- UF-ID-3: Classes are based on the return period associated with extreme events. Return period of 1 year can be classified as 0, 5 years as 1, 10 years as 2, and return periods greater than 10 as 3.

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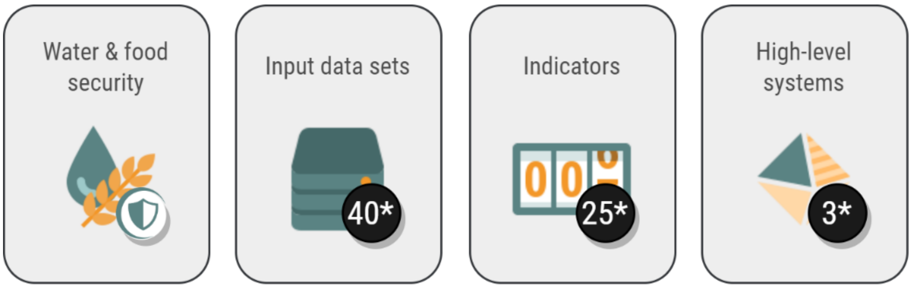
- UF-ID-4: Classes are defined according to the flooded area of the urban center of the AOI. If less than 2% of the centre are flooded, a value of 0 is assigned; 1 for up to 10%; 2 for up to 30%; and 3 if more than 30% of the centre are flooded.
- UF-ID-5: Classes are determined by calculating the proportion of the total number of elements classified with damage classes such as 0 for none, 1 for low, 2 for medium, and 3 for high.
- UF-ID-6: This indicator's main purpose is to provide data to validate and refine UF-ID-5 it is not considered for the impact assessment model.

In conclusion, this conceptual model provides a framework that helps in understanding the primary components of the urban flood system, along with their interactions. The dual-phase system described in this section relies on historical, current, and prospective data to enhance monitoring of flood-prone urban areas. Composite indexes, based on a combination of meteorological, flood, socio-economic and media-derived indicators not only allow to monitor and predict urban flood events, but also to gain insights into their (potential) impact on populations, urban habitats, and assets.

3.3.2 Water and food security indexes

CENTAUR's WFS track focuses on developing applications for early warning, situational awareness, and analysis around drought-related risk to human security (including food security, livelihoods, political stability, and displacements). In this context, the CENTAUR team develops a **Risk monitoring** and a **Situation monitoring** tool, as well as a **Data viewer** (dashboard) for situational awareness and analysis of relevant data (Figure 11).

Figure 11: The WFS track and its conceptual model in numbers. * indicates the number is liable to change during the project, due to unforeseen circumstances (e.g., additional input data required for validation, indicator not computed due to complexity in data collection, creation of a new index, etc.). Moreover, some input data sets are shared with the UF track.



All three applications rely on input data and innovative indicators previously defined as part of deliverable D1.1 ([RD03]). Figure 12 gives an overview of meteorological and vegetation indicators (shown in light blue), as well as socioeconomic and demographic indicators (light purple) that are combined into composite indices (dark purple) that ultimately feed into the three applications (dark blue). For the sake of simplicity, input data for all indicators is not shown here. The interested reader is invited to consult deliverable D2.1 ([RD04]) where input data and data sources for every indicator are detailed.

Figure 12 also shows how the three applications interact. Data and indicators for the **Risk monitor** are produced on a continuous basis for all countries covered (while developing the application, CENTAUR focusses first on Somalia, Mali, and Mozambique but further countries could be added as the project progresses). Based on these data, the risk monitor produces regular forecasts for four risks: drought-induced risks for food security (1) and economic security (2), as well as drought-related risks of political instability and violence (3) and forced displacement (4).

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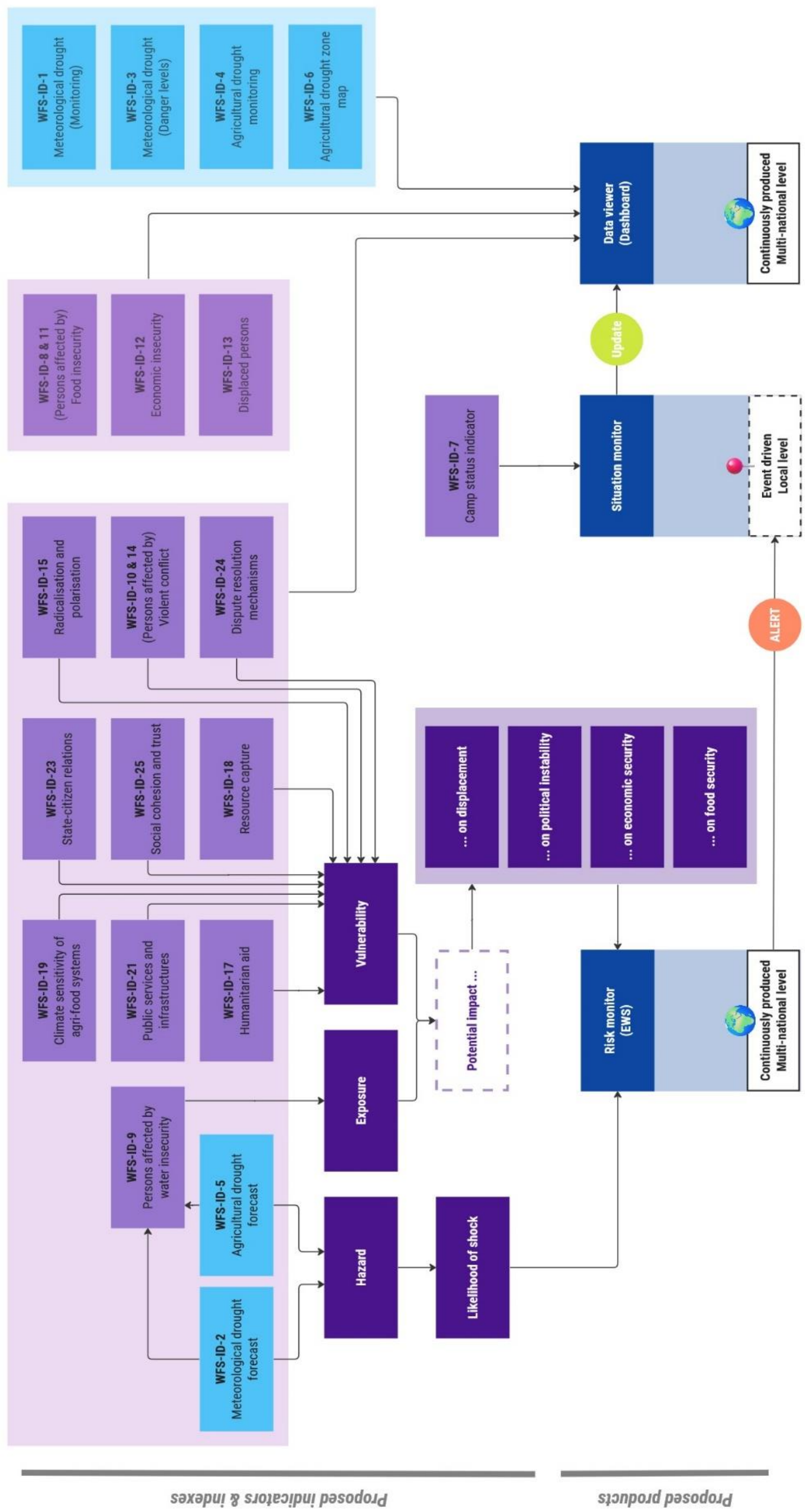

Figure 12: Conceptual model for the water and food security track.

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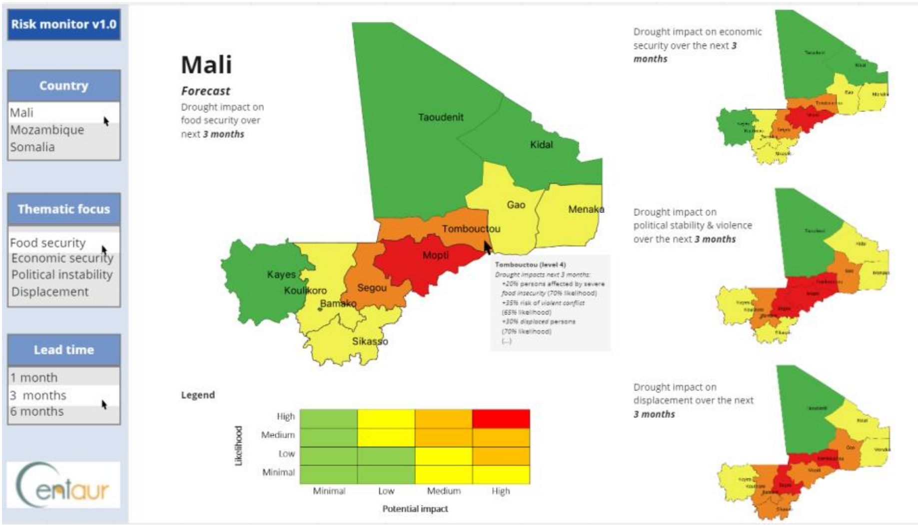
Last but not least, all data produced will be accessible through a user-friendly interface in the **Data viewer**[14] that will allow for zooming in on specific areas, access context-specific information (e.g., from social and traditional media sources), and visualize trends across time (including available forecasts).

Risk monitor

The **risk monitor** is at the core of CENTAUR's WFS track. It synthesizes several meteorological, agricultural, demographic, socioeconomic, and political indicators into an intuitive and actionable metric. This metric differentiates the **likelihood** of an adverse shock – a drought in this case - from its **potential impacts** – in this case on food security, livelihoods, political stability, and the displacement of people – along two axes of a risk matrix (see Figure 10 in the previous section). Using these two dimensions is common practice in **forecasting for anticipatory action**[11] and allows to capture both situations of low-probability impacts with a high potential to cause harm and situations of low-level impact events with high probability.

Forecast produced by the Risk monitor could be visualised and made accessible in a dedicated section of the Data viewer dashboard (see for example Figure 13). Further formats are possible, e.g., a PDF report emailed to users once a certain threshold is crossed on one or more of the risk indices.

Figure 13: Rudimentary design proposal for the risk monitor. The dashboard allows to visualise all four risks simultaneously on four choropleth maps that show the forecasted level of risk for each index. More detailed information can be obtained by hovering over the administrative units in the map at the centre, including more precise information on anticipated effects (e.g., 72% chance of a 31% increase in food insecurity in the next 3 months).



The scalability of the risk monitor and its extension to further countries will be assessed in collaboration with the advisory board and key users as the CENTAUR project progresses.

Four composite risk indices

Four composite risk indices are produced by the Risk monitor up to a few months in advance:

- Drought-induced increase in food insecurity.
- Drought-induced increase in economic insecurity.
- Drought-related instability and violence.
- Drought-related displacement.

[14] Both the Situation monitor and the Data viewer will be further developed and fleshed out as part of WP2 and WP4.

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It is important to note here that the indices do not provide a measure of the absolute level of food insecurity or violence, or of the absolute number of displaced people to expect, but rather a **measure of additional strains** to expect in connection with imminent drought conditions. Forecasts of the Risk monitor thus *always need to be interpreted against the backdrop of prevailing humanitarian and security conditions* in monitored areas. Therefore, the user is always encouraged to explore the Data viewer for contextual information.

Also, the risk monitor will never display high values in the absence of predicted drought conditions, making it a strictly climate-sensitive tool, which sets it apart from other systems like ACLED cast[15], UNEP STRATA[16] or INFORM subnational[17]. That being said, data and forecasts for absolute levels of violence, food insecurity etc., irrespective of drought, can always be accessed via the Data viewer.

Risk dimensions and components

The **composite risk indices** measure risk at the intersection of *hazard*, *exposure*, and *vulnerability*, as defined in the 5th Assessment Report of the Intergovernmental Panel on Climate Change[18]. Measures for the three dimensions are multiplied to produce risk indices in CENTAUR.

- **Hazard** defines the likelihood of an adverse event like drought occurring. In CENTAUR's WFS track it is computed based on a meteorological forecast indicator (WFS-ID-3)[19] and a forecast indicator for agricultural drought based on vegetation data (WFS-ID-5). The same data and computation methods are used for all four risk indices.
- **Exposure** determines who (or what) is potentially exposed to the hazard. In CENTAUR, exposure is computed based on high resolution population estimates and forecasts that capture the number of people exposed to water insecurity (WFS-ID-8). The same data and computation methods are used for all four risk indices.
- **Vulnerability** determines the extent to which people, assets, and infrastructures potentially exposed to the hazard can be adversely affected by it. A number of indicators can be used to measure vulnerability to climate-related security risks[20]. In CENTAUR, vulnerability is computed based on several socioeconomic and political indicators: Climate-sensitivity of agricultural and food systems (WFS-ID-19), availability of humanitarian aid (WFS-ID-17), quality of public services (WFS-ID-21), and disruptions by violent conflicts (WFS-ID-14) to represent the vulnerability of people and local economies to the effects of drought; indicators for the quality of social cohesion (WFS-ID-25) and state-citizen relations (WFS-ID-23), as well as for social/political tensions (WFS-ID-15 and WFS-ID-18), and the weakness of conflict resolution institutions (WFS-ID-24) to capture the susceptibility of drought-affected areas to political instability and conflict. Different data will be used for each one of the four risk indices based on how well they predict the variable of interest - i.e. food insecurity, economic insecurity, political instability and violence, displacement. Depending on the structure in the underlying data (e.g., variance and correlations between indicators, missing values etc.), the CENTAUR team will determine the most appropriate computation method for each risk index. WFS-ID-11 to 14 will be used for validation of the above indicators and calibration of predictive models.

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[15] Raleigh, C., Linke, R., Hegre, H., & Karlsen, J. (2010). Introducing ACLED: An Armed Conflict Location and Event Dataset. Journal of Peace Research, 47(5), 651–660. https://doi.org/10.1177/0022343310378914

[16] Young, H. R., Cha, Y., Den Boer, H., Schellens, M., Nash, K., Watmough, G. R., Donovan, K., Patenaude, G., Fleming, S., Butchart, B., & Woodhouse, I. H. (2023). Strata: Mapping climate, environmental and security vulnerability hotspots. Political Geography, 100, 102791. https://doi.org/10.1016/j.polgeo.2022.102791

[17] https://drmkc.jrc.ec.europa.eu/inform-index

[18] IPCC. (2014). Climate Change 2014: Synthesis Report. (p. 151). IPCC. https://www.ipcc.ch/site/assets/uploads/2018/05/SYR_AR5_FINAL_full_wcover.pdf

[19] A detailed description of all indicators and underlying data is provided in CENTAUR deliverables D1.1 ([RD03]) and D2.1 ([RD04]).

[20] Adrien, D., & Adrian, F. (2023, June 20). Context matters: A review of the evidence of how social, economic, and other variables influence the relationship between climate and security | Weathering Risk. Weathering Risk. https://weatheringrisk.org/en/publication/context-matters

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In conclusion, activities in the WFS track aim at developing relevant forecasting and data exploration tools for humanitarian, development, and security-sector professionals. The emphasis is on tools that allow to predict likely changes in in food and economic security, displacement, and violent conflict in connection with imminent drought events, as well as to offer an intuitive interface for practitioners to seek more detailed background and historical data for relevant events and contexts.

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4 DEFINITION OF USE CASES

In line with CENTAUR's operational objectives to enhance the Copernicus EMS and SEA portfolios, several use cases were carefully selected (Figure 14). They serve to **evaluate the performance and added value of the proposed framework**, which includes the continuous monitoring system, early warning system, and foresight tools. Additionally, these use cases **highlight the potential of emerging datasets and methodologies** in Earth Observation for the detection of climate security and urban flood risks.

Figure 14: CENTAUR use cases in numbers. The cross-cutting use case could count towards the sum of use cases for each track. In this setting, there are 5 and 3 use cases for the UF and WFS tracks respectively. * indicates that the number of hot cases is liable to change depending on the circumstances (e.g., no crisis on an area of interest during the lifetime of the project).

Use cases correspond to areas of interest where crisis events have either transpired in the past, are currently unfolding, or are anticipated to occur during the project's duration. This temporal dimension categorizes them into **cold and hot cases**. Cold cases focus on past crisis events where validation data is on hand, facilitating the evaluation and calibration of methodologies, iterating between model and indicator development and testing. This **track changes driven process** is crucial in establishing an efficient and robust system before its deployment on hot cases and in demonstrating the strength of our framework.

Prior to the launch of CENTAUR, an **initial set of 22 use cases was pre-selected**. This selection underwent a prioritization process, guided by feedback from stakeholders such as Copernicus EMS and SEA end-users. The primary goal was to curate use cases that not only showcase comprehensiveness but also highlight the adaptability and reproducibility of the proposed framework in various settings.

Following this initial screening, the final selection of use cases (Figure 15) was based on several criteria. Most importantly cases were selected according to their **pertinence to end-users** willing to participate in the project. Their involvement would encompass formulating expected requirements for the project, providing insights on crisis events, offering feedback, and supplying various forms of data, including those for validation purposes. In addition, different criteria were used to select cold and hot cases. The **cold case selection** was informed by a **comprehensive review of past crises**, predominantly major events, archived by Copernicus EMS and SEA. **Hot cases** were chosen based on the **likelihood of crises emerging or escalating** in the areas previously identified as cold cases, at a manageable scale and with immediate effect. Furthermore, cases for the Water and Food Security track of CENTAUR were selected as to highlight the interaction between expected climatic pressures, the resilience and vulnerability of impacted populations, and potential threats to political stability and peace. With the support of the Advisory Board, this selection might be broadened to encompass newly emerging hot cases as the project progresses.

The **final selection comprises seven use cases in total** (Table 6). For the UF track, there are four use cases, which include **four cold cases** and **three hot cases**. Meanwhile, the WFS track features three use cases, each serving as both cold and hot cases. Notably, both tracks have a use case in Mozambique. This **cross-cutting demonstrator** will

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help evaluate the synergies of proposed methodologies and assess the framework's performance in contexts susceptible to both categories of crisis events.

Figure 15: use cases evaluated within CENTAUR. The primary use cases will undergo comprehensive evaluation within the CENTAUR project during WP4. Additionally, optional use cases may be considered for exploration, primarily if further calibration or validation is deemed necessary, or in instances where a main use case encounters impediments that hinder partial or complete evaluation.

Table 6: Summary of the main CENTAUR use cases.

Use Case	Scope	Cold Case	Hot Case*
Ebro basin, Spain	Urban Flood	✓	✓
Piedmont region, Italy	Urban Flood	✓	✓
Bad Neuenahr-Ahrweiler, Germany	Urban Flood	✓	✗
Landes, France	Urban Flood	✓	✓
Somalia	Water and Food Security	✓	✓
Mali	Water and Food Security	✓	✓
Mozambique	Cross-cutting	✓	✓

** Depending on the occurrence of an event during the project lifetime*

The specific area studied for each use case was chosen either by CENTAUR partners or suggested by the end-users. The selection was finalized during a **User Requirement Review** (URR) on June 8, 2023, which resulted in the creation of one working group per use case, in order to organize work and data collection. Moreover, some end-users and partners proposed **additional use cases** (Figure 15). These will be considered either for calibration, as backup, or as potential supplementary demonstrators in the future.

The 7 use cases feature a broad spectrum of challenges, showcasing CENTAUR's ability to adapt to diverse and complex crisis situations.

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Use cases for urban floods

The use cases **selected for the UF track** focus on well-known events. Located in flood-prone areas, the availability of historical data and extensive support from end-users will help characterize the main components of a prototypical urban flood risk assessment.

The **Ebro basin in Spain**, marked by recurring flood events and a medium hazard level for riverine floods[21], offers a unique context. Notably, since the 1960s, the channelization of the Ebro river and its tributaries, coupled with rapid urbanization and soil sealing, has escalated both flood occurrences and resultant damages. In response, comprehensive initiatives, including hydro-geomorphological restoration and improved land planning, have been implemented to progressively mitigate flood risks[22]. This use case employs an extensive archive of meteorological data, land cover metrics, and hydrological records, in addition to VHR LiDAR scans, to assess CENTAUR's effectiveness in regions with intricate river systems and urban layouts.

Focusing on the **Piemonte region** surrounding the Po river, the Italian use case also delves into frequent flood events. Archive data indicates that the region has faced a crisis event every 2 years on average since 1800[23]. Given its medium hazard level for riverine floods[24], the region is especially susceptible to flooding. With a dense population and an abundance of infrastructure, particularly industrial, measures like levee construction and real-time forecasting have been implemented for flood risk mitigation[25]. Augmented by high-resolution datasets and LiDAR scans, this use case enables the integration of advanced 3D modelling techniques for enhanced flood prediction and impact evaluation.

In July 2021, severe rainfall led to devastating floods in **Germany's Ahr Valley** and tributaries of the Rhine and Saar. This event in particular is said to be amongst the most destructive ones within the last five decades, causing up to EUR 32 billion in damage in the affected regions[26]. Rhineland-Palatinate, the Land in which the use case is located, has a medium hazard level for riverine floods[27]. Bad Neuenahr-Ahrweiler and neighbouring villages were especially affected, due to their location downstream of steep slopes, with little to no natural mitigating factors to prevent destruction and human fatalities[26].

From December 2020 to February 2021, **France** saw a 30% rise in average rainfall, leading to significant flooding, especially in south-western regions like Dax and Tartas. The Landes region, in which the use case is located, has a high hazard level for riverine floods[28]. In Dax, water levels neared historic records from the 1980s and 1990s, while Tartas experienced its second-highest water level since 1843. The Copernicus EMS Rapid Mapping service documented this extensive flooding in early 2021.

Use cases for water and food security

The selected use cases **for the WFS track** are regions where climate security implications are the most severe. Their challenges encompass erratic precipitation patterns, seasonal water scarcity, violent conflicts, displaced

[21] https://thinkhazard.org/en/report/25786-spain-aragon-zaragoza/FL
[22] Tomás, A. C., Cañero, D. G., Fernández, L. P., Santaengracia, M. L. M., Duque, M. P., & Saldaña, J. S. R. (2020). Prevention, protection, preparation and repair: Measures to reduce flood risk along the axis. Consor Seguros Revista Digital. Number 12, Spring 2020.
[23] Rabuffetti, D., & Barbero, S. (2003). Italy: Piemonte Region meteo-hydrological alert and real-time flood forecasting system (Integrated Flood Management, p. 12) [Case study]. WMO/GWP APFM. https://www.floodmanagement.info/publications/casestudies/cs_italy_full.pdf
[24] https://thinkhazard.org/en/report/1627-italy-piemonte/FL
[25] Franzi, L., Bianco, G., Bruno, A., & Foglino, S. (2016). Flood Risk Assessment and Quantification in the Piedmont Region, Italy. In M. Tiepolo, Planning to cope with tropical and subtropical climate change (pp. 354–375). De Gruyter Open. https://doi.org/10.1515/9783110480795-021
[26] Mohr, S., Ehret, U., Kunz, M., Ludwig, P., Caldas-Alvarez, A., Daniell, J. E., Ehmele, F., Feldmann, H., Franca, M. J., Gattke, C., Hundhausen, M., Knippertz, P., Küpfer, K., Mühr, B., Pinto, J. G., Quinting, J., Schäfer, A. M., Scheibel, M., Seidel, F., & Wisotzky, C. (2022). A multi-disciplinary analysis of the exceptional flood event of July 2021 in central Europe. Part 1: Event description and analysis [Preprint]. Hydrological Hazards. https://doi.org/10.5194/nhess-2022-137
[27] https://thinkhazard.org/en/report/1318-germany-rheinland-pfalz/FL
[28] https://thinkhazard.org/en/report/16242-france-aquitaine-landes/FL

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Company General Use

populations, and extremism. These contexts are well suited for developing and testing applications that monitor and help anticipate climate impacts on livelihoods, (food) security, and displacement.

Mali, situated in the climate-vulnerable Sahel, faces periodic water deficits and erratic precipitation. Climatic trends and extreme weather events further strain communal relations, deepen poverty, and undermine rural livelihoods. Moreover, tensions between farmers and herders are magnified due to the activity of extremist groups and militias. Mali's situation offers insights that might be useful for understanding broader climate security trends in the Sahel region.

Somalia has faced persistent droughts since 2020, due to successive failed rainy seasons. This excessive drought has driven many to relocate, primarily to urban centres, in pursuit of water, sustenance, and economic opportunities. Moreover, armed groups, such as Al Shabaab, exploit climate-related crises, presenting themselves as relief providers. The insights from this case study are relevant for assessing climate security risks in other countries in the Horn of Africa as well.

Use case for the cross-cutting analysis

Finally, **Mozambique, the use case selected for a cross-cutting analysis**, is an example for the convergence of climate vulnerabilities, disaster risks, and the growing threat of violent extremism.

Mozambique, primarily a coastal lowland region, is highly susceptible to rising temperatures, cyclones, and tropical storms. The country has faced repeated climatic events in recent years, notably the 2019 Idai Tropical Cyclone which severely impacted the city of Beira, especially its vulnerable slums. Moreover, agriculture is crucial in Mozambique, supporting over 80% of its population. Flooding in this region is often known for its devastating consequences on food storage, crop hectares, and fisheries infrastructure. Concurrently, since 2017, the Northern Province of Cabo Delgado has witnessed upheaval due to insurgent extremist groups. Given Mozambique's recurring climatic challenges and political instability, it is quite possible that the country might experience an intensification of climate security threats, both in terms of urban floods and fragility in connection with water and food insecurity, over the duration of CENTAUR.

4.1 URBAN FLOOD USE CASES

The use cases for urban flood analysis correspond to AOIs of past Copernicus EMS activations. Therefore, all relevant input layers for these use cases have been gathered at a scale appropriate to each specific activation. Consequently, the creation of indicators and indexes will also be carried out at these corresponding scales.

4.1.1 Ebro basin, Spain

The Spanish Directorate General of Civil Protection has provided damage documentation related to the April 2018 episode collected by the Government Delegation in Zaragoza. This document shows the results of an exhaustive job of compiling data on damage per municipality throughout the Zaragoza area. The Directorate General of Civil Protection has facilitated Tracasa's contact with the Ebro Hydrographic Confederation (CHE). The CHE is the management, regulatory and maintaining body of the waters and rivers of the Ebro hydrographic basin. This body generates and shares a multitude of data to monitor and manage the Ebro River. The partners asked for access to the collection of oblique images during the flood that occurred in April 2018 within the limits of the AOI. CHE is analysing the request.

The context for the Spanish use case is described in Table 7. The data sets that have been collected are listed in Table 8, Table 9 and

Table 10 for post-event data, pre-event data and socioeconomic data respectively.

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Table 7: Ebro use case description.

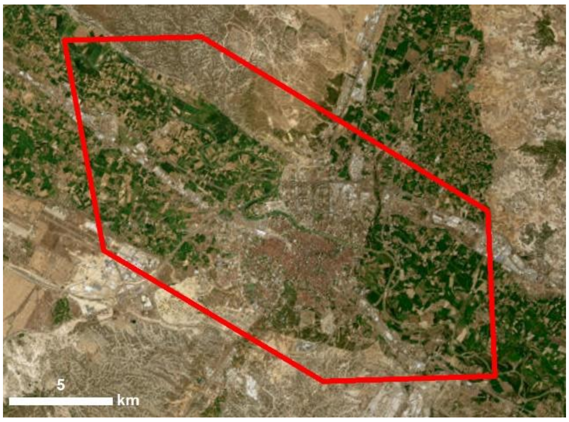
Country	Spain	
Locality	Zaragoza	
Event type	Riverine flood	
Event date (cold case)	12/04/2018	
Context	Since 12th April 2018, an extraordinary flood event is occurring in the Ebro basin due to the snow that is melting in the Pyrenees. The first flooded areas were registered in Castejón (Navarra) and the peak in Zaragoza city is foreseen on 15th April around 12:00 UTC.	
Use Case objective	Map potentially major urban flood, map flood depth	
UF Indicator list	UF-ID-1, UF-ID-2UF-ID-3, UF-ID-4, UF-ID-5, UF-ID-6, UF-ID-7	
SE indicator list	UF-ID-14	
Index list	Early warning forecast index Flood hazard index	

Table 8: Archive post-event data available for the Ebro use case.

Type	Date	Source	Comment or quicklook
SPOT-7	14/04/2018 10:33 UTC	AIRBUS	Partial coverage of the AOI  UF-ID-3, UF-ID-5

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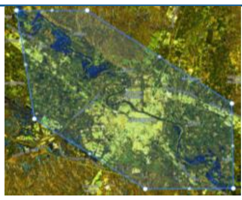
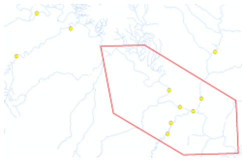
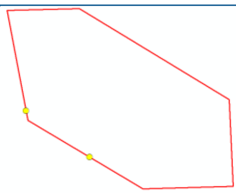
Type	Date	Source	Comment or quicklook
SkySat	14/04/2018 10:51 UTC	Planet Explorer	Partial coverage of the AOI  UF-ID-3, UF-ID-5
Sentinel-1	13/04/2018 17:54 UTC	COPERNICUS	 UF-ID-4
Oblique aerial images	14 -17/04/ 2018	CHE	 UF-ID-3
Event water gauges for Ebro Basin for de analysed event.	04/2018	SAIH Ebro, CHE	Level, flow, rainfall  UF-ID-3, UF-ID-5
Rainfall data for Zaragoza	04/2018	AEMET	 UF-ID-1, UF-ID-2

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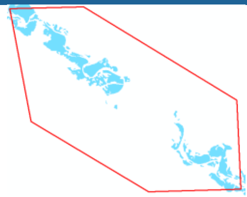
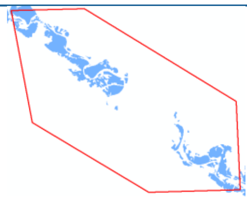
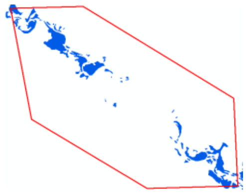
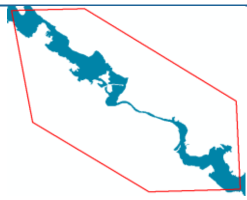
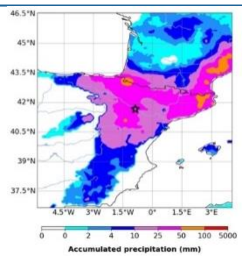
Type	Date	Source	Comment or quicklook
CEMS Flood masks	16/04/2018	CEMS RM 16/04/2018 from COSMO-SkyMed	 UF-ID-3, UF-ID-5
	15/04/2018	CEMS RM 15/04/2018 from RADARSAT 2	 UF-ID-3, UF-ID-5
	13/04/2018	CEMS RM 13/04/2018 from S1	 UF-ID-3, UF-ID-5
CHE Flood masks	14 -17/04/ 2018	CHE	 UF-ID-3, UF-ID-5
Precipitation	11/04/2018	E-OBS	 UF-ID-1, UF-ID-2

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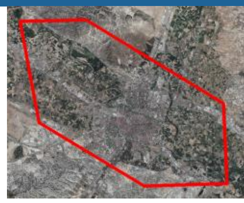
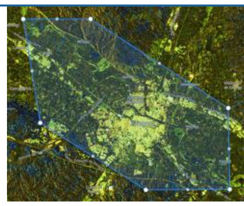
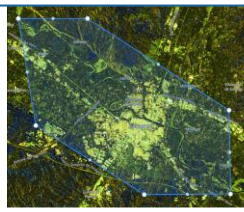
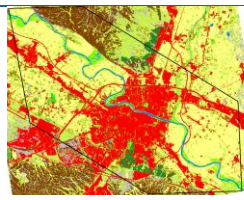
Type	Date	Source	Comment or quicklook
Social media markers	Since 2018	Traditional and social media	 UF-ID-5

Table 9: Archive pre-event data available for the Ebro use case.

Type	Date	Source	Comment or quicklook
ORTHO PNOA18	2018	CNIG	 UF-ID-3, UF-ID-5
Sentinel-1A	20/03/2018 17:54 UTC	COPERNICUS	 UF-ID-4
Sentinel-1A	01/04/2018 17:54 UTC	COPERNICUS	 UF-ID-4
CLC+	2018	COPERNICUS Land 2018	 UF-ID-3, UF-ID-5

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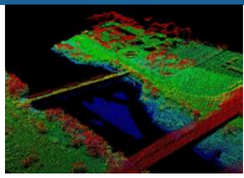
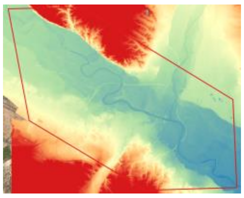
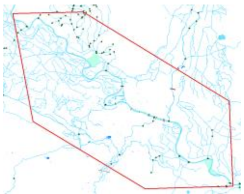
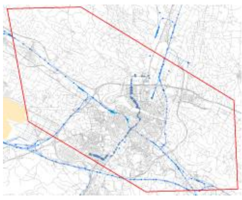
Type	Date	Source	Comment or quicklook
LiDAR - PNOA 2a cobertura	2016	CNIG	 UF-ID-3, UF-ID-5, UF-ID-9, UF-ID-10, UF-ID-13
MDT02 - PNOA 2a cobertura	2016	CNIG	 UF-ID-3, UF-ID-5
MDT14 - ARPSI	2014	MITECO	 UF-ID-3, UF-ID-5
Hydro DH_Ebro	2019	CHE	 UF-ID-3, UF-ID-5
Roads & Transport RT_ZARAGOZA	2023	CNIG	 UF-ID-9, UF-ID-13
MHFP CADASTRE	2023	MHFP	 UF-ID-9

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Company General Use

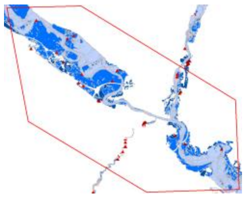
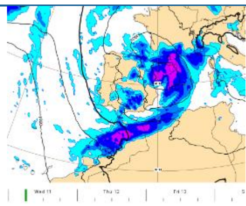
Type	Date	Source	Comment or quicklook
SNCZI Flood Hazard mask T10, T50, T100, T500	N/A	MITECO/CHE	 UF-ID-3, UF-ID-5
SNCZI Flood Risk mask T10, T100, T500	N/A	MITECO/CHE	Economic activity, affected population, points of interest  UF-ID-3, UF-ID-5
Precipitation forecast (6h)	10/04/2018	ECMWF high-resolution forecast	 UF-ID-1, UF-ID-2

Table 10: Socio-economic data available for the Ebro use case.

Type	Date	Source	Comment or quicklook
Built-up settlements (WSF-Binary)	From 2016 onwards	DLR	 (e.g., 2019) UF-ID-4, UF-ID-5, UF-ID-7
Building volume (WSF-3D)	2012	DLR	 UF-ID-4, UF-ID-5, UF-ID-9

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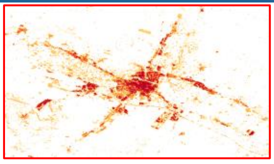
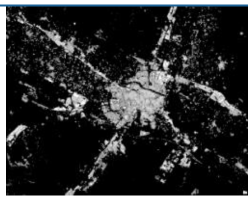
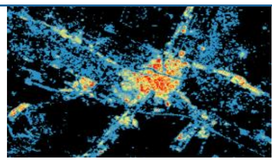
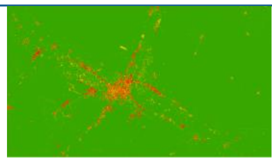
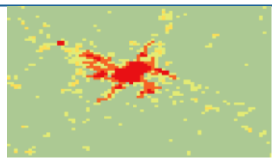
Type	Date	Source	Comment or quicklook
Population (WSF-Pop)	From 2016 onwards	DLR	 (e.g., 2019) UF-ID-5, UF-ID-7
Built-up settlements (GHS-BUILT-S)	1975-2020 (5 years interval); 2025 and 2030	JRC - GHSL Data portal	 (e.g., 2020) UF-ID-4, UF-ID-5, UF-ID-7
Building volume (GHS-BUILT-V)	1975-2020 (5 years interval); 2025 and 2030	JRC - GHSL Data portal	 (e.g., 2020) UF-ID-4, UF-ID-5
Boundaries of Human Settlements with functional use (GHS-BUILT-C)	2018	JRC - GHSL Data portal	 UF-ID-7
Degree of Urbanisation (GHS-SMOD)	1975-2020 (5 years interval); 2025 and 2030	JRC - GHSL Data portal	 (e.g., 2020) UF-ID-7

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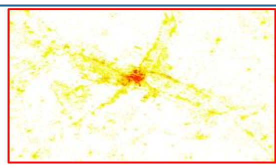
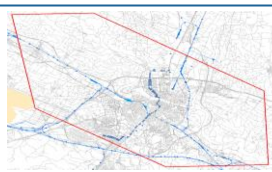
Type	Date	Source	Comment or quicklook
Degree of urbanisation classification (GHSL-DUC)	1975-2020 (5 years interval); 2025 and 2030	JRC - GHSL Data portal	GADM41 units with different attributes derived from GHS-SMOD, GHS-POP, etc.  (e.g., ADMIN4) UF-ID-7
Population (GHS-Pop)	1975-2020 (5 years interval); 2025 and 2030		 (e.g., 2020) UF-ID-5, UF-ID-7, UF-ID-9, UF-ID-13
Social/Traditional media indicator on public services and (government) support	2018	Open-source providers	Latest available data pre- or during crisis, rough localisation. UF-ID-10
Social/Traditional media indicator on ability to evacuate	2018	Open-source providers	Earliest available data post- or during crisis, rough localisation. UF-ID-13
Social/Traditional media data on economic impacts of floods	2018	Open-source providers	Earliest available data post- or during crisis, rough localisation. UF-ID-14
OSM (Roads, highways, railways, distance to hospitals, etc.)	2018	OSM	Latest available pre-crisis data. UF-ID-13
Roads & Transport RT_ZARAGOZA	2023	CNIG	 UF-ID-5, UF-ID-7, UF-ID-9

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4.1.2 Piedmont region, Italy

Contrary to other use cases, Italy has two areas of interest, Turin Centre and Ceva Centre. Both correspond to different Copernicus EMS activations, with extensive documentation and a wealth of available data.

As a member of the Advisory Board committed to following the implementation of Italian use cases in the Piedmont Region, the Municipality of Turin has been providing support by facilitating bureaucratic procedures for LiDAR data acquisition in the Ceva area, in line with their ongoing contribution to the data collection process.

The context for the Italian use case in Turin Centre is described in Table 11. The data sets that have been collected are listed in Table 12,

Table 13 and Table 14 for post-event data, pre-event data and socioeconomic data respectively.

Table 11: Turin Centre use case description.

Country	Italy	
Locality	Turin Centre	
Event type	Flood	
Event date (cold case)	21/11/2016 – 25/11/2016	
Context	Heavy rainfall - River Po: In November 2016, the Piedmont region was affected by a flood event triggering persistent and abundant rainfall in the region. The most intense precipitation of the entire event was recorded on the 24th and the precipitation during the event led to significant increases in the water levels of the Piedmont's river network.	
Use Case objective	Map potentially major urban flood, map flood depth	
UF Indicator list	UF-ID-1, UF-ID-2, UF-ID-3, UF-ID-4, UF-ID-5, UF-ID-6, UF-ID-7	
SE indicator list	UF-ID-14	
Index list	Early warning forecast index Flood hazard index	

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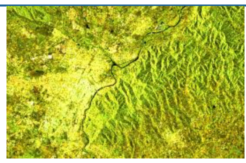
Company General Use

Table 12: Archive post-event data available for the Turin Centre use case.

Type	Date	Source	Comment or quicklook
Pléiades-1A	26/11/2016 10:41 UTC	CNES	
Sentinel-1B	23/11/2016 17:21 UTC	COPERNICUS	 UF-ID-4
Water gauges	2016	ARPA Piemonte	 UF-ID-3, UF-ID-5
Flood masks	24/11/2016[29]	ARPA Piemonte	 UF-ID-3, UF-ID-5

[29] The flood mask data for the 2016 flood were published by ARPA on November 24, 2017. The flooded areas were identified in the Turin area through terrain surveys conducted on November 24, 2016, and CNR imagery.

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Company General Use

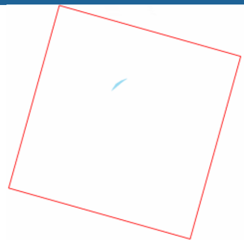
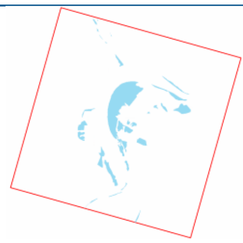
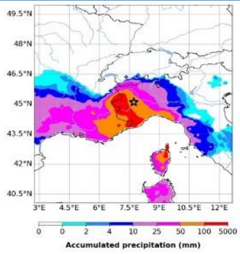
Type	Date	Source	Comment or quicklook
	27/11/2016	EMSR192 AOI06 Delineation Product (Cosmo-SkyMed)	 UF-ID-3, UF-ID-5
	26/11/2016	EMSR192 AOI16 Grading Product (Pleiades-1A)	 UF-ID-3, UF-ID-5
Precipitation	24/11/2016	E-OBS	 UF-ID-1, UF-ID-2
Social media markers	Since 2018	Traditional and social media	 UF-ID-5

Table 13: Archive pre-event data available for the Turin Centre use case.

Type	Date	Source	Comment or quicklook
Sentinel-1A	05/11/2016 17:22 UTC	COPERNICUS	 UF-ID-4

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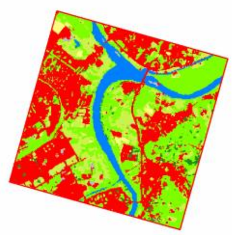
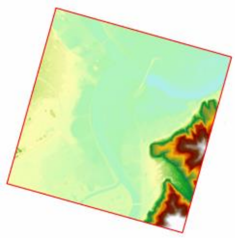
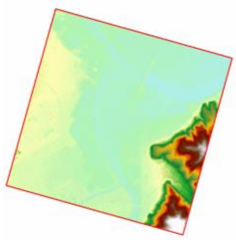
Type	Date	Source	Comment or quicklook
Sentinel-1B	11/11/2016 17:21 UTC	COPERNICUS	 UF-ID-4
VHR REF-OrthoImagery	2015	Geoportale Regione Piemonte (Data property rights: AGEA)	 UF-ID-3, UF-ID-5
CLC+	2018	COPERNICUS Land 2018	 UF-ID-3, UF-ID-5
DTMs	2009 MASE + 2022 PoliTO	Italian Ministry of the Environment and Energy Security (MASE) + Polytechnic University of Turin (PoliTO) – Digital Terrain Model (1 m)	 UF-ID-3, UF-ID-5
	2004-2005 AdBPo[3] + 2022 PoliTO	Po Basin Authority (AdBPo[3]) + Polytechnic University of Turin (PoliTO) – Digital Terrain Model (2 m)	 UF-ID-3, UF-ID-5

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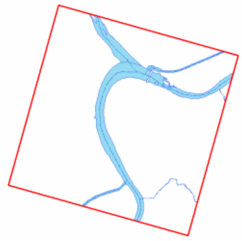
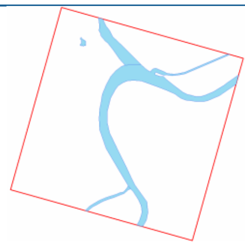
Type	Date	Source	Comment or quicklook
Hydrography	First release 2010; updates in 2016 and 2020	Geoportale Regione Piemonte (Data property rights: AGEA) Hydrography (polygon + line)	 UF-ID-3, UF-ID-5
	27/11/2016	EMSR192 AOI06 Hydrography (polygon)	 UF-ID-3, UF-ID-5
Land Cover	2021	Geoportale Regione Piemonte (Data property rights: AGEA) Land Cover	 UF-ID-3, UF-ID-5
	27/11/2016	EMSR192 AOI06 Land Cover	 UF-ID-3, UF-ID-5
Building Footprints	First release 2022; update 2023	Geoportale Regione Piemonte (Data property rights: AGEA)	 UF-ID-5, UF-ID-7, UF-ID-9

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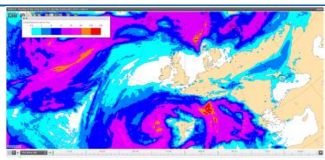
Type	Date	Source	Comment or quicklook
Transportation data	First release 2010; updates in 2020 and in 2022	Geoportale Regione Piemonte (Data property rights: AGEA)	 UF-ID-10, UF-ID-13
	27/11/2016	EMSR192 AOI06 Transportation (line)	 UF-ID-10, UF-ID-13
Census Data	2016	Comune di Torino	N/A UF-ID-7, UF-ID-9, UF-ID-13
	2023 (updates every three months)	Comune di Torino	N/A UF-ID-7, UF-ID-9, UF-ID-13
Precipitation forecast (48h)	24/11/2016	ECMWF high-resolution forecast	 UF-ID-1, UF-ID-2
Social/Traditional media indicator on public services and (government) support	2018	Open-source providers	Latest available data pre- or during crisis, rough localisation. UF-ID-10
Social/Traditional media indicator on ability to evacuate	2018	Open-source providers	Earliest available data post- or during crisis, rough localisation. UF-ID-13
Social/Traditional media data on economic impacts of floods	2018	Open-source providers	Earliest available data post- or during crisis, rough localisation. UF-ID-14

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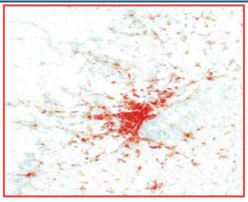
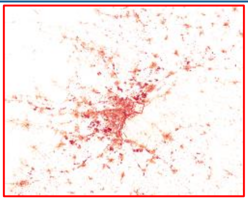
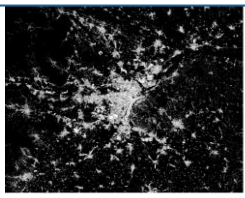
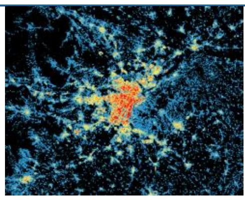
Table 14: Socio-economic data available for the Turin Centre use case.

Type	Date	Source	Comment or quicklook
Built-up settlements (WSF-Binary)	From 2016 onwards	DLR	 (e.g., 2019) UF-ID-4, UF-ID-5, UF-ID-7
Building volume (WSF-3D)	2012	DLR	 UF-ID-4, UF-ID-5, UF-ID-9
Population (WSF-Pop)	From 2016 onwards	DLR	 (e.g., 2019) UF-ID-5, UF-ID-7, UF-ID-9
Built-up settlements (GHS-BUILT-S)	1975-2020 (5 years interval); 2025 and 2030	JRC - GHSL Data portal	 (e.g., 2020) UF-ID-4, UF-ID-5, UF-ID-7
Building volume (GHS-BUILT-V)	1975-2020 (5 years interval); 2025 and 2030	JRC- GHSL Data portal	 (e.g., 2020) UF-ID-4, UF-ID-5, UF-ID-9

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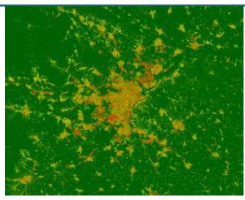
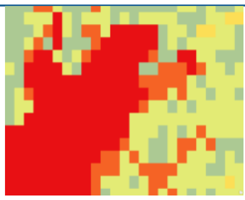
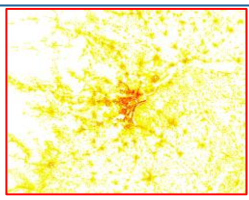
Company General Use

Boundaries of Human Settlements with functional use (GHS-BUILT-C)	2018	JRC- GHSL Data portal	 UF-ID-7
Degree of Urbanisation (GHS-SMOD)	1975-2020 (5 years interval); 2025 and 2030	JRC- GHSL Data portal	 (e.g., 2020) UF-ID-7
Degree of urbanisation classification (GHSL-DUC)	1975-2020 (5 years interval); 2025 and 2030	JRC- GHSL Data portal	GADM41 units with different attributes derived from GHS-SMOD, GHS-POP, etc.  (e.g., ADMIN3) UF-ID-7
Population (GHS-Pop)	1975-2020 (5 years interval); 2025 and 2030	JRC- GHSL Data portal	 (e.g., 2020) UF-ID-5, UF-ID-7, UF-ID-9, UF-ID-13

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Company General Use

The context for the Italian use case in Ceva Centre is described in Table 15. The data sets that have been collected are listed in Table 16, Table 17 and Table 18 for pre-event data, post-event data and socioeconomic data respectively.

Table 15: Ceva Centre use case description.

Country	Italy	
Locality	Ceva Centre	
Event type	Flood	
Event date (cold case)	02/10/2020 – 03/10/2020	
Context	Heavy rainfall - River Tanaro: Between October 2nd and 3rd, 2020, the Piedmont experienced exceptionally intense rainfall that affected the entire region. In the southern sectors, particularly in the Upper Tanaro area, there were very sudden and significant increases in water levels both along the main course of the Tanaro River and its secondary network. Specifically, at the Ponte di Nava and Garessio gauges, the historical values of 2016 were exceeded.	
Use Case objective	Map potentially major urban flood, map flood depth	
UF Indicator list	UF-ID-1, UF-ID-2, UF-ID-3, UF-ID-4, UF-ID-5, UF-ID-6, UF-ID-7	
SE indicator list	UF-ID-14	
Index list	Early warning forecast index Flood hazard index	

Table 16: Archive post-event data available for the Ceva Centre use case.

Type	Date	Source	Comment or quicklook
Sentinel-1A	03/10/2020 17:21 UTC	COPERNICUS	 UF-ID-4

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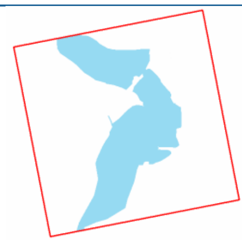
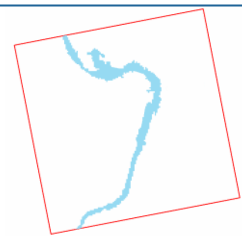
Type	Date	Source	Comment or quicklook
Water gauges	2020	ARPA Piemonte	 UF-ID-3, UF-ID-5
Flood masks	2020	ARPA Piemonte	 UF-ID-3, UF-ID-5
	03/10/2020	EMSR468 AOI02 Delineation Product (Sentinel-2B)	 UF-ID-3, UF-ID-5
Social media markers	Since 2018	Traditional and social media	 UF-ID-5

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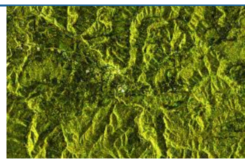
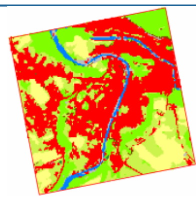
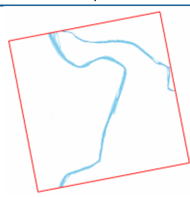
Table 17: Archive pre-event data available for the Ceva Centre use case.

Type	Date	Source	Comment or quicklook
Sentinel-1B	15/09/2020 17:22 UTC	COPERNICUS	 UF-ID-4
Sentinel-1B	27/09/2020 17:22 UTC	COPERNICUS	 UF-ID-4
VHR REF-OrthoImagery	2018	Geoportale Regione Piemonte (Data property rights: AGEA)	 UF-ID-3, UF-ID-5
CLC+	2018	COPERNICUS Land 2018	 UF-ID-3, UF-ID-5
DTM (1m) (to be Updated)	2009 MASE	Italian Ministry of the Environment and Energy Security (MASE)	 UF-ID-3, UF-ID-5
Hydrography	First release 2010; updates in 2016 and 2020	Geoportale Regione Piemonte (Data property rights: AGEA)	 UF-ID-3, UF-ID-5

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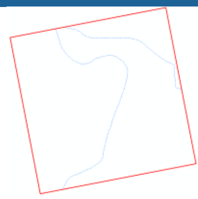
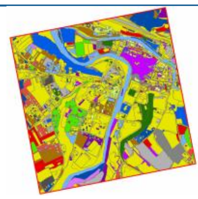
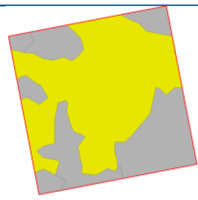
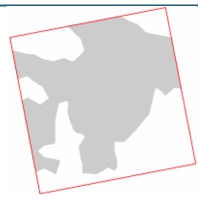
Type	Date	Source	Comment or quicklook
	03/10/2020	EMSR468 AOI02 Hydrography	 UF-ID-3, UF-ID-5
Land Use Land Cover	2021	Geoportale Regione Piemonte (Data property rights: AGEA)	 UF-ID-3, UF-ID-5
	03/10/2020	EMSR468 AOI02 Land Use	 UF-ID-3, UF-ID-5
Building Footprints	First release 2022; update 2023	Geoportale Regione Piemonte (Data property rights: AGEA) Buildings (polygon)	 UF-ID-5, UF-ID-7, UF-ID-9
	03/10/2020	EMSR468 AOI02 Built up	 UF-ID-5, UF-ID-7, UF-ID-9
Transportation data	First release 2010; updates in 2020 and in 2022	Geoportale Regione Piemonte (Data property rights: AGEA) Transportation (polygon)	 UF-ID-10, UF-ID-13

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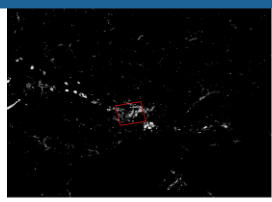
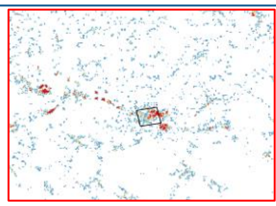
Type	Date	Source	Comment or quicklook
	03/10/2020	EMSR468 AOI02 Transportation (line)	 UF-ID-10, UF-ID-13
Social/Traditional media indicator on public services and (government) support	2018	Open-source providers	Latest available data pre- or during crisis, rough localisation. UF-ID-10
Social/Traditional media indicator on ability to evacuate	2018	Open-source providers	Earliest available data post- or during crisis, rough localisation. UF-ID-13
Social/Traditional media data on economic impacts of floods	2018	Open-source providers	Earliest available data post- or during crisis, rough localisation. UF-ID-14

Table 18: Socio-economic data available for the Ceva Centre use case.

Type	Date	Source	Comment or quicklook
Built-up settlements (WSF-Binary)	2016-to-present	DLR	 (e.g., 2019) UF-ID-4, UF-ID-5, UF-ID-7
Building volume (WSF-3D)	2012	DLR	 UF-ID-4, UF-ID-5, UF-ID-9

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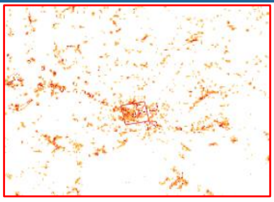
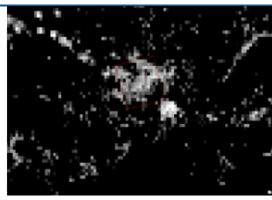
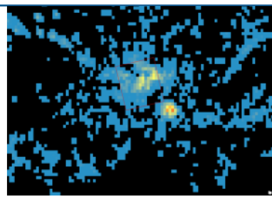
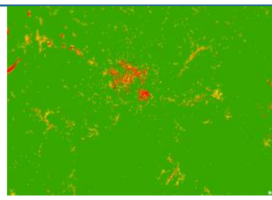
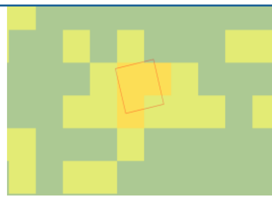
Type	Date	Source	Comment or quicklook
Population (WSF-Pop)	2016-to-present	DLR	 (e.g., 2019) UF-ID-5, UF-ID-7, UF-ID-9
Built-up settlements (GHS-BUILT-S)	1975-2020 (5 years interval); 2025 and 2030	JRC - GHSL Data portal	 (e.g., 2020) UF-ID-4, UF-ID-5, UF-ID-7
Building volume (GHS-BUILT-V)	1975-2020 (5 years interval); 2025 and 2030	JRC - GHSL Data portal	 (e.g., 2020) UF-ID-4, UF-ID-5, UF-ID-9
Boundaries of Human Settlements with functional use (GHS-BUILT-C)	2018	JRC - GHSL Data portal	 UF-ID-7
Degree of Urbanisation (GHS-SMOD)	1975-2020 (5 years interval); 2025 and 2030	JRC - GHSL Data portal	 (e.g., 2020) UF-ID-7

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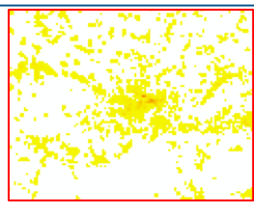
Type	Date	Source	Comment or quicklook
Degree of urbanisation classification (GHSL-DUC)	1975-2020 (5 years interval); 2025 and 2030	JRC - GHSL Data portal	GADM41 units with different attributes derived from GHS-SMOD, GHS-POP, etc.  (e.g., ADMIN3) UF-ID-7
Population (GHS-Pop)	1975-2020 (5 years interval); 2025 and 2030	JRC - GHSL Data portal	 (e.g., 2020) UF-ID-5, UF-ID-7, UF-ID-9, UF-ID-13

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4.1.3 Bad Neuenahr-Ahrweiler, Germany

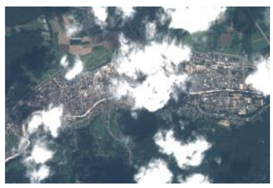
The BBK (Bundesamt für Bevölkerungsschutz und Katastrophenhilfe), Germany's Federal Office of Civil Protection and Disaster Assistance, has contributed to providing aerial imagery of the July 2021 floods. This imagery, captured by DLR and the Koblenz University of Applied Sciences, has been instrumental in crisis analysis. Additionally, the BBK facilitated communication between the consortium and the local authorities in Bad Neuenahr-Ahrweiler. This dialogue aimed to explore the possibility of accessing elevation and topographic data. Unfortunately, due to the costs associated with data acquisition, free access was not feasible. However, the established contacts have opened discussions for potential alternative solutions.

The context for the German use case is described in Table 19. The data sets that have been collected are listed in Table 20, Table 21 and Table 22 for post-event data, pre-event data and socioeconomic data respectively.

Table 19: Bad Neuenahr-Ahrweiler use case description.

Country	Germany	
Locality	Bad Neuenahr-Ahrweiler	
Event type	Heavy rainfall, riverine flood	
Event date (cold case)	13/07/2021	
Context	Exceptional rainfall event in Rhineland-Palatinate, Germany, leading to historic floods and major damage in urban areas	
Use Case objective	Map potentially major urban flood, map flood depth	
UF Indicator list	UF-ID-1, UF-ID-2, UF-ID-3, UF-ID-4, UF-ID-5, UF-ID-6, UF-ID-7	
SE indicator list	UF-ID-14	
Index list	Early warning forecast index Flood hazard index	

Table 20: Archive post-event data available for the Bad Neuenahr-Ahrweiler use case.

Type	Date	Source	Comment or quicklook
Pléiades-1A	18/07/2021 10:50 UTC	COPERNICUS	Partial coverage of the AOI 

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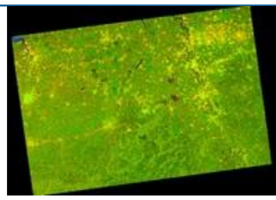
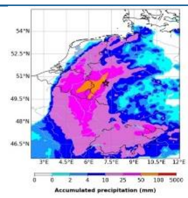
Type	Date	Source	Comment or quicklook
Pléiades-1B	20/07/2021 10:35 UTC	COPERNICUS	Full coverage of the AOI 
Sentinel-1A	17/07/2021 05:34 UTC	COPERNICUS	 UF-ID-4
Aerial imagery	16/07/2021	DLR	Partial coverage of the AOI  UF-ID-3, UF-ID-5
Water gauges	N/A	Rheinland Pfalz Open Data	 UF-ID-3, UF-ID-5
Flood masks	16/07/2021 (Aerial, 12 cm) 18/07/2021 (Pléiades) 20/07/2021 (Pléiades)	CEMS RM Grading products (Pléiades, 18/07 and 20/07/2021) DLR Flood masks (Aerial, 16/07/2021)	 UF-ID-3, UF-ID-5  UF-ID-3, UF-ID-5
Precipitation	13–14/07/2021	E-OBS	 UF-ID-1, UF-ID-2

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Company General Use

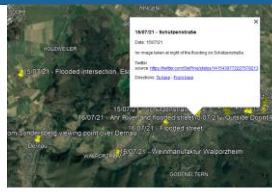
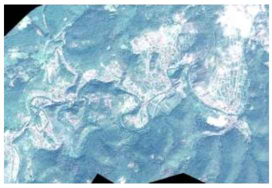
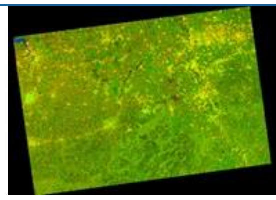
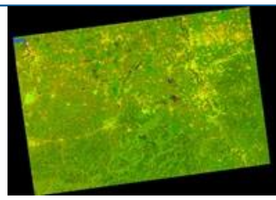
Type	Date	Source	Comment or quicklook
Social media markers	Since 2018	Traditional and social media	 UF-ID-5

Table 21: Archive pre-event data available for the Bad Neuenahr-Ahrweiler use case.

Type	Date	Source	Comment or quicklook
Pléiades-1A	24/02/2019 10:31 UTC	COPERNICUS	Full coverage of the AOI 
Pléiades-1B	08/09/2020 10:59 UTC	COPERNICUS	Partial coverage of the AOI 
Sentinel-1A	23/06/2021 05:34 UTC	COPERNICUS	 UF-ID-4
Sentinel-1A	05/07/2021 05:34 UTC	COPERNICUS	 UF-ID-4
Copernicus VHR	01/07/2018 14/07/2018 06/08/2018	COPERNICUS	To be collected UF-ID-3, UF-ID-5

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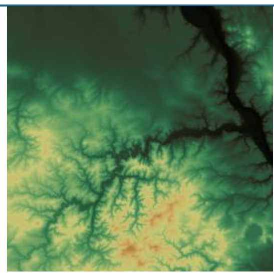
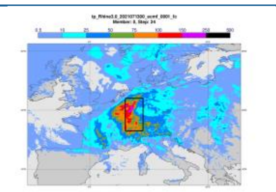
Type	Date	Source	Comment or quicklook
CLC+	2018	COPERNICUS Land 2018	 UF-ID-3, UF-ID-5
DTM (10 m)	2018	BKG	 UF-ID-3, UF-ID-5
Topographic data			 UF-ID-3, UF-ID-5, UF-ID-7, UF-ID-9, UF-ID-10, UF-ID-13
Precipitation forecast (72h)	13/07/2021	ECMWF high-resolution forecast	 UF-ID-1, UF-ID-2
Social/Traditional media indicator on public services and (government) support	2018	Open-source providers	Latest available data pre- or during crisis, rough localisation. UF-ID-10
Social/Traditional media indicator on ability to evacuate	2018	Open-source providers	Earliest available data post- or during crisis, rough localisation. UF-ID-13
Social/Traditional media data on economic impacts of floods	2018	Open-source providers	Earliest available data post- or during crisis, rough localisation. UF-ID-14

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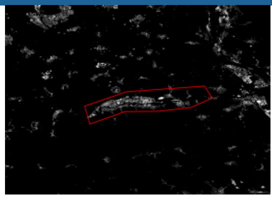
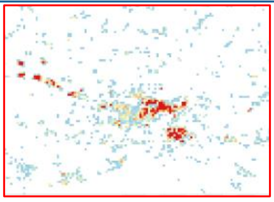
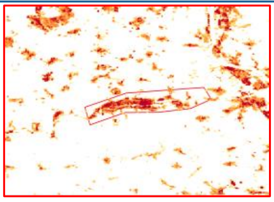
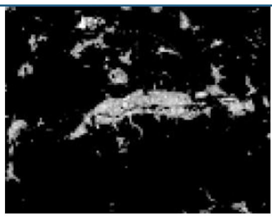
Table 22: Socio-economic data available for the Bad Neuenahr-Ahrweiler use case.

Type	Date	Source	Comment or quicklook
Built-up settlements (WSF-Binary)	From 2016 onwards	DLR	 (e.g., 2019) UF-ID-4, UF-ID-5, UF-ID-7
Building volume (WSF-3D)	2012	DLR	 UF-ID-4, UF-ID-5, UF-ID-9
Population (WSF-Pop)	From 2016 onwards	DLR	 (e.g., 2019) UF-ID-5, UF-ID-7, UF-ID-9
Built-up settlements (GHS-BUILT-S)	1975-2020 (5 years interval); 2025 and 2030	JRC- GHSL Data portal	 (e.g., 2020) UF-ID-4, UF-ID-5, UF-ID-7

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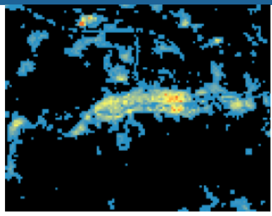
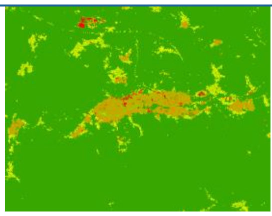
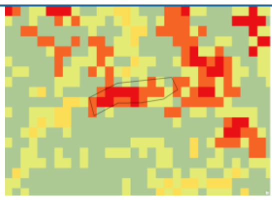
Company General Use

Type	Date	Source	Comment or quicklook
Building volume (GHS-BUILT-V)	1975-2020 (5 years interval); 2025 and 2030	JRC- GHSL Data portal	 (e.g., 2020) UF-ID-4, UF-ID-5, UF-ID-9
Boundaries of Human Settlements with functional use (GHS-BUILT-C)	2018	JRC- GHSL Data portal	 UF-ID-7
Degree of Urbanisation (GHS-SMOD)	1975-2020 (5 years interval); 2025 and 2030	JRC- GHSL Data portal	 (e.g., 2020) UF-ID-7
Degree of urbanisation classification (GHSL-DUC)	1975-2020 (5 years interval); 2025 and 2030	JRC- GHSL Data portal	GADM41 units with different attributes derived from GHS-SMOD, GHS-POP, etc.  (e.g., ADMIN4) UF-ID-7

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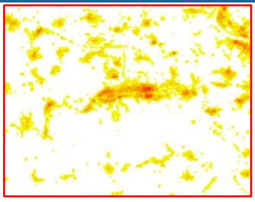
Type	Date	Source	Comment or quicklook
Population (GHS-Pop)	1975-2020 (5 years interval); 2025 and 2030	JRC- GHSL Data portal	 (e.g., 2020) UF-ID-5, UF-ID-7, UF-ID-9, UF-ID-13

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4.1.4 Landes, France

As a member of CENTAUR's Advisory Board, CCR (French reinsurance company) has supported the use case definition process with recommendations to enlarge the original Area of Interest focused on the city of Dax, based on their own database. They also suggested useful ancillary information that can be used for validation purposes, such as the "Repères de crues" database[30] that collects high water marks in France.

The context for the French use case is described in Table 23. The data sets that have been collected are listed in Table 24, Table 25 and Table 26 for post-event data, pre-event data and socioeconomic data respectively.

Table 23: Landes use case description.

Country	France	
Locality	Dax to Mont-de-Marsan	
Event type	Storm Bella, heavy rainfall	
Event date (cold case)	01/01/2021	
Context	Part of the Landes department has started the year dealing with heavy rainfall (corresponding to the passage of storm Bella). The heavy rain combined with soils saturated with water due to the rainfall in the previous weeks, caused significant overflows of rivers which have reached historic levels in some places.	
Use Case objective	Map potentially major urban flood Flood depth	
UF Indicator list	UF-ID-1, UF-ID-2, UF-ID-3, UF-ID-4, UF-ID-5, UF-ID-6, UF-ID-7	
SE indicator list	UF-ID14	
Index list	Early warning forecast index Flood hazard index	

[30] French collaborative platform for gauge data: https://www.reperesdecrues.developpement-durable.gouv.fr/.

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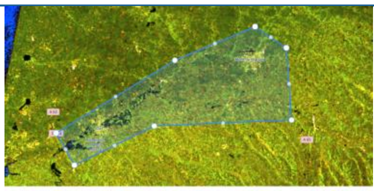
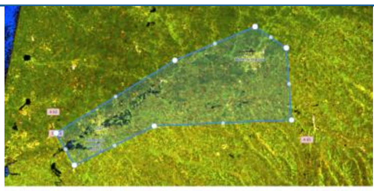
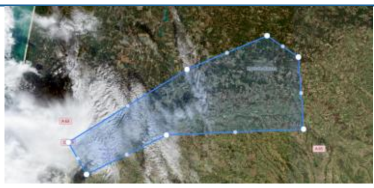
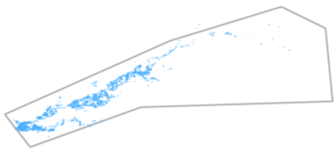
Table 24: Archive post-event data available for the Landes use case.

Type	Date	Source	Comment or quicklook
Sentinel-1	02/01/2021 06:09 UTC	COPERNICUS	 UF-ID-4
Sentinel-1	01/01/2021 06:16:11 UTC	COPERNICUS	 UF-ID-4
Sentinel-1	03/01/2021 17:56:00 UTC & 17:56:25 UTC	COPERNICUS	 UF-ID-4
Sentinel-2	03/01/2021 11:03:49 UTC	COPERNICUS	 UF-ID-3, UF-ID-5
Water Gauges	01/07/2020 - 30/06/2021	HYDRO EAU France	Public dataset UF-ID-3, UF-ID-5
Flood Mask	02/01/2021	CEMS RM EMSR492	 UF-ID-3, UF-ID-5

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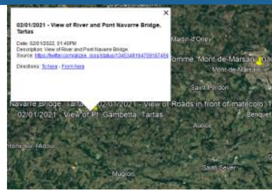
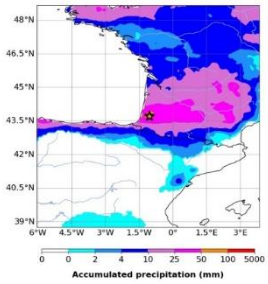
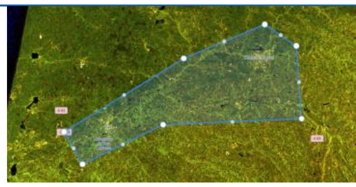
Type	Date	Source	Comment or quicklook
Social media markers	Since 2018	Traditional and social media	 UF-ID-5
Precipitation	28/11/2020	E-OBS	 UF-ID-1, UF-ID-2

Table 25: Archive pre-event data available for the Landes use case.

Type	Date	Source	Comment or quicklook
Sentinel-2B	06/08/2020 10:56 UTC	COPERNICUS	 UF-ID-4
Sentinel-1	09/11/2020 06:08 UTC	COPERNICUS	 UF-ID-4

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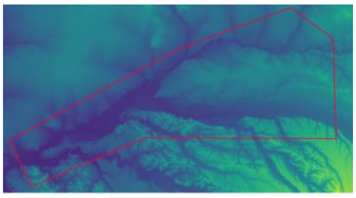
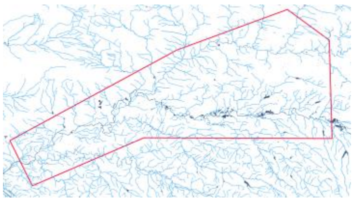
Type	Date	Source	Comment or quicklook
DTM	2021	IGN 1m, LiDAR HD	RGE Alti 1m available over complete AOI. LiDAR HD covering the AOI should be made available in the near future by IGN France.  UF-ID-3, UF-ID-5
Topographic data	2023	IGN	BD Topo V3.3 contains 3D information about administrative units; buildings; hydrography; land cover; activities and services; transportations; restricted area  UF-ID-3, UF-ID-5, UF-ID-7, UF-ID-9, UF-ID-10, UF-ID-13
VHR	19/05/2020 13:03:54 UTC (KS03) 30/08/2021 11:12:34 UTC (PH1A) 15/09/2020 10:57:41 UTC (PH1B) 05/09/2021 11:16:32 UTC (PH1B) 14/06/2021 10:38:24 UTC (SP06) 11/08/2021 10:40:53 UTC (SP07)	COPERNICUS CONTRIBUTING MISSIONS	Full coverage requires several acquisitions. 2021 coverage was chosen, although partly post-event, over 2018 coverage that is too distant from the event date.  UF-ID-3, UF-ID-5

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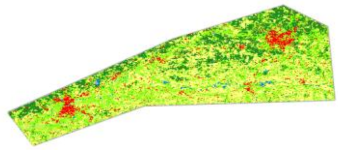
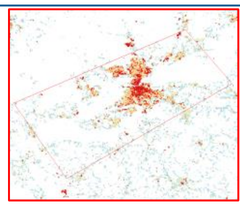
Type	Date	Source	Comment or quicklook
CLC+	2018	COPERNICUS	 UF-ID-3, UF-ID-5
Social/Traditional media indicator on public services and (government) support	2018	Open-source providers	Latest available data pre- or during crisis, rough localisation. UF-ID-10
Social/Traditional media indicator on ability to evacuate	2018	Open-source providers	Earliest available data post- or during crisis, rough localisation. UF-ID-13
Social/Traditional media data on economic impacts of floods	2018	Open-source providers	Earliest available data post- or during crisis, rough localisation. UF-ID-14

Table 26: Socio-economic data available for the Landes use case.

Type	Date	Source	Comment or quicklook
Built-up settlements (WSF-Binary)	2016-to-present	DLR	 (e.g., 2019) UF-ID-4, UF-ID-5, UF-ID-7
Building volume (WSF-3D)	2012	DLR	 UF-ID-4, UF-ID-5, UF-ID-9

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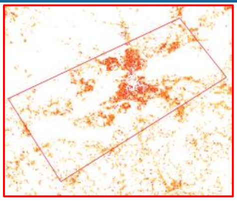
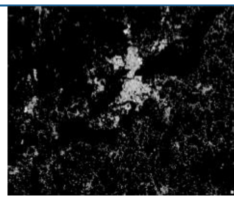
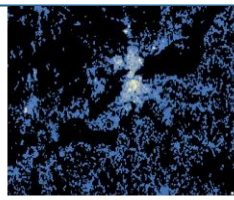
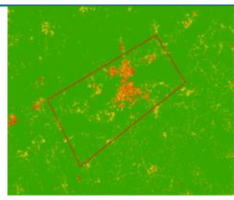
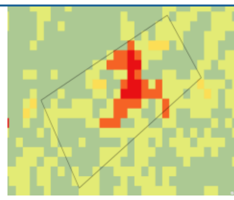
Company General Use

Type	Date	Source	Comment or quicklook
Population (WSF-Pop)	2016-to-present	DLR	 (e.g., 2019) UF-ID-5, UF-ID-7, UF-ID-9
Built-up settlements (GHS-BUILT-S)	1975-2020 (5 years interval); 2025 and 2030	JRC- GHSL Data portal	 (e.g., 2020) UF-ID-4, UF-ID-5, UF-ID-7
Building volume (GHS-BUILT-V)	1975-2020 (5 years interval); 2025 and 2030	JRC- GHSL Data portal	 (e.g., 2020) UF-ID-4, UF-ID-5, UF-ID-9
Boundaries of Human Settlements with functional use (GHS-BUILT-C)	2018	JRC- GHSL Data portal	 UF-ID-7
Degree of Urbanisation (GHS-SMOD)	1975-2020 (5 years interval); 2025 and 2030	JRC- GHSL Data portal	 (e.g., 2020) UF-ID-7

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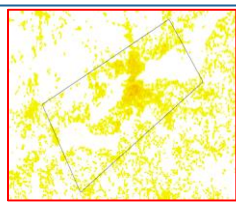
Type	Date	Source	Comment or quicklook
Degree of urbanisation classification (GHSL-DUC)	1975-2020 (5 years interval); 2025 and 2030	JRC- GHSL Data portal	GADM41 units with different attributes derived from GHS-SMOD, GHS-POP, etc.  (e.g., ADMIN5) UF-ID-7
Population (GHS-Pop)	1975-2020 (5 years interval); 2025 and 2030	JRC- GHSL Data portal	 (e.g., 2020) UF-ID-5, UF-ID-7, UF-ID-9, UF-ID-13
Population	2020	INSEE	Dataset available at communal level UF-ID-7, UF-ID-9, UF-ID-13
Housing	2020	INSEE	Dataset available at communal level UF-ID-7, UF-ID-9, UF-ID-13
Natality/mortality	2021	INSEE	Dataset available at communal level UF-ID-7, UF-ID-9, UF-ID-13
Income	2020	INSEE	Dataset available at communal level UF-ID-7, UF-ID-9, UF-ID-13
Employment	2020	INSEE	Dataset available at communal level UF-ID-7, UF-ID-9, UF-ID-13

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Company General Use

4.1.5 Beira, Mozambique

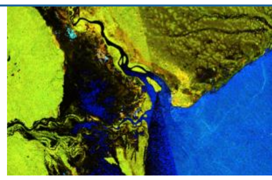
The end-user was not able to provide the consortium with reference or crisis data.

The context for the Mozambican use case is described in Table 27. The data sets that have been collected are listed in Table 28, Table 29 and Table 30 for post-event data, pre-event data and socioeconomic data respectively.

Table 27: Beira use case description.

Country	Mozambique	
Locality	Beira	
Event type	Riverine flood, coastal surge	
Event date (cold case)	15/03/2019	
Context	Tropical Cyclone Idai in Mozambique leading to widespread flooding both in rural and urban areas	
Use Case objective	Map potentially major urban flood, map flood depth	
UF Indicator list	UF-ID-1, UF-ID-2, UF-ID-3, UF-ID-4, UF-ID-5, UF-ID-6, UF-ID-7	
SE indicator list	UF-ID-9, UF-ID-10, UF-ID-13, UF-ID-14	
Index list	Early warning forecast index Flood hazard index	

Table 28: Archive post-event data available for the Beira use case.

Type	Date	Source	Comment or quicklook
Pléiades-1B	26/03/2019 07:54 UTC	COPERNICUS	 UF-ID-3, UF-ID-5
Sentinel-1B	20/03/2019 03:08 UTC	COPERNICUS	 UF-ID-4

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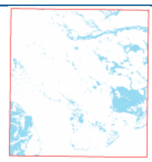
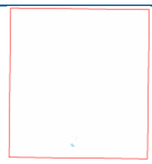
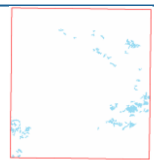
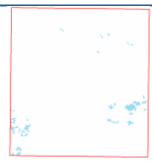
Type	Date	Source	Comment or quicklook
Water gauges	N/A	N/A	At the time this report was issued, the data was unavailable. UF-ID-3, UF-ID-5
Flood masks	16/03/2019 14:41 UTC	EMSR348 AOI03 Delineation Product (Cosmo-SkyMed)	 UF-ID-3, UF-ID-5
	19/03/2019 16:14 UTC	EMSR348 AOI03 Delineation Monitoring 01 (Sentinel-1B)	 UF-ID-3, UF-ID-5
	20/03/2019 03:08 UTC	EMSR348 AOI03 Delineation Monitoring 02 (Sentinel-1B)	 UF-ID-3, UF-ID-5
	26/03/2019 07:54 UTC	CHARTER SERTIT Flood traces (Pléiades)	 UF-ID-3, UF-ID-5
	13/03/2019	CHARTER UNOSAT Water extent Sofala Province (Sentinel-1)	 UF-ID-3, UF-ID-5
	14/03/2019	CHARTER UNOSAT Water extent Sofala Province (Sentinel-1)	 UF-ID-3, UF-ID-5

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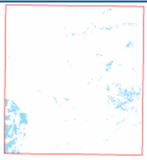
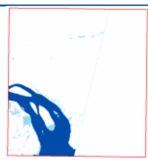
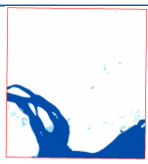
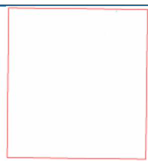
Type	Date	Source	Comment or quicklook
	19/03/2019	CHARTER UNOSAT Water extent Manica and Sofala Provinces (Sentinel-1)	 UF-ID-3, UF-ID-5
	19/03/2019	CHARTER UNOSAT Water extent Sofala Province (Sentinel-1)	 UF-ID-3, UF-ID-5
	20/03/2019	CHARTER UNOSAT Water extent Sofala Province (Sentinel-1)	 UF-ID-3, UF-ID-5
	26/03/2019	CHARTER UNOSAT Water extent Sofala Province (Sentinel-1)	 UF-ID-3, UF-ID-5
	23/03/2019 03:10 UTC	DLR Flood extent and standing water (TerraSAR-X)	 UF-ID-3, UF-ID-5
	25/03/2019 16:16 UTC	DLR Flood extent and standing water (Sentinel-1)	 UF-ID-3, UF-ID-5
	26/03/2019 03:08 UTC	DLR Flood extent (Sentinel-1)	 UF-ID-3, UF-ID-5

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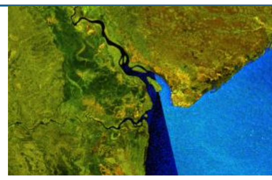
Company General Use

Type	Date	Source	Comment or quicklook
	26/03/2019 03:09 UTC	DLR Flood extent and standing water (Sentinel-1)	 UF-ID-3, UF-ID-5
	26/03/2019 16:07 UTC	DLR Flood extent and standing water (Sentinel-1)	 UF-ID-3, UF-ID-5
	29/03/2019 16:16 UTC	DLR Flood extent and standing water (TerraSAR-X)	 UF-ID-3, UF-ID-5
Social media markers	Since 2018	Traditional and social media	N/A UF-ID-5

Table 29: Archive pre-event data available for the Beira use case

Type	Date	Source	Comment or quicklook
Sentinel-2B	02/12/2018 07:32 UTC	COPERNICUS	 UF-ID-3, UF-ID-5
Sentinel-1A	06/02/2019 03:09 UTC	COPERNICUS	 UF-ID-4

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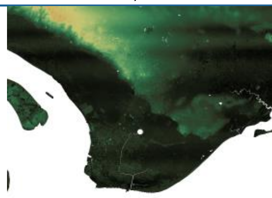
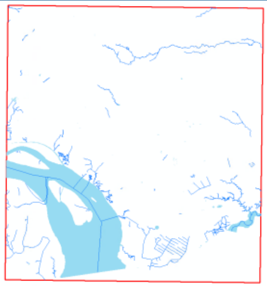
Type	Date	Source	Comment or quicklook
Sentinel-1A	18/02/2019 03:09 UTC	COPERNICUS	 UF-ID-4
DTM	N/A	FABDEM 30m	 UF-ID-3, UF-ID-5
	15/04/2018	STEREO Pléiades DTM *This DTM was generated by UNISTRA, using photogrammetry on stereoscopic Pléiades data acquired within CENTAUR*	 UF-ID-3, UF-ID-5
Hydrography	02/12/2018 07:32 UTC	EMSR348 Delineation Product Hydrography (polygon + line)	 UF-ID-3, UF-ID-5
	2023	OpenStreetMap Hydrography (polygon + line)	 UF-ID-3, UF-ID-5

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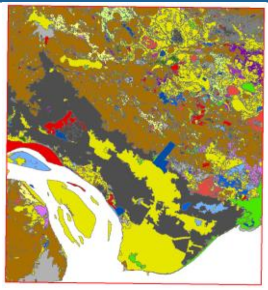
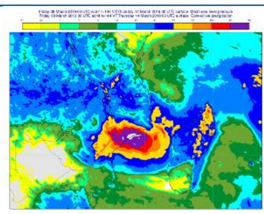
Type	Date	Source	Comment or quicklook
Land Use Land Cover	2004-2006	GlobeCover30	 UF-ID-3, UF-ID-5
Building Footprints	2023	OpenStreetMap Built up (polygon)	 UF-ID-5, UF-ID-7, UF-ID-9, UF-ID-10, UF-ID-13
Transportation data	2023	OpenStreetMap Transportation (polygon + line)	 UF-ID-5, UF-ID-7, UF-ID-9, UF-ID-10, UF-ID-13
Precipitation forecast (6 days)	08/03/2019	ECMWF high-resolution forecast	 UF-ID-1, UF-ID-2
Social/Traditional media indicator on public services and (government) support	2018	Open-source providers	Latest available data pre- or during crisis, rough localisation. UF-ID-10

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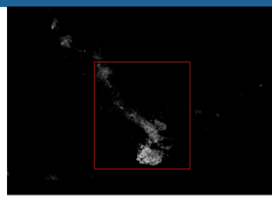
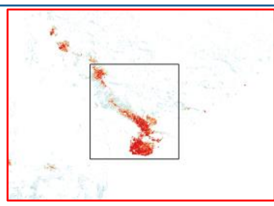
Type	Date	Source	Comment or quicklook
Social/Traditional media indicator on ability to evacuate	2018	Open-source providers	Earliest available data post- or during crisis, rough localisation. UF-ID-13
Social/Traditional media data on economic impacts of floods	2018	Open-source providers	Earliest available data post- or during crisis, rough localisation. UF-ID-14

Table 30: Socio-economic data available for the Beira use case.

Type	Date	Source	Comment or quicklook
Built-up settlements (WSF-Binary)	2016-to-present	DLR	 (e.g., 2019) UF-ID-4, UF-ID-5, UF-ID-7
Imperviousness (WSF-Imp)	2016-up-to date	DLR	 (e.g., 2019) UF-ID-9
Building volume (WSF-3D)	2012	DLR	 UF-ID-4, UF-ID-5, UF-ID-9

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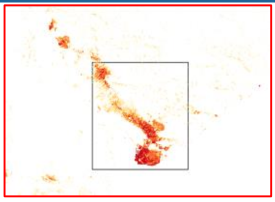
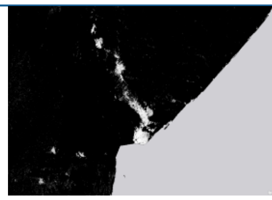
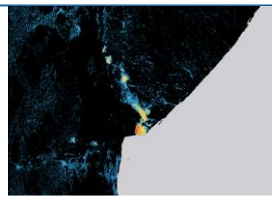
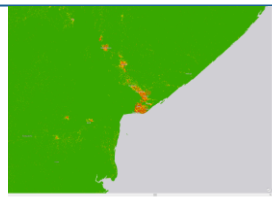
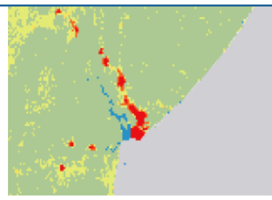
Type	Date	Source	Comment or quicklook
Population (WSF-Pop)	2016-to-present	DLR	 (e.g., 2019) UF-ID-5, UF-ID-7, UF-ID-9
Built-up settlements (GHS-BUILT-S)	1975-2020 (5 years interval); 2025 and 2030	JRC- GHSL Data portal	 (e.g., 2020) UF-ID-4, UF-ID-5, UF-ID-7
Building volume (GHS-BUILT-V)	1975-2020 (5 years interval); 2025 and 2030	JRC- GHSL Data portal	 (e.g., 2020) UF-ID-4, UF-ID-5, UF-ID-9
Boundaries of Human Settlements with functional use (GHS-BUILT-C)	2018	JRC- GHSL Data portal	 UF-ID-7
Degree of Urbanisation (GHS-SMOD)	1975-2020 (5 years interval); 2025 and 2030	JRC- GHSL Data portal	 (e.g., 2020) UF-ID-7

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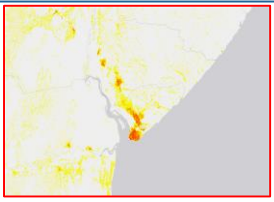
Type	Date	Source	Comment or quicklook
Degree of urbanisation classification (GHSL-DUC)	1975-2020 (5 years interval); 2025 and 2030	JRC- GHSL Data portal	GADM41 units with different attributes derived from GHS-SMOD, GHS-POP, etc.  (e.g., ADMIN3) UF-ID-7
Population (GHS-Pop)	1975-2020 (5 years interval); 2025 and 2030	JRC- GHSL Data portal	 (e.g., 2020) UF-ID-5, UF-ID-7, UF-ID-9, UF-ID-13
Restaurant prices	Latest available	Google Maps	N/A UF-ID-9

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4.2 WATER AND FOOD SECURITY USE CASES

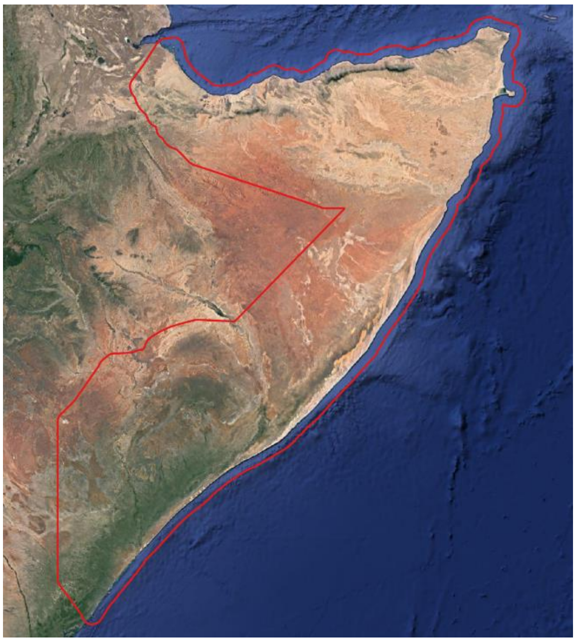
The use cases for water and food security correspond to first-level administrative divisions, commonly referred to as ADMIN1, which typically represent countries. All input layers pertinent to these use cases have been compiled at this administrative level. Accordingly, the generation of indicators and indexes will also be conducted at this level. Owing to the uniformity in the analysis scale, a standardized data collection procedure has been employed across all cases. Contrary to the approach detailed in the section on UF use cases, the datasets for WFS use cases are not isolated but shared and are collectively itemized in consolidated tables.

Whenever feasible, the analysis scale could be expanded to ADMIN2, which are regions within ADMIN1. However, as of the submission of this document, such an upscaling has not yet been implemented.

4.2.1 Somalia

The end-user was not able to provide the consortium with reference or crisis data. The context for the Somalian use case is described in Table 31.

Table 31: Somalian use case description.

Country	Somalia	
AOI	Somalia	
Scale	Regional, aggregate at ADMIN1 (in case where feasible, ADMIN2 may be used for increased detail).	
Context	Consecutive failed rainy seasons, droughts, political instability, extremism, civil unrest, 2nd most vulnerable country to climate change, high poverty (70 % of the population), high dependence on pastoralism.	
Date	Ongoing	
Observation period	From 2018 onwards, specifically the growing seasons October - December 2016, October - December 2020 and March - June 2022.	
Computation frequency	Quarterly (every 3 months)	
Forecast range	Quarterly ahead (every 3 months)	
WFS Indicator list	WFS-ID-1 to -7, WFS-ID-11 to -15, WFS-ID-17 to -19, WFS-ID-21, WFS-ID-23 to -25	
High-level systems	Risk monitor, situation monitor, data viewer	

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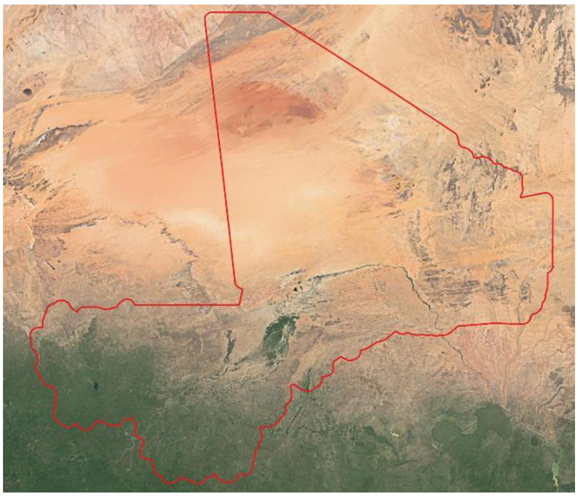
4.2.2 Mali

The end-user was not able to provide the consortium with reference or crisis data. The context for the Malian use case is described in Table 32.

Table 32: Malian use case description.

Country	Mali	
AOI	Mali	
Scale	Regional, aggregate at ADMIN1 (in case where feasible, ADMIN2 may be used for increased detail).	
Context	Limited access to water, consistent increase in temperature, droughts, political instability, extremism, landlocked country, high poverty (78 % of the population), food insecurity affecting 1.84 million people, drought from June 2021 to December 2021.	
Date	Ongoing	
Observation period	From 2018 onwards	
Computation frequency	Quarterly (every 3 months)	
Forecast range	Quarterly ahead (every 3 months)	
Context	Landlocked country, high poverty (78%), 1.84 million people suffer from food insecurity.	
WFS Indicator list	WFS-ID-1 to -7, WFS-ID-11 to -15, WFS-ID-17 to -19, WFS-ID-21, WFS-ID-23 to -25	
High-level systems	Risk monitor, situation monitor, data viewer	

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4.2.3 Mozambique

The end-user was not able to provide the consortium with reference or crisis data. The context for the Mozambican use case is described in Table 33.

Table 33: Mozambican use case description.

Country	Mozambique	
AOI	Mozambique	
Scale	Regional, aggregate at ADMIN1 (in case where feasible, ADMIN2 may be used for increased detail).	
Context	Limited access to water, limited preparedness against natural disasters, food insecurity, drought, High poverty (more than 50 % of the population), high dependence on agriculture.	
Date	Ongoing	
Observation period	From 2018 onwards	
Computation frequency	Quarterly (every 3 months)	
Forecast range	Quarterly ahead (every 3 months)	
WFS Indicator list	WFS-ID-1 to -7, WFS-ID-11 to -15, WFS-ID-17 to -19, WFS-ID-21, WFS-ID-23 to -25	
High-level systems	Risk monitor, situation monitor, data viewer	

4.2.4 Optional use case in Jordan

Due to constraints with data availability, it was not possible to develop a demonstrator for WFS-ID-7, focusing on cold cases drawn from the main use cases.

Jordan has only been included recently as an optional use case (Figure 15), because of a significant displacement event in 2012, triggered by political conflict. This incident led to the establishment of the Zaatari refugee camp, which provided shelter for the large influx of people who had migrated from Syria to Jordan. As of September 2022, the camp is home to approximately 80,000 people. The tents that provided temporary shelter in the initial weeks and months were replaced by thousands of metal shelters. Roads, schools, and hospitals were built to meet the needs of residents, and shops and small businesses sprang up, run by enterprising refugees.

Considering the lack of archive EO data for all the other main use cases, the Zaatari refugee camp in Jordan is currently being studied to develop a cold case demonstrator for WFS-ID-7, and the subsequent situation monitor for IDP camps.

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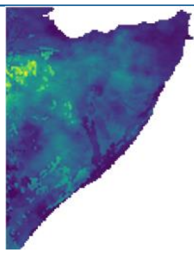
4.2.5 Data sets for water and food security use cases

The data sets that have been collected are listed in described in Table 34, Table 35 and Table 36 for environmental data, socioeconomic data and cross-cutting data respectively. They are common to the main use cases, described in Table 31, Table 32 and Table 33. However, these data sets may not be applicable to all optional use cases. This especially applies to the demonstrator that is being developed in Jordan (Section 4.2.4), where only IDP data and VHR EO imagery will be collected.

Table 34: Environmental data for water & food security use cases.

Type	Source	Variables	Spatiotemporal resolution, scale	Comment or screenshot
Vegetation response	Proba-V and Sentinel-3 from Copernicus Global Land	NDVI, NDWI	1 km Dekadal (10 days)	 WFS-ID-4, WFS-ID-5, WFS-ID-6
Land surface temperature	NASA MODIS	Land surface temperature	1 km Dekadal (10 days)	 WFS-ID-4, WFS-ID-5, WFS-ID-6
Soil moisture	NASA GRACE/GRACE-FO	Root zone soil moisture, ground water	25 km Weekly	 WFS-ID-4, WFS-ID-5, WFS-ID-6
Soil moisture	NASA SMAP	Root zone soil moisture	9 km Daily	 WFS-ID-4, WFS-ID-5, WFS-ID-6

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Type	Source	Variables	Spatiotemporal resolution, scale	Comment or screenshot
ERA5 reanalysis	ECMWF (Copernicus climate data store)	Air temperature, precipitation, runoff	*Temperature* 25 km, hourly/daily *Precipitation* 25 km, daily to monthly *Runoff* 9 - 25 km, monthly	 WFS-ID-4, WFS-ID-5, WFS-ID-6
Climate Forecast	ECMWF	Air temperature, precipitation, soil moisture	9 - 36 km Lead times of 1 day up to 6 months ahead	 WFS-ID-1, WF-ID2, WFS-ID-3, WFS-ID-4, WFS-ID-5, WFS-ID-6
Land cover	Copernicus Global Land	Land cover	100 m Yearly	 WFS-ID-4, WFS-ID-5, WFS-ID-6
VHR-HR SAR EO	CCM	Amplitude Backscattering	VHR (1 to 5 m)	N/A WFS-ID-7
ERA5-Land runoff	ECMWF (Copernicus climate data store)	Monthly average runoff to express water availability as m^3/month	1 km	 WFS-ID-9

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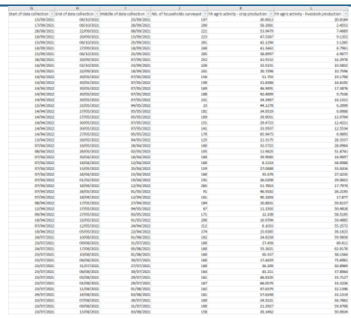
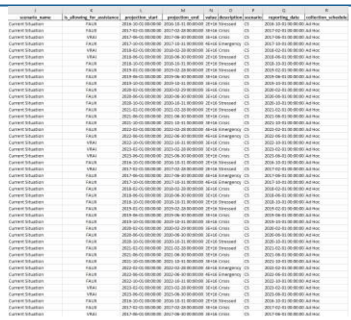
Table 35: Socioeconomic data for water & food security use cases.

Source	Variables	Spatiotemporal resolution, scale	Comment or screenshot
WSF-Pop and GHS-POP	Populations at risk of food security, water security and violence	10 m From 2016 onwards 100 m 1975-2020, 2025-2030	 WFS-ID-8, WFS-ID-9, WFS-ID-10
FAO DIEM	Food security, economic security, aid	ADMIN1 Every 3 to 4 months From 2020 onwards	 WFS-ID-11, WFS-ID-12, WFS-ID-17
Afrobarometer	Food security, economic security, infrastructure and services, social relations, state-citizen relations	ADMIN1-2 Multiple-year frequency 2002 - 2022	N/A WFS-ID-11, WFS-ID-12, WFS-ID-15,WFS WFS-ID-21,WFS-ID-23,WFS-ID-24,WFS-ID-25
FEWS NET	Food security	ADMIN1-2 Every month From 2009 onwards Up to 4-month forecast	 WFS-ID-11
Global integration (KOFGI)	Economic security, state-citizen relations, social cohesion	N/A	N/A WFS-ID-12,WFS-ID-21, WFS-ID-23, WFS-ID-25

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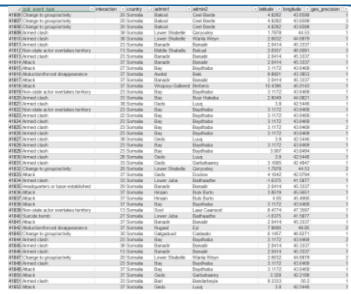
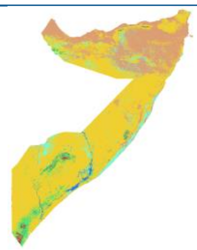
Source	Variables	Spatiotemporal resolution, scale	Comment or screenshot
IOM DTM Mobility tracking	Displacement	From ADMIN level to displacement site Monthly From 2015 onwards	N/A WFS-ID-13
Internal Displacement Monitoring Centre (IDMC)	Displacement associated with sudden-onset natural hazard-related disasters	N/A	N/A WFS-ID-13
ACLED	Conflict	ADMIN1 From 1997 onwards Up to 6-month forecast	 WFS-ID-14
FAO WaPOR: Land Cover Classification 2021	Climate sensitivity	250 m Yearly From 2009 onwards	 WFS-ID-19
Rangeland land cover change	Resource capture	300 m Yearly From 1992 onwards with one year delay	 WFS-ID-18
DHS (Demographic and Health Surveys)	Public services and infrastructure, social relations	ADMIN1 Every 5 to 10 years 1997 - 2023	N/A WFS-ID-11, WFS-ID-21

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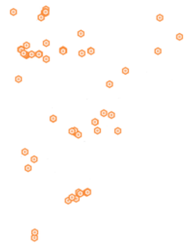
Source	Variables	Spatiotemporal resolution, scale	Comment or screenshot
EOG Night-time light	Public services and infrastructure	500 m Monthly 2012-2021	 WFS-ID-21
HOT (Humanitarian OpenStreetMap)	Public services and infrastructure	Monthly From 2020 onwards	 WFS-ID-21
OpenStreetMap	Infrastructure & services (main roads)	10 m Yearly From 2015 onwards	 WFS-ID-21
World Bank, WDI (Worldwide Governance, Government Effectiveness)	Public services and infrastructure, State – Citizen relations	Quarterly	N/A WFS-ID-21, WFS_ID 23 WFS-ID-25
World Bank, WDI, (Worldwide Governance, Political Stability)	Crime, radicalisation and polarisation, Social Cohesion and Trust	Quarterly	N/A WFS-ID-14, WFS-ID-15, WFS-ID 22, WFS-ID-23, WFS-ID-25
World Bank WDI (Worldwide Governance, Voice and accountability)	State - Citizen relations, Conflict Resolution, Social Cohesion	Quarterly	N/A WFS-ID-23,WFS-ID-24, WFS-ID-25

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Source	Variables	Spatiotemporal resolution, scale	Comment or screenshot
Social/Traditional media data on food security	Food security	Spatial and temporal resolution and scope TBC pending data availability	N/A WFS-ID-11
Social/Traditional media data on economic security	Economic security	Spatial and temporal resolution and scope TBC pending data availability	N/A WFS-ID-12
Social/Traditional media data on displaced persons	Displaced persons	Spatial and temporal resolution and scope TBC pending data availability	N/A WFS-ID-13
Social/Traditional media data on violent conflict	Violent conflict	Spatial and temporal resolution and scope TBC pending data availability	N/A WFS-ID-14
Social/Traditional media data on humanitarian aid	Humanitarian aid	Spatial and temporal resolution and scope TBC pending data availability	N/A WFS-ID-17
Social/Traditional media data on	Climate sensitivity of agrifood systems	Spatial and temporal resolution and scope TBC pending data availability	N/A WFS-ID-19

Table 36: Cross-cutting data for water & food security use cases.

Source	Variables	Comment	Comment or screenshot
Livestock heat stress	Livestock	0.1° (historic), 0.5° (anticipated) Yearly 1950 - 2098	 WFS-ID-12

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5 CROSS-CUTTING ANALYSIS OF CENTAUR CLIMATE-RELATED CRISIS EVENTS

5.1 OVERVIEW OF COMPOUND CLIMATE AND WEATHER EVENTS AND THEIR RELATED IMPACTS

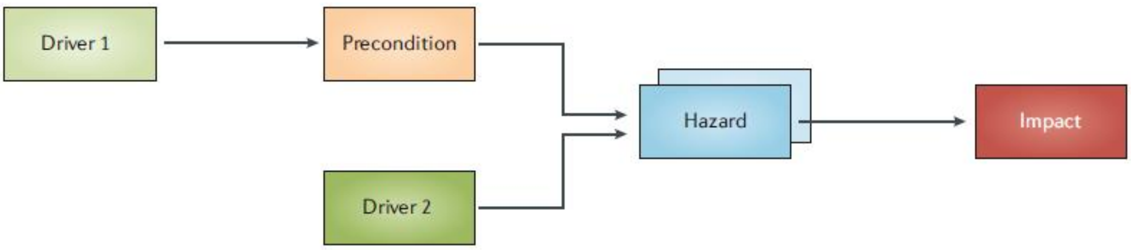
The challenges of urban flooding, water availability, and food security are becoming increasingly linked with **compound climatic and meteorological events**. These events, characterized by the concurrent or successive occurrence of multiple climate and meteorological related hazards, are growing in frequency and severity in the current changing climate[31].

Research indicates that floods, wildfires, heatwaves, and droughts, which are typical examples of compound events, often result from the interaction of multiple physical processes across various scales. Thus, traditional risk assessment techniques, which usually focus on a single driver or hazard, are unlikely to fully **capture the complex risks associated with these events**[32,33].

Ongoing work on this topic has resulted in the **classification of compound events** into four main categories[36]:

- **Preconditioned events** (Figure 16). They are the result of one or multiple pre-existing drivers. While these drivers may not always have a causal relationship, they can be interconnected.

Figure 16: Overview of preconditioned compound events. Drivers correspond to various processes (e.g., incident sunlight, water cycle). Hazards correspond to disruptive extreme events (e.g. floods, wildfires), caused by drivers and sometimes other ancillary factors. Impacts are the consequences of said hazards (e.g. destroyed crops, damaged infrastructures).[36]



- **Multivariate events** (Figure 17). They are the result of the simultaneous presence of multiple drivers within the same area, leading to significant hazards and impacts.

[31] Leonard, M., Westra, S., Phatak, A., Lambert, M., Van Den Hurk, B., McInnes, K., Risbey, J., Schuster, S., Jakob, D., & Stafford-Smith, M. (2014). A compound event framework for understanding extreme impacts. WIREs Climate Change, 5(1), 113–128. https://doi.org/10.1002/wcc.252

[32] Zscheischler, J., Westra, S., Van Den Hurk, B. J. J. M., Seneviratne, S. I., Ward, P. J., Pitman, A., AghaKouchak, A., Bresch, D. N., Leonard, M., Wahl, T., & Zhang, X. (2018). Future climate risk from compound events. Nature Climate Change, 8(6), 469–477. https://doi.org/10.1038/s41558-018-0156-3

[33] Bevacqua, E., De Michele, C., Manning, C., Couasnon, A., Ribeiro, A. F. S., Ramos, A. M., Vignotto, E., Bastos, A., Blesić, S., Durante, F., Hillier, J., Oliveira, S. C., Pinto, J. G., Ragno, E., Rivoire, P., Saunders, K., Van Der Wiel, K., Wu, W., Zhang, T., & Zscheischler, J. (2021). Guidelines for Studying Diverse Types of Compound Weather and Climate Events. Earth's Future, 9(11), e2021EF002340. https://doi.org/10.1029/2021EF002340

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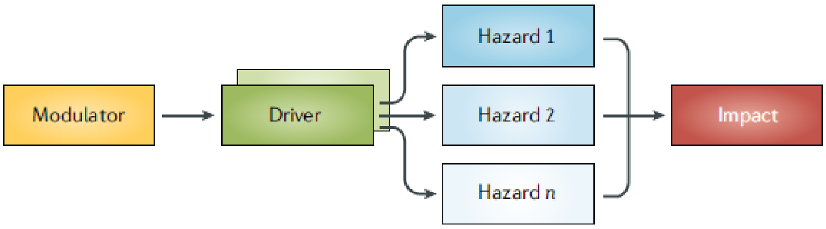
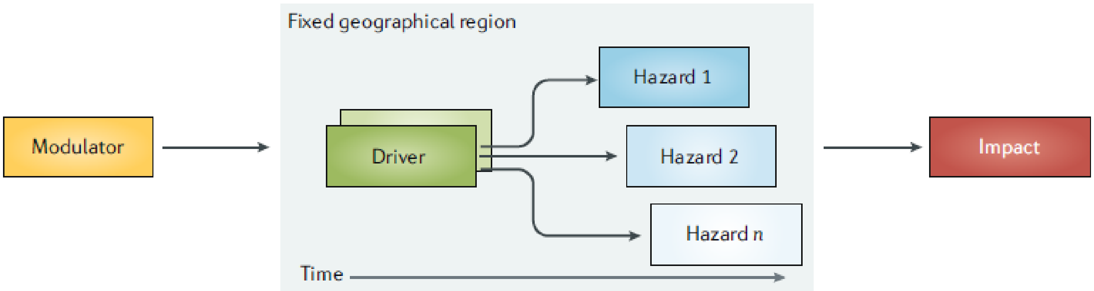
Figure 17: Overview of multivariate compound events. Modulators correspond to large weather patterns, that can influence drivers.[36]



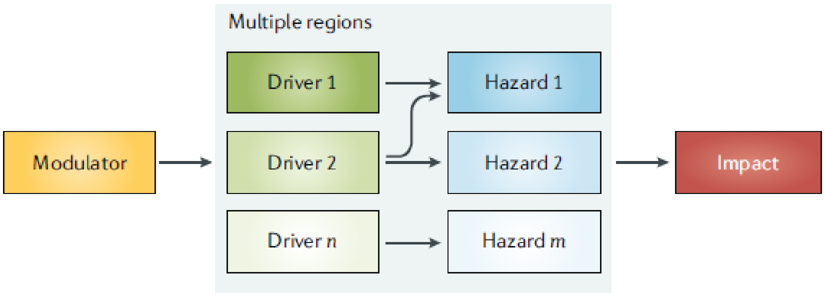
- **Temporally compounding events** (Figure 18). They correspond to successive hazards that affect a specific area and either initiate or intensify an impact beyond what a single hazard could produce. The corresponding hazards can either be of the same type or not.

Figure 18: Overview of temporally compounding events.[36]



- **Spatially compounding events** (Figure 19). They correspond to the same or different hazards that affect multiple areas within a short time frame. In such a case, the system accumulates the impacts of hazards across different locations, sometimes far from one another. Modulating factors, such as large-scale climate modes (e.g., El Niño Southern Oscillation [ENSO], North Atlantic Oscillation [NAO]), can be responsible for the creation of a physical connection between areas.

Figure 19: Overview of spatially compounding events.[36]



This provides a framework for understanding the mechanisms and impacts of compound events, which is vital for developing effective adaptation and mitigation strategies, especially in the context of urban environments and the global South[31].

The socio-economic impacts of compound events are notably significant. They tend to result in **greater economic losses and higher death tolls** compared to isolated hazards. The interaction of multiple hazards in multivariate

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compound events, for instance, enhances their impacts significantly[34]. For example, the increasing frequency of compound drought – heatwave events generates substantial risks to over 90% of the global population and gross domestic product, with poorer and rural areas facing the most severe effects[35].

In the realm of civil security, the consequences of these compound events are deep, especially regarding water and food security. The synergy of multiple climate hazards can severely strain water resources, impacting both the quantity and quality of available water. This not **only affects direct human consumption** but also has **repercussions for agricultural productivity**, endangering food security. In urban settings, where the demand for water is high and the reliance on stable food supply chains is critical, the effects of these compound events can be particularly disruptive.

Moreover, the occurrence of these events can exacerbate existing **vulnerabilities**, leading to amplified **civil unrest** and **insecurity**. For instance, prolonged droughts followed by intense floods can damage critical infrastructure, disrupt supply chains, and lead to food and water shortages. In turn, it can trigger social and political tensions, especially in regions already struggling with socio-economic challenges.

By **integrating data and insights from both tracks**, it is possible to develop a more comprehensive understanding of the interactions between urban flooding, water availability, food security and their compound impacts. This approach aims at improving informed decision-making, as well as the development of effective strategies to address the interconnected challenges of urban floods and water & food security. Even though the **cross-cutting analysis** was not directly considered for both tracks during the development of indicators, high-level indexes and systems, highlighting the capabilities of the proposed system is an essential step to advance the CENTAUR project within current climate considerations, as well as develop connections between Copernicus EMS and SEA.

5.2 EXAMPLES OF COMPOUND EVENTS AND IMPACTS IN CENTAUR USE CASES

This section aims at showcasing various **examples of compound events and their impacts**. When undertaking a cross-cutting analysis, it is crucial to acknowledge that while floods, including those in urban environments, are classified as hazards, issues of water and food security are typically considered to be hazard impacts. Despite this distinction, there is a tangible link between these phenomena, particularly when examined through the lens of CENTAUR use cases. Given that water and food security challenges are not common in EU countries**, this section focuses on the WFS use cases**, including Mozambique, which are also susceptible to severe flooding, notably in urban and densely populated areas.

As mentioned earlier, compound events fall into four categories: preconditioned events, multivariate events, temporally compounding events, and spatially compounding events[36]. The distinction between these categories is becoming less obvious in light of the **staggering increase in extreme weather events** (Figure 20). Between 2000 and 2019, there were 7,348 reported disasters, a significant increase from the 4,212 events recorded from 1980 to 1999[37]. Although the following examples are described separately to depict each type of compound event clearly, it is important to note that these events can be closely related.

[34] Ridder, N. N., Pitman, A. J., Westra, S., Ukkola, A., Do, H. X., Bador, M., Hirsch, A. L., Evans, J. P., Di Luca, A., & Zscheischler, J. (2020). Global hotspots for the occurrence of compound events. Nature Communications, 11(1), 5956. https://doi.org/10.1038/s41467-020-19639-3

[35] Increase in drought–heatwave events worsens socio-economic productivity and carbon uptake. (2023). Nature Sustainability, 6(3), 241–242. https://doi.org/10.1038/s41893-022-01026-z

[36] Zscheischler, J., Martius, O., Westra, S., Bevacqua, E., Raymond, C., Horton, R. M., Van Den Hurk, B., AghaKouchak, A., Jézéquel, A., Mahecha, M. D., Maraun, D., Ramos, A. M., Ridder, N. N., Thiery, W., & Vignotto, E. (2020). A typology of compound weather and climate events. Nature Reviews Earth & Environment, 1(7), 333–347. https://doi.org/10.1038/s43017-020-0060-z

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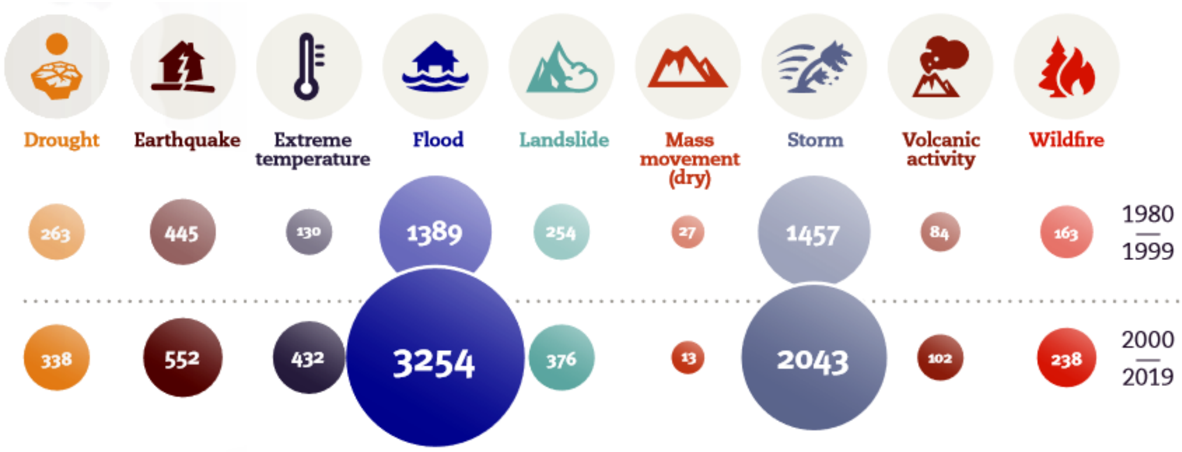
According to the United Nations, Somalia has recently experienced its worst drought since 1981. Since 2020, the country has had **multiple consecutive failed rainy seasons**, corresponding to **a temporally compounded event**. As a result, over 7 million Somalis are in need of humanitarian aid, up 30% in one year. The situation has deteriorated, as the succession of droughts has wiped out crop harvests. Moreover, many farmers have reported livestock dying due to a lack of water and pasture, depriving many pastoral communities of their only source of income.

Figure 20: Total reported disaster events by type: 1980-1999 vs. 2000-2019.[37]



The drought has had a significant impact on water availability, food scarcity, famine, and civil security. The lack of rainfall has led to a severe shortage of water (Figure 21), with many communities having to travel long distances to access clean water. In total, almost 1,2 million individuals have been displaced due to water scarcity, between January 2021 and September 2022[38]. These consecutive failed rainy seasons have led to food scarcity, the situation being particularly dire for the youngest, with over 1.8 million children under the age of five at risk of malnutrition. The lack of food and water has also led to an increase in the number of people displaced from their homes, with many seeking refuge in overcrowded camps. The displacement of people has led to a breakdown in civil security, with many people forced to live in unsafe and unsanitary conditions[39].

Even though this example is not directly related to urban floods, it showcases the interplay between temporally compounded events and water & food security, as well as civil security as a whole.

Due to changing weather patterns however, the situation in Somalia has recently been going from one extreme to the other, which is currently common to many countries that experience the full-blown effects of the ENSO. In itself, **the ENSO acts as a large modulator for spatially compounded events across Africa**, with contrasting influences on different regions. Its diverse impacts encompass enhanced flood risk at a global scale[40], as well as stress on agrifood systems[41].

[37] CRED. (2020). The human cost of disasters: An overview of the last 20 years (2000-2019) (p. 30). UNDRR. https://www.undrr.org/publication/human-cost-disasters-overview-last-20-years-2000-2019

[38] OCHA, PRNM, & DTM. (2023). Somalia: Drought Displacement Monitoring Dashboard (September 2022). https://reliefweb.int/report/somalia/somalia-drought-and-famine-displacement-monitoring-dashboard-september-2022

[39] WHO. (2023). SITUATION REPORT: 01 Apr—30 Jun 2023—Greater Horn of Africa Food Insecurity and Health Grade 3 Emergency (p. 18) [Situation report]. WHO. https://reliefweb.int/report/somalia/situation-report-greater-horn-africa-food-insecurity-and-health-grade-3-emergency-1-april-2023-30-june-2023

[40] Ward, P. J., Jongman, B., Kummu, M., Dettinger, M. D., Sperna Weiland, F. C., & Winsemius, H. C. (2014). Strong influence of El Niño Southern Oscillation on flood risk around the world. Proceedings of the National Academy of Sciences, 111(44), 15659–15664. https://doi.org/10.1073/pnas.1409822111

[41] Rojas, O., Li, Y., & Cumani, R. (2014). Understanding the drought impact of El Niño on the global agricultural areas: An assessment using FAO's Agricultural Stress Index (ASI). FAO. https://www.fao.org/3/i4251e/i4251e.pdf

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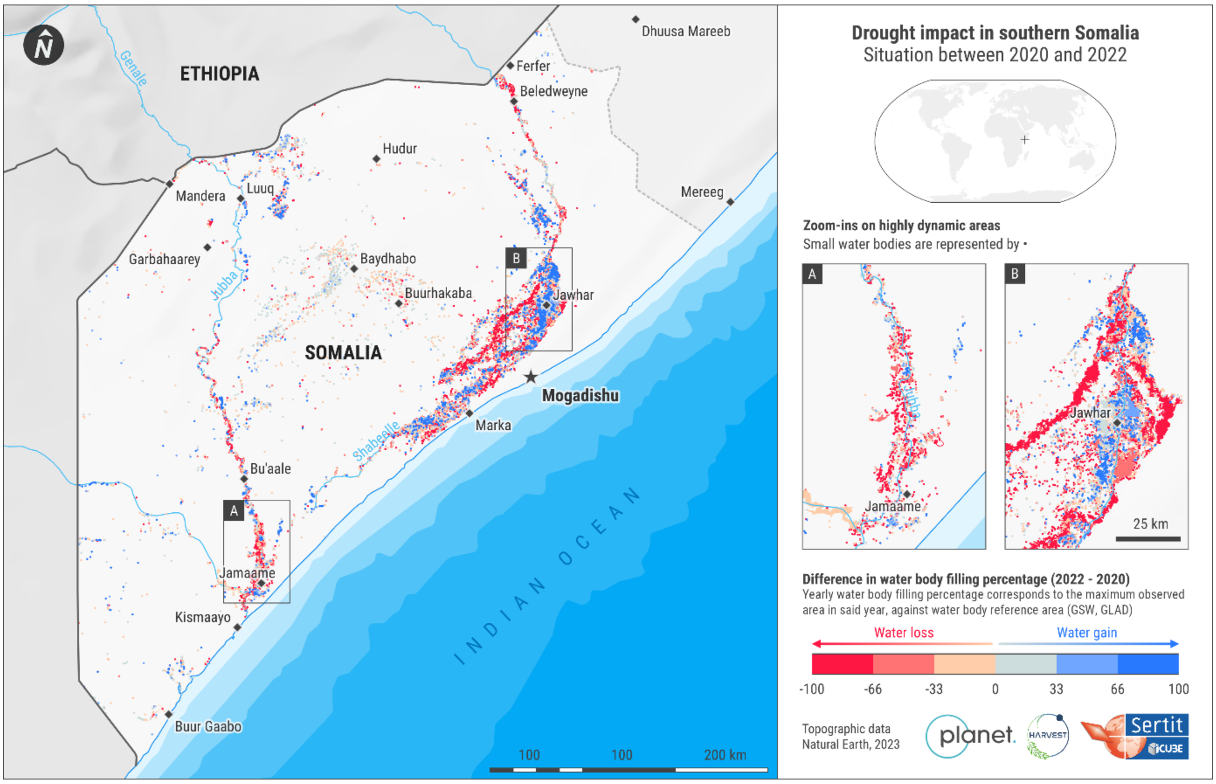
Figure 21: Impact of drought on Somalian water bodies, between 2020 and 2022. This unpublished UNISTRA study leveraged a time series of PlanetScope imagery to unveil a 52% reduction in Somalia's inland surface water over a two-year period.



Mali, featured as one of the CENTAUR use cases, sits in the Sahel and Western Africa region where the ENSO typically leads to drier conditions from July to September. In 2023, Mali experienced this expected pattern with irregular rainfall in June and July, followed by an acute deficit in September and October[42]. This disruption has delayed the planting season and resulted in crop yields that are below average, but still close to that of the preceding five years thus far[43]. Some crop loss has also been attributed to flooding, due to the Mopti and Segou rivers overflowing their banks[44]. Fortunately, the current conditions do not approach the severity of previous droughts, such as the 2015 – 2016 period influenced by El Niño, or the devastating drought of 1972 – 1974, which led to the loss of 40% of Mali's livestock, coupled with substantial economic damages and food scarcity affecting around 3.5 million people[45]. Compounding the current environmental challenges in Mali, civil unrest and military conflicts have further complicated agricultural activities in certain areas of the country, following a political coup in 2012 and frequent terrorist raids on the population[44].

Contrasting with Mali's experience, the eastern portion of Africa, particularly the Horn of Africa, has been experiencing wet conditions due to the ENSO, which typically induces increased rainfall from October to January (Figure 22). Somalia, preconditioned by a series of droughts, has been subjected to rare flood events that are

[42] WFP. (2023). West Africa Seasonal Monitor 2023 Season—October Update (p. 21) [Situation report]. WFP. https://reliefweb.int/report/mali/west-africa-seasonal-monitor-2023-season-october-update
[43] FEWS NET. (2023). Perspectives de récoltes 2023/24 moyennes avec toutefois des baisses au Sahel (p. 2) [Afrique de l'Ouest - Mise à jour des messages clés]. FEWS NET. https://fews.net/fr/afrique-de-louest/mise-jour-des-messages-cles/septembre-2023
[44] FEWS NET. (2023). Despite ongoing harvest, Crisis (IPC Phase 3) persists in conflict-affected areas of central Mali (p. 8) [Food Security Outlook]. FEWS NET. https://fews.net/west-africa/mali/food-security-outlook/october-2022
[45] GFDRR & World Bank. (2019). Disaster Risk Profile—Mali (p. 16) [Analysis]. GFDRR. https://www.gfdrr.org/en/publication/disaster-risk-profile-mali

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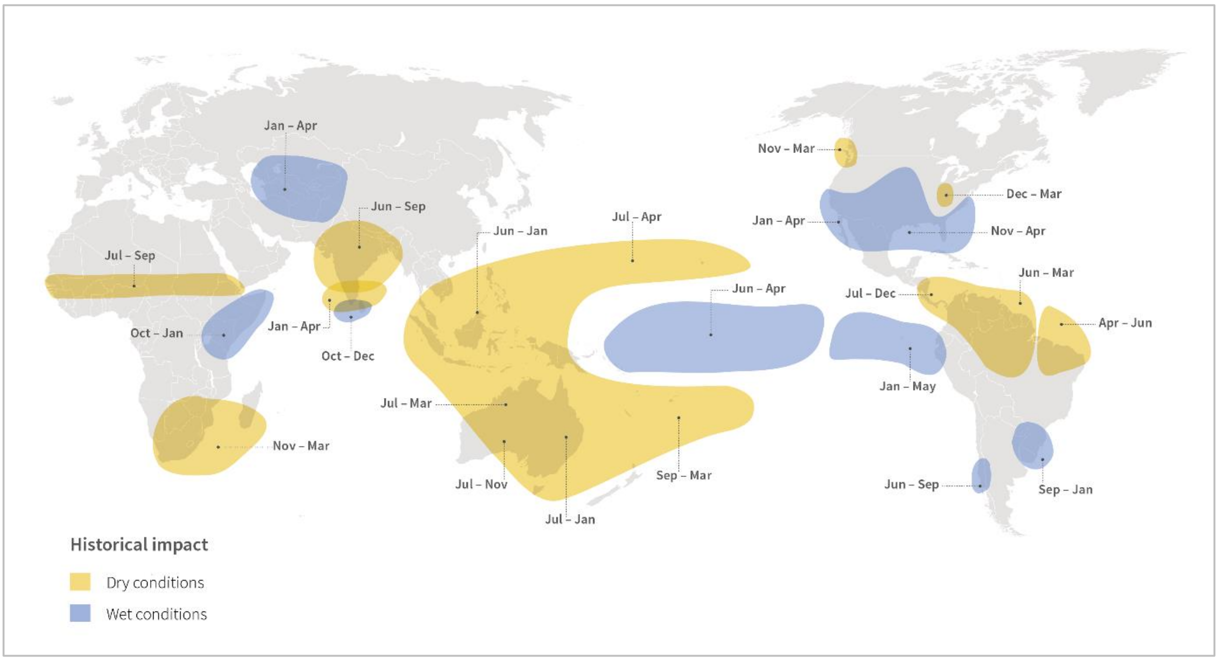
considered to have a one-in-a-hundred-year occurrence rate. Reports from the United Nations indicate that the Somalian Deyr rainy season, spanning October to December, has brought unusually heavy precipitation across the country, especially in the states of Puntland, Galmudug, South West, Hirshabelle, and Jubaland. Global climate models confirm the existence of El Niño conditions as the principal cause behind the increase in rainfall and flooding, a pattern anticipated to last until at least April 2024[46].

Figure 22: Consequences of El Niño on rainfall patterns across the globe.[47]



Since October 2023, the floods have damaged permanent settlements, including several internally displaced person (IDP) sites. The numbers of casualties, affected individuals, and displaced persons are currently estimated at around 100, 1,700,000, and 650,000, respectively[48]. This extreme event follows the May 2023 floods during the Gu rainy season, which already led to the displacement of almost 250,000 people following the inundation of Beledweyne by the Shabelle River. The May floods resulted in 22 fatalities and impacted over 450,000 individuals, occurring in the midst the country's worst drought since 1981[49].

The **conditions in Somalia highlight the complex relationship between flooding and security**, as well as the broader implications of extreme weather events. Despite humanitarian aid, the situation remains challenging. The financial consequences have led to food costs rising by up to 35%, and prices for essential commodities like charcoal and firewood quadrupling from US$3 to US$12[50]. As of November 2023, there is an estimated 3.7 million people in a state of severe food insecurity[50]. Compounding the issue, floods have inflicted damage on critical water infrastructure, including latrines and wells for daily consumption, especially within IDP camps (Figure 23),

[46] AFP. (2023, November 21). Somalia flash floods kill dozens, leave hundreds of thousands homeless. France 24. https://www.france24.com/en/africa/20231121-somalia-flash-floods-kill-dozens-leave-hundreds-of-thousands-homeless
[47] Lenssen, N. J. L., Goddard, L., & Mason, S. (2020). Seasonal Forecast Skill of ENSO Teleconnection Maps. Weather and Forecasting, 35(6), 2387–2406. https://doi.org/10.1175/WAF-D-19-0235.1
[48] Saeed, W., & Chinyama, V. (2023). Rapid Response Team (RRT)—Response to El Niño (p. 2) [Situation report]. UNICEF. https://reliefweb.int/report/somalia/unicef-somalia-rapid-response-el-nino-17-november-2023-sunday-26-november-2023
[49] AFP. (2023, May 14). 22 people killed in Somalia floods: UN. France 24. https://www.france24.com/en/live-news/20230514-22-people-killed-in-somalia-floods-un
[50] OCHA. (2023). Somalia—Situation report (p. 15) [Situation report]. OCHA. https://reports.unocha.org/en/country/somalia/

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increasing the risk of disease. As a result, thousands of Somalians are vulnerable to water-borne illnesses, with children under five constituting over half of the cases of acute watery diarrhoea currently reported[51]. This situation not only reflects a public health emergency but also a significant security concern, as the struggle for essential resources can heighten tensions and instability.

Figure 23: Flooded shelters in Somalian IDP camps. Source: Ayub/OCHA.[52]

Finally, the ENSO is also expected to modulate weather patterns in austral Africa, resulting in dryer than usual conditions from November to March (Figure 22). This includes Mozambique, a country that is prone to multivariate compound events. Past CEMS activations reveal a dire context, with large areas that are prone to coastal flooding, storm surges, riverine floods, erosion, etc. The Idai cyclone has triggered a plethora of hazards and exposed the fragilities of the local food systems, thereby presenting food insecurity challenges that potentially undermined the drive towards the achievement of Sustainable Development Goal of level 2 on hunger eradication[53]. The study also found that the disaster management responses in both Mozambique and Zimbabwe focussed on the emergency needs in the affected areas without giving much attention to making the food systems more resilient.

UNICEF reported that the cyclone had a significant impact on water and sanitation infrastructure, with an estimated 1.8 million people affected by the destruction of water supply systems[54]. In addition, the World Food Programme reported that the cyclone had a devastating impact on crops and livestock, which led to a sharp increase in food prices and a decline in food availability. The World Food Programme also reported that the cyclone had a significant impact on the livelihoods of smallholder farmers, who were already vulnerable to food insecurity before the cyclone. This situation has had crippling effects on food security, with major crop die-off. Indeed,

[51] OCHA. (2023). SOMALIA: Deyr rainy season 2023—Flash Update No. 1: Floods in South West State (Flash Update, p. 2) [Situation report]. OCHA. https://reliefweb.int/report/somalia/somalia-deyr-rainy-season-2023-flash-update-no-1-floods-south-west-state-7-october-2023
[52] https://reports.unocha.org/en/country/somalia/card/5eTcUnb3e2/
[53] Macamo, C. (2021). After Idai: Insights from Mozambique for Climate Resilient Coastal Infrastructure. 22.
[54] Lequechane, J. D., Mahumane, A., Chale, F., Nhabomba, C., Salomão, C., Lameira, C., Chicumbe, S., & Semá Baltazar, C. (2020). Mozambique's response to cyclone Idai: How collaboration and surveillance with water, sanitation and hygiene (WASH) interventions were used to control a cholera epidemic. Infectious Diseases of Poverty, 9(1), 68. https://doi.org/10.1186/s40249-020-00692-5

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parcels were submerged for more than 40 days in some places[55]. In total, it is estimated that around 715,000 hectares of crops were destroyed, as much as 50 percent of Mozambique's annual crops[56].

The cyclone killed and injured more than 500 and 1,600 people respectively, and displaced almost 100,000 people. Due to water sanitation issues, it is estimated that around 10,000 individuals within the city of Beira only, which is particularly prone to flooding, have reported cases of acute watery diarrhoea, cholera and water-borne infections. According to a report, Idai damaged critical housing, energy and transportation infrastructure. It has had a significant impact on the economy, with the cost of damage estimated to be around $773 million[57].

5.3 AVAILABLE DATASETS TO ADDRESS THE CROSS-CUTTING ANALYSIS OF COMPOUND EVENTS AND IMPACTS

Given the extensive scope of data and use cases encompassed by the CENTAUR project, the conceptual models for both tracks were designed to address specific issues with pronounced end-user needs, and where the availability of data and methods ensures timely development. Consequently, both the UF track and the WFS track were developed concurrently but within clearly defined scopes. Nonetheless, the **interconnected nature of extreme climate and weather events, along with their impacts, indicates a strong and likely intensifying connection between urban flooding and water & food security**, particularly as urbanization continues to concentrate activities within cities and their outskirts.

This section is dedicated to exploring how the input data, indicators, indexes, and high-level tools currently at our disposal could be leveraged to **enhance the CENTAUR system's capabilities** in the future, thereby **enriching the portfolios of both Copernicus EMS and SEA**. With this objective in mind, the section has been structured to emphasize a **data-centric approach**, aiming to highlight the potential synergies between the two tracks.

5.3.1 Physical environmental monitoring

As of today, **meteorological trends** (Table 37) are an invaluable tool for monitoring climate change and extreme events[58]. Both have been integrated within the UF and WFS conceptual models, but could be further extent. Indeed, **high temperatures** can contribute to urban flooding by intensifying rainfall events[59], and drought conditions notably by increasing evapotranspiration rates[60]. Thus, monitoring temperature anomalies can provide a broader context for assessing climate-related risks. While **extreme precipitation** can trigger urban floods in certain areas, the absence of precipitation can also indicate an ongoing drought in others. Monitoring precipitation

[55] Bofana, J., Zhang, M., Wu, B., Zeng, H., Nabil, M., Zhang, N., Elnashar, A., Tian, F., Da Silva, J. M., Botão, A., Atumane, A., Mushore, T. D., & Yan, N. (2022). How long did crops survive from floods caused by Cyclone Idai in Mozambique detected with multi-satellite data. Remote Sensing of Environment, 269, 112808. https://doi.org/10.1016/j.rse.2021.112808

[56] Figure of the week: Cyclone Idai's impact on Mozambique. (n.d.). Brookings. Retrieved November 30, 2023, from https://www.brookings.edu/articles/figure-of-the-week-cyclone-idais-impact-on-mozambique/

[57] IFRC. (2022). Mozambique: Tropical Cyclones Idai and Kenneth—Emergency Appeal n° MDRMZ014, Final Report (p. 65) [Situation report]. IFRC. https://reliefweb.int/attachments/a2282438-3684-4915-8a78-9e53d56509a6/MDRMZ014efr.pdf

[58] Karl, T. R., & Easterling, D. R. (1999). Climate Extremes: Selected Review and Future Research Directions. Climatic Change, 42(1), 309–325. https://doi.org/10.1023/A:1005436904097

[59] Higher Temperature Enhances Spatiotemporal Concentration of Rainfall. (2021). Journal of Hydrometeorology, 22(12), 3159–3169. https://doi.org/10.1175/JHM-D-21-0034.1

[60] Abtew, W., & Melesse, A. (2013). Climate Change and Evapotranspiration. In W. Abtew & A. Melesse, Evaporation and Evapotranspiration (pp. 197–202). Springer Netherlands. https://doi.org/10.1007/978-94-007-4737-1_13

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anomalies helps assess climate-related risks, as excess rainwater can also impede crop development and livestock rearing[61].

Table 37: Meteorological data available for a cross-cutting extension of the CENTAUR system.

	Track	Identifier	Full name
Input datasets		Input-ID-59	European Meteorological Observations (EMO)
		Input-ID-60	GPM constellation data referred to the period of interest
		Input-ID-61	E-OBS daily gridded meteorological data for Europe
		Input-ID-65	ECMWF forecasts
		Input-ID-77	Rainfall data for Zaragoza
		Input-ID-08	S3-LST
		Input-ID-09	MODIS-LST
		Input-ID-10	GRACE RZSM
		Input-ID-14	SMAP L4 RZSM
		Input-ID-62	ERA5 air temperature
		Input-ID-63	ERA5 precipitation
		Input-ID-65	ECMWF forecasts
Indicators		UF-ID-01	Static map of precipitation associated to return period
		UF-ID-02	Forecast of return period
		WFS-ID-01	Meteorological drought indicator (Monitoring)
		WFS-ID-02	Meteorological drought indicator (Forecast)
		WFS-ID-03	Meteorological drought indicator (danger levels)
		WFS-ID-04	Agricultural drought monitoring (near real-time)
		WFS-ID-05	Agricultural drought forecast
		WFS-ID-06	Agricultural drought risk zone map

Soil moisture data (Table 38), often used to assess drought conditions, can also be valuable for understanding flood risk. Indeed, saturated soils contribute to runoff during heavy rainfall, potentially exacerbating urban flooding. Conversely, as evidenced by the compound events in Somalia, dry soils can also render entire region more susceptible to water runoff or inundation[62]. Similarly, understanding soil moisture levels in agricultural areas can provide insights into crop health and potential water stress.

Table 38: Soil moisture data available for a cross-cutting extension of the CENTAUR system.

	Track	Identifier	Full name
Input datasets		Input-ID-10	GRACE RZSM
		Input-ID-14	SMAP L4 RZSM
Indicators		WFS-ID-04	Agricultural drought monitoring (near real-time)
		WFS-ID-05	Agricultural drought forecast
		WFS-ID-06	Agricultural drought risk zone map

[61] Lesk, C., Rowhani, P., & Ramankutty, N. (2016). Influence of extreme weather disasters on global crop production. Nature, 529(7584), 84–87. https://doi.org/10.1038/nature16467

[62] He, X., & Sheffield, J. (2020). Lagged Compound Occurrence of Droughts and Pluvials Globally Over the Past Seven Decades. Geophysical Research Letters, 47(14), e2020GL087924. https://doi.org/10.1029/2020GL087924

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Land use and land cover (LULC) management (Table 39) has been shown to have an extensive impact on urban floods[63,64] and water & food security[65], especially due to alterations in soil properties. For example, soil sealing in urban areas favours water runoff due to low permeability, resulting in inundation within city centres, and erosion on the outskirts. Moreover, urbanization is also one of the key factors behind changes in agrifood systems, including cropland loss[66]. Thus, monitoring these states and changes can provide insights into how LULC dynamics affects agriculture and natural water bodies. Conversely, shifts in agricultural land use can influence urban runoff and flood patterns.

Table 39: Land use and land cover data available for a cross-cutting extension of the CENTAUR system.

	Track	Identifier	Full name
Input datasets		Input-ID-02	Land Use
		Input-ID-03	Hydrography
		Input-ID-04	BD TOPO® v3.3 – (French territory and infrastructures)
		Input-ID-29	OpenStreetMap
		Input-ID-12	Land Cover
		Input-ID-13	FAO Wapor: Land Cover Classification 2021
		Input-ID-15	Rangeland land cover change

In scenarios where high-level datasets are unavailable, **remote sensing** becomes an invaluable tool. **Satellite imagery** (Table 40) is particularly useful not only for mapping the extent of urban floods but also for assessing changes in vegetation health, which serves as an indicator of agricultural productivity. Conversely, monitoring changes in agricultural land cover can shed light on the expansion of urban areas and flood-prone zones. During flooding events, remote sensing can help outline the inundated areas in both urban and rural environments, enabling the generation of reports on impacted land parcels that are likely to experience reduced crop yields. In the context of WFS, remote sensing data, when integrated with additional information sources, are also valuable for IDP camp analysis. This involves comparing data from a baseline condition to an event-driven analysis, thereby facilitating the creation of products that track changes in the size and distribution of population concentrations. These hotspots are tracked in humanitarian reports, and monitoring begins as soon as the CENTAUR system's risk and hazard indicators trigger an alert.

[63] Ma, S., Wang, L.-J., Jiang, J., & Zhao, Y.-G. (2024). Land use/land cover change and soil property variation increased flood risk in the black soil region, China, in the last 40 years. Environmental Impact Assessment Review, 104, 107314. https://doi.org/10.1016/j.eiar.2023.107314
[64] Sugianto, S., Deli, A., Miswar, E., Rusdi, M., & Irham, M. (2022). The Effect of Land Use and Land Cover Changes on Flood Occurrence in Teunom Watershed, Aceh Jaya. Land, 11(8), 1271. https://doi.org/10.3390/land11081271
[65] Okeleye, S. O., Okhimamhe, A. A., Sanfo, S., & Fürst, C. (2023). Impacts of Land Use and Land Cover Changes on Migration and Food Security of North Central Region, Nigeria. Land, 12(5), 1012. https://doi.org/10.3390/land12051012
[66] Satterthwaite, D., McGranahan, G., & Tacoli, C. (2010). Urbanization and its implications for food and farming. Philosophical Transactions of the Royal Society B: Biological Sciences, 365(1554), 2809–2820. https://doi.org/10.1098/rstb.2010.0136

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Table 40: Remote sensing data available for a cross-cutting extension of the CENTAUR system.

	Track	Identifier	Full name
Input datasets		Input-ID-05	VHR_IMAGE_2021
		Input-ID-06	PREs and POST event INSAR compatible data
		Input-ID-17	VHR DTM
		Input-ID-18	VHR DTM (Piedmont)
		Input-ID-19	RGE ALTI® 1m
		Input-ID-67	DH_Ebro
		Input-ID-69	CHE Oblique aerial mages
		Input-ID-70	ORTHO PNOA18
		Input-ID-71	MDT14 – ARPSI
		Input-ID-72	MDT02 - PNOA 2a cobertura
		Input-ID-73	LiDAR - PNOA 2a cobertura
		Input-ID-07	NDVI
		Input-ID-08	S3-LST
		Input-ID-09	MODIS-LST
		Input-ID-34	HR-VHR SAR EO
		Input-ID-50	EOG Nighttime Light

5.3.2 Water resources impacts

Water is a common denominator between the urban flood and the water & food security tracks. It acts as a pivotal factor, where its abundance can lead to urban floods or failed crops, while its scarcity can undermine water and food security. Beyond mere availability, water quality is also essential for ensuring safe human consumption and for the prevention of waterborne diseases. Thus, it is mandatory to assess the different ways water-related data can support the broader concept of climate security.

Monitoring **groundwater levels** (Table 41) is crucial, as it offers critical insights into urban flood risks by indicating potential saturation points. It also aids in gauging agricultural water availability, particularly during drought conditions. This dual functionality highlights the importance of groundwater data in both disaster preparedness and sustainable water resource management[67,68].

Table 41: Groundwater data available for a cross-cutting extension of the CENTAUR system.

	Track	Identifier	Full name
Input datasets		Input-ID-11	GRACE ground water

At the surface, **streamflow data** (Table 42) serve a dual purpose in risk assessment and resource management. They are not only important for evaluating urban flood risks, but also indicative of water resource availability for agricultural use, given a suitable infrastructure like irrigation systems. Diminished streamflow may signal impending water scarcity, potentially disrupting irrigation and resulting in food and water insecurity. This link

[67] Taylor, R. G., Scanlon, B., Döll, P., Rodell, M., Van Beek, R., Wada, Y., Longuevergne, L., Leblanc, M., Famiglietti, J. S., Edmunds, M., Konikow, L., Green, T. R., Chen, J., Taniguchi, M., Bierkens, M. F. P., MacDonald, A., Fan, Y., Maxwell, R. M., Yechieli, Y., … Treidel, H. (2013). Ground water and climate change. Nature Climate Change, 3(4), 322–329. https://doi.org/10.1038/nclimate1744
[68] Famiglietti, J. S. (2014). The global groundwater crisis. Nature Climate Change, 4(11), 945–948. https://doi.org/10.1038/nclimate2425

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between hydrology and socio-economic stability is well-documented, with research suggesting that effective streamflow management is vital for sustainable urban[69] and agricultural[70] development.

Table 42: Hydrological data available for a cross-cutting extension of the CENTAUR system.

	Track	Identifier	Full name
Input datasets	UF	Input-ID-78	Water gauges for the analysed event
	WFS	Input-ID-64	ERA5-Land runoff
Indicators	UF	UF-ID-03	High-Resolution urban flood risk maps for various return periods

Urban floods often result from heavy rainfall. **Rainwater collection and storage systems** (Table 43), designed to capture excess water, can help mitigate flood risks[71]. Additionally, this water can supplement resources for irrigation and thus improve food security[72], and there is less chance of contaminating water for human consumption[73].

Table 43: Rainwater collection and storage data available for a cross-cutting extension of the CENTAUR system.

	Track	Identifier	Full name
Input datasets	UF	Input-ID-04 Input-ID-29	BD TOPO® v3.3 – (French territory and infrastructures) Open Street Map (OSM)

5.3.3 Socioeconomic and community impact

Urban flood events often disproportionately impact vulnerable communities. These communities may also be more susceptible to water and food insecurity. Thus, **socioeconomic indicators** can provide a comprehensive view of vulnerability for both of the UF and WFS tracks, albeit at different scales. Additionally, they can also indicate presence of conflict, which is an important matter within the WFS track.

Understanding urban **population density and distribution** (Table 44) is crucial for effective flood management, in terms of urban planning, infrastructure development and emergency service deployment. This information can also be valuable for targeting interventions related to food and water security, such as distributing relief resources in case of drought or famine.

[69] Sivapalan, M., Savenije, H. H. G., & Blöschl, G. (2012). Socio-hydrology: A new science of people and water. Hydrological Processes, 26(8), 1270–1276. https://doi.org/10.1002/hyp.8426
[70] Rodriguez-Iturbe, I. (2000). Ecohydrology: A hydrologic perspective of climate-soil-vegetation dynamies. Water Resources Research, 36(1), 3–9. https://doi.org/10.1029/1999WR900210
[71] Jamali, B., Bach, P. M., & Deletic, A. (2020). Rainwater harvesting for urban flood management – An integrated modelling framework. Water Research, 171, 115372. https://doi.org/10.1016/j.watres.2019.115372
[72] Zhu, Q., & Li, Y. (2004). Rainwater harvesting—An alternative for securing food production under climate variability. Water Science and Technology, 49(7), 157–163. https://doi.org/10.2166/wst.2004.0443
[73] Bitterman, P., Tate, E., Van Meter, K. J., & Basu, N. B. (2016). Water security and rainwater harvesting: A conceptual framework and candidate indicators. Applied Geography, 76, 75–84. https://doi.org/10.1016/j.apgeog.2016.09.013

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Table 44: Population density and distribution data available for a cross-cutting extension of the CENTAUR system.

	Track	Identifier	Full name
Input datasets		Input-ID-20	WSF World Settlement Footprint
		Input-ID-21	WSF-Imperviousness
		Input-ID-22	WSF-3D
		Input-ID-23	BDTRE Struttura Aggregata for Piedmont Region and Settlements
		Input-ID-24	GHS-Built-S R2023A
		Input-ID-25	GHS-Built-V R2023A
		Input-ID-26	GHS-Built-C R2023A
		Input-ID-27	GHS-SMOD- R2023A
		Input-ID-28	GHS-DUC R2023A
		Input-ID-31	BD TOPO® v3.3 - (French settlement data)
		Input-ID-48	Resident Population by Municipality of Turin
		Input-ID-49	INSEE census
		Input-ID-50	EOG Nighttime Light
		Input-ID-54	IOM DTM Flow monitoring
		Input-ID-55	IOM DTM Mobility tracking
		Input-ID-57	DHS (Demographic and Health Surveys)
		Input-ID-46	WSF-Population
		Input-ID-47	GHS-Pop R2023A
Indicators		UF-ID-07	Hazard web sources indicator
		UF-ID-09	Assets and financial resources
		WFS-ID-07	IDP camps status indicator
		WFS-ID-08	Populations at risk of food insecurity
		WFS-ID-09	Populations at risk of water insecurity
		WFS-ID-10	Number of people living in conflict-affected areas

As previously illustrated by African use cases, urban flooding frequently impacts vulnerable populations, who are also at heightened risk for water and food insecurity. Socioeconomic indicators (Table 45), therefore, are key in delivering a nuanced perspective on the vulnerabilities pertinent to both tracks, despite the differences in scale. Furthermore, these indicators can signal the existence of conflict, a significant concern in the WFS track, where tensions may exacerbate resource scarcity and hinder relief efforts.

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Table 45: Socioeconomic data available for a cross-cutting extension of the CENTAUR system.

	Track	Identifier	Full name
Input datasets		Input-ID-20	WSF World Settlement Footprint
		Input-ID-21	WSF-Imperviousness
		Input-ID-22	WSF-3D
		Input-ID-23	BDTRE Struttura Aggregata for Piedmont Region and Settlements
		Input-ID-24	GHS-Built-S R2023A
		Input-ID-25	GHS-Built-V R2023A
		Input-ID-26	GHS-Built-C R2023A
		Input-ID-27	GHS-SMOD- R2023A
		Input-ID-28	GHS-DUC R2023A
		Input-ID-35	Media data on assets and financial resources
		Input-ID-36	Media on public services and government support
		Input-ID-38	Media data on economic impacts of floods
		Input-ID-45	Media data related to a flooding event
		Input-ID-48	Resident Population by Municipality of Turin
		Input-ID-49	INSEE census
		Input-ID-58	Restaurant prices
		Input-ID-39	Media data on radicalisation and polarisation
		Input-ID-40	Media indicator on resource capture
		Input-ID-41	Media data on public services and infrastructure
		Input-ID-42	Media data on state-citizen relations
		Input-ID-43	Media data on dispute resolution mechanisms
		Input-ID-44	Media data on social cohesion and trust
		Input-ID-53	Afrobarometer
		Input-ID-57	DHS (Demographic and Health Surveys)
		Input-ID-81	Media on economic security
		Input-ID-82	Media on displaced persons
		Input-ID-83	Media on violent conflict
		Input-ID-84	Media on humanitarian aid
		Input-ID-46	WSF-Population
		Input-ID-47	GHS-Pop R2023A
Indicators		UF-ID-09	Assets and financial resources
		UF-ID-14	Economic impact of floods
		WFS-ID-12	Economic security
		WFS-ID-18	Resource capture

Finally, during urban flood events, **social networks** play a crucial role in **community assistance** (Table 46). These networks can also be leveraged to enhance water and food security through collective actions, such as resource sharing during periods of scarcity[74]. Even though their spatial and temporal availability might be limited depending on the area, they still provide an invaluable wealth of information in the context of crisis management.

[74] Mertens, F., Fillion, M., Saint-Charles, J., Mongeau, P., Távora, R., Sousa Passos, C. J., & Mergler, D. (2015). The role of strong-tie social networks in mediating food security of fish resources by a traditional riverine community in the Brazilian Amazon. Ecology and Society, 20(3), art18. https://doi.org/10.5751/ES-07483-200318

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Table 46: Social network and community data available for a cross-cutting extension of the CENTAUR system.

	Track	Identifier	Full name
Input datasets	UF	Input-ID-35 Input-ID-36 Input-ID-38 Input-ID-45	Media data on assets and financial resources Media on public services and government support Media data on economic impacts of floods Media data related to a flooding event
	WFS	Input-ID-39 Input-ID-40 Input-ID-41 Input-ID-42 Input-ID-43 Input-ID-44 Input-ID-53 Input-ID-81 Input-ID-82 Input-ID-83 Input-ID-84	Media data on radicalisation and polarisation Media indicator on resource capture Media data on public services and infrastructure Media data on state-citizen relations Media data on dispute resolution mechanisms Media data on social cohesion and trust Afrobarometer Media on economic security Media on displaced persons Media on violent conflict Media on humanitarian aid
Indicators	UF	UF-ID-11	Social networks and community support
	WFS	WFS-ID-07 WFS-ID-15 WFS-ID-25	IDP camps status indicator Radicalisation and polarisation Social cohesion and trust

5.3.4 Resilience and adaptation

Effective responses to UF and WFS challenges require coordination among various stakeholders to improve resilience and adapt to climate change and compound extreme events. **Integrated policies** that address both tracks can lead to more efficient resource allocation and risk reduction efforts, highlighting the importance of considering information on **governance** (Table 47) within CENTAUR and cross-cutting systems[75,76].

Table 47: Governance and integrated policy data available for a cross-cutting extension of the CENTAUR system.

	Track	Identifier	Full name
Input datasets	UF	Input-ID-36	Media on public services and government support
	WFS	Input-ID-42 Input-ID-43 Input-ID-44 Input-ID-53	Media data on state-citizen relations Media data on dispute resolution mechanisms Media data on social cohesion and trust Afrobarometer
Indicators	UF	UF-ID-10	Public services and government support

[75] Cumiskey, L., Priest, S. J., Klijn, F., & Juntti, M. (2019). A framework to assess integration in flood risk management: Implications for governance, policy, and practice. Ecology and Society, 24(4), art17. https://doi.org/10.5751/ES-11298-240417
[76] Pahl-Wostl, C. (2019). Governance of the water-energy-food security nexus: A multi-level coordination challenge. Environmental Science & Policy, 92, 356–367. https://doi.org/10.1016/j.envsci.2017.07.017

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	Track	Identifier	Full name
		WFS-ID-24	Public services and government support

Governance includes urban planning policies, that can help mitigate the effects of extreme events related to climate change. **Green infrastructure** (Table 48), such as parks and wetlands, can provide such services by absorbing some of the excess streamflow in case of inundation[77] and preventing runoff[78]. Moreover, these areas can also contribute to local food production, and even enhance water quality[79].

Table 48: Green infrastructure data available for a cross-cutting extension of the CENTAUR system.

	Track	Identifier	Full name
Input datasets		Input-ID-02 Input-ID-04 Input-ID-36	Land Use BD TOPO® v3.3 – (French territory and infrastructures)
		Input-ID-29	OpenStreetMap

Moreover, flood events can damage critical infrastructure, such as roads and bridges, impacting transportation and access to markets for agricultural products, but also health infrastructures for example. Thus, data on **general infrastructure vulnerability** (Table 49) can inform both flood risk management and the transportation of water and food resources[80].

Table 49: Infrastructure vulnerability data available for a cross-cutting extension of the CENTAUR system.

	Track	Identifier	Full name
Input datasets		Input-ID-38	Media data on economic impacts of floods
		Input-ID-41	Media data on public services and infrastructure
Indicators		UF-ID-4 UF-ID-5 UF-ID-7 UF-ID-8	Inferred INSAR urban flood extent Enhanced urban flood damage assessment Hazard web sources indicator Robustness and quality of the built environment
		WFS-ID-16 WFS-ID-21	Disruptions in food supply chains Public services and infrastructures

[77] Mei, C., Liu, J., Wang, H., Yang, Z., Ding, X., & Shao, W. (2018). Integrated assessments of green infrastructure for flood mitigation to support robust decision-making for sponge city construction in an urbanized watershed. Science of The Total Environment, 639, 1394–1407. https://doi.org/10.1016/j.scitotenv.2018.05.199

[78] Yang, B., & Li, S. (2013). Green Infrastructure Design for Stormwater Runoff and Water Quality: Empirical Evidence from Large Watershed-Scale Community Developments. Water, 5(4), 2038–2057. https://doi.org/10.3390/w5042038

[79] Hamel, P., & Tan, L. (2022). Blue–Green Infrastructure for Flood and Water Quality Management in Southeast Asia: Evidence and Knowledge Gaps. Environmental Management, 69(4), 699–718. https://doi.org/10.1007/s00267-021-01467-w

[80] Wilbanks, T. J., & Fernandez, S. (Eds.). (2014). Climate Change and Infrastructure, Urban Systems, and Vulnerabilities. Island Press/Center for Resource Economics. https://doi.org/10.5822/978-1-61091-556-4

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Finally, decisions can also be informed by the **impacts of previous events** (Table 50) within an area of interest, or regions that share similar challenges. For example, data related to emergency response efforts during urban flood events, such as resource allocation and relief distribution, can provide insights into the capacity to address food and water security challenges in crisis situations[81,82].

Table 50: Retrospective emergency data available for a cross-cutting extension of the CENTAUR system.

	Track	Identifier	Full name
Input datasets		Input-ID-33	Global Disaster Alert and Coordination System (GDACS) indicator
		Input-ID-34 Input-ID-52 Input-ID-53 Input-ID-54 Input-ID-55 Input-ID-56 Input-ID-79	HR-VHR SAR EO FAO DIEM (Data in Emergencies Monitoring) Afrobarometer IOM DTM Flow monitoring IOM DTM Mobility tracking ACLED UNHCR CCCM
Indicators		UF-ID-07 UF-ID-10	Hazard web sources indicator Public services and government support
		WFS-ID-17	Humanitarian aid

[81] Albright, E. A., & Crow, D. A. (2021). Capacity Building toward Resilience: How Communities Recover, Learn, and Change in the Aftermath of Extreme Events. Policy Studies Journal, 49(1), 89–122. https://doi.org/10.1111/psj.12364

[82] De Bruijn, K., Buurman, J., Mens, M., Dahm, R., & Klijn, F. (2017). Resilience in practice: Five principles to enable societies to cope with extreme weather events. Environmental Science & Policy, 70, 21–30. https://doi.org/10.1016/j.envsci.2017.02.001

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6 CONCLUSIONS

This deliverable provides a clear overview of the **criteria and considerations for selecting use cases** in the CENTAUR project. It summarizes the process of selecting use cases for the CENTAUR, which was not just a matter of identifying regions or situations most affected by urban flooding, water scarcity, and food insecurity. Instead, it involved a strategic approach, with regard to the **complex interplay of environmental, socio-economic, and governance factors**.

Key to this selection process was the **identification of areas where the phenomenon of compound climatic events is most pronounced**. Regions where the impacts of these compound events are acute offer valuable opportunities for in-depth study and the application of integrated solutions. Moreover, with the direct **involvement of end-users**, these cases provide practical insights into managing and mitigating the impacts of such complex climatic events, using various data. In total, 7 use cases have been selected:

- 4 use cases for the urban flood track, including Spain, Italy, Germany and France.
- 2 use cases for the water & food security track, including Mali and Somalia.
- 1 cross-cutting use case, with Mozambique.

The chosen use cases will serve as a platform for testing and refining the project's methodologies and tools. The insights from these cases will contribute to the **development of scalable and adaptable models** that can be applied in other contexts facing similar challenges. In this deliverable, the initial conceptual models for the UF and WFS tracks were designed, but will be improved upon in WP2 and WP4. This **iterative process** ensures that the project remains responsive to evolving needs and can continuously improve its impact in a changing climate context.

Finally, the selection of use cases in the CENTAUR project is a critical step that **bridges the theoretical insights of our cross-cutting analysis with practical application**. By carefully selecting these cases based on the complex dynamics of compound climatic events and their socio-economic ramifications, the project aims to develop robust, context-sensitive solutions that can significantly contribute to enhancing urban resilience and sustainability in the face of climate change and its associated challenges.

To address these challenges and test the platform, an extensive list of data sets has been collected for each use case. They will be leveraged for the **computation of novel indicators and indexes, as well as for triggering alerts and interactive situational reporting**. In total, the CENTAUR system:

- Takes 85 input data sets.
- Generates 39 indicators, including 14 for the UF track and 25 for the WFS track.
- Generates 2 indexes for the urban flood track.
- Integrates data within 3 high-level visualization tools for the water & food security track.

All of these are describe in the **catalogue of CENTAUR data and specifications** ([RD04]). However, changes are prone to happen during the lifetime of the project, as data engineering in WP2 and demonstrator execution in WP4 are expected to bring nuance to the initially proposed system. In particular, additional data sets are expected to be collected, especially to perform validation during the cold case phase.

System development and data collection was mostly conducted at **track-level**, thus resulting in distinctive specifications for each track. However, the cross-cutting analysis undertaken in this deliverable has illuminated the intricate nature of the challenges raised by urban flooding, water availability, and food security in the context of climate change. Through the lens of **compound climatic events**, it is possible to gain a deeper understanding of how intertwined and complex these challenges are. These events, amplified by climatic phenomena like ENSO, highlight the necessity of an **integrated approach to resilience and sustainability** at the level of urban communities and agrifood systems.

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The analysis of preconditioned events in regions like Mozambique and Somalia has revealed how existing climatic conditions can set the stage for **cascading impacts on water and food security and urban settlements**. These impacts are not isolated; they ripple through socio-economic systems, affecting livelihoods, health, and regional stability. Similarly, the analysis of multivariate events underscores the compounded impacts generated by intersecting climate drivers.

This integrated approach has also highlighted the importance of **considering socio-economic factors alongside environmental ones**. The disproportionate impact of these compound events on vulnerable populations, particularly in developing regions, calls for a nuanced understanding of resilience that encompasses not just infrastructure and environmental management, but also socio-economic background and resource distribution. The cross-cutting Mozambican use case will provide insight in the relationship between all these compounding factors and impacts. An initial assessment was proposed in this deliverable, but other dimensions likely contribute to both urban floods and water & food security.

Finally, this analysis has highlighted the need for **adaptive and forward-looking strategies in urban planning and governance**. With the increasing frequency and severity of compound events, cities must develop **flexible, multi-sectoral strategies** that address both immediate and long-term risks. This involves not only strengthening physical infrastructure but also investing in human capital and community engagement, which **traditional and social media markers** can help foster.

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