D2.3 – Urban Flood and Water&Food Insecurity Service Pipelines v1 (baseline setup)

Deliverable#	**D2.3**
WP#	**WP2**
WP Leader:	**e-GEOS**
Revision Date:	30.11.2023
Submission Date:	30.11.2023
Document Type:	Demonstrator
Authors:	Luisa Bettili (Project Coordinator, e-GEOS)
Contributor(s):	CENTAUR Consortium
Verified by:	CENTAUR Consortium Board and CENTAUR Steering Committee
Approved by:	Luisa Bettili (Project Coordinator, e-GEOS) and shared with the Consortium
Version	1.0
Dissemination Level:	Public (PU)

Disclaimer

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.*

HISTORY OF CHANGES

Date	Version	Author	Change Description
03.10.2023	1.0	EG	Initial version with a ToC
30.11.2023	1.0	EG, GMV, ITH, ADE, CLS, ECM, VIT, UNISTRA, DLR	First version of the document

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1 EXECUTIVE SUMMARY

The present document represents the deliverable D2.3 - Urban Flood and Water & Food Insecurity Service Pipelines v1 (baseline setup) and it is produced under the WP2 – Thematic Product engineering, particularly under Task 2.4, 2.5, and 2.6 carried out in parallel, which have the aim of developing and designing social, economic, and political indicators, urban flood indicators and water & food insecurity indicators.

The document includes the following contents:

- CENTAUR products demonstration: summary and results produced by each innovative indicators in the context of Urban Flood, Water& Food insecurity and Socio-economic related (whether feasible at the present stage).
- Baseline demonstration of processing chains designed and under development for the generation of CENTAUR products, in the thematic areas reported here above.
- CENTAUR platform architecture and preliminary demonstration where the pipelines will be integrated.

In the annex section, three specific input data generated through dedicated pipelines are demonstrated and related pipelines workflow provided.

2 INTRODUCTION

2.1 SCOPE OF THE DOCUMENT

This document is produced under the **WP2 – Thematic product engineering**, that has the objective to generate workflows for collecting necessary data for the development of risk indicators and crisis indexes as well as for their implementation accounting for the user requirements collected in WP1. The final output of this package shall consist in several service pipelines that will combine earth observations and forecasts of meteorological and hydrological data; open intelligence data from traditional and social media, socio-economic and political data; other types of geospatial data, using geospatial and temporal information as common homogenising feature to merge these data into synthetic indexes.

Particularly, the present deliverable lays under the ongoing activities part of Task 2.4, Task 2.5, and Task 2.6, where pre-processed data will be used to design and implement the service pipelines for the generation of complex Urban Flood, Food/Water Insecurity, and socio-political-economic indicators, properly combining and integrating dataset for supporting monitoring services, crisis, and impact assessment.

D2.3 provides a demonstration of products generated in CENTAUR, from each innovative indicator and a related summary of technical specification. Particularly, a comprehensive demonstration sheets were compiled with a provision of technical specifications of products and products preview. The fields listed here below are compiled per products sheets in a standardized format: products owner, product description, Service level, EO input data, non-EO input data, outputs, archive length, spatial resolution, temporal coverage, spatial coverage, validation, dependencies software and hardware, analytics, challenges, and product sample.

In addition, the demonstration comprises the visual representations of the processing chains of the CENTAUR products at the present stage: a workflow of each processing chain is presented. Whether relevant, an update of each representation can be produced in the future versions foreseen (i.e. D2.4), if needed, to show the evolution of the processes and to support the integration of the processing chains into the platform.

Lastly, the present deliverable provides an overview of how the pipelines developed in the context of CENTAUR are integrated in the platform.

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To cover the above objectives, the document is structured into the following sections:

- Section 1. Executive summary.
- Section 2. Introduction.
- Section 3. CENTAUR products.
- Section 4. Processing chains – Baseline v1.
- Section 5. CENTAUR platform for pipelines integration.
- Section 6: Conclusions.
- Section 7: Annex.

2.2 DEFINITIONS, ABBREVIATIONS AND ACRONYMS

Table 1. Table with abbreviations and acronyms.

Acronym	Description
ACD	Automatic Change Detection
ACLED	Armed Conflict Location & Event Data Project
AOI	Area of Interest
API	Application Programming Interface
CD	Change Detection
CEMS RM	Copernicus Emergency Management Service Rapid Mapping
CEMS RRM	Copernicus Emergency Management Service Risk and Recovery Mapping
CLC	Corine Land Cover
CNN	Convolutional Neural Network
CPU	Central Processing Unit
CSS-SEA	Copernicus Security Service in Support to EU External Action
DHS	Demographic and Health Survey
DIEM	Data in Emergencies Monitoring
DSM	Digital Surface Model
DTM	Digital Terrain Model
EC	European Commission
ECMWF	European Centre for Medium-Range Weather Forecasts
EO	Earth Observation
E-OBS	ENSEMBLES daily gridded observational dataset
ESA	European Space Agency
EU	European Union
EWS	Early Warning System

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Acronym	Description
FAO	Food and Agriculture Organisation of the United Nations
FEWSNET	Famine Early Warning Systems Network
FLORIA	FLOodwater detection over urban areas using Radar and artificIAl intelligence
GDACS	Global Disaster Alert and Coordination System
GDAL	Geospatial Data Abstraction Library
GHSL	Global Human Settlement Layer
GLC30	Globe Land Cover 30
GEV	Generalized extreme value
GIS	Geographic Information System
GPCC	Global Precipitation Climatology Centre
GPM	Global Precipitation Measurement
GPU	Graphics processing unit
HAND	Height Above Nearest Drainage
HOT	Humanitarian OpenStreetMap
IDP	Internally Displaced Persons
IFS	Integrated Forecast System
IGN	Institut Géographique National
InSAR	Interferometric Synthetic Aperture Radar
INSEE	National Institute of Statistics and Economic Studies
IOM DTM	International Organization for Migration Displacement Tracking Matrix
IPC	Integrated Food Security Phase Classification
JRC	Joint Research Centre
LHZ	Livelihood Zones
MSWEP	Multi-Source Weighted-Ensemble Precipitation
NDVI	Normalized Difference Vegetation Index
NDWI	Normalized Difference Water Index
NTL	Night-time Light
OSINT	Open-Source Intelligence
OSM	OpenStreetMap
SAR	Synthetic-Aperture Radar
SNAP	Sentinel Application Platform

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Acronym	Description
THI	Temperature Humidity Index
UF	Urban Flood
UNHCR CCCM	United Nations High Commissioner for Refugees Camp Coordination and Camp Management
WaPOR	Water Productivity Open-access portal
WFS	Water & Food Security
WSF	World Settlement Footprint
WSI	Water Stress Index
VHR	Very High Resolution

2.3 APPLICABLE AND REFERENCE DOCUMENTS

ID	Document name
[RD01]	Copernicus Service in Support to EU External Action: https://sea.security.copernicus.eu/
[RD02]	Copernicus Emergency Management Service – Rapid Mapping and Risk & Recovery: https://emergency.copernicus.eu/
[RD03]	D1.1 - Report on Urban Flood and Water & Food security indicators
[RD04]	D2.2 - Urban flood and Water & Food Insecurity Design
[RD05]	D3.1 - PlatformDesignDocument_v1
[RD06]	D7.5 – IPR and Innovation Plan v1

Table 2: Applicable and reference documents.

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3 CENTAUR PRODUCTS

Following the content generated in the deliverable D2.2 - Urban Flood and Water & Food Insecurity design generated in M9 [RD04], the present chapter aims at providing a demonstration of the products generated I CENTAUR project through the development of innovative indicators.

3.1 URBAN FLOOD INDICATORS SUMMARY AND RESULTS

3.1.1 UF-ID-1: Static map of precipitation associated to return period

UF-ID-1: Static map of precipitation associated to return period	
Product Owner	ECMWF
Product Description	This indicator estimates the return periods of extreme precipitation over urban areas in Europe and Mozambique using historical observations. The resulting maps of 1-, 10-, 20-, 50-, 100-, 500-year return periods will be used in conjunction with the speed-flood hydraulic model to derive inundation maps (UF-ID-3). The output of this indicator is a static catalogue of precipitation totals associated with return periods for all urban areas in Europe and Mozambique that enables an ad-hoc identification of extreme events.
Service Level	UF-ID-1 serves as the basis for UF-ID-2, as well as a historical reference in the computation of the early warning forecast index (likelihood of a crisis event draws from past observations).
EO input data	No EO data are used to compute UF-ID-1.
Non-EO input data	- E-OBS precipitation (EO-derived product). - MSWEP precipitation (EO-derived product). - ECMWF reanalysis ERA5 (EO-derived product).
Output	- Return period for extreme precipitation events (netCDF and GeoTiff). - Precipitation associated with return period classes (netCDF and GeoTiff).
Archive Length	- E-OBS precipitation → available from 1950 to today. - MSWEP precipitation → available from 1979 to today. - ECMWF reanalysis ERA5 → available from 1940 to today. - ECMWF high-resolution forecast → reforecasts available for the past; forecasts with updates at 00, 06, 12, and 18 UTC every day, covering a lead time of 10 days.
Spatial resolution	- E-OBS precipitation → approximately 0.1 degrees (about 10 km) grid spacing. - MSWEP precipitation → approximately 0.1 degrees (about 10 km) grid spacing. - ECMWF reanalysis ERA5 → approximately 0.25 degrees (about 31 km) grid spacing in both latitude and longitude at the equator. - ECMWF high-resolution forecast → approximately 0.1 degrees (about 9 km) grid spacing in both latitude and longitude at the equator.
Temporal coverage	Instantaneous, or aggregated over up to 72 hours (3 days).

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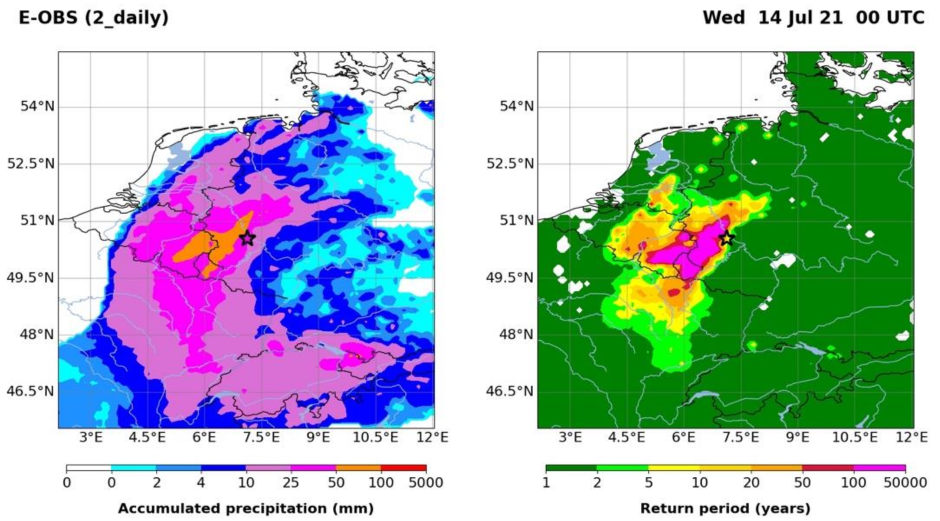
Spatial coverage	Worldwide
Validation	Comparison of the return period estimated from various observation-based products (e.g., E-OBS, ERA5, MSWEP) to get an idea of the associated uncertainty
Dependencies Software	Open-source python modules
Dependencies Hardware	CPU
Analytics	- GEV fitting and estimation of return periods algorithms - Downscaling algorithm
Challenges	The identification of extreme precipitation in the observation-based historical archive is impeded by observational uncertainty and only exists at relatively coarse resolution (0.1 degree) for a long time period, which is needed to estimate the extreme return periods.
Product sample	

3.1.2 UF-ID-2: Forecast of return period

UF-ID-2: Forecast of return period	
Product Owner	ECMWF
Product Description	This indicator presents a novel forecast of extreme precipitation events over urban areas, expressed in return periods. Using the catalogue of observed extreme precipitation events and estimated return periods presented above (see UF-ID-1), a convolutional neural network (CNN) model is trained to predict return periods of precipitation events up to three days in advance to be able to identify extreme precipitation events that may cause flooding.
Service Level	UF-ID-2 is a key input for the computation of the early warning forecast index (future crisis event likelihood).
EO input data	No EO data are used to compute UF-ID-2.

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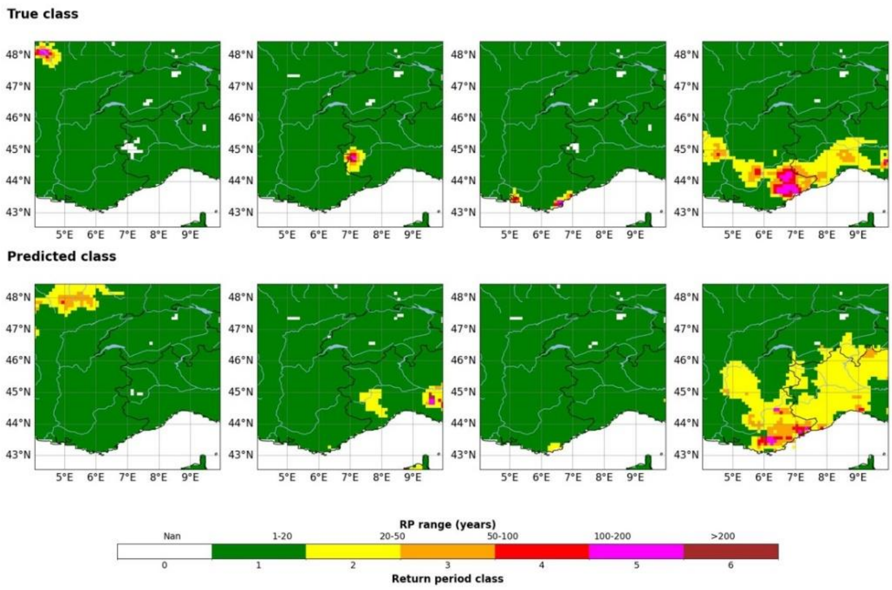
Non-EO input data	- ECMWF high-resolution forecast - UF-ID-1
Output	- Forecast of return period class for extreme precipitation (netCDF or GeoTiff)
Archive Length	- ECMWF high-resolution forecast → reforecasts available for the past; all forecasts with updates at 00, 06, 12, and 18 UTC every day, covering a lead time of 10 days. - UF-ID-1 → since 1940, 1950 or 1979 for ERA5, E-OBS and MSWEP inputs
Spatial resolution	- ECMWF high-resolution forecast → approximately 0.1 degrees (about 9 km) grid spacing in both latitude and longitude at the equator. - Forecast of return period class → to be determined, between 0.1 degree and 0.01 degree
Temporal coverage	Up to 3 days of lead time with up to 4 updates each day
Spatial coverage	Europe and Mozambique, eventual extension to global coverage possible
Validation	Validation will be performed with observations post-event. A comparison to the ECMWF high-resolution forecast of precipitation and the corresponding return period will be done to unravel the added value of the neural network prediction.
Dependencies Software	Open-source python modules
Dependencies Hardware	CPU / GPU
Analytics	- Algorithms to retrieve latest ECMWF high-resolution forecasts (input for the CNN). - Algorithms to train the CNN using UF-ID-1 and ECMWF high-resolution forecasts. - Algorithms to predict extreme precipitation through return period classes.
Challenges	The prediction of extreme events remains challenging and uncertain.
Product sample	

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3.1.3 UF-ID-3 High-Resolution urban flood maps for various return periods

UF-ID-3: High-Resolution urban flood maps for various return periods	
Product Owner	ECMWF for the generation of return periods meteorological maps and e-geos for the generation of flood maps.
Product Description	The flood indicator is derived from the Speedy-flood model, incorporating precipitation intensity maps generated through return period analysis. This integration enables the projection of potential future flood scenarios. This tool serves a dual purpose: primarily, it aids in comprehending floods from a management standpoint, and secondarily, it offers insights into the high-hazard flood zones within a given urban context. The indicator is meticulously crafted to delineate flooding across various magnitudes of rainfall events. The outputs derived from this indicator are predicted flood extent and depth maps.
Service Level	This indicator is used for the computation of both, the early warning forecast- and flood impact index.
EO input data	n/a
Non-EO input data	- ECMWF reanalysis ERA5 (EO derived product). - ECMWF high-resolution forecast (EO derived product). - The flood extent, if available, referencing past events with specific return periods, is delineated using satellite images (EO derived product). - Land Use (EO derived product). - DTM (EO derived product). - Social/traditional media markers (from web, sources and social media). - Hydrography layer for DTM preprocessing (EO derived product).
Output	- Estimated flood extent (.shp). - Estimated flood depth (GeoTiff).
Archive Length	ECMWF reanalysis ERA5 → available from 1940 to today. - ECMWF high-resolution forecast → reforecasts available for the past; all forecasts with updates at 00, 06, 12, and 18 UTC every day, covering a lead time of 10 days. - The flood extent referencing past events with specific return periods → event related - Land Use → CLC+ in Europe and GLC30 in other geographic areas. Both layers are available from 2021. - DTM → NA, cold case areas related. - Social/traditional media markers → event related.
Spatial resolution	- ECMWF reanalysis ERA5 → approximately 0.25 degrees (about 31 km) grid spacing in both latitude and longitude at the equator. - ECMWF high-resolution forecast → approximately 0.1 degrees (about 9 km) grid spacing in both latitude and longitude at the equator. - The flood extent referencing past events with specific return periods → NA, satellite sensor related. - Land Use → CLC+ 10m and GLC30 30m. - DTM → n/a, depends on the availability on the cold cases areas.

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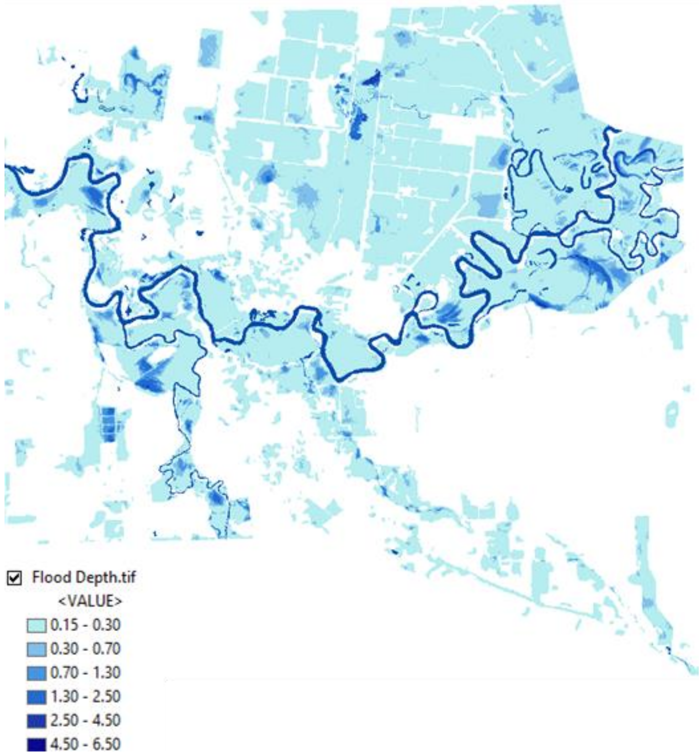
	- Social/traditional media markers → NA
Temporal coverage	Anytime
Spatial coverage	Wordwide
Validation	Validation will be conducted by comparing the flood extent calculated with the JRC Flood hazard maps for various return periods (link of JRC flood hazard maps: https://data.jrc.ec.europa.eu/collection/id-0054).
Dependencies Software	Open-Source Python based modules and GIS Software.
Dependencies Hardware	CPU
Analytics	Speedy Flood: - Global Flood Index geomorphological modelling algorithm. - DTM preprocessing for hydraulic conditioning. - Return period maps (see UF-ID-1 and UF-ID-2).
Challenges	Implement automatic processing modules that allow to integrate the forecast return period maps in the Speedy Flood workflow.
Product sample	 In the figure, a flood map for a 25-year return period is reported.

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3.1.4 UF-ID-4: Inferred INSAR urban flood extent

UF-ID-4 Inferred INSAR urban flood extent	
Product Owner	SERTIT
Product Description	FLOodwater detection over urban areas using Radar and artificIAl intelligence (FLORIA). This indicator is purely based on available SAR data and uses other types of information available as a validation source. The goal of this indicator is to give an information with respect to the flood extent in urban areas, after inundation has started. SAR imagery captured during flood peak result in the most exhaustive delineation. Quality of the output is also dependent on urban morphology, as well as acquisition parameters (i.e., view angle, polarization, spatial resolution, etc.).
Service Level	Flood impact index. While it is not a direct input to the flood impact index, UF-ID-4 is mandatory for the computation of UF-ID-5 and UD-ID-6 and thus also essential for event-based regional analysis.
EO input data	3 SAR products: two acquired before the flood event, at two different times, and one acquired during the flood. It is important to note that the 3 SAR products must have a small temporal baseline (few days or at the very least they must have been acquired in the same season as the flood event) and a small perpendicular baseline (inferior to 150 m).
Non-EO input data	Binary raster delimitating urban areas, used by the algorithm to discard results in non-urban areas. This mask is for now derived from the GHSL (Global Human Settlement Layer) built areas product, released in 2018.
Output	Inferred INSAR urban flood extent as a raster (made out of confidence scores) and a vector (shapefile).
Archive Length	EO: availability since 2014 Non EO: availability since 2018
Spatial resolution	10 meters.
Temporal coverage	Since the beginning of the Sentinel-1 mission (3 April 2014). The flood extent is computed from a SAR product acquired at a specific time, so the computed flood extent extent is only correct at the time of the acquisition of the SAR product.
Spatial coverage	Worldwide. For a specific product, the same as a Sentinel-1 Single Look Complex (SLC) product, so a swath of 250 km.
Validation	A consistency check of the generated products is carried out manually. The quality check consists of manual steps in order to verify the quality level of the generated products. Products with not enough quality and/or consistency are discarded. Data sources for validation may include social media sources, news reports or aerial images.
Dependencies Software	ESA SNAP, Python 3 and in house processing tools (SARPAIR, RUST)
Dependencies Hardware	RAM 64Go (the higher the RAM, the faster the process due to a bottleneck in the InSAR pipeline) GPU (fast inference) or CPU (slow inference)

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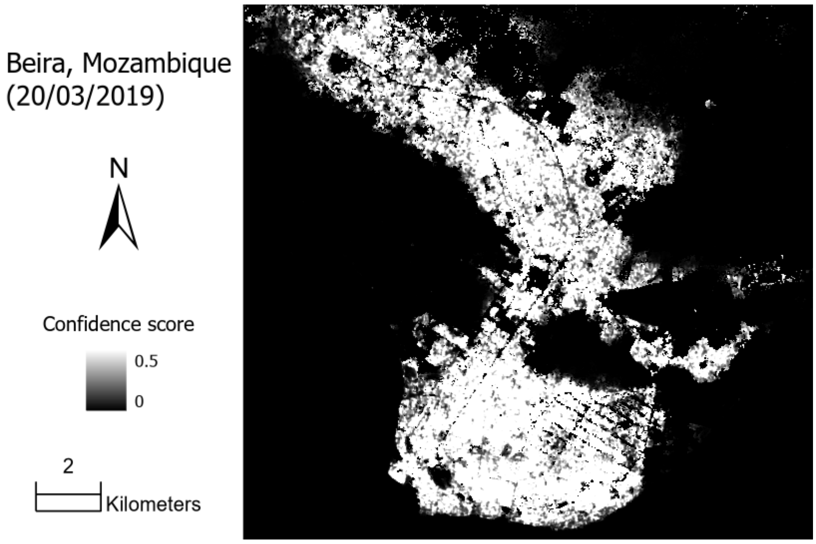
Analytics	The information extracted from the 3 SAR products are combined in one stack: two bands for the coherence of the pre-event pair and the co-event pair, two bands for the pre-event amplitude based on respectively VV and VH polarizations and two for the co-event amplitude based on VV and VH polarizations. The previously generated stack is ingested in a U-Net model. This model is trained on a database of previous flood events where ground truth was available. The algorithm generates a confidence flood map from the ingested stack. Each urban pixel gets a confidence score between 0 and 1. The post-processing consists in masking the results in non-urban areas to minimize errors. The first output is the resulting masked raster file. The urban flood is then generated as a vector file through adaptive thresholding. Another output is computed by classifying the confidence scores in five intervals based on the minimum and maximum values of the results. This is also outputted as a vector file.
Challenges	Today, FLORIA only operates using Sentinel-1 data. Considering the fact that only one satellite of this constellation is currently operational, the chances of a Sentinel-1 product being acquired during the flood are slim. Sometimes, the complete area might not be covered by one SAR product only. Furthermore, the process is still time-consuming. Hence the integration of additional SAR sensors and the adaptation of the tool are planned.
Product sample	Below is an example of the raster output on the cold case of Beira, Mozambique. 

3.1.5 UF-ID-5: Enhanced Urban Flood Damage Assessment

UF-ID-5 Enhanced Urban Flood Damage Assessment	
Product Owner	e-GEOS and SERTIT
Product Description	The flood indicator is a product of the synergistic combination of the Speedy-flood and FLORIA models. This integration harnesses the capabilities of Speedy Flood for precise flood delineation and depth calculation, while the FLORIA model employs AI techniques to enhance flood delineation within urban regions. By amalgamating the outcomes of these two methodologies, an exceptionally accurate flooding map can be reconstructed for urban environments. Utilizing this amalgamated flooding map, it becomes feasible to estimate

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	flood-related damages (in €/m^2), focusing on urban infrastructure and key components. This indicator is related to the post-event phase of an extreme rainfall event.
Service Level	Component of the Flood impact index
EO input data	- 3 SAR products for FLORIA (UF-ID-4) algorithm running (InSAR analysis): two acquired before the flood event, at two different times, and one acquired during the flood. It is important to note that the 3 SAR products must have a small temporal baseline (few days or at the very least they must have been acquired in the same season as the flood event) and a small perpendicular baseline (inferior to 150 m). - SAR and/or Optical images useful for the flood mask extraction.
Non-EO input data	- The flood extent delineated using satellite images (EO derived product). - UF-ID-4 Inferred INSAR urban flood extent indicator (EO derived product). - Land Use (EO derived product). - DTM (EO derived product). - Social/traditional media markers on water depth (from web, sources, and social media). - Hydrography layer for DTM preprocessing (EO derived product). - WFS - Population (EO derived product). - WSF - World Settlement Footprint (EO derived product). - Ancillary data layers useful for the flooding damage assessment like buildings, transportations, facilities, etc (EO derived product). - WSF-3D (EO derived product).
Output	- Flood extent (.shp). -Flood depth (.GeoTiff). - Flood damage assessment (.shp).
Archive Length	- The flood extent referencing past events with specific return periods → event related. - Land Use → CLC+ in Europe and GLC30 in other geographic areas. Both layers are available from 2021. - DTM → NA, cold case areas related. - Social/traditional media markers → event related. - Hydrography layer for DTM preprocessing → dataset related (OSM data from 2004) - WSF - Population → from 1985. - WSF - World Settlement Footprint → from 1985. - Ancillary data layers useful for the flooding damage assessment like buildings, transportations, facilities, etc → dataset related (OSM data from 2004). - WSF-3D → from 1985. - UF-ID-4 Inferred INSAR urban flood extent indicator → event related.
Spatial resolution	- The flood extent referencing past events with specific return periods → NA, satellite sensor related. - Land Use → CLC+ 10m and GLC30 30m. - DTM → NA, depends on the availability on the cold cases areas. - Social/traditional media markers → NA

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	- Hydrography layer for DTM preprocessing → NA - WFS - Population → 10m - WSF - World Settlement Footprint → 10m - Ancillary data layers useful for the flooding damage assessment like buildings, transportations, facilities, etc → n/a - WSF-3D →10 m - UF-ID-4 Inferred INSAR urban flood extent indicator → sensor related
Temporal coverage	Anytime
Spatial coverage	Worldwide
Validation	The product will be validated using social and traditional media markers for flood extent and depth, as well as VHR1 optical images for the damage assessment classification, calculated by Speedy Flood.
Dependencies Software	Open-Source Python based modules and GIS Software.
Dependencies Hardware	CPU
Analytics	Speedy Flood: - Global Flood Index geomorphological modelling algorithm -DTM preprocessing for hydraulic conditioning. FLORIA model (UF-ID-4): - U-Net model for generating the urban flood confidence map, from InSAR data. - Post-processing by (1) masking non-urban areas from the urban flood confidence map using ancillary reference data, (2) applying an adaptative threshold to discretize confidence levels, and (3) generate a vector file.
Challenges	Implement automatic processing modules that allow perform damage assessment analysis on the Speedy Flood and FLORIA models results.

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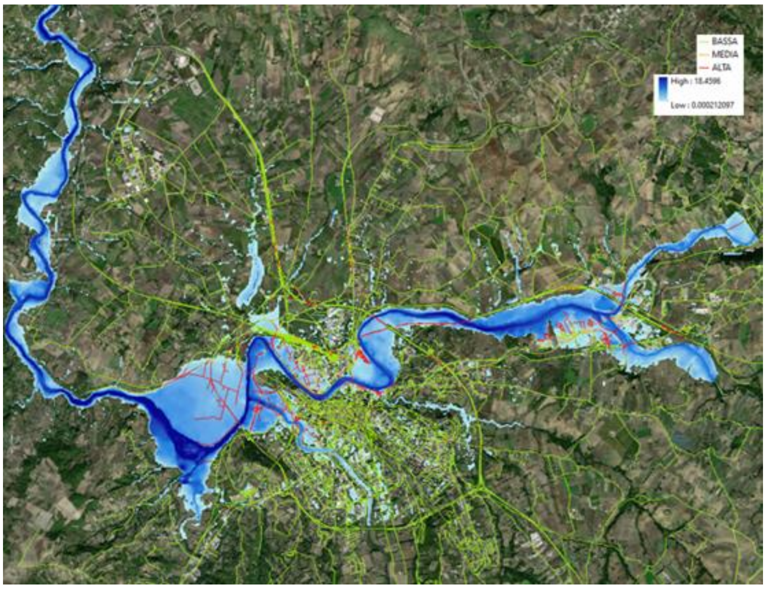
Product sample	 In the figure, a flood damage assessment related to the transportation network is presented. Areas classified as damaged are shown in red, those with probable damage in yellow, and those with no damage in green.

3.1.6 UF-ID-6: Social/Traditional media indicators for Urban Flooding Map

UF-ID-6 Social/Traditional media indicators for Urban Flooding Map	
Product Owner	Hensoldt
Product Description	This indicator is exclusively derived from social and traditional media reporting on the specific event of interest. Geolocalized visual data originating from images and videos depicting the event (media markers) represent a crucial view offering accitional information about an ongoing situation. As a result, a comprehensive understanding of the situation within the area of interest is achieved.
Service Level	Component of the Flood impact index
EO input data	n/a
Non-EO input data	Social and traditional media, in particular images and videos
Output	Vector data containing media markers (.shp, .klm, or .geoJson)
Archive Length	Event-related
Spatial resolution	n/a

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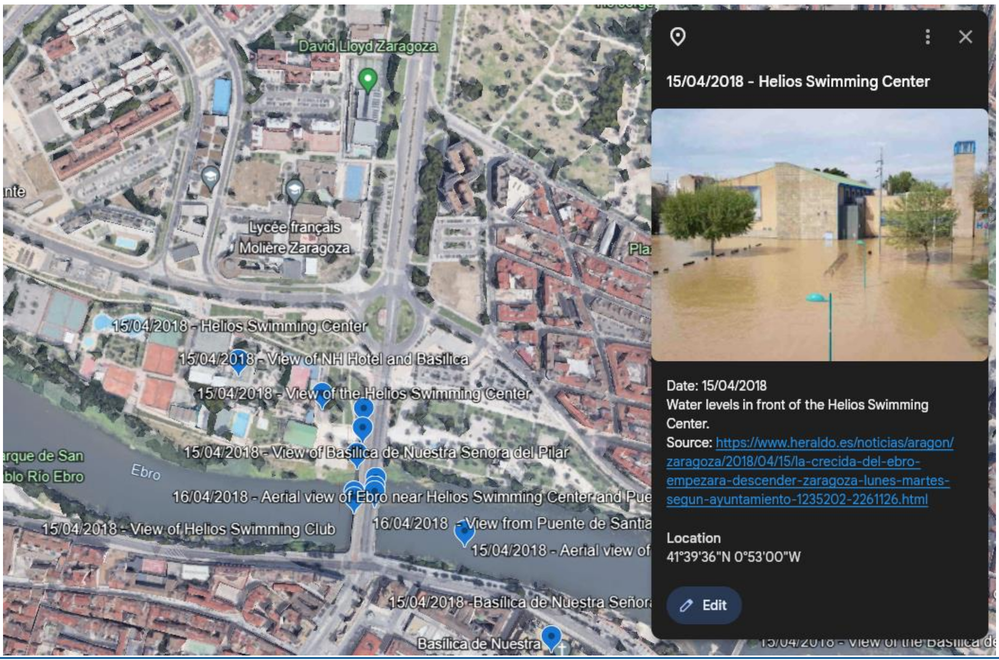
Temporal coverage	Anytime
Spatial coverage	France, Germany, Italy, Mozambique, and Spain
Validation	A validation process is carried out to ensure the integrity of the generated products, encompassing both automated and manual checks. The automatic validation involves employing filters to sift through the data and eliminate potential fake news or misinformation. Subsequently, a manual validation is executed, wherein an operator visually assesses the products, gauging their quality and coherence. Any products that do not meet the required quality and consistency standards are excluded from further consideration.
Dependencies Software	Hensoldt's Media Mining System
Dependencies Hardware	None
Analytics	Input social and traditional media is pre-processed using natural language processing (NLP) and automatic speech recognition (ASR) techniques to identify and annotate potential entities of interest in a multi-lingual manner. For this indicator, collected social and traditional media is filtered according to a pre-defined query. Following, the collected data is extracted and refined using multimodal analysis to further increase the relevance and diversity of the results. The resulting list of media items (with the corresponding location hints) is then processed by an analyst to precisely geolocate the visual evidence.
Challenges	➢ The amount and reliability of available open-source data and the identification of relevant sources of information; ➢ Sensitivity to changes in the media landscape.
Product sample	

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	Caption: media markers in Zaragoza.

3.1.7 UF-ID-7: Flood impact index

Flood impact index	
Product Owner	e-GEOS
Product Description	Index based on several input data available on the web that allow to assess the impact of an extreme flood event in an area of interest. This indicator is supposed to facilitate flood management and targeted interventions for addressing flood impacts in severely affected areas. This indicator is related to the post-event phase of an extreme rainfall event, allowing to characterize it in terms of impact and magnitude.
Service Level	Flood impact index and essential part of the event-driven regional assessment
EO input data	n/a
Non-EO input data	- European Union portal Copernicus where it is possible to see in detail the cartographies and the damages of the specific event. - Global Disaster Alert and Coordination System (GDACS) portal which is a cooperation framework between the United Nations, the European Commission and disaster managers worldwide to improve warnings in case of risky events. - CEMS RM and/or RRM activations info in terms of affected population and size of the flooded area. - WFS-Population data (EO derived). - GHS-Pop R2023A (EO derived). - WSF - World Settlement Footprint (EO derived). - GHS-Built-S R2023A (EO derived).
Output	Flood impact index (.csv)
Archive Length	- European Union portal Copernicus where it is possible to see in detail the cartographies and the damages of the specific event. → event related - Global Disaster Alert and Coordination System (GDACS) portal which is a cooperation framework between the United Nations, the European Commission and disaster managers worldwide to improve warnings in case of risky events. → event related - CEMS RM and/or RRM activations info in terms of affected population and size of the flooded area. → event related - WFS-Population data (EO derived). → from 1985 - GHS-Pop R2023A (EO derived). → from 1985 - WSF - World Settlement Footprint (EO derived). → from 1985 - GHS-Built-S R2023A (EO derived). → from 1985
Spatial resolution	- European Union portal Copernicus where it is possible to see in detail the cartographies and the damages of the specific event. → n/a - Global Disaster Alert and Coordination System (GDACS) portal which is a cooperation framework between the United Nations, the European Commission and disaster managers worldwide to improve warnings in case of risky events. → n/a

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	- CEMS RM and/or RRM activations info in terms of affected population and size of the flooded area. → n/a - WFS-Population data (EO derived). → 10m - GHS-Pop R2023A (EO derived). → 100m - WSF - World Settlement Footprint (EO derived). → 10m - GHS-Built-S R2023A (EO derived). → 100m
Temporal coverage	Anytime
Spatial coverage	Worldwide
Validation	In this indicator, each weight used in the calculation of FH(Ix) will undergo validation. These weights can be derived from various sources, and for each source, a ground truth will be sought for robust validation. For example, consider the weight related to precipitation amount in the algorithm. If this data can be obtained from the GPM NASA constellation (Global Precipitation Measurement), a comparison with gauge stations will be conducted to validate and ensure that there are no underestimations, which are typical of this sensor used for precipitation retrieval.
Dependencies Software	Open-Source Python based modules and GIS Software.
Dependencies Hardware	CPU
Analytics	Each indicator considered is represented in the model as a weight (Ix) and forms part of an equation to calculate the Flood impact index. For example, an equation for an index based on four input indicators could look like: FI(Ix) = (I1) + (I2) + (I3) + (I4) – see also example below fir Pakistan. The concrete form of the equation will be determined at a later stage of the project, as input indicators are being fleshed out in subsequent parts of WP2. For clarity and simplicity, results of the equation could be classified as “low”, “medium”, and “high”.
Challenges	Deciding on an appropriate model (and functional form of the underlying equation) and assigning weights to the different input indicators.

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Product sample

FH(Ix)	Hazard class
0-2	LOW
2-4	MEDIUM
4-6	HIGH

- GDACS index (I_1)
- Poverty index (I_2)
- Company type index (I_3)
- Number of event seasonality index (I_4)

$$FH(I_x) = (I_1) + (I_2) + (I_3) + (I_4)$$

	YEAR	I_1	I_2	I_3	I_4	$FH(Ix)_1$	FH(Ix)
PAKISTAN	2007	0.46	0.23	0.5	1	2.19	3.285
	2008	0.46	0.23	0.5	0.33	1.52	2.28
	2010	1	0.23	0.5	1	2.73	4.095
	2011	0.53	0.23	0.5	0.5	1.76	2.64
	2012	0.53	0.23	0.5	0.33	1.59	2.385
	2013	0.34	0.23	0.5	0.33	1.4	2.1
	2014	0.46	0.23	0.5	0.25	1.44	2.16
	2015	0.39	0.23	0.5	0.5	1.62	2.43
	2016	0.34	0.23	0.5	0.33	1.4	2.1
	2019	0.33	0.23	0.5	1	2.06	3.09
	2022	1	0.23	0.5	1	2.73	4.095

For illustrative purposes, a Flood impact index is shown here for Pakistan. It characterizes historical events in terms of their impact severity.

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3.2 WATER&FOOD INSECURITY INDICATORS SUMMARY AND RESULTS

3.2.1 WFS-ID-1: Meteorological drought indicator (Monitoring)

WFS-ID-1: Meteorological drought indicator (Monitoring)	
Product Owner	ECMWF
Product Description	This indicator estimates the return periods of extreme precipitation over urban areas in Europe and Mozambique using historical observations. The resulting maps of 1-, 10-, 20-, 50-, 100-, 500-year return periods will be used in conjunction with the speed-flood hydraulic model to derive inundation maps (UF-ID-3). The output of this indicator is a static catalogue of precipitation totals associated with return periods for all urban areas in Europe and Mozambique that enables an ad-hoc identification of extreme events.
Service Level	WFS-ID-1 feeds into the Data Viewer (Dashboard) tool
EO input data	No EO data are used to compute WFS-ID-1
Non-EO input data	- ECMWF reanalysis ERA5 (EO derived product); - GPCC precipitation (EO derived product);
Output	- Drought indicator at various aggregation time scales (1-,3-,6-, and 12-month aggregations, format: netCDF and GeoTiff)
Archive Length	- ECMWF reanalysis ERA5 → available from 1940 to today. - GPCC precipitation → available from 1891 to today.
Spatial resolution	- ECMWF reanalysis ERA5 → approximately 0.25 degrees (about 31 km) grid spacing. - GPCC precipitation → approximately 1 degree (100 km) grid spacing.
Temporal coverage	See archive length
Spatial coverage	Globally
Validation	For validation purposes, an uncertainty analysis will be performed. Uncertainty will be estimated using various products (e.g., ERA5 and GPCC) but also using model internal parameters in the estimation of the drought index. Further, the impact of meteorological drought on food- and water security will be estimated through a comparison with agricultural drought indicators, such as WFS-ID-4, and impact-based data bases, such as EM-DAT.
Dependencies Software	Open-source python modules, development of 'SPIDI' library for the calculation of drought indicators
Dependencies Hardware	CPU
Analytics	- Pre-processing of input data (e.g., aggregation over various time scales, from 1 to 12 months)

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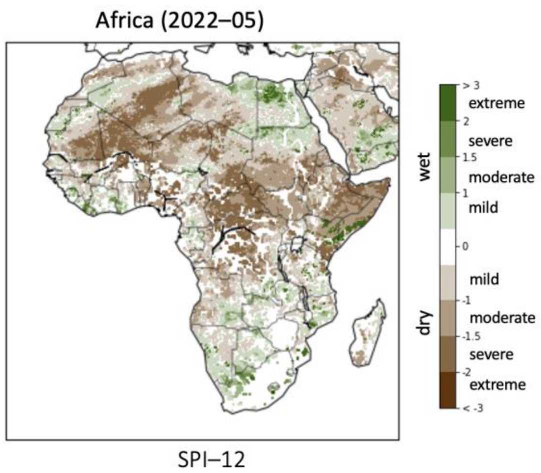
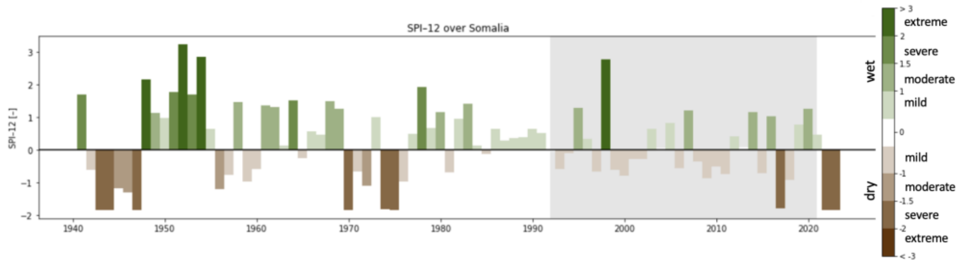
	- Calculation of drought indices for various time scales using the newly developed SPIDI library
Challenges	n/a
Product sample	 

3.2.2 WFS-ID-2: Meteorological drought indicator (Forecast)

WFS-ID-2: Meteorological drought indicator (Forecast)	
Product Owner	ECMWF
Product Description	This indicator is based on meteorological forecasts from ECMWF, and it forecasts the occurrence and severity of meteorological droughts at the global scale at lead times spanning from 1 day to 6 months ahead. While it focuses on droughts, it can also forecast unusually wet periods that may cause flooding, and thus enables us to forecast potential impacts of those natural hazards on water and food security up to 6 months ahead. The indicator is produced at variable resolutions — from 9 km to 35 km, depending on lead time — and will be updated monthly.
Service Level	WFS-ID-2 is a key component of the Hazard index for the continuous monitoring (EWS) tool
EO input data	No EO data are used to compute WFS-ID-2
Non-EO input data	- ECMWF forecasts (modelled predictions using medium-range ensemble forecasts (ENS) with a lead time of 15 days and 51 ensemble members, extended-range ensemble forecasts (ENS-ER) with a lead time of 46 days and 101 ensemble members, seasonal forecasts with a lead time of 7 months and 51 ensemble members). - ECMWF reanalysis ERA5 (EO derived product).

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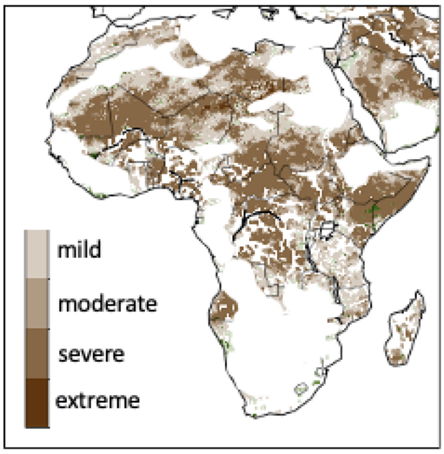
Output	- Predicted drought occurrence and severity at various aggregation time scales (1-,3-,6-, and 12-month aggregations, format: netCDF or GeoTiff); details and thresholds to be developed during the project. - Predicted probability of moderate/severe/extreme drought at various aggregation time scales (1-,3-,6-, and 12-month aggregations, format: netCDF or GeoTiff); details and thresholds to be developed during the project.
Archive Length	- For the full ECMWF re-forecast archive with frequent updates depending on new ECMWF forecast releases
Spatial resolution	Varying (between 9 and 35 km), also aggregated to ADMIN-1 and ADMIN-2 levels
Temporal coverage	Up to 6 months of lead time
Spatial coverage	Globally
Validation	(Re-)Forecasts will be validated with WFS-ID-1, i.e., the meteorological drought monitoring product.
Dependencies Software	Open-source python modules
Dependencies Hardware	CPU
Analytics	- Pre-processing algorithms (creation of a seamless forecast and aggregation over various time scales, i.e., from 1 to 12 months). - Calculation of drought indicators using the newly developed SPIDI library.
Challenges	The limitations of different weather forecast models for predicting precipitation over 6 months of lead time; hence ensemble forecasts will be used to evaluate the probability of drought occurrence and the most likely drought severity.
Product sample	Predicted drought intensity intensity 

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	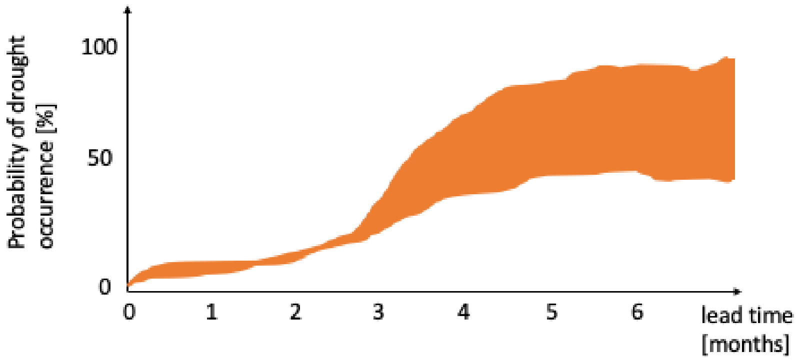

3.2.3 WFS-ID-3: Meteorological drought indicator (danger levels)

WFS-ID-3: Meteorological drought indicator (danger level)	
Product Owner	ECMWF
Product Description	This indicator evaluates the meteorological drought forecast with respect to the monitoring state and estimates danger levels. It is based on the two previous meteorological drought indicators, i.e., WFS–ID1 and WFS– ID2. Over already existing drought regions, the probabilities of drought continuation, drought aggravation and drought recovery are estimated. Over regions that do not experience drought yet, the probability of drought occurrence and the corresponding severity are estimated. The indicator is produced at a resolution of 35 km and will be updated monthly.
Service Level	WFS-ID-3 feeds into the Data Viewer (Dashboard) tool
EO input data	No EO data are used to compute WFS-ID-3
Non-EO input data	- WFS-ID-1 - WFS-ID-2
Output	- Probability of drought aggravation (netCDF or GeoTiff). - Probability of drought recovery (netCDF or GeoTiff). - Probability of drought occurrence (netCDF or GeoTiff).
Archive Length	Available for all re-forecasts with frequent updates near-real-time.
Spatial resolution	Varying (9 to 36 km), aggregated to ADMIN-1 and ADMIN-2 levels.
Temporal coverage	Up to 6 months of lead time
Spatial coverage	Globally
Validation	Validation of this indicator is challenging; however, in general, WFS-ID-1 can be used to validate the predicted occurrence and severity of droughts in a probabilistic manner.

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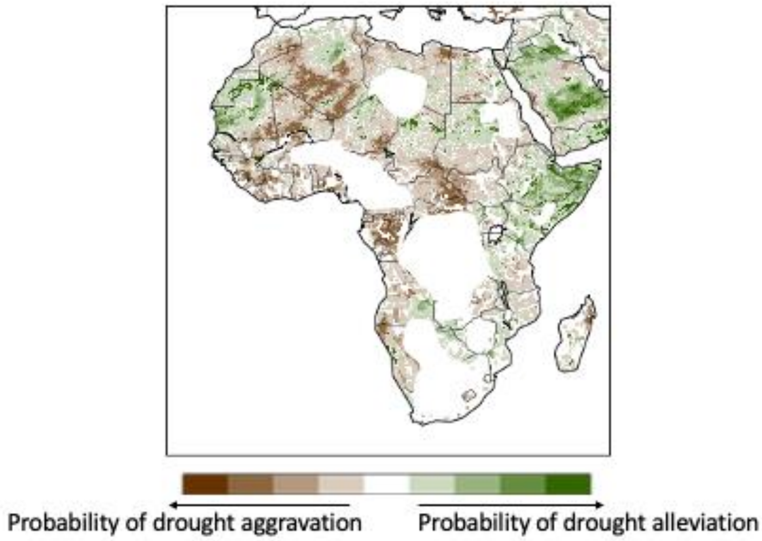
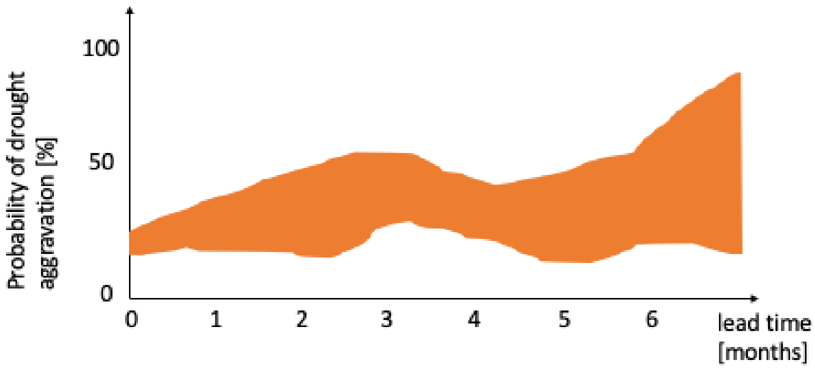
Dependencies Software	Open-source python modules
Dependencies Hardware	CPU
Analytics	- Pre-processing of both input indicators (re-gridding, aggregation to same time scales, etc.). - Delineation of (i) regions already experiencing drought, and (ii) regions not yet experiencing drought. - Evaluation of the above probabilities.
Challenges	Validation
Product sample	 

3.2.4 WFS-ID-4: Agricultural drought monitoring (near real-time)

WFS-ID-4: Agricultural drought monitoring (near real-time)	
Product Owner	VITO
Product Description	Indicator that expresses the relative impact of drought events on the current vegetation condition and productivity. It compares the current situation in terms of plant condition

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	(Normalized Difference Vegetation Index, NDVI), plant drought stress (thermal stress indicator) and soil moisture conditions to a "normal baseline" for the region under consideration, the latter being based on a historical archive of indicators. The spatial resolution of this product will be 1 km and it will be updated every 10 days.
Service Level	WFS-ID-4 will be generated continuously at low resolution and is part of the continuous monitoring system.
EO input data	NDVI, NDWI, LST, root zone soil moisture, land cover
Non-EO input data	ECMWF reanalysis ERA5 data on air temperature and precipitation
Output	Relative impact of drought events on the current vegetation condition and productivity, expressed on a 0-100 scale. Updated every 10 days in near-real time mode. Output will be raster files in GeoTiff format.
Archive Length	A 20 year NDVI archive will be used to generate this indicator. We expect the indicator to be available from 2018 onwards.
Spatial resolution	1 km
Temporal coverage	Indicator will be available from 2018 onwards and be updated every 10 days.
Spatial coverage	Country scale
Validation	Estimated drought impacts will be cross-checked with the results obtained from other drought early warning platforms.
Dependencies Software	Open-source python modules
Dependencies Hardware	CPU
Analytics	Pre-processing of all input datasets, creation of homogeneous zones per country, growing season detection, determination of drought thresholds and automated monitoring at dekadal interval.
Challenges	The mutual relation between the different inputs and the link with drought severity is highly depending on the local context. The main challenge is to find a generic method that will work across the large variety of environmental conditions encountered across the African continent.

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Product sample	 Current drought impact on vegetation productivity (0-100%); updated every 10 days

3.2.5 WFS-ID-5: Agricultural drought forecast

WFS-ID-5: Agricultural drought forecast	
Product Owner	VITO
Product Description	Indicator that expresses the relative impact, on a 0-100 scale of future drought events on the expected vegetation condition and productivity for different lead times ranging from a few days up to several months. It starts from the current situation in terms of agricultural drought conditions and looks at forecasts of meteorological and soil moisture conditions to determine the expected impact of drought conditions on vegetation productivity weeks up to months in advance. The spatial resolution of this product will be 1 km and it will be updated every 10 days.
Service Level	WFS-ID-5 is a key component of the Hazard index for the continuous monitoring (EWS) tool.
EO input data	WFS-ID-4
Non-EO input data	- Precipitation and air temperature forecasts provided by ECMWF. - Soil moisture anomaly forecasts provided by ECMWF.
Output	Predicted drought impact on vegetation productivity (0-100%) and associated uncertainty at various aggregation time scales (1-,3-,6-, and 12-month aggregations, format: netCDF or GeoTiff).
Archive Length	A 20 year NDVI archive will be used to generate this indicator.

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Spatial resolution	1 km
Temporal coverage	Indicator will be available from 2018 onwards and be updated every 10 days.
Spatial coverage	Country scale
Validation	Forecasts will be validated with WFS-ID-4, i.e., the agricultural drought monitoring product.
Dependencies Software	Open-source python modules
Dependencies Hardware	CPU
Analytics	Pre-processing of all input datasets and combination of current drought conditions with meteorological forecasts in a threshold-based decision framework.
Challenges	As pointed out for WFS-ID-2, obtaining high quality meteorological forecasts is a challenge. Hence, any derived product will likely be characterized by high uncertainty levels.
Product sample	Development is ongoing. An example of how the product will look like, is presented below:  Future drought impact on vegetation productivity (0-100%); updated every 10 days

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3.2.6 WFS-ID-6: Agricultural drought risk zone map

WFS-ID-6: Agricultural drought risk zone map	
Product Owner	VITO
Product Description	Risk of occurrence of adverse drought impacts on vegetation productivity, expressed at a categorical scale (high risk – no risk), considering both the present-day situation and future occurrence of agricultural drought events. Based on the outputs of indicators WFS-ID-4 and WFS-ID-5, each zone in a country will be classified into a risk category. The indicator will be updated every dekad based on the latest information on current vegetation condition and current/future meteorological conditions.
Service Level	WFS-ID-6 will be generated continuously at low resolution and is part of the continuous monitoring system. It will provide the user a synthesized and easy to interpret integration of WFS-ID-4 and WFS-ID-5.
EO input data	WFS-ID-4 and WFS-ID-5
Non-EO input data	None
Output	Risk of occurrence of adverse drought impacts on vegetation productivity, expressed at a categorical scale (high risk – medium risk – no risk), considering both the present-day situation and future occurrence of agricultural drought events. Result will be integrated at admin 2 level and delivered as shapefile (GeoPackage format).
Archive Length	A 20 year NDVI archive will be used to generate this indicator.
Spatial resolution	1 km – final result to be aggregated at admin 2 level.
Temporal coverage	Available from 2018 onwards, updated every 10 days.
Spatial coverage	Country scale
Validation	Drought risk zone maps will be cross-checked with indicator WFS-ID-4 and other drought early warning systems and reports.
Dependencies Software	Open-source python modules
Dependencies Hardware	CPU
Analytics	A threshold-based decision support system will be calibrated for each individual country based on a large historical archive of the agricultural drought indicator (WFS-ID-4) and agricultural drought forecasts (WFS-ID-5). This will result in zone specific thresholds (same zones will be used as were developed for WFS-ID-4 indicator) indicating the risk (expressed in risk categories) in terms of occurrence and impact of agricultural droughts, both present-day and near future.
Challenges	Interaction between present drought conditions and future meteorological conditions is highly dependent on local environmental conditions. Generating a generic threshold-based

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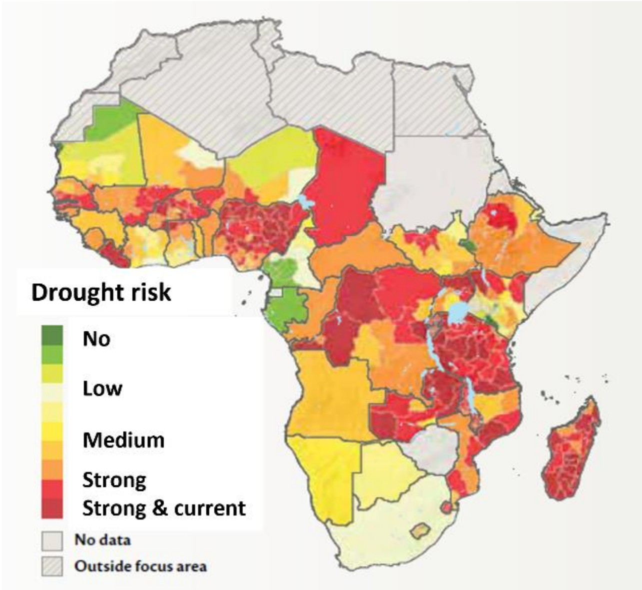
	system which will perform well across the entire African continent will be the major challenge.
Product sample	Development is ongoing. An example of how the product will look like, is presented below: 

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3.3 SOCIO-POLITICAL-ECONOMIC INDICATORS SUMMARY AND RESULTS

3.3.1 UF-ID-9: Assets & financial resources

Assets & financial resources	
Product Owner	Adelphi*
Product Description	Indicator of household economic endowments and opportunities to withstand the effects of urban floods
Service Level	Component of the vulnerability composite indicator that is part of the flood impact index.
EO input data	n/a
Non-EO input data	DLR (all cases): - WSF-Imperviousness - WSF-Population - WSF-3D - GHS-Pop - GHS-Built-V Hensoldt (France, Mozambique, Spain): - Social/traditional media data CLS (France): - BD TOPO (IGN) - INSEE census - OSM SERTIT (France): - Google Maps amenities (e.g., restaurants) SERTIT (Germany): - OSM SERTIT (Mozambique): - Google maps amenities (e.g., restaurants) - OSM TRACASA (Spain): - Roads & Transport Zaragoza - OSM
Output	General socioeconomic level (estimate of wealth) in different neighbourhoods of the AOI as table and/or shapefile. Metric to be defined after initial tests with the input data.
Archive Length of input data	- WSF-Imperviousness: available from 2016-to present. - WSF-Population: available from 2016-to present.

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	- WSF-3D: available for 2012; with potential yearly updates up to present. - GHS-POP: available from 1975 to 2020 in a 5-year interval; and projection to 2025 and 2030. - GHS-Built-V: available from 1975 to 2020 in a 5-year interval; and projection to 2025 and 2030. - BD TOPO -> From 2008 onwards. - INSEE census -> From 1946 onwards for exhaustive census data. - OSM -> From 2013 onwards. - Google maps -> Most current data. - Roads & Transport Zaragoza -> Updated to 2023. - Social/traditional media data -> From 2018 onwards.
Spatial resolution of input data	- WSF-Imperviousness: 10m spatial resolution at the Equator. - WSF-Population: 10m spatial resolution at the Equator. - WSF-3D: 90m spatial resolution at the Equator. - GHS-POP: 100m spatial resolution at the Equator. - GHS-Built-V: 100m spatial resolution at the Equator. - BD TOPO: vector data (up to a scale of 1:2 000). - INSEE census: Not applicable (tabular data, one row per communal entity). - OSM: vector data (up to a scale of 1:500). - Google maps: vector data (up to a scale of 1:500). - Roads & Transport Zaragoza: vector data. - Social/traditional media data: to be defined after initial tests with the input data.
Temporal coverage of output	Present situation/most recent information
Spatial coverage of output	AOIs
Validation	Information to be included in V2 of the service pipeline documentation, pending initial tests with input data
Dependencies Software	- Access to an internet connection and web browser to download the Spanish (Roads & Transport Zaragoza) French data (BD TOPO, INSEE census), as well as OSM and Google Maps data. - Access to HENSOLDT Media Mining System for media-based factors
Dependencies Hardware	Information to be included in V2 of the service pipeline documentation
Analytics	UF-ID-9, 10 and 13 will be combined into a flood vulnerability index. Most appropriate methods for fusing the data will be chosen depending on the structure of the input data (e.g. whether underlying data and indicators are highly correlated or not, missing

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	observations etc.). This work will be performed at a later stage of the project as part of Task 2.4 and Task 2.7).
Challenges	- Availability (i.e. spatial & temporal coverage, missing & unknown values) of input data. - Further challenges may arise during indicator development.
Product sample	To be included at a later stage of the project, pending progress in Task 2.4 and 2.5

3.3.2 UF-ID-10 Public services & government support

Public services & government support	
Product Owner	Adelphi*
Product Description	Indicators of access to basic health and other emergency response services, as well as the general capacity and predisposition of responsible actors to protect people against the detrimental effects of floods
Service Level	Component of the vulnerability composite indicator that is part of the Flood impact index.
EO input data	n/a
Non-EO input data	Hensoldt (France, Mozambique, Spain) : - Social/traditional media data CLS (France): - BD TOPO (IGN) - OSM SERTIT (France): - Google Maps amenities (e.g., restaurants) SERTIT (Germany): - OSM SERTIT (Mozambique): - Google maps amenities (e.g., restaurants) - OSM TRACASA (Spain): - Roads & Transport Zaragoza - OSM
Output	Estimate of the level of access to relevant services and support in different neighbourhoods of the AOI as table and/or shapefile. Metric tbd after initial tests with the input data
Archive Length of input data	- BD TOPO -> From 2008 onwards - Roads & Transport Zaragoza -> Updated to 2023 - OSM -> From 2013 onwards - Google maps -> Most current data - Social/traditional media data -> From 2018 onwards

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Spatial resolution of input data	- BD TOPO: vector data (up to a scale of 1:2 000) - Roads & Transport Zaragoza: vector data - OSM: vector data (up to a scale of 1:500) - Google maps: vector data (up to a scale of 1:500) - Social/traditional media data: tbd after initial tests with the input data
Temporal coverage of output	Present situation/most recent information
Spatial coverage of output	AOIs
Validation	Information to be included in V2 of the service pipeline documentation, pending initial tests with input data
Dependencies Software	- Access to an internet connection and web browser to download Roads & Transport Zaragoza, BD TOPO, OSM and Google Maps data. - Access to HENSOLDT Media Mining System for media-based factors
Dependencies Hardware	Information to be included in V2 of the service pipeline documentation
Analytics	UF-ID-9, 10 and 13 will be combined into a flood vulnerability index. Most appropriate methods for fusing the data will be chosen depending on the structure of the input data (e.g. whether underlying data and indicators are highly correlated or not, missing observations etc.). This work will be performed at a later stage of the project as part of Task 2.4 and Task 2.7).
Challenges	- Availability (i.e. spatial & temporal coverage, missing & unknown values) of input data - Further challenges may arise during indicator development
Product sample	To be included at a later stage of the project, pending progress in Task 2.4 and 2.5

3.3.3 UF-ID-13 Ability to evacuate

Ability to evacuate	
Product Owner	Adelphi*
Product Description	Indicator of people's abilities to move out of harm's way
Service Level	Component of the vulnerability composite indicator that is part of the Flood impact index.
EO input data	n/a
Non-EO input data	DLR (all cases): - WFS-Population - GHS-Pop Hensoldt (France, Mozambique, Spain) : - Social/traditional media data CLS (France):

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	- BD TOPO (IGN) - INSEE census - OSM SERTIT (Germany): - OSM SERTIT (Mozambique): - OSM TRACASA (Spain): - Roads & Transport Zaragoza - OSM
Output	Estimate of the likelihood people different neighbourhoods of the AOI will be able to move out of harm's way as table and/or shapefile. Metric tbd after initial tests with the input data
Archive Length of input data	- WSF-Population: available from 2016-to present. - GHS-POP: available from 1975 to 2020 in a 5-year interval; and projection to 2025 and 2030. - BD TOPO -> From 2008 onwards. - INSEE census -> From 1946 onwards for exhaustive census data. - Roads & Transport Zaragoza -> Updated to 2023. - OSM -> From 2013 onwards. - Social/traditional media data -> From 2018 onwards.
Spatial resolution of input data	- WSF-Population: 10m spatial resolution at the Equator. - GHS-POP: 100m spatial resolution at the Equator. - BD TOPO: vector data (up to a scale of 1:2 000). - INSEE census: Not applicable (tabular data, one row per communal entity). - OSM: vector data (up to a scale of 1:500). - Roads & Transport Zaragoza: vector data. - Social/traditional media data: to be defined after initial tests with the input data.
Temporal coverage of output	Present situation/most recent information
Spatial coverage of output	AOIs
Validation	Information to be included in V2 of the service pipeline documentation, pending initial tests with input data
Dependencies Software	- Access to an internet connection and web browser to download Roads & Transport Zaragoza, BD TOPO, INSEE and OSM data. - Access to HENSOLDT Media Mining System for media-based factors.

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Dependencies Hardware	Information to be included in V2 of the service pipeline documentation
Analytics	UF-ID-9, 10 and 13 will be combined into a flood vulnerability index. Most appropriate methods for fusing the data will be chosen depending on the structure of the input data (e.g. whether underlying data and indicators are highly correlated or not, missing observations etc.). This work will be performed at a later stage of the project as part of Task 2.4 and Task 2.7).
Challenges	- Availability (i.e. spatial & temporal coverage, missing & unknown values) of input data - Further challenges may arise during indicator development
Product sample	To be included at a later stage of the project, pending progress in Task 2.4 and 2.5

3.3.4 UF-ID-14 Economic impacts of floods

Economic impact of floods	
Product Owner	Adelphi, e-GEOS, Hensoldt
Product Description	Estimate of economic impact of flooding
Service Level	Component of the Flood impact index.
EO input data	n/a
Non-EO input data	- UF-ID-5 - Social/traditional media data
Output	Estimate of economic impact of flooding. Metric to be defined after initial tests with the input data
Archive Length of input data	- UF-ID-5 - Social/traditional media data -> available from 2018 to present
Spatial resolution of input data	- See description of UF-ID-5 - Social/traditional media data: country level, admin1 level where sufficient sources are active.
Temporal coverage of output	Present situation/most recent information
Spatial coverage of output	AOIs
Validation	UF-ID-5 data will be compared with data from social and traditional media

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Dependencies Software	Access to HENSOLDT Media Mining System for media-based factors
Dependencies Hardware	Information to be included in V2 of the service pipeline documentation
Analytics	This indicator relies on flood damage estimates from UF-ID5. These estimates will be validated and, if possible, refined with information from social and traditional media, such as pictures and reports of destroyed buildings and infrastructure or damage assessment shared by news agencies, civil protection services, non-governmental organisations, and the like.
Challenges	- Availability (i.e. spatial & temporal coverage, missing & unknown values) of input data. - Further challenges may arise during indicator development.
Product sample	To be included at a later stage of the project, pending progress in Task 2.4 and 2.5

3.3.5 WFS-ID-7: IDP camps status indicator

WFS-ID-7: IDP camps status indicator	
Product Owner	e-GEOS
Product Description	Change Detection (CD) is a SAR data-based product that allows to create a false colour composite RGB image where: i) the red channel is associated with the backscattering map related to the first acquisition date; ii) the green and blue channels are associated with backscattering map related to the second acquisition date. Then, an automatic change detection tool (ACD) is applied to extract features that exceed a certain threshold based on the colour code of the image.
Service Level	This indicator is triggered only when the monitoring system threshold is exceeded
EO input data	HR-VHR SAR data
Non-EO input data	Refugee camps location from: IOM DTM / UNHCR CCCM
Output	The output is given by the settlement new area extent as the result of the ACD tool extraction in a raster file format Further quantitative characterization of the new areas extent is under study.
Archive Length	2017 but very limited in global coverage locations
Spatial resolution	VHR (res < 3m)
Temporal coverage	Dependes on archived data availability and time scheduling of new acquisitions.

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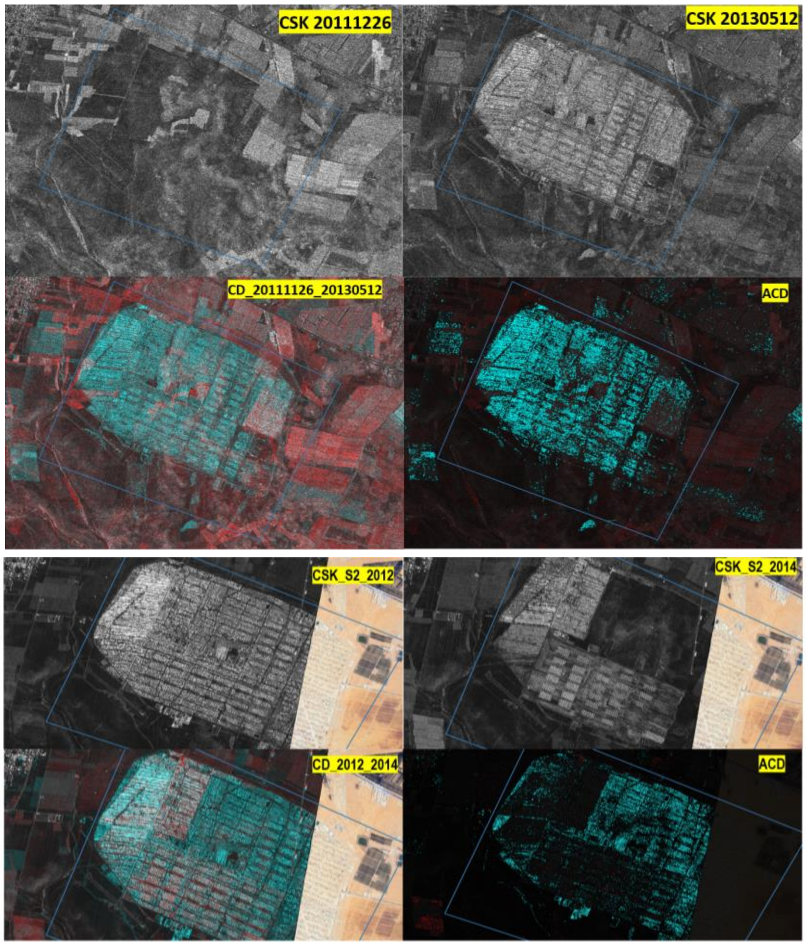
<table>
<tr><td>Spatial coverage</td><td>Local scale depending on coverage over the area of interest</td></tr>
<tr><td>Validation</td><td>Results validation obtained from EO-based products with reports from UNHCR or IOM</td></tr>
<tr><td>Dependencies Software</td><td>Open source code; proprietary software; Python; SNAP ; GIS software</td></tr>
<tr><td>Dependencies Hardware</td><td>CPU</td></tr>
<tr><td>Analytics</td><td>Import of the data, co-registration, geocoding, change detection product, automatic change detection tool.</td></tr>
<tr><td>Challenges</td><td>The major challenge is to translate EO-based change detection product in a quantitative characterization of settlement extent and possibly people hosted.</td></tr>
<tr><td>Product sample</td><td>Development is ongoing. An example of how the product will look like, is presented below.

</td></tr>
</table>

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3.3.6 WFS-ID-8 Populations at risk of food insecurity

WFS-ID-8: Populations at risk of food insecurity	
Product Owner	DLR
Product Description	Population at risk of food insecurity is a compound-indicator that estimates the total number (proportion or percentage) of people at risk of food insecurity derived from level or status of food security within a given area.
Service Level	Input to the Data Viewer (dashboard)
EO input data	No EO data are used
Non-EO input data	- WSF-Population - GHS-Population - Scale of food insecurity at the administrative level
Output	- Estimated number of people per administrative unit (.shp). - Estimated number of people per administrative unit (.csv).
Archive Length	- WSF-Population: available from 2016-to present. - GHS-POP: Available from 1975 to 2020 in a 5-year interval; and projections to 2025 and 2030. - FAO DIEM: available from 2020 to present (input to WFS-ID-11 that feeds into WFS-ID-8) - FEWSNET: available from 2009 to present (input to WFS-ID-11 that feeds into WFS-ID-8)
Spatial resolution	- WSF-Population: 10m spatial resolution at the Equator. - GHS-POP: 100m spatial resolution at the Equator. - Food Security data: Admin 1 or Admin 2 level (WFS-ID-11)
Temporal coverage	2016-to present, with monthly updates
Spatial coverage	Country level
Validation	Historical food security data from FEWSNET will be compared with FAO DIEM data, as well as with survey data from DHS and Afrobarometer. If possible, food security data from FAO DIEM and FEWSNET will also be compared with data from social and traditional media.
Dependencies Software	Open source code Python and GDAL libraries.
Dependencies Hardware	CPU
Analytics	We compute populations at risk of food insecurity indicator using a Zonal Statistic analysis which summarizes population counts at the pixel level within the predefined administrative

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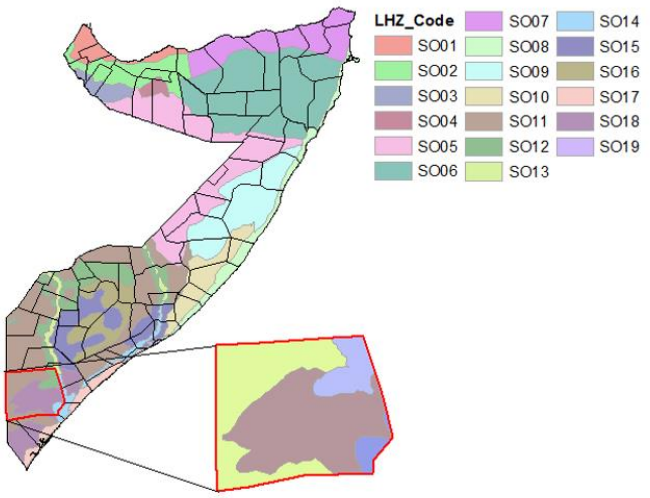
	units. Here, the administrative units are previously classified according to the food security scale defined in WFS-ID-11.
Challenges	We compute populations at risk of food insecurity indicator using a Zonal Statistic analysis method which simply summarizes population counts at the pixel level within the predefined livelihood zones (LHZ) from the FEWSNET data. At the administrative unit level (e.g. level 1 or level 2) the final indicator will then report on the estimated no. of people living in: minimal, stressed, crisis, emergency and/or famine levels, which represent the sum of people found within the LHZ holding a corresponding food-security status. Therein, "0" values can be expected when the LHZ found within a given administrative level do not report a particular food security status.
Product sample	

ADMIN2	Minimal	Stressed	Crisis	Emergency	Famine	Y-M
Afmadow	123890.743683	8522.231433	4402.082517	0	0	2020-2

3.3.7 WFS-ID-9 Populations at risk of water insecurity

Populations at risk of water insecurity	
Product Owner	DLR
Product Description	The populations at risk of water insecurity indicator are a compound-indicator that measures the potentially available physical water per person, allowing to derive the degree of water (in) sufficiency, and estimate the total number (proportion or percentage) of people at risk of water insecurity.
Service Level	WFS-ID-9 is the main component for the Exposure index of the Risk Monitor (EWS) tool
EO input data	No EO data are used
Non-EO input data	WSF-Population ERA5-Land monthly average water availability
Output	Water stress classification map (Raster) Estimated number of people per administrative unit (.shp).

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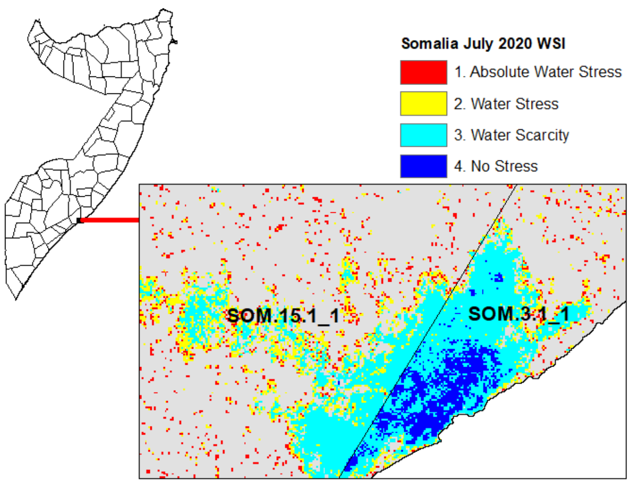
<table>
<tr><td></td><td>Estimated number of people per administrative unit (.csv).</td></tr>
<tr><td>Archive Length</td><td>WSF-Population → available from 2016-to present.
- ERA5-Land monthly average water availability→ available from 2016 – to present.</td></tr>
<tr><td>Spatial resolution</td><td>WSF-Population → 10m spatial resolution at the Equator
- ERA5-Land monthly average water availability → ~ 9 km</td></tr>
<tr><td>Temporal coverage</td><td>- 2016-to present, with monthly updates</td></tr>
<tr><td>Spatial coverage</td><td>- Country level</td></tr>
<tr><td>Validation</td><td>N/A</td></tr>
<tr><td>Dependencies Software</td><td>Open source code Python and GDAL libraries.</td></tr>
<tr><td>Dependencies Hardware</td><td>CPU</td></tr>
<tr><td>Analytics</td><td>To compute the populations at risk of water insecurity indicator, we first derive a water availability per person map using an overlay analysis. With this pre-processing step we create a new raster layer where each cell represents the division of water availability (m^3) by the population in each cell. Then, using the Falkenmark indicator, each cell is classified into different levels of water stress, namely: low, moderate, high or extreme. From here, population counts are derived for each class and aggregated at the administrative unit level by means of a Zonal Statistic analysis.</td></tr>
<tr><td>Challenges</td><td>The nature of input population data challenges the validation of the final estimates reported by the indicator. The challange at hand, revolves around the unavailability of independent population data for validation, where verifying the accuracy of the outputed estimates relies heavily on benchmarks that cannot be established. Therefore, caution should be applied when interpreting and applying the estimates.</td></tr>
<tr><td>Product sample</td><td>



<table>
<tr><th>GID_2</th><th>GID_0</th><th>COUNTRY</th><th>GID_1</th><th>NAME_1</th><th>NAME_2</th><th>POP_CLASS1</th><th>POP_CLASS2</th><th>POP_CLASS3</th><th>POP_CLASS4</th></tr>
<tr><td>SOM.3.1_1</td><td>SOM</td><td>Somalia</td><td>SOM.3_1</td><td>Banaadir</td><td>Mogadisho</td><td>4542.99</td><td>6847.68</td><td>570069.67</td><td>490701</td></tr>
</table>

</td></tr>
</table>

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3.3.8 WFS-ID-10: Number of people living in conflict-affected areas

Number of people living in conflict-affected areas	
Product Owner	DLR
Product Description	The number of people living in conflict-affected areas is compound-indicator that estimates the total number of people that could be potentially affected by violent-crime events due to their spatial proximity. At the level of administrative units, it also reports the overall crime rate by means of a crime index.
Service Level	Part of the Vulnerability component of the Risk monitor (EWS) and input to the Data Viewer (dashboard)
EO input data	n/a
Non-EO input data	WSF-Population Violent Conflict (Number and frequency of crime events) (WFS-ID-14)
Output	Number of estimated people living in the proximity of violent crime events (.shp) Number of estimated people living in the proximity of violent crime events (.shp) Crime rate and Crime index (.shp) Crime rate and Crime index (.shp)
Archive Length	WSF-Population → available from 2016-to present. Violent Conflict → 1997-to-present
Spatial resolution	WSF-Population → 10m spatial resolution at the Equator Violent Conflict → Point data reported at admin. level 1 and admin. level 2
Temporal coverage	2016-to present, with monthly updates
Spatial coverage	Country level
Validation	Validation tasks for this indicator will not be conducted, please refer to "Challenges" for more details.
Dependencies Software	Open source code Python and GDAL libraries.
Dependencies Hardware	CPU
Analytics	To compute the number of people living in conflict areas we rely on two analyses. First a proximity analysis is performed, in which buffer areas are created at 2,4,6,8,10 and 50km of all reported crime-events (point data) per month, per country. Within these areas/buffers, we then estimate the total population by means of a Zonal Statistic analysis and aggregate the results at the administrative unit level 1 or level 2. Here, the results indicate the number of people that are affected by at least one crime-event at a particular distance, per unit, per month. The second analysis consists of the computation of the crime rate index per administrative units. First, for each unit and month we summarize the number of crime events and total

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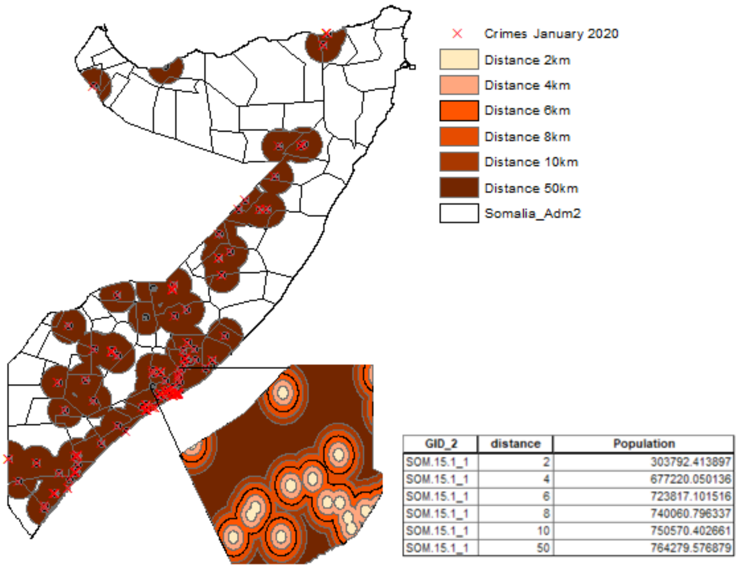
	population. With this we derive the crime per capita and multiply this value time 100,000 as crime rate is typically reported as N number of crimes per 100,000 people.
Challenges	The nature of input population data challenges the validation of the final estimates reported by the indicator. The challange at hand, revolves around the unavailability of independent population data for validation, where verifying the accuracy of the outputed estimates relies heavily on benchmarks that cannot be established. At the same time, conflicts and ongoin violence will drive people away, creating offsets on the data. Therefore, caution should be applied when interpreting and applying the estimates.
Product sample	

3.3.9 WFS-ID-11 Food insecurity

Food insecurity	
Product Owner	Adelphi
Product Description	Indicator for the level of food insecurity of the population in a given area
Service Level	WFS-ID-11 feeds into the Data Viewer (Dashboard) tool. It is also used to calibrate Vulnerability indices for the Risk Monitor (EWS) tool.
EO input data	WFS-ID-11 does not rely on any EO data
Non-EO input data	- FEWSNET - FAO DIEM - Afrobarometer - Demographic and Health Survey (DHS) - Social/traditional media data
Output	- Estimate of the level food insecurity of the population in a given area on a scale from 1-5 (compatible with IPC scale) at admin1 level for Risk Monitor (EWS) tool - Same at admin2 level for Data Viewer (Dashboard) tool

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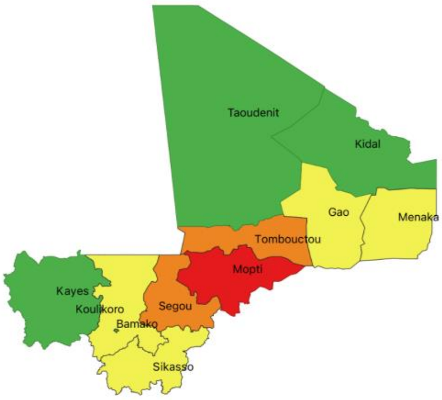
Archive Length of input data	- FEWSNET -> available from 2009 to present - FAO DIEM -> available from 2020 to present - Afrobarometer (Mali) -> available from to 2001 to 2023 - Afrobarometer (Mozambique) -> available from 2002 to 2022 - DHS (Mali) -> available from 1987 to 2024 - DHS (Mozambique) -> available from 1997 to 2023 - Social/traditional media data -> available from 2018 to present
Spatial resolution of input data	- FEWSNET: admin2 - FAO DIEM: admin1 - Afrobarometer: admin1 or admin2 - DHS: admin1 - Social/traditional media data: country level, admin1 level where sufficient sources are active.
Temporal coverage of output	Monthly observations: for current month, for past X months (number depending on input data), and up to 6 months in advance
Spatial coverage of output	Mali, Mozambique, Somalia fully covered; other countries to be potentially added
Validation	FEWSNET data and data from social/traditional media will be compared with FAO DIEM, DHS, and Afrobarometer data
Dependencies Software	- Access to FEWSNET API - Access to HENSOLDT Media Mining System for media-based factors
Dependencies Hardware	Information to be included in V2 of the service pipeline documentation
Analytics	Information on concrete steps to be included in V2 of the service pipeline documentation. For a rudimentary workflow please refer to [RD03].
Challenges	- Availability (i.e. spatial & temporal coverage, missing & unknown values) of input data - Further challenges may arise during indicator implementation
Product sample	 Template: admin1-level choropleth map (Risk Monitor)

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3.3.10 WFS-ID-12 Economic insecurity

Economic insecurity	
Product Owner	Adelphi
Product Description	Indicator for the level of economic insecurity of the population in a given area
Service Level	WFS-ID-12 feeds into the Data Viewer (Dashboard) tool. It is also used to calibrate Vulnerability indices for the Risk Monitor (EWS) tool.
EO input data	WFS-ID-12 does not rely on any EO data
Non-EO input data	- FAO DIEM - Livestock heat stress (produced by GMV, see annex) - Afrobarometer - Social/traditional media data
Output	Estimate of the level economic insecurity of the population in a given admin1-month. Metric to be defined after initial tests with the input data
Archive Length of input data	- FAO DIEM -> available from 2020 to present - Livestock heat stress -> potentially 1950 to present - Afrobarometer (Mali) -> available from to 2001 to 2023 - Afrobarometer (Mozambique) -> available from 2002 to 2022 - Social/traditional media data -> available from 2018 to present
Spatial resolution of input data	- FAO DIEM: admin1 - Livestock heat stress: 0,1° - Afrobarometer: admin1 or admin2 - Social/traditional media data: country level, admin1 level where sufficient sources are active.
Temporal coverage of output	Monthly observations: for current month, for past X months (number depending on input data)
Spatial coverage of output	Mali, Mozambique, Somalia fully covered; other countries to be potentially added
Validation	Comparison between FAO DIEM data, Livestock heat stress data, data from social/traditional media, and Afrobarometer data
Dependencies Software	- Access to FAO DIEM API - Access to HENSOLDT Media Mining System for media-based factors - Access to Livestock heat stress data
Dependencies Hardware	Information to be included in V2 of the service pipeline documentation

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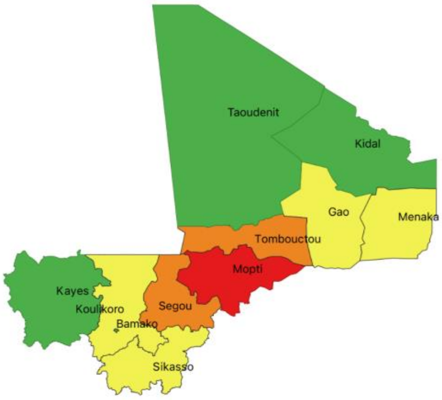
Analytics	Information on concrete steps to be included in V2 of the service pipeline documentation. For a rudimentary workflow please refer to [RD03].
Challenges	- Availability (i.e. spatial & temporal coverage, missing & unknown values) of input data. - Further challenges may arise during indicator implementation.
Product sample	 Template: admin1-level choropleth map (Risk Monitor)

3.3.11 WFS-ID-13 Displaced persons

Displaced persons	
Product Owner	Adelphi
Product Description	Estimate of the number of persons displaced (IDPs and refugees from other countries).
Service Level	WFS-ID-13 feeds in to the Data Viewer (Dashboard) tool. It is also used to calibrate Vulnerability indices for the Risk Monitor (EWS) tool.
EO input data	WFS-ID-13 does not rely on any EO data
Non-EO input data	- IOM-DTM Mobility tracking - Social/traditional media data
Output	- Estimate of the number of displaced people in a given admin1-month (for Risk Monitor) - Spatial and temporal level tbd for Data Viewer (Dashboard) depending on feasibility and user requirements
Archive Length of input data	- IOM-DTM Mobility tracking (Mali) -> 2014-present - IOM-DTM Mobility tracking (Mozambique) -> 2015-present - IOM-DTM Mobility tracking (Somalia) -> 2016-present - Social/traditional media data -> available from 2018 to present
Spatial resolution of input data	- IOM-DTM Mobility tracking -> admin1 - Social/traditional media data -> Social/traditional media data: country level, admin1 level where sufficient sources are active.

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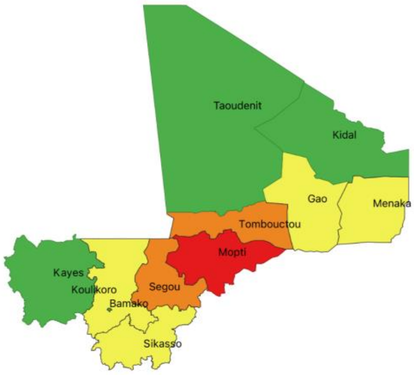
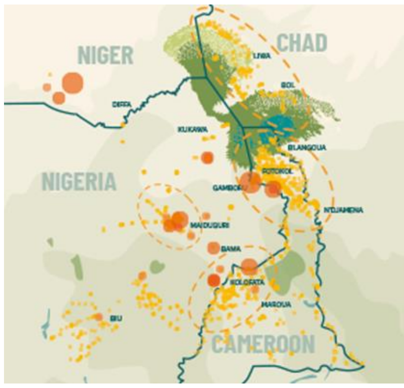
<table>
<tr><td>Temporal coverage of output</td><td colspan="2">Monthly observations: for current month, for past X months (number depending on input data)</td></tr>
<tr><td>Spatial coverage of output</td><td colspan="2">Mali, Somalia, Mozambique partly to fully covered; other countries to be potentially added</td></tr>
<tr><td>Validation</td><td colspan="2">Comparison of IOM data and data from social/traditional media</td></tr>
<tr><td>Dependencies Software</td><td colspan="2">Access to HENSOLDT Media Mining System for media-based factors</td></tr>
<tr><td>Dependencies Hardware</td><td colspan="2">Information to be included in V2 of the service pipeline documentation</td></tr>
<tr><td>Analytics</td><td colspan="2">Information on concrete steps to be included in V2 of the service pipeline documentation. For a rudimentary workflow please refer to [RD03].</td></tr>
<tr><td>Challenges</td><td colspan="2">- Availability (i.e. spatial & temporal coverage, missing & unknown values) of input data
- Further challenges may arise during indicator implementation</td></tr>
<tr><td>Product sample</td><td>


Template: admin1-level choropleth map (Risk Monitor)</td><td>


Template: size of IDP population in different locations (point shapefile for Data Viewer)</td></tr>
</table>

3.3.12 WFS-ID-14 Violent conflict

Violent conflict	
Product Owner	Adelphi
Product Description	Indicator for the level of violent conflict in a given area
Service Level	WFS-ID-14 feeds into the Data Viewer (Dashboard) tool. It is also used to create Vulnerability indices for the Risk Monitor (EWS) tool.
EO input data	WFS-ID-14 does not rely on any EO data
Non-EO input data	- ACLED - Social/traditional media data
Output(s)	- Number of violent conflict events in a given admin1-month (for Risk Monitor)

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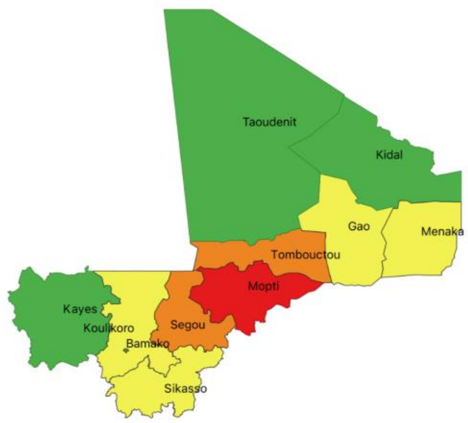
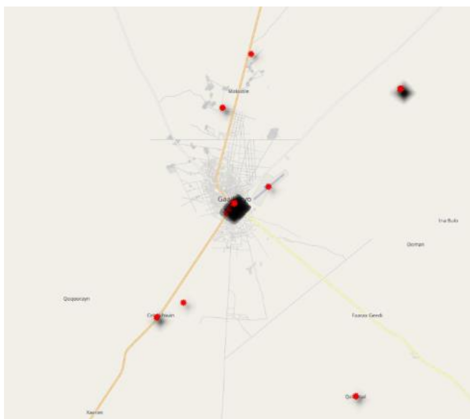
	- Number of victims of violent conflicts in a given admin1-month (for Risk Monitor) - Spatial and temporal level tbd for Data Viewer (Dashboard), depending on feasibility and user requirements: possibility for disaggregation down to exact event coordinates for each day
Archive Length of input data	- ACLED: point coordinates with varying geo-precision (exact, admin3, admin2, admin1) - Social/traditional media data: country level, admin1 level where sufficient sources are active.
Spatial resolution of input data	- Monthly observations: for current month, for past X months (number depending on input data), and up to 6 months into the future
Temporal coverage of output	Mali, Mozambique, Somalia fully covered; other countries to be potentially added
Spatial coverage of output	Comparison of IOM data and data from social/traditional media
Validation	- Access to ACLED API - Access to HENSOLDT Media Mining System for media-based factors - Access to Livestock heat stress data
Dependencies Software	- Information to be included in V2 of the service pipeline documentation
Dependencies Hardware	Information on concrete steps to be included in V2 of the service pipeline documentation. For a rudimentary workflow please refer to [RD03].
Analytics	- Availability (i.e. spatial & temporal coverage, missing & unknown values) of input data Further challenges may arise during indicator implementation
Challenges	- ACLED: point coordinates with varying geo-precision (exact, admin3, admin2, admin1) - Social/traditional media data: country level, admin1 level where sufficient sources are active.
Product sample	  Template: violent events in different locations (point shapefile for Data Viewer)

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	Template: admin1-level choropleth map (Risk Monitor)	

3.3.13 WFS-ID-15 Radicalisation and polarisation

Radicalisation and polarisation indicator	
Product Owner	Adelphi and Hensoldt
Product Description	Indicator that provides an estimate for the level of radicalization, polarization, and animosity in the population that is conductive to periodic outbursts of violence (e.g., riots, clashes) and/or recruitment into armed groups. If necessary, possibility to distinguish sub-classes for this indicator (e.g., anti-government sentiment, ethnic/communal tensions, ideological/religious radicalization).
Service Level	WFS-ID-15 is a component of the Vulnerability index for the Risk Monitor (EWS) tool
EO input data	WFS-ID-15 does not rely on any EO data
Non-EO input data	- Social/traditional media data - ACLED - Afrobarometer
Output	- Estimate of the degree/level of radicalisation and polarisation in the population at the admin1-month level (for Risk Monitor) - Spatial and temporal level tbd for Data Viewer (Dashboard) depending on feasibility and user requirements
Archive Length of input data	- Social/traditional media data -> available from 2018 to present. - ACLED -> available from 1997 to present - Afrobarometer (Mali) -> available from to 2001 to 2023 - Afrobarometer (Mozambique) -> available from 2002 to 2022
Spatial resolution of input data	- Social/traditional media data: basic accumulation on the country and admi1 level (where sufficient sources are active), per language in case several ones are present in the AOI. - ACLED: point coordinates with varying geo-precision (exact, admin3, admin2, admin1) - Afrobarometer: admin1 or admin2
Temporal coverage of output	Monthly observations: for current month, for past X months (number depending on input data)
Spatial coverage of output	Mali, Somalia, Mozambique fully covered; other countries to be potentially added
Validation	Data from social and traditional media will be compared with ACLED and Afrobarometer data.
Dependencies Software	- Access to HENSOLDT Media Mining System for media-based factors - Access to ACLED API
Dependencies Hardware	CPU

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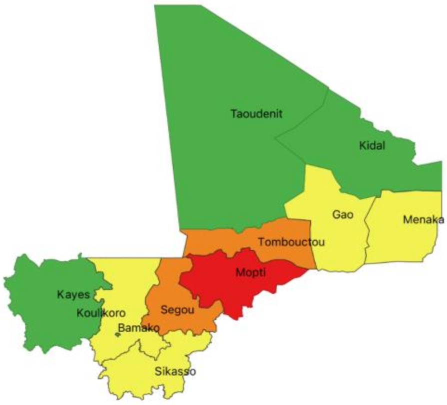
Analytics	This indicator combines (fuses) information of different nature: on the one hand, this makes it an innovative feature. Different levels of granularity, reliability and data-completeness will need to be considered (and unknown/missing values be dealt with). Regarding media contents, sentiment analysis, hate speech or toxicity will be computed. For a rudimentary workflow please refer to [RD03].
Challenges	The different nature of input data poses novel challenges to the construction process of this indicator. The exact manner of combination is yet to be determined; several alternatives will need to be explored along the way. In particular, the different granularity, reliability of data as well as missing and unknown values will need to be addressed.
Product sample	 Template: admin1-level choropleth map (Risk Monitor)

3.3.14 WFS-ID-17 Humanitarian aid

Humanitarian aid	
Product Owner	Adelphi
Product Description	Indicator for the level of aid provided by national and international actors (e.g., government, international organisations, NGOs) to people in a given area
Service Level	WFS-ID-17 feeds into the Data Viewer (Dashboard) tool. It is also used to create Vulnerability indices for the Risk Monitor (EWS) tool.
EO input data	WFS-ID-17 does not rely on any EO data
Non-EO input data	- FAO DIEM - Social/traditional media data
Output(s)	- Extent of humanitarian aid provided to people in a given admin1-month (for Risk Monitor); metric: tbd after initial tests with the input data - Spatial and temporal level tbd for Data Viewer (Dashboard) depending on feasibility and user requirements
Archive Length of input data	- FAO DIEM -> available from 2020 to present - Social/traditional media data -> available from 2018 to present
Spatial resolution of input data	- FAO DIEM: admin1

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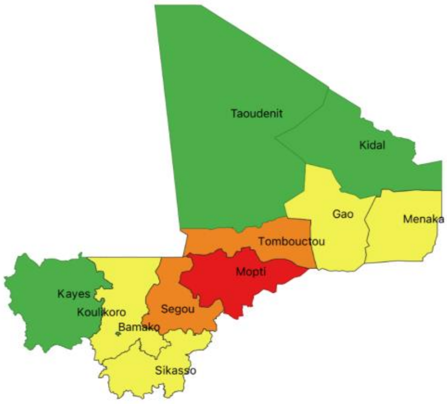
	- Social/traditional media data: country level, admin1 level where sufficient sources are active.
Temporal coverage of output	Monthly observations: for current month, for past X months (number depending on input data)
Spatial coverage of output	Mali, Mozambique, Somalia fully covered; other countries to be potentially added
Validation	FAO DIEM data and data from social/traditional media will be compared
Dependencies Software	- Access to FAO DIEM API - Access to HENSOLDT Media Mining System for media-based factors
Dependencies Hardware	Information to be included in V2 of the service pipeline documentation
Analytics	Information on concrete steps to be included in V2 of the service pipeline documentation. For a rudimentary workflow please refer to [RD03].
Challenges	- Availability (i.e. spatial & temporal coverage, missing & unknown values) of input data - Further challenges may arise during indicator implementation
Product sample	 Template: admin1-level choropleth map (Risk Monitor)

3.3.15 WFS-ID-18 Resource capture

Resource capture	
Product Owner	Adelphi
Product Description	Indicator for the appropriation of natural resources essential for food production and/or sustaining agricultural and pastoralist livelihoods by powerful actors (e.g., land grabbing by large companies) or specific groups (e.g., communal groups)
Service Level	WFS-ID-18 feeds in to the Data Viewer (Dashboard) tool. It is also used to create Vulnerability indices for the Risk Monitor (EWS) tool.
EO input data	WFS-ID-18 does not rely on any EO data

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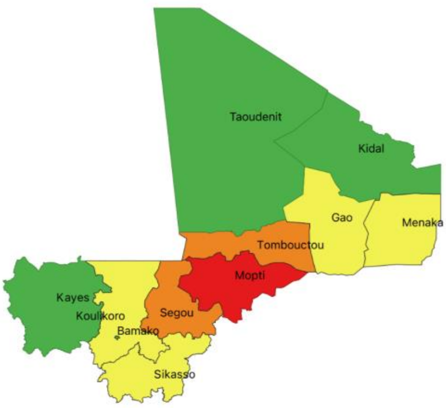
Non-EO input data	- Rangeland cover change (produced by GMV, see annex) - Social/traditional media data
Output(s)	- Level of "resource capture" in a given admin1-month (for Risk Monitor); metric: tbd after initial tests with the input data - Spatial and temporal level tbd for Data Viewer (Dashboard) depending on feasibility and user requirements
Archive Length of input data	- Rangeland cover change -> available from 1992 to 2020 (possibly data for later periods available in the future) - Social/traditional media data -> available from 2018 to present
Spatial resolution of input data	- Rangeland cover change: 300m - Social/traditional media data: country level and admin1 level where sufficient sources are active.
Temporal coverage of output	Monthly observations: for current month, for past X months (number depending on input data)
Spatial coverage of output	Mali, Mozambique, Somalia fully covered; other countries to be potentially added
Validation	Information to be included in V2 of the service pipeline documentation, pending initial tests with social and traditional media input data
Dependencies Software	- Access to Rangeland change data - Access to HENSOLDT Media Mining System for media-based factors
Dependencies Hardware	Information to be included in V2 of the service pipeline documentation
Analytics	Information on concrete steps to be included in V2 of the service pipeline documentation. For a rudimentary workflow please refer to [RD03].
Challenges	- Availability (i.e. spatial & temporal coverage, missing & unknown values) of input data - Further challenges may arise during indicator implementation
Product sample	 Template: admin1-level choropleth map (Risk Monitor)

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3.3.16 WFS-ID-19 Climate sensitivity of agri-food systems

Climate sensitivity of agri-food systems	
Product Owner	Adelphi
Product Description	Degree to which rural livelihoods and food production are sensitive to erratic climatic conditions
Service Level	WFS-ID-19 feeds in to the Data Viewer (Dashboard) tool. It is also used to create Vulnerability indices for the Risk Monitor (EWS) tool.
EO input data	WFS-ID-19 does not rely on any EO data
Non-EO input data	- FAO Wapor - Social/traditional media data
Output(s)	- Level of "climate sensitivity" in a given admin1-month (for Risk Monitor); metric: tbd after initial tests with the input data - Spatial and temporal level tbd for Data Viewer (Dashboard) depending on feasibility and user requirements
Archive Length of input data	- FAO Wapor -> available from 2009 to present - Social/traditional media data -> available from 2018 to present
Spatial resolution of input data	- FAO Wapor: 250m - Social/traditional media data: country level and admin1 level where sufficient sources are active.
Temporal coverage of output	Monthly observations: for current month, for past X months (number depending on input data)
Spatial coverage of output	Mali, Mozambique, Somalia fully covered; other countries to be potentially added
Validation	Information to be included in V2 of the service pipeline documentation, pending initial tests with social and traditional media input data
Dependencies Software	- Access to FAO Wapor API - Access to HENSOLDT Media Mining System for media-based factors
Dependencies Hardware	Information to be included in V2 of the service pipeline documentation
Analytics	Information on concrete steps to be included in V2 of the service pipeline documentation. For a rudimentary workflow please refer to [RD03].
Challenges	- Availability (i.e. spatial & temporal coverage, missing & unknown values) of input data - Further challenges may arise during indicator implementation

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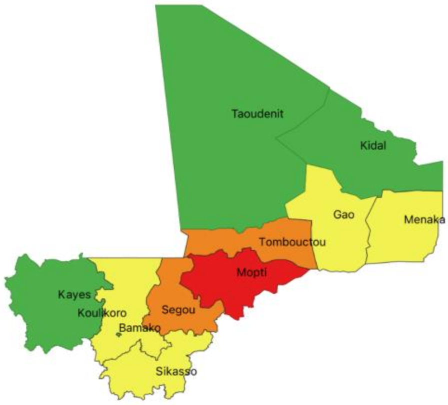
Product sample	 Template: admin1-level choropleth map (Risk Monitor)

3.3.17 WFS-ID-21 Public services and infrastructures

Public services and infrastructures	
Product Owner	Adelphi
Product Description	Degree to which the government effectively and inclusively delivers services that are essential for withstanding extreme climatic conditions
Service Level	WFS-ID-21 feeds into the Data Viewer (Dashboard) tool. It is also used to create Vulnerability indices for the Risk Monitor (EWS) tool.
EO input data	EOG Night time Light (NTL)
Non-EO input data	- Main roads (provided by GMV) - HOT OSM - Social/traditional media data
Output(s)	- Level of “service provision” in a given admin1-month (for Risk Monitor); metric: to be defined after initial tests with the input data. - Spatial and temporal level to be defined for Data Viewer (Dashboard) depending on feasibility and user requirements.
Archive Length of input data	- Main roads (provided by GMV) -> time invariant; latest available data (29/09/2023) - HOT OSM -> time invariant; latest available data. - EOG Night time Light (NTL) -> 2012-2021. - Social/traditional media data -> available from 2018 to present.
Spatial resolution of input data	- Main roads (provided by GMV): n/a; vector data. - HOT OSM: n/a; vector data. - EOG Night time Light (NTL): 500m. - Social/traditional media data: country level and admin1 level where sufficient sources are active.
Temporal coverage of output	Monthly observations: for current month, for past X months (number depending on input data)

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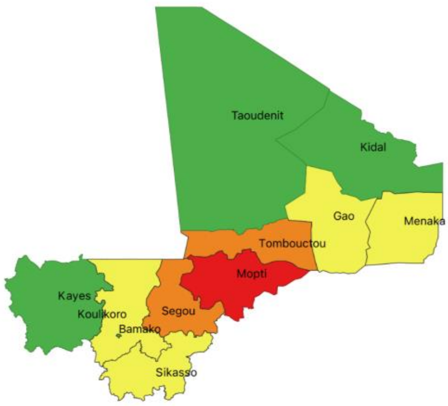
Spatial coverage of output	Mali, Mozambique, Somalia fully covered; other countries to be potentially added
Validation	Data on main roads will be compared with HOT OSM road data
Dependencies Software	- Access to Main road data - Access to NTL API - Access to HENSOLDT Media Mining System for media-based factors
Dependencies Hardware	Information to be included in V2 of the service pipeline documentation
Analytics	Information on concrete steps to be included in V2 of the service pipeline documentation. For a rudimentary workflow please refer to [RD03].
Challenges	- Availability (i.e. spatial & temporal coverage, missing & unknown values) of input data - Further challenges may arise during indicator implementation
Product sample	 Template: admin1-level choropleth map (Risk Monitor)

3.3.18 WFS-ID-23 State-citizen relations

State-citizen relations	
Product Owner	Adelphi
Product Description	Degree to which citizens trust public officials and feel included in political decision making. High levels of trust and inclusion are expected to motivate people to seek non-violent means of addressing concerns and grievances
Service Level	WFS-ID-23 feeds into the Data Viewer (Dashboard) tool. It is also used to create Vulnerability indices for the Risk Monitor (EWS) tool.
EO input data	WFS-ID-23 does not rely on any EO data
Non-EO input data	- Social/traditional media data - Afrobarometer
Output(s)	- "Quality" of state-citizen relations in a given admin1-month (for Risk Monitor); metric: tbd after initial tests with the input data

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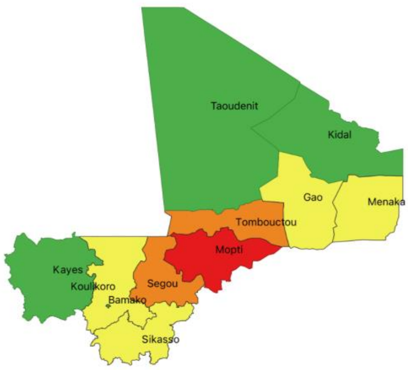
	- Spatial and temporal level tbd for Data Viewer (Dashboard) depending on feasibility and user requirements
Archive Length of input data	- Afrobarometer (Mali) -> available from to 2001 to 2023 - Afrobarometer (Mozambique) -> available from 2002 to 2022 - Social/traditional media data -> available from 2018 to present
Spatial resolution of input data	- Afrobarometer: admin1 or admin2 - Social/traditional media data: country level and admin1 level where sufficient sources are active.
Temporal coverage of output	Monthly observations: for current month, for past X months (number depending on input data)
Spatial coverage of output	Mali, Mozambique, Somalia fully covered; other countries to be potentially added
Validation	Social/traditional media data will be compared with Afrobarometer data
Dependencies Software	Access to HENSOLDT Media Mining System for media-based factors
Dependencies Hardware	Information to be included in V2 of the service pipeline documentation
Analytics	Information on concrete steps to be included in V2 of the service pipeline documentation. For a rudimentary workflow please refer to [RD03].
Challenges	- Availability (i.e. spatial & temporal coverage, missing & unknown values) of input data - Further challenges may arise during indicator implementation
Product sample	 Template: admin1-level choropleth map (Risk Monitor)

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3.3.19 WFS-ID-24 Dispute resolution mechanisms

Dispute resolution mechanisms	
Product Owner	Adelphi
Product Description	Presence of trusted formal and informal mechanisms (e.g., legal recourse, inter- and intra-community dialogue) to address disputes, for e.g., over access to and usage of resources.
Service Level	WFS-ID-24 feeds into the Data Viewer (Dashboard) tool. It is also used to create Vulnerability indices for the Risk Monitor (EWS) tool.
EO input data	WFS-ID-24 does not rely on any EO data
Non-EO input data	- Social/traditional media data - Afrobarometer
Output(s)	- "Quality" of dispute resolution mechanisms in a given admin1-month (for Risk Monitor); metric: tbd after initial tests with the input data - Spatial and temporal level to be defined for Data Viewer (Dashboard) depending on feasibility and user requirements
Archive Length of input data	- Afrobarometer (Mali) -> available from to 2001 to 2023 - Afrobarometer (Mozambique) -> available from 2002 to 2022 - Social/traditional media data -> available from 2018 to present
Spatial resolution of input data	- Afrobarometer: admin1 or admin2 - Social/traditional media data: country level and admin1 level where sufficient sources are active.
Temporal coverage of output	Monthly observations: for current month, for past X months (number depending on input data)
Spatial coverage of output	Mali, Mozambique, Somalia fully covered; other countries to be potentially added
Validation	Social/traditional media data will be compared with Afrobarometer data
Dependencies Software	Access to HENSOLDT Media Mining System for media-based factors
Dependencies Hardware	Information to be included in V2 of the service pipeline documentation
Analytics	Information on concrete steps to be included in V2 of the service pipeline documentation. For a rudimentary workflow please refer to [RD03]
Challenges	- Availability (i.e. spatial & temporal coverage, missing & unknown values) of input data - Further challenges may arise during indicator implementation

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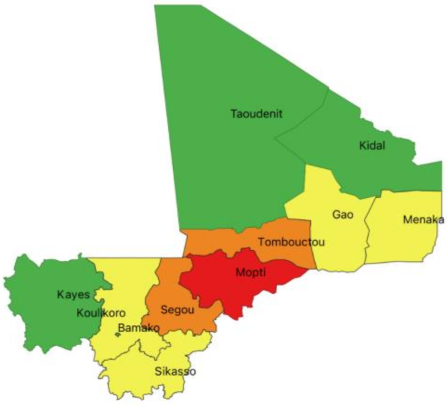
Product sample	 Template: admin1-level choropleth map (Risk Monitor)

3.3.20 WFS-ID-25 Social cohesion and trust

Social cohesion and trust	
Product Owner	Adelphi
Product Description	Presence of trusted formal and informal mechanisms (e.g., legal recourse, inter- and intra-community dialogue) to address disputes, for e.g., over access to and usage of resources.
Service Level	WFS-ID-25 feeds into the Data Viewer (Dashboard) tool. It is also used to create Vulnerability indices for the Risk Monitor (EWS) tool.
EO input data	WFS-ID-25 does not rely on any EO data.
Non-EO input data	- Social/traditional media data - Afrobarometer
Output(s)	- "Quality" of social cohesion in a given admin1-month (for Risk Monitor); metric: to be defined after initial tests with the input data. - Spatial and temporal level to be defined for Data Viewer (Dashboard) depending on feasibility and user requirements.
Archive Length of input data	- Afrobarometer (Mali) -> available from to 2001 to 2023 - Afrobarometer (Mozambique) -> available from 2002 to 2022 - Social/traditional media data -> available from 2018 to present
Spatial resolution of input data	- Afrobarometer: admin1 or admin2 - Social/traditional media data: country level and admin1 level where sufficient sources are active.
Temporal coverage of output	Monthly observations: for current month, for past X months (number depending on input data)
Spatial coverage of output	Mali, Mozambique, Somalia fully covered; other countries to be potentially added.
Validation	Social/traditional media data will be compared with Afrobarometer data.

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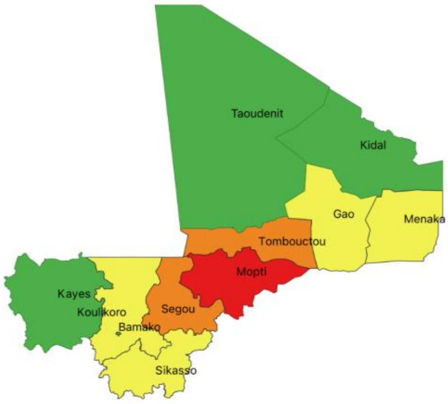
Dependencies Software	Access to HENSOLDT Media Mining System for media-based factors.
Dependencies Hardware	Information to be included in V2 of the service pipeline documentation.
Analytics	Information on concrete steps to be included in V2 of the service pipeline documentation. For a rudimentary workflow please refer to [RD03].
Challenges	- Availability (i.e. spatial & temporal coverage, missing & unknown values) of input data. - Further challenges may arise during indicator implementation.
Product sample	 Template: admin1-level choropleth map (Risk Monitor)

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4 PROCESSING CHAINS – BASELINE V1

4.1 URBAN FLOOD AND RELATED SOCIO-POLITICAL-ECONOMIC PIPELINES

This section includes the visual representations of the processing chains of the CENTAUR products at the current stage. The workflows represent the processing chains from the inputs that will be used to the outputs that will be generated as a result. These representations will be updated in the future versions, if needed, to show the evolution of the processes and to support the integration of the processing chains into the platform. The technological components showcased in the subchapters below are those identified in the D7.5 – IPR and Innovation Plan v1, produced in M9 ([RD06]).

4.1.1 Meteorological Component

Meteorological data is used to calculate a set of urban flood indicators (UF-ID-1 and UF-ID-2), which are in turn used as inputs for other indicators (e.g., UF-ID-3). The meteorological data can be subdivided into data representing observations or observation-based data sets (i.e., reanalysis), as well as forecasts.

The most important meteorological input data is precipitation, for both, urban flood and water and food security indicators. For any type of monitoring, and where available, in-situ observations are used. For the forecasts of precipitation, in the context of providing an early-warning system for urban floods, 3-day forecasts from ECMWF's high-resolution ensemble forecast are used. To overcome the uncertainty of predicting extreme precipitation with numerical weather models, UF-ID-2 aims to predict return period classes of extreme precipitation instead. Therefore, a convolutional neural network is trained using the historical catalogue of return period classes (UF-ID-1) and additional predictors from the Integrated Forecast System (IFS) implemented at ECMWF. These predictors include, for example, horizontal and vertical wind, temperature, potential vorticity, convective available potential energy, total column water vapor, total column rainwater, orography, cloud cover, and precipitation.

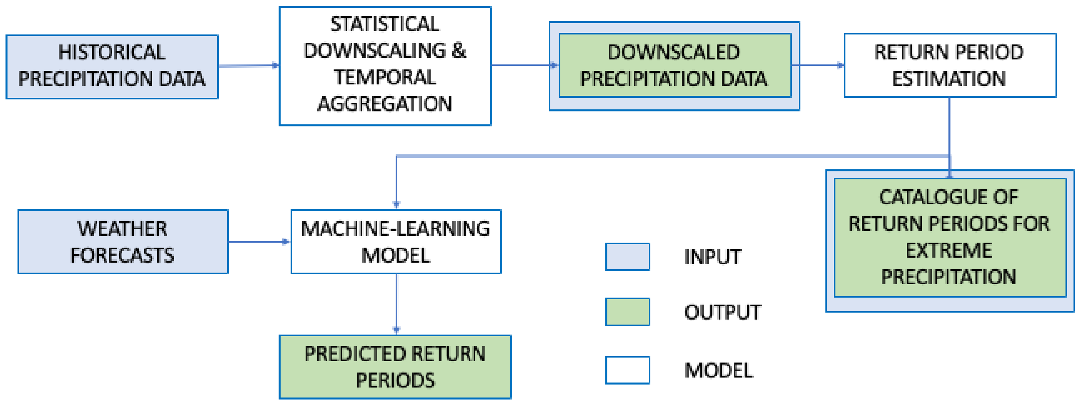

Figure 1: Processing chain for the computation of the meteorological component – Urban Flood

The urban flood branch of the meteorological workflow comprises two main purposes:

1. To create a historical catalogue of return periods for extreme precipitation events.
2. To forecast return periods of extreme precipitation using a machine-learning model.

To create a historical catalogue of return periods for extreme precipitation events,

- A statistical downscaling to a relevant spatial resolution for flooding (e.g., 1.5 km) may be performed, if the quality of this downscaled data set permits.

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- The data is aggregated to the relevant time scale (e.g., 6-hour integrations for 3 days lead time).
- Return periods are estimated by fitting a Generalized Extreme Value (GEV) distribution to annual maxima over the full time series of precipitation at each grid point. Return periods are chunked into 1-, 10-, 20-, 50-, 10-, 200-, 500- year classes. The precipitation totals for each return period class are extracted.

To forecast return periods of extreme precipitation using a machine-learning model,

- For the training of Convolutional Neural Network (CNN), the entire history of ERA5 reanalyses is used (once) in addition to the above-described catalogue (UF-ID-1). For the daily forecasts of return periods with the trained CNN, the latest forecasts of the ECMWF high-resolution at 9km are collected.
- Additional predictors are extracted from the ECMWF archive (see list of variables above).
- In a first step, the full record of ERA5 data is used to train the CNN. In a second step, high-resolution forecasts of 3 days lead time of the same variables are used as input to the CNN to forecast return periods of precipitation. The predicted return periods present 1-, 10-, 20-, 50-, 100-, 500-year periods and are indicative of extreme precipitation events in the coming days, asserting a warning level. Using the catalogue from UF-ID-1. This return period can be translated to a total precipitation quantity, which in turn can be used as forcing for the speedy model.

4.1.2 Flood components

4.1.2.1 Speedy Flood

The Speedy Flood component is based on three main steps: i) Digital Terrain Model (DTM) hydraulically conditioned suitable for the geomorphological analysis; ii) running the geomorphological model; iii) water depth calculation step.

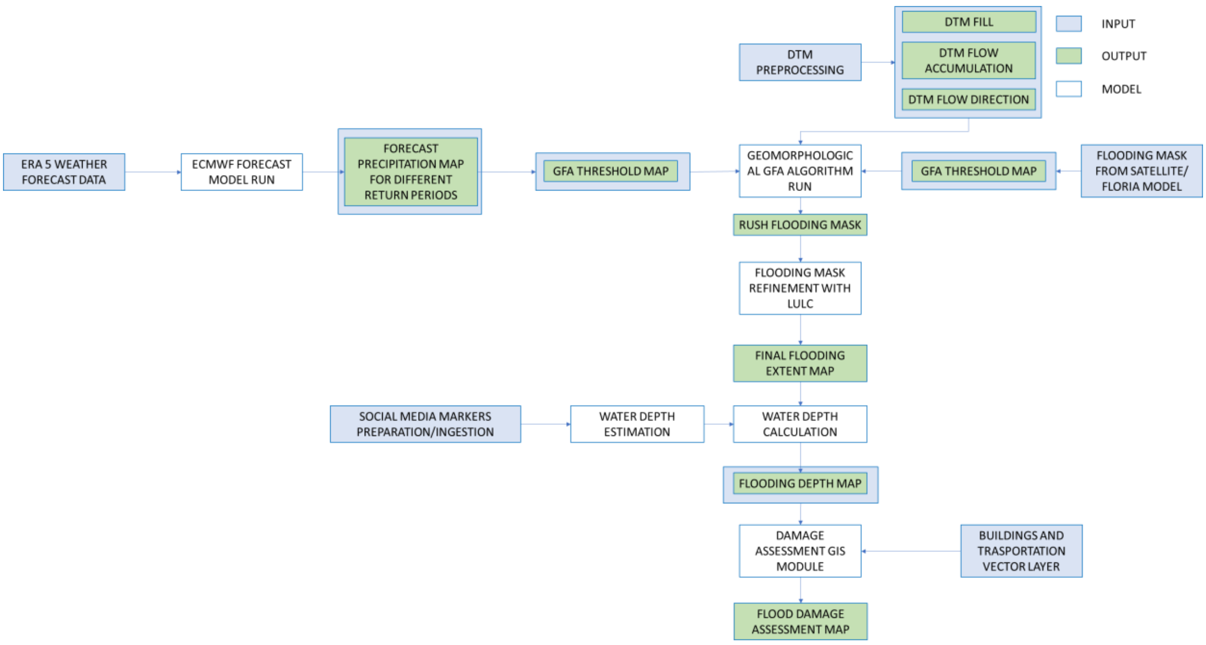

Figure 2: Processing chain for the computation of the speedy flood component – Urban Flood

The operations performed within step 1 mentioned above includes: In summary, the DTM fill to lift depressions in, the flow accumulation calculation to estimate the amount of water flow through a specific point, the flow direction which indicates the direction this water will move. These concepts are essential in hydrological analyses and water system modelling and can be used to assess flood risks, study rainwater runoff, and much more.

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This algorithm allows for a rapid and cost-effective delineation of floodplains in contexts where data availability is limited for conducting hydrological/hydraulic analyses. In addition to the three inputs derived from DTM preprocessing, an additional input comes from the satellite-derived flooding mask and InSAR analysis obtainable through the FLORIA algorithm. The satellite-derived flooding mask provides information regarding the extent of flooding in suburban areas, while that obtainable from InSAR techniques is used in urban areas (blind spots to satellites, especially to SAR sensors). More details about the FLORIA algorithm and the water mask extraction methodology are provided in the following chapter.

The extent of flooding obtained by combining data from suburban areas with that from FLORIA is used to calibrate the GFA algorithm. The water mask is transformed using appropriate tools into a raster represented by a binary matrix for flooded areas and 0 for non-flooded areas), which allows accounting for the contribution of precipitation in the AOI.

By utilizing these four inputs, DTM fill, flow accumulation, flow direction, and the binary matrix related to the water mask, it is possible to run the GFA algorithm to generate the post-event. As the simulation results in an overestimation of the flooding extent, a cleanup process is performed using the land use layer. The cleanup is carried out in suburban areas, utilizing satellite data, being ground truth in that context, while maintaining what was obtained in suburban and satellite blind spot areas.

Calibration of the geomorphological model GFA also involves utilizing maps derived from precipitation data. This occurs when replicating scenarios with different return periods, using maps derived from meteorological analyses of past events to calculate the threshold value necessary for GFA calibration. In our case, data from the ERA5 dataset is employed, and through ECMWF-owned models, precipitation maps with various return periods can be generated. Each of these maps, processed to identify two specific thresholds, designates one threshold representing accumulated precipitation contributing to flooding as 1 and another threshold representing precipitation inconsequential to flooding as 0. This preprocessing enables the generation of the binary matrix essential for GFA calibration. The values of these two thresholds are determined through a statistical analysis conducted on historical precipitation data: 1 represents all values beyond which there is a 90th percentile probability of flooding occurrence, while 0 represents the rest.

The water mask extracted from this latter operation is used as an input for depth calculation. The approach used for depth calculation within the water mask is the HAND method.

The HAND (Height Above Nearest Drainage) approach is a method used for water depth calculation in flood modelling. It is based on digital elevation models (DEMs) and is particularly useful for estimating flood depth in flat or low-gradient areas where water flow and drainage patterns are not well-defined.

Here's how the HAND approach works:

1. **Calculation of HAND Values:** For each cell in a digital elevation model (DEM), the HAND value represents the height of the cell above the nearest drainage, such as a river, stream, or any other watercourse. HAND values are computed using algorithms that analyses the DEM to identify flow paths and determine the elevation difference between cells and their nearest drainage features.
2. **Flood Depth Estimation:** Once HAND values are calculated, they can be used to estimate flood depths. During a flood event, the inundation depth at a specific location is equal to the HAND value of that location minus the water level during the flood event. If the HAND value is negative, it means the location is below the water level, indicating flooding.
3. **Mapping Inundation:** By comparing HAND values with the water level elevation, flood inundation maps can be created. Locations with positive HAND values indicate areas that are above the flood level and are not flooded, while locations with negative HAND values indicate areas submerged during a flood.

The HAND approach is particularly useful in areas where traditional hydrological models might face challenges, such as in flat coastal regions, urban areas with complex drainage patterns, or areas lacking detailed hydrological

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data. It provides a valuable tool for flood risk assessment and management, helping to identify vulnerable areas and plan for flood mitigation strategies.

In this phase, social media markers are used as a control element to assess the accuracy of the result and as weights for calculating flood depths. Photos, videos, comments from social and traditional media allow for precise evaluation of what is happening in the AOI, particularly in urban areas. Having this information available allows for precise estimation of depths from photos, videos, etc., and incorporating them into the depth calculation module, improving the quality of the result.

Thanks to the flooding depth map obtained, it is possible to define damage classes levels using a GIS module, which is linked to the transportation network and buildings within the area of interest. There exists a relationship that can connect the degree of expected damage to the post-event water level calculated through the Speedy Flood model. The following table provides a better understanding of the rationale behind the classification of flood hazard for buildings and the transportation network. The damage classification utilized refers to the one proposed by the European Commission in the CLARITY project (https://csis.myclimateservice.eu/node/1353).

RESIDENTIAL BUILDINGS

Water Depth (m)	0-0,11	0,12-0,19	0,2-0,8	> 0,8
DAMAGE CLASS	LOW	MEDIUM	HIGH	VERY HIGH
Impact €/m2	1	25	84	270

NON-RESIDENTIAL BUILDINGS

Water Depth (m)	0-0,05	0,06-0,19	0,2-1	> 1
DAMAGE CLASS	LOW	MEDIUM	HIGH	VERY HIGH
Impact €/m2	1	16	55	247

Figure 3: Classification utilized refers to the one proposed by the European Commission in the CLARITY project

4.1.2.2 FLORIA

Currently, FLORIA computes the flood extent from 3 SAR products (Input-ID-06). After the inference by the U-Net model, the results are masked to keep the information on urban areas only. The outputs are a raster containing the confidence scores (meaning, the confidence that a specific pixel is a flooded urban pixel) and a vector file generated from the thresholder raster (Figure 4). The flood extent computed by FLORIA is also an input for UF-ID-5, identified as Input-ID-01.

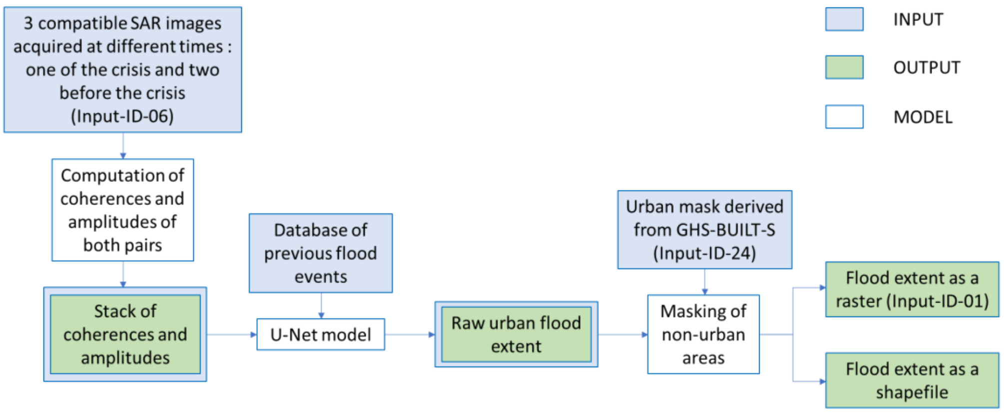

Figure 4: Processing chain for the computation of the FLORIA component – Urban Flood

To get further into details, the FLORIA processing chain consists in three steps: the data computation, the inference using a pre-trained U-Net model and the post-processing of the output.

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The three compatible SAR products, acquired at three different dates (T0 of crisis product and T-1 and T-2, the pre-event products) are organised in two pairs:

- Pre-event pair: T-2 and T-1 producT.
- Co-event pair: T-1 and T0 product.

The data computation consists in generating a single stack containing all the necessary information for the inference. This step is done using SNAP, a software developed by ESA. The information extracted from the 3 SAR products are combined in one stack: two bands for the coherence of the pre-event pair and the co-event pair, two bands for the pre-event amplitude based on respectively VV and VH polarizations and two for the co-event amplitude based on VV and VH polarizations. The detection of the flood based on amplitude and coherence values has been validated by the scientific community.

The previously generated stack is ingested in a U-Net model. This model is trained on a database of previous flood events where ground truth (mainly the vectors produced by past CEMS activations) was available. The algorithm generates a confidence flood map from the ingested stack. Each urban pixel gets a confidence score between 0 and 1. The post-processing consists in masking the results in non-urban areas using GHSL database to minimize errors. The first output of the FLORIA processing chain is the resulting raster file, containing information in urban areas only.

The urban flood is then generated as a vector file through adaptive thresholding. This thresholding is done manually by comparing the obtained flood extent with news sources or any type of information able to confirm the state (flooded or not) of a specific area. Another output is computed by classifying the confidence scores in five intervals based on the minimum and maximum values of the results. This is also outputted as a vector file.

4.1.2.3 Flood impact

For defining the flood hazard in the ID-7, the following steps are necessary: searching for input data, harmonizing these data, defining weights associated with each indicator, and finally, running the algorithm to determine the hazard. Below is the workflow diagram illustrating the various steps involved in defining the flood hazard index for ID-7 as envisaged in the project (Figure 5).

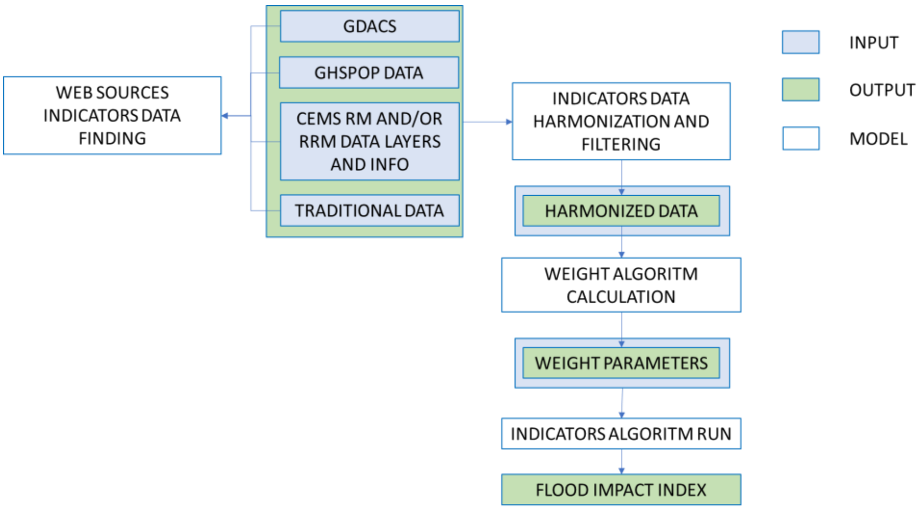

Figure 5: Processing chain for the computation of the flood impact index – Urban flood

Flood impact index achieved in this project was created by examining various aspects. The analysis is based on frequency of events that have occurred in countries analysed over a period of about 15 years to have a history of the areas subject to floods and the consequences in terms of deaths and displaced persons. The data was taken

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from European Union portal Copernicus where it is possible to see in detail the cartographies and the damages of the specific event and from GDACS portal which is a cooperation framework between the United Nations, the European Commission and disaster managers worldwide to improve warnings in case of risky events.

The other parameters used to construct the flood hazard index are:

- The data on the poverty threshold as a percentage of the Countries concerned. These data were taken from the web info; therefore, they refer to multiple sources These data were taken from the web info; therefore, they refer to multiple sources.
- The prevailing type of industries. There are three categories of industries to which three types of risk correspond: Agricultural and livestock industries which correspond to a low risk (R1), light industries (manufacturing, energy sector, trade, transport, ...) which corresponds to a medium risk (R2), heavy industries (mining, steel, petrochemical, ...) which corresponds to a elevate risk (R3). These data were taken from the web info; therefore, they refer to multiple sources.
- The number of seasonal events that occurred for the analysed year. It is very important to observe whether these events occurred during the rainy season or not. The precipitation data are taken from the NASA Giovanni portal, where it is possible to find the parameters relating to the precipitation time series and other geophysical parameters of different uses.

The data processing for the construction of the index has been conceived as the sum of 4 parameters to which a score ranging from 0 to 1 is assigned based on the data taken:

- GDACS index (I_1)
- Poverty index (I_2)
- Company type index (I_3)
- Number of event seasonality index (I_4)

The indicators listed are the most representative and available for all areas of interest.

The flood impact index equation is as follows:

$$FH(I_x) = (I_1) + (I_2) + (I_3) + (I_4)$$

Each parameter has a weight that has been calculated ad hoc for each event and country involved; analysing from time to time the data on the seriousness of the event, on the presence of industries in the affected areas, on the poverty of the affected population and on the period in which the event occurred. The result will be to have indices on different time frames for each area of interest.

The sum of the parameters must be put in proportion to the total size of the classes (6) to meet project requirements.

$$4 : 6 = FH(I_x)_1 : FH(I_x)$$

- 4 is the number of indices calculated.
- 6 is a total size of the classes (project).
- $FH(I_x)_1$ is the sum of the index.
- $FH(I_x)$ is the sum of the index in proportion.

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In quantitative terms (Table 3), the sum of the proposed indices will result in 3 possible hazard classes (Table 3:): “Low”, “Medium”, “High”.

FH (I_x)	Hazard class
0-2	Low
2-4	Medium
4-6	High

Table 3: Classes and related range identified for the flood impact index

4.1.3 Social/traditional media component

The UF-related indicators produced by social and traditional media processing can be divided into two basic categories (Figure 6):

- Social/traditional *media markers* representing geo-localised visual media items (images/videos) depicting a particular event of interest such as urban flooding.
- Socio-economic and political indicators derived from social and traditional media.

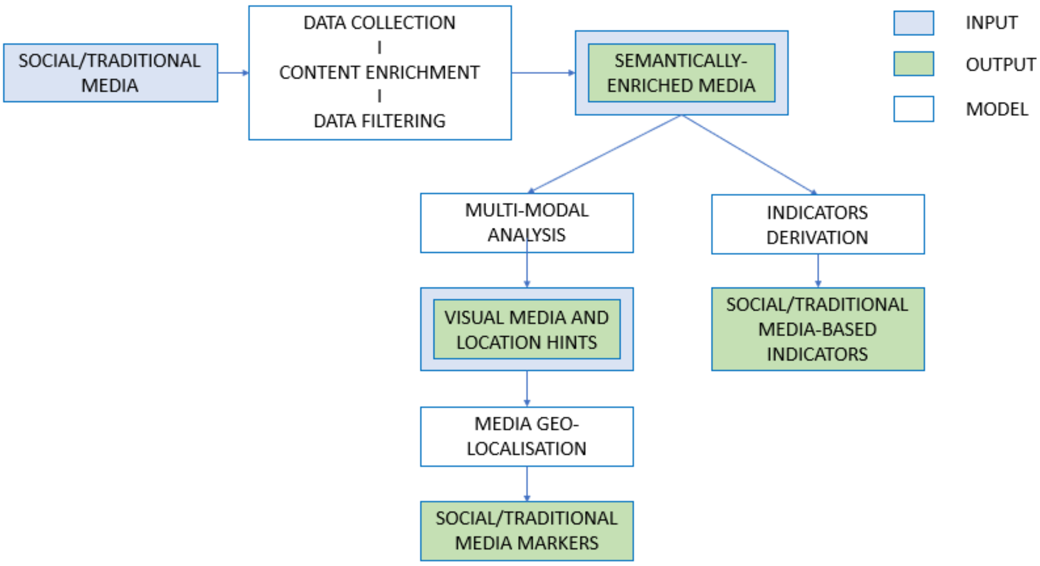

Figure 6: Processing chain for the generation of the social-traditional media components – Urban flood

Both categories share a common first stage covering the collection and pre-processing of data. Data is continuously collected from a broad range of social and traditional media sources and platforms. The underlying assumption is that the set of media sources and platforms represents the corresponding media-landscape in a relevant manner, i.e., that relevant and influential sources are employed to ensure sufficient data coverage for the underlying use case and indicator. In following, the extracted multi-modal data and the accompanying metadata are processed and enriched in a multi-lingual manner. The resulting data is filtered according to the given use case and indicators using sets of keywords, entities, languages, sources, origin, mentioned locations, etc.

For the generation of social/traditional media markers, the focus in the next stage is set on the visual content. In order to increase the relevance of the selected data and to speed up the geo-localisation step, a multi-modal analysis is performed. Accompanying textual content and textual transcriptions of the audio tracks from videos a processed to extract any locations mentioned (from city-level to low-level locations such as bridges, dams, or streets). Such location hints can be of great help for the geo-localisation of images and videos. The visual content itself is classified and filtered according to the type of event (e.g., flood or damage) and contained objects so that selected images can be efficiently used, for example, to leverage flooding maps optimisation. Eventually, the

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selected images and videos are geo-localised resulting in a set of social/traditional media markers including GPS coordinates, description, and link to the original content.

The derivation of the socio-economic and political indicators is based on the underlying characteristics of both the indicators and the data itself and it describes various aspects of the data, such as volume, sentiment, stability, etc. The result is provided as a timeline of normalized values which can serve as a basis for further analysis, such as the detection of anomalies, etc. The indicators produced in this manner will exhibit biases of various kinds. These will be identified and mitigated as much as possible. However, these indicators differ in nature from EO-derived ones and thus any combination/fusion will need to take this into account. Potentially, these indicators should be viewed as 'modulating' (strengthening, weakening) other kinds of indicators in the process of fusion.

4.2 WATER & FOOD INSECURITY AND RELATED SOCIO-POLITICAL-ECONOMIC PIPELINES

4.2.1 Meteorological Component

Like the meteorological component of the urban flood pipeline, the meteorological component of the water- and food security domain can be subdivided into observational products and forecasts. For the definition of meteorological droughts (WFS-ID-1), gridded observation-based precipitation products are used. For the water- and food security domain, high-resolution forecasts extending up to 6 months ahead, are required. Here, a suite of forecasts, from medium-range weather forecasts from ECMWF, covering the coming 15 days, to seasonal forecasts covering the coming 6 months, are concatenated to create a seamless forecast of precipitation. The creation of a seamless forecast bridges the gap between short-term weather forecasting and climate forecasts. Key benefits of seamless forecasts over seasonal forecasts are an improved accuracy and reliability and more frequent updates (Figure 7). The same forecasts, but for additional variables (e.g., temperature and net radiation) are used as inputs for the agricultural drought indicators (WFS-ID-5).

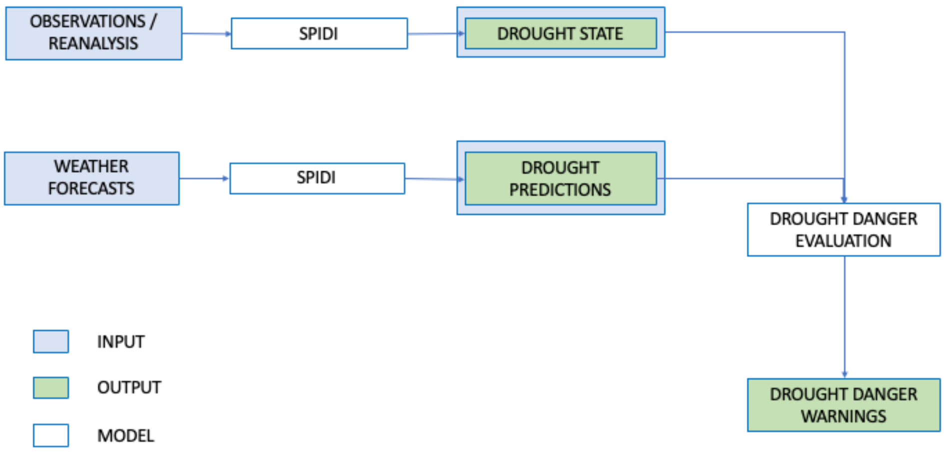

Figure 7: Processing chain for the computation of the meteorological component – Water & Food Insecurity

The meteorological component of the water- and food security branch contains three streams:

1. To monitor meteorological droughts.
2. To predict meteorological droughts.
3. To provide meteorological predictors that aid the prediction of agricultural drought.

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The workflow for monitoring meteorological droughts (WFS-ID-1) is as follows. First, observation-based precipitation is collected and quality-checked. The input files are properly harmonized before they are passed to the SPIDI library that evaluates the drought indicator at different timescales. The most recent drought indicator values are always concatenated to the historical values, generating a drought archive near real-time. An automated quality check of the generated product will be performed.

For the prediction of meteorological droughts (WFS-ID-2), the workflow is as follows. First, a range of forecasts, covering lead times from 0-15 days (medium- range ensemble forecast ENS), 16–42 days (extended-range medium-range ensemble forecast ENS-ER), and up to 6 months (seasonal forecast SEA) are collected from the ECMWF internal data base. All forecasts are pre-processed and concatenated according to their lead time, creating a seamless prediction of precipitation from day 1 to 6 months ahead that benefits from the strength of each forecast product. To create a long-time series covering at least 40 years, corresponding reforecasts are used and concatenated analogously. The input files are properly harmonized before they are passed to the SPIDI library that evaluates the drought indicator at different time scales. The drought indicators are then calculated using the SPIDI library. Together with the current state of drought (WFS-ID-1), the danger of forecasted drought events can be evaluated (WFS-ID-3).

The workflow for the provision of meteorological data is simple. A set of predictors from all forecasts (ENS, ENS-ER, SEA) is collected and a seamless forecast is created. These forecasts are quality-checked and the provided to project partners, such as VITO, for, e.g., the prediction of agricultural drought.

4.2.2 Agricultural Drought Component

Related to agricultural droughts, three inter-related indicators will be generated: WFS-ID-4 (current drought impact), WFS-ID-5 (future drought impact) and WFS-ID-6 (combined drought risk). All indicators are updated every 10 days (dekad).

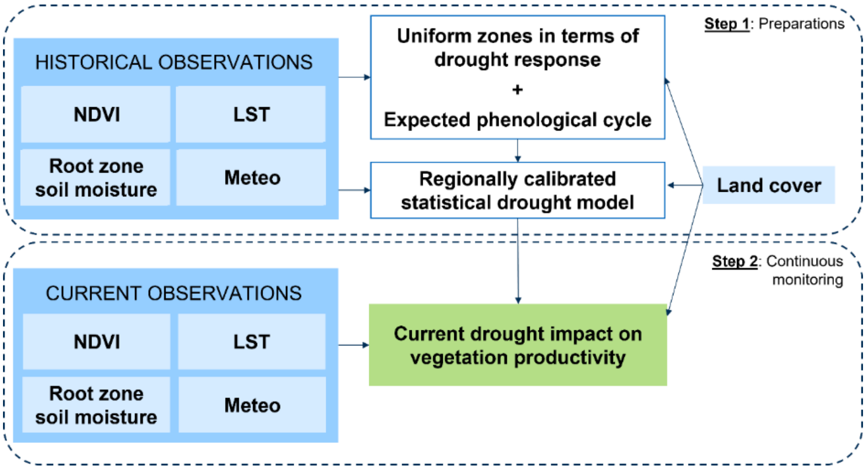

Figure 8: Processing chain for the agricultural component - current impact of agricultural drought on vegetation productivity

Figure 8 displays the workflow for generating WFS-ID-4. Before the indicators can be offered operationally for a given country, the “normal baseline” needs to be established for this country (see Figure 8 upper part). This baseline will be constructed based on analysing an extensive historical archive of all identified input datasets and will result in a zonation of the country, along with the dominant phenological cycles and specific thresholds to identify drought events. Next, for each dekad, an analysis will be made in near-real time comparing recent and present meteorological and vegetation conditions to the normal baseline situation as expected based on the long-term archive of said indicators, which will result in the estimate of current impact of drought on productivity.

Once the current impact of drought is known for a particular dekad, this indicator will be used as input to estimate the future impact of drought events (WFS-ID-5; see Figure 9). Again, a threshold-based and zone-specific decision

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support system will be calibrated for each individual country based on a large historical archive of the agricultural drought indicator (WFS-ID-4) and historical forecasts of meteorological conditions and soil moisture anomalies. For each dekad the indicator will estimate the likelihood of occurrence and the impact (in relative terms) of future agricultural drought events for several lead times, ranging from a few days up to six months in advance.

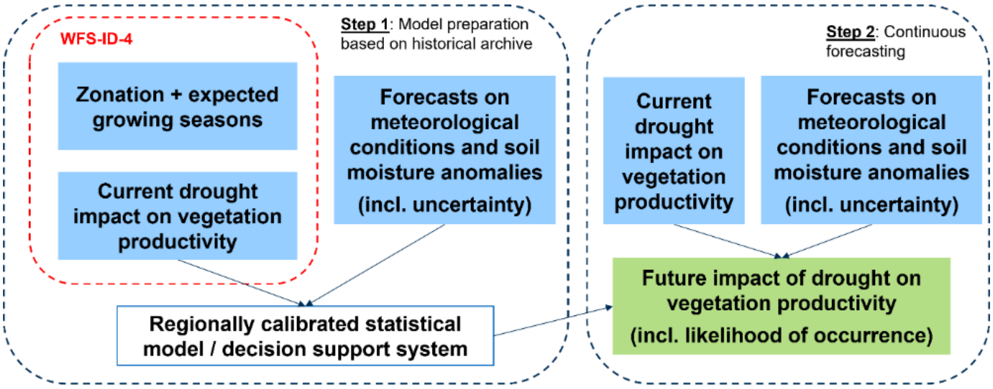

Figure 9: Generic workflow to generate indicator WFS-ID-5 (future impact of agricultural drought on vegetation productivity).

Finally, both indicators WFS-ID-4 and WFS-ID-5 will be combined into a categorical drought risk indicator, aggregated at admin 2 level (WFS-ID-6). The risk will be expressed in risk categories in terms of occurrence and impact of agricultural droughts, both present-day and near future.

4.2.3 Population and Settlement Component

The population component within in the CENTAUR project can be divided in two main tasks as described in Figure 10. The first main task involves the collection and production of multitemporal gridded population density estimates at high spatial resolution. The second task involves different processing workflows that allow combining gridded population data with other biophysical and socio-economic factors, to better understand the spatial distribution of exposure and vulnerability of the population, including the computation of population at risk (forecasting - or currently affected - nowcasting) of food insecurity) for food insecurity, population at risk of water insecurity, and population living in conflict-affected areas.

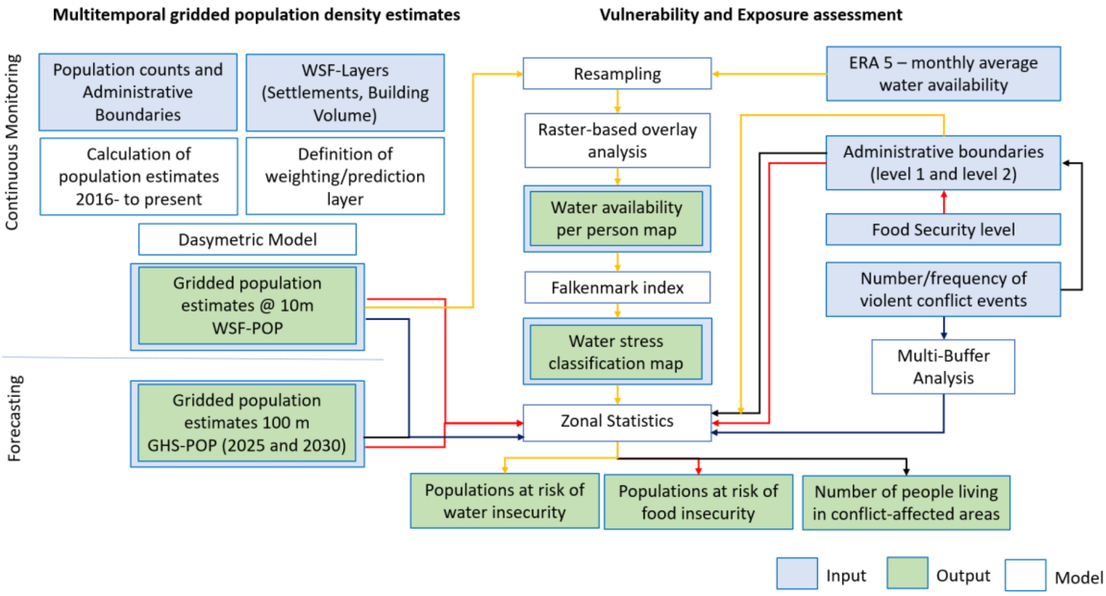

Figure 10: Processing chain for the population and settlements components – Water & Food Insecurity

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A detailed description of each task is presented in the following subsections.

4.2.3.1 Collection and production of gridded population estimates

For the task of **continuous monitoring**, the first step is to harvest and catalogue total population counts aggregated at the level of administrative units (e.g. municipalities, districts, etc.) for each AOI. These data are collected at least from 2 points in time, which at best, represent the population counts derived from official censuses.

The second step is to produce population estimates from 2016 up-to-date. To do this, exponential growth rates are determined for each administrative unit by aligning the total population from the most recent census with that of a prior census[1]. The growth rate is calculated using the following formula:

$$r = \frac{\ln(P_2/P_1)}{t}$$

where 'r' represents the annualized growth rate, 'P1' denotes the population count at the time of the earlier census, 'P2' stands for the population count from the most recent census, and 't' signifies the number of years between the two census points. Population estimates for target years are then determined using the following equation:

$$P_x = P_2 e^{rt}$$

where, 'Px' represents the population estimate in the target year 'x,' and 'P2,' 'r,' and 't' are defined as previously explained. Therein, the population estimates are adjusted, so that the total population of a country matches that reported by the United Nations World Population Prospect report in 2022.

The third step is to produce gridded population estimates for each target year by disaggregating population counts from administrative units into pixels of 10m spatial resolution. For this process, a “weighting or prediction” layer is produced based on the World Settlement Footprint layers, to determine the presence/absence of population per pixel (e.g. residential or not residential pixel), as well as the amount (e.g. more volume, more people). Using this weighting layer, the distribution of population counts is done using a dissymmetric model or algorithm using the following formula[2] :

$$Pop_{(p \in IU)} = Pop_{(IU)} \frac{W_p}{\sum_{p=1}^{n}(W_p)}$$

where the total population per pixel in a given administrative unit at a given year $(Pop_{(p \in IU)})$ is a proportion of the total population of that unit $(Pop_{(IU)})$ relative to their weight (W_p).

For **forecasting or predictive tasks,** the first and only step is to collect gridded population estimates from the GHS-Pop dataset for each AOI. Currently, the GHS-POP dataset is the only product that offers population projections for the years 2025 and 2030 at a spatial resolution of 100m. GHS has its own proprietary method to produce gridded population estimates.

4.2.3.2 Populations at risk of food insecurity

The workflow for the computation of populations at risk of food insecurity (WFS-ID-8) is demarcated in red in Figure 10. Overall, the processing framework is based on a “Zonal Statistical” analysis that integrates the inputs of gridded population data and food security.

[1] Lloyd, C. T., Chamberlain, H., Kerr, D., Yetman, G., Pistolesi, L., Stevens, F. R., et al. (2019). Global spatio-temporally harmonised datasets for producing high-resolution gridded population distribution datasets. Big Earth Data, 3(2), 108-139.

[2] Palacios-Lopez, D., et al. (2021). High-Resolution Gridded Population Datasets: Exploring the Capabilities of the World Settlement Footprint 2019 Imperviousness Layer for the African Continent. Remote Sensing, 13, 1142.

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As indicated, the data on food security is available at the level of livelihood-zones (LHZ) that hold the status of food security as defined by indicator WSF-ID-11. Using these units, the first step is to identify the "portions" of LHZ that fall within the different administrative units (e.g. level 1 or level 2). Here, for example, one or more LHZ can be found within an administrative unit, holding different food-security status.

From here, a Zonal Statistics analysis is performed to extract the number of people in these new spatial units. Finally, for each administrative unit we report the estimated number of people living in minimal, stressed, crisis, emergency and/or famine levels of food security, which represent the sum of population calculated per LHZ.

For this indicator it is important to notice that for every month within a given year, the number of people per administrative unit will remain unchanged as population data is updated on yearly basis. However, considering the updating frequency of food security data, there can changes in the total number of people that fall within a given food status class at the country level.

4.2.3.3 Populations at risk of water insecurity

The workflow for the computation of populations at risk of water security (WFS-ID-9) is demarcated in yellow in Figure 10. As illustrated, the first step consists in resampling the gridded population data (WSF-Population) to the spatial resolution of the ERA 5 monthly average availability data.

The second step is to produce the water availability per person map (raster). This is achieved through a raster-based overlay analysis, in which we divide the monthly water availability [m^3] by the number of people per pixel [pp].

Using this new raster, the third step consist in producing a water stress classification map (raster). Here, we rely on the Falkenmark Water Stress Index (WSI) which uses the following thresholds (Table 4) and classes/categories [3]:

Category	Water stress in
No Stress	>1700
Water Scarcity	1700-1000
Water Stress	1000-500
Absolute water stress	<500

Table 4: Water Stress Index (WSI) thresholds and classes/categories

Once the water stress map has been produced, the fourth step is to summarize the number of people that belong to a given WSI-category at the administrative level. For this we employ a Zonal Statistic analysis to extract the estimate number of people per WSI-category.

4.2.3.4 Number of people living in conflict areas

The workflow for the computation of number of people living in proximity to violent conflict events (WFS-ID-10) is demarcated in black in Figure 10. As illustrated, this indicator produces two alternative outputs. First, using a

[3] Falkenmark, M., J. Lundqvist, and C. Widstrand. 1989. Macro-scale water scarcity requires micro-scale approaches. Natural Resources Forum 13: 258–267.

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multi-buffer analysis we estimate the number of people that could be potentially affected by at least one violent event at distances of 2,4,6,8,10 and 50km of any reported event at the administrative unit level per month. Here, a zonal statistics analysis is used to estimate the number of people found at any given distance, aggregating the results at the administrative level.

At the administrative unit level, we also report on the crime rate, where a zonal statistics analysis is performed on monthly basis to estimate the number of crime events and the total population. This data is then used to calculate the crime per capita and estimate the crime rate for every 100,000 people.

For this indicator it is important to notice that for every month within a given year, the number of people per administrative unit will remain unchanged as population data is updated on yearly basis. However, considering the updating frequency of violent crime data, there can changes in the number of people potentially affected, as well as in the crime rate reported at the administrative level on monthly basis.

4.2.4 Displacements Component

The workflow for the WFS-ID-7 indicator starts with the activation from the alert system of the CENTAUR project, when a significant number of people begin to leave a certain area affected by climate change related events or political instability (Figure 11). Then, analysing the displaced people reports redacted by humanitarian organization as (IOM/UNHCR), the exact location of a refugee camp is retrieved. Starting from this area of interest, needed EO imagery acquisition is scheduled, and after the data are delivered and prepared, automatic change detection is applied to extract useful information about the spatial development of the camp, such as if it has increased after the previous event or its dimension remains the same.

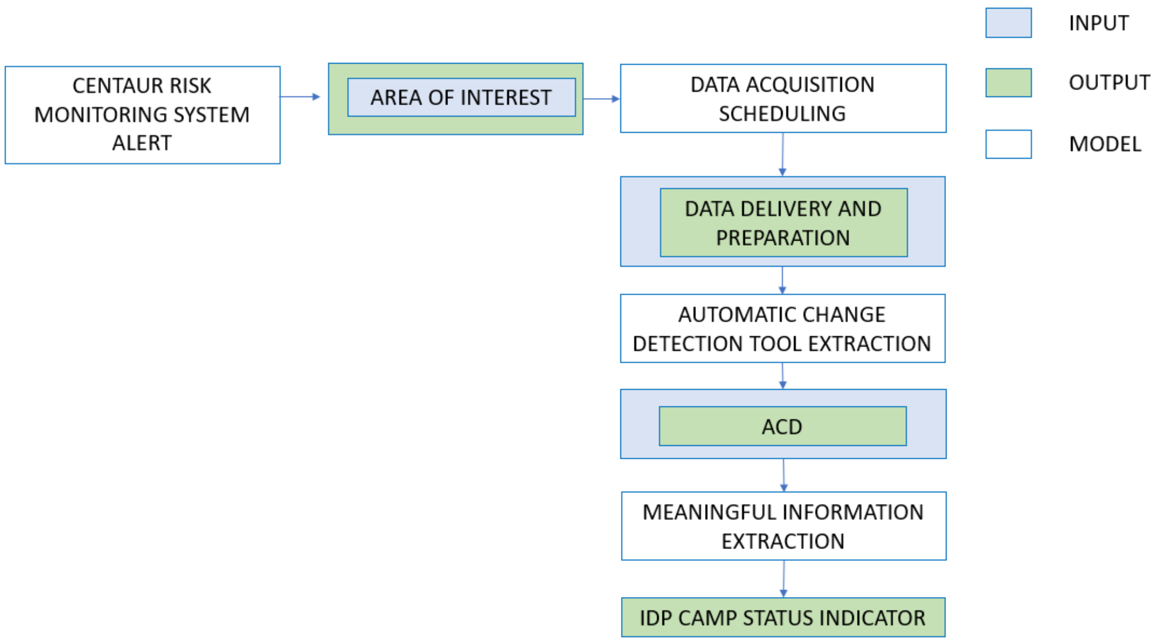

Figure 11: Processing chain for the displacements' component – Water & Food Insecurity

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4.2.5 Social/traditional media Component

The WFS indicators produced by social and traditional media processing are based on multi-lingual and multi-modal media data in textual, visual and auditive formats. In addition to the content itself, accompanying meta-data (e.g., descriptions) is considered. In addition to the content itself, accompanying meta-data (e.g., descriptions) is considered (Figure 12).

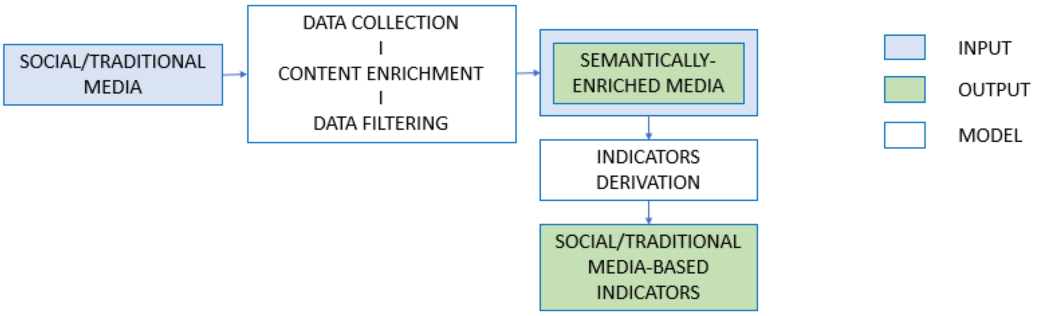

Figure 12: Processing chain for the social/traditional media component – Water & Food Insecurity

The workflow compromises two main steps:

1. **Data collection and pre-processing**. Data is continuously collected from a broad range of social and traditional media sources and platforms. The underlying assumption is that the set of media sources and platforms represents the corresponding media-landscape in a relevant manner, i.e., that relevant and influential sources are employed to ensure sufficient data coverage for the underlying use case and indicator. In following, the extracted multi-modal data and the accompanying metadata are processed and enriched in a multi-lingual manner. The resulting data is filtered according to the given use case and indicators using sets of keywords, entities, languages, sources, origin, mentioned locations, etc.
2. **Indicators derivation**. The derivation of the individual indicators is based on the underlying characteristics of both the indicators and the data and describe various data aspects, such as volume, sentiment, stability, etc. The result is provided as a timeline of normalized values which can serve as a basis for further analysis, such as the detection of anomalies, etc.

The indicators produced in this manner will exhibit biases of various kinds. These will be identified and mitigated as much as possible. However, these indicators differ in nature from EO-derived ones and thus any combination/fusion will need to take this into account. Potentially, these indicators should be viewed as 'modulating' (strengthening, weakening) other kinds of indicators in the process of fusion.

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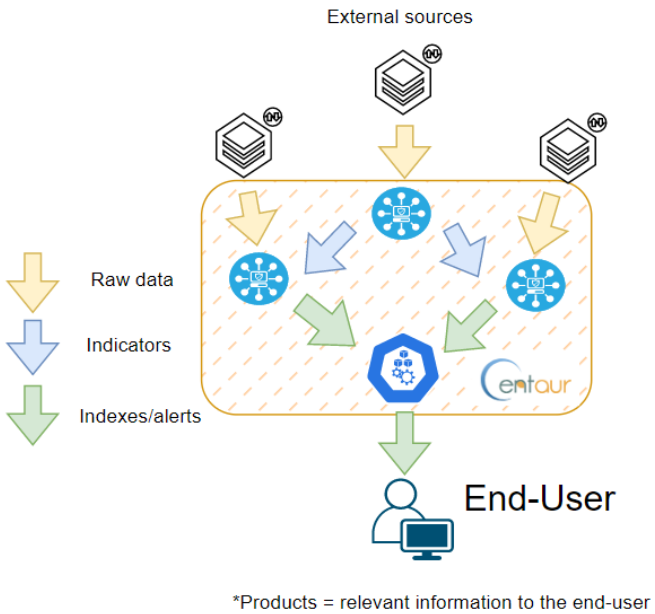
5 CENTAUR PLATFORM FOR PIPELINES INTEGRATION

CENTAUR platform is a distributed platform where multiple processors generate data that is stored in a central repository, all components are allocated in a hybrid cloud. For this purpose, external sources feed the processor which generates the relevant information to be stored. OpenEO is used for requesting information from the central node to the local node and buckets are used to exchange information, it is used as temporarily before the data is cataloged and archived in the central repository, see D3.1 deliverable for a detailed description of the platform (Figure 13).



Element	Description	Cardinality
Local node	Produces products	Multiples
Central node	Interface with end-user	One

Figure 13: CENTAUR platform

Most Water & Food insecurity indicators are going to be handled by submitting the output through a bucket and then the central node will ingest them and display them to the end user. On the other hand, Urban Flood indicators are going to use OpenEO standard as on-demand requests can trigger the generation of the output.

A preliminary dashboard of the prototype to explore the dataset stored in the central node is Figure 14. They depicted the integration of WFS-ID-01, WFS-04, and UF-ID-4.

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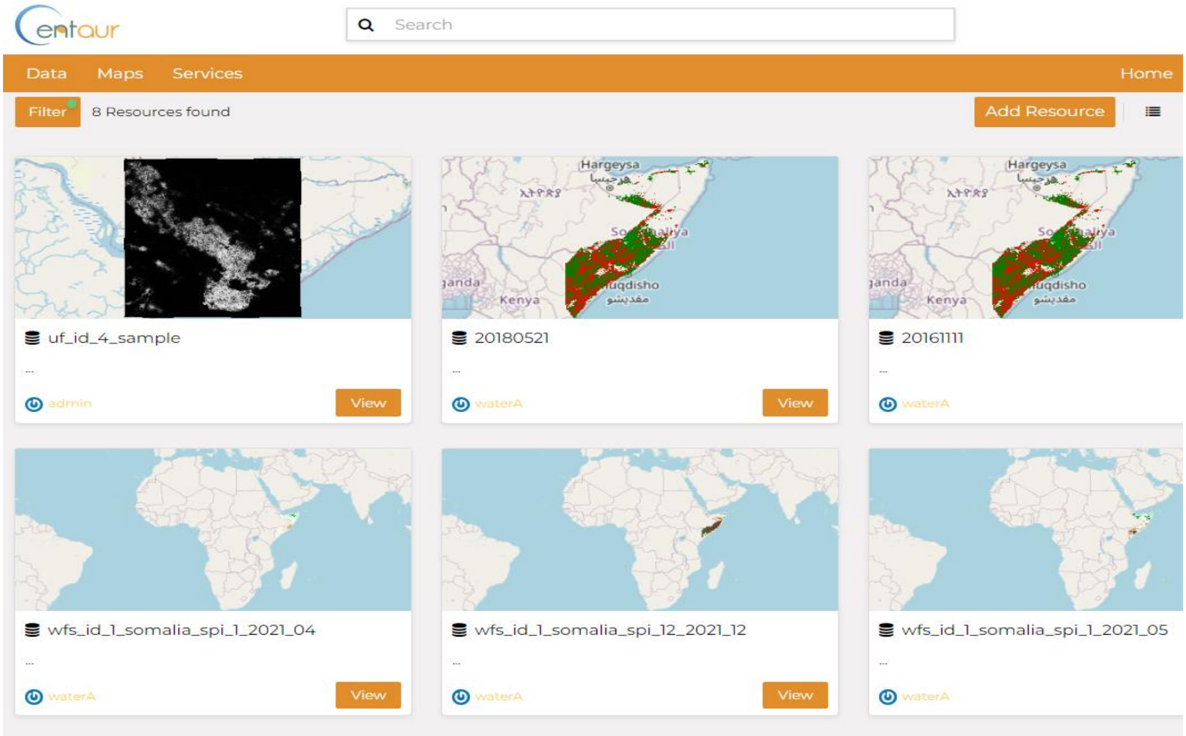

Figure 14: Preliminary dashboard of the catalogue in the prototype

An example of the visualization of WFS-ID-1 with the tools installed in the central node (Figure 15).

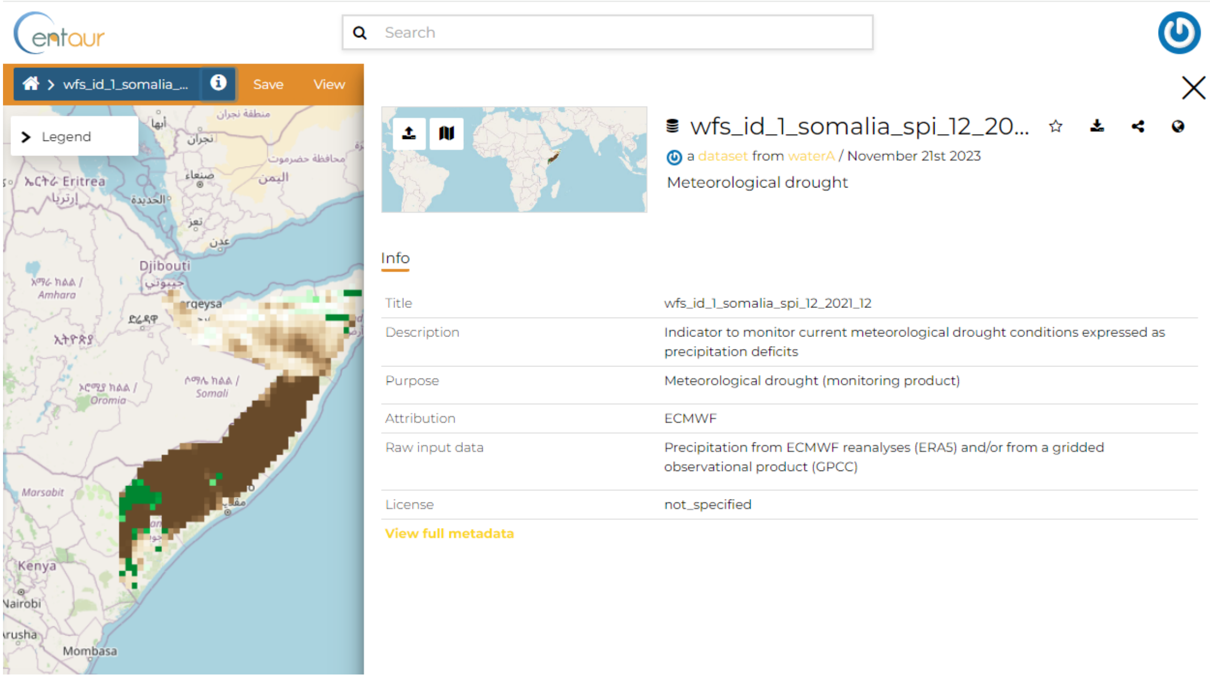

Figure 15: WFS-ID-1: Meteorological drought visualization in the platform

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An example of the visualization of WFS-ID-4 with the tools installed in the central node (Figure 16).

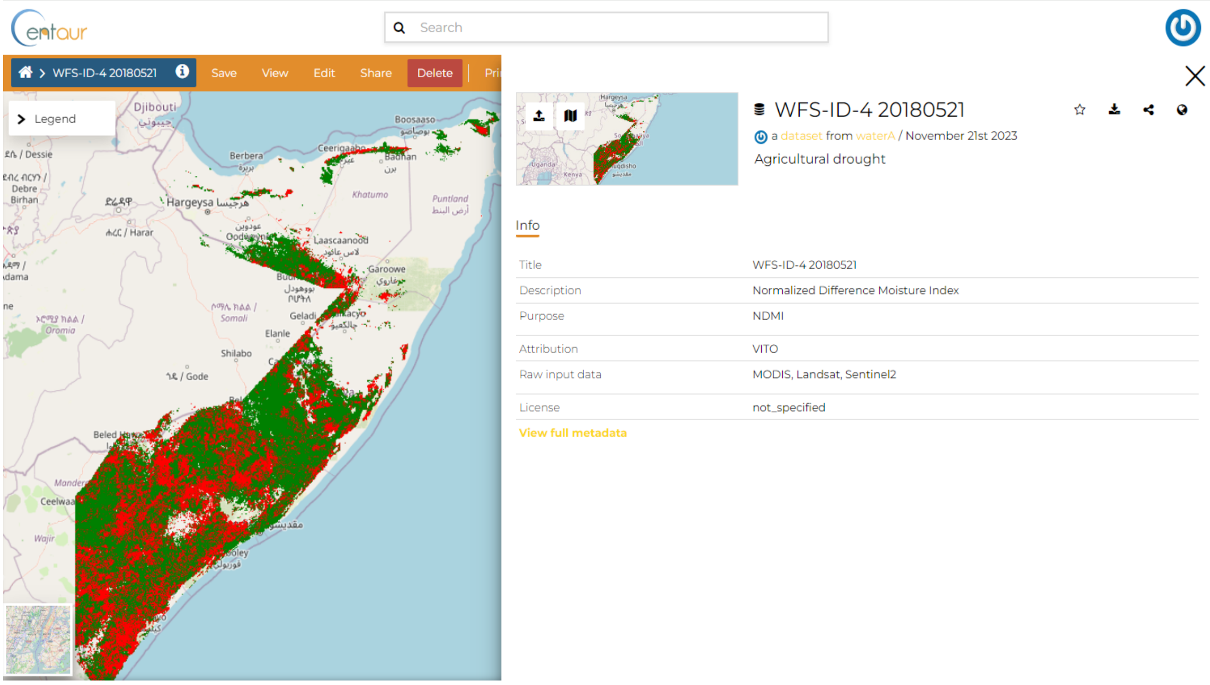

Figure 16: WFS-ID-4: Agricultural drought

An example of the visualization of UF-ID-4 with the tools installed in the central node (Figure 17).

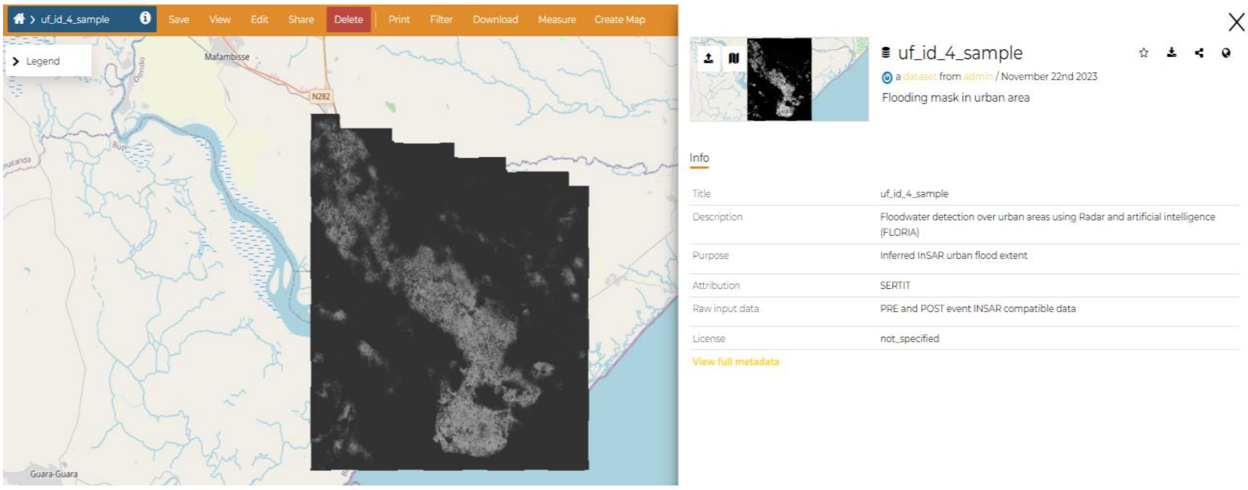

Figure 17: UF-ID-4: Flooding mask in urban area

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6 CONCLUSIONS

The baseline setup of the CENTAUR service pipelines for the generation of complex Urban Flood, Water & Food Insecurity, and Socio-Political-Economic pipelines, properly combining and integrating dataset from different sources were showcase in the present report.

Results demonstration generated per specific product (i.e. innovative indicators) within CENTAUR have been provided in dedicated ID-Card and generated for each indicator within the Urban Flood, for the Water & Food Insecurity. Conversely, in the Socio-Political-Economic thematic areas, there are some indicators for which a general product overview is given, specifically for the following (products in the data viewer are under production):

- UF-ID-9, UF-ID-10, UF-ID-13, UF-ID-14 (due to pending progresses in T2.4 and T2.5).
- WFS-ID-11, WFS-ID-12, WFS-ID-15, WFS-ID-17, WFS-ID-18, WFS-ID-19, WFS-ID-21, WFS-ID-23, WFS-ID-24, WFS-ID-25.

Furthermore, the baseline v1 processing chains are described with a comprehensive workflow and more crucial details related to the innovative methodology and technologies employed. The technological components described refers to those already announced in the D7.5 deliverable ([RD06]), distinguished in the following categories:

1. Urban flood and related socio-economic pipelines
    1.1 Meteorological component (UF-related).
    1.2 Flood components (i.e. Speedy Flood, FLORIA, Flood impact).
    1.3 Social/traditional media component (UF-related).
2. Water&Food Insecurity and related socio-economic pipelines:
    2.1 Meteorological component (WFS-related).
    2.2 Agricultural drought component
    2.3 Population and settlement component (i.e. Collection and production of gridded population estimates; Populations at risk of food insecurity; Populations at risk of water insecurity; Number of people living in conflict areas).
    2.4 Displacements component.
    2.5 Social/traditional media component (WFS-related)

In addition, it is foreseen to generate intermediate products as reported in the annex that will be used as input data for specific socio-economic-political indicators.

The tuning and adaptation version is planned to be delivered by M15 (D2.4 - Urban Flood and Water & Food Insecurity service pipelines v2 (tuning and adaptation), where demonstration of the present results of specific indicators (as above mentioned) will be integrated.

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7 ANNEX

7.1 INTERMEDIATE PRODUCTS

7.1.1 Input-ID-15 Rangeland land cover change

Input-ID-15 Rangeland land cover change	
Product Owner	©GMV
Product Description	Long-term land cover transitions over rangelands useful for identifying resource competition and conflict-prone resource appropriation. LULC map changes classify as LC transitions over rangelands systems
Service Level	Input-ID-15 is one of the inputs for the Political Vulnerability Index for the Risk Monitor (EWS) tool
EO input data	C3S Land cover classification gridded maps (AVHRR, SPOT-VGT, PROBA-V and S3 OLCI)
Non-EO input data	N/A
Output	Gridded (GeoTiff)
Archive Length	Raw C3S data available 1992-2020. Data currently not available 2021-present.
Spatial resolution	300m
Temporal coverage	Yearly Land transitions have been calculated for every year from the period 2020 to 2001 in comparison to the previous year (X Year -1 yr.); five year before(X Year -5 yr.); and ten years before (X Year – 10 yrs.); E.g., 2020 vs 2019; 2020 vs 2015; 2020 vs 2005.
Spatial coverage	Somalia, Mozambique, Mali (*Potentially for other countries in Africa)
Validation	The C3S Land cover classification gridded maps are assessed by the Evaluation and Quality Control (EQC) function of C3S independently of the data supplier. EQC encompasses a framework of processes aimed to assure technical and scientific quality harmonized across all dataset types available through the Climate Data Store. During the EQC process, the documentation provided with the dataset is scrutinized and data are checked for usability and reliability. If possible, data will be compared with social and traditional media data on competition over land, land grabbing etc.

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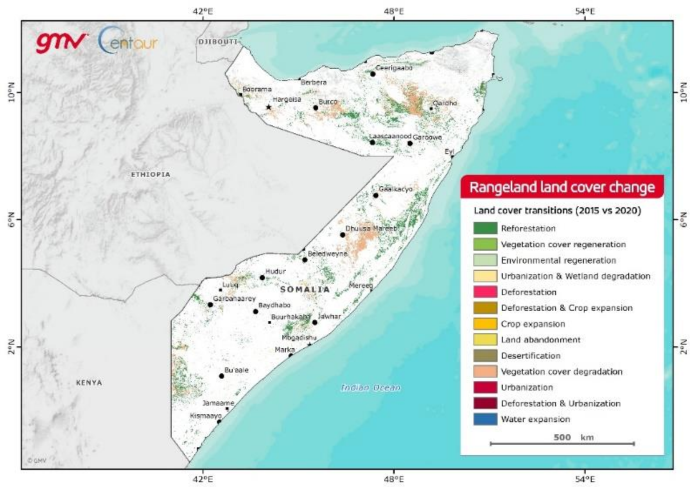
Dependencies Software	n/a
Dependencies Hardware	n/a
Analytics	The product is based on the Land cover (LC) classification gridded maps from the Copernicus Climate Change (C3S) service. The C3S provides global LC maps from 1992 to 2020 at 300m spatial resolution that describe the land surface following the UN Land Cover Classification System (LCCS). These land cover maps are entirely consistent with the timeseries of the global annual LC maps produced by the ESA Climate Change Initiative (CCI). To produce this dataset, the entire Medium Resolution Imaging Spectrometer (MERIS) archive from 2003 to 2012 was first classified into a unique 10-year baseline LC map. This is then back- and up-dated using change detected from: • Advanced Very-High-Resolution Radiometer (AVHRR) time series from 1992 to 1999. • SPOT-Vegetation (SPOT-VGT) time series from 1998 to 2012. • PROBA-Vegetation (PROBA-V) and Sentinel-3 OLCI (S3 OLCI) time series from 2013. This dataset provides long-term consistency, yearly updates, and high thematic detail on a global scale is, therefore, well-suited for monitoring rangeland systems. The definition of the land cover transitions is derived from the Copernicus Global Land Service (CGLS).
Challenges	The Gaussian machine learning approach underlying the supervised classification algorithm assumes that each spectral class can be described by a Gaussian distribution. It assumes that classes in the input data have a Gaussian distribution and that signatures were well selected; this is not always a safe assumption. The ISODATA clustering technique employed relies on the assumption that each land cover class can be well represented by a single mean vector. It is assumed that the land cover is stable between two dates of change. And it relies on stable radiometric corrections from year to year. The main limitation of the algorithm is the absence of data during the compositing period. It is assumed that urban footprints expand over time, with no destruction; a temporal shift in the urban change detection could be present in highly cloud-covered areas resulting from the gap filling procedure.
Product sample	

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7.1.2 Input-ID-16 Livestock heat stress

Input-ID-16 Livestock heat stress	
Product Owner	©GMV
Product Description	Livestock heat stress tailored by livestock type and country and expressed as risk. The livestock heat stress risk indicator is computed using reanalysis climate data and livestock density data.
Service Level	If possible, data will be compared with social and traditional media data on competition over land, land grabbing etc.
EO input data	none
Non-EO input data	Meteorological reanalysis: C3S ERA5-Land hourly data (0.1 degrees) Livestock density distribution: FAO's Gridded Livestock of the World for 2015 (GLW4) (5 min or arc)
Output	Format: GeoTIFF
Archive Length	Potentially 1950-Present
Spatial resolution	Country average
Temporal coverage	2018-2023, Annual values. Note 2023 data computed with Jan-June data only by the time of processing.
Spatial coverage	Somalia, Mozambique, Mali
Validation	The C3S ERA5-Land data are assessed by the Evaluation and Quality Control (EQC) function of C3S independently of the data supplier. EQC encompasses a framework of processes aimed to assure technical and scientific quality harmonized across all dataset types available through the Climate Data Store. During the EQC process, the documentation provided with the dataset is scrutinized and data are checked for usability and reliability. If possible, the data will be compared with timeseries information (at the admin1 level) about food and economic security of pastoralist households from the FAO DIEM data (Input-ID-52)
Dependencies Software	N/A
Dependencies Hardware	N/A
Analytics	We evaluate the livestock heat stress at pixel scale (9 km) through the Temperature Humidity Index (THI) from Raimi et al., 2021, which combines the effect of air temperature and relative humidity and is considered to be a suitable indicator for assessing the level of heat stress on animals caused by weather conditions. Thresholds are applied to the resulting THI values to categorize the results into four qualitative heat stress qualitative categories for each livestock category as described in the table below.

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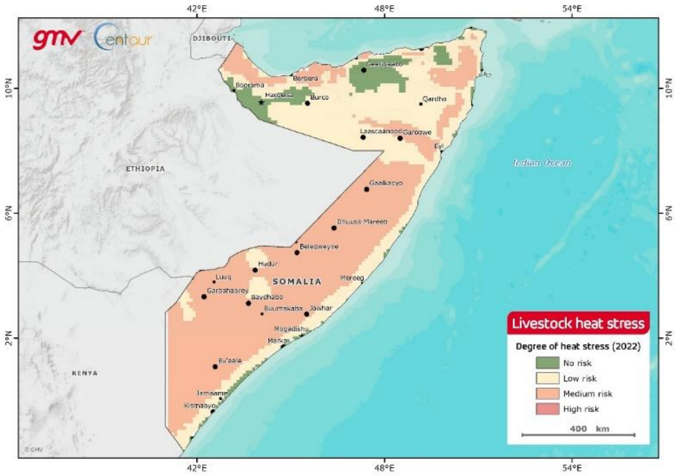
	Cattle	Sheep	Goat
No stress	THI≤72	THI≤25	THI≤27
Mild	72<THI≤78	25<THI≤30	27<THI≤32
Moderate	78<THI≤88	30<THI≤35	32<THI≤37
Severe	THI>88	THI>35	THI>37

To intercompare the heat stress in livestock obtained for different countries or for different regions over the same country, the THI index used to estimate the stress must be normalized by the density of livestock species. The index is calculated per livestock species and the distributions of species change geographically, therefore without the normalization the geospatial comparison of risk is not realistic. The heat stress risk index can be interpreted as the risk of being the total livestock under significant heat stress. The risk (ranging from no risk to low risk, medium risk, and high risk) is computed as weighted average of the heat stress index values normalized by the livestock species density in the country. The livestock densities for cattle, sheep, and goats are obtained from the FAO's Gridded Livestock of the World for 2015 (GLW 4). This dataset provides the global distribution of several livestock species in 2015 expressed in total number of animals per pixel (5 min of arc).

Challenges	No particular challenges encountered.
Product sample	

7.1.3 Input-ID-30 Main roads

Input-ID-30 Main roads	
Product Owner	©GMV
Product Description	Main roads as a proxy measure for public service provision; political marginalisation; ease of access (e.g., for government troops).
Service Level	Input-ID-30 is an important input to the Drought Vulnerability component of the Risk Monitor (EWS) tool.
EO input data	VHR WMS layers (e.g., Google satellite layer) for visual validation The tests performed with the Sentinel-1 and Sentinel-2 were not successful in providing meaningful results with this data.

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Non-EO input data	Open Street Maps (OSM). Full OSM data. For Somalia extracted from Geofrabric: https://download.geofabrik.de/africa/somalia.html Primary roads. E.g., Somalia_Primary_Roads_UNOCHA — GeoNode (faoswalim.org)
Output	ESRI geodatabase format (.gdb) other formats could be delivered upon request
Archive Length	The OSM information used was the most up-to date available on 29/09/2023 (the geofabric information is updated daily, but not the final product). The file size was approximately 133 Mb.
Spatial resolution	Not applicable since we have used vector data.
Temporal coverage	Latest available information, i.e. from 29/09/2023
Spatial coverage	Somalia, Mali, Mozambique
Validation	In the first release of the product (Somalia), a visual validation was performed with independent validators perform by an analyst. This visual validation was performed to the full extent of the product.
Dependencies Software	N/A
Dependencies Hardware	N/A
Analytics	Processing flow applied to the input data: 1. Extract the most updated OSM information available for a given country (roads and populated places), using geofabrik data: https://download.geofabrik.de. 2. For populated placed, only towns and cities classified in the OSM are considered relevant. 3. For roads, consider only main and secondary roads. However, to have connections to all towns/cities, we added a new classification to the roads (tertiary roads). The following ancillary data was also used in the update: https://spatial.faoswalim.org/layers/geonode:SOM_Primary_Roads_UNOCHA#/We 4. Automatically populated the Load-Bearing Surface Type using OSM information (paved or unpaved). In cases where this information is missing, the information is manually filled by analysing the Google Layers image. 5. Perform an automatic (topological) and visual quality control on the roads to ensure their connectivity. 6. Review the names if they are in the Latin alphabet (a transliteration may need to be applied).
Challenges	The amount of EO data needed to cover each country, is already a challenge. Processing the data to train a machine learning algorithm and provide meaningful results to these countries could be highlighted as the biggest challenge of this product.

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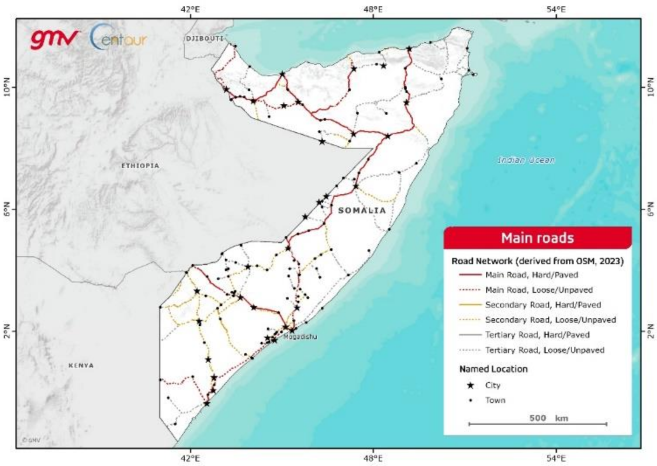
Product sample	

7.2 INTERMEDIATE PROCESSING CHAINS

7.2.1 Input-ID-15 Rangeland land cover change

For selected countries in Africa, datasets on Land Cover (CV) changes over rangelands have been provided based on the Land cover (LC) classification gridded maps from the Copernicus Climate Change (C3S) service. The C3S provides global LC maps from 1992 to 2020 at 300m spatial resolution that describe the land surface following the UN Land Cover Classification System (LCCS). These land cover maps are entirely consistent with the timeseries of the global annual LC maps produced by the ESA Climate Change Initiative (CCI). To produce this dataset, the entire Medium Resolution Imaging Spectrometer (MERIS) archive from 2003 to 2012 was first classified into a unique 10-year baseline LC map. This is then back- and up-dated using change detected from:

- Advanced Very-High-Resolution Radiometer (AVHRR) time series from 1992 to 1999
- SPOT-Vegetation (SPOT-VGT) time series from 1998 to 2012
- PROBA-Vegetation (PROBA-V) and Sentinel-3 OLCI (S3 OLCI) time series from 2013.

The LC maps from C3S provide long-term consistency, yearly updates, and high thematic detail on a global scale, and are, therefore, well-suited for monitoring rangeland systems. According to the Rangelands Atlas (ILRI, 2021), rangelands can be described as land on which the vegetation is predominantly grasses, grass-like plants, forbs, or shrubs, and often with trees that are grazed or have the potential to be grazed by livestock and wildlife. This is the definition employed in the Rangeland land cover change, and the selection of rangeland types for the countries in Africa follows the approach as well taken in the Atlas. Five of fourteen biomes or rangeland types made up of terrestrial ecoregions as defined by WWF has been selected:

- Tropical and subtropical grasslands, savannas and shrublands
- Flooded grasslands and savannas
- Montane grasslands and shrublands
- Mediterranean forest, woodlands, and scrubs
- Deserts and xeric shrublands

The final product are the 30-years land cover transitions experienced over the rangeland types in the given country in Africa. The product workflow is depicted in the figure below.

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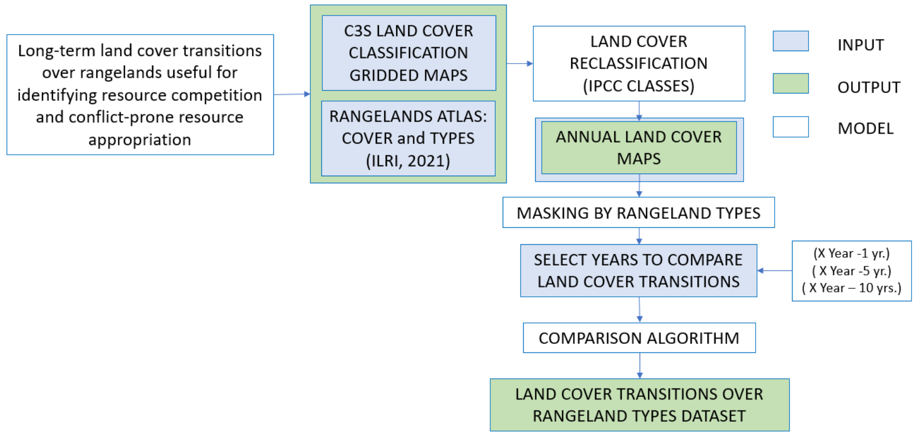

The definition of the land cover transitions is derived from the Land Cover product of the Copernicus Global Land Service (CGLS). The matrix of the land cover transitions is shown in Table 5.

		t1 - change into							
		Forest	Shrubland	Grassland	Wetland	Bare land	Cropland	Built-up	Water body
t0 - change from	Forest	No change	Deforestation				Deforestation & Crop expansion	Deforestation & Urbanization	Water expansion
	Shrubland	Reforestation	No change	Vegetation cover degradation	Wetland regeneration	Desertification	Crop expansion	Urbanization	
	Grassland		Vegetation cover regeneration	No change					
	Wetland		Wetland degradation		No change	Desertification & Wetland degradation	Crop expansion & Wetland degradation	Urbanization & Wetland degradation	
	Bare land		Environmental regeneration			No change	Crop expansion	Urbanization	
	Cropland		Land abandonment			Land abandonment & Desertification	No change		
	Built-up		Deurbanization				Deurbanization & Crop expansion	No change	
	Water body	Water reduction							No change

Table 5: Matrix of LC transformation processes.

To facilitate the analysis of the transformation processes, the land cover classes from the original C3S Land Cover (following the ESA CCI definition) have been assigned to the IPCC classes considered for the change detection. Note that the correspondence of land cover classes is provided by the ESA CCI Land Cover team.

The new land cover classes align well with the ones used by the Copernicus Land Cover transitions. However, sparse vegetation is not considered. Therefore, following Radwan et al. 2021, the sparse vegetation class is included in bare soil. The new classification is given in Table 6.

Colour	Original C3S Land Cover classes	IPCC reclassified classes
	Cropland, rainfed	Cropland
	Herbaceous cover	Cropland
	Tree or shrub cover	Cropland
	Cropland, irrigated or post-flooding	Cropland

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	Mosaic cropland (>50%) / natural vegetation (tree, shrub, herbaceous cover) (<50%)	Cropland
	Mosaic natural vegetation (tree, shrub, herbaceous cover) (>50%) / cropland (<50%)	Cropland
	Tree cover, broadleaved, evergreen, closed to open (>15%)	Forest
	Tree cover, broadleaved, deciduous, closed to open (>15%)	Forest
	Tree cover, broadleaved, deciduous, closed (>40%)	Forest
	Tree cover, broadleaved, deciduous, open (15-40%)	Forest
	Tree cover, needleleaved, evergreen, closed to open (>15%)	Forest
	Tree cover, needleleaved, evergreen, closed (>40%)	Forest
	Tree cover, needleleaved, evergreen, open (15-40%)	Forest
	Tree cover, needleleaved, deciduous, closed to open (>15%)	Forest
	Tree cover, needleleaved, deciduous, closed (>40%)	Forest
	Tree cover, needleleaved, deciduous, open (15-40%)	Forest
	Tree cover, mixed leaf type (broadleaved and needleleaved)	Forest
	Mosaic tree and shrub (>50%) / herbaceous cover (<50%)	Forest
	Tree cover, flooded, fresh or brakish water	Forest
	Tree cover, flooded, saline water	Forest
	Mosaic herbaceous cover (>50%) / tree and shrub (<50%)	Grassland
	Grassland	Grassland
	Shrub or herbaceous cover, flooded, fresh/saline/brakish water	Wetland
	Urban areas	Built-up
	Shrubland	Shrubland
	Evergreen shrubland	Shrubland
	Deciduous shrubland	Shrubland
	Lichens and mosses	Bare land
	Sparse vegetation (tree, shrub, herbaceous cover) (<15%)	Bare land
	Sparse tree (<15%)	Bare land
	Sparse shrub (<15%)	Bare land
	Sparse herbaceous cover (<15%)	Bare land
	Bare areas	Bare land
	Consolidated bare areas	Bare land
	Unconsolidated bare areas	Bare land
	Water bodies	Water body

Table 6: Land cover reclassification

The data is provided per country (Table 7) and the comparison is done between two years within the period 1992 - 2020, resulting in the land cover transitions between the two years selected for the rangelands systems of that country. In this case, the comparison requested were for a given year X vs 1 year earlier (X Year -1 yr.); a given year X vs 5 years earlier (X Year -5 yr.); and a given year X vs 10 years earlier (X Year – 10 yrs.)

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Data	Baseline	Data	Baseline	Data	Baseline	Data	Baseline
2001	2000	2006	2005	2011	2010	2016	2015
2001	1996	2006	2001	2011	2006	2016	2011
2001	N/A	2006	1996	2011	2001	2016	2006
2002	2001	2007	2006	2012	2011	2017	2016
2002	1997	2007	2002	2012	2007	2017	2012
2002	1992	2007	1997	2012	2002	2017	2007
2003	2002	2008	2007	2013	2012	2018	2017
2003	1998	2008	2003	2013	2008	2018	2013
2003	1993	2008	1998	2013	2003	2018	2008
2004	2003	2009	2008	2014	2013	2019	2018
2004	1999	2009	2004	2014	2009	2019	2014
2004	1994	2009	1999	2014	2004	2019	2009
2005	2004	2010	2000	2015	2014	2020	2019
2005	2000	2010	2005	2015	2010	2020	2015
2005	1995	2010	2000	2015	2005	2020	2005

Table 7: Land cover transition comparison years.

The resulting yearly accumulated change extent for each land cover transition is provided. The period analyzed corresponds to the period pre-selected. As already explained, the results provided by the tool are masked by the rangeland types as defined by WWF.

7.2.2 Input-ID-16 Livestock heat stress

For this product, GMV has carried out an analysis of the heat stress in livestock species (cattle, sheep, and goats) for selected countries in Africa. These new datasets have been created ad-hoc for this study, covering historical period currently 2018- (mid)2023, for selected countries.

Heat stress in livestock is usually evaluated by using different environmental variables (e.g., temperature, relative humidity, solar radiation, air movement or precipitation), either individually or combined into an index. The temperature humidity index (THI) combines the effect of air temperature and relative humidity and is considered to be a suitable indicator for assessing the level of heat stress on animals caused by weather conditions.

There are several THI equations for estimating the degree of thermal heat stress experienced by cattle, sheep, and goats. In this study we used the THI equations from Raimi et al., 2021.

For cattle, the THI was calculated using an equation developed for the Holstein-Friesian breed:

$$\boldsymbol{THI = (1.8 * Tmax + 32) - [(0.55 - 0.0055 * RH) * (1.8 * Tmax - 26.8)}$$

Where T_{max} is the daily maximum air temperature (ºC), and RH the relative humidity.

For sheep and goats, the THI was calculated using the livestock and poultry heat stress indices (LPHSI) from Marai et al., 2000:

$$\boldsymbol{THI = Tmax\ [(0.31 - 0.0031 * RH) * (Tmax - 14.4)]}$$

The degree of heat stress with corresponding THI value for different livestock is taken from Raimi et al., 2021 too (Table 8). For cattle, we used thresholds proposed by Wiersma (1990), which have been used in many studies in tropical regions. For sheep and goat, we have modified thresholds proposed by Marai et al. (2000) which was used

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for male lambs, based on available studies about their upper critical temperature and their physiological responses under heat stress events (Table 8).

	Cattle	Sheep	Goat
No stress	THI≤72	THI≤25	THI≤27
Mild	72<THI≤78	25<THI≤30	27<THI≤32
Moderate	78<THI≤88	30<THI≤35	32<THI≤37
Severe	THI>88	THI>35	THI>37

Table 8: Degree of heat stress with corresponding THI value for cattle, sheep, and goats

In **Errore. L'origine riferimento non è stata trovata.**, "no stress" means without heat stress and allowing livestock to be at optimum productive and reproductive performance, "mild" means with heat stress, but the livestock's body is able to control the heat stress by chemical and physical means, "moderate" means that the body temperature increases and can negatively impact the livestock's performance, and "severe' means events that result in significant decreases in productive and reproductive performances.

Historic heat stress

The calculation of the historic record of heat stress in livestock is performed using the variables and the full period of ERA5-Land data, i.e., from 1950 to mid-2023. ERA5-Land is a meteorological reanalysis dataset that provides a consistent view of the evolution of land variables over several decades at 9km. ERA5-Land has been produced by replaying the land component of the ECMWF ERA5 climate reanalysis. This reanalysis combines model data with observations from across the world into a globally complete and consistent dataset using the laws of physics. ERA5-Land produces data that goes several decades back in time, providing an accurate description of the climate from the past to the present.

In this case, ERA5-land hourly values have been used to extract the maximum daily temperature, and to approximate relative humidity from dew point and temperature using the expression below:

$$RH \approx 100 - 5(T - T_{dew})$$

Where T and T_{dew} stand for the average daily temperature and dew point temperature respectively. In this way, THI values are calculated for each livestock at a pixel level for the selected countries from 2018 to mid-2023. Then, these values are normalized by livestock density to obtain a single Heat stress risk indicator per country. Finally, the heat stress risk values are aggregated into annual values.

The product workflow is depicted in the figure below.

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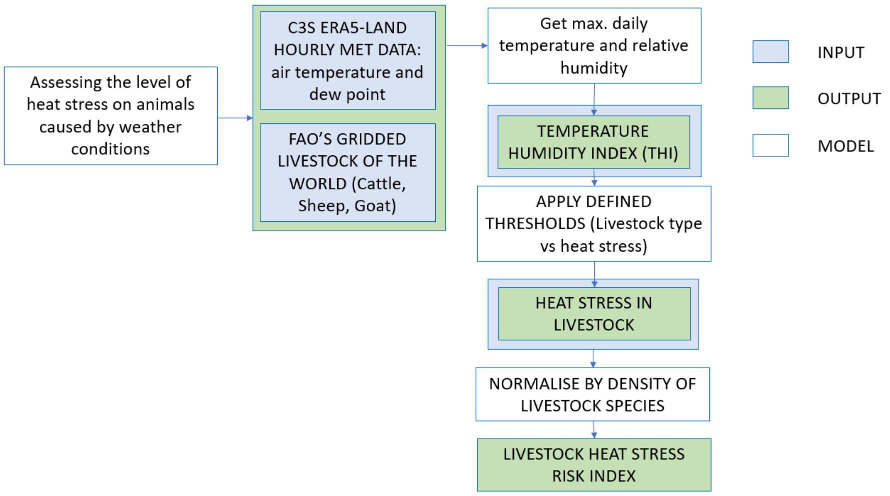


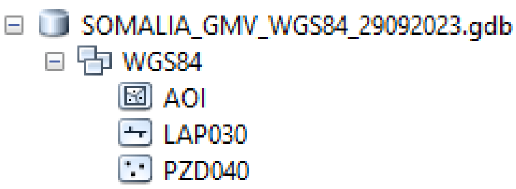
7.2.3 Input-ID-30 Main roads

This product delivers a geodatabase of main roads for entire countries as a proxy measure for:

- public service provision;
- political marginalization;
- ease of access.

The product contains a geodatabase (GDB) with the information about the major roads for a given country. The information used to generate the product is based on the primary and secondary roads available on OSM, that are then updated by other ancillary data where information of the most important roads is available (e.g. Google maps, Bing, UNOCHA, etc.). Besides the ancillary data already mentioned, points representing the major cities and towns from OSM are also used to ensure exiting road connections. For the cases where city or towns were isolated, the most important road connection was identified and classified has tertiary road.

The final GDB with the road information for a specific country is delivered in a ZIP file using the following naming convention: COUNTRY_GMV_WGS84_Date.zip. The organization of the GDB delivered is represented in the following figure:



Where:

AOI - is the area of the country of interest.

LAP030 - the feature with the major road identified.

PZD040 – The city and towns used for completing the road network connectivity

The major steps used to generate the road product were:

1. Extract the most updated OSM information available for a given country (roads and populated places), using geofabrik data.
2. For populated placed, only towns and cities classified in the OSM were considered relevant.
3. For roads, the product considered only main and secondary roads, however, to have connections to all towns/cities, a new classification to the roads was added (i.e, tertiary roads). To complement the road network the UNOCHA ancillary data was also used in the update.

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4. Automatically populated the Load-Bearing Surface Type using OSM information (paved or unpaved). In cases where this information was missing, the information was manually filled by analysing the Google and BING Layers image.
5. The name attribute was reviewed to check if the names were represented by the Latin alphabet (a transliteration is applied if necessary).
6. Quality control was performed using an automatic (topological) and visual approach, to ensure the road connectivity.

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