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D2.4 – Urban Flood and Water & Food Insecurity Service Pipelines v2 (Tuning and Adaptation)

Deliverable#	**D2.4**
WP#	**WP2**
WP Leader:	**e-GEOS**
Revision Date:	27.02.2024
Submission Date:	29.02.2024
Document Type:	Demonstrator
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Verified by:	CENTAUR Consortium Board and CENTAUR Steering Committee
Approved by:	Valerio Botteghelli (Project Coordinator, e-GEOS) and shared with the Consortium
Version	2.0
Dissemination Level:	Public (PU)

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

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HISTORY OF CHANGES

Date	Version	Author	Change Description
15.01.2024	1.0	EG	Second version with a ToC for Tuned and adapted components
29.02.2024	1.0	EG, GMV, ITH, ADE, HEN, CLS, ECM, VIT, UNISTRA, DLR	Complemented version of the document

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1 EXECUTIVE SUMMARY

The present document represents the deliverable D2.4 - Urban Flood and Water & Food Insecurity Service Pipelines v2 (tuning and adaptation) 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 present document represents a consolidated version of the D2.3 - Urban Flood and Water & Food Insecurity Service Pipelines v1 (baseline) delivered in M12.

The document includes the following contents, within the same outline already adopted in D2.3:

- CENTAUR products demonstration: summary and tuned/adapted results produced by each innovative indicators in the context of Urban Flood, Water& Food insecurity and Socio-economic related.
- Tuned and adapted demonstration of processing chains designed and under development for the generation of CENTAUR products, per thematic area.
- Results integrated in the platform for visualization.

In the annex section, tuned and adapted specific input data used by specific pipelines for related innovative indicators generation are reported.

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.

D2.4 provides a demonstration of products generated in CENTAUR, from each innovative indicator and a related summary of technical specification. Particularly, enhancements produced with respect to the D2.3 are reported.

In addition, the demonstration comprises the visual representations of the processing chains of the CENTAUR products at the present stage. Whether relevant, updated workflows and results of each processing chain is presented with respect to what has been already delivered in D2.3.

Lastly, the present deliverable provides examples of innovative indicators ingestion and visualization into the platform.

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

- Section 1. Executive summary.
- Section 2. Introduction.

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- Section 3. CENTAUR products.
- Section 4. Processing chains – Tuning and Adaptation v2.
- Section 5. CENTAUR platform – Innovative indicators results ingestion.
- 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
FAO	Food and Agriculture Organisation of the United Nations
FEWSNET	Famine Early Warning Systems Network

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Acronym	Description
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
THI	Temperature Humidity Index
UF	Urban Flood

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Acronym	Description
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
[RD07]	D2.3 – Urban Flood and Water & Food insecurity service pipelines v1(baseline setup)

Table 2: Applicable and reference documents.

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3 CENTAUR PRODUCTS

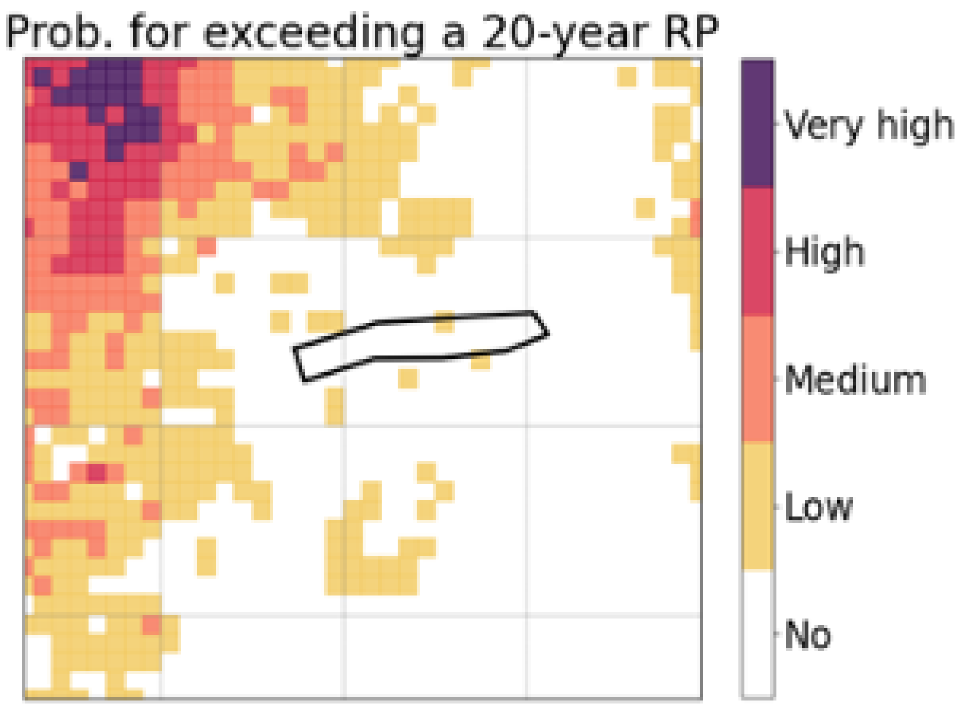
Following the content generated in the deliverable D2.3 – Urban Flood and Water & Food Insecurity service pipelines v2 (baseline setup) in M12 [RD07], the present chapter aims at providing details on the products (innovative indicators/indices)/technical components (service pipelines) tuned and adapted up to M15 in CENTAUR project.

3.1 URBAN FLOOD INDICATORS SUMMARY AND RESULTS

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

The spatial resolution of UF-ID-1 has been improved to better reflect the extent of urban areas. Therefore, the precipitation of the original observational data sets at approx. 10 km is used and a statistical downscaling to 1 km is performed. Due to the uncertainty inherent in this downscaling, an ensemble of 10 high-resolution ensemble members is constructed and used to calculate the probability of exceeding a certain return period of extreme precipitation (10, 20 and 50 years).

Most information for this indicator has been provided in D2.3. Additional outputs at 1 km are provided, see updated information below.

Static map of precipitation associated to return period and probabilities of exceeding critical return periods at high resolution (Update)	
Output	Probability of exceeding an extreme precipitation return period of 10, 20 or 50 years
Spatial resolution	1 km
Product sample	

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3.1.2 UF-ID-2: Forecast of return period

The development of this indicator is ongoing. In line with updates of UF-ID-1, it aims to predict the probability of exceeding a certain return period of extreme precipitation. This probability of the hazard will be used in conjunction with socio-economic indicators of population and critical infrastructure to define the early warning index.

Forecasts of return period (Update)	
Output	Predicted probability of exceeding an extreme precipitation return period of 10, 20 or 50 years
Spatial resolution	1 km

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

Differently from what was stated in document 2.3, we had to reconsider the approach for generating this indicator. The declared indicator is intended to produce a flood map for various return periods, utilizing precipitation data from the ECMWF ERA5 reanalysis and, in general, the output derived from the UF ID-1 indicator.

During the application of this indicator, it was realized that the spatial resolution of approximately 30 km proved to be a limiting factor, given the relatively small extent of the area of interest. The observed result was that within the area of interest, there were too few pixels to conduct robust analyses. Additionally, the precipitation forecast data representing the indicator at various time steps did not capture the event's peak adequately, especially reproducing the scenario closest to the desired return period (10y, 20y, and 50y).

For this reason, contrary to what was stated in D2.3, we will use JRC flooding hazard maps as calibration elements for the model for the three different return periods of the event. This input is a flood hazard map, a raster, allowing for an understanding of the achievable extents during the specific event. These maps can be freely downloaded from the JRC website.

The use of these maps facilitated proper calibration of the geomorphological model, enabling the reproduction of the desired flood scenarios.

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

No changes were conducted on the processing chain of UF-ID-4 from M12 to M15. This indicator is still based on 3 SAR products and outputs an inferred flood extent only in urban areas. The urban flood extent is not based on ground observations, so the result must be used with caution.

However, considering preliminary feedback on the first results obtained for the cold cases, new post-processing ideas have started emerging to reduce commissions on the flood extent. In the future, a post-processing based on a HAND (Height Above Nearest Drainage) layer, derived from a hydrologically compatible DTM, might be implemented in the UF-ID-4 processing chain to automatically remove any non-realistic flood surface.

The workflow behind UF-ID-4 is currently being converted to a single tool rather than a sequence of processes, in order to facilitate its use. For now, the processing chain remains the exact same as the one described in previous deliverables.

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

This indicator has not changed since the last update in D2.3. The flood map for the specific event is reproduced using the declared methodology (Speedy Flood tool and FLORIA InSAR model), and the damage assessment analyses follow the classification outlined in previously submitted document (D2.3).

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

This indicator has not changed since the last update in D2.3.

3.1.7 UF-ID-7: Flood impact index

This indicator has not changed since the last update in D2.3.

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3.2 WATER&FOOD INSECURITY INDICATORS SUMMARY AND RESULTS

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

This indicator has not changed since the last update in D2.3.

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

This indicator is still in development. The information for this indicator that has been provided in D2.3 is still up to date.

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

This indicator is still in development. The information for this indicator that has been provided in D2.3 is still up to date.

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

This indicator has not changed since the last update in D2.3

3.2.5 WFS-ID-5: Agricultural drought forecast

This indicator is still in active development: experiments are ongoing to select the most appropriate forecasting method and the most relevant inputs to produce reliable forecasts of agricultural droughts.

Updated information related to this indicator can be found below:

WFS-ID-5: Agricultural drought forecast	
Product Owner	VITO
Product Description	Indicator that expresses the relative impact 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 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. Results will be expressed as a categorical score ranging from no drought up to severe agricultural drought.
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

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Non-EO input data	- Precipitation and air temperature anomaly forecasts as provided by ECMWF (SPI and SPEI indicators), with different lead times. - 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.
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	We will employ a classification algorithm (Random Forest or CatBoost) to forecast agricultural drought in a categorical way (no drought, medium agricultural drought, severe agricultural drought) using as inputs WFS-ID-4 (integrated over different time intervals ranging back up to 6 months in the past) combined with SPI and/or SPEI forecasts over different lead times. The result will consist of the classification label per pixel, along with the pixel-based probabilities for each drought class.
Challenges	As pointed out for WFS-ID-2, obtaining high quality meteorological forecasts is a challenge. Hence, any derived product will likely be characterised by high uncertainty levels.
Product sample	Development is ongoing. The future drought impact on vegetation productivity will be updated every 10 days for different lead times and will be expressed as a categorical score, along with probabilities for each class.

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

This indicator is still in development. The information for this indicator that has been provided in D2.3 is still up to date.

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3.3 SOCIO-POLITICAL-ECONOMIC INDICATORS SUMMARY AND RESULTS

3.3.1 UF-ID-9: Assets & financial resources

This indicator is still in active development: updates vis-à-vis D2.3 are summarised in the table below.

Assets & financial resources (Update)	
Non-EO input data	DLR (all cases): WSF-Population WSF-3D Hensoldt (France, Mozambique, Spain): - Social/traditional media data CLS (France): BD TOPO (IGN) INSEE census 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 Household income distribution atlas 2021 OSM
Output	Spatial estimate of wealth/socioeconomic level as raster data with 30m resolution. Metric to be defined after initial tests with the input data.
Archive Length of input data	WSF-Population: available from 2016-to present. WSF-3D: available for 2012; with potential yearly updates up to present. 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. Household income distribution atlas -> 2015 to 2021 Social/traditional media data -> From 2018 onwards.
Spatial resolution of input data	WSF-Population: 10m spatial resolution at the Equator. WSF-3D: 30m 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).

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	Roads & Transport Zaragoza: vector data (1:500 to 1:25000 depending of the item) Household income distribution atlas (Provided by municipalities, districts and census sections) Social/traditional media data: to be defined after initial tests with the input data.
Validation	Some of the data listed under non-EO inputs will be used to validate (parts) of the indicator: - For France, UF-ID-9 output will be compared to INSEE census information on incomes and poverty at the commune level. Comparable data will be used for Mozambique and Spain, when available. For Spain, Household income distribution atlas 2021 (National Statistics Institute) could be used as comparable data per neighbourhood, if needed. - UF-ID-9 output will be compared to a measure of the desirability of different parts of the city/town based on OSM and Google maps data on amenities (e.g. restaurant prices, proximity to motorways and busy/noisy roads etc.). - Validation with data from social and traditional media, depending on geo-precision (e.g. mentions of socioeconomic status or desirability of particular parts of town).
Product sample	 Raster data for Zaragoza representing building volume (m3) in each cell as a component of an indicator for wealth and economic assets.

3.3.2 UF-ID-10 Public services & government support

This indicator is still in active development: updates vis-à-vis D2.3 are summarised in the table below.

Public services & government support (Update)	
Output	Estimate of the level of access to relevant services and support in different neighbourhoods of the AOI as raster data with 30m resolution. Metric to be defined after initial tests with the input data

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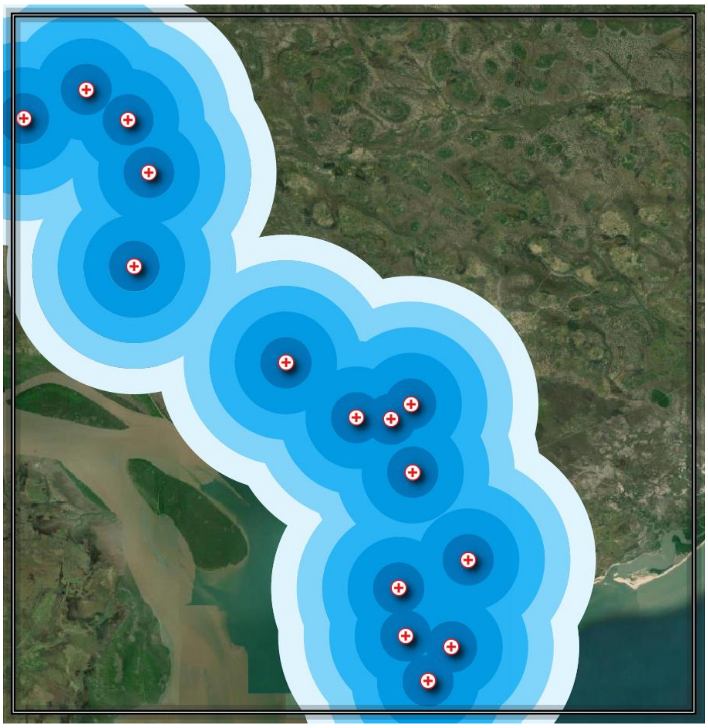
Validation	Validation with data from social and traditional media (e.g. about difficulty to receive support and/or access key services).
Product sample	 Example of distance to the nearest hospital, a component of UF-ID-10 (preliminary result for Beira with Euclidean distance, that will be improved by integrating network routing for realistic accessibility measurements).

3.3.3 UF-ID-13 Ability to evacuate

Most information for this indicator has been provided in D2.3. Below are reported updated information.

Ability to evacuate (Update)	
Non-EO input data	DLR (all cases): WFS-3D WFS Imperviousness Hensoldt (France, Mozambique, Spain): - Social/traditional media data CLS (France): BD TOPO (IGN) SERTIT (Germany): OSM SERTIT (Mozambique): OSM TRACASA (Spain):

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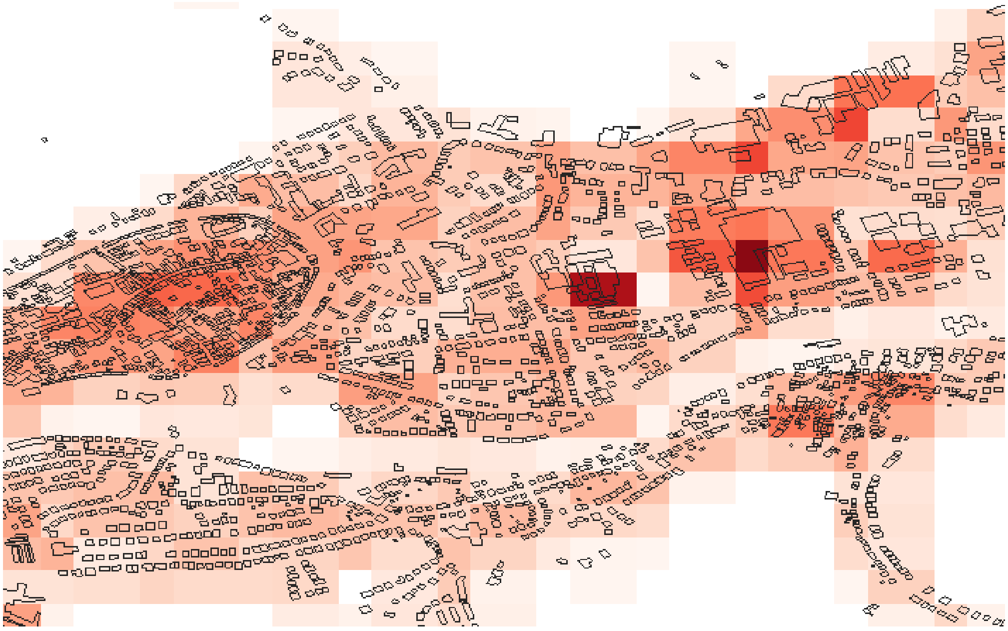
	Roads & Transport Zaragoza OSM
Output	Estimate of the likelihood people in different parts of the AOI will be able to move out of harm's way, based on proximity of buildings to each other/road width, building height, travel speed on roads, etc. as raster data with 30m resolution. Metric tbd after initial tests with the input data
Archive Length of input data	WSF-Imperviousness: available from 2016-to present. WSF-3D: available for 2012; with potential yearly updates up to present.BD TOPO -> From 2008 onwards. Roads & Transport Zaragoza -> Updated to 2023. OSM -> From 2013 onwards. Social/traditional media data -> From 2018 onwards.
Spatial resolution of input data	WSF-Imperviousness: 10m spatial resolution at the Equator. WSF-3D: 30m spatial resolution at the Equator. BD TOPO: vector data (up to a scale of 1:2 000). OSM: vector data (up to a scale of 1:500). Roads & Transport Zaragoza: vector data (1:500 to 1:25000 depending of the item). Social/traditional media data: to be defined after initial tests with the input data.
Validation	Some of the data listed under non-EO inputs will be used to validate (parts) of the indicator: For France, UF-ID-13 output will be compared to BD TOPO information on building height. Comparable data will be used for Mozambique and Spain, when available. UF-ID-13 output will be compared to a measure of building density, based on OSM data. Validation with data from social and traditional media, depending on geo-precision (e.g. mentions of blocked roads and other impediments to traffic in particular parts of town).
Product sample	 Raster data for the German case representing % area occupied by buildings in each cell as (component of) an indicator for the ability to reach and/or evacuate affected people. OSM building overlay added for comparison.

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3.3.4 UF-ID-14 Economic impacts of floods

This indicator is still in active development: updates vis-à-vis D2.3 are summarised in the table below.

Economic impact of floods (Update)	
Output	Estimate of economic impact of flooding. Format in line with UF-ID-5 Metric to be defined after initial tests with the input data
Archive Length of input data	See description of UF-ID-5 Social/traditional media data -> available from 2018 to present
Validation	UF-ID-5 data will be compared with data from social and traditional media (e.g. mentions or pictures of damages)
Product sample	See UF-ID-5

3.3.5 WFS-ID-7: IDP camps status indicator

This indicator is still in active development: updates vis-à-vis D2.3 are summarised in the table below.

Economic impact of floods (Update)	
Output	Change detection in the format of a Raster file
Archive Length of input data	- N/A
Validation	WFS-ID-7 will be compared with optical references as open source Google Earth or OPT acquisitions, if available

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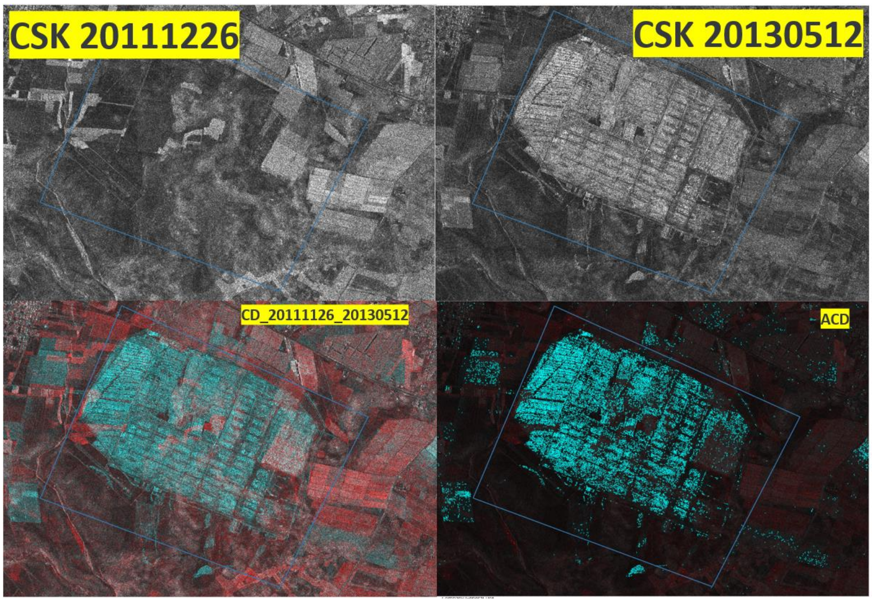
Product sample	 Such products will be linked with a vectorial shapefile with the indication of the tent/refugee camp status with respect to the last information known. **CAMP STATUS** Camp, New Camp, Changed Camp, No longer present

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

The workflow described in D2.3 has not changed. Currently tests are run.

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

The workflow described in D2.3 has not changed. Currently tests are run.

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

The workflow described in D2.3 has not changed. Currently tests are run.

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3.3.9 WFS-ID-11 Food insecurity

This indicator is still in active development: updates vis-à-vis D2.3 are summarised in the table below.

Food insecurity (Update)	
Analysis	More precise description pending progress in Task 2.7
Product sample	Updated Product sample pending availability of innovative indicator data on the FTP

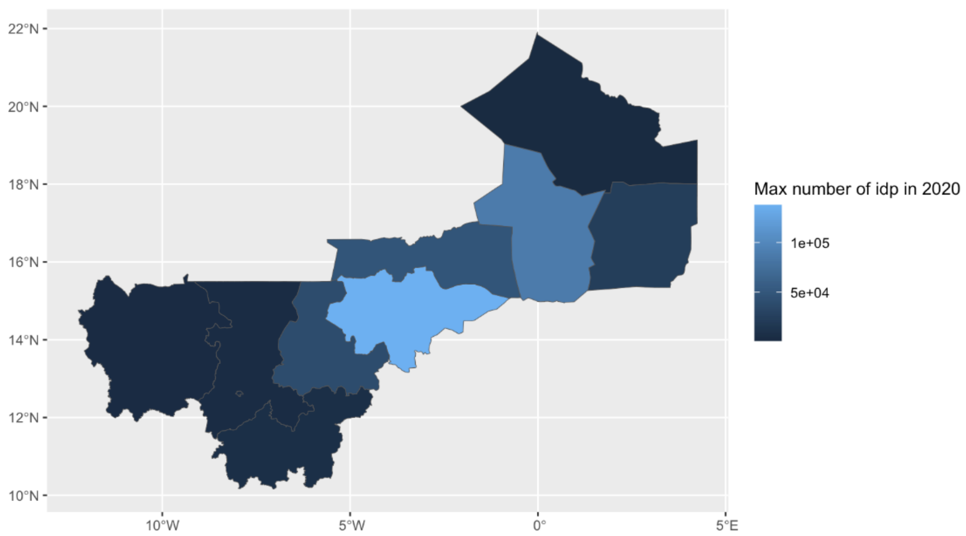
3.3.10 WFS-ID-12 Economic insecurity

This indicator is still in active development: updates vis-à-vis D2.3 are summarised in the table below.

Economic insecurity (Update)	
Analysis	More precise description pending progress in Task 2.7
Product sample	Updated Product sample pending availability of innovative indicator data on the FTP

3.3.11 WFS-ID-13 Displaced persons

This indicator is still in active development: updates vis-à-vis D2.3 are summarised in the table below.

Displaced persons (Update)	
Analysis	More precise description pending progress in Task 2.7
Product sample	 Sample 1: Total number of IDP in different admin1 of Mali in 2020 (note that no data are available for Taoudénit in the north-west)

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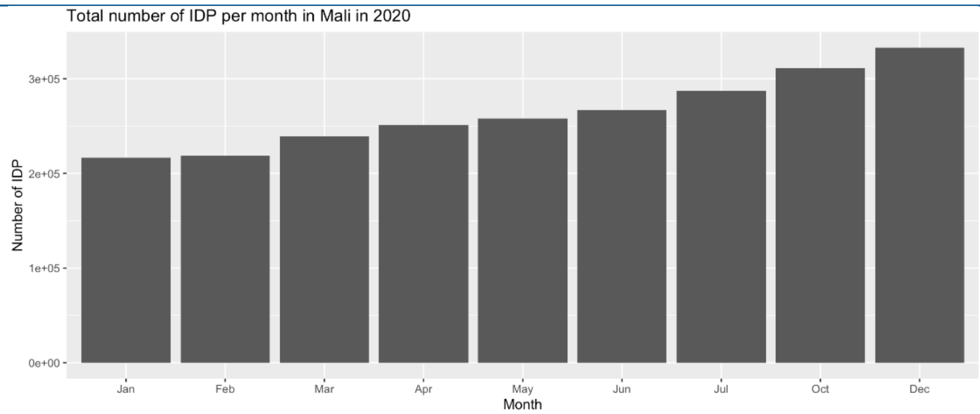
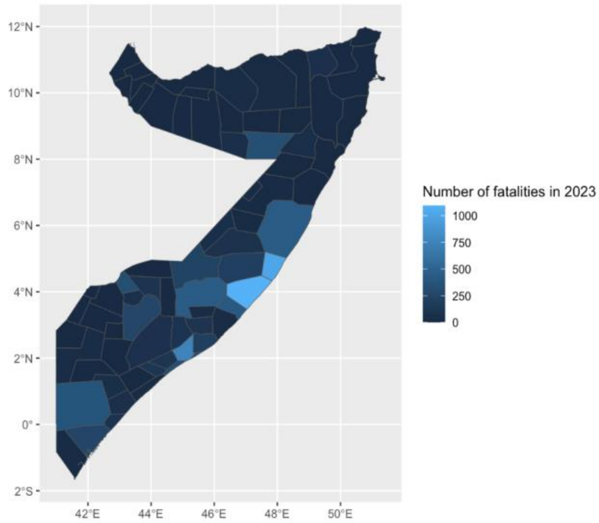
	 Sample 2: Total number of IDP per month in Mali in 2020

3.3.12 WFS-ID-14 Violent conflict

This indicator is still in active development: updates vis-à-vis D2.3 are summarised in the table below.

Violent conflict (Update)	
Analysis	More precise description pending progress in Task 2.7
Product sample	 Sample 1 WFS-ID-14: Total number of fatalities in different admin2 of Somalia in 2023

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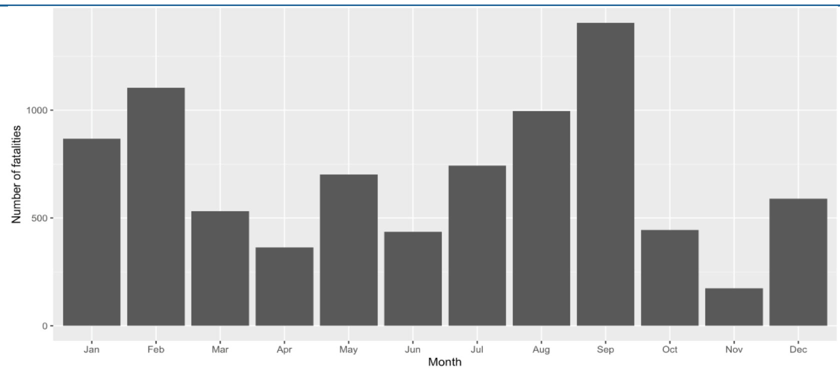
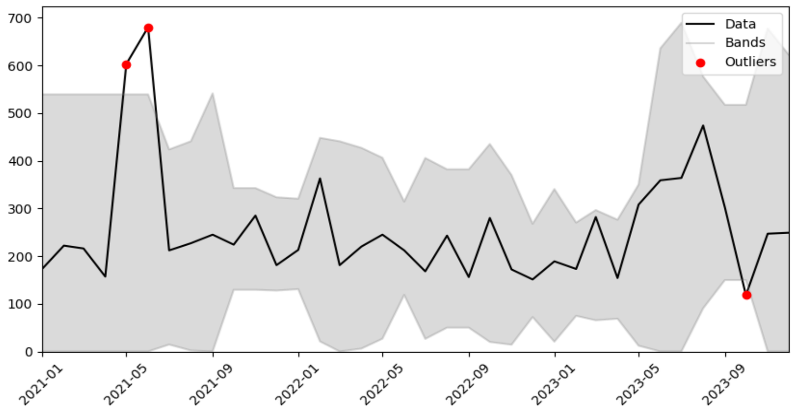
	 Sample 2 WFS-ID-14: Total number of fatalities per month in Somalia in 2023

3.3.13 WFS-ID-15 Radicalisation and polarisation

This indicator is still in active development: updates vis-à-vis D2.3 are summarised in the table below.

Radicalisation and polarisation indicator (Update)	
Analysis	More precise description pending progress in Task 2.7
Product sample	Updated Product sample pending availability of innovative indicator data on the FTP  Sample 1 WFS-ID-15: Volume-based trend graph of mentions of radicalization in relation to Mali in social and traditional media (2021-2023). The peaks in May/June 2021 relates to the putch in Mali in May 2021 and the follow-up threats by the French president Manuel Macron to withdraw the French troops from Mali.

3.3.14 WFS-ID-17 Humanitarian aid

Most information for this indicator has been provided in D2.3. Updated information below.

Humanitarian aid (Update)	
Analysis	More precise description pending progress in Task 2.7
Product sample	Updated Product sample pending availability of innovative indicator data on the FTP

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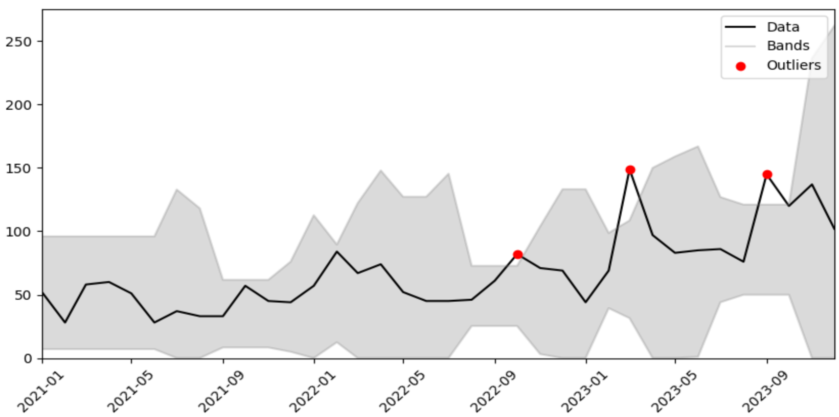
3.3.15 WFS-ID-18 Resource capture

This indicator is still in active development: updates vis-à-vis D2.3 are summarised in the table below.

Resource capture (Update)	
Validation	Process to be specified pending progress on Social and traditional media indicators in T2.4
Analysis	More precise description pending progress in Task 2.7
Product sample	 Sample 1 WFS-ID-18: Volume-based trend graph of mentions of water supply in relation to Mozambique in social and traditional media (2021-2023). The peak in March 2023, for example, relates to the consequences from the cyclone Freddy that hit Malawi and Mozambique in March 2023 whereas a number of villages were flooded and water supplies contaminated.

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

Most information for this indicator has been provided in D2.3. Updated information below.

Climate sensitivity of agri-food systems (Update)	
Validation	Process to be specified pending progress on Social and traditional media indicators in T2.4
Analysis	More precise description pending progress in Task 2.7
Product sample	Updated Product sample pending availability of innovative indicator data on the FTP

3.3.17 WFS-ID-21 Public services and infrastructures

This indicator is still in active development: updates vis-à-vis D2.3 are summarised in the table below.

Public services and infrastructures (Update)	
Analysis	More precise description pending progress in Task 2.7
Product sample	

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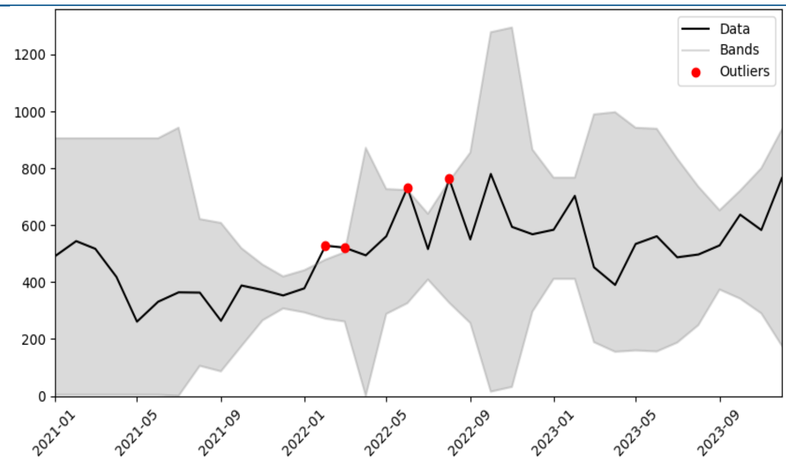
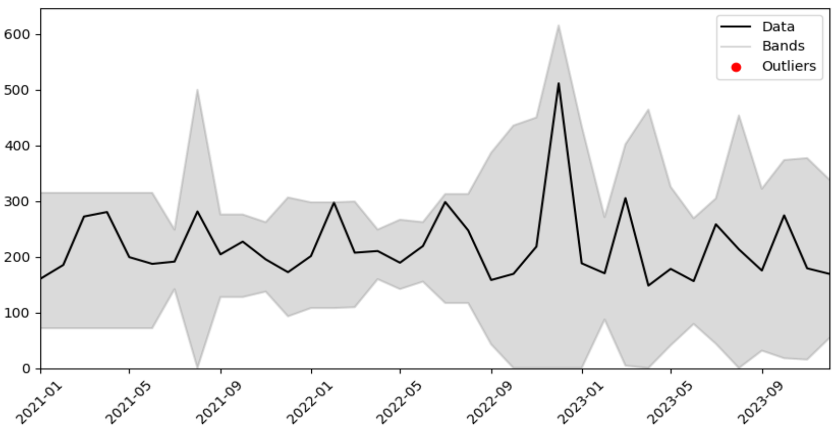
	 Sample 1 WFS-ID-21: Volume-based trend graph of mentions of healthcare-related terms and concepts in relation to Somalia in social and traditional media (2021-2023). The peak in June 2022, for example, relates to several cases of malnutrition reported in Somali hospitals.

3.3.18 WFS-ID-23 State-citizen relations

This indicator is still in active development: updates vis-à-vis D2.3 are summarised in the table below.

State-citizen relations (Update)	
Analysis	More precise description pending progress in Task 2.7
Product sample	 Sample 1 WFS-ID-23: Volume-based trend graph of mentions of corruption in relation to Mozambique in social and traditional media (2021-2023). The notable peak in December 2022, for example, relates to the accusation of the ex-president's son of graft and corruption.

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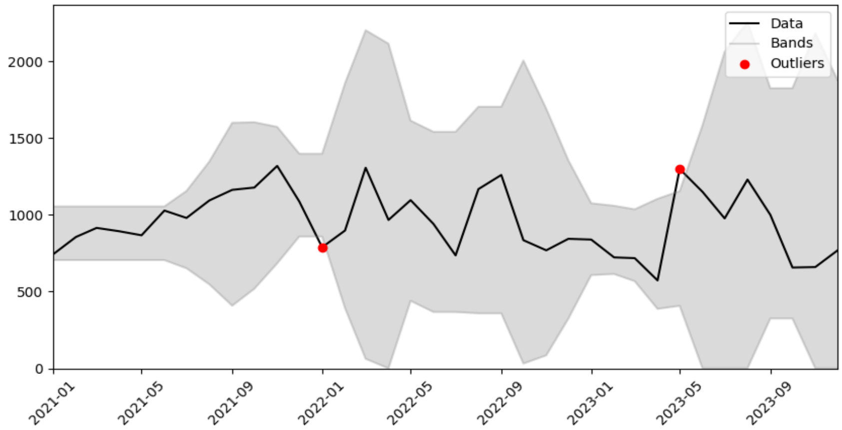
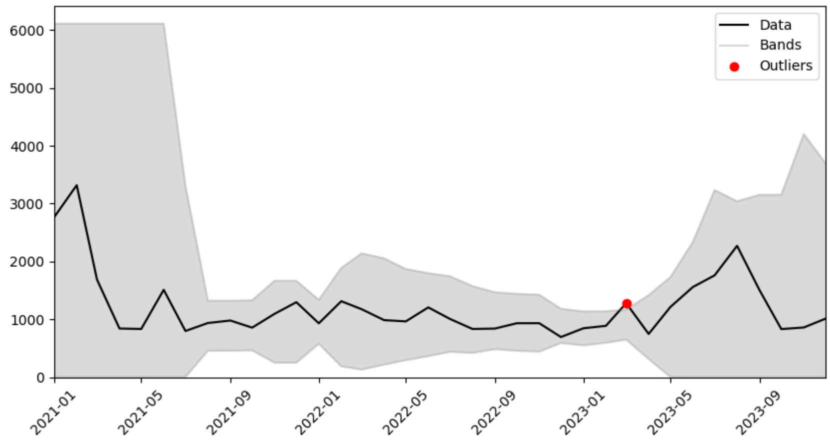
3.3.19 WFS-ID-24 Dispute resolution mechanisms

This indicator is still in active development: updates vis-à-vis D2.3 are summarised in the table below.

Dispute resolution mechanisms (Update)	
Analysis	More precise description pending progress in Task 2.7
Product sample	 Sample 1 WFS-ID-24 Volume-based trend graph on mentions of terms and concepts related to the legal/court system in Mali in social and traditional media (2021-2023). The peak in May 2023 relates to a novel draft code of criminal procedure and penalties in Mali.

3.3.20 WFS-ID-25 Social cohesion and trust

This indicator is still in active development: updates vis-à-vis D2.3 are summarised in the table below.

Social cohesion and trust (Update)	
Analysis	More precise description pending progress in Task 2.7
Product sample	 Sample 1 WFS-ID-25 Volume-based trend graph on mentions of migration with relation to Mali (2021-2023) as one of the fundamental aspects in the context of social cohesion. The peak in January 2023 relates to the increasing numbers of migrants in the neighbouring Niger and the

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	approximately 500 Malians among the several thousand migrants stranded in Assamaka, Niger. The second notable peak in August 2023 relates to the increasing discussions and warnings issued by experts that migrants can be used as leverage by the rebels in the region.

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4 PROCESSING CHAINS – TUNING AND ADAPTATION V2

4.1 URBAN FLOOD AND RELATED SOCIO-POLITICAL-ECONOMIC PIPELINES

This section includes the visual representations of the processing chains of the CENTAUR products tuned and adapted with respect to the baseline version delivered in the D2.3 [RD07] delivered in M12.

4.1.1 Meteorological Component

The processing chain for the meteorological component has undergone improvements for the urban flood track. In particular, the output of UF-ID-1 now also entails a probability estimate for exceeding critical thresholds of return periods of extreme precipitation. This output is also used as an input for the prediction component (UF-ID-2) and the early-warning index.

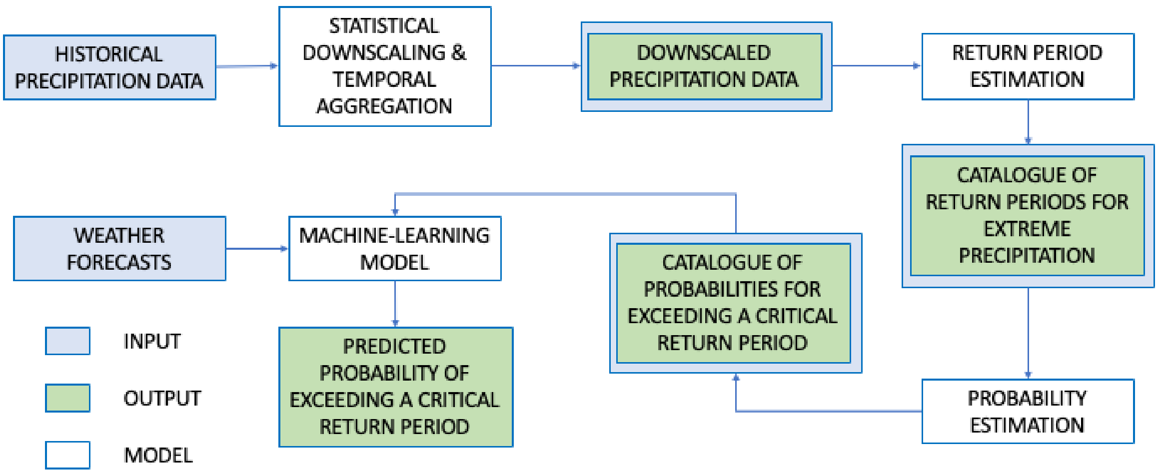

Figure 1: Updated processing chain of the meteorological component – Urban Flood

4.1.2 Flood Components

4.1.2.1 Speedy Flood

After several analyses, also thanks to Copernicus projects parallel to Centaur, we identified certain limitations of the tool. Specifically, we intervened in correcting the input related to the flood mask obtained from satellites, used for calibrating the geomorphological model in Speedy Flood and calculating depths.

Regarding the first improvement made in Speedy Flood, concerning the satellite-derived flood mask, it was realized that it couldn't be directly utilized in analyses as it wasn't aligned with the reference DTM. The satellite-derived water mask relies on a DTM, typically the SRTM, which is different and less detailed than what is used for calculating flood extents and depths with Speedy Flood. This difference in DTMs leads to issues in accurately reproducing the flood mask, with varying morphologies and terrain altitudes due to different DTM resolutions. These differences result in errors in reproducing the flood shape and calculating flood depths.

Thanks to the changes made to the Speedy Flood workflow, we can now fully address this issue by perfectly aligning the satellite-derived water mask (a crucial element for geomorphological model calibration) with the DTM used in the analyses. This evolution allows for more accurate results in both urban and non-urban areas.

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The second aspect addressed in the Speedy Flood workflow concerns depth calculation. Due to the peculiarities of the resolved DTMs, it was decided to increase the number of points at the edge of the water mask polygon to enable more robust depth calculations. A higher number of points, combined with the use of social media markers derived from ID-6 (representing absolute truth on the ground), allows for rather accurate flood depth analyses. However, it's important to note that limitations persist due to the resolutions of the DTM used and representation errors that may omit artificial elements influencing water flow and, consequently, flood depth.

4.1.2.2 FLORIA

As previously described, the processing chain for FLORIA (UF-ID-4) did not evolve from M12 to M15.

Currently, FLORIA computes the flood extent from 3 SAR products (Input-ID-06). After inference from 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. The flood extent computed by FLORIA is also an input for UF-ID-5, identified as Input-ID-01, as well as for collecting social media markers under UF-ID-6.

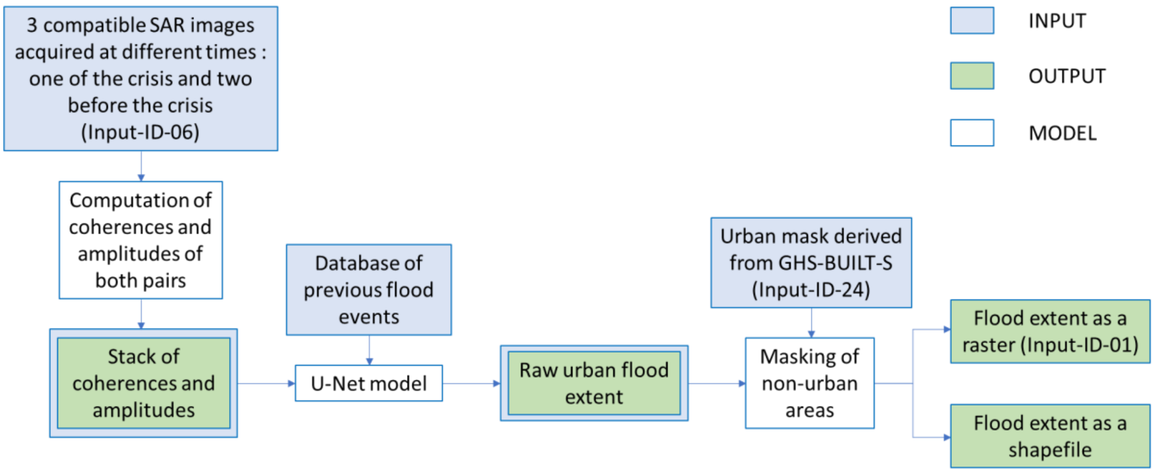

Figure 2: Updated processing chain for the computation of the FLORIA component – Urban Flood

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

4.1.2.3 Flood impact

As previously described, the processing chain for the flood impact index did not evolve from M12 to M15.

4.1.3 Social/traditional media component

The processing chain for the social/traditional media component has not changed since the last update in D2.3.

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

4.2.1 Meteorological Component

The processing chain for the meteorological component has not changed since the last update in D2.3.

4.2.2 Agricultural Drought Component

The generic framework for agricultural drought monitoring/forecasting as described in D2.3 remains valid. The way in which the near-real time drought indicator (WFS-ID-4) will be combined with meteorological forecasts into an agricultural drought forecast (WFS-ID-5) has slightly changed: instead of using rule-based decision frameworks, we will employ trained classification algorithms (Random Forest or gradient boosting) which will result in a categorical score related to future agricultural droughts. Alongside these categorical scores, a pixel-based confidence score will be provided for each class to clearly indicate model confidence and, as such, uncertainties.

4.2.3 Population and Settlement Component

The workflow described in D2.3 has not changed. Currently tests are run.

4.2.3.1 Populations at risk of food insecurity

The workflow described in D2.3 has not changed. Currently tests are run.

4.2.3.2 Populations at risk of water insecurity

The workflow described in D2.3 has not changed. Currently tests are run.

4.2.3.3 Number of people living in conflict areas

The workflow described in D2.3 has not changed. Currently tests are run.

4.2.4 Displacements Component

The generic framework for the development of this indicator remains the same as described in D2.3.

The workflow for the WFS-ID-7 is triggered by the activation from the alert system of the CENTAUR project. In this case, an alert from the central node of the CENTAUR platform is sent to the local node, in charge of starting the activities to produce the requested indicator.

When a significant number of people begin to leave a certain area affected by climate change related events or political instability, all this migratory flux sometimes converge into aggregating points in which people finds a temporary or permanent host. Hence, starting from the specific area of interest, needed EO imagery acquisition is scheduled manually, 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

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observation or its dimension are still the same. From this spatial development, the magnitude and temporal development of the migration event can be used, as a tool to monitor the situational awareness.

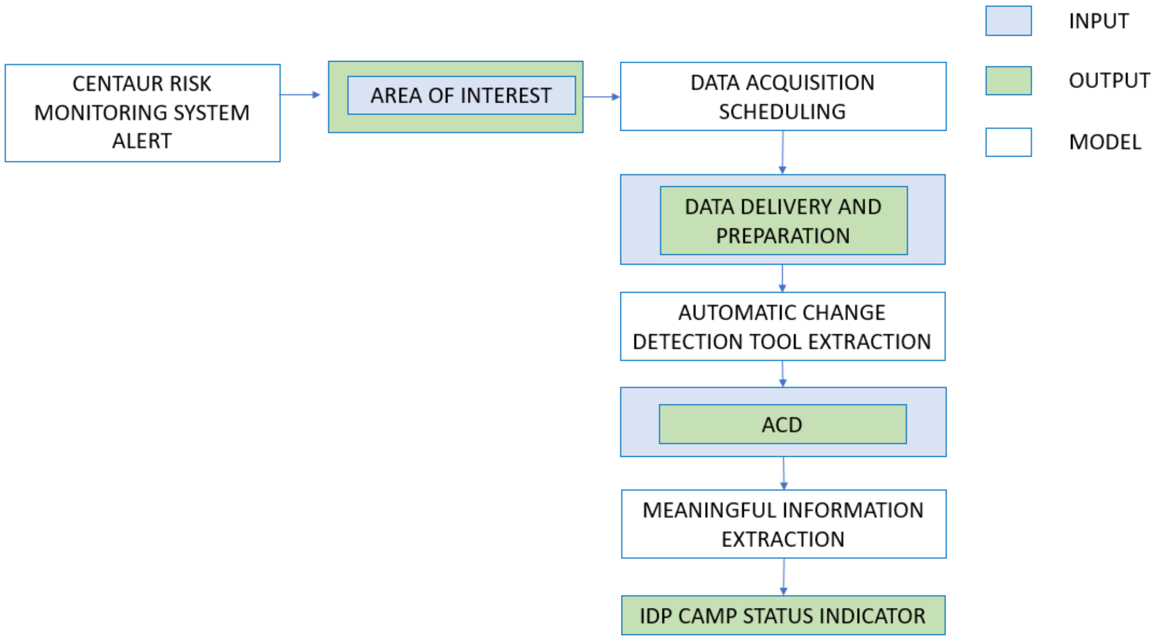

Figure 3: Updated processing chain for the displacements' component – Water & Food Insecurity

4.2.5 Social/traditional media Component

The processing chain for the social/traditional media component has not changed since the last update in D2.3.

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5 CENTAUR PLATFORM FOR PIPELINES INTEGRATION

This chapter is outlined in the documents "D3.2 - Platform design document" and "D3.3 - CENTAUR integrated platform including Urban Flood and Water&Food Indexes v1 (baseline)", which describe the design and the integrated pipelines in CENTAUR platform.

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6 CONCLUSIONS

This report illustrates the fine-tuning and adapted configuration of CENTAUR service pipelines for generation of complex Urban Flood, Water & Food Insecurity, and Socio-Political-Economic pipelines, properly combining and integrating dataset from different sources.

Results generated by specific product (i.e., innovative indicators) within CENTAUR provided in dedicated ID-Cards and generated for each indicator within the Urban Flood, for Water & Food Insecurity had already been presented in D2.3. However, the updates that were made during M12-M15 are reported here, particularly for the following indicators:

- UF-ID-1, UF-ID-2, UF-ID-3, UF-ID-4

Conversely, for the Socio-Political-Economic thematic areas, the indicators are still under development and updates of the results obtained so far are reported here:

- UF-ID-9, UF-ID-10, UF-ID-13, UF-ID-14 .
- 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. (More precise description will be provided once the necessary progress is achieved in Task 2.7)

Furthermore, in chapter 4 of this report, the visual representations of the processing chains of the CENTAUR products have been fine-tuned and adapted from the baseline version delivered in the D2.3 [RD07] during M12. 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)

As said above, the Chapter 5 “CENTAUR PLATFORM FOR PIPELINES INTEGRATION”, describes the design and the integrated pipelines in CENTAUR platform, outlined in “D3.2 - Platform design document” and “D3.3 - CENTAUR integrated platform including Urban Flood and Water&Food Indexes v1 (baseline)”.

In conclusion, the annex shows tuned and adapted intermediate products that used by specific pipelines as input data for certain socio-economic-political indicators.

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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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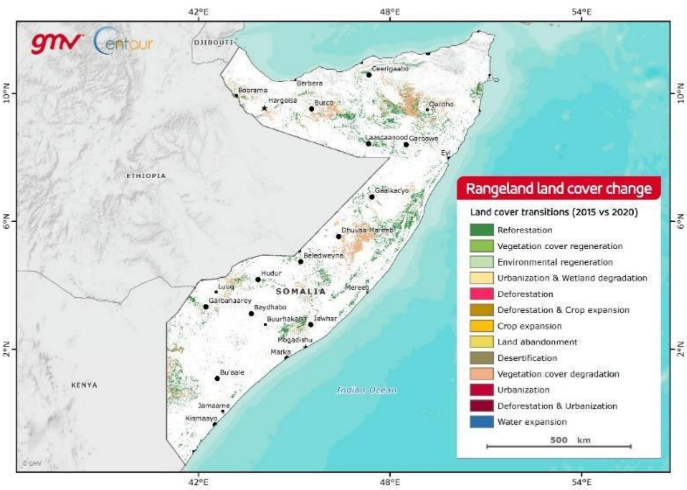
<table>
<tr><td>Dependencies Software</td><td>n/a</td></tr>
<tr><td>Dependencies Hardware</td><td>n/a</td></tr>
<tr><td>Analytics</td><td>The product is based on the Land cover (LC) classification gridded maps from the Copernicus Climate Change (C3S) service. The C3S provides global LC maps from 1992 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).</td></tr>
<tr><td>Challenges</td><td>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.</td></tr>
<tr><td>Product sample</td><td>
</td></tr>
</table>

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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. 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

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provides the global distribution of several livestock species in 2015 expressed in total number of animals per pixel (5 min of arc).

THI	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.

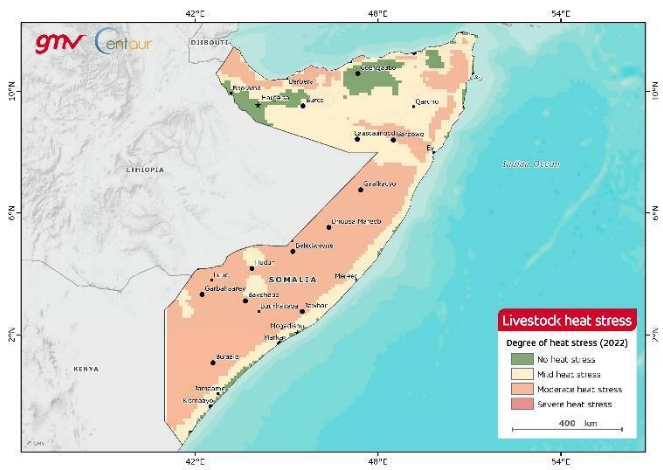
The heat stress risk index can be interpreted as the risk of being the total livestock under significant heat stress. The risk (ranging from no stress, mild, moderate to severe) is computed as weighted average of the heat stress index values normalized by the livestock species density in the country. The table below shows the final values of the weighted average livestock heat stress.

Livestock heat stress	Weighted average livestock THI	Grid value
No stress	0	0
Mild	0 < THI ≤ 0.33	1
Moderate	0.33 < THI ≤ 0.66	2
Severe	THI > 0.66	3

Challenges

No particular challenges encountered.

Product sample



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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.
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) and for platform integration, a text format (.json)
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:

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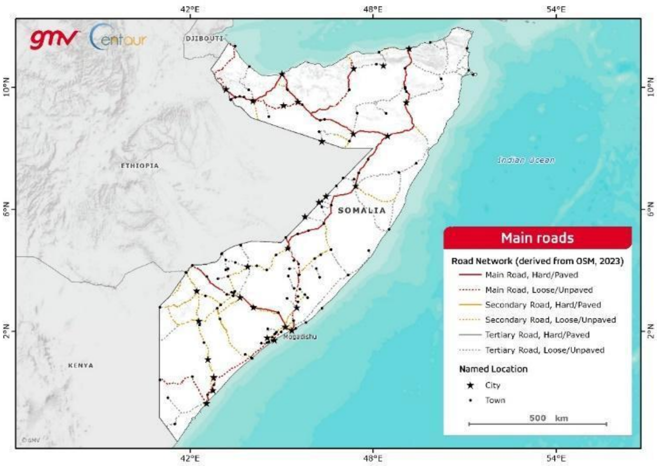
	https://spatial.faoswalim.org/layers/geonode:SOM_Primary_Roads_UNOCHA#/We 4. Automatically populated the Load-Bearing Surface Type using OSM information (paved or unpaved). In cases where this information is missing, the information is manually filled by analysing the Google Layers image. 5. Perform 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.
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

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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.

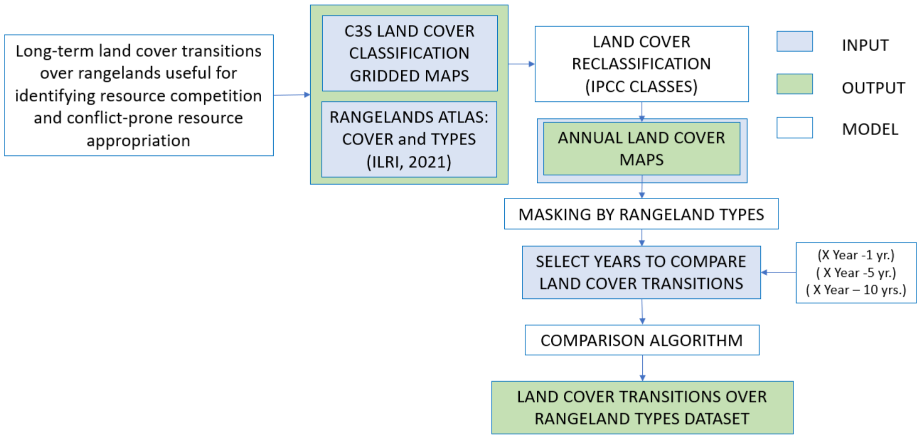

Figure 4: Product Workflow

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 Figure 5.

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t0 - change from		t1 - change into							
		Forest	Shrubland	Grassland	Wetland	Bare land	Cropland	Built-up	Water body
	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

Figure 5: Matrix of LC transformation processes

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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 3.

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
	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

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	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 3: Land cover reclassification

The data is provided per country (Table 4) 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.)

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 4: 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

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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:

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

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:

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

The degree of heat stress with corresponding THI value for different livestock is taken from Raimi et al., 2021 too (Table 5). 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 for male lambs, based on available studies about their upper critical temperature and their physiological responses under heat stress events (Table 5).

THI	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 5: Degree of heat stress with corresponding THI value for cattle, sheep, and goats

In Table 5, "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 as shown in Table 6. Finally, the heat stress risk values are aggregated into annual values.

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Livestock heat stress	Weighted average livestock THI	Grid value
No stress	0	0
Mild	0 < THI ≤ 0.33	1
Moderate	0.33 < THI ≤ 0.66	2
Severe	THI > 0.66	3

Table 6: Livestock heat stress categories, weighted average livestock THI values and grid values

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:

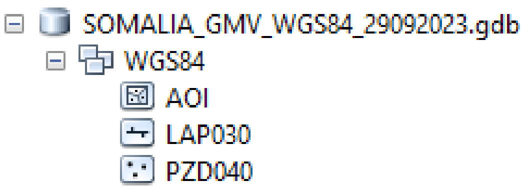

Figure 6: GDB organization

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 roads (LAP030) are also provided in .json format to be compatible with the formats required by CENTAUR platform and to allow the integration of this product into the platform.

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.
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.

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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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