SAVECROPS4EU: A DIGITAL TWIN COMPONENT AGRICULTURE WITH A FOCUS ON EO DATA USE

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[6] CropOM

BACKGROUND

From Berger, Machwitz,…. , Kefauver, …,Verrelst, …, Prikaziuk, …, Sulis, …, Rozenstein, … and Schlerf: 2022, *Rem. Sens. Environ.* 280

SENSECO heritage: Better understanding of RS of crop stress and of RS + CGM integration

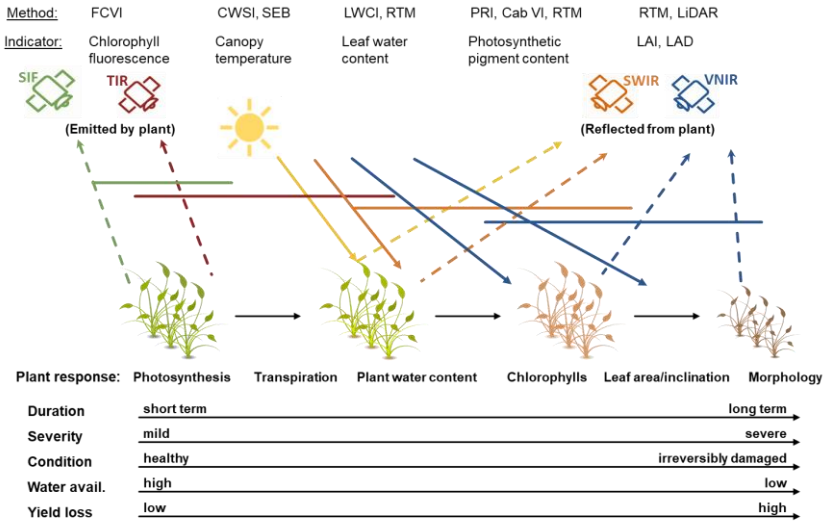


Fig. 4: Integrated concept of plant responses to (drought) stress with optimal sensing domains for estimating trait groups and exemplary stress proxies

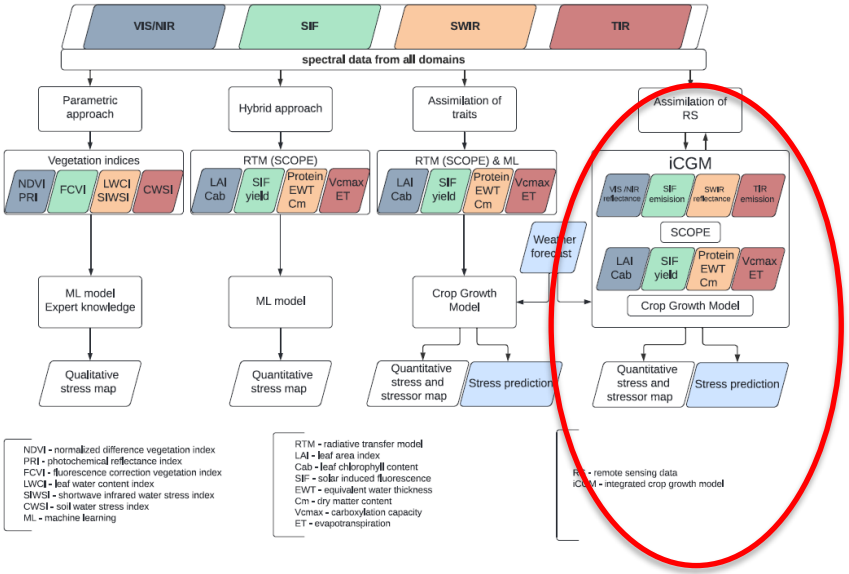
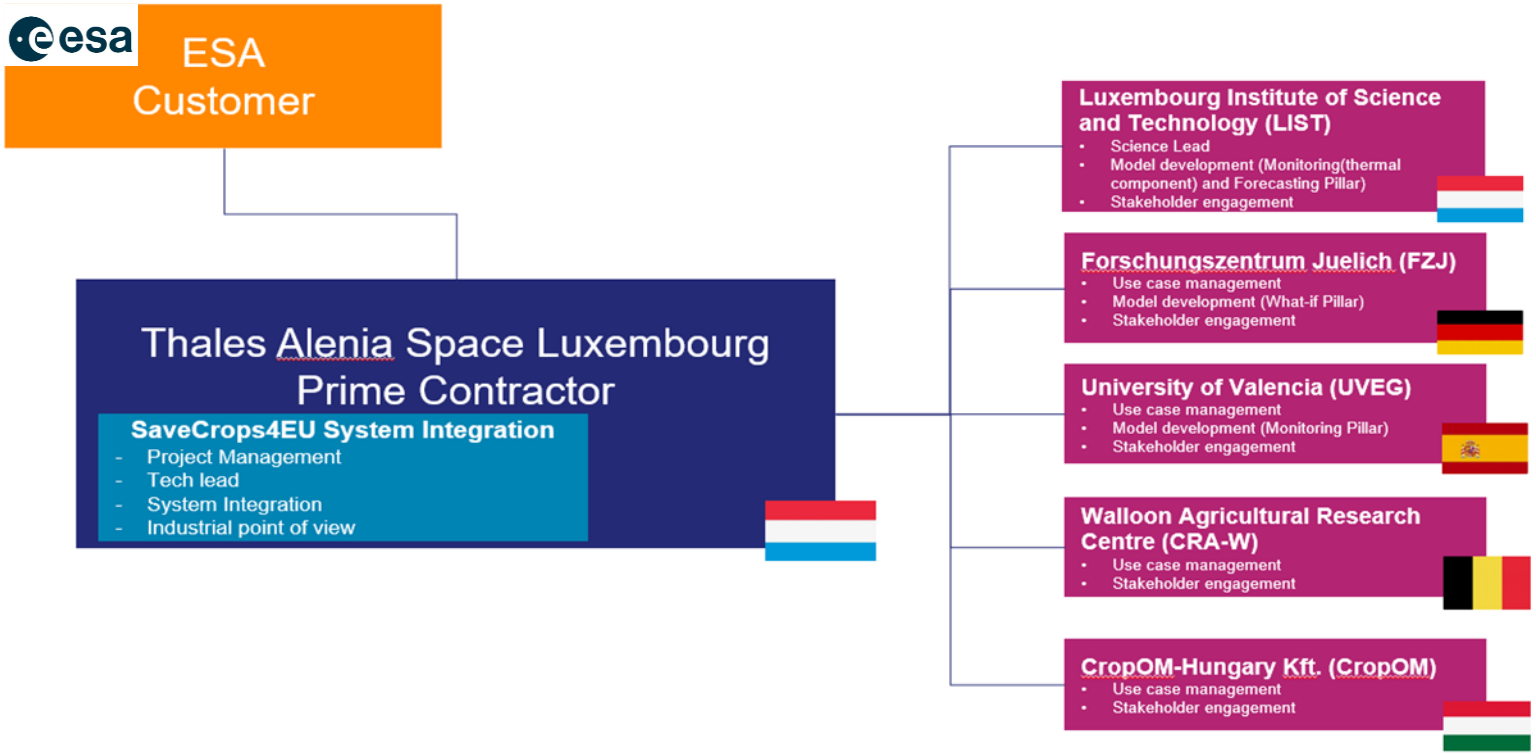


Fig. 13: Assimilation of multi-sensor EO data into coupled CGM-RTM model for crop stress and yield prediction

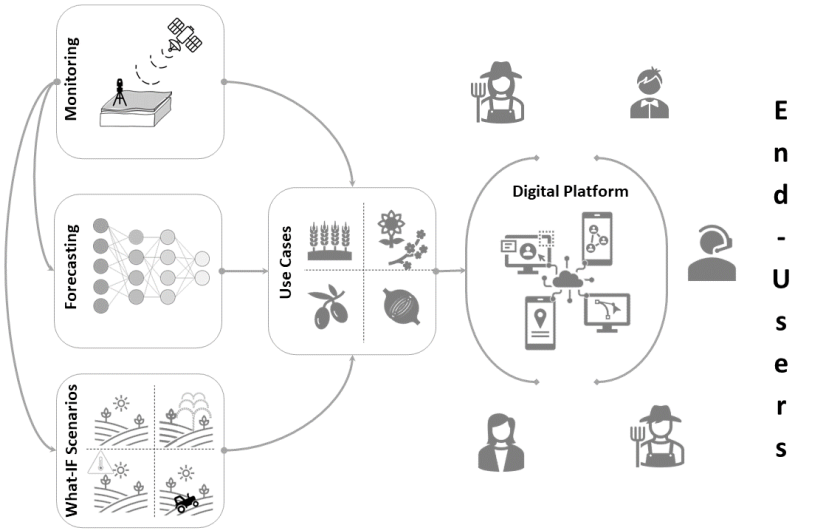
PROJECT OVERVIEW: CONSORTIUM



PROJECT OVERVIEW: SOLUTION

The to be developed SaveCrops4EU DTC solution is based on:

- End-User driven development, solution will collect requirements from a wide range of stakeholders and implement a selection within the project
- Maximum Reuse of Destination Earth Platform existing solutions
- 3 scientific pillars:
  - Monitoring (advanced EO-Based Agricultural products)
  - Forecasting (district level yield forecasting)
  - Advanced Decision Making (“What if” focused on abiotic stressors)
- Applied to 4 use cases in Various EU Regions:
  - Belgium, Germany, Hungary, Spain
- Focused on Major EU Crops
  - Wheat, potato, winter wheat, barley, maize, etc.
- Scientifically valid including Uncertainty calculation
- Pre-Operational Solution (TRL 6-7) at the end of the project



Overview of the key parts of the solution space from the proposal

PROJECT OVERVIEW: USE CASES

4 initial use cases to validate model predictions and outputs:

Use case 1: Crop nitrogen status and fertilisation mgmt

- Overfertilization, nitrate in groundwater and water bodies
- Validate Pillar 1 and Pillar 2 outputs: large amount of ground truth on N, LAI, yield for winter wheat and potato to compare against monitoring & forecasting outputs
- Access user requirements through close collaboration with several stakeholders

User case 2: Crop drought stress and irrigation mgmt

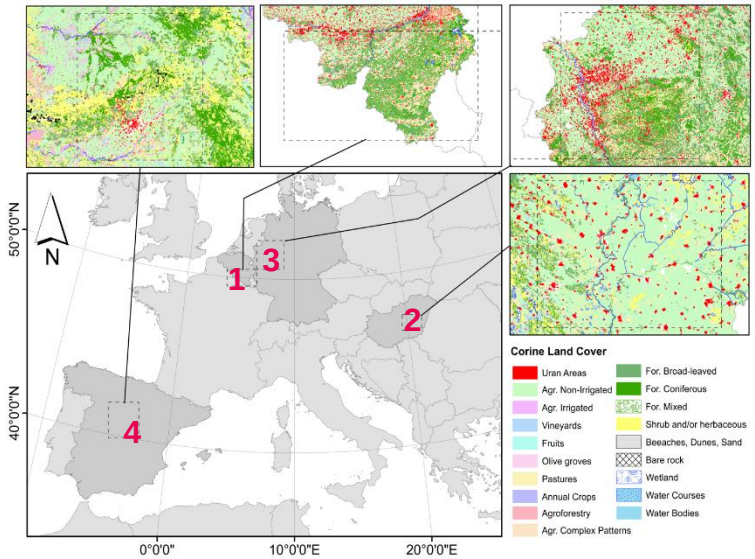
- CropOM has developed the CropModel API (CGM+EO) solution which lacks reliable and advanced input data
- Improve CropOM with data from Pillar 1 (soil moisture, LST, ET)
- Benchmark Pillar 2 (yield forecasting) and Pillar 3 (what-if scenario) outputs against existing ones from CropOM

Use case 3: Effects of abiotic stress on yield predictions

- Assessment of yield predictions under extreme temperature and drought conditions (occurred in 2018)
- Yield prediction simulations and uncertainty quantifications over the existing Selhausen agricultural research site

Use case 4: Effects on yield management

- Assessment of yield predictions under strong rainfall variability across scales
- Validation and error analysis of DTC yield predictions using
  - i) a 4-year field dataset for 12 parcels on yield, sowing and harvest dates
  - ii) An operational crop yield forecasting system based on AquaCrop which runs on few input data



Geographic location of the identified use cases

PILLAR-1 MONITORING

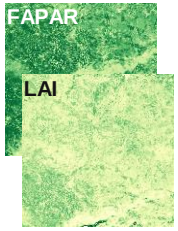
User Interface
- Create user defined polygons
- Plot time series of variables, their anomalies and calculate statistics
- Provide attribute maps

Standard variables from CLMS, Terrascope, Sen2Agri
[vegetation properties, vegetation phenology, soil moisture, meteorological variables]

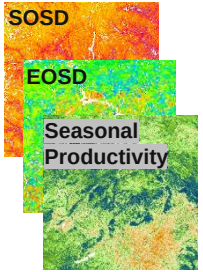
Additional crop traits from Copernicus S-2 and Expansion Missions (CHIME, LSTM) and national missions
[pigment, nitrogen, water content, land surface temp.]

Land Monitoring Service

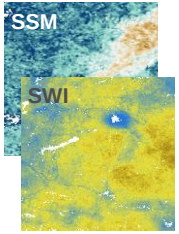
Veg. properties
10 m Europe daily
2016-present



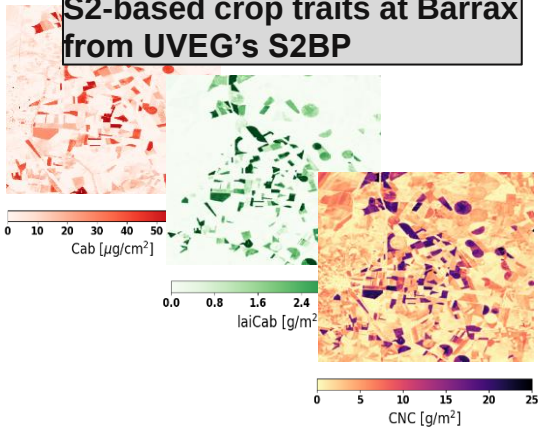
Veg. Phenology
10 m Europe yearly
2017-present



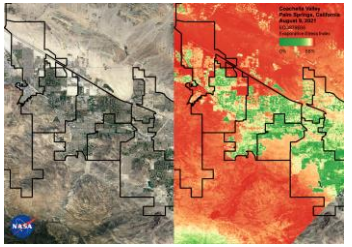
Soil Moisture
1 km Europe daily
2014-present



S2-based crop traits at Barrax from UVEG's S2BP



ECOSTRESS ESI
Evaporative Stress Index



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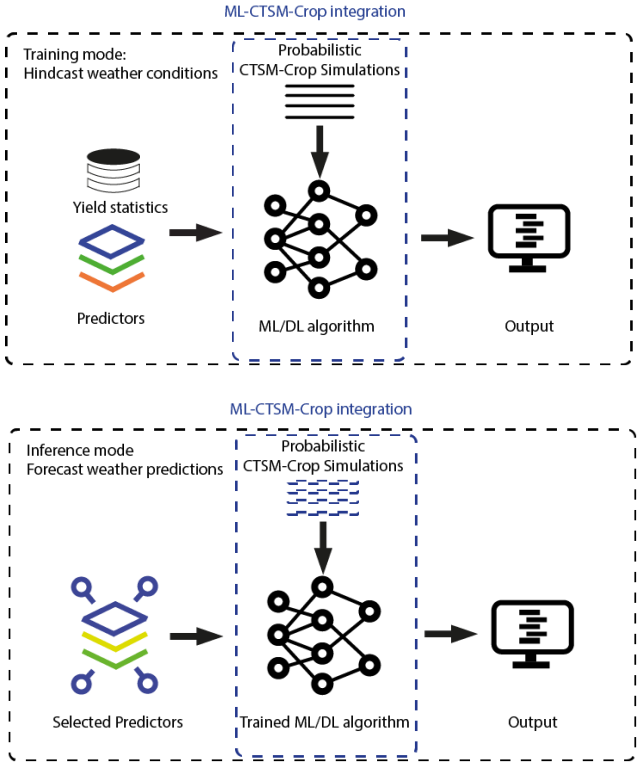
PILLAR-2 FORECASTING



Schematic of the workflow of the hybrid crop yield forecasting chain

- Target: district-level yield
- Predictor variables:
  - meteorological in situ / reanalysis (ERA5)
  - soil variables (EU Soil Observatory)
  - All available EO surface variables from Pillar-1
  - simulated dataset generated by a physically based crop growth model (CLM5 land surface model)
- Training mode:
  - Use ML/DL methods to identify the most skilful predictors of crop yield
  - Hindcast weather, EO and yield data (past available years)
- Inference mode:
  - Apply the trained ML/DL model to predict the yield of the running season
  - Forecast weather (one to several weeks)
  - Available EO variables of the current season
  - The trained model uses only some of the EO / CGM variables (the selected predictors)

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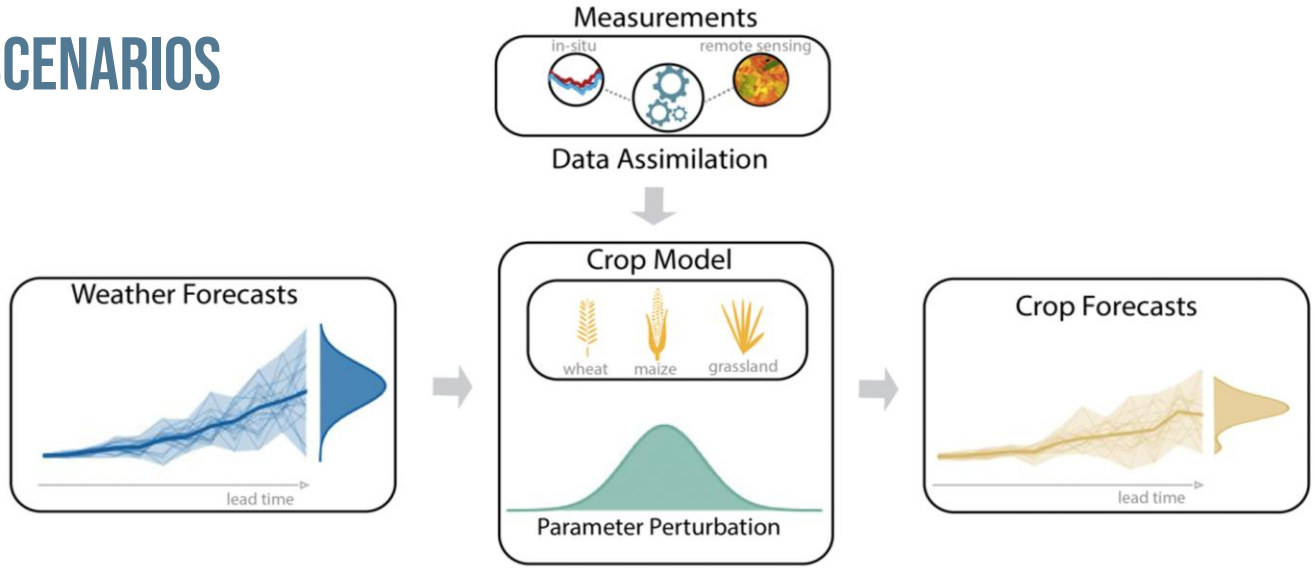
PILLAR-3 WHAT-IF SCENARIOS

Schematic of the scenatio-testing framework based on the assimilation of in-situ and EO datastreams into a physically-based crop growth model with perturbed parameters and atmospheric forcing.



- The CLM5 model will be used for predicting land surface states and fluxes
- many CLM5 model parameters are unknown; it has been coupled with a data assimilation framework
- The CLM5-PDAF can assimilate RS soil moisture and leaf area index to reduce the uncertainty of model projections
- The model simulations will allow to run what-if scenarios, e.g.:
  - a) what is the impact of different irrigation scenarios (timing, amount of water irrigated) on crop yield, in combination with different weather predictions?
  - b) what is the impact of nitrogen fertilization on crop yield on one hand and environmental indicators, like nitrate leaching to ground water on the other hand?

ESA'S DIGITAL TWIN CONCEPT

- The **ESA Digital Twin Earth (DTE)** Programme Framework provides the tools and infrastructure necessary for creating digital twins. Moreover, it integrates data from ESA's Earth Explorer missions into the **DestinE** platform, which serves as the foundation for building, testing, and deploying digital twin services.

- The core element of DTE are the Earth Observation Digital Twin Components (**EO DTCs**) which are focused projects that demonstrate how Earth observation data can be used to simulate different aspects of Earth's systems. **These digital twins dynamically reconstruct and simulate elements such as forests, hydrology, agriculture, ice sheets and coastal processes, providing actionable insights and enabling 'what-if' scenario modelling.**

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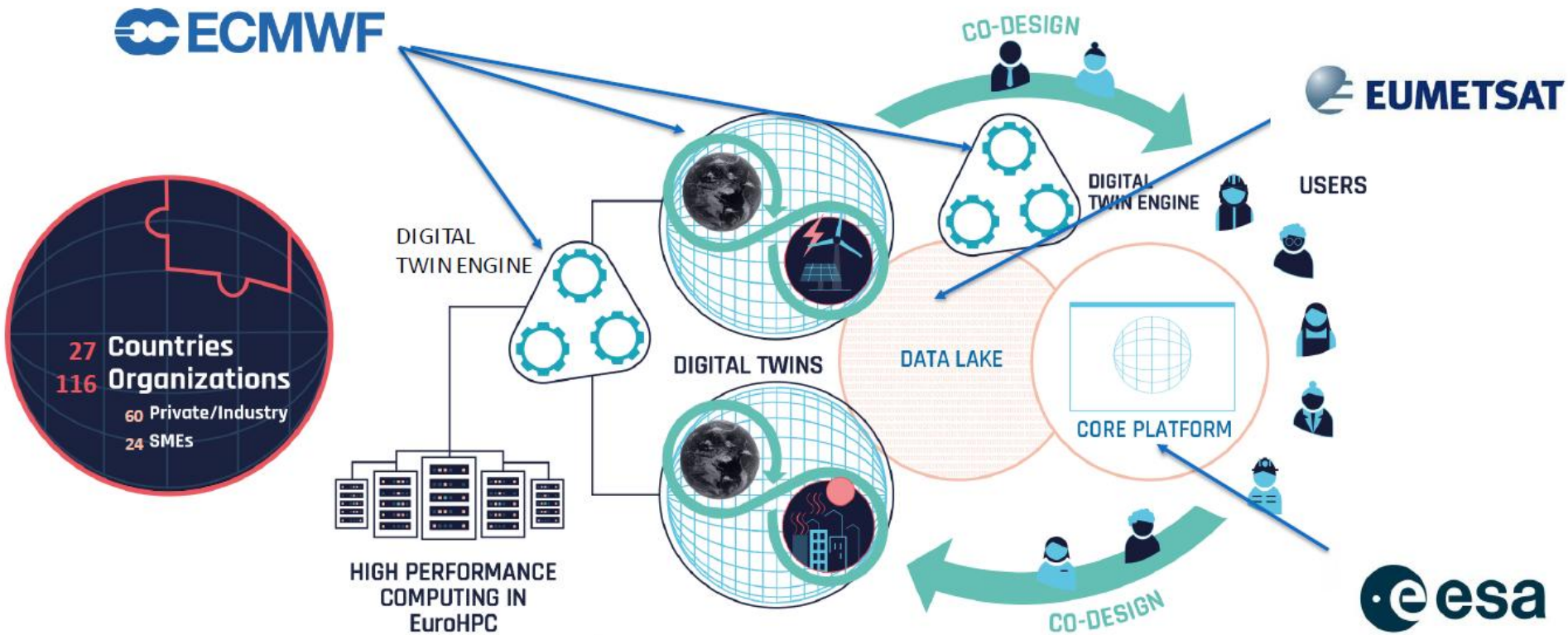
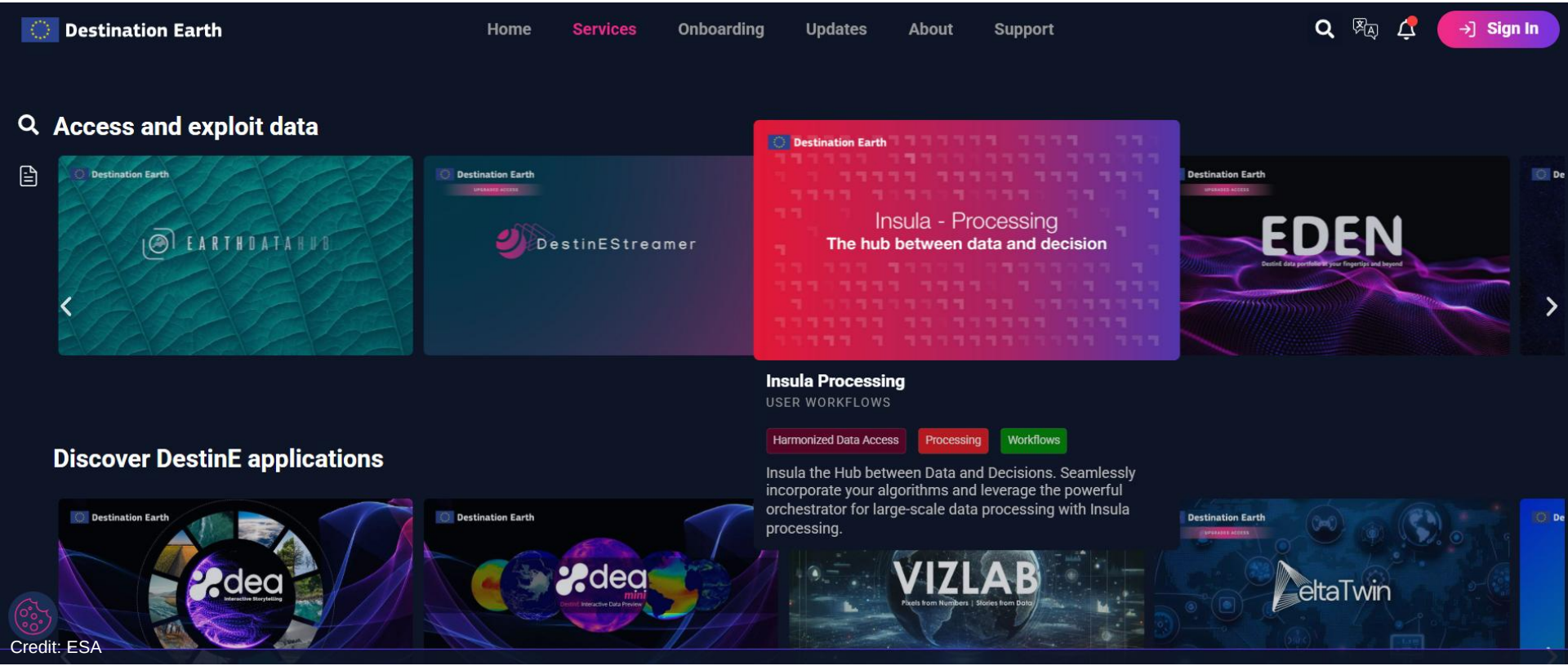
DESTINE: A NOVEL INFORMATION SYSTEM



DESTINATION EARTH SERVICES



Credit: ESA

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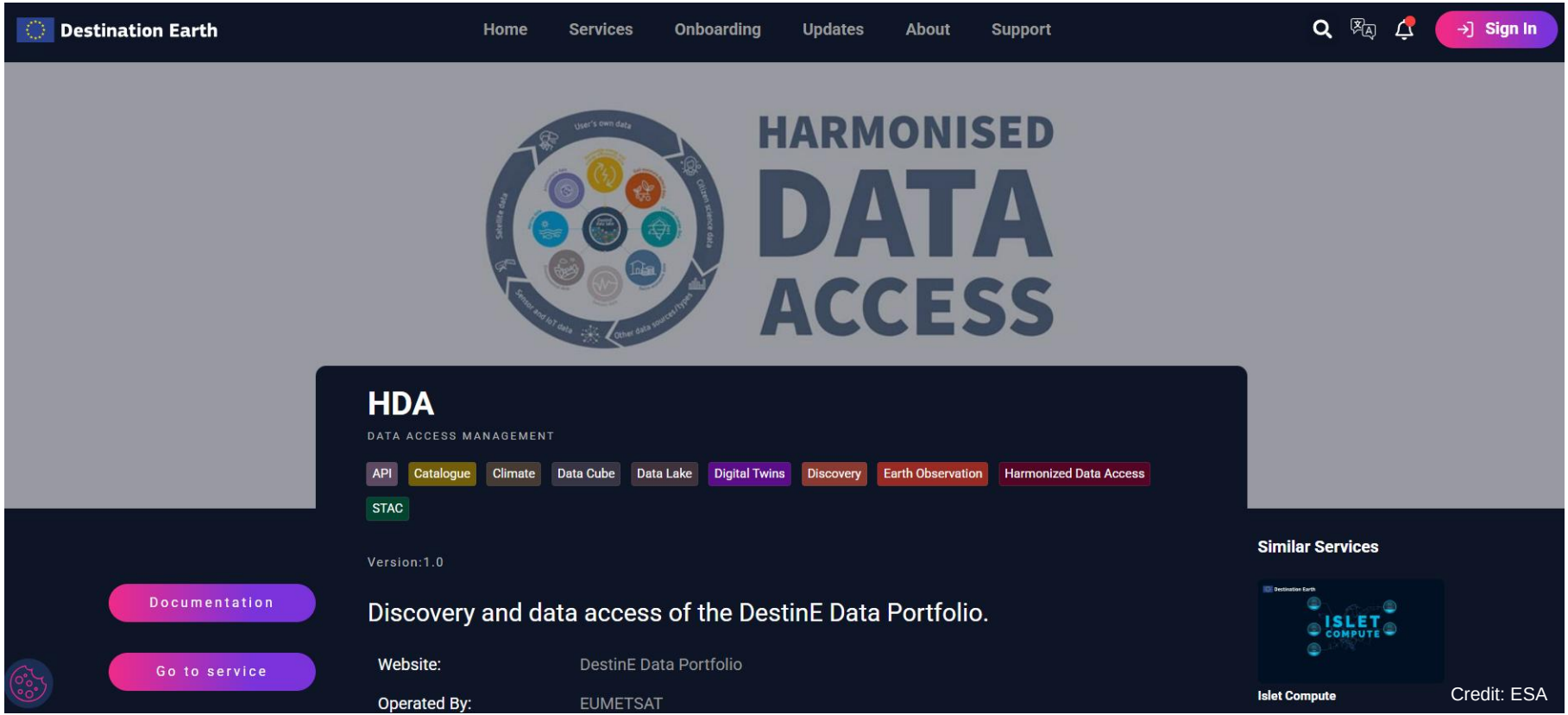
HAD: HARMONISED DATA ACCESS



Credit: ESA

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EO PROCESSING TASK

PyEOGPR

Biophysical models

STAC

API

Central Site

LUMI

Leonardo

MareNostrum

Eumetsat Bridge

Data Lake

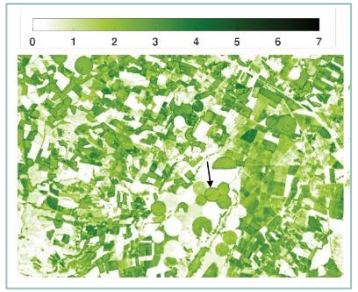
S2 data

Destination Earth

Insula - Code

The hub between data and decision

Leaf Area Index Map



eurostat

EUMETSAT

IAGOS

ECMWF

ISIMIP

WEKEO

esa

CREODIAS

Copernicus

DestinE Platform

Your gateway to a sustainable future

A unique ecosystem of services harnessing the power of Destination Earth.

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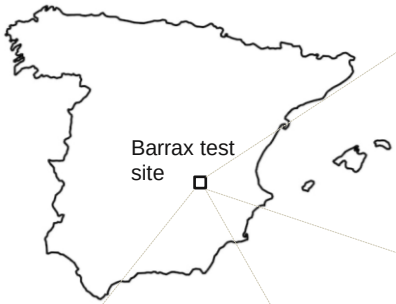
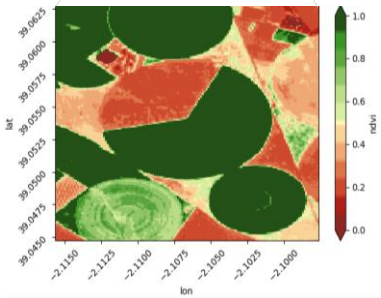
EO PROCESSING TASK

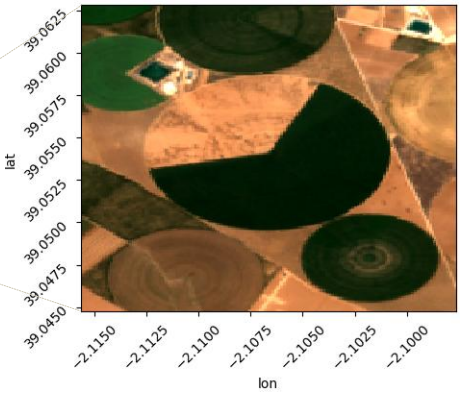
Work in progress





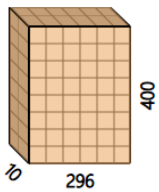
S2 2023-04-03: NDVI

S2 2023-04-03: RGB



xarray.DataArray (**band**: 10, **lat**: 400, **lon**: 296)

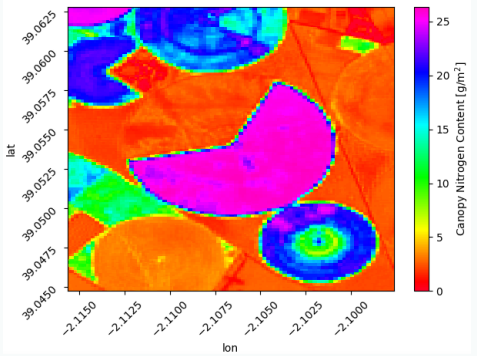
	Array	Chunk
Bytes	9.03 MiB	19.53 kiB
Shape	(10, 400, 296)	(1, 50, 50)
Dask graph	480 chunks in 8 graph layers	
Data type	float64 numpy.ndarray	



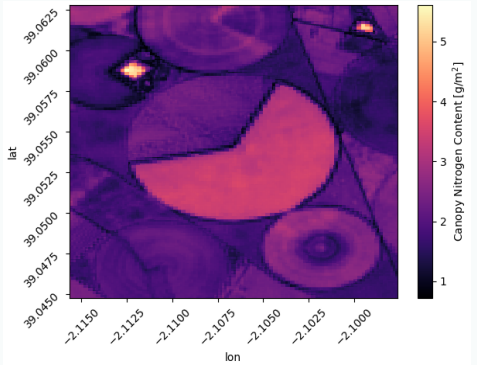
Insula - code platform

CNC GPR modeling

S2 2023-04-03: Protein-based CNC estimation



S2 2023-04-03: Uncertainty (standard deviation)



Destination Earth

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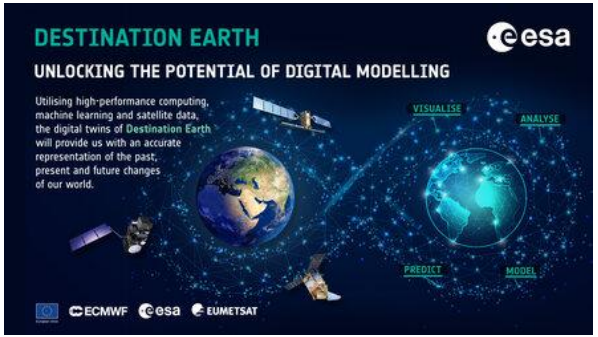
CONCLUSIONS



- As part of SAVECROPS4EU we entered into ESA's DT platform DestinE
- DestinE is ambitious, but also still in its infancy
- Our task is to integrate the vegetation trait models into DestinE (see also presentation Emma)
- With DestinE the idea is that then scenarios can be created