From URs to an EO based SOC monitoring system
Julia Yagüe, GMV.

ESA Symposium on Earth Observation for Soil Protection and Restoration

WORLDSOILS

Contract 400131273/20/I-NB

WORLDSOILS – A SOC PREDICTION SYSTEM

- Develop a **pre-operational** monitoring system in **cloud** environment capable of:

  - **Predicting** Topsoil Organic Carbon (**SOC**) at **regional and continental** scales from EO satellite data

  - Leveraging upon **multitemporal soil-spectral data archives** (3-year time series) and modelling techniques

- Joining end users and EO experts for developing **soil indices**, relevant for monitoring topsoil at **regional and continental** scales.

PROTOTYPE CHARACTERISTICS

- **Yearly estimations** of topsoil organic carbon at continental/regional scales.
- **Modular**: allowing future extension to additional soil indices.
- Spatial **resolution**: 100x100m and 50x50m

Case Studies	100x100m		50x50m	
	SOC Prediction	**Validation**	**SOC Prediction**	**Validation**
#1 Wallonia, Belgium	Yes	Yes	Yes	Yes
#2 Czech Republic	Yes	Yes	Yes	Yes
#3 Central Macedonia, Greece	Yes	Yes	Yes	Yes
Continental Europe	Yes			
#4 Pirasicaba, Sao Paulo, Brazil	Yes			

- Large multitemporal satellite **series** (3 years)
- **Confidence** metrics provision.
- **Validation** over the three European regions.

Phase 1

Phase 2

Phase 3

Sep.
2020

July
2021

Sep.
2021

Dec
2022

Jan
2023

April
2024

- Feasibility studies
- Requirements specification

- Design
- Implementation
- Testing
- Verification

- 1 year of operations
  - ✓ Wallonie (Belgium)
  - ✓ Czech Republic
  - ✓ Central Macedonia (Greece)
  - ✓ Pirasicaba (Brasil)

- Validation

Requirements
Workshop

Symposium
6-7/03/2024

ESA Symposium on Earth Observation for Soil Protection and Restoration, 06 – 07 March 2024, ESA-ESRIN, Frascati (Rome), Italy

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NRCs AND STEERING COMMITTEE

- **National Reference Centres for Soil**

- **Steering Committee**

STAKEHOLDERS
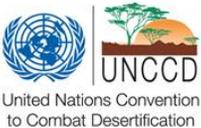
And many more to mention ……

PHASE 1 – FEASIBILITY & REQUIREMENTS

- **Feasibility studies – How well can EO measure SOC and other soil properties?**
  - Development of SOC prediction models for bare soils and vegetated soils.
  - Assessing the effects of applying laboratory spectral models to the remote sensing signal.
  - Combining prediction and Digital Soil Mapping.

- **Requirements gathering process – What are end users' needs/expectations?**
  - Large enquire questionnaire gathering **system** and **scientific** requirements and **implementation options.**
  - **Desirable** end users' requirements across the engaged community, some falling beyond the project's scope.

- **Reqs baseline consolidation – What requirements paved the project?**
  - Review process with Steering Committee, National Soil Reporting Centers and End Users.
  - Requirements Workshop – read here the report about **system and product** reqs.

- **System design – What system components assembled the system?**

  - Methodology and algorithm **theoretical** basis for SOC index, metadata, ancillary information and production workflow.

  - EO, in-situ and ancillary data/products **needed** for operation and validation.

  - Detailed **system architecture** and processing steps as per methodology above.

  - System implementation **plan**: data availability, storage, software libraries and tools, computing power required, operational costs.

  - Successful results during Acceptance Review (Nov. 2022)

- **System implementation – What technologies were used to attain the pipeline?**

 - Open Telekom Cloud Infrastructure
  - Docker & Kubernetes
  - Apache Airflow (scheduler and web user interface)
  - Object Storage service-S3 buckets

- **Production line: Deployment and Demonstration –** Functional system tests
  - ○ Successful results during Acceptance Review (Nov. 2022)
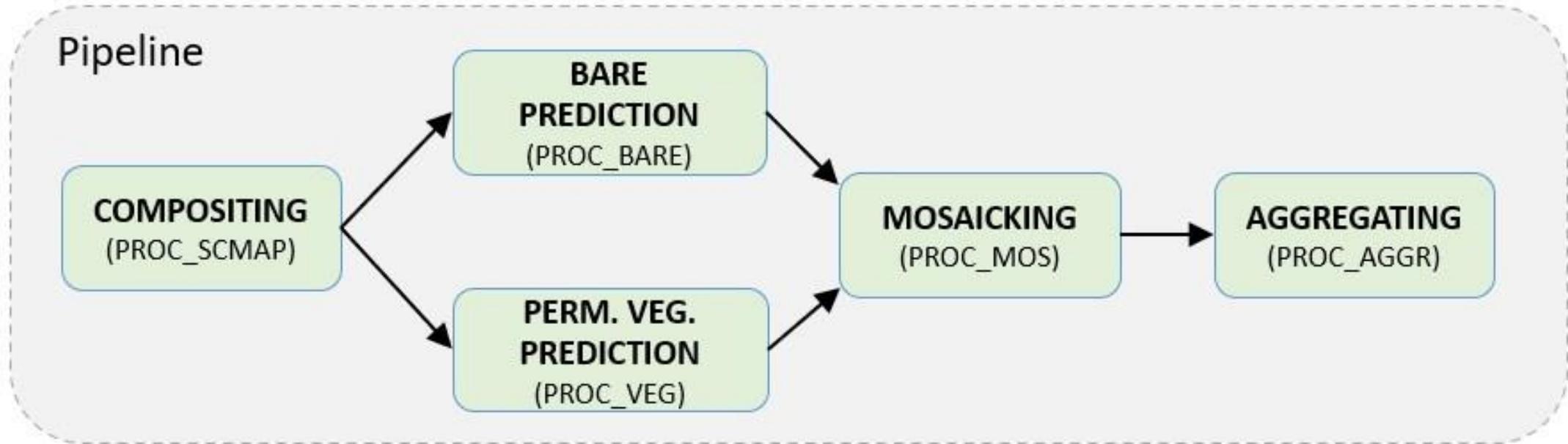
Outcomes – WORLDSOILS Graphic User Interface

o Developed by ISRIC

o Data visualisation and inspection

o Data download

Outcomes – Portfolio

- Visit portfolio details at https://world-soils.com/resources/portfolio/

| EO Product	Pixel Resolution (meters)	Minimum Mapping Unit (MMU, ha)	Periodicity and EO data
1. European topsoil SOC content	100 m	1 ha	Annual Integrating 3-years of Sentinel-2 imagery
2. SOC pixel based uncertainty			
3. Regional topsoil SOC content	50 m	0.25 ha	
4. SOC pixel based uncertainty			
5. Mean reflectance composites	20 m	0.04 ha	2018-2020, 2019-2021, 2020-2022
6. Bare soil mask			
7. Soil reflectance composite			
8. Bare soil frequency			
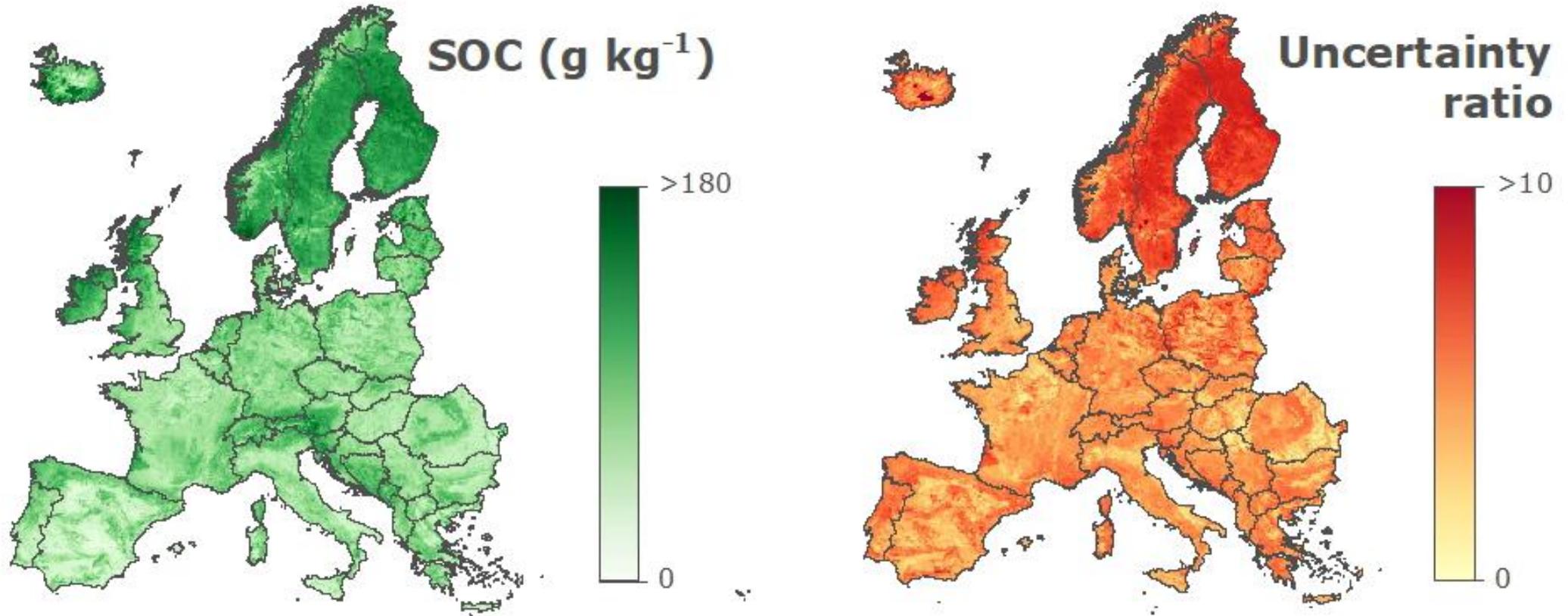
European Topsoil SOC

Regional Topsoil SOC
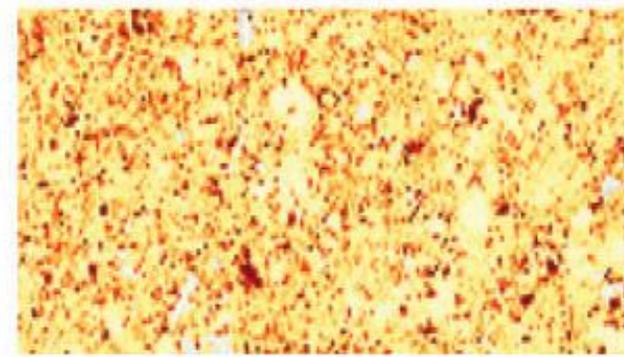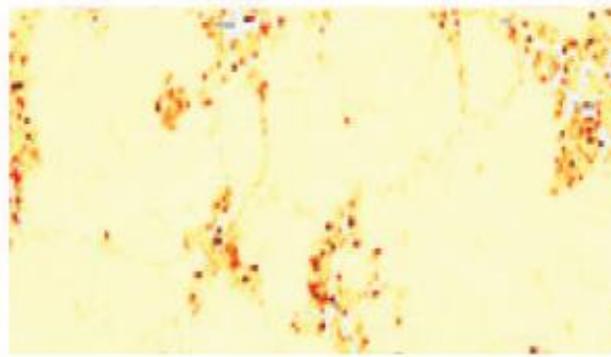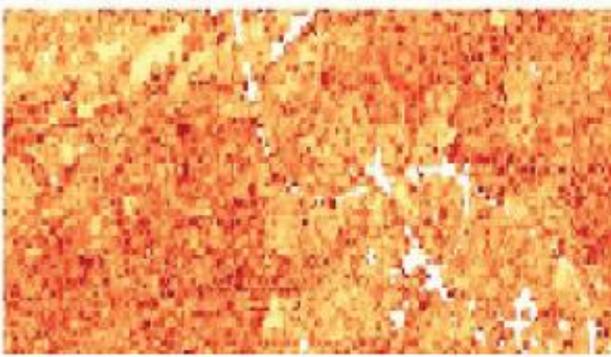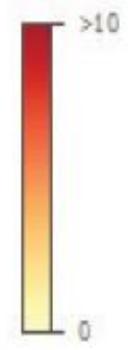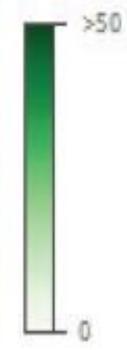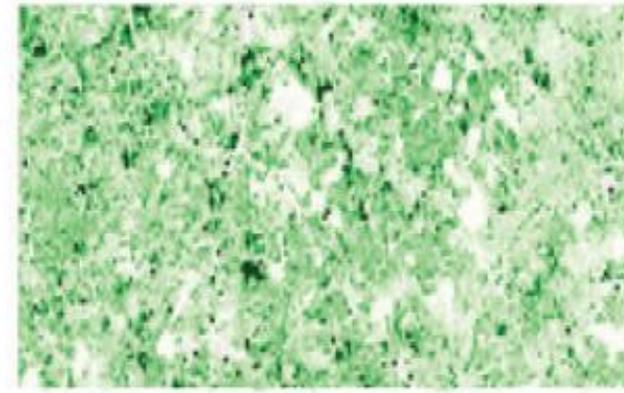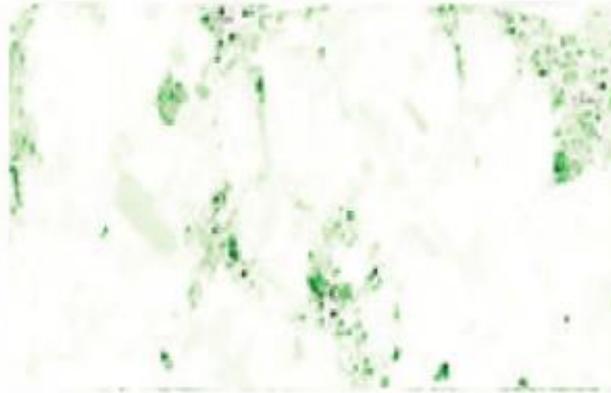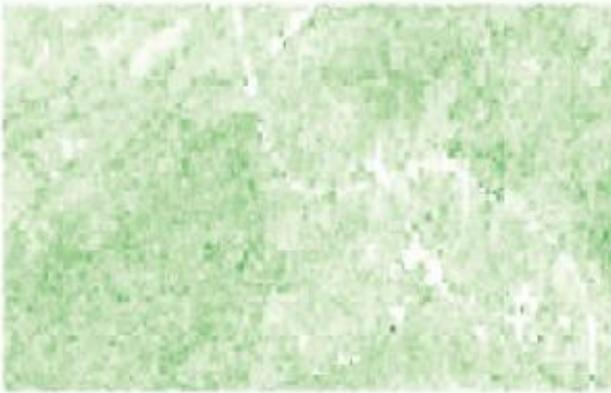
■ **Validation case studies – How has the system been validated?**

o Validation plan, with NRCs and Brazil → validation methods and metrics; validation input and reference data.

o Validation stages:

- ▪ Validation data sets description sheet

- ▪ Validation methodology (general and/or specifics per site)

- ▪ Results of internal validation process

- ▪ External validation and demonstration of final product by NCRs through a qualitative questionnaire

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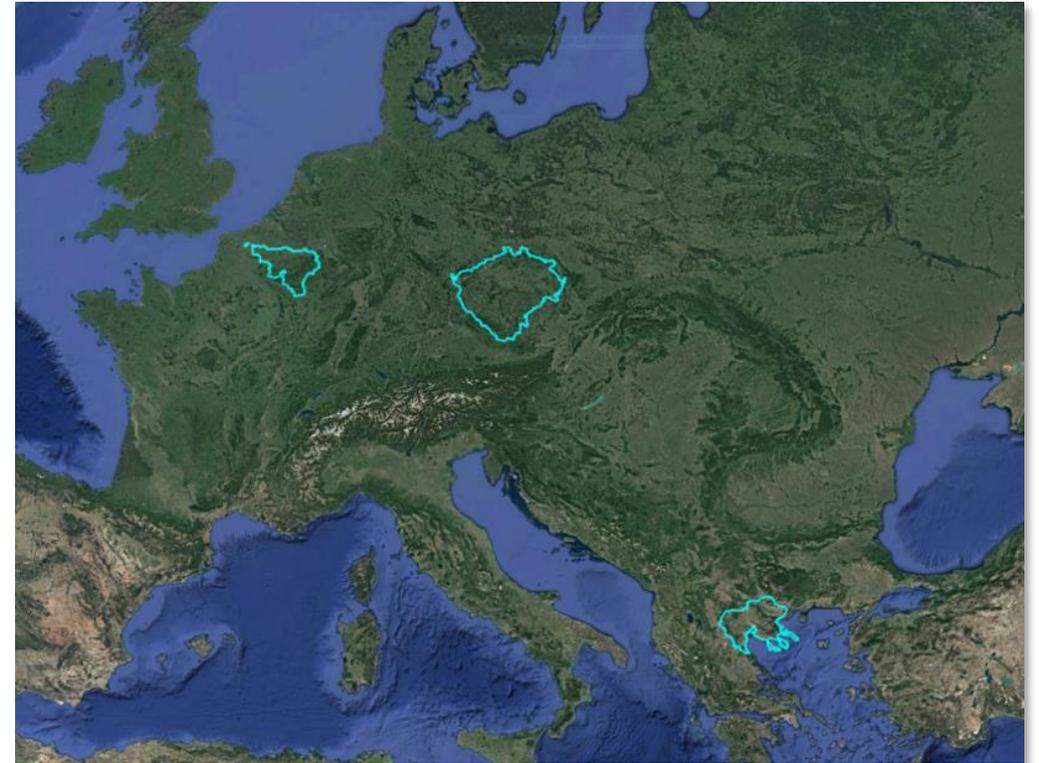
Validation against regional data sets

- Performance of the two SOC prediction models (vegetated & bare soils) →assessed by a rigorous ten-fold cross validation.

- 50m Product → Validation performed against an independent reference SOC dataset in agricultural soils provided by the National Reporting Centers on soils, distributed across agricultural land:
  - **Wallonia**: accuracy of the bare soil vs vegetated soil distinction of the Worldsoils model was very high
  - **Czech Republic**: tendency of the models to overpredict SOC values
  - **Macedonia**: mosaiced Mediterranean cropland pattern increases the difficulty of rigorous soil pixel assignation

- **Value of** multitemporal satellite spectral **composites** to derive soil properties

- **Methodology** to the operability of Algorithms

- Results in **each pilot area** in Europe: Wallonia, C: Macedonia, Czech Republic

- **Trial** in Piracicaba (Brazil). Projection of satellite SOC algorithms beyond regions.

- **Potential applications** of the WORLDSOILS model: SOC content evolution, comparison of SOC content in fields under conventional and conservation agriculture, spatial patters of SOC in agricultural soils

Thank you!

Presenter e-mail

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