EO for Monitoring, Reporting, and Verification of Carbon Removals

Copenhagen, October 8-11

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 (Europe)** 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.

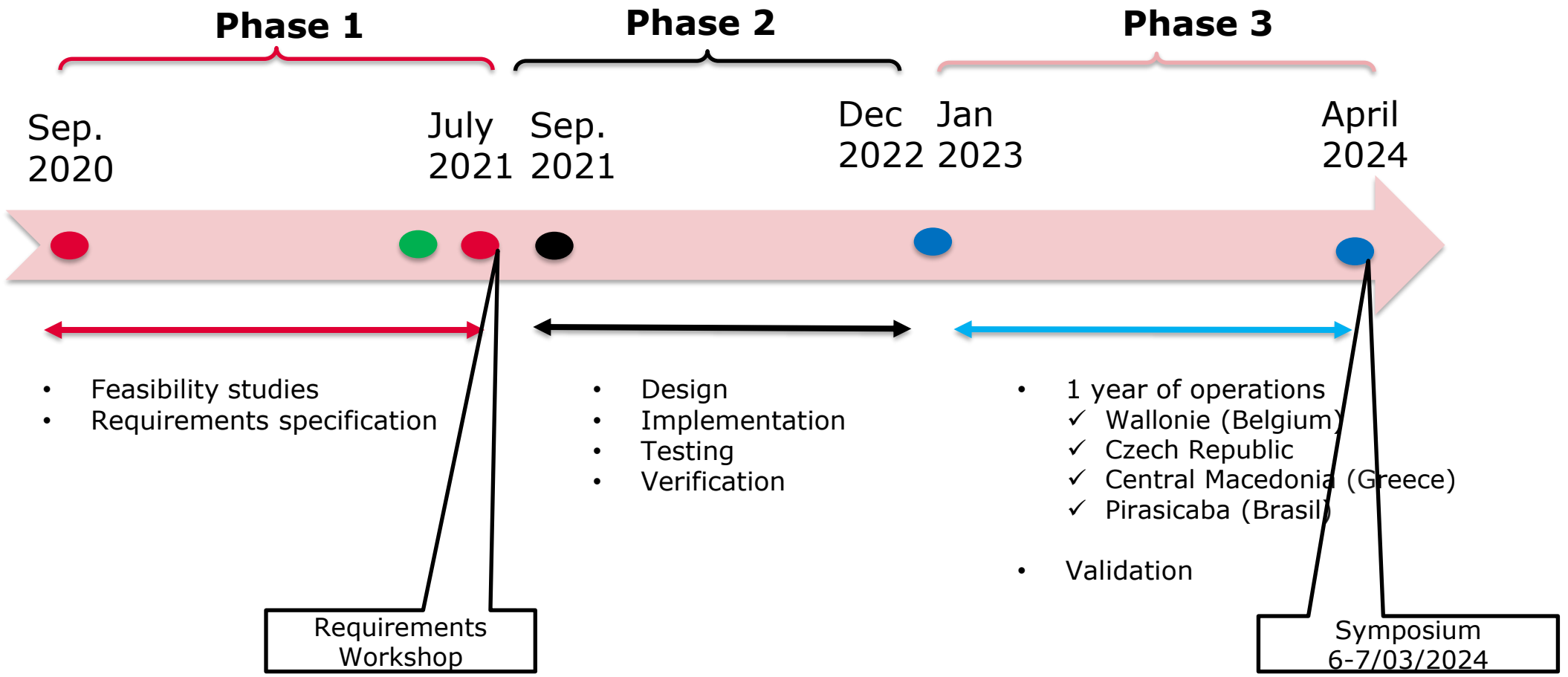
PROTOTYPE CHARACTERISTICS

- **Yearly estimations** of topsoil (0-20cm) SOC at continental/regional scales.
- **Modular**: allowing future extension to additional soil indices.
- Spatial **resolution**:100x100m and 50x50m

	100x100m		50x50m	
Case Studies	**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.

PHASES & ACTIONS



NRCs AND STEERING COMMITTEE

- **National Reference Centres for Soil**

- **Steering Committee**

STAKEHOLDERS

DEFIS

European Environment Agency

European Commission
Joint Research Centre

United Nations Convention to Combat Desertification

REGIONAL CENTRE FOR MAPPING OF RESOURCES FOR DEVELOPMENT

Food and Agriculture Organization of the United Nations

USP ESALQ

HARVEST

SWRI Soil and Water Resources Institute

Wallonie service public SPW

ÚKZÚZ

AgroParisTech
Talents d'une planète soutenable

Agroscope

NMA
NACIONALINĖ MOKĖJIMO AGENTŪRA

THE OHIO STATE UNIVERSITY

FACULTY OF SCIENCE AND MATHEMATICS · 1969 · NOVI SAD

AgroApps

Freie Universität Berlin

CQuest

waila
WELL INTENDED. WELL PERFORMED

DE DATABOERIN

inagro
ONDERZOEK & ADVIES IN LAND- & TUINBOUW

WAGENINGEN
UNIVERSITY & RESEARCH

CSIC
Consejo Superior de Investigaciones Científicas
VNIVERSITAT DE VALÈNCIA

The James Hutton Institute

PERSISTENCE
DATA MINING

Institute of Agricultural Research & Training

cirad
AGRICULTURAL RESEARCH FOR DEVELOPMENT

SOILCAPITAL

BGR

Cairo University

ResearchTurk Space

BOKU University of Natural Resources and Life Sciences, Vienna

Bodemkundige Dienst van België VZW

And many more to mention ……

WORLDSOILS

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?**
  - Questionnaire gathering **system** and **scientific** requirements and **implementation options.**
  - **Desirable** end users' requirements across the engaged community, some falling beyond the project's scope.

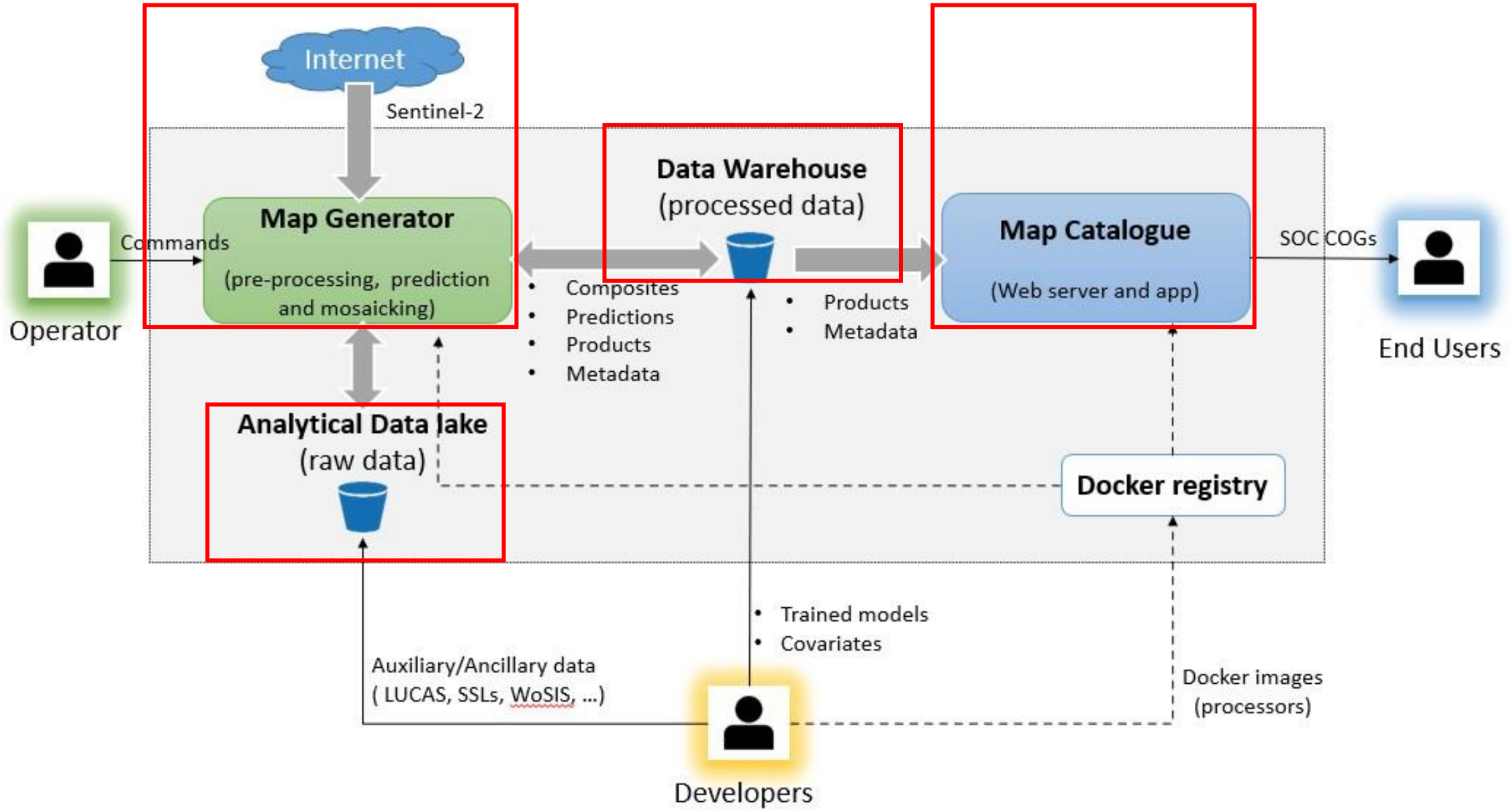
- **Reqs baseline consolidation – What requirements paved the project?**
  - Review process with Steering Committee, National Soil Reporting Centers and End Users.
  - Requirements Workshop – read here the report about **system and product** reqs.

PHASE 2 – WHAT'S THE SYSTEM LIKE?

- **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.

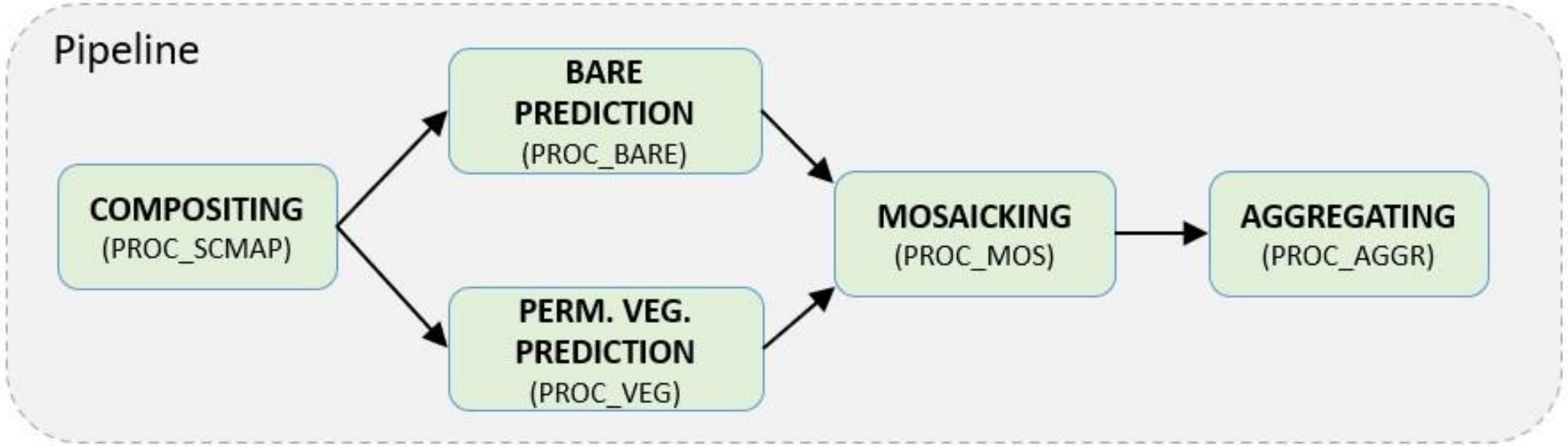
- **System implementation – What technologies were used to attain the pipeline?**
  - Open Telekom Cloud Infrastructure
  - Docker & Kubernetes
  - Apache Airflow (scheduler and web user interface)
  - Object Storage service-S3 buckets

MODULAR ARCHITECHTURE OF THE SOC PRETICTION SYSTEM



PHASE 2 – WHAT'S THE SYSTEM LIKE?

- **Production line: Deployment and Demonstration –** Functional system tests
  - Successful results during Acceptance Review (Nov. 2022)



Phase 3 – OUTCOMES & VALIADTION

Outcome – WORLDSOILS Graphic User Interface

- Developed by ISRIC
- Data visualisation and inspection
- Data download

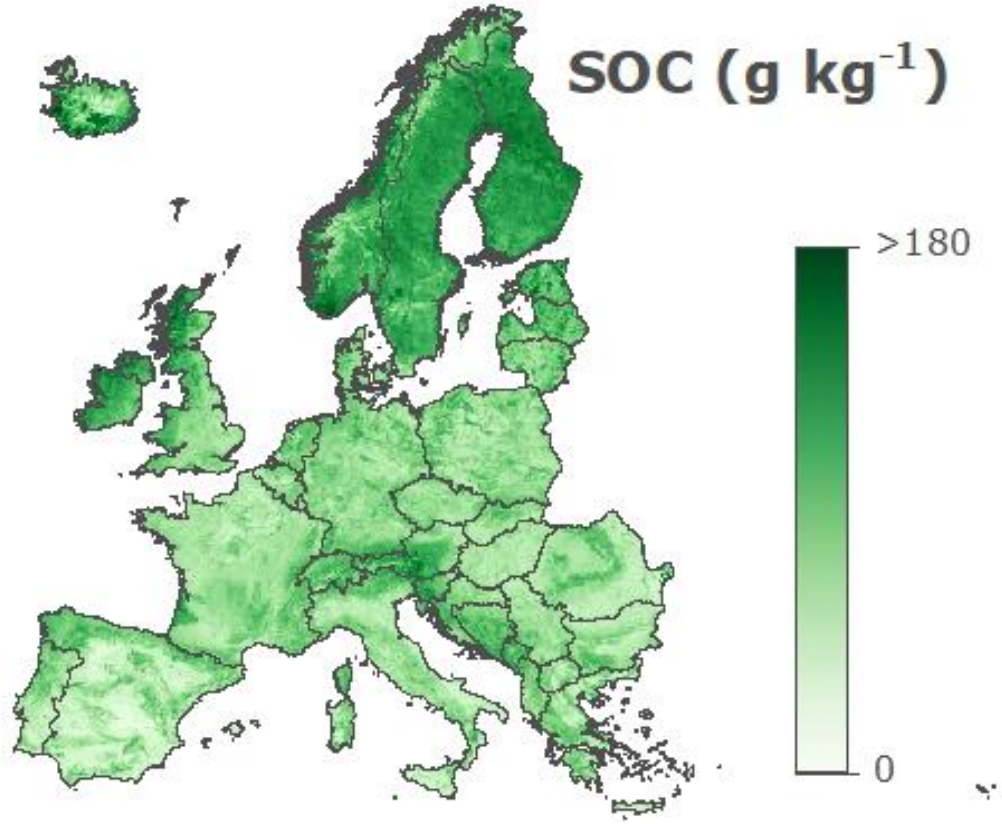
Outcomes – Portfolio

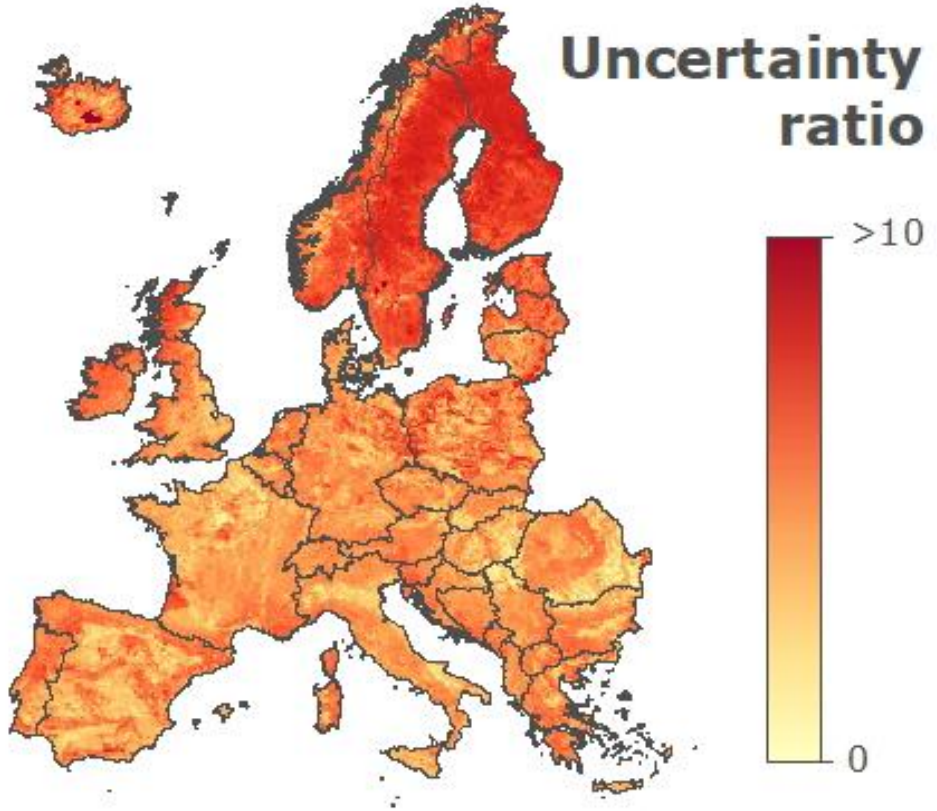
- Visit portfolio details at https://world-soils.com/resources/portfolio/

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 2018-2020, 2019-2021, 2020-2022
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	
6. Bare soil mask			
7. Soil reflectance composite			
8. Bare soil frequency			

Phase 3 – OUTCOMES & VALIADTION

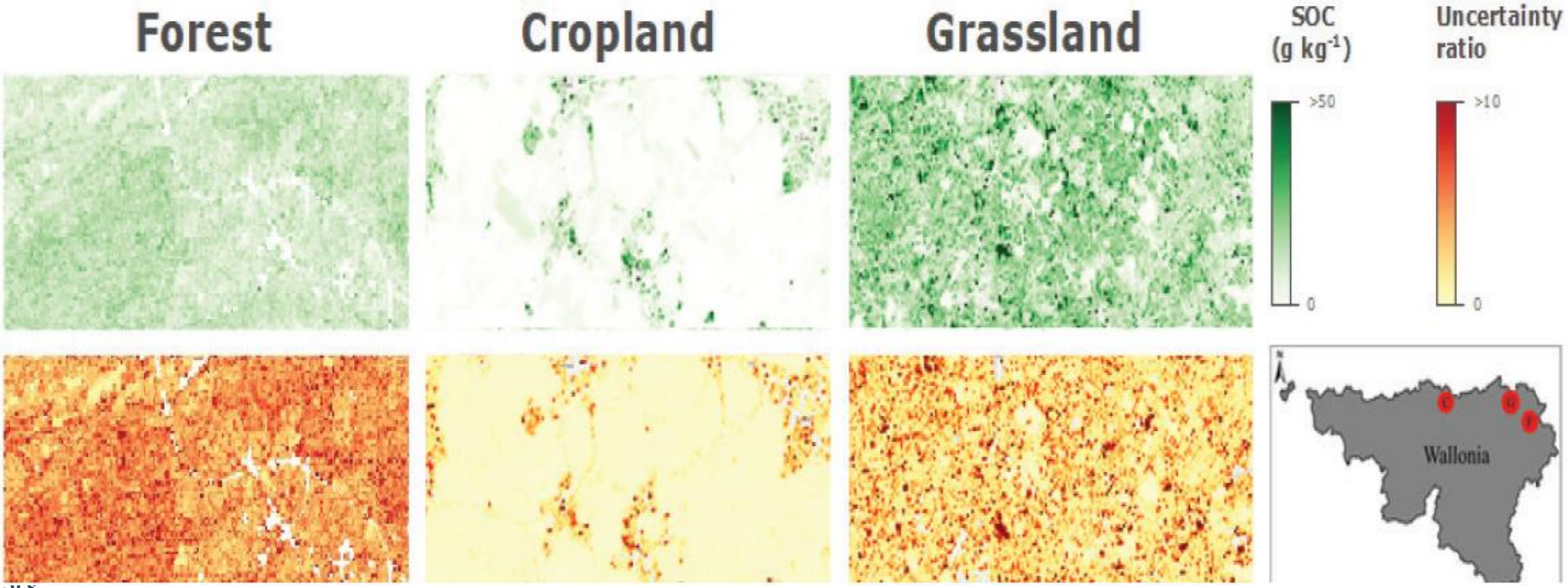
European Topsoil SOC





Phase 3 – OUTCOMES & VALIADTION

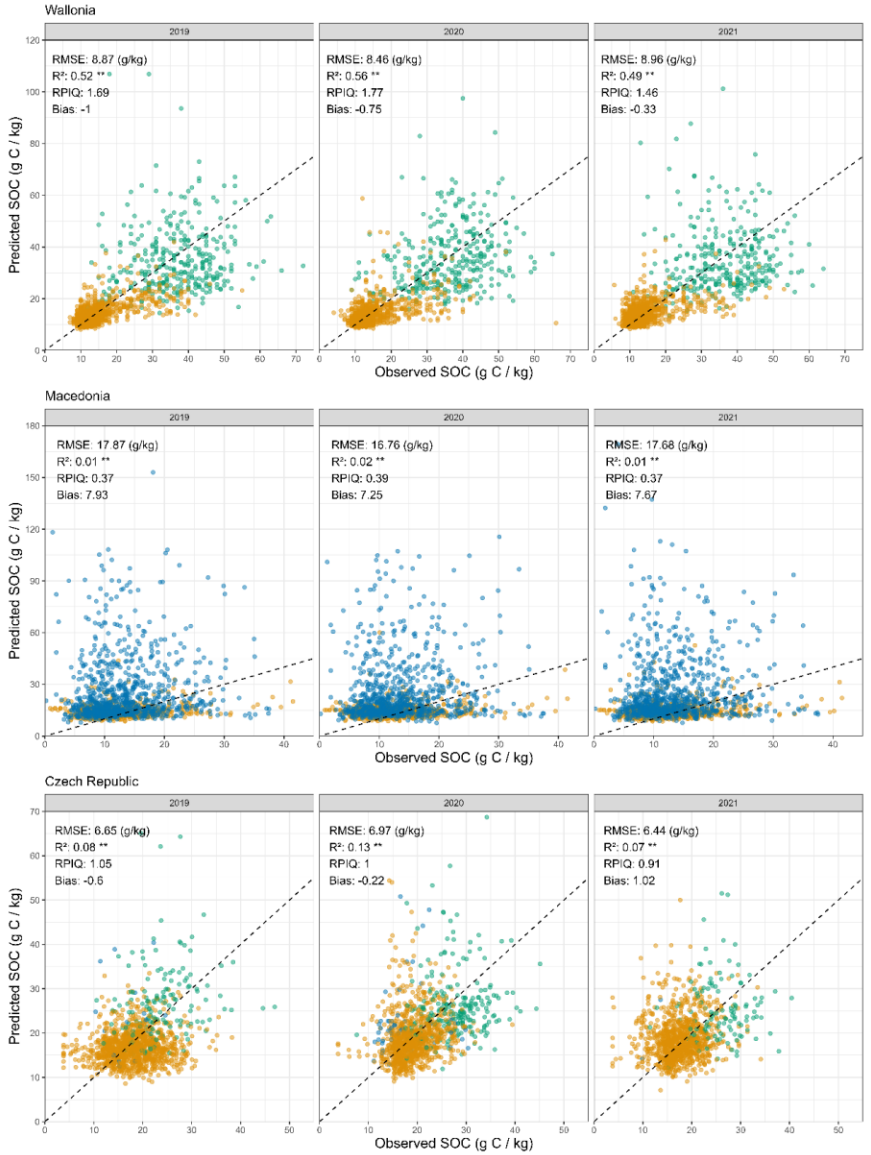
Regional Topsoil SOC



Phase 3 – OUTCOMES & VALIADTION

- **Published results in GEODERMA** (*under review*)
  - A European Soil Organic Carbon Monitoring System Leveraging Sentinel 2 Imagery and the Lucas Soil Data Base

- **Validation case studies – How has the system been validated?**
  - Validation plan, with NRCs and Brazil, for the various components
    - Attribution of the pixels to one of the two SOC algorithms
    - Mosaicking
    - Aggregation from the Sentinel 2 resolution to the 50 m (regions) and 100 m resolution (Europe)



Predicted versus observed SOC contents for agricultural soils, top: Wallonia, middle: Macedonia, bottom: Czech Republic. Symbols: annual crops in orange, tree crops in blue and grasslands in green

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

WAY FORWARD

- **Value of** multitemporal satellite spectral **composites** to derive soil properties
- **Refine Methodology** to the operability of Algorithms (semiarid areas)
- Results in **each pilot area** in Europe: Wallonia,Macedonia, Czech Republic
- **Extend Trials** in Piracicaba (Brazil), Africa, Asia . Projection of satellite SOC algorithms beyond EU 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, an indicator for the length of the bare soil exposure during the growing season

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