MONITORING SOIL PARAMETERS: EARTH OBSERVATION AS A TRUSTWORTHY TECHNIQUE

Earth Observation as a trustworthy technique for monitoring soil parameters

(6 minute presentations)

Calogero Schillaci and the EUSO Team
European Soil Observatory
European Commission - JRC Ispra

ESA Symposium on Earth Observation for Soil Protection and Restoration

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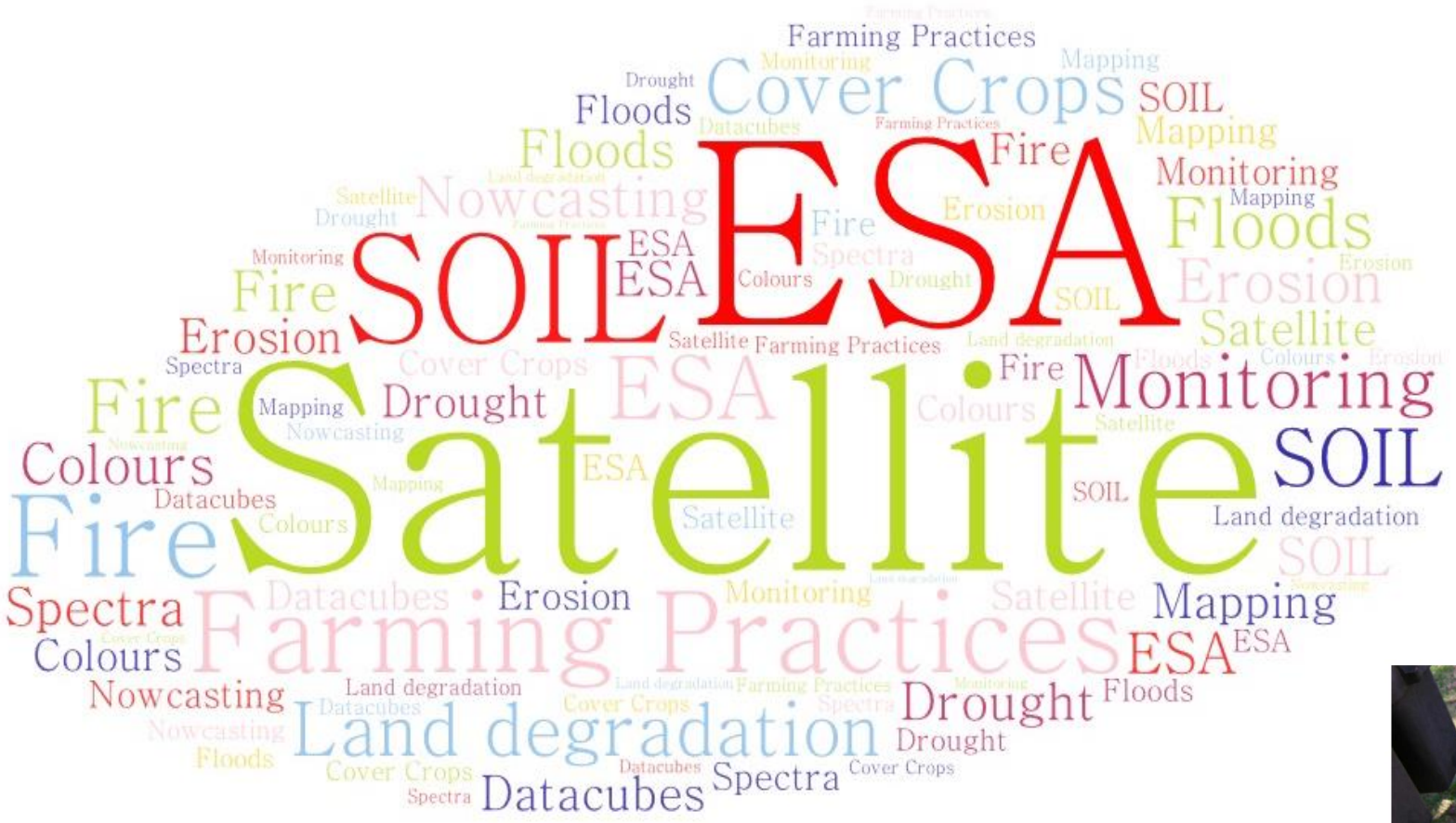

Our soils, the earth upper surface, with its key role for terrestrial life functions: plant growth, gas exchange with the atmosphere, retention of water and nutrients, among the objectives of many of us, …Soils are being rediscovered from numerous stand viewpoints: biochemical, ecologic, technical, analytical, social, policy, economic, etc..

Earth Observation (EO) and Copernicus data are needed for achieving the objectives, the scientific community, “policy stakeholders” will serve to monitor the requirements of the various soil health indicators stated in the law

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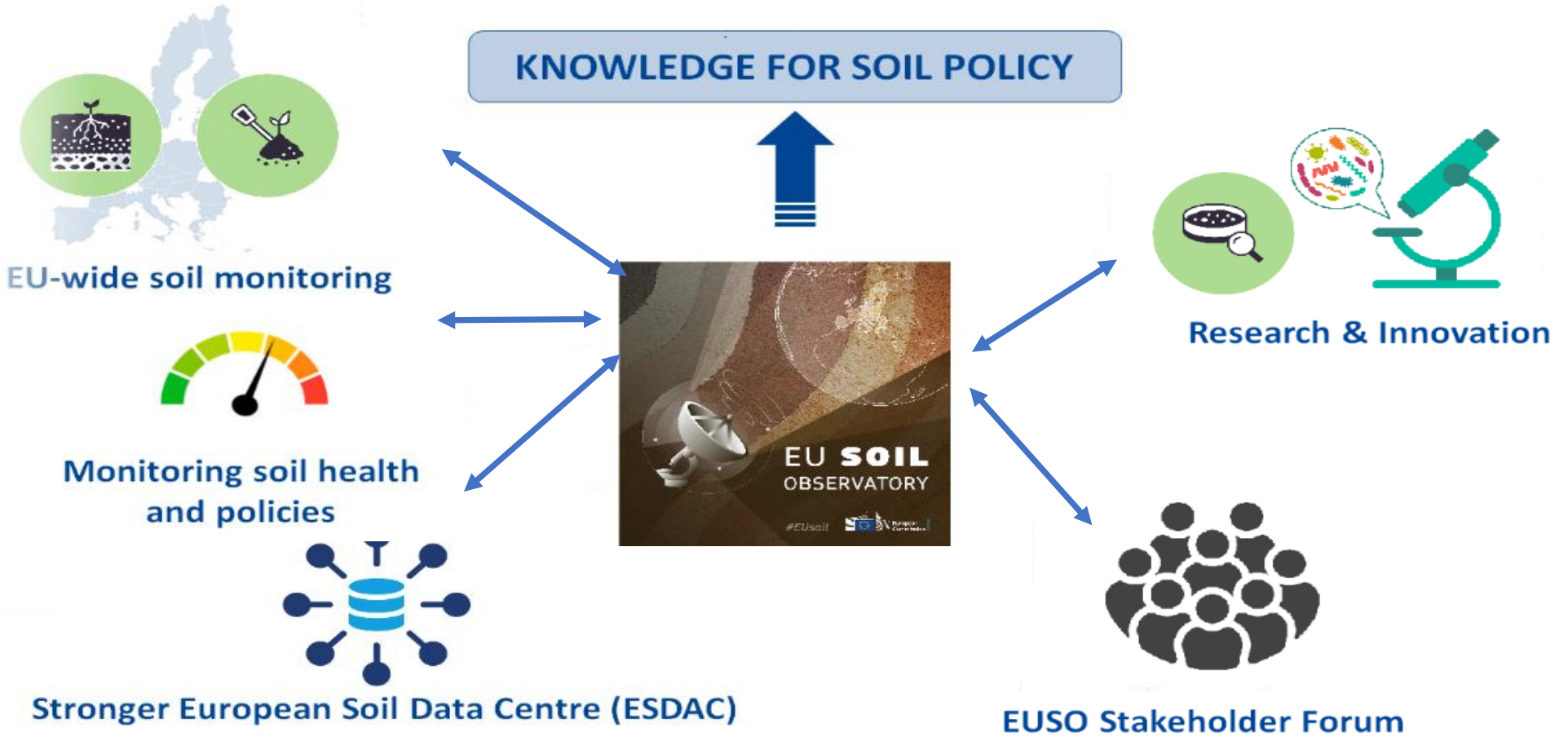
1. We need data flows to populate indicators of soil health and create knowledge for policy



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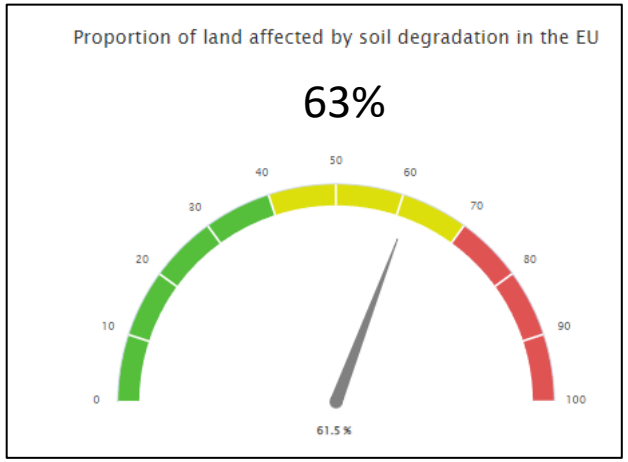
2. **EUSO Soil Dashboard** is based on the convergence of scientific evidence – question how to monitor change. How can EO help?

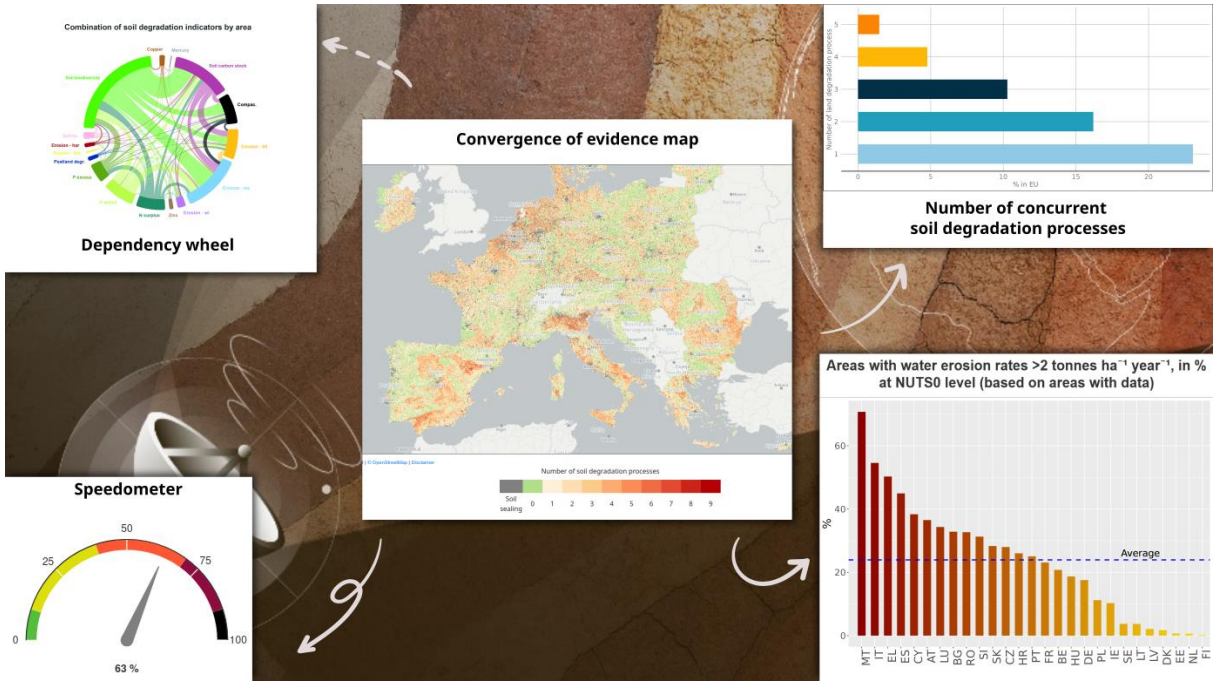
Convergence of scientific evidence

- 18 Soil degradation indicators
- 63 % of unhealthy soils
- Dashboard shows location and different types of soil degradation in the EU

Assessing Policy Impact

https://esdac.jrc.ec.europa.eu/esdacviewer/euso-dashboard/





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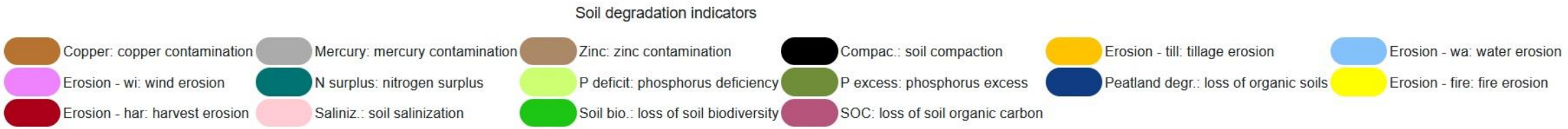
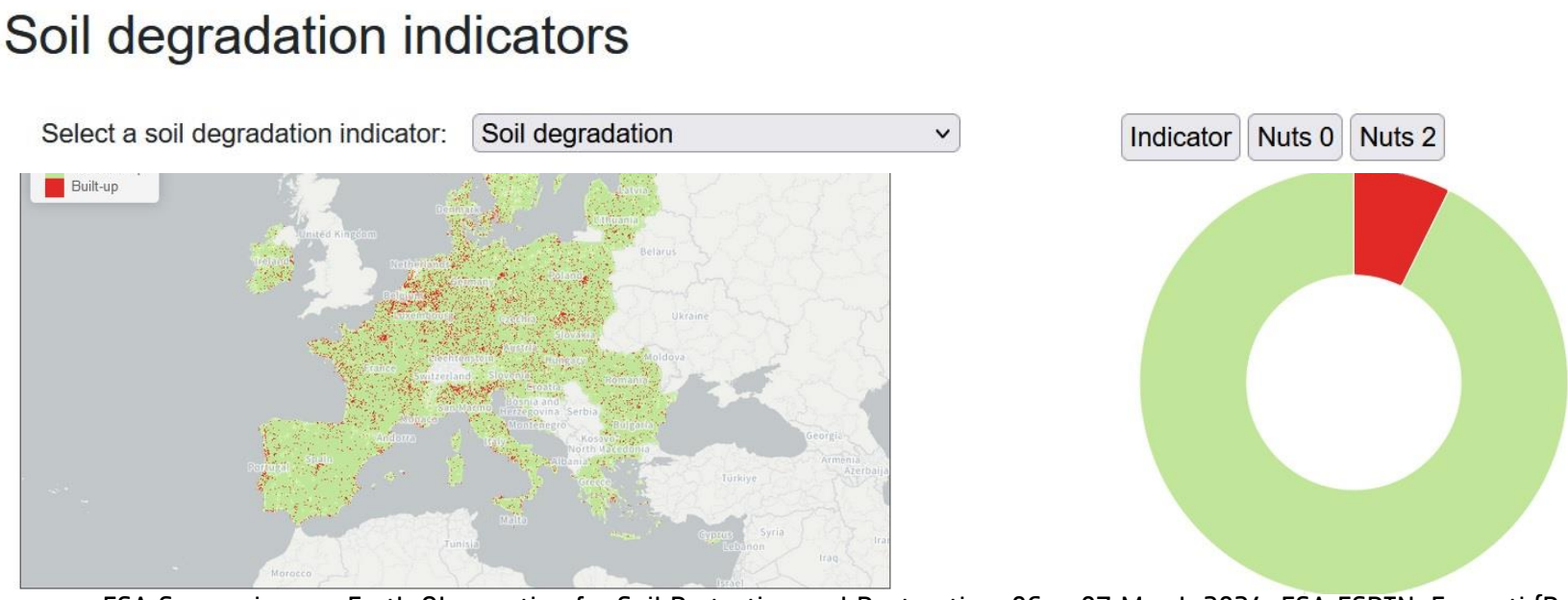
3. Out of all indicators, only soil sealing comes from EO directly, in other indicators EO data are co-variat





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4. Imperviousness/ Sealing Copernicus Land Monitoring Service CLMS

Copernicus — Land Monitoring Service

CLMS portfolio | Dataset catalogue | Data viewer | Use cases | About us

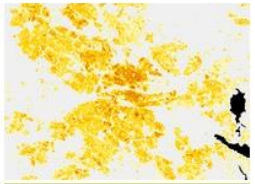
Home > CLMS portfolio > High Resolution Layer Impervious Built-up > Impervious Built-up 2018 (raster 10 m and 100 m), Europe, 3-yearly

Impervious Built-up 2018 (raster 10 m and 100 m), Europe, 3-yearly

General Info

Download

Provides at pan-European level in the spatial resolution of 10 m binary information (building / no building) within the sealing outline derived from the Imperviousness Density 2018 including the aggregated Share of Built-up layer in the spatial resolution of 100 m showing the percentage of built-up areas across Europe.



View in the data viewer

Validation status

Validated

Dataset citation

- **DOI (raster 100 m):** https://doi.org/10.2909/a807e528-431a-4dca-a6cd-0e8947563fce
- **DOI (raster 10 m):** https://doi.org/10.2909/3e412def-a4e6-4413-98bb-42b571afd15e

You can find instructions on how to cite CLMS data in our Data policy section.

Services

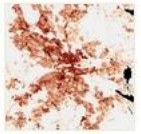
WMS

REST API

Characteristics

Release / Major version: V1	Temporal extent: 2017-2019	Type: Satellite products	Position accuracy: According to ortho-rectified satellite image
Projection: EPSG:3035	Temporal usability: Archive with regular updates	Platform: Sentinel-2	Thematic accuracy: ≥ 90%
Spatial coverage: Europe	Update frequency: 3-yearly		
Spatial resolution:			

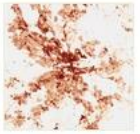
Datasets



Imperviousness Density 2018 (raster 10 m and 100 m), Europe, 3-yearly

Provides at pan-European level in the spatial resolution of 10 m and 100 m the sealing density in the range from 0% to 100% for the 2018 reference year.

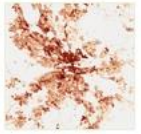
View more | Download | View in the data viewer



Imperviousness Density 2015 (raster 20 m and 100 m), Europe, 3-yearly

Provides at pan-European level in the spatial resolution of 20 m and 100 m the sealing density in the range from 0% to 100% for the 2015 reference year.

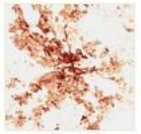
View more | Download | View in the data viewer



Imperviousness Density 2012 (raster 20 m and 100 m), Europe, 3-yearly

Provides at pan-European level in the spatial resolution of 20 m and 100 m the sealing density in the range from 0% to 100% for the 2012 reference year.

View more | Download | View in the data viewer



Imperviousness Density 2009 (raster 20 m and 100 m), Europe, 3-yearly

Provides at pan-European level in the spatial resolution of 20 m and 100 m the sealing density in the range from 0% to 100% for the 2009 reference year.

View more | Download | View in the data viewer

Imperviousness Density 2006 (raster 20 m and 100 m), Europe, 3-yearly

Provides at pan-European level in the spatial resolution of 20 m and 100 m the sealing density in the range from 0% to 100% for the 2006 reference year.

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5. Other indicators currently possible from EO ?

→ EO data for **Management Practices** (tillage intensity, cover crops, irrigation)

→ EO data used as parameters of models or as covariates for **soil spatial modelling** (geostatistics and AI)

→EO data high resolution **Digital Elevation Models** and **Vegetation indices** (Net primary productivity, biomass)

→ EO data for **soil salinity**

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6. Some 1st principles, to classify and monitor land objects with EO we are trying to use reflected energy, radar frequencies

→ this implies that by using EO as a proxy for soil assessment we replicate complex laboratory techniques e.g.

- Nutrient content
- N
- P
- K
- Micronutrients (Zn, Br, Mn, …)
- Abundance of salts
- NaCL
- K2O
- Texture,
- Clay
- Sand
- Silt
- Moisture
- Wilting point
- Ksat
- Temperature
- Tmax
- T min
- Prolonged droughts

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7. Many of promising case studies on soils (you can find some example, soil moisture, albedo) but to date, very limited operational services specifically on soils.

Normalized Difference Vegetation Index

The Normalized Difference Vegetation Index (NDVI) is an indicator of the greenness of the biomes.

Even though it is not a physical property of the vegetation cover, its very simple formulation
NDVI = (REF_nir – REF_red)/(REF_nir + REF_red)
where REF_nir and REF_red are the spectral reflectances measured in the near infrared and red wavebands respectively, makes it widely used for ecosystems monitoring.

NDVI product updates

NDVI 300m - reprocessing for missing blocks in October and November 2023 products
Fri, 22 Dec 2023
NDVI 300m for July 2022 reprocessed
Mon, 27 Mar 2023

Often these products comes in temporal series and need to be harmonized to be effective for soil modelling

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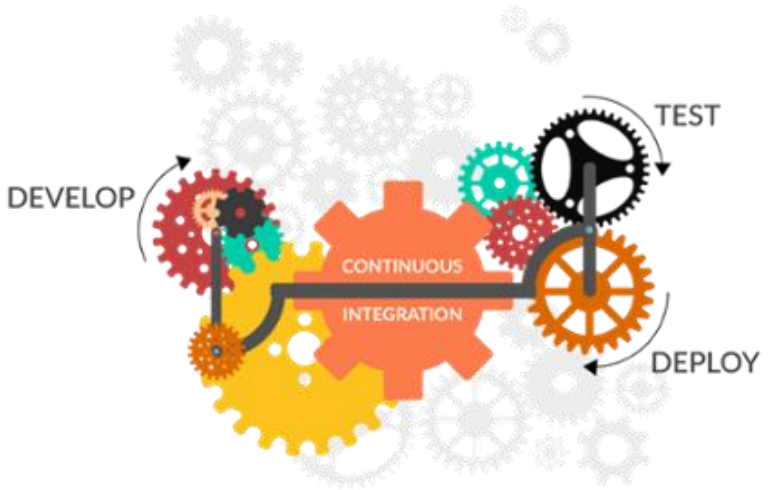
8. Now we have the WORLDSOILS Carbon product

→ It need commitment from ESA/COPERNICUS for repeat and continued development

→ Continuous development and temporal release of the product will allow for wide usage and extensive validation (e.g with LUCAS soil organic carbon).



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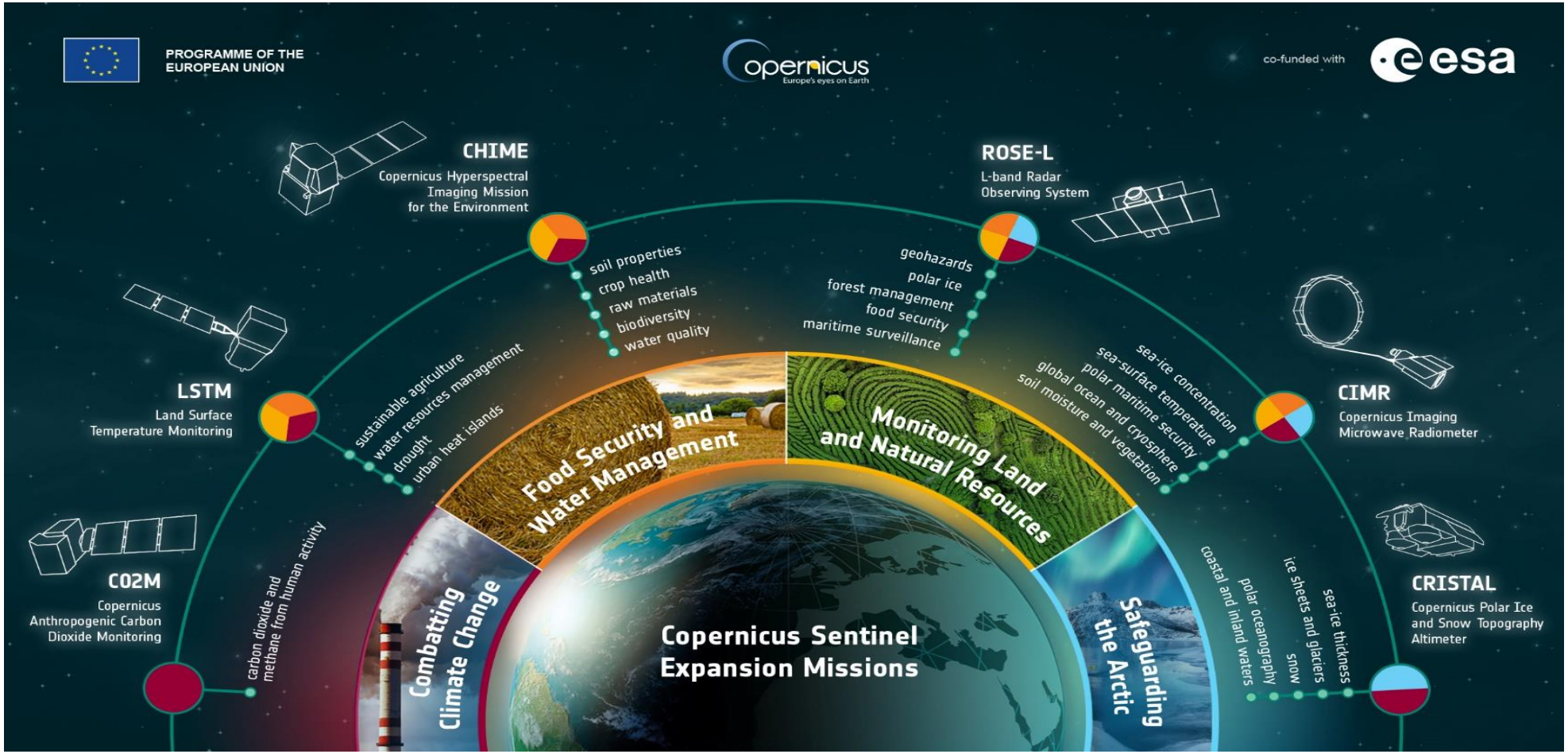
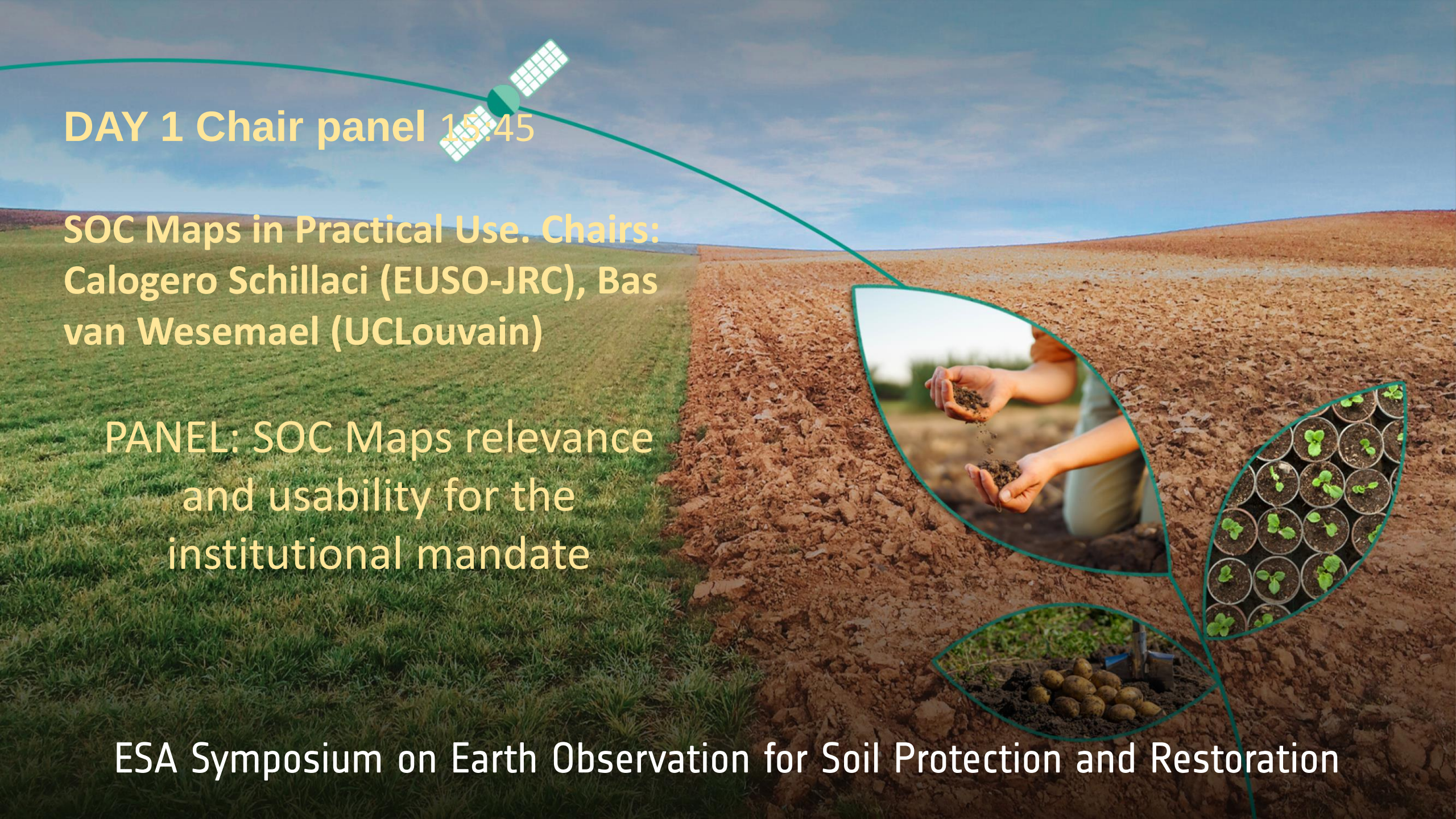
9. Lot of promise in COPERNICUS Expansion Programme this will be discussed in the session 5





DAY 1 Chair panel 15:45

SOC Maps in Practical Use. Chairs: Calogero Schillaci (EUSO-JRC), Bas van Wesemael (UCLouvain)

PANEL: SOC Maps relevance and usability for the institutional mandate

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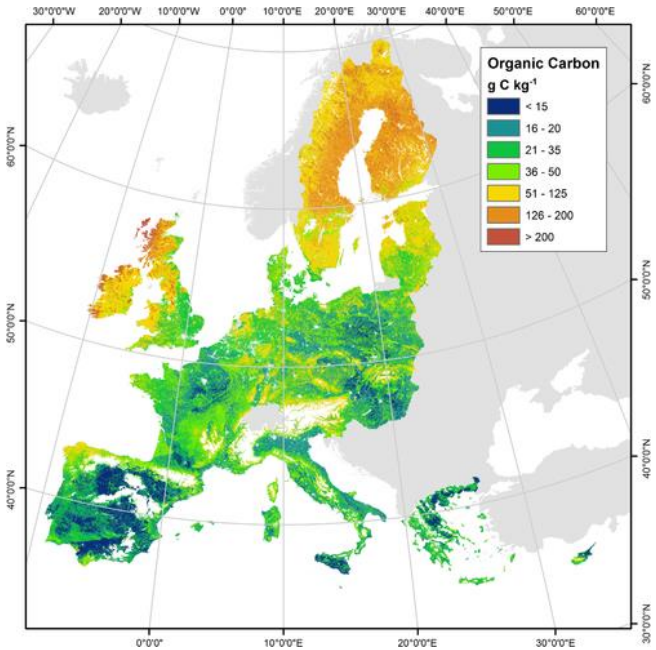
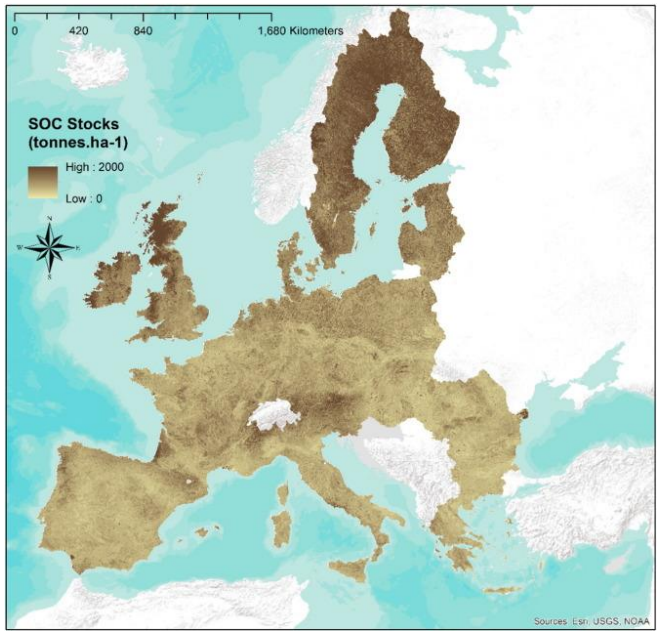
JRC has developed several SOC assessment at European Scale based on LUCAS

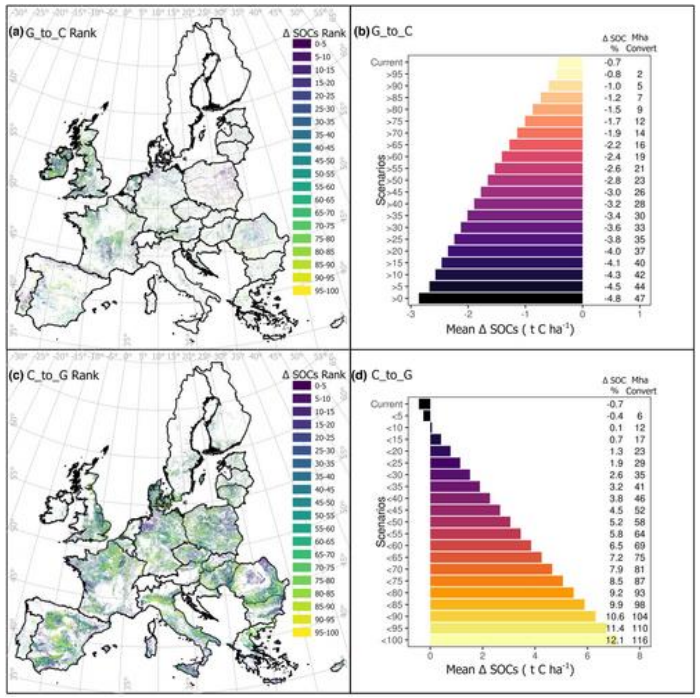
- These are used in policy implementation and monitorig (e.g CAP, SML, NRL, CRCF)
- Thanks to the unprecedented EO high resolution (spectral, spatial and temporal) over continental areas, are an essential component for monitoring the SOC seamlessly



A map of the topsoil organic carbon content of Europe generated by a generalized additive model, De Brogniez et al 2015



Assessment of soil organic carbon stocks under future climate and land cover changes in Europe, Yigini and Panagos 2016,



Soil organic carbon stocks in European croplands and grasslands: How much have we lost in the past decade? De Rosa et al. 2024

DAY 1 WORLDSOILS SOC Prediction Maps Results and Way Forward 16:30-17.

Conclusion and way forward

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Day 2 9:00-9:30 PARALLEL SESSIONS IN MAGELLAN (Hall 2)

Keynote SESSION 5 - ADVANCED SATELLITE INSTRUMENTATION FOR SOIL HEALTH

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1. Why we need EO for soil monitoring?

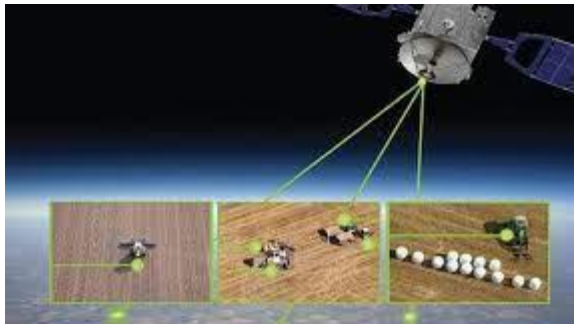
→ **Monitoring our soils**

→ **Earth Observation (EO) and Copernicus**

→ **The scientific community**

→ **Policy stakeholders**

→ **Soil health indicators stated in the law**



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2. Scientific peer-review literature

European Space Agency - ESA

8-10 rue Mario Nikis, Paris
France
Affiliation ID: 60029398
Other name formats: European Space Agency, European Space Agency (esa), Esa, European Space Agency (esa-estec), European Space Agency (esa/estec), European Space Agency (esa, Esa Neo Coordination Centre, Rhea For European Space Agency (esa), Aurora Technology For European Space Agency (esa), Esa Headquarters

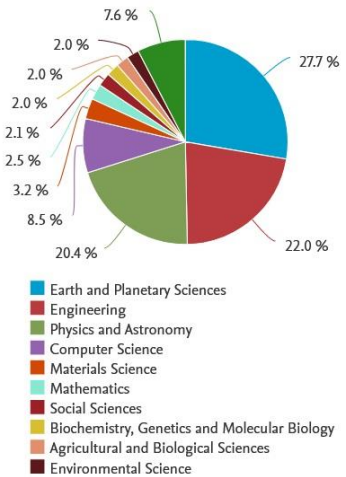
Affiliation profile actions
Give feedback
Set document alert
Export subject area data

Documents by subject area | Collaborating affiliations | Documents by source

Sort by: Document count (high-low)

Earth and Planetary Sciences	4101	Energy	89
Engineering	3258	Pharmacology, Toxicology and Pharmaceutics	68
Physics and Astronomy	3027	Neuroscience	44
Computer Science	1264	Arts and Humanities	36
Materials Science	477	Economics, Econometrics and Finance	36
Mathematics	364	Decision Sciences	32
Social Sciences	313	Immunology and Microbiology	30
Biochemistry, Genetics and Molecular Biology	296	Business, Management and Accounting	25
Agricultural and Biological Sciences	292	Nursing	18
Environmental Science	291	Health Professions	15
Chemistry	277	Psychology	8
Medicine	249	Veterinary	2
Multidisciplinary	103	Dentistry	1

European Space Agency - ESA



ESRIN - ESA Centre for Earth Observation

Frascati
RM, Italy
Affiliation ID: 60073749
Other name formats: Esrin, Esa-esrin, Esa/esrin, Esa Esrin, European Space Research Institute, European Space Research Institute (esrin), European Space Agency, C/o Esrin, European Space Agency (esa-esrin), European Space Agency/esrin

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Documents by subject area | Collaborating affiliations | Documents by source

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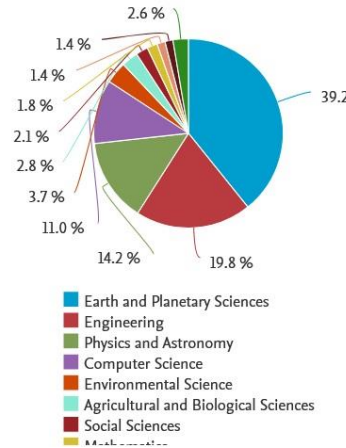
Earth and Planetary Sciences	1504	Multidisciplinary	23
Engineering	759	Chemical Engineering	20
Physics and Astronomy	546	Chemistry	20
Computer Science	420	Decision Sciences	11
Environmental Science	143	Medicine	10
Agricultural and Biological Sciences	109	Biochemistry, Genetics and Molecular Biol...	8
Social Sciences	79	Business, Management and Accounting	5
Mathematics	68	Economics, Econometrics and Finance	2
Materials Science	53	Arts and Humanities	1
Energy	52	Neuroscience	1

ESRIN - ESA Centre for Earth Observation



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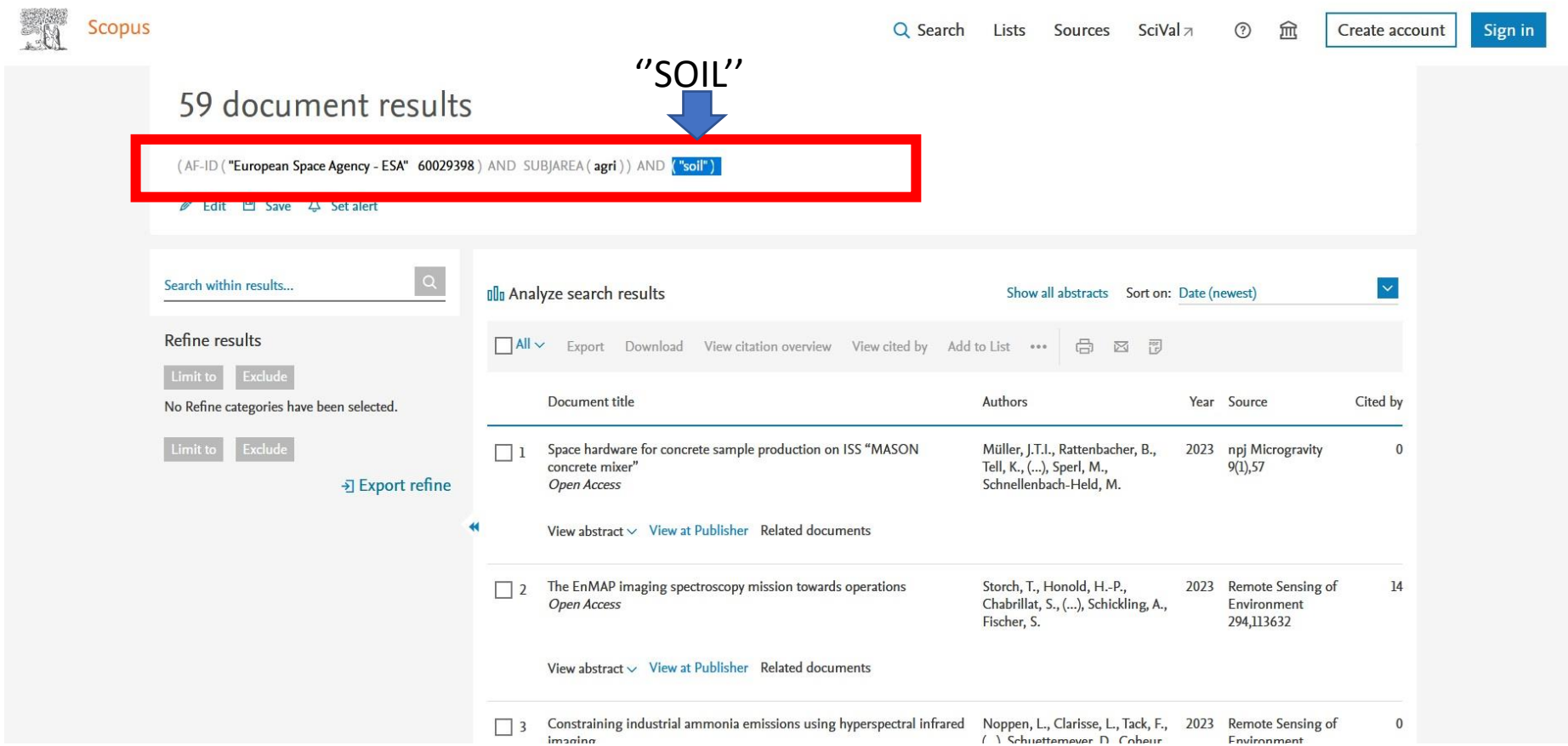
2. Scientific peer-review literature



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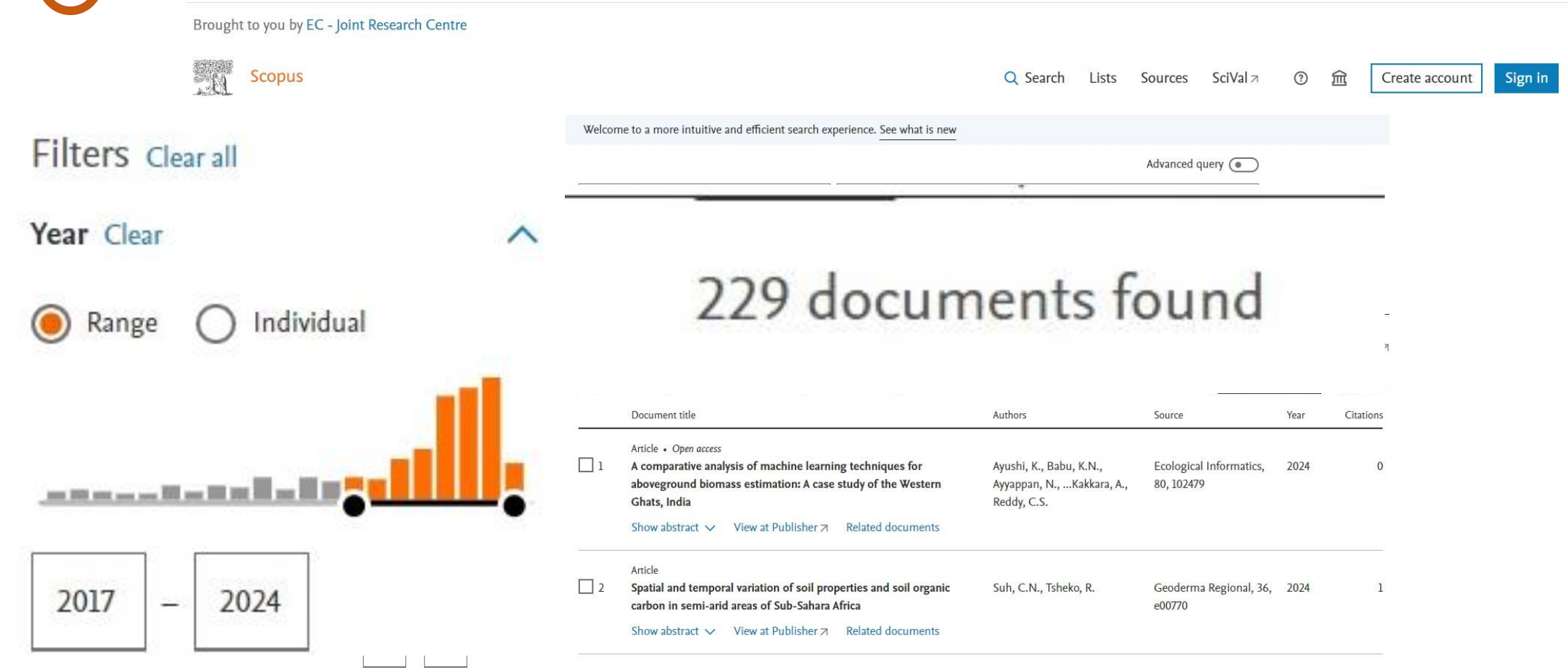

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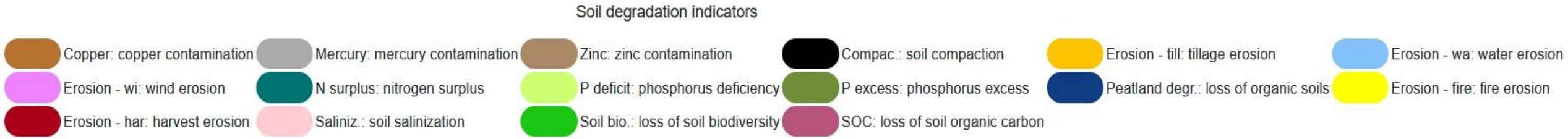
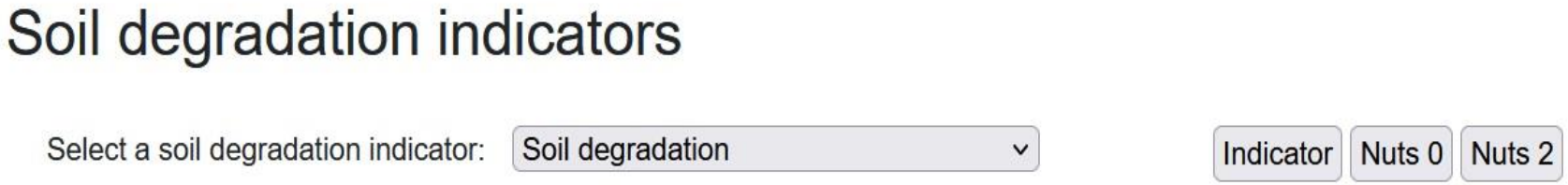
3. To populate the **EUSO dashboard** with soil indicators we need numerous EO data to provide valuable indicators of soil health





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3. **EUSO Soil Dashboard** is based on the convergence of scientific evidence – question how to monitor change. How can EO help?

Convergence of scientific evidence

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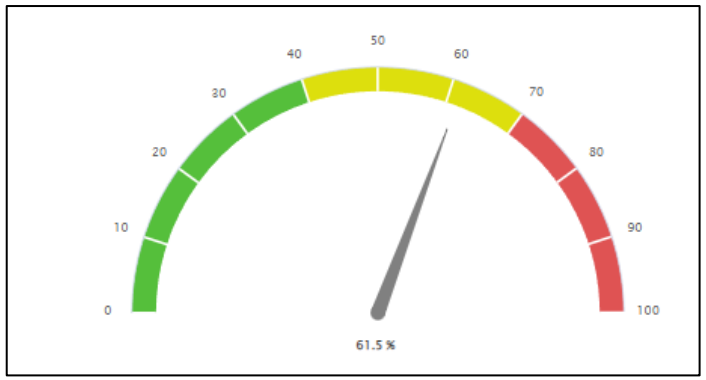
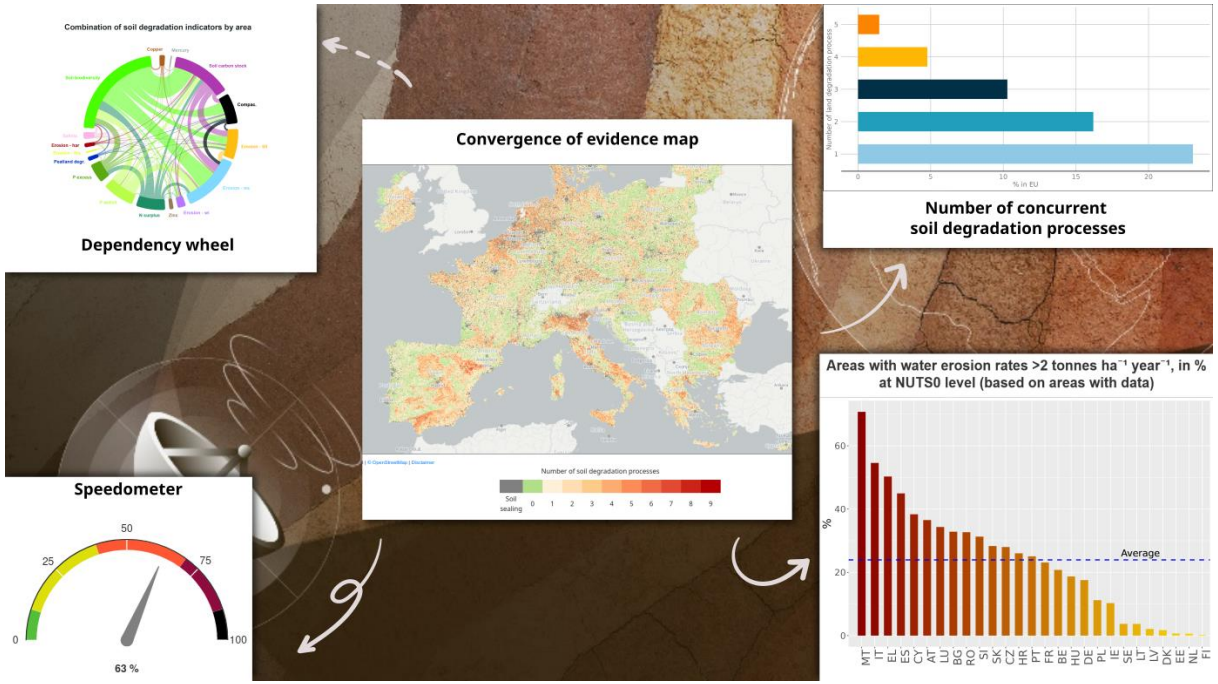
- Dashboard shows location and different types of soil degradation in the EU



Proportion of land affected by soil degradation in the EU

Assessing Policy Impact

https://esdac.jrc.ec.europa.eu/esdacviewer/euso-dashboard/



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3. In EUSO Dashboard **Convergence of Evidence** is used to stack together the soil threats and determine how much pressure is occurring in each unit (pixel)

→ question **how to monitor change**. How can EO help map soil degradation processes?

As a committment on the soil strategy the soil monitoring law is expected to come bringing some key changes in EU

- By **2050**, all EU soil ecosystems are in **healthy** condition and are thus more **resilient**, which will require very **decisive changes** in this decade.
- By then, **protection, sustainable use and restoration of soil** has become the norm.
- Healthy soils are essential to achieve **climate neutrality**, a clean and **circular economy**, revert **biodiversity loss**, safeguard **human health**, halt **desertification** and revert **land degradation**.
- Legislative proposal by 2023

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4. The new soil monitoring directive[1] relies on soil monitoring network and soil Indicators – are we able to derive them from EO – why not?

→ **Sensors** and products predominantly designed for vegetation.

→ In addition, remote sensing data **acquisition** and **accuracy** can be limited under dense vegetation cover with the obstructed view of the **soil surface** making it impossible to directly detect soil characteristics.

Soil descriptor	**aspect of soil degradation**
Electrical Conductivity	salinization
Soil erosion rate	loss of soil by erosion
SOC concentration	loss of organic matter
Bulk density in subsoil	compaction
Bulk density in topsoil	
Extractable phosphorus	excess nutrients
Nitrogen in soil	
Concentration of heavy metals	contamination
Concentration of other contaminants	
Soil water holding capacity	loss of capacity for water retention
Soil acidity (pH)	acidification
Soil basal respiration	loss of soil biodiversity

Soil basal respiration	loss of soil biodiversity

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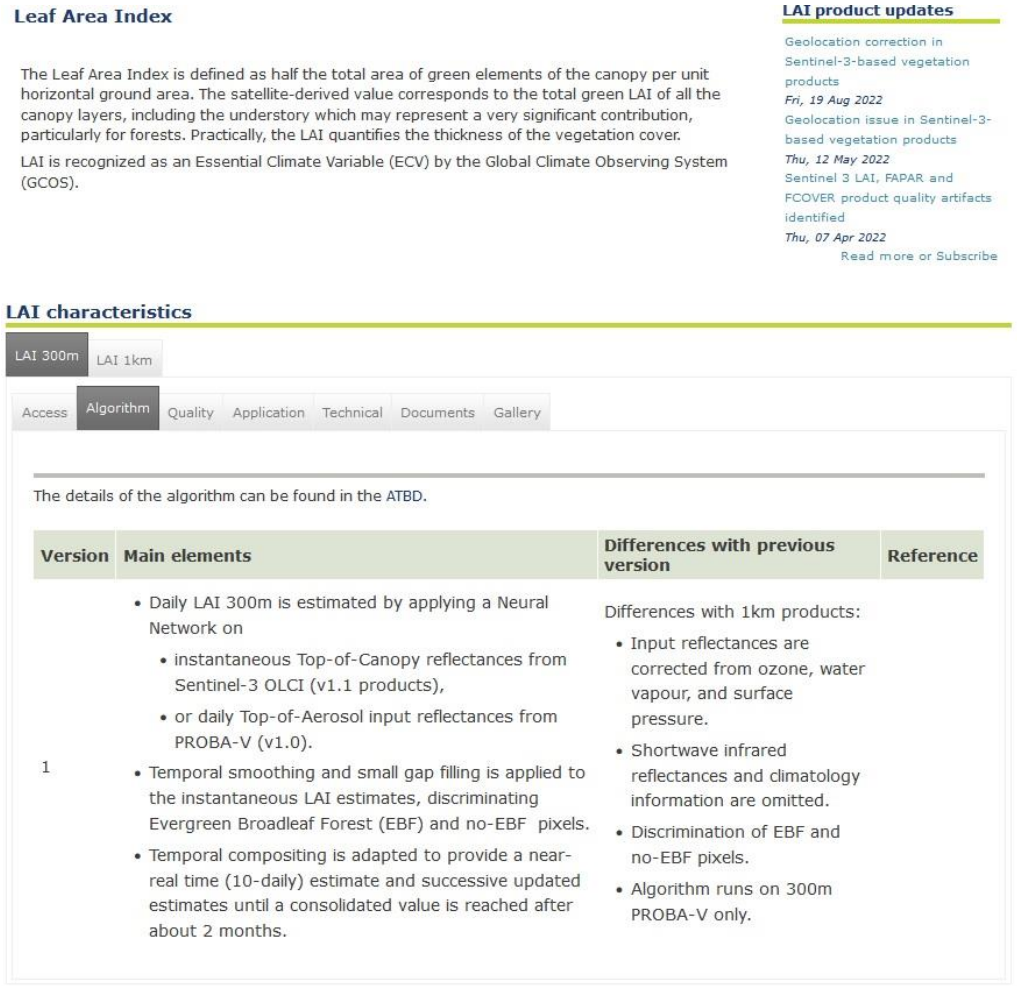
5. Trying to use **measurement of reflectance** to replicate **complex laboratory techniques**. EO data are proxies.

→ Refers to indirect measurements used to estimate plant or vegetation status, or microwave data can estimate soil moisture content. (E.g. LAI, measurements obtained by Neural network algorithm) provide valuable information for soil monitoring, but they often require validation against ground-based measurements for accuracy



Leaf Area Index

The Leaf Area Index is defined as half the total area of green elements of the canopy per unit horizontal ground area. The satellite-derived value corresponds to the total green LAI of all the canopy layers, including the understory which may represent a very significant contribution, particularly for forests. Practically, the LAI quantifies the thickness of the vegetation cover.

LAI is recognized as an Essential Climate Variable (ECV) by the Global Climate Observing System (GCOS).

LAI product updates

Geolocation correction in Sentinel-3-based vegetation products
Fri, 19 Aug 2022
Geolocation issue in Sentinel-3-based vegetation products
Thu, 12 May 2022
Sentinel 3 LAI, FAPAR and FCOVER product quality artifacts identified
Thu, 07 Apr 2022
Read more or Subscribe

LAI characteristics

LAI 300m | LAI 1km

Access | Algorithm | Quality | Application | Technical | Documents | Gallery

The details of the algorithm can be found in the ATBD.

Version	Main elements	Differences with previous version	Reference

1	• Daily LAI 300m is estimated by applying a Neural Network on
	  • instantaneous Top-of-Canopy reflectances from Sentinel-3 OLCI (v1.1 products),
	  • or daily Top-of-Aerosol input reflectances from PROBA-V (v1.0).
	• Temporal smoothing and small gap filling is applied to the instantaneous LAI estimates, discriminating Evergreen Broadleaf Forest (EBF) and no-EBF pixels.
	• Temporal compositing is adapted to provide a near-real time (10-daily) estimate and successive updated estimates until a consolidated value is reached after about 2 months.
		Differences with 1km products:
		• Input reflectances are corrected from ozone, water vapour, and surface pressure.
		• Shortwave infrared reflectances and climatology information are omitted.
		• Discrimination of EBF and no-EBF pixels.
		• Algorithm runs on 300m PROBA-V only.	

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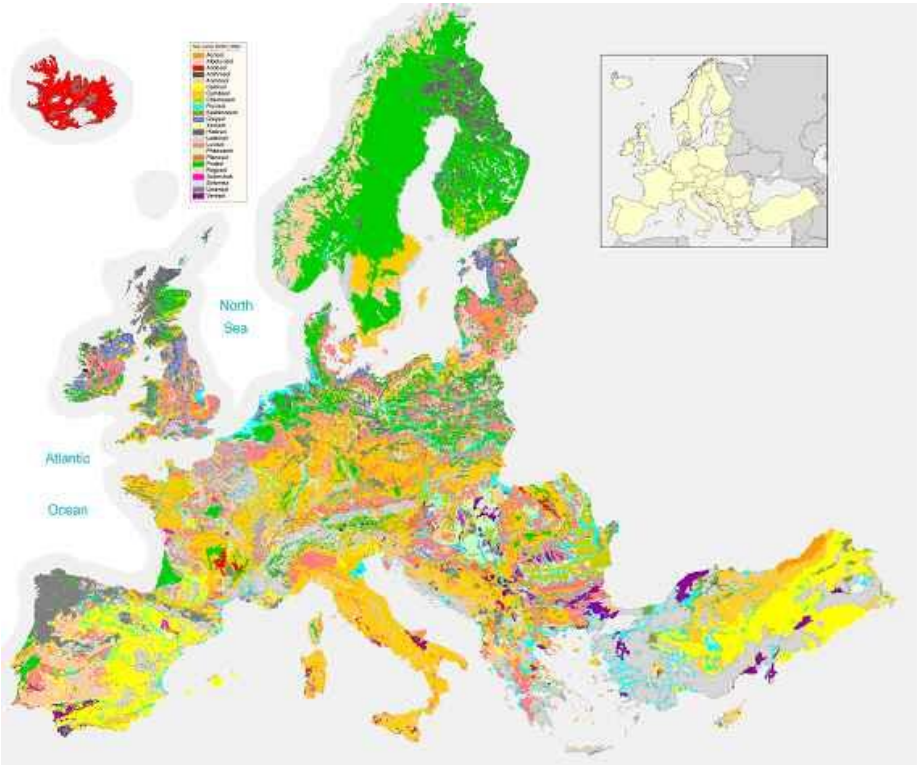
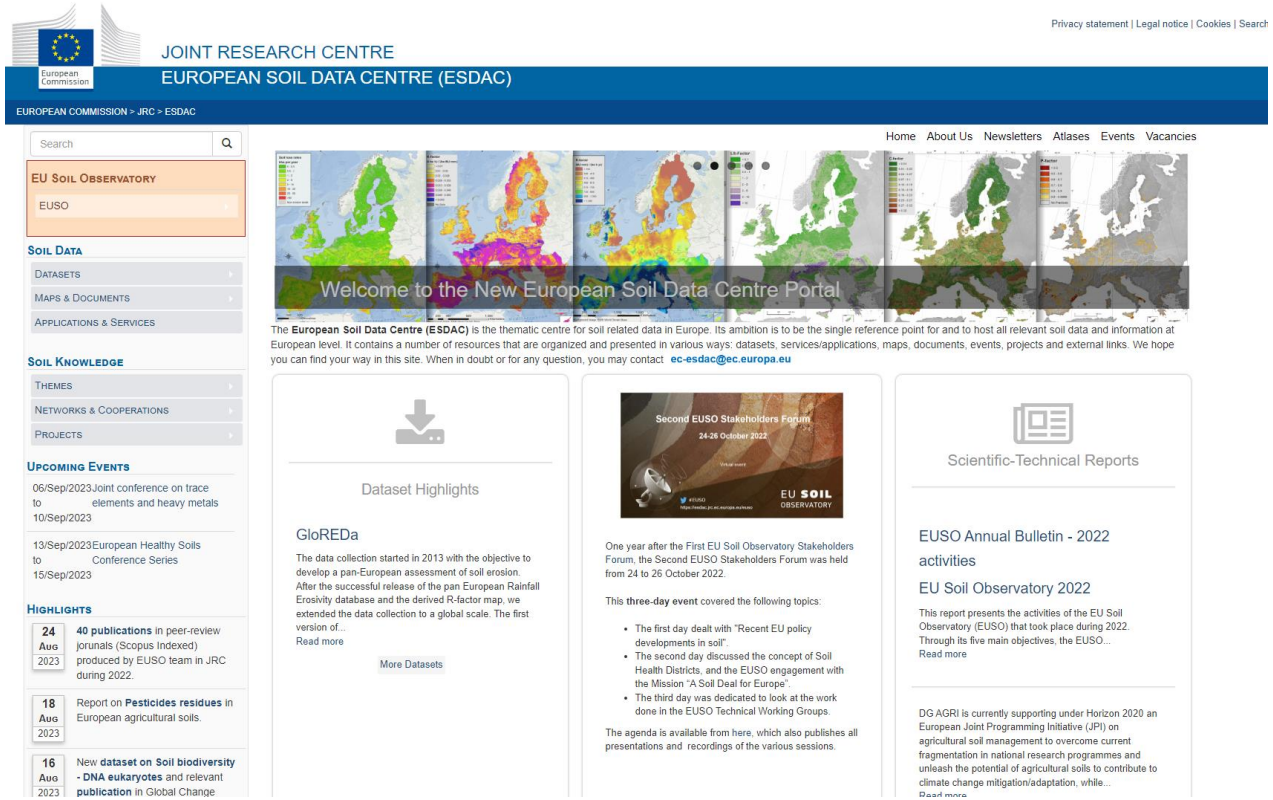
6. However, clear that **traditional soil mapping** involves labour-intensive field surveys, which can be expensive and time-consuming so we should be able to better benefit from EO data using space-borne sensor that provide a **synoptic view of the soils and its properties dynamics.**



Soil Map of the European Union and bordering countries (source: Soil Atlas of Europe).



European soil data Centre ESDAC

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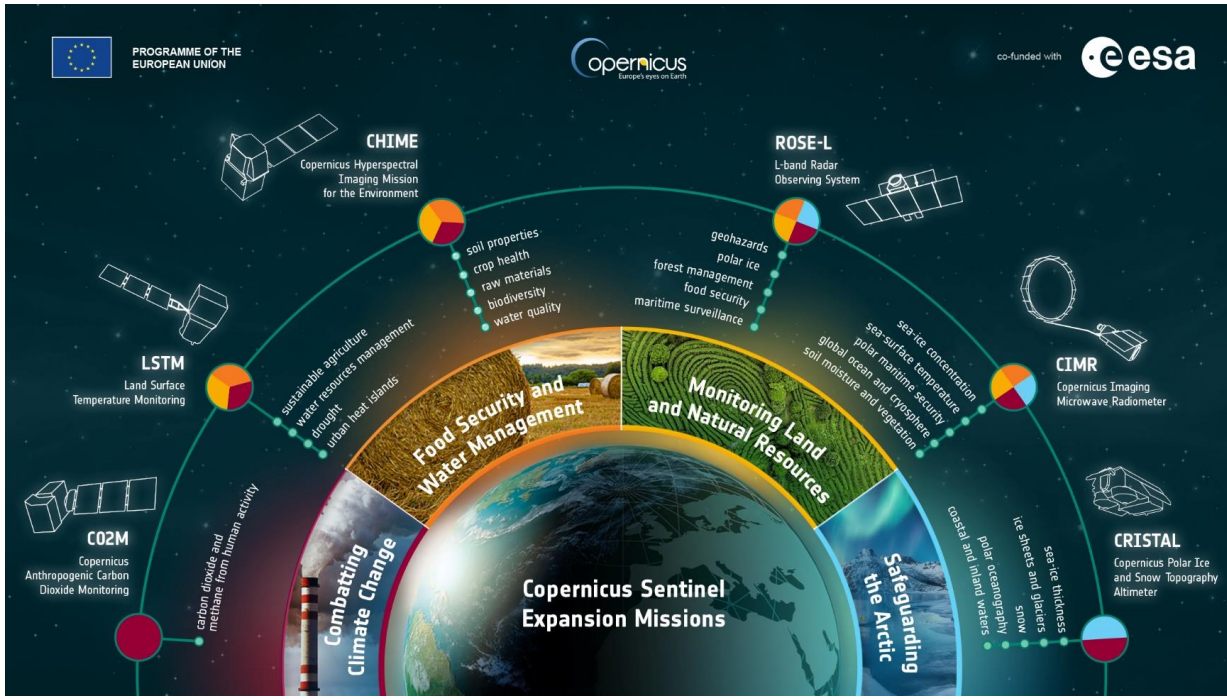
7. Need targeted sensors/instrumentation – **Soil Indices**

→ Integrated sensor products (e.g. thermal-SAR-Optical)

→ Example of LIDAR + vegetation for land degradation
Slope+ vegetation (biomass, NPP, NDVI or LAI)

→ Include the Sentinel 5 in the soil monitoring tools, Methane (CH_4), as the second most important GHG following carbon dioxide, holds significant implications for global warming and the carbon cycle (IPCC, 2021).



The new relevant sensors in the Copernicus Extension Programme can provide for soils and in particular the SML and other policy areas (e.g. pollution, desertification)

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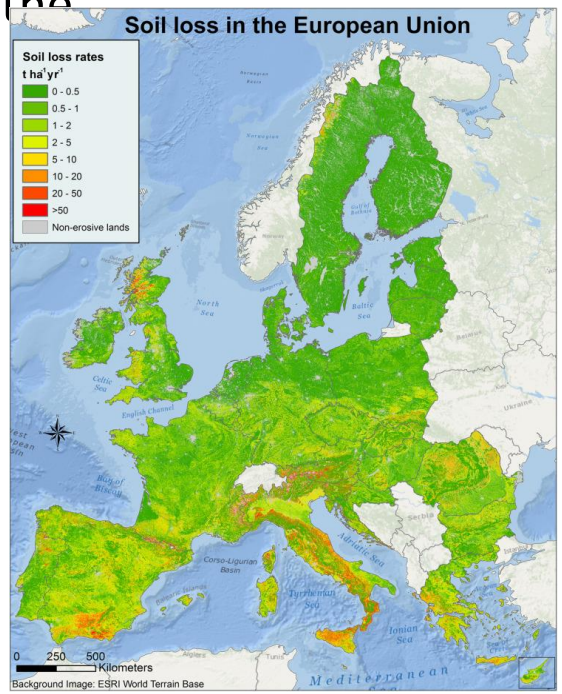
8. Altimetry LIDAR and soils modelling, we need better Digital Elevation Models for:

→ Mapping pedogenic processes,

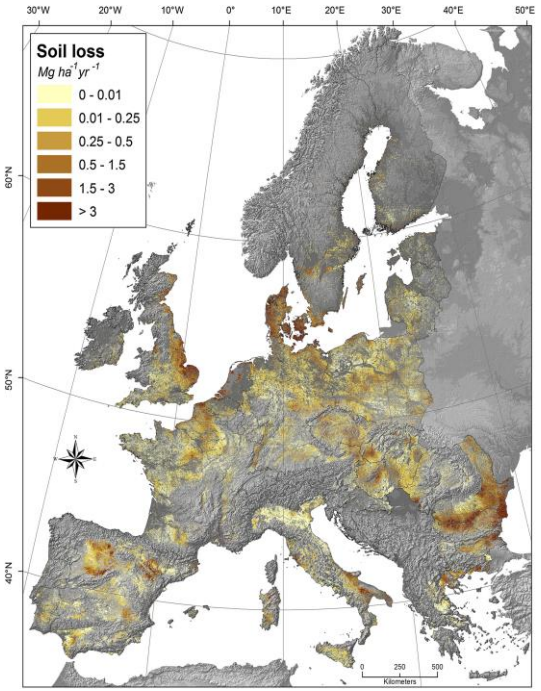
- soil formation (possible to some extent),
- horizonation (challenging but feasible with the radar application for the topsoil)

→ Monitoring erosion:

- Water erosion (sheet, rill, gully and Badland)
- Wind erosion (sand dunes, sand storms)
- Coastal erosion (riverbank erosion and coastline retreat)



Panagos et al., 2015 The new assessment of soil loss by water erosion in Europe



Borrelli et al, 2017 A New Assessment of Soil Loss Due to Wind

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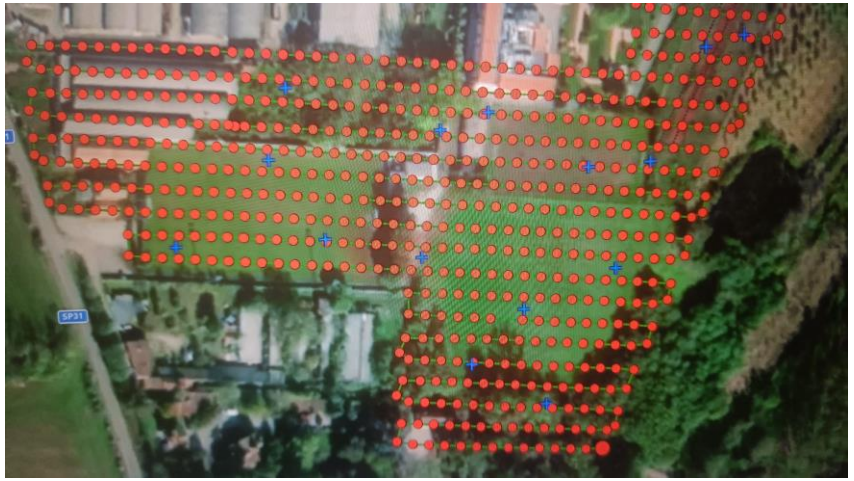
9. Unmanned aerial vehicles ''Drones'' are increasingly used for soil mapping?

→ Drones particularly useful for localized, high-resolution mapping and monitoring tasks



→ EO via RS offers a wide coverage area, suitable for large-scale regional mapping and monitoring, can be acquired at regular intervals, cost-effective

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10. Imperviousness/ Sealing Copernicus Land Monitoring Service CLMS

Copernicus Land Monitoring Service

CLMS portfolio | Dataset catalogue | Data viewer | Use cases | About us

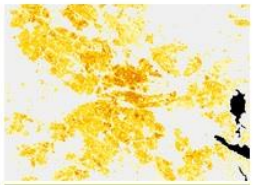
Home > CLMS portfolio > High Resolution Layer Impervious Built-up > Impervious Built-up 2018 (raster 10 m and 100 m), Europe, 3-yearly

Impervious Built-up 2018 (raster 10 m and 100 m), Europe, 3-yearly

General Info

Download

Provides at pan-European level in the spatial resolution of 10 m binary information (building / no building) within the sealing outline derived from the Imperviousness Density 2018 including the aggregated Share of Built-up layer in the spatial resolution of 100 m showing the percentage of built-up areas across Europe.



View in the data viewer

Validation status

Validated

Dataset citation

- **DOI (raster 100 m):** https://doi.org/10.2909/a807e528-431a-4dca-a6cd-0e8947563fce
- **DOI (raster 10 m):** https://doi.org/10.2909/3e412def-a4e6-4413-98bb-42b571afd15e

You can find instructions on how to cite CLMS data in our Data policy section.

Services

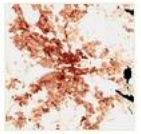
WMS

REST API

Characteristics

Release / Major version: V1	Temporal extent: 2017-2019	Type: Satellite products	Position accuracy: According to ortho-rectified satellite image
Projection: EPSG:3035	Temporal usability: Archive with regular updates	Platform: Sentinel-2	Thematic accuracy: ≥ 90%
Spatial coverage: Europe	Update frequency: 3-yearly		
Spatial resolution:			

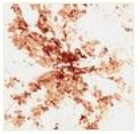
Datasets



Imperviousness Density 2018 (raster 10 m and 100 m), Europe, 3-yearly

Provides at pan-European level in the spatial resolution of 10 m and 100 m the sealing density in the range from 0% to 100% for the 2018 reference year.

View more | Download | View in the data viewer



Imperviousness Density 2015 (raster 20 m and 100 m), Europe, 3-yearly

Provides at pan-European level in the spatial resolution of 20 m and 100 m the sealing density in the range from 0% to 100% for the 2015 reference year.

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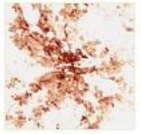

Imperviousness Density 2012 (raster 20 m and 100 m), Europe, 3-yearly

Provides at pan-European level in the spatial resolution of 20 m and 100 m the sealing density in the range from 0% to 100% for the 2012 reference year.

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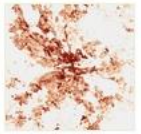

Imperviousness Density 2009 (raster 20 m and 100 m), Europe, 3-yearly

Provides at pan-European level in the spatial resolution of 20 m and 100 m the sealing density in the range from 0% to 100% for the 2009 reference year.

View more | Download | View in the data viewer

Imperviousness Density 2006 (raster 20 m and 100 m), Europe, 3-yearly

Provides at pan-European level in the spatial resolution of 20 m and 100 m the sealing density in the range from 0% to 100% for the 2006 reference year.

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10. Also need for soil dedicated **sealing** detection and **classification** CLMS –

Even attempt to mitigate soil sealing not working

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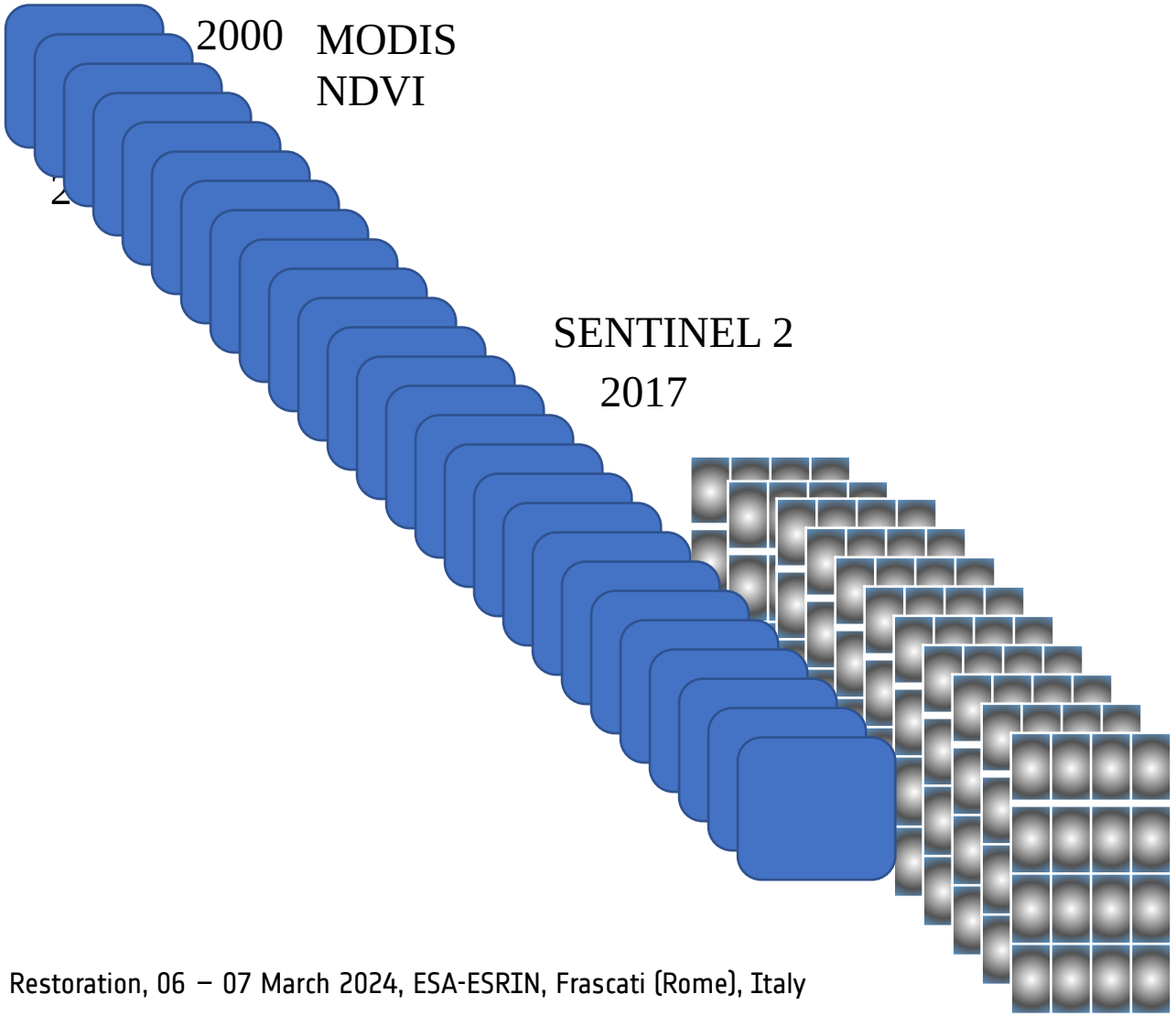
11 High-resolution (spatial and temporal) satellite imagery can be used as covariates of information in digital soil mapping

→ Land surface temperature
→ topography and derivatives (Slope, aspect, curvature, SPI, TWI, etc)
→ Air fluxes/emissions mapping (CO_2, CH_4, NOX)
→ Photogrammetry
→ ESA's soil moisture



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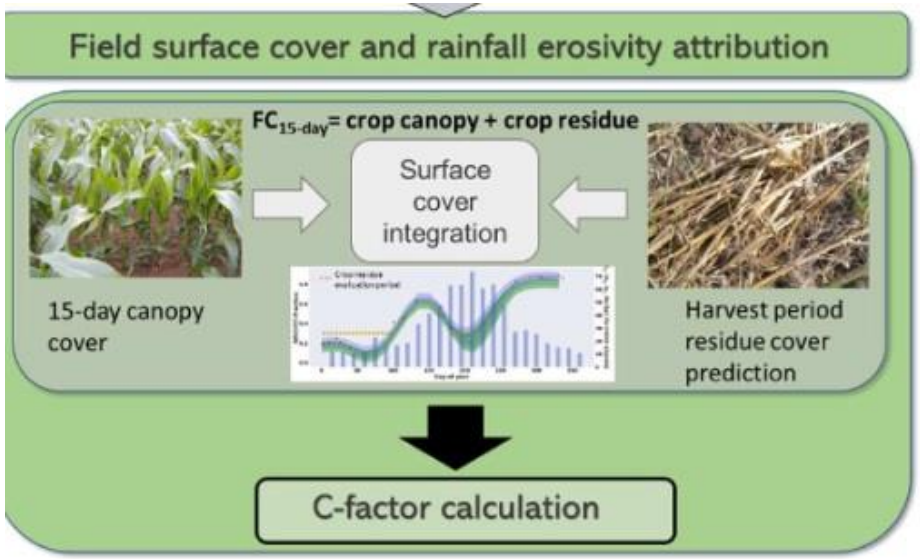
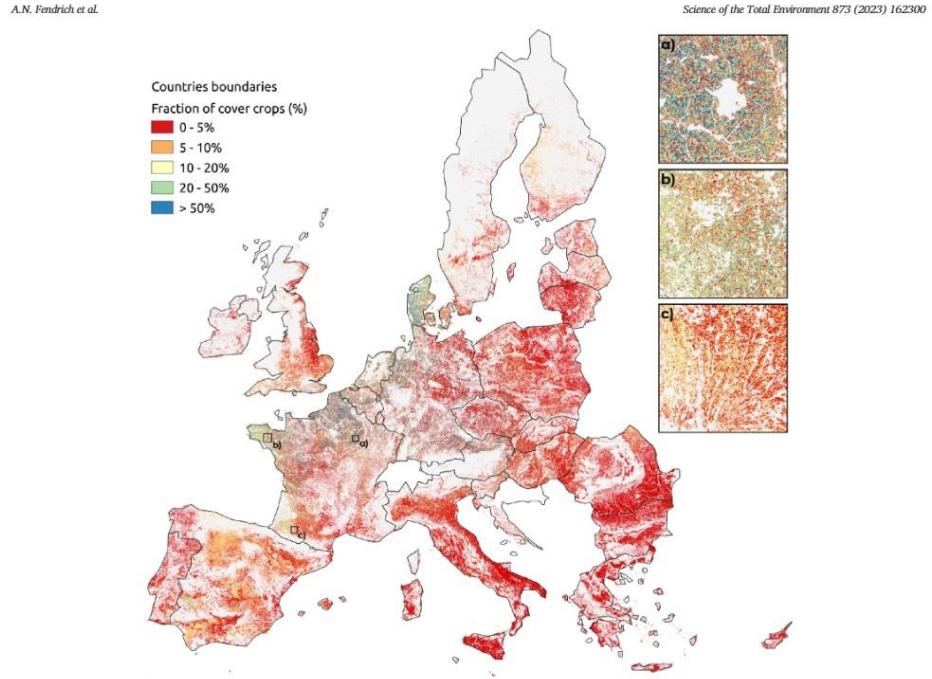
12. Soil Agricultural Practices

→ BARE SOIL there are several studies, but in EU it's usually due tillage and happen often in fall-winter cloudy months so application of optical remote sensing need to be complemented with the radar interferometry measurement.

→ AGRICULTURAL PRACTICES have been object of study by colleagues at the JRC



Matthews, F., et al., 2023. ISWCR, A field parcel-oriented approach to evaluate the crop cover-management factor and time-distributed erosion risk in Europe. Int. 10.1016/j.iswcr.2022.09.005



Fendrich et al 2023 STOTEN From regional to parcel scale: A high-resolution map of cover crops across Europe combining satellite data with statistical surveys, 10.1016/j.scitotenv.2023.162300

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13. Hyperspectral

→ Enmap The Environmental Mapping and Analysis Program (*EnMAP*) is a German hyperspectral satellite mission that aims at monitoring and characterizing the Earth's measures geochemical, biochemical and biophysical variables providing information on the status and evolution of terrestrial and aquatic ecosystems

→ ASI ‘’PRecursore IperSpettrale della Missione Applicativa’’ PRISMA lanched in 2019 in Kourou provides VNIR (Visible and Near-InfraRed), SWIR (Short-Wave InfraRed), at 30 m spatial resolution, and pancromatic at 5 m.

DAY 2 Closure 16.30-17:30 JRC