JOURNÉE THÉMATIQUE PNTS

10 ans d'observations par la mission Sentinel-2 apports et perspectives

Bordeaux - 20 Mai 2025

Sentinel-2: une mission pour transformer l'agriculture européenne ?

Pierre Defourny (UCLouvain, Belgique)

thanks to the contribution of our research team
and many key international partners

UCLouvain · AGRO LOUVAIN

Moving towards a more healthy and sustainable EU food system, a corner stone of the European resilience

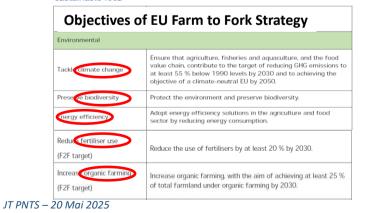Make sure Europeans get healthy, affordable and sustainable food · Tackle climate change · Protect the environment and preserve biodiversity · Fair economic return in the food chain · Increase organic farming

Objectives of EU Farm to Fork Strategy

Environmental	
Tackle climate change	Ensure that agriculture, fisheries and aquaculture, and the food value chain, contribute to the target of reducing GHG emissions to at least 55 % below 1990 levels by 2030 and to achieving the objective of a climate-neutral EU by 2050.
Preserve biodiversity	Protect the environment and preserve biodiversity.
Energy efficiency	Adopt energy efficiency solutions in the agriculture and food sector by reducing energy consumption.
Reduce fertiliser use (F2F target)	Reduce the use of fertilisers by at least 20 % by 2030.
Increase organic farming (F2F target)	Increase organic farming, with the aim of achieving at least 25 % of total farmland under organic farming by 2030.

EU food system monitoring framework. From concepts to indicators

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Copernicus & IT (r)evolution change the game for EO agriculture applications

Free, open and long term data policy (US, EU,....)

Server farms with full EO data archives Exploitation at low/no cost

Open source processing tools using ML & AI algo.

Mobile internet for many

CE⦿S

Coordination for EO systems redundancy & harmonization

JECAM
Joint Experiment for Crop Assessment and Monitoring
Global network with cross site experim.

Best practices & standards

Agromet & models

Improved Meteo Data (e.g. GPM, ERAS,...)

EO ag. products => (intra-) field level
1. **Cropland mapping**
2. **Crop type mapping**
3. **Biophys. var.** (fCover, LAI, fAPAR, CCC)
4. **Crop condition monitoring**
5. **Ag. practices monitoring**
   (e.g. emergence and harvest dates, N efficiency)

6. ***Nat./reg. production estimate***

Internet of things Crowd sourcing AI exploitation

1. Yield estimation
2. Yield quality assessment
3. Agriculture statistics
4. Water use efficiency
5. Pest and disease
...../...

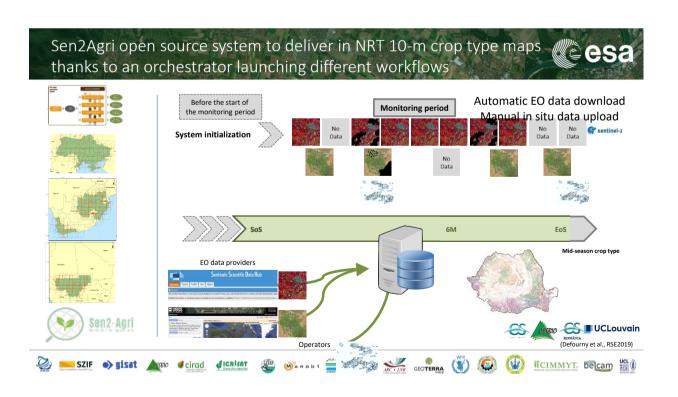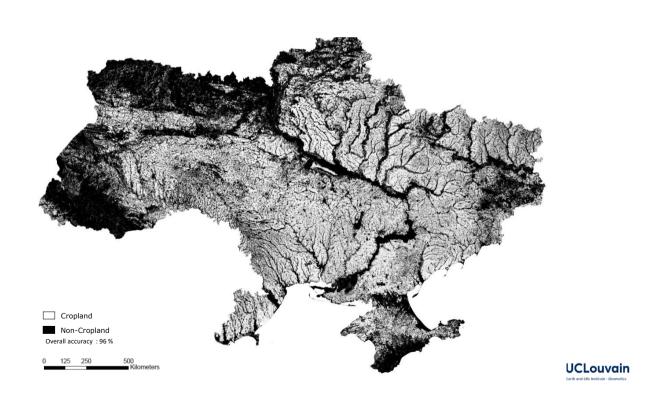UCLouvain
Earth and Life Institute - Geomatics

Sen2Agri open source system to deliver in NRT 10-m crop type maps thanks to an orchestrator launching different workflows

Before the start of the monitoring period

Monitoring period

System initialization

No Data

Automatic EO data download
Manual in situ data upload

SoS   6M   EoS

EO data providers

Sentinels Scientific Data Hub

USGS

Operators

CESBIO   UCLouvain
ROMÂNIA
(Defourny et al., RSE2019)

European Space Agency

Sen2Agri open source system to deliver in NRT 10-m crop type maps thanks to an orchestrator launching different workflows

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Sen2Agri open source system to deliver in NRT 10-m crop type maps thanks to an orchestrator launching different workflows

(Defourny et al., RSE2019)

☐ Cropland
■ Non-Cropland
Overall accuracy : 96 %

0   125   250   500
                  Kilometers

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Sen2-Agri open source system to deliver along the season 10-m cropland and crop type maps for Ukraine (July 2016)

Cropland
Non-Cropland
Overall accuracy : 96 %

0   125   250   500
Kilometers

Winter Wheat
Sunflower
Maize
Soybeans
Winter Barley
Other Crops
Overall accuracy : 81 %

Crop area Indicator at mid-season and end of season

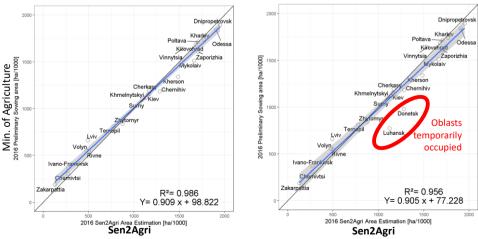(Defourny et al., 2016)

Early estimates of sowing areas: Ukraine (2016)
Sen2Agri matching figures of Ministry of Agriculture

Kiev, Oct.2016
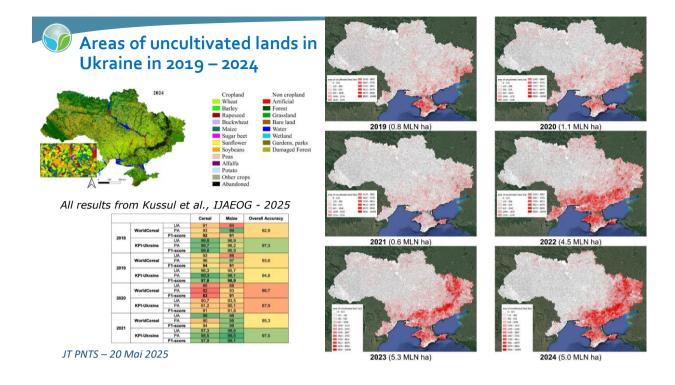
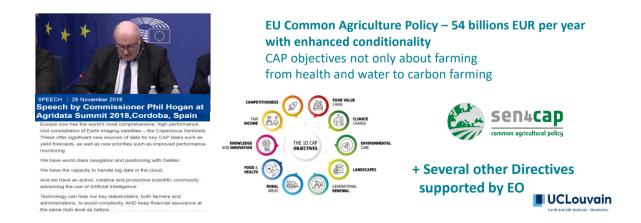***...and providing estimates for unaccessible oblasts in 2016***

Min. of Agriculture
2016 Preliminary Sowing area [ha/1000]

Dnipropetrovsk
Kharkiv
Poltava
Kirovohrad   Odessa
Vinnytsia   Zaporizhia
Mykolaiv
Cherkasy   Kherson
Khmelnytskyi   Chernihiv
Sumy   Kiev
Zhytomyr
Ternopil
Lviv
Volyn   Rivne
Ivano-Frankivsk
Chernivtsi
Zakarpattia

R²= 0.986
Y= 0.909 x + 98.822

2016 Sen2Agri Area Estimation [ha/1000]
Sen2Agri

2016 Preliminary Sowing area [ha/1000]

Dnipropetrovsk
Kharkiv
Poltava
Kirovohrad   Odessa
Vinnytsia   Zaporizhia
Mykolaiv
Cherkasy   Kherson
Khmelnytskyi   Chernihiv
Sumy   Kiev
Zhytomyr   Donetsk
Ternopil
Lviv   Luhansk
Volyn   Rivne
Ivano-Frankivsk
Chernivtsi
Zakarpattia

Oblasts temporarily occupied

R²= 0.956
Y= 0.905 x + 77.228

2016 Sen2Agri Area Estimation [ha/1000]
Sen2Agri

RUS Remote Training – Agriculture Monitoring for ESA BIC Start-Ups 9 September 2021- P. Defourny

(Defourny et al. 2016)

Areas of uncultivated lands in Ukraine in 2019 – 2024

2024

Cropland	Non cropland
Wheat	Artificial
Barley	Forest
Rapeseed	Grassland
Buckwheat	Bare land
Maize	Water
Sugar beet	Wetland
Sunflower	Gardens, parks
Soybeans	Damaged Forest
Peas	
Alfalfa	
Potato	
Other crops	
Abandoned	

All results from Kussul et al., IJAEOG - 2025

			Cereal	Maize	Overall Accuracy
2018	WorldCereal	UA	91	84	92,9
		PA	93	99	
		F1-score	92	91	
	KPI-Ukraine	UA	98,8	96,9	97,3
		PA	98,7	96,2	
		F1-score	98,8	96,9	
2019	WorldCereal	UA	93	86	93,6
		PA	96	97	
		F1-score	94	91	
	KPI-Ukraine	UA	96,3	95,7	94,8
		PA	99,3	98,1	
		F1-score	97,8	96,9	
2020	WorldCereal	UA	85	88	86,7
		PA	82	93	
		F1-score	83	91	
	KPI-Ukraine	UA	90,7	93,5	87,9
		PA	91,2	90,1	
		F1-score	91	91,8	
2021	WorldCereal	UA	99	98	95,3
		PA	90	98	
		F1-score	94	98	
	KPI-Ukraine	UA	97,3	98,6	97,5
		PA	98,5	99,5	
		F1-score	97,9	99,1	

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2019 (0.8 MLN ha)

2020 (1.1 MLN ha)

2021 (0.6 MLN ha)

2022 (4.5 MLN ha)

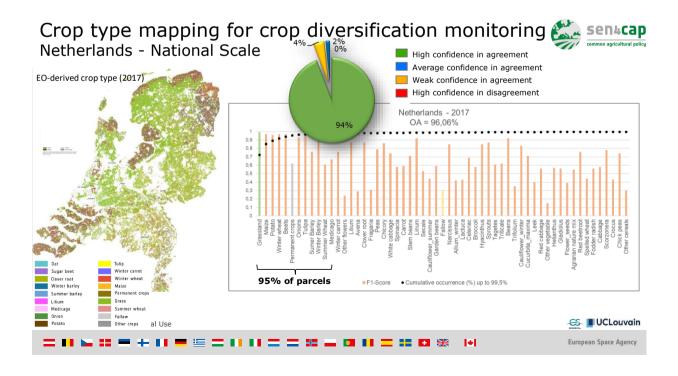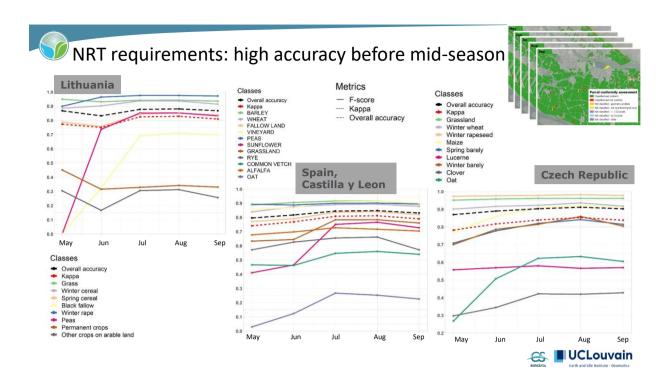2023 (5.3 MLN ha)

2024 (5.0 MLN ha)

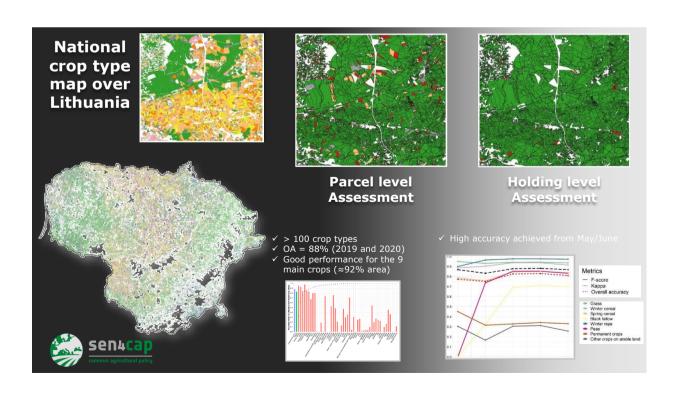## An incredible momentum for Earth Observation from space

Technological maturity of in-orbit EO satellites currently very competitive

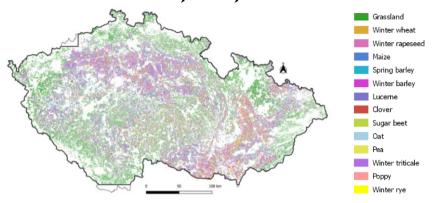**Endorsment of S1&2 data sources by policy makers** and private stakeholders

SPEECH | 26 November 2018
Speech by Commissioner Phil Hogan at Agridata Summit 2018,Cordoba, Spain

Europe now has the world's most comprehensive, high performance, civil constellation of Earth imaging satellites – the Copernicus Sentinels. These offer significant new sources of data for key CAP tasks such as yield forecasts, as well as new priorities such as improved performance monitoring.

We have world class navigation and positioning with Galileo.

We have the capacity to handle big data in the cloud.

And we have an active, creative and productive scientific community advancing the use of Artificial Intelligence.

Technology can help our key stakeholders, both farmers and administrations, to avoid complexity, AND keep financial assurance at the same high level as before.

EU Common Agriculture Policy – 54 billions EUR per year with enhanced conditionality
CAP objectives not only about farming
from health and water to carbon farming

THE 10 CAP OBJECTIVES

COMPETITIVENESS · FOOD VALUE CHAIN · CLIMATE CHANGE · ENVIRONMENTAL CARE · LANDSCAPES · GENERATIONAL RENEWAL · RURAL AREAS · FOOD & HEALTH · KNOWLEDGE AND INNOVATION · FAIR INCOME

sen4cap
common agricultural policy

+ Several other Directives supported by EO

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Building a large database of markers from Sentinel-1 & Sentinel-2 for each LPIS/GSAA parcel along the season

DB

E.g. Spain : **17 millions parcels**
x **60+ metrics** + S2&1 signal
x 40 weeks / year

**Supporting the monitoring
of agricultural practices (e.g. CAP)
and guiding farmers in their practices**

Crop type mapping for crop diversification monitoring

Netherlands - National Scale

sen4cap
common agricultural policy

EO-derived crop type (2017)

- High confidence in agreement
- Average confidence in agreement
- Weak confidence in agreement
- High confidence in disagreement

4%   2%
0%

94%

Netherlands - 2017
OA = 96,06%

95% of parcels

F1-Score   • Cumulative occurrence (%) up to 99,5%

Oat	Tulip
Sugar beet	Winter carrot
Clover root	Winter wheat
Winter barley	Maize
Summer barley	Permanent crops
Lilium	Grass
Medicago	Summer wheat
Onion	Fallow
Potato	Other crops

al Use

European Space Agency

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NRT requirements: high accuracy before mid-season

National crop type map over Lithuania

"This is not a 2020 crop map !"

Legend:
- Grassland
- Winter wheat
- Winter rapeseed
- Maize
- Spring barley
- Winter barley
- Lucerne
- Clover
- Sugar beet
- Oat
- Pea
- Winter triticale
- Poppy
- Winter rye

sen4cap
common agricultural policy

2020 National crop type map over Czechia
from S1, S2 & L8 from Mar-Aug. 2020

✓ 90.3% overall accuracy for 60+ crop types

✓ 95,9% parcels assessed

✓ 99,5% area assessed

*...at most this is a crop map
for 31ˢᵗ May 2020 !*

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Sen4CAP – CAP use cases : user-driven approach allowing to communicate with each farmer along the seaon at parcel level

1st User Workshop, EU, Brussels, July 2017

EU Direct Payment Committee, Brussels, March 2018

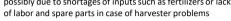| Use case |
|---|
| Crop diversification |
| Permanent grassland identification |
| EFA-Land lying fallow |
| EFA-Catch crops |
| EFA-Nitrogen-fixing crops |
| Interactive visualization |
| ... keeping in mind much more |
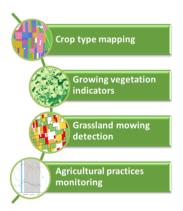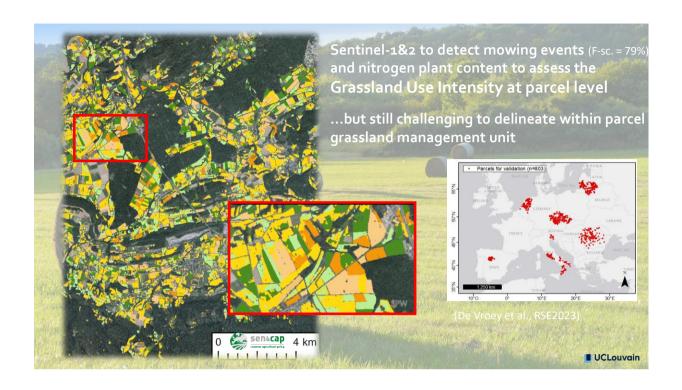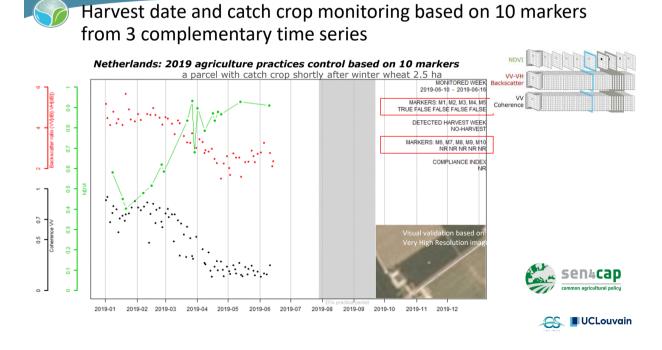
- Crop type mapping
- Growing vegetation indicators
- Grassland mowing detection
- Agricultural practices monitoring

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Sentinel-1&2 to detect mowing events (F-sc. = 79%) and nitrogen plant content to assess the Grassland Use Intensity at parcel level

...but still challenging to delineate within parcel grassland management unit

(De Vroey et al., RSE2023)

Harvest date and catch crop monitoring based on 10 markers from 3 complementary time series

Netherlands: 2019 agriculture practices control based on 10 markers
a parcel with catch crop shortly after winter wheat 2.5 ha

MONITORED WEEK
2019-06-10 - 2019-06-16

MARKERS: M1, M2, M3, M4, M5
TRUE FALSE FALSE FALSE FALSE

DETECTED HARVEST WEEK
NO-HARVEST

MARKERS: M6, M7, M8, M9, M10
NR NR NR NR NR

COMPLIANCE INDEX
NR

Visual validation based on Very High Resolution image

Rapid Action Coronavirus Earth observation dashboard platform

Earth Observation for transparency to avoid covid induced food crisis – *use case of winter cereals harvest in Spain*

Monitoring of delay or disruption of winter cereals harvesting in Spain
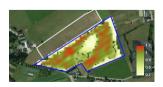possibly due to shortages of inputs such as fertilizers or lack of labor and spare parts in case of harvester problems

Weekly reporting of delay of winter cereals harvesting with regards to 2019

using Sen4CAP "harvest" markers for each wheat parcel in Spain
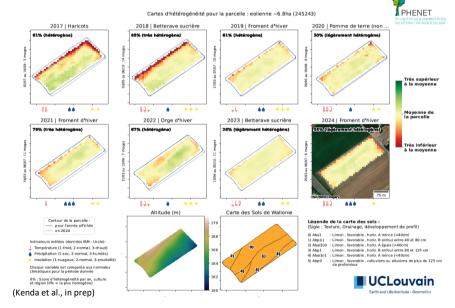

eodashboard.org

Farming advices to support sustainable practices

Multi-year within-field heterogeneity to better manage soil spatial variability

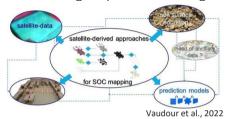Nitrogen wheat plant saturation to inform the farmer in NRT

Cartes d'hétérogénéité pour la parcelle : eolienne ~6.8ha (245243)

(Kenda et al., in prep)

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Carbon farming practices to enhance Soil Organic Carbon

Barbato,et al., 2023

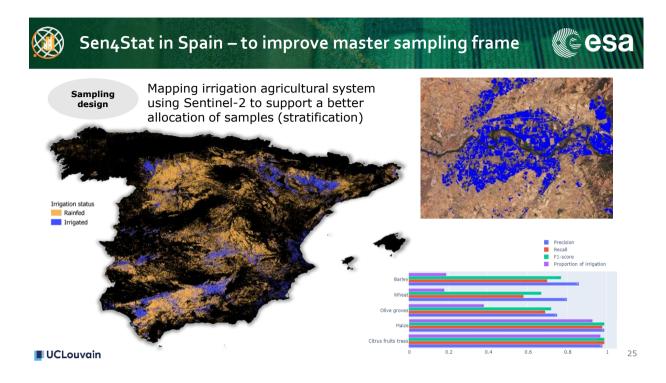## Sentinel-2 indices to estimate SOC content using empirical modeling

Vaudour et al., 2022

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Sentinel-2 to quantify agriculture practices to be assimilated in crop growth model

Ceschia et al., 2021

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Sen4Stat: coupling EO data and statistical surveys for improved crop statistics

Sentinel-1 and -2

Agri. surveys

EO cloud Sen4stat

EO products

SENEGAL – NIORO DU RIP
Cropland – non cropland map
Crop type map
OA: 88,2 %
F-Score Groundnut : 95,2%
F-Score Mil : 83,8 %
F-Score Maize : 54,8%

SPAIN – CASTILLA Y LEON
Soft wheat yield estimation

SENEGAL
Crop growing metrics evolution

Improved national agricultural statistics

COST EFFICIENCY | STAT. GRANULARITY | STAT. TIMELINESS | SAMPLING DESIGN | SURVEY & DATA QA | OTHER APPLICATIONS

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Sen4Stat in Spain – to improve master sampling frame

Sampling design

Mapping irrigation agricultural system using Sentinel-2 to support a better allocation of samples (stratification)

Irrigation status
- Rainfed
- Irrigated

Precision, Recall, F1-score, Proportion of irrigation (Barley, Wheat, Olive groves, Maize, Citrus fruits trees)
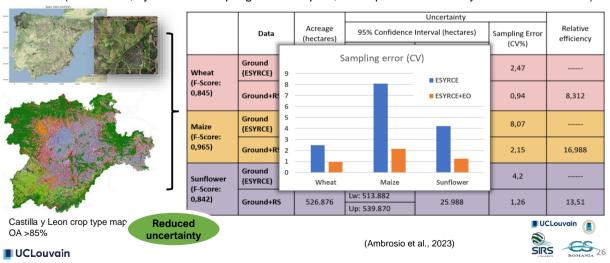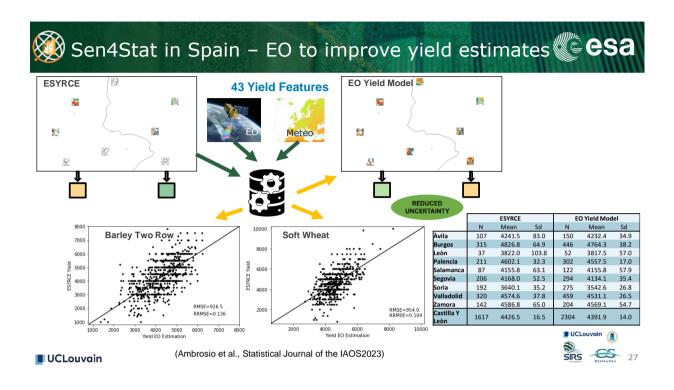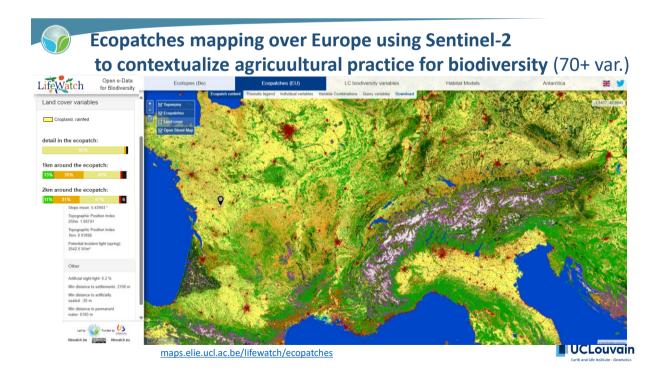
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Sen4Stat in Spain – to improve acreage estimates

ESYRCE (Spanish National Stat. Office): integrated list and area frame survey
(49 ha ESU; systematic sampling over all Spain; all crops within ESU + yield over 1/3 of ESU)

Data		Acreage (hectares)	Uncertainty		Sampling Error (CV%)	Relative efficiency
			95% Confidence Interval (hectares)			
Wheat (F-Score: 0,845)	Ground (ESYRCE)				2,47	------
	Ground+RS				0,94	8,312
Maize (F-Score: 0,965)	Ground (ESYRCE)				8,07	------
	Ground+RS				2,15	16,988
Sunflower (F-Score: 0,842)	Ground (ESYRCE)				4,2	------
	Ground+RS	526.876	Lw: 513.882 Up: 539.870	25.988	1,26	13,51

Sampling error (CV) — ESYRCE, ESYRCE+EO (Wheat, Maize, Sunflower)

Castilla y Leon crop type map
OA >85%

Reduced uncertainty

(Ambrosio et al., 2023)

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SIRS

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Sen4Stat in Spain – EO to improve yield estimates

ESYRCE

43 Yield Features

EO   Meteo

EO Yield Model

REDUCED UNCERTAINTY

Barley Two Row

RMSE=926.5
RRMSE=0.136

Soft Wheat

RMSE=954.0
RRMSE=0.104

	ESYRCE			EO Yield Model		
	N	Mean	Sd	N	Mean	Sd
Àvila	107	4241.5	83.0	150	4232.4	34.9
Burgos	315	4826.8	64.9	446	4764.3	38.2
Leòn	37	3822.0	103.8	52	3817.5	57.0
Palencia	211	4602.1	32.3	302	4557.5	17.0
Salamanca	87	4155.8	63.1	122	4155.8	57.9
Segovia	206	4168.0	52.5	294	4134.1	35.4
Soria	192	3640.1	35.2	275	3542.6	26.8
Valladolid	320	4574.6	37.8	459	4531.1	26.5
Zamora	142	4586.8	65.0	204	4569.1	54.7
Castilla Y Leòn	1617	4426.5	16.5	2304	4391.9	14.0

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(Ambrosio et al., Statistical Journal of the IAOS2023)

SIRS   ES ROMANIA   27

Ecopatches mapping over Europe using Sentinel-2 to contextualize agricuultural practice for biodiversity (70+ var.)

maps.elie.ucl.ac.be/lifewatch/ecopatches

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A brand new Copernicus Land Monitoring Service in 2025
10m High Resolution Layer – Croplands (12 variables)

currently available 2017-2021

Product User Manual, March 2025

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How does Sentinel-2 support agriculture transformation ?

- **Technological and methodological maturity** for near real time EO allowing to support **policy implementation** over large areas
    - ex. initial CAP reform defining key EO-supported green indicators

- EO insures **transparency and data consistency to monitor multi-year crop management practices** potentially highligthing great farming practices

- Sentinel-2 supports **unique services at parcel level for farming advices**

- **EO analytics still to be developed for climate adaptation and carbon farming** by documenting all EU crop growth at parcel level since 2017

- **New Space industry or AI could play in a near future** a disruptive or accelerator role in the adoption of EO-derived information

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Merci pour votre attention