



Sen4Stat
Sustainable Agriculture Statistics

<https://esa-sen4stat.org/>



ESA project "Sentinels for Agricultural Statistics"

*NoR sponsorship
Final report*

 UCLouvain



CLS

COLLECTE LOCALISATION SATELLITES



ROMANIA

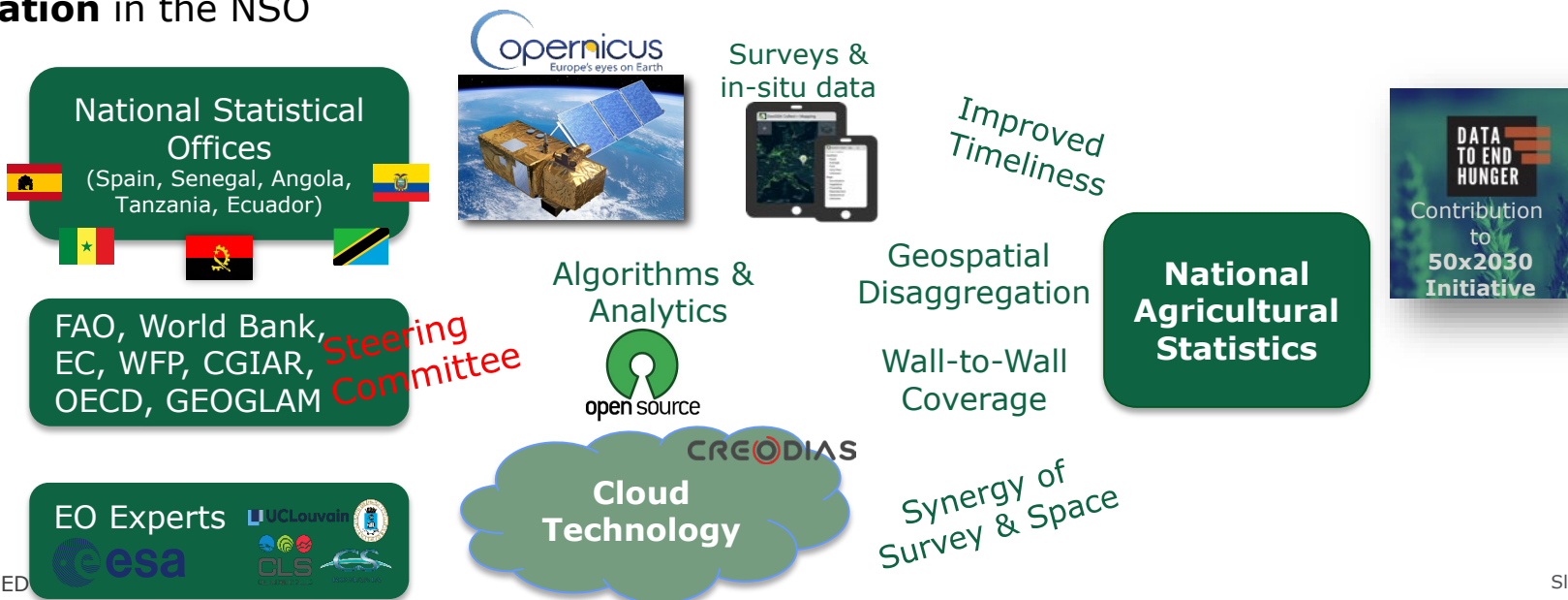
ESA UNCLASSIFIED - For Official Use



European Space Agency



- Engage **agricultural National Statistical Offices (NSO)** to demonstrate the **benefit of EO information** within their operational workflows
- Provide & demonstrate validated algorithms, open source tools, products and best practices** for national agricultural statistics with EO **facilitating the uptake of EO information** in the NSO





Statistical applications identified by pilot NSOs & relevant EO products



COST EFFICIENCY

STAT. GRANULARITY

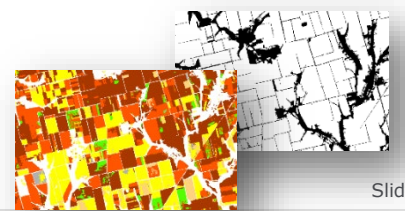
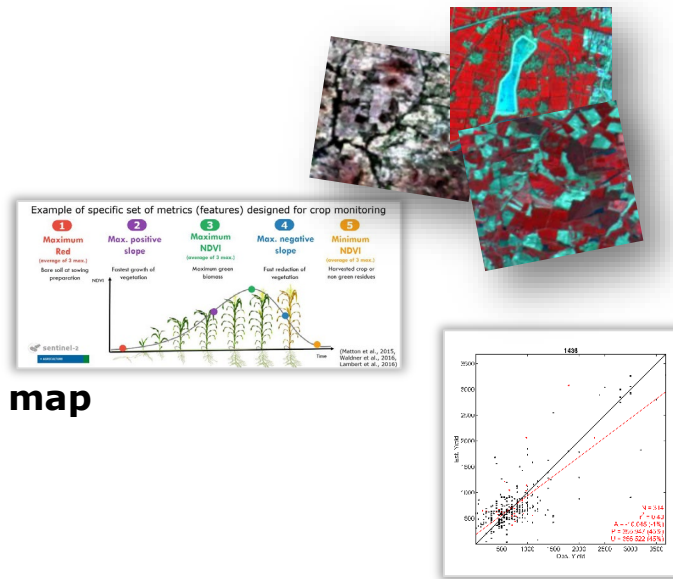
STAT. TIMELINESS

SAMPLING DESIGN

SDG's REPORTING

DATA COLLECTION PROTOCOL

- Pre-processed reflectance / metrics time series
- Biophysical indicators, e.g. NDVI or LAI
- Crop growth condition metrics
- Cloud-free color composites at segment-level
- Wall-to-wall cropland – non-cropland map
- **Wall-to-wall annual vs permanent cropland map**
- Wall-to-wall map of the main crop type groups
- Wall-to-wall crop type map
- **Annual and permanent crop type map at segment-level**
- **National crop distribution probability map at pixel-level**
- **Crop yield estimate** at reporting unit



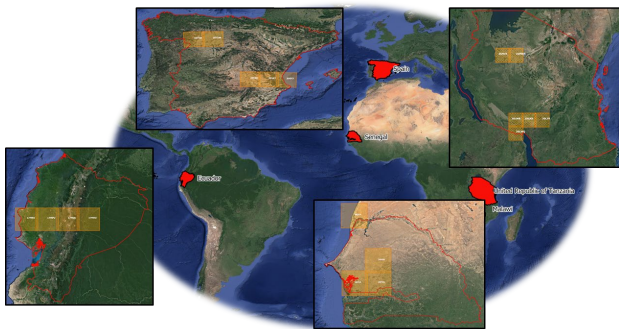


Study area, from local to national scale

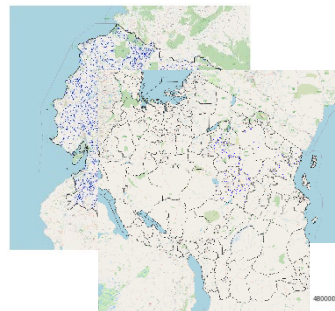


Methods development
Working on test sites

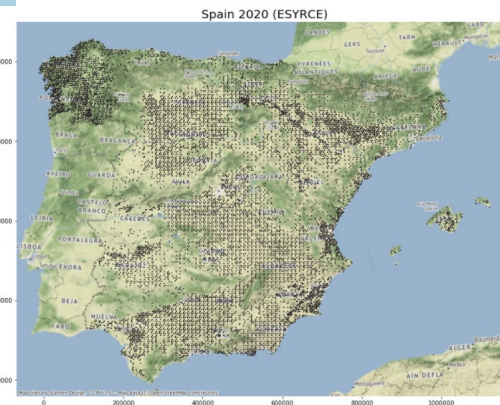
System demonstration
Up to national scale



- Test sites all over the world
 - Run on local servers



- From 2018 to 2020, depending on the country
- Sentinel-2 L1C & L2A + Sentinel-1 SLC full archive

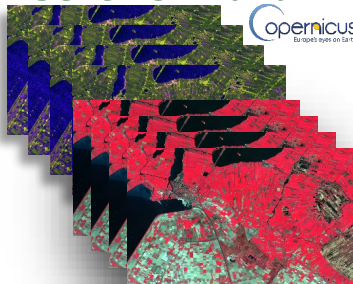




Results in brief



Sentinel-1 and -2



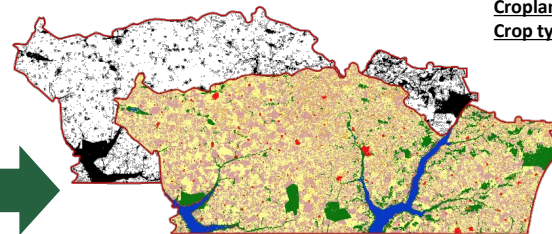
Agri. surveys



EO
Cloud



EO products



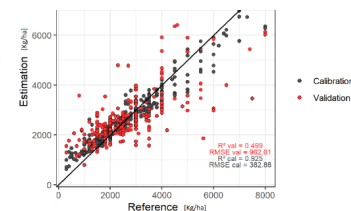
SENEGAL – NIORO DU RIP
Cropland – non cropland map
Crop type map

OA: 88,2 %
F-Score Groundnut : 95,2%
F-Score Mil : 83,8 %
F-Score Maize : 54,8%

SENEGAL Crop growing metrics evolution



SPAIN – CASTILLA Y LEON Soft wheat yield estimation



OPTIMIZING FIELD DATA COLLECTION

Co-design of new protocols



IMPROVING COST-EFFICIENCY

Estimation error reduced with EO
for main crops

Crop	Estimation error (coeff. var)		EO efficiency
	In situ only	In situ & EO	
Maize	1.37	1.62	0.72
Mil	3.37	1.73	3.79
Groundnut	3.34	1.78	3.52

INCREASING STATS GRANULARITY

Crop area estimates at communes level



Slide 5



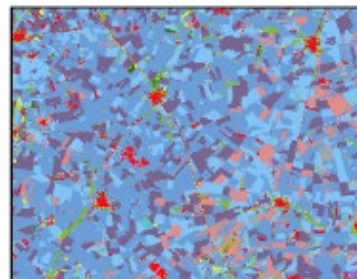
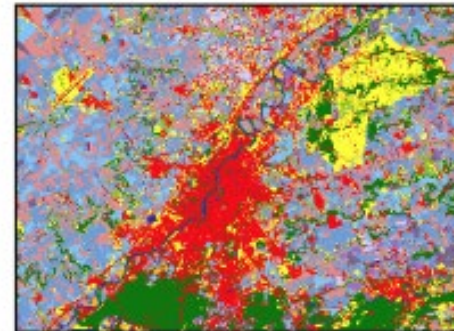
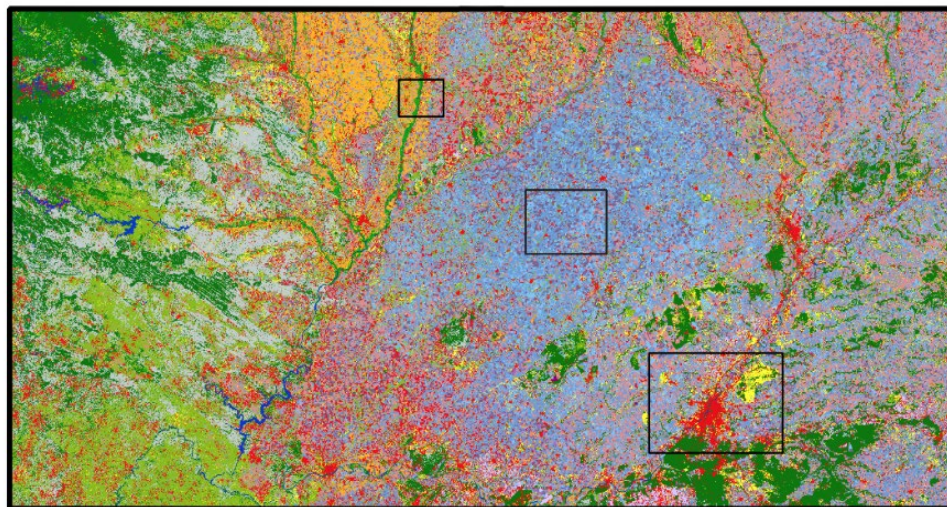


Example of use case in Spain

Prerequisite EO-product : 10-m crop map (35 crop types)



Very similar accuracies for Random Forest and Neural Net (Transformer)



Crop Type			
Wheat	Leafy or stem vegetables	Spice crops	Vineyards
Maize	Fruit-bearing vegetables	Hops	Olive groves
Rice	Root tub or tuberous vegetables	Leguminous crops	Trees
Sorghum	Mushrooms and truffles	Sugar beet	Succulent plant
Barley	Soya beans	Sugar cane	Shrub land
Rye	Groundnuts	Grassland and meadows	Forest
Oats	Other oilseed crops	Fibre crops	Bare soil
Millets	Potatoes	Medicinal aromatic pesticidal or similar crops	Build-up surface
Quinoa	Sweet potatoes	Flowers crops	Water bodies
	Yams	Cassava	
		Fruits trees	

Overall Accuracy :
80% for crop types
88% for crop groups

ESA UNCLAS

Slide 6



European Space Agency



Cost-efficiency on crop acreage (barley in Spain)

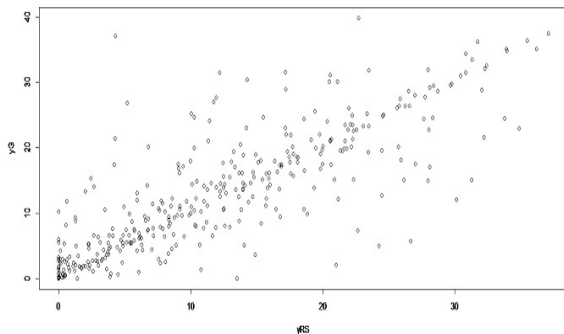


COST EFFICIENCY

Using EO data in the statistical framework to maximize the statistics accuracy (i.e. low variance) at low cost (free data, « simple » methods)

Same level of barley acreage estimation with and without EO data
Lower confidence interval with EO -> higher efficiency

Barley acreage estimates (R2=0.71)



Data	Barley acreage (Hectares) in the study area. Spain. 2018	Uncertainty		Sampling Error (CV%)	Relative efficiency
		95% Confidence Interval (Hectares)			
		Limits	Amplitude		
Ground (ESYRCE)	236165.4	Lw: 215951.7	40427.24	4.37	-----
		Up: 256379			
Ground+EO	228550.1	Lw: 219699.8	17700.51	1.98	5.2
		Up: 237400.3			





Example of use cases in Senegal: optimization of field protocols to facilitate the EO integration



DATA QUALITY

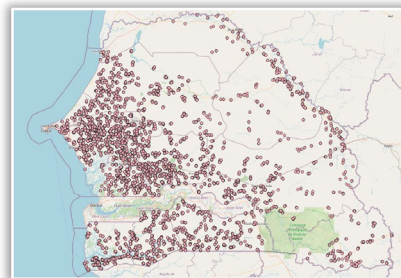
Improving the quality of the ground database (data collection protocol & quality control procedure)


In-depth analysis of the data collected by National Statistical Offices

Collaborative effort to improve the collection protocols



Dakar, April 2022



GPS Tablet (ODK) 
GPS Garmin 

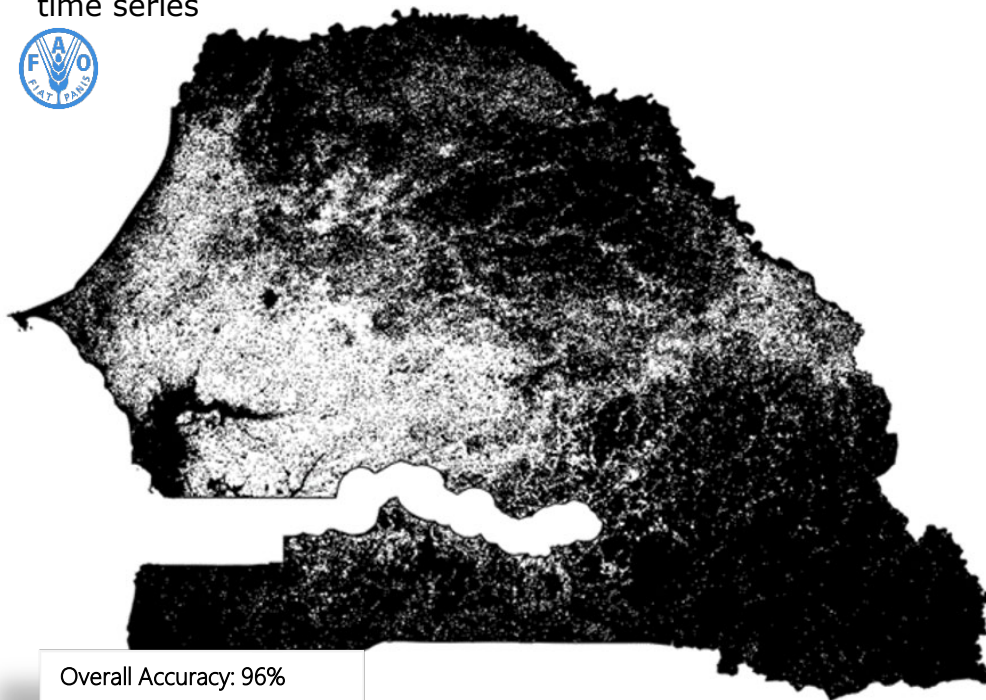




High impact of in situ data collection on EO crop mapping performance



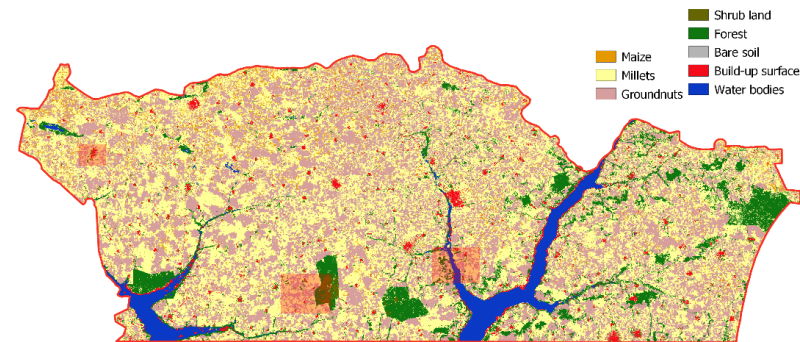
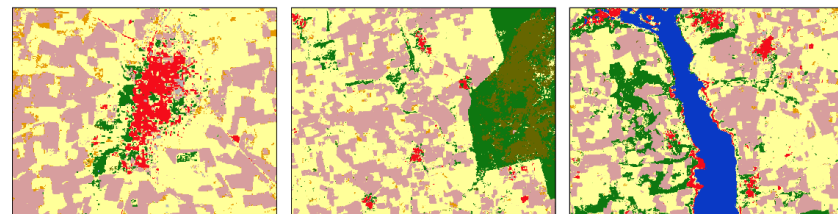
National cropland mask at 10-m resolution
Per-pixel Random Forest classification based on S2 L2A time series



Overall Accuracy: 96%
F-Score cropland: 97%
F-Score non-cropland: 88%

Pilot in situ collection adjusted for EO

- Random Forest
- Transformer with spatial context (*deep learning*)



Slide 9





Development of the Sen4Stat open source system

S-1 & S-2 full processing supporting the improvement of ag. Stats at national scale

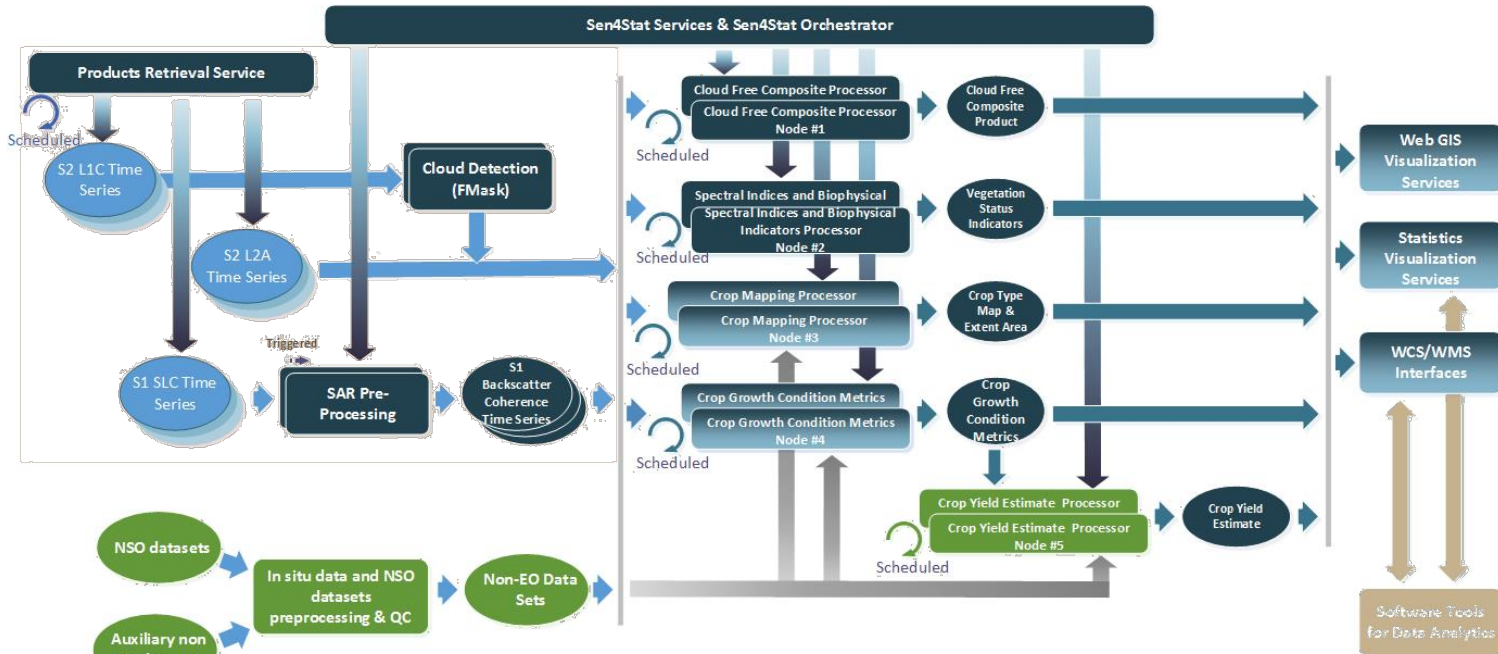


Data access /download

Pre-processing In situ quality control

Processors of products

Analytics and visualization



Can be run locally or on the cloud, in NRT or after the season





System operations running according to different modes: NRT with orchestrator (fully automated) or on request



Automated mode through the web graphical user interface (GUI)

a) based on the Orchestrator with by-default parameterization, automatic data download and processing until the end of the season, on-time delivery
=> **operational production in near real time (NRT)**

a) Processor execution on user request, with by-default parameterization



Manual mode: to run processor independently, with custom parameters

a) through the GUI, with the *Custom job* approach

b) in command line through a linux terminal

The screenshot shows a web interface with a navigation bar (sites, products, system overview, dashboard, custom jobs, monitoring, logout) and a main content area. The 'system overview' tab is active, displaying resource utilization statistics for various processors (L2A, L3A, L3B, L3E, L4A, L4B) and a 'Default Configuration' table. The 'Output' section shows job statistics, and the 'Add New Job' section includes a table for job details.

Resource Utilization	Value
Last Run On	19-03-08 09:53:13
Average Duration	03:00:14
Average User CPU	207.56%
Average System CPU	212.02:102
Average Mem RSS	3.02 MB
Average Mem VM	3.02 MB
Average Disk Read	1.64 MB
Average Disk Write	2.07 MB

Default Configuration	Value
season	16/17/18
temporal resampling mode	100%
random seed	9
window	6
smoothing kernel	3
padding	0
segmentation spatial radius	10
range radius	100
segmentation minsize	100
arbitr radius	1
classifier	4
classified files	100%
classifier threshold	100
classifier njobs	20
classifier nruns	20
classifier saveopt	1

Output	Value
Number of Products	15
Average Time per Product	1
Average Duration per Title	00:03:00:24

Job name	Site name	Season name	Schedule type	First run time	Repeat	Action
Orchestrator_MF0000	MF0000	L3B160001	select a series			

```
lai_retrieve_processing.py --input
/mnt/archive/maccs_def/mall/12a/S2A_OPER_PRD_MSIL2A_PDMC_20160718T093045_R008_V2016
0717T104833_20160717T104833_SAFE/S2A_OPER_SSC_L2VALD_30PVV_20160717_HDR --res 10
--outdir /mnt/archive/temp/test_lai --rsrcfg /usr/share/sen2agri/rsr_cfg.txt --
modelsfolder /mnt/archive/temp/test_lai --generatemodel YES --generatemonodate YES --
genreprocessedlai NO --genfittedlai NO
```





- Sen4Stat open-source system developed to be run locally or on the cloud
- Cloud facilities:
 - Direct access to Sentinel data
 - No need to download (band width might be an issue in many countries)
 - No need to store
 - Direct access to the full archive of Sentinel data (>< SciHub)
 - Optimization of the resources during the production (dynamic allocation of resources, machines created and paid during production peaks only)
- Precautionary measures:
 - Data privacy and security issues: agricultural surveys NSOs are very sensitive data => some reluctance to work on the cloud (specific protocol / cryptation would be an asset)
 - Clouds proposed in the NoR not always well-known in non European countries



- Need of timely data on agricultural practices and natural resources
 - To support an increase of sustainable agricultural productivity
 - To monitor the Sustainable Development Goals (SDG) at the national level
 - To contribute to the agricultural markets transparency and support food security
- Agricultural monitoring at national scale is a pre-requisite for analyzing the agricultural resources and activities by mandated authorities (NSOs)
 - Most NSOs collect data through agricultural survey – costly !!
 - Potential of EO recognized for long but not yet adopted
- Most benefits will come from the mutual adjustment between in situ sampling (quantity, representativeness and quality) and innovative EO products
 - Sen4Stat demonstration phase to convince about EO benefit
 - Sen4Stat open source system & capacity building to facilitate the EO adoption



- Demonstration will continue in 2023
 - Results from cycle 1 analyzed with pilot countries
 - Cycle 2 building on cycle 1 (extending spatial scale and/or focusing on more applications)
- Sen4Stat system will be evolving
 - Yield estimation module will be added – crop production is key !
- Strong focus on capacity building
 - Capacity building activities with the 5 pilot countries
 - Distribution of the Sen4Stat open source system to external users
 - Forum, GitHub, webinars, videos, etc.
- Scientific publications (methods, results and success stories) & conferences