https://esa-sen4stat.org/

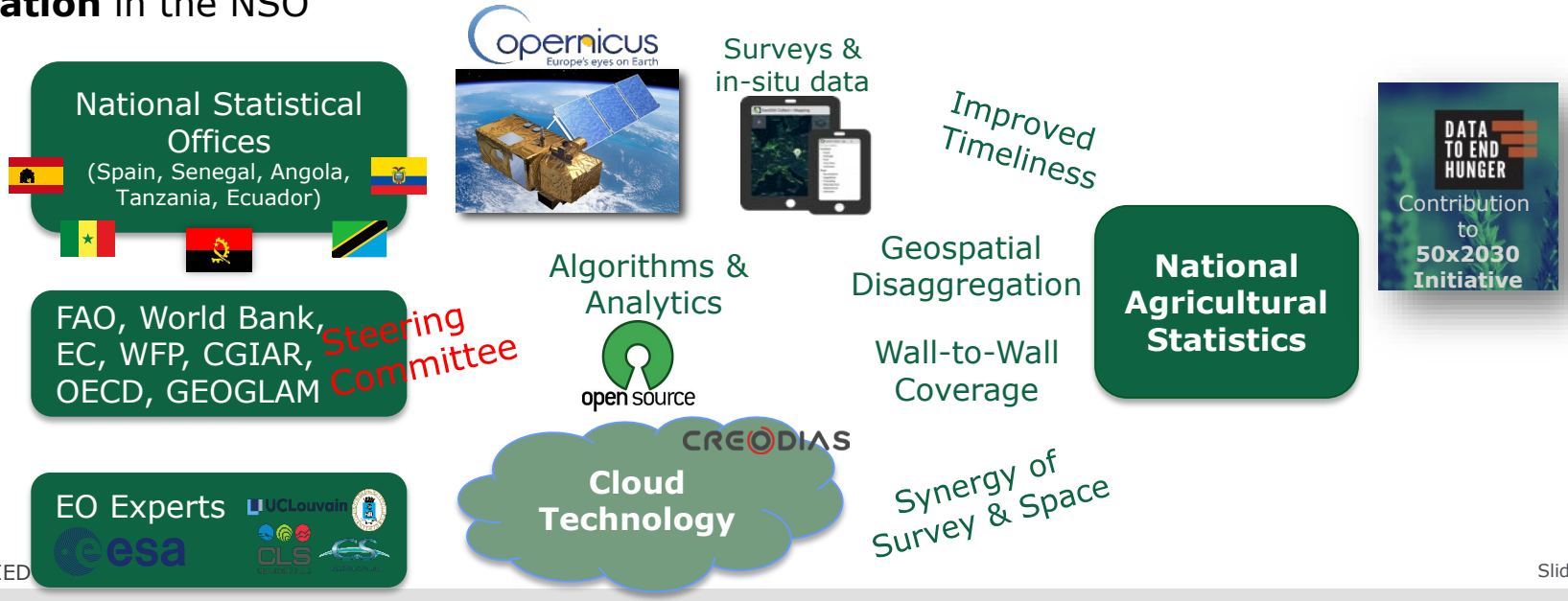
ESA project
“Sentinels for Agricultural Statistics”

NoR sponsorship
Final report

ESA UNCLASSIFIED - For Official Use

ESA Sen4Stat
EO to support official agricultural statistics

- 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

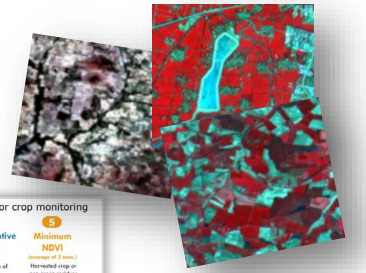
STAT. TIMELINESS

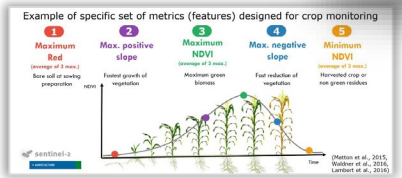
SAMPLING DESIGN

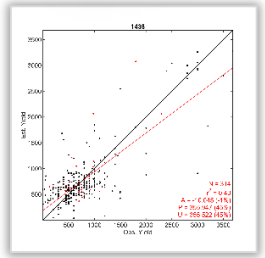
SDG's REPORTING

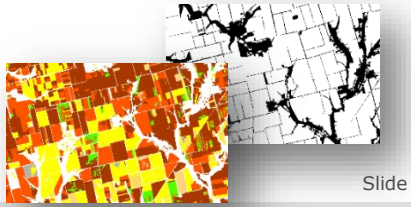
DATA COLLECTION PROTOCOL

- 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





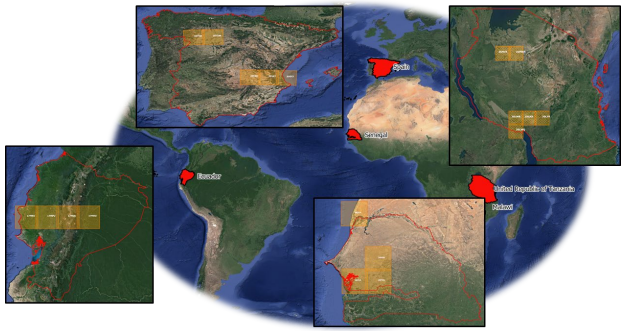




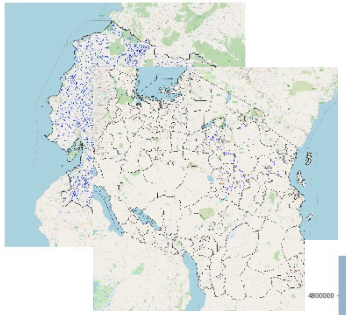
Study area, from local to national scale

Methods development
Working on test sites

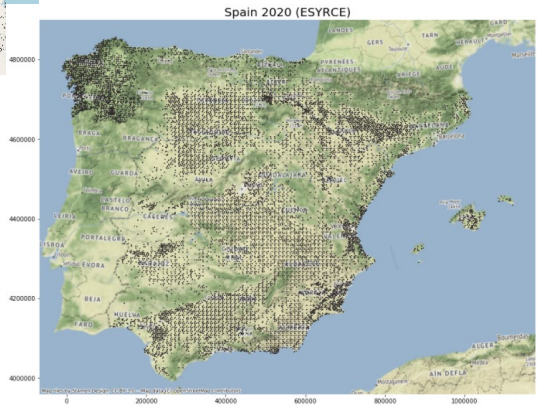
System demonstration
Up to national scale



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

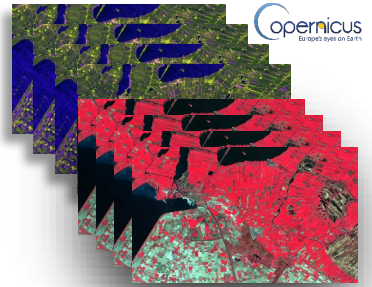


- From 2018 to 2020, depending on the country
- Sentinel-2 L1C & L2A + Sentinel-1 SLC full archive



Results in brief

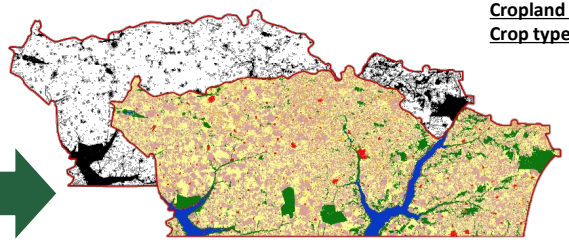
Sentinel-1 and -2



Agri. surveys

EO Cloud

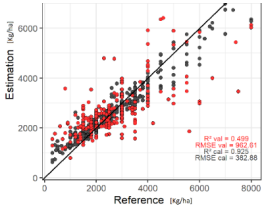
EO products



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%

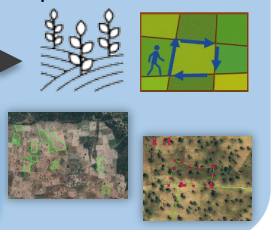
SENEGAL
Crop growing metrics evolution

SPAIN – CASTILLA Y LEON
Soft wheat yield estimation



OPTIMIZING FIELD DATA COLLECTION

Co-design of new protocols



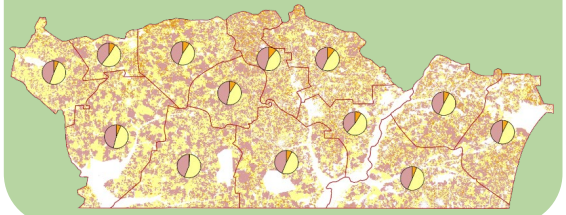
IMPROVING COST-EFFICIENCY

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**

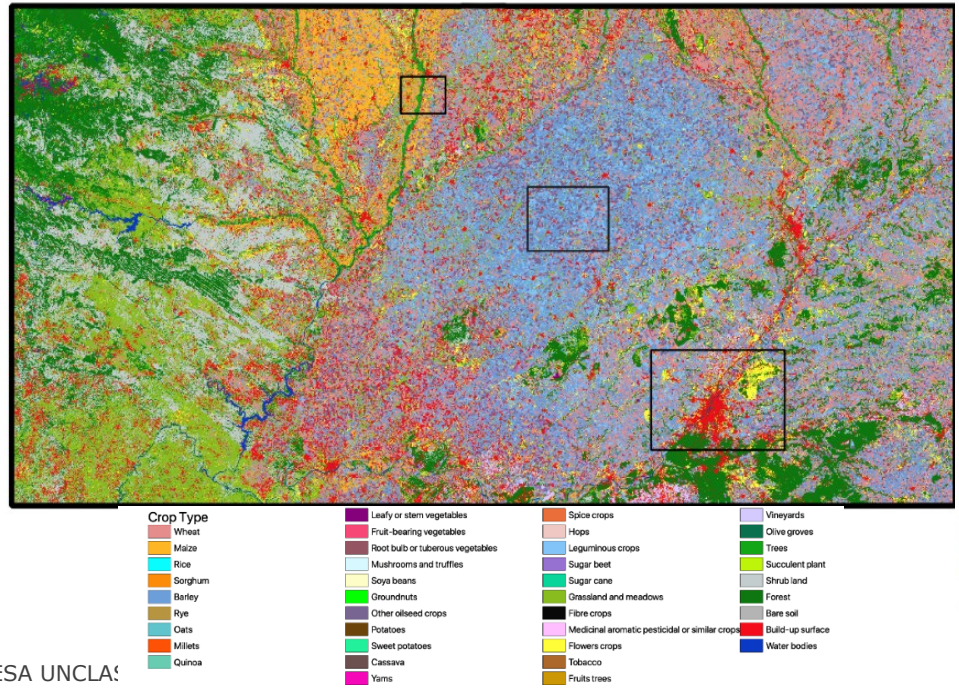
INCREASING STATS GRANULARITY

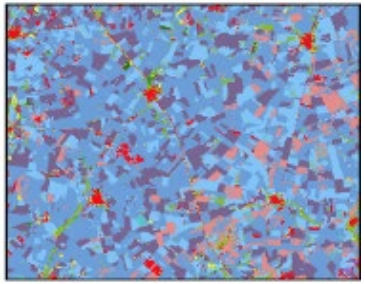
Crop area estimates at communes level

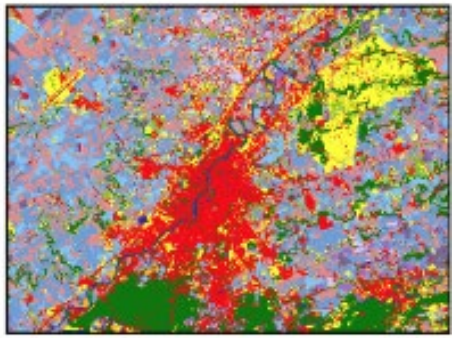


Example of use case in Spain
Prerequisite EO-product : 10-m crop map (35 crop types)

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







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

Cost-efficiency on crop acreage (barley in Spain)

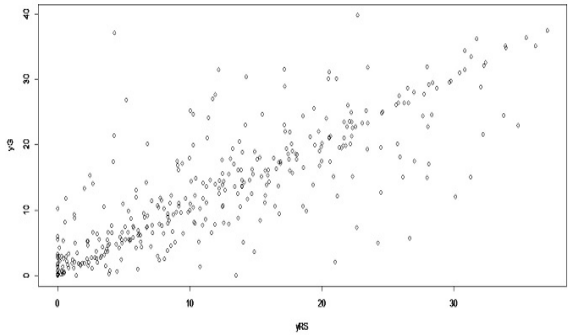
COST EFFICIENCY

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			Relative efficiency
		95% Confidence Interval (Hectares)		Sampling Error (CV%)	
		Limits	Amplitude		
Ground (ESYRCE)	236165.4	Lw: 215951.7 Up: 256379	40427.24	4.37	------
Ground+EO	228550.1	Lw: 219699.8 Up: 237400.3	17700.51	1.98	5.2

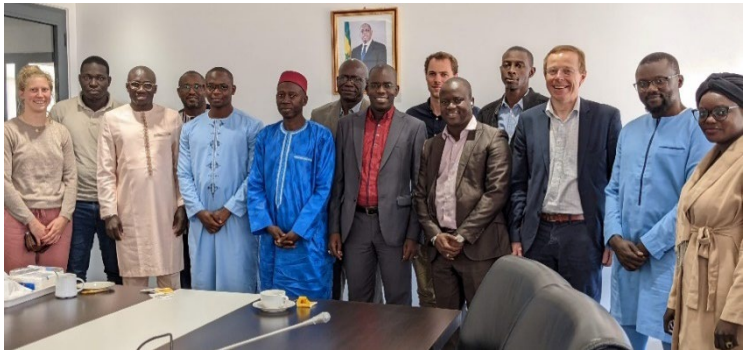
Example of use cases in Senegal: optimization of field protocols to facilitate the EO integration

DATA QUALITY

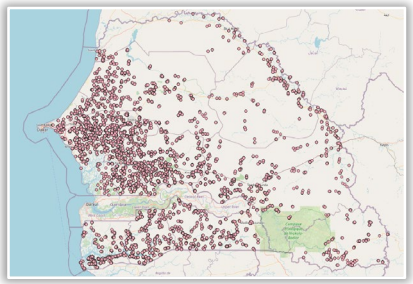
Improving the quality of the ground database (data collection protocol & quality control procedure)

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

Collaborative effort to improve the collection protocols



Dakar, April 2022



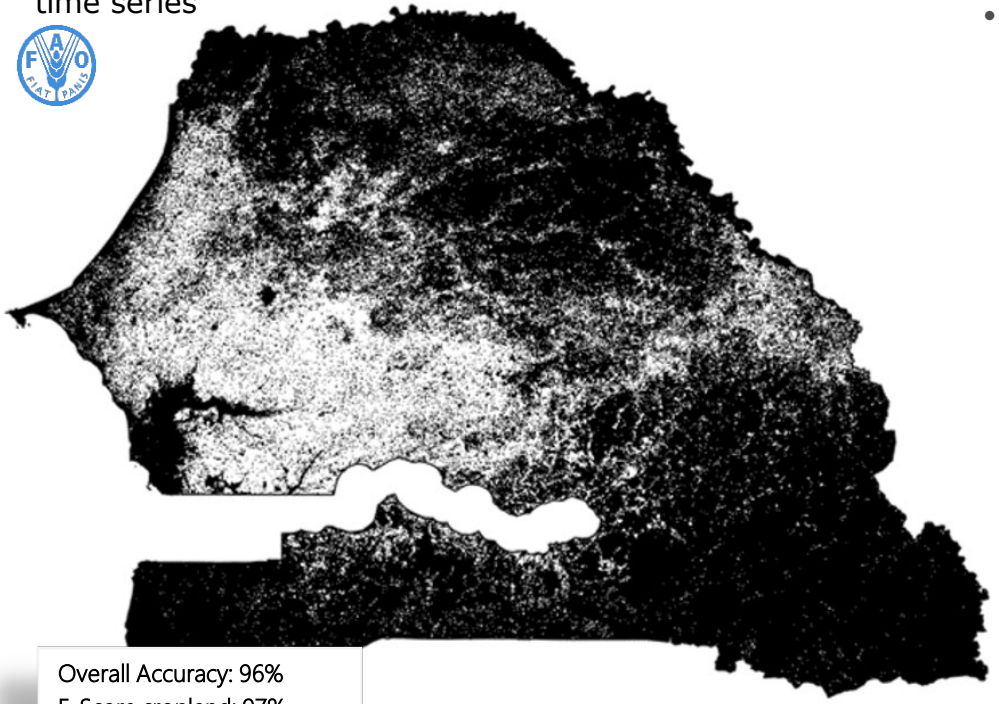
GPS Tablet (ODK)

GPS Garmin

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

National cropland mask at 10-m resolution

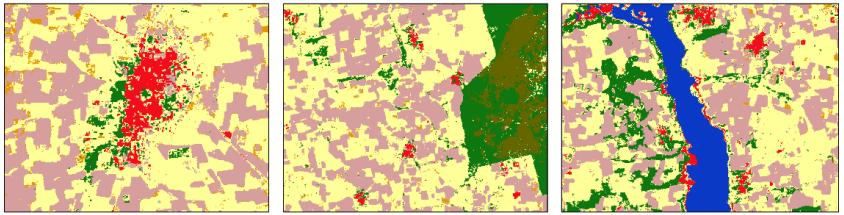
Per-pixel Random Forest classification based on S2 L2A time series

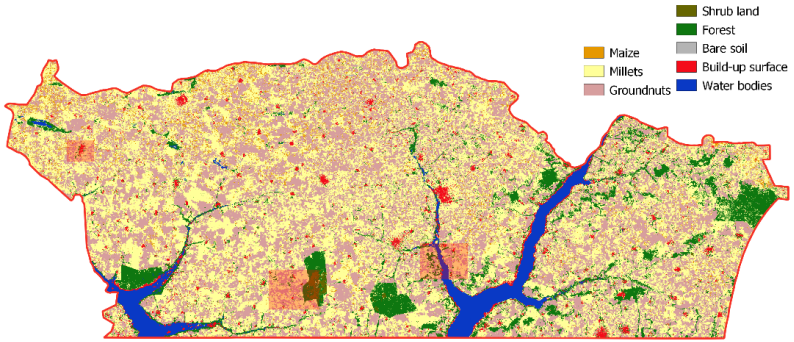


Overall Accuracy: 96%
F-Score cropland: 97%
F-Score non-cropland: 88%

Pilot in situ collection adjusted for EO

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

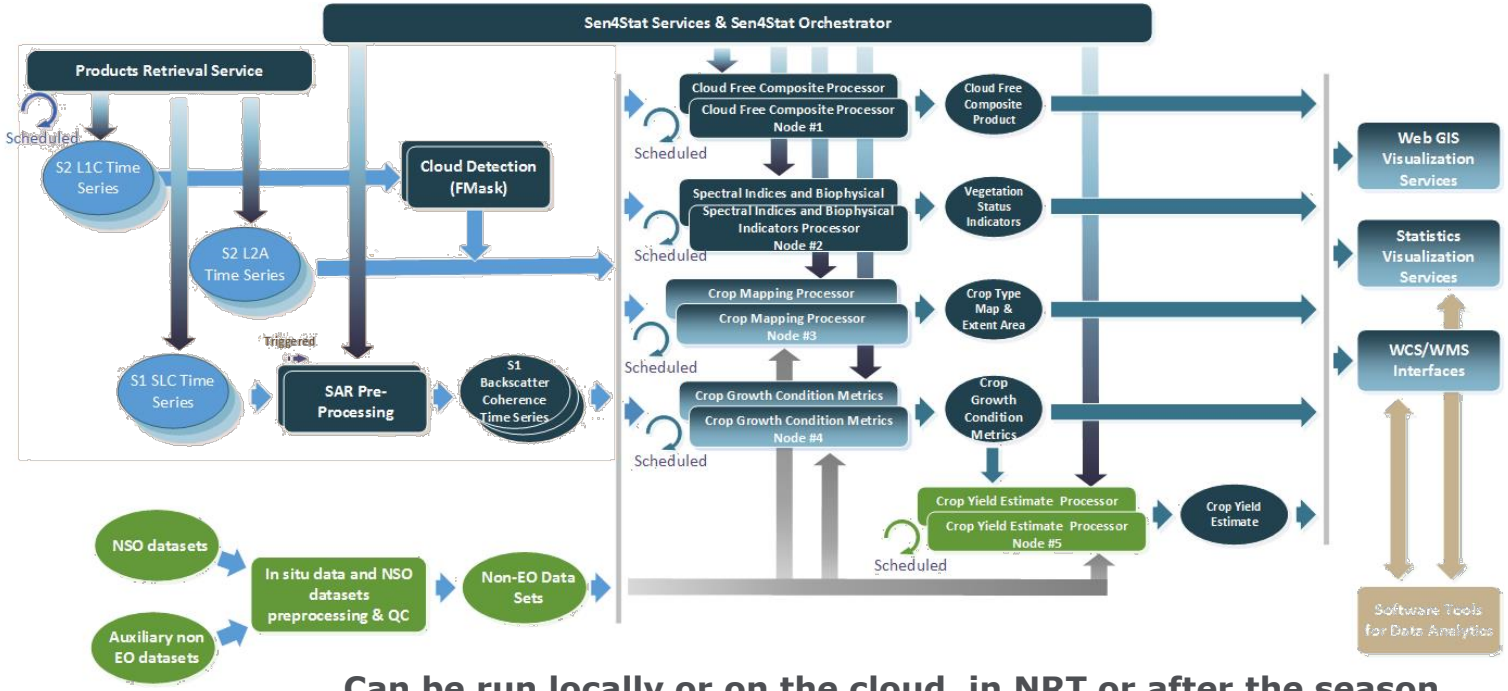




Development of the Sen4Stat open source system

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


```
lai_retrieve_processing.py                                          --input
/mnt/archive/maccs_def/mali/l2a/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 on the cloud

- 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

Sen4Stat benefits for society

- 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

Sen4Stat next steps

- 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