Open Source alapú rendszer fejlesztése mezőgazdasági támogatások műholdas monitoringjára

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Magyar Államkincstár

ULYSSYS

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CAP monitoring is the most demanding operational application of Sentinel data

- Carried out at national scale across the whole EU
- Done by national/regional paying agencies and their (IT/EO) subcontractors
- Repeated several times every year
- Typically involves image time series of several months
- Parcel-level output (red/yellow/green)

Common Agricultural Policy (CAP) monitoring in a nutshell

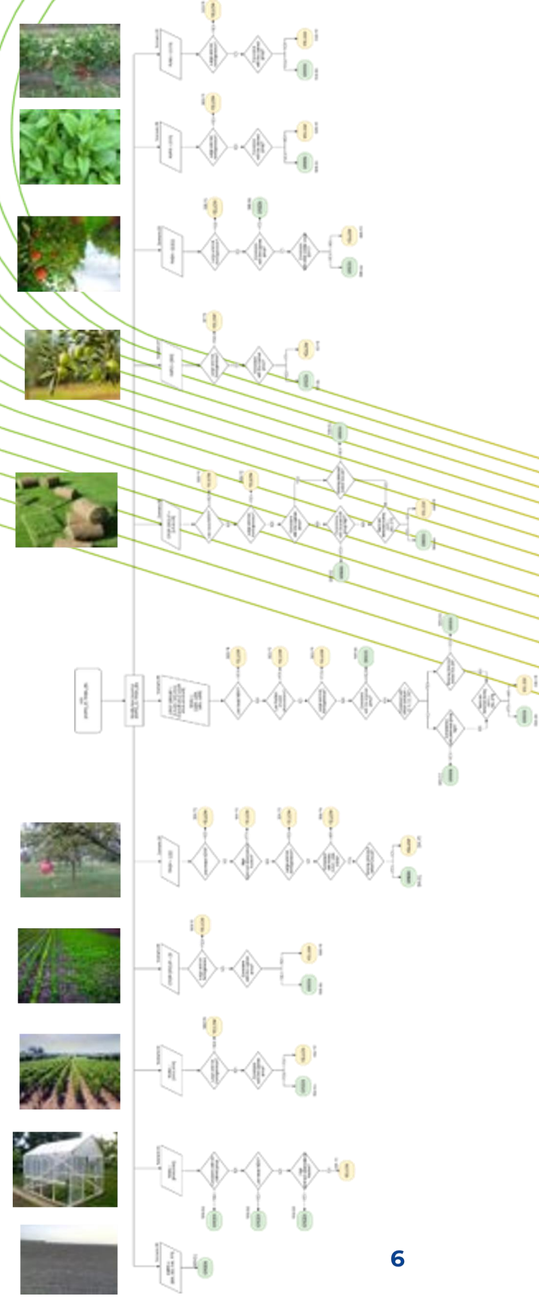
Direct payment → accurate monitoring of compliance

- **A multi-indicator system**
  - **Parcel integrity**
  - **Cultivation practices and timing**
  - **Presence of ineligible areas**
  - **Crop type**

Satellite-based monitoring is a game changer, from 5% field checks to full evaluation of all parcels

Requirements for successful CAP monitoring – what paying agencies want

- Accuracy, high performance and extreme reliability
- Traceability of all processing steps from final decision all the way to initial satellite imagery
- Compatibility with image sharing & viewing to allow farmers to follow up on notifications
- New functionality should easily be added on top of existing code



Hungary – agricultural remote sensing

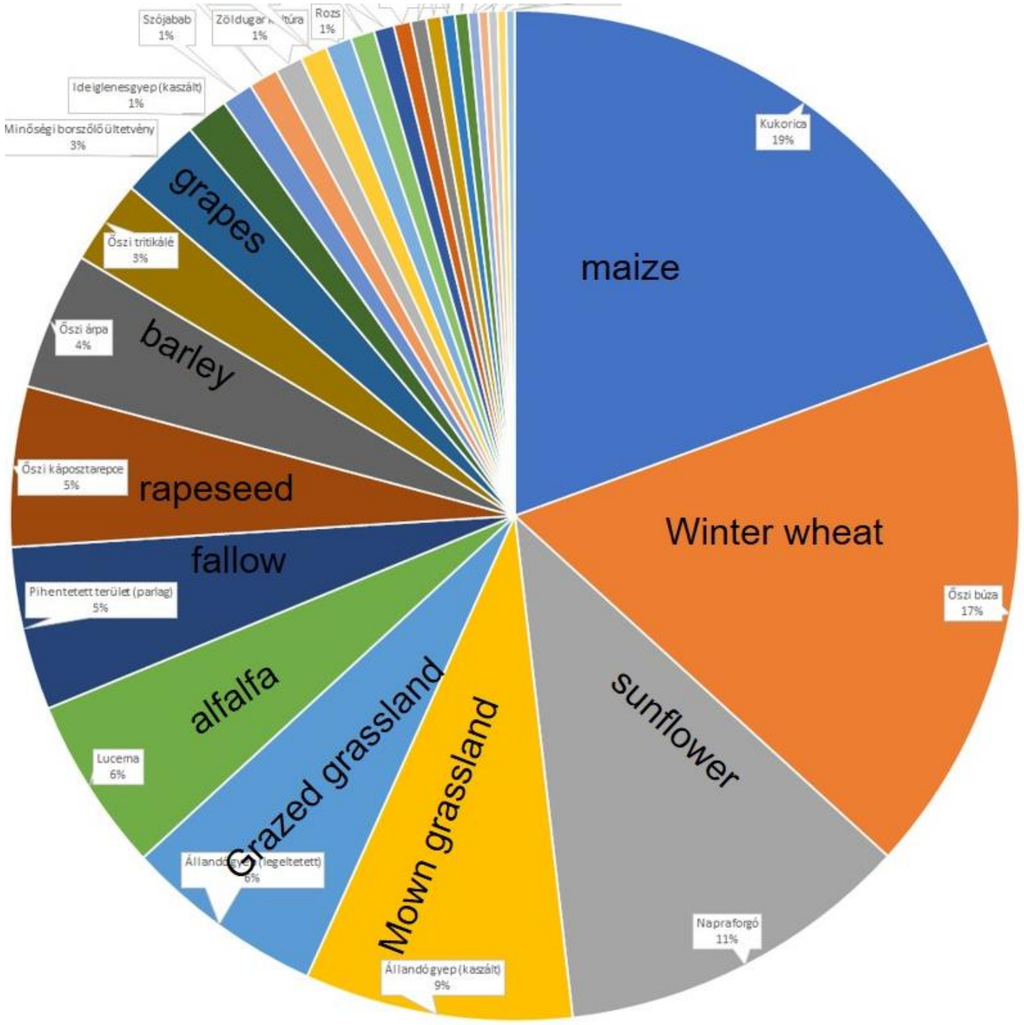
Total area: 93 000 km^2

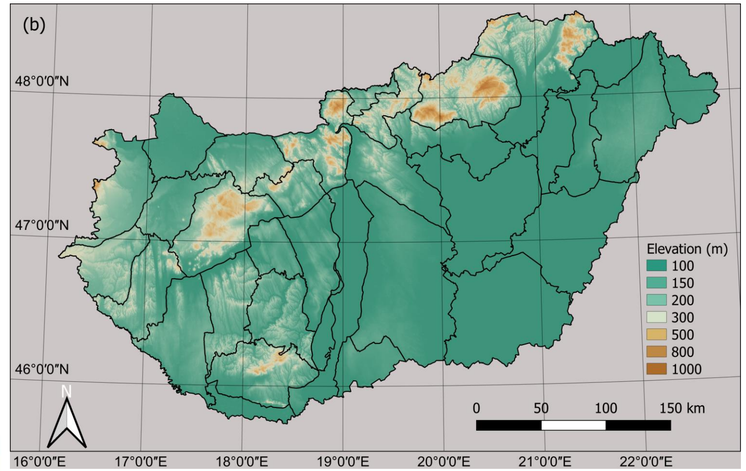
~1 200 000 individual parcels

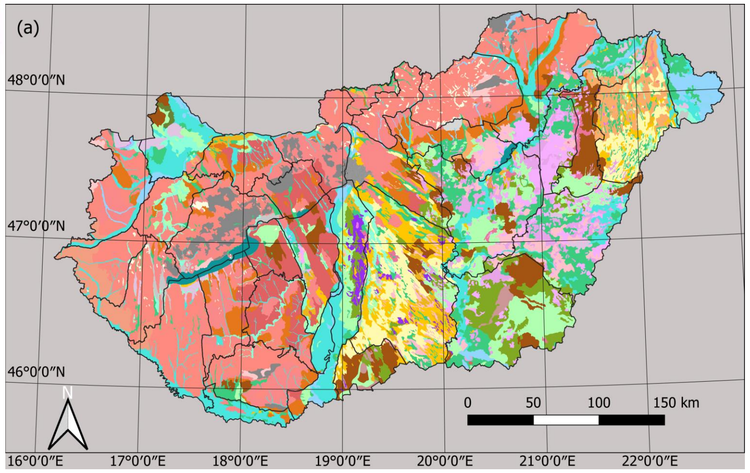
Many small parcels, often cultivated as part of larger units but claimed separately

Continental climate, ca. 50% of Sentinel-2 images are cloudy

Diverse soil types and microclimates







Soil map based on Pásztor (2018)

Ulyssys CAP monitoring pilot

Pilot project: how can Sentinel-2 be used for operational monitoring of Single Area Payment Scheme (SAPS) and Greening subsidies

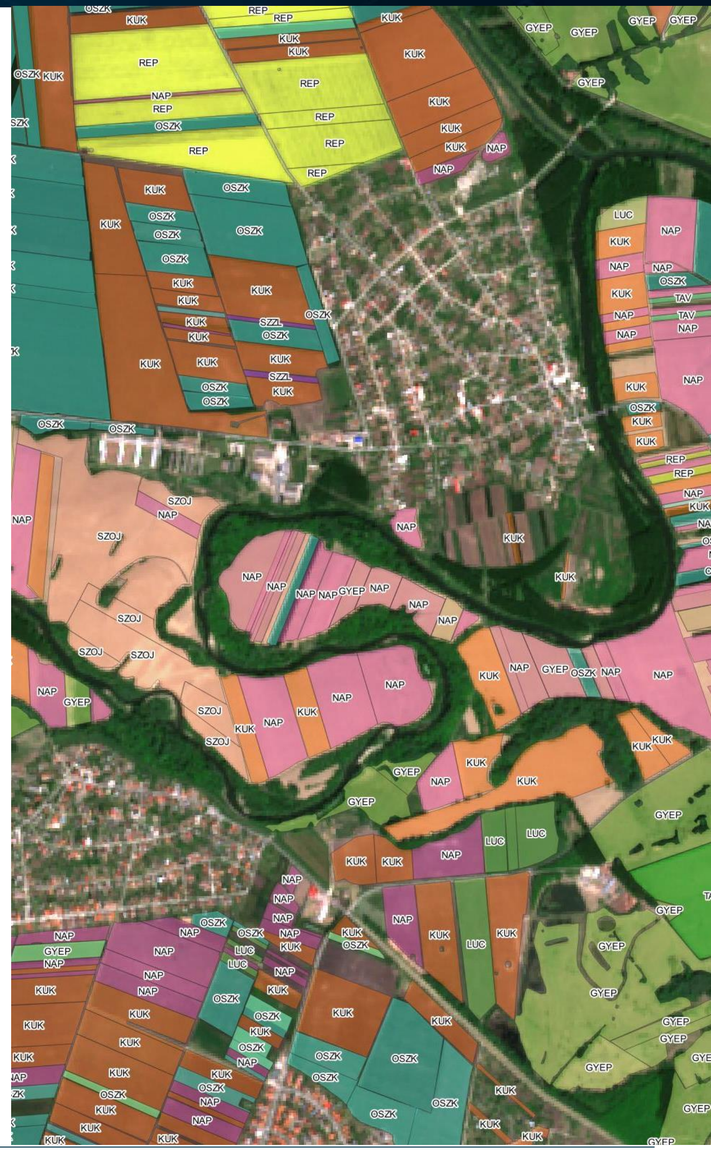
SAPS basic criteria:

- The parcel is covered by an agricultural crop or temporary fallow
- In case of grasslands, the area is grazed or mown and not dominated by weeds

Greening basic criteria:

- Crop diversification
- Maintenance of sensitive grasslands
- Fallow land
- Nitrogen-fixing crops
- Catch crops

Based on Sentinel-2 time series of the whole year (2020)



FORCE analysis ready data

In-house Sentinel data archive based on FORCE
(Framework for Operational Radiometric Correction for Environmental Monitoring, Frantz 2019)

Image downloading

Geometric correction

Atmospheric correction

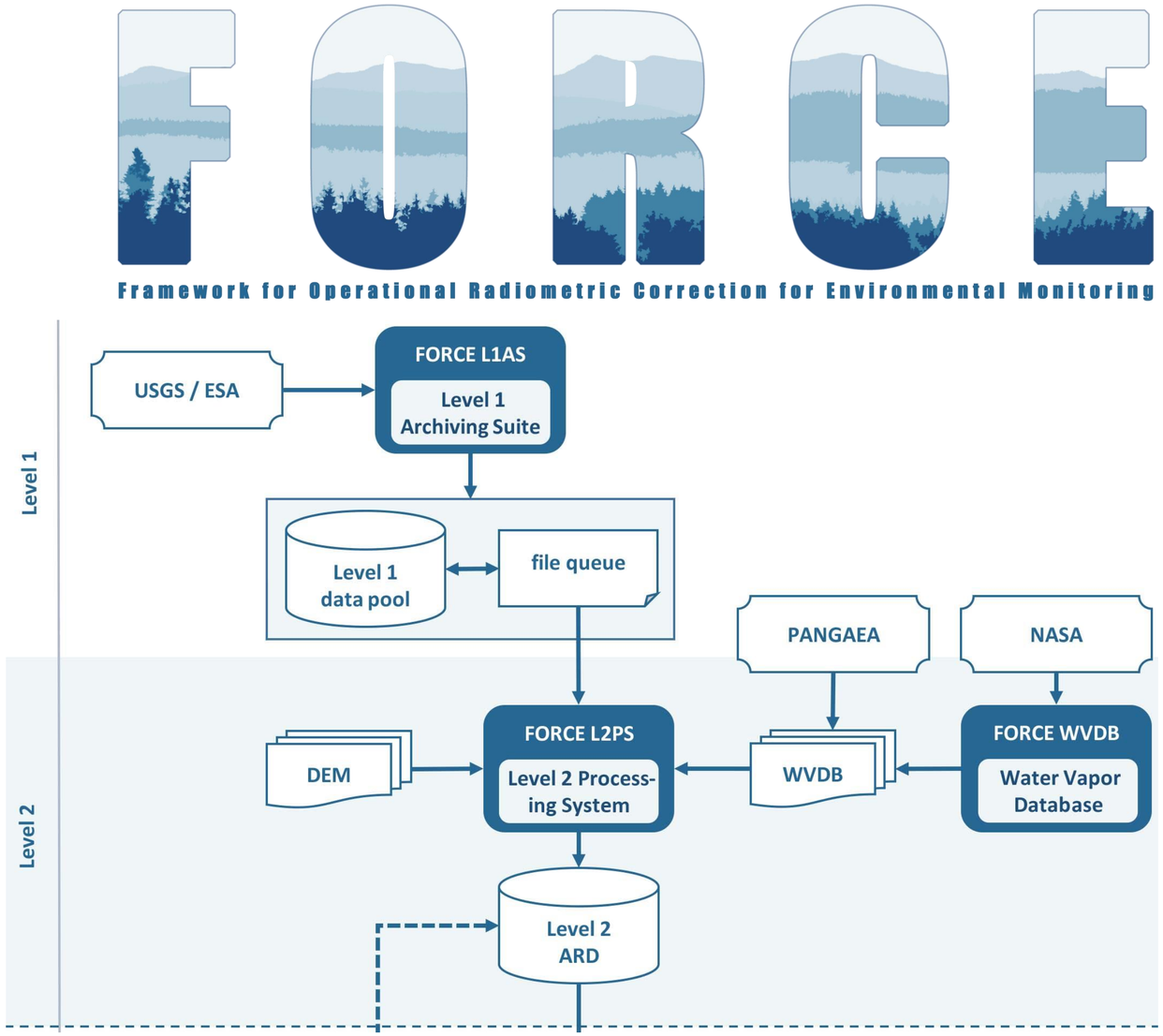
Radiometric correction

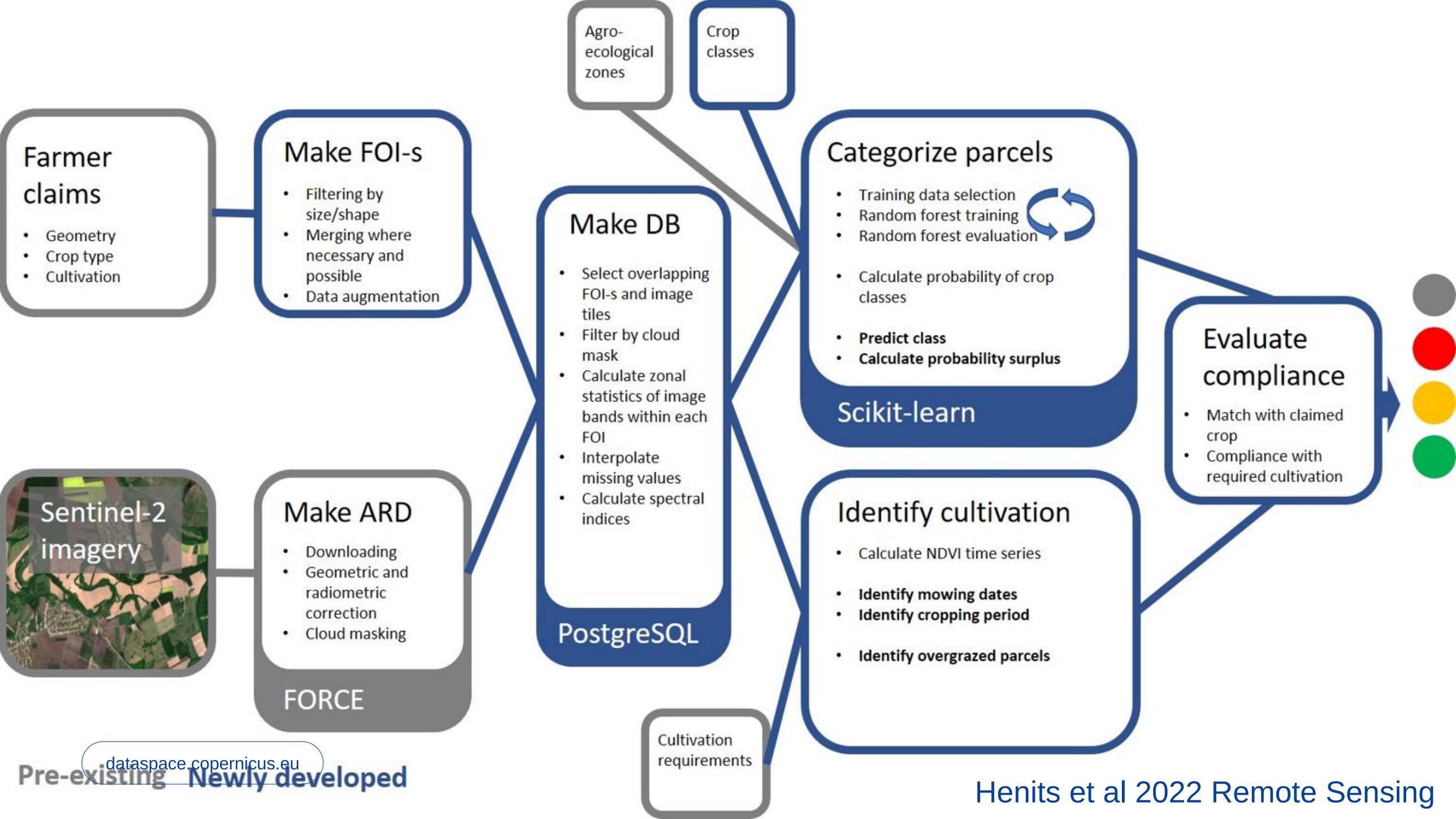
Cloud masking

Output: Level 2 ARD for **Sentinel-2**

Spectral indices: NDVI, BSI, EVI, SIPI, YCI

$$YCI = (B04 + B03) - (2 \times B02)$$





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CAP monitoring pilot: classification on full time series

Sentinel-2 FORCE Level 2 imagery was used

Parcel size limit: parcel area after 10 m internal buffer larger than 20m × the longest edge – 59% of parcels are of sufficient size (82% of claimed area)

But small parcels with similar crops were merged – additional 25% of parcels included (14% of area)

16.5% of parcels too small for Sentinel-2 based classification (3% of area)

24 crop classes included, overall accuracy 88.07%

Class data	*Reference Data*																							
	SHR	SUG	OTH	ENER	FRST	TREE	GRAS	HERB	WEED	MAIZ	ALF	REED	SUNF	WCER	FLAND	RAPS	RICE	FIBP	SOY	GRPE	FVEG	FPLA	SCER	VEG
SHR	11%	0%	0%	0%	0%	21%	22%	0%	0%	1%	4%	0%	1%	1%	12%	0%	0%	0%	0%	27%	0%	0%	0%	1%
SUG	0%	87%	0%	0%	0%	0%	0%	0%	0%	3%	0%	0%	7%	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%	1%
OTH	0%	0%	78%	0%	0%	0%	11%	0%	0%	0%	0%	0%	0%	0%	11%	0%	0%	0%	0%	0%	0%	0%	0%	0%
ENER	0%	0%	0%	25%	0%	2%	45%	0%	0%	5%	8%	1%	0%	2%	11%	0%	0%	0%	0%	1%	0%	0%	0%	1%
FRST	0%	0%	0%	0%	70%	7%	15%	0%	0%	1%	1%	0%	0%	0%	3%	0%	0%	0%	0%	2%	0%	0%	0%	1%
TREE	0%	0%	0%	0%	1%	71%	12%	0%	0%	1%	2%	0%	0%	1%	6%	0%	0%	0%	0%	5%	0%	0%	0%	1%
GRAS	0%	0%	0%	0%	0%	1%	91%	0%	0%	0%	4%	0%	0%	1%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%
HERB	0%	0%	0%	0%	0%	5%	7%	21%	0%	7%	4%	0%	4%	7%	13%	3%	0%	0%	0%	3%	4%	1%	2%	18%
WEED	0%	0%	0%	0%	0%	0%	1%	0%	98%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
MAIZ	0%	0%	0%	0%	0%	0%	0%	0%	0%	97%	0%	0%	1%	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%
ALF	0%	0%	0%	0%	0%	1%	11%	0%	0%	1%	82%	0%	1%	1%	2%	0%	0%	0%	0%	1%	0%	0%	1%	0%
REED	0%	0%	0%	0%	5%	4%	32%	0%	0%	15%	0%	40%	1%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	1%
SUNF	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	0%	0%	96%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%
WCER	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%	97%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%
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SOY	0%	0%	0%	0%	0%	0%	0%	0%	0%	6%	0%	0%	3%	0%	1%	0%	0%	0%	89%	0%	0%	0%	0%	0%
GRPE	0%	0%	0%	0%	0%	2%	3%	0%	0%	0%	0%	0%	0%	0%	3%	0%	0%	0%	0%	90%	0%	0%	0%	0%
FVEG	0%	0%	0%	0%	0%	1%	1%	0%	0%	4%	1%	0%	11%	1%	7%	0%	0%	0%	0%	1%	61%	2%	3%	7%
FPLA	0%	0%	0%	0%	0%	1%	15%	0%	0%	10%	9%	0%	4%	7%	7%	1%	0%	0%	1%	1%	2%	35%	6%	1%
SCER	0%	0%	0%	0%	0%	0%	2%	0%	0%	14%	1%	0%	3%	8%	7%	0%	0%	0%	0%	1%	1%	1%	60%	1%
VEG	0%	0%	0%	0%	0%	3%	1%	0%	0%	4%	1%	0%	6%	2%	10%	0%	0%	0%	0%	3%	4%	1%	2%	62%

CAP monitoring pilot: NDVI time series analysis

In addition to classification, we had to check mowing dates and cultivation periods

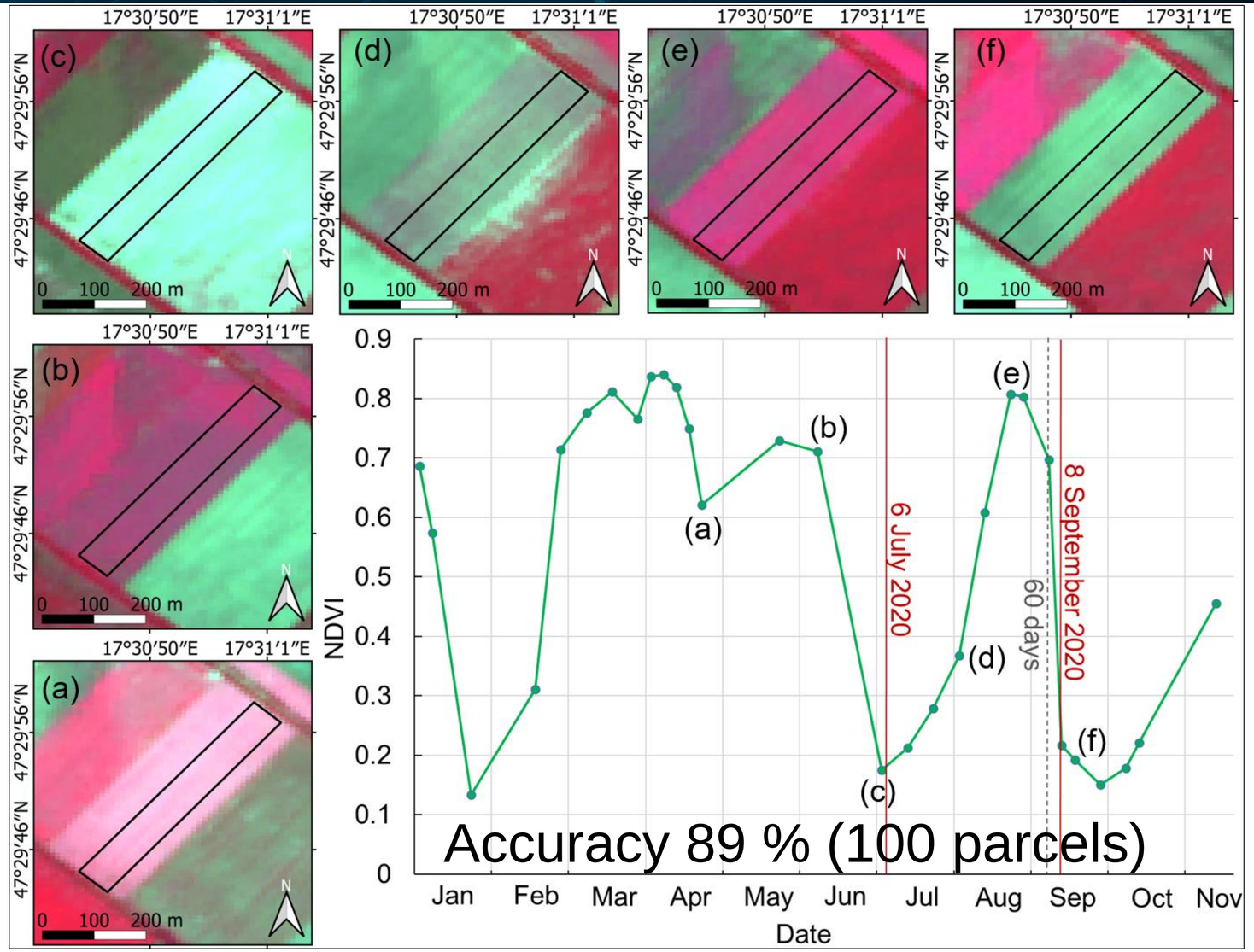
Cultivation was detected based on changes in the NDVI time series

Mowing

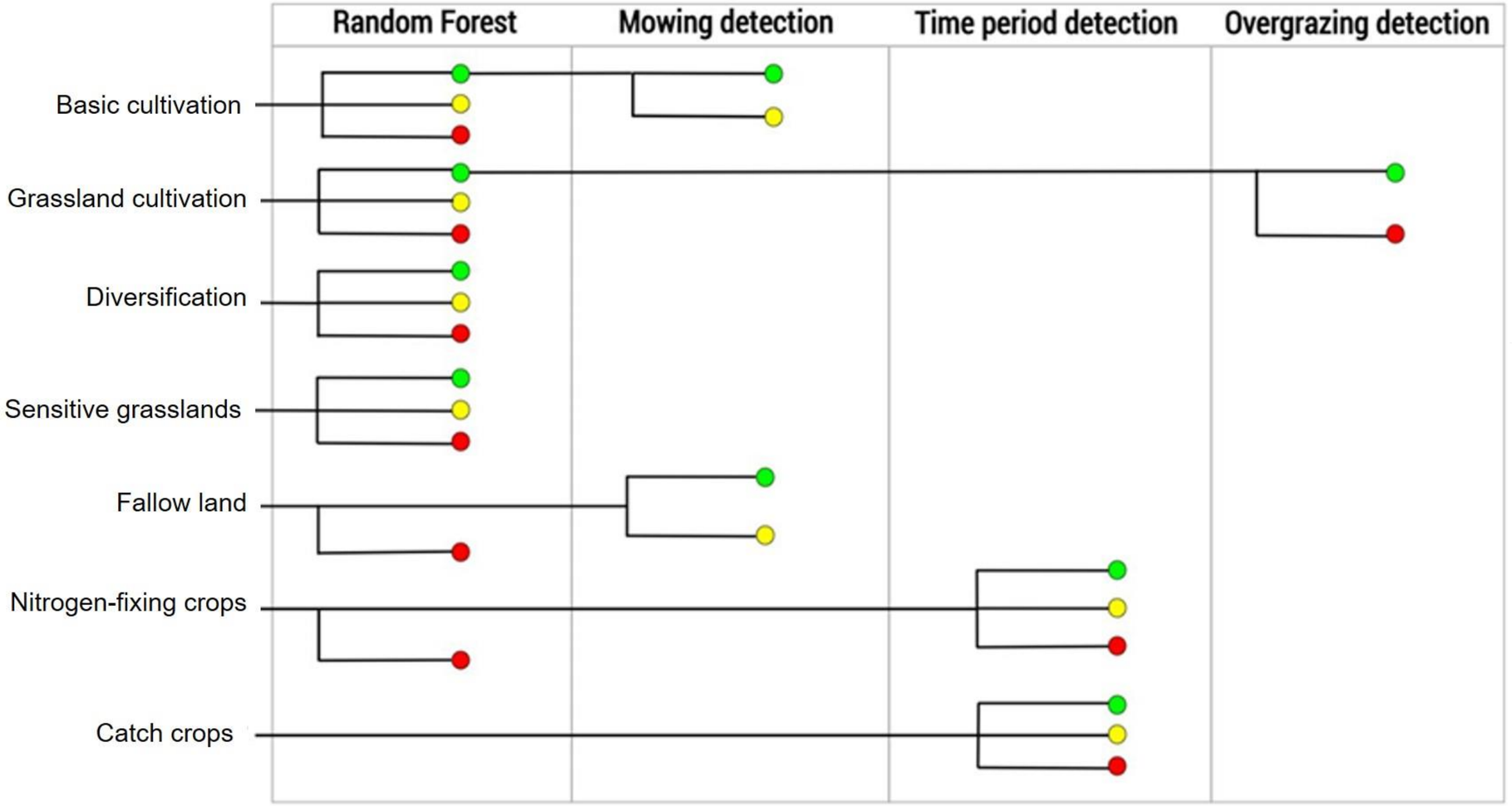
Catch crop seeding and harvesting

The minimum NDVI and dates with NDVI < NDVImin + 0.075 are bare soil. Time between first bare soil after maximum and next bare soil event is calculated

Overgrazing



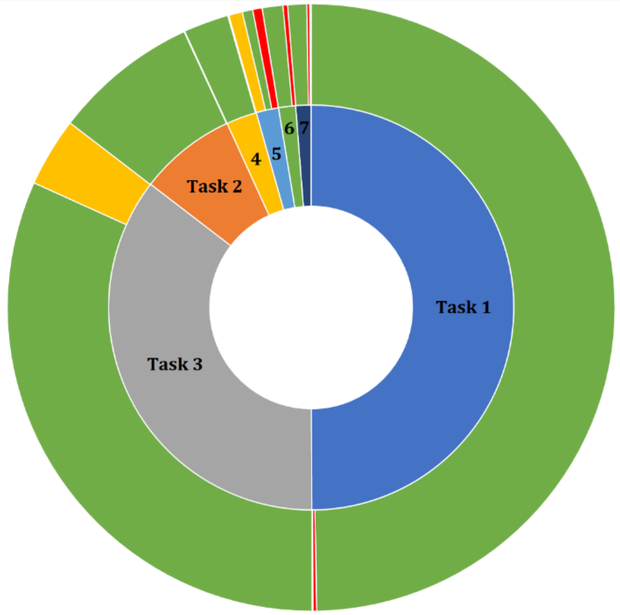
CAP monitoring pilot – decision tree & results



94% of all monitoring operations (parcel + requirement) were found eligible

1.5% are erroneous

4.5% require followup



State of the art for most paying agencies

What paying agencies want	How this is achieved
Accuracy, high performance, reliability	High-performance in-house computing centers at paying agencies/contractors
Traceability of all processing steps from final decision all the way to initial satellite imagery	Storing many intermediate products
Compatibility with image sharing & viewing for farmers to follow up	Re-hosting the data and sharing to farmers
New functionality should easily be added on top of existing code	External open code modules, in-house code bases

Agro-ecological zones

Crop classes

Farmer claims

- Geometry
- Crop type
- Cultivation

Make FOI-s

- Filtering by size/shape
- Merging where necessary and possible
- Data augmentation

Make DB

- Select overlapping FOI-s and image tiles
- Filter by cloud mask
- Calculate zonal statistics of image bands within each FOI
- Interpolate missing values
- Calculate spectral indices

PostgreSQL

Categorize parcels

- Training data selection
- Random forest training
- Random forest evaluation
- Calculate probability of crop classes
- **Predict class**
- **Calculate probability surplus**

Scikit-learn

Evaluate compliance

- Match with claimed crop
- Compliance with required cultivation

Hosted Online

Make ARD

- Downloading
- Geometric and radiometric correction
- Cloud masking

FORCE

Identify cultivation

- Calculate NDVI time series
- **Identify mowing dates**
- **Identify cropping period**
- **Identify overgrazed parcels**

Cultivation requirements

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Pre-existing **Newly developed**

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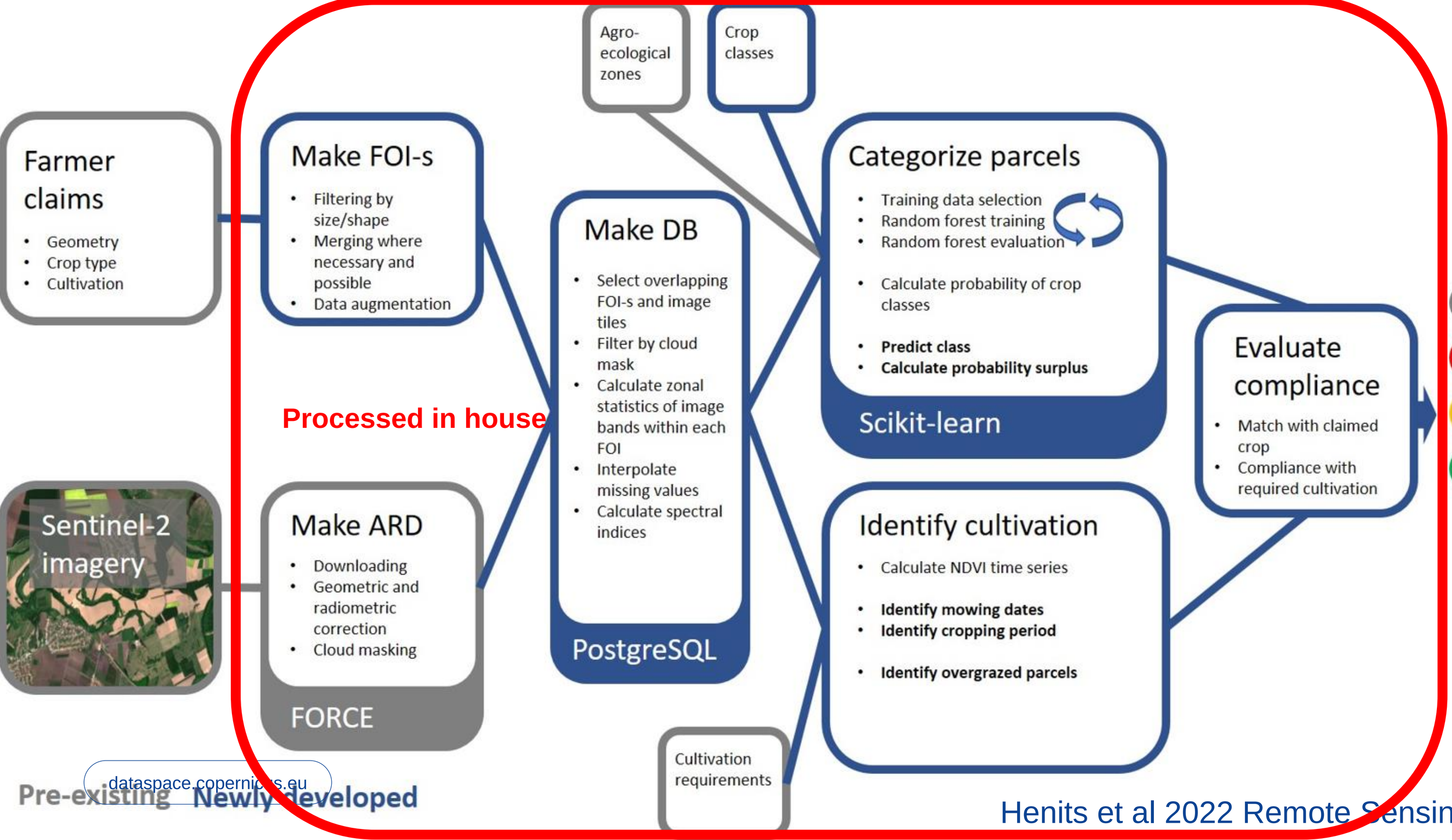

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Main principles of Copernicus Data Space Ecosystem

Contribute to building an attractive and efficient European solution to access and process Copernicus Sentinel data

Provide users a long-term perspective building trust and unlocking the potential of Sentinel data

Support European industry in developing high-quality competitive operational services

Replaces Copernicus Open Data Hub from September 2023!

Main features of Copernicus Data Space Ecosystem

Full Sentinel Data Archive

Additional Copernicus data

Copernicus Contributing missions Data

Dataspace Ecosystem Browser for individual image view and download

- Images
- Time series
- Custom visualizations

Open data distribution service with downloading and processing API-s

- Platform for building new software solutions
- Access to imagery and data products

Cloud computing capacity with adjustable capacity and performance

- CREODIAS
- Open Telekom Cloud
- Third-party resources

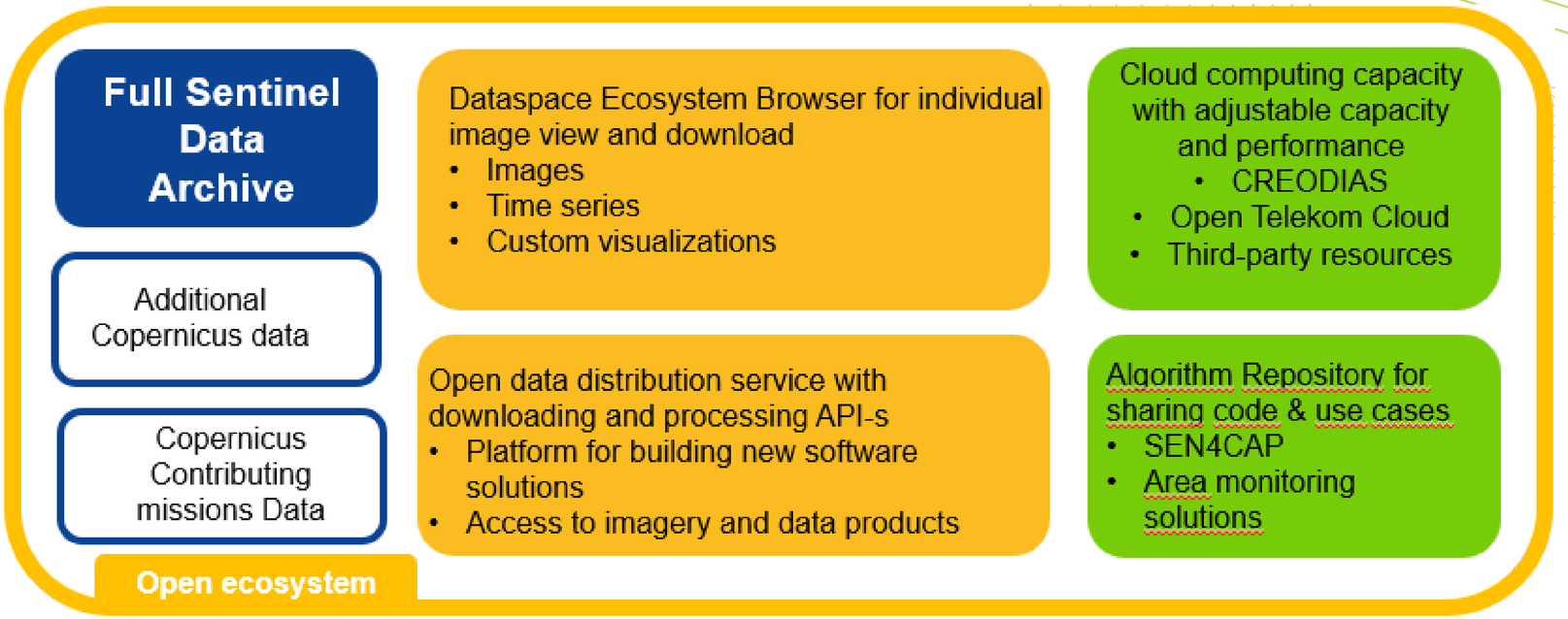
Algorithm Repository for sharing code & use cases

- SEN4CAP
- Area monitoring solutions

Open ecosystem

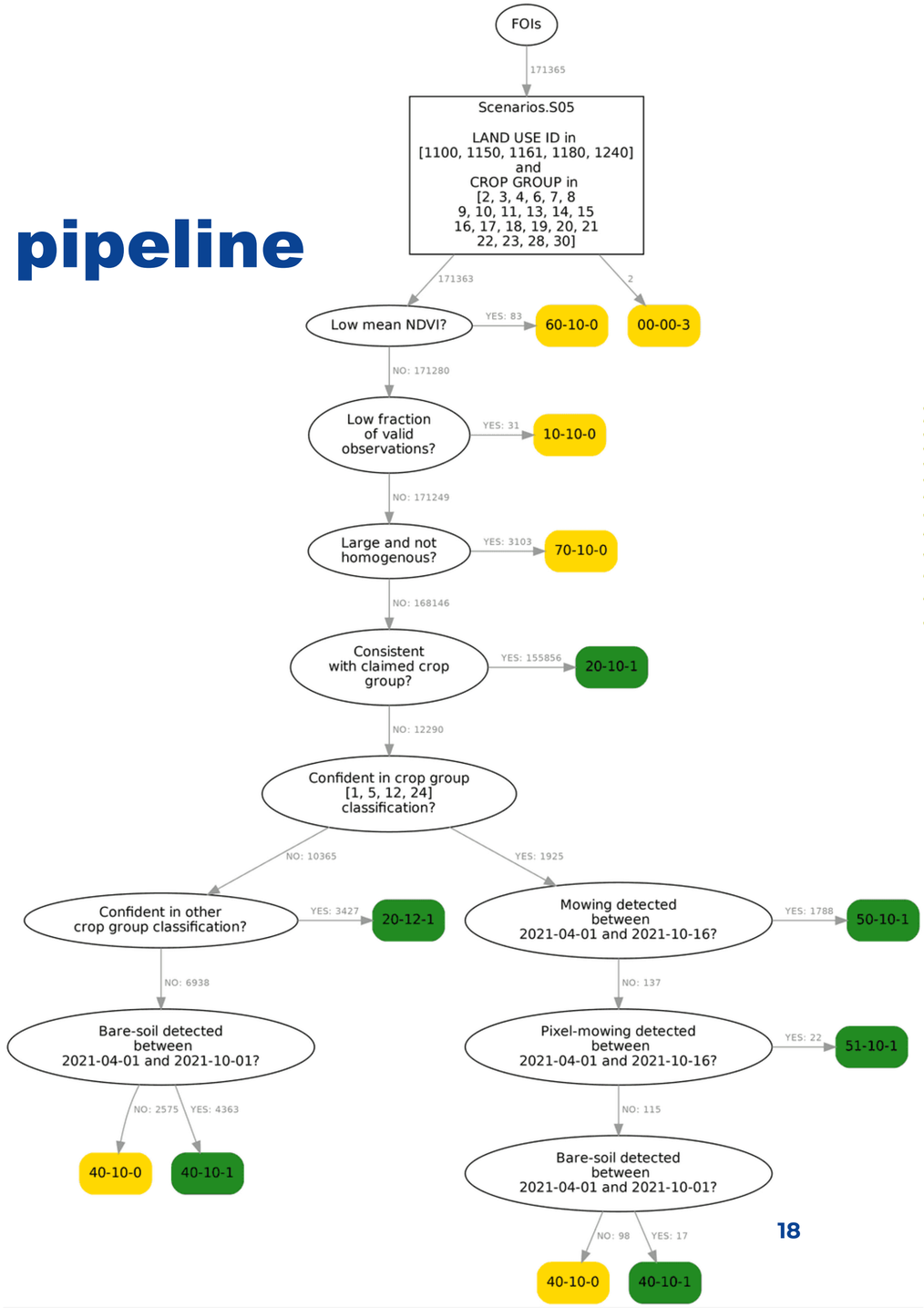
With Copernicus Data Space Ecosystem, any part of this can be hosted online

- **Virtual machine processing capacity directly connected to the data archive**
- System of API-s for streamlined in-application data access and machine learning
- **Code libraries/packages directly on board**
- Software as a service solutions available
- Fast prototyping and high scalability, easy commercialization



Example of an API-based analysis pipeline

- Selecting imagery, Cloud masking, Outlier filtering
- Integration with parcel outlines and claim data
- Mean NDVI – Cultivation
- Size and homogeneity
- Consistency with claimed crop group
- Mowing detection or bare soil detection
- Output of monitoring results for parcel



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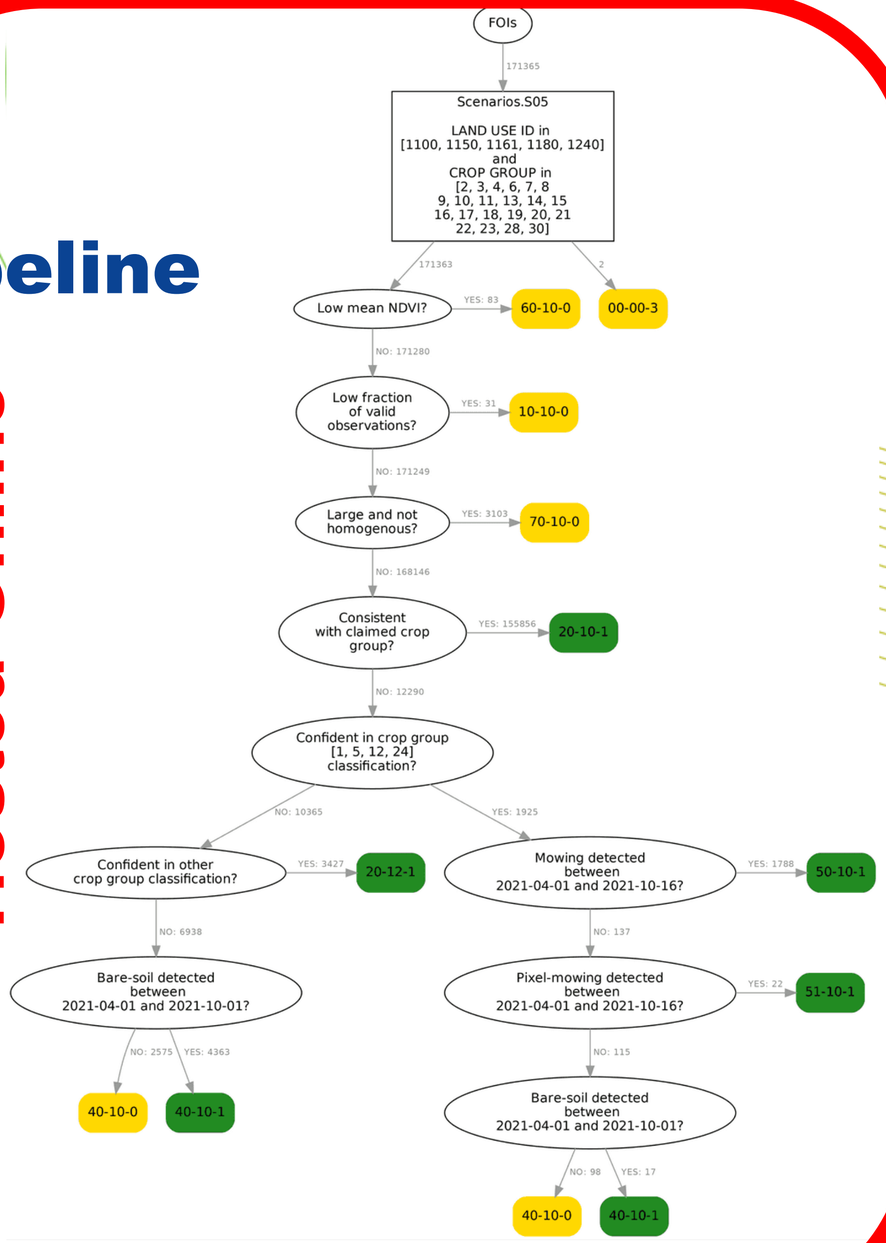
- **The complete pipeline can be processed online**

Hosted Online

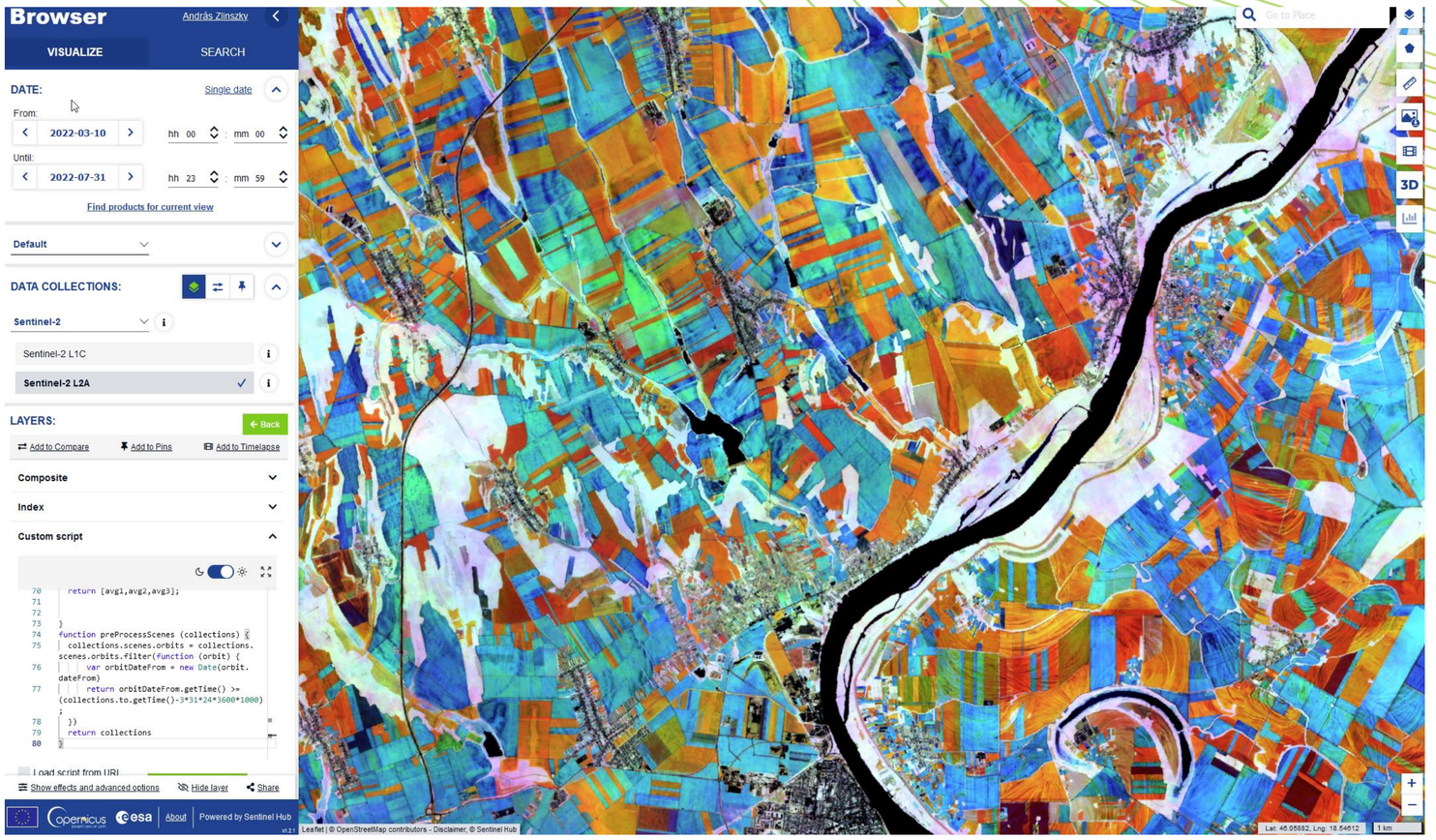


Benefits of Copernicus Data Space Ecosystem hosted CAP monitoring

What paying agencies want	How this is achieved
Accuracy, high performance, reliability	• Long-term commitment to stable processing environment, data archives and virtual machines • Standard-ready pipelines
Traceability of all processing steps from final decision all the way to initial satellite imagery	• Traceability of satellite data and products • Documented processing tools • Open code
Compatibility with image sharing & viewing for farmers to follow up	• Direct links to interactive visualization of hosted imagery in Copernicus Browser
New functionality should easily be added on top of existing code	• Flexible, modular processing tools • Rapid prototyping and scaling

Open and free data visualization service: Copernicus Browser

- Free satellite image visualization service provided by ESA
- Interactive environment for operators of the paying agency
- Highly suitable for sharing imagery with farmers related to their claim process
- Advanced custom script visualizations available – eg. Agricultural Growth stage



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Copernicus Data Space Ecosystem is transformative for CAP monitoring

Completely new approach to CAP monitoring:

- API-based cloud processing
- Easy integration of commercial data
- On-board codebases
- Algorithm and code sharing

The ideal platform for OS solutions

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Additional benefits of Copernicus Data Space Ecosystem - upstream

- Wide range of code libraries/packages and analysis tools already available in the ecosystem, eg.
  - VITO CropSAR data integration as a service
  - EO-learn, a full set of data processing and machine learning tools in a python package
  - Sen4CAP, a complete CAP monitoring service

README.md

pypi package 1.4.2 | conda-forge v0.10.1 | python 3.8 | 3.9 | 3.10 | 3.11 | build passing
docs passing | license MIT | downloads 100k | downloads/month 2k | docker pulls 1.1k
codecov 89% | DOI 10.5281/zenodo.7966005

eo-learn

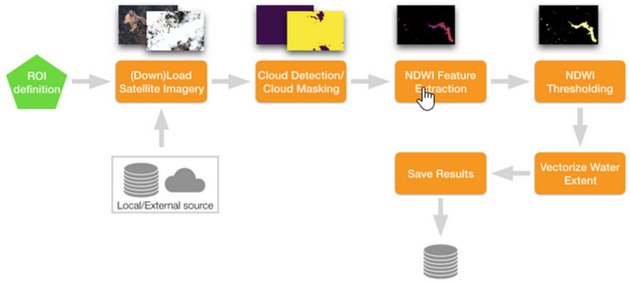
eo-learn

eo-learn makes extraction of valuable information from satellite imagery easy.

The availability of open Earth observation (EO) data through the Copernicus and Landsat programs represents an unprecedented resource for many EO applications, ranging from ocean and land use and land cover monitoring, disaster control, emergency services and humanitarian relief. Given the large amount of high spatial resolution data at high revisit frequency, techniques able to automatically extract complex patterns in such *spatio-temporal* data are needed.

`eo-learn` is a collection of open source Python packages that have been developed to seamlessly access and process *spatio-temporal* image sequences acquired by any satellite fleet in a timely and automatic manner. `eo-learn` is easy to use, it's design modular, and encourages collaboration -- sharing and reusing of specific tasks in a typical EO-value-extraction workflows, such as cloud masking, image co-registration, feature extraction, classification, etc. Everyone is free to use any of the available tasks and is encouraged to improve the, develop new ones and share them with the rest of the community.

`eo-learn` makes extraction of valuable information from satellite imagery as easy as defining a sequence of operations to be performed on satellite imagery. Image below illustrates a processing chain that maps water in satellite imagery by thresholding the Normalised Difference Water Index in user specified region of interest.



`eo-learn` *library acts as a bridge between Earth observation/Remote sensing field and Python ecosystem for data science and machine learning.* The library is written in Python and uses NumPy arrays to store and handle remote sensing data. Its aim is to make entry easier for non-experts to the field of remote sensing on one hand and bring the state-of-the-art tools for computer vision, machine learning, and deep learning existing in Python ecosystem to remote sensing experts.

Package Overview

Additional benefits of Copernicus Data Space Ecosystem - downstream

- Experience has already shown that many of these methods adapt well to different locations
  - Parcel delineation
  - Crop identification
  - Ineligible area detection
- Code repository structure supports sharing of best practices
  - Adaptation to local needs and legislation possible without starting from scratch
- **Spin-off applications of CAP monitoring expected in precision agriculture and habitat conservation**