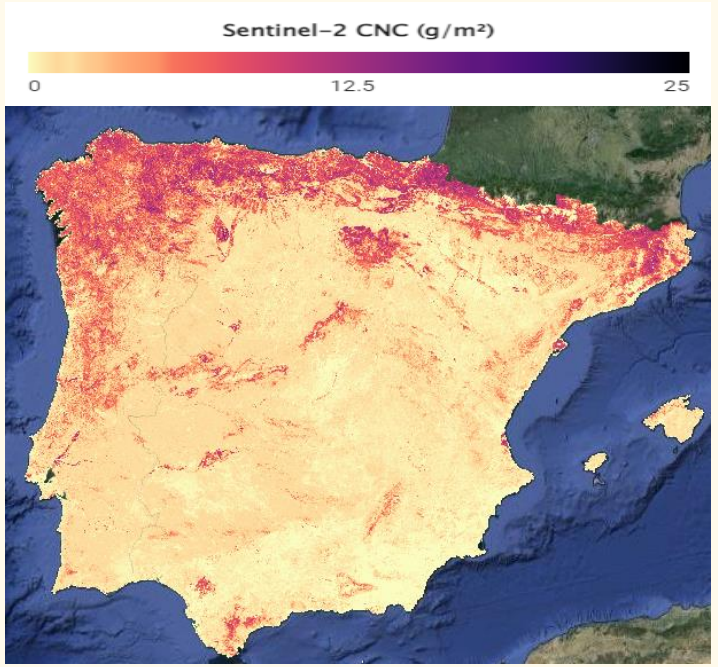
Canopy nitrogen content mapping using a hybrid machine learning method with Sentinel-2 data in Google Earth Engine



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erc European Research Council

flexinel

ARTMO

VNIVERSITAT DE VALÈNCIA

IPL IMAGE PROCESSING LABORATORY

PANGEOS

Laboratory for Earth Observation

Canopy Nitrogen Content

Estimate

Map

- Canopy Nitrogen Content (CNC)
  - Nitrogen is an essential plant macro-nutrient
  - CNC is leaf N upscaled to the canopy
  - Important for agriculture: crop yield, vegetative growth, fertilizers…
- Hybrid Machine Learning method
  - Machine learning algorithm & radiative transfer models (RTM)
- Sentinel-2
  - S2 MSI - Level 2A provides bottom of atmosphere spectral data in 10 bands
  - With revisit time of 5 days, often used in vegetation monitoring

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RTM
Full training data
CNC
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Full training data
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NV
Training data
GPR
GEE
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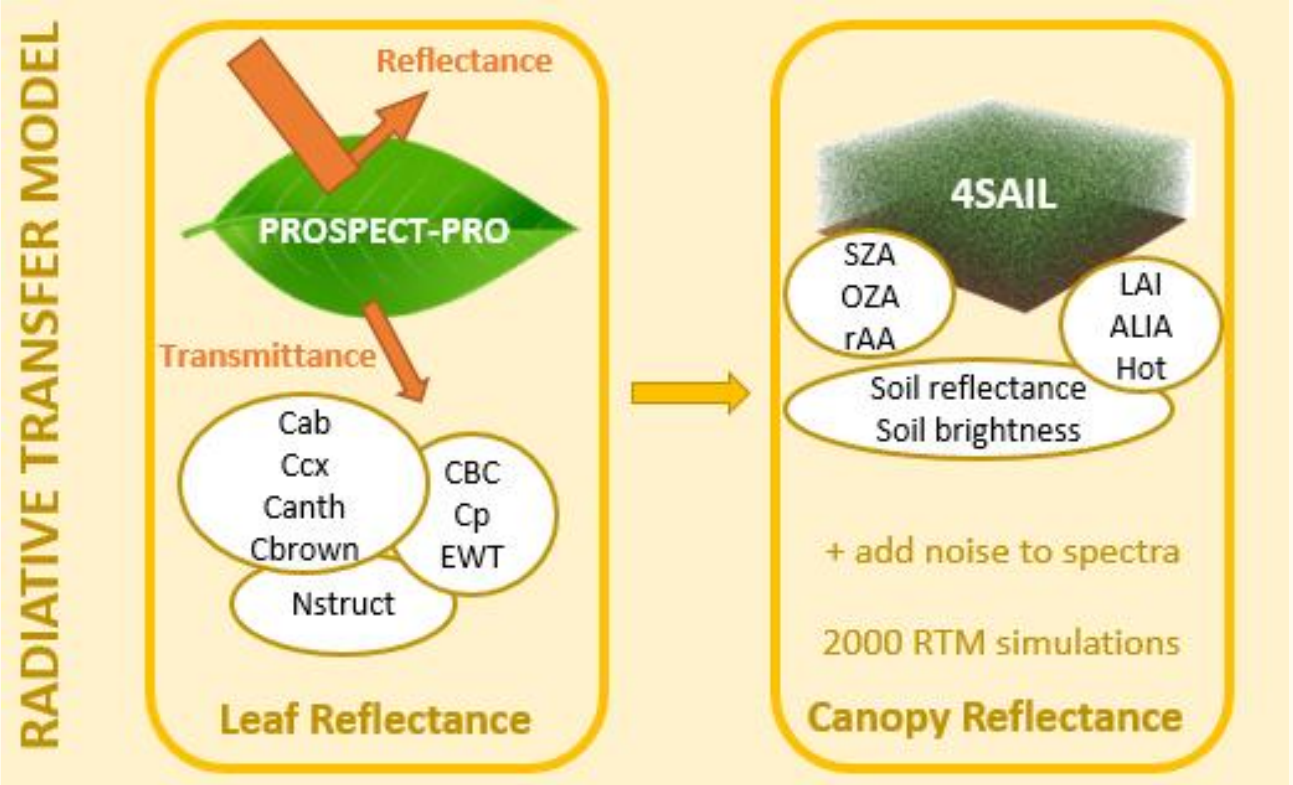
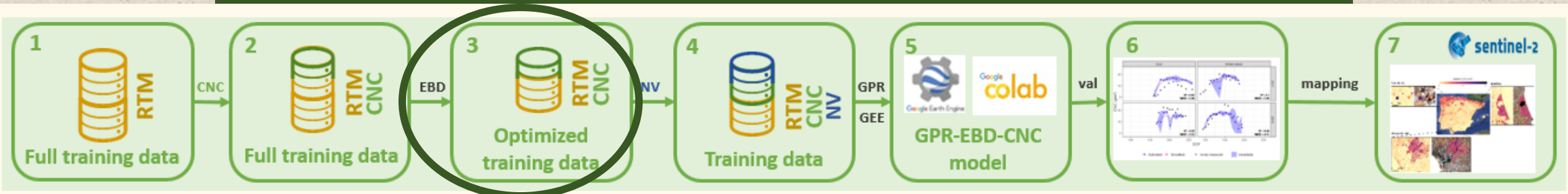
colab
GPR-EBD-CNC model
val
6
mapping
7
sentinel-2

PROSAIL-PRO


RADIATIVE TRANSFER MODEL
Reflectance
PROSPECT-PRO
Transmittance
Cab
Ccx
Canth
Cbrown
CBC
Cp
EWT
Nstruct
Leaf Reflectance
4SAIL
SZA
OZA
rAA
LAI
ALIA
Hot
Soil reflectance
Soil brightness
+ add noise to spectra
2000 RTM simulations
Canopy Reflectance

$$CNC\ \left[\frac{g}{m^2}\right] = C_{prot}\ \left[\frac{g}{cm^2}\right] * \frac{10\,000}{4.43} * LAI\ \left[\frac{m^2}{m^2}\right]$$

(Yeoh and Wee, 1994)

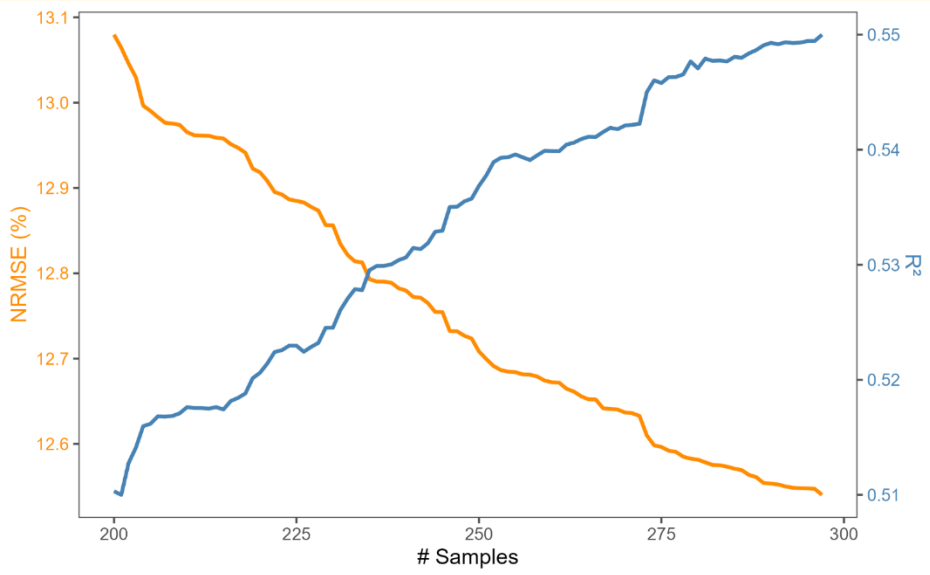


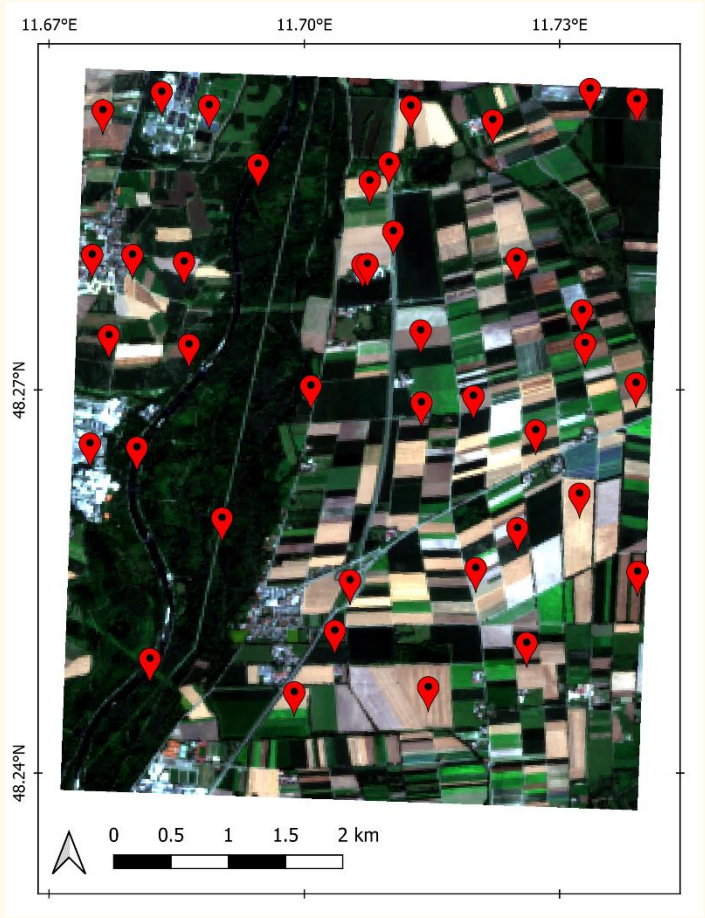
Active learning

- Reduce training data size
- Keep information

→ Euclidean distance-based diversity (EBD)

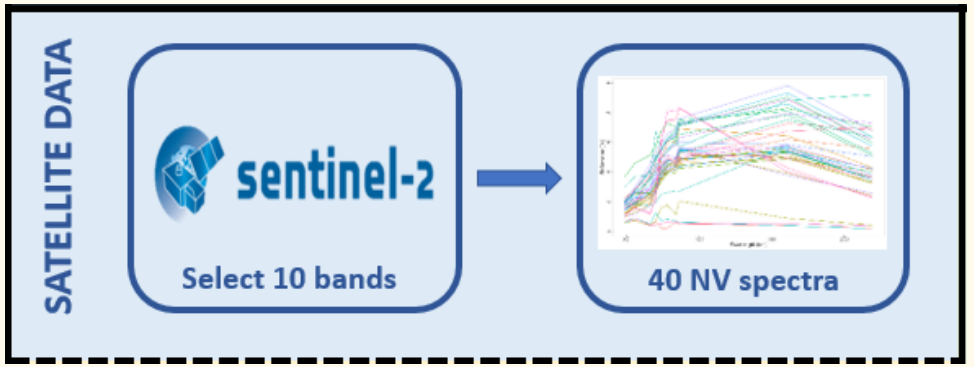
$$d_E = \|x_i - x_j\|_2^2$$

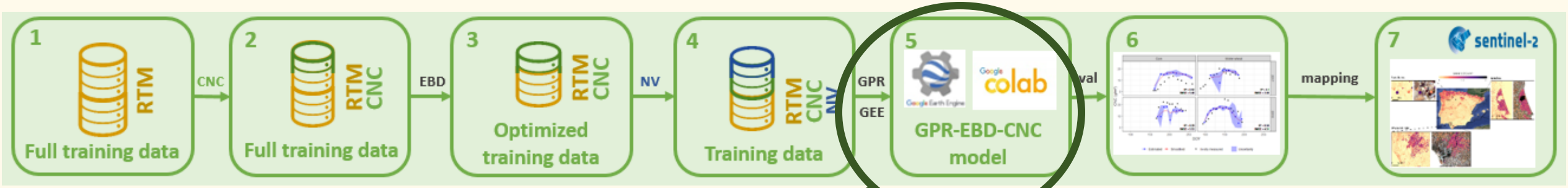




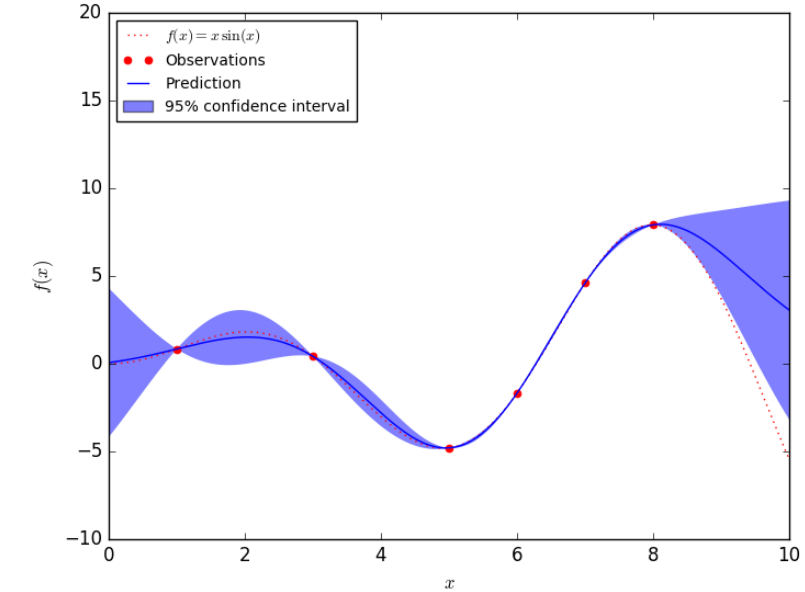
Non-vegetated (NV) samples

↳ Bare soil, water bodies and man-made surfaces





Gaussian Process Regression



CNC estimation with 10 S2 bands

Google Earth Engine

Google colab

https://github.com/SentiFLEXinel

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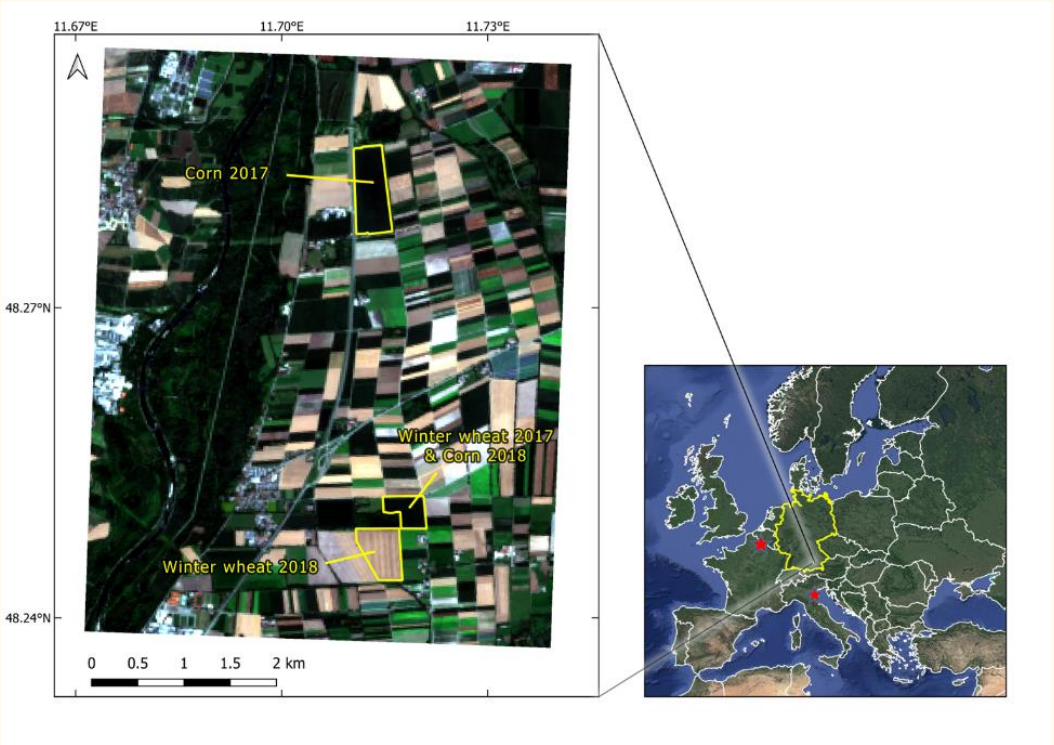
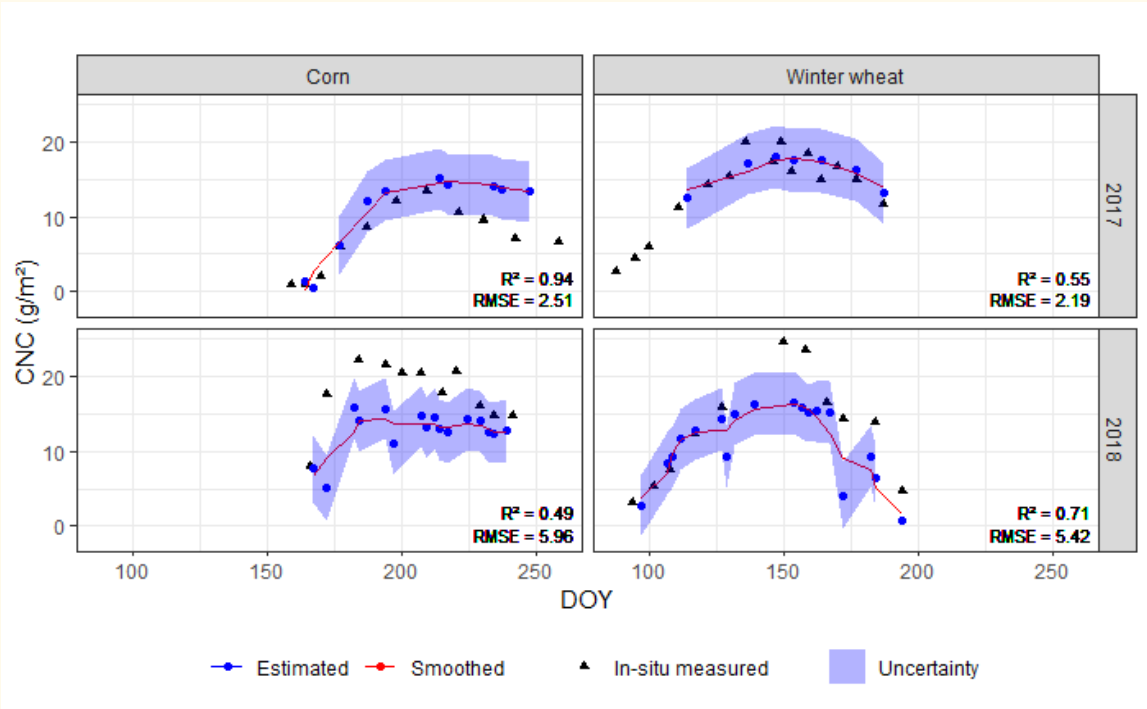
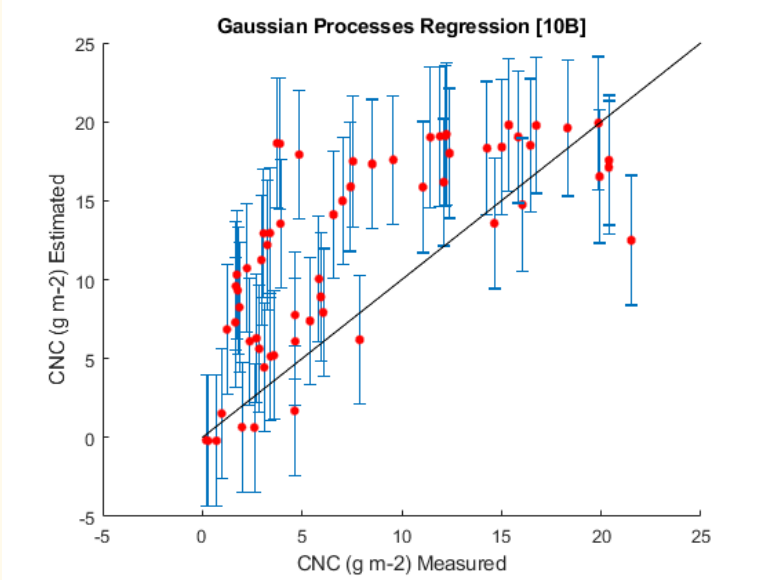

11.67°E
11.70°E
11.73°E
48.27°N
48.24°N
Corn 2017
Winter wheat 2017 & Corn 2018
Winter wheat 2018
0 0.5 1 1.5 2 km


Corn
Winter wheat
2017
2018
CNC (g/m²)
DOY
R² = 0.94
RMSE = 2.51
R² = 0.55
RMSE = 2.19
R² = 0.49
RMSE = 5.96
R² = 0.71
RMSE = 5.42
Estimated
Smoothed
In-situ measured
Uncertainty

- Temporal reconstruction performed well
- Validation with in-situ data showed good results



Fr-Be: k-cross validation
R^2 = 0.68 and NRMSE = 13.04%

MNI: independent validation
R^2 = 0.58 and NRMSE = 22.18%

JdS: independent validation
R^2 = 0.51 and NRMSE = 29.24%

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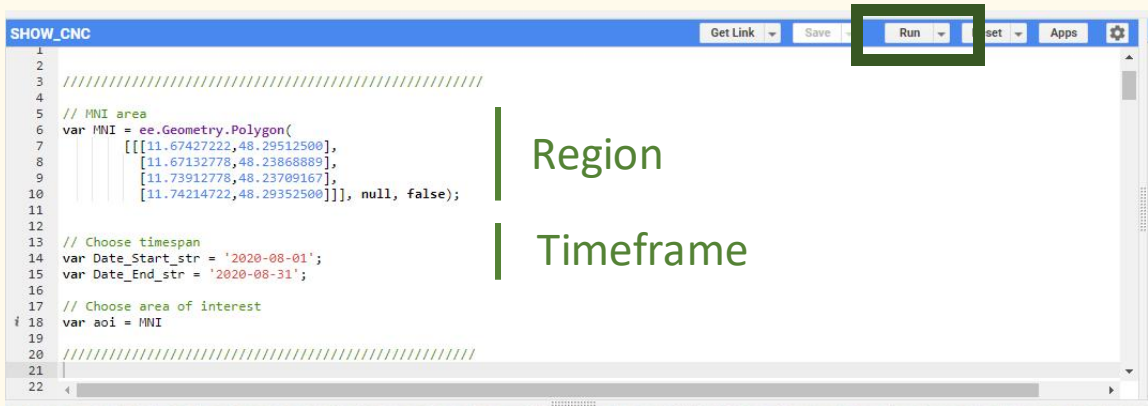
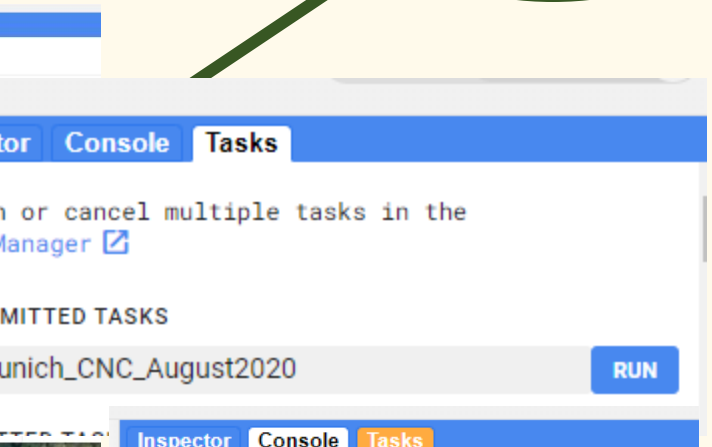
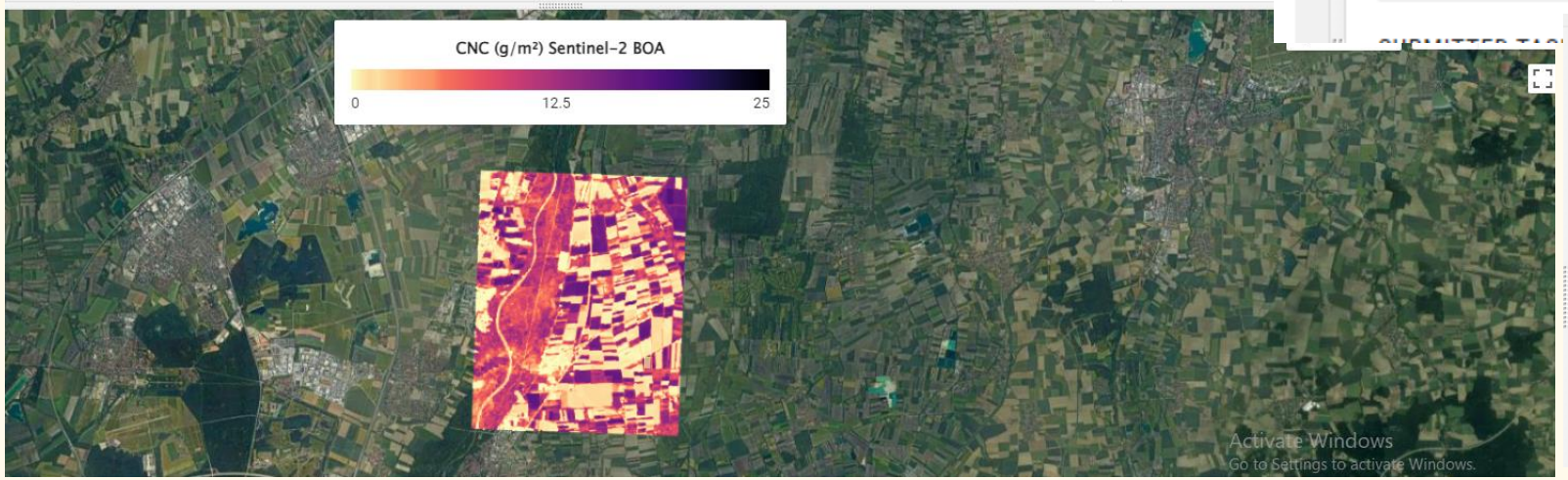
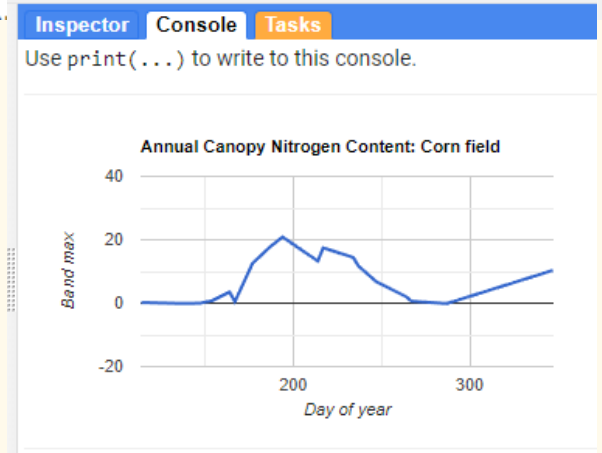
Google Earth Engine


SHOW_CNC
Get Link
Save
Run
Apps
// MNI area
var MNI = ee.Geometry.Polygon(
[[[11.67427222,48.29512500],
[11.67132778,48.23868889],
[11.73912778,48.23709167],
[11.74214722,48.29352500]]], null, false);
// Choose timespan
var Date_Start_str = '2020-08-01';
var Date_End_str = '2020-08-31';
// Choose area of interest
var aoi = MNI
Region
Timeframe


Inspector
Console
Tasks
Search or cancel multiple tasks in the
Task Manager
UNSUBMITTED TASKS
Munich_CNC_August2020
RUN


CNC (g/m²) Sentinel-2 BOA
0
12.5
25
Activate Windows
Go to Settings to activate Windows.


Inspector
Console
Tasks
Use print(...) to write to this console.
Annual Canopy Nitrogen Content: Corn field
Band max
40
20
0
-20
200
300
Day of year

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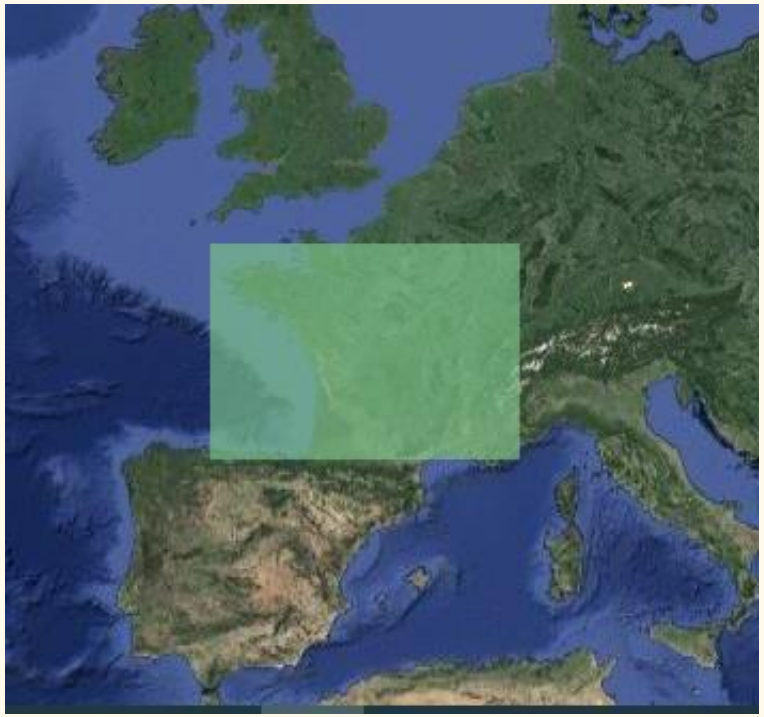
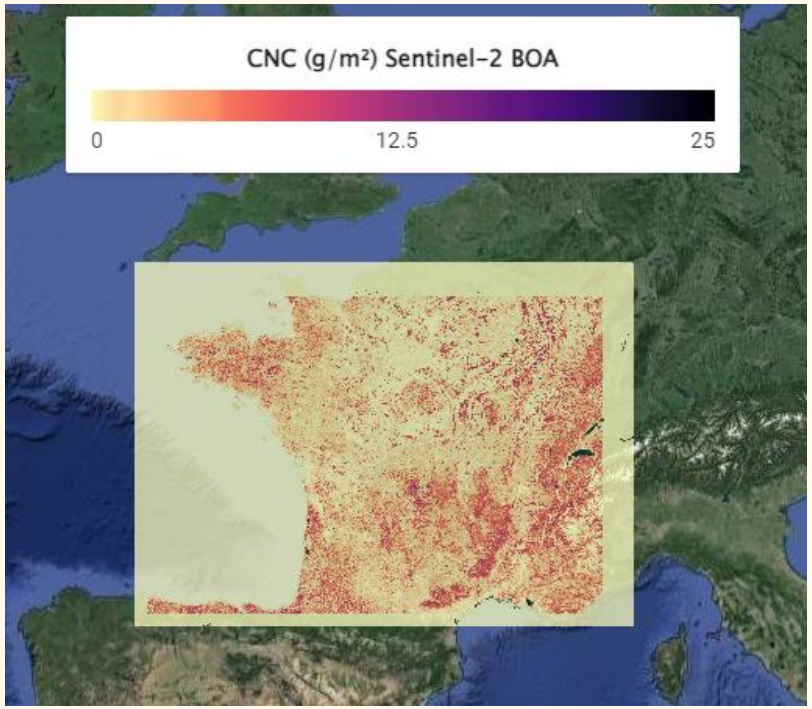
geometry
Rectangle drawing.
Exit
CNC (g/m²) Sentinel-2 BOA
0
12.5
25

Google Earth Engine





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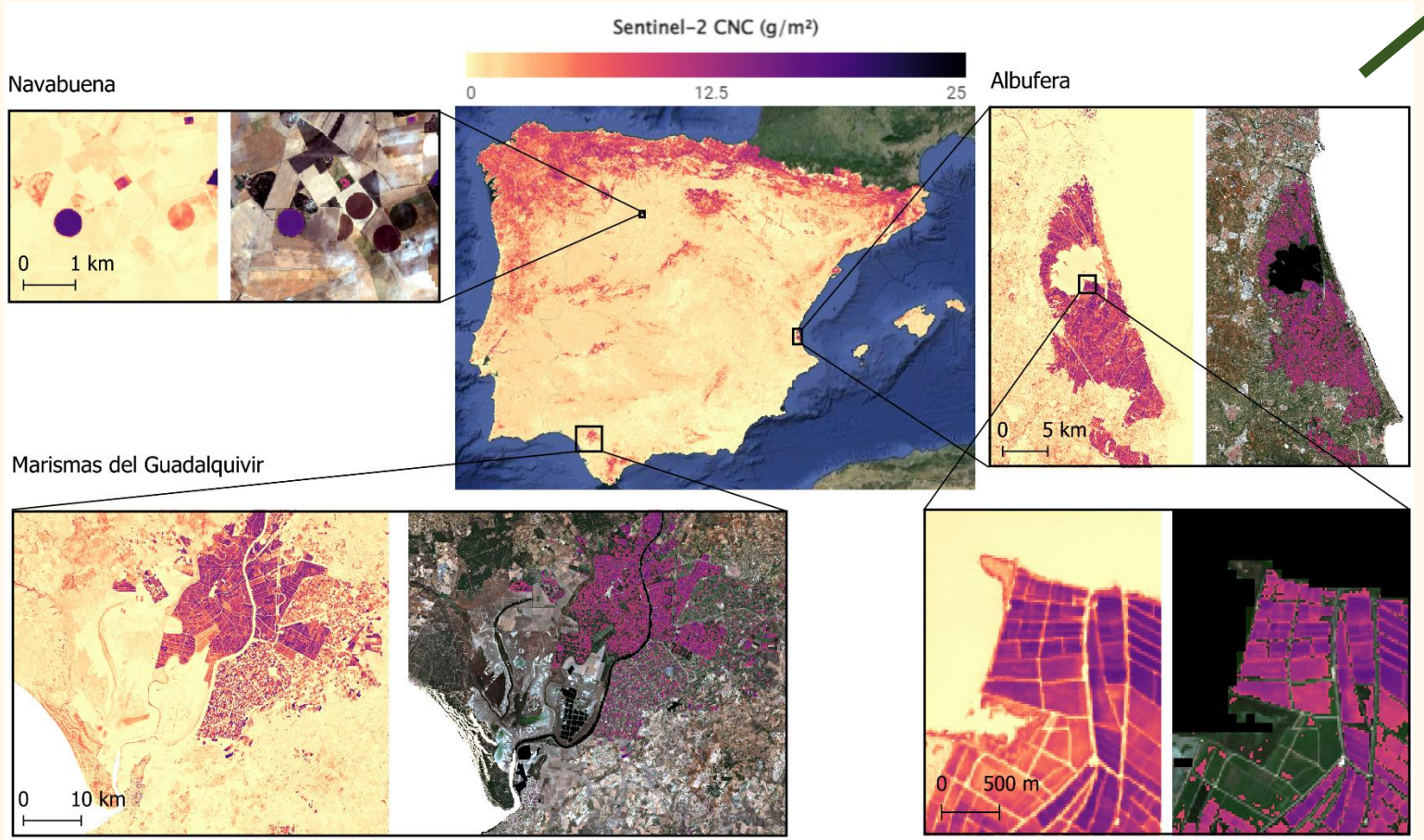
Sentinel-2 CNC (g/m²)
0
12.5
25
Navabuena
0 1 km
Albufera
0 5 km
Marismas del Guadalquivir
0 10 km
0 500 m

- Hybrid machine learning method with PROSAIL-PRO, AL and GPR resulted in a **good performing model** to estimate CNC
- Applicable model for **CNC mapping** (easy with Google Earth Engine)
- **Temporal reconstruction** with S2 imagery possible
- Hyperspectral and future Sentinel and Landsat missions have potential to enhance accuracy of routinely retrieved CNC for more precise cropland monitoring

THANK YOU FOR YOUR ATTENTION

QUESTIONS?

emma.clerck@uv.es