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TAKING THE PULSE OF OUR PLANET FROM SPACE

Control of Landfills and Environment Assessment Research Using PRISMA (CLEAR-UP project)

Prof. Giovanni Laneve, Stefano Pignatti, Enrico G. Cadau, Renato Aurigemma, Valerio Pisacane, Silvia Scifoni

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25/05/2022

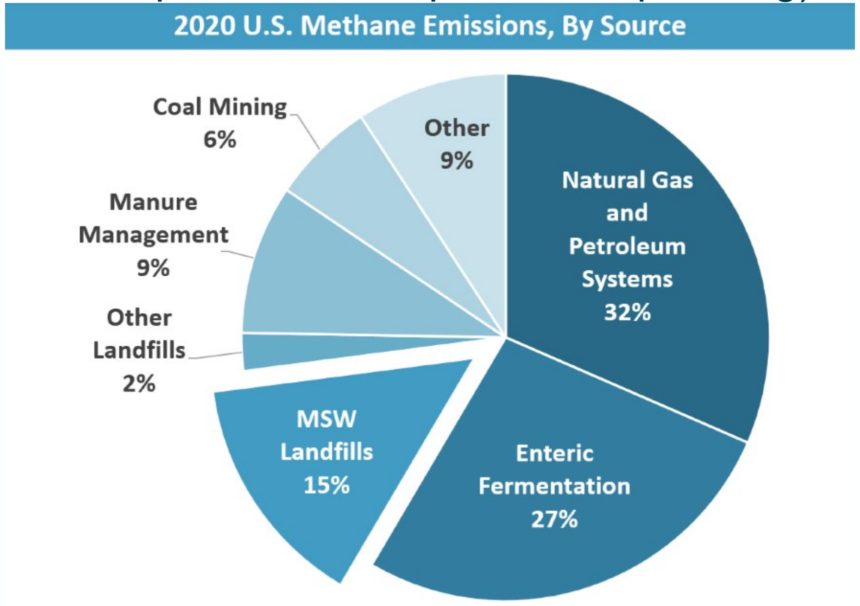
Background

- **Waste management** is considered an important indicator of sustainable development closely intertwined with many interdependent and cross-border issues.
- In this perspective, it has already been amply demonstrated in previous projects and studies that **remote sensing** can be useful in monitoring the impact, if present, of landfills on the surrounding environment, through the collection of remotely sensed information useful for the identification and classification of potentially contaminated areas using non-invasive methods.
- For example, biogas leaks or leachate can produce effects at different spatial and temporal scales that require careful analysis to correctly interpret local environmental dynamics.

Past Studies

Many researchers have explored the possibilities offered by remote sensing in environmental analysis, in particular, for:

- the **classification** and estimate of the quantity of waste stored in landfills;
- the **identification** of appropriate sites (geology and hydrology studies, waste transport, urban displacement planning);
- in situ **management** of the landfill (support for operations);
- **monitoring** the evolution of the landfill over time (compliance with procedures and regulations, prevention of pollution risk);
- the **identification** of **unauthorized** landfills;
- **identify** biogas emissions;
- the **estimate** of leachate not captured;
- **estimation** of the generation and deposition of dust.



Note: All emission estimates from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020*. U.S. EPA. 2022.

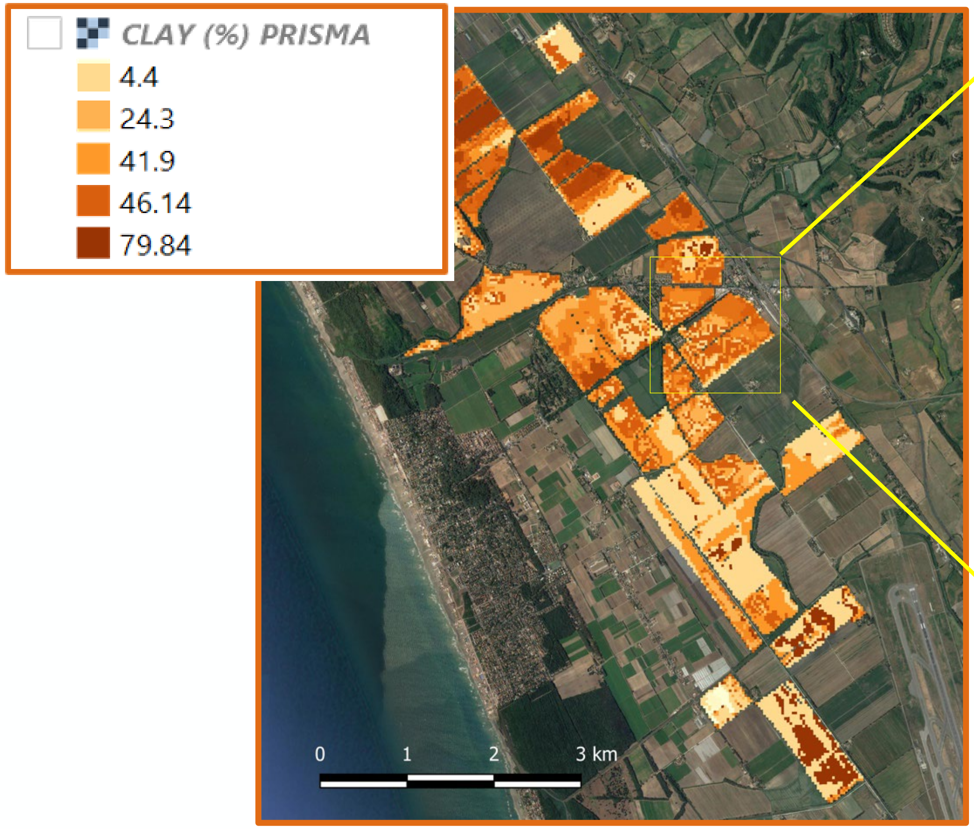
Project objectives

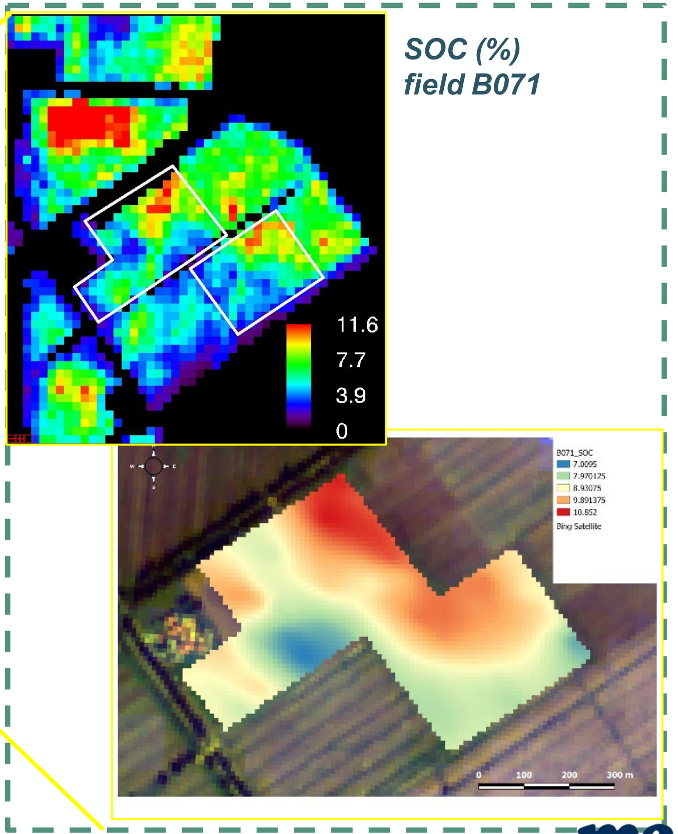
- The main objective of the **CLEAR-UP** project (funded by ASI) concerns the use of **PRISMA** hyperspectral images for the study, development and implementation of indicators of the presence of pollutants in the soil and in the air close to areas affected by the presence of landfills.
- The availability of **PRISMA** hyperspectral images, with the limitations related to spatial resolution, makes it possible in principle to achieve this goal with unprecedented accuracy.
- The **goal** of the study concerns therefore the possibility of:

  - Detecting the presence of heavy metals in the soils in the area next to landfills;
  - Identifying the presence of stress conditions affecting the vegetation close to the area of the landfill;
  - Identifying potentially harmful emissions (CH4, CO2, NOX) caused by spontaneous combustion and/or due to uncontrolled practices against the material in the landfill;
  - Determining the extent of the area possibly affected by the presence of the landfill.

Monitoring of the soil contamination: Agricultural soil analysis

- Site near farmland can be the main source of heavy metal pollution in agricultural soils that may have potential risk to human health through food chain.
- **PRISMA** has been already used in soil science to predict SOC (soil organic carbon) and texture by MLR (multi-linear regression) analysis, but not yet explored to predict heavy metal / optical active pollutant concentrations in agricultural soils.





PH, clays, SOC and other soil components could be assessed on agricultural soil, surroundings of the industrial plant, as indicator of anomalous soil behaviour

Mzid, N., Castaldi, F., Tolomio, M., Pascucci, S., Casa, R., Pignatti, S., Evaluation of Agricultural Bare Soil Properties Retrieval from Landsat 8, Sentinel-2 and PRISMA Satellite Data, Remote Sensing, 14 (3), p. 714.

Monitoring of the soil contamination:

Melfi (IT) experiments – proximal sensing (in-situ)

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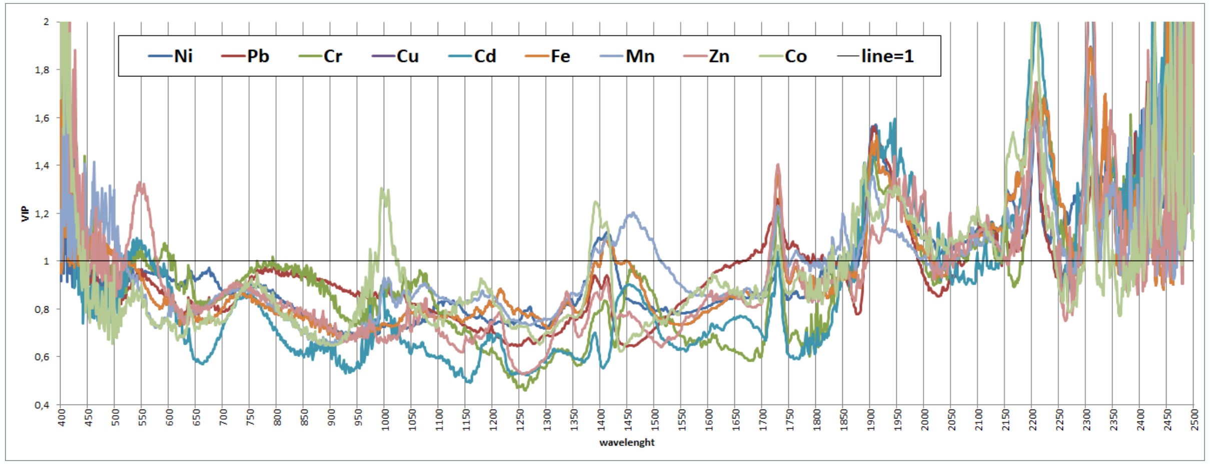
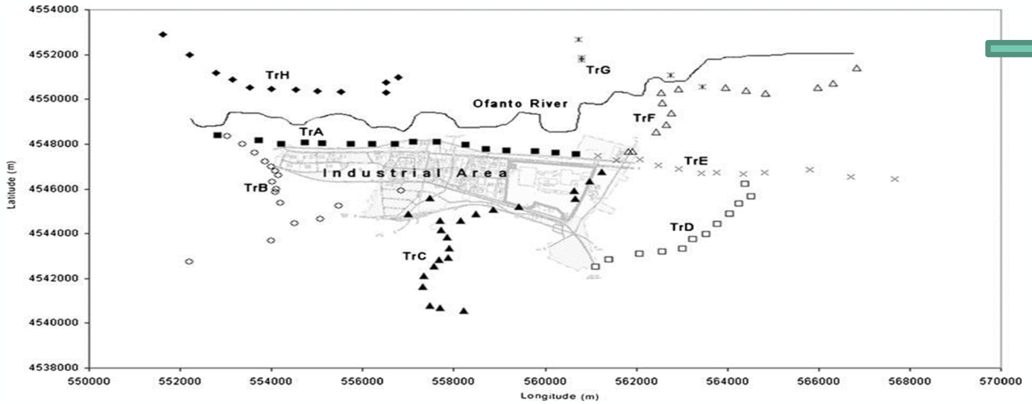
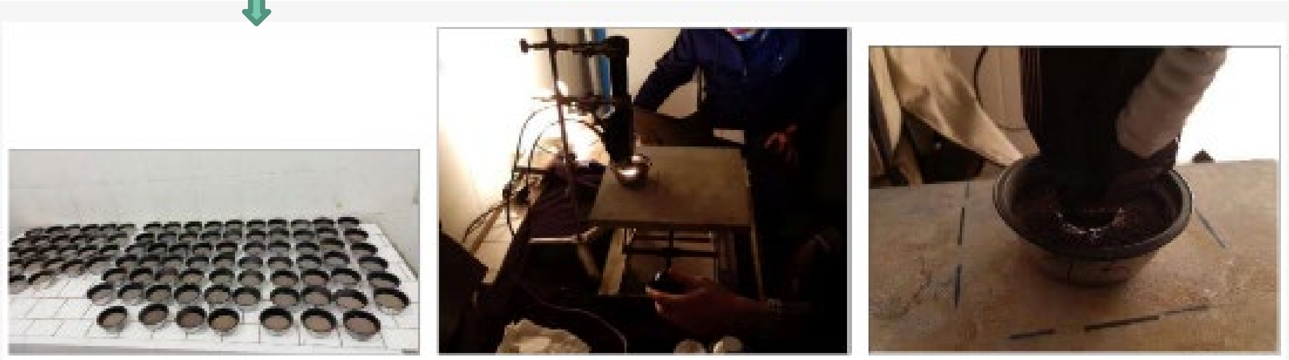


	PLSR				RF				
	RMSE	RPD	RPIQ	R2		RMSE	RPD	RPIQ	R2
Cd	0.563	1.074	1.400	0.139	Cd	0.609	1.002	1.359	0.004
Co	0.353	1.120	2.104	0.202	Co	0.398	1.043	1.852	0.064
Cr	0.609	1.121	1.953	0.219	Cr	0.603	1.008	1.682	0.017
Fe	0.100	2.292	3.204	0.808	Fe	0.181	1.284	1.670	0.277
Mn	0.223	1.198	1.795	0.299	Mn	0.240	1.031	1.615	0.105
Ni	0.223	1.335	1.895	0.432	Ni	0.247	1.160	1.689	0.292
Pb	0.238	1.301	2.014	0.405	Pb	0.269	1.242	1.684	0.173
Zn	0.173	1.042	1.525	0.070	Zn	0.171	1.074	1.428	0.058

Left: Variance Importance in Projection (VIP) on the data set of 62 spectral sample identifying the wavelengths most useful for the PLSR prediction, *Right*: First evaluation of the heavy metal retrieval accuracy by using PLSR and Random Forest (RF) and a SG filter.



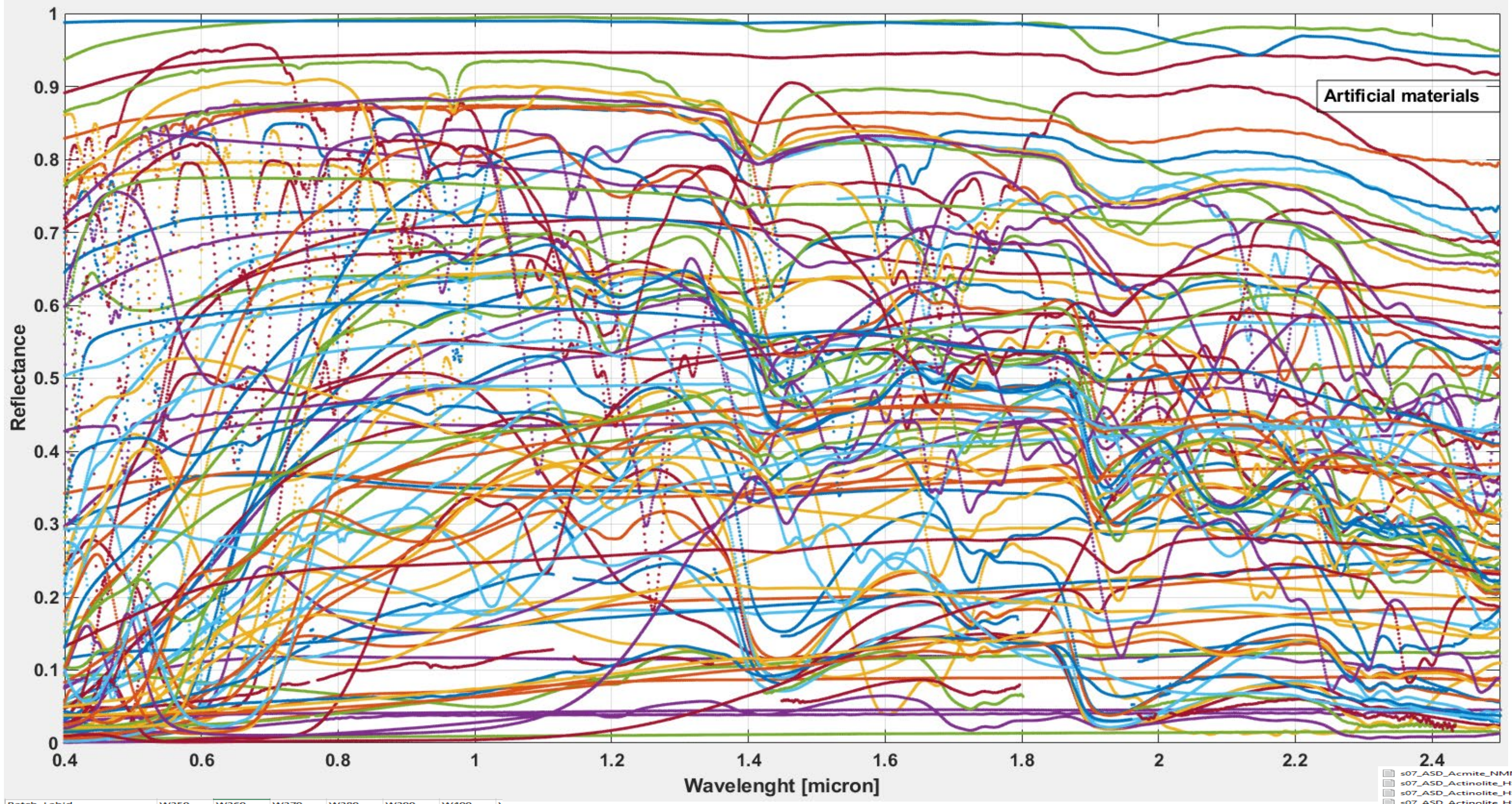
PLSR = Partial Least Square Regression



Soil Spectral Library of the Melfi sample, acquired in laboratory with ASD. (IMAA)

imaa Euro.Soft BEYOND INNOVATION serco

Monitoring of the soil contamination: Spectral Libraries



Vegetation spectral libraries: University of California, Santa Barbara

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Artificial materials spectral libraries: U.S. Geological Survey (USGS) Spectral Library Version 7

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Batch_Labid	W350	W360	W370	W380	W390	W400
FS15R_FS4076	0.087267	0.072294	0.067883	0.071279	0.070909	0.075602
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FS15R_FS4078	0.089091	0.069347	0.069658	0.068197	0.070051	0.071531
FS15R_FS4079	0.094945	0.088997	0.081051	0.083512	0.085434	0.086396
FS15R_FS4080	0.091239	0.065713	0.065946	0.066217	0.066276	0.064272
FS15R_FS4081	0.091103	0.077681	0.071049	0.069468	0.068232	0.068433
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FS15R_FS4083	0.06861	0.053932	0.050583	0.049495	0.0545	0.05467
FS15R_FS4084	0.063874	0.053167	0.052075	0.053676	0.054829	0.055085
FS15R_FS4085	0.061739	0.050505	0.047442	0.047695	0.049629	0.050175
FS15R_FS4086	0.064619	0.051373	0.047279	0.04953	0.051287	0.050792
FS15R_FS4087	0.08151	0.059976	0.054855	0.056135	0.056486	0.058502
FS15R_FS4088	0.062165	0.050029	0.051286	0.051308	0.053574	0.052878
FS15R_FS4089	0.032692	0.026642	0.023296	0.02436	0.023163	0.024975
FS15R_FS4090	0.045326	0.026793	0.025267	0.026222	0.02514	0.024363
FS15R_FS4091	0.028145	0.029073	0.027973	0.027544	0.026236	0.024175
FS15R_FS4092	0.031314	0.029504	0.030159	0.027687	0.028377	0.024809
FS15R_FS4093	0.03546	0.033213	0.027103	0.023289	0.024715	0.025785
FS15R_FS4094	0.03057	0.027168	0.022646	0.022899	0.022885	0.023349
FS15R_FS4095	0.032888	0.02654	0.031411	0.025967	0.024179	0.023866
FS15R_FS4096	0.031275	0.017825	0.025654	0.025071	0.022794	0.024499
FS15R_FS4097	0.019069	0.022859	0.025528	0.027551	0.023842	0.025164
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FS15R_FS4099	0.029804	0.025226	0.027651	0.024601	0.024117	0.023645
FS15R_FS4100	0.05058	0.048623	0.045766	0.039859	0.041059	0.04
FS15R_FS4101	0.056748	0.040481	0.039677	0.036557	0.038952	0.038157
FS15R_FS4102	0.043083	0.041748	0.040722	0.03631	0.039393	0.038873
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FS15R_FS4104	0.05733	0.050368	0.045492	0.048171	0.044326	0.043399
FS15R_FS4105	0.02836	0.028088	0.029954	0.030037	0.029994	0.028506
FS15R_FS4106	0.038032	0.026162	0.027016	0.027696	0.029071	0.026541
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Soil spectral libraries: International Soil Reference and Information Centre

Minerals spectral libraries: U.S. Geological Survey (USGS) Spectral Library Version 7

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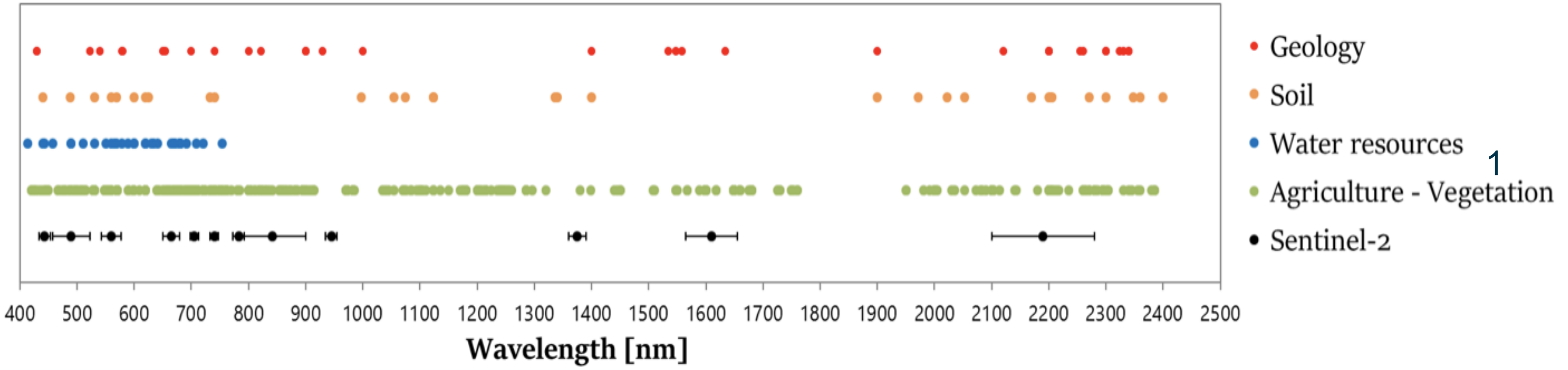
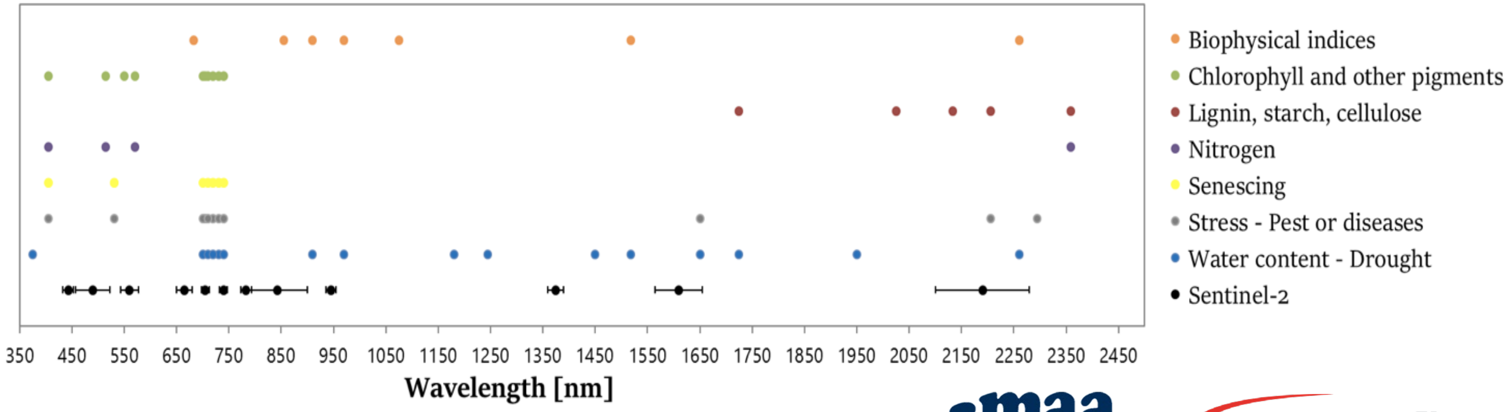
Soil Contamination – Vegetation effects

- We aim at studying the Vegetation status to detect potential **soil contamination;**
- Several vegetation indexes to be used (SAVI, EVI, HMSSI, LAI, etc.)



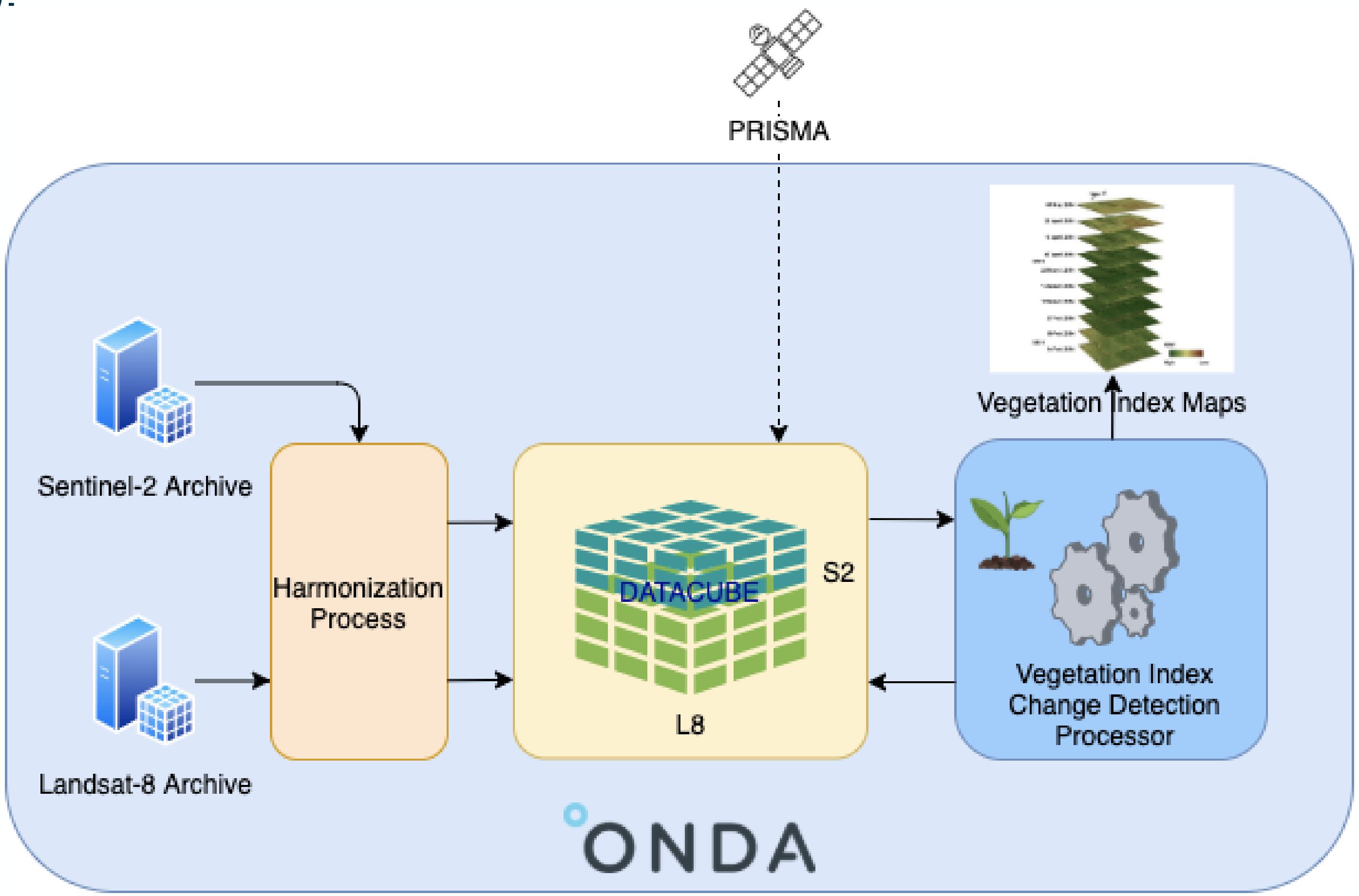
[1] Thenkabail, P.S.; Gumma, M.K.; Teluguntla, P.; Mohammed, I.A. Hyperspectral remote sensing of vegetation and agricultural crops. Photogramm. Eng. Remote Sens., 80, 697–709, 2014.

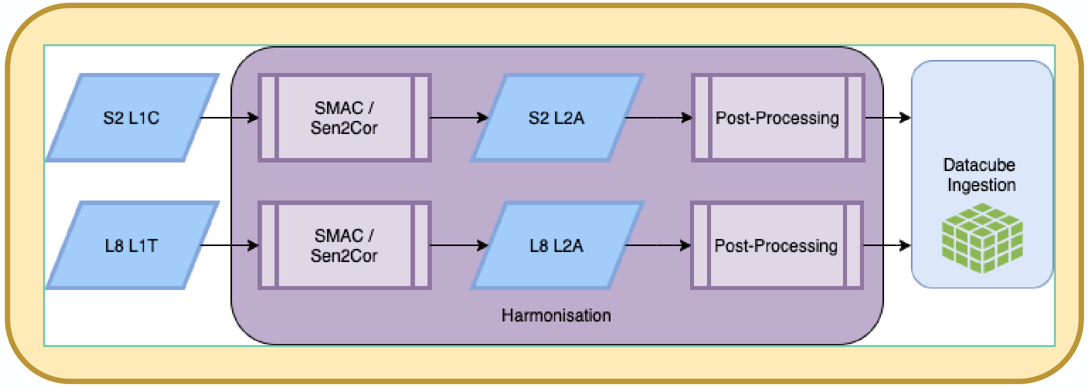
[2] Miglani, A.; Ray, S.S.; Pandey, R.; Parihar, J.S. Evaluation of EO-1 Hyperion Data for Agricultural Applications. J. Indian Soc. Remote Sens., 36, 255–266, 2008



EO Imagery time-series densification

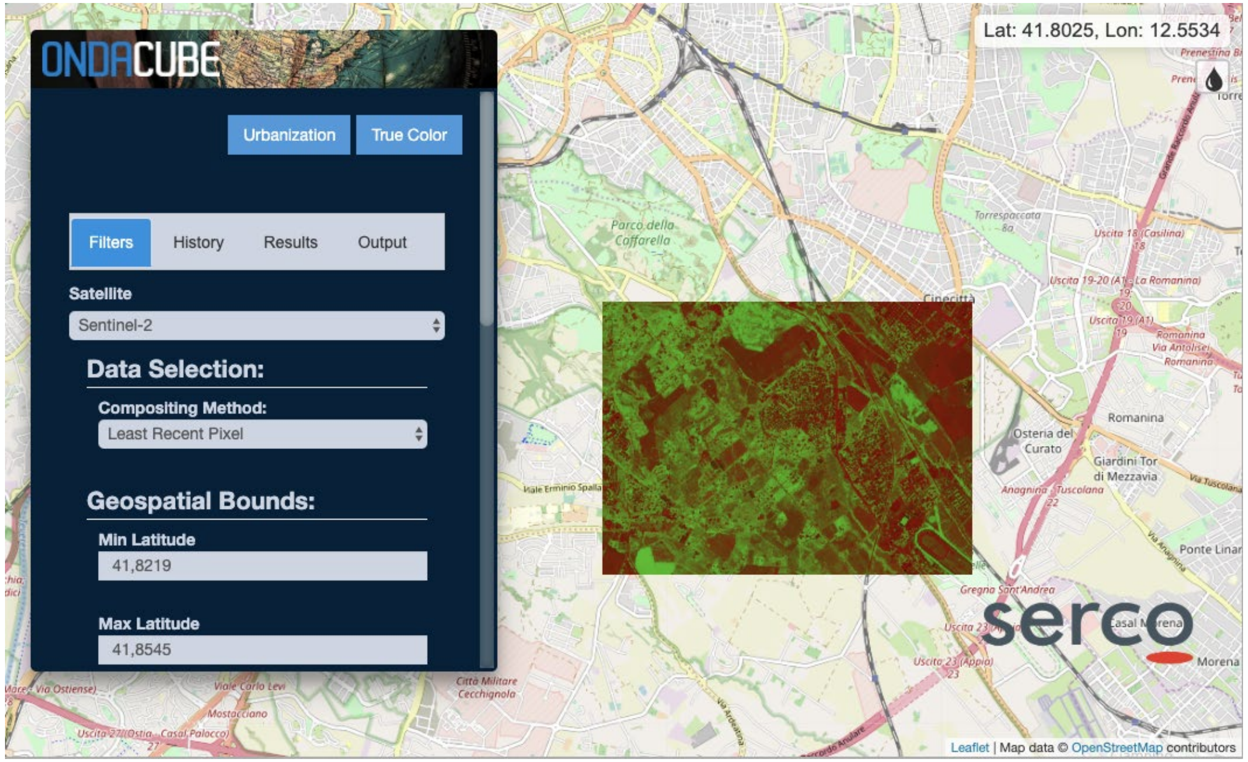
- Harmonisation Process (Sen2Like, HLS):
- S2, L8/9, PRISMA data integration;
- DataCube population;
- Vegetation Index computation;
- Anomaly detection.

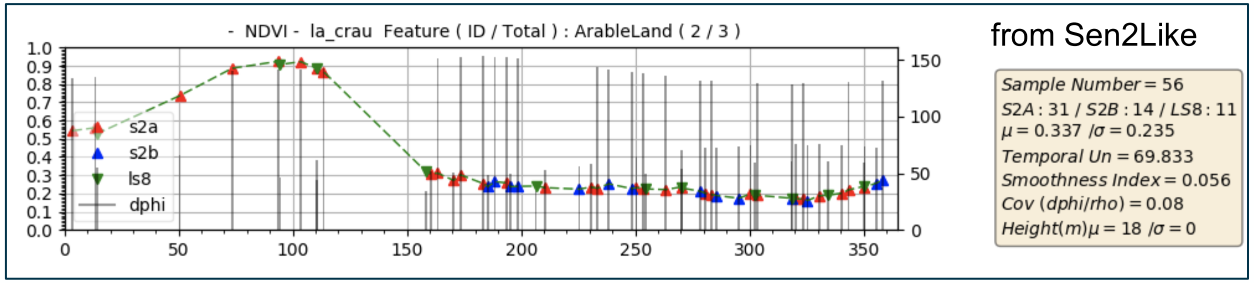




ARD products exploitation - ODC

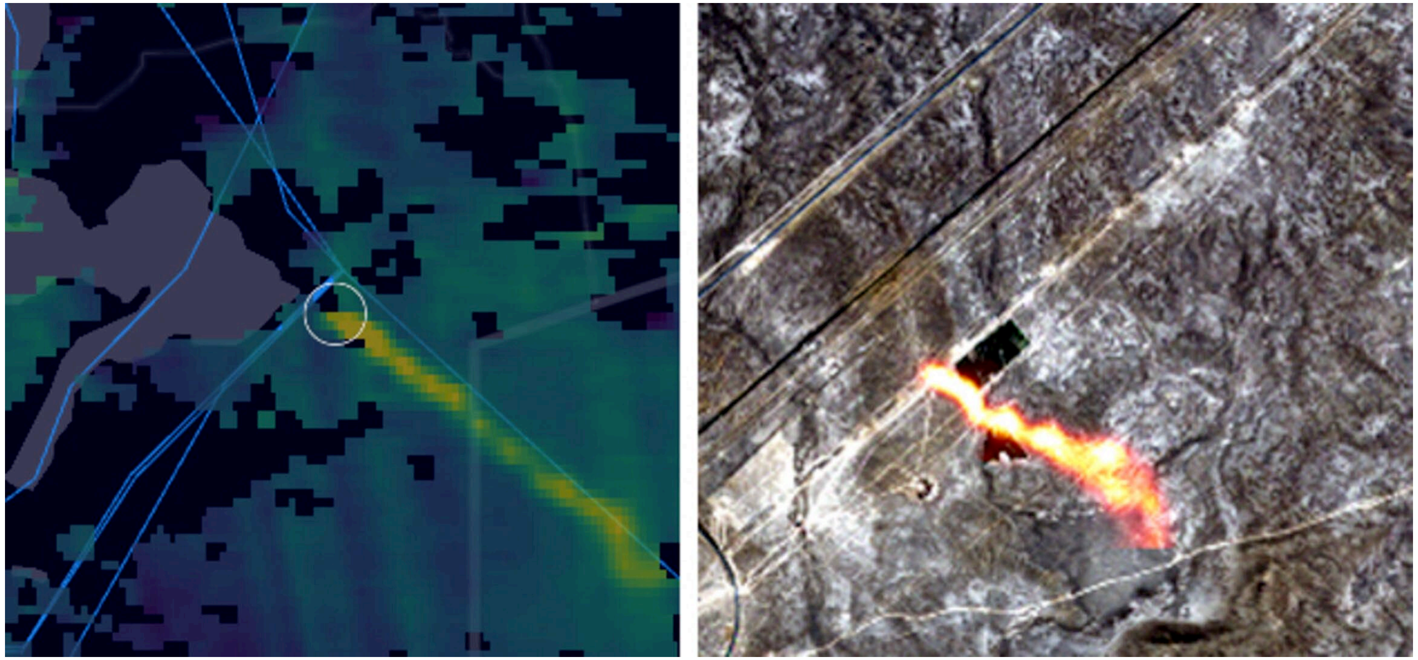
- The DataCube will be populated by ARD harmonised data as output of the Sen2Like processor.
- A set of Vegetation indexes are calculated.
- A change detection algorithm looks for anomalies wrt the nominal trends.
- In case of anomaly detected in the vegetation index a deeper investigation is triggered based on **PRISMA** hyper-spectral data.



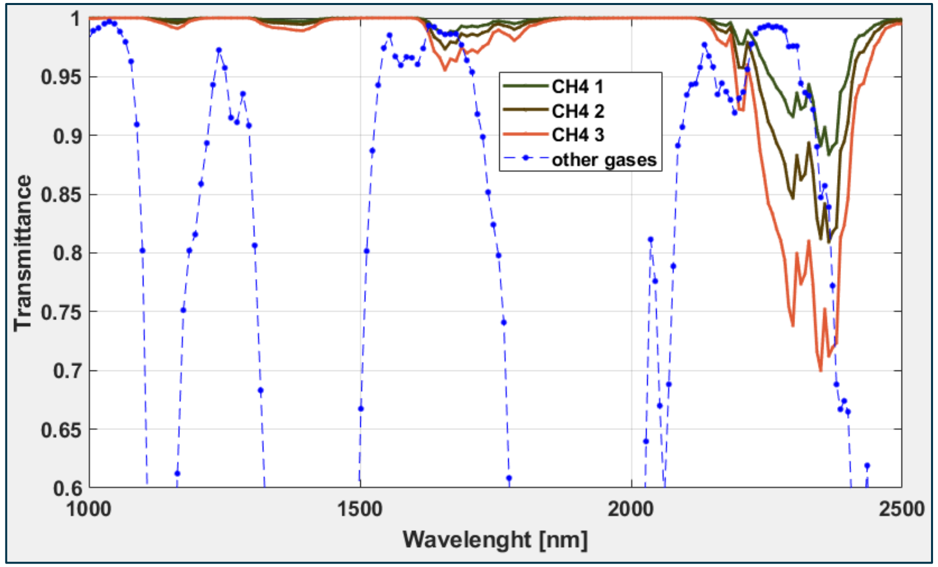


Gas Emissions Detection

- SWIR bands can be used for Methane gas detection.
- Similar capability has been already demonstrated on S2.
- We expect more accuracy when using PRISMA.

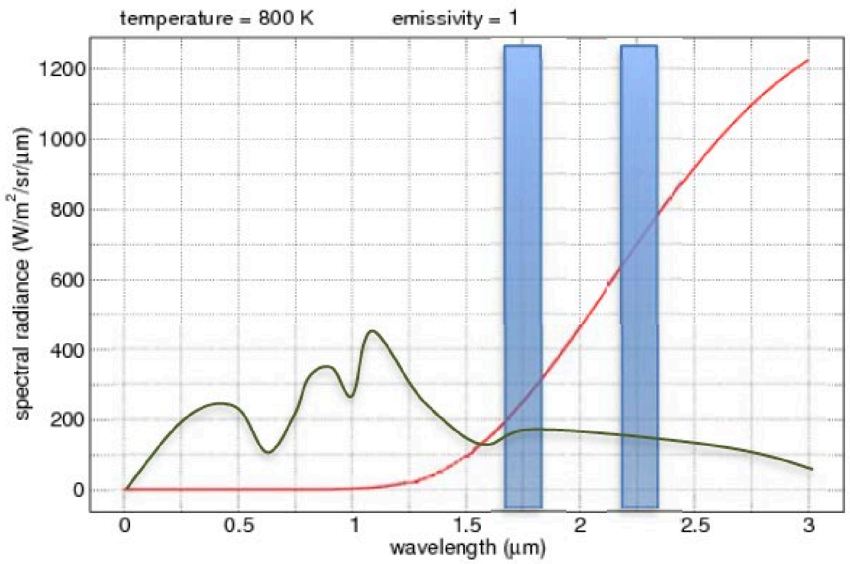


Absorption band of methane at 1.6 and 2.3 μm versus other atmospheric gases



Hot Spot detection

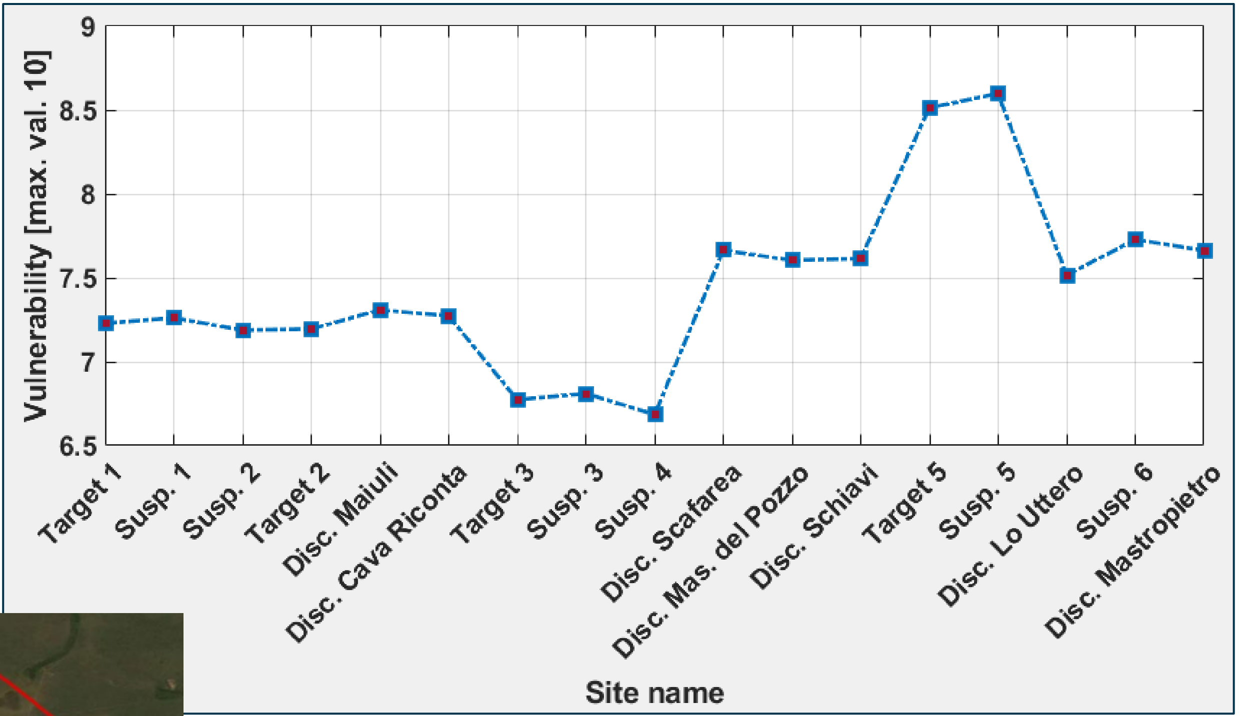
- The exploitation of Sentinel-2 - PRISMA SWIR channels for the detection of thermal anomalies (hot spots), useful in detecting unauthorized fires of wasted materials.
- PRISMA could be able to monitor the effect of events.



Vulnerability Index

- Hypothesis of creating a **vulnerability index** to prioritize the areas to monitor based weighting the presence of following classes in a buffer area (a 5km buffer has been considered) around the landfill:

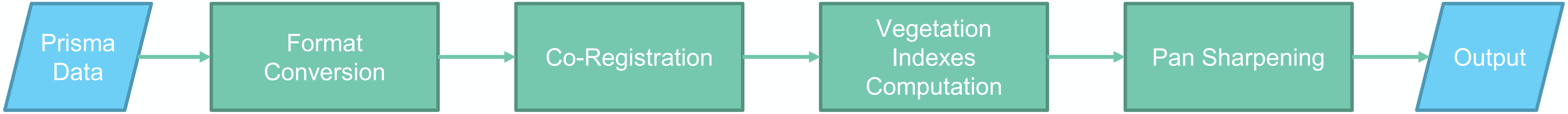
- cropland (10),
- water bodies (7),
- natural/forest (5),
- urban (10)



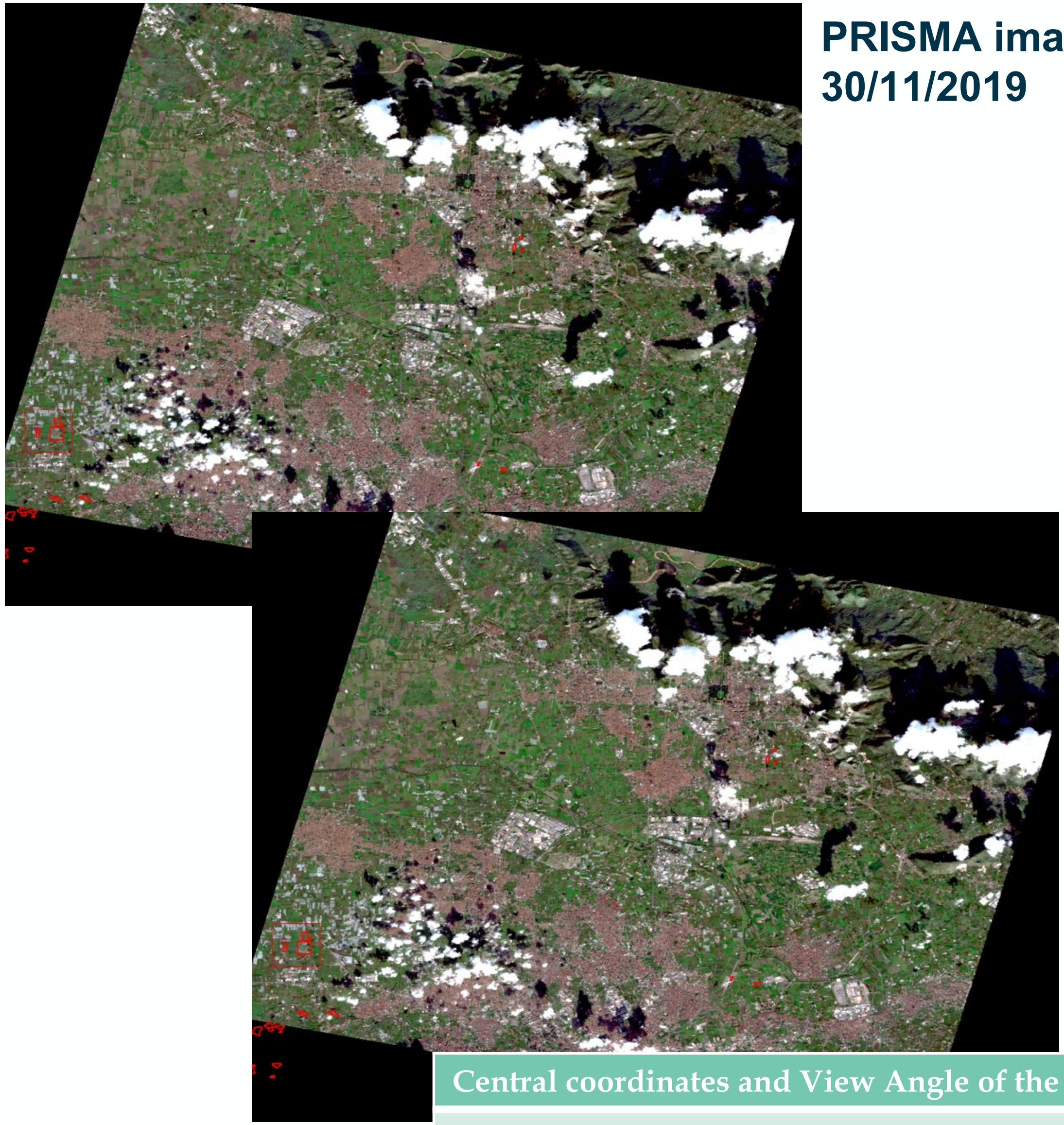
CLEAR-UP Project, PRISMA image pre-processing

Matlab (with Python and Gdal) and R based procedure:

1. Conversion from HDF5 to Geotiff;
2. Automated co-registration of the PRISMA image on the nearest S2 image;
3. Compute vegetation indices;
4. Apply PCA approach to pan-sharpening PRISMA channels falling in the PAN range (0.4 – 0.7), that is 34 PRISMA channels.

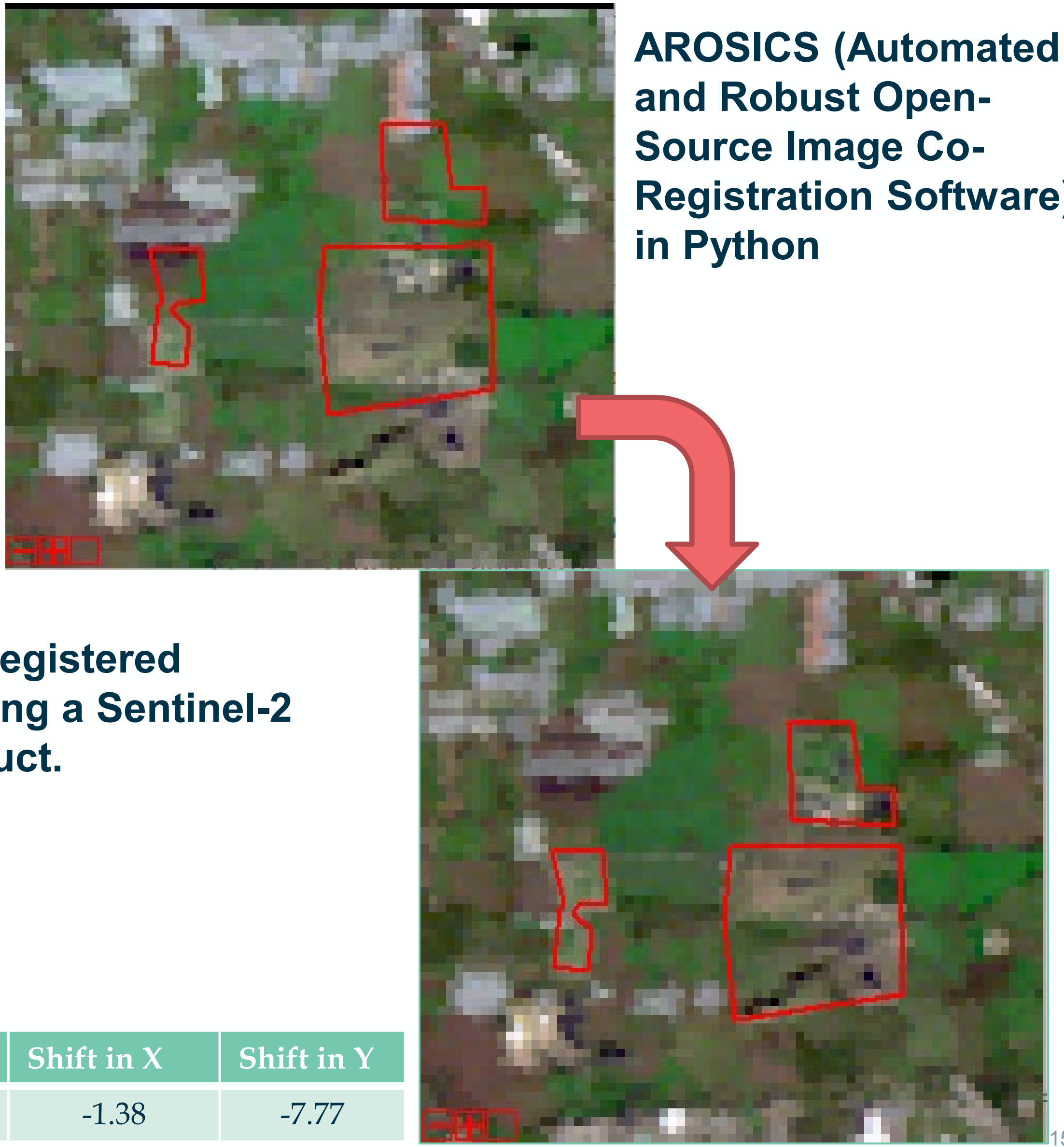


Example of PRISMA image pre-processing: co-registration to S2 image



PRISMA image of 30/11/2019

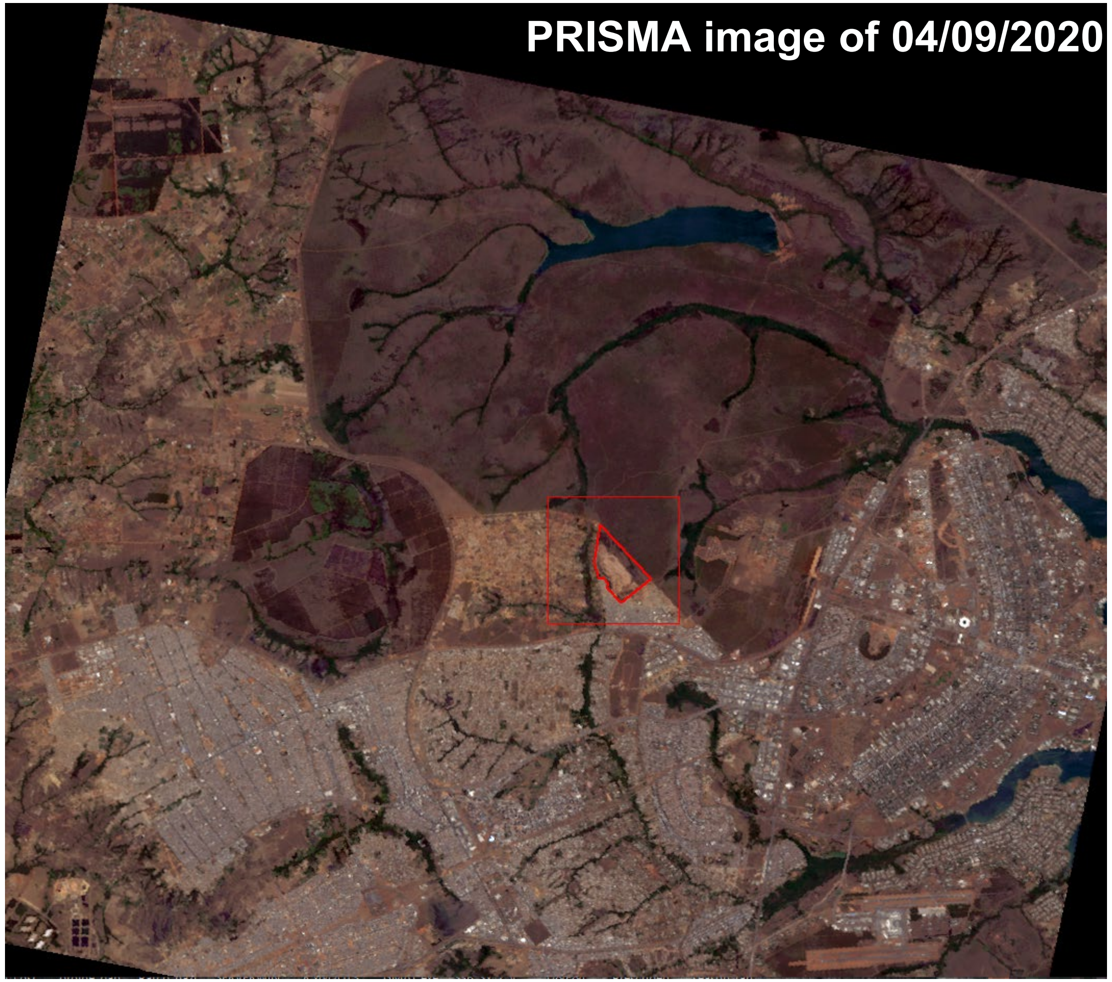
PRISMA co-registered image by using a Sentinel-2 refined product.

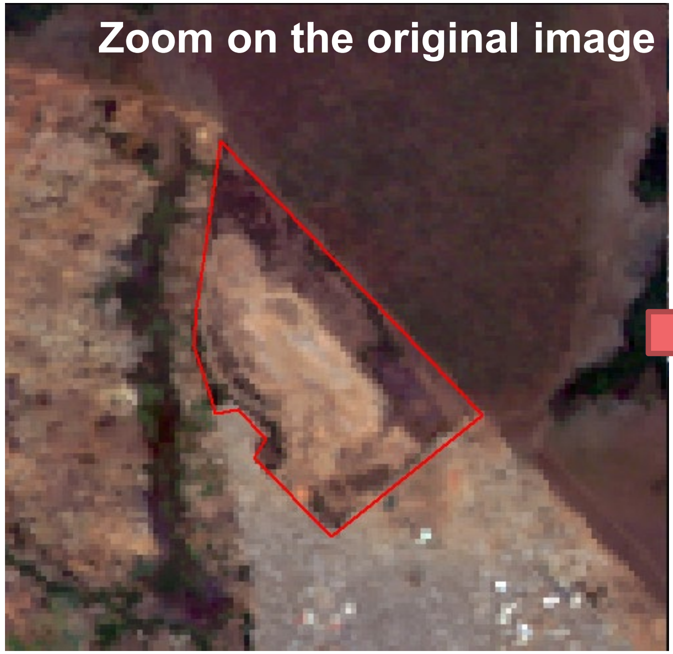


AROSICS (Automated and Robust Open-Source Image Co-Registration Software) in Python

Central coordinates and View Angle of the PRISMA image	Shift in X	Shift in Y
lat: 41.011, lon: 14.289, VA = 3.3°	-1.38	-7.77

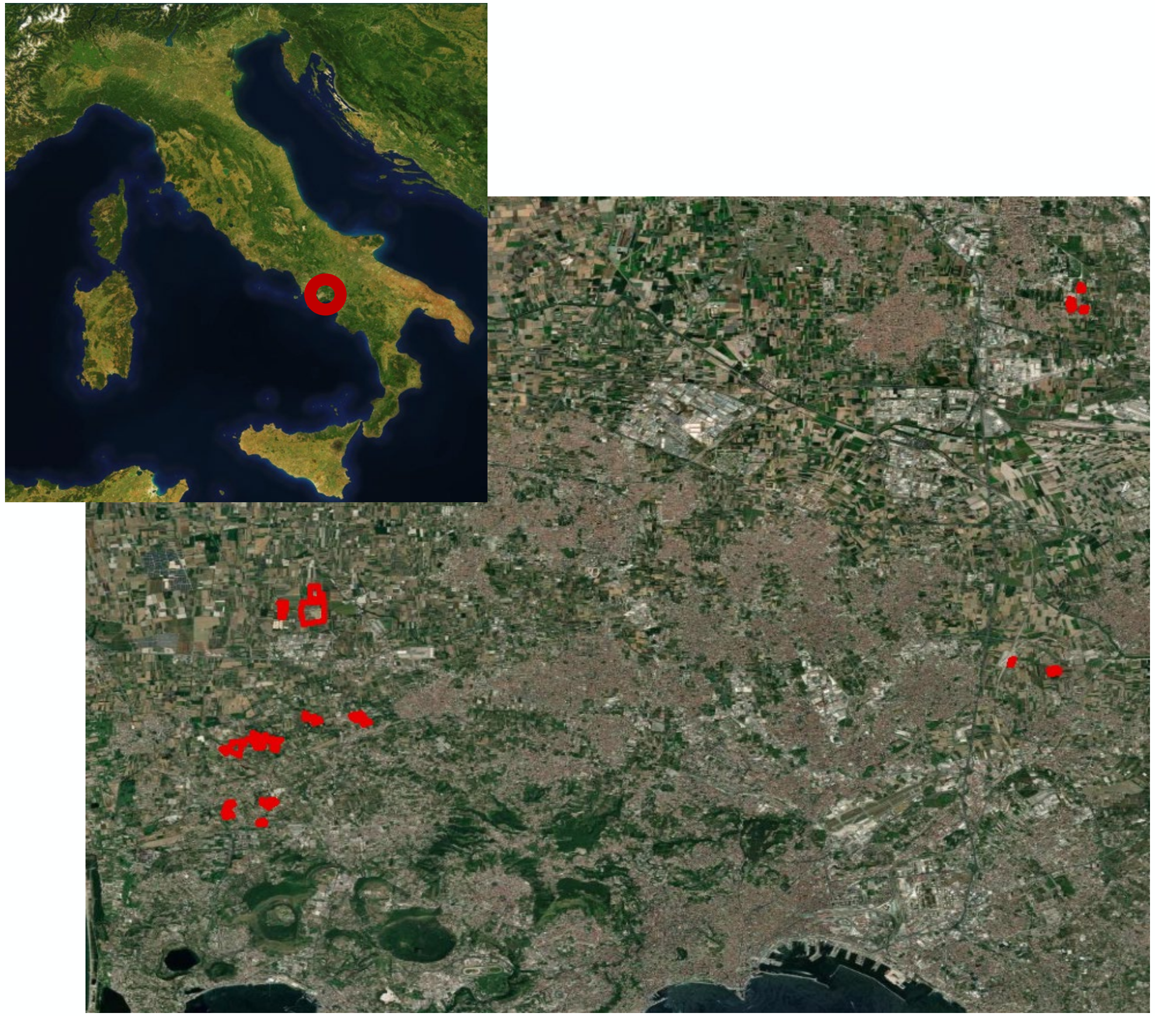
Example of PRISMA image pre-processing: co-registration to S2 image

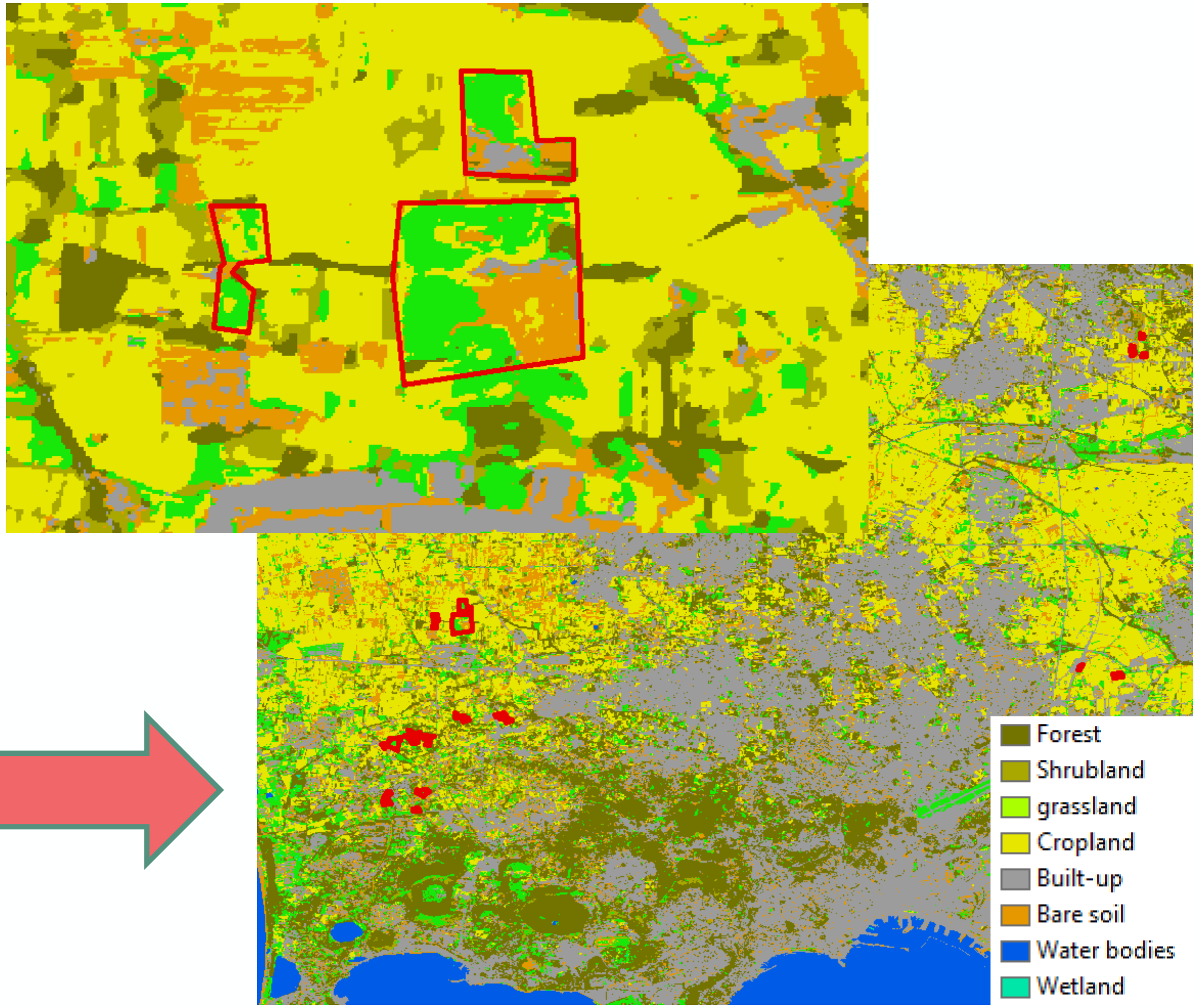




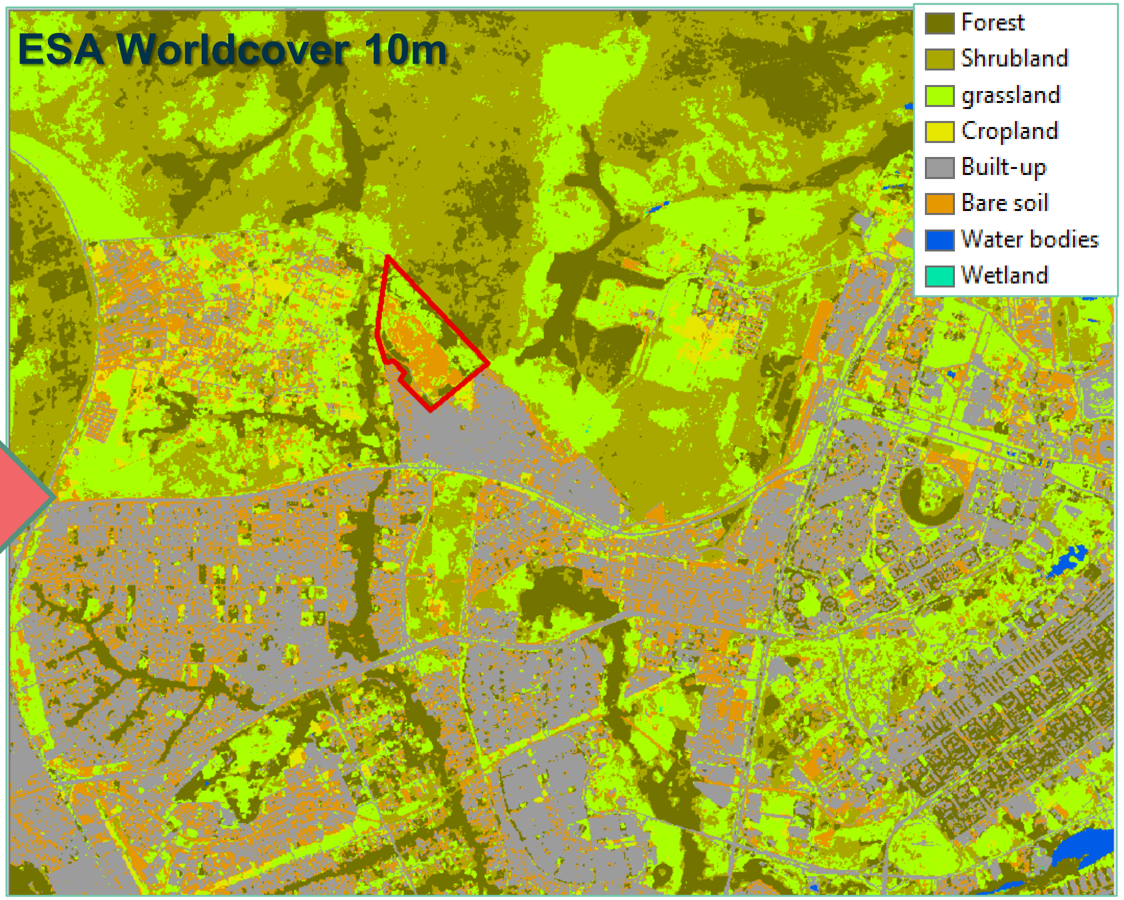
Central coordinates and View Angle of the PRISMA image	Shift in X	Shift in Y
lat: -15.770, lon: -48.00, VA = 21.0°	-0.15	0.86

Preliminary study areas: South Italy





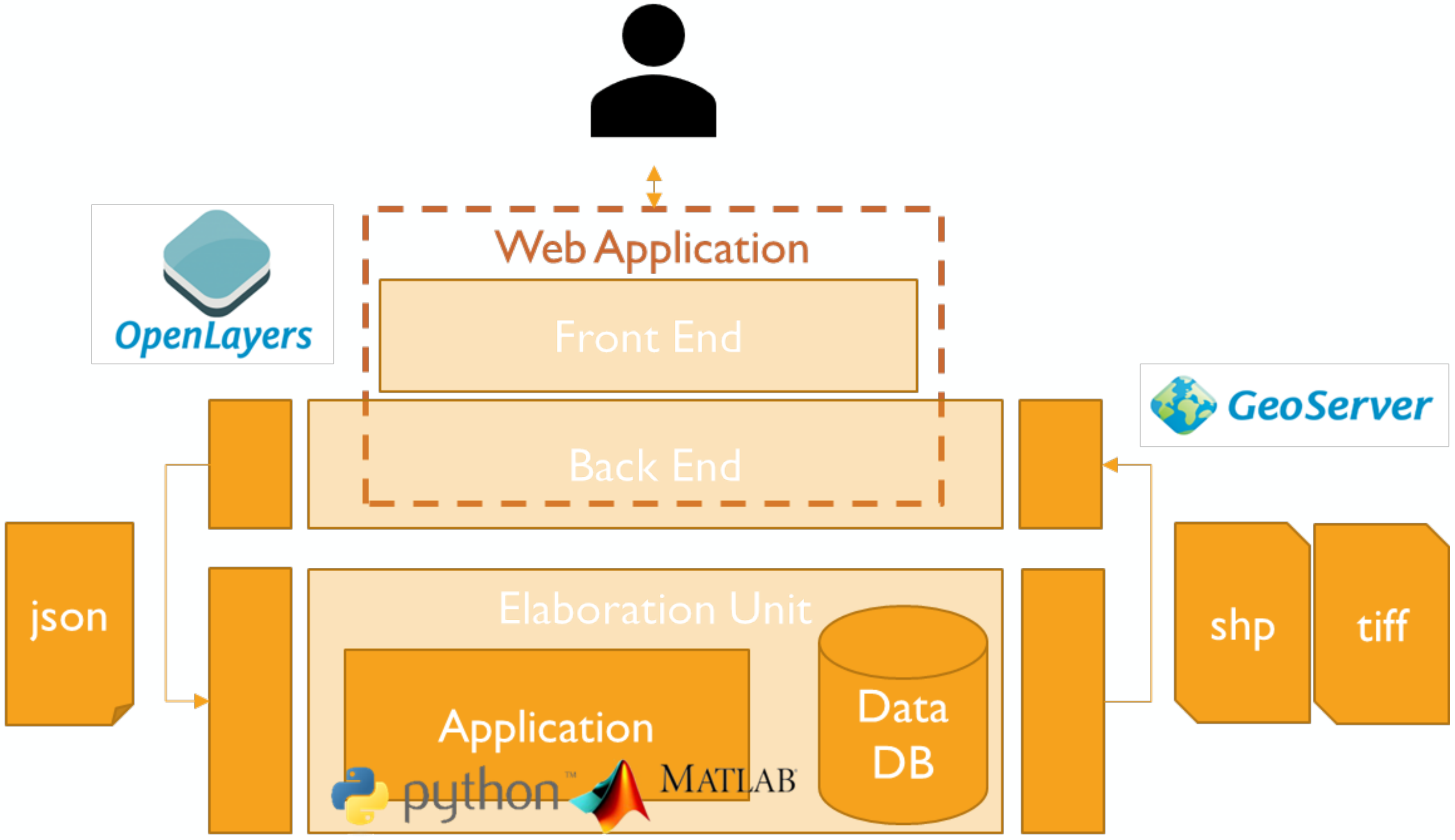
Preliminary study areas: Brazil



Prototype Design

The prototype will be a Web Application, based on **3** components:

1. Front End developed in Open Layer that will manage user requests and allow viewing of the outputs.
2. A Back End that will manage the processes in progress, the cataloging and publication of the products in Output.
3. An Elaboration Unit that will integrate the developed and optimized experimental codes and will manage their execution.



Conclusions

CLEAR_UP project will exploit PRISMA data for the:

- Detection of the presence of heavy metals in the soils in the area next to landfills;

- Identifying the presence of stress conditions affecting the vegetation close to the area of the landfill;

- Identifying potentially harmful emissions (CH_4, CO_2, NO_X) caused by spontaneous combustion and/or due to uncontrolled practices against the material in the landfill;

- Determining the extent of the area possibly affected by the presence of the landfill.

Thank you for your attention!

Agenzia Spaziale Italiana

Giovanni.Laneve@uniroma1.it