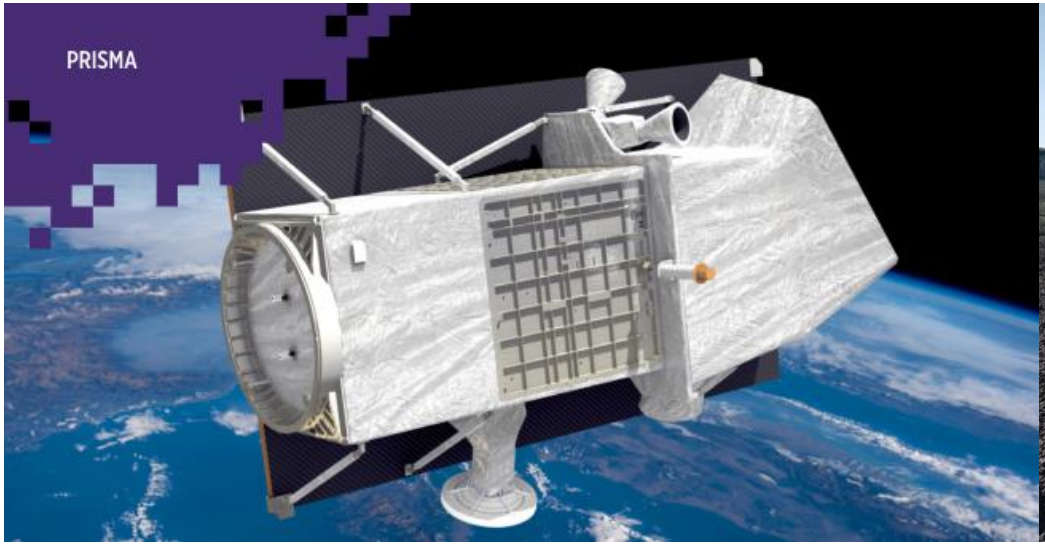

Assessment of PRISMA imaging spectrometer data for the estimation of topsoil properties of agronomic interest at the field scale

Raffaele Casa[1], Stefano Pignatti[2], Simone Pascucci[2], Victoria Ionca[2], Nada Mzid[1], Irina Veretelinkova[1]

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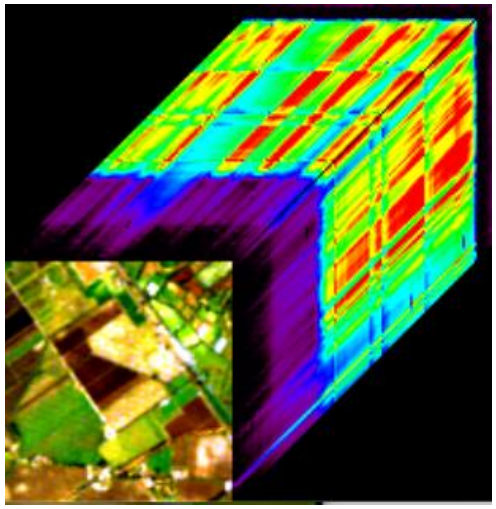
On the 22 March 2019 the Italian Space Agency (ASI) launched the hyperspectral PRISMA scientific mission, having onboard an imager covering the 400-2500 nm range with 234 spectral bands and about 10 nm of bandwidth.



Spatial resolution	
Hyperspectral:	30 m
PAN:	5 m
VNIR:	400 - 1010 nm (66 spectral bands)
SWIR:	920 - 2505 nm (174 spectral bands)

Spectral Accuracy: ±0.1 nm
Absolute Radiometric Accuracy: 5%
with 12 bits quantized data

SNR

VNIR (400-1010 nm): >160:1 (>450:1 at 650nm)
SWIR (920-2505 nm): > 100:1 (>360:1 at 1550nm)
PAN (400-700 nm): > 240:1

ASI L2d product:
Geolocated & geocoded at surface reflectance (Hyperspectral / PAN).
It includes:
- Aerosol Characterization Product (VNIR);
- Water Vapour Map - Cloud Characterization

One of the potential application areas of this scientific mission is for mapping of **field-scale topsoil properties** is of particular interest.

PRISCAV Project: first assessment of PRISMA data

PRISMA and **Sentinel-2** images were acquired over the Maccarese farm (Fiumicino, Central Italy) **on the same day**: **February 8th 2020**

PRISMA 30 m
Hyperspectral
L2D product (reflectance)

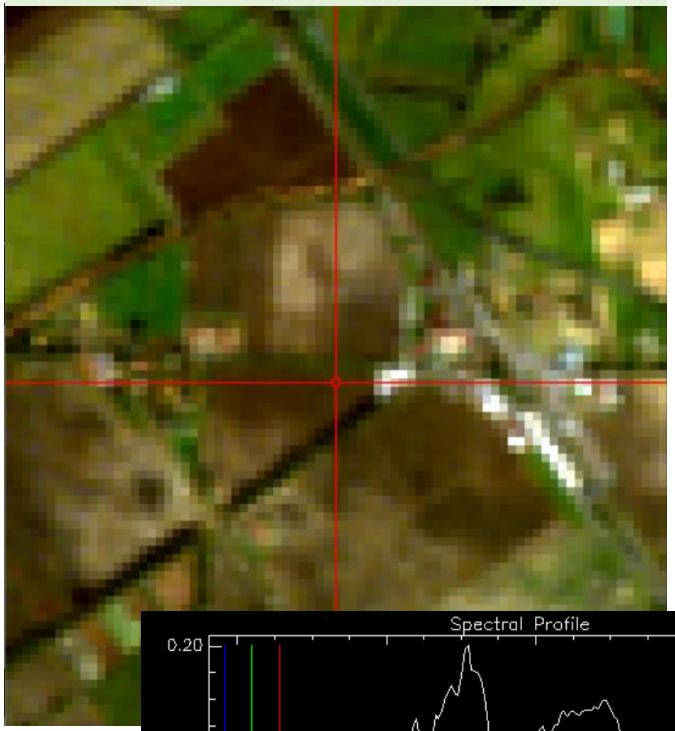
PRISMA 5 m
panchromatic

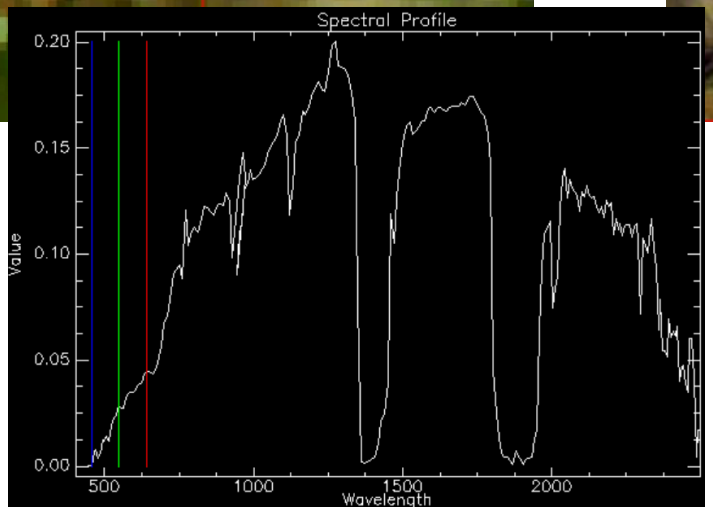
Sentinel-2 10 m
multispectral

Since PRISMA has a 5 m PAN band it is possible to do tests using pan-sharpening of the 30 m hyperspectral image.

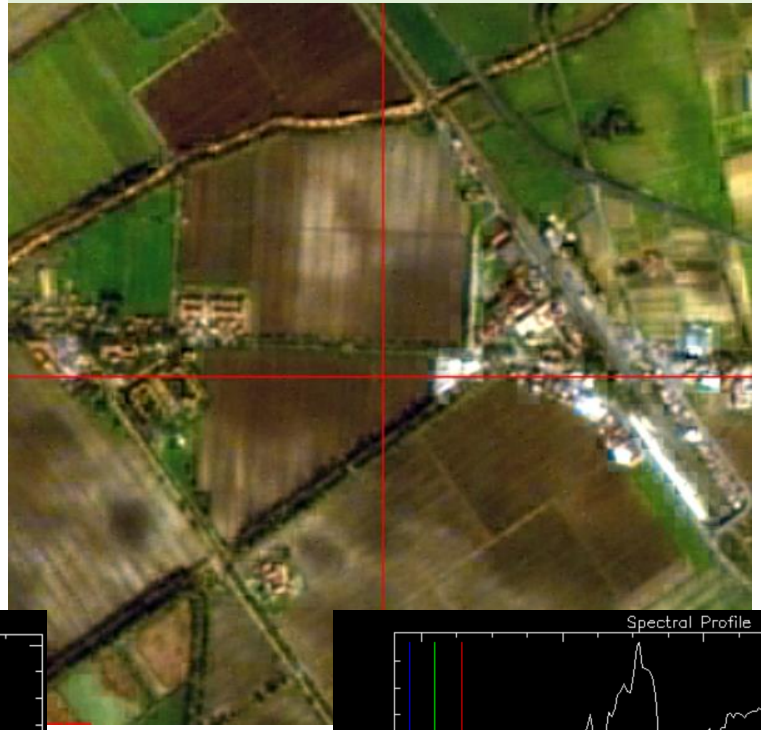
We tried the **Gram-Schmidt Spectral Sharpening in ENVI**

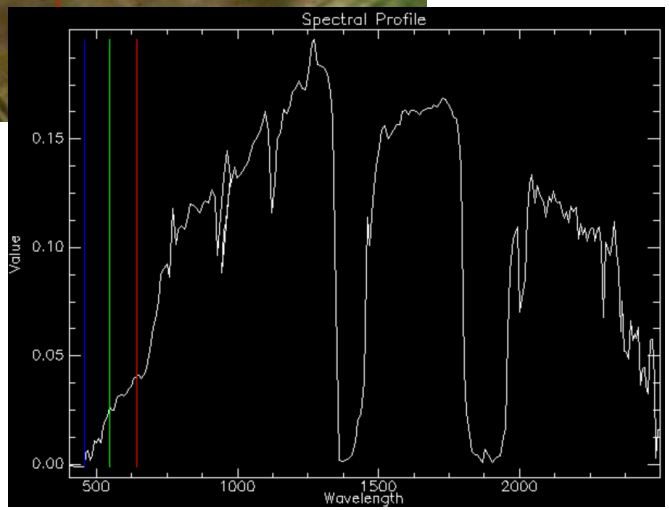
PRISMA Hyperspectral **30 m**

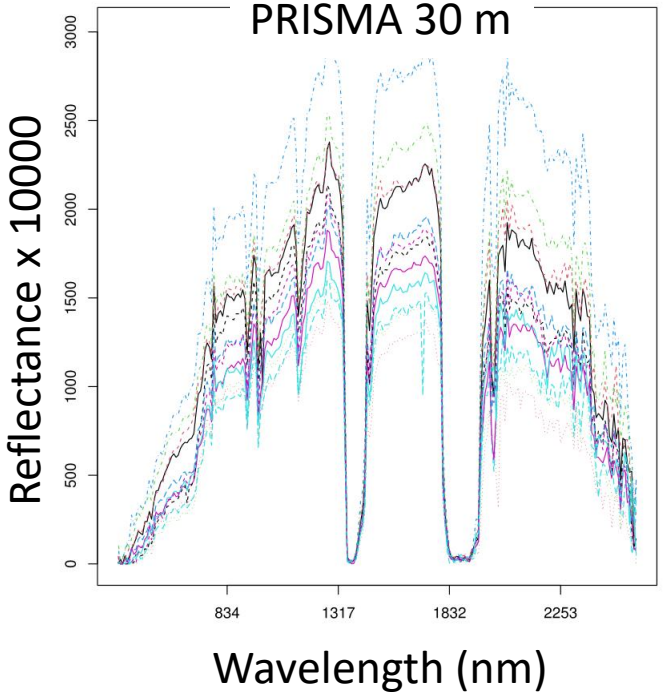


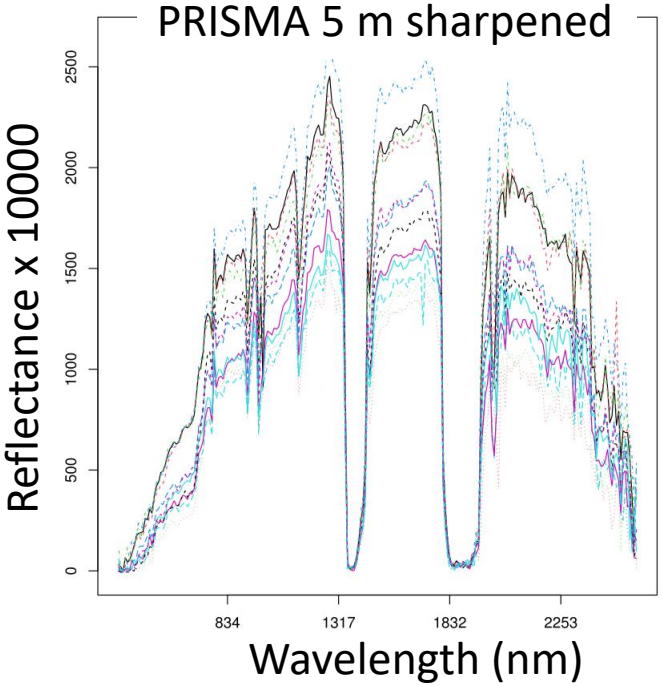


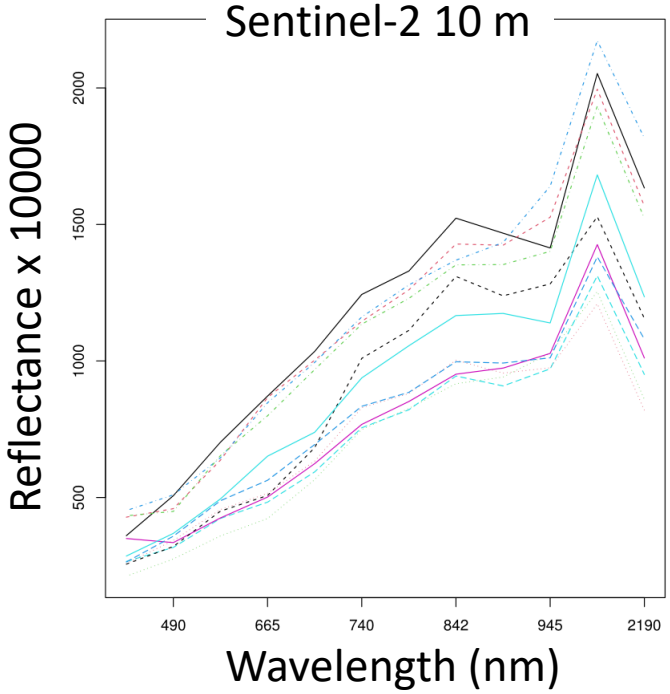
PRISMA Hyper-sharpened **5 m**





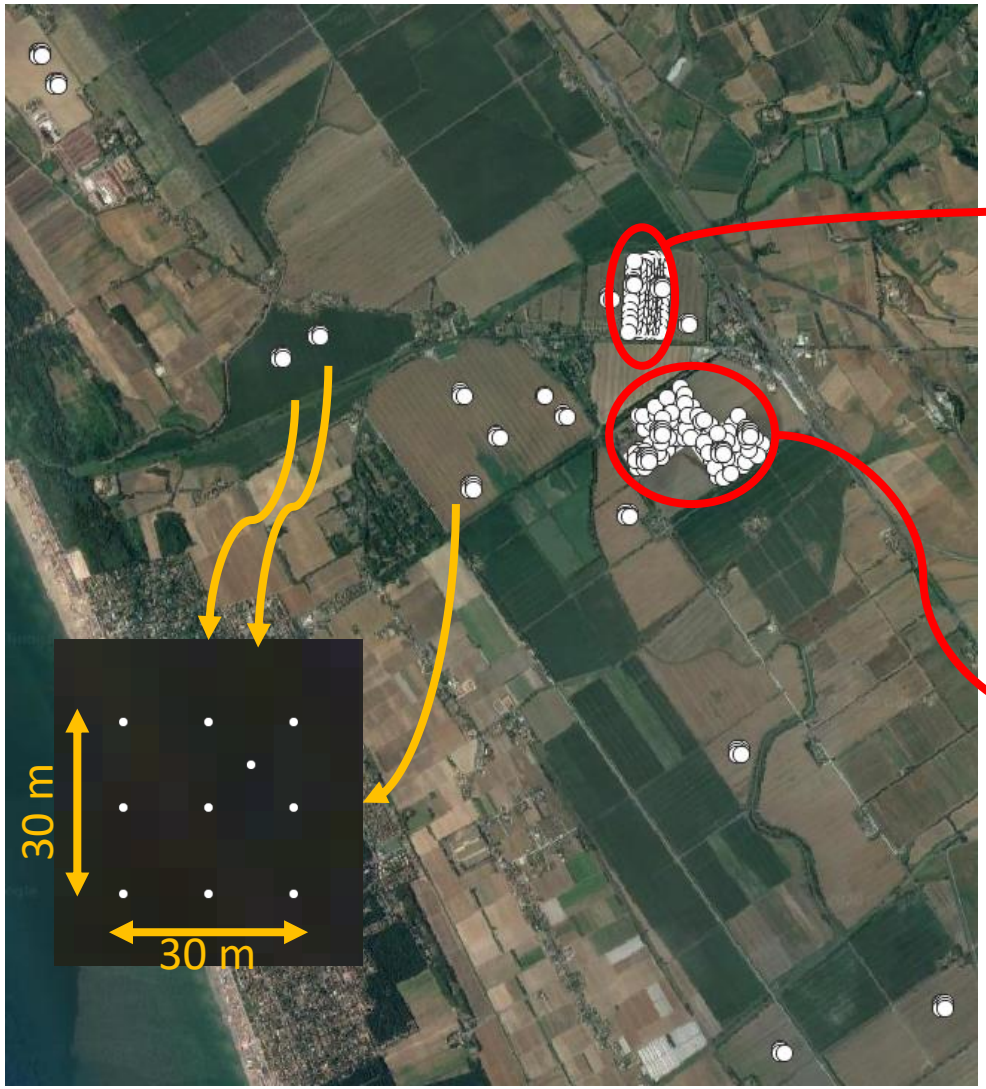


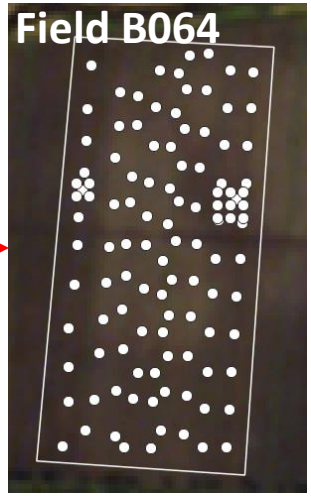




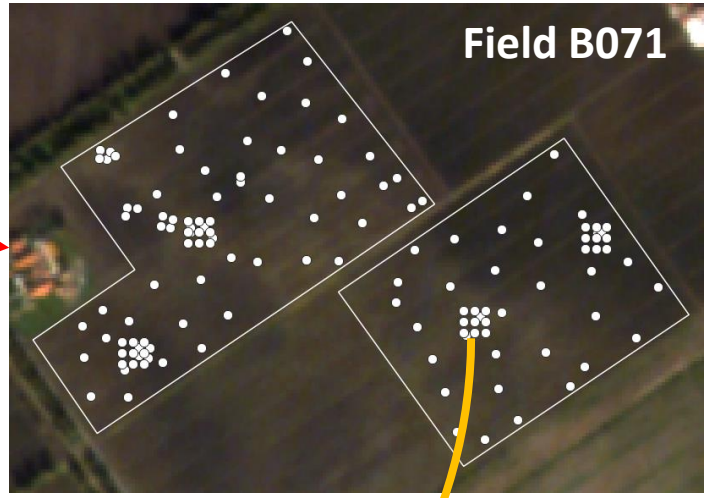
Spectra for the «same»
Soil sampling points

Past and current (2020) soil sampling campaigns carried out in Maccarese (3500 ha farm)

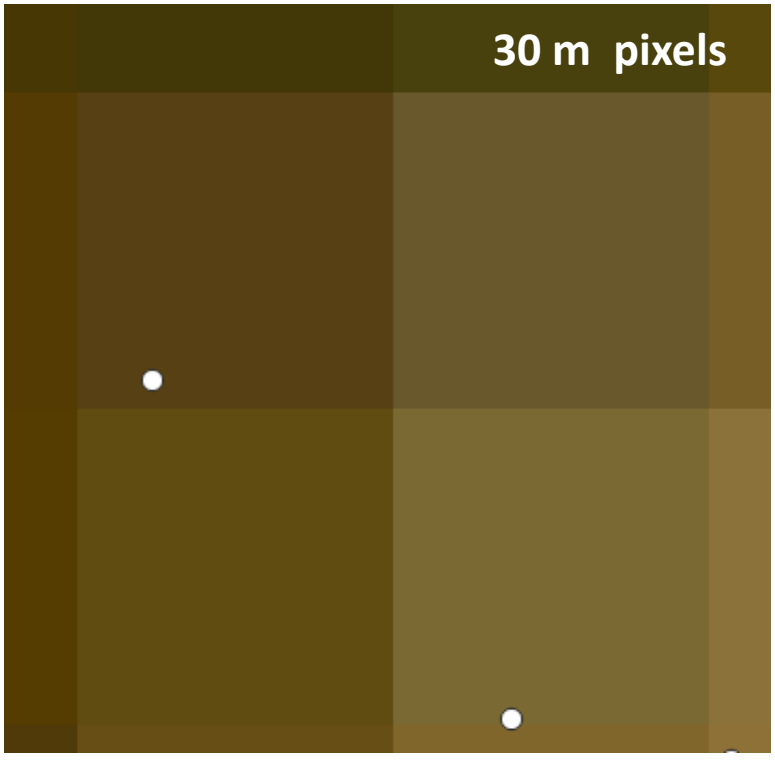


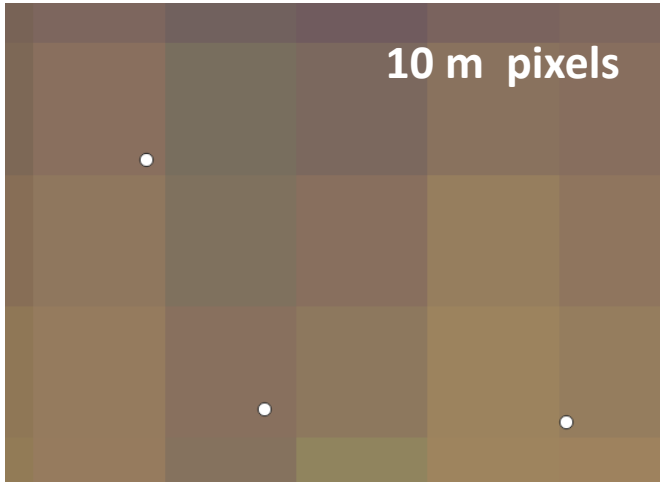


Past intensive sampling ~ 100 samples per field



Current sampling according to a 30 x 30 m Elementary Sampling Unit with 10 points



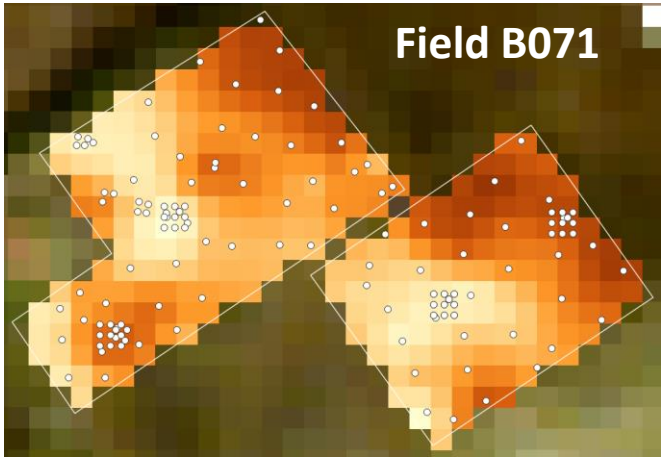


Soil sampling support size issue:

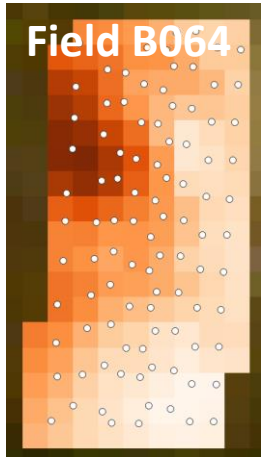
- Ground sample support ~ 2 m (bulked samples collected in a circle with 2 m diameter)
- Satellite image pixel support:
  - 5 m (PRISMA sharpened);
  - 10 m (Sentinel-2);
  - 30 m (PRISMA L2d hyperspectral)

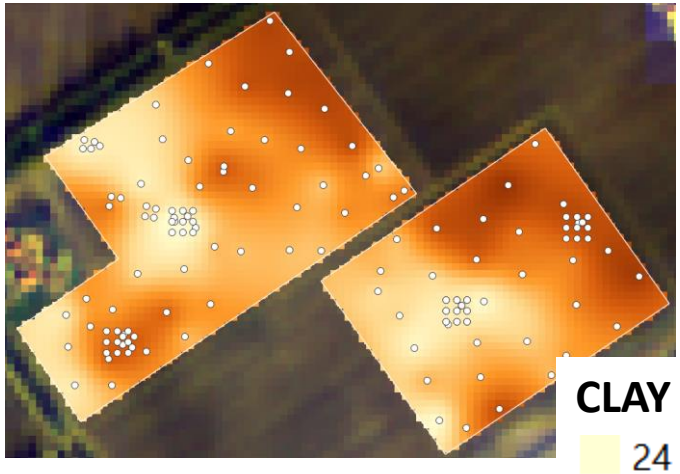
The sample support size is not consistent with the pixel of the image:

- **We used block kriging of densely sampled soil points to spatialize the points to the pixels, with the same grids as the satellite images**

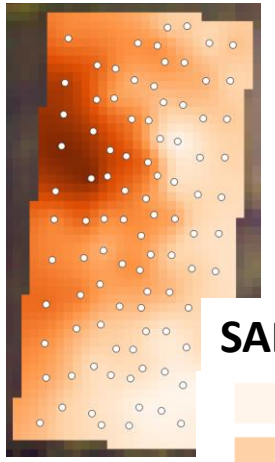


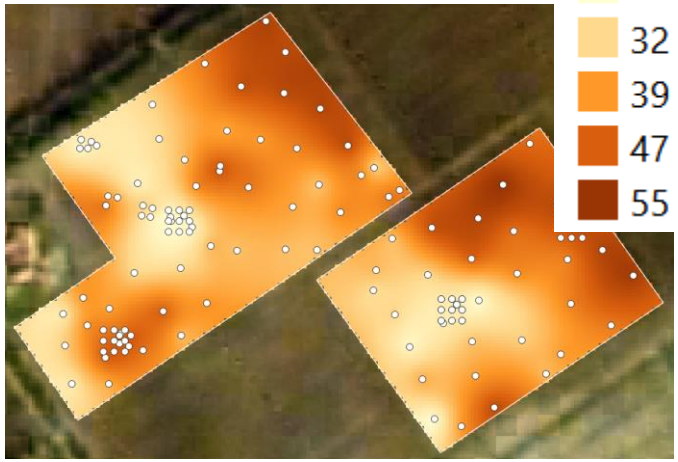
30 m



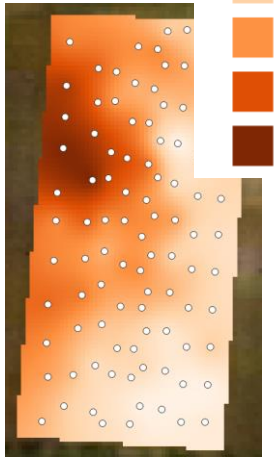


10 m





5 m



CLAY

24
32
39
47
55

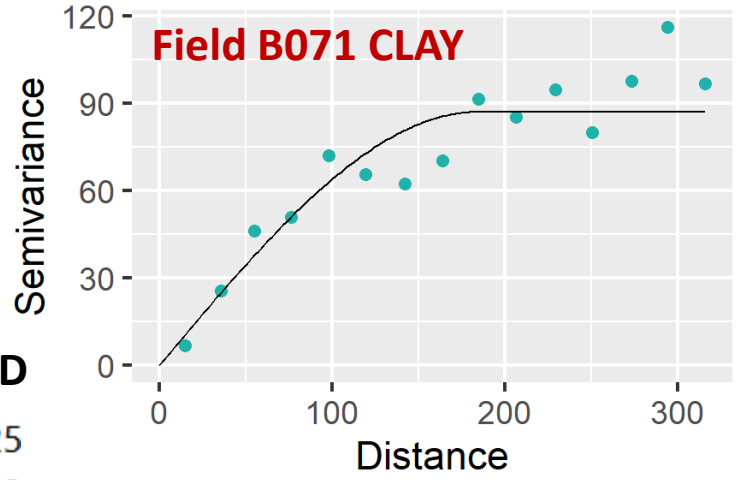
SAND

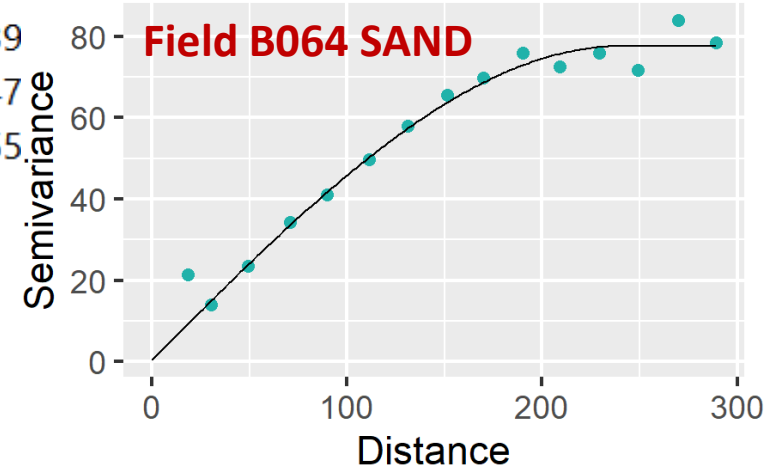
25
32
39
47
55

Block kriging of sampled soil points to:

- PRISMA 30 pixel grid
- Sentinel-2 10 m pixel grid
- PRISMA sharpened 5 m pixel grid

For CLAY and SAND for 2 fields: B064 and B071





Methodology

Extraction of CAL & VAL samples:

90 image pixels extracted from images with associated soil properties from block kriging grids

Sample extraction based on the same statistical distribution as soil properties (CLAY and SAND)

PRISMA 30 m

CAL N=90

VAL N=90

PRISMA Sharpened 5 m

CAL N=90

VAL N=90

Sentinel -2 10 m

CAL N=90

VAL N=90

Spectral pre-treatments

1. Absorbance (1/log(reflectance)
2. 1st Derivative
3. SNV
4. SNV detrend

Pre-processing:

Removal of noisy bands

Spectral pre-treatments:

1. Savitsky-Golay
2. Absorbance (1/log(reflectance)
3. 1st Derivative
4. Standard Normal Variate (SNV)
5. SNV detrend

Partial Least Squares Regression (**PLSR**)

Random Forests (**RF**)

Partial Least Squares Regression (**PLSR**)

Random Forests (**RF**)

Assessment of results

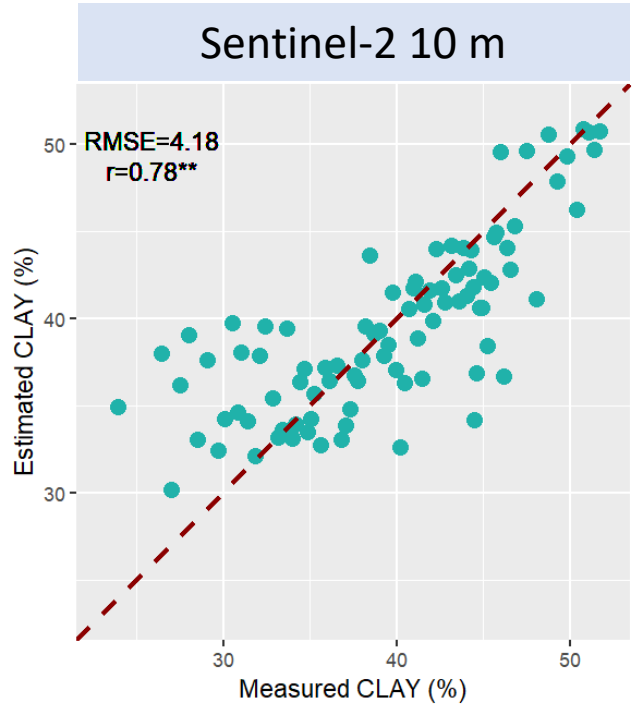
1.Bias

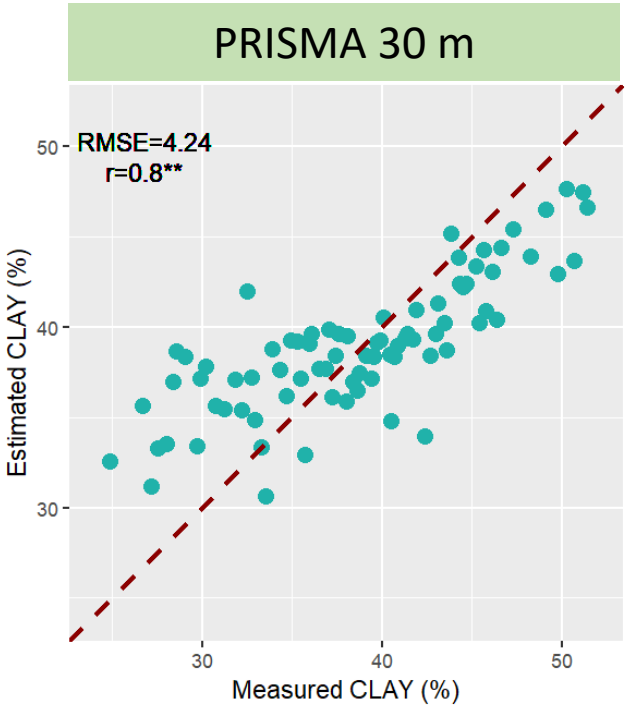
2. Relative Bias
3. R^2 and r (correlation)
4. Root Mean Squared Error (RMSE)
5. Relative RMSE (rRMSE)
6. Mean Absolute Error (MAE)
7. Ratio of Preformance to Deviation (RPD)
8. Ratio of performance to interquartile range (RPIQ)

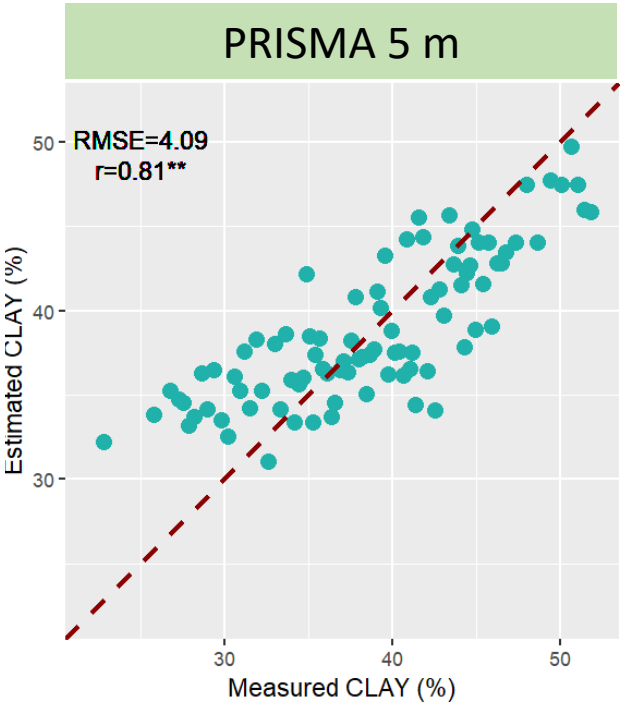
Results: best performances among spectral pre-treatments

CLAY - B071 and B064 fields bulked data

Sensor	Resolution (m)	Technique	Variable	pretratment	Bias	rBias	R2	r	signif	RMSE	rRMSE	MAE	RPD	RPIQ
Sentinel-2	10	PLSR	CLAY	SNV	-0.30	-0.76	0.50	0.71	**	4.76	3.63	11.96	1.40	2.12
Sentinel-2	10	RF	CLAY	Refl	-0.07	-0.18	0.60	0.78	**	4.18	3.01	10.56	1.59	2.42
PRISMA	30	PLSR	CLAY	Abs	-0.05	-0.12	0.58	0.76	**	4.19	3.40	10.87	1.54	2.34
PRISMA	30	RF	CLAY	Der	-0.27	-0.70	0.64	0.80	**	4.24	3.48	10.88	1.55	2.33
PRISMA	5	PLSR	CLAY	Abs	-0.44	-1.12	0.57	0.75	**	4.44	3.57	11.36	1.52	2.24
PRISMA	**5**	**RF**	**CLAY**	**SNV_det**	**-0.24**	**-0.62**	**0.65**	**0.81**	**	**4.09**	**3.37**	**10.54**	**1.65**	**2.43**







Results: best performances among spectral pre-treatments

CLAY - B071 field

Sensor	Resolution (m)	Technique	Variable	pretratment	Bias	rBias	R2	r	signif	RMSE	rRMSE	MAE	RPD	RPIQ
Sentinel-2	10	PLSR	CLAY	SNV	-0.58	-1.43	0.85	0.92	**	3.27	2.51	8.13	2.56	4.60
Sentinel-2	10	RF	CLAY	Refl	-0.43	-1.07	0.88	0.94	**	2.95	2.31	7.35	2.84	5.10
PRISMA	30	PLSR	CLAY	SNV	-0.28	-0.72	0.78	0.88	**	3.57	2.67	9.22	2.12	2.81
PRISMA	30	RF	CLAY	Der	-0.4	-1.1	0.7	0.9	**	3.95	3.023	9.96	2	3.1
PRISMA	5	PLSR	CLAY	SNV	-0.06	-0.15	0.81	0.90	**	3.37	2.55	8.60	2.30	4.05
PRISMA	**5**	**RF**	**CLAY**	**Der**	**-0.06**	**-0.14**	**0.92**	**0.96**	**	**2.34**	**1.77**	**5.97**	**3.31**	**5.83**

CLAY - B064 field

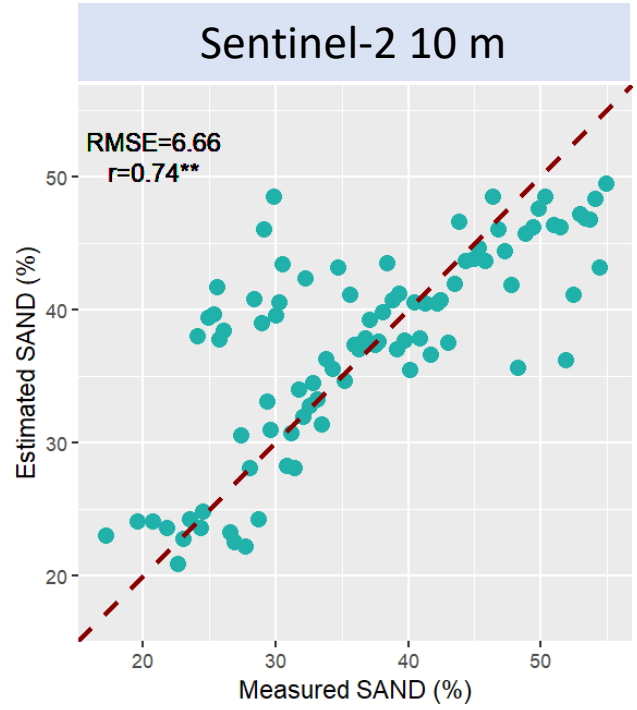
Sensor	Resolution (m)	Technique	Variable	pretratment	Bias	rBias	R2	r	signif	RMSE	rRMSE	MAE	RPD	RPIQ
Sentinel-2	10	PLSR	CLAY	SNV	0.30	0.75	0.38	0.62	**	3.88	3.19	9.86	1.27	1.92
Sentinel-2	10	RF	CLAY	Abs	-0.32	-0.80	0.45	0.67	**	3.65	2.58	9.14	1.35	2.05
PRISMA	**30**	**PLSR**	**CLAY**	**Der**	**0.01**	**0.03**	**0.96**	**0.98**	**	**1.02**	**0.80**	**2.56**	**4.84**	**7.11**
PRISMA	30	RF	CLAY	SNV_det	0.01	0.02	0.97	0.98	**	1.11	0.87	2.81	4.42	6.49
PRISMA	5	PLSR	CLAY	Der	-0.13	-0.33	0.93	0.96	**	1.34	1.00	3.32	3.73	6.08
PRISMA	5	RF	CLAY	Der	-0.07	-0.17	0.89	0.94	**	1.98	1.31	4.93	2.52	4.10

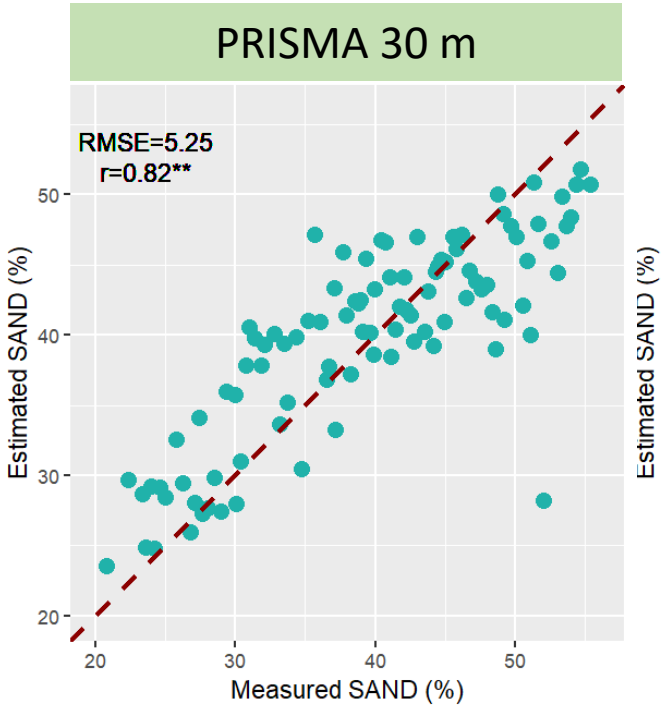
For CLAY, always better results for PRISMA than for Sentinel-2, but in one case @5m and in the other @30m

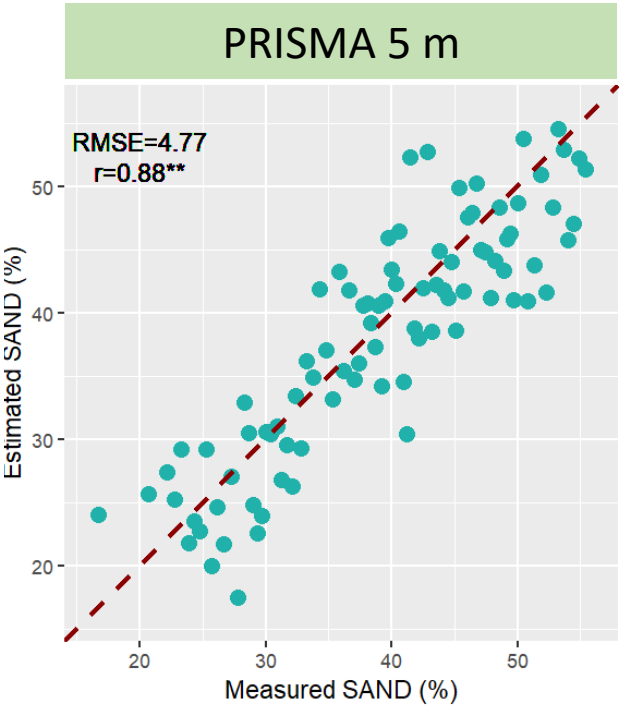
Results: best performances among spectral pre-treatments

SAND - B071 and B064 fields bulked data

Sensor	Resolution (m)	Technique	Variable	pretratment	Bias	rBias	R2	r	signif	RMSE	rRMSE	MAE	RPD	RPIQ
Sentinel-2	10	PLSR	SAND	Abs	0.26	0.72	0.57	0.75	**	6.41	5.01	17.65	1.53	2.38
Sentinel-2	10	RF	SAND	Refl	-0.92	-2.45	0.54	0.74	**	6.66	4.73	17.74	1.47	2.30
PRISMA	30	PLSR	SAND	SNV	0.42	1.07	0.67	0.82	**	5.36	3.99	13.74	1.71	2.75
PRISMA	30	RF	SAND	SNV_det	-0.35	-0.89	0.67	0.82	**	5.25	3.99	13.19	1.75	2.81
PRISMA	**5**	**PLSR**	**SAND**	**SNV**	**0.97**	**2.56**	**0.77**	**0.88**	**	**4.77**	**3.88**	**12.54**	**2.02**	**3.24**
PRISMA	5	RF	SAND	SNV_det	1.02	2.69	0.76	0.87	**	4.93	3.90	12.98	1.95	3.14







Results: best performances among spectral pre-treatments

SAND - B071 field

Sensor	Resolution (m)	Technique	Variable	pretratment	Bias	rBias	R2	r	signif	RMSE	rRMSE	MAE	RPD	RPIQ
Sentinel-2	10	PLSR	SAND	Abs	-0.41	-1.07	0.93	0.96	**	3.23	2.52	8.30	3.73	7.03
Sentinel-2	10	RF	SAND	Abs	-0.42	-1.09	0.93	0.96	**	3.25	2.41	8.35	3.71	6.99
PRISMA	30	PLSR	SAND	SNV	0.52	1.24	0.83	0.91	**	4.22	3.00	10.17	2.39	2.86
PRISMA	30	RF	SAND	SG	0.32	0.76	0.8	0.9	**	3.92	3.093	9.39	2.6	3.09
PRISMA	**5**	**PLSR**	**SAND**	**Der**	**-0.22**	**-0.53**	**0.94**	**0.97**	**	**2.63**	**2.07**	**6.28**	**3.96**	**5.25**
PRISMA	5	RF	SAND	Der	0.03	0.07	0.93	0.96	**	2.81	2.14	6.77	3.70	4.90

SAND - B064 field

Sensor	Resolution (m)	Technique	Variable	pretratment	Bias	rBias	R2	r	signif	RMSE	rRMSE	MAE	RPD	RPIQ
Sentinel-2	10	PLSR	SAND	Refl	-0.39	-1.09	0.41	0.64	**	5.49	4.47	15.43	1.27	1.83
Sentinel-2	10	RF	SAND	Refl	0.02	0.06	0.43	0.65	**	5.28	3.97	15.02	1.32	1.90
PRISMA	30	PLSR	SAND	Der	-0.04	-0.12	0.93	0.97	**	1.92	1.42	5.30	3.85	5.18
PRISMA	**30**	**RF**	**SAND**	**SNV**	**-0.07**	**-0.21**	**0.96**	**0.98**	**	**1.66**	**1.30**	**4.60**	**4.44**	**5.98**
PRISMA	5	PLSR	SAND	Der	0.18	0.50	0.92	0.96	**	2.15	1.61	6.05	3.51	4.86
PRISMA	5	RF	SAND	SNV	-0.30	-0.82	0.89	0.94	**	2.75	2.10	7.65	2.74	3.79

Also for CLAY, always better results for PRISMA than for Sentinel-2, but in one case @5m and in the other @30m

Conclusions

On the basis of this **preliminary** assessment of PRISMA data for topsoil mapping at the field-scale:

1. PRISMA L2d data is of good spectral quality
2. The possibility offered by sharpening the hyperspectral 30 m image to the 5 m of the PAN band seems interesting
3. Using a **fair** comparison for CLAY and SAND estimation accuracy, i.e. using equivalent CAL/VAL sets, & taking into account the appropriate spatial support, based on pixel size (5 / 10 / 30 m):
    a. PRISMA performs better than Sentinel-2 for both CLAY and SAND estimation
    b. The 5 m resolution pan-sharpened hyperspectral PRISMA image performes particularly well
    c. Better results for CLAY than for SAND

Of course, the local calibration with data from the image itself is an "*easy case*" …

N.B. a further more in-depth assessment will be carried out once all new samples have been processed (…we had some delays in the lab due to lockdown !)