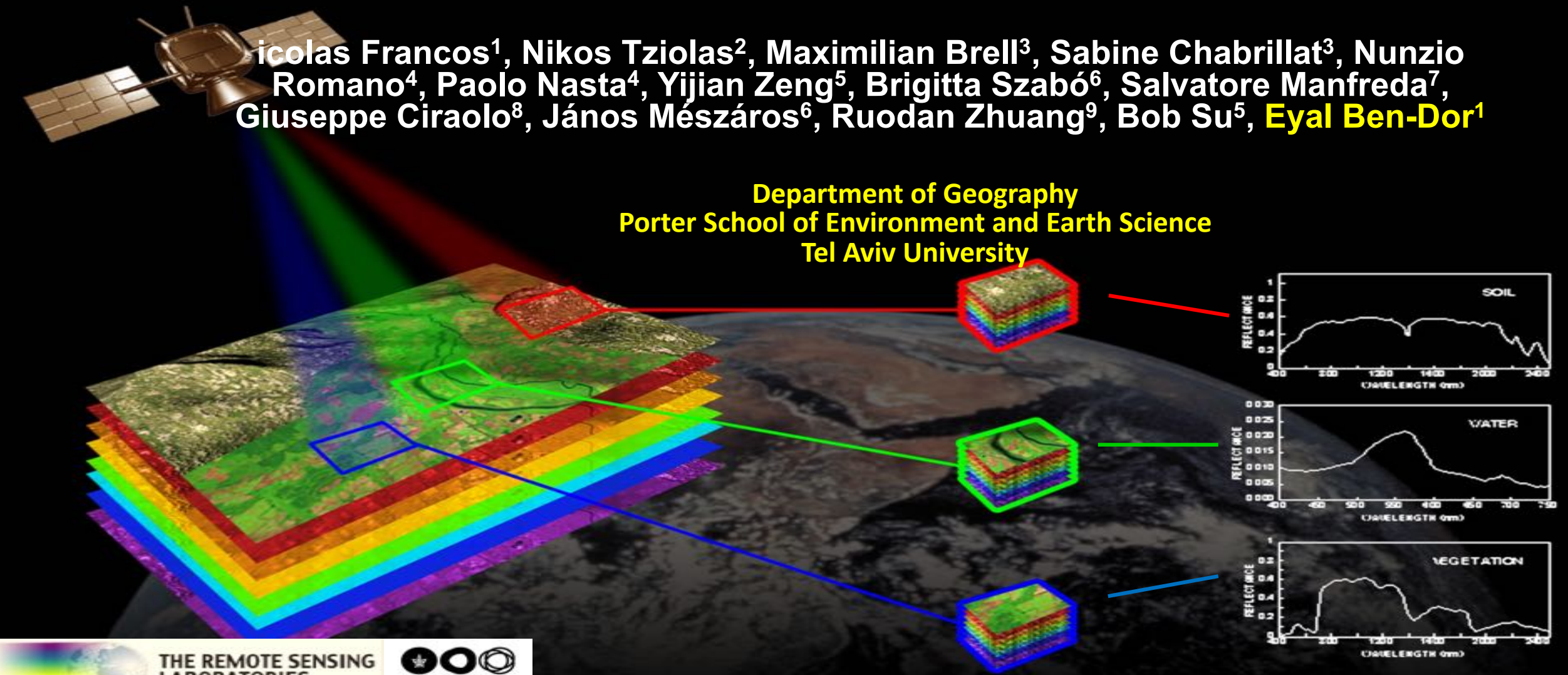


Estimation Of Water Infiltration Rate In Mediterranean Soils Using Airborne Hyperspectral Sensors

Nicolas Francos¹, Nikos Tziolas², Maximilian Brell³, Sabine Chabrillat³, Nunzio Romano⁴, Paolo Nasta⁴, Yijian Zeng⁵, Brigitta Szabó⁶, Salvatore Manfreda⁷, Giuseppe Ciruolo⁸, János Mészáros⁶, Ruodan Zhuang⁹, Bob Su⁵, **Eyal Ben-Dor¹**

Department of Geography
Porter School of Environment and Earth Science
Tel Aviv University



The Problem

- Soil Spectral Libraries are an important set of data to develop quantitative models to map soil properties
- The SSL however not able to mimic the surface condition as they are seen by EO means (disturbed by sampling, sieving, and drying)
- Soil Sealing is emerged due to physical and biogenic processes on the upper micrometer of the soil surface
- Although the crust “horizon” is neglected within the soil profile – it has a significant impact on the soil stabilization and water regime

Soil samples at storage, with wet chemistry data plus reflectance spectra measured under a well accepted protocol process and ancillary data

Soil Attributes

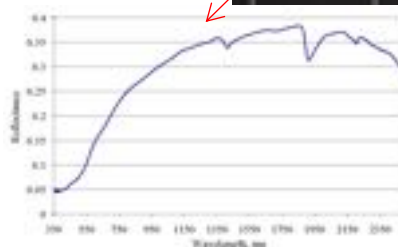
A Tremendous effort is being carried out today by many groups to develop a comprehensive world wide soil spectral library



Sample ID	Location	OM	Clay	Lime...
A1	34,5467.67	2.4 %	34%	23.4%
A2	36,654,32			

Soil Spectra Files

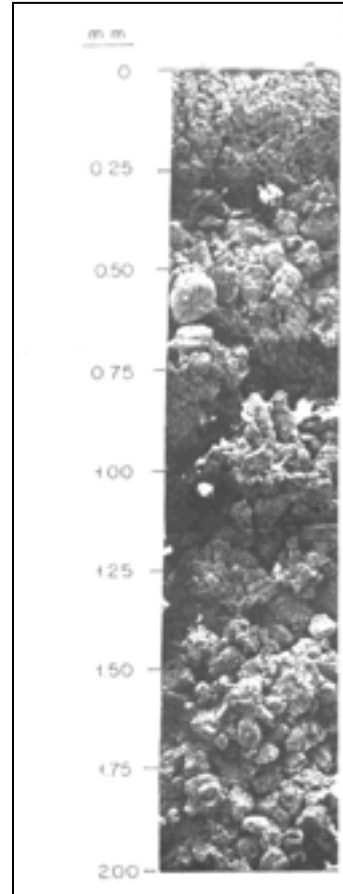
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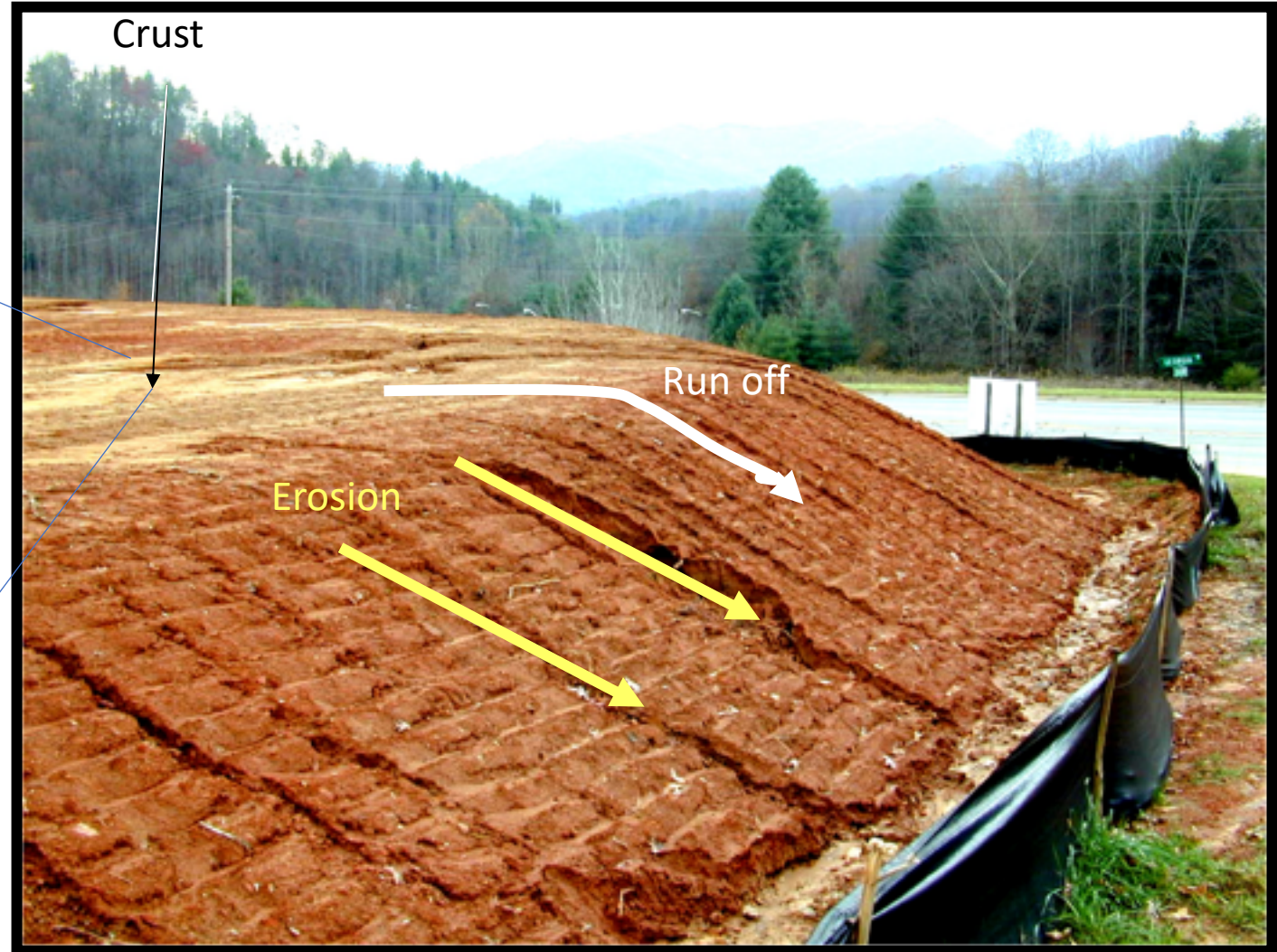
Soil Crust : Effect of Erosion and Water Runoff

Microscope Cross Section View of Physical Crust

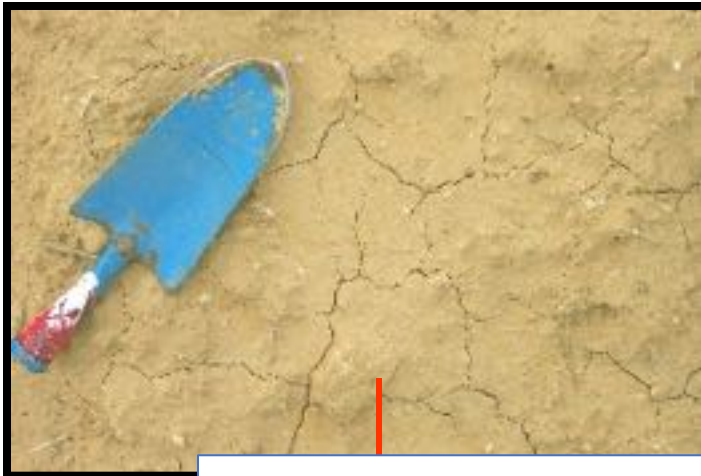


Crust

Sole



Crust



Braking Crust



Not only harmonization between measurement protocol but MOSTLY the state of soil in the field is matter



2mm grinding



Lab Measurements

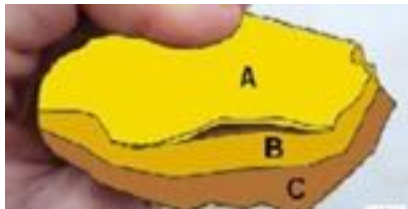
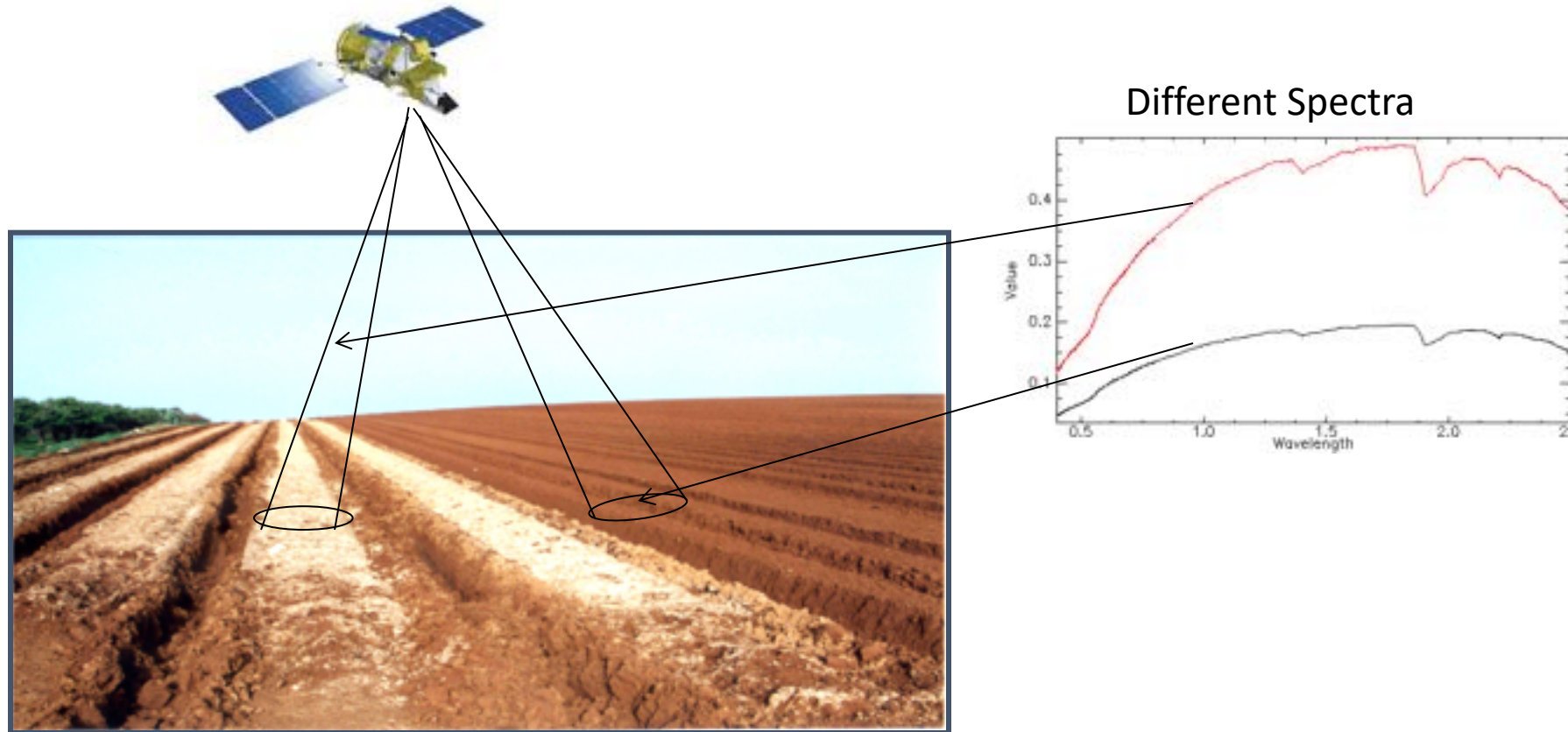


Field Measurements



Soil physical crust in the field and way to measure soil reflectance

Same soil – Physical Crust



Solution: Field SSL

De Jong S.M., E.A. Addink, D. Duijsing & L.P.H. van Beek, 2011, Physical Characterization and Spectral Response of Mediterranean Soil Surface Crusts. [CATENA](#) 86(1), 24-35

The soil in the rain simulator is disturbed (just as the soil in the SSL
AND
does not mimic the field condition

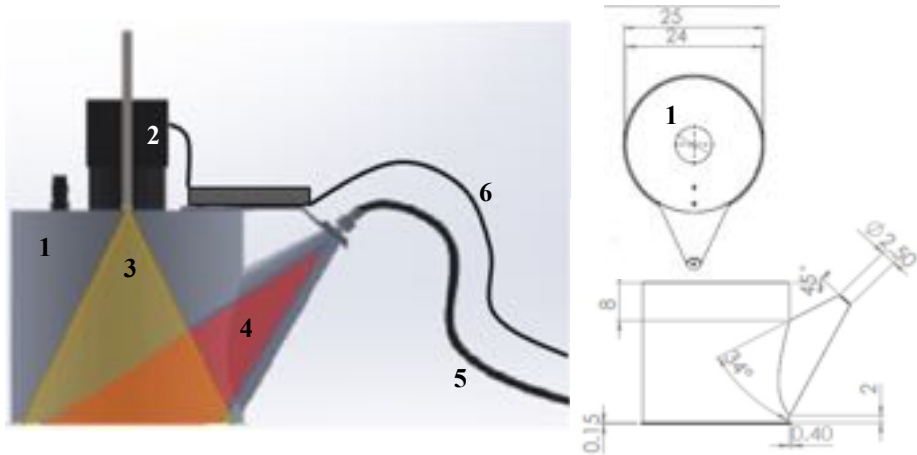
Undisturbed soil – Mimic the field condition: both spectral and infiltration rates are measured under the natural environment and at the viewpoint of the EO means

CHALLENGE: How to measure soil surface reflectance in the field and assess it directly to the surface-related properties

The SOIL field PROB **assembly** – SoilPro[®]

- The **SoilPro** is lightweight assembly and easy to operate, suitable to be connected to optic fiber of any field spectrometer.
- The **SoilPro** combines the advantages of the two common methods: acquiring a representative reflectance of large surface area, while keeping all factors
- constant.

The **SoilPro** - design and operation



The **SoilPro** set up

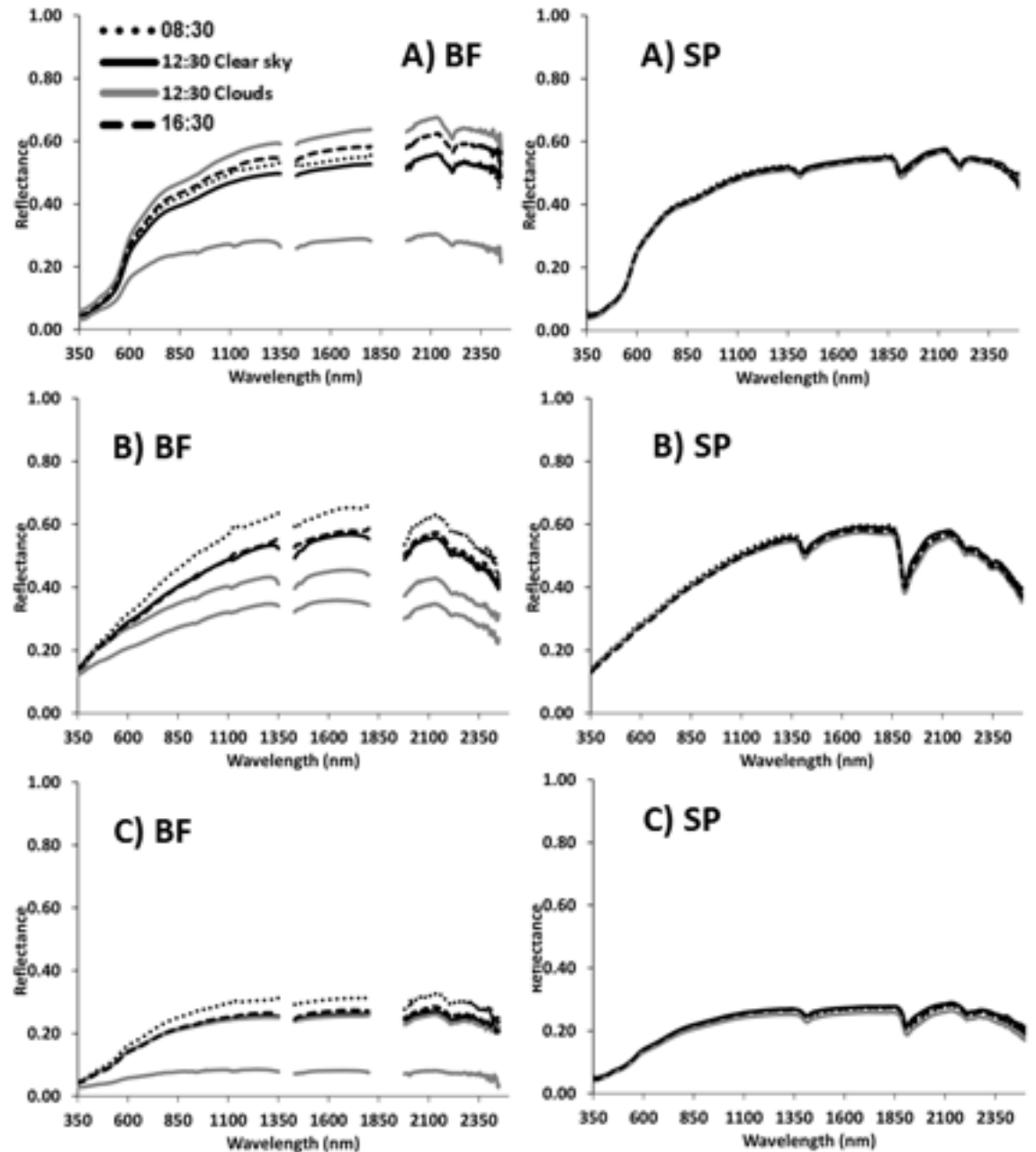


- 1) SoilPro, 2) portable battery,
3) ASD[®] fieldSpec

The **SoilPro** in the field



Quality Performance SoilPro (SP) VS bare fiber (BF)



WIR is defined as the length units per unit time of water entering into the soil. (Kirkham, 2014)

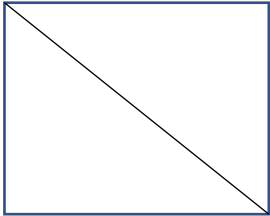
Using Water Infiltration Rate (WIR) by the SoilPRO®

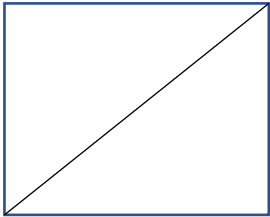
- ▶ **WIR** is a very important hydrological parameter, which is strongly dependent on soil surface conditions.
- ▶ **WIR** is an excellent soil property to investigate the gap between lab and field spectral observations

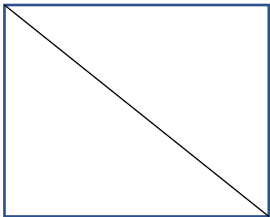


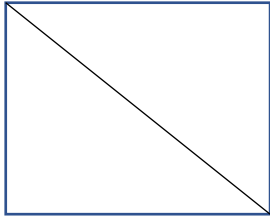
WIR is defined as the length units per unit time of water entering into the soil. (Kirkham, 2014)

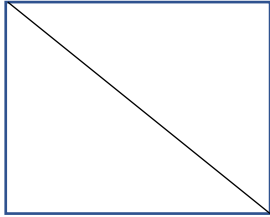
Why WIR?

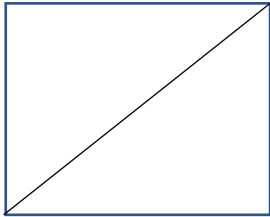
WIR  Agassi et al., 1985 and 1994.
Energy Drops

WIR  Lado et al., 2004.
OM

WIR  Capriel et al., 1997.
OM (Aliphatic Bonds)

WIR  Ben Hur & Letey 1989.
Clay

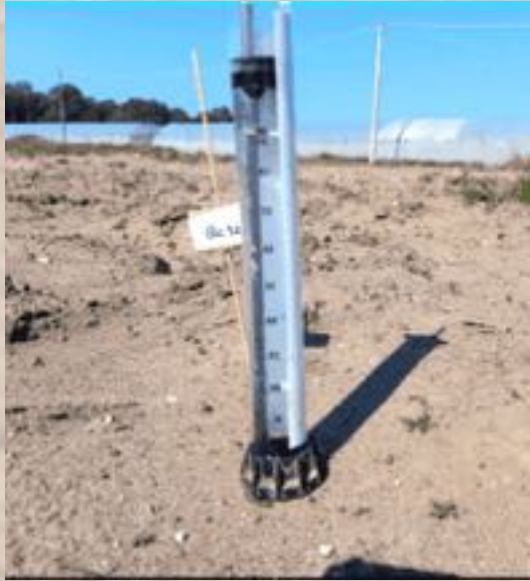
WIR (Seal & Erosion)  Stern 1991.
Smectite

WIR (Seal & Erosion)  Stern 1991.
Illite & Kaolinite



Field Spectral Measurements using ASD connected to SoilPRO.





The Mini-disk Infiltrometer



The experiments

Data Acquisition

► This dataset contain samples of 6 different fields along the Mediterranean Basin:

- i) Kibbutz Sde Yoav, Israel (30 Samples)
- ii) Afeka, Tel Aviv, Israel (18 Samples)
- iii) Alento, Italy (21 Samples)
- iv) Aminteo, Greece (45 Samples of 3 different fields)
- v) Southern Israel (110 samples)



Tel Aviv, Israel

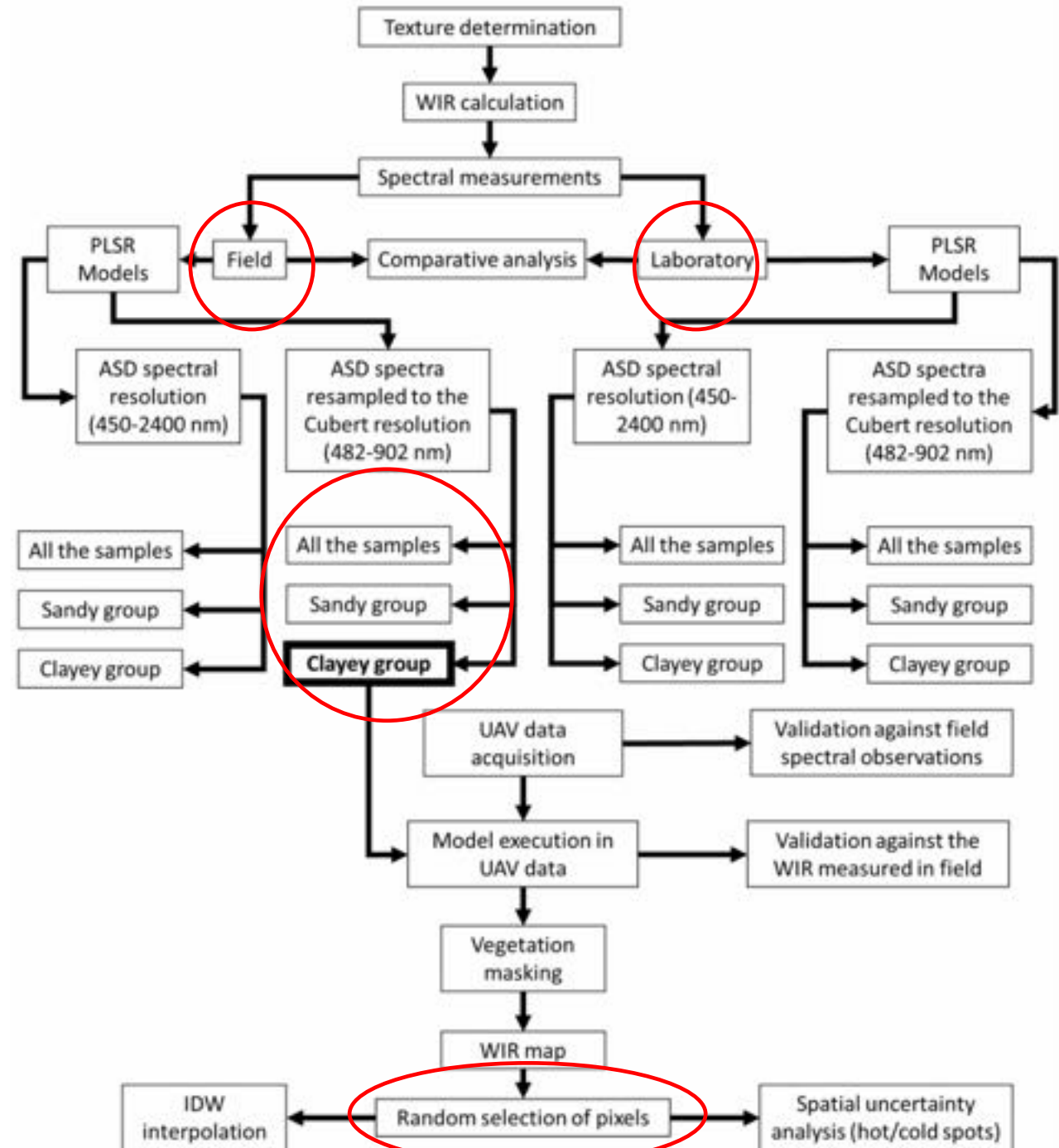


Alento, Italy



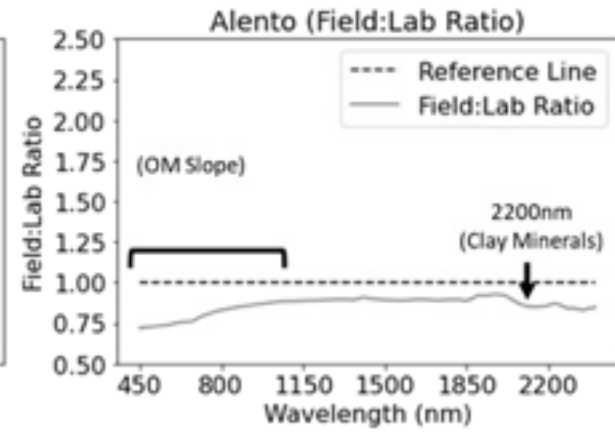
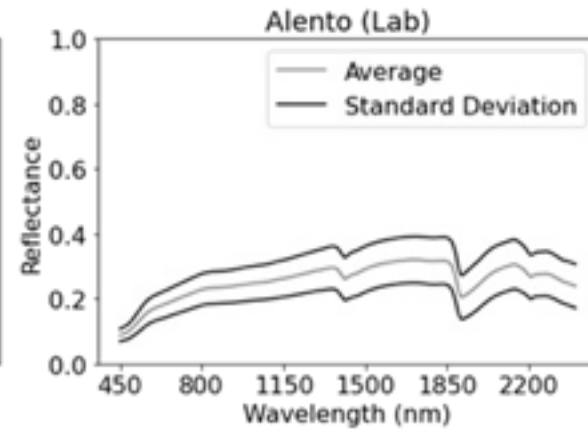
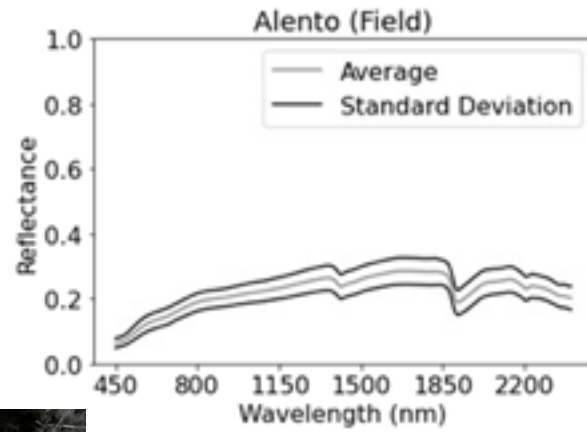
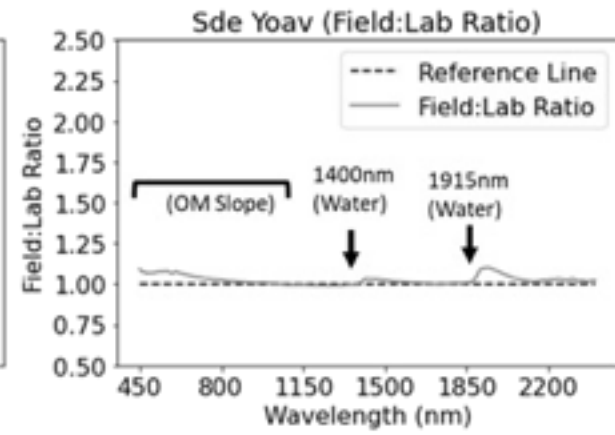
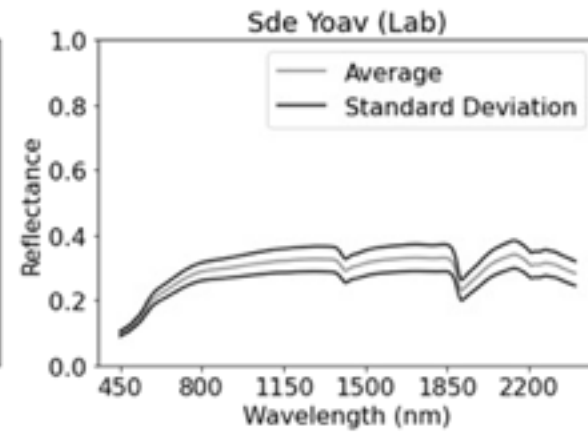
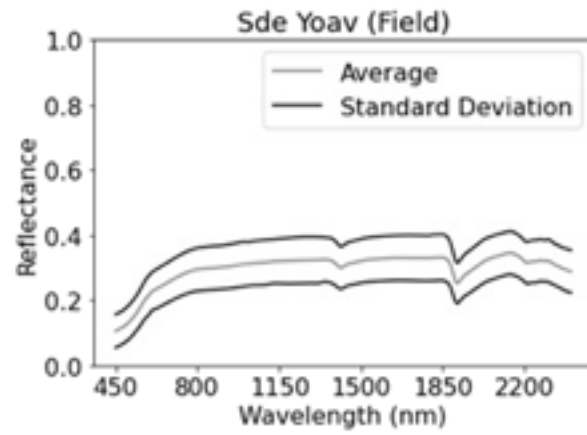
Sde Yoav, Israel

Flowchart



The Clayey Group

Same applies to the Sandy Group



Undisturbed

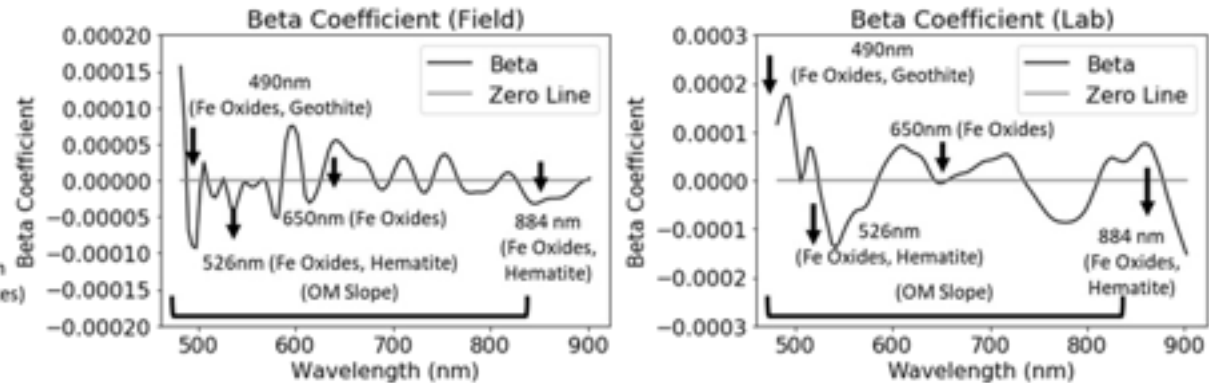
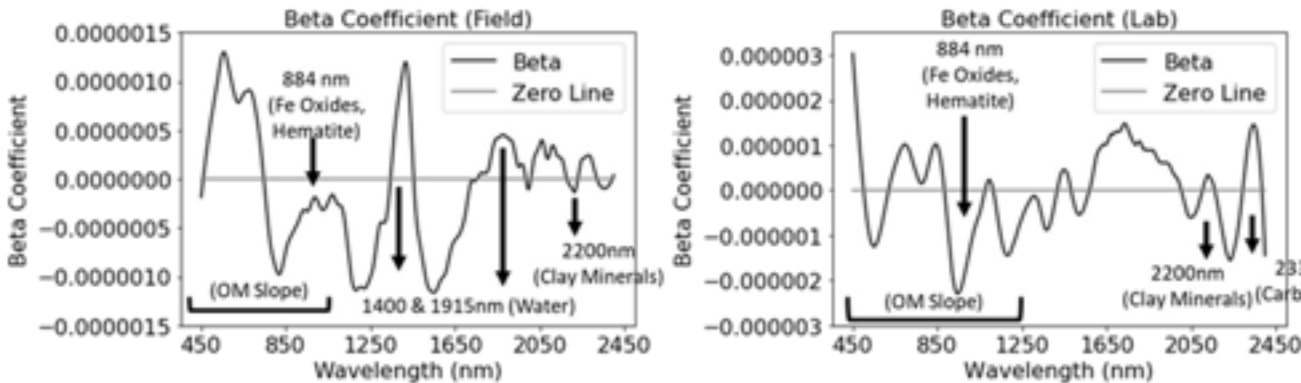
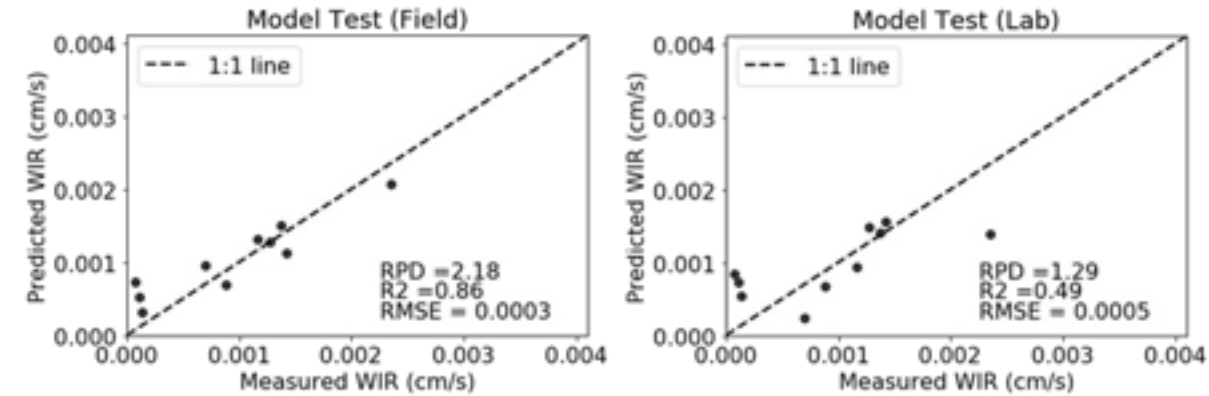
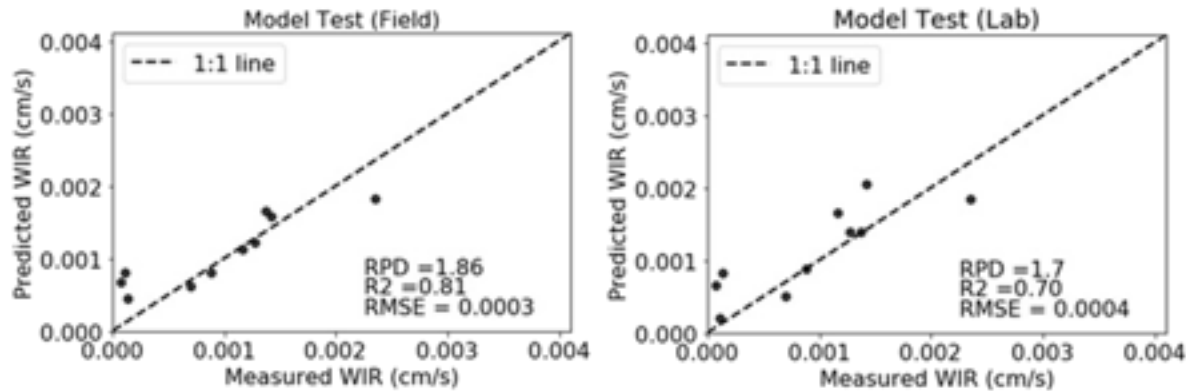
Disturbed



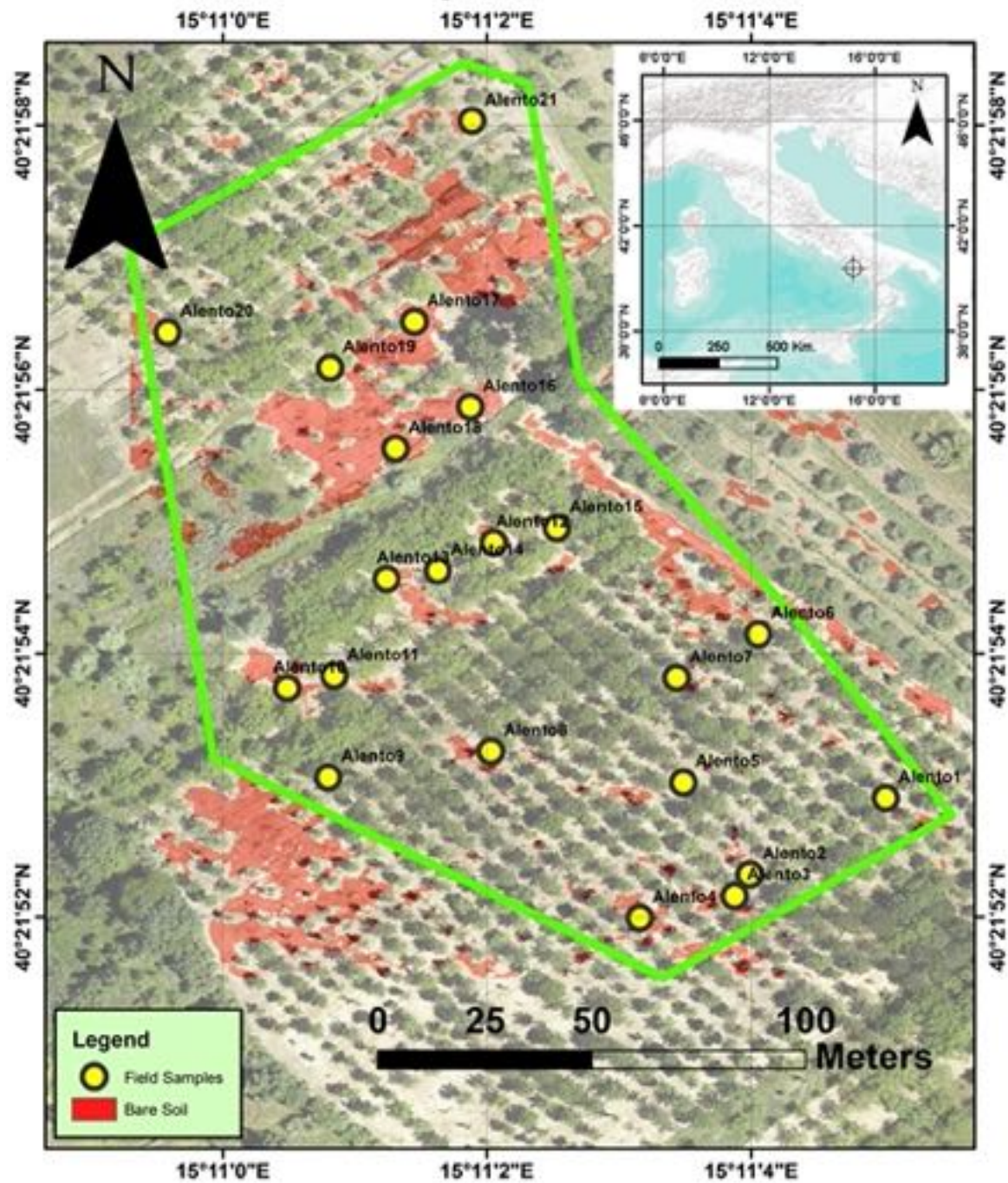
The Clayey Soils

ASD SPECTRAL RESOLUTION (VIS-NIR-SWIR)

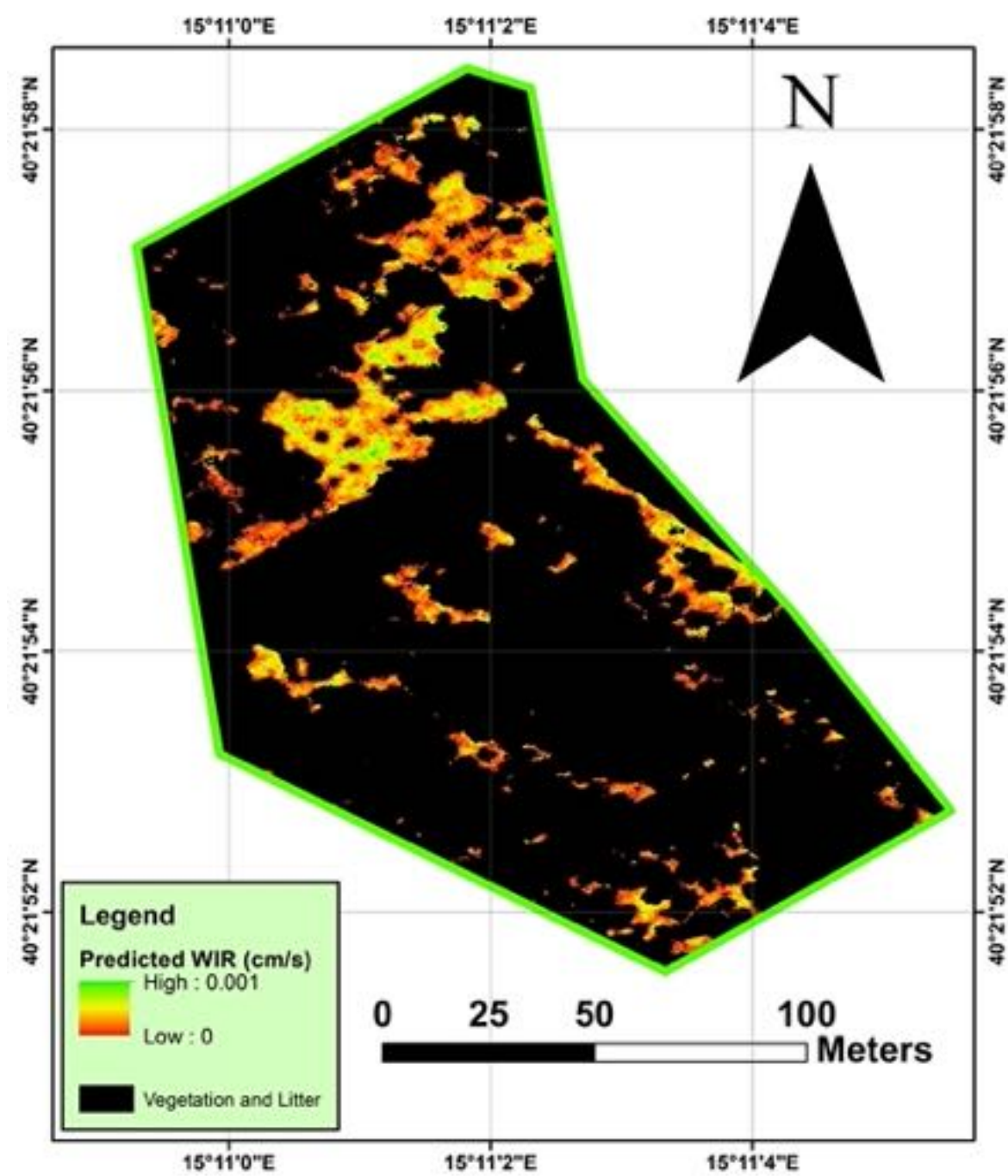
CUBERT UHD-185 SPECTRAL RESOLUTION (VIS-NIR)



Field samples in Alento



Predicted WIR





SPECIFICATIONS

Wavelength Range
350 - 1000 nm

Number of Bands
164

FWHM
Constant 10 nm

Max Resolution
410 x 410 pixel

Weight
350 g

Dimensions
60 x 60 x 57 mm

Technology
Light Field

Sensor(s)
20 MP

Spectral Sampling
4 nm

Wavelength Error
< 4 nm

Total Spectra / Image
168 000

Total Data Points (Data Points / Cube)
27 million

Data Depths
12 Bit

Readout
Global shutter

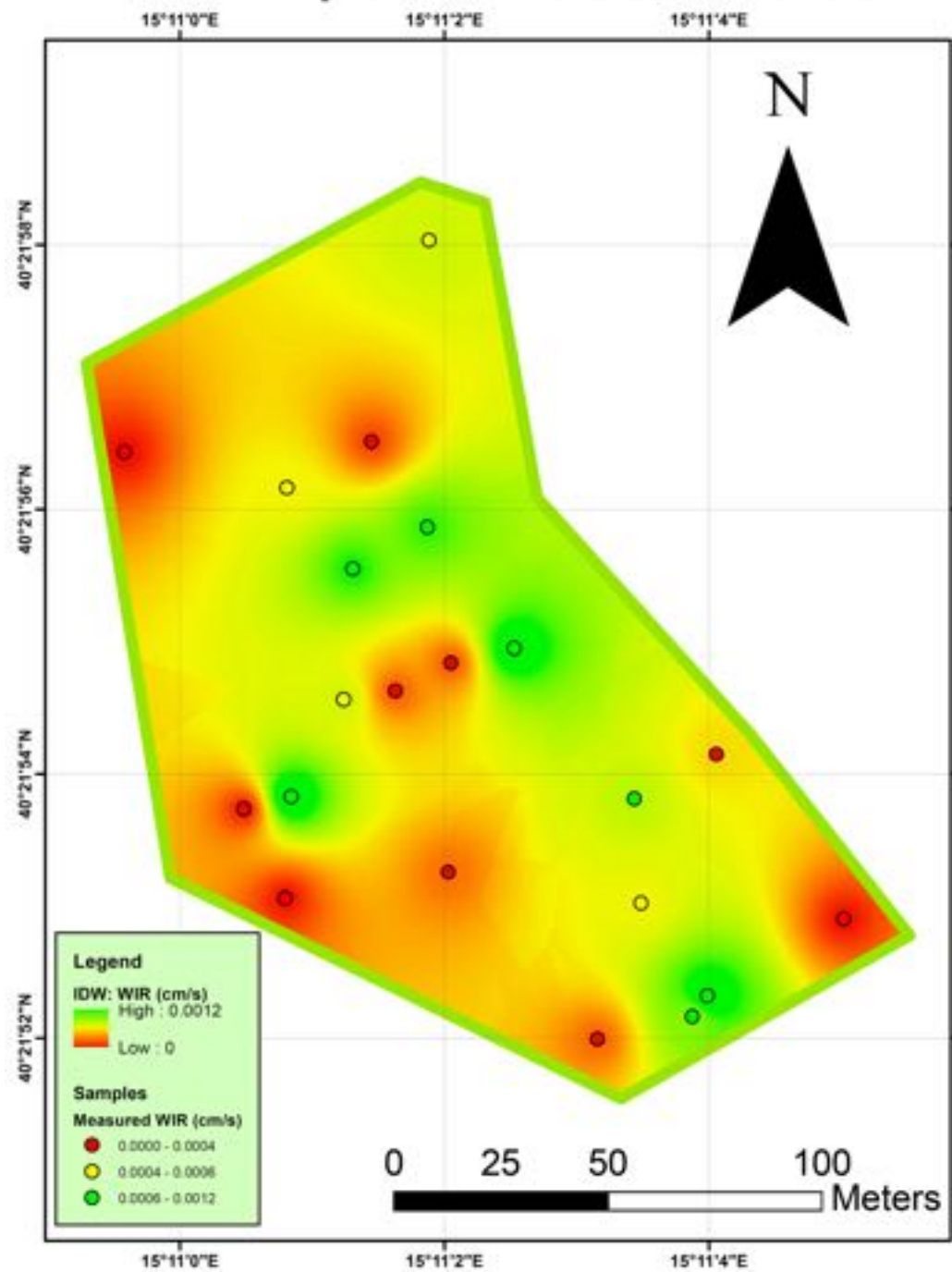
Max Frame Rate
8 Hz

Integration Time
0.1 - 1000 ms

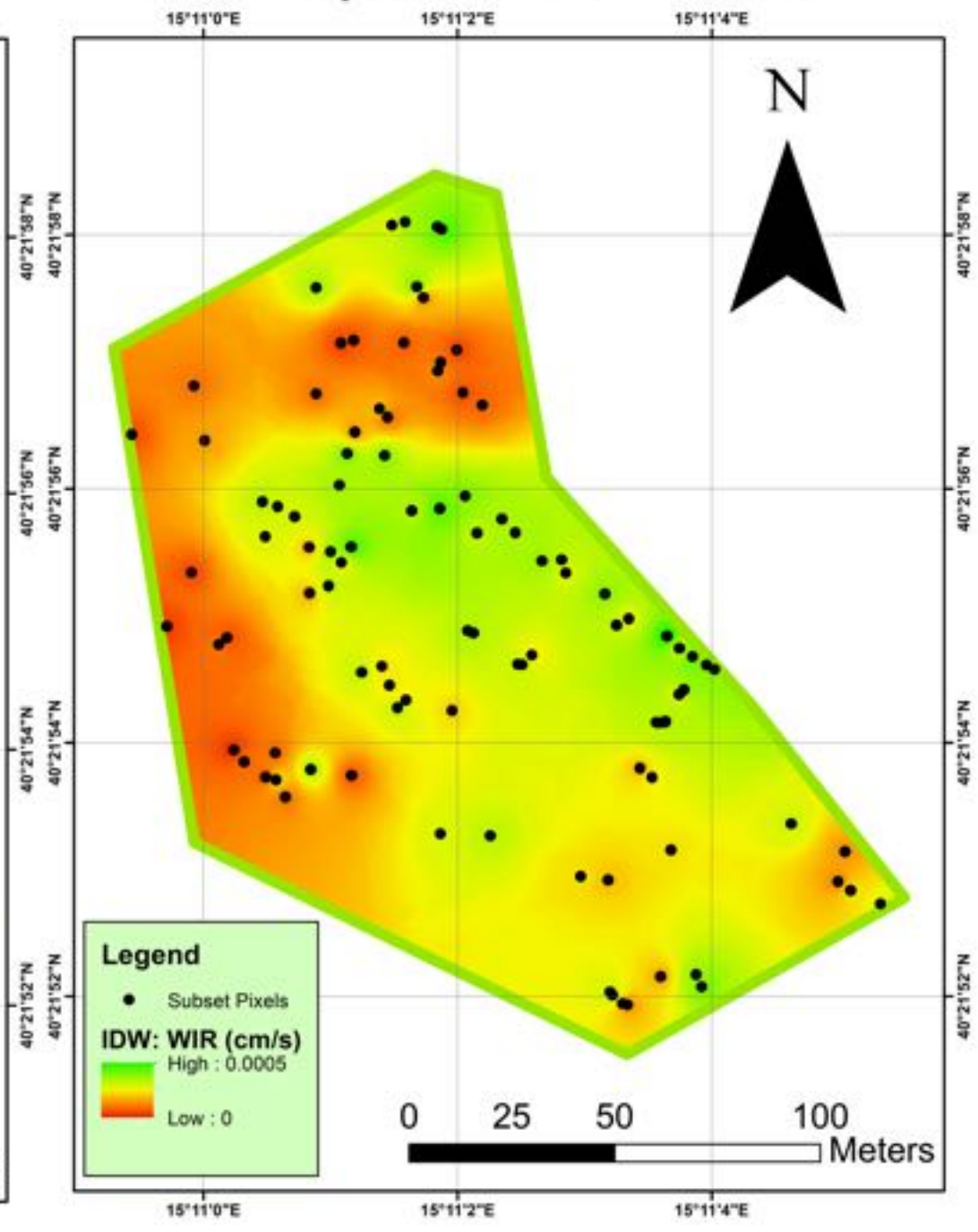
Field of View (FOV)
35°

Power Consumption
8 W

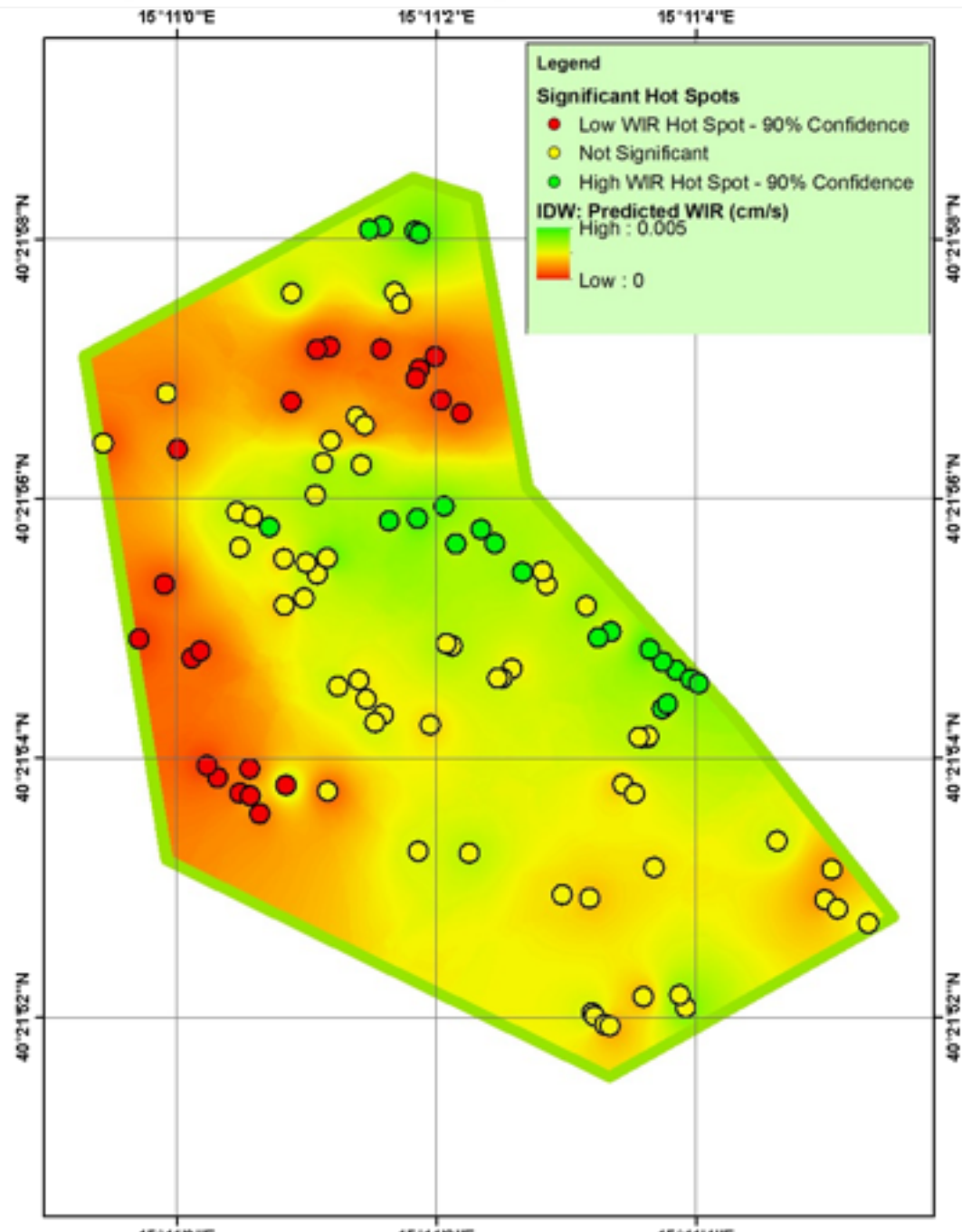
IDW Interpolation: Measured WIR



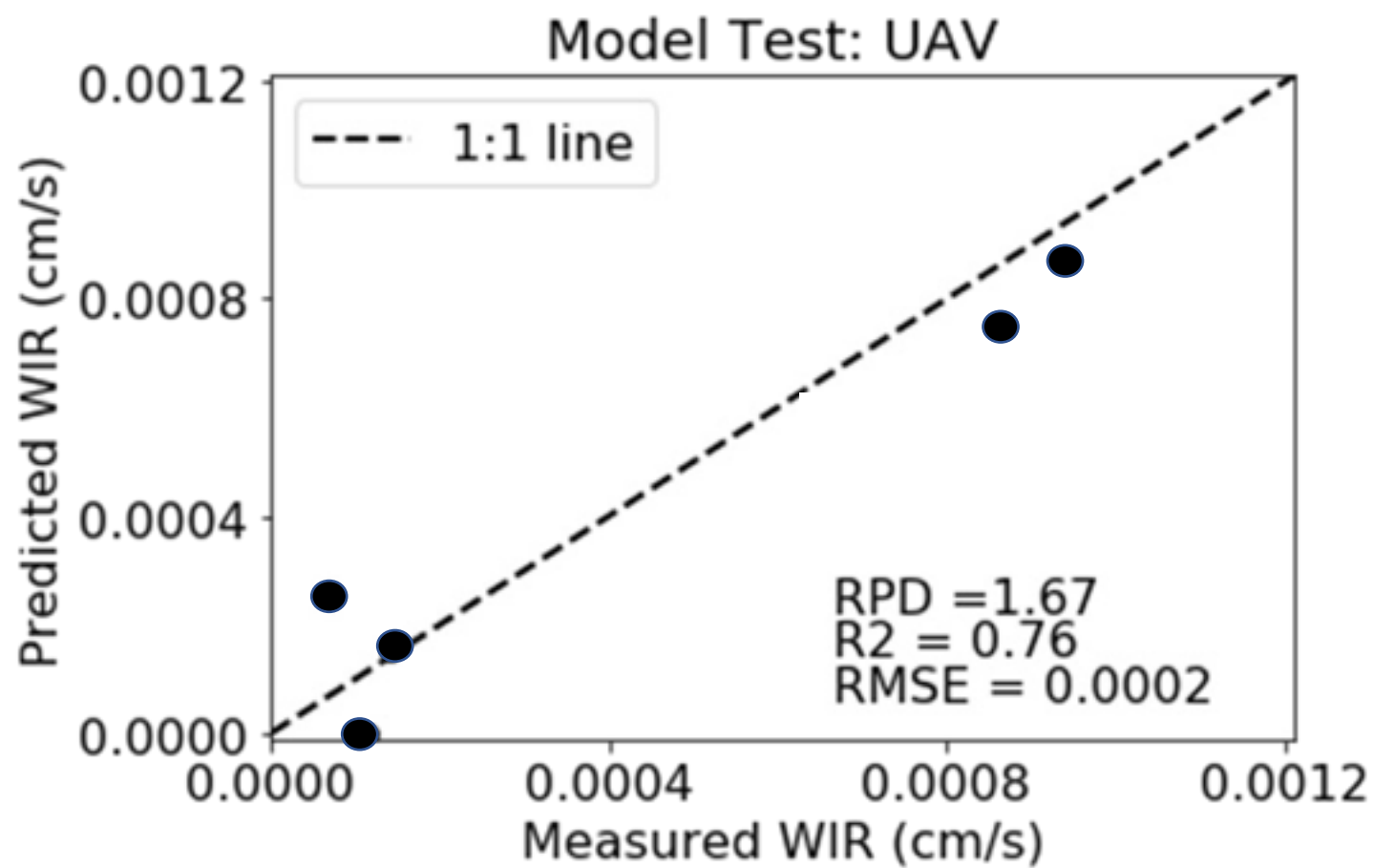
IDW Interpolation: Predicted WIR



Spatial Uncertainty: Predicted WIR



Validation



Article

Mapping Water Infiltration Rate Using Ground and UAV Hyperspectral Data: A Case Study of Alento, Italy

Nicolas Francos ^{1,*}, Nunzio Romano ², Paolo Nasta ², Yijian Zeng ³, Brigitta Szabó ⁴, Salvatore Manfreda ⁵, Giuseppe Cirraolo ⁶, János Mészáros ⁴, Ruodan Zhuang ⁷, Bob Su ³ and Eyal Ben-Dor ¹

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 - ³ Faculty of Geo-Information Science and Earth Observation, University of Twente, Hengelosestraat 99, 7514 AE Enschede, The Netherlands; y.zeng@utwente.nl (Y.Z.); z.su@utwente.nl (B.S.)
 - ⁴ Centre for Agricultural Research, Institute for Soil Sciences, 1022 Budapest, Hungary; toth.brigitta@tkk.hu (B.S.); meszaros.janos@rissac.hu (J.M.)
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 - ⁷ Department of European and Mediterranean Cultures, Architecture, Environment and Cultural Heritage, University of Basilicata, 75100 Matera, MT, Italy; ruodan.zhuang@unibas.it
- * Correspondence: nicolasf@mail.tau.ac.il



Citation: Francos, N.; Romano, N.; Nasta, P.; Zeng, Y.; Szabó, B.; Manfreda, S.; Cirraolo, G.; Mészáros, J.; Zhuang, R.; Su, B.; et al. Mapping Water Infiltration Rate Using Ground and UAV Hyperspectral Data: A Case Study of Alento, Italy. *Remote Sens.* **2021**, *13*, 2006. <https://doi.org/10.3390/rs13132006>

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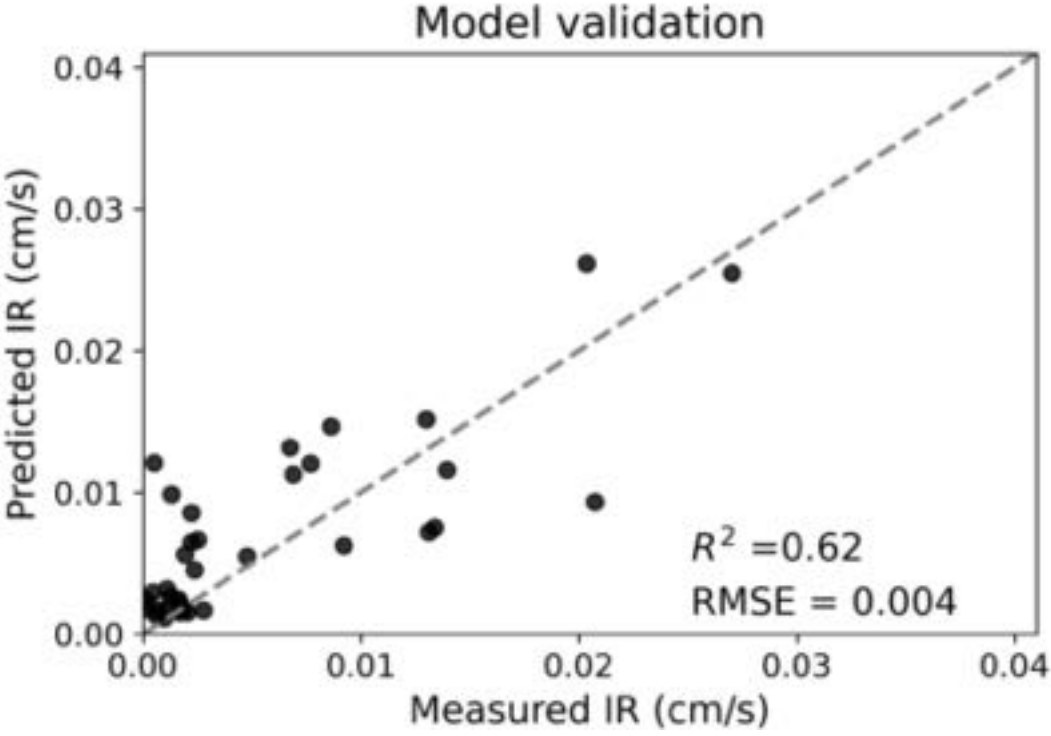
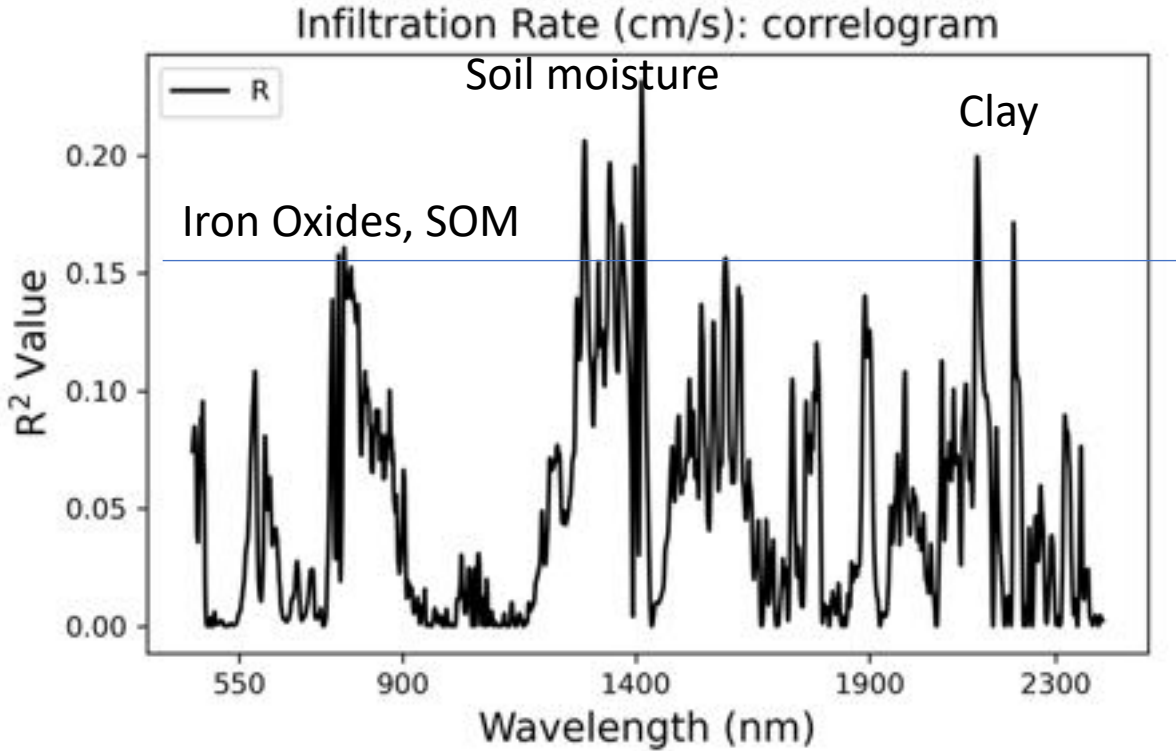
Abstract: Water infiltration rate (WIR) into the soil profile was investigated through a comprehensive study harnessing spectral information of the soil surface. As soil spectroscopy provides invaluable information on soil attributes, and as WIR is a soil surface-dependent property, field spectroscopy may model WIR better than traditional laboratory spectral measurements. This is because sampling for the latter disrupts the soil-surface status. A field soil spectral library (FSSL), consisting of 114 samples with different textures from six different sites over the Mediterranean basin, combined with traditional laboratory spectral measurements, was created. Next, partial least squares regression analysis was conducted on the spectral and WIR data in different soil texture groups, showing better performance of the field spectral observations compared to traditional laboratory spectroscopy. Moreover, several quantitative spectral properties were lost due to the sampling procedure, and separating the samples according to texture gave higher accuracies. Although the visible near-infrared–shortwave infrared (VNIR–SWIR) spectral region provided better accuracy, we resampled the spectral data to the resolution of a Cubert hyperspectral sensor (VNIR). This hyperspectral sensor was then assembled on an unmanned aerial vehicle (UAV) to apply one selected spectral-based model to the UAV data and map the WIR in a semi-vegetated area within the Alento catchment, Italy. Comprehensive spectral and WIR ground-truth measurements were carried out simultaneously with the UAV-Cubert sensor flight. The results were satisfactorily validated on the ground using field samples, followed by a spatial uncertainty analysis, concluding that the UAV with hyperspectral remote sensing can be used to map soil surface-related soil properties.

Keywords: water infiltration rate; hyperspectral remote sensing; soil spectroscopy; soil surface; unmanned aerial vehicle

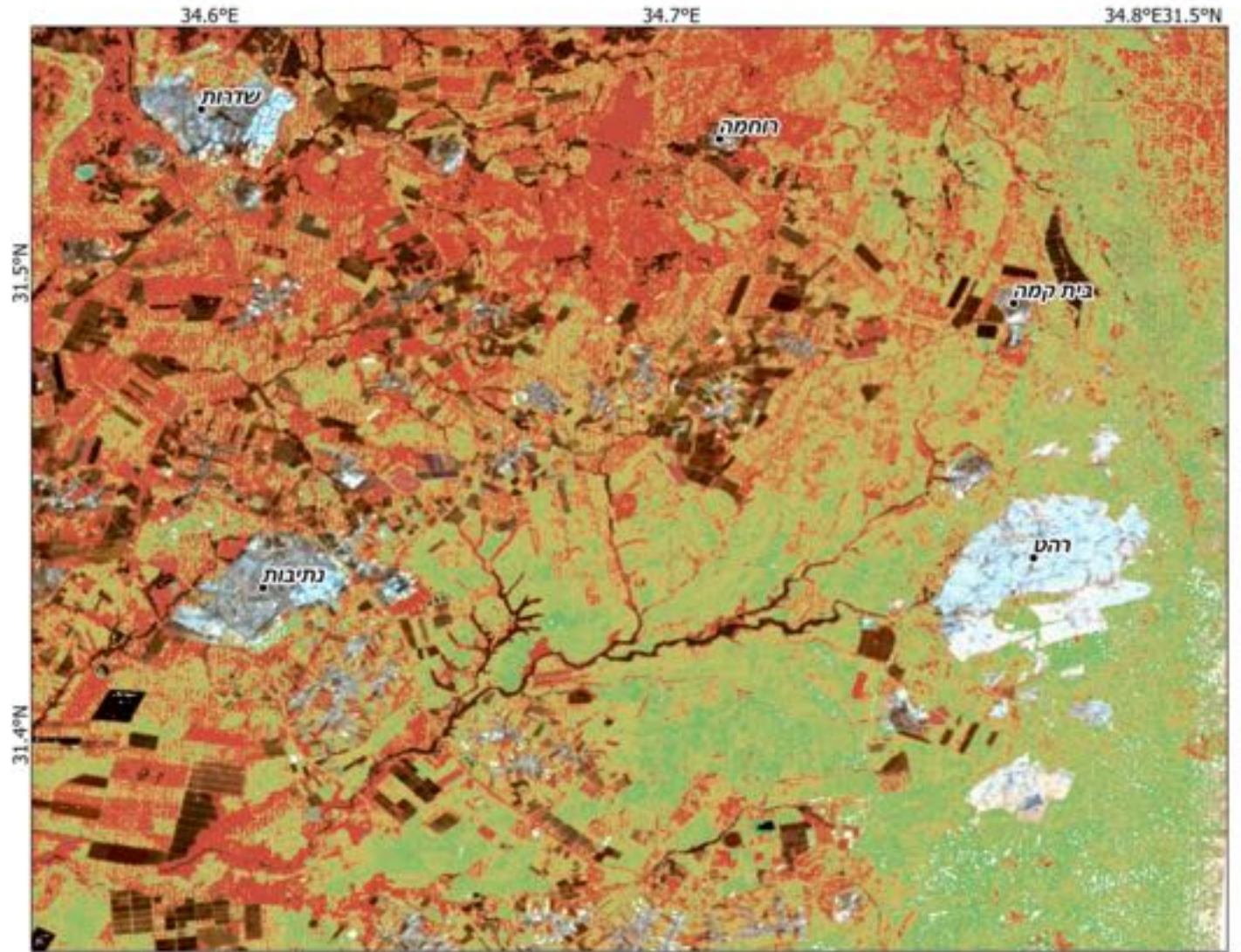


PRISMA model using Field SSL (Clayey Soils)

Important Features



Infiltration Rate Map, South Israel, July 2020



• Settlements

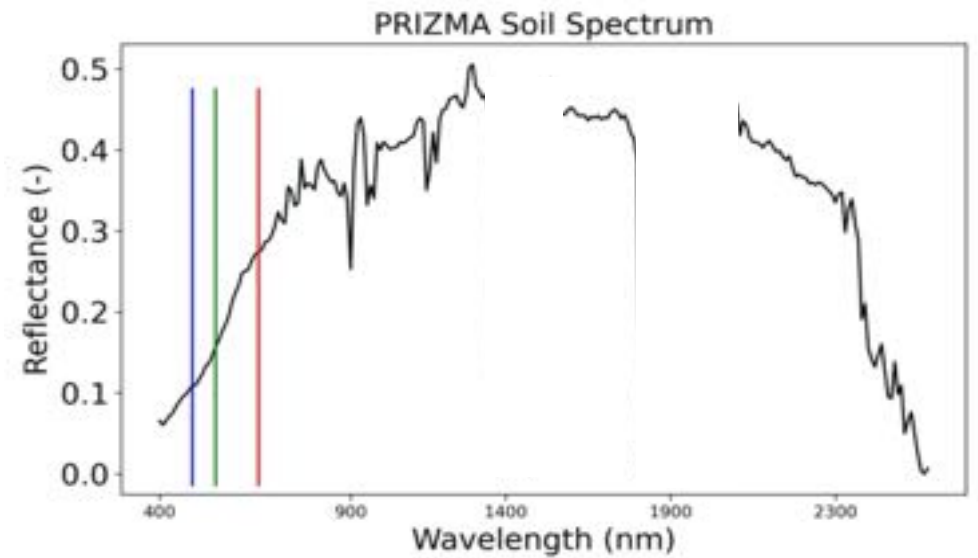
Infiltration Rate

- Low Infiltration
- Medium Infiltration
- High Infiltration

High erosion risk

Low erosion risk

Negev Southern Israel PRISMA image



Conclusions

- The soil **surface** reflectance is an important parameter to retrieve soil “seals” property (e.g. WIR).
- A method to measure soil “seal” reflectance properties in the field has been proposed using the SoilPRO®.
- The field-based models showed better results than the lab-based models
- The WIR is heavily dependent on the soil texture
- The soil attributes that control the WIR are: organic matter, texture, and iron oxides.
- Adopting the field-based model to map WIR using both UAV - HSR and Orbital-HSR is possible.

Thank you!



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