
Food and Agriculture Organization of the United Nations
GLOSOLAN Soil spectroscopy training workshops
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Online webinars
GLOBAL SOIL PARTNERSHIP
THE REMOTE SENSING LABORATORIES
TEL AVIV UNIVERSITY
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Food and Agriculture Organization of the United Nations

6th webinar on soil spectroscopy:

GLOSOLAN Soil spectroscopy training workshops

Measuring reflectance of undisturbed soil surface in the field under laboratory quality: A method to assess surface related properties

Eyal Ben Dor

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Online webinars

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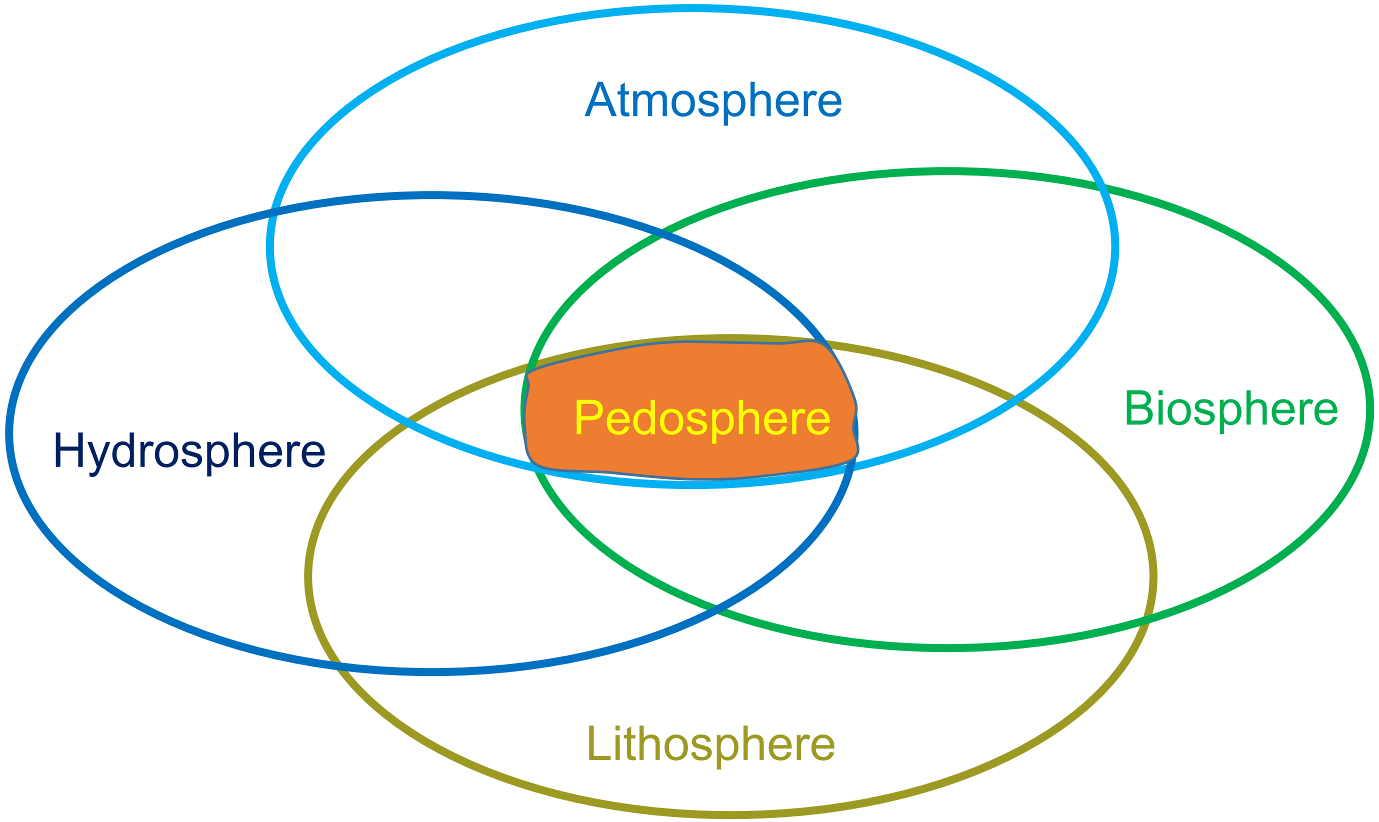
27/10/2021

GLOBAL SOIL PARTNERSHIP

Outline

- Soil and soil spectroscopy importance
- Soil Spectral Libraries and its powerful potential
- Standard and protocols for SSL
- Hyperspectral remote sensing of soil – the new era of soil mapping
- Problem to exploit SSL for hyperspectral remote sensing
- The idea for standard and protocol for undisturbed soil spectral measurements
- The SoilPRO assembly – rational and technical information
- Testing the SoilPRO relative to other methods
- Exploiting the SoilPRO to measure soil surface related properties: WIR and WR
- Water repellency (WR) exercise
- Water infiltration rate (WIR) exercises
- Israel
- Italy
- Greek
- Conclusion and future notes



CHAPTER ONE

Soil: The Forgotten Piece of the Water, Food, Energy Nexus

Jerry L. Hatfield*[,1], Thomas J. Sauer*, Richard M. Cruse[†]
*USDA-ARS, National Laboratory for Agriculture and the Environment, Ames, IA, United States
[†]Iowa State University, Ames, IA, United States
[1]Corresponding author: e-mail address: jerry.hatfield@ars.usda.gov

"Soil is an essential component in the environment and is vital for food security. It provides ecosystem services, filters water, supplies nutrients to plants, provides us with food, stores carbon, regulates greenhouse gases emissions and it affects our climate"

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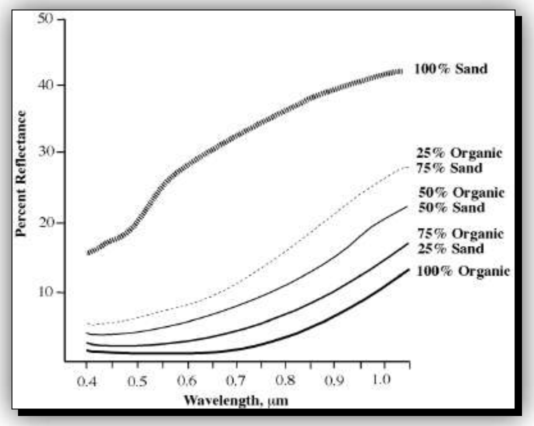
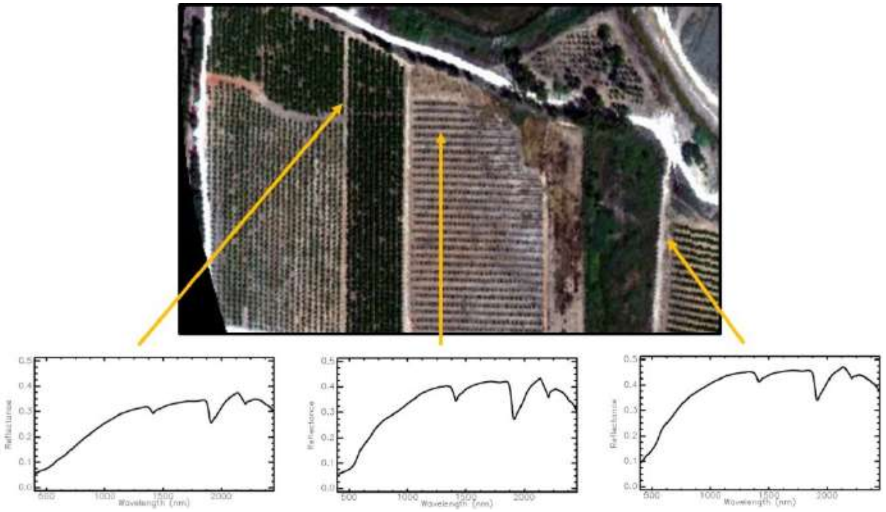
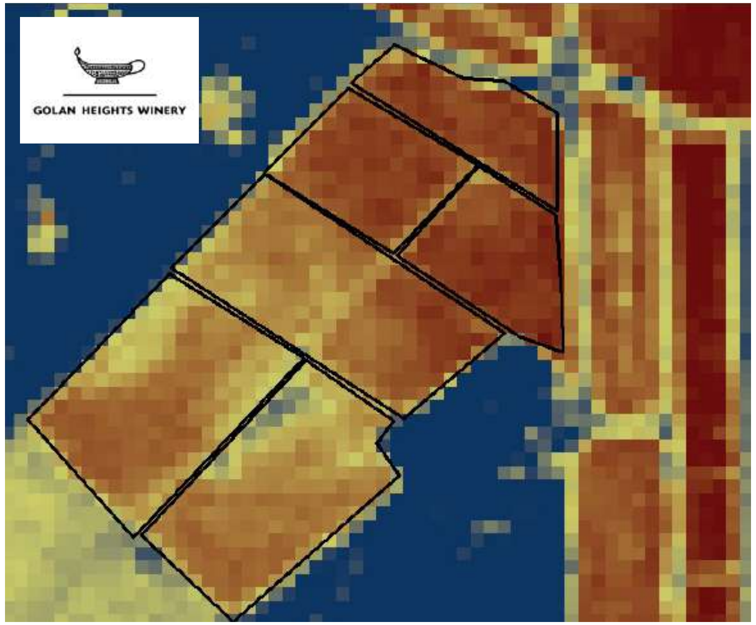
Variance of exposed soil – very important for the quality of wine







Soil : not only field quantity but also food quality

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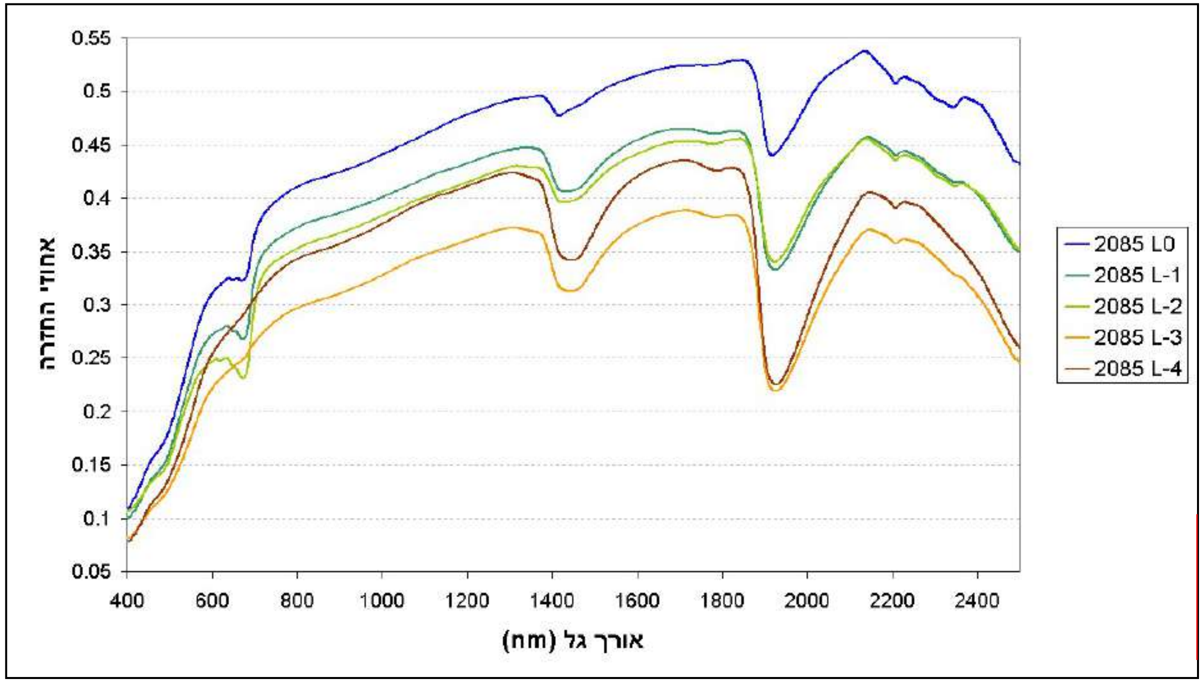
- Soil Spectroscopy refers to the reflectance/emittance part of the electromagnetic radiation that interacts with the soil matter across the VIS-NIR-SWIR-TIR spectral region range (0.35-14μm).



Point – one pixel

Why Soils Are so Important?

Soil, like air and water, is **critical to life on earth**. Soils are incredibly resilient, but they are also fragile and can easily be damaged or lost. Improved management of our planet's limited soil resource is essential to ensure a sustainable future and guarantee healthy and productive soils for **food security,** as well as to support many essential ecosystem services that **enable life on earth**


theguardian

Third of Earth's soil is acutely degraded due to agriculture

Fertile soil is being lost at rate of 24bn tonnes a year through intensive farming as demand for food increases, says UN-backed study

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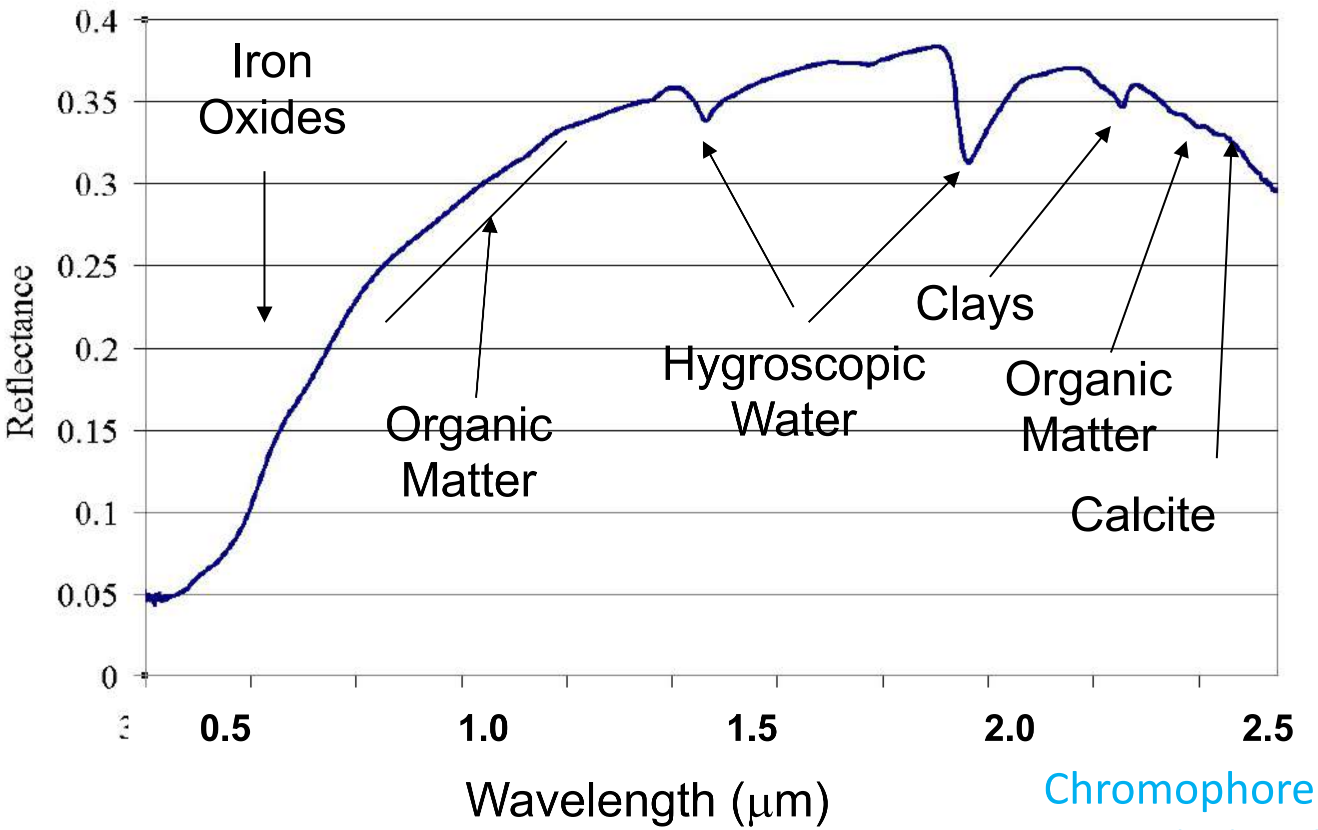
A typical Soil Spectrum

An effective way to simplest the complexity of the soil system



Chromophore = An attribute that interact with the electromagnetic radiation

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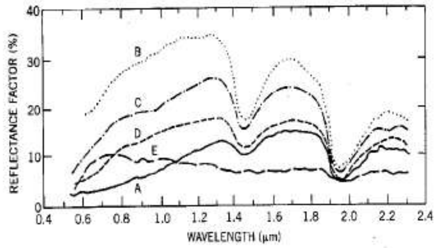
Soil is a Complex System with 5 Formation Factors

Complex

1) Parent Material (P)
2) Climate (C)
3) Topography (T)
4) Biotic Components (O)
5) Time (t)

Soil Spectroscopy

Simple



$$Soil = f(P,C,T,O,t)$$

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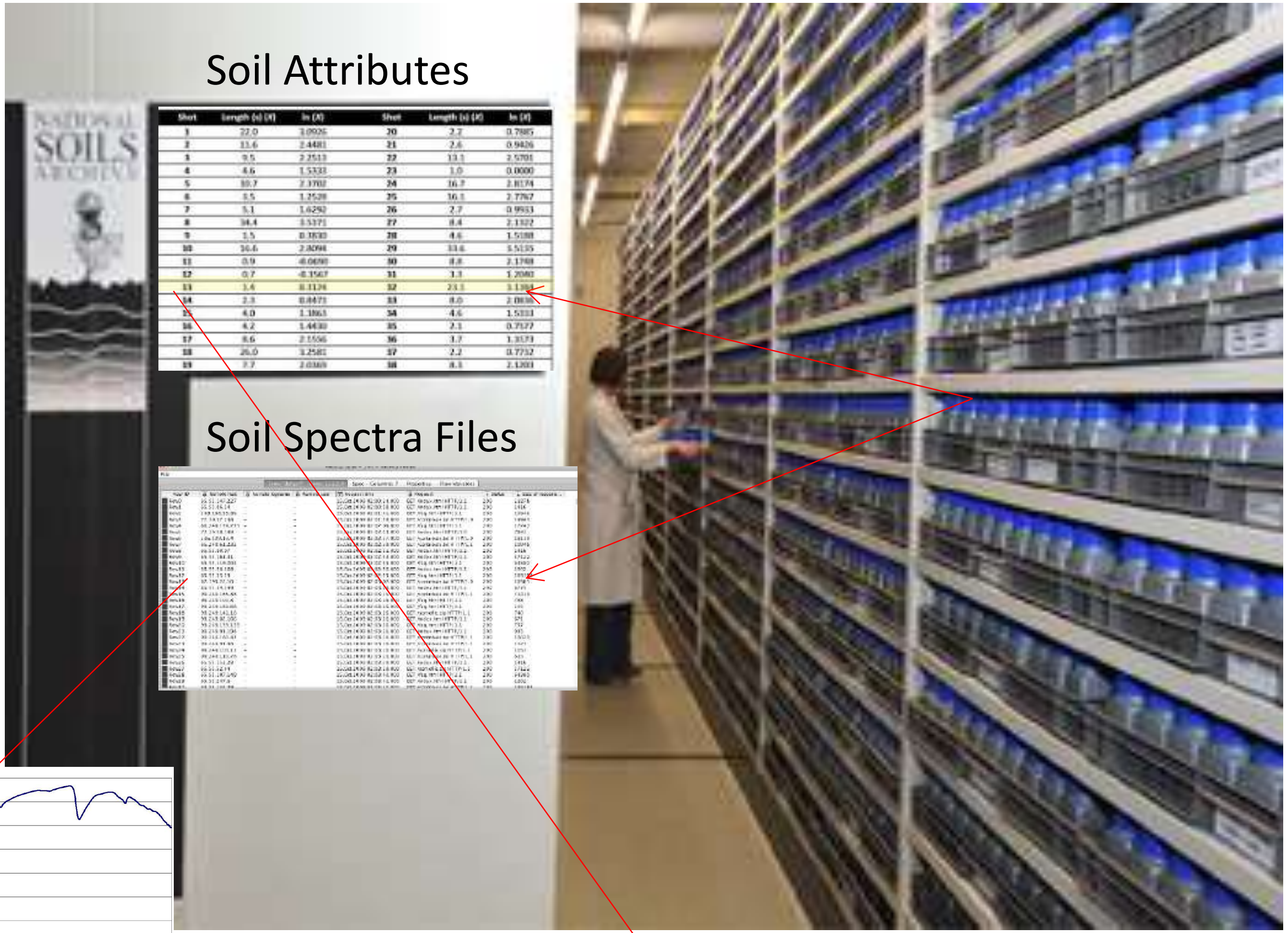
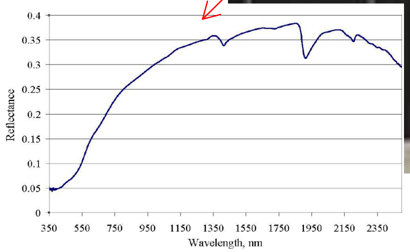
Soil Spectral library

Importance and Utilization for Food Security

Soil Spectral Library : The Practical Structure

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





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

Quantitative Soil Spectroscopy

Examples of some of the soil attributes that can be extracted from spectral library (1)

Soil attribute	Spectral region	Spectral range (nm)	Multivariate method[a]	n_{calib} | n_{valid}[b]	RMSE	R^2	Authors
Mg; g/kg	VIS–NIR	400–2500	modified PLSR	315		0.90	Cozzolino and Moron (2003)
Mg (exch.); cmol(+)/kg	VIS–NIR	350–2500	MARS	493|246	11	0.81	Shepherd and Walsh (2002)
Mg (exch.); mg/kg	VIS–NIR	400–2498	PCR (9)	30|119	12.8	0.68	Chang et al. (2001)
Mg; mmol(+)/kg	UV–VIS–NIR	250–2500	PCR	121|40		0.63	Islam et al. (2003)
Mn (DTPA); mg/kg	MIR	2500–25,000	PLSR	183		0.57	Janik et al. (1998)
Mn (exch.); cmol/kg	MIR	2500–25,000	PLSR	183		0.66	Janik et al. (1998)
Mn (Mehlich III); mg/kg	VIS–NIR	400–2498	PCR (12)	30|119	56.4	0.70	Chang et al. (2001)
OC; %	MIR	2500–20,000	PLSR			0.92	Janik and Skjemstad (1995)
OC; %	MIR	2500–25,000	PLSR	188		0.93	Janik et al. (1998)
OC; g/kg	MIR	2500–25,000	PLSR (17)	177|60		0.94	McCarty et al. (2002)
OC; (acidified soil) g/kg	MIR	2500–25,000	PLSR (19)	177|60		0.97	McCarty et al. (2002)
OC; %	NIR	1100–2500	MLR (1744, 1870, 2052)	72|48		0.93	Dalal and Henry (1986)
OC; %	NIR	1100–2500	RBFN	140|60	0.32	0.96	Fidêncio et al. (2002)
OC; %	NIR	700–2500	PCR	121|40		0.68	Islam et al. (2003)
OC; g/kg	NIR	1100–2498	PLSR (18)	177|60		0.82	McCarty et al. (2002)
OC; mg/kg	NIR	1100–2300	PLSR (8)	180 x-val		0.94	Reeves and McCarty (2001)
OC (acidified soil); g/kg	NIR	1100–2498	PLSR (17)	177|60		0.80	McCarty et al. (2002)
OC; g/kg	VIS–NIR	400–2498	PLSR (6)	76|32	0.62	0.89	Chang and Laird (2002)
OC; g/kg	VIS–NIR	350–2500	MARS	449|225	0.31	0.80	Shepherd and Walsh (2002)
OC; dag/kg	VIS–NIR	350–1050	PLSR (5)	43|25	0.36		Viscarra Rossel et al. (2003)
OC; %	UV–VIS–NIR	250–2500	PCR	121|40		0.76	Islam et al. (2003)
OM; %	MIR	2500–25,000	PLSR (4)	31 x-val	0.72	0.98	Masserschmidt et al. (1999)
OM; %	NIR	1000–2500	MRA (30 bands)	39|52		0.55	Ben–Dor and Banin (1995)
OM; %	VIS–NIR	400–1100	NN	41		0.86	Daniel et al. (2003)
OM; %	VIS–NIR	400–2400	SMLR (606, 1311, 1238)	15|10		0.65	Shibusawa et al. (2001)
P (avail.); mg/kg	MIR	2500–25,000	PLSR	186		0.07	Janik et al. (1998)
P (avail.); mg/kg	VIS–NIR	400–1100	NN	41		0.81	Daniel et al. (2003)
pH	MIR	2500–20,000	PLSR			0.72	Janik and Skjemstad (1995)
pH	NIR	1100–2300	PLSR (8)	180 x-val		0.74	Reeves and McCarty (2001)
pH	NIR	1100–2498	PLSR (11)	120|59		0.73	Reeves et al. (1999)
pH	VIS–NIR	350–2500	MARS	505|253	0.43	0.70	Shepherd and Walsh (2002)
pH_{Ca}	MIR	2500–25,000	PLSR	183		0.67	Janik et al. (1998)

R.A. Viscarra Rossel et al. / Geoderma 131 (2006) 59–75

The "flood"
(2000 and on)

Quantitative Soil Spectroscopy:

Examples of some of the soil attributes that can be extracted from spectral library (2)

Soil attribute	Spectral region	Spectral range (nm)	Multivariate method[a]	n_{calib} | n_{valid} [b]	RMSE	R^2	Authors
OC; %	MIR	2500–20,000	PLSR			0.92	Janik and Skjemstad (1995)
OC; %	MIR	2500–25,000	PLSR	188		0.93	Janik et al. (1998)
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OM; %	VIS–NIR	400–1100	NN	41		0.86	Daniel et al. (2003)
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pH	NIR	1100–2300	PLSR (8)	180 x-val		0.74	Reeves and McCarty (2001)
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pH_{Ca}	MIR	2500–25,000	PLSR	183		0.67	Janik et al. (1998)

The "flood"

R.A. Viscarra Rossel et al. / Geoderma 131 (2006) 59–75

Most studied Soil Properties

Aggregate Stability

Adsorbed Isotherm

Infiltration

Water Hydrophobicity

More to come!

Salinity

SSA
Specific Surface Area

Carbonates
$CaCO_3$

HIGF
Hygroscopic Water

CEC
Cation Exchange Capacity

OM, OC
Organic Matter, Carbon

Clay
Clay Size Fraction

The Global Soil Spectral Library GSSL (2015)

Contents lists available at ScienceDirect

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journal homepage: www.elsevier.com/locate/earscirev

A global spectral library to characterize the world's soil

R.A. Viscarra Rossel [a,*], T. Behrens [b], E. Ben-Dor [c], D.J. Brown [d], J.A.M. Demattê [e], K.D. Shepherd [f], Z. Shi [g], B. Stenberg [h], A. Stevens [i], V. Adamchuk [j], H. Aïchi [k], B.G. Barthès [l], H.M. Bartholomeus [m], A.D. Bayer [n], M. Bernoux [l], K. Böttcher [o,p], L. Brodský [q], C.W. Du [r], A. Chappell [a], Y. Fouad [s], V. Genot [t], C. Gomez [u], S. Grunwald [v], A. Gubler [w], C. Guerrero [x], C.B. Hedley [y], M. Knadel [z], H.J.M. Morrás [aa], M. Nocita [ab], L. Ramirez-Lopez [ac], P. Roudier [y], E.M. Rufasto Campos [ad], P. Sanborn [ae], V.M. Sellitto [af], K.A. Sudduth [ag], B.G. Rawlins [ah], C. Walter [s], L.A. Winowiecki [f], S.Y. Hong [ai], W. Ji [a,g,j]

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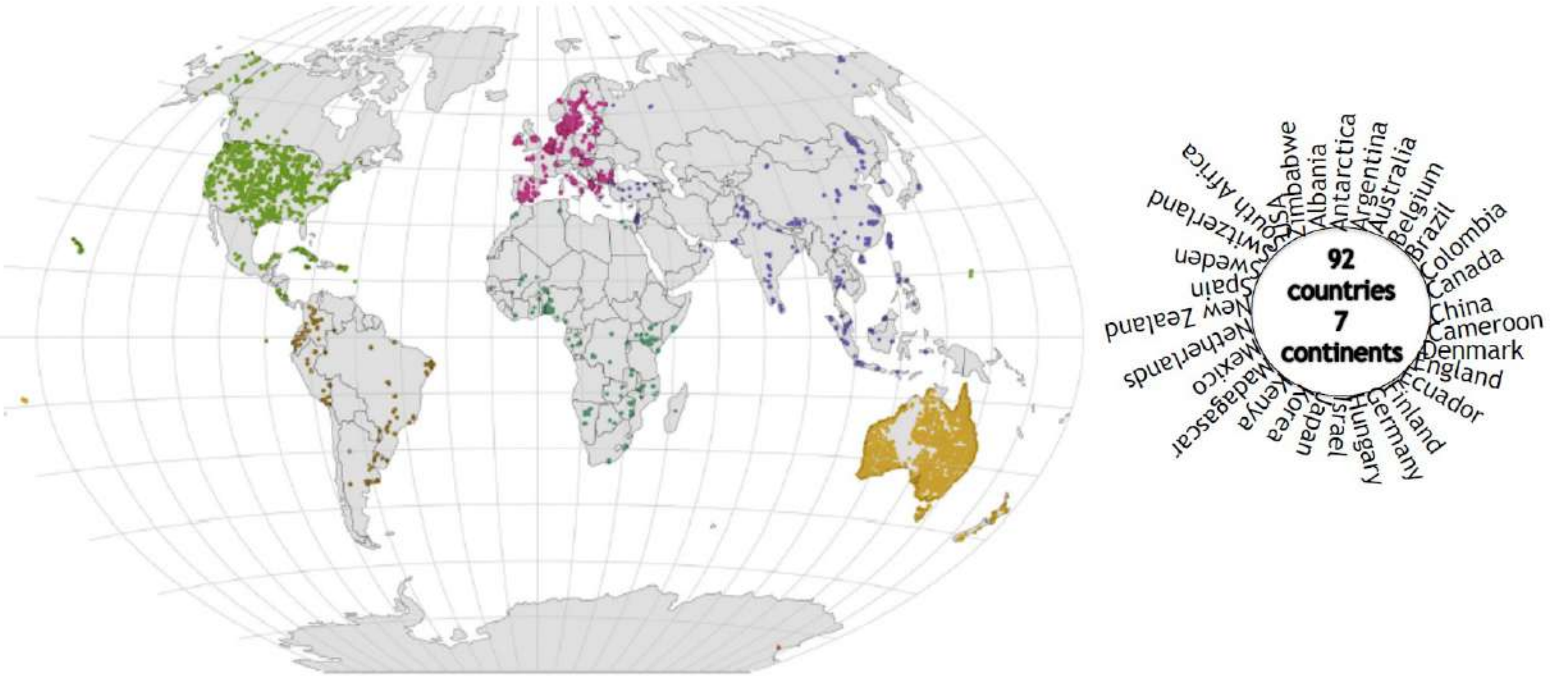
Globa Soil VNIR-SWIR Spectra

Some 20,000+ vis-NIR (350-2500 nm) spectra from 12,509 sites

45 collaborators from 35 institutions

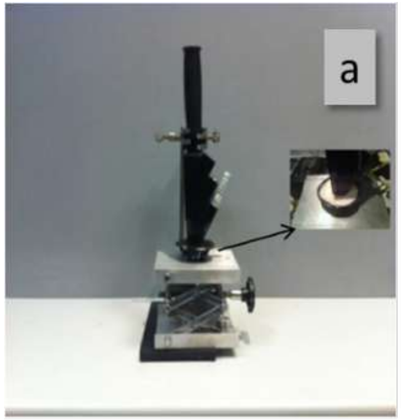


provided by Viscorra Rossel

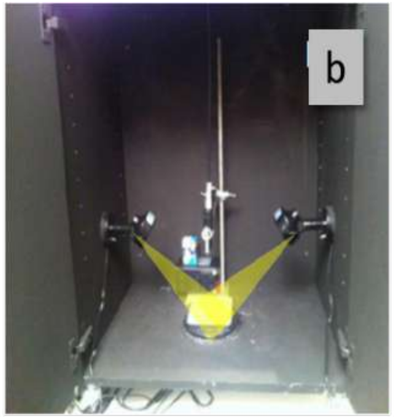
The SoilPRO assembly

Deferent laboratory spectral measurements protocols and configuration:
DIFFERENT RESULTS!

CSIRO: CP



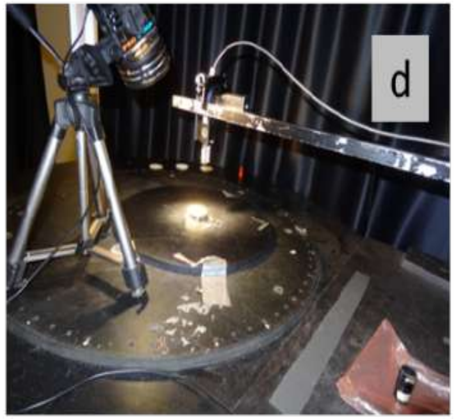
CSIRO: Dark box

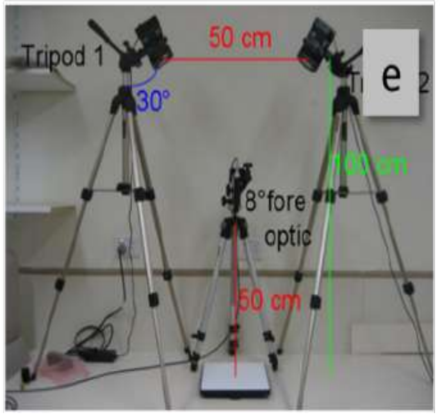


TAU RSL: CP

(Ben Dor et al., 2015b)

GFZ Potsdam:
8° for optic fiber





the Australian government's department of sustainability's protocol: dual lamps and 8° for optic fiber (Pfitzner et al., 2011).

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Protocol to generate Soil Spectral Library

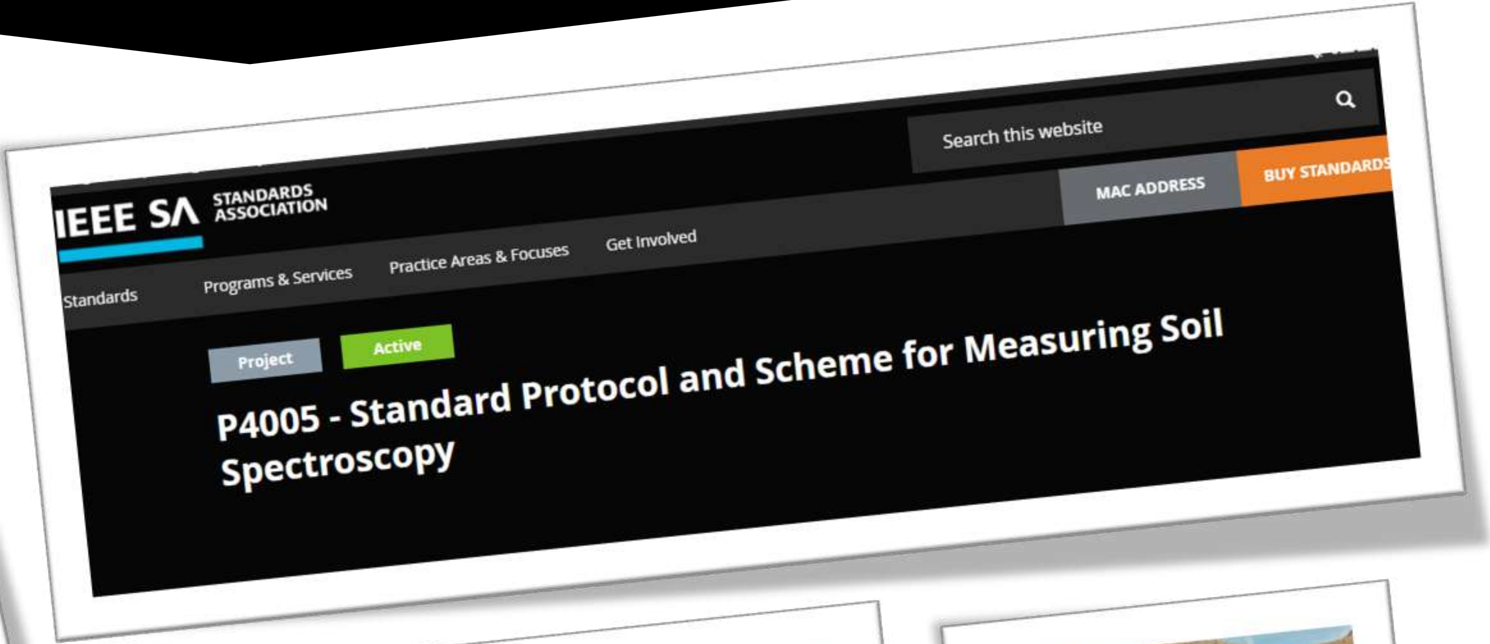


Fig. 1. Some early field spectroradiometers in use in the field (source unknown).

Definition 3

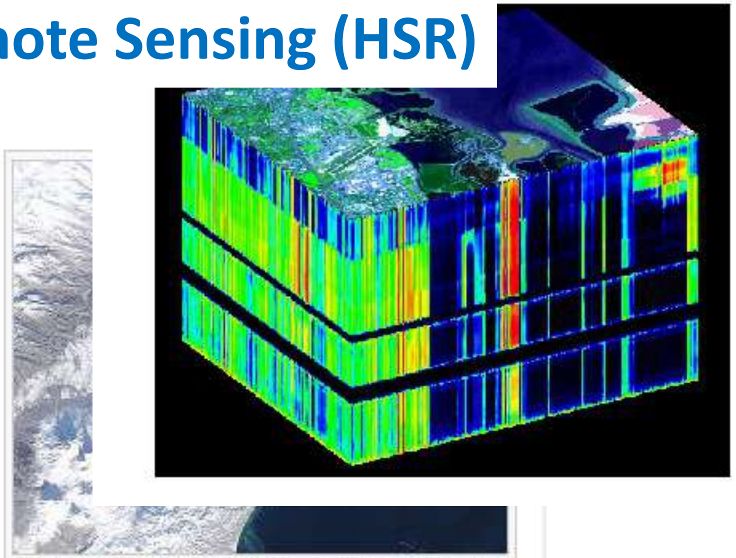
Imaging spectroscopy

Hyperspectral Remote Sensing (HSR)

From Wikipedia, the free encyclopedia

Imaging spectroscopy is the simultaneous acquisition of spatially coregistered images in many spectrally contiguous bands. To be scientifically useful, such measurement should be done using an internationally recognized system of units. The image produced by imaging spectroscopy is similar to an image produced by a digital camera, except each pixel has many bands of light intensity data instead of just three bands: red, green and blue.

Imaging spectrometer data acquisition allows the quantitative and qualitative characterization of both, the surface and the atmosphere, using geometrically coherent spectrodirectional radiometric measurements. These measurements can then be used for the unambiguous direct and indirect identification of surface materials and atmospheric trace gases, the measurement of their relative concentrations, subsequently the assignment of the proportional contribution of mixed pixel signals (e.g., the spectral unmixing problem), the derivation of their spatial distribution (mapping problem), and finally their study over time (multi-ter



Ash plumes on Kamchatka Peninsula, eastern Russia. A MODIS image.

adjusted From A. Goetz 1994

Simultaneous acquisition of images in many registered spectrally- high resolution continuous bands at selected (or all) spectral domains across the UV-VIS-NIR-SWIR–MWIR-LWIR spectral region (0.3-12μm)

HSR of soils from airborne sensors

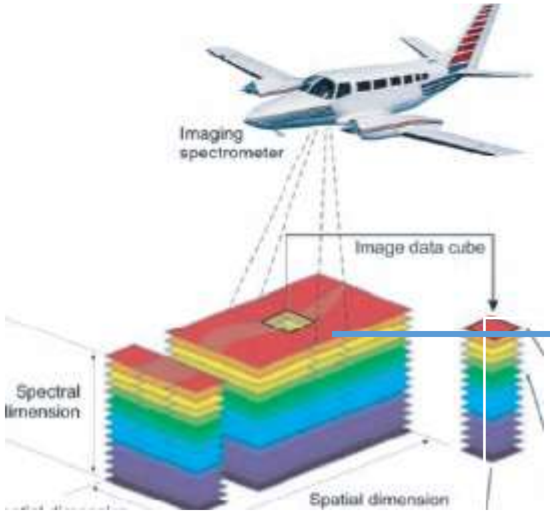
Image Spectroscopy

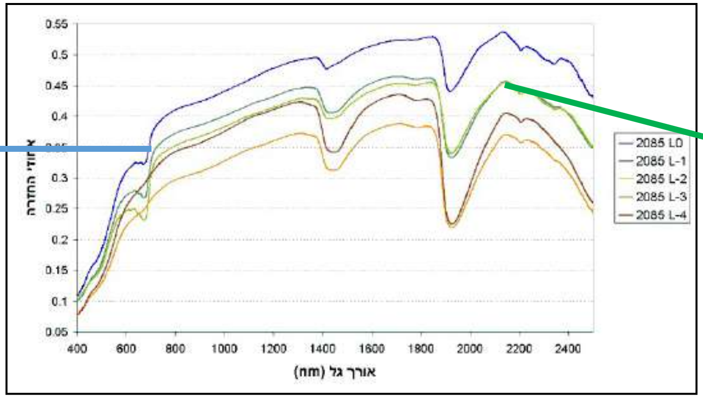
Geology
Vegetation
Water

Point Spectroscopy

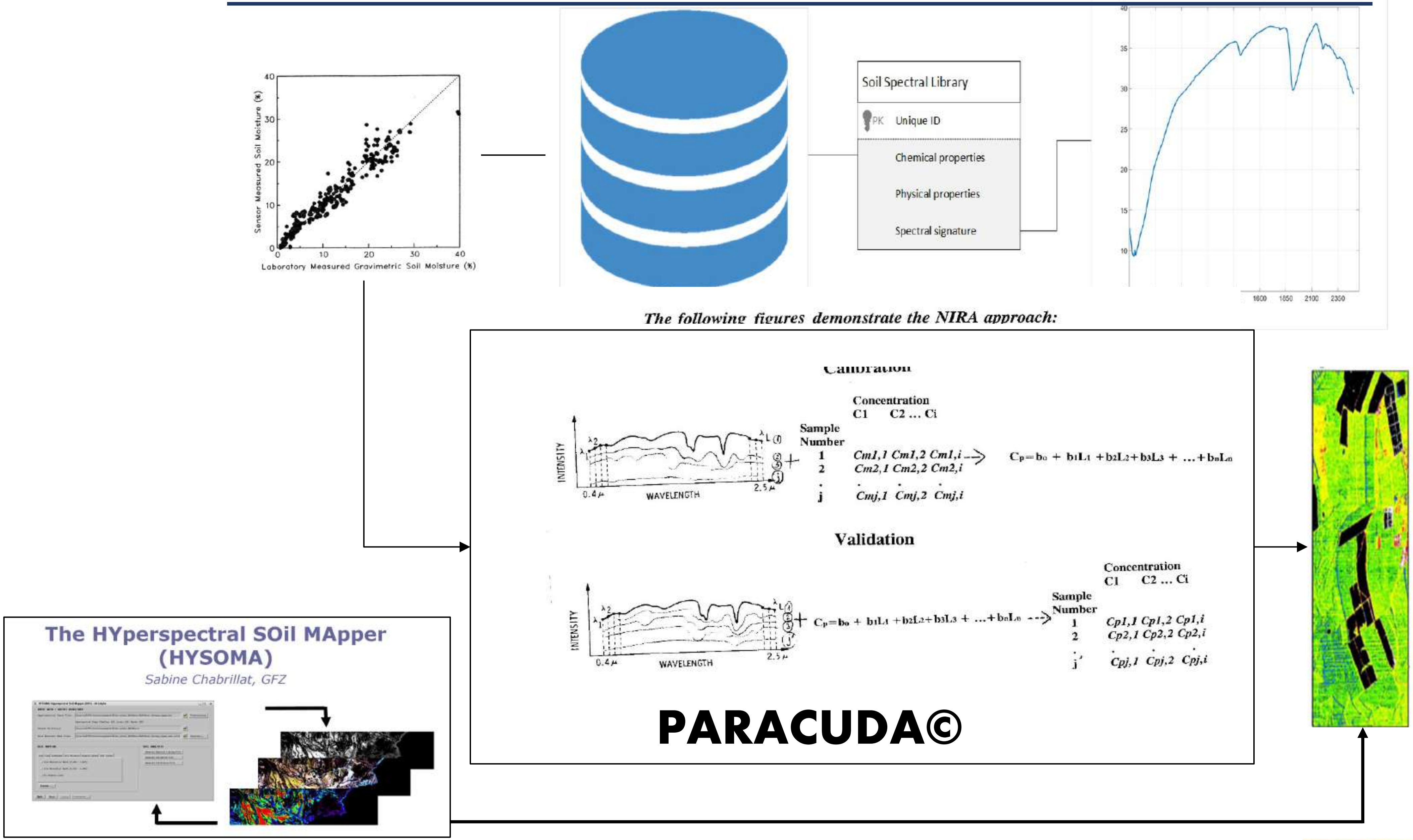
Soil

!





PARCUDA II ® and HYSOMA on Image Cube Sapce



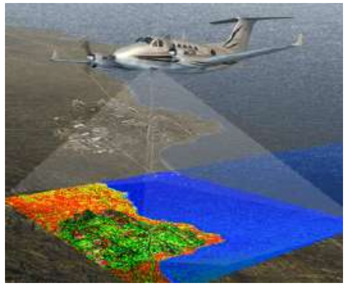
MRA	Multiple Regression Analysis
PLSR	Partial Least Square Regression

First

SVMR	Support Vector Machine Regression
MBL	Memory Based Learning
RF	Random Forest
ANN	Artificial Neural Network
FRM	Fuzzy Relational Model

Today

Agricultural Soil Mapping based on Local SSL and airborne HSR sensor Israel (semi arid)



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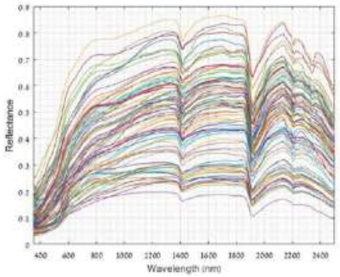
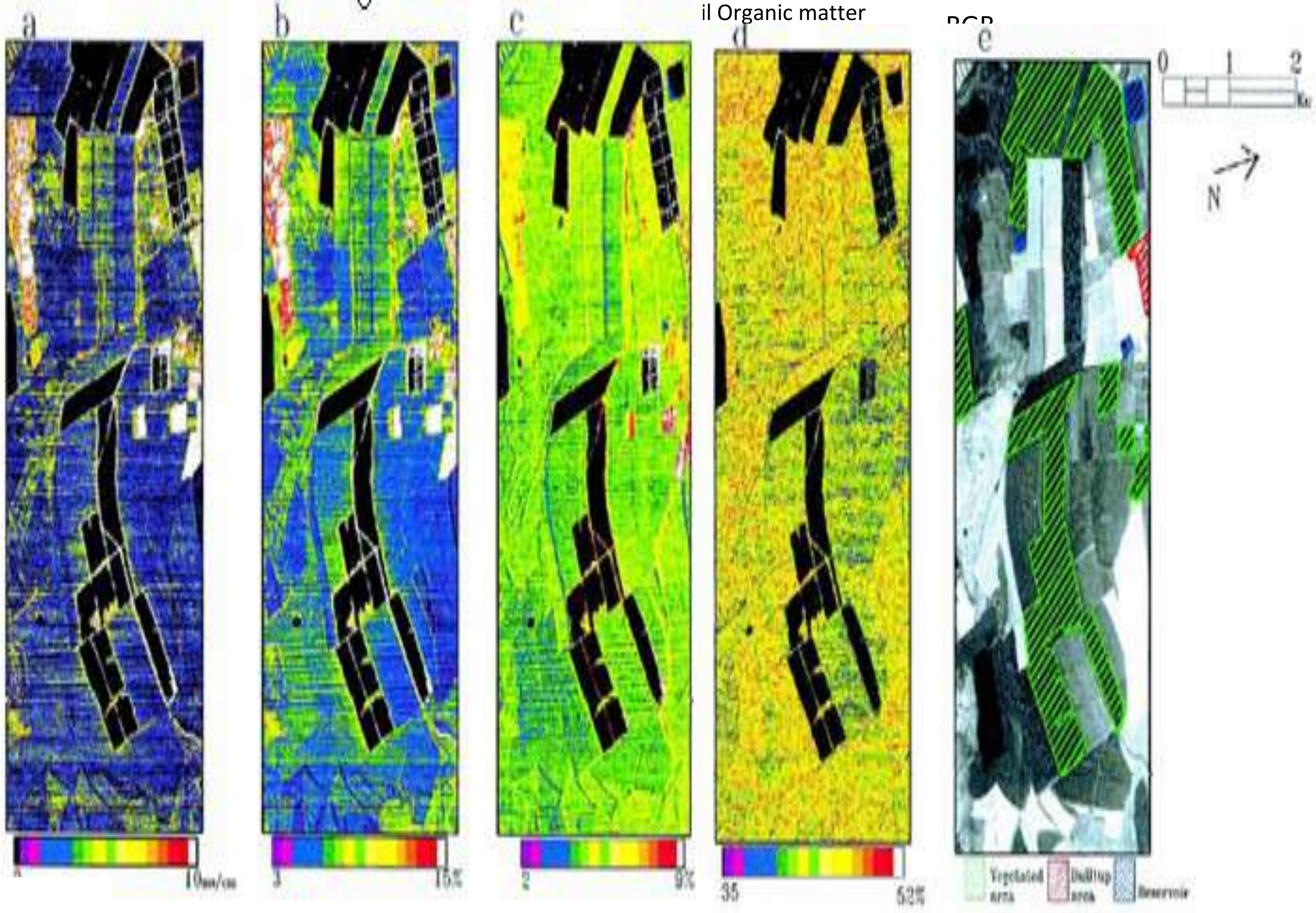




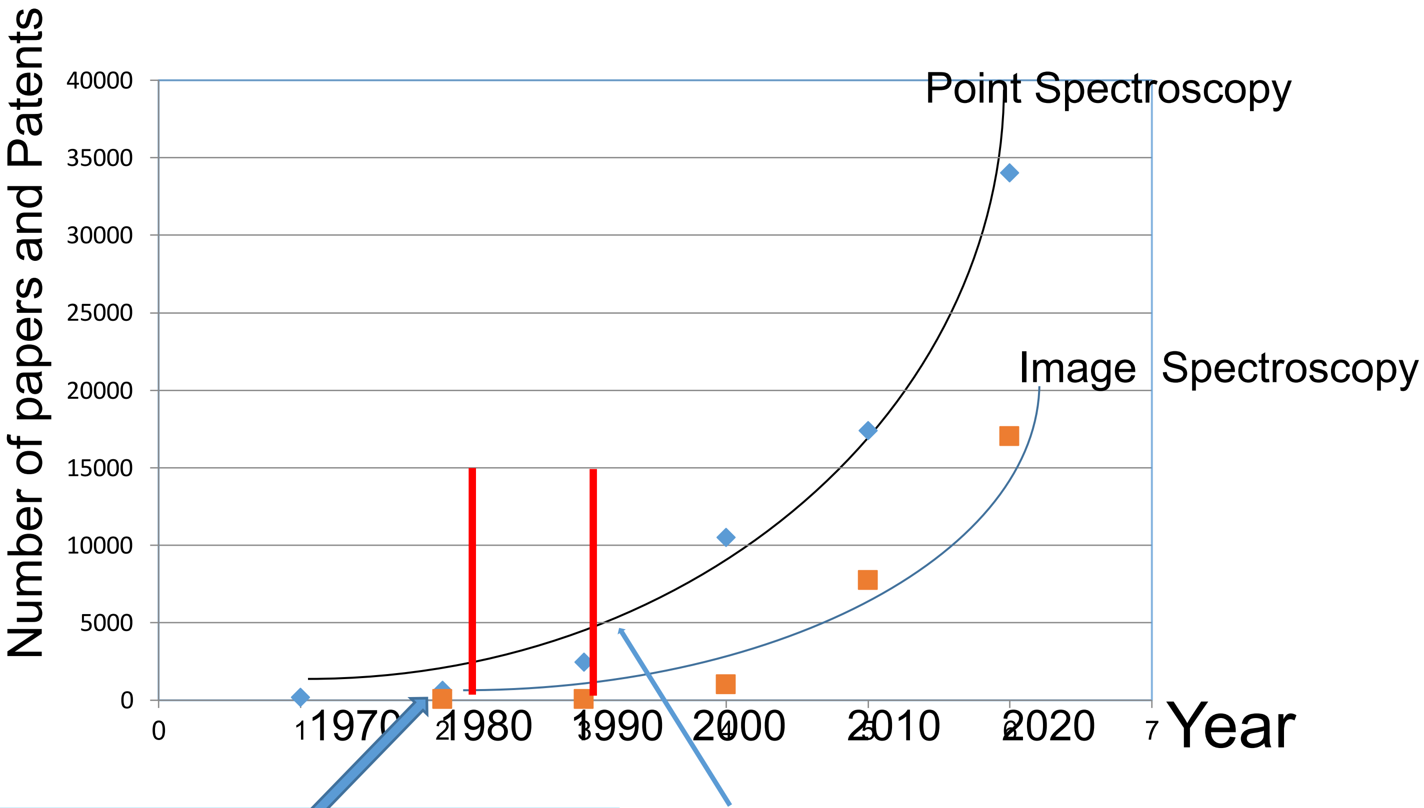
Mapping of several soil properties using DAIS-7915 hyperspectral scanner data—a case study over clayey soils in Israel

2002

E. BEN-DOR[1], K. PATKIN[1], A. BANIN[2] and A. KARNIELI[3]
[1]Department of Geography, Tel-Aviv University, Ramat Aviv, Tel-Aviv
[2]Department of Soil and Water Sciences, Faculty of Agricultural, Food and Environmental Quality Sciences, The Hebrew University, Rehovot, Israel
[3]J. Blaustein Institute for Desert Research Sde-Boker Campus, Negev, Israel

Soil Spectroscopy as a growing discipline

Number of papers published in soil spectroscopy over the years : Point and Image domains



Dalal, R.C., and R.J. Henry. 1986. Simultaneous determination of moisture, organic carbon and total nitrogen by near infrared reflectance spectroscopy. Soil Science Society of America Journal 50:120-12

Near-Infrared Analysis as a Rapid Method to Simultaneously Evaluate Several Soil Properties

E. Ben-Dor* and A. Banin

Attention is given recently to HSR of soils from space

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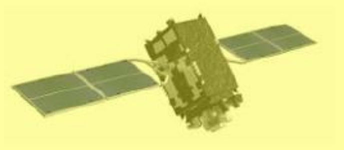
Image Spectroscopy

Geology
Vegetation
Water

Point Spectroscopy

?



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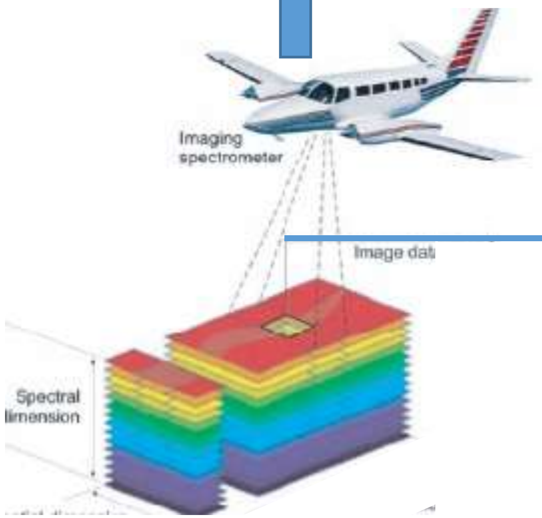
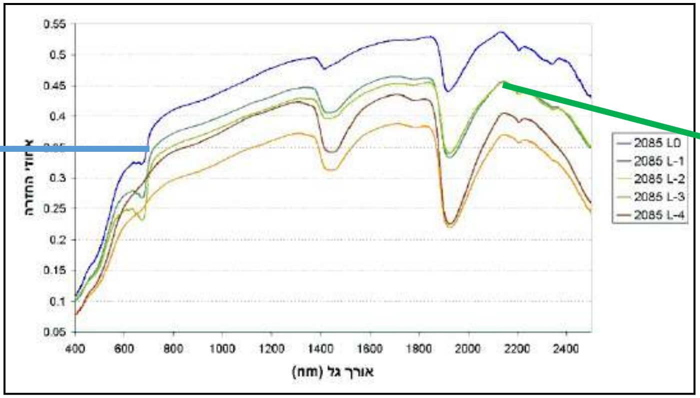


Soil



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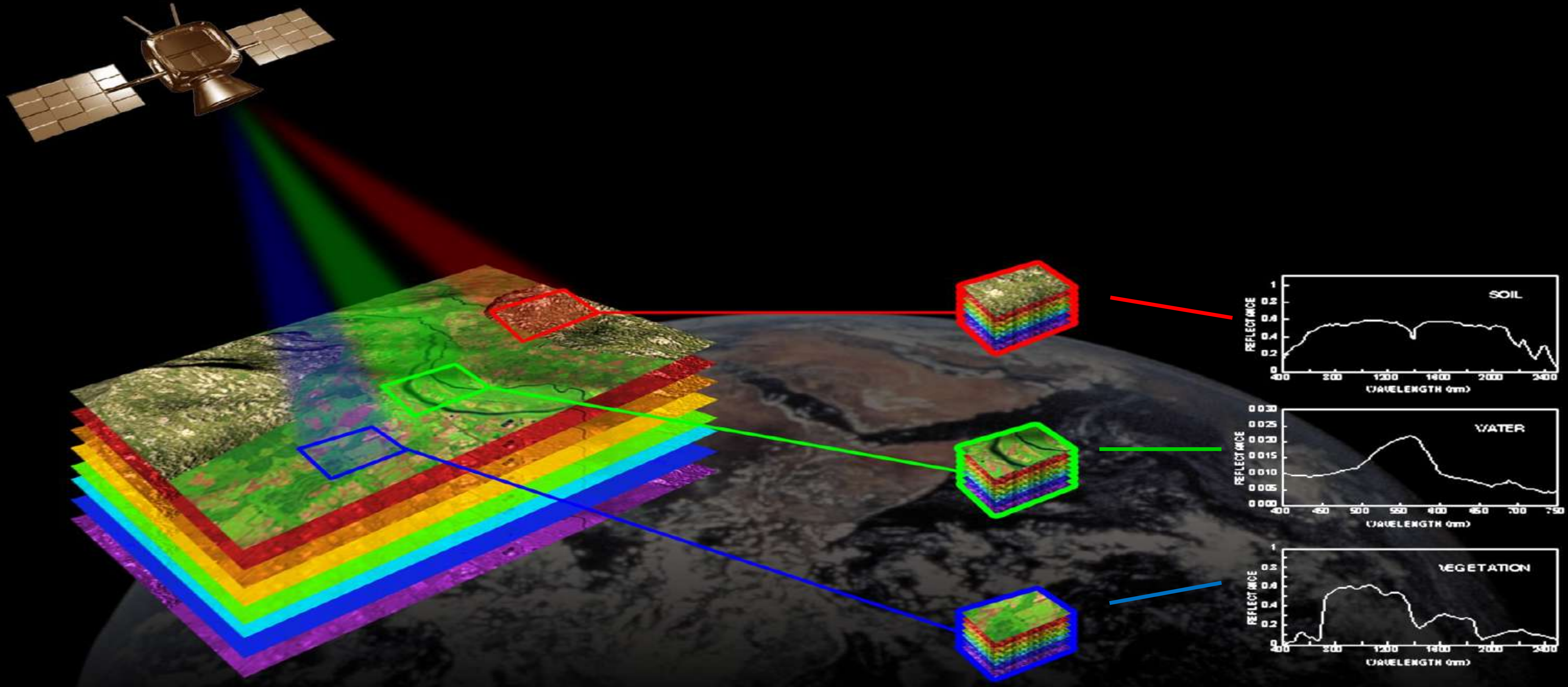
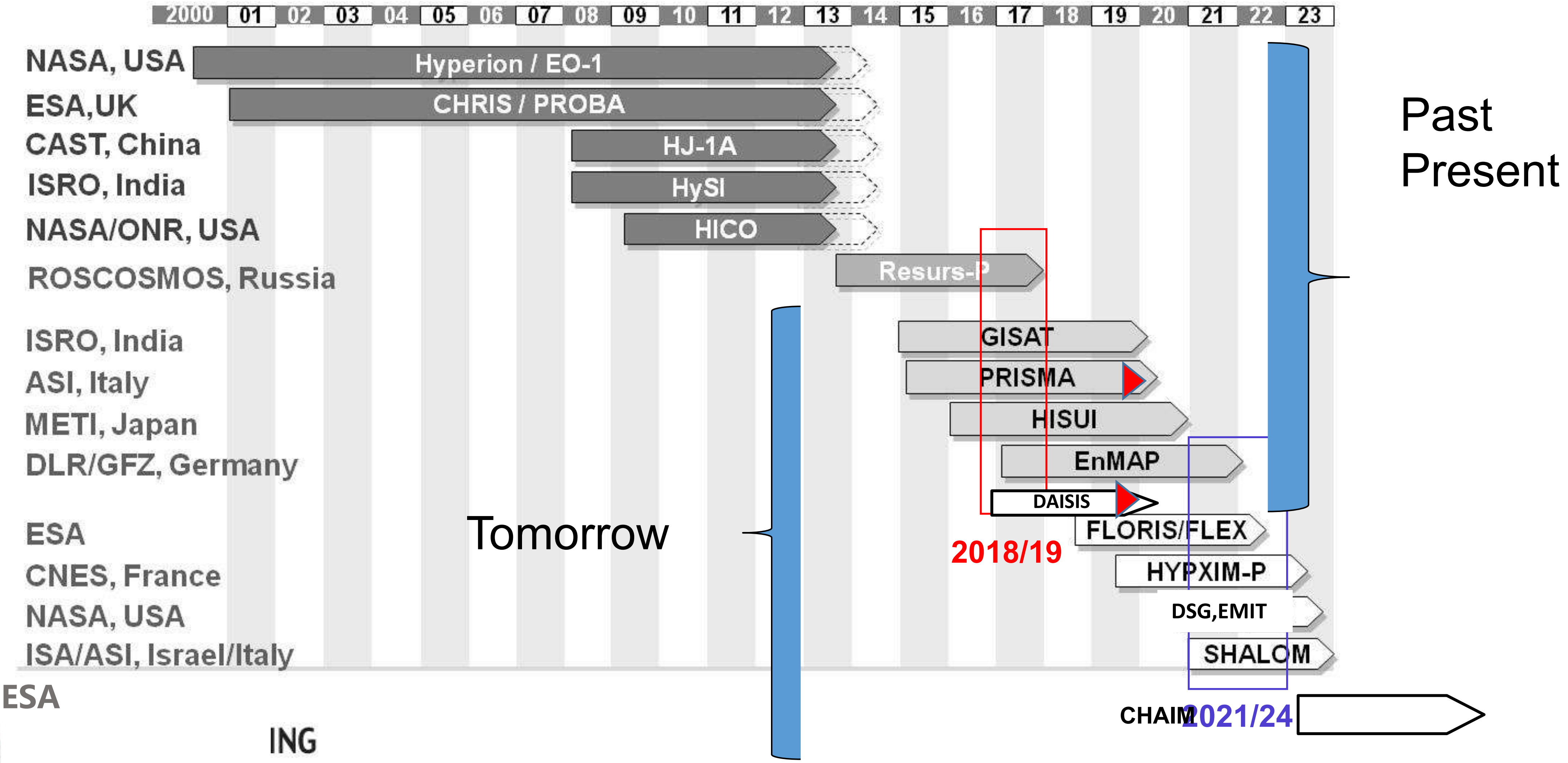
HYPERSPECTRAL REMOTE SENSING FROM SPACE

A NEW ERA FOR SOIL MAPPIN



HSR Orbital Mission



TAU-RSL
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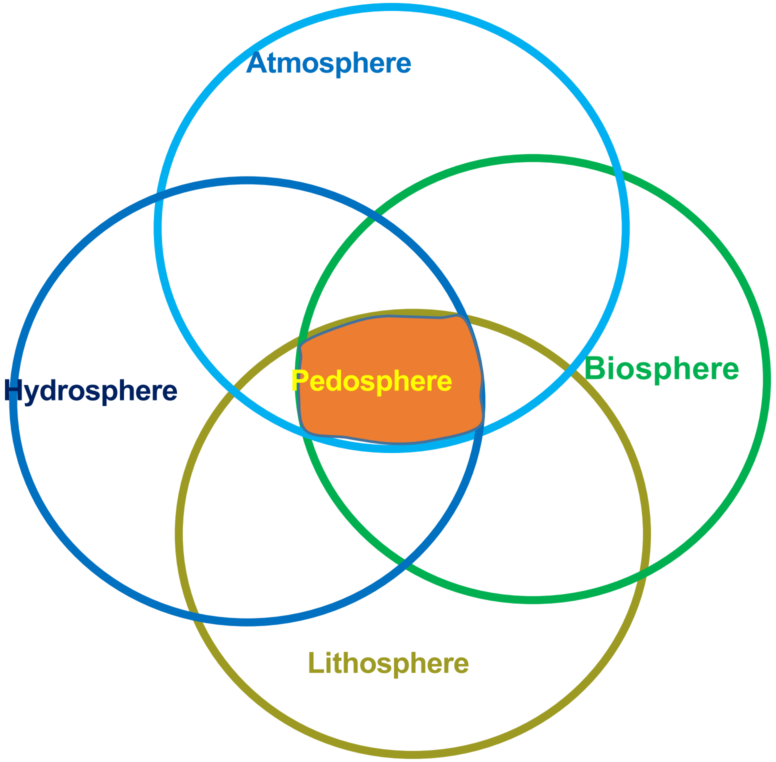

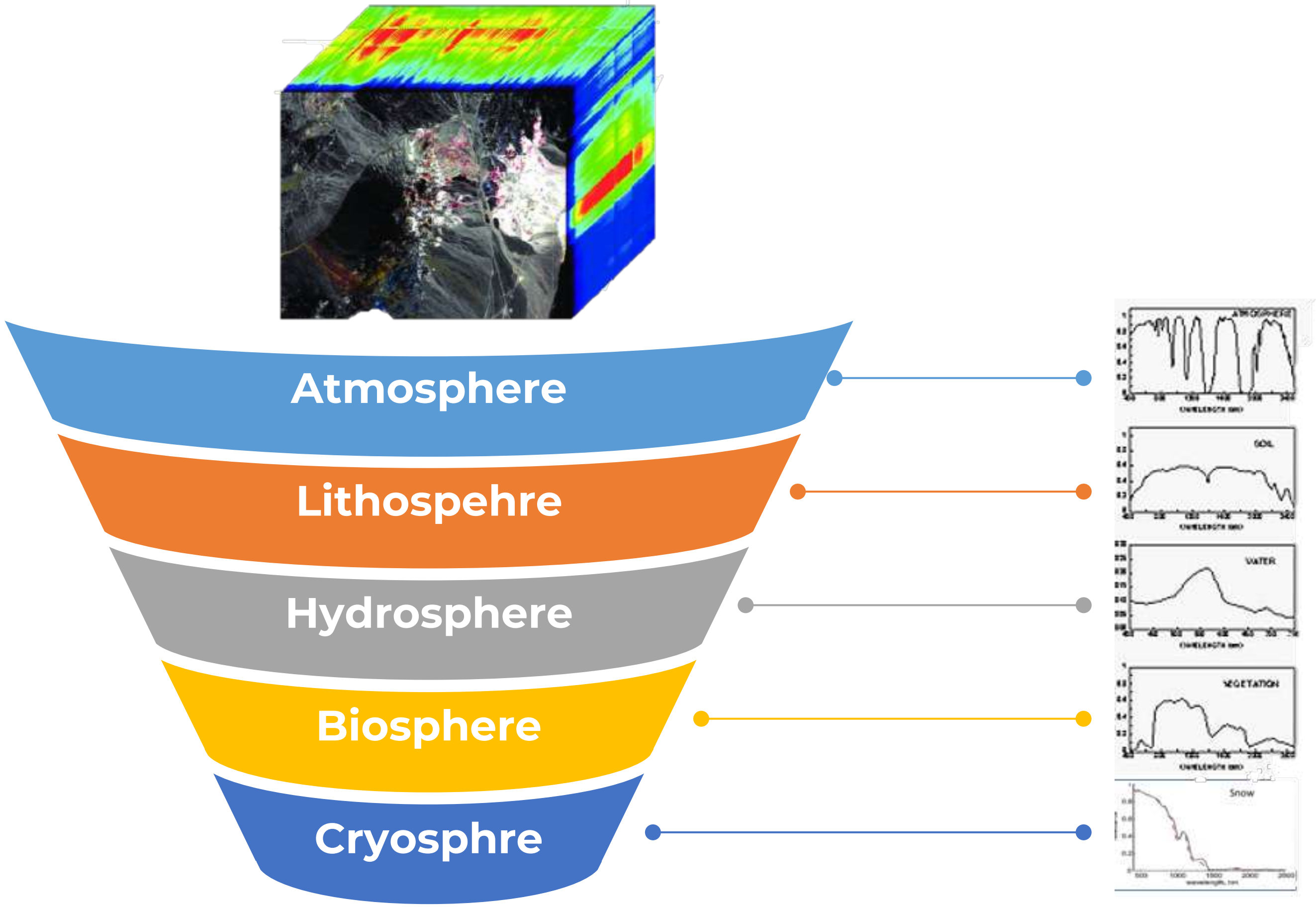

CHAPTER ONE

Soil: The Forgotten Piece of the Water, Food, Energy Nexus

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*USDA-ARS, National Laboratory for Agriculture and the Environment, Ames, IA, United States
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TEL AVIV UNIVERSITY אוניברסיטת תל אביב

SHALOM - Spaceborne Hyperspectral Applicative Land and Ocean Mission

Soil monitoring from space are playing a major role in SHALOM missions

Product Name
Crop, Rangeland and Invasive Species Map
Burnt Area Map
Vegetation Status Indicators
Vegetation Damage and Stress Indicators
Fire Fuel Map
Mineral Map
Coastal Bathymetry Map
Urban And industrial Functional Area Map
Lithological Map
Lava Flow Parameters
Soil Surface Pollutants Map
Volcanic Gas And Aerosol Emission Map
Forest Species Map
Forest Biomass Map
Ice Cover Map
Soil Characterization Map
Land Cover Map
Land Cover Change Detection Map
Snow Cover Map
Forest Nitrogen and Chlorophyll Map
Wetlands Classification Map
Marine And Aquatic Quality And Productivity Indicators
Lava and ash distribution map
Snow And Ice Cover Characterization

Soil Salinity: (gypsum, sodium)

Soil Minerals: (iron oxides, organic matter, clay, carbonates, CEC, SSA, Quartz)

Soil infiltration: (crust, classes)

Soil Formation: (clay, iron oxides)

Soil Erosion (Iron Oxised, Clay Minerals)

Soil Contamination: (heavy metals, TPH)

Soil Hydrophobicity (Organic Matter)

Soil Moisture: (H_2O)

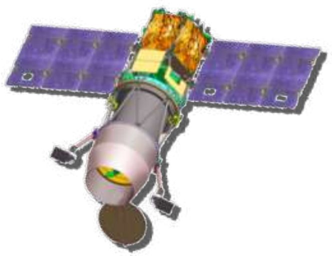
Soil Quality : (Bio Assay test)

Soil Nutrition (N, P,K)

Soil Degradation: (all the above)

Spectral Change Detection (all the above)

Many others by Indirect Relationship



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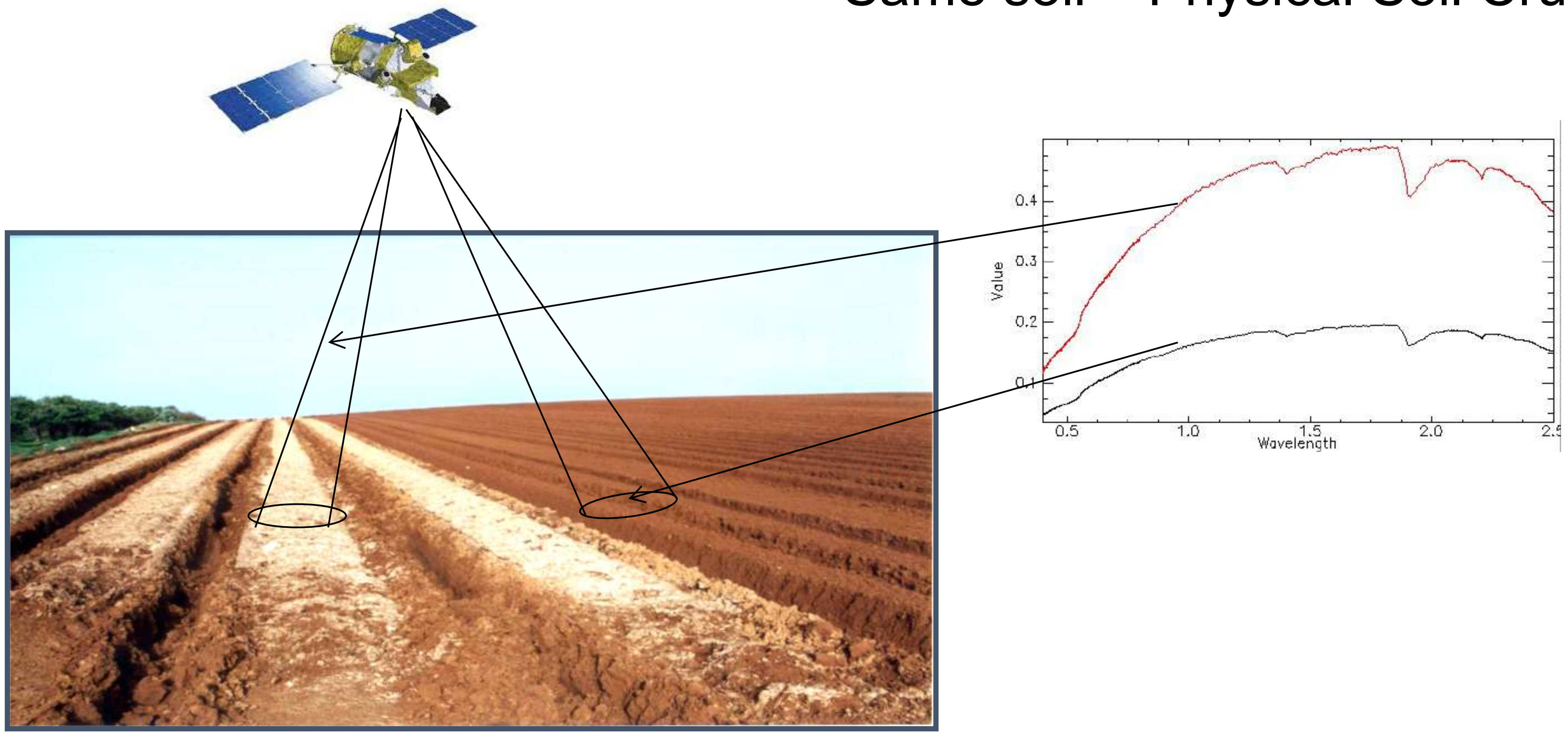
Same soil – Physical Soil Crust



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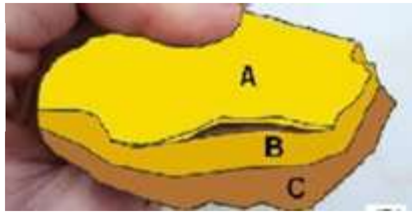

Solution: Field SSL

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

Soil Sampling for labortaoty

Sampling un disturbed soil

Sampling disturbed soil

Crust may be preserved but field condition is not Complicated and uncomfortable

Crust is completely destroyed.
Not applicable for Hydrophobicity

Ground truth measurements

Soil Field Spectroscopy: Problems

(Non Systematic >> Systematic)

- Atmospheric Attenuation: No information at 1.4 and 1.9 mm, cirrus clouds
- Sun Radiation: Changes along the spectral measurement time
- Time: Limited duration in a given camping to acquire spectral measurements
- BRDF effects: To the sun and with the sun –crucial
- Pointing position: Stability and experience of the operator
- Demolishing of the soil surface: if Contact probe is used.

Soil Field Spectroscopy → Soil Sptrcal Libaries : Problems

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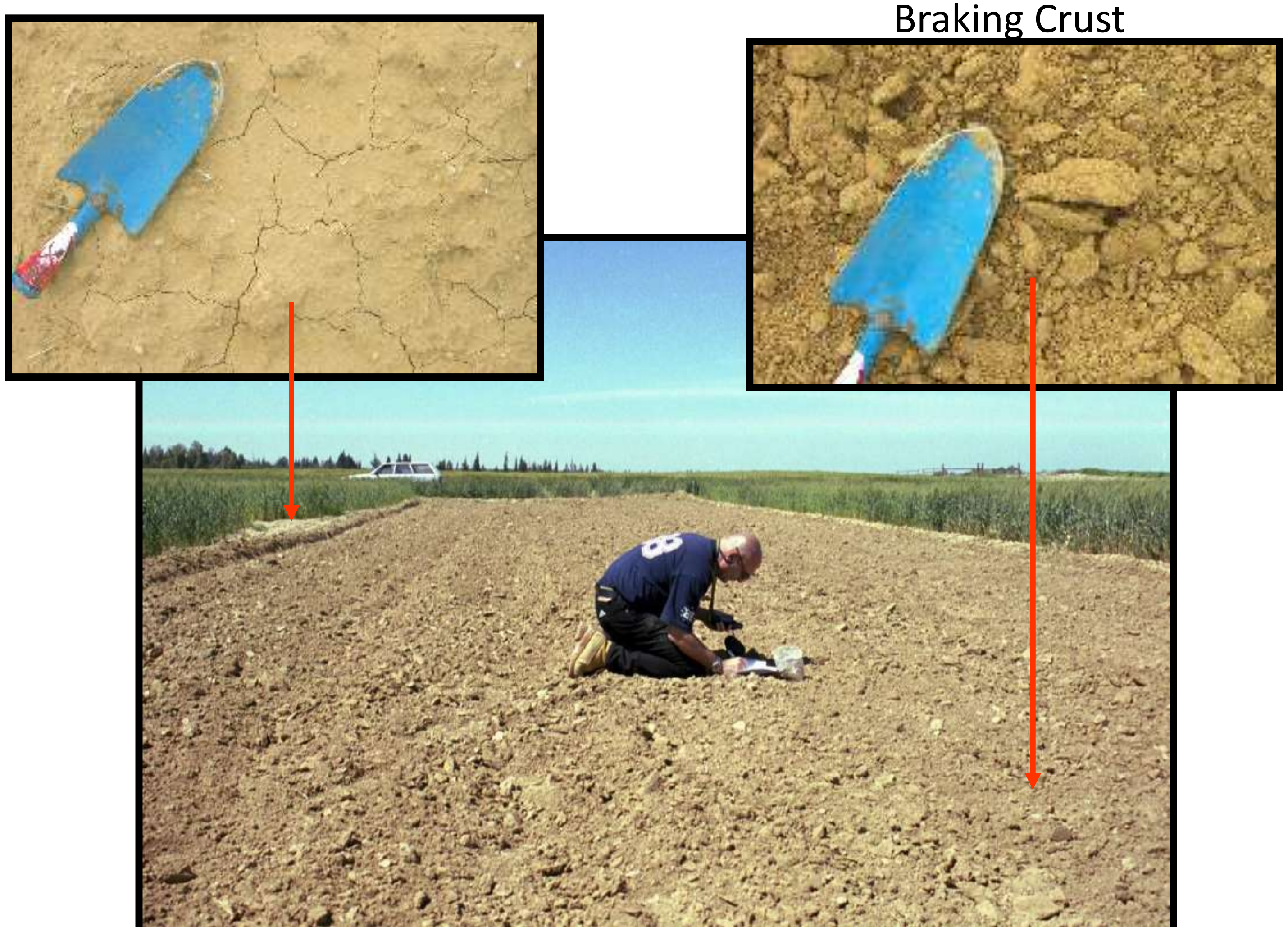
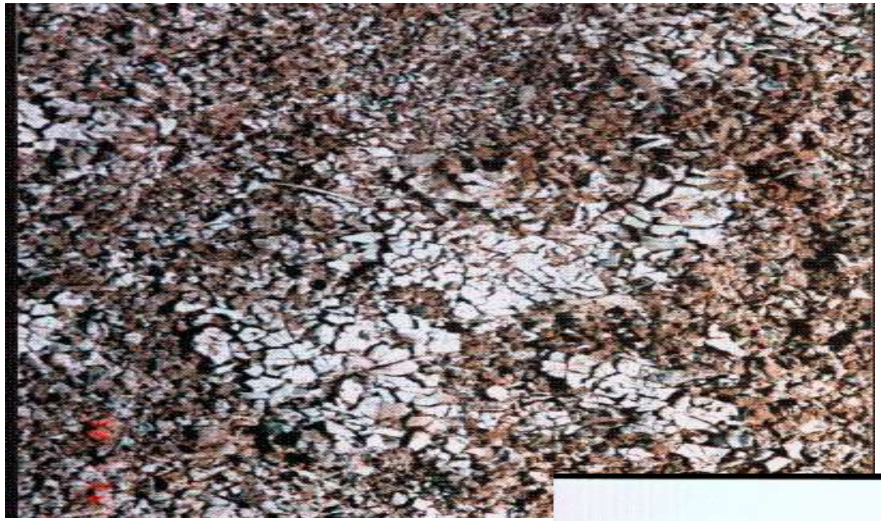
- Sample surface is disturbed : the Soil surface properties are out of range.

Crust

Braking Crust



Soil Salinity



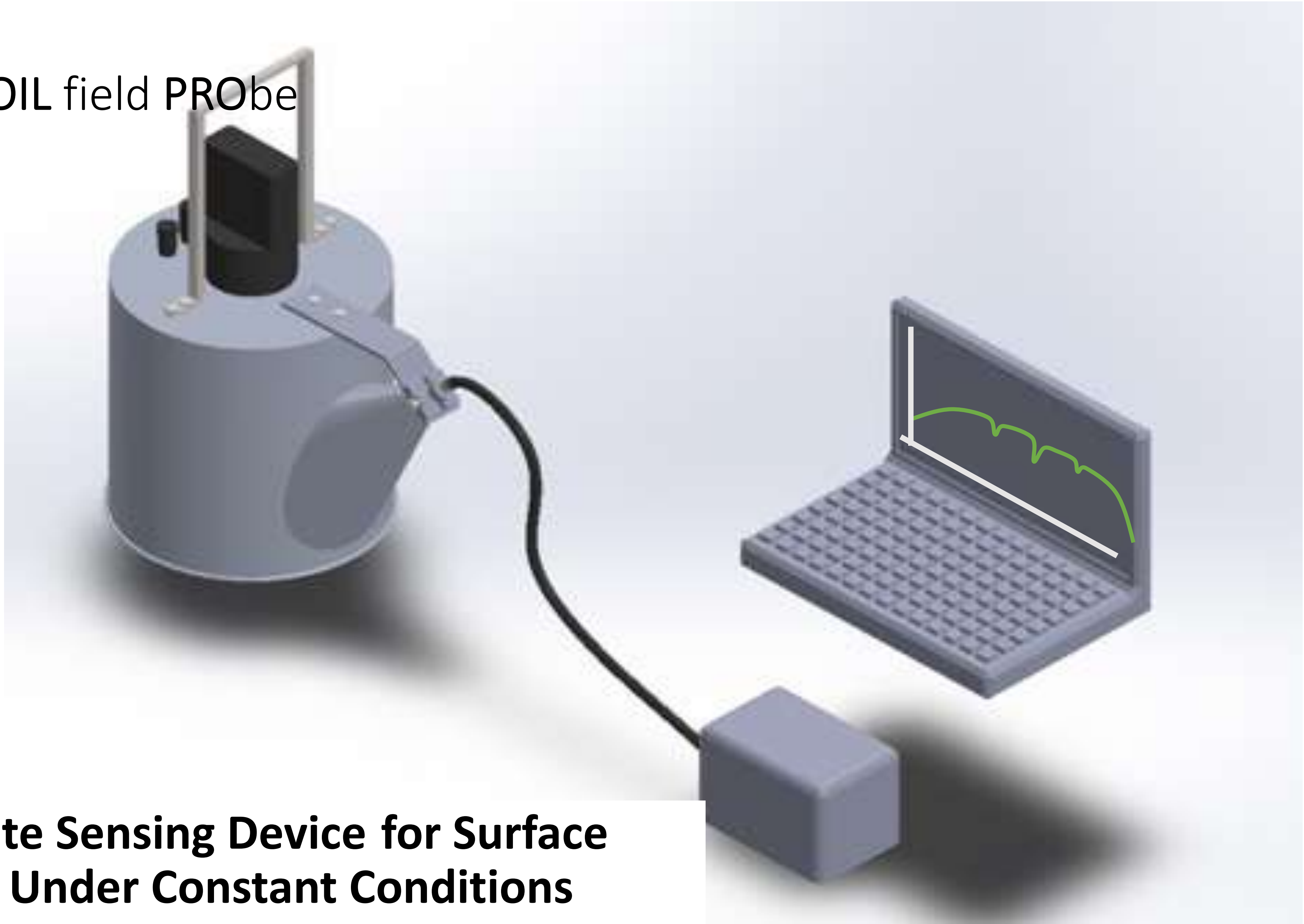
To check the surface disturbed issue – direct surface properties should be examined

1) Assembly that will solved all threats described previously (sampling, atmosphere quality….)

2) Measuring the surface properties that are strongly controlled by the first 50 nm of the soil surface

Assembly that will solved all threats described previously (sampling, atmosphere quality)

“SoilPro” SOIL field PRObe

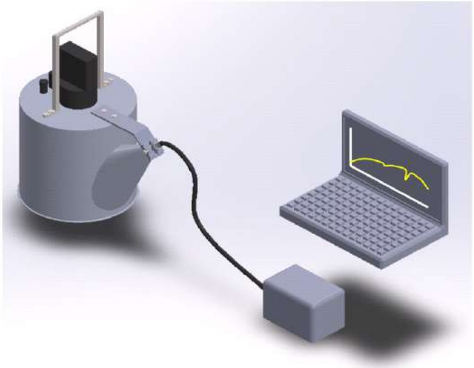


An In-situ Remote Sensing Device for Surface Measurement Under Constant Conditions

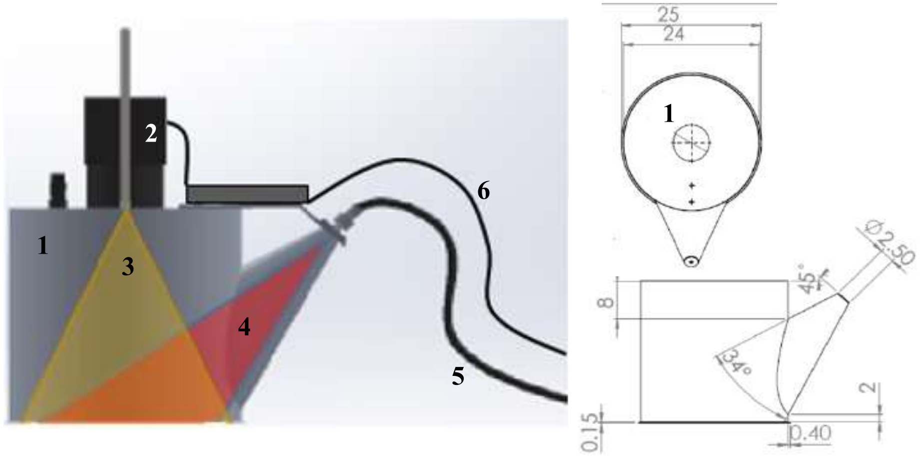
The SOIL field PRObe assembly – SoilPro

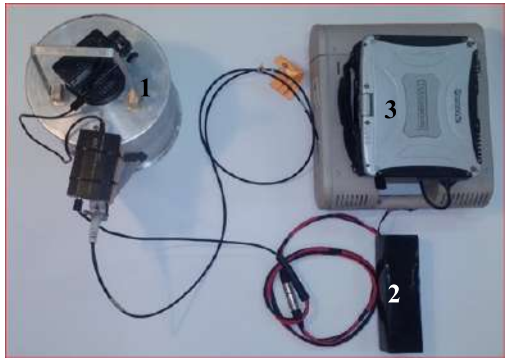
Soil field Probe (SoilPRO®)

- 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 constan



The **SoilPro** - design and operation





1) SoilPro, 2) portable battery,
3) ASD® fieldSpec

The **SoilPro** in the field

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The SoilPRO assembly is under patent pending process, Patent application no.
Patent Application: No. 62/278,471, Filed: 14/01/2016.

CRADLE

GEO GROUP ON EARTH OBSERVATIONS

Common methods for field reflectance measurements

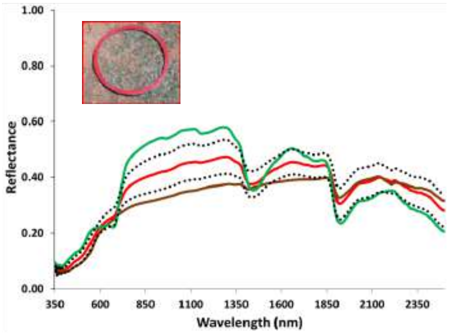
Contact Probe Measurements

Without dependence on environmental conditions

Measuring small surface area by contact

Surface Deformation

Contact probe field spectra

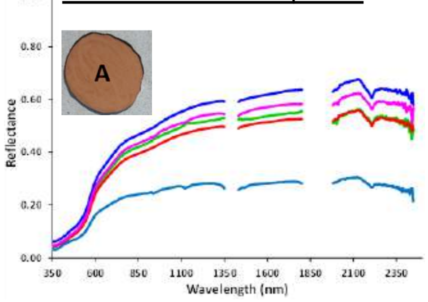


Bare Fiber Measurements

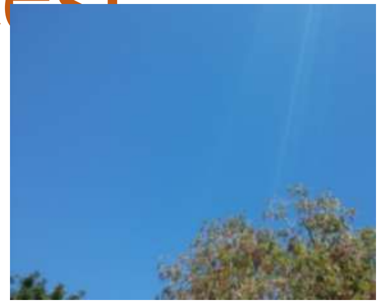
Depending on environmental conditions and influenced by the operator

Measuring large surface area without interrupting the texture

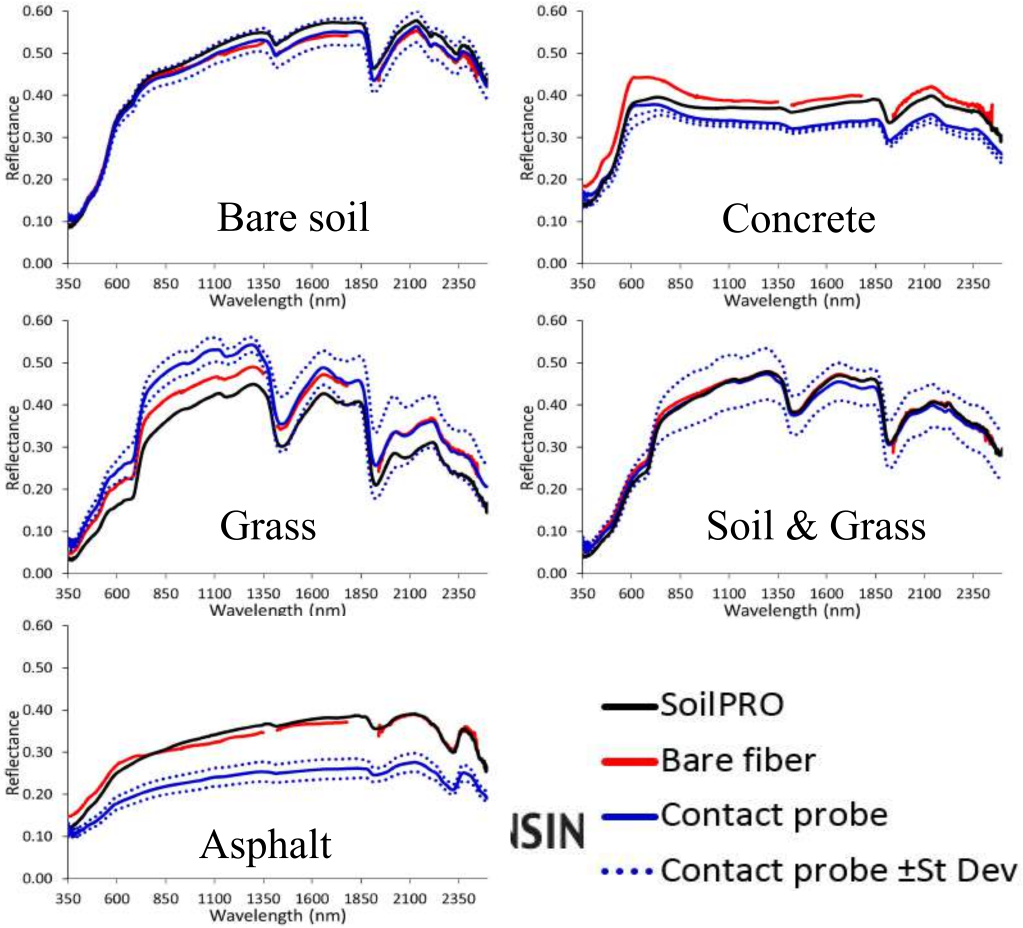
Bare fiber outdoor spectra



The SoilPRO assembly – Field targets test



The SoilPRO's products were evaluated in comparison the those of commons used methods



Bare soil

Concrete

Grass

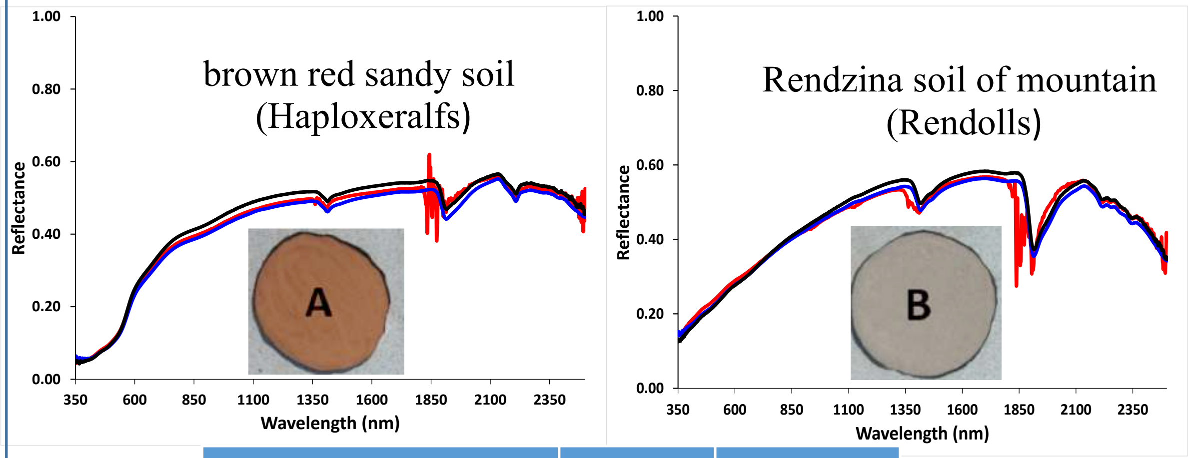
Soil & Grass

Asphalt

Testing the SoilPro

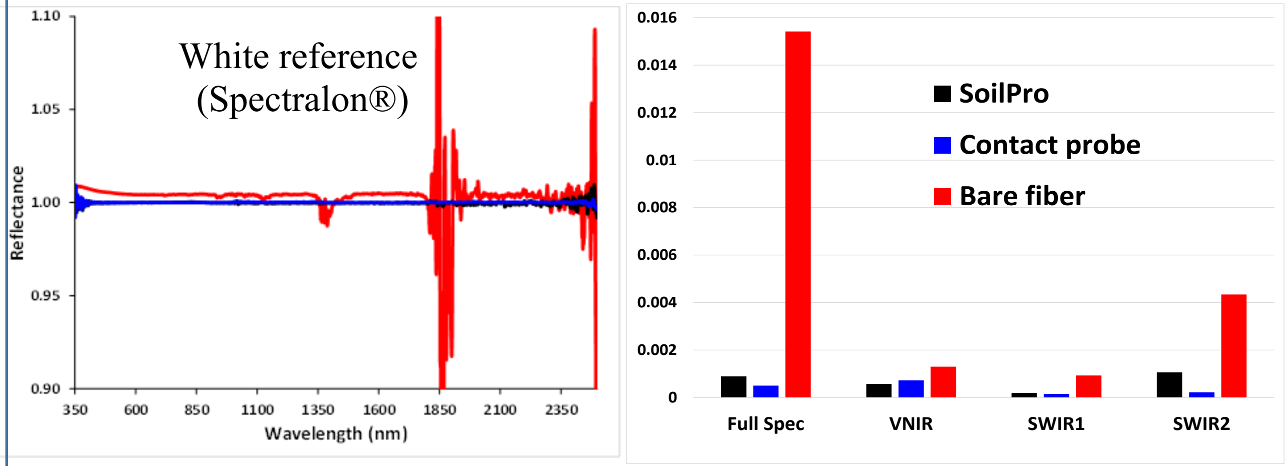
- The SoilPro products were evaluated in the laboratory and outdoor under different conditions, compared to the bare fiber and contact probe (ASDi®).

Spectra similarity



Reference spectrum	SAM Test	ASDS Test
A - Contact probe	0.012	0.021
B - Contact probe	0.010	0.012

Noise ratio



$$\text{RMSD} = \sqrt{\frac{\sum_{t=1}^{n}(\hat{y}_t - y_t)^2}{n}}.$$

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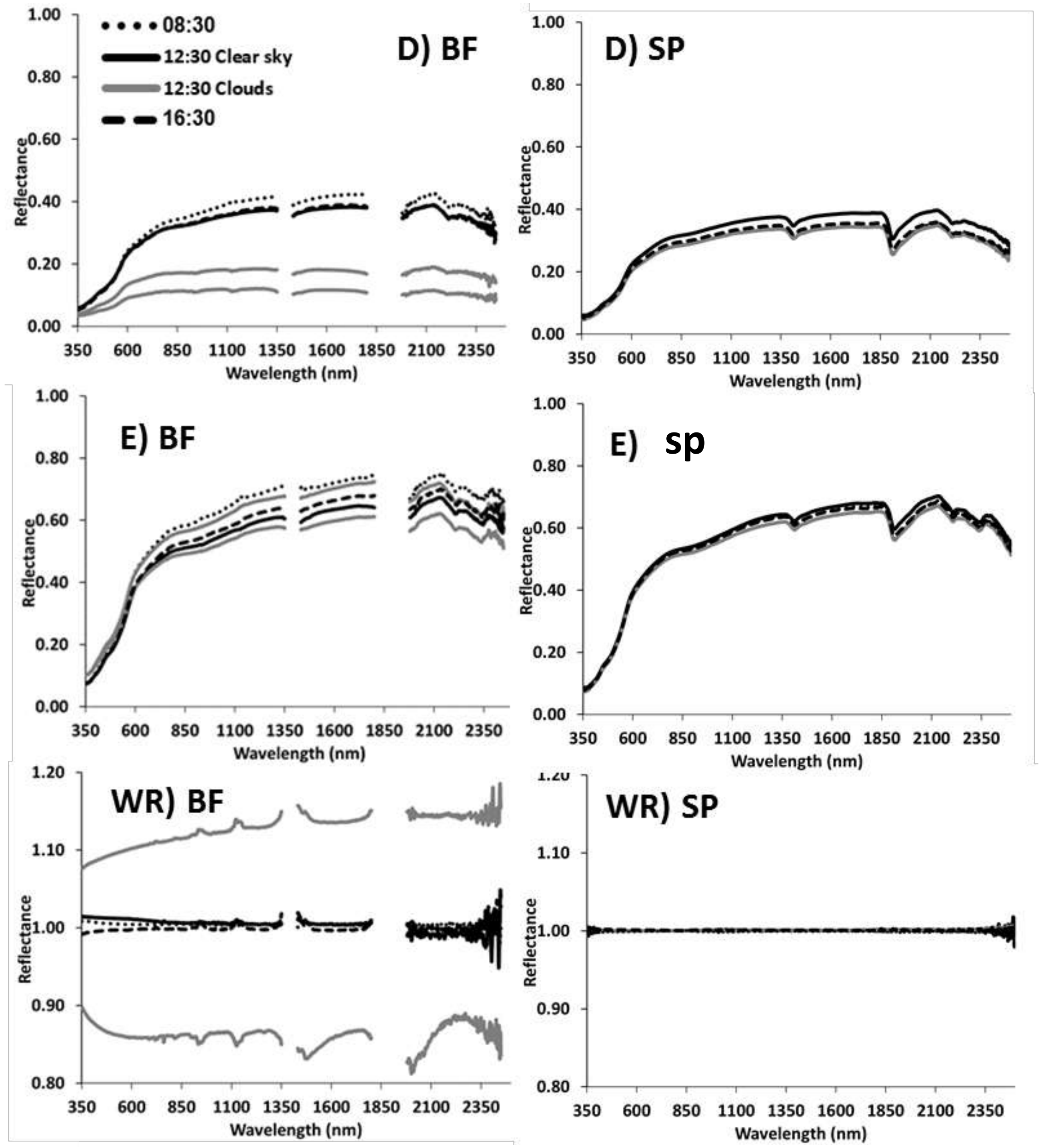
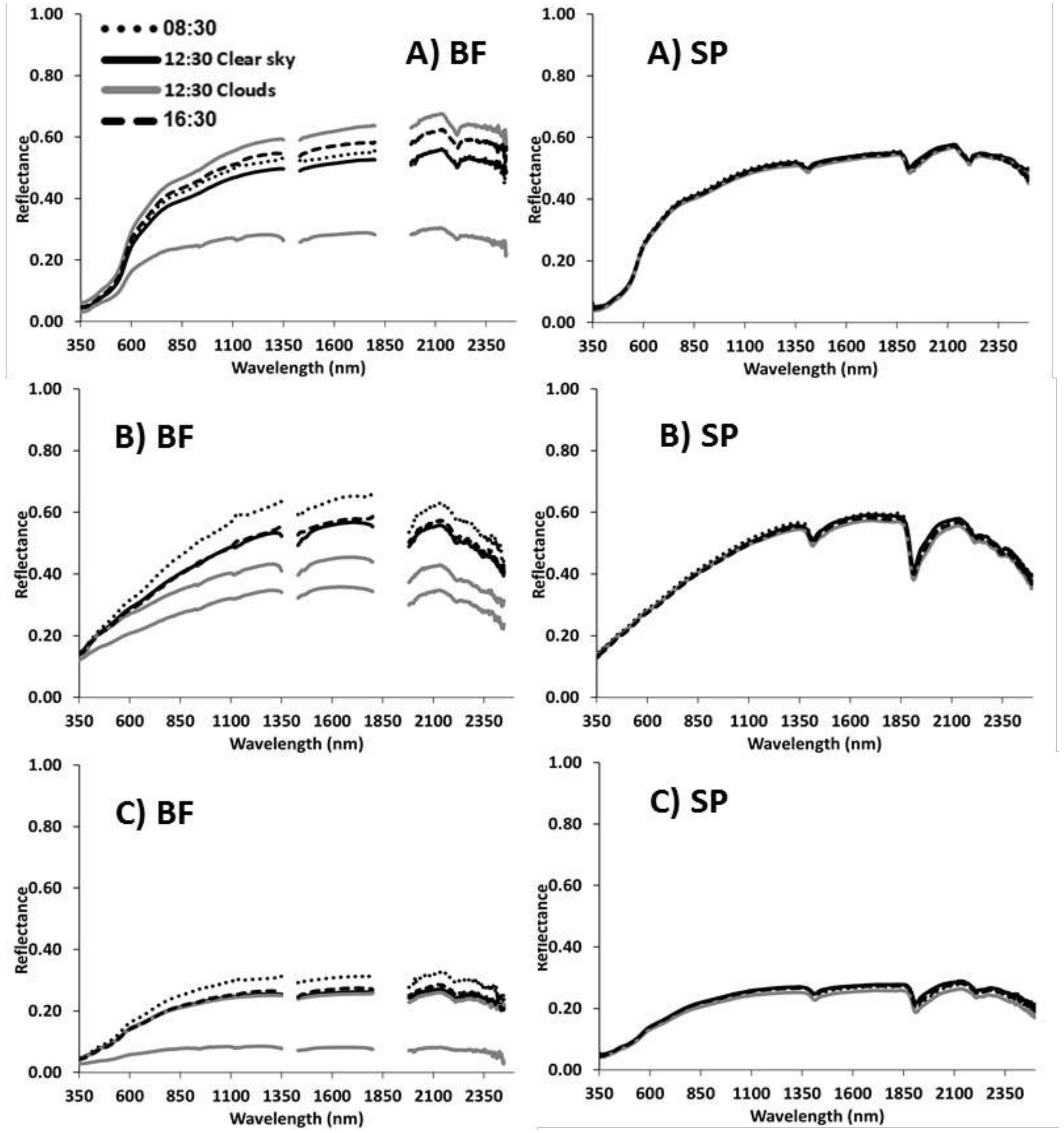

08:30
12:30 Clear sky
12:30 Clouds
16:30
D) BF
D) SP
E) BF
E) sp
WR) BF
WR) SP
Reflectance
Wavelength (nm)
350 600 850 1100 1350 1600 1850 2100 2350
0.00 0.20 0.40 0.60 0.80 1.00
0.80 0.90 1.00 1.10 1.20

FILED

SoilPRO versus BareFiber at different times, same day

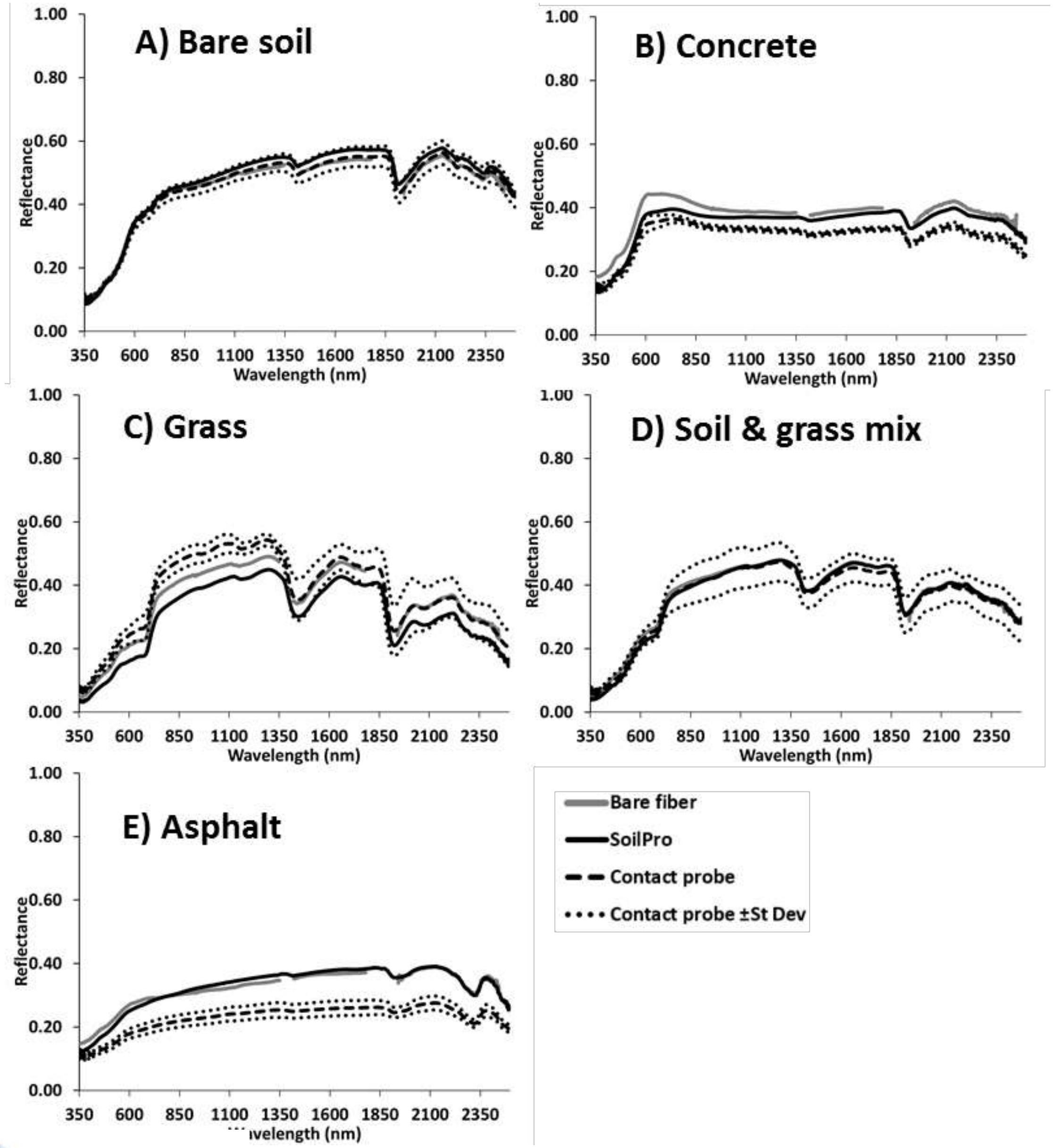


Soil c

Soil D

Soil F

Reflectance using SP



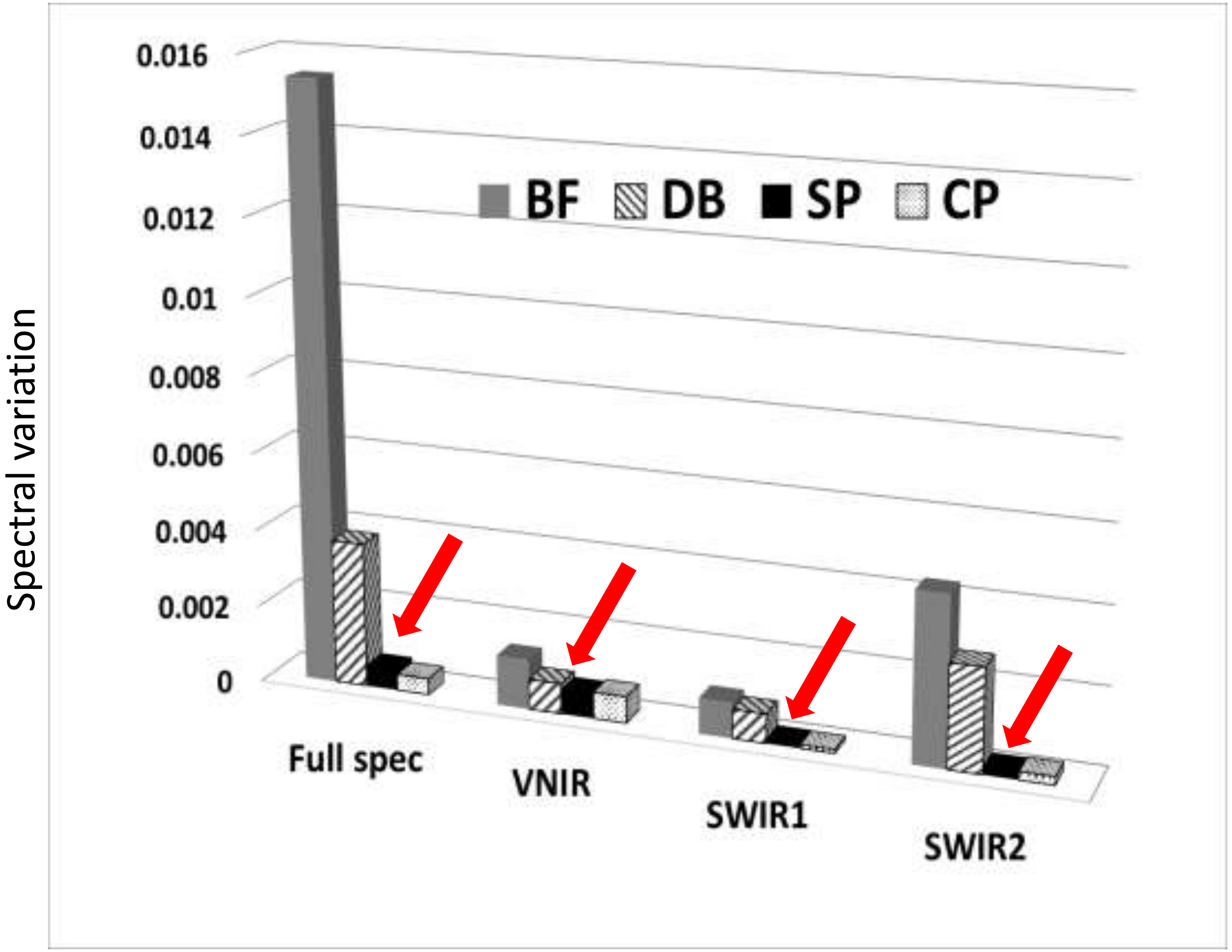
ASDS = Average Sum of Deviation Square
(Ben-Dor et al., 2004)

$$ASDS = \frac{\sum_{\lambda=350}^{2500} \sigma\left(1 - \rho_{\lambda} / \rho^{*}_{\lambda}\right)^{2}}{2151}$$

ρ : sample reflectance
ρ * : reference reflectance

ASDS → 0 = good match

Spectral Variation across the Spectrum for the different methods for a given soil

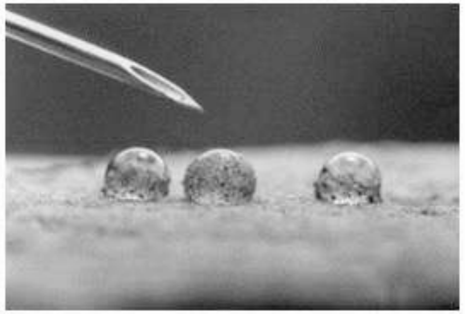


Measuring the surface properties that are strongly controlled by the first 50 nm of the soil surface

Soil hydrophobicity

- Soil hydrophobicity (water repellency) reduces the affinity of soils to water such that they resist wetting for periods ranging from a few seconds to hours.

- Factors controlling the occurrence of soil Water repellency:
    - Chemical characteristics
    - Soil texture
    - Soil moisture
    - Microbial activity
    - Soil temperature
    - Soil organic Matter



Doerr et al., (1998)

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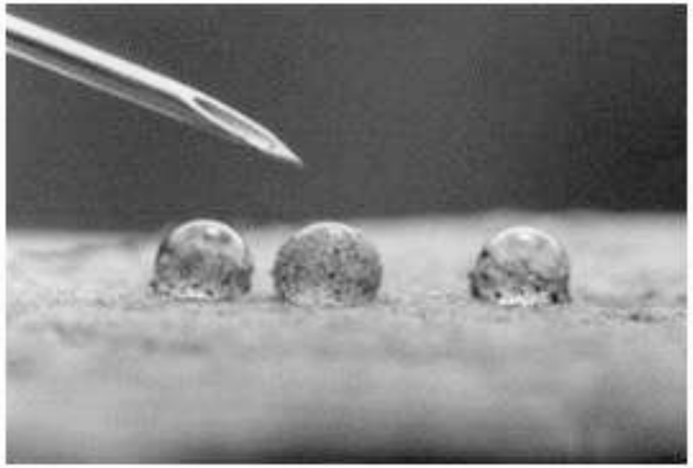
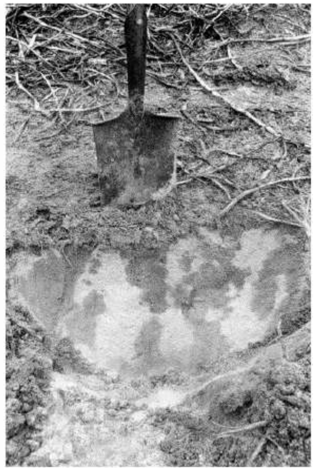
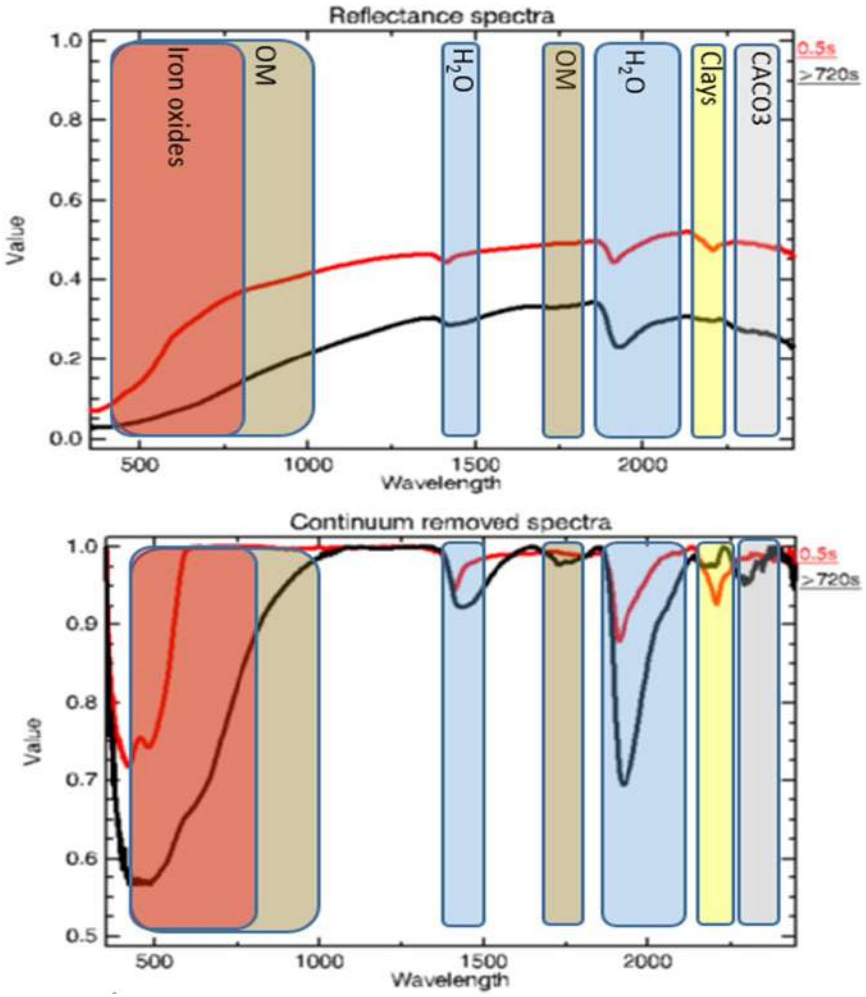
Doerr et al., (1998) Soil water repellency: its causes, characteristics and hydro-geomorphological significance, Earth Science Reviews: 51, 1-4

Soil hydrophobicity proxy by spectral means





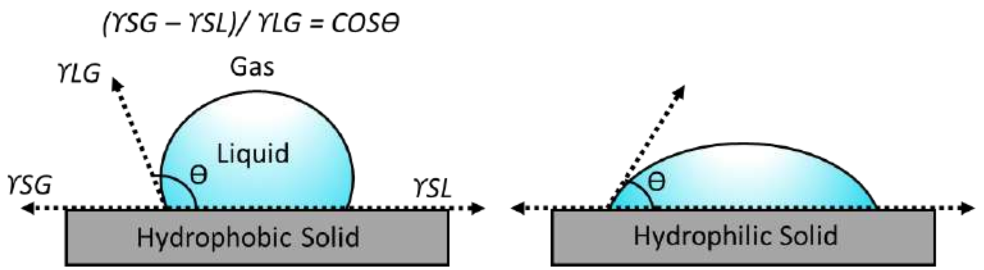


Doerr, S.H., Shakesby, R.A., Walsh, R.P.D., 2000. Soil water repellency: its causes, characteristics and hydro-geomorphological significance. Earth-Sci. Rev. 51, 33–65.

Soil hydrophobicity proxy by spectral means

Common methods for determine the hydrophobicity of soil

Connectivity angle (CA)



Can be carried out only at the lab for disturbed samples
Objective

Water drop penetration time (WDPT)

Class	Severity	WDPT
0	Wet table, non-repellent	<5s
1	Slightly water repellent	5-60s
2	Strongly water repellent	60-600s
3	Severely water repellent	600-3600s
4	Extremely water repellent	1-3h
5		3-6h
6		>6h

Can be carried out anywhere
Semi objective

Soil hydrophobicity proxy by spectral means

Until now two studies have investigated this issue based on disturbed samples

Knadel, M., Masís-Meléndez, F., Wollesen de Jonge, L., Moldrup, P., Arthur, E., Humlekrog Greve, M., 2016. **Assessing soil water repellency of a sandy field with visible near infrared spectroscopy**. J. Infrared Spectrosc. 24, 215. doi:10.1255/jnirs.1188

Kim, I., Pullanagari, R.R., Deurer, M., Singh, R., Huh, K.Y., Clothier, B.E., 2014. **The use of visible and near-infrared spectroscopy for the analysis of soil water repellency**. Eur. J. Soil Sci. 65, 360–368. doi:10.1111/ejss.12138

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Geoderma 406 (2022) 115486

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journal homepage: www.elsevier.com/locate/geoderma

Rapid assessment of soil water repellency indices using Vis-NIR spectroscopy and pedo-transfer functions

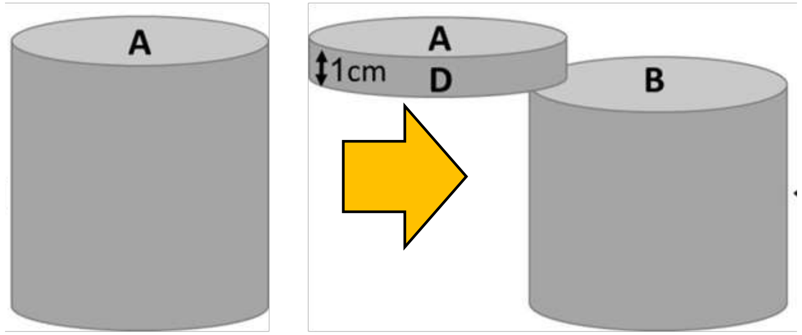
Masoud Davari [a,*], Soheyla Fahmideh [a], Mohammad Reza Mosaddeghi [b]

[a] Department of Soil Science, Faculty of Agriculture, University of Kurdistan, Sanandaj 15175-416, Iran
[b] Department of Soil Science, College of Agriculture, Isfahan University of Technology, Isfahan 84156-83111, Iran

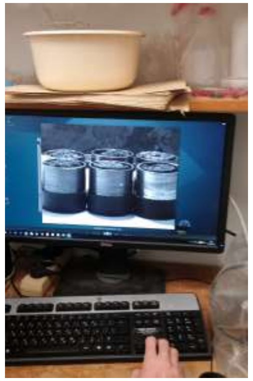
Spectral - Soil hydrophobicity mechanism investigation

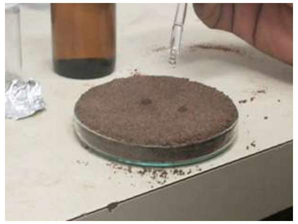
Spectral and Water repellency laboratory measurements

Cylinder’s levels

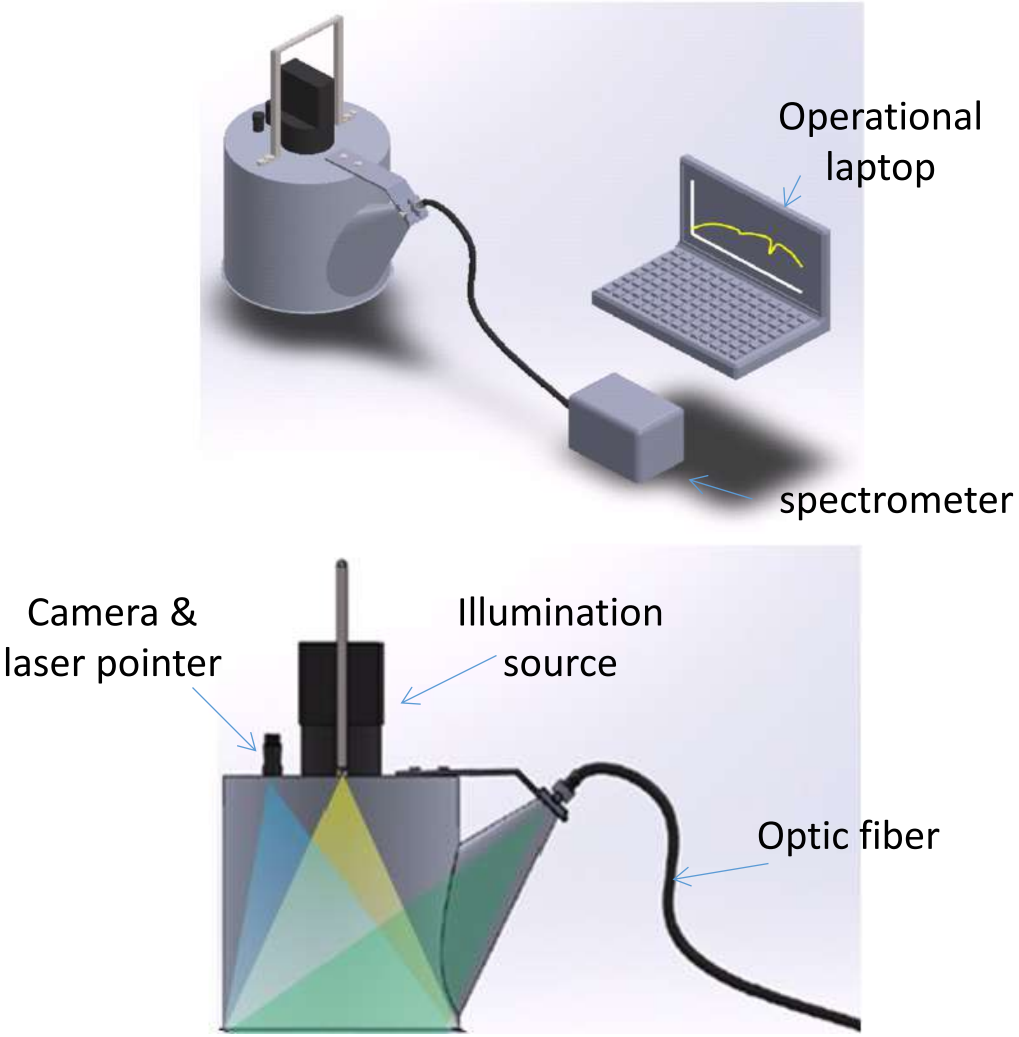


WDPT using continuous filming





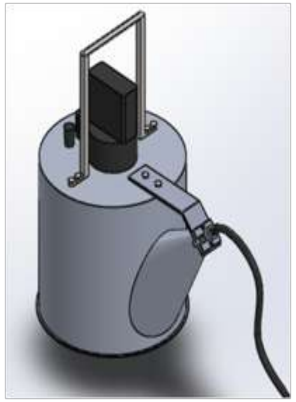
The "SoilPro" takes the advantages from each method while it is leave the disadvantages out

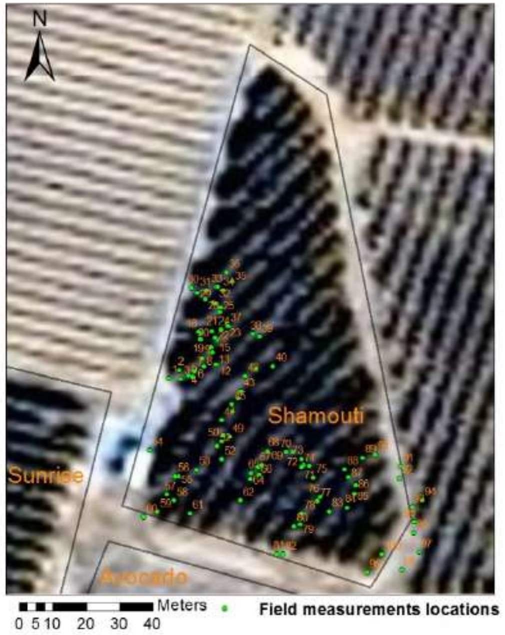


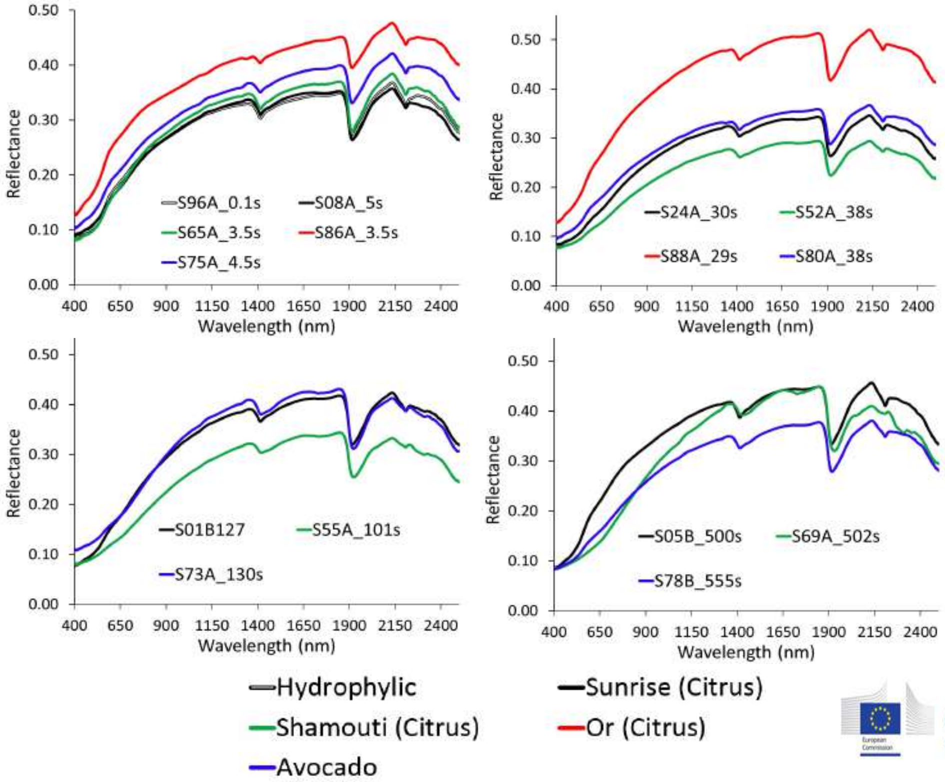
Field campaign

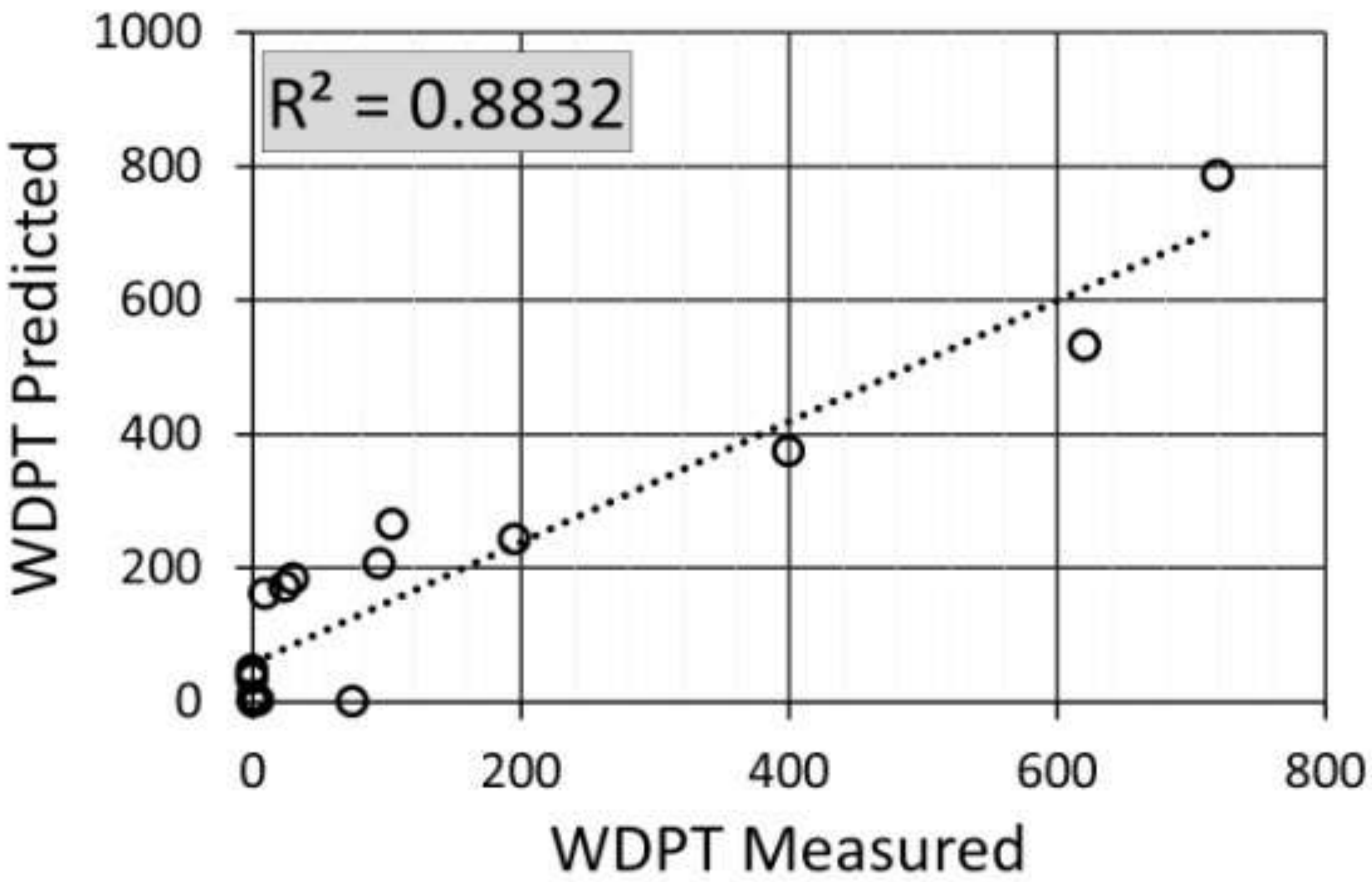
- The campaign was carried out in one plot
- Reflectance spectra obtain by utilizing the SoilPRO assembly
- Each location was marked and registered.
- During the campaign three testers were performing WDPT tests in the exact locations

100 SAMPLES 4 HOURS ONE USER



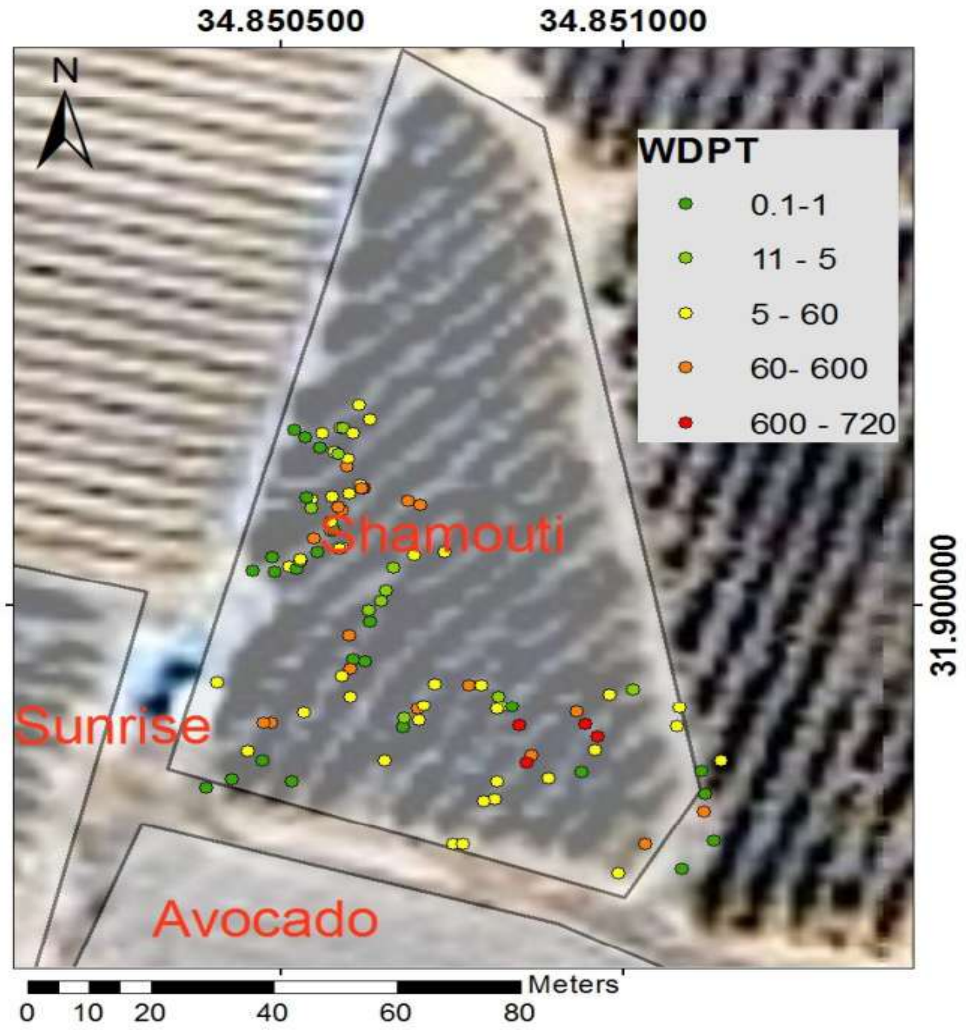






$R^2 = 0.8832$
WDPT Predicted
WDPT Measured
1000
800
600
400
200
0
0
200
400
600
800

Hydrophobicity quantity map of soil under shaded orchards trees



Infiltration rate to the soil profile (WIR)

Why Use Water Infiltration Rate (WIR)

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

- WIR is a very important hydrological parameter, which is strongly dependent on soil surface conditions.

- Thus, WIR is an excellent soil property to investigate the gap between lab and field spectral observations

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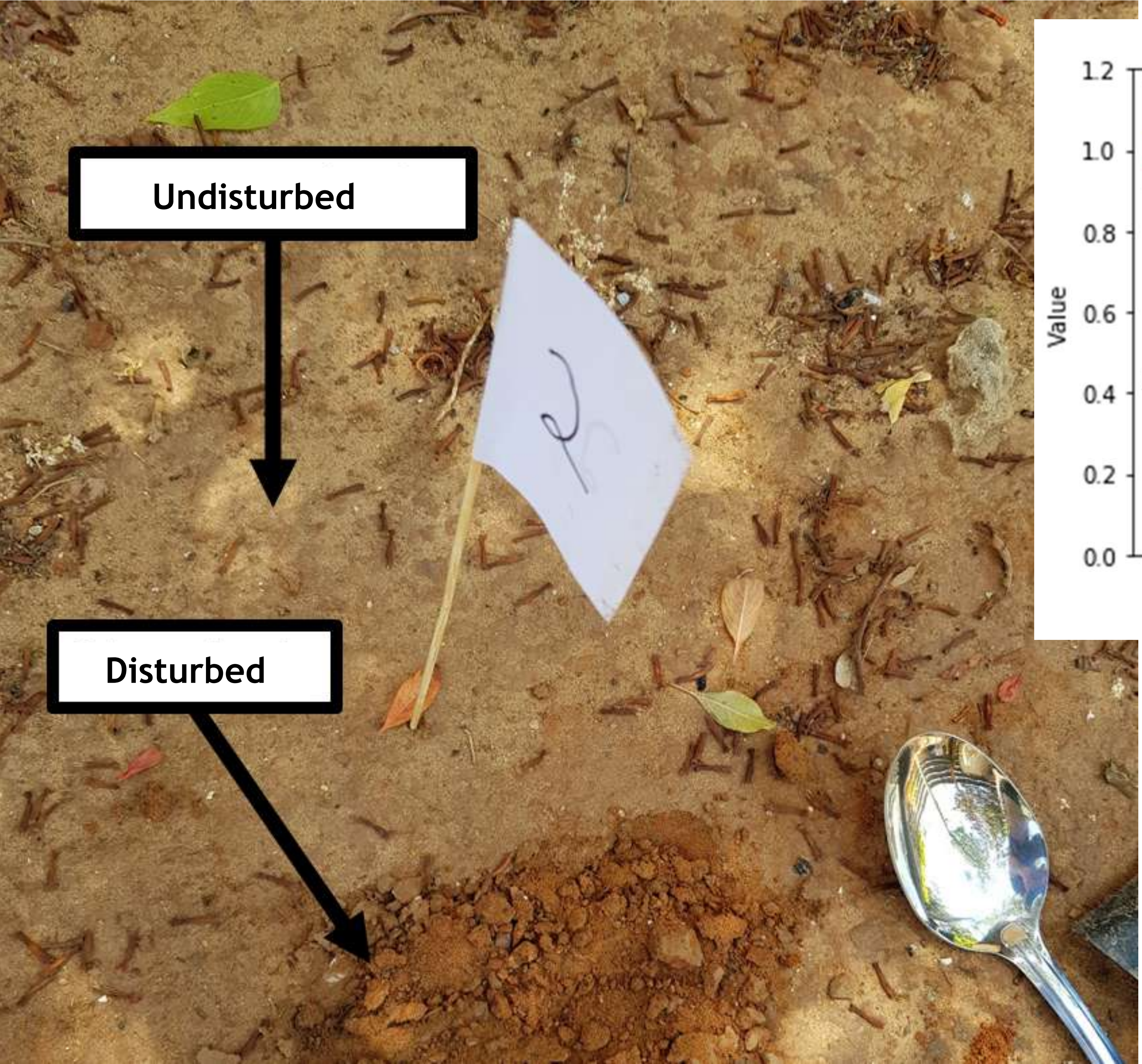
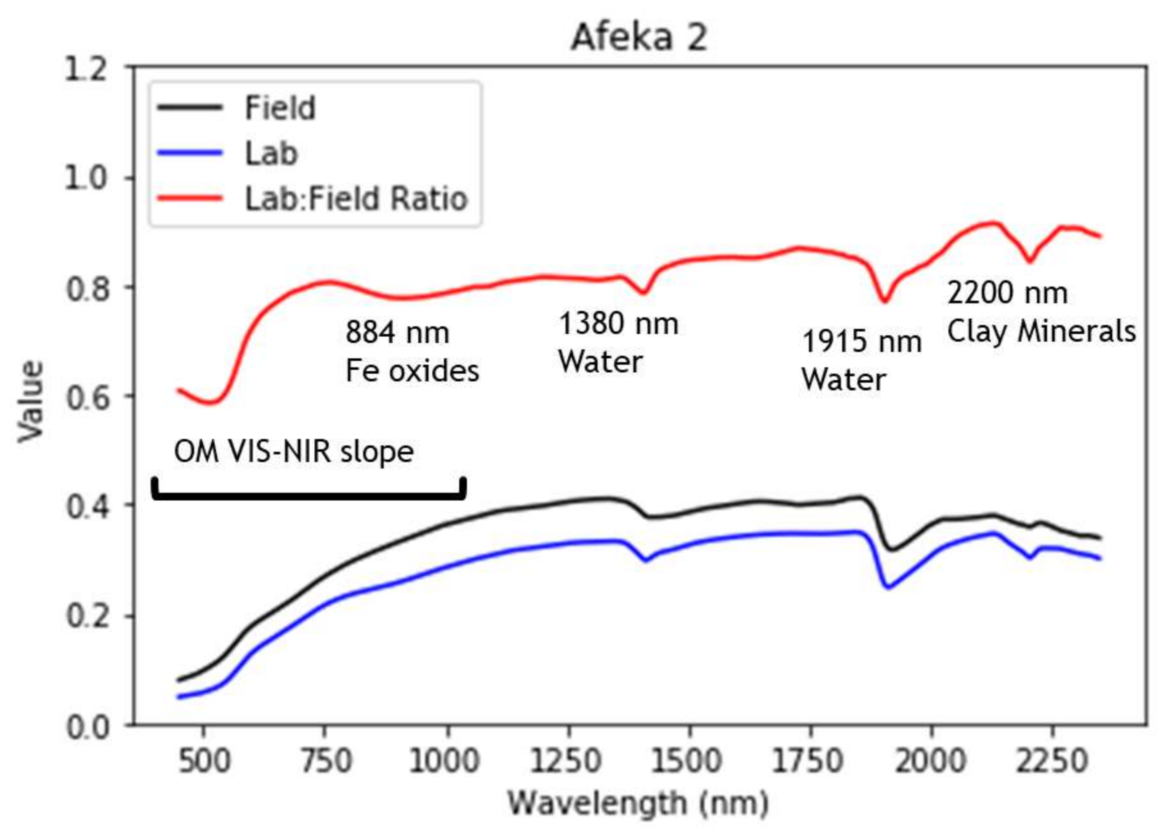
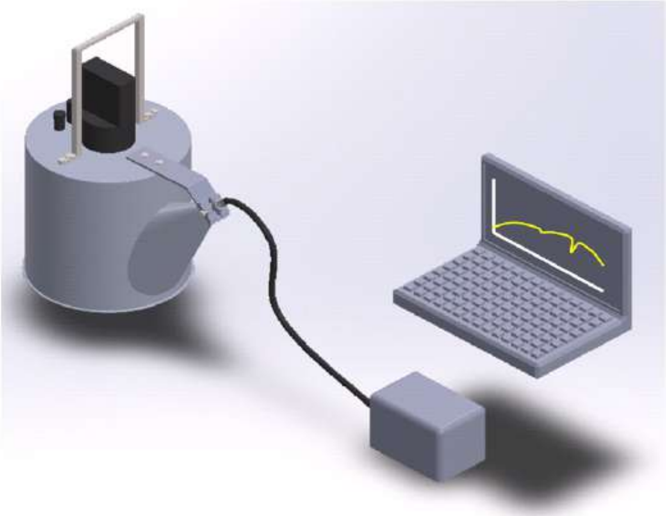
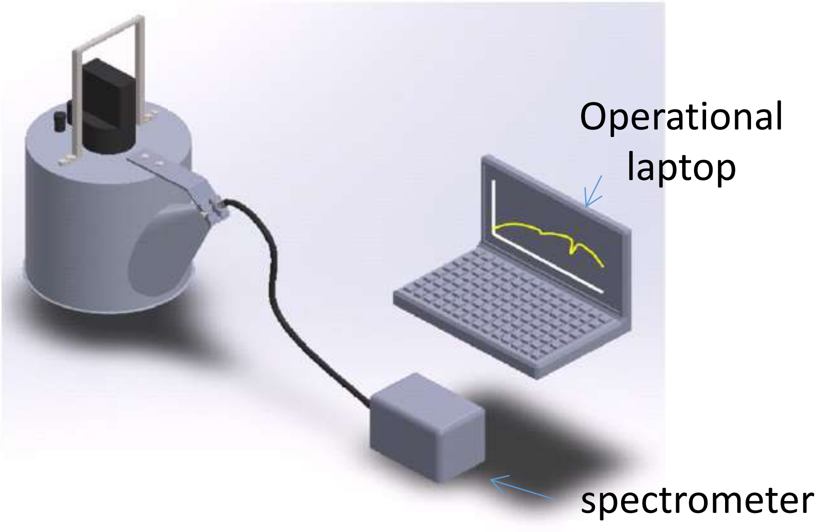

Undisturbed
Disturbed

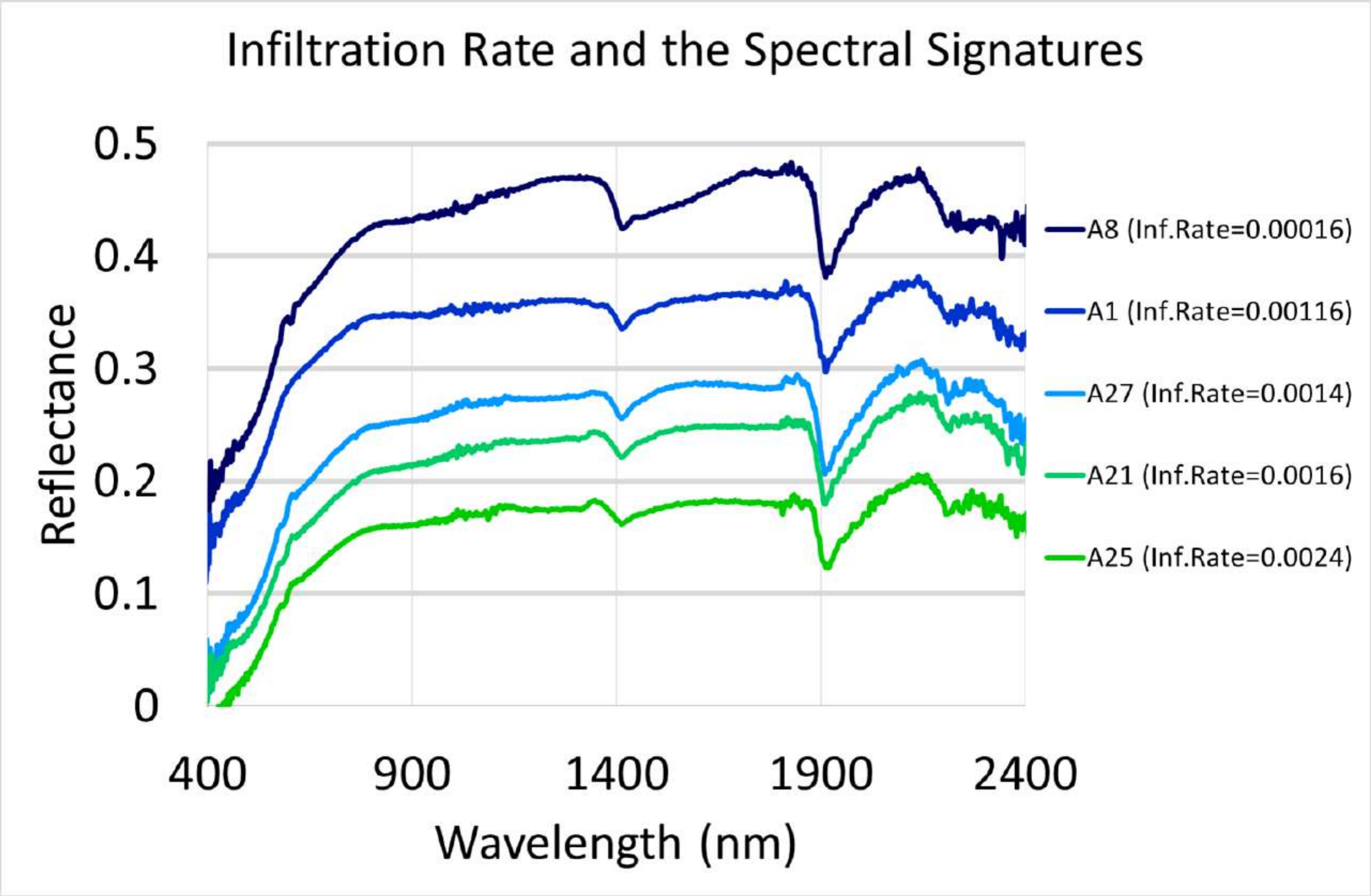

Afeka 2
Field
Lab
Lab:Field Ratio
884 nm
Fe oxides
1380 nm
Water
1915 nm
Water
2200 nm
Clay Minerals
OM VIS-NIR slope
Value
Wavelength (nm)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
500
750
1000
1250
1500
1750
2000
2250

- Field Spectral Measurements using ASD connected to SoilPro.

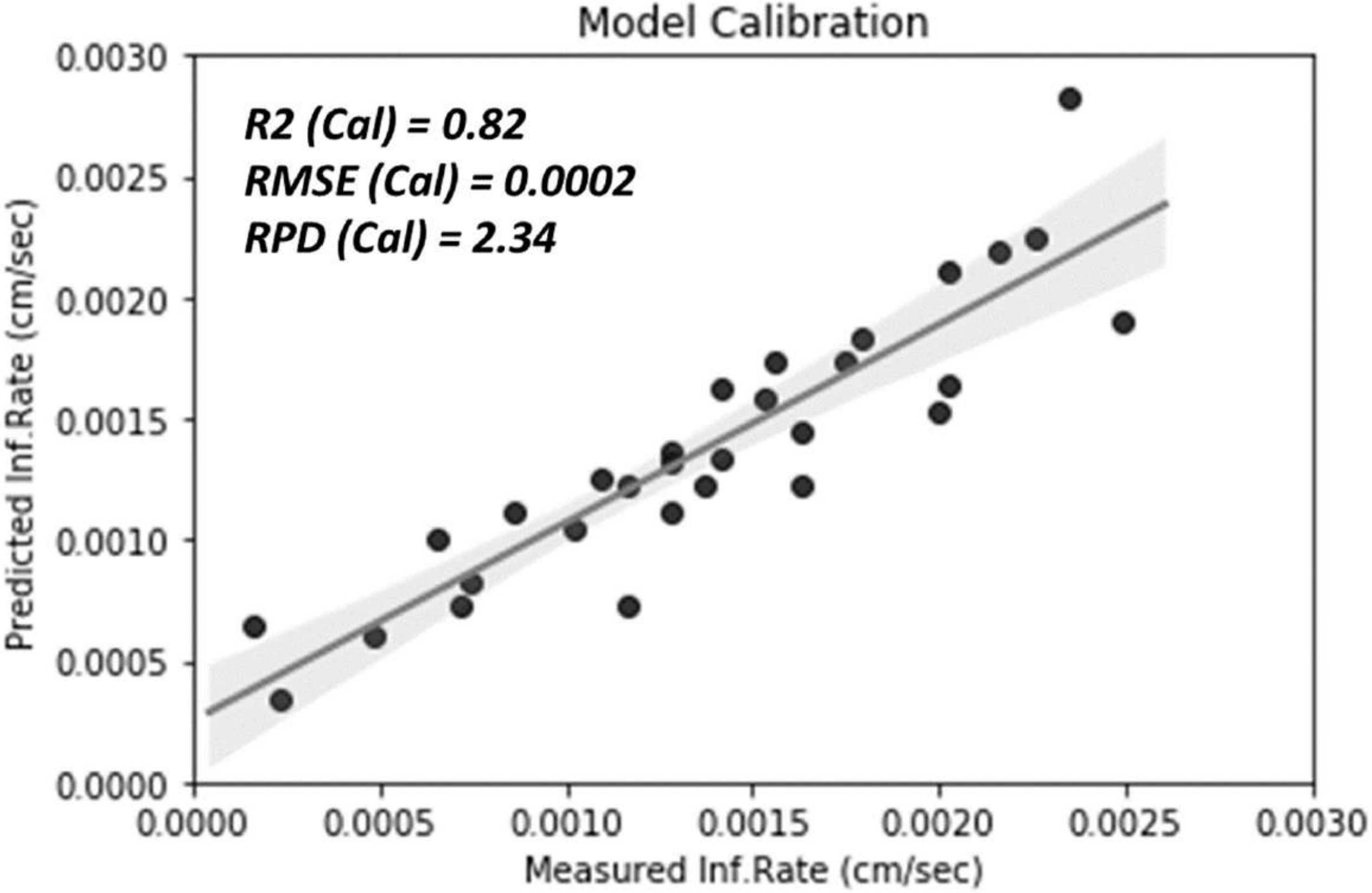


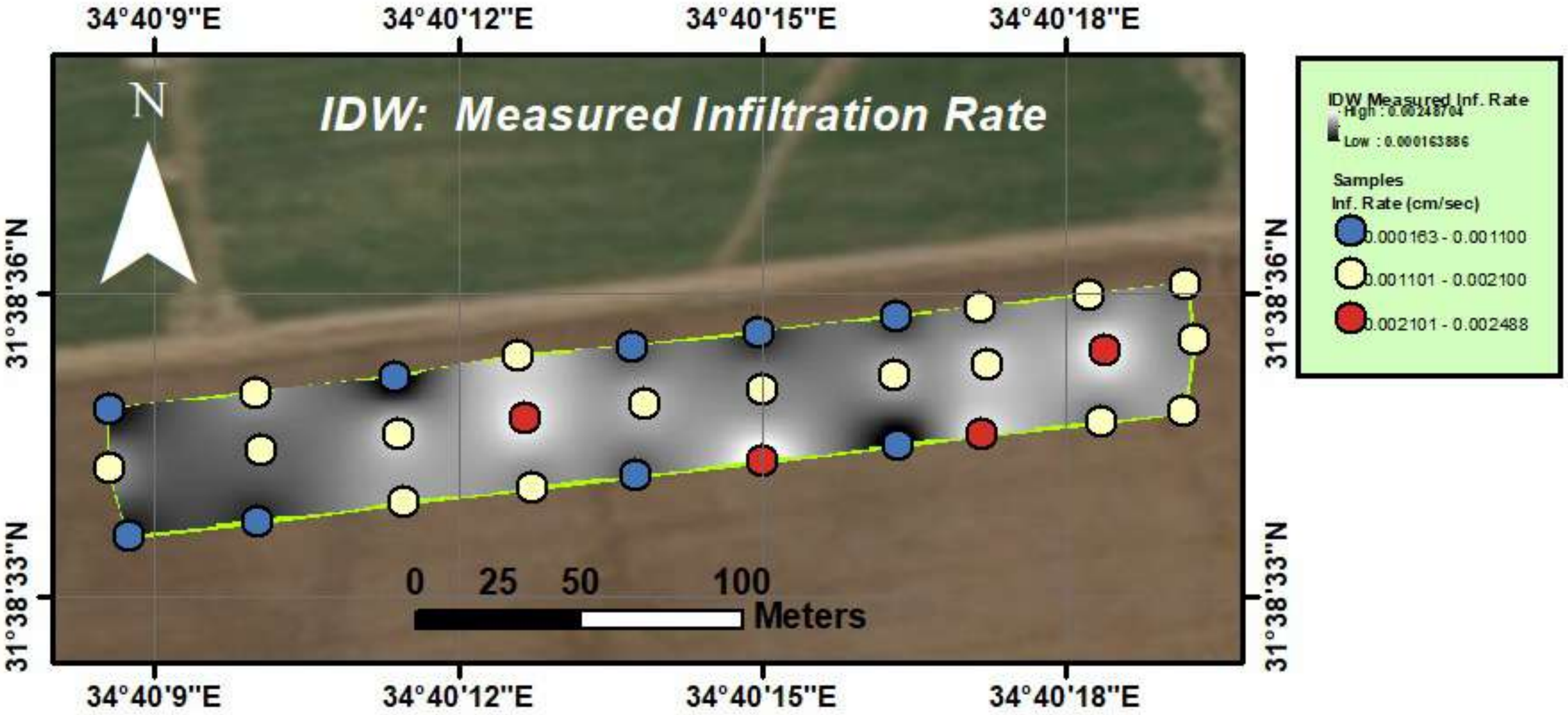
The "SoilPro" takes the advantages from each method while it is leave the disadvantages out




Infiltration Rate and the Spectral Signatures
0.5
0.4
0.3
0.2
0.1
0
Reflectance
400
900
1400
1900
2400
Wavelength (nm)
A8 (Inf.Rate=0.00016)
A1 (Inf.Rate=0.00116)
A27 (Inf.Rate=0.0014)
A21 (Inf.Rate=0.0016)
A25 (Inf.Rate=0.0024)


Lebanon
Beirut
Damascus
Golan Heights
Tel Aviv-Yafo
West Bank
Amman
Jerusalem
Sde Yoav
Gaza
Gaza Strip
Israel
North Sinai
Jordan
Google Earth


Model Calibration
R2 (Cal) = 0.82
RMSE (Cal) = 0.0002
RPD (Cal) = 2.34
Predicted Inf.Rate (cm/sec)
Measured Inf.Rate (cm/sec)
0.0000
0.0005
0.0010
0.0015
0.0020
0.0025
0.0030



IDW: Measured Infiltration Rate
N
34°40'9"E
34°40'12"E
34°40'15"E
34°40'18"E
31°38'36"N
31°38'33"N
0 25 50 100
Meters
IDW Measured Inf. Rate
High : 0.00248704
Low : 0.000163886
Samples
Inf. Rate (cm/sec)
0.000163 - 0.001100
0.001101 - 0.002100
0.002101 - 0.002488

(a)

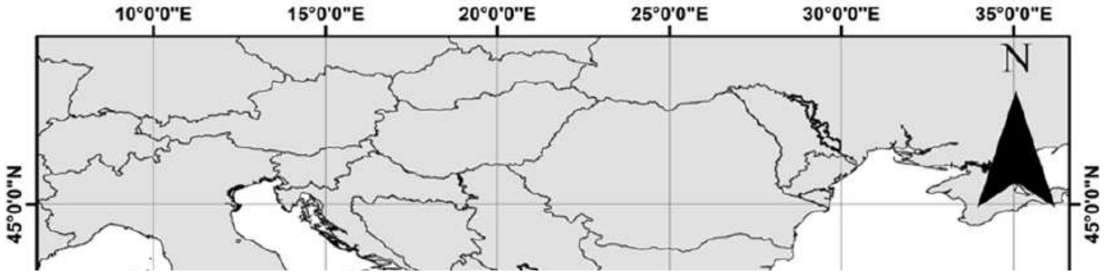
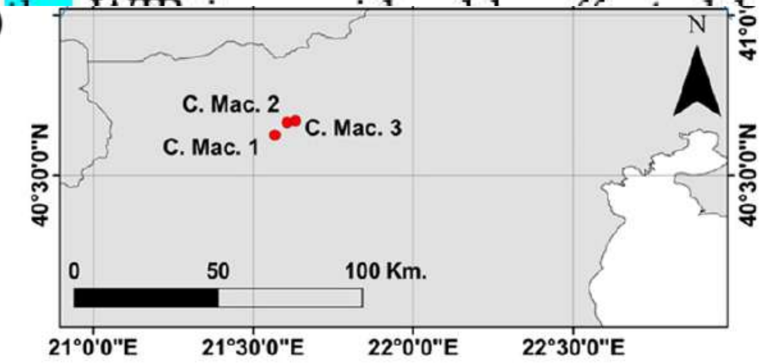


Table 1. Texture classes based on the assigned texture classification of the studied sites.

Field	Country	No. of Samples	Classification	Texture Group
Sde Yoav	Israel	30	Clay Loam	Clayey (heavy)
Afeka	Israel	18	Sandy Clay Loam	Clayey (heavy)
Alento	Italy	21	Loam	Clayey (heavy)
C. Macedonia 1	Greece	16	Sand	Sandy (light)
C. Macedonia 2	Greece	15	Sandy Loam	Sandy (light)
C. Macedonia 3	Greece	14	Sandy Loam	Sandy (light)

(b)



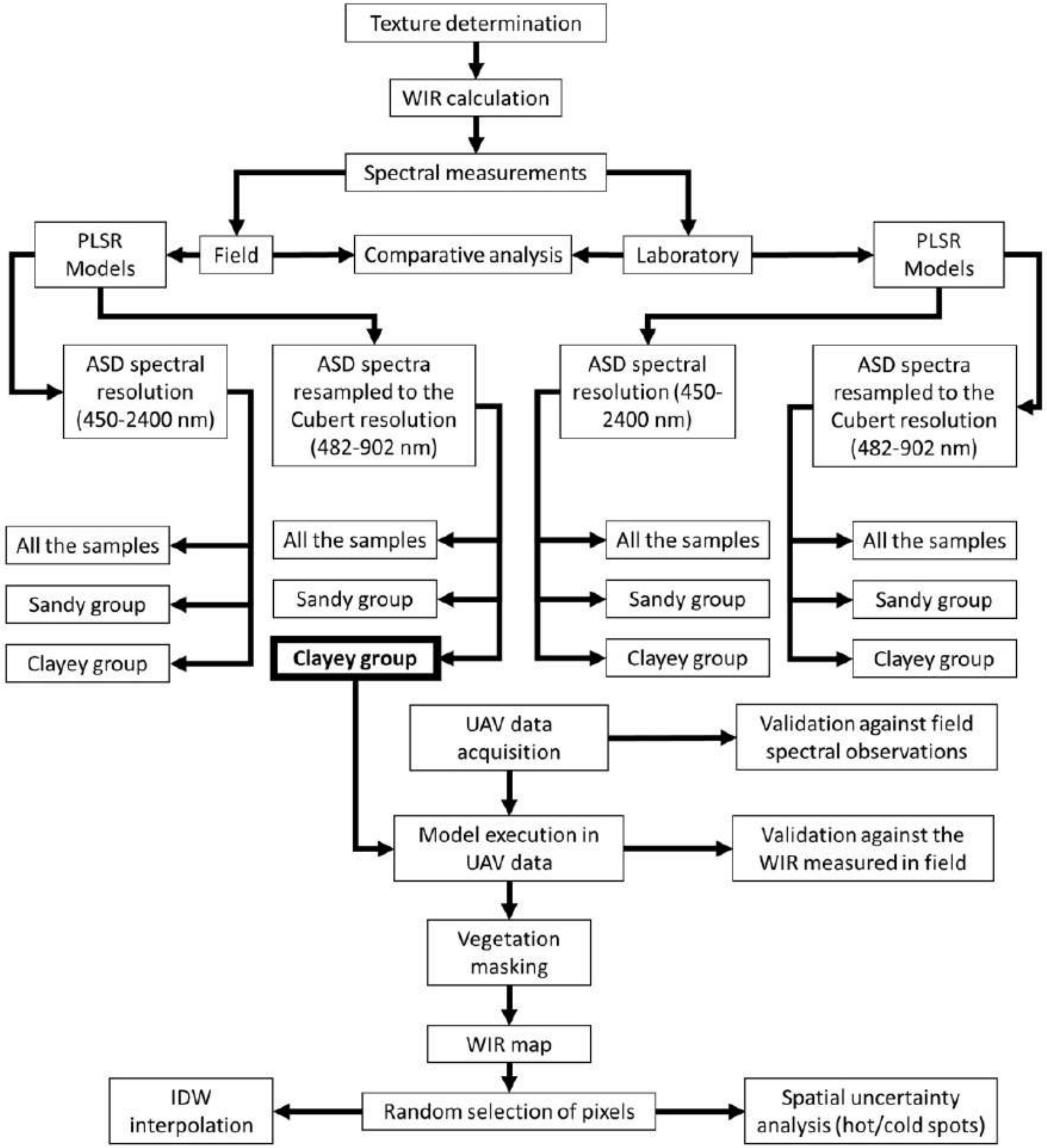
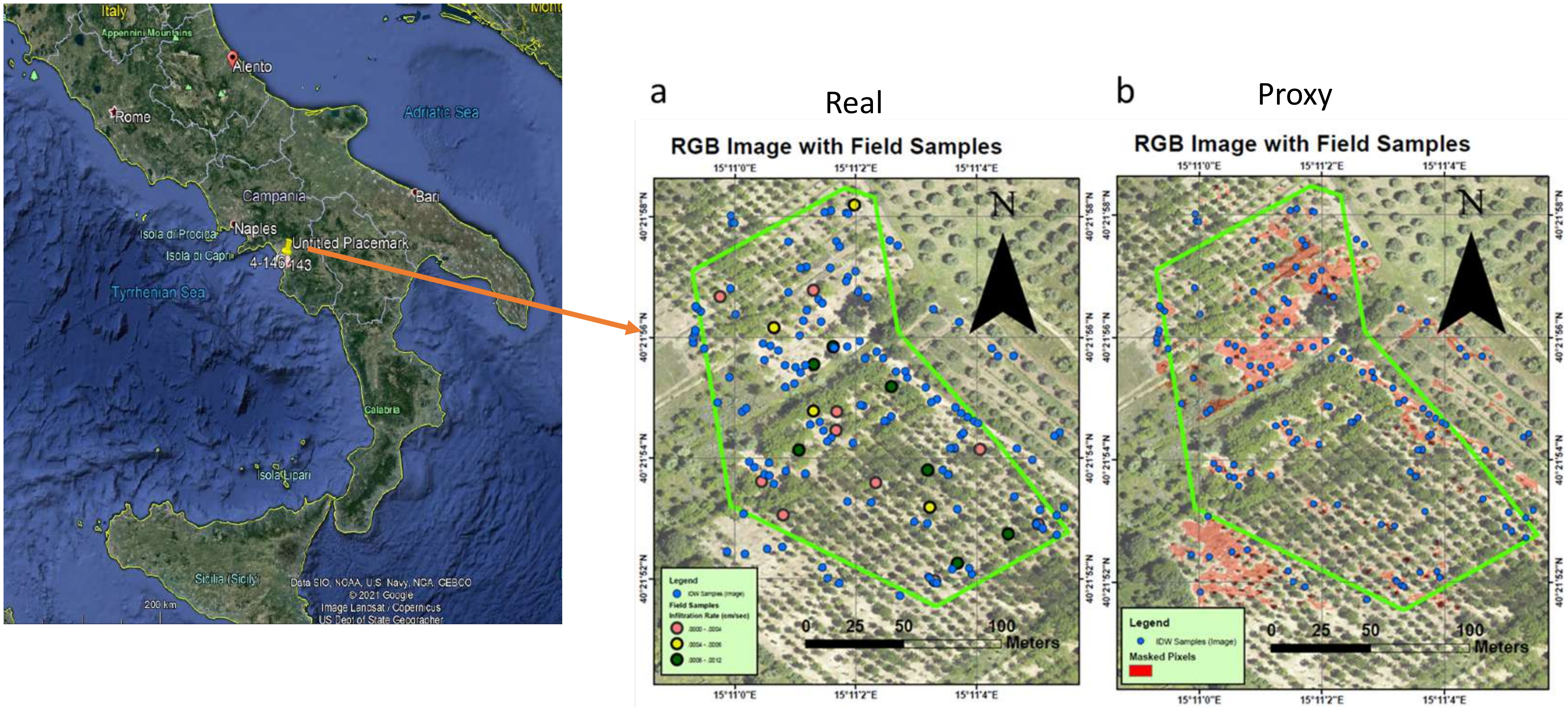
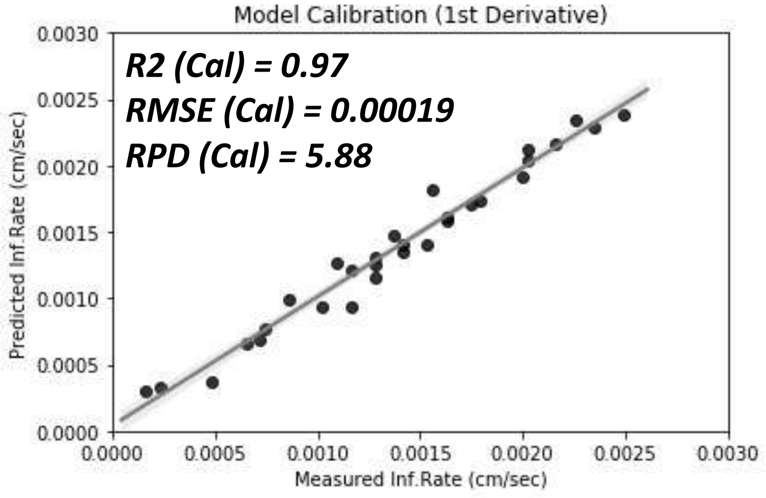
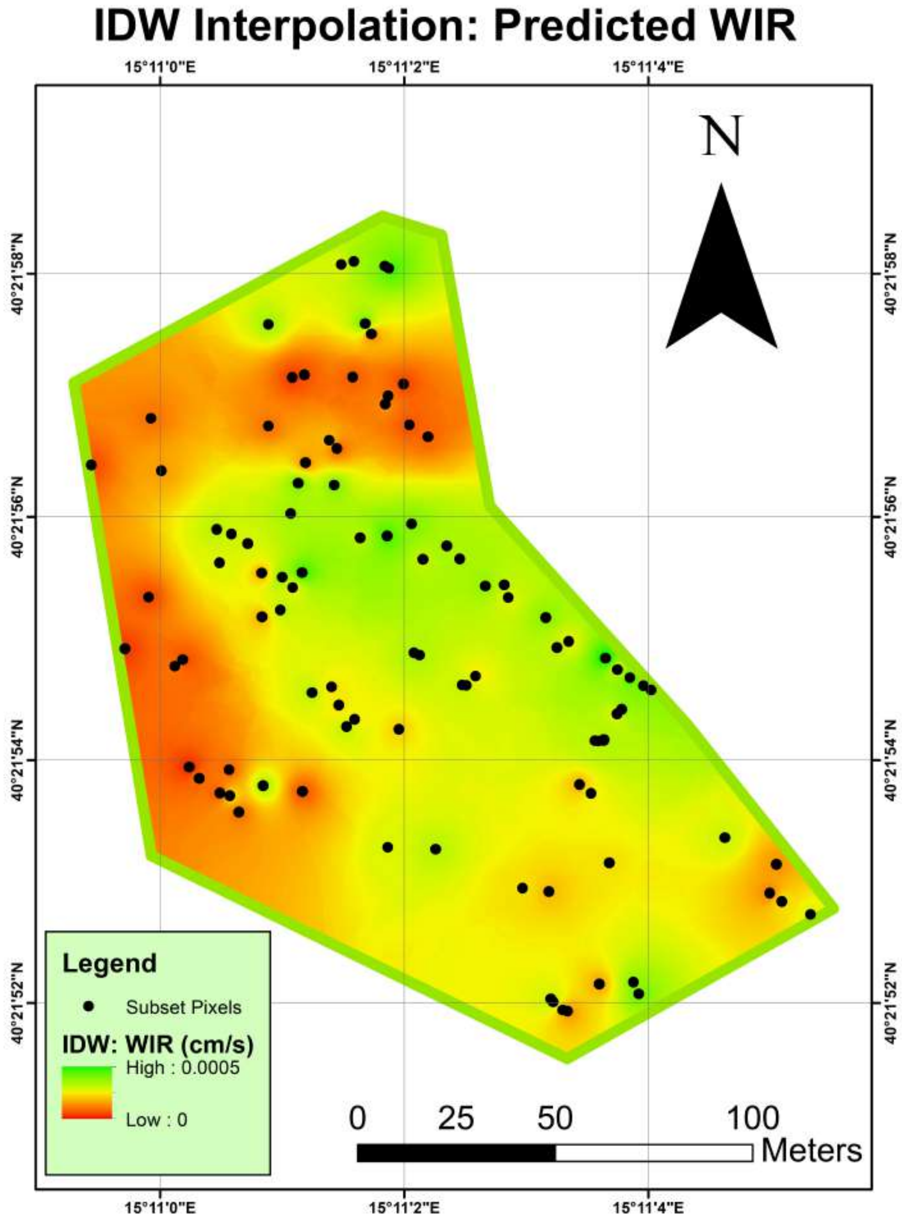


Figure 4. Flowchart of the methods followed in this work.

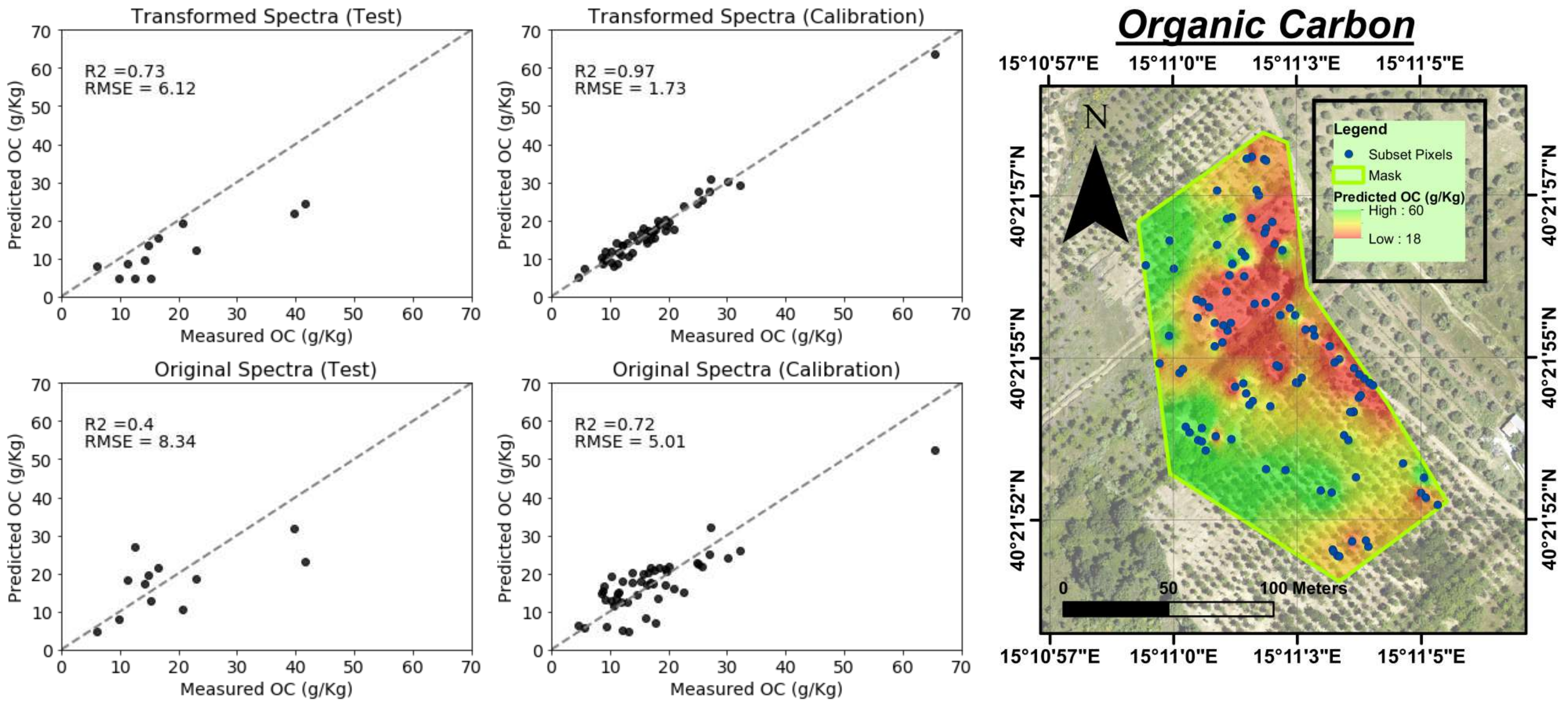


Italy
Appennini Mountains
Aliento
Rome
Adriatic Sea
Campania
Bari
Naples
Isola di Procida
Isola di Capri
Untitled Placemark
Tyrrhenian Sea
Calabria
Isola Lipari
Sicilia (Sicily)
200 km
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2021 Google
Image Landsat / Copernicus
US Dept of State Geographer
a
Real
RGB Image with Field Samples
15°11'0"E
15°11'2"E
15°11'4"E
40°21'58"N
40°21'56"N
40°21'54"N
40°21'52"N
N
Legend
Field Samples
0
25
50
100
Meters
b
Proxy
RGB Image with Field Samples
Legend
IDW Samples (Image)
Masked Pixels

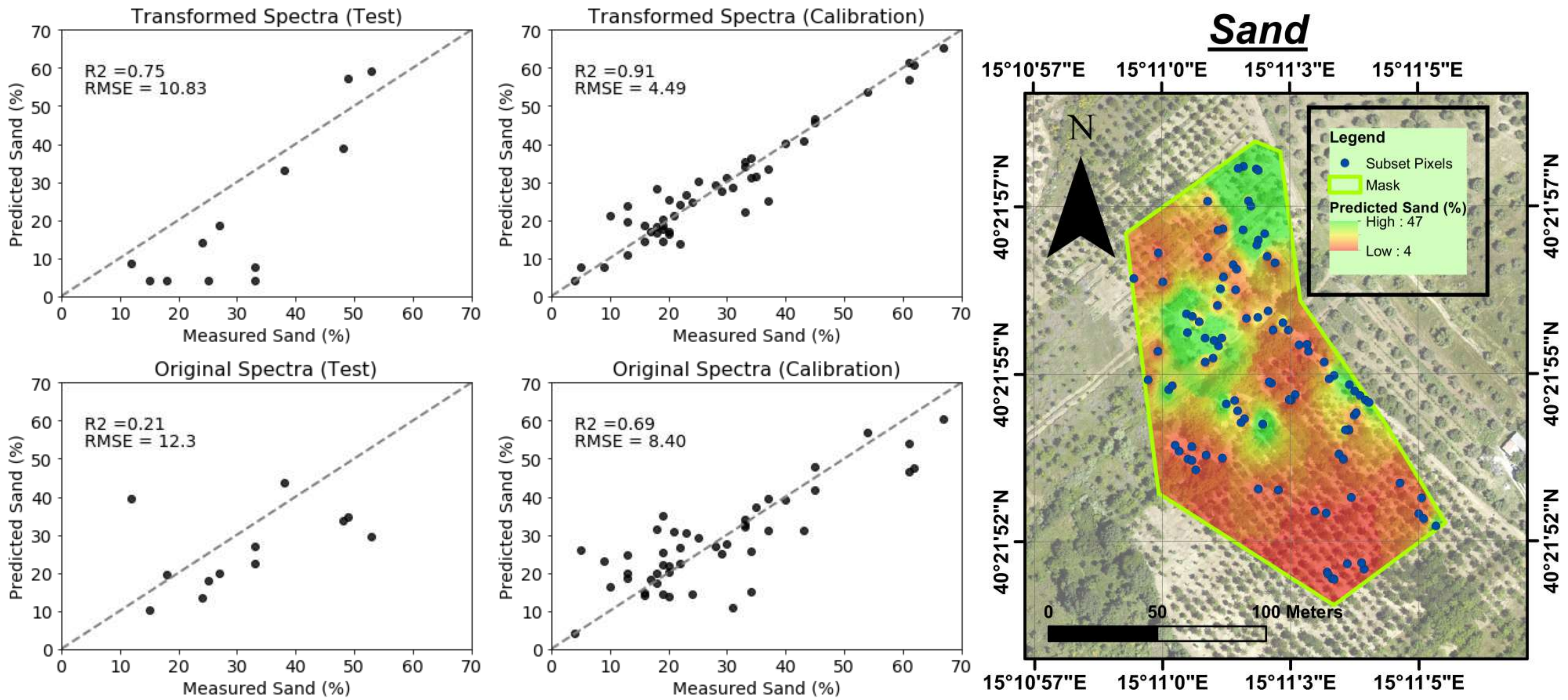




THE REMOTE SENSING LABORATORIES



THE REMOTE SENSING LABORATORIES



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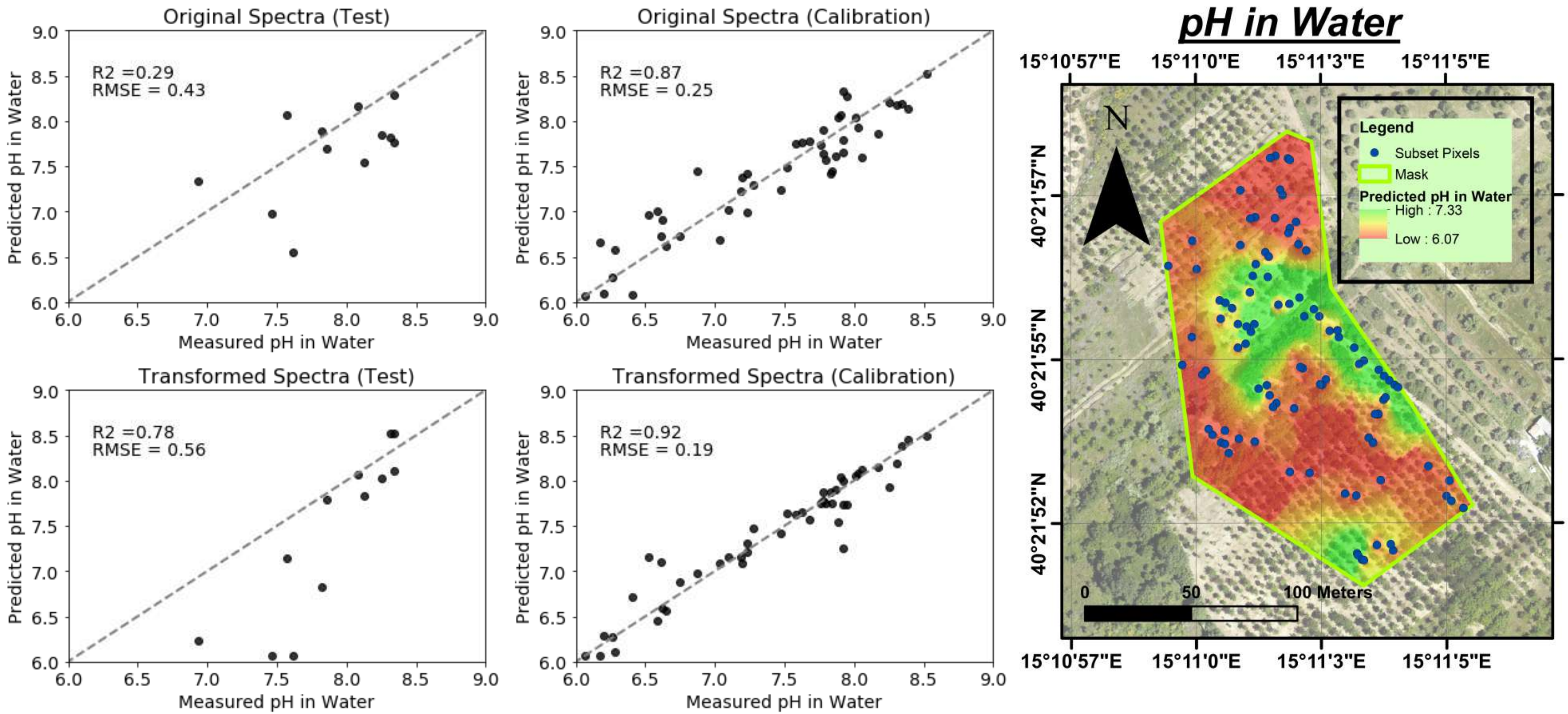

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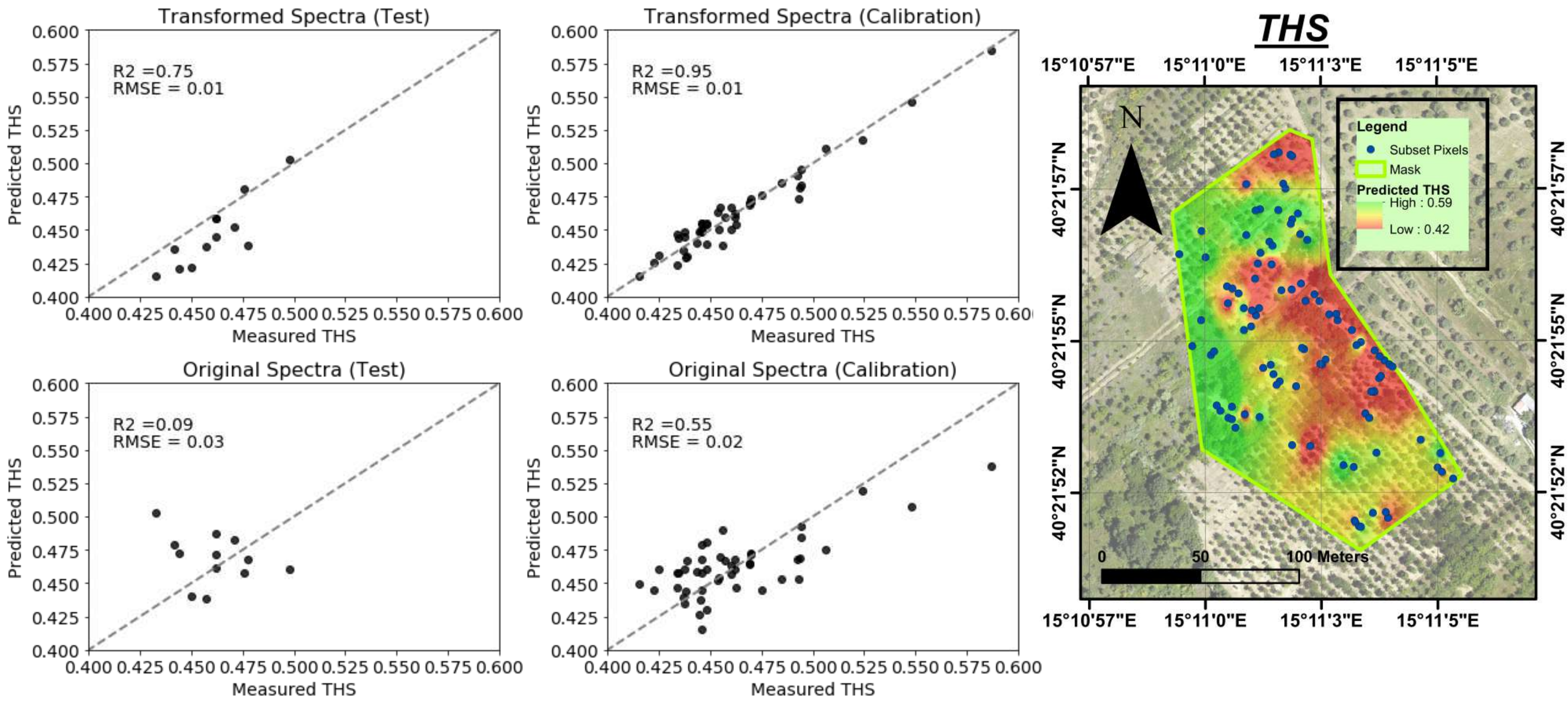

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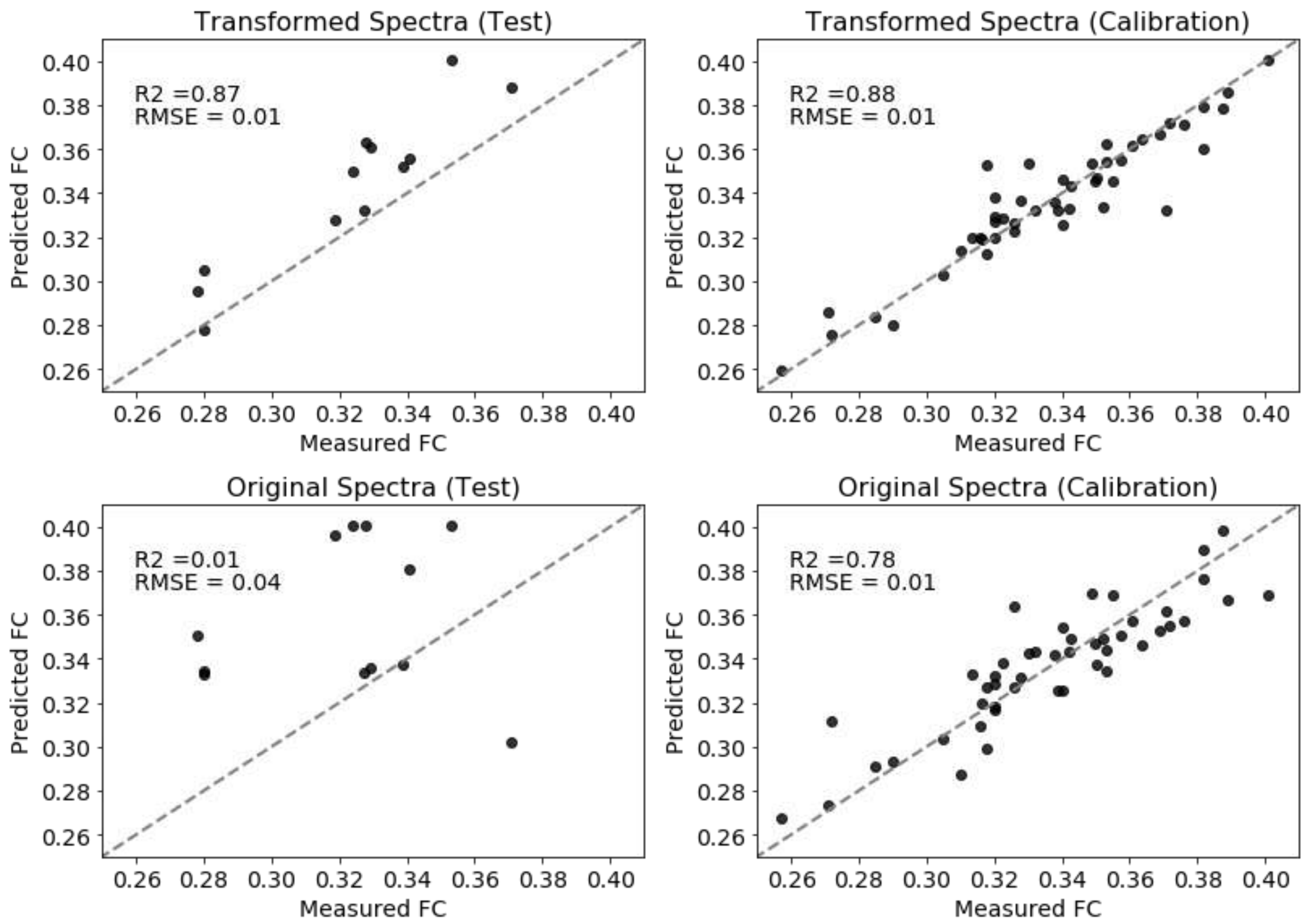

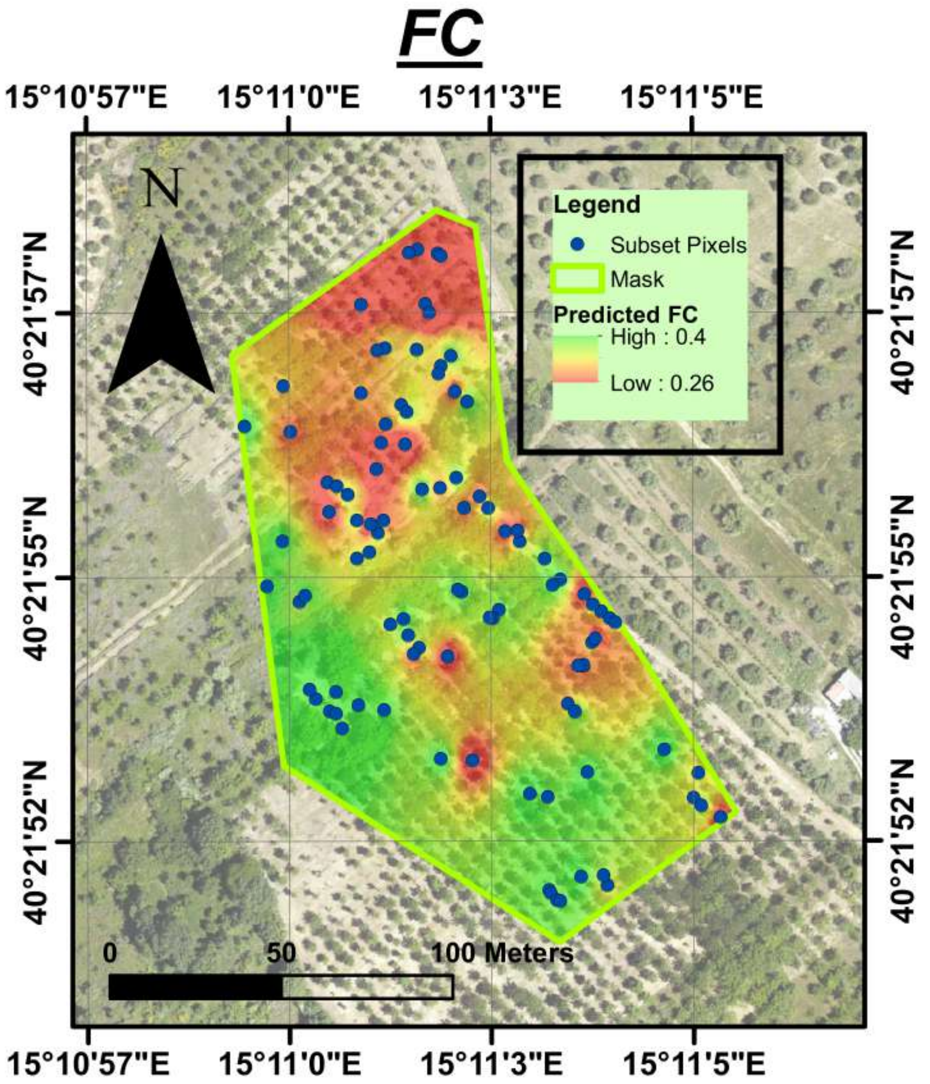

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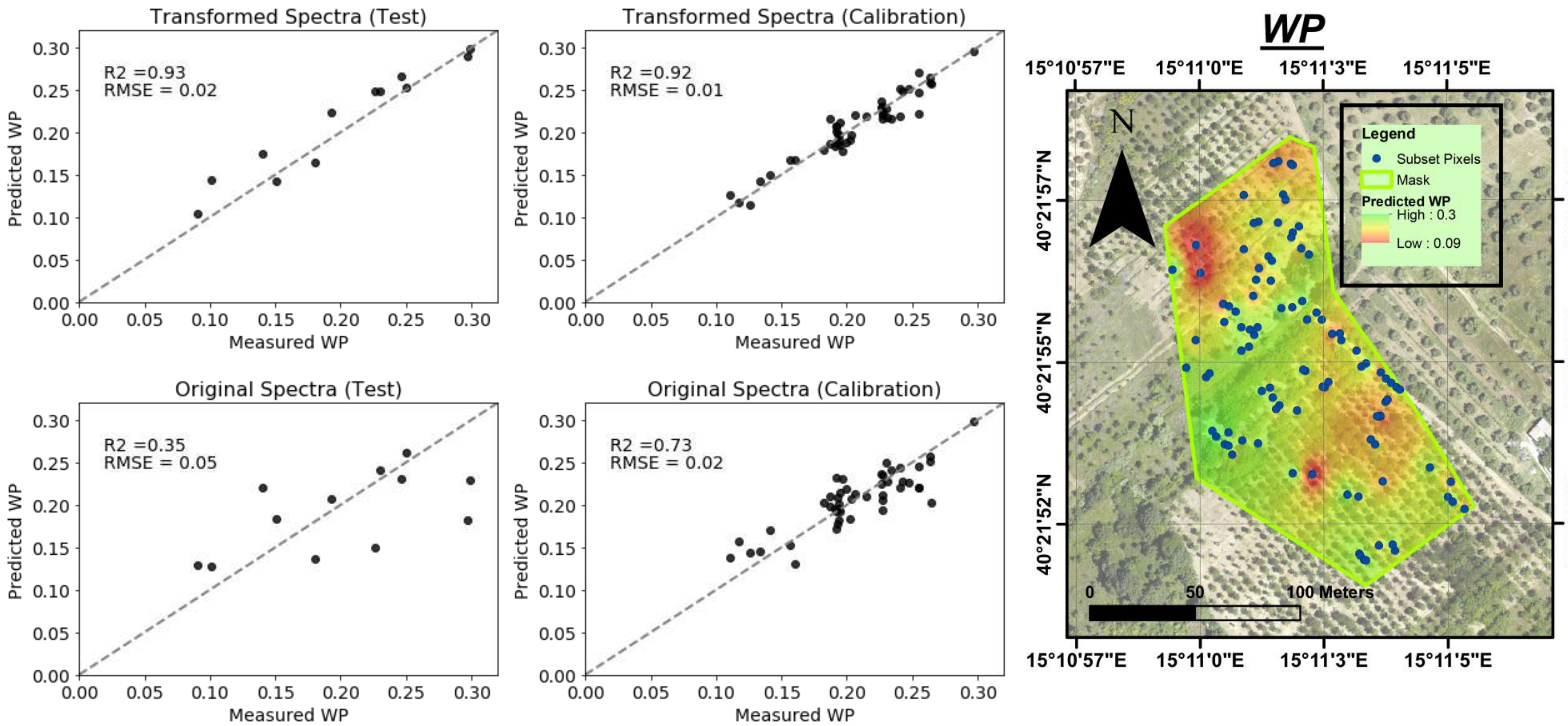

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Soil Spectral Library – lab vs. field

- In different areas of the Mediterranean Basin we measured the WIR using a Mini Disk infiltrometer.

- Next, we measured the spectral signature in field and in the lab.

- The field spectra was measured using a ASD connected to SoilPro (Ben Dor et al., 2017) in order to get optimal spectral signatures in field

- Soil in the laboratory measured by the CSIRO protocol

THE REMOTE SENSING LABORATORIES

Estimating WIR in Soils Using Airborne HRS and S2 –Greec

Hyspex

HySpex
by neo

Spectral range	960-2500 nm
Spatial pixels	640
Spectral channels	360
Spectral sampling	4.38 nm
FOV*	16°
Pixel FOV across/along*	0.44/0.44 mrad
Bit resolution	16 bit
Noise floor	80 e-
Dynamic range	7500
Peak SNR (at full resolution)	> 800
Max speed (at full resolution)	140 fps
Power consumption	10 W
Dimensions (l–w–h)	36 – 11– 15 cm
Weight	4.1 kg
Camera Interface	CameraLink

*Can be doubled with FOV expander

Sentinel 2

Spectral bands for the Sentinel-2 sensors[17]

Sentinel-2 bands	Sentinel-2A		Sentinel-2B		
	Central wavelength (nm)	Bandwidth (nm)	Central wavelength (nm)	Bandwidth (nm)	Spatial resolution (m)
Band 1 – Coastal aerosol	442.7	21	442.2	21	60
Band 2 – Blue	492.4	66	492.1	66	10
Band 3 – Green	559.8	36	559.0	36	10
Band 4 – Red	664.6	31	664.9	31	10
Band 5 – Vegetation red edge	704.1	15	703.8	16	20
Band 6 – Vegetation red edge	740.5	15	739.1	15	20
Band 7 – Vegetation red edge	782.8	20	779.7	20	20
Band 8 – NIR	832.8	106	832.9	106	10
Band 8A – Narrow NIR	864.7	21	864.0	22	20
Band 9 – Water vapour	945.1	20	943.2	21	60
Band 10 – SWIR – Cirrus	1373.5	31	1376.9	30	60
Band 11 – SWIR	1613.7	91	1610.4	94	20
Band 12 – SWIR	2202.4	175	2185.7	185	20

Campaign of Greece, September, 2019

The study sites in Central Macedonia, Greece: a) the 1st study site, b) the 2nd study site, and c) the 3rd study site.

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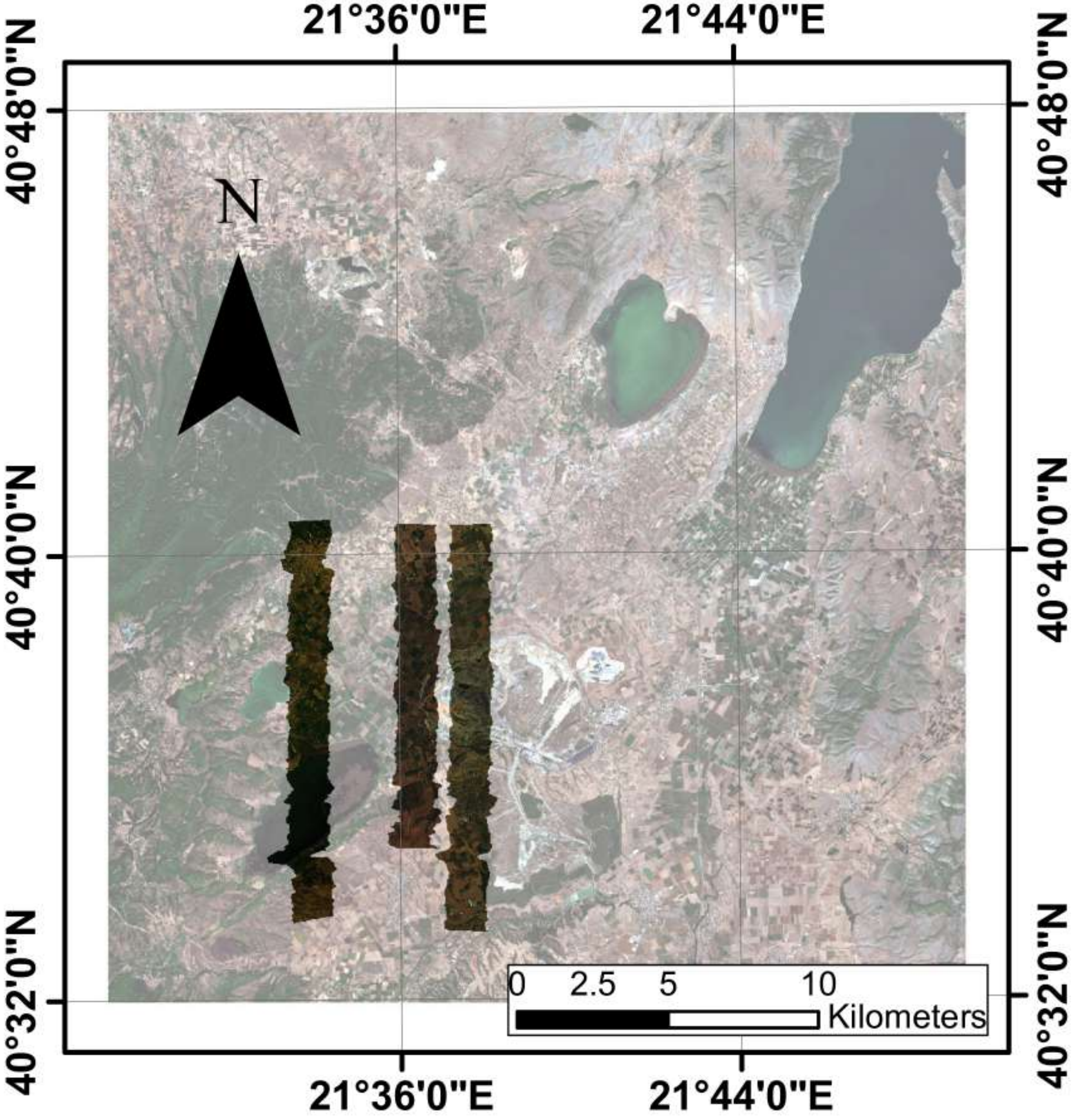
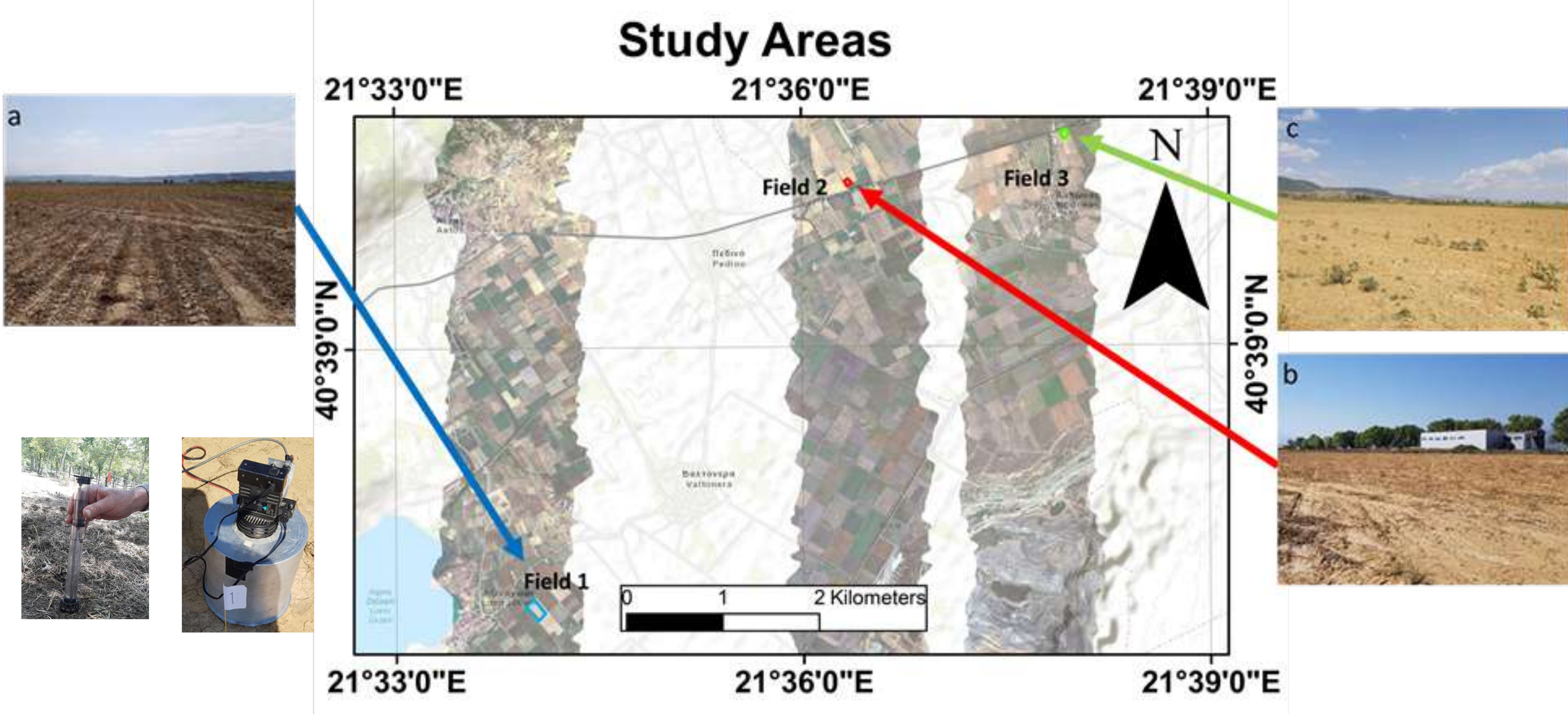
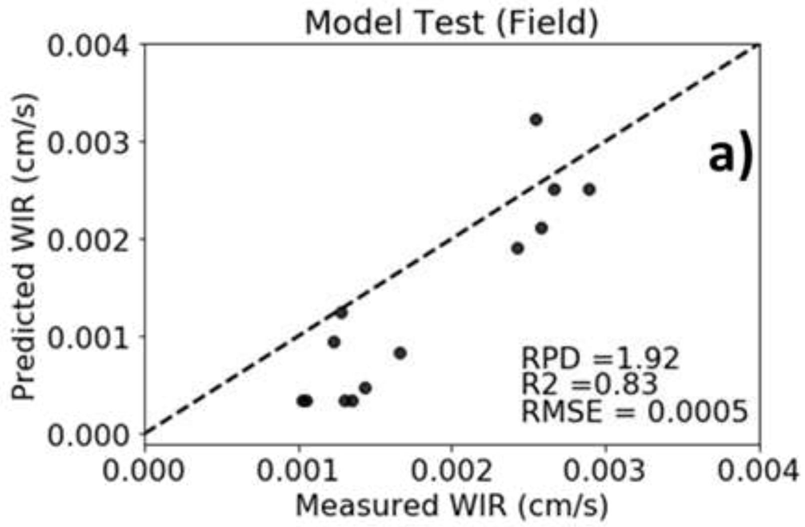
S2 subset and the Hyspex flights

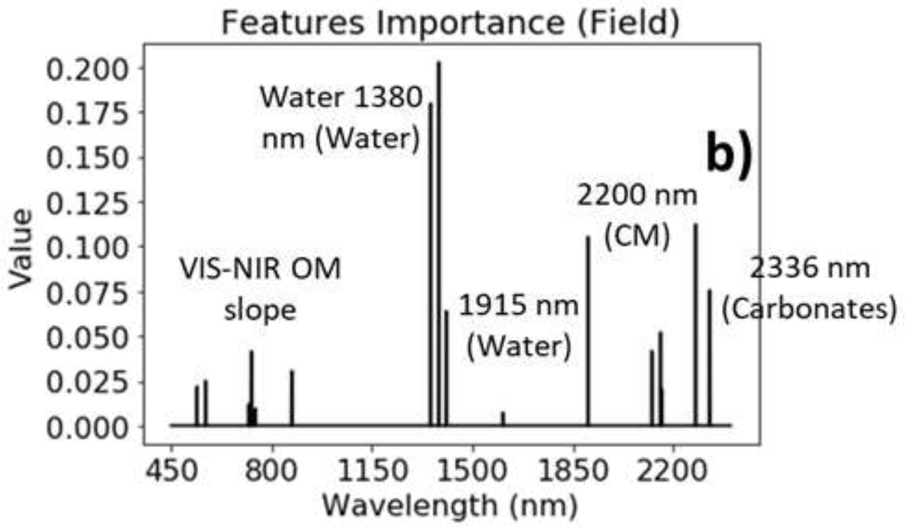


Study Areas


Study Areas
21°33'0"E
21°36'0"E
21°39'0"E
40°39'0"N
Field 1
Field 2
Field 3
N
0
1
2 Kilometers
a
b
c

ASD RESOLUTION





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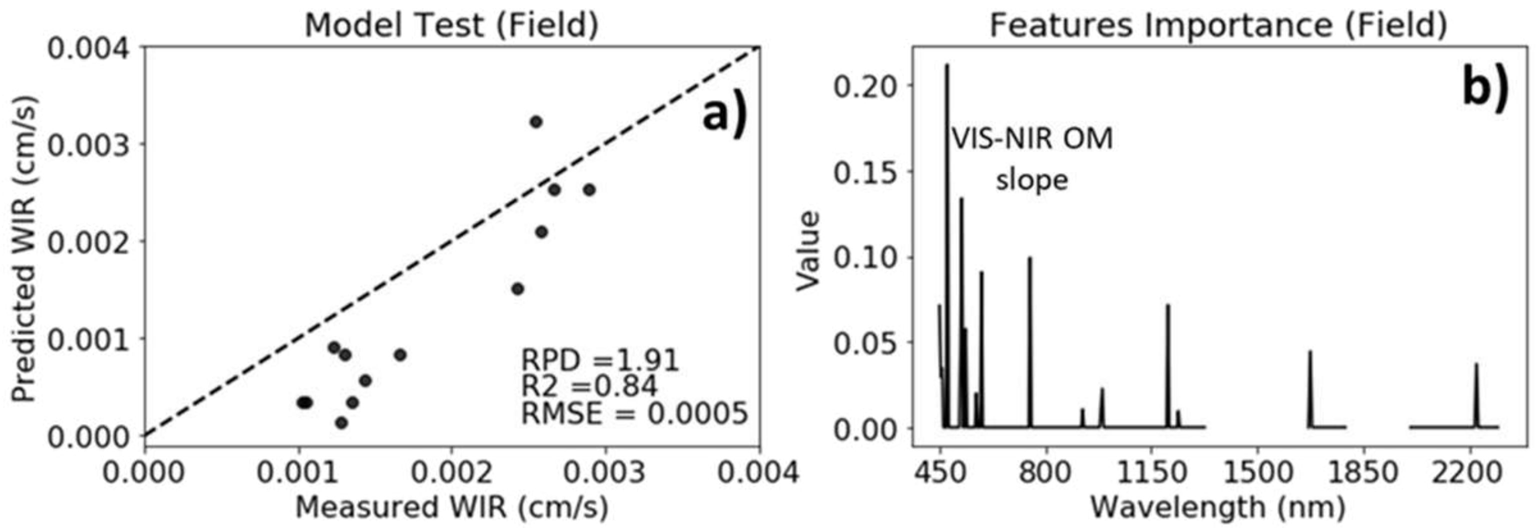
HYSPEX RESOLUTION



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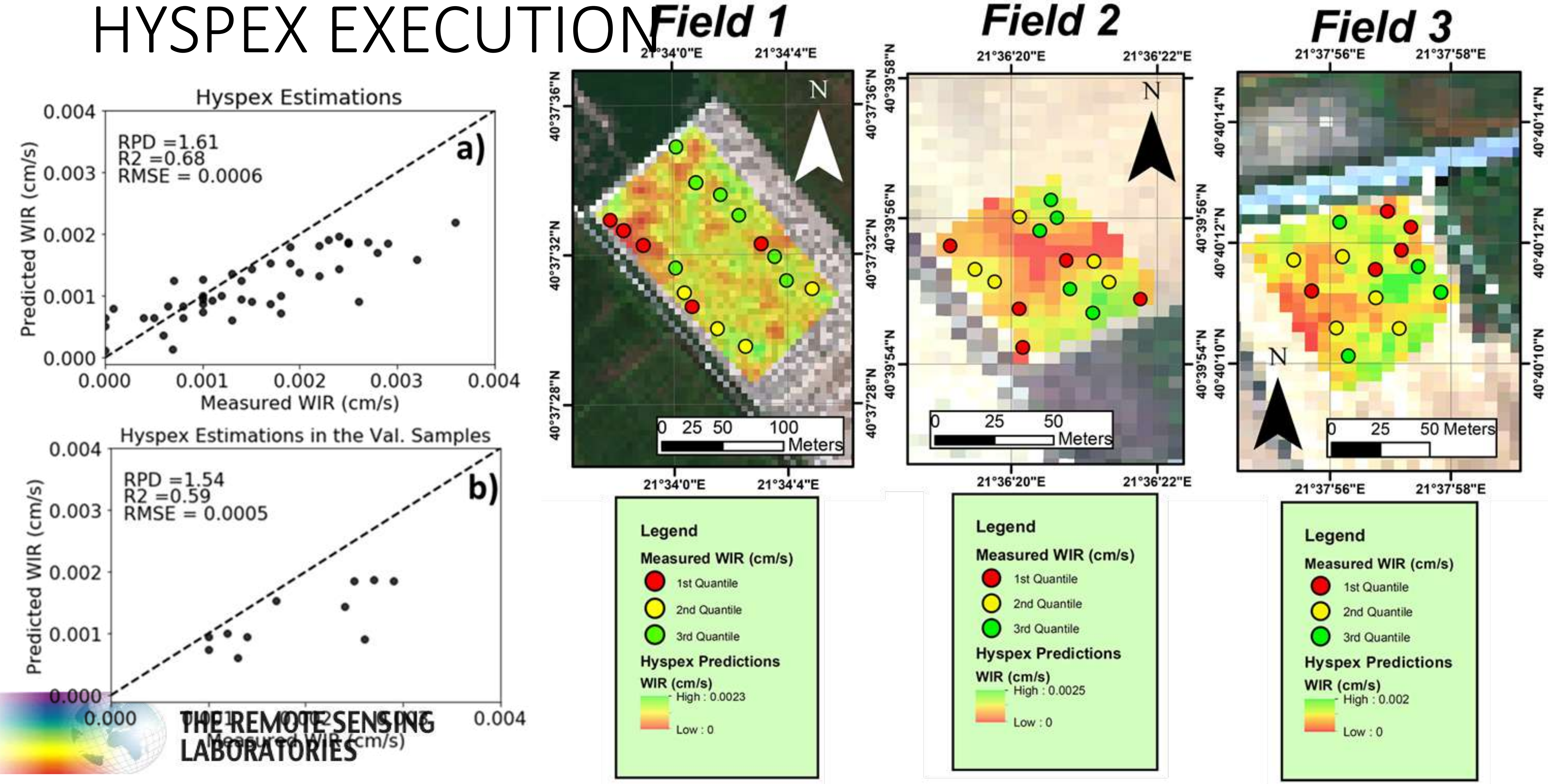
HYSPEX EXECUTION



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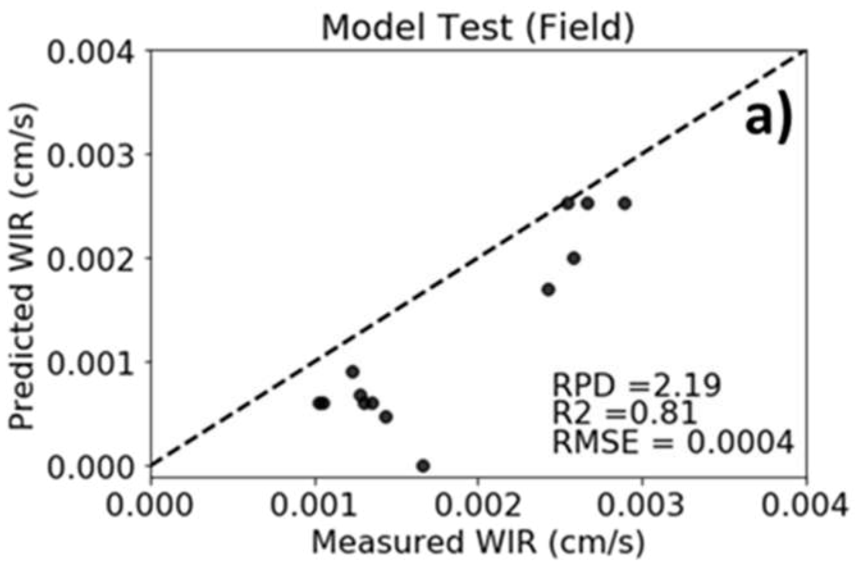
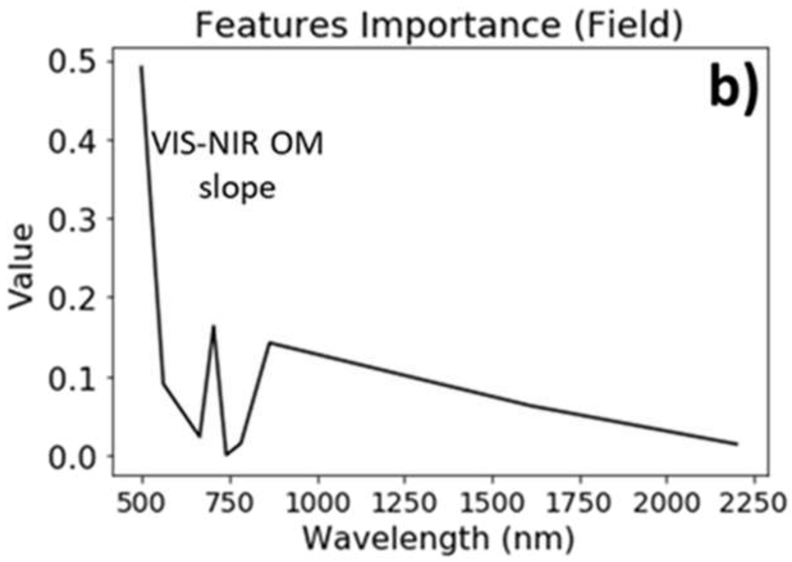
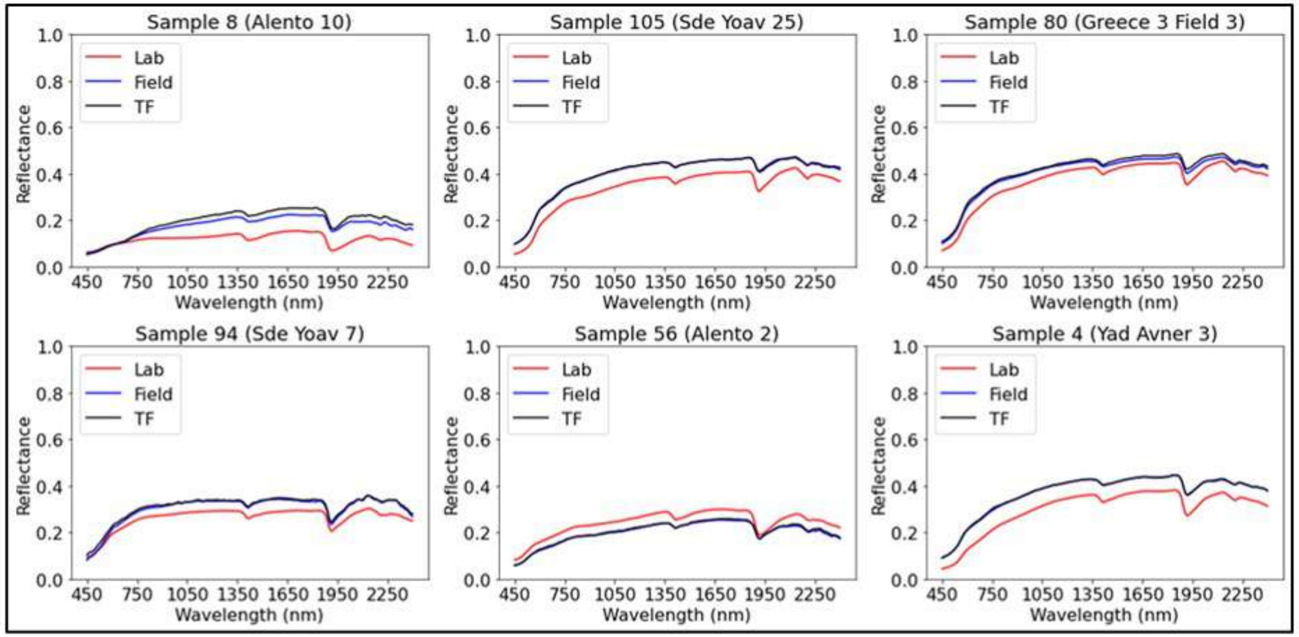
S2 RESOLUTION

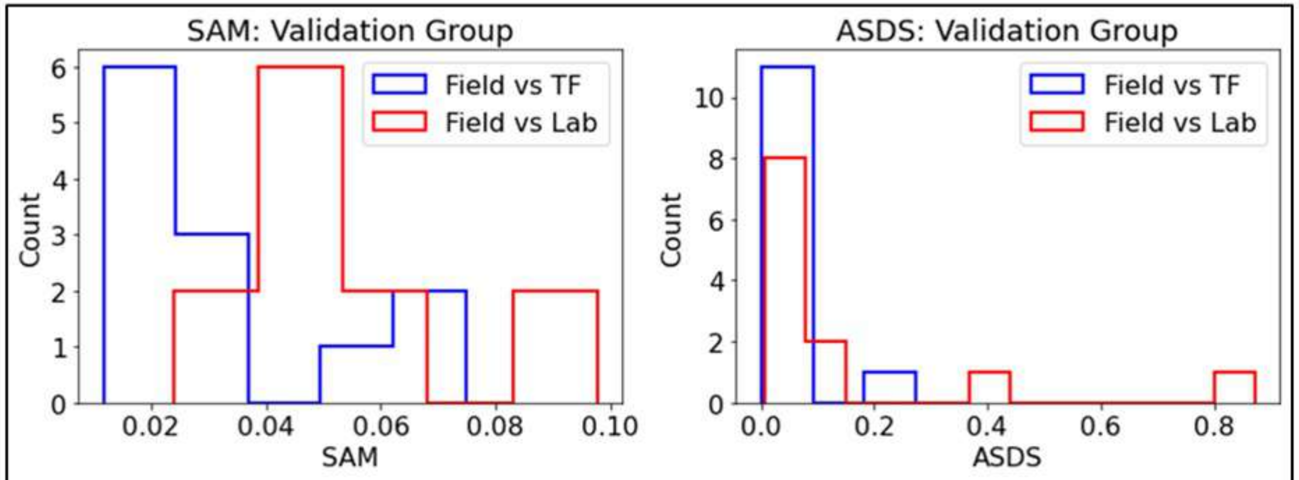




a)



b)



SAM

Parameter	Field vs TF	Field vs Lab
Mean	0.034	0.055
Max	0.075	0.098
Min	0.012	0.02
S. Deviation	0.021	0.021

ASDS

Parameter	Field vs TF	Field vs Lab
Mean	0.028	0.144
Max	0.28	0.87
Min	0.006	0.0003
S. Deviation	0.077	0.247

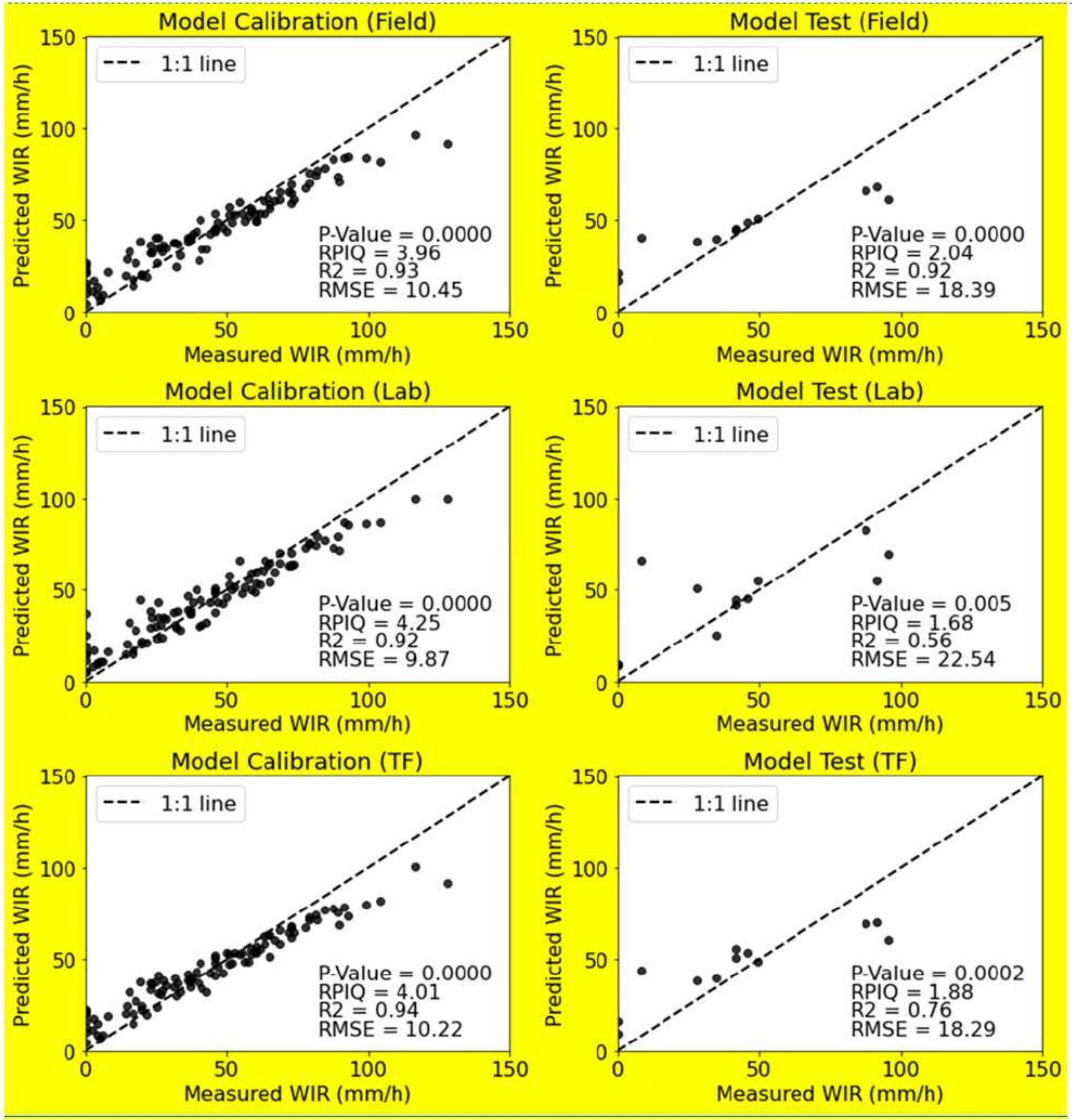


Fig. 2. The RF models with their predictions in the calibration and validation stages.

Geoderma 405 (2022) 115432

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A transfer function to predict soil surface reflectance from laboratory soil spectral libraries

Nicolas Francos*, Eyal Ben Dor

The Remote Sensing Laboratory, Tel Aviv University, Zelig 10, Tel Aviv 69978, Israel

A R T I C L E I N F O

Handling Editor: Budiman Minasny

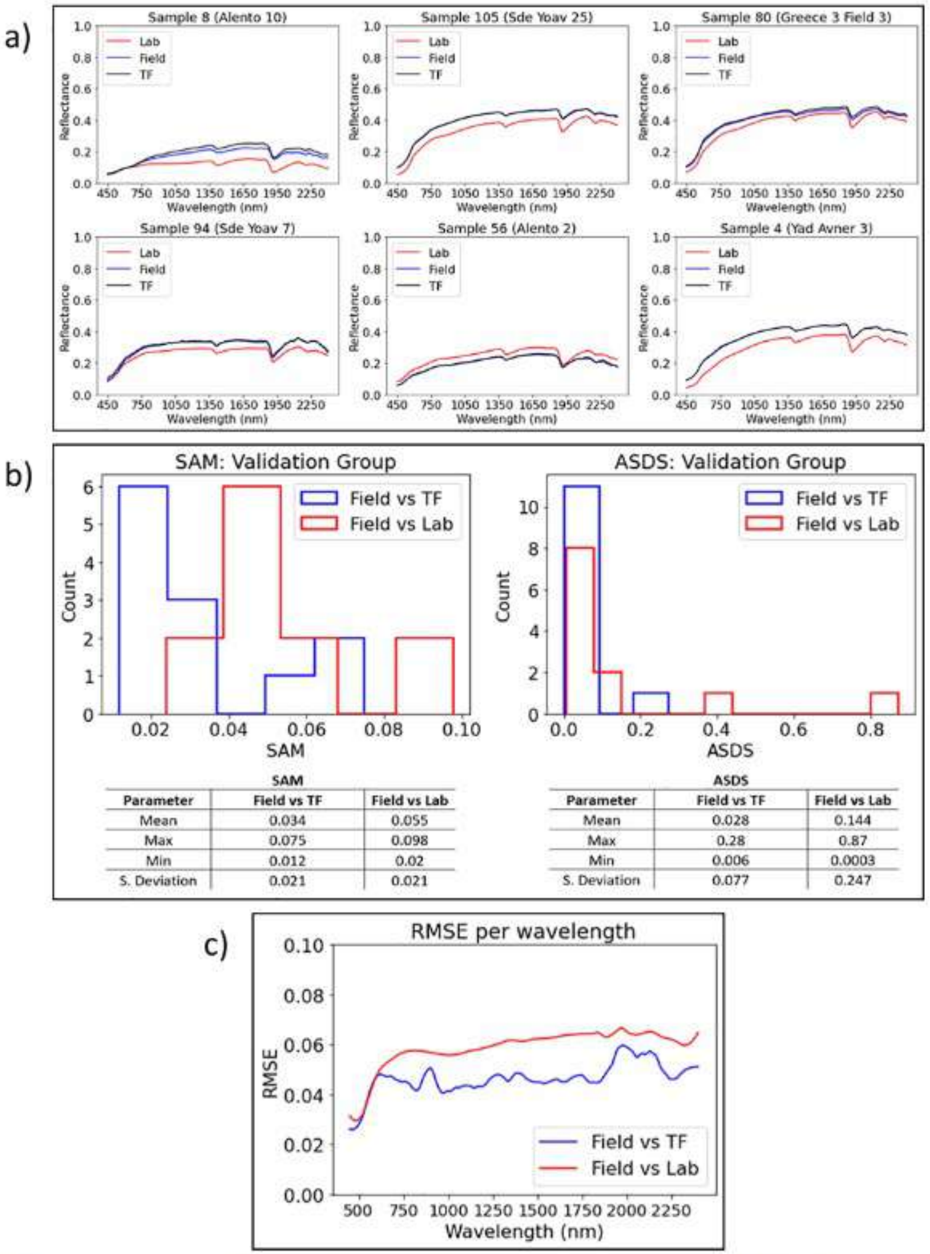
Keywords:
Transfer function
Soil spectroscopy
Water-infiltration rate
Soil surface

A B S T R A C T

Spectral-based models extracted from laboratory reflectance in the 400–2500 nm spectral range to predict soil attributes may not be applicable to soil spectra acquired in the field. This is because laboratory sampling procedures disturb the natural soil surface's status. We investigated this issue by using the soil surface-dependent property of water-infiltration rate (WIR). We created a dataset with 114 samples collected from six fields with varying textures located in three different Mediterranean countries (Israel, Greece, Italy). Using the field and laboratory spectral datasets, we demonstrated that WIR is better predicted by field vs. laboratory measurements ($R^2 = 0.92$ and 0.56, respectively). We also developed a transfer function (TF) to predict the field spectral measurements from the laboratory spectra. Use of the TF-processed dataset considerably improved the WIR prediction using laboratory information (from $R^2 = 0.56$ to 0.76). It was concluded that soil surface reflectance values can be estimated based on laboratory spectra using a TF. The generated TF enables exploiting soil spectral libraries for remote-sensing views and for assessing surface-related soil properties.

Table 1
The six fields that compose the used dataset.

Field	WRB–FAO Classification	Central Location	Number of Samples
Sde Yoav, Israel	Alluvial	31°38′35″ N, 34°40′15″ E	30
Alento, Italy	Leptosol	40°21′53.68″ N, 15°11′1.42″ E	21
Afeka, Israel	Ferrosol	32°7′9.16″ N, 34°48′14.84″ E	18
Central Macedonia 1, Greece	Fluvisol	40°37′32.03″ N, 21°34′1.23″ E	16
Central Macedonia 2, Greece	Cambisol	40°39′55.31″ N, 21°36′20.49″ E	15
Central Macedonia 3, Greece	Cambisol	40°40′11.46″ N, 21°37′56.67″ E	14



SAM

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Mean	0.034	0.055
Max	0.075	0.098
Min	0.012	0.02
S. Deviation	0.021	0.021

ASDS

Parameter	Field vs TF	Field vs Lab
Mean	0.028	0.144
Max	0.28	0.87
Min	0.006	0.0003
S. Deviation	0.077	0.247

Fig. 1. (a) Spectral signatures of some samples that were satisfactorily adapted to their field status. (b) Distribution of ASDS and SAM values of field vs. laboratory spectra (before and after TF adaptation to the field conditions). (c) RMSE per wavelength.

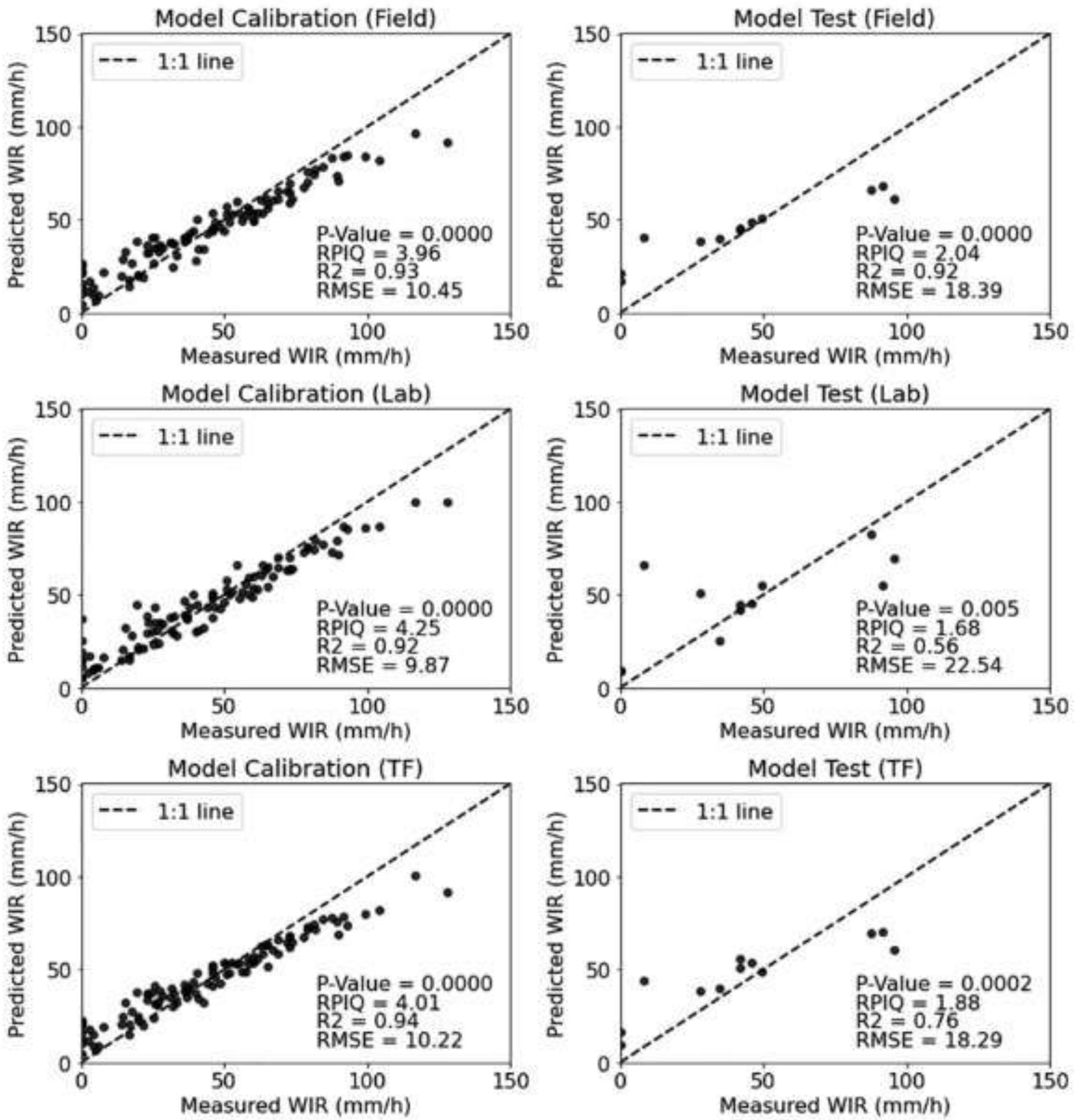
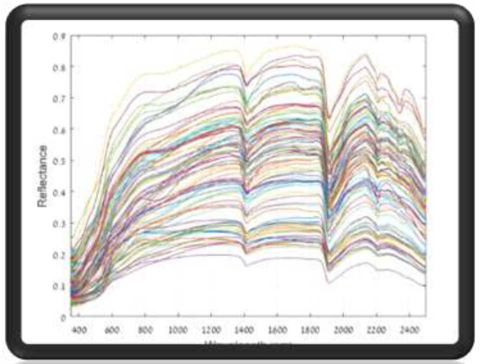
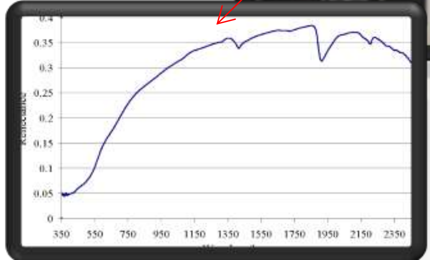


Fig. 2. The RF models with their predictions in the calibration and validation stages.

Soil Spectral Library : The Practical Structure

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





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

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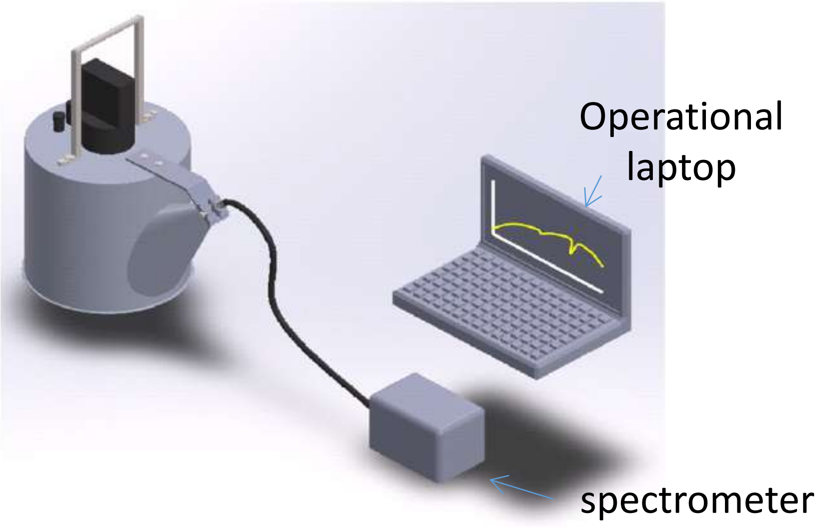
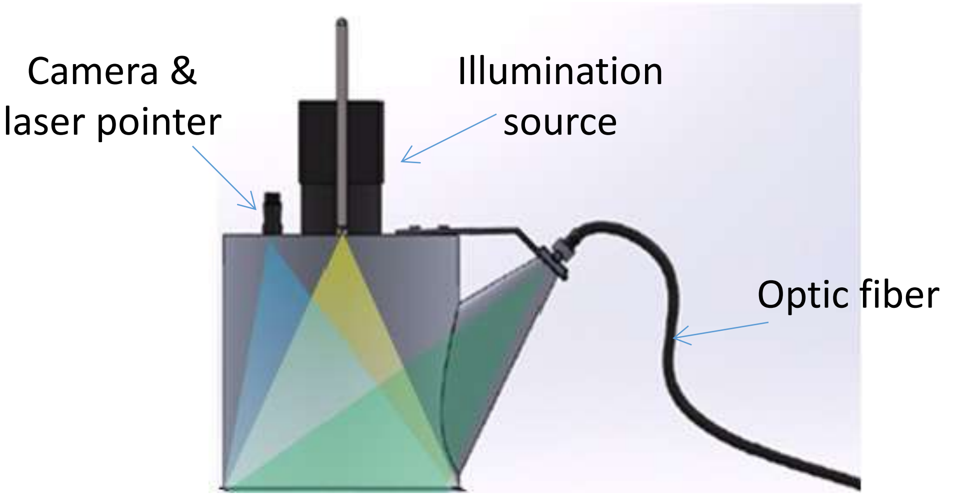
The "SoilPro" takes the advantages from each method while it is leave the disadvantages out





THE LAB

Protocol to generate Soil Spectral Library

Reflectance Measurement of Soils in the Laboratory: Standards and Protocols

Ben Dor E*, Ong O. and I. Lau

This document provides a detail instructions and routines on how to measure soil reflectance in the laboratory systematically and accurately in order to receive high performance and reproducibility. The document presents two standards and two protocols. The protocols are for a contact probe and a fixed geometry assemblies and the two standards are white sand dunes from Western Australia. It also provides a method on how to standardize each reflectance measurement to the proposed standard samples. The sand samples are used to check the stability of the measurement set up and more important to enable the user to exchange spectral libraries which were acquired under similar standardization conditions.

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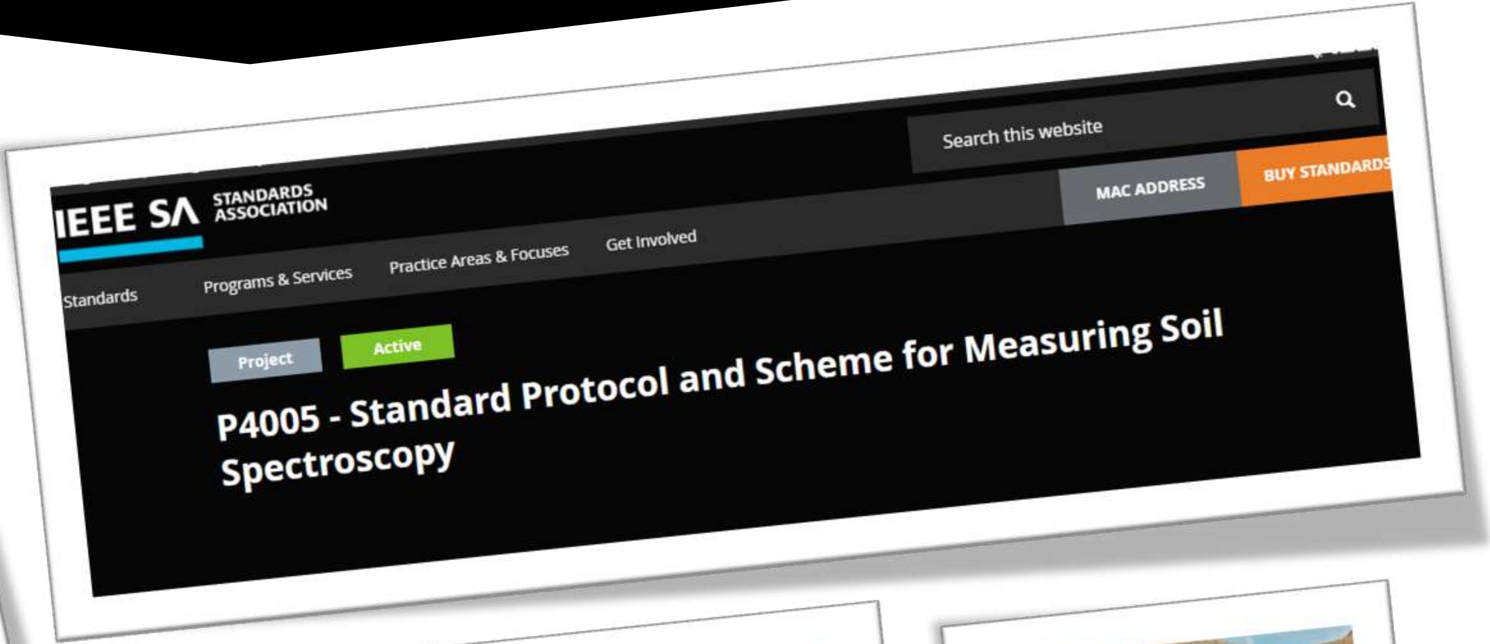
5/20/2013



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ELSEVIER

Reflectance measurements of soils in the laboratory: Standards and protocols

Eyal Ben Dor[a,*], Cindy Ong[b], Ian C. Lau[b]

[a] Tel Aviv University (TAU), Israel
[b] CSIRO, Perth, Western Australia, Australia

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ABSTRACT

For the past 20 years, soil reflectance measurement in the laboratory has been a common and extensively used procedure. Based on soil spectroscopy, a proxy strategy using a chemometrics approach has been developed for soils, along with massive construction of soil spectral libraries worldwide. Surprisingly however, there are no agreed-upon standards or protocols for reliable reflectance measurements in the laboratory and field. Consequently, almost every user reconstructs his or her own protocol based on the literature, experience, convenience and infrastructure. This yields significant problems for comparing and sharing soil spectral data between users, as

Fig. 1. Some early field spectroradiometers in use in the field (source unknown).

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IEEE SA
STANDARDS
ASSOCIATION

STANDARDS DEVELOPMENT PROCESS
IEEE P4005

MEETING #3

STANDARD PROTOCOL AND SCHEME FOR MEASURING SOIL SPECTROSCOPY
IEEE GEOSCIENCE AND REMOTE SENSING SOCIETY STANDARDS COMMITTEE (GRSS-SC)

October 8, 2020

IEEE

SCOPE

To develop a standard and protocol scheme that will be well agreed upon by the whole soil spectral and remote sensing community. The interested groups are: Pedometrics, HSR, soil spectroscopy, proximal sensing precision agriculture, FAO (GLOSLAN)

NEED FOR THE PROJECT

As many SSLs are being generated today worldwide and others are in preparation, merging them is highly important for their implementation into worldwide HSR data. Another important need for this project is to join the SSL databases into a large homogeneous database that will cover all soil types worldwide and can be used by anyone at any time.

S-WG suggested leaders

- **SWG1 - Optical operational scheme (0.4-2.5 um): Eyal Ben Dor + Sabine Chabrillat (RSL-TAU, GFZ)**
- **SWG2- Thermal operational scheme (3-15 um): Martin Schodlok (BGR)**
- **SWG3- Data saving and archiving (optical + thermal): Jose Dematte (USP)**
- **SWG4 - Cross calibration for spectral exchange (optical + thermal): Milla Luleva (AgroCares)**
- **SWG5- Spectral performance assessment for Optical and Thermal spectral ranges: Bas van Wesemael (UCL)**
- **SWG6- Field operational scheme (Optical): Thomas Schmid + Nicolas Francos (CIEMAT, RSL-TAU)**

In all SWG - Consideration to Mineral and Organic soil Should be given

S-WG overview

- **SWG1 - Optical Operational Scheme (0.4-2.5 um): This sub Working group will cover the operational scheme concerning the usage of optical sensing instruments and contains: The warming process, the measurements' method (contact/no contact), the geometry of measurements, illumination, sample preparation (sensing area, dryness, particle size, smoothing the surface), replications/measurements quantity, internal standard, reflectance. conversion (halon, irr/rad), list of valid instrumentation for which this protocol applies (spectral range, spectral resolution, SNR, Fore optics, detector, point (fiber, no fiber), imaging (push broom whisk broom, snape shot, periodic calibration at vendor (rad, spec), Illumination (source) and room conditions optimal number of measurements taken for each sample, in order to minimize the underperformance of spectral measurements**

- **SWG2- Thermal Operational Scheme (3-15 um): This sub Working group will cover the operational scheme concerning the usage of thermal sensing instruments and contains: physical quantity (emittance, reflectance, transmittance), spectral range, warming process, the geometry of measurements, sampling preparation (sensing area, dryness, particle size, smoothing the surface, sample heating), replications/measurements quantity, internal standard, temperature-emissivity separation conversion (gold), list of valid instrumentation for which this protocol applies, (spectral resolution, SNR, Fore optics, detector, point (fiber, no fiber), imaging (push broom whisk broom, snape shot, periodic calibration at vendor (rad, spec), Illumination (source)) and room conditions optimal number of measurements taken for each sample, in order to minimize the underperformance of spectral measurements**

S-WG overview

- SWG3- Data saving and archiving (optical + thermal): This sub Working Group will cover the data definition and associated metadata (emissivity, reflectance, radiance, DN), the saving format, nomenclature, spectral resampling and smoothing (yes, no), provide an agreed glossary.

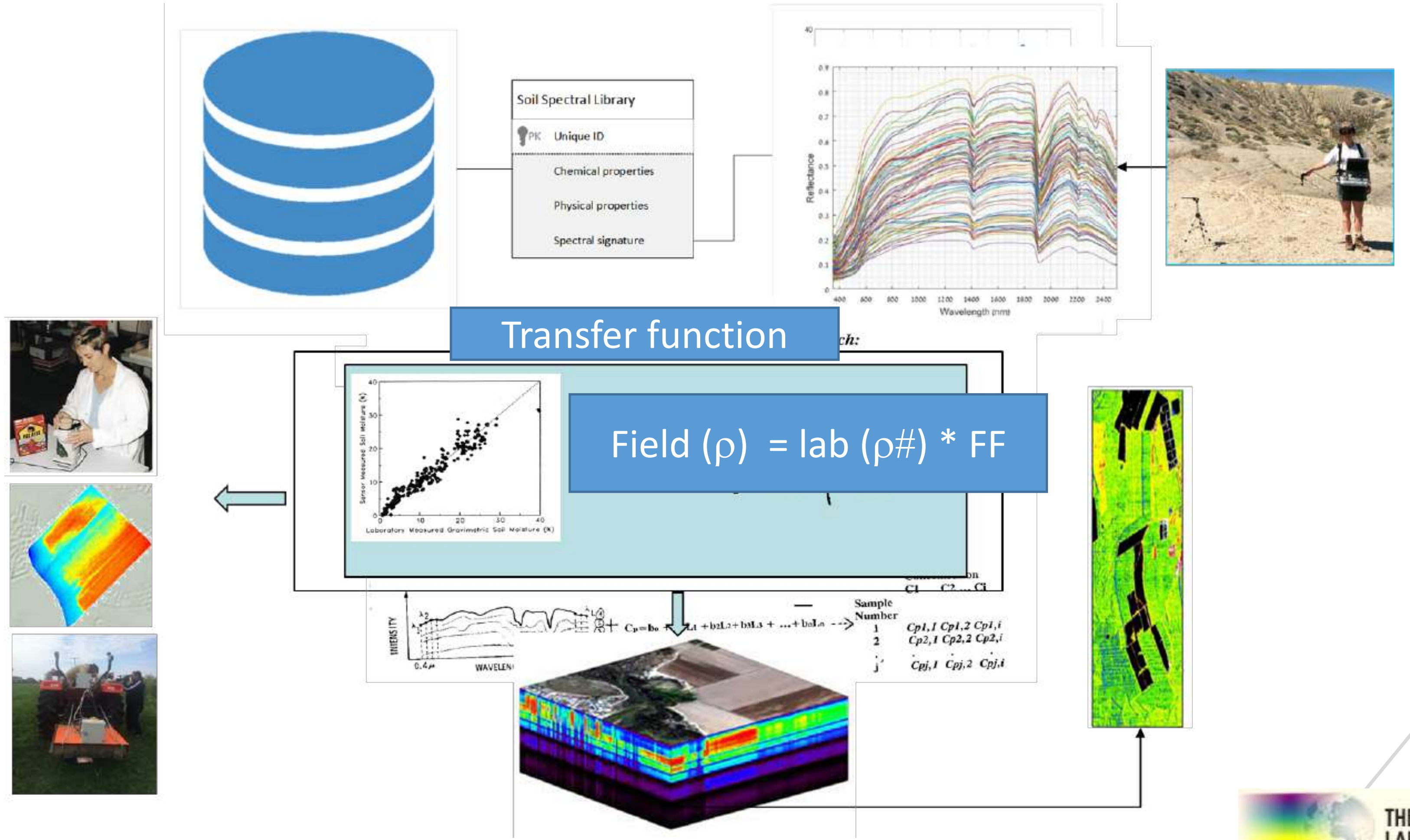
- SWG4 - Cross calibration for spectral exchange (optical + thermal): The key scopes of this sub Working Group covers the post data base transfer , new data base, Internal standards, (LB, WB, Polymers, and/or other spectral calibration materials - pros and cons).

S-WG overview

- SWG5- Spectral performance assessment for Optical and Thermal spectral ranges: This sub Working Group will evaluate and enhance the performance assessment techniques. These concern the stability, replication, threshold error, QA and QI parameters, uncertainties and variation, during and after measurements, and the Proxy quality

- SWG6- Field Operational Scheme (Optical): This sub Working group will cover the operational scheme concerning the usage of optical sensing instruments in the field and contains: The warming process , the measurements' method (contact/, no contact), the geometry of measurements, illumination, replications/measurements quantity, internal standard , reflectance conversion (halon, irr/rad), list of valid instrumentation for which this protocol applies, minimum atmospheric conditions (for measurements with solar electromagnetic radiation source)

Laboratory soil spectral library proximate the field spectral response for hyperspectral remote sensing



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Thank You !

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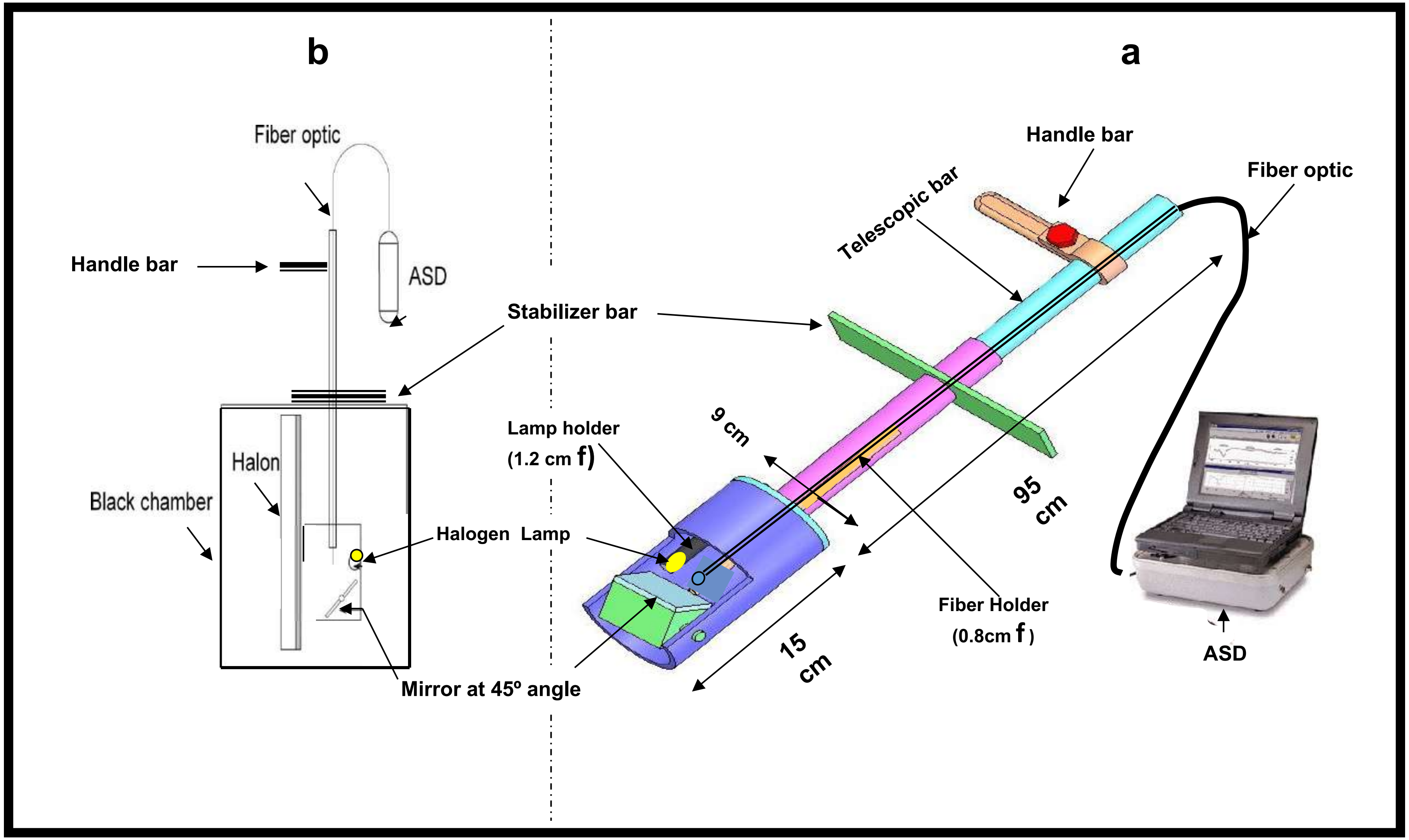
12 אנשים סטודנטים וחוקרים מגובשת ומקושרת
בישראל ובעולם

Accessory for ASD



Ben-Dor, Eyal, Daniela Heller, and Alexandra Chudnovsky. "A novel method of classifying soil profiles in the field using optical means." *Soil Science Society of America Journal* 72, no. 4 (2008): 1113-1123.

POS Penetrating Optical Sensor (a temporary name)

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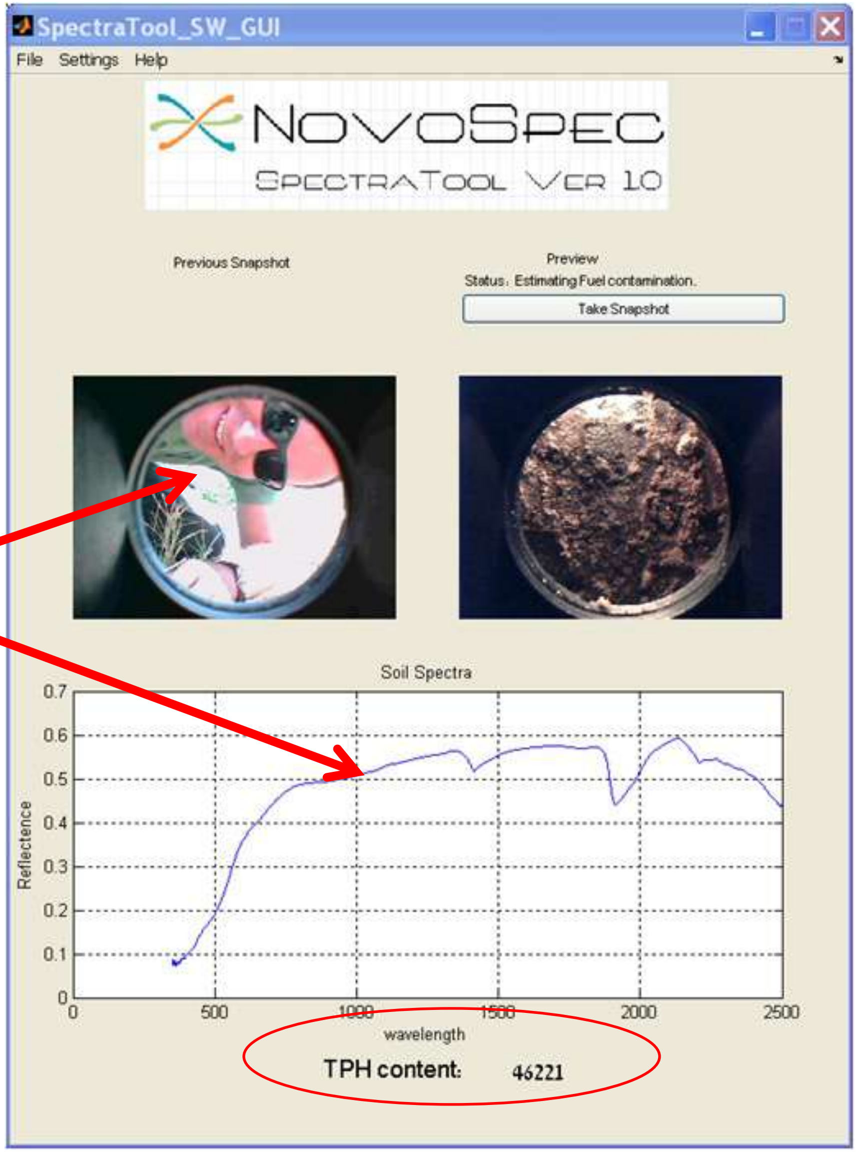
POS® - Penetrating Optical Sensor



No need to sample the soil any more. Quantitative profile description can be done in situ !

Key issue:
Soil Spectroscopy

Soil Science Society of America Journal

Pedology | Full Access

A Novel Method of Classifying Soil Profiles in the Field using Optical Means

Eyal Ben-Dor, Daniela Heller, Alexandra Chudnovsky,

Ben-Dor, E., Heller, D., & Chudnovsky, A. (2008). A novel method of classifying soil profiles in the field using optical means. *Soil Science Society of America Journal*, *72*(4), 1113-1123.

Table 1. Some statistical values (Min.–minimum, Max. –maximum, Avg.–average) that describe the drill population of the four profiles examined. The data was taken from the laboratory "wet" determination. Each profile is identified by its USDA nomenclature definition.

	Soil moisture			Organic matter			Soil carbonates			Free iron oxides			Specific surface area		
	Min	Max	Avg.	Min	Max	Avg.	Min.	Max.	Avg	Min.	Max.	Avg.	Min.	Max.	Avg
	$g\ kg^{-1}$												$m^2\ g^{-1}$		
Soil suborder															
Rhodoxeralf	9	23	15	2	5	3	0	0	0	0.7	0.8	0.8	27.3	70.1	57.1
Haploxeralf	31	56	38	6	16	11	172	226	190	1.8	2.4	2.1	86.5	118.5	85.5
Haploaquept	105	294	155	17	56	31	425	875	642	0.3	1.4	0.8	33.7	98.5	69.7
Chromoxeret	187	213	196	19	29	23	29	90	58	4.6	6.0	5.3	302.1	407.1	330.1

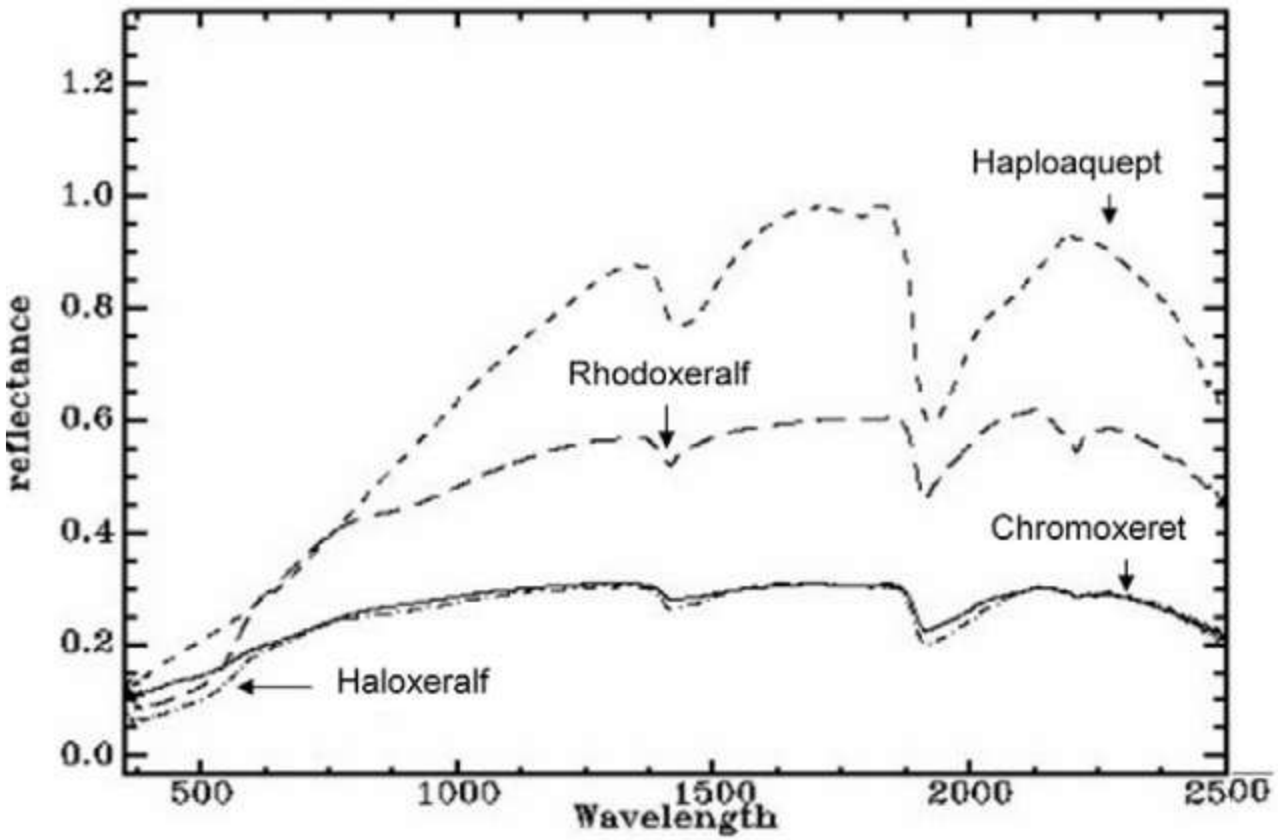
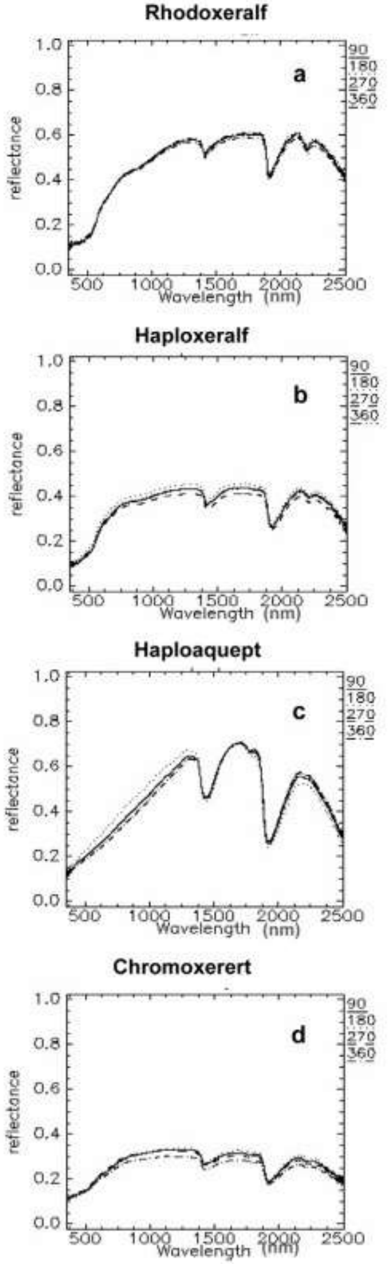


Fig. 3. The spectra of Ao horizon (0–10 cm) in all four soils selected for the study. Each spectrum represents an average of four spectra taken from a 90° increment of the drilled holes by the sub-surface spectral head device (3S-HeD) assembly in the field as described in Fig. 4.



,b,c,d). The spectra of four measurements taken by the sub-surce spectral head device (3S-HeD), at a given depth (40 cm) for ıch of the soil profiles selected for this study. Each measurement as taken from a 90° increment of the drilled holes to represent the lected depth as accurately as possible (a = Rhodoxeralf soil, b = aploxeralf soil, c = Haploaquept soil, d = Chromoxeret soil).

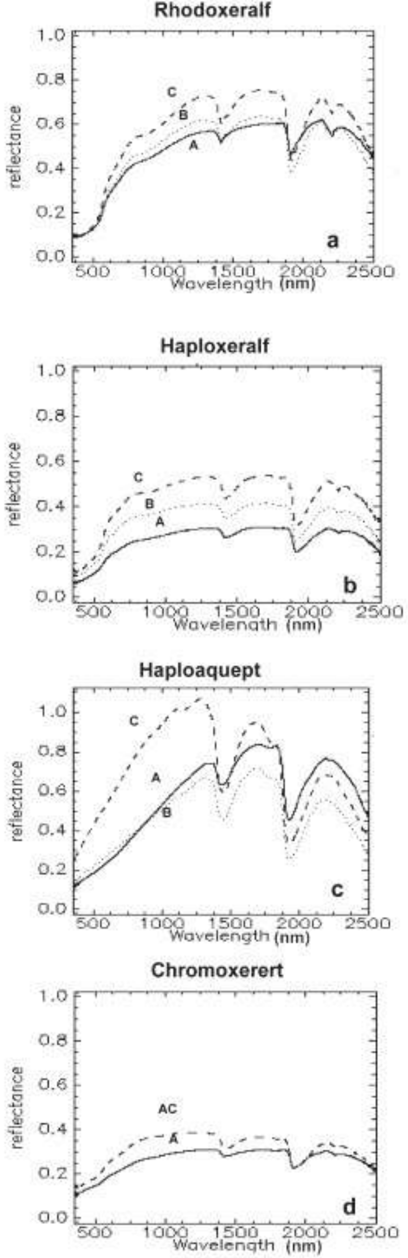
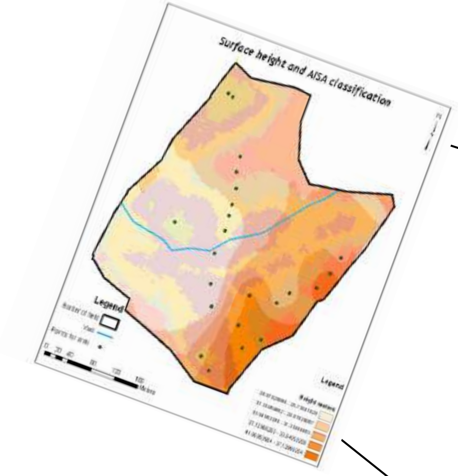


Fig. 5(a,b,c,d). Spectral plots of selected soil profiles, taken from the four soils, obtained by the sub-surface spectral head device (3S-HeD) assembly. The spectra represent typical horizons in the soils horizons (A, B, C) and represent the mean of four readings as described in Fig. 5. (a = Rhodoxeralf soil, b = Haploxeralf soil, c = Haploaquept soil, d = Chromoxeret soil)

Table 3. Traditional soil profile description as was done in the field at nearby trenches.

Horizon	Depth	Description
	cm	
Rhodoxeralf		
A	0–40	Bare cover, small amount of dry weed, no carbonate content, dry soil, color 2.5 YR 4/8 red, sandy texture.
Bt	40–55	Elovial horizon, accumulation of clay and iron oxides, no carbonates, color 2.5 YR 3/6 dark red.
B	55–80	No carbonates, sandy soil, color 2.5 YR 4/6 red.
C	80–100	Sandy soil, brighter color, higher humidity, color 5 YR 4/6 yellowish red.
Haploxeralf		
A	0–20	The surface is covered with wild vegetation, high carbonate content, clay loam texture, color 10 YR 6/4 light brown.
B	20–70	High carbonate content, decreased organic matter, sandy clay loam texture, a high concentration of carbonate pebbles in the horizon, color 10 YR 6/4 light brown.
C	70–90	Sandy soil texture, decreased carbonate content, color 10 YR 8/8 reddish yellow.
Haploaquept		
A	0–15	Very rich in organic matter, dark color, rich in carbonates, loam sandy texture, color 10 YR 4/1 dark gray.
A3	15–50	Very rich in organic matter, high soil moisture, loam sandy texture, color 10 YR 4/1 dark gray.
B	50–80	High water table and bad drainage in the soil increase the moisture; the horizon contains evidence of its original lake materials as shells. Drastic change in color; color 10 YR 7/1 light gray.
C	80–100	Highly rich in carbonates, high moisture, contains free water, very bright color 10 YR 8/3 very pale brown, clay loam texture.
Chromoxerert		
A	0–65	Rich in organic matter, high carbonate content, clay texture, color 10 YR 4/3 brown.
AC	65–100	Rich in organic matter, high soil moisture, clay texture, color 10 YR 3/3 dark brown.

Soil Profile information 3D view of the SSA property in the study field



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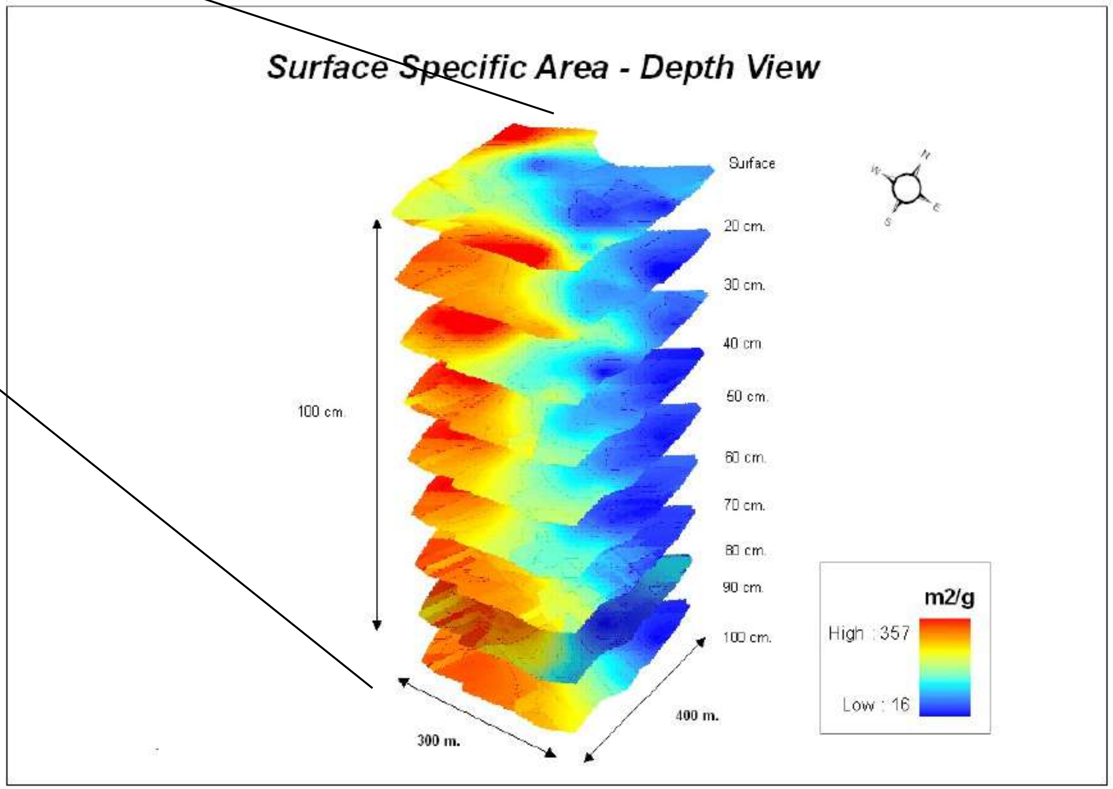

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Ben-Dor, Eyal, Daniela Heller, and Alexandra Chudnovsky. "A novel method of classifying soil profiles in the field using optical means." *Soil Science Society of America Journal* 72, no. 4 (2008): 1113-1123.

Table 4. Optically based soil profile description as was done in the field using sub-surface spectral head device (3S-HeD) in drills.

Horizon	Depth	Description
	cm	
Rhodoxeralf		
A	0–20	Low organic matter (0.32 g kg^{-1}), the soil does not contain carbonates, the soil is sandy with a low specific surface area (69 m^2 g^{-1}), low moisture (0.92 g kg^{-1}), iron oxides (0.56 g kg^{-1}), color 10R 4/6 red.
AB	20–40	Low organic matter (0.30 g kg^{-1}), increased soil moisture (2 g kg^{-1}), SSA (76 m^2 g^{-1}), iron oxides (0.58%); color 10R 4/8 red.
Bt	40–60	Elovial horizon; there is an accumulation of clay minerals, an increase in SSA (85 m^2 g^{-1}), and increased iron oxides (0.5 g kg^{-1}); organic matter (0.29 g kg^{-1}); color 10R 4/8 red.
B3	60–80	Decreased clay minerals, SSA (27 m^2 g^{-1}) and iron oxides (0.5 g kg^{-1}), organic carbon (0.29 g kg^{-1}), color 7.5 YR 6/6 reddish yellow.
C	80–100	Low organic matter (0.27 g kg^{-1}), little content of clay minerals, SSA (26 m^2 g^{-1}), decreased iron oxides (0.3 g kg^{-1}), color 7.5 YR 6/6 reddish yellow.
Haploxeralf		
A	0–20	Rich in organic matter (2 g kg^{-1}); high carbonate content (26 g kg^{-1}); soil moisture (3.7 g kg^{-1}); iron oxides (1.3 g kg^{-1}), SSA (102 m^2 g^{-1}, color 10YR 6/3 pale brown.
AB	20–40	A slight decrease in organic matter (1.3 g kg^{-1}), a decrease in iron oxides (0.8 g kg^{-1}), an increase in soil moisture (5.2 g kg^{-1}), an increase in clay minerals SSA (134 m^2 g^{-1}), the color is the same as the A horizon, color 10YR 6/3 pale brown.
B ca	40–70	Accumulation of carbonates (28 g kg^{-1}), low organic matter (0.6 g kg^{-1}), soil moisture (4.5 g kg^{-1}), decreased clay minerals SSA (72 m^2 g^{-1}) that will make the texture more sandy loam, color 10YR 6/3 pale brown.
C	70–80	Low organic matter (0.44 g kg^{-1}), carbonates (24 g kg^{-1}), low iron oxides (0.46 g kg^{-1}), decreased soil moisture (2.7 g kg^{-1}), the texture is more sandy loam SSA (54 m^2 g^{-1}), color 10YR 6/4 light yellowish brown.
Haploaquept		
A1	0–20	Highly rich in organic matter (4 g kg^{-1}), rich in carbonates (44 g kg^{-1}), soil moisture (17 g kg^{-1}), SSA (54 m^2 g^{-1}), iron oxides (0.6 g kg^{-1}), color 10YR 4/1 dark gray.
A3	20–50	High carbonates content (61 g kg^{-1}), high organic matter (3.1 gkg^{-1}), iron oxides (0.6 g kg^{-1}), SSA (75 m^2 g^{-1}), color 10YR 4/1 dark gray.
B	50–70	Increased soil moisture (22 g kg^{-1}), decreased iron oxides (0.14 g kg^{-1}), a slight decrease in organic matter (1.9 gkg^{-1}1), very high carbonate content (71 g kg^{-1}), soil moisture (22 g kg^{-1}), SSA (55 m^2 g^{-1}), color 2.5Y 8/4 pale yellow.
C	70–100	Very high carbonate content (66 g kg^{-1}), high soil moisture (25 g kg^{-1}), SSA (46 m^2 g^{-1}), low content of iron oxides (0.05 g kg^{-1}), the color is very bright; color 2.5Y 8/4 pale yellow.
Chromoxerert		
A	0–70	Rich in organic matter (2.5 g kg^{-1}), carbonate content (8 g kg^{-1}), high soil moisture (18 g kg^{-1}), iron oxides (0.63 g kg^{-1}), the texture is clayey SSA (280 m^2 g^{-1}), the color of the soil is dark; color 10YR 4/3 dark grayish brown.
AC	70–100	Organic matter (2.1 g kg^{-1}), decreased carbonates (4 g kg^{-1}), high soil moisture (21 g kg^{-1}), clay texture SSA (310 m^2 g^{-1}), iron oxides (0.86 g kg^{-1}), color 10YR 3/4 dark yellowish brown.

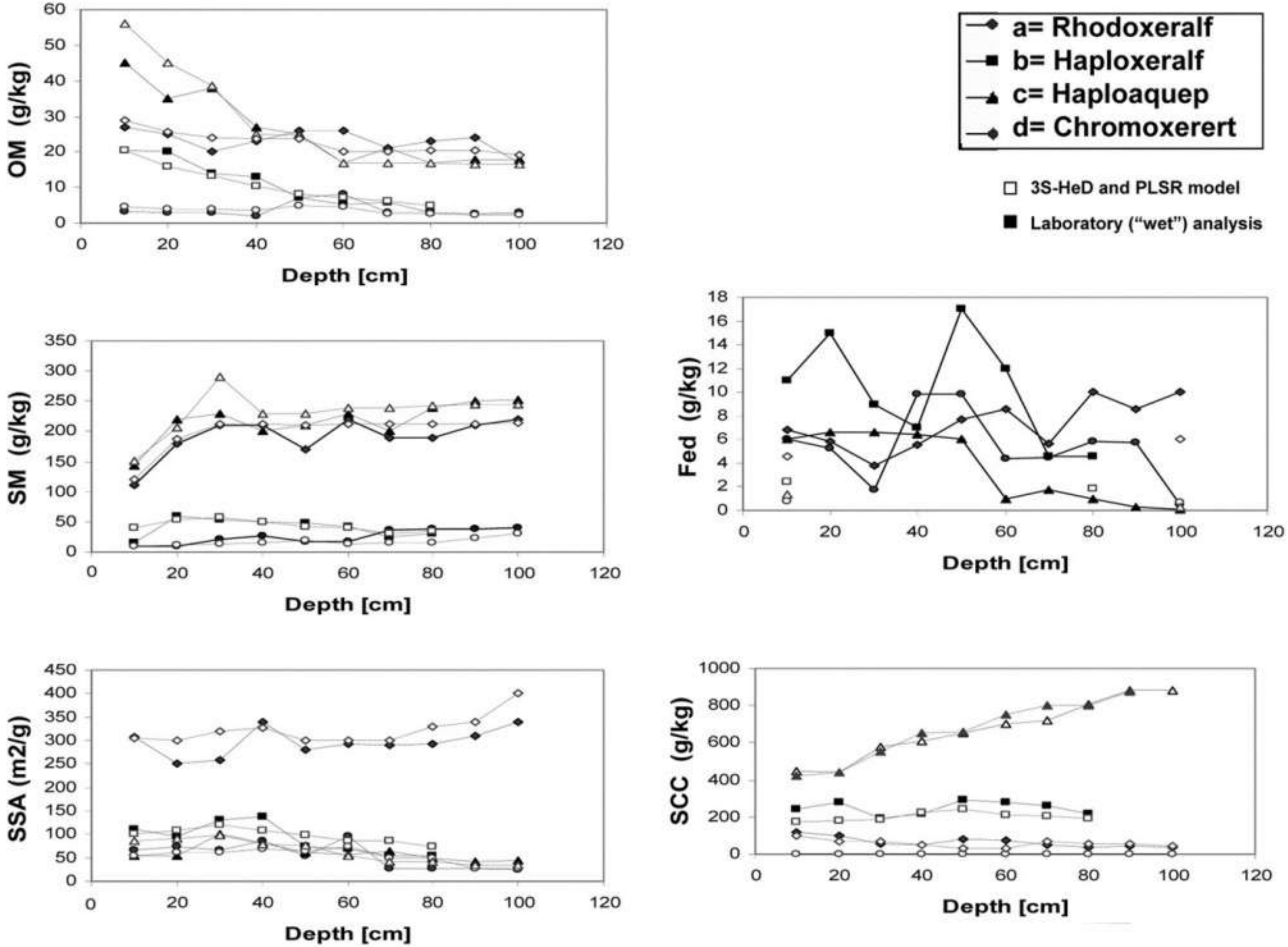

Fig. 6. Profile plots (quantity vs. depth) of all properties, as derived from the sub-surface spectral head device (3S-HeD) and the partial least squares regression (PLSR) models for the four profiles examined (empty points). Also given are the actual values of each property as derived by the laboratory "wet" analysis (filled points).

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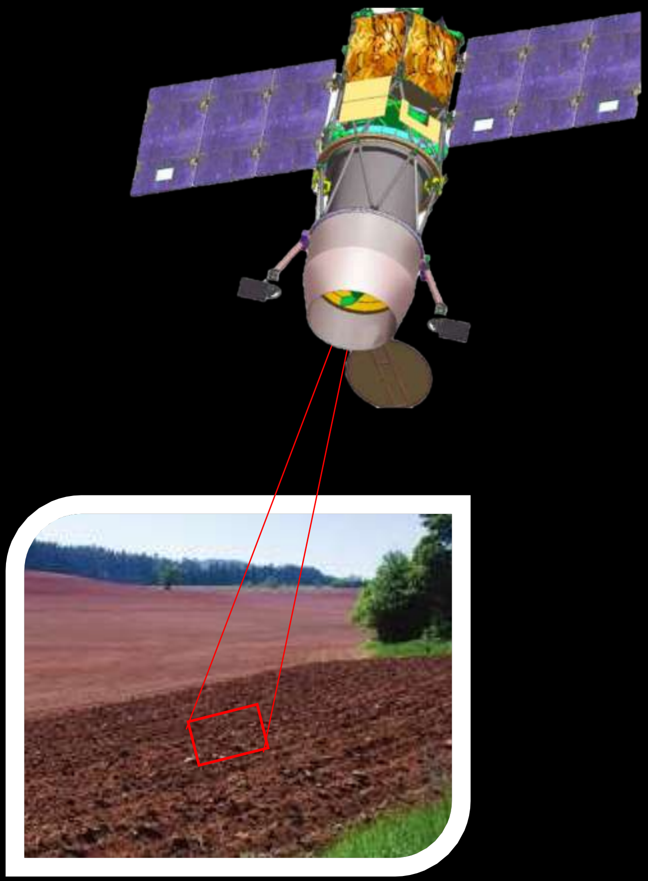
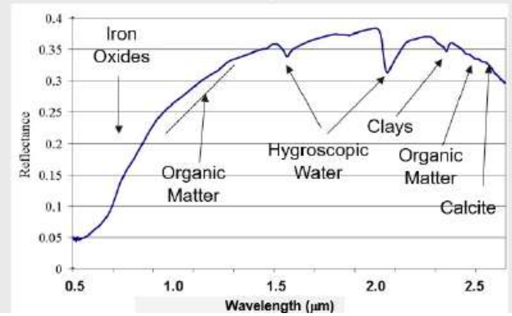


2m PAN, 9 m spectral, 4 days, 244 channels

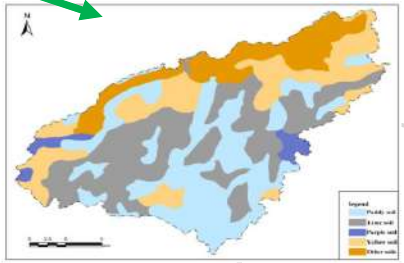
Product Name
Crop, Rangeland and Invasive Species Map
Burnt Area Map
Vegetation Status Indicators
Vegetation Damage and Stress Indicators
Fire Fuel Map
Mineral Map
Coastal Bathymetry Map
Urban And industrial Functional Area Map
Lithological Map
Lava Flow Parameters
Soil Surface Pollutants Map
Volcanic Gas And Aerosol Emission M
Forest Species Map
Forest Biomass Map
Ice Cover Map
Soil Characterization Map
Land Cover Map
Land Cover Change Detection Map
Snow Cover Map
Forest Nitrogen and Chlorophyll Map
Wetlands Classification Map
Marine And Aquatic Quality And Productivity Indicators
Lava and ash distribution map
Snow And Ice Cover Characterization

The Major and Important Agent

Soil



SHALOM: Data Analytic R&D Center



Regional (quantitative) map

Field (quantitative) map

Smart cultivation

Conclusions

- The execution of field based spectral models in airborne HRS data of high quality (0.5 meters) presented good accuracy to map the WIR due to the contribution of the SWIR region.
- The low resolution of S2 (spatial and spectral) was detrimental for this analysis.
- Due to the good conditions of the study area, with a simple algorithm (decision trees) was possible to obtain satisfactory results to map the WIR

Thank You !!

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