The Role of the Mediterranean Soil Spectral Library within the GEO-CRADLE Framework

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CRADLE

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Coordinating and integRating state-of-the-art Earth Observation Activities in the regions of North Africa, Middle East and Balkans and Developing Links with GEO related intiatives toward GEOSS

(4.2)
The role of soil spectroscopy for food security & tools to create a SSL

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The GEO-CRADLE project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 690133.

Why Soil is 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**


Third of Earth's soil is acutely degraded due to agriculture | Environment | The Guardian 14/09/2017 10:15

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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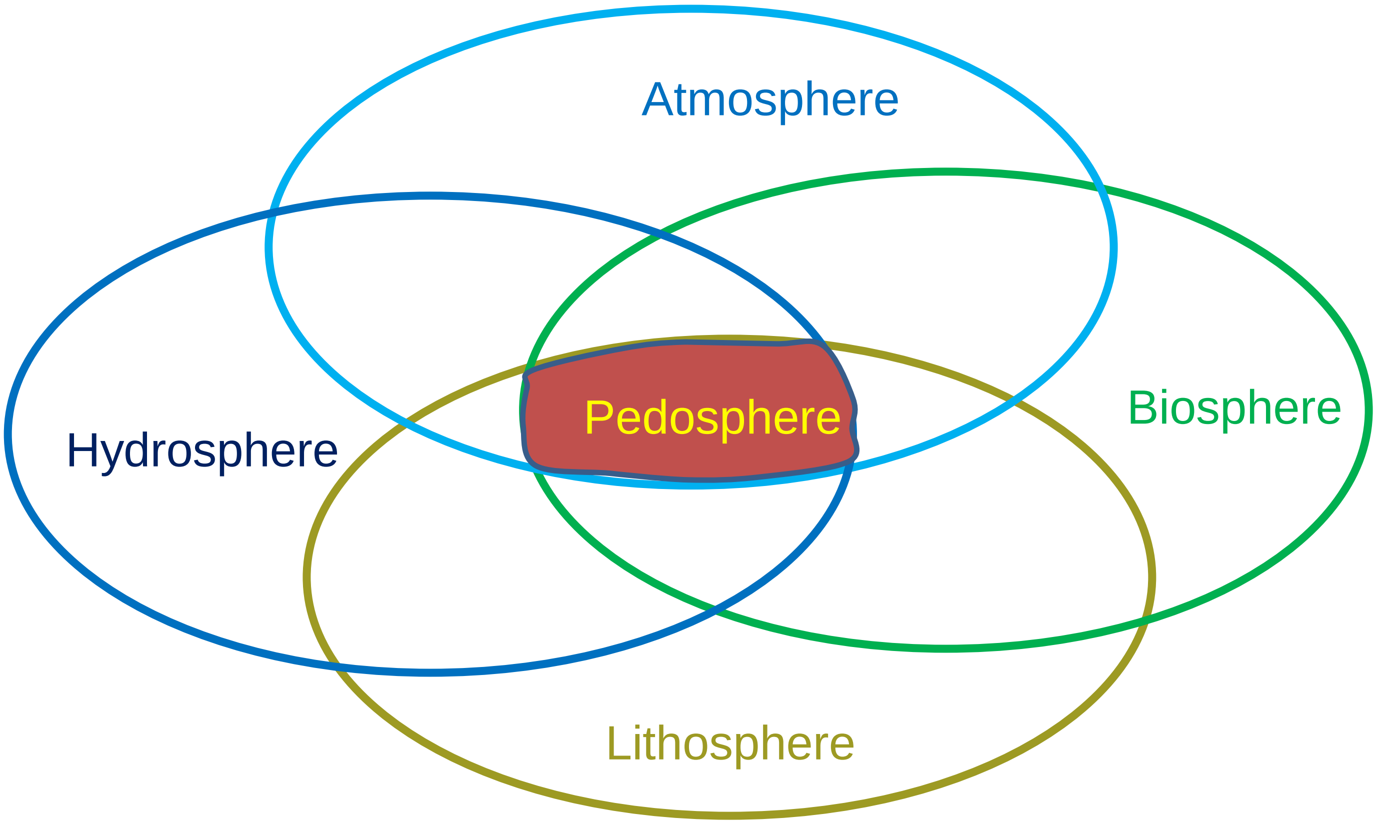

CHAPTER ONE

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

Jerry L. Hatfield*[,1], Thomas J. Sauer*, Richard M. Cruse[†]
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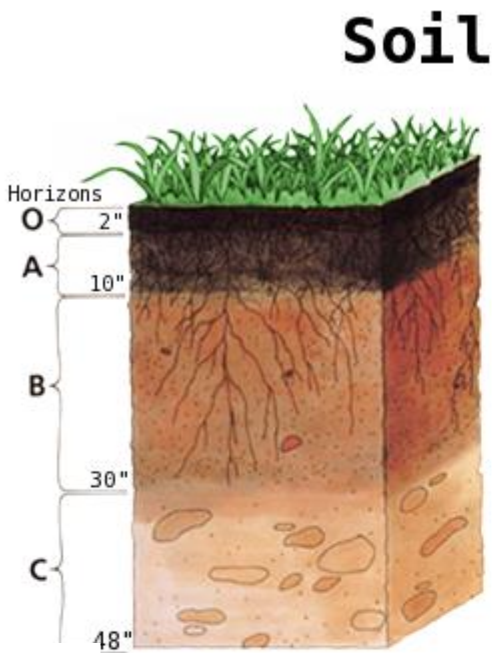
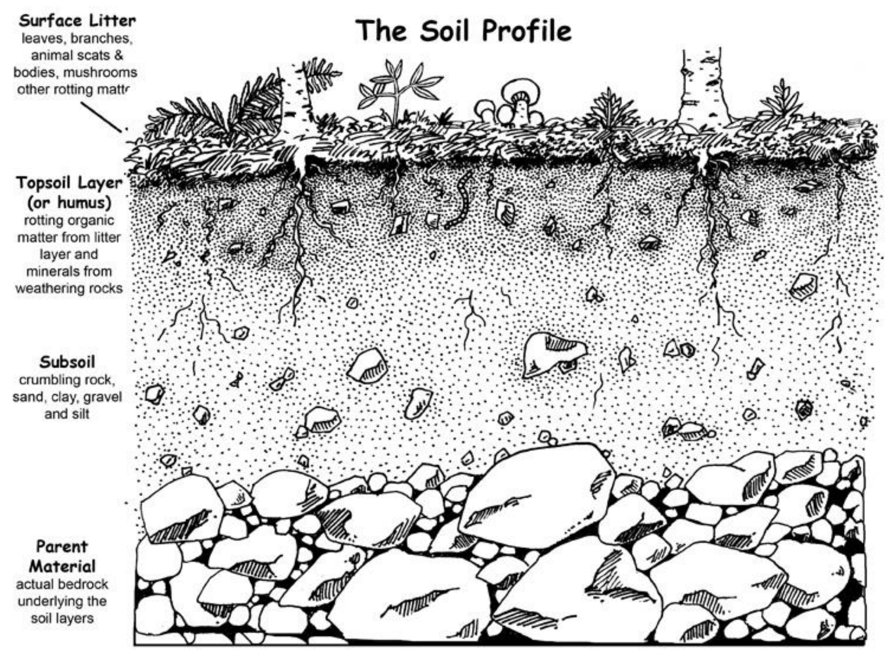
Soil

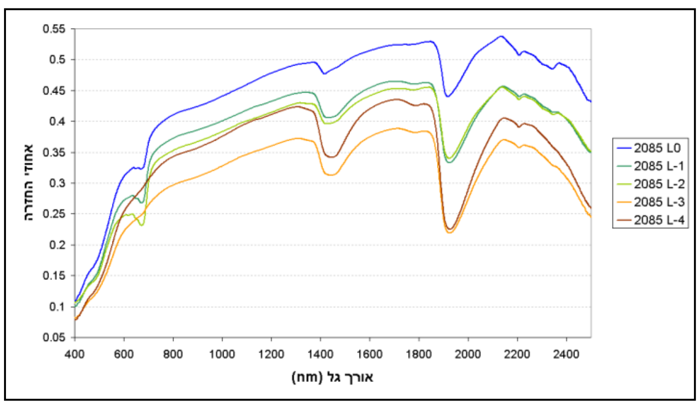
The upper layer of the earth (≈0-2m) represent its loose surface material which is dug, plowed and being a medium for plants to grow. **(Thompson 1957)**





Soil Spectroscopy

- 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

Hyperspectral Remote Sensing

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Imaging spectroscopy

From Wikipedia, the free encyclopedia

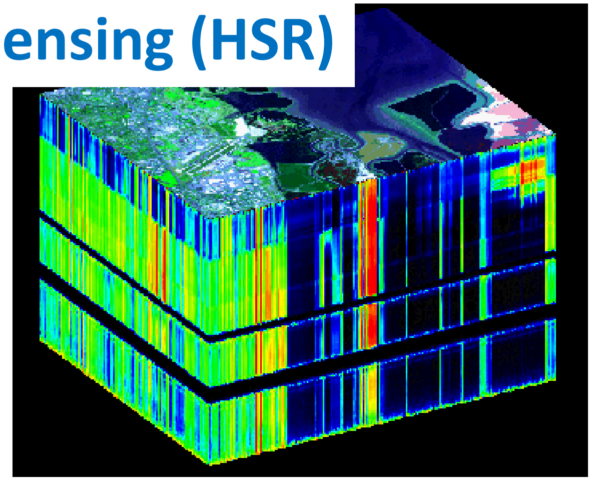
Imaging spectroscopy is the simultaneous acquisition of spatially coregistered images in many spectrally contiguous bands. To be scientifically useful, such measurement should be done using an internationally recognized system of units. The image produced by imaging spectroscopy is similar to an image 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-

te

Hyperspectral Remote Sensing (HSR)

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



adjusted From A. Goetz 1994

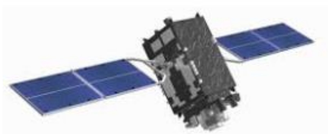
Simultaneous acquisition of images in many registered spectrally- high resolution continuous bands at selected (or all) spectral domains across the UV-VIS-NIR-SWIR–MWIR-LWIR spectral region (0.3-12μm)

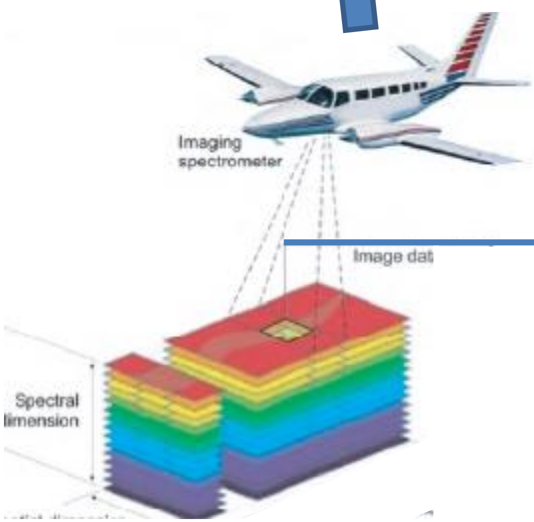
Strong Link between Point and Image Spectroscopy

Image Spectroscopy

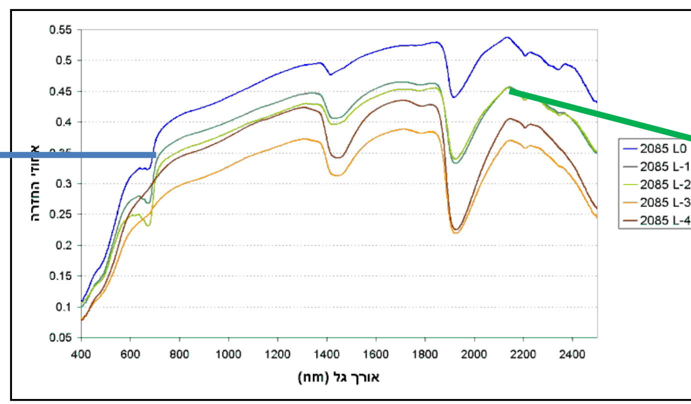
Geology
Vegetation
Water

Point Spectroscopy





Soil



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A typical Soil Spectrum

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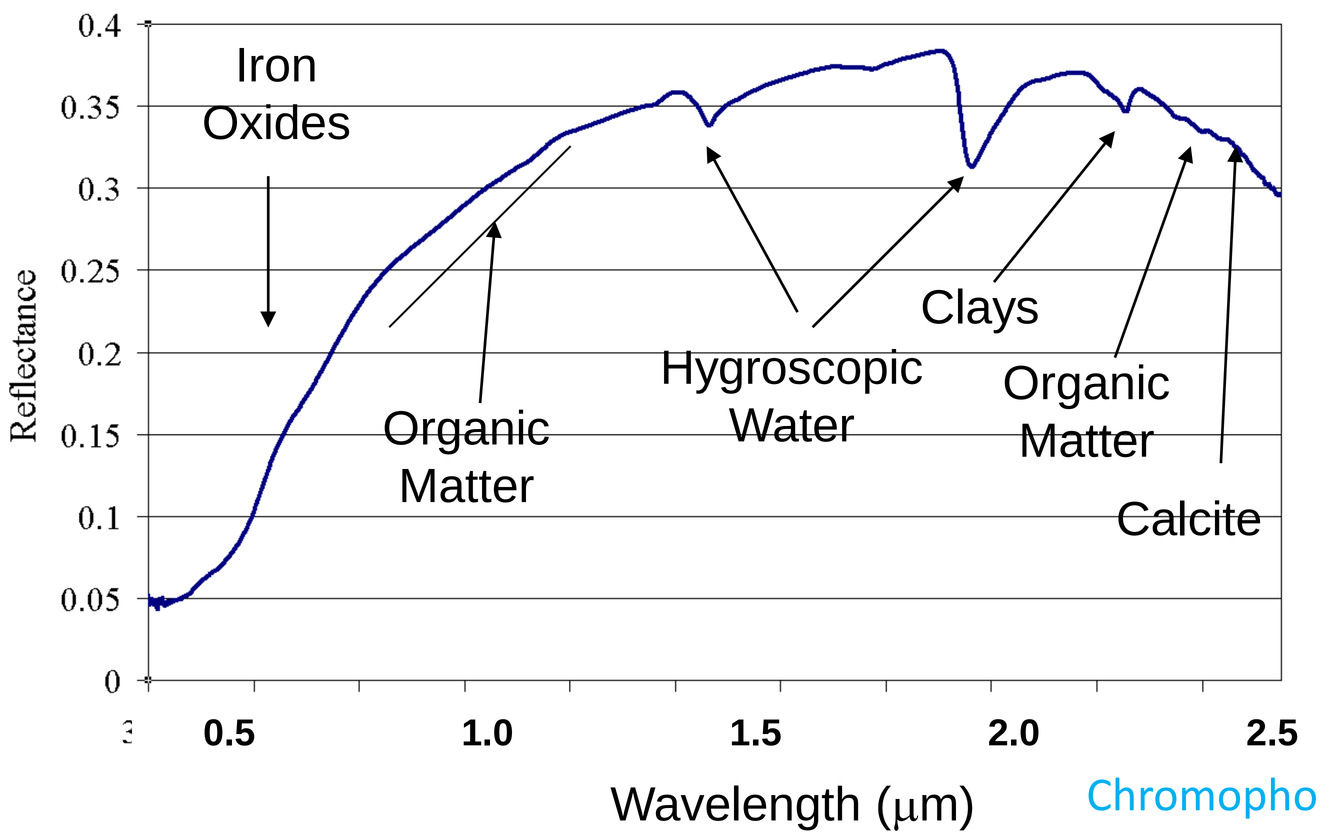
An effective way to simplest the complexity of the soil system

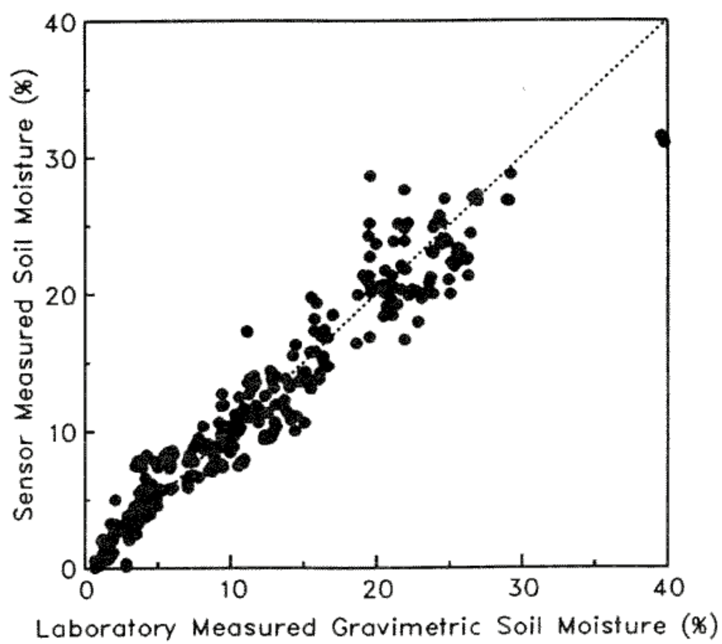


Chromophore = An attribute that interact with the electromagnetic radiation

Soil Spectroscopy

Quantitative Information on soil attributes can be Extracted from soil spectral information

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



Simple, rapid, inexpensive and

can be applied from large domains (laboratory, field, air and space)

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

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)
OC; g/kg	MIR	2500–25,000	PLSR (17)	177|60		0.94	McCarty et al. (2002)
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OM; %	VIS–NIR	400–1100	NN	41		0.86	Daniel et al. (2003)
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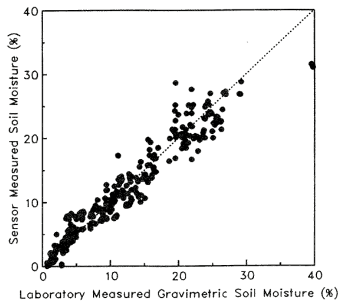
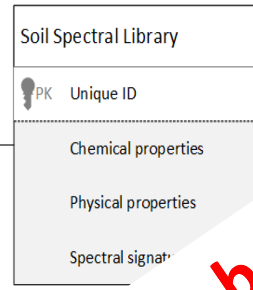
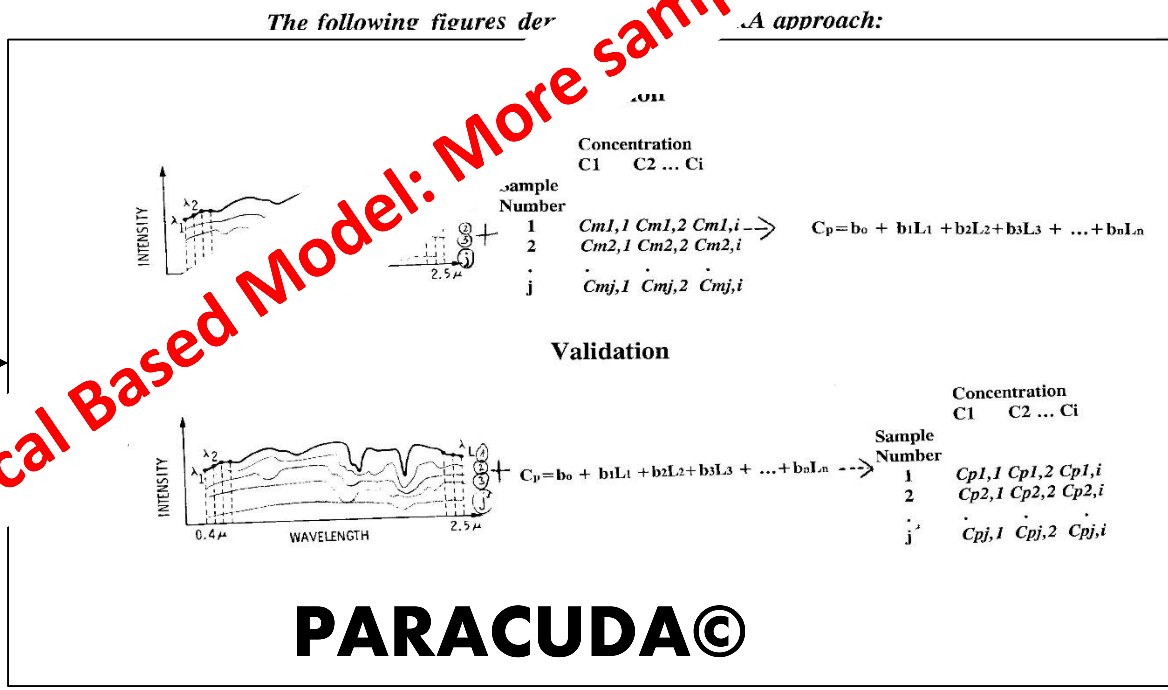
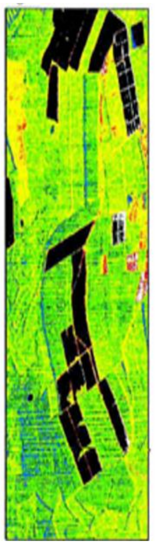
Data Mining Approach from SSLs





Statistical Based Model: More sample better accuracy





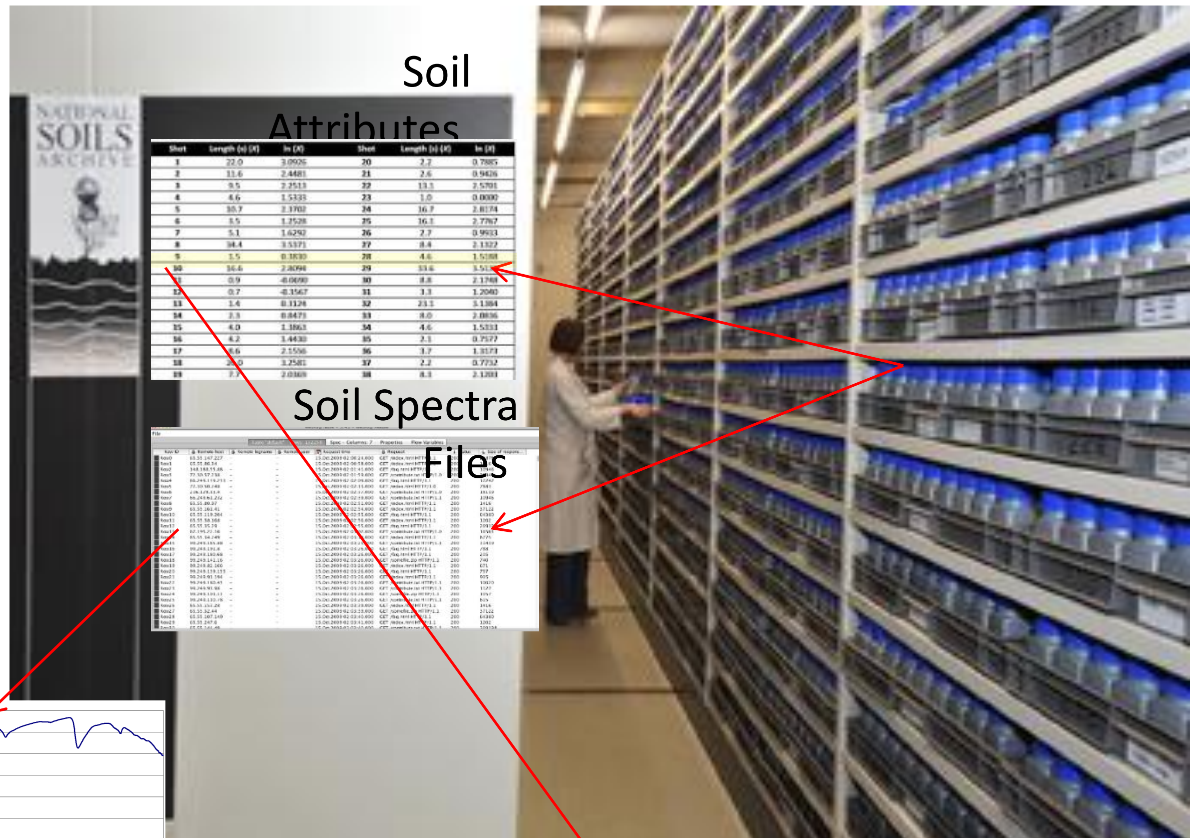
WP 4 –mission

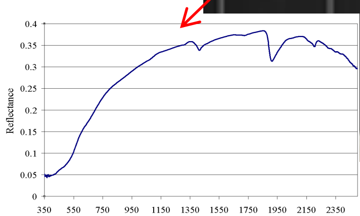
- To establish a soil spectral library SSL for the **North Africa, Middle East and Balkans**
- To establish a basic foundation to use the SSL for EO means (from field, air and domains)
- To built a data base Within the GEOSS sharing regulation

SSL – Soil Spectral Library

Soil Spectral Library (SSL)

A collocation of soil samples with measured attributes and meta data (geographical collocation, profile field description) PLUS spectral measurement data that were aquiered under standard protocol.





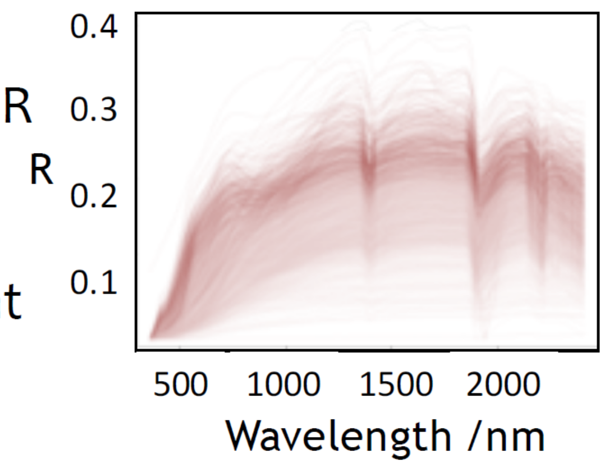
Sample	Location	OM	Clay	Lime....
A1	34,5467.67	2.4 %	34%	23.4%
				36,654,32

The Global Soil Spectral Library (GSSL)

In 2006 *Raphael Viscorra Rossel* understood the GSSL importance and initiated an activity toward establishing the first GSSL

Global spectral library project

- Started in 2008 as voluntary collaboration in response to growing interest in soil vis–NIR spectroscopy



- Scientists from each continent coordinated and developed guidelines and protocols
- Aim to bring together a community of scientists, encourage research, development of new applications and adoption of spectroscopy in the soil, earth and environmental sciences.

provided by Viscorra Rossel

GSSL

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There is a publication on the global library

Authors: Those who contribute to GSSL established by Viscorra Rossel

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A global spectral library to characterize the world's soil

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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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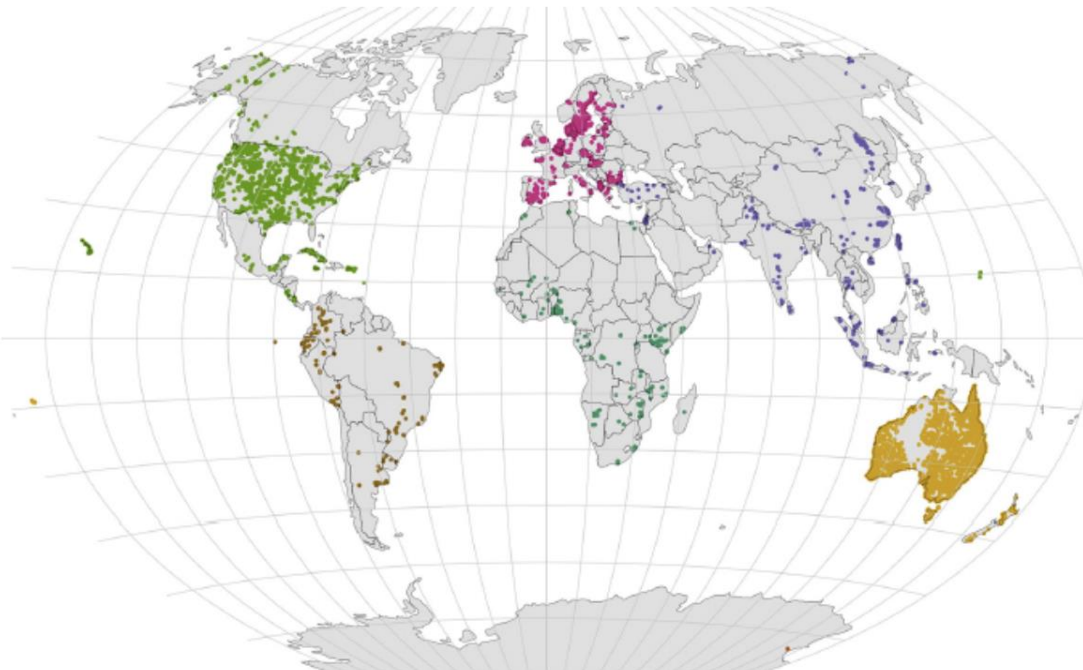
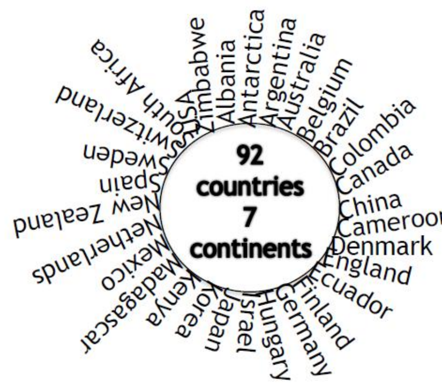
In 2015 Raphael effort yield the first GSSL

Global soil Soil VNIR-SWIR Spectra

Some 20,000 VNIR-SWIR (350-2500 nm) spectra from 12,509 sites

45 collaborators from 35 institutions



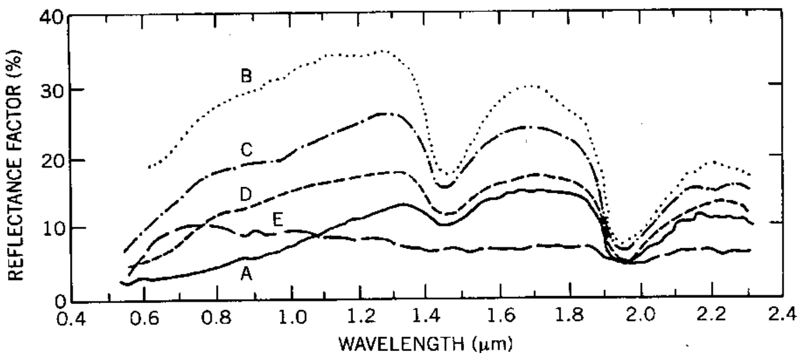


provided by Viscorra Rossel

First Soil Spectral Library

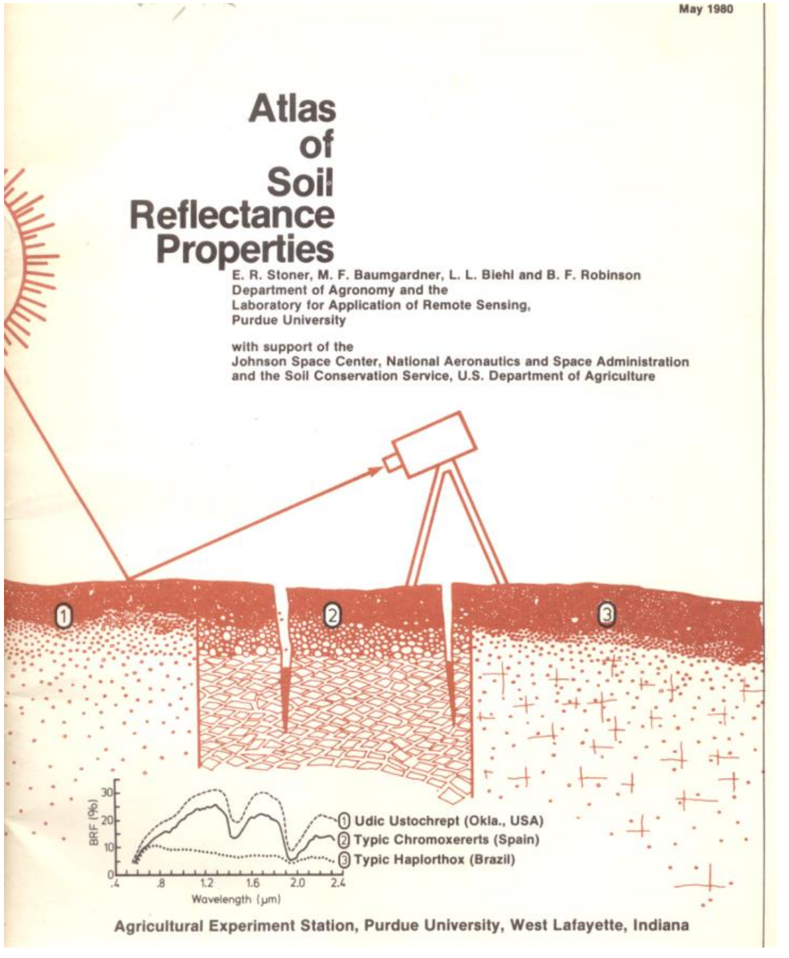
1980

5 spectral types
in USA



Stoner, E.R. and M.F., Baumgardner, 1981. Characteristic variations in reflectance of surface soils. Soil Science Society of American Journal 45: 1161-1165

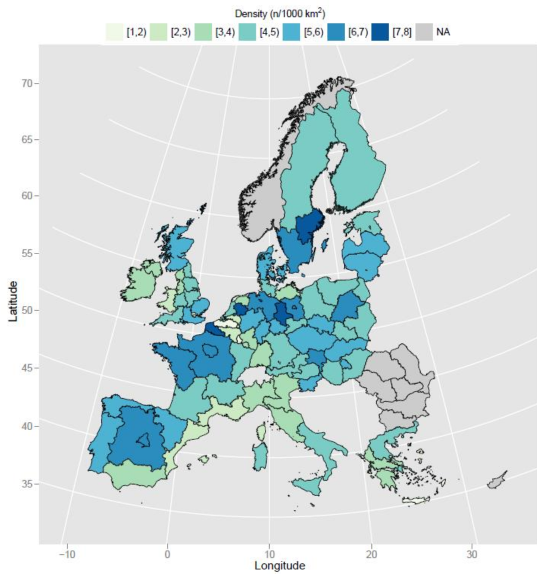
Around 4000 spectra

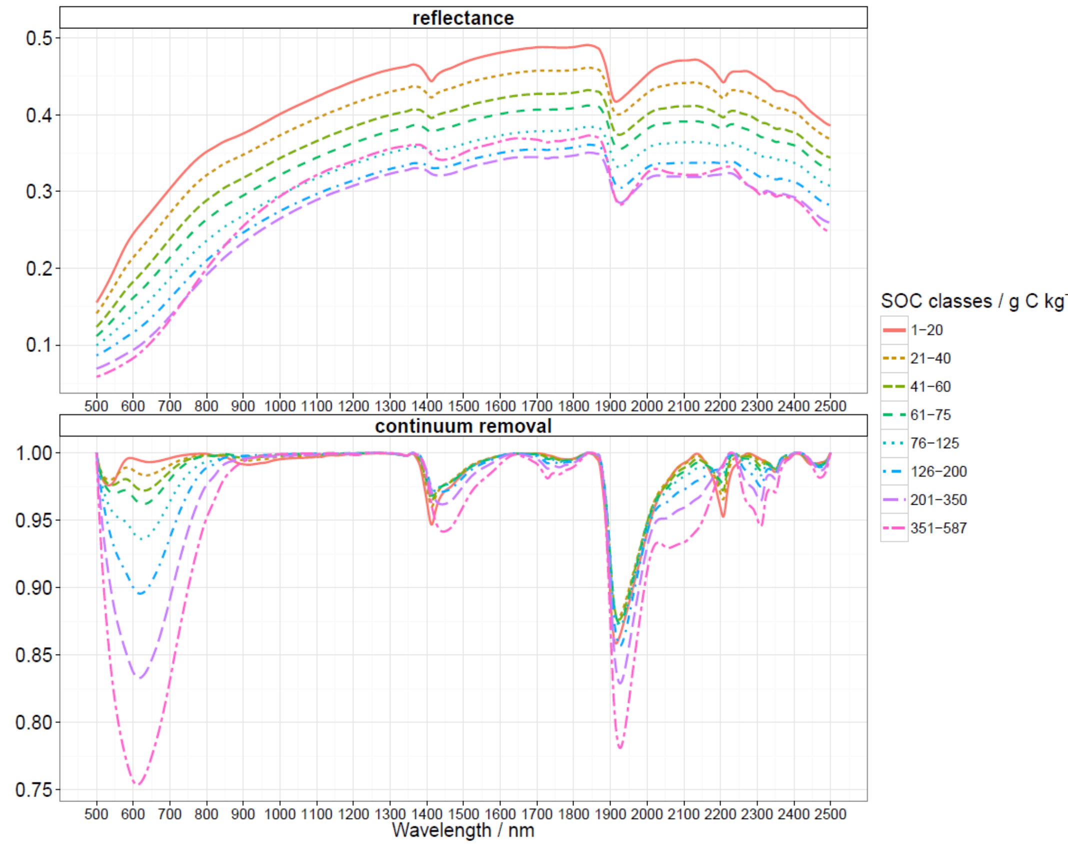


The European Soil Spectral Library

The LUCAS spectral library

2011





- Current status:
- 23 European countries
- ~20,000 high quality spectral readings
- Metadata: Clay, silt, sand, OC, pH, CEC, $CaCO_3$, Geographical coordinates, land use, etc

Creation of four subsets: Cropland, Grassland, Woodland, and Organic soils

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The Problem

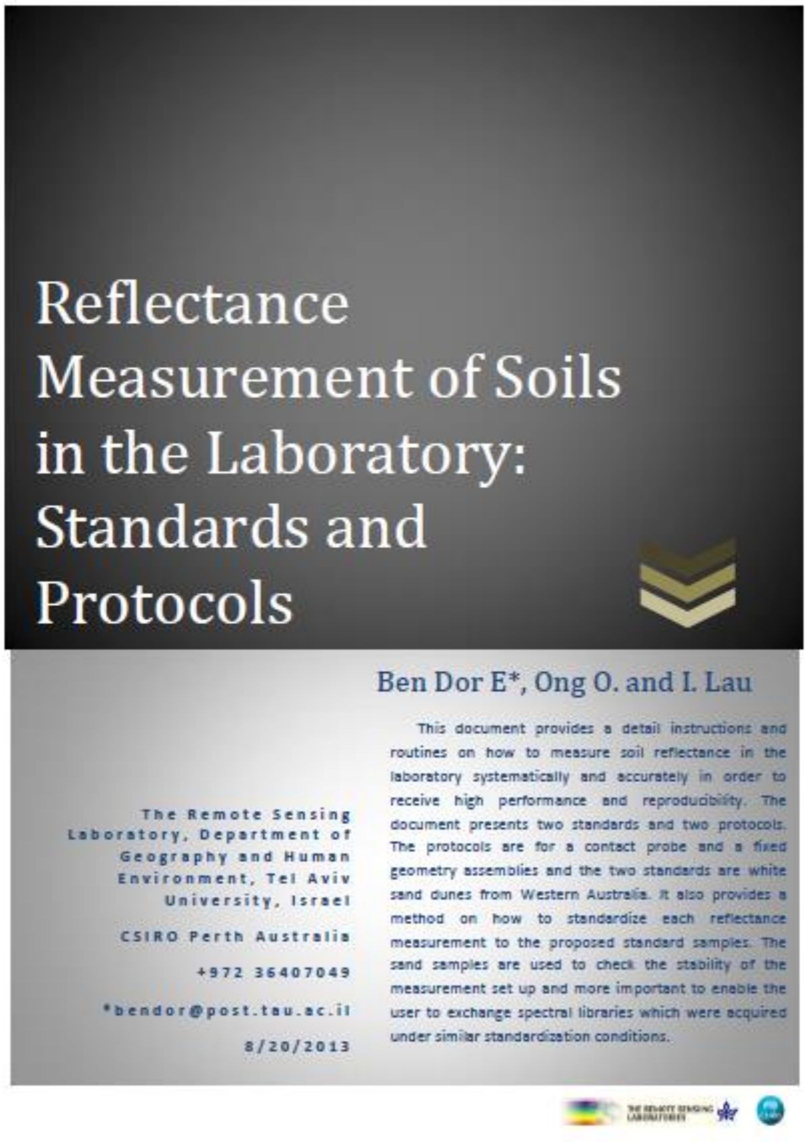
- Users are focused on their own protocols (*measurement methods and instrumentation*)

- Protocol may affects the final spectrum……
(Spectral information is not reliable)

- Quantitative models are sensitive to these effects (small spectral changes) …..

- The *Chmometric* models from one protocol can not be used by other protocol

Protocol



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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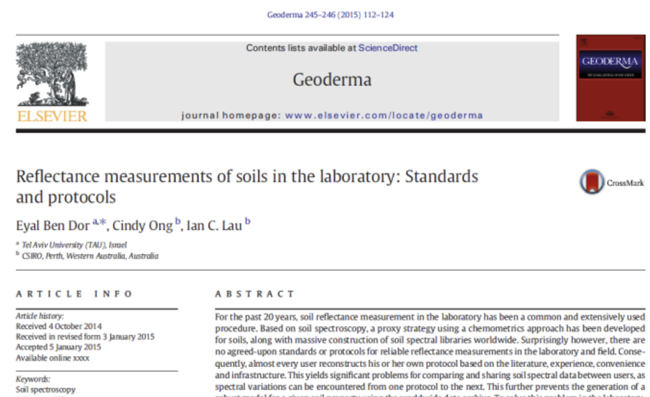
8/20/2013

A simple protocol has established for new users Since 2014



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Reflectance measurements of soils in the laboratory: Standards and protocols

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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 spectral variations can be encountered from one protocol to the next. This further prevents the generation of a

The GEO – CRADLE WG-4 Achievements

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Coordinating and integRating state-of-the-art Earth Observation Activities in the regions of North Africa, Middle East and Balkans and Developing Links with GEO related intiatives toward GEOSS

To initiate and demonstrate a new SSL paradigm:

- Building a SSL under a recognized World Standard
- Demonstrate this standard on a regional domain

Get prepared for the new orbital Hyper and Super spectral sensors

European Commission

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Team


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cima
OBSERVE TO PREDICT, PREDICT TO PREVENT.
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ALBANIA
IBEC
INTERBALKAN ENVIRONMENT CENTER
GREECE
TÜBİTAK
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TURKEY
Cyprus University of Technology
CYPRUS
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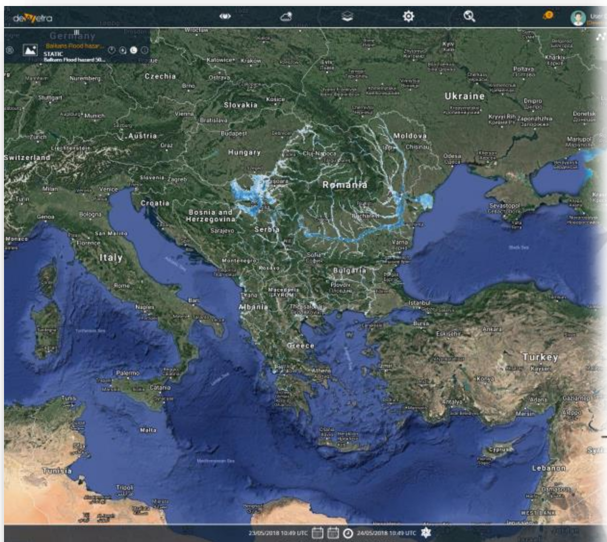
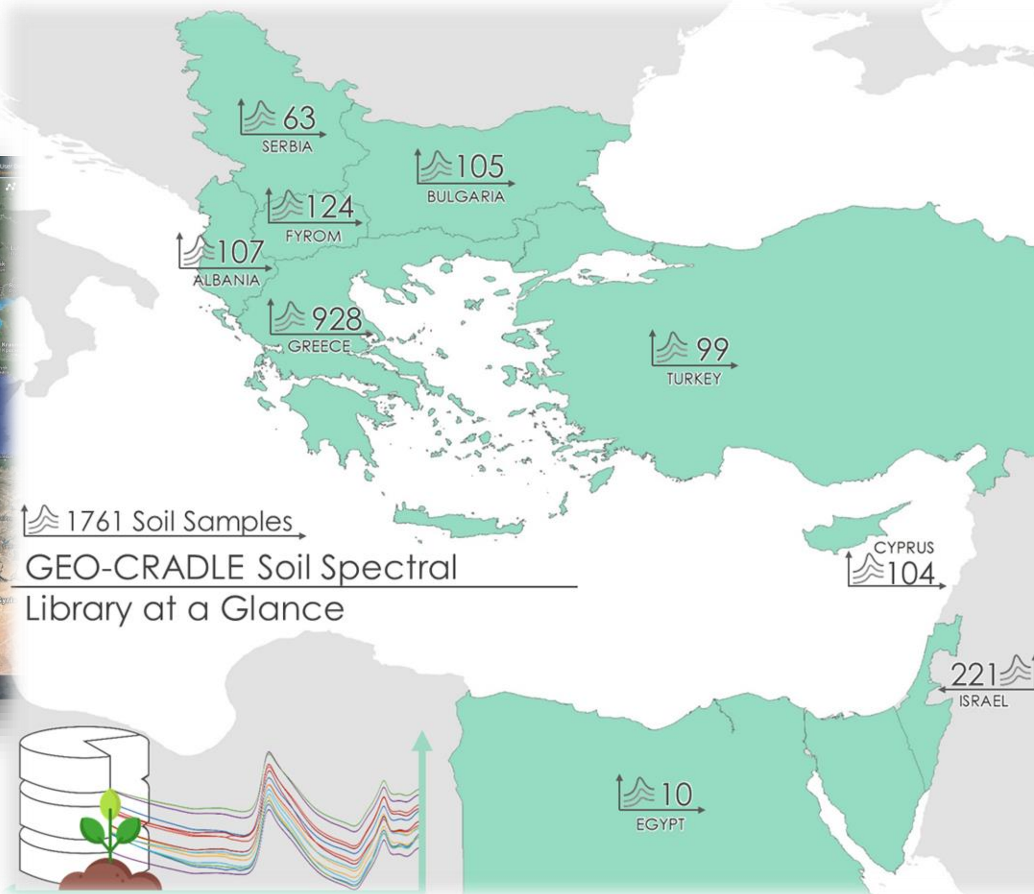
ISRAEL
CEDARE
EGYPT

Pilot Highlights





Soil Classes
in Number of Samples

Cambisols CM	257
Fluvisols FL	457
Gleysols GL	7
Histosols HS	1
Luvisols LV	199
Phaeozems PH	8
Vertisols VR	164
Arsenosol AR	133
Chernozems CH	16
Leptosols LP	340
Planosols PL	4
Umbrisols UM	2
Regosols RG	41
Calcisols CL	82
Gypsisols GY	1
Kastanozems KS	16
Solonchaks SC	15
Solonetz SN	4

Soil Properties
in Number of Samples

OM	1527
Texture	1618
$CaCO_3$	1241
NO_3	991
pH	529
EC	241
CEC	105

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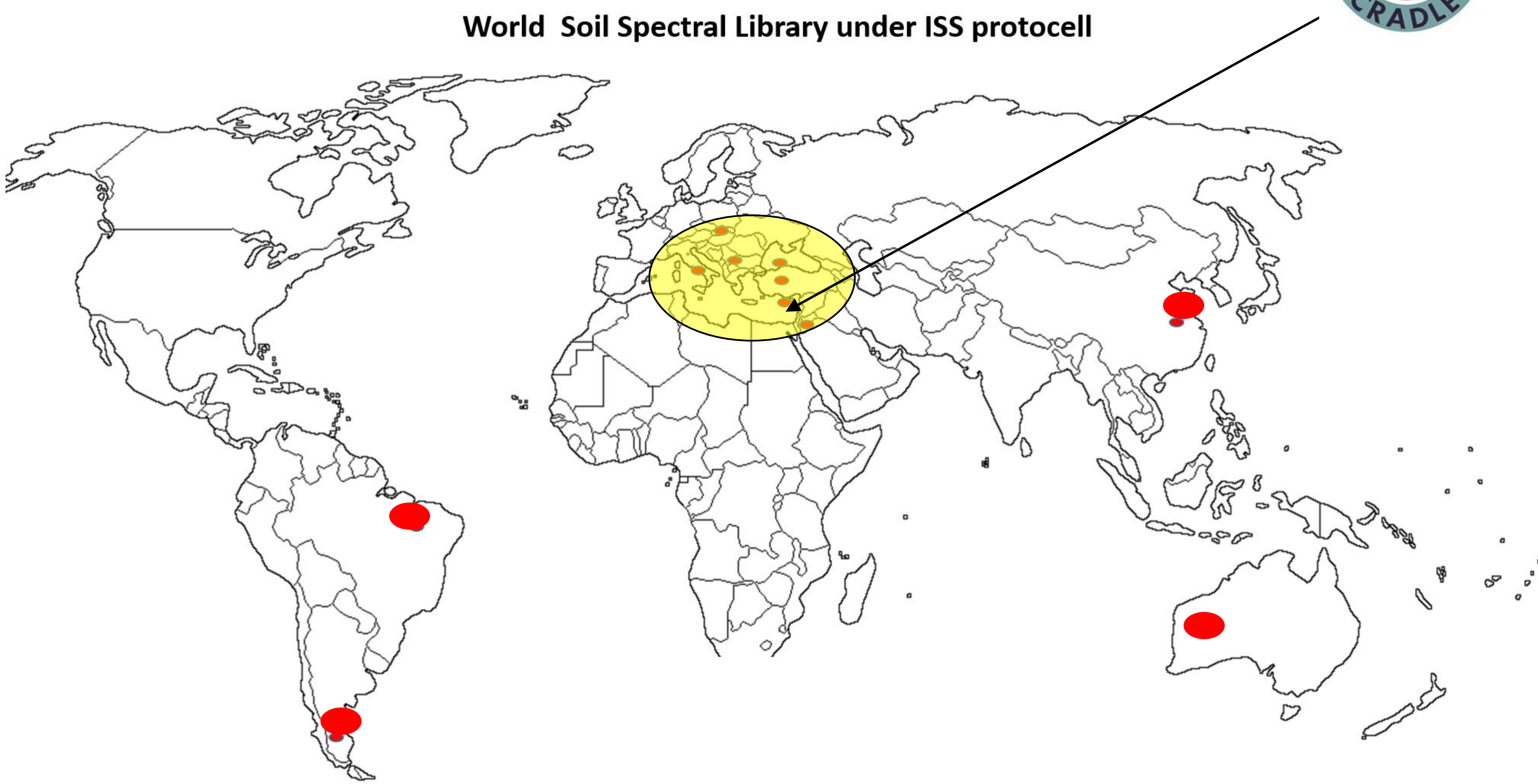
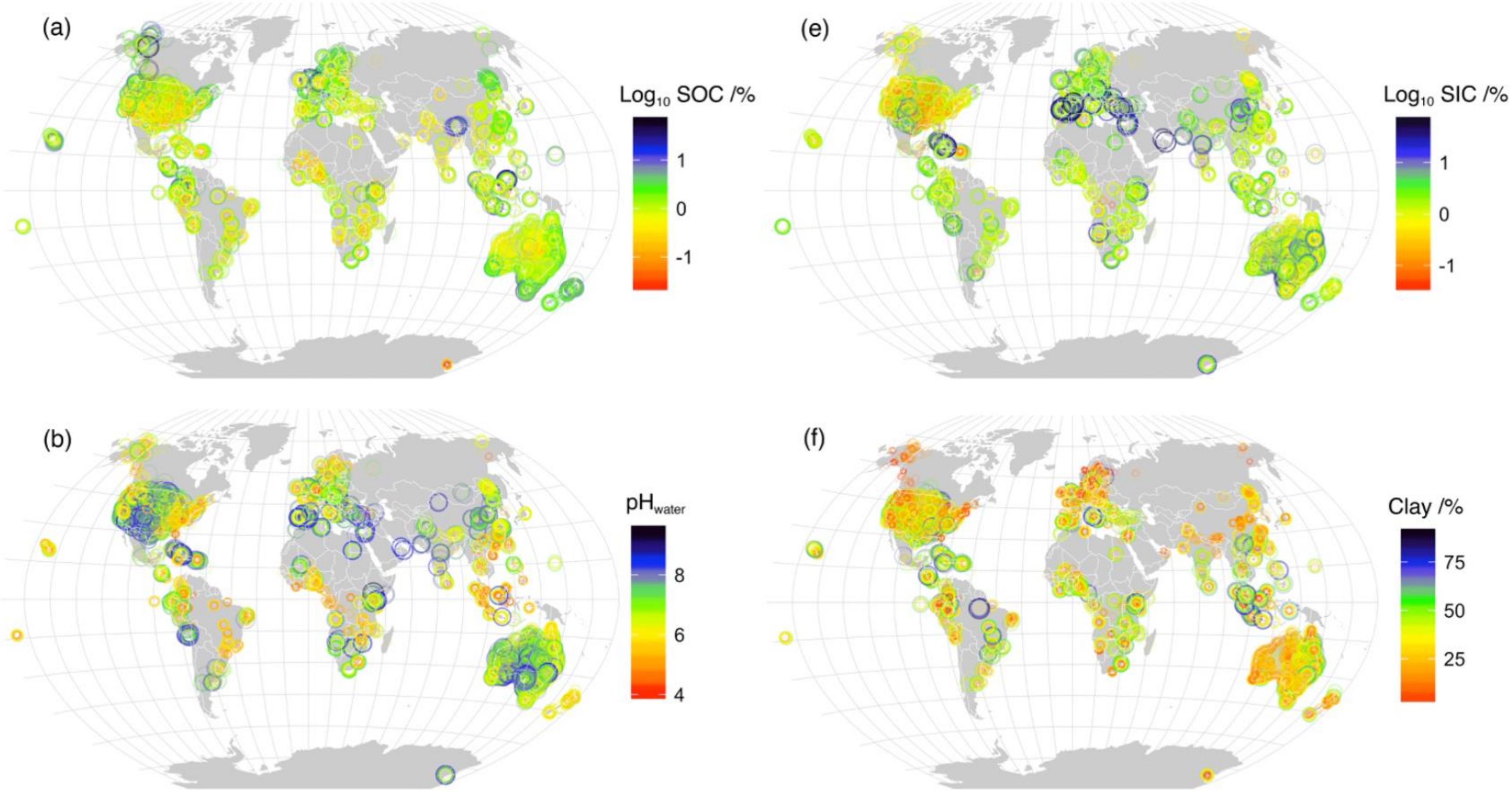
New Standard (ISO) world wide Soil Spectral Library



GSSL – Example

Chemomtric (non linear spectral data mining) from the GSSL

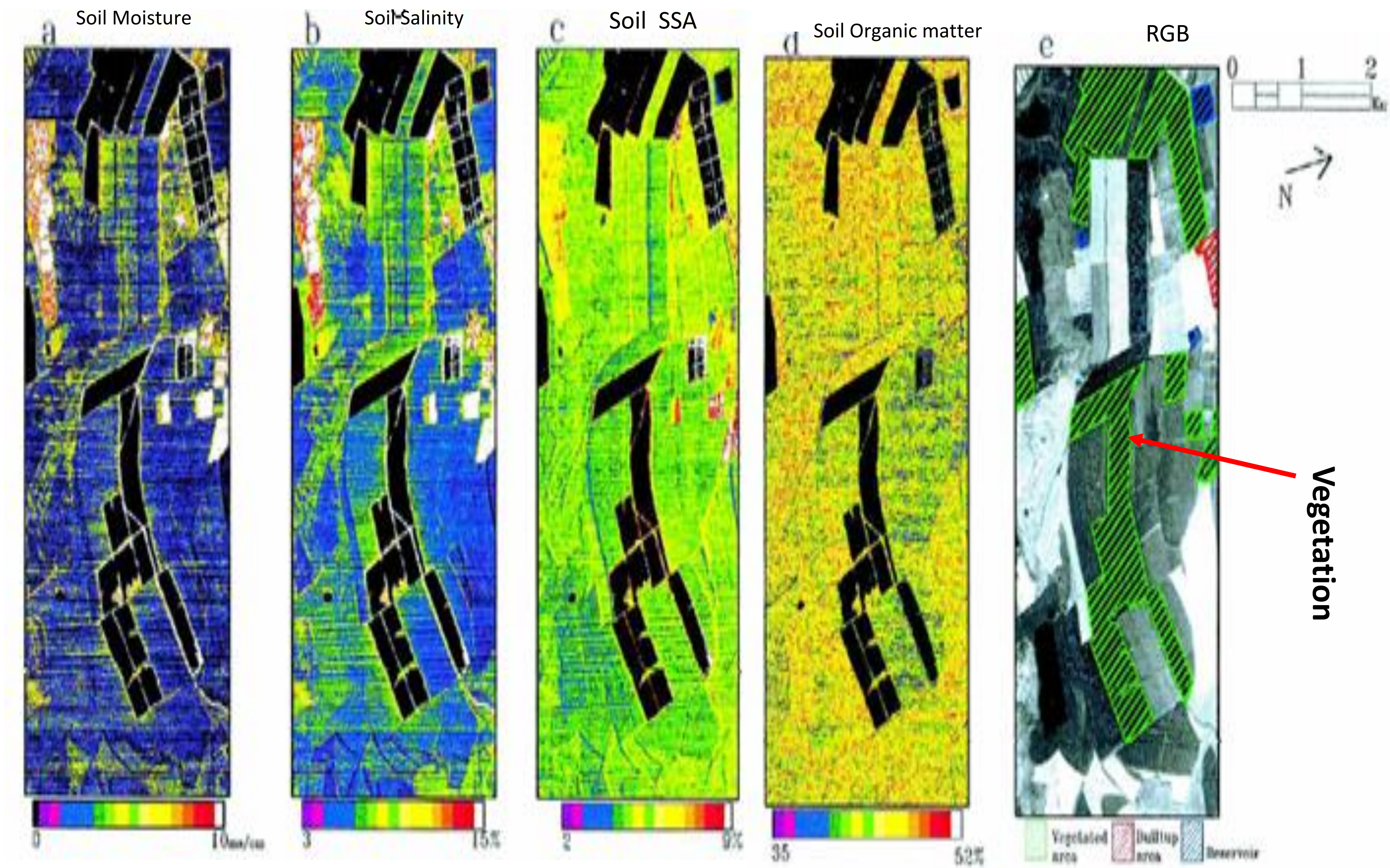
Spatial distribution of predictions



Viscorra Rossel 2015

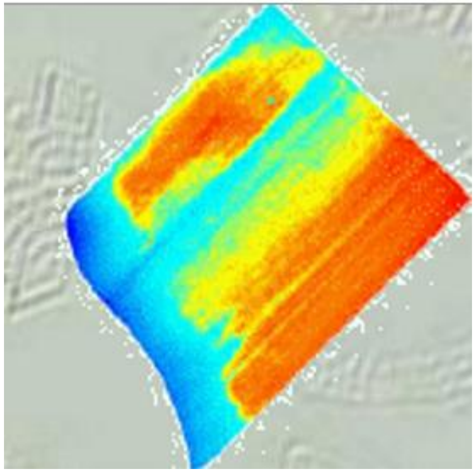
Local field Spectral Library : The Practical Value (4)

Agricultural Soil Mapping based on Local SSL and HSR technology



Ben-Dor et al., 2004

Soil Mapping in the Field using Local SSL



Mobile Soil Sensor System

- vis-NIR (350-2500 nm) sensor
- Mobile data acquisition system
- Customized cooling system
- Long duration battery
- Custom air pump to clear the optic fiber at regular intervals
- Triangular soil flattening unit to eliminate soil roughness, set aside plant residues and other litter, and ensure measurement of topsoil.
- In continuous operation acquires roughly 12 measurements / minute; tractor moves at 5 km/h

(Tziolas et al. 2018) [AgEng conference]

remote sensing

MDPI

January 2018

Article

Soil Organic Carbon Estimation in Croplands by Hyperspectral Remote APEX Data Using the LUCAS Topsoil Database

Fabio Castaldi [1,*], Sabine Chabrillat [2], Arwyn Jones [3], Kristi
Bas van Wesemael [1]

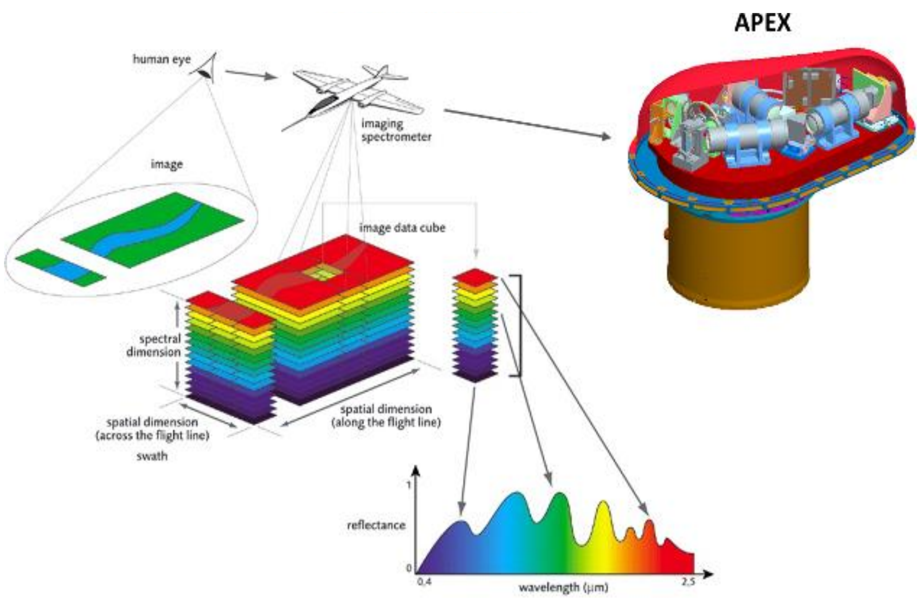


Figure 2. Flow chart concerning the two soil organic carbon (SOC) estimation approacl

om-up.

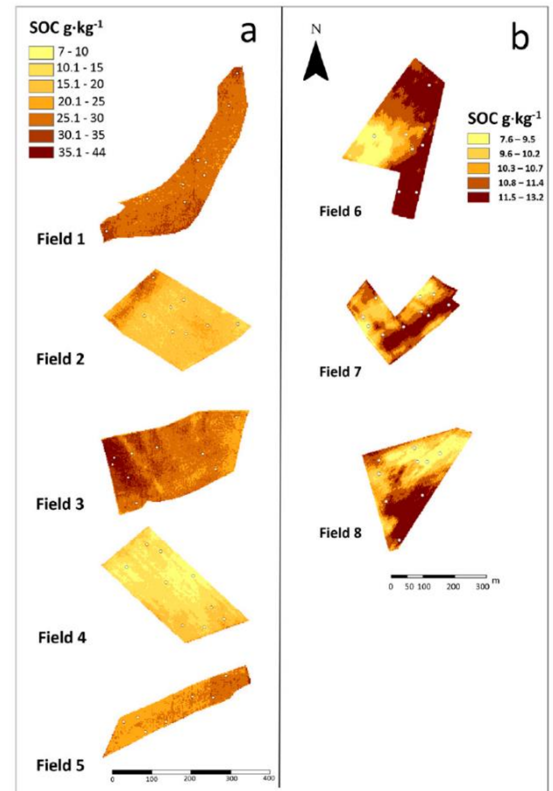


Figure 4. SOC maps of the validation fields in Luxembourg (**a**), and Belgium (**b**), using
approach. The white points in the fields correspond to the validation dataset.

The concept of using SSL : Drone utilization

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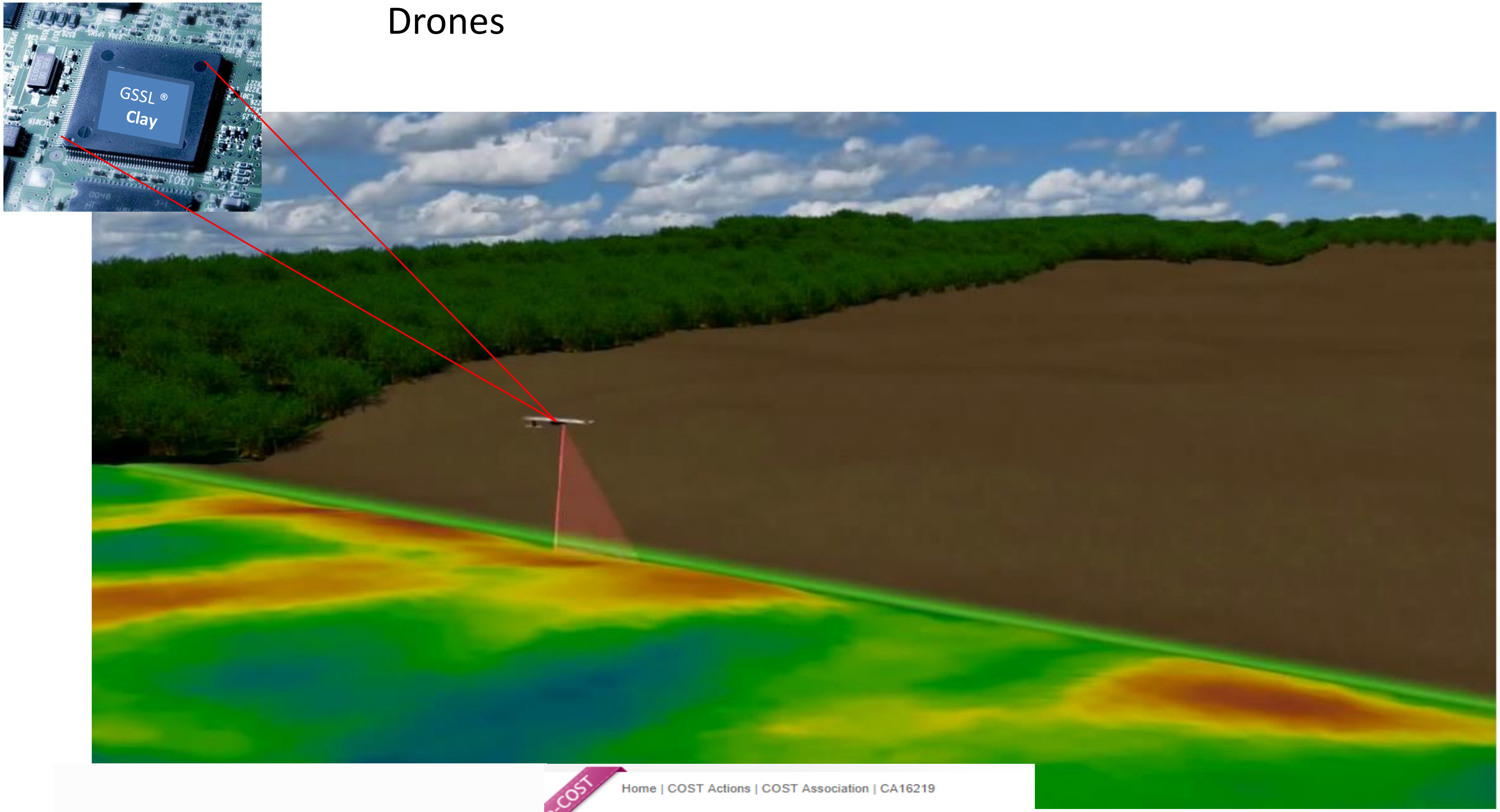
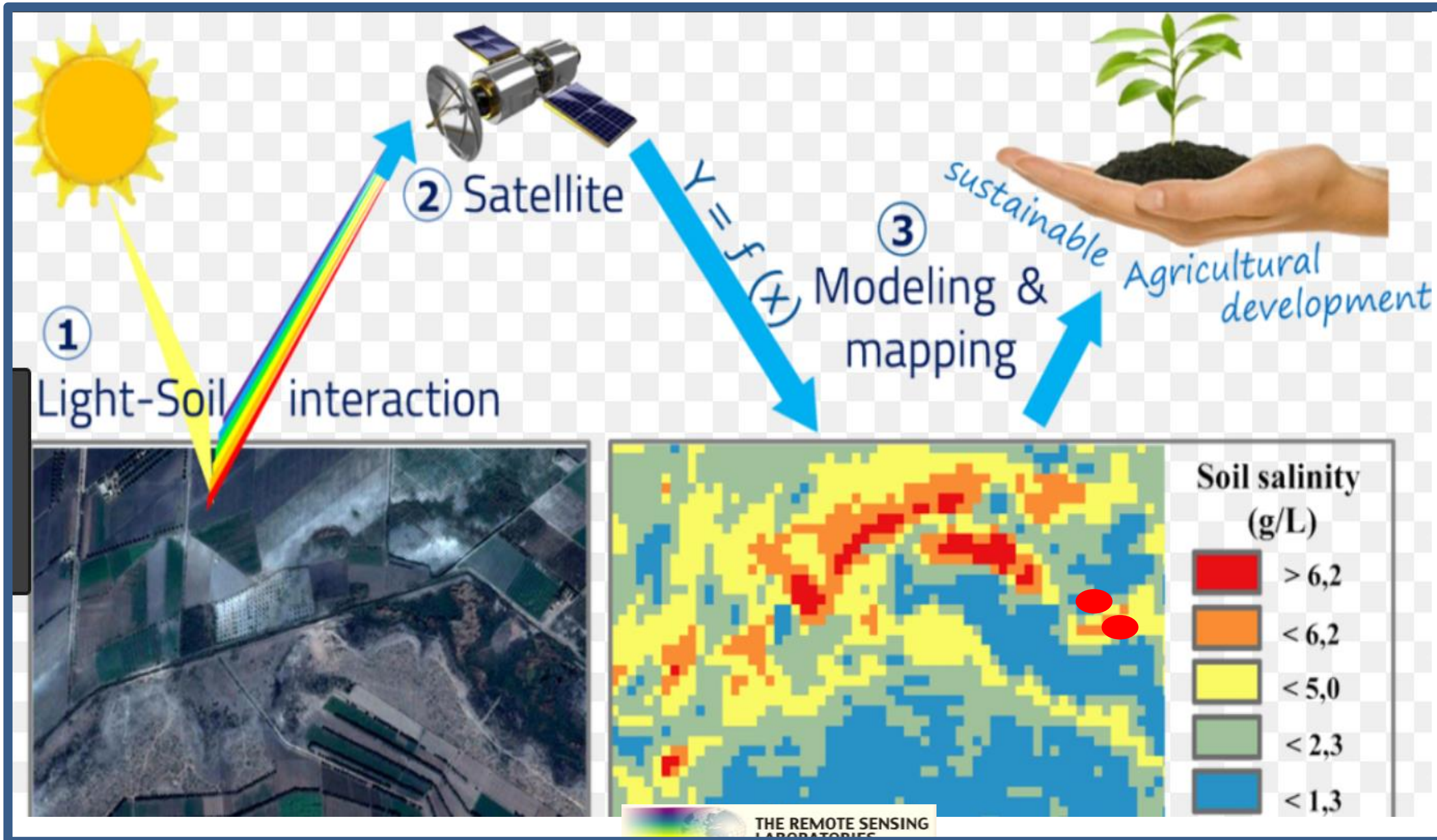
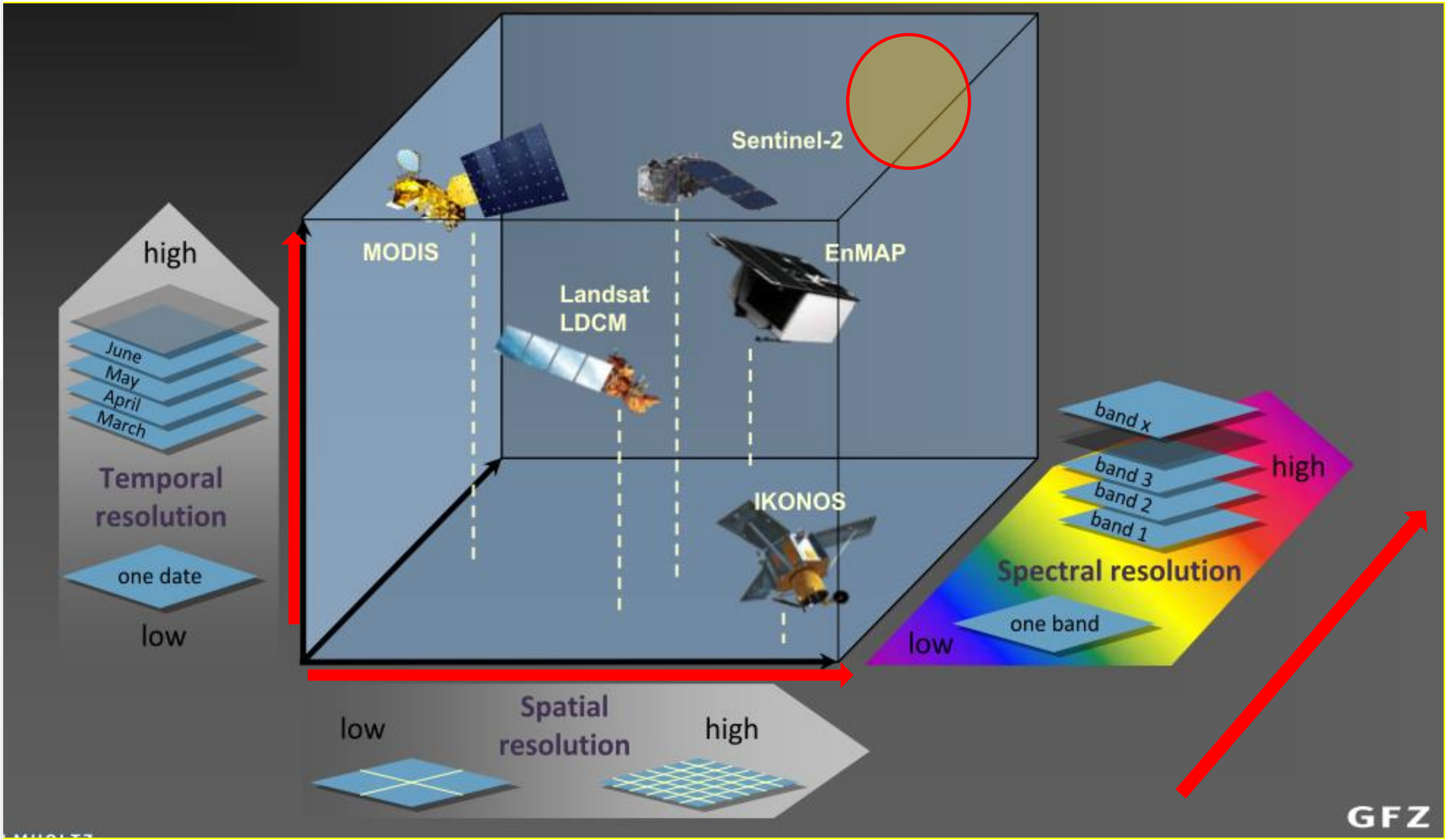
Drones



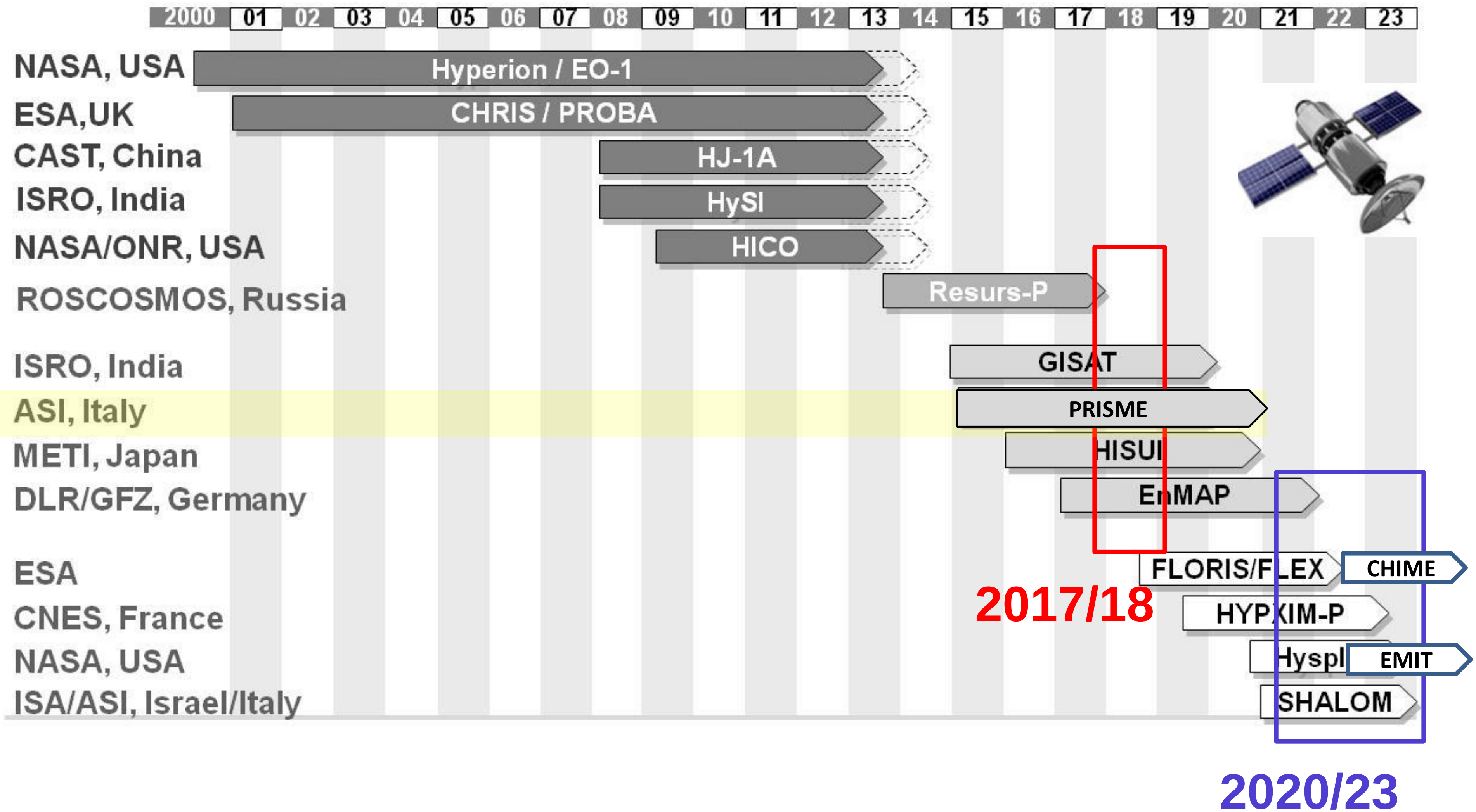
The concept of using SSL : Satellite utilization (near future)





Sentinel-2
MODIS
EnMAP
Landsat
LDCM
IKONOS
high
June
May
April
March
Temporal
resolution
one date
low
band x
band 3
band 2
band 1
high
Spectral resolution
one band
low
low
Spatial
resolution
high
GFZ

HSR Satellites Program



The HSR Satellites Program

Sentinel 10 – CHAIM

esa

estec

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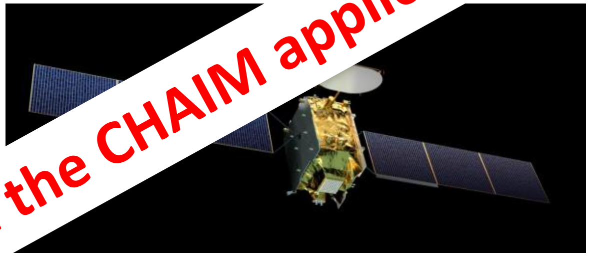

Soils play a major role in the CHAIM applications

Copernicus Hyperspectral Imaging Mission
Mission Requirements Document

HIMAG Group

CHAIM sensor

- 224 channels
- 0.4-2.5 mm
- 5nm Spec Res
- 20m GDS

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The HSR Satellites Program

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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 An. Productivity Indicators
Lava and ash distribution map
Snow And Ice Cover Characterization

Soil Salinity: (gypsum, sodium)

Soil Minerals: (iron oxides, organic matter, clay, carbona… …, Quartz)

Soil infiltration: (crust, classes)

Soil Formation: (clay, iron oxides)

Soil Erosion (Iron Oxised, Clay M…

Soil Contamination: (heav…

Soil Hydrophobicity (… …r)

Soil Moisture: (…

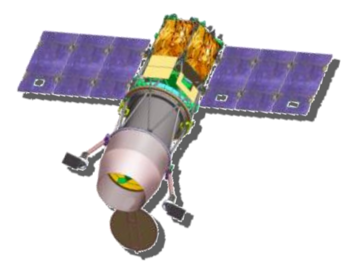
Soil Quali… … test)

Soil … …, P,K)

…ation: (all the above)

…al Change Detection (all the above)

…any others by Indirect Relationship



Soils play a major role in the SHALOM applications

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The HSR Satellites Program

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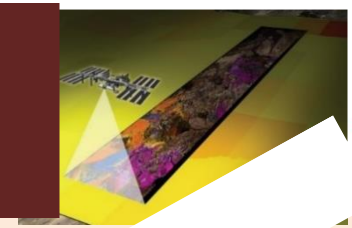
EMIT: Earth Surface Mineral Dust Source Investigation



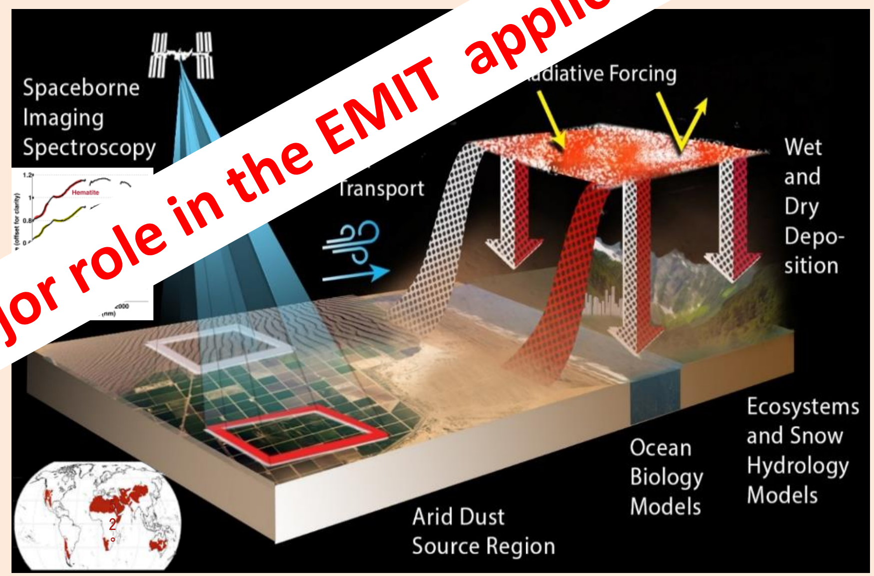
Soils play a major role in the EMIT applications

- **Challenge:**
- Mineral dust radiative forcing is the single largest uncertainty in aerosol direct radiative forcing (USGCRP & IPCC)
- Mineral dust emitted from the surface is a principal contributor to direct radiative forcing over arid regions, impacting agriculture, precipitation, and desert encroachment around the globe
- Composition is critical: a chang… 1% in relative abundance … oxide can cause a ~5… radiative forcin…
- The com… …th's min… …egions is poorly

…eses Tested by EMIT:

- …ne net contribution of mineral dust to regional and global radiative forcing is to warm the atmosphere (positive forcing)

Measuring the Earth's Mineral D… …egions to Improve Forecasts of the Im… …t on the Earth



JPL NASA National Aeronautics and Space Administration Goddard Institute for Space Studies New York, N.Y. Cornell University NOAA PSI UCLA USGS Barcelona Supercomputing Center

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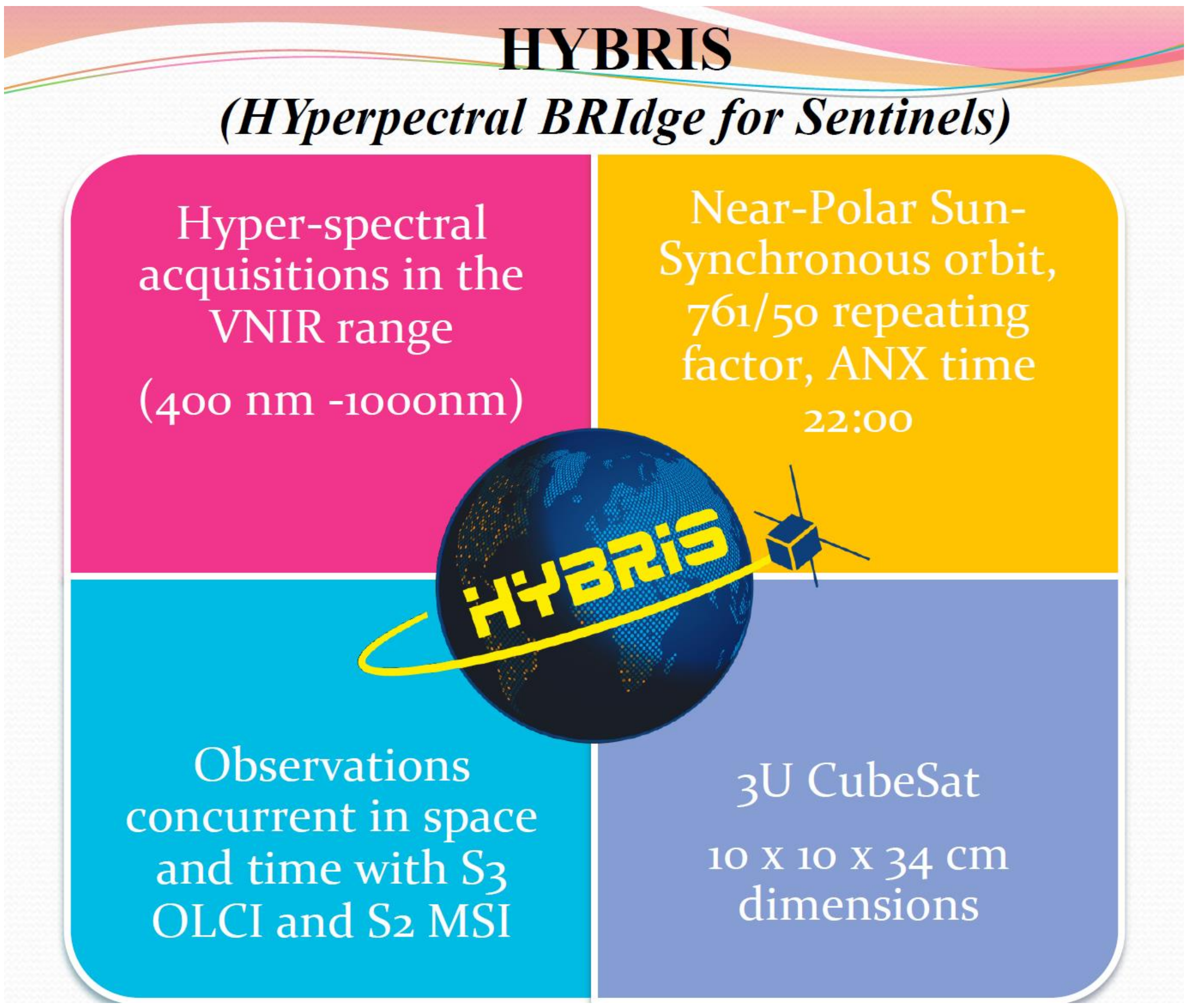
CUBESAT



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Cyprus SSL : Example of PARACUDA-II Analysis (3)

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Paracuda-II analyses

12 bands 400-1000μm

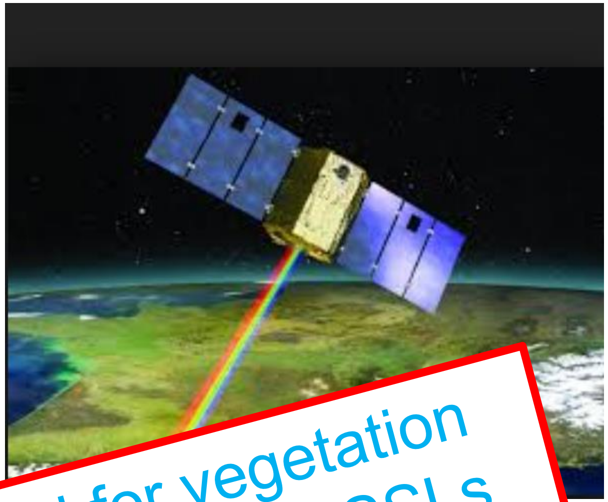
(Venus – Spectral configuration)

attributes	N	Factors	R2 Cal	R2 Val	RMSEP	SEC
Ca_ICP_A	104 (52 Cal,52Val)	7	0.76	0.73	5.64	304.82
Fe_ICP_A	104 (52 Cal,52Val)	8	0.41	0.57	1.56	84.37
TC_percent	104 (52 Cal,52Val)	8	0.79	0.5	3.56	3.56
TOC_percent	104 (52 Cal,52Val)	3	0.31	0.26	2.1	2.1

The Super Spectral Satellites Program

Current Super spectral sensor in orbit: Venus

12 channels in the
VIS-NIR
A Suepr Spectral Sensor



Paracuda-II

although Venus was spectrally designed for vegetation and water applications our previous and current SSLs shows that Venus is **capable to assess soil attributes** as well !!!!!

					RMSEP	SEC
Ca			0.76	0.73	5.64	304.82
Fe_		8	0.41	0.57	1.56	84.37
TC_p	(52 Cal,52Val)	8	0.79	0.5	3.56	3.56
TOC_percent	104 (52 Cal,52Val)	3	0.31	0.26	2.1	2.1

Conclusions

- The current and future space missions will need an ISO recognized SSLs
- GEO-CRADLE WG-4 has established the first ISO –SSL data base for the Mediterranean to be a “lighthouse” for the World SSL
- The GEO-CRADLE’s SSL proved its potential for agriculture applications using online soil HRS mapping
- A regional soil spectral libraries (SSL) is an important data base to study the potential of new HSR space or airborne sensors as well as acts as a vehicle to map soil attributes in an innovative way in all domains (laboratory, field airborne)

Thank You !!