Regional Soil Spectral Library for Better Management of Agricultural Activity and Food Security

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

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Why Soil

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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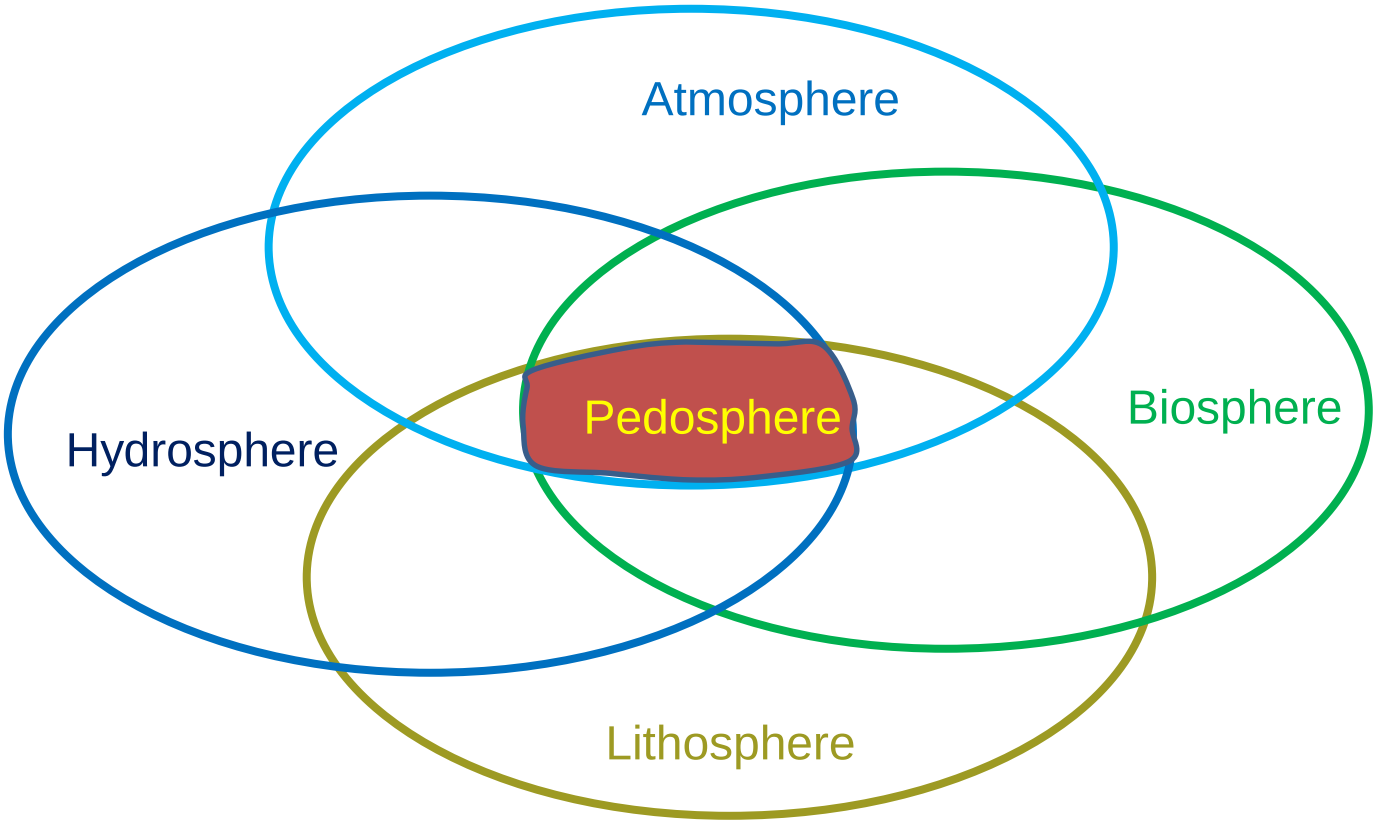

CHAPTER ONE

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

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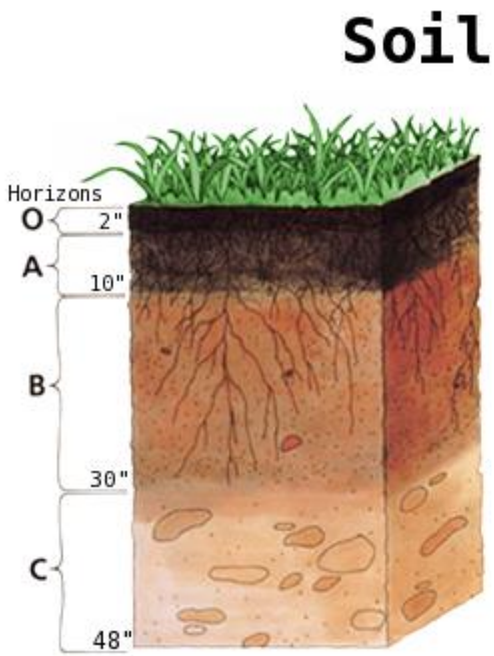
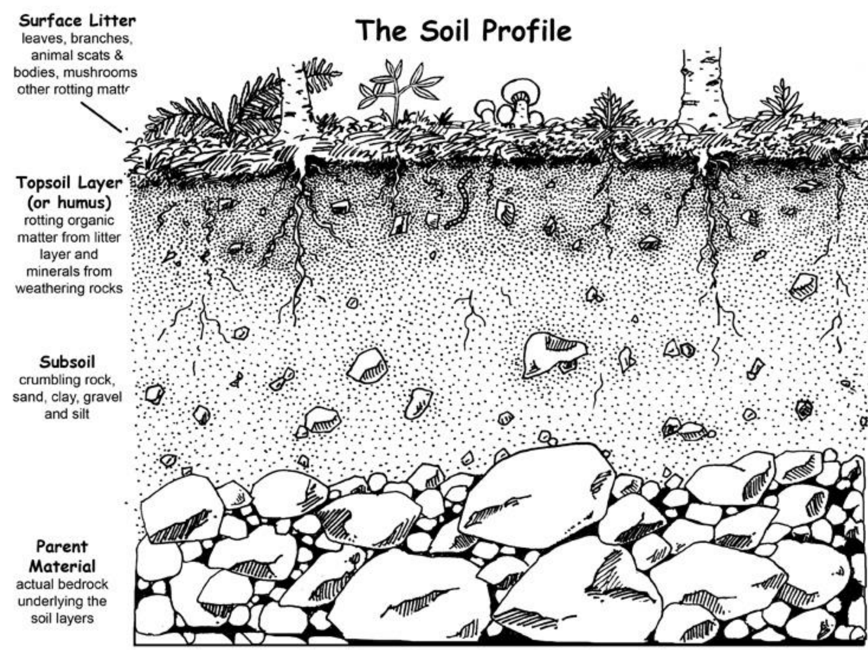
Definition 1

Soil

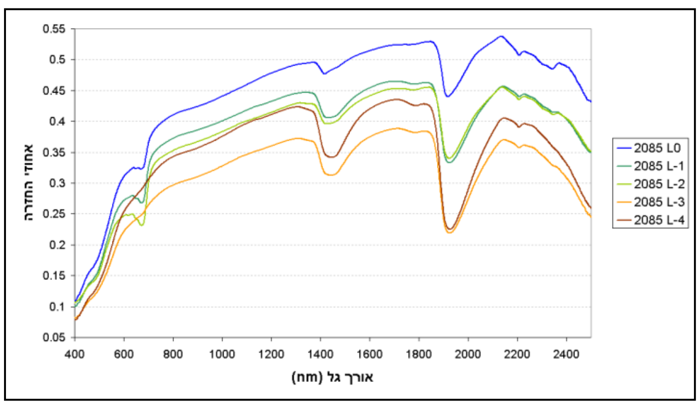
***The upper layer of the earth (≈0-2m) represent its loose surface material which is dug, plowed and being a medium for plants to grow*. (Thompson 1957)**





Definition 2

- 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).



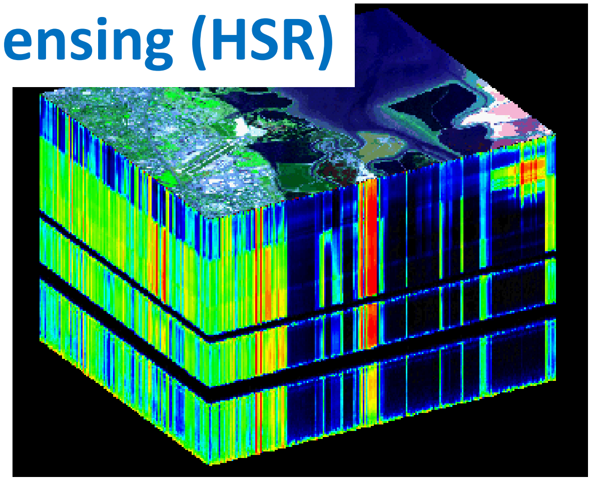
Point – one pixel

Definition 3

Imaging spectroscopy

From Wikipedia, the free encyclopedia

Hyperspectral Remote Sensing (HSR)



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

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)

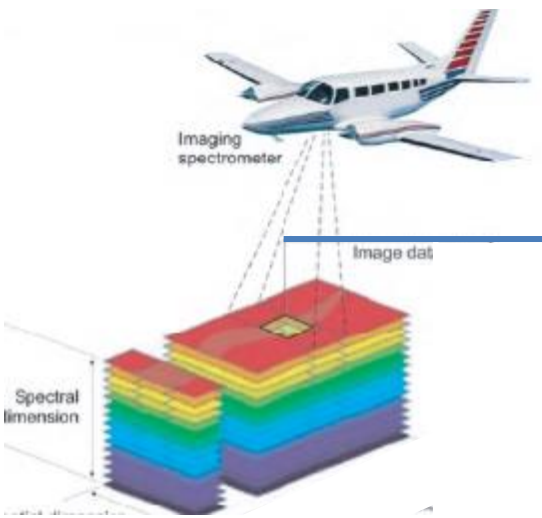
Strong Link between Point and Image Spectroscopy

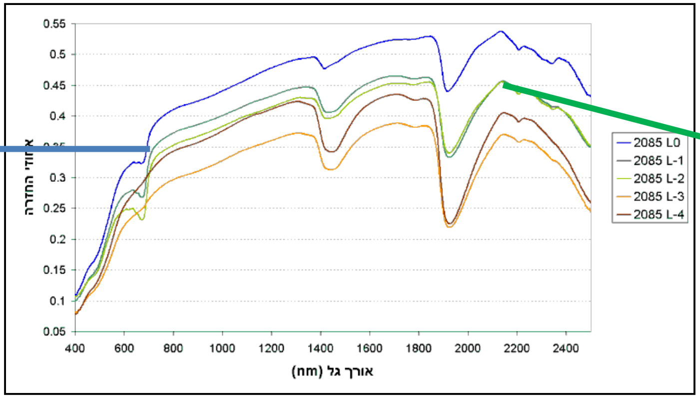
Image Spectroscopy

Geology
Vegetation
Water

Point Spectroscopy

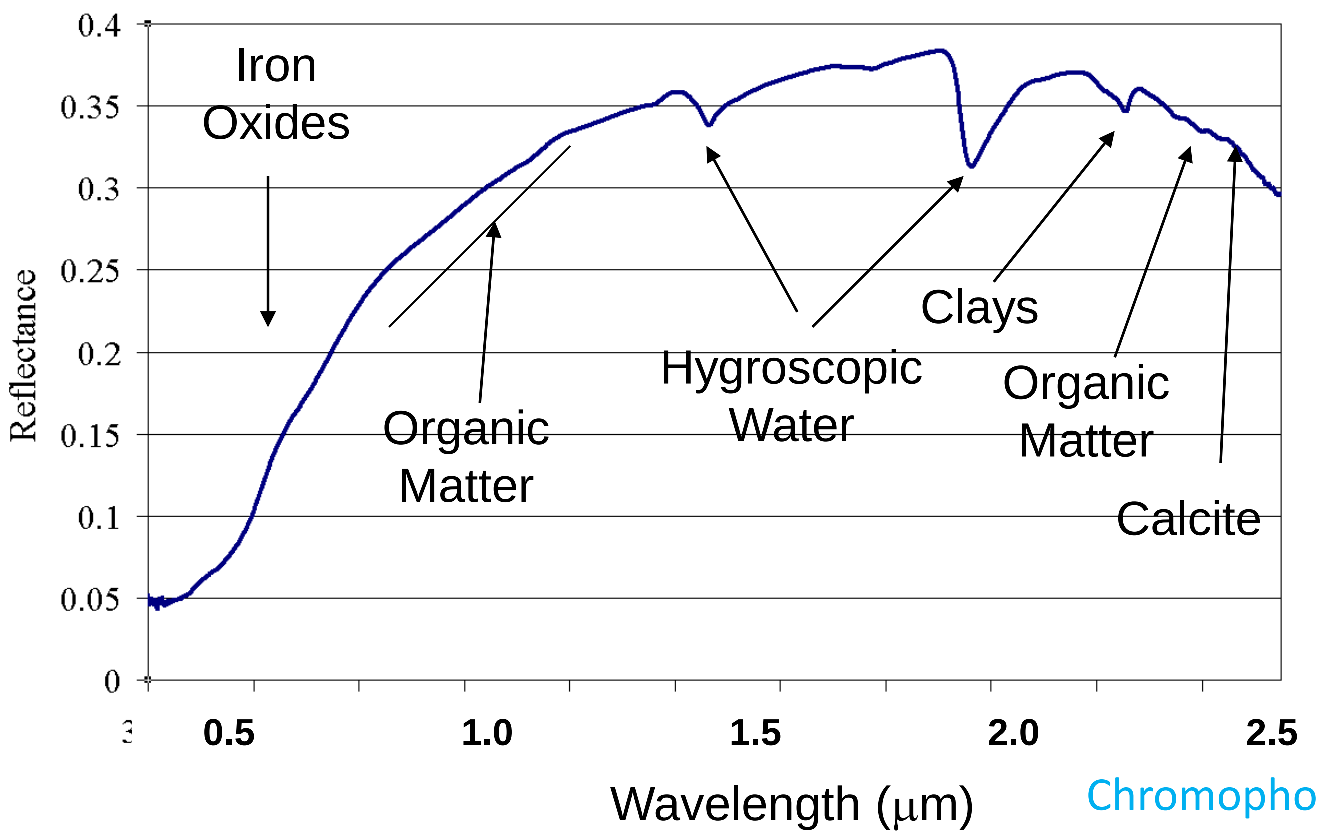
Soil





A typical Soil Spectrum

An effective way to simplest the complexity of the soil system

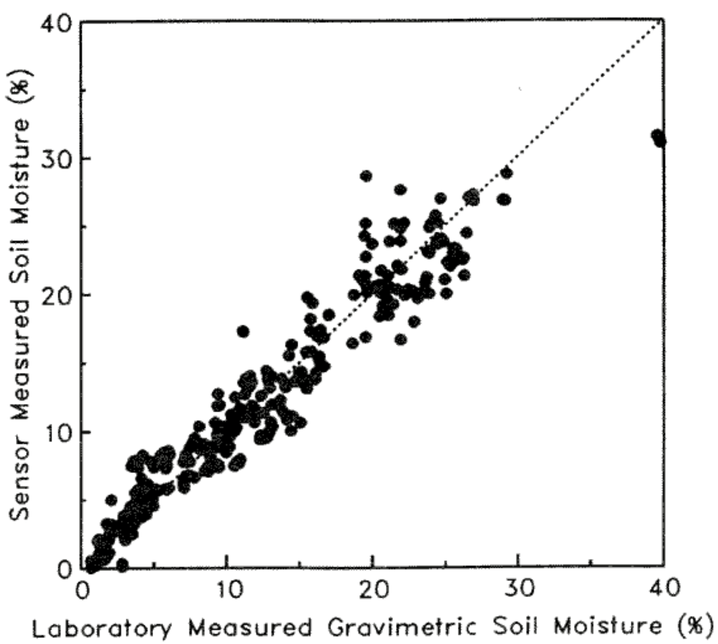


Chromophore = An attribute that interact with the electromagnetic radiation

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

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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)

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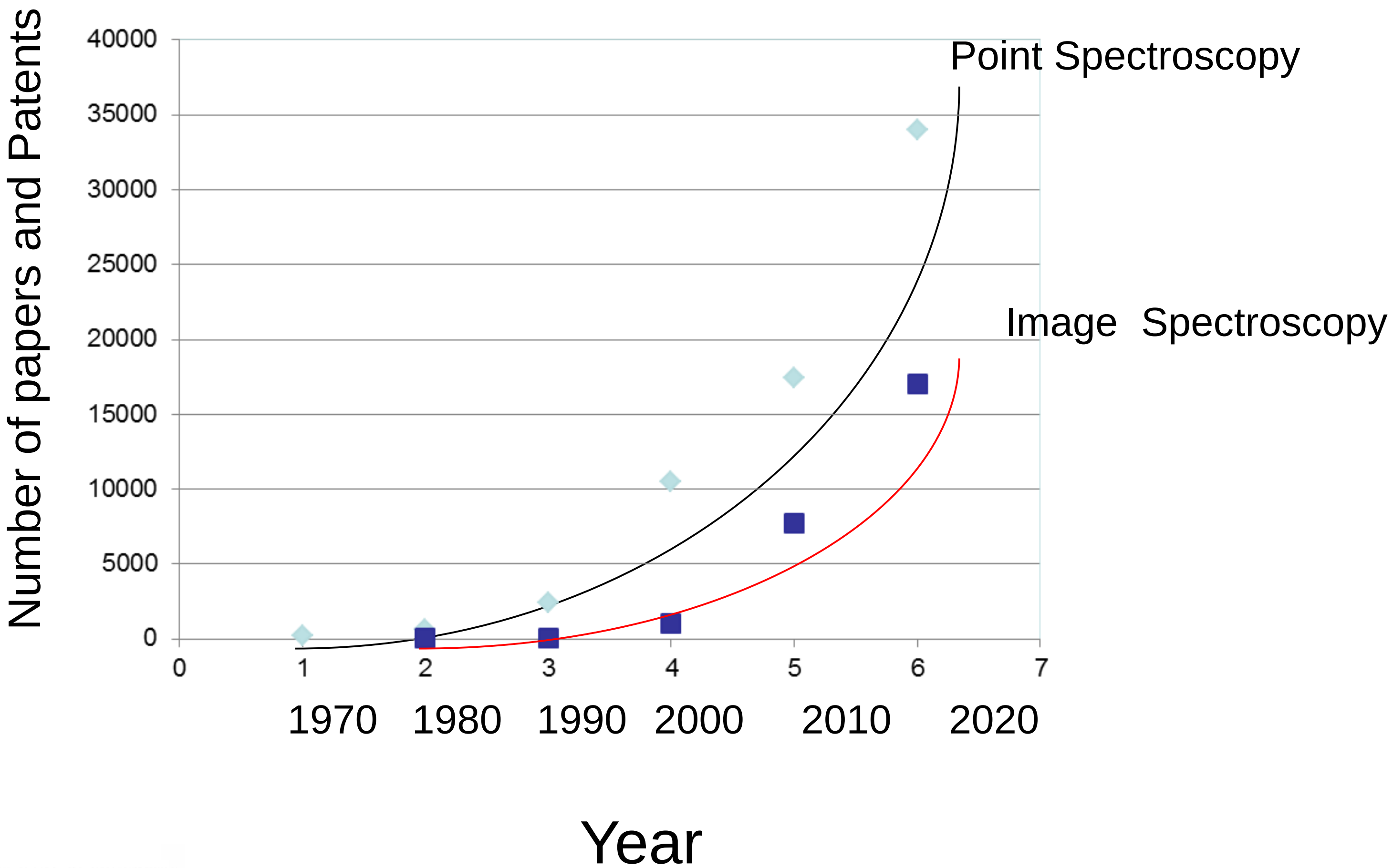
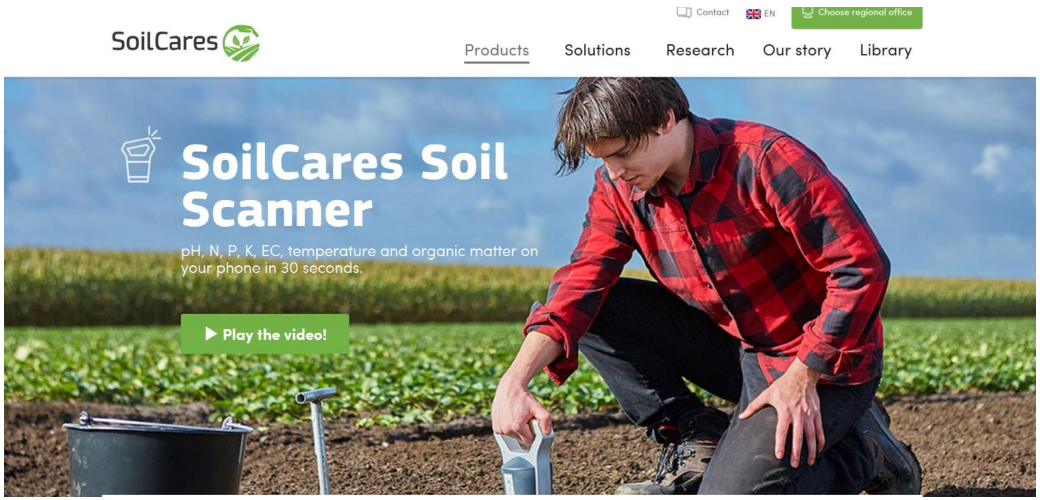
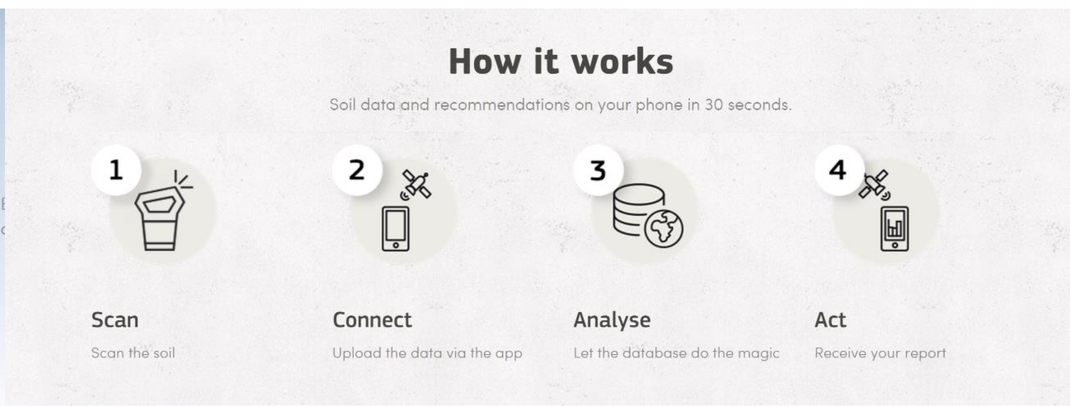
Number of papers published in soil spectroscopy over the years : Point and Image domains



Soil Spectral Library : The Commercial Value (1)





http://www.soilcares.com/en/products/scanner/

Soil Spectral Library : The Commercial Value (2)

Rapid (and massive) analyses of soil samples with out the need for “wet” laboratories

2016

News

10.18.16 | Research, Development and Innovation

Innovative technology analyzes soil in just 30 seconds

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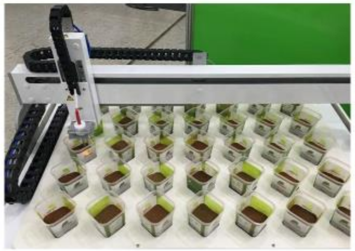
Photo: André Marcelo de Souza

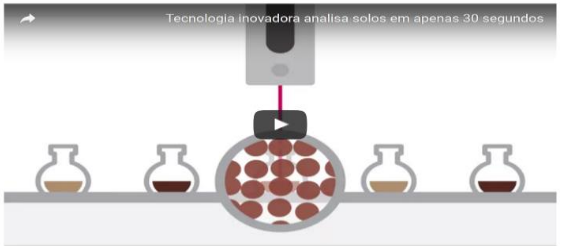


Embrapa Solos (RJ), in partnership with the private sector, has developed a technology package for the soil analysis that will revolutionize the market in Brazil. Called SpecSolo, it has the advantage of analyzing soil samples non-destructively, quickly and economically. Tens of fertility parameters (soil organic carbon, pH, calcium, magnesium, phosphorus, potassium, among others) and physical soil (clay, silt, sand) can be analyzed simultaneously in 30 seconds. Conventional analysis takes days to present the same parameters.

"The SpecSolo is based on the use of techniques of vibrational spectroscopy and artificial intelligence," explains André Marcelo de Souza, from Embrapa Solos researcher and responsible for technology. Souza explains that the technology makes use of accurate and efficient algorithms. "These algorithms", explains the scientist, "will use a robust database with over one million representative soil samples from Brazil." Souza says that the samples and related analytical data were obtained from one of the largest laboratories in the world soil analysis, the Brazilian Institute of Analysis (IBRA), development of project partner and co-responsible for technology.

"The SpecSolo analytical solution is one of the greatest innovations in the analysis of the last five decades soils in Brazil, resuming the mission of Embrapa to propose and implement new methodologies for soil analysis in the Brazilian agricultural scenario," reiterates the general head of Embrapa Solos Daniel Vidal Pérez. Both the instrument and technology have the seal of Embrapa. Therefore, the SpecSolo will be an official method recommended by the Company for soil analysis in Brazil.

How it works



For the duo of directors of IBRA Armando Saretta Parducci Parducci and Thiago Camargo, the partnership between Embrapa Soils and IBRA enabled the development of technology. "We are the pioneers in Brazil to build a robust database with such a significant number of samples of Brazilian soil, essential for the development and success of technology," says Armando Parducci.

In addition to the large database, the technology package SpecSolo has a unique hosted software in the cloud for processing information and innovative equipment dedicated to soil analysis, called SpecSolo-Scan.

The equipment has an automatic sampler that allows simultaneous analysis of 40 soil samples and autonomy to work alone for 20 minutes. After that time, the analytical results are generated automatically, remotely accessing the database. The results can be released according to the service purchased by the customer and may be in the form of analytical results of each soil parameter or interpretation of bands of soil fertility.

The project also includes an expert system to generate fertilizer recommendations and liming, according to the main manual available in the country. SpecSolo-Scan is the first commercial instrument near infrared spectroscopy and visible (VisNIR) the world to present an autosampler and an integrated system with database fully dedicated to soil analysis.

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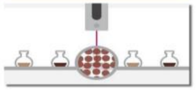


The need of Soil Spectral Library

- For quantitative applications: many soil samples are needed (**Soil data mining of a “model” requires hundreds of spectra samples in order to provide reliable results**

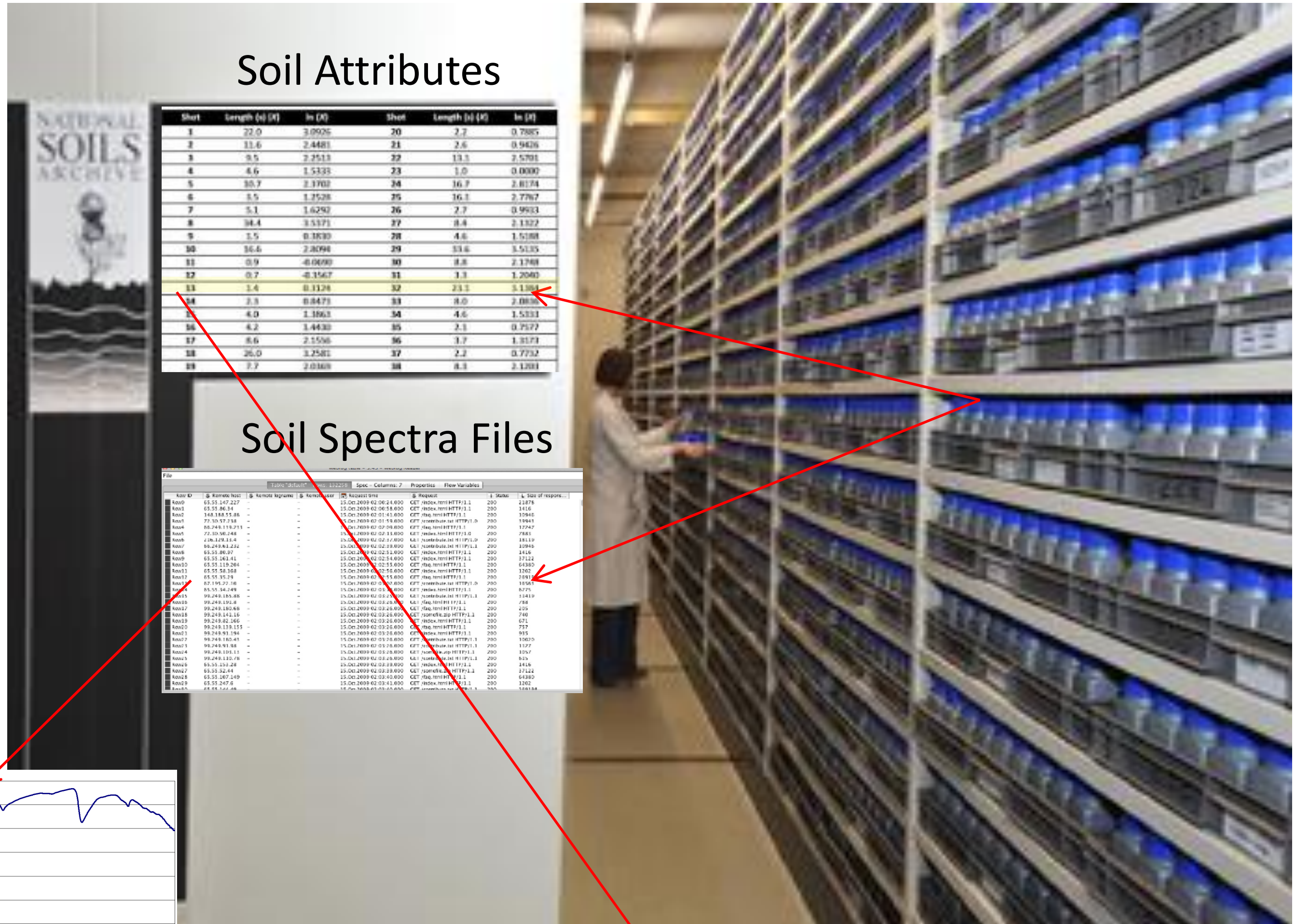
- Users are gathering many soil samples mostly under local scale

- A need for regional and global scales’ library is essential

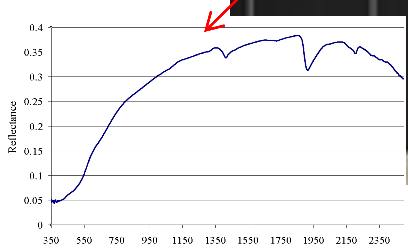
- Gathering local and regional spectral data (soil spectral library) needs agreed “standard and protocols”

Soil Spectral Library : The Practical Structure

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



Shot	Length (s) (X)	ln (X)	Shot	Length (s) (X)	ln (X)
1	22.0	3.0926	20	2.2	0.7885
2	11.6	2.4481	21	2.6	0.9426
3	9.5	2.2513	22	13.1	2.5701
4	4.6	1.5333	23	1.0	0.0000
5	10.7	2.3702	24	16.7	2.8174
6	3.5	1.2528	25	16.1	2.7767
7	5.1	1.6292	26	2.7	0.9933
8	34.4	3.5371	27	8.4	2.1322
9	1.5	0.3830	28	4.6	1.5188
10	16.6	2.8094	29	33.6	3.5135
11	0.9	-0.0690	30	8.8	2.1748
12	0.7	-0.3567	31	3.3	1.2040
13	1.4	0.3124	32	23.1	3.1384
14	2.3	0.8471	33	8.0	2.0836
15	4.0	1.3863	34	4.6	1.5333
16	4.2	1.4430	35	2.1	0.7577
17	8.6	2.1556	36	3.7	1.3173
18	26.0	3.2581	37	2.2	0.7732
19	7.7	2.0369	38	8.3	2.1203

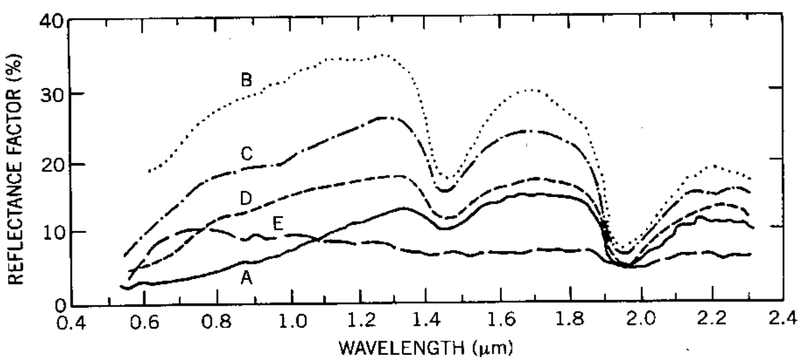


Sample	Location	OM	Clay	Lime….
A1	34,5467.67 36,654,32	2.4 %	34%	23.4%

First Soil Spectral Library

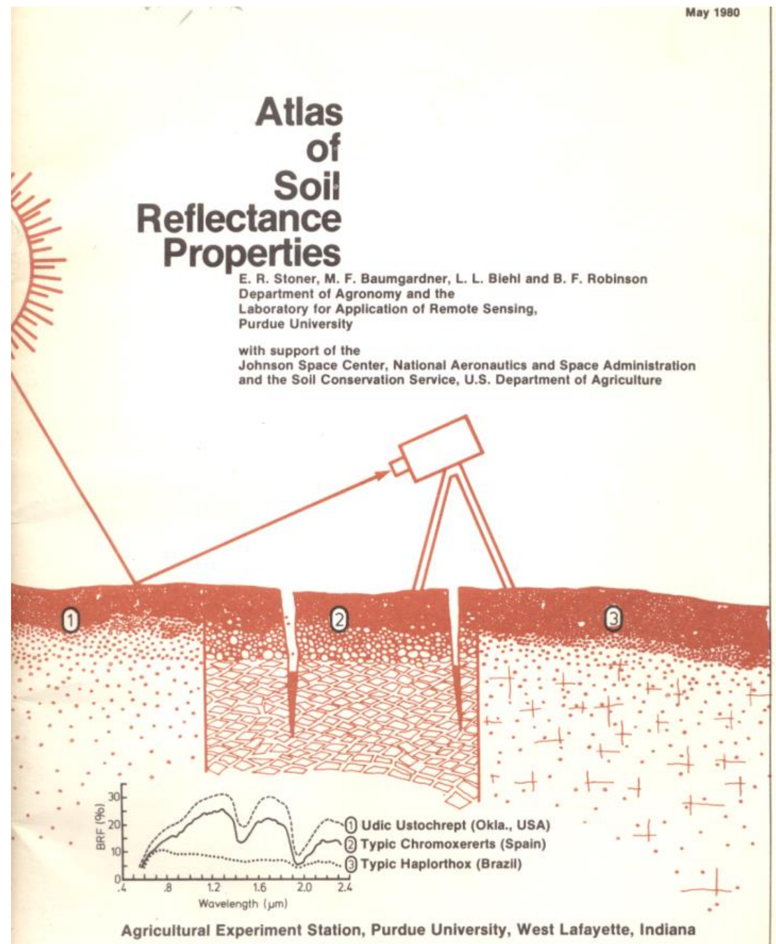
1980

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 Global Soil Spectral Library (GSSL)

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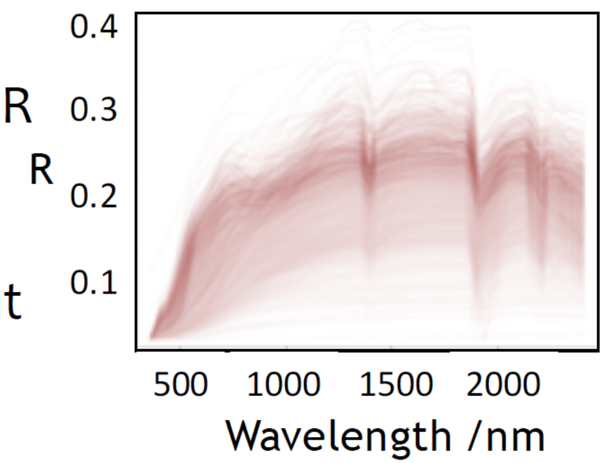
In 2006 *Raphael Viscorra Rossel* understood the GSSL importance and initiated an activity toward establishing the first GSSL

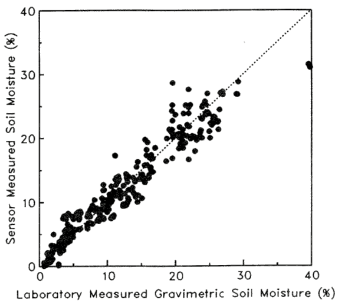
Global spectral library project

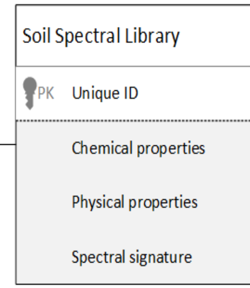
- Started in 2008 as voluntary collaboration in response to growing interest in soil vis–NIR spectroscopy

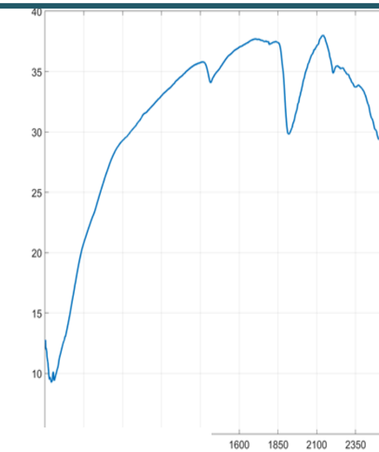


- Scientists from each continent coordinated and developed guidelines and protocols
- Aim to bring together a community of scientists, encourage research, development of new applications and adoption of spectroscopy in the soil, earth and environmental sciences.

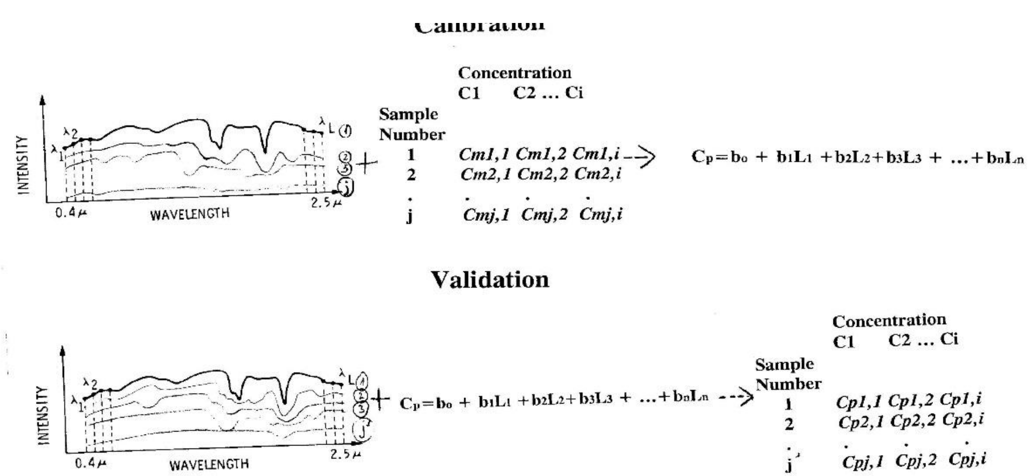
provided by Viscorra Rossel



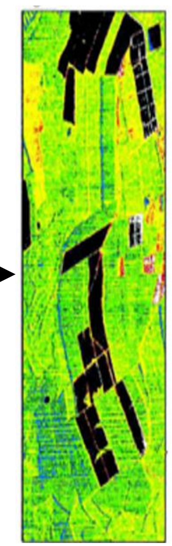




The following figures demonstrate the NIRA approach:



PARACUDA©



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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In 2015 Raphael effort yield the first GSSL

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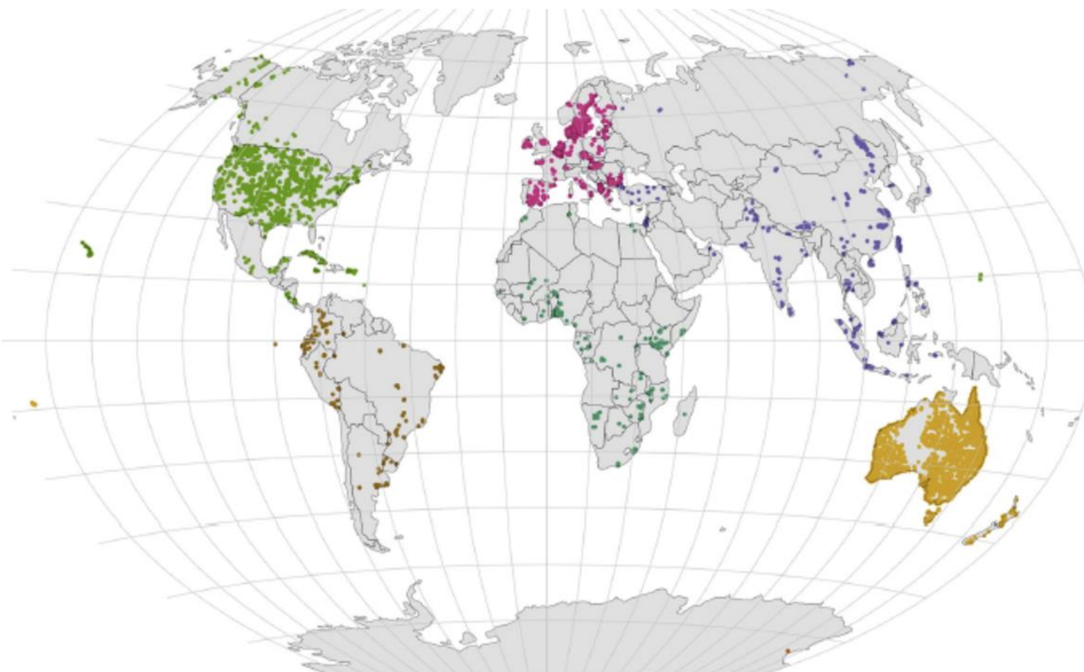
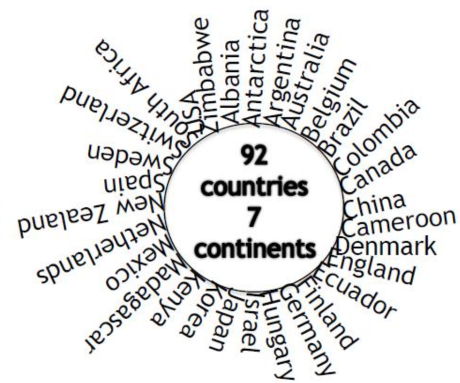
Global soil Soil VNIR-SWIR Spectra

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

45 collaborators from 35 institutions





provided by Viscorra Rossel

GSSL

Global soil vis–NIR spectra in numbers

Continent

- 8646 **Oceania**
- 5198 **North, Central America**
- 3518 **Europe**
- 3097 **Asia**
- 1621 **Africa**
- 1407 **South America**
- 144 **Antarctica**

Position

- 84% with **coordinates**
- 60% from the **0–30 cm**
- 30% from the **30–100 cm**
- 10% from **> 1m**

Attributes

- **pH** 20,515 (20,515)
- **Organic C** 17,931 (9757)
- **Clay** 17,463 (10,064)
- **Sand** 12,058 (3395)
- **CEC** 9588 (5014)
- **Silt** 9542 (1280)
- **Fe** 4151 (3311)
- **$CaCO_3$** 2960 (1388)

Description

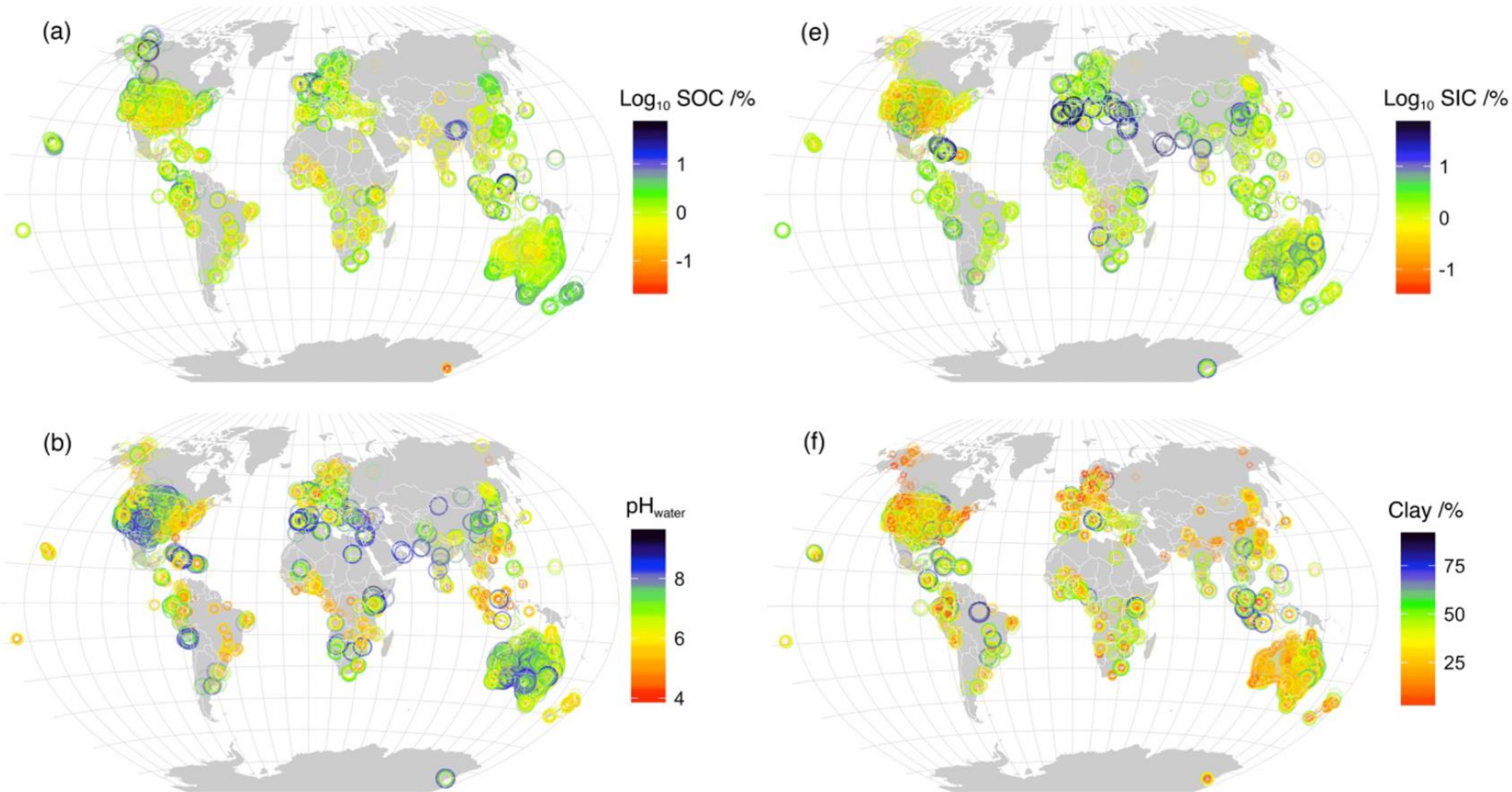
- 15% have **soil horizon**
- 95% with **FAO WRB**
- 80% with **land cover**

provided by Viscorra Rossel

GSSL – Example

Chemomtric (non linear spectral data mining) from the GSSL

Spatial distribution of predictions

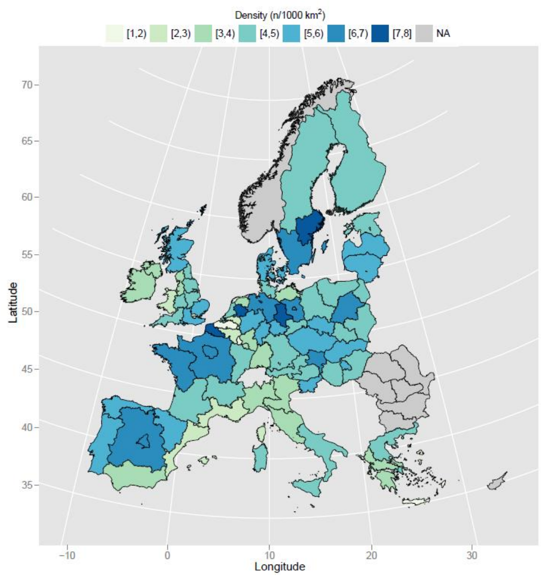


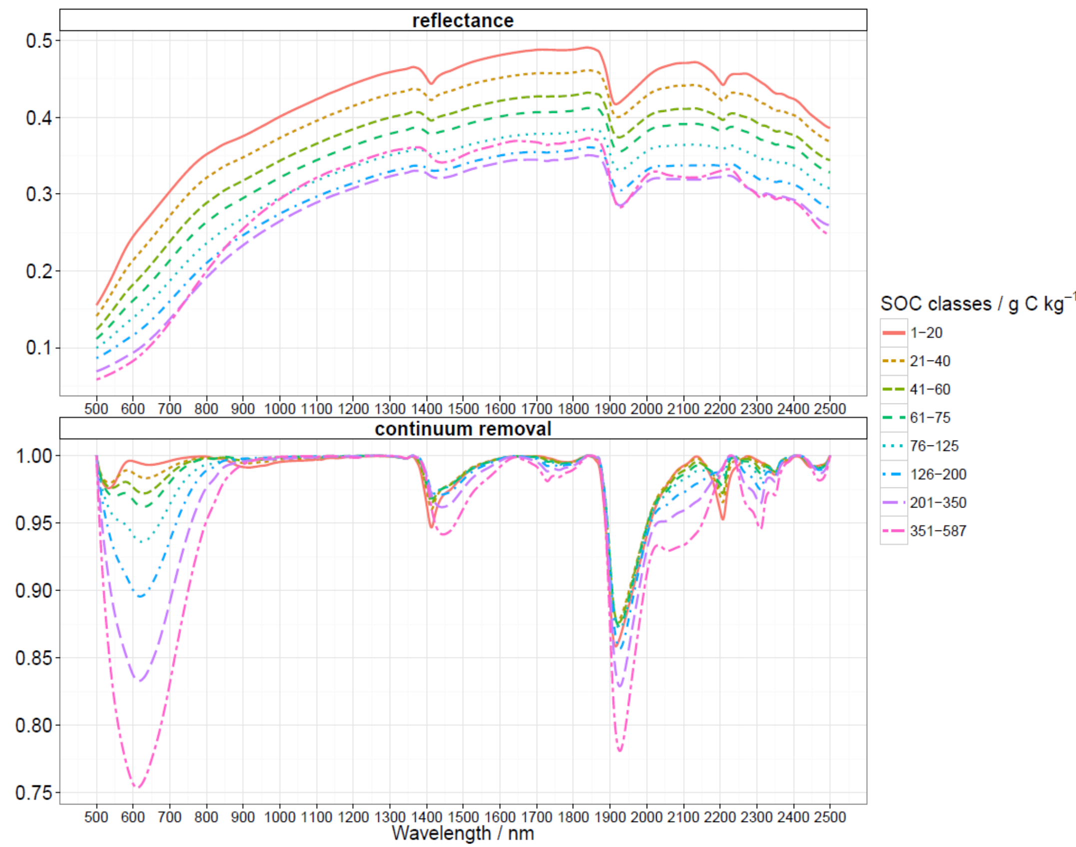
Viscorra Rossel 2015

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

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]

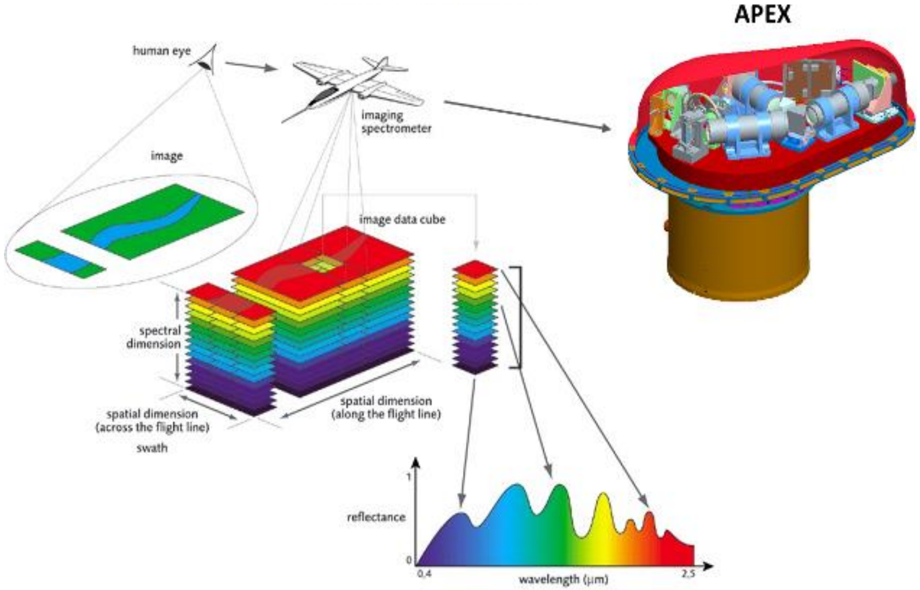


Figure 2. Flow chart concerning the two soil organic carbon (SOC) estimation approach work: traditional and bottom-up.

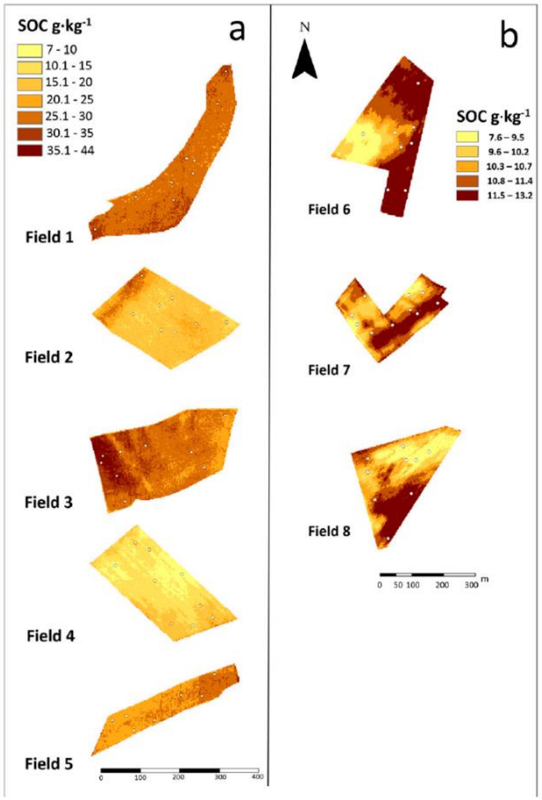


Figure 4. SOC maps of the validation fields in Luxembourg (**a**), and Belgium (**b**), using approach. The white points in the fields correspond to the validation dataset.

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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

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8/20/2013

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.

A simple protocol has established for new users Since 2014

Geoderma 245–246 (2015) 112–124

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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

Standardization

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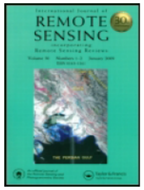
Lucky Bay   Wiely Bay



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Normalizing reflectance from different spectrometers and protocols with an internal soil standard

Veronika Kopačková & Eyal Ben-Dor

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Soil Mineralogy

Performance of Three Identical Spectrometers in Retrieving Soil Reflectance under Laboratory Conditions

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A wide range of electronic and mechanical noise factors can affect soil spectra when using different instruments or even when repeating a specific sample's measurements with the same spectrometer. In soil samples where very weak spectral features are monitored for chemometric purposes, alterations in wavelength location, peak absorption shape, or albedo intensity can limit the use of previously developed spectral models. To quantify this alteration and propose a standardization method, 12 soil samples and three different materials for internal standards (sand, glass and polyethylene) were analyzed. This population was concurrently measured with three identical spectrometers using a strict measurement protocol, and then by different operators with different protocols. Significant changes in the soil spectra were found when different operators performed the measurements, being reduced >50% when the strict protocol was applied. Sand was found to be the ideal internal standard for correcting the spectra to a reference spectrometer, even when different measuring protocols were used. This standardization also showed an improvement in the prediction of soil properties when applying chemometric spectral models even with different instruments, concluding that the use of an internal standard and a strict protocol must be applied for soil spectral measurements. As the measuring factors described in this research also affect any infrared diffuse reflectance spectroscopy measurements, the proposed method should be applicable to any instrumentation and configuration being used. This is crucial to enabling spectral comparisons between different spectrometers or, more importantly, to establishing robust chemometric models and to exchange soil spectral information.

Abbreviations: ASD, Analytical Spectral Devices, Inc.; CR, continuum removal; NIRS, near infrared analysis; PLS, partial least squares; RGB, red-green-blue color model; RMSEP, root mean square error of prediction; SAM, spectral angle mapper; TAU, Tel Aviv University.

Many reflectance spectroscopy applications have been developed for soils in the last 20 yr (Malley et al., 2004). Today, reflectance in the VIS-NIR-SWIR region is considered to be a solid and mature technique for qualitative and quantitative analyses of soil material (Ben-Dor et al., 2008b). Soil spectroscopy has advanced the discipline of soil science by providing a rapid and accurate methodology for quantitative analyses that bypasses the traditional "wet" laboratory analyses. Whereas most of the work in evaluating soil information from reflectance spectroscopy has been performed under controlled laboratory conditions, field applications are now rapidly gaining an important place in soil spectroscopy (Ben-Dor et al., 2009; Cecillon et al., 2009). Accordingly, portable spectrometers are being developed and utilized worldwide for many natural resource applications, such as soil, rock, vegetation, and water studies. In addition, a wide range of soil spectral measurements are being gathered around the globe with the intention of building a universal soil spectral library (Viscarra Rossel, 2009). However, this kind of initiative, or even the routine analyses of spectral data collected in one specific laboratory, are limited by the differences that are usually obtained when different spectrometers and protocols are used (Milton et al., 2009; Price, 1994). Spectral performance may vary among different types of spectrometers, or even among models from the same manufacturer, being therefore important to characterize

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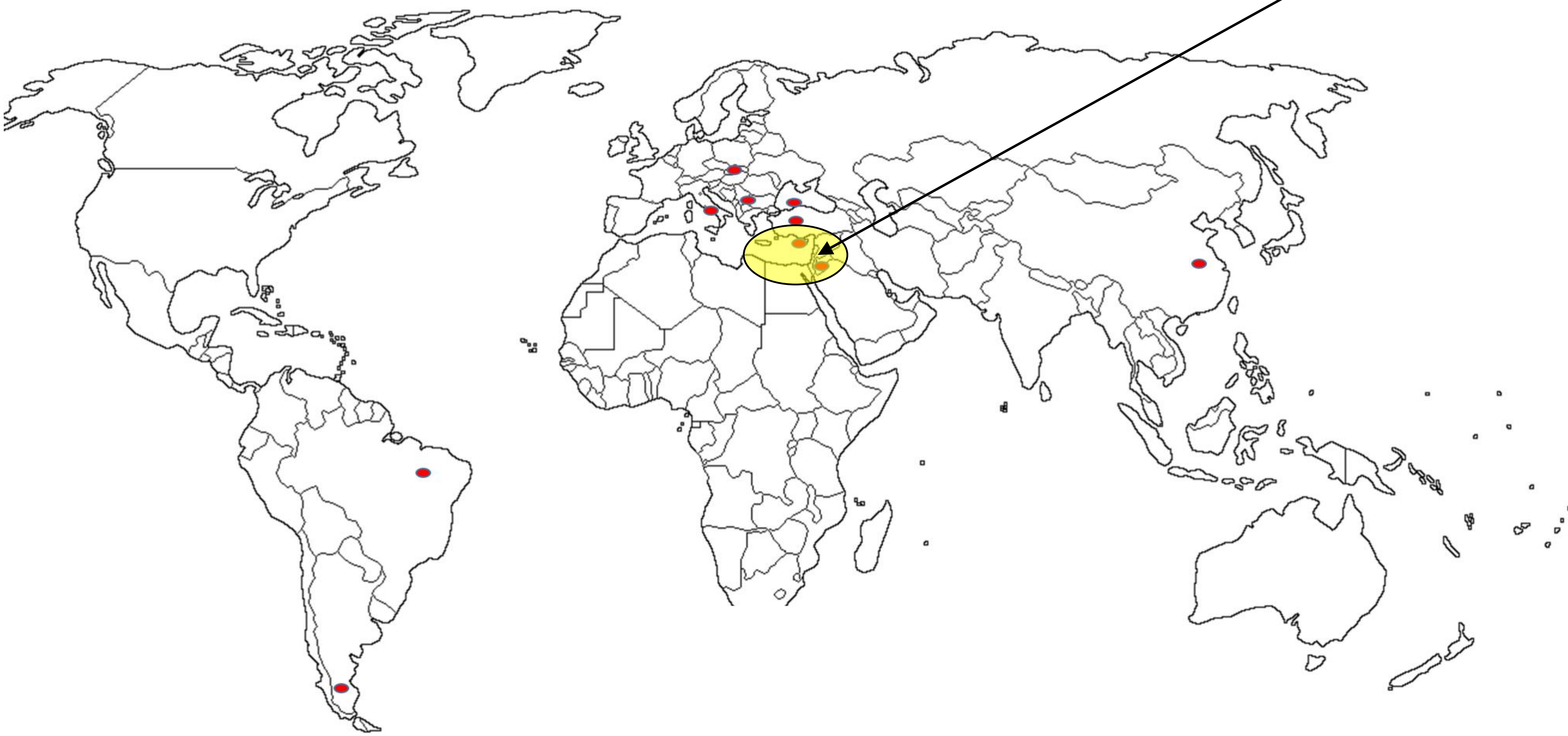
Received 20 Apr. 2010.
*Corresponding author (pimstein@uc.cl).

Tomorrow : *New Standard world wide Soil Spectral Library*

World Soil Spectral Library under ISS protocell



European Commission

GEO GROUP ON EARTH OBSERVATIONS

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The concept of using SSL : A vision

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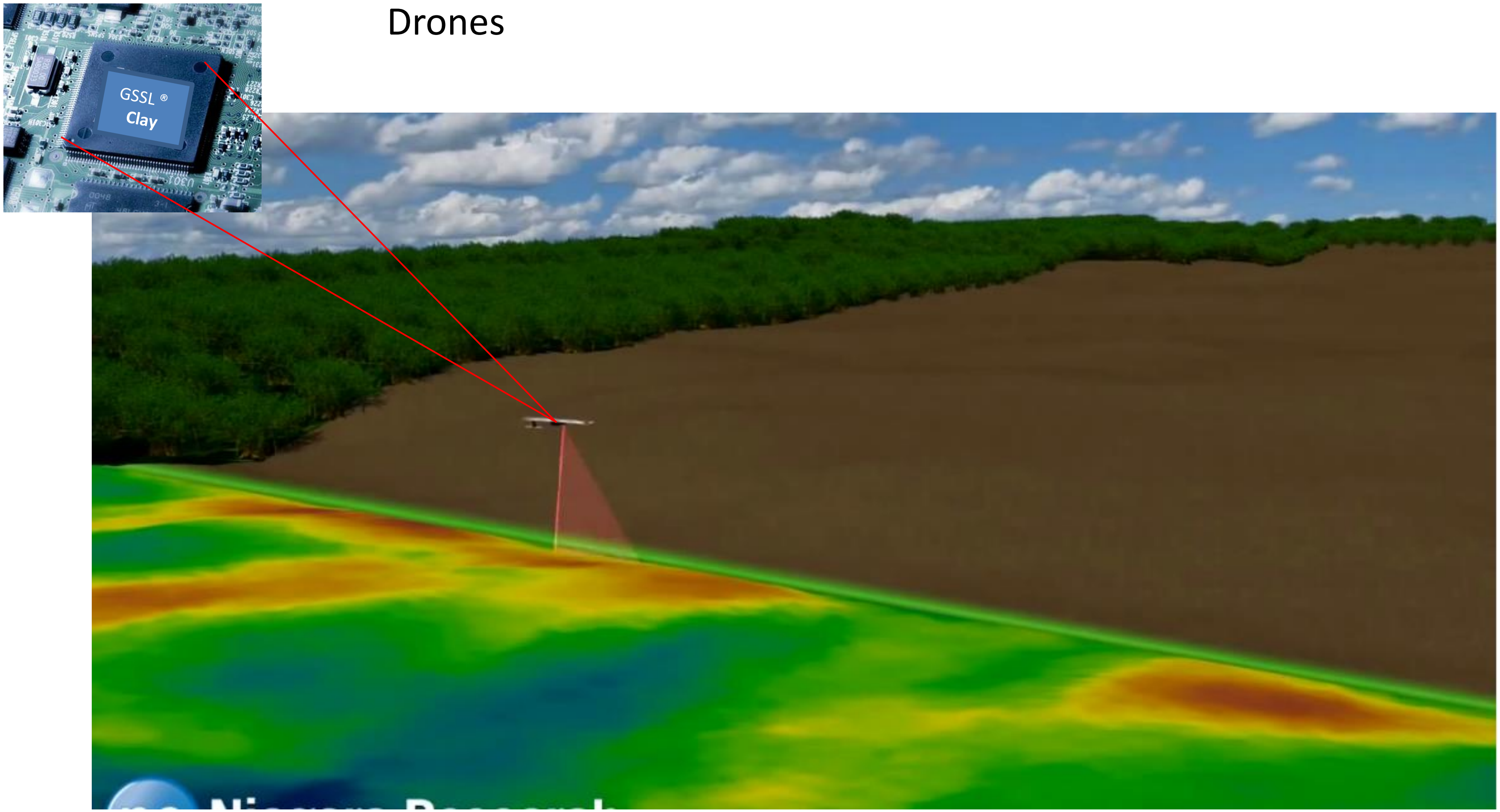
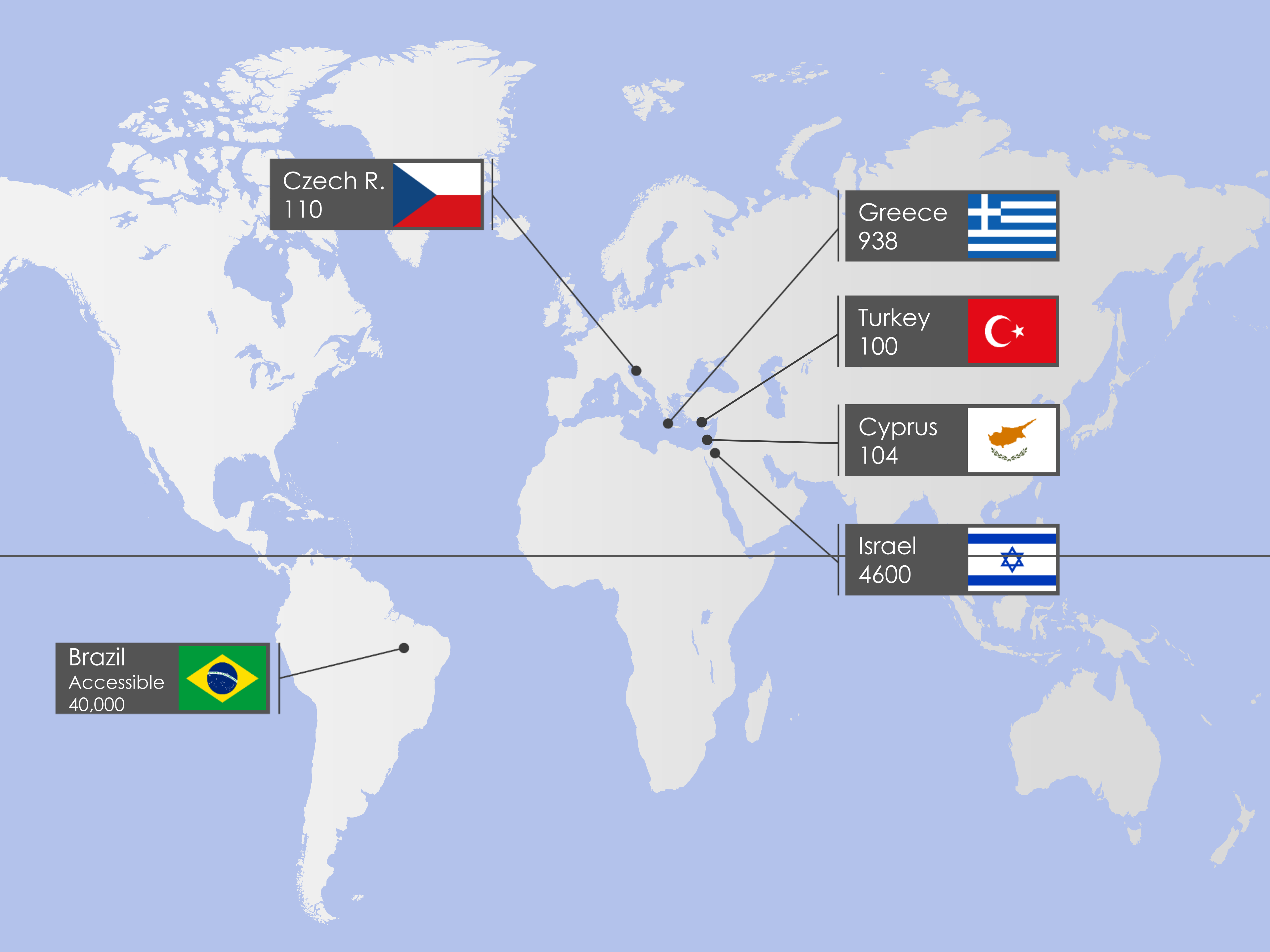
Drones




Czech R.
110
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938
Turkey
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Cyprus
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Israel
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Brazil
Accessible
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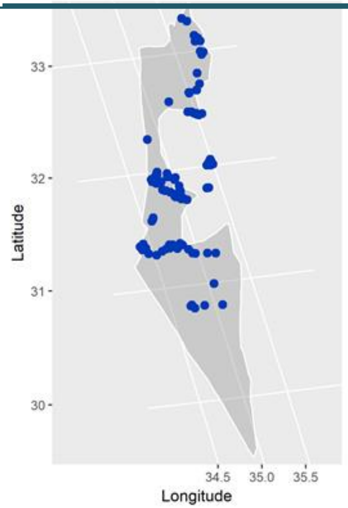
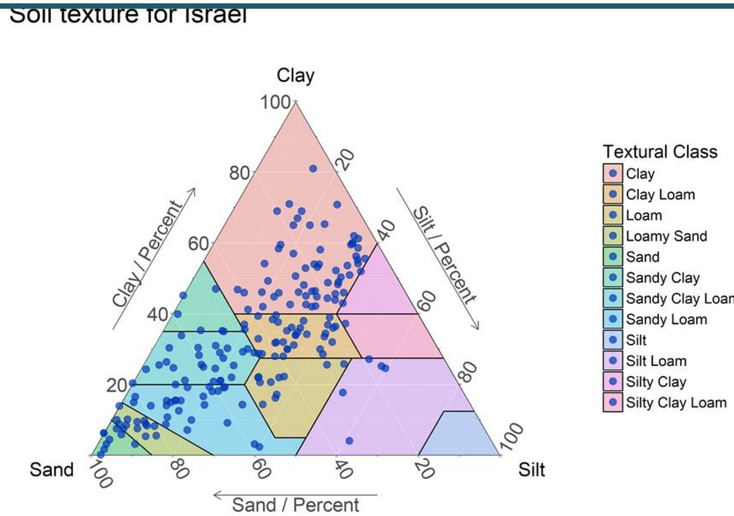
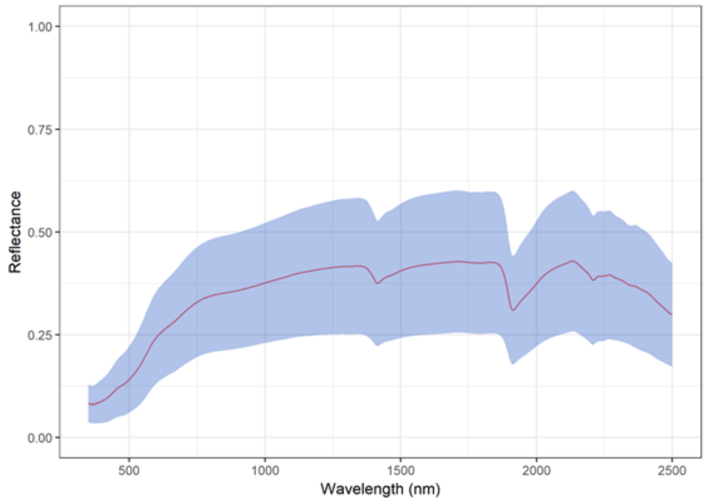
Israel SSL

Israel





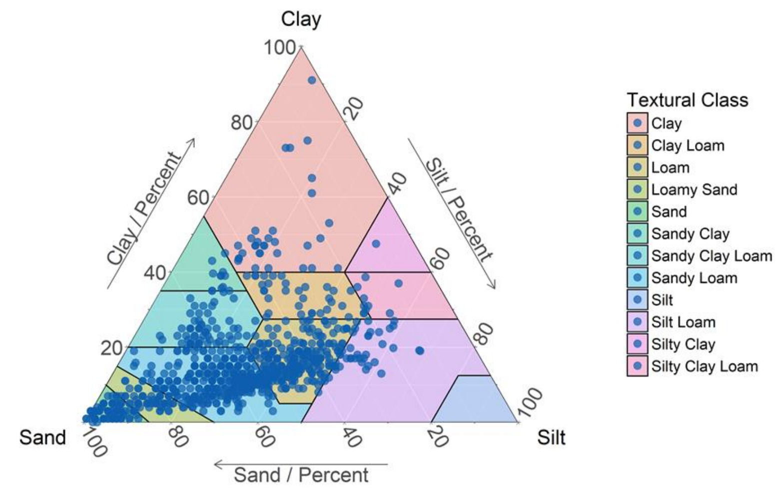
Property	Min	Mean	Median	Max	SD	Skew	Kurtosis	N
OM (%)	0.09	2.5834	2.01	13.23	2.1595	2.0876	6.1077	106
Sand (%)	4.03	44.6271	41.01	97.50	25.4006	0.2936	-1.0303	193
Silt (%)	0.00	23.4967	23.28	61.13	13.3401	0.1493	-0.4687	193
Clay (%)	0.20	31.9954	30.38	81.00	17.7866	0.2759	-0.7015	192
$CaCO_3$ (%)	0.00	26.8847	22.15	74.27	19.2755	0.5332	-0.6957	150
pH (H20)	6.50	7.5484	7.50	8.40	0.3730	0.0062	-0.2642	137
EC (µS)	0.07	3.8497	0.86	88.10	10.5869	5.6206	36.3869	141



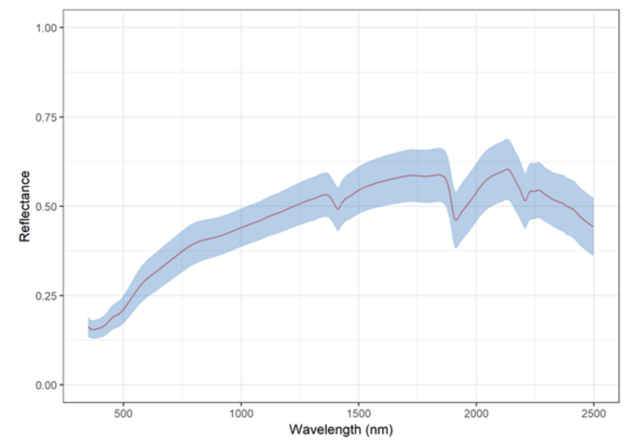
Greece SSL

Soil texture for Greece

Greece

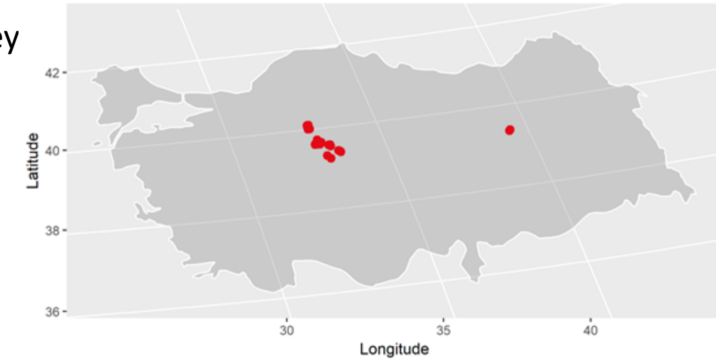


Property	Min	Mean	Median	Max	SD	Skew	Kurtosis	N
OM (%)	0	0.9401	0.86	4.18	0.6287	1.0880	2.0493	928
Sand (%)	2	59.0043	59.00	99.00	20.4710	0.0945	-0.6216	928
Silt (%)	0	26.1272	26.00	68.00	14.7009	0.0858	-0.8567	928
Clay (%)	0	14.9321	13.00	91.00	11.1773	1.8031	5.5072	928
NO_3 ppm	0	17.7938	5.60	661.20	38.9528	7.4106	92.3701	928
$CaCO_3$ (%)	0	0.5033	0.00	40.30	2.1806	11.4630	172.7943	928

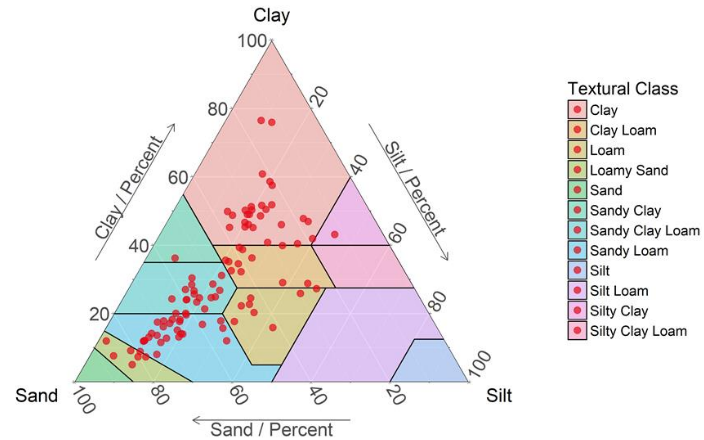


Turkey SSL

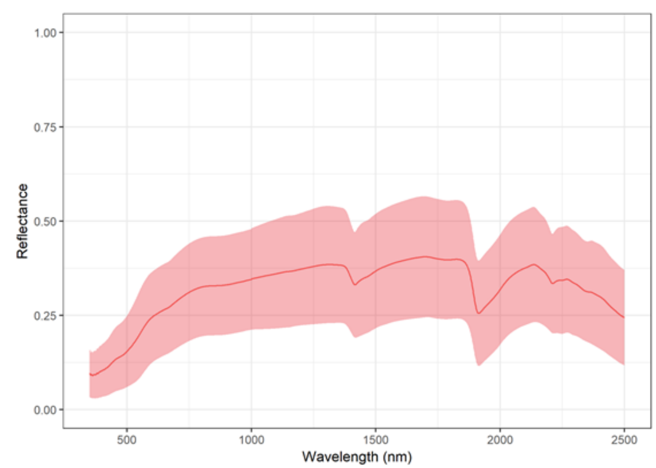
Turkey



Soil texture for Turkey

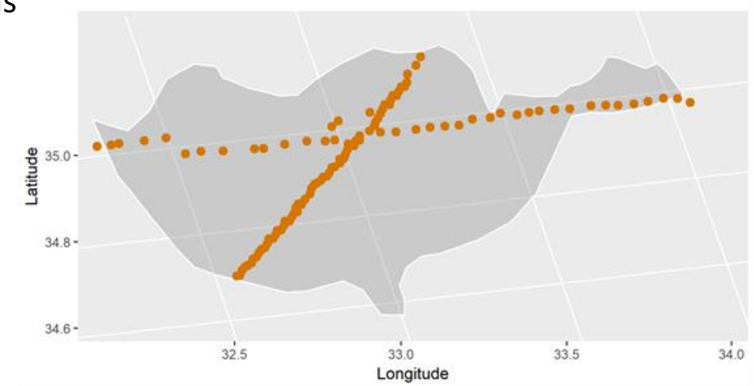


Property	Min	Mean	Median	Max	SD	Skew	Kurtosis	N
OM (%)	0.00	1.4545	1.26	5.09	1.1312	1.0019	0.7350	94
Sand (%)	11.95	48.9943	50.57	86.20	19.6373	-0.0058	-1.1223	98
Silt (%)	2.09	21.4671	19.90	47.78	9.1021	0.8811	0.5022	98
Clay (%)	5.07	29.5386	25.78	76.46	15.9816	0.6435	-0.2519	98
$CaCO_3$ (%)	0.58	21.2726	18.48	89.99	17.8601	1.5676	2.9893	100
pH (H20)	5.75	8.1471	8.17	9.76	0.5849	-0.7216	2.9174	100
EC (µS)	2.11	178.2563	141.55	1225.00	156.4308	4.5675	24.8432	100

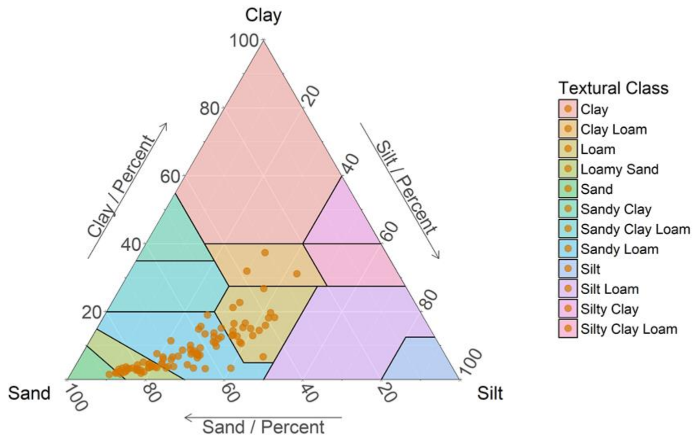


Cyprus SSL

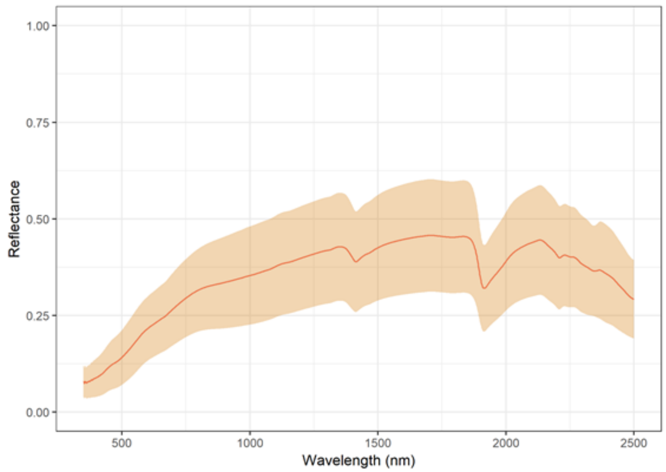
Cyprus



Soil texture for Cyprus

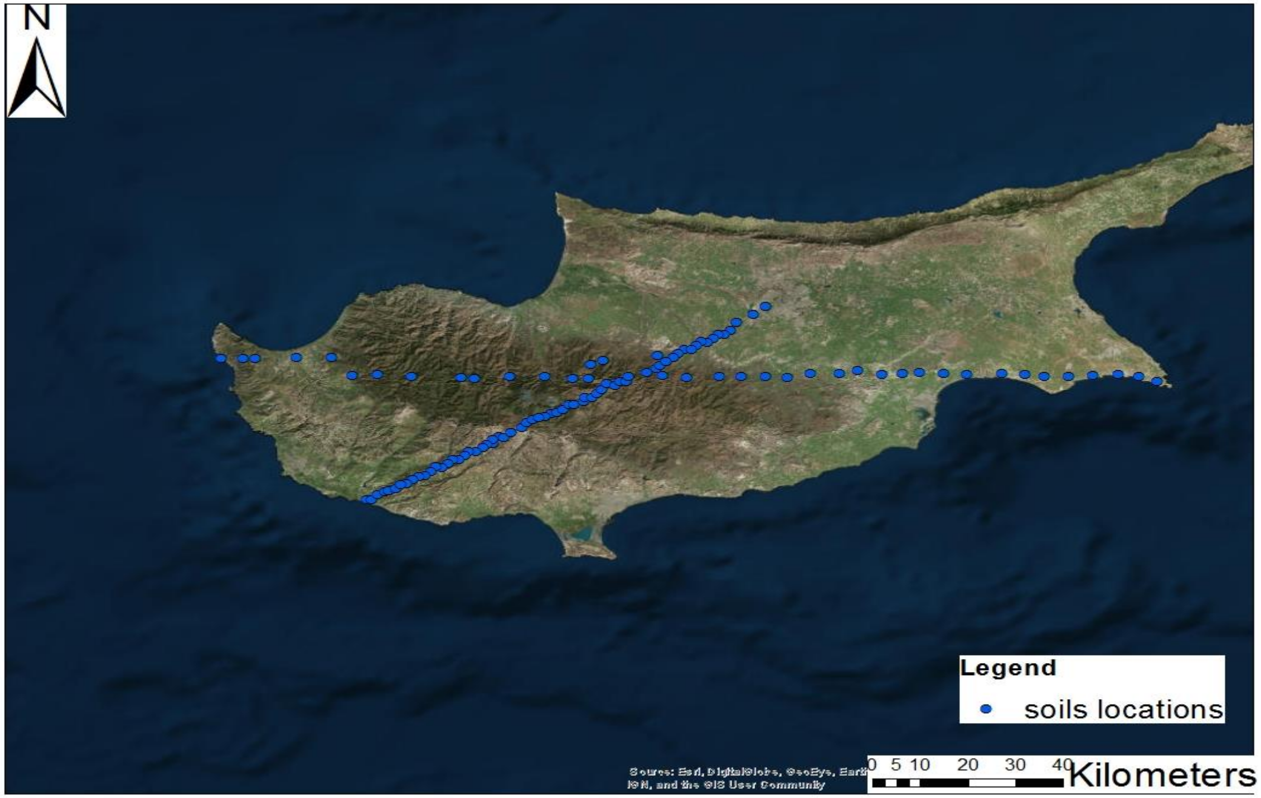


	Min	Mean	Median	Max	SD	Skew	Kurtosis	N
OM (%)	0.00	0.66	0.08	6.30	1.41	2.51	5.14	96
Sand (%)	25.80	64.14	63.75	88.10	14.95	-0.35	-0.81	94
Silt (%)	10.00	26.36	26.60	46.50	9.22	0.12	-0.98	94
Clay (%)	1.50	9.12	7.10	37.20	7.15	1.51	2.57	94
$CaCO_3$ (%)	1.25	22.47	7.30	81.50	24.96	0.84	-0.93	96
pH (H20)	5.95	7.91	7.97	10.07	0.72	0.08	0.61	96
EC (µS)	0.05	0.15	0.14	0.66	0.10	2.30	8.16	96



Cyprus Soil Spectral Library

100 samples out of 1000< samples across Cyprus were measured at TAU using the GEO-CRADEL protocol as a SSL proof of concept for Cyprus



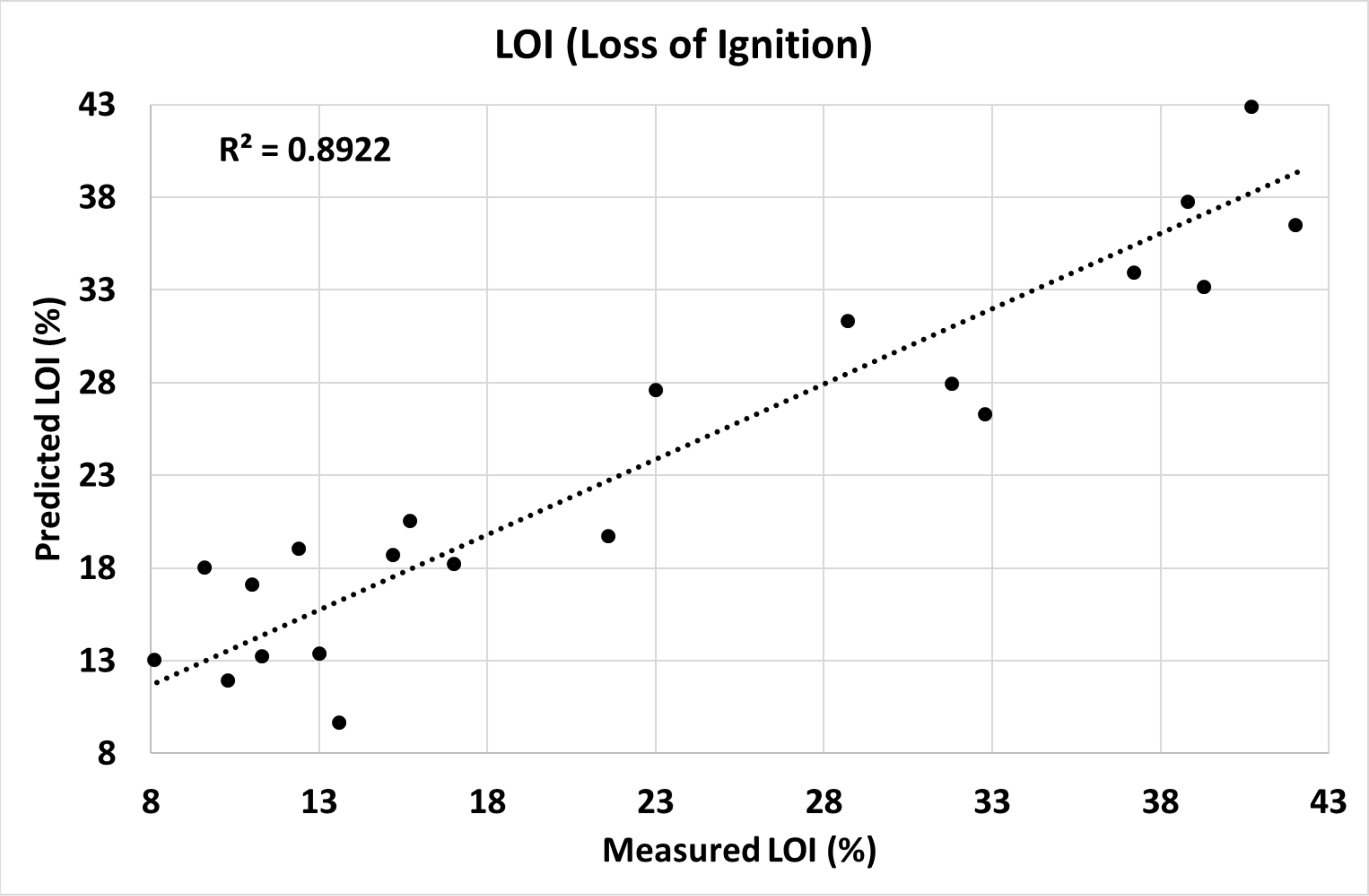
Paracuda-II analysis

1200 bands 400-2500μm

attributes	R2test	R2cal	R2cv	RPD	RMSEP	RMSEC	Factors	nSamples
Ca_ICP_A	0.814535	0.878246	0.589983	1.758655	5.839741	3.648851	7	100
Fe_ICP_A	0.918421	0.83375	0.641008	2.724214	0.856039	0.929646	7	98
TC_percent	0.850408	0.785889	0.663803	2.62447	1.742019	2.143751	7	99
TOC_percen	0.848366	0.898744	0.192273	1.901086	0.418841	0.265254	7	95

	R2test	R2cal	R2cv	RPD	RMSEP	RMSEC	Factors	nSamples
LOI_A	0.892231	0.939477	0.759291	2.948313	4.284826	3.006276	8	101
PH_A	0.299897	0.994668	0.536386	1.187499	0.484736	0.041637	9	95
EC_A	0.612321	0.963388	0.377227	1.532643	0.038274	0.012269	7	97
SurfArea_A	0.455239	0.990774	0.592458	1.255305	0.506724	0.059904	7	95

Cyprus SSL : Example of PARACUDA-II Analysis (5)



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

Conclusions

- Soil Spectral Library is a power full data base to map soil properties

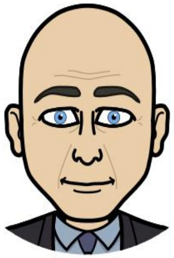
- Standard protocol is important in order to share and combine all related measurements that is being acquired by diverse groups and users

- In GEO CRADEL activity, a good example how standard SSL can be generated to the Mediterranean and Balkan countries

- The era of hyperspectral remote sensing from space is approaching and thus the SSL built-up is mandatory

- We urge all possible users who foreseen activity in précising agriculture to take part in this intiative.

Thank You !!



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