Spectral measurements of soils: Protocols, metadata and spectral libraries

Madrid, Instituto Nacional de Técnica Aeroespacial (INTA)
Jueves 7 de marzo 2019

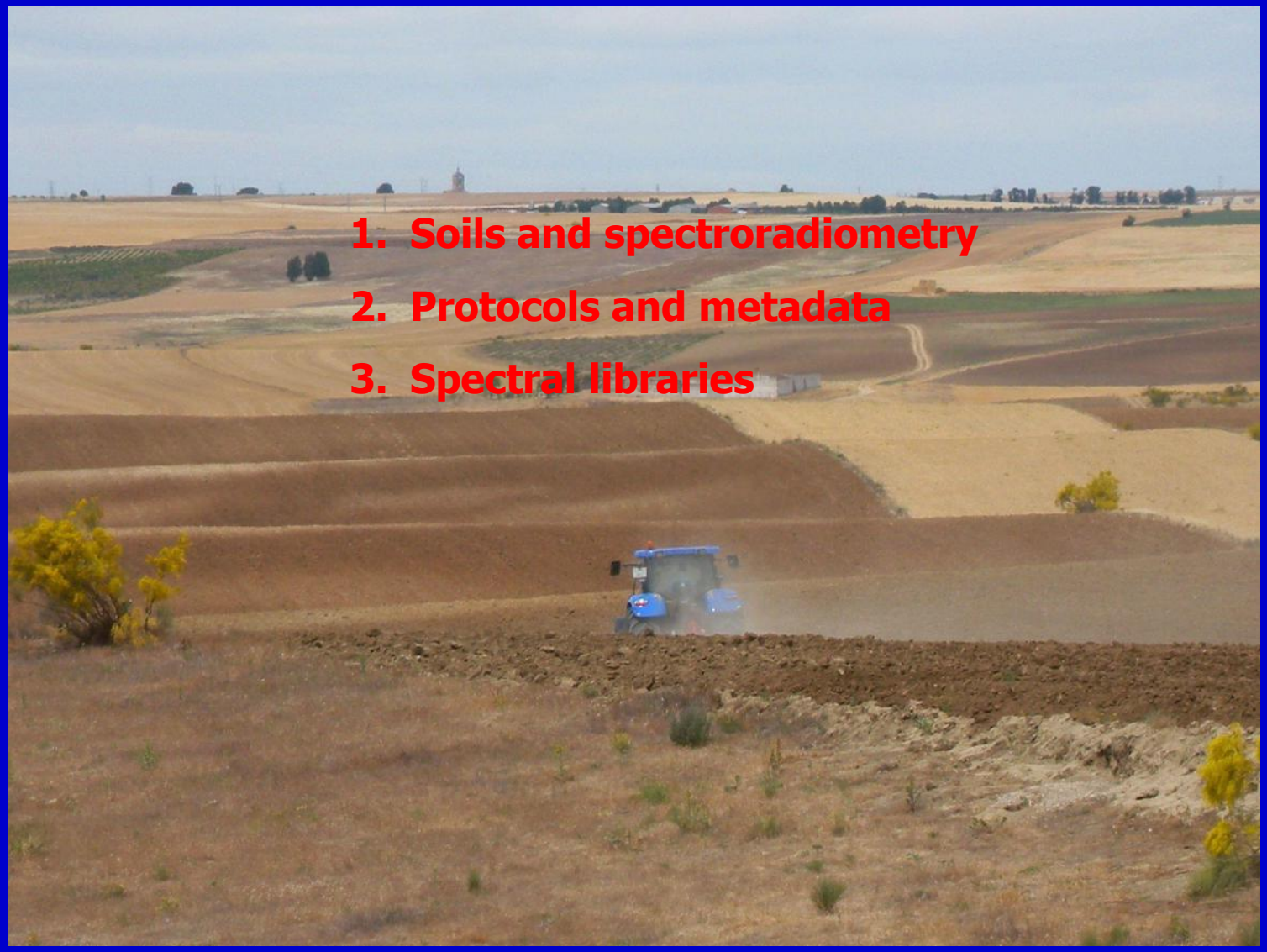
Dr. Thomas Schmid
thomas.schmid@ciemat.es
www.ciemat.es

GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES
Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

Unidad de Conservación y Recuperación de Suelos

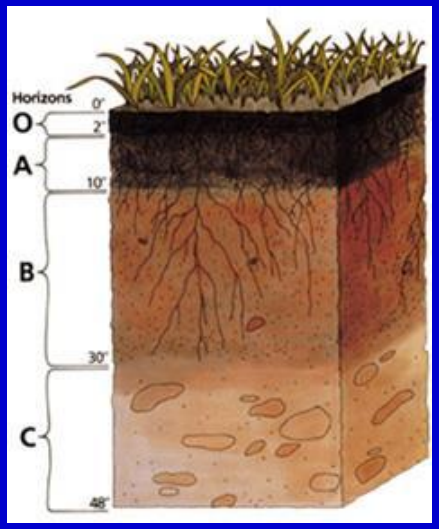
Departamento de Medio Ambiente

Content


1. Soils and spectroradiometry
2. Protocols and metadata
3. Spectral libraries

Soil

Soil is a natural body that includes solids (minerals and organic matter), liquids, and gases that occur on the surface of the earth, which occupies a space, and which is characterized by one or both of the following: horizons or layers that are distinguished from the initial material as a result of additions, losses, transfers, and transformations of energy and matter or for the ability to support plants rooted in a natural environment.(USDA and NRCS, 2006).



What affects soils in a European context

- Demographic pressure leads to expanding urban areas
- Population migration to urban centers, rural land abandonment
- Over exploitation of natural resources
- Highly fragmented landscape (high spatial variability)
- Huge variety of ecosystems, different functioning
- Ecosystems are often highly vulnerable
- Complex land management patterns
- Contaminatión: mining minerals, agriculture, industry, urban centres
- Influence of climate change and economic situation

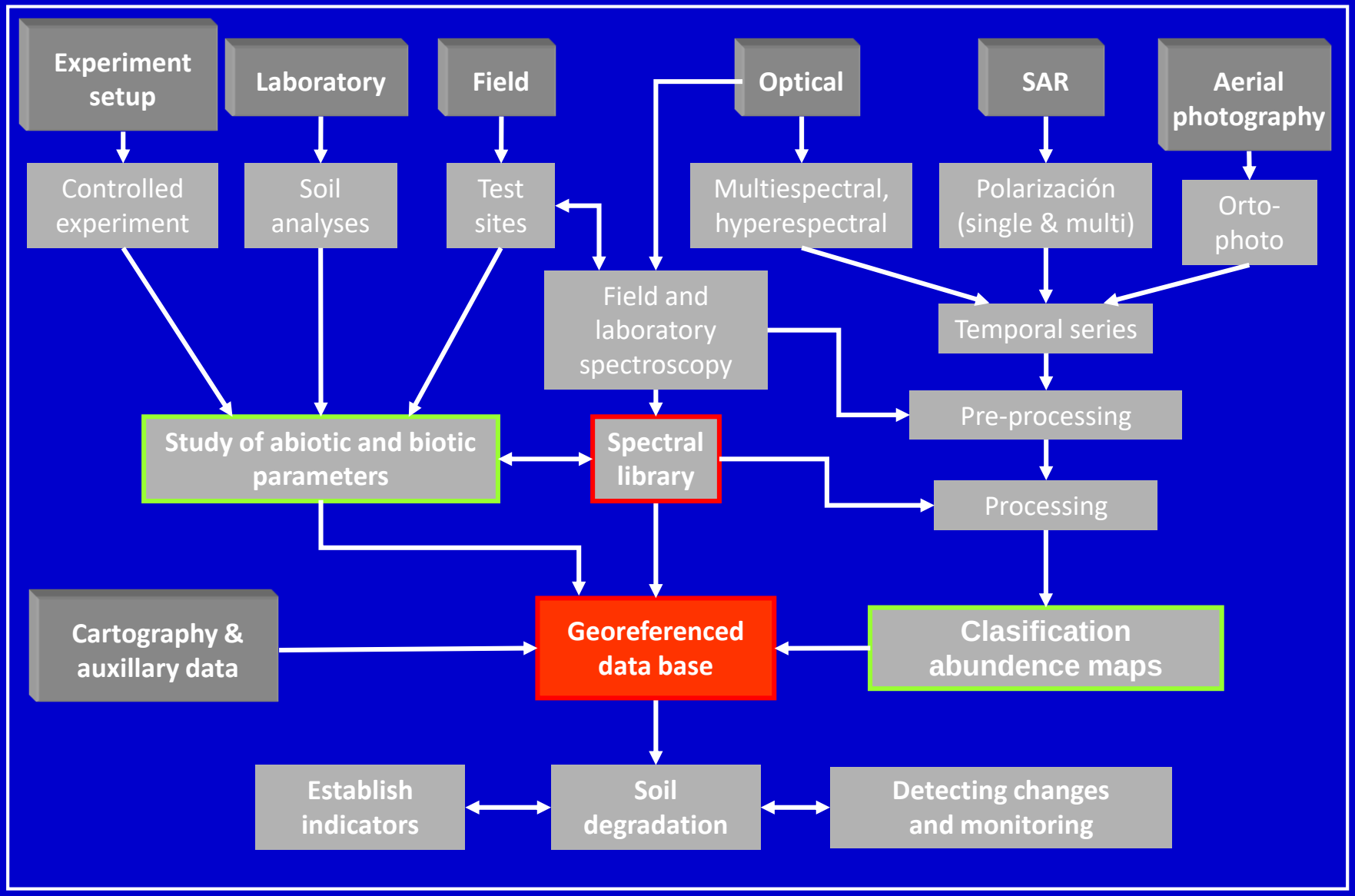
Needs

- Detailed characterization
- Identifying and monitoring trends
- Determine threshold values
- Working at different scales
- Sustainable solutions

Integrated approach

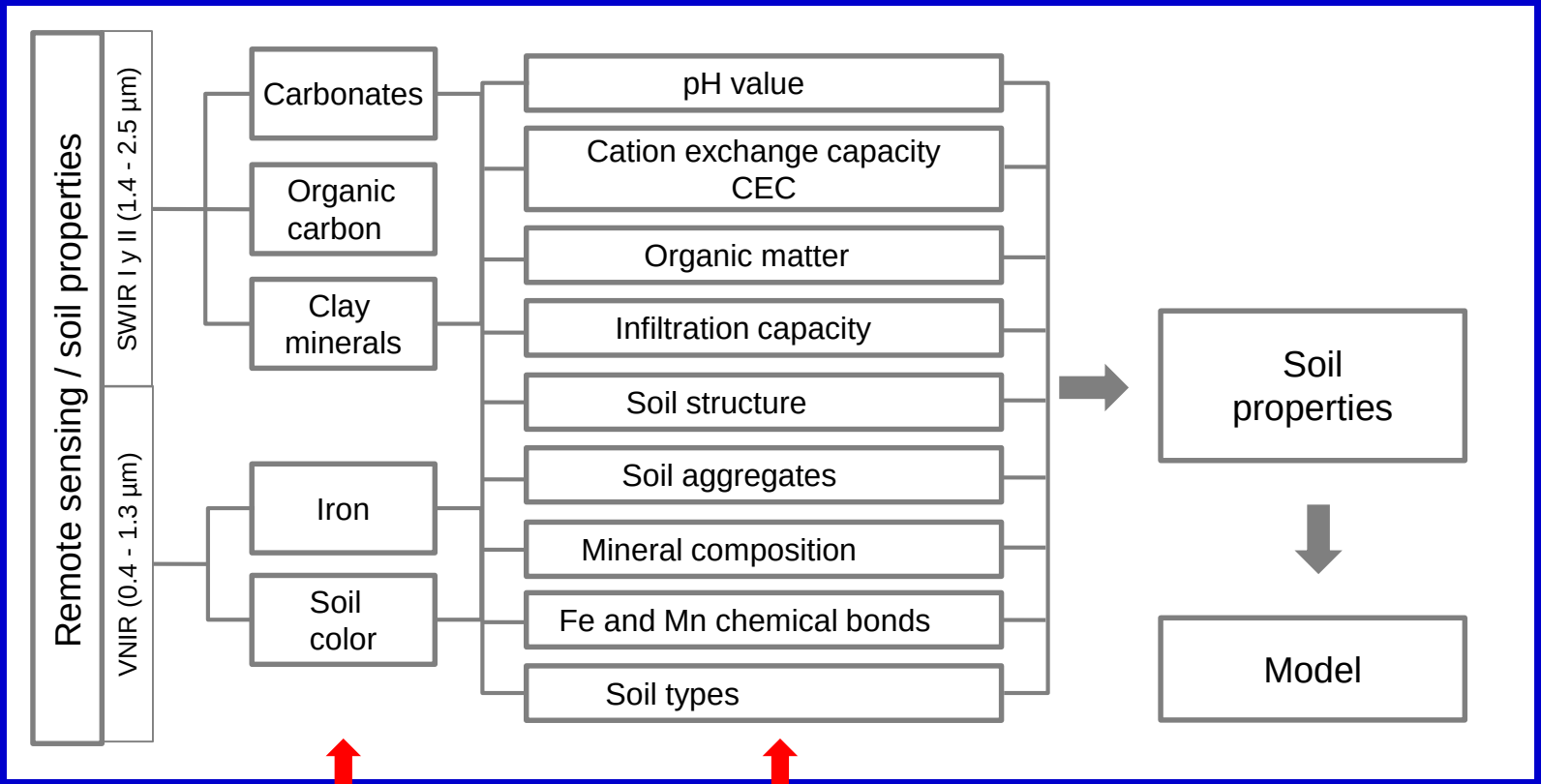
- Terrestrial compartments
- Spatial & spectral resolution
- Multi & temporal scale
- Time series
- Multi-sensor

Method


Experiment setup
Laboratory
Field
Optical
SAR
Aerial photography
Controlled experiment
Soil analyses
Test sites
Multiespectral, hyperespectral
Polarización (single & multi)
Orto-photo
Field and laboratory spectroscopy
Temporal series
Pre-processing
Study of abiotic and biotic parameters
Spectral library
Processing
Cartography & auxillary data
Georeferenced data base
Clasification abundence maps
Establish indicators
Soil degradation
Detecting changes and monitoring

Soil properties that can be determined with remote sensors

Each material has its characteristic disturbance (spectral response)



Protocolo

1. Objective of work
2. Sampling strategy
3. Location and conditions
4. Sensors and instruments
5. Standardization

→ Pre-processing of spectral data → Analysis and interpretation of data

ASD Field Campaign – Measurement Protocol

Date*	
Campaign*	
Team*	
Site*	Name*:
GPS coordinates	E N, waypoint:
Target details	Name*: Base file name*: Type: Condition:
Photos	File names:
Cloud cover	☐ 0 (clear sky) ☐ 5/8 ☐ 1/8 ☐ 6/8 ☐ 2/8 ☐ 7/8 ☐ 3/8 ☐ 1 (total cloud cover) ☐ 4/8
Geometry	☐ standard (0°,0°) or sensor zenith: .....° azimuth: .....° Distance (sensor - sample): ..... cm
Begin / End	Start time: End time:
Notes	

REGISTRO DE DATOS DE ESPECTROMETRIA Hoja N°

ZONA:	PANEL DE REFERENCIA:		ILUMINACIÓN:
FECHA:	OPTICA:	5° 10°	SIN
PERSONA:	FIBRA OPTICA:	1 2.5	
INSTRUMENTO:	MODO:	Raw	White Ref

HORA	OPT	DC	WR	ARCHIVO ROOT	Ficha INICIO	Ficha FINAL	DESCRIPCIÓN	PYRANO	CIELO	FOTO	Comentarios

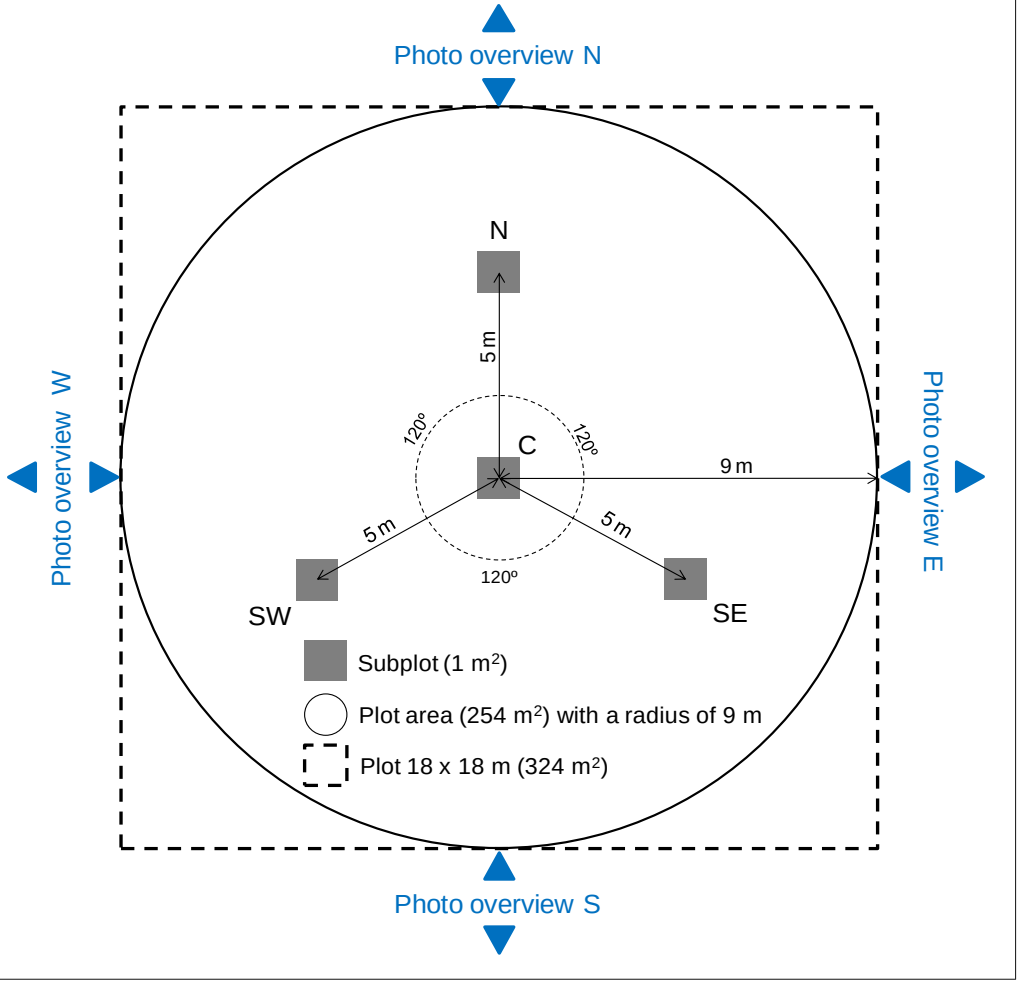
Códigos cielo: [0] cielo claro; [1] niebla; [2] cirros finos - sin bloquear el sol; [3] cirros finos - bloqueando el sol; [4] cúmulos esparcidos - sin bloquear el sol; [5] cúmulos por todo el cielo - sin bloquear el sol; [6] cúmulos - bloqueando el sol; [7] cobertura completa de cúmulos; [8] Estratos - sin bloquear el sol; [9] llovizna.

Field spectroradiometry – sample strategy

ASD - Protocolo CIEMAT

Field spectroradiometry – sample strategy

ASD - Protocolo CIEMAT



Source: Schmid et al., 2016. Characterization of Soil Erosion Indicators Using Hyperspectral Data From a Mediterranean Rainfed Cultivated Region. IEEE JSTARS, Vol. 9/2, 845 - 860.

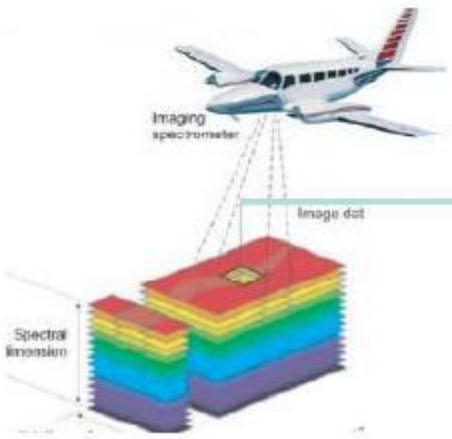
Strong link between field and image spectroscopy

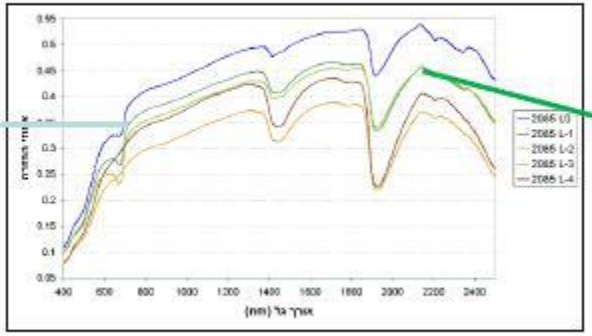
Image spectroscopy

Geology
Vegetatión
Water

Soil -

Field spectroscopy





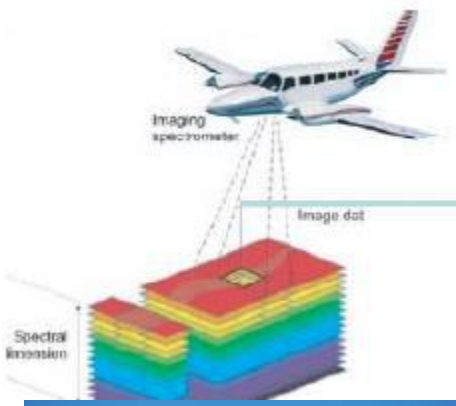
Strong link between field and image spectroscopy

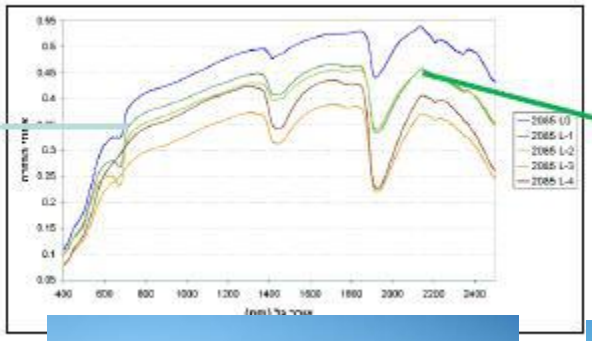
Image spectroscopy

Geology
Vegetatión
Water

Soil -

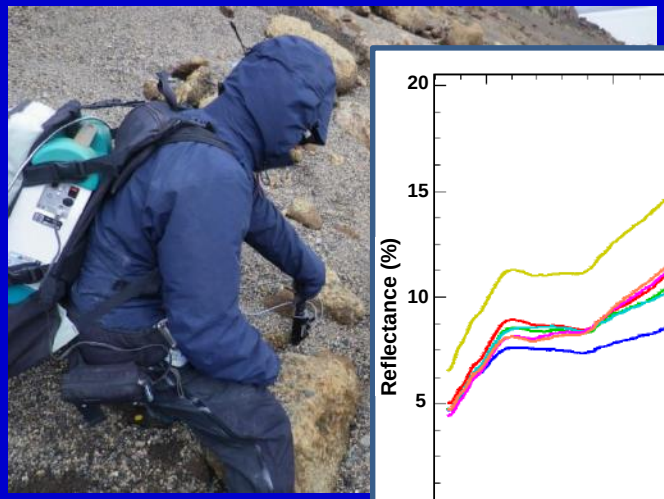
Field spectroscopy

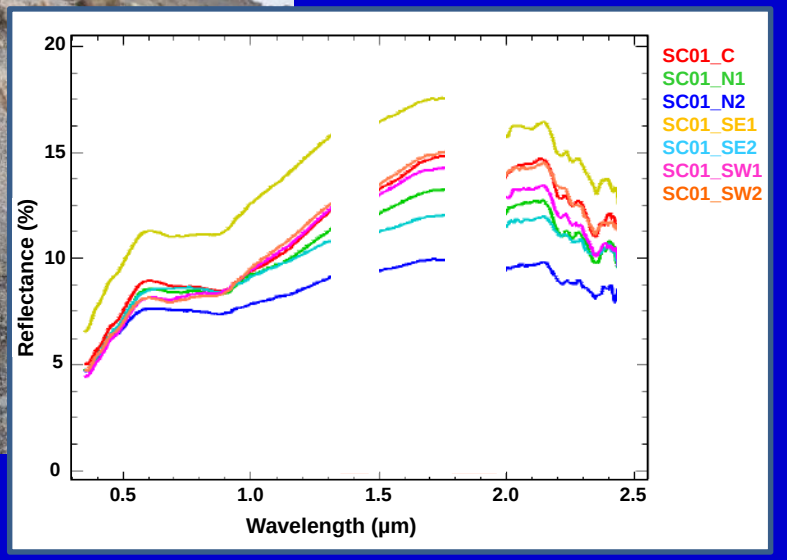




In the field: each location, adapted protocol

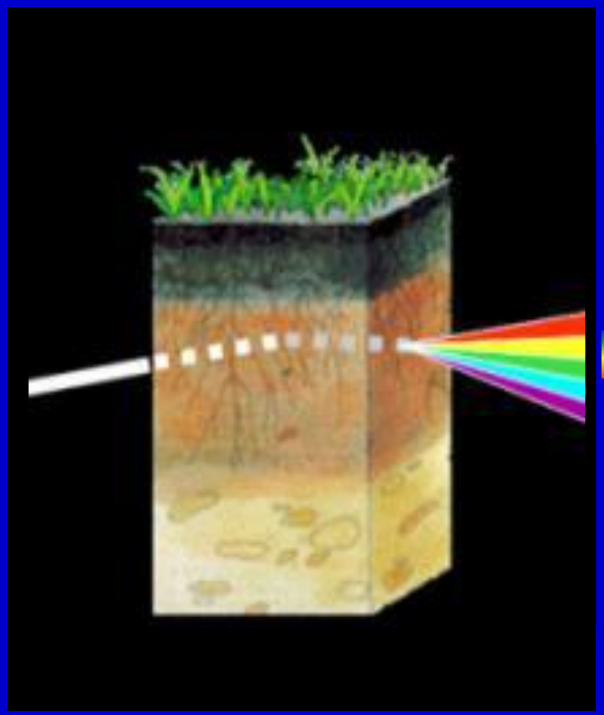
In the field: each location, adapted protocol

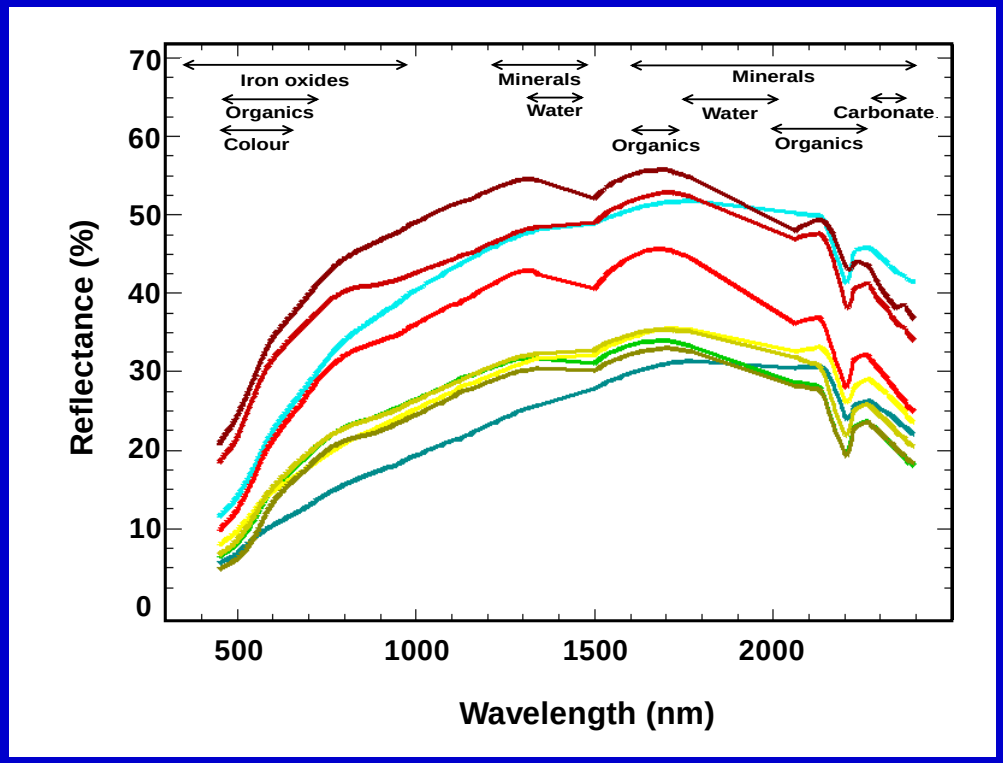




Muestra	KGI003C
Tipo de muestra	Bare soil
Número de muestras	7
Lugar	Fildes Peninsula, sur de la Base Escudero
Fecha de adquisición	22/12/2012
Eastings (UTM WGS84)	397554
Northings (UTM WGS84)	3101165
Altitud (msnm)	45
Pendiente (%)	2-8
Geomorfología	Volcanic deposits, andesite
Vegetación	Escaso musgo negro y *Usnea*
Cobertura (%)	5
Observaciones	Grava angular, escasos bloques
pH (1:2.5)	6.46
CE (1:5) (mS m^{-1})	61
$CaCO_3$ (%)	0.0
M.O. (%)	0.2
Ca (cmoles+ kg^{-1})	14.7
Mg (cmoles+ kg^{-1})	26.5
K (cmoles+ kg^{-1})	1.2
Na (cmoles+ kg^{-1})	2.2
CEC (cmoles+ kg^{-1})	51.7
V (%)	86
<2 mm fracción	73
> 2 mm fracción	27
Arcilla (%)	14
Limo (%)%	17
Arena (%)%	69
Textura	Franco arenosa

Spectroscopy of a soil profile





Form

Position

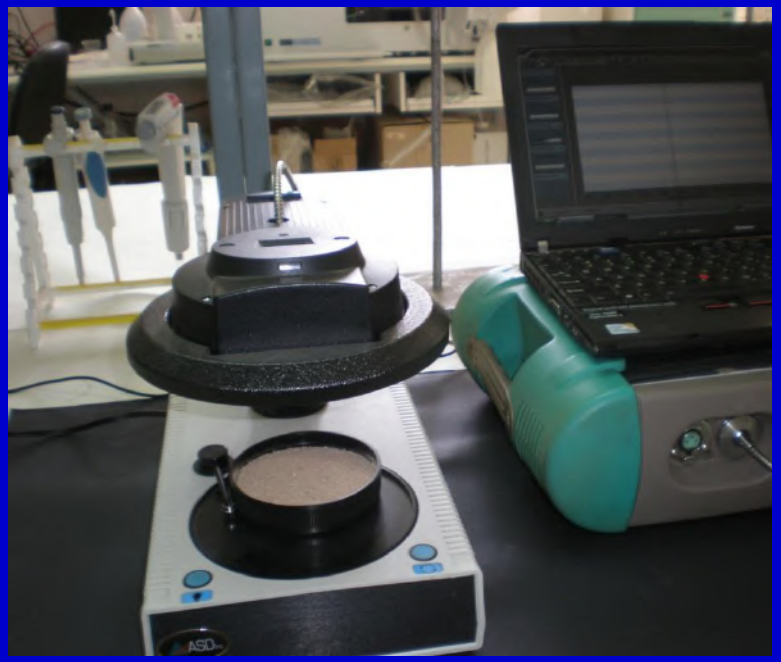
} Identification

Depth ➡ Quantification

Related field measurements

Laboratory spectra

ASD - Protocolo CIEMAT

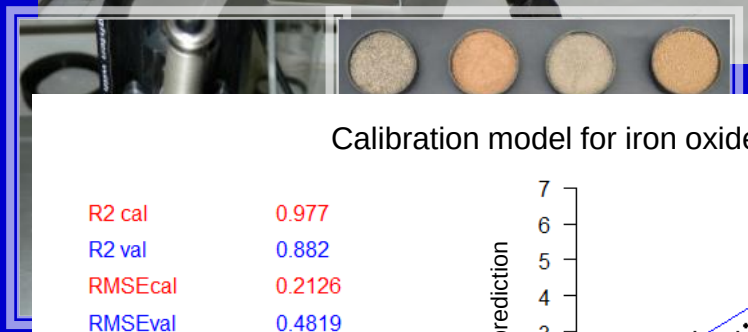


Contact probe

Turntable

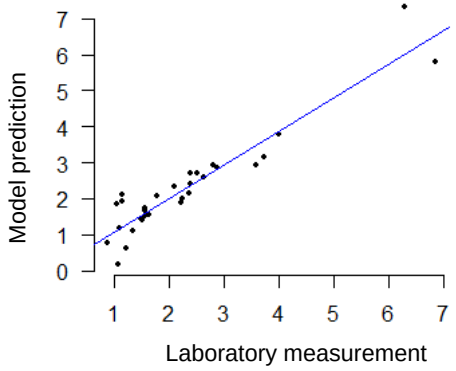
Laboratory spectra

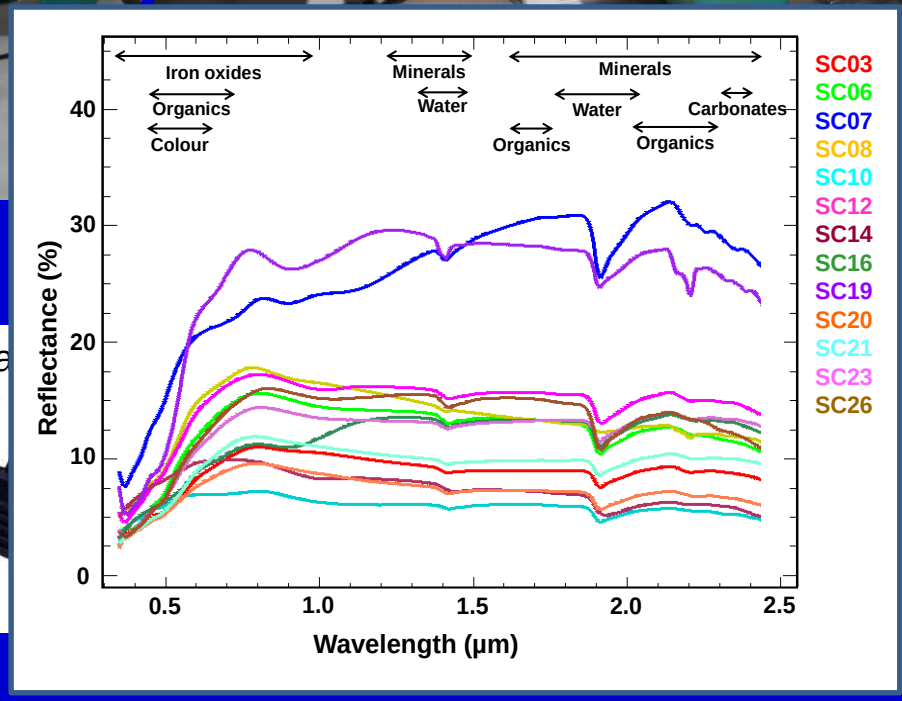
ASD - Protocolo CIEMAT



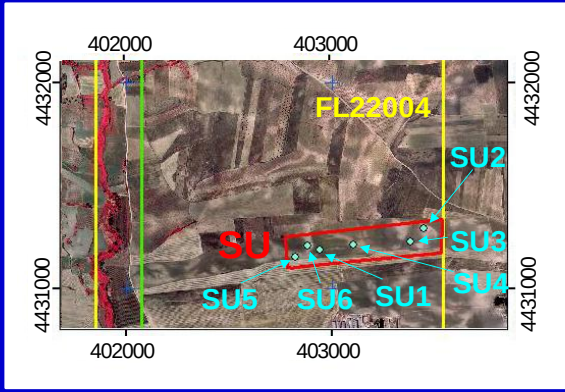
Calibration model for iron oxides

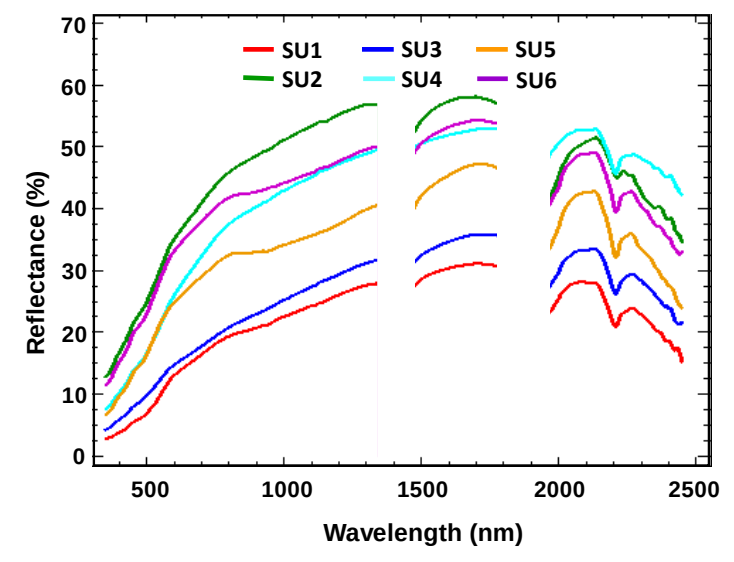
R2 cal	0.977
R2 val	0.882
RMSEcal	0.2126
RMSEval	0.4819
# LVs	6
# sig preds	27
method	PLSR





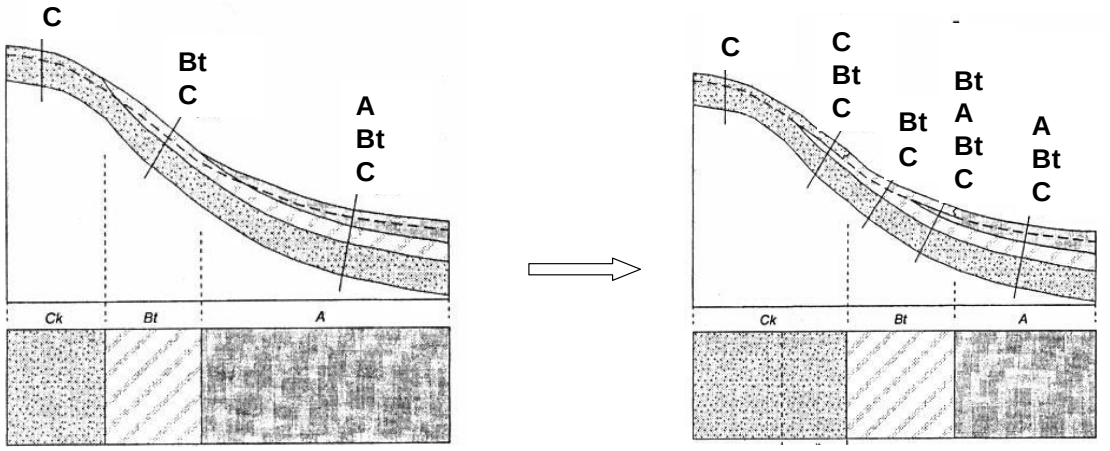
Soil surface covers



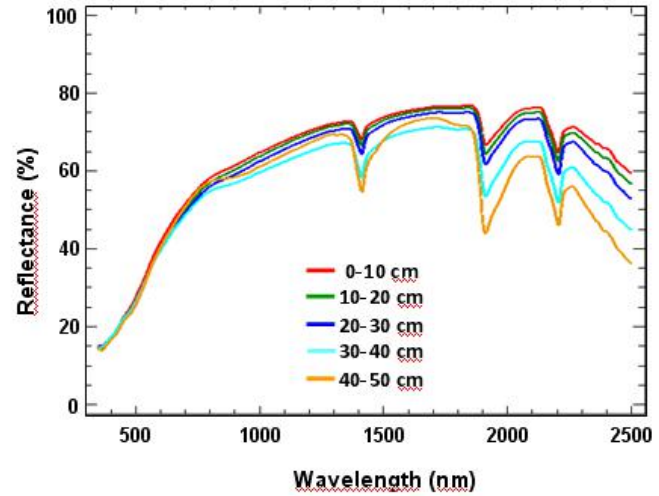


SOIL PARAMETERS		SANTA ÚRSULA AREA PLOTS (SU)					
		SU1	SU2	SU3	SU4	SU5	SU6
pH (H_2O, 1:2,5)		7.80	8.22	7.80	5.24	8.46	8.28
Electrical Conductivity (1:5; $\mu S.cm^{-1}$)		152.6	173.5	145.4	100.6	186.5	192.1
Organic Matter (% w/w)		0.8	1.1	0.5	0.5	0.5	1.0
Calcium carbonate ($CaCO_3$ % w/w)		1,0	33,3	0,0	0,0	5,4	26,0
Iron oxides (Fe_2O_3 % w/w)		0.43	0.08	0.17	0.17	0.22	0.25
Mineralogy (%, semiquantitative)	Quartz	48	21	50	52	24	14
	K-Feldspars	6	9	16	29	7	6
	Plagioclase	6	15	8	12	9	6
	Phyllosilicates	36	13	27	7	54	33
	Calcite	5	42	0	0	7	40
Coarse fragments (>2mm fraction; %)		1.4	36.2	14.8	1.7	1.6	3.3
Texture (<2mm fraction; %)	Clay (<0,002 mm)	32.8	20.3	21.4	7.8	27.8	37.8
	Silt (0,002-0,05 mm)	18.7	23.7	10.1	14.2	38.7	26.2
	Sand (0,05-2 mm)	48.5	56.0	68.5	78.0	33.5	36.0
Munsell Soil Color (dry)	Hue	7.5YR	10YR	10YR	10YR	10YR	10YR
	Value	5	7.5	5	7.5	6.5	7
	Chroma	3	2	2.5	3	3	2.5

Characterization of soil profiles



Source: De Alba, S., 2000. Redistribución del suelo por las prácticas de laboreo. Edafología. Volumen 7-2, pp 75-90.



	PARAMETERS	UNITS	TEST PLOT P02				
			0-10 cm	10-20 cm	20-30 cm	30-40 cm	40-50 cm
PHYSICAL	soil moisture	% w/w	1.0	3.3	4.1	3.6	4.2
	bulk density	$g*cm^{-3}$	1.6	1.5	1.8	1.7	1.8
	sand	%	86	86	83	81	75
	silt	%	9	3	6	3	9
	clay	%	5	11	11	16	16
	colour (dry)	MUNSELL	10YR 7/3	10YR 7.5/4	10YR 7/3.5	10YR 7/3.5	2.5Y 7/3
	colour (moist)	MUNSELL	10YR 4/3.5	10YR 4.5/4	10YR 5/4	10YR 5/4	10YR 4.5/4
CHEMICAL	pH		5.19	5.30	5.36	6.00	6.12
	electrical conductivity	$\mu s*cm^{-1}$	29.2	23.7	23.5	14.3	17.8
	organic matter	% w/w	0.6	0.3	0.4	0.3	0.4
	calcium carbonate	%w/w	0.0	0.0	0.0	0.0	0.0
	iron oxides (as Fe_2O_3)	% w/w	1.3	1.3	1.3	1.8	2.3
	cation exchange capacity	$cmol^{+}*kg^{-1}$	2.7	2.9	3.3	4.3	10.3

Metadata

- “Metadata is defined as structured information about an information resource of any type or format” (P. Caplan).

- According to Ukoln, “metadata is structured data about digital (and non-digital) resources that can be used to help in a wide range of operations. For example, in the description and location of resources, in the management of information resources, including the management of intellectual property rights and in their long-term preservation ”.
- (http://www.ukoln.ac.uk/metadata)

Why are metadata useful?

- To locate resources
- To describe resources
- To control resources
- To identify versions
- To preserve the information

Metadata for spectroradiometry

Metadata	Variables
Location of the point of interest	• Latitude and longitude • Altitude above sea level
Site description	• Class of soil cover • Topography • Geomorphology
Time of measurement	Coordinated Universal Time (UTC)
Sky conditions	• Type of clouds • Extension of the cloud cover
Meteorological data	• Temperature of air • Relative humidity • Atmospheric pressure
Instrument	• Model and serial number • Last calibration • Angular field of view
Method of measurement	• Type of reference panel and serial number • Date of calibration
Field technique	• Viewing geometry • Method to hold the sensor (optical fiber)
Type of measurement	Radiance, reflectance

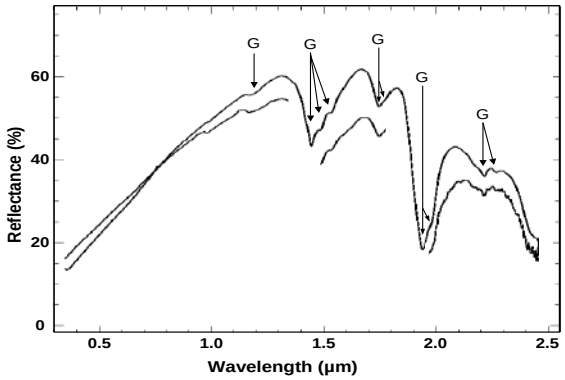
Metadata for soils

Descripción de parcela:						Foto:	
Autores:							
Fecha observación:							
Localización:							
Municipio:							
Hoja MN:							
Topografía circundante:							
Material original:						Afloramienta:	
Uso de terreno:							
Vegetación	tipo:						
	especies:						
	cubierta:						

Muestra:					Foto:	
Coordenadas:	Latitude N:		Longitude E:		Altitude (m):	
Posición fisiográfico						
Clase de pendiente (%)	0-2	2-6	6-13	13-25	25-55	>55
Forma de pendiente:	concava	recta	convexa	aterrazada	compleja	
Microtopografía:					Drenaje:	
Profundidad:						
Color	seco:				húmedo:	
Humedad:	mojado	húmedo	seco	manchas húmedo	manchas seco	
Fragmentos de rocas	ninguno	muy pocos	pocos	frecuentes	muchos	abundantes
Observaciones:						

Muestra:					Foto:	
Coordenadas:	Latitude N:		Longitude E:		Altitude (m):	
Posición fisiográfico						
Clase de pendiente (%)	0-2	2-6	6-13	13-25	25-55	>55
Forma de pendiente:	concava	recta	convexa	aterrazada	compleja	
Microtopografía:					Drenaje:	
Profundidad:						
Color	seco:				húmedo:	
Humedad:	mojado	húmedo	seco	manchas húmedo	manchas seco	
Fragmentos de rocas	ninguno	muy pocos	pocos	frecuentes	muchos	abundantes
Observaciones:						

Spectral library – Georeferenced data base



Mineral	Absorption positions (µm) –(Crowley 1991)	P.R*
Calcite	2.335	48
Halite	**1.432**, 1.936	61
Hexahydrite	0.976, 1.232, **1.436**, 1.462, 1.572, 1.932, 1.960	6
Pentahydrite	0.984, 1.188, 1.224, 1.458, 1.556, 1.932, 1.976	6
Starkeyite	0.972, **1.202**, **1.436**, 1.460, 1.548, 1.596, 1.938, 2.412	9
Gypsum	0.992, **1.196**, **1.440**, 1.484, 1.530, 1.740, 1.768, 1.936, 1.964	18

* P.R. Percentage reflectance at 2.5 µm.

Registration and location

Sample id: P8LS096T26E_Salt crust (H44)

Acquisition date: 07/07/2003 Acquisition time: 13:21:04

Location: La Lagunilla Municipality: Villafranca de los Caballeros

UTM-Easting: 471423 UTM-Northing: 4365514 Elevation (m): 638

Abiotic and biotic characteristics

Geomorphic environment: Lacustrine

Landscape: Lake plain Landform: Lake bed

Topography: Flat Microtropography: Even

Slope class (%): 0 - 0.1 Slope form: Hillslope position:

Land use: Not used and not managed

Anthropogenic influence: No influence

Surface cover feature: Salt crust

Parent material: Marl and gypsum sediments

Soil properties

Carbonates (%): 7.2 pH (1:25 H2O): 8.6

Fe2O3 (%): 0.4 Organic matter (%): 2.4

Electric conductivity (dSm-1): 37.8

Munsell colour: Dry 10YR8/2 (very pale brown) Wet 10YR6/2 (light brownish grey)

Mineralogical composition*

Bloedite: Halite: +

Hexahydrite: Tr. Pentahidrite: +

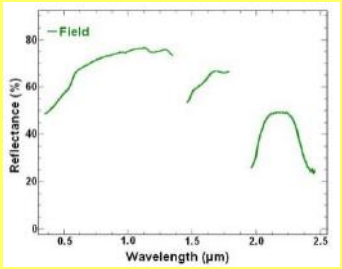
Starkeyite: + Tridimite:

Gypsum: ++ Calcite: +

Dolomite: Quartz: Tr.

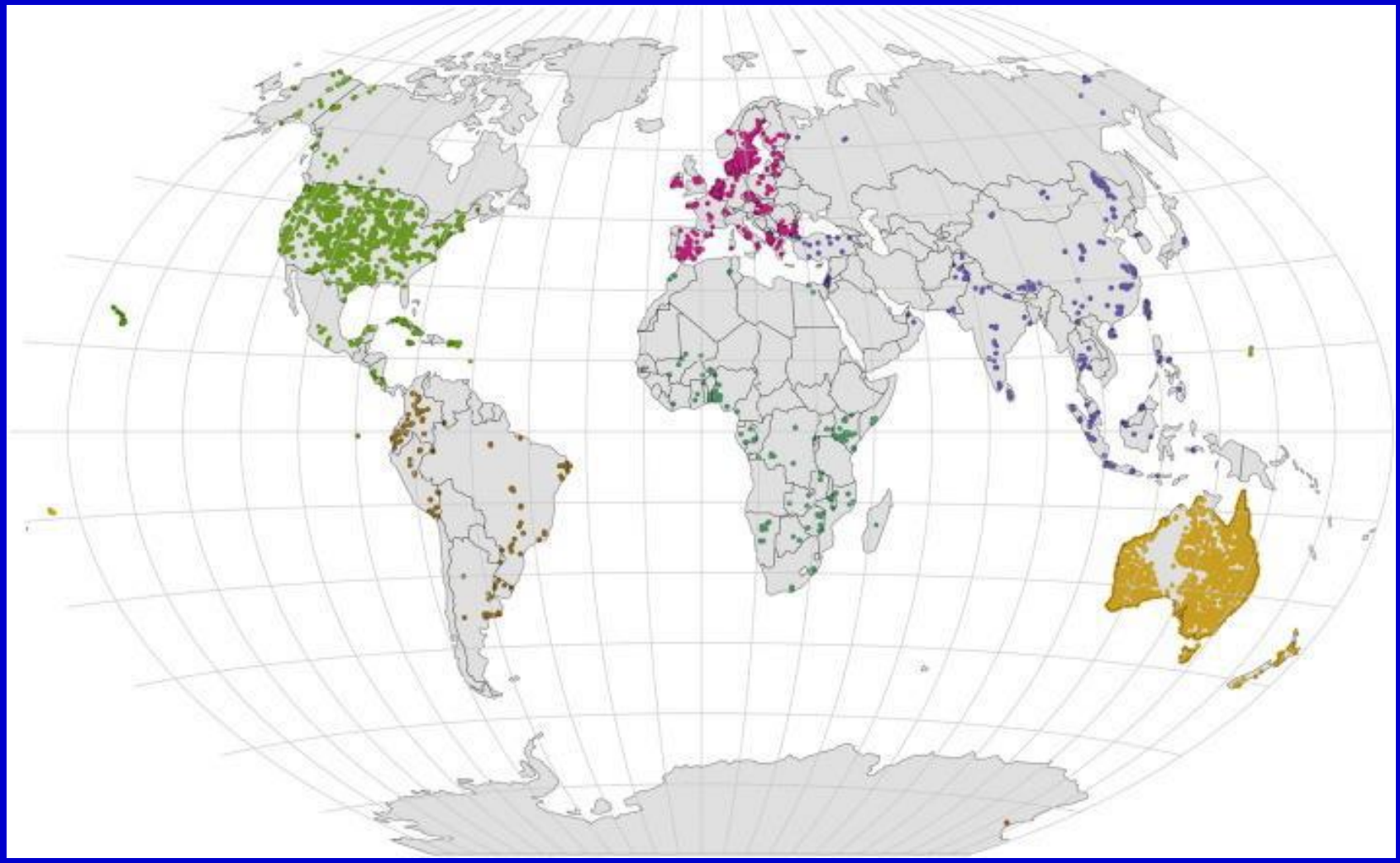
K-feldespar: + Na-feldespar:

Phyllosilicates: + (illite)



*(Tr. - trace; + common; ++ abundant; +++ very abundant)

Spectral libraries (global)



Source: Viscarra Rossel, R.A., et al., 2016. A global spectral library to characterize the world's soil. Earth-Science Reviews, Vol. 155, 198-230.

Available spectral libraries

Soil Spectra Library containing visible near infrared spectra of 785 soil profiles (4,438 samples)
http://www.worldagroforestry.org/sd/landhealth/soil-plant-spectral-diagnostics-laboratory/soil-spectra-library

Brazilian Soil Spectral Library
https://bibliotecaespectral.wixsite.com/english

USGS Spectral Library by USGS. Reference library of mainly laboratory based samples.
https://speclab.cr.usgs.gov/spectral-lib.html

ASTER Spectral Library - Version 2.0 by JPL. ECOSTRESS Spectral Library - Version 1.0 .
https://speclib.jpl.nasa.gov/

SPECCHIO a spectral information system for reference spectra and spectral campaign data.
http://www.specchio.ch

SPECTATION by GFZ. Windows based spectral database solution, mainly vegetation.
http://www-app2.gfz-potsdam.de/spectation/?file=main

EcoSIS Spectral Library, an online database containing 71,259 spectra.
https://ecosis.org/

Mineral spectroscopy server (Cal Tech) free mineral Raman, UV/VIS-near-infrared, mid-IR spectra.
http://minerals.gps.caltech.edu/

"A nation that destroys its soils, destroys itself"

President Franklin D. Roosevelt, 1937