Visible and near infrared soil spectroscopy: field and laboratory experiences

ASD WORKSHOP

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Centro de Ciencias Humanas y Sociales, CSIC

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GOBIERNO DE ESPAÑA

MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD

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Unidad de Conservación y Recuperación de Suelos

Departamento de Medio Ambiente

What affects soils in semi-arid environments

- 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
- Influence of climate change and economic situation

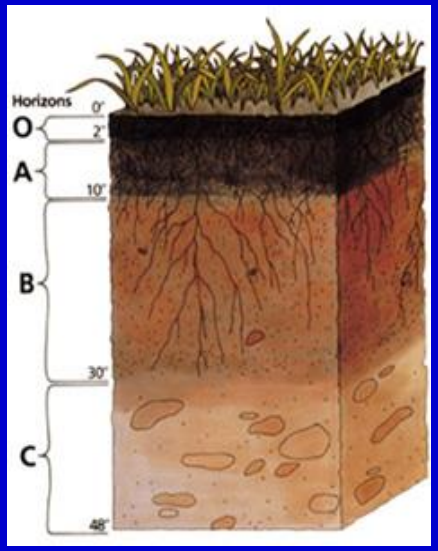
Needs

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

RS approach

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

Soil surface and profile

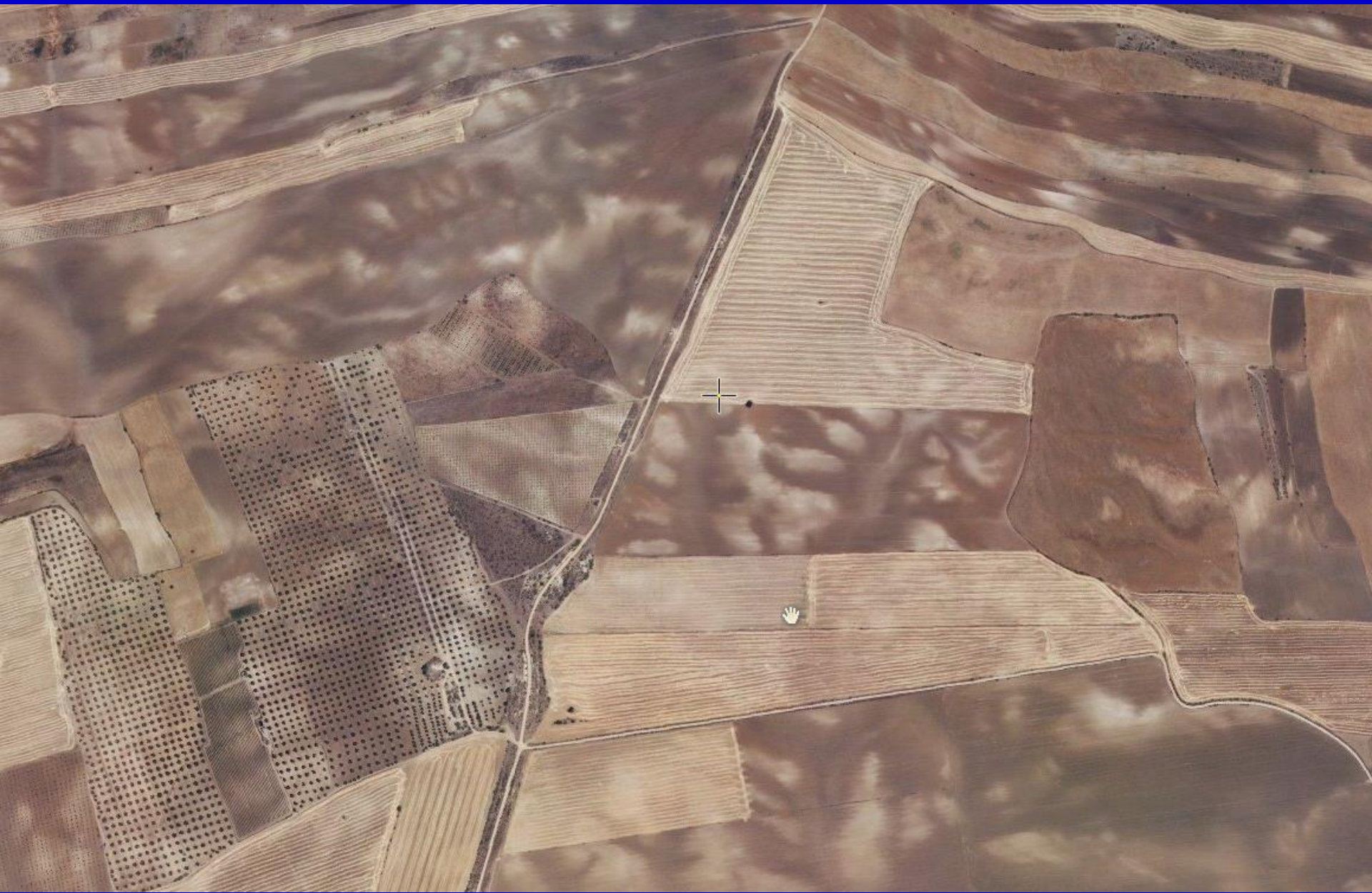


Fuente: PD-USGov-USD

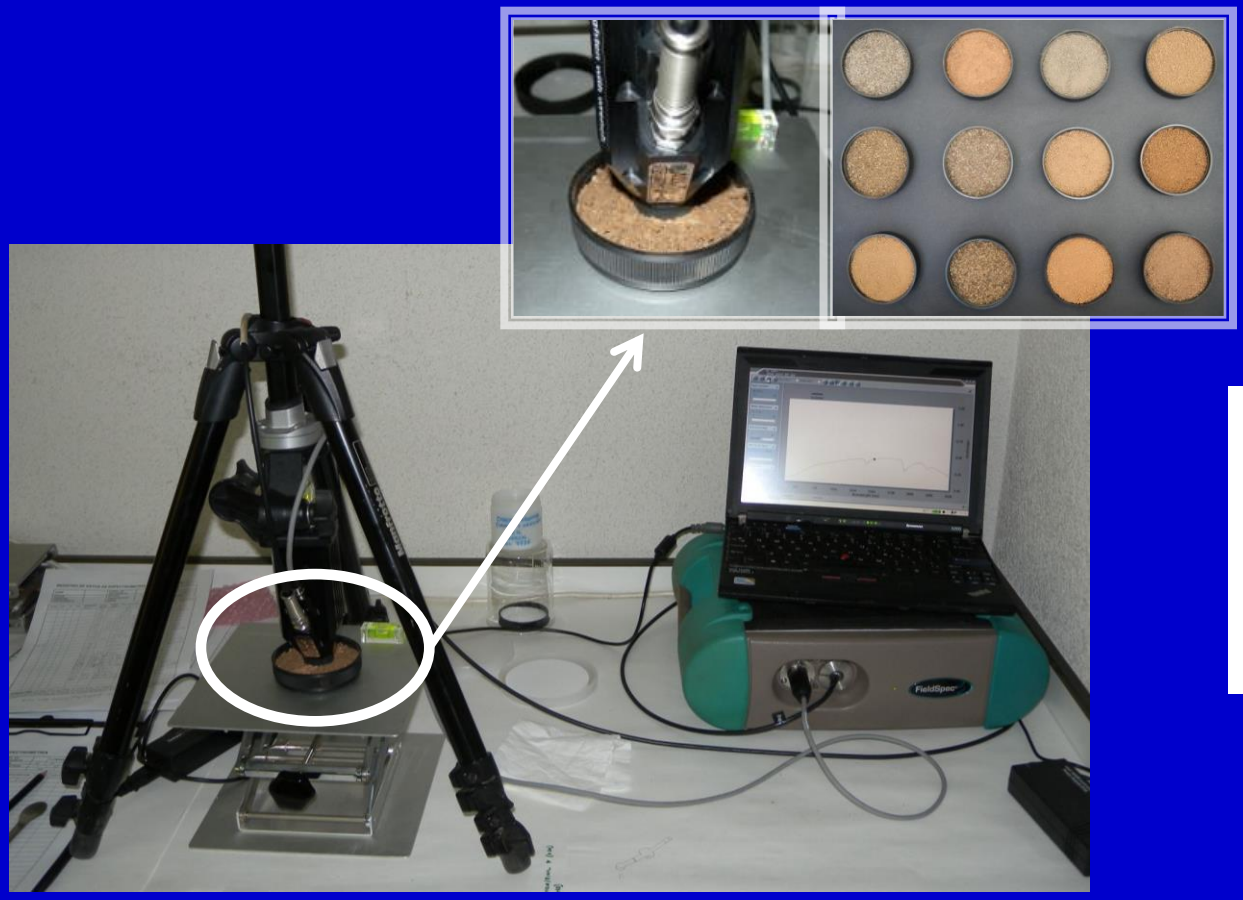
Pedosphere as a whole

Soil surface cover

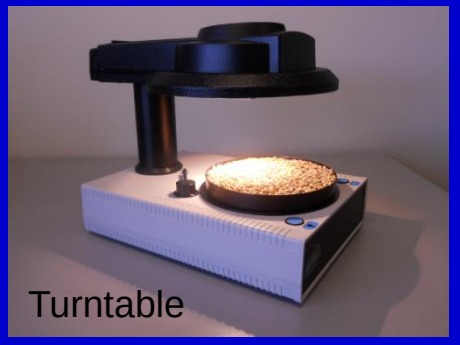
Aerial view of the soils



Laboratory spectra



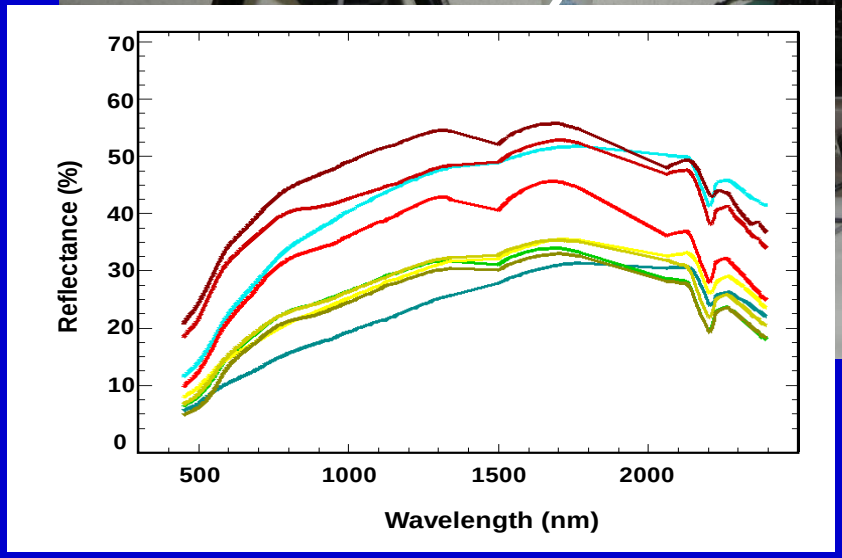
Contact probe

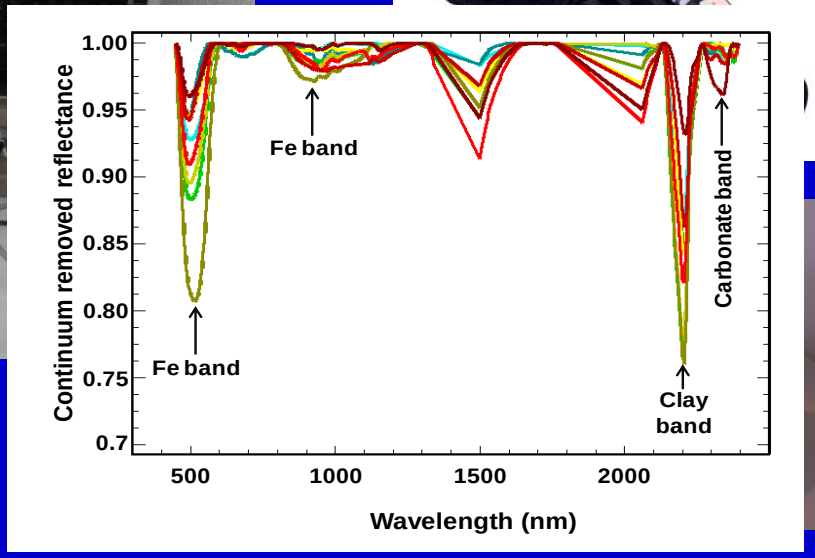


Turntable

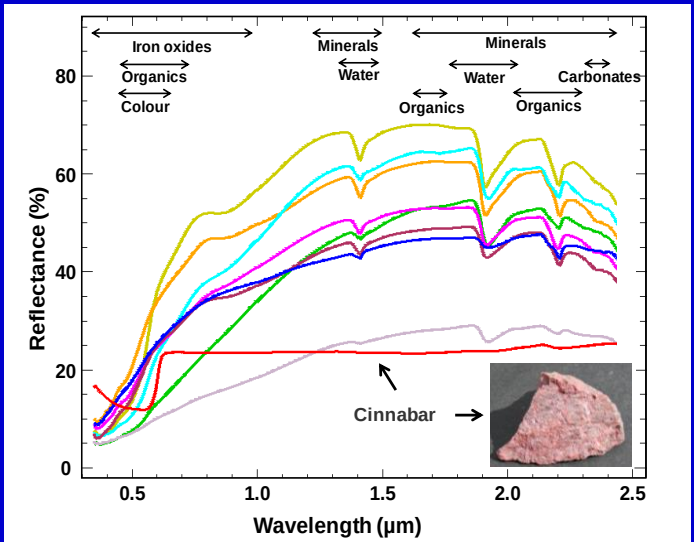
Laboratory spectra

Contact probe





Total Hg content

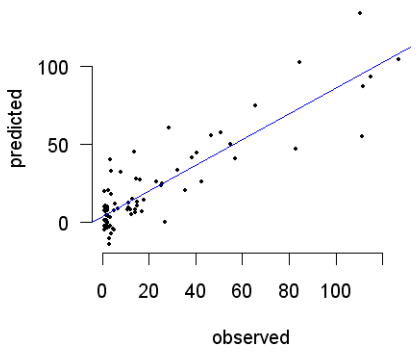


Land uses / *Dominant soil types (WRB-FAO)*	Hg (mg kg-1)			pH (1:2.5)			EC 1:5 (μS cm-1)			OM (%)			Clay (%)			Minerals (semiquantitative average %)	
	average	max	min	average	max	min	average	max	min	average	max	min	average	max	min	quartz+feldspars	phyllosilicates
Irrigated cultivated areas / *Fluvisols-Regosols*	**17**	29	7	**6.9**	7.4	6.3	**1593**	4520	100	**3.6**	6.4	0.6	**17**	18	16	**64**	**32**
Non-active mining areas / *Tecnosols*	**4279**	16091	192	**6.8**	7.6	5.7	**260**	567	69	**4.1**	12.2	0.9	**19**	37	4	**58**	**42**
Pasture soils and dehesas / *Regosols-Cambisols*	**17**	66	3	**5.9**	7.3	4.5	**417**	900	200	**2.7**	4.3	1.9	**15**	21	11	**63**	**37**
Rainfed cultivated areas / *Cambisols-Luvisols*	**3**	3	2	**5.4**	5.8	4.9	**100**	100	100	**1.6**	1.9	1.2	**13**	18	9	**59**	**41**
Restored mining areas / *Tecnosols*	**21**	48	9	**6.2**	7.7	4.8	**688**	2103	100	**1.1**	2.4	0.3	**19**	28	7	**70**	**29**
Riparian formations downstream mining areas / *Fluvisols-Regosols*	**193**	323	119	**6.1**	7.3	5.3	**497**	1061	151	**1.1**	2.7	0.3	**9**	19	2	-	-
Riparian formations upstream mining areas / *Fluvisols-Regosols*	**2**	6	1	**6.5**	6.8	6.1	**177**	337	108	**1.0**	1.9	0.5	**12**	24	4	-	-
Shrublands and woodlands / *Umbrisols-Regosols-Leptosols*	**7**	15	2	**5.7**	6.4	4.7	**169**	500	64	**3.0**	5.9	0.6	**15**	25	11	**68**	**32**

model fit

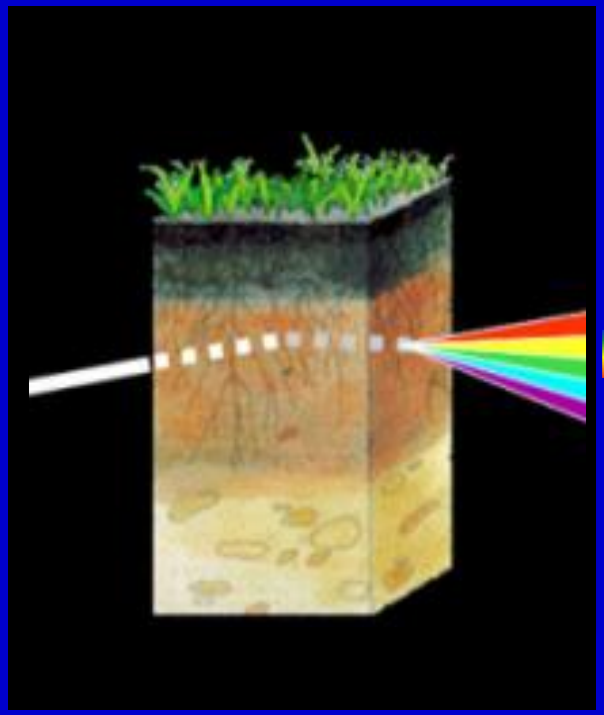
R2 cal	0.87
R2 val	0.778
RMSEcal	11.3119
RMSEval	14.7834
# LVs	8
# sig preds	8
method	PLSR

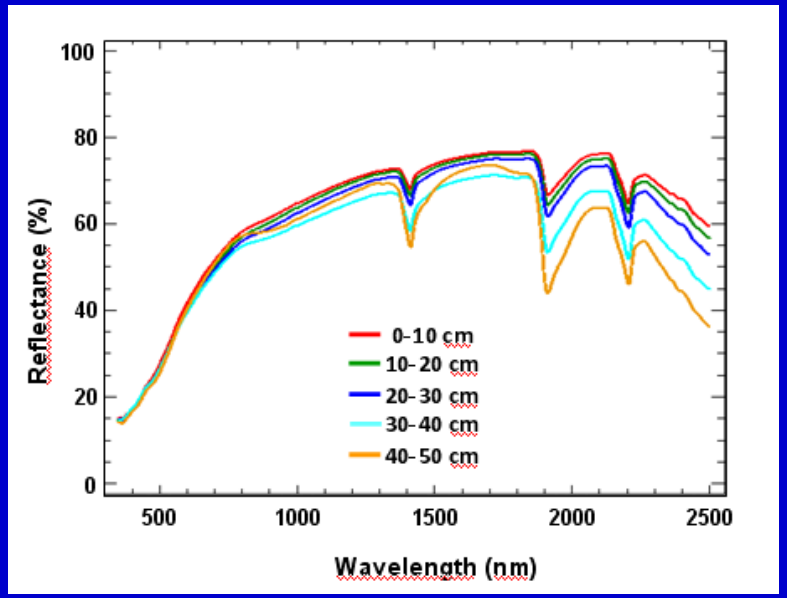
predicted vs. observed



Spectral range (μm)	R2cal	R2val	RMSEcal	RMSEval	Latent vectors	sig. Predictors	Significance
0.35 - 2.5	0.87	0.778	11.312	14.783	8	8	0.01
0.35 - 1.0	0.8	0.71	14.018	16.894	6	7	0.01
1.0 - 2.5	0.863	0.749	11.623	15.722	7	1	0.01
First derivative							
0.35 - 2.5	0.846	0.739	12.323	16.037	4	48	0.01
0.35 - 1.0	0.803	0.671	13.937	17.989	4	10	0.01
1.0 - 2.5	0.781	0.686	14.679	17.587	3	30	0.01
Second derivative							
0.35 - 2.5	0.836	0.736	12.696	16.13	4	56	0.01
0.35 - 1.0	0.779	0.645	14.767	18.71	4	13	0.01
1.0 - 2.5	0.779	0.686	14.766	17.578	3	33	0.01

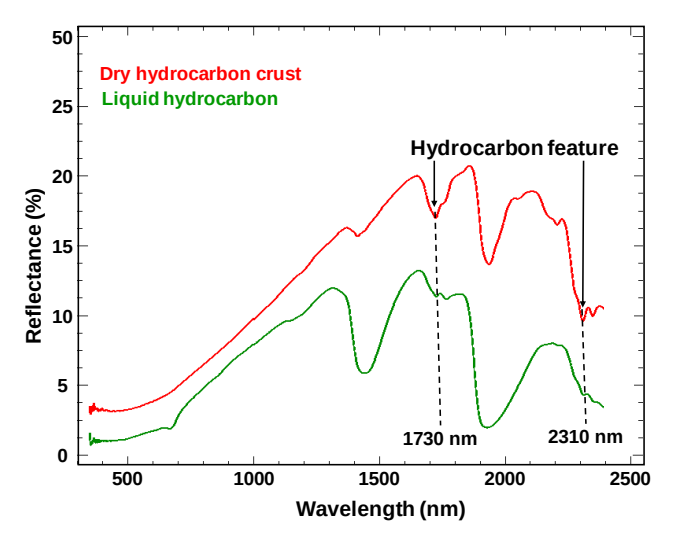
Determining properties within soil horizons

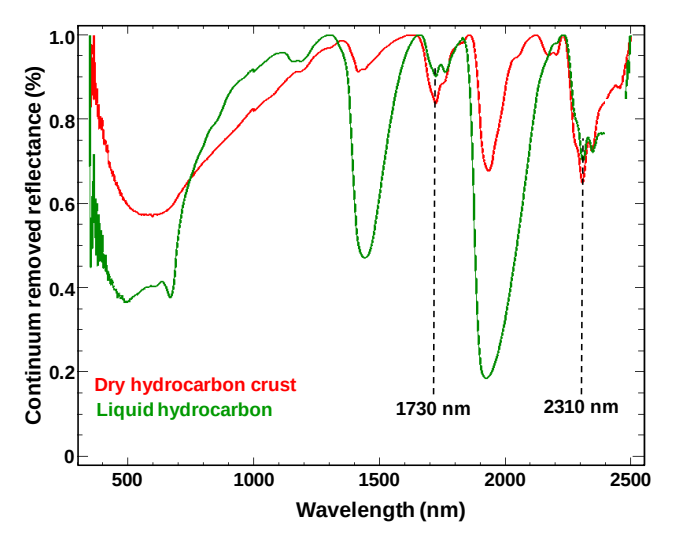


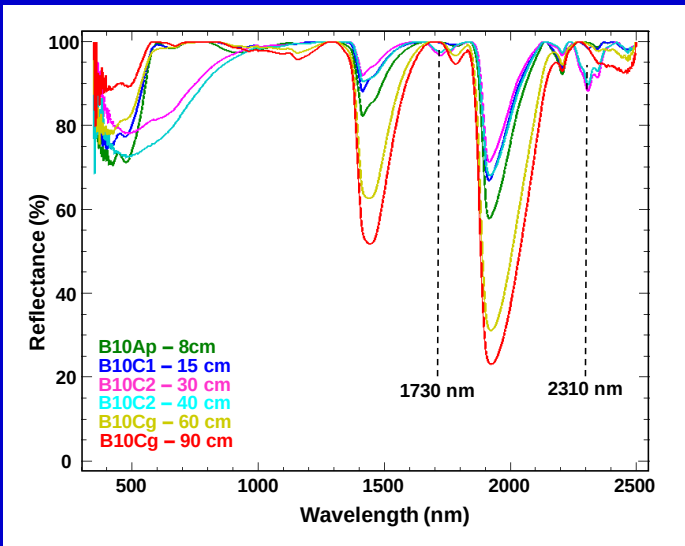


	PARAMETERS	UNITS	TEST PLOT P02				
			0-10 cm	10-20 cm	20-30 cm	30-40 cm	40-50 cm
PHYSICAL	soil moisture	% w/w	1.0	3.3	4.1	3.6	4.2
	bulk density	$g*cm^{-3}$	1.6	1.5	1.8	1.7	1.8
	sand	%	86	86	83	81	75
	silt	%	9	3	6	3	9
	clay	%	5	11	11	16	16
	colour (dry)	MUNSELL	10YR 7/3	10YR 7.5/4	10YR 7/3.5	10YR 7/3.5	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

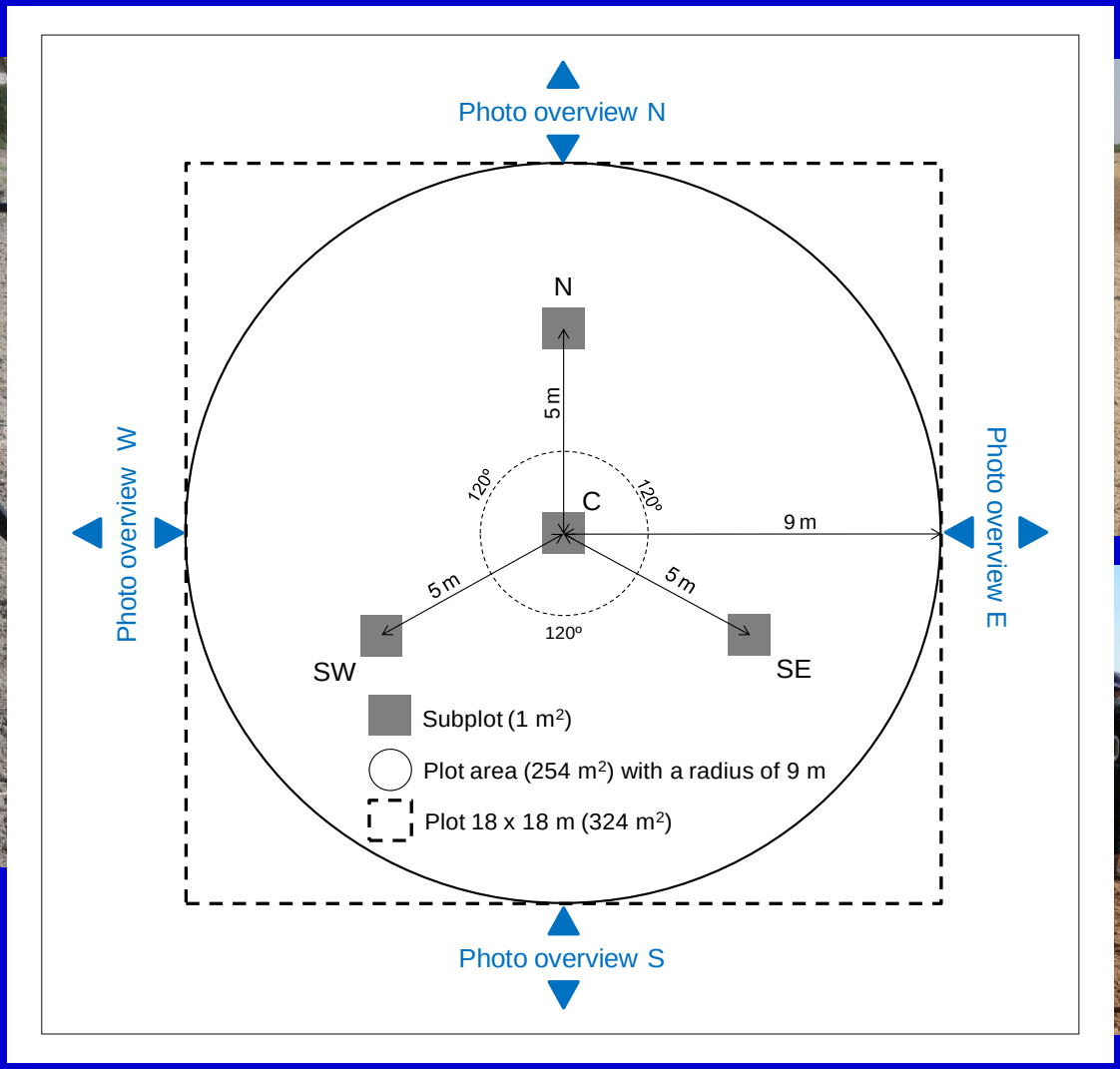
Hydrocarbons







Field work



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

Field protocol

ASD Field Campaign – Measurement Protocol

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

REGISTRO DE DATOS DE ESPECTROMETRÍA

Hoja Nº

ZONA		PANEL DE REFERENCIA		ILUMINACIÓN			
FECHA		ÓPTICA	1°	8°	Cos	NONE	
PERSONA		FIBRA ÓPTICA	1	2		NONE	
INSTRUMENTO		MODO	Raw				

HORA	OPT	DC	WR	ARCHIVO ROOT	ARCHIVO EXT.	Ficha INICIO	Ficha FINAL	DESCRIPCIÓN

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

Field survey

Part 1: General site description

Sampling site: .... Authors:						
Acquisition data: .... Meteo cond.:						
Photos – overall plot view:						
Photos – nadir subplot (sp) 1: .... sp2: sp3:						
.... sp4: .... sp5: .... sp6: sp7:						
Photos - surrounding N: .... E: .... S: .... W:						
Coordinates: Latitude N: Longitude E:						
Altitude (m a.s.l.):						
Location:						
Plot position[1]: .... Topography[2]:						
Landform[2]: .... Microtopography[2]:						
Slope gradient (%)[2]	0-0.1	0.1-2	2-8	8-16	16-30	>30
Slope form[2]:	straight	concave	convex	terraced	complex	
Human influence[2]:						
Parent material[2]: .... Parent rock[2]:						
Vegetation: .... % cover:						

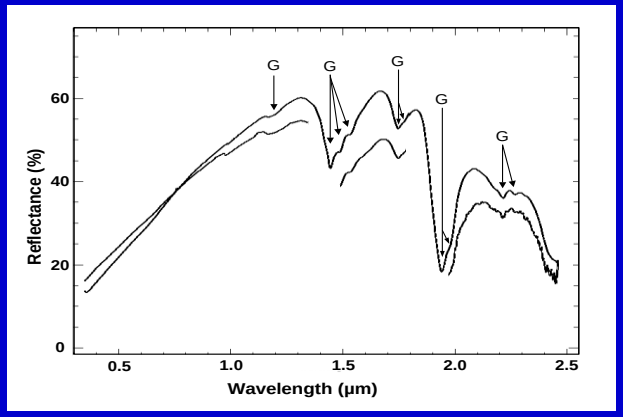
Part 2: Surface properties

Color (Munsell):							
Moisture condition[4]:	dry	slightly moist	moist	wet			
Sealing – crusting[4]:	nil	crust	slight sealing	moderate sealing	strong sealing		
Texture:							
Stones abundance[4]:	nil	very few	few	common	many	abundant	dominant
Stones size[4]:	gravel	fine gravel	medium gravel	coarse gravel	stones	boulders	large boulders

Observations:

1 Schoenaberger et al., 2002
2 De la Rosa et al., 2002

Spectral library



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: +

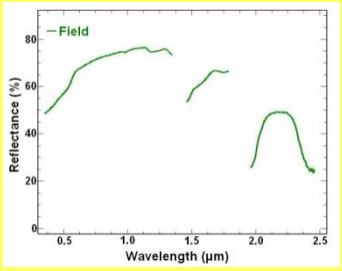
Starkeyite: + Tridimite:

Gypsum: ++ Calcite: +

Dolomite: Quartz: Tr.

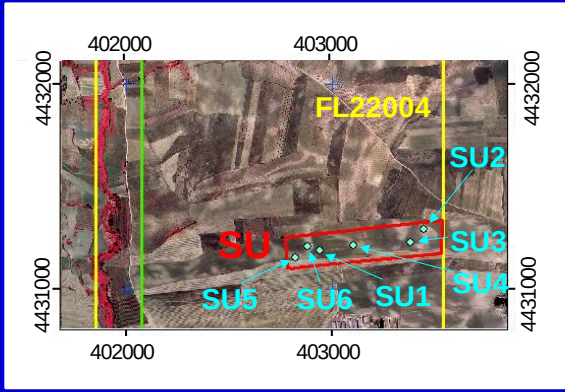
K-feldespar: + Na-feldespar:

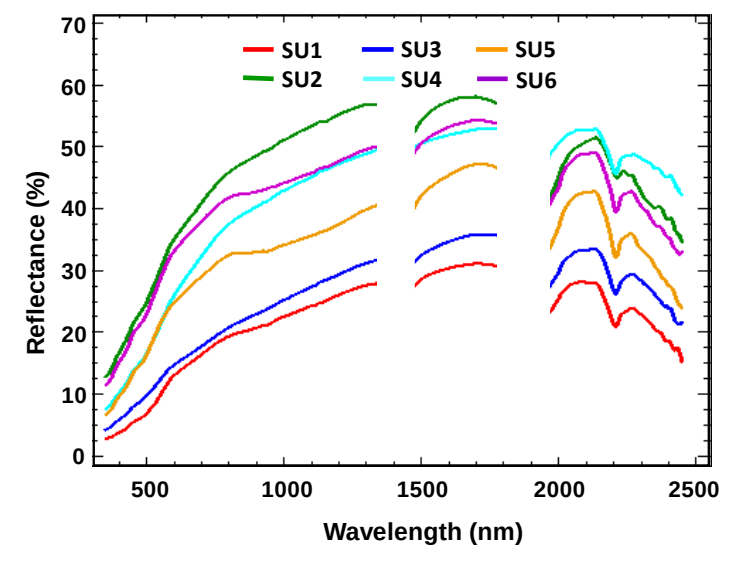
Phyllosilicates: + (illite)



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

Topsoils





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