Soil spectroscopy as a tool for the spatial assessment of soil erosion states in agricultural semi-arid Spain

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Introduction

- I come from the remote sensing community
- We do similar work, but of course with extension / application to remote sensing scale airborne or spaceborne
- Jargon is different
  - VNIR → ONLY 0.4- 1.3 microns
  - VNIR – Short Wave Infrared (SWIR)

Background

- Soils
  - carry out a number of key environmental functions
  - Fragile soils in agricultural arid and semi-arid regions very sensitive to erosion processes
  - Processes monitoring and modeling requires a proven approach for soil properties estimation (→applicable at all scales, repeatable, transferable)

- VNIR-SWIR spectroscopic methods as a soil analytical tool for the accurate estimation of surface soil properties
  - Proven capability to derive key soil variables
  - Capabilities to infer deposition and erosion stages not demonstrated

- High relevance nowadays
  - Digital soil mapping and soil monitoring initiatives
  - Upcoming availability of next generation orbiting hyperspectral sensors e..g EnMAp 2017

SEDMEDHY - Soil Erosion Detection within MEDiterranean agricultural areas using Hyperspectral data

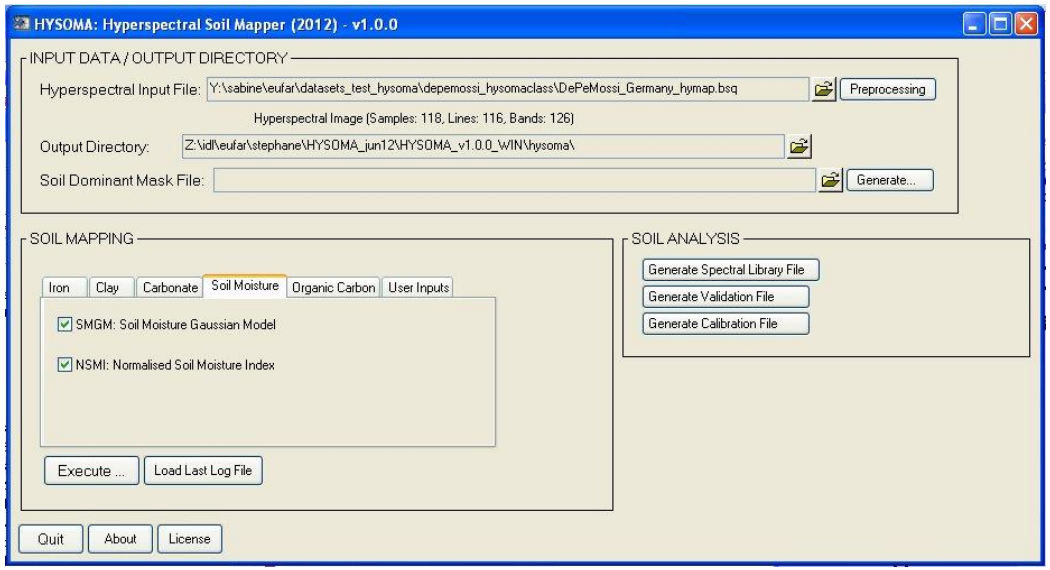
- EU-FP7 EUFAR Transnational Access project (Lead: CIEMAT)

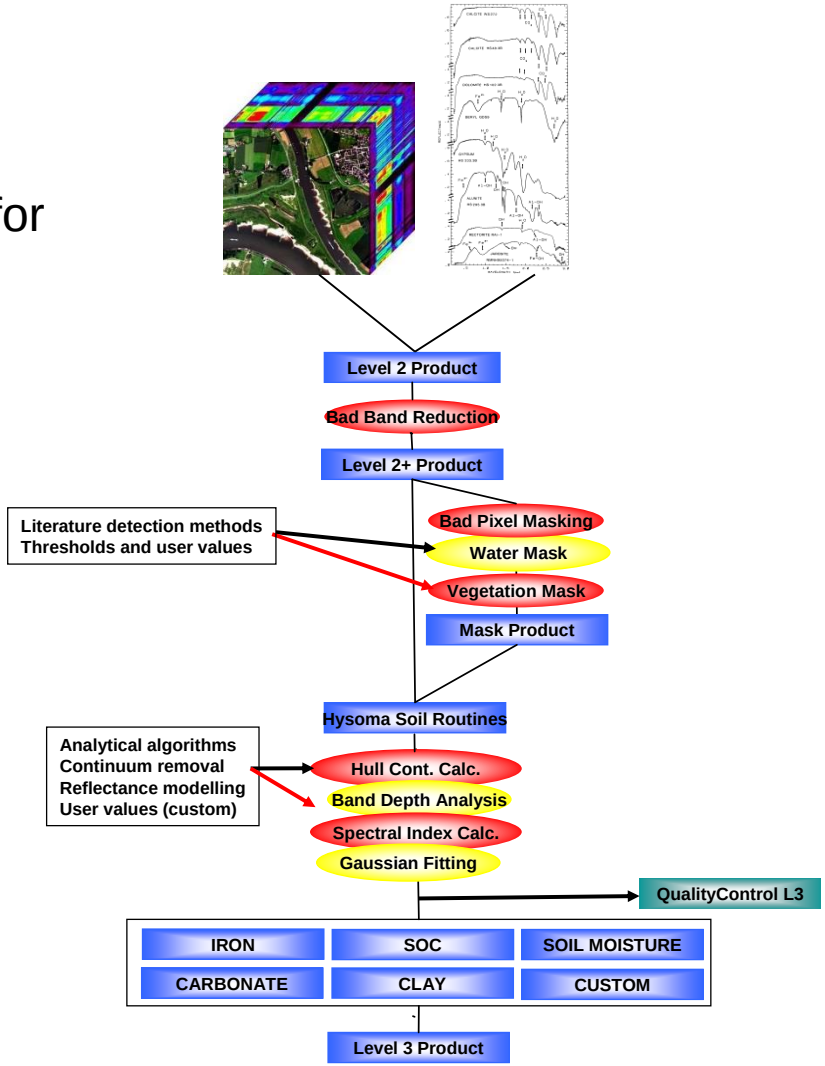
- Main objective: Examine the potential of soil spectroscopy for the mapping and identification of soil erosion and deposition states,
  - Analyses of the spatial distribution of combined varying surface soil properties (OM, $CaCO_3$, texture, Fe)

- Scientific issues
  - Discriminate crop residue, sparse vegetation, bare soil types
  - Integrate detailed terrain information for small scale topographic variations
  - Definition of soil surface characteristics as indicators of soil erosion stages
  - Determination of a map of soil erosion assessment
  - Address scaling issues of future spaceborne hyperspectral sensors

Methods: HYSOMA software interface

- Experimental toobox
- To provide non-expert spectroscopy users (hyperspectral users) with a suite of tools for soil applications
- Download: www.gfz-potsdam.de/hysoma





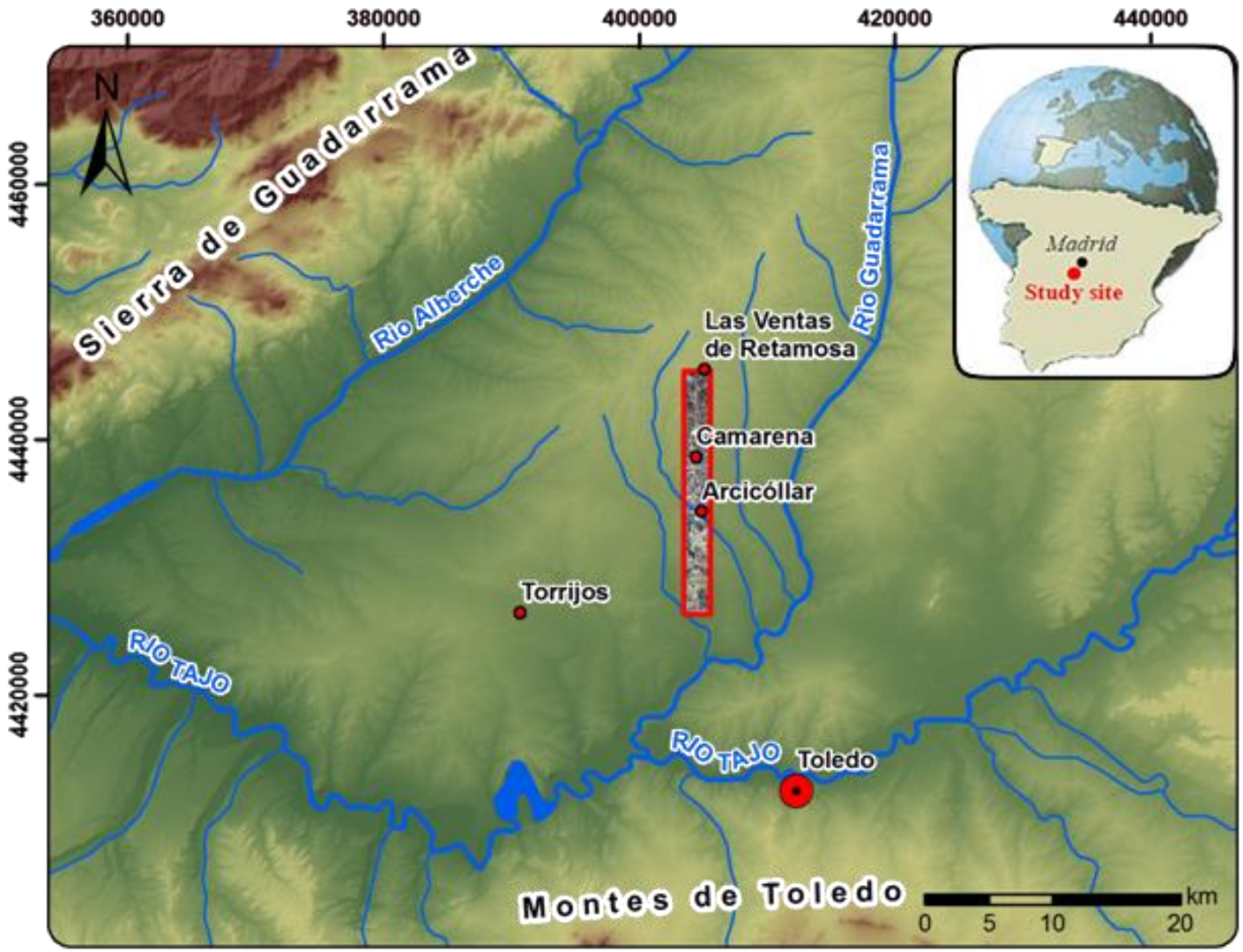
HYSOMA soil algorithms

Soil Chromophores	Soil Algorithm	Spectral Region (nm)	Estimated soil parameter
Iron oxides Fe_2O_3 content	Redness Index (RI)	477, 556, 693	Hematite content (Madeira et al., 1997; Matthieu et al.,1998)
	Spectral feature analysis 1	460 - 620	Iron oxide content
	Spectral feature analysis 2	760 - 1050	Iron oxide content
Clay Minerals Al-OH content	SWIR Fine Particle Index (SWIR FI)	2209, 2133, 2225	Clay mineral content (Levin et al., 2007)
	Spectral feature analysis	2120 - 2250	Clay mineral content
Carbonates Mg-OH content	Spectral feature analysis	2300 - 2400	Carbonate content
Soil moisture content	Normalised SM Index (NSMI)	1800, 2119	Soil moisture content (Haubrock et al. 2008a, 2008b)
	SM Gaussian Model (SMGM)	~1500 - 2500	Soil moisture content (Whiting et al. 2004)
Soil Organic Carbon	Spectral feature analysis SOC 1	400 - 700	Organic matter content (Bartholomeus et al., 2008)
	Spectral feature analysis SOC 2	400, 600	Organic matter content (Bartholomeus et al., 2008)
	Spectral feature analysis SOC 3	2138, 2209	Indirect organic matter content (Bartholomeus et al., 2008)

→ Currently 11 automatic soil functions for identification and semi-quantification

→ Fully quantitative mapping using field data for calibration (Option: “Generate calibration file”)

Study area: Camarena test site



Traditional rainfed agricultural activities:

- Wheat/ Barley crops
- Vineyards
- Olive Groves

Mediterranean climate:

- Avg. annual temp of 15.4°C
- Avg. annual precipitation of 357 mm

Undulating topography, avg. ele.v. 625m a.s.l.

Legend

Study Area
River
Settlement

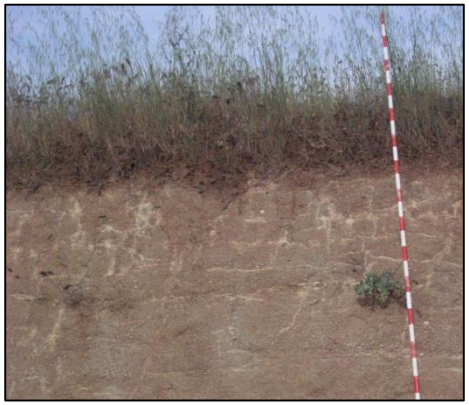
Elevation [m asl]
1949 m
372 m

Study area: Soils

→ Mostly evolved soils such as Calcic Haploxeralfs or Calcic Luvisols

→ Typical soil profile (arcosic area)

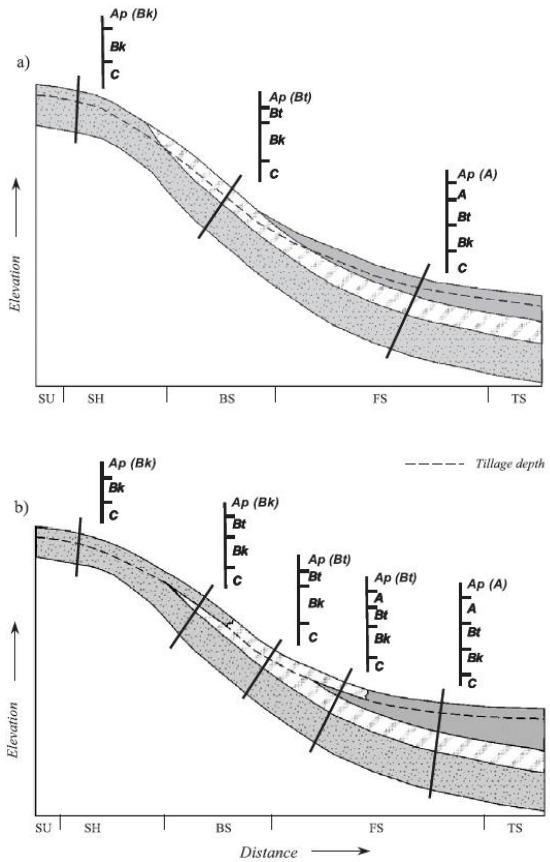
A Horizon	• Moderate Organic Matter Content • Coarse Textured
Bt Horizon	• Fine-textured • Rich in Fe-Oxides
Ck Horizon	• Rich in Carbonates • Coarse Textured
C Horizon	• Arcosic Sediment



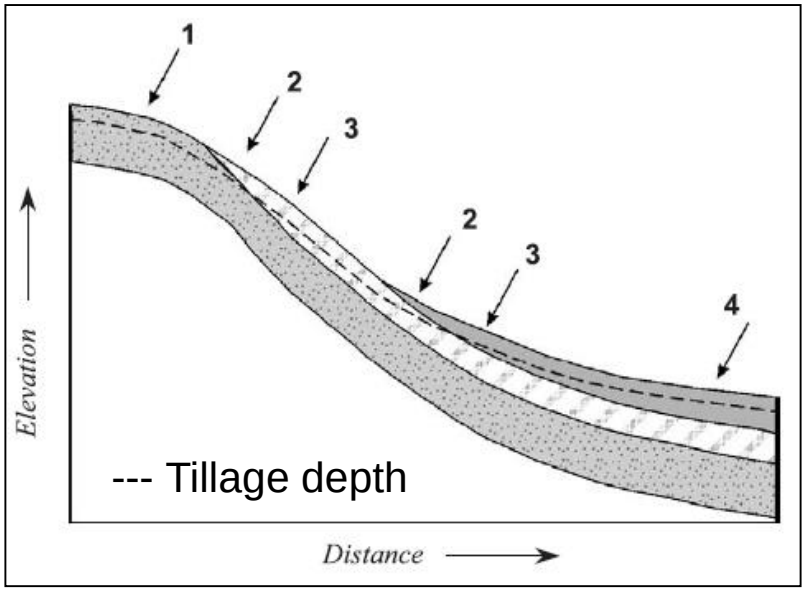
→ Erosion features (water erosion) associated with contrasting soil horizons

Erosion model

→ Soil profile modification by tillage along the slope (De Alba et al., 2004)



1- Soil truncation due to net soil loss
2- Substitution of surface horizons
3- Inversion of horizons
4- Soil accumulation

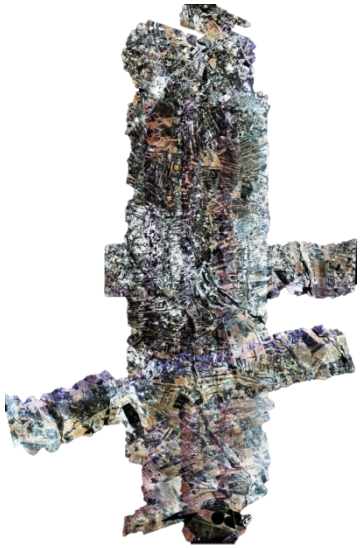


Data

- Field and laboratory data
  - Field and laboratory spectroscopic analyses at selected sites linked with geo- and bio-geochemical analyses (soil characterisation, LAI, crop production)
  - Soil sampling (0-10, 20-30, 30-50 cm) in the different erosional stages
  - Soil characterisation: pH, EC, OM, $CaCO_3$, Fe oxides, coarse fragments, texture, color, description, soil mineralogy
  - Spatial multiscale sampling protocol

- Airborne data
  - NERC AISA Eagle and Hawk hyperspectral data (400-2400 nm) at different altitudes: 1.5 and 3 m Low Alt, 3 and 6 m High Alt
  - LIDAR ALS50 (DEM <1m)

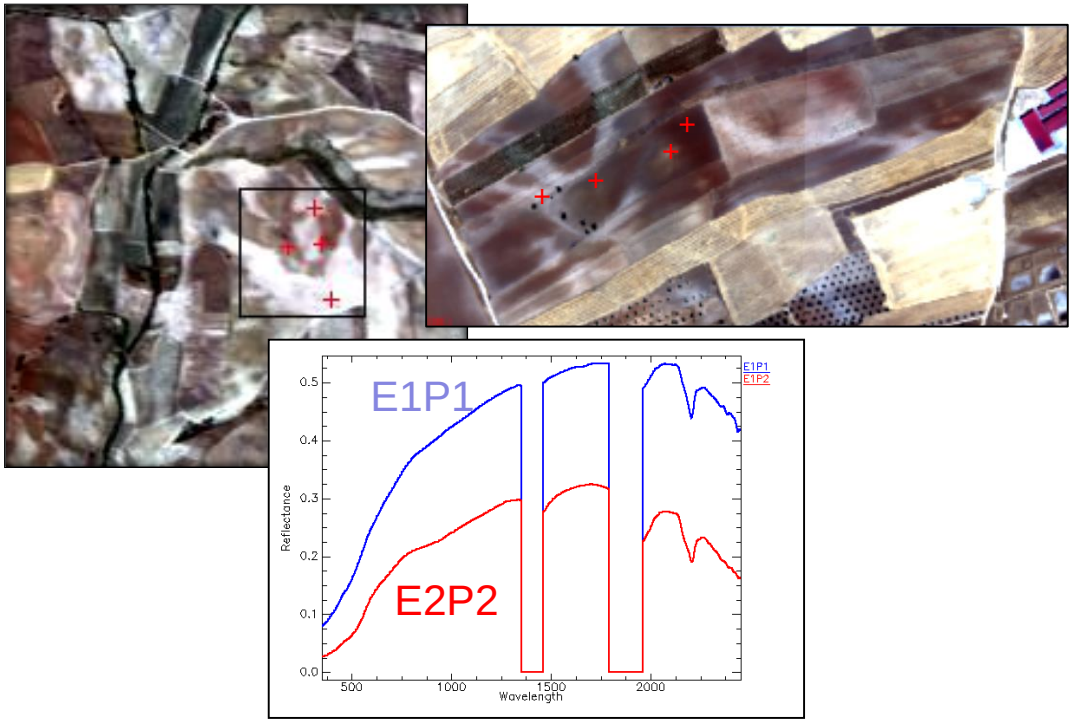
LA Eagle mosaic (Aug.8/2011)



HA Eagle mosaic (Aug.10/2011)

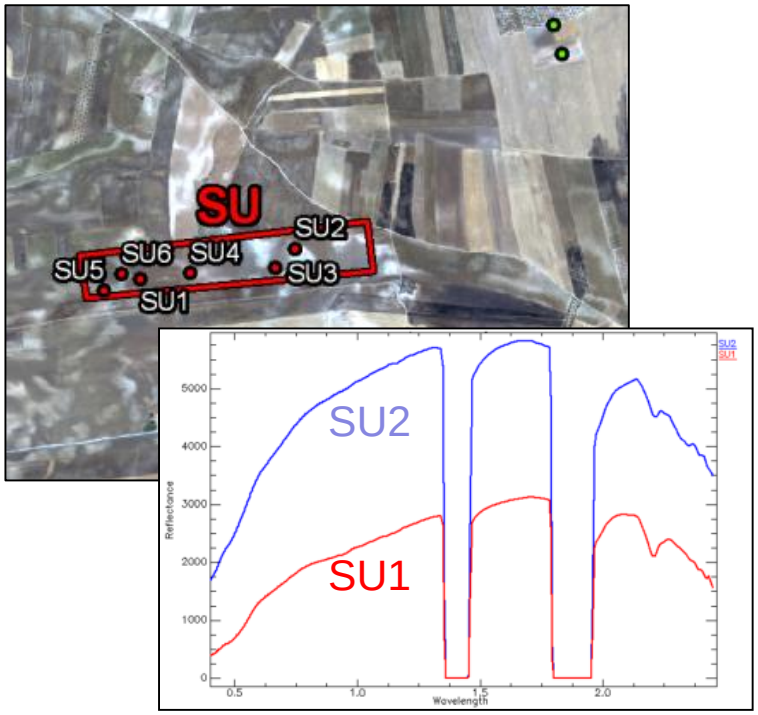
Analyses at selected sites

NORTH
E1/s2 location: Arcosic area



pH~5.5, B-horizons (clay & iron-rich) exposed at top slope, Sands in accumulation areas, locally carb precipitates

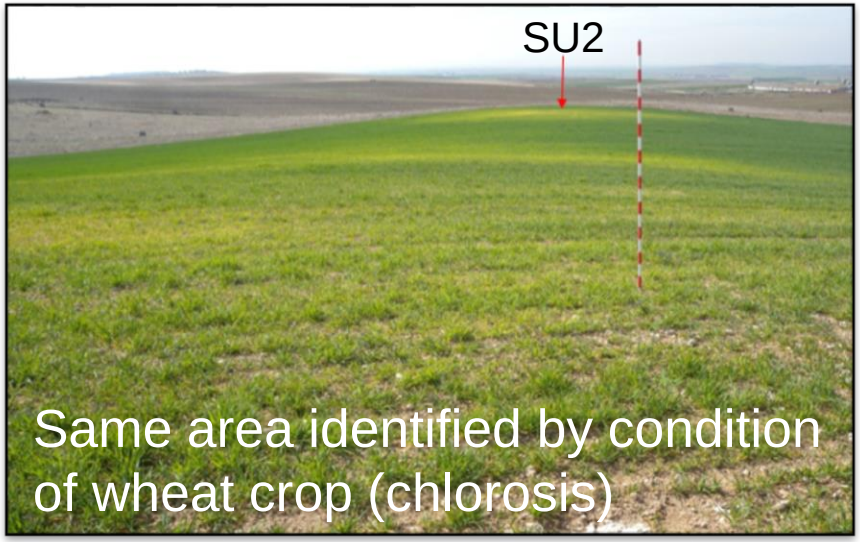
SOUTH
SU location: Carbonatic area



pH~8 at SU2 point, carbonate horizons at top slope situation (Ck) due to net soil loss

Multitemporal observations

SU location: Carbonatic area

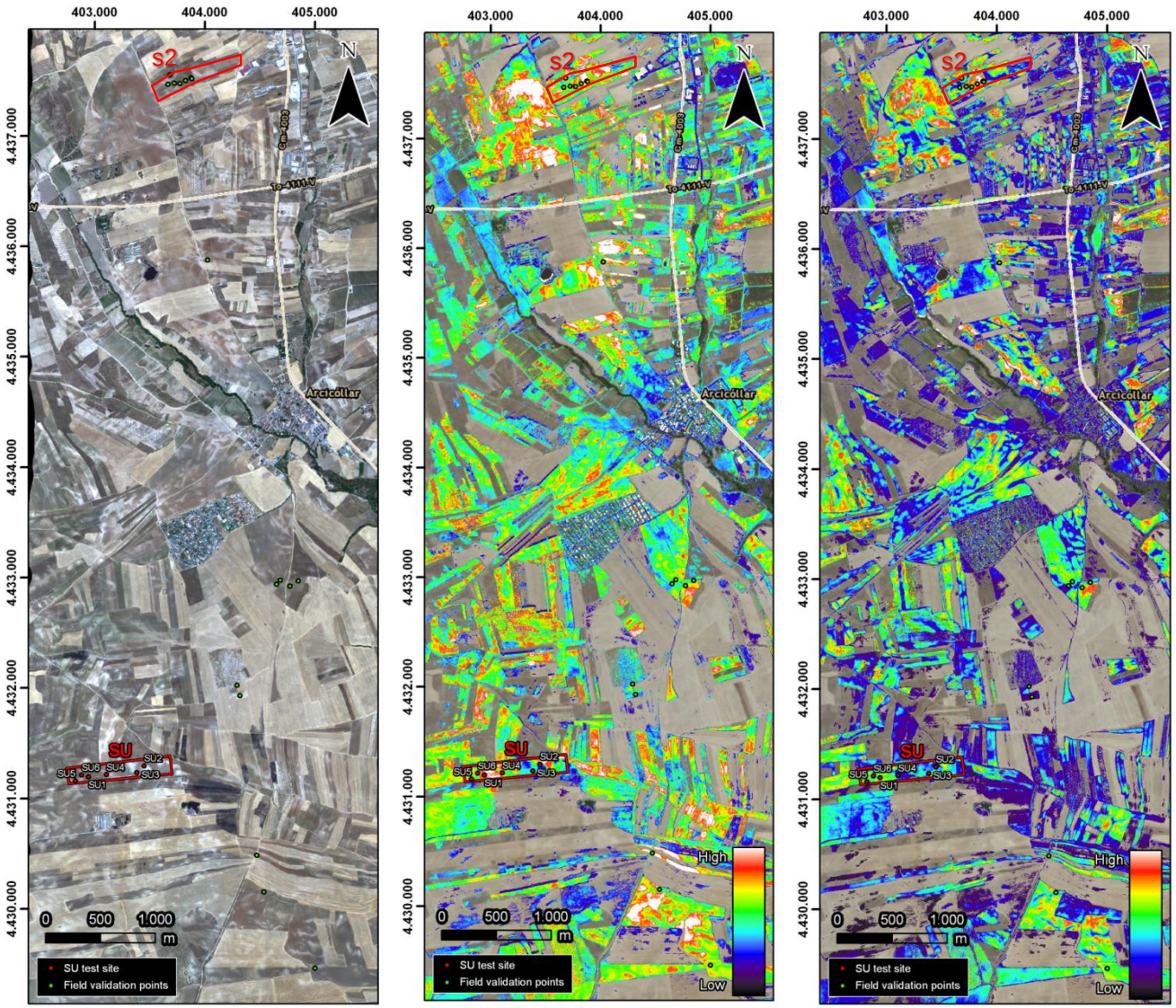


SU test site in fallow (08.Aug.11) and with wheat cultivation (23.Mar.12)

→ Soil surface characteristics can be related with soil erosion states, land management and vegetation conditions

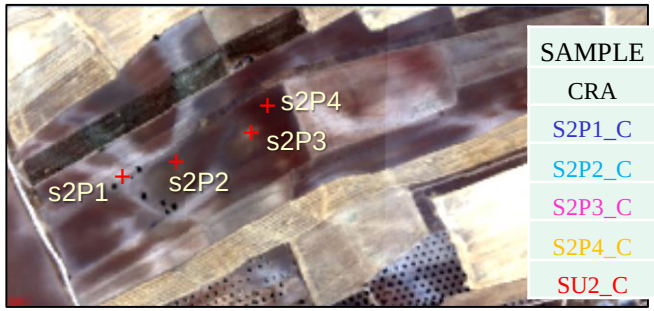
Mapping of soil properties based on AISA images

Camarena reflectance cube and predicted clay and iron spatial content

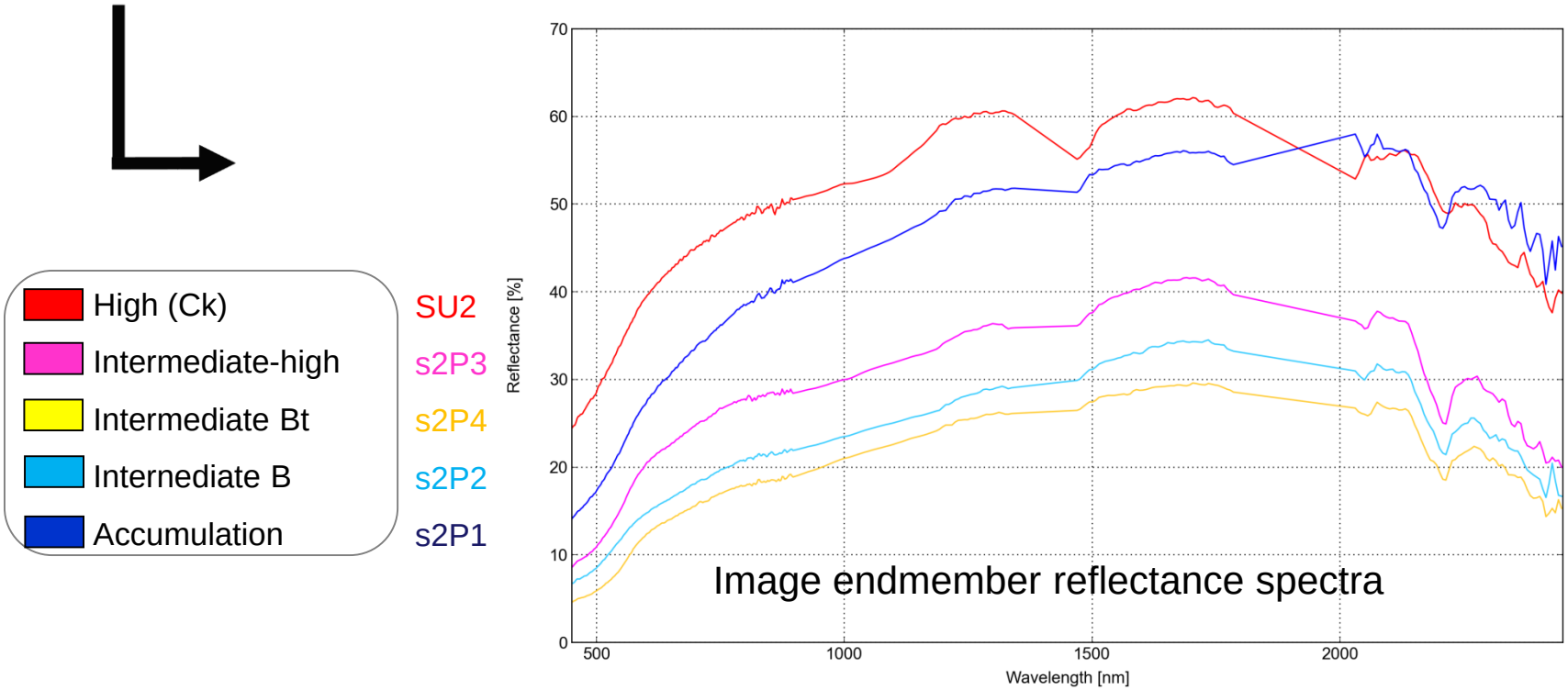


RGB image | Soil iron content (CRAD_460_620) | Soil clay content (CRAD_2120_2250)

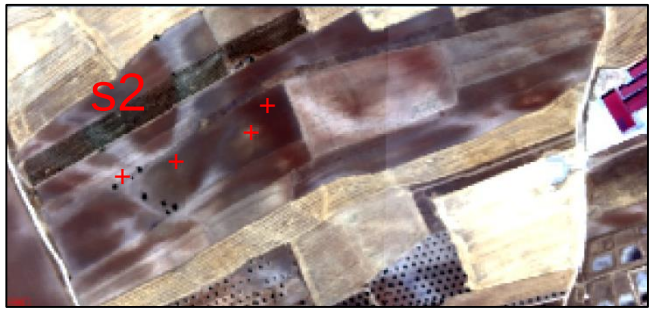
Definition of soil erosional stages classes

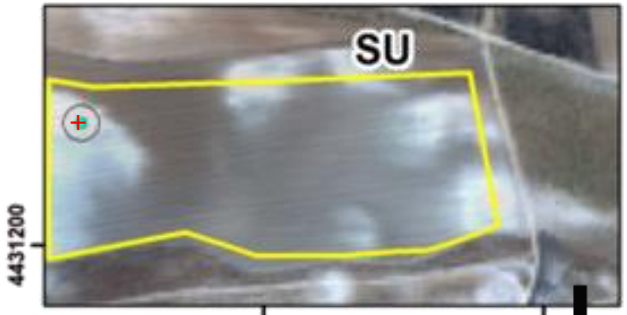


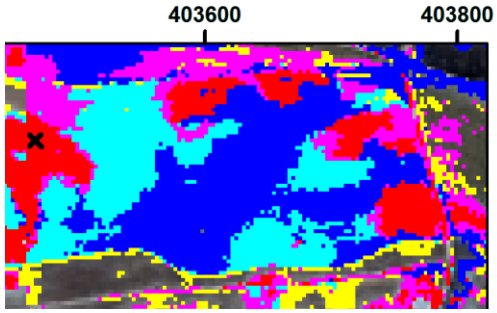
SAMPLE	pH	EC	CaCO3	organic matter	Fe oxides	TEXTURE (% in <2mm fraction)			
CRA	(H2O 1:2,5)	µS/cm	(% w/w)	(% w/w)	(Holmgren, 1967)	CLAY	SILT	SAND	class
S2P1_C	6,71	27	0,9	0,23	0,15	11	9	80	sandy loam
S2P2_C	6,69	43	1,0	0,30	0,27	36	16	48	sandy clay
S2P3_C	8,21	111	9,7	0,17	0,15	32	21	48	sandy clay loam
S2P4_C	6,92	59	1,1	0,61	0,43	39	22	40	clay loam
SU2_C	8,32	174	31,8	1,1	0,08	20	24	56	sandy clay loam

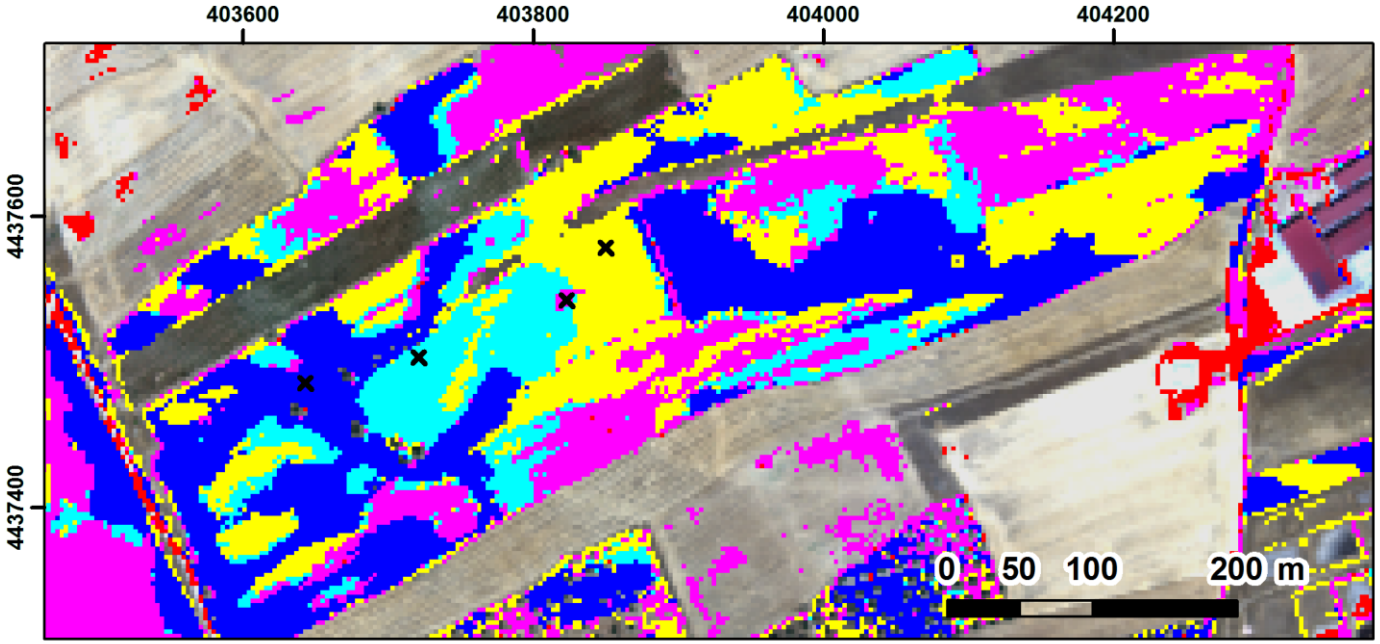


Mapping of soil erosional stages



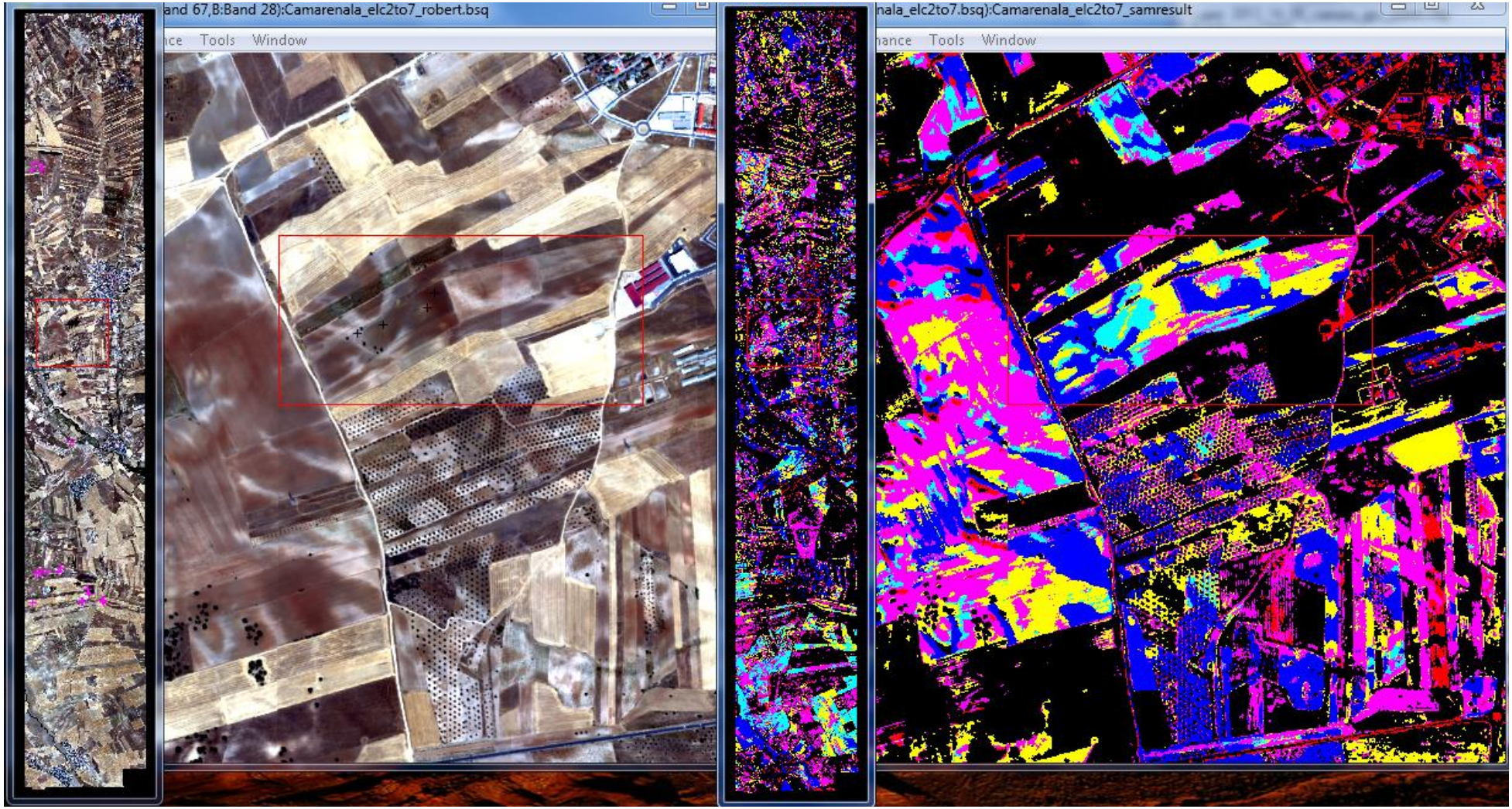






- High
- Intermediate-high
- Intermediate Bt
- Internediate B
- Accumulation

Mapping of soil erosional stages (outlook)



Summary/Outlook

- Results
  - Spatial distribution of combined variable occurrences in clay, carbonate, iron and sand content can be successfully detected at the field level and in most case at the remote sensing level
  - Depending on lithological background, identification and mapping of different soil horizons could be tentatively linked to soil erosion states and accumulation areas
  - Use of classification methods vs. quantification

- Next steps
  - Prediction accuracy: Validation using representative number of locations
  - More generic approaches (SVM)
  - Upscale to higher spatial scale (3m – 6m – 30m)

    → Transferability/ Application of the approach to other lithological and environmental background

    → Link with hydrological and erosion modeling

Thank you for your attention!