FP7-DIGISOIL

An integrated system of data collection technologies for mapping soil properties

G.Grandjean & DIGISOIL Team

Introducing DIGISOIL

> The Environmental call

- FP7-ENV-2007-1 work-programme
- Area 6.3.1.2 Soil
- Call: "Development and improvement of technologies for data collection in (digital) soil mapping "
- Duration: 36 months

> The DIGISOIL Project

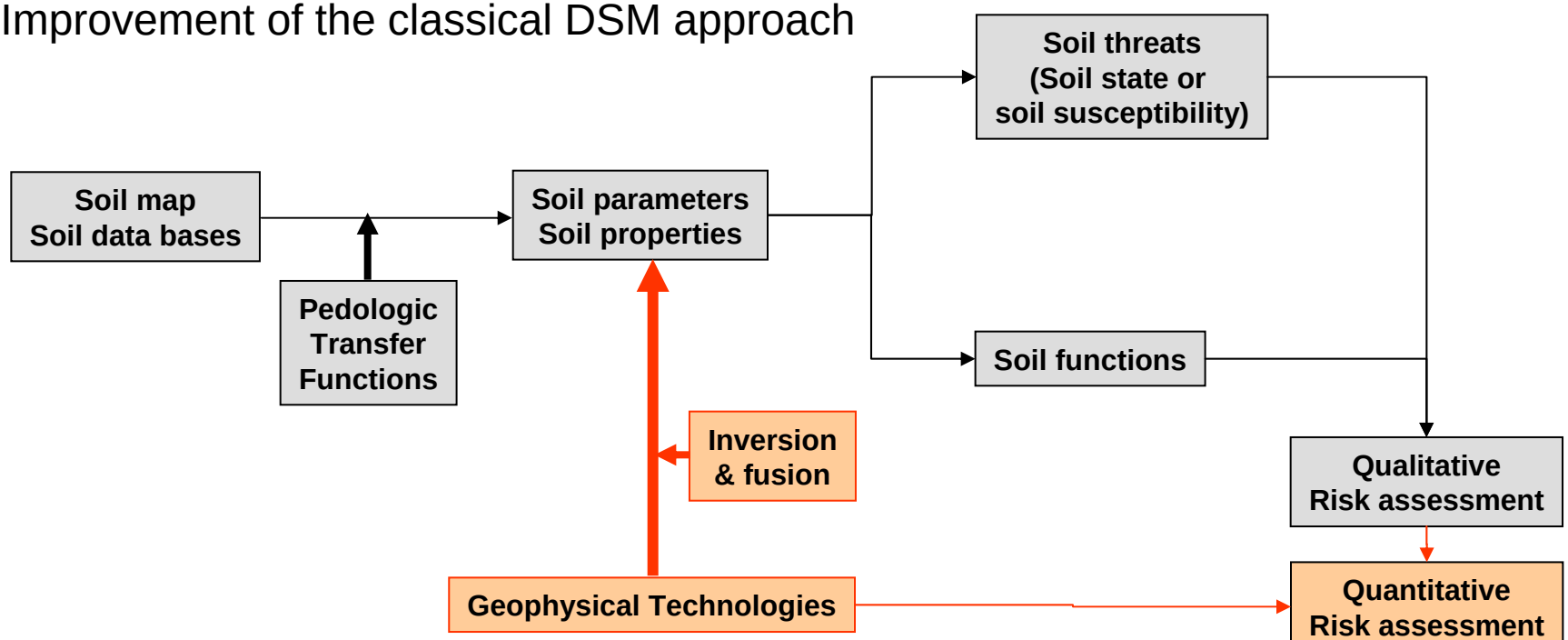
- Based on new technologies for *in situ* soil data collection
- Budget: 4.4M€ (3.4M€ funded)
- Starting date: Sept. 2008
- 10 scientific partners (universities, research centers, SMEs)

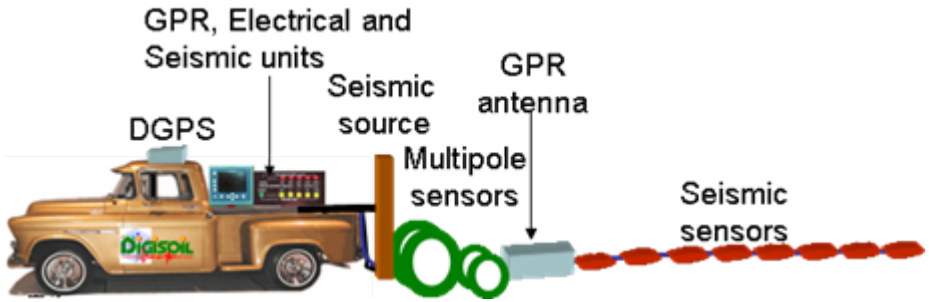
DIGISOIL's objectives

- **<u>To develop, test and validate</u> the most relevant geophysical technologies for mapping soil properties** (geoelectric, seismic, GPR/EMI, magnetic and airborne hyperspectral);
- **<u>To establish correlations</u> between the measured geophysical measurements and the soil properties involved in soil functions / threats** (erosion, compaction, organic matter decline, salinisation and shallow landslides) **by using innovative data processing and correlation protocols;**
- **<u>To evaluate the societal impact</u> of the developed techniques by investigating their relevance relative to the end-user needs, the technical feasibility and the cost effectiveness;**
- **<u>To produce an exploitation plan</u> including the standardization of the processes and the technical specifications of the developed methodologies describing the system components in terms of equipment** (sensors, acquisition system, mobile vector), **techniques** (signal processing, inversion or fusion processes, specialization) **and operational protocols.**

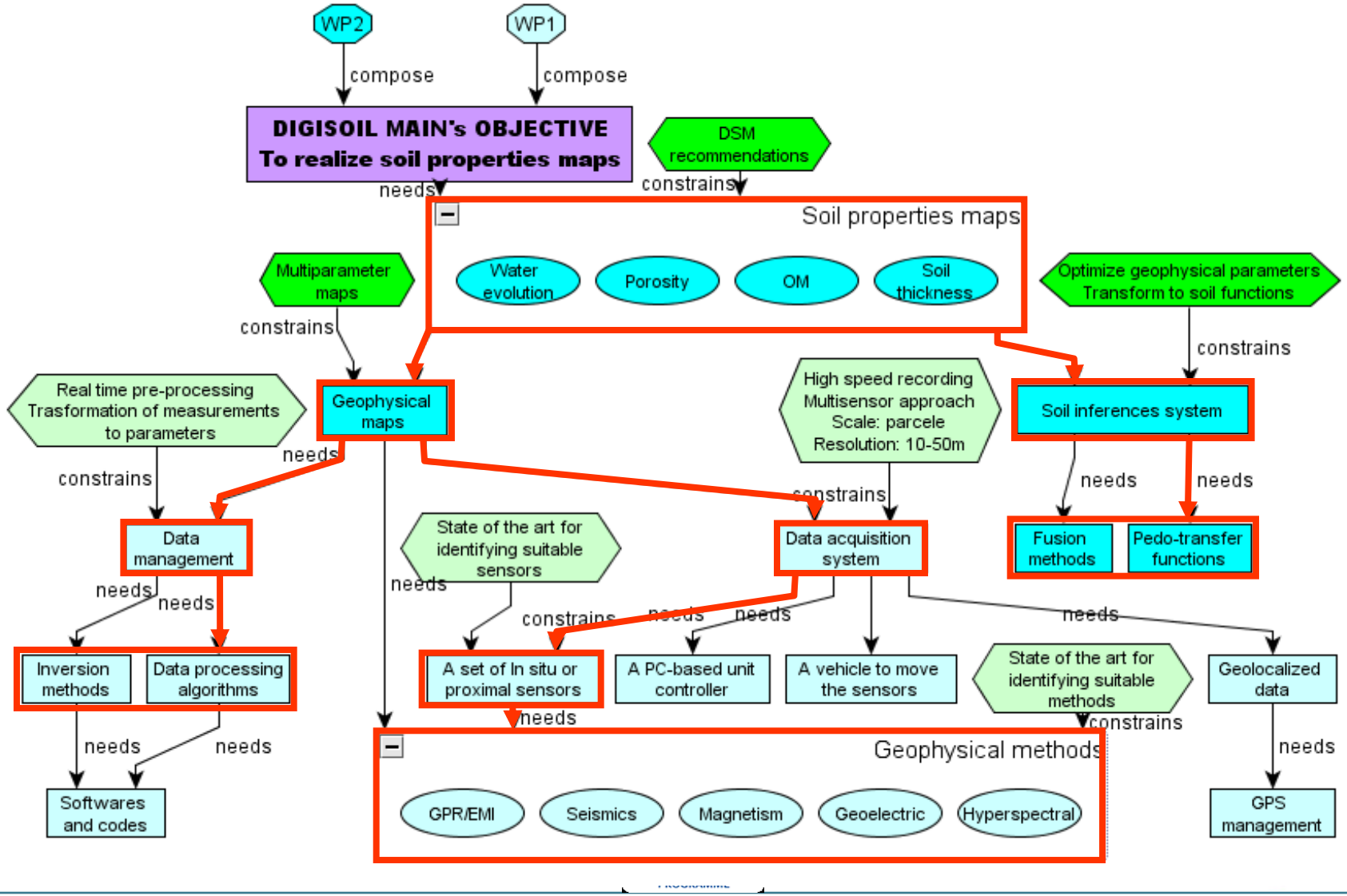
DIGISOIL strategy

Improvement of the classical DSM approach





DIGISOIL's Concept: from Geophysical methods to soil properties



DIGISOIL's thematic context: from soil threats to soil parameters

SOIL THREATS				
Soil erosion	**OM decline**	**Compaction**	**Salinisation**	**Landslide**
SOIL PROPERTIES				
Soil texture	Soil texture/clay content	Soil texture	Soil texture	
Soil density		Soil density		
Soil hydraulic properties		Soil hydraulic properties	Soil hydraulic properties	
	Soil organic Carbon	Soil organic matter		
ANCILLIARY DATA				
Topography	Topography	Topography		Topography
Land cover	Land cover	Land cover		Land cover
Land use	Land use	Land use	Irrigation areas	Land use
Climate	Climate	Climate	Climate	Climate
Hydrological conditions				
Agro-ecological zone				
				Occurrence/density of existing landslides
			Groundwater information	
				Bedrock
				Seismic risk

DIGISOIL's technological state of the art

> Established technologies:

- Electrical resistivity tomography
- GPR/Electromagnetic induction
- Hyperspectral / Spectrometry

> Innovative technologies:

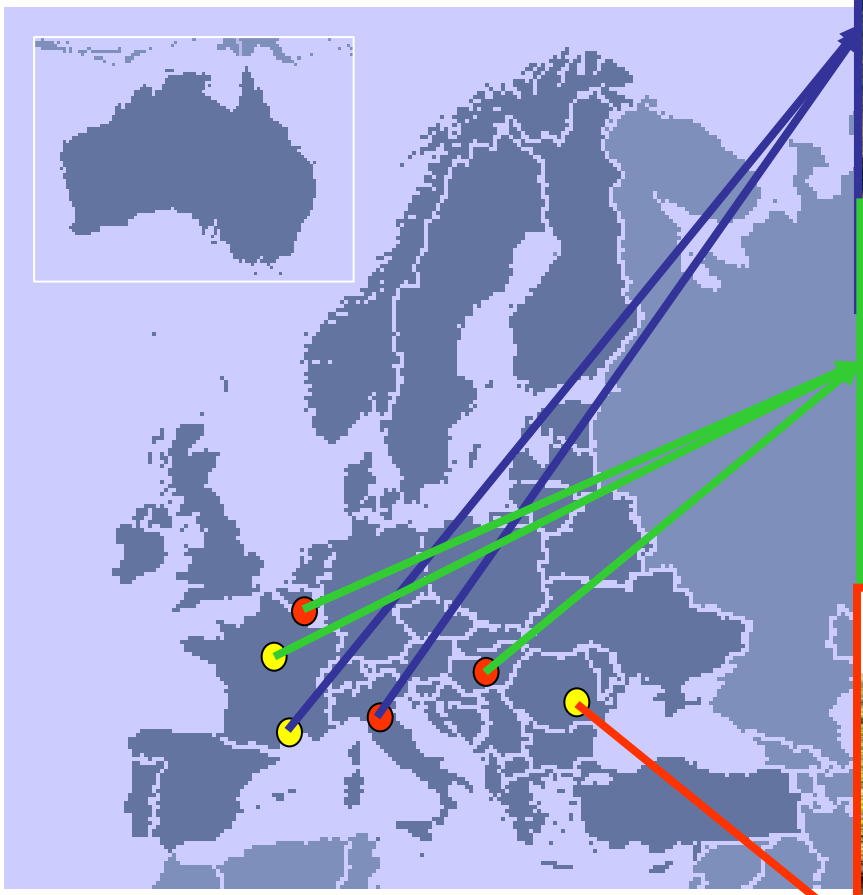
- **Seismics**
- Magnetics

> Rejected technologies:

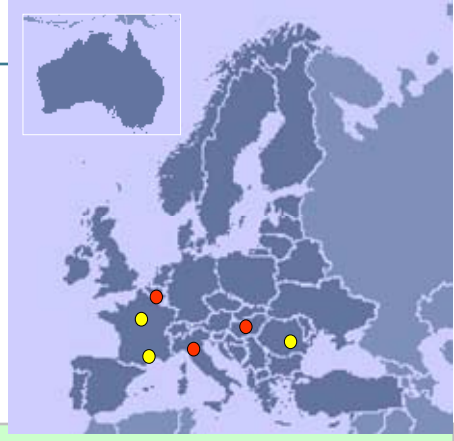
- Airborne thermic
- Gravity
- Airborne gammametry

Geophysical methods	**Physical parameters**
Ground-penetrating radar (GPR):	Dielectric permittivity, electric conductivity, magnetic permeability, frequency dependence of these electromagnetic properties
Seismic methods:	Volume and shear-wave velocities
Electromagnetic induction (EMI):	Electrical resistivity (electric conductivity and frequency dependence)
Electrical resistivity (geoelectric):	Electrical resistivity (almost zero-frequency)
Gravity:	*Density*
Magnetics:	Magnetic susceptibility and viscosity
Airborne thermic:	*Surface temperature*
Airborne hyperspectral:	Spectral reflectance
Gammametry:	*Gamma spectrum (U, K, Th)*

Sites to be studied



Test sites

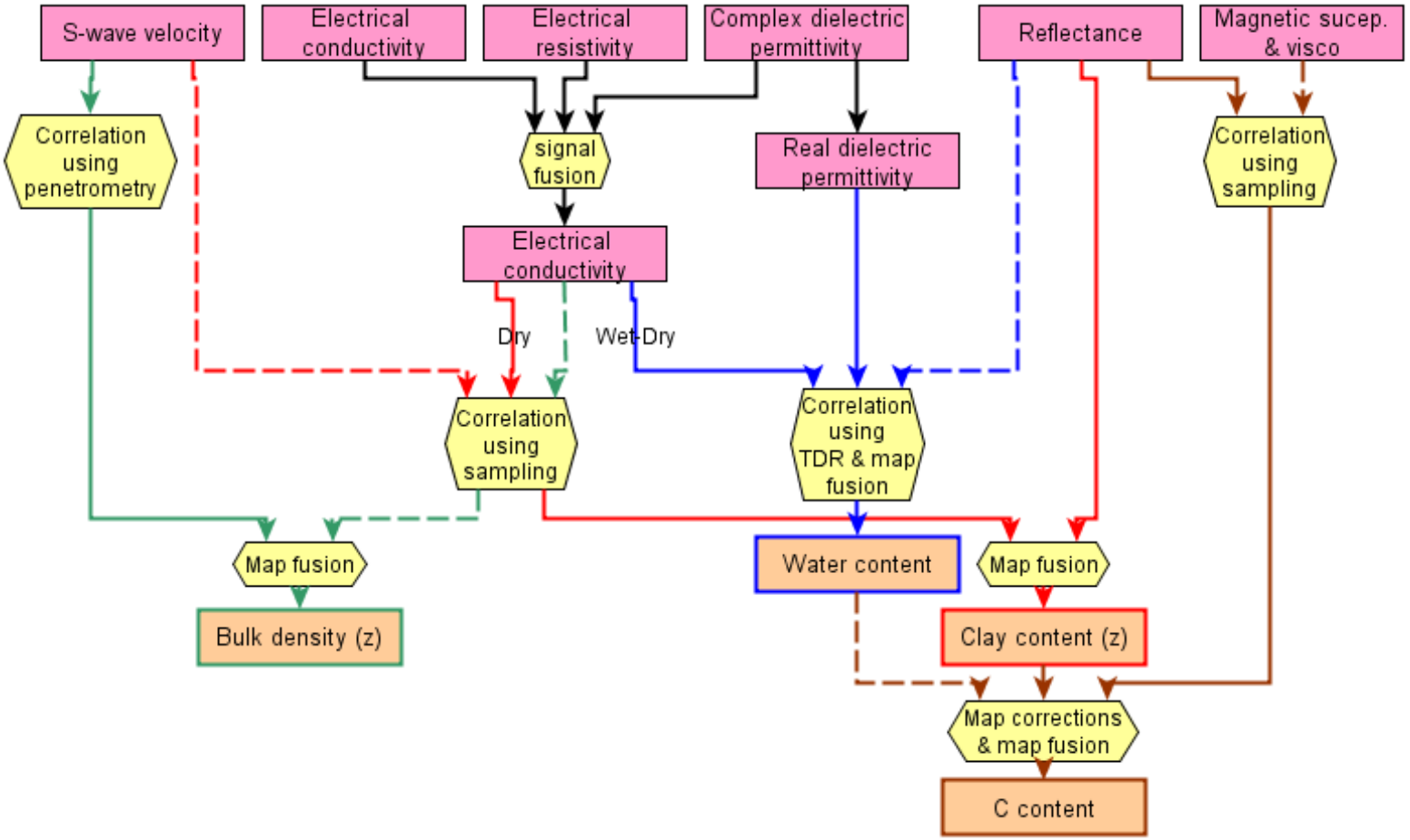


> **Sites for developments**

> **Sites for validation**

Localization *Site coordinator*	Soil properties	Tested techniques	Site characteristics
Beauce/Normandie-FR *INRA*	C content Bulk density Hydro. Prop.	Geoelectric Seismic Magnetism	Center France: atlantic area Intensive agriculture Existing database of soil properties
Roujan-FR *INRA*	Soil depth	Geolectric	Southern France: mediterranean area Traditional agriculture Soil depths & erosion measurements maps & models available
Telega-RO *GIR*	Soil mechanics	Seismic	Southern Carpaths: alpine area Peri-alpine context Forest and grassland
Luxembourg *UCL*	C content Bulk density Hydro. Prop. Soil depth	Hyperspectral Magnetism Geoelectric/EM Seismic GPR	Southern Belgium/Luxembourg: atlantic area Intensive agriculture Airborne & field data available
Chianti-IT *UNIFI*	C content Soil depth	Hyperspectral Seismic GPR/EM	Centre Italy: mediterranean area Traditional agriculture Soil database availlable (OM, erosion model)
Zala-HU *UPA*	Bulk density Soil depth	Geoelectric GPR	Western Hungary: continental area Intensive & traditional agriculture

Data assimilation strategy



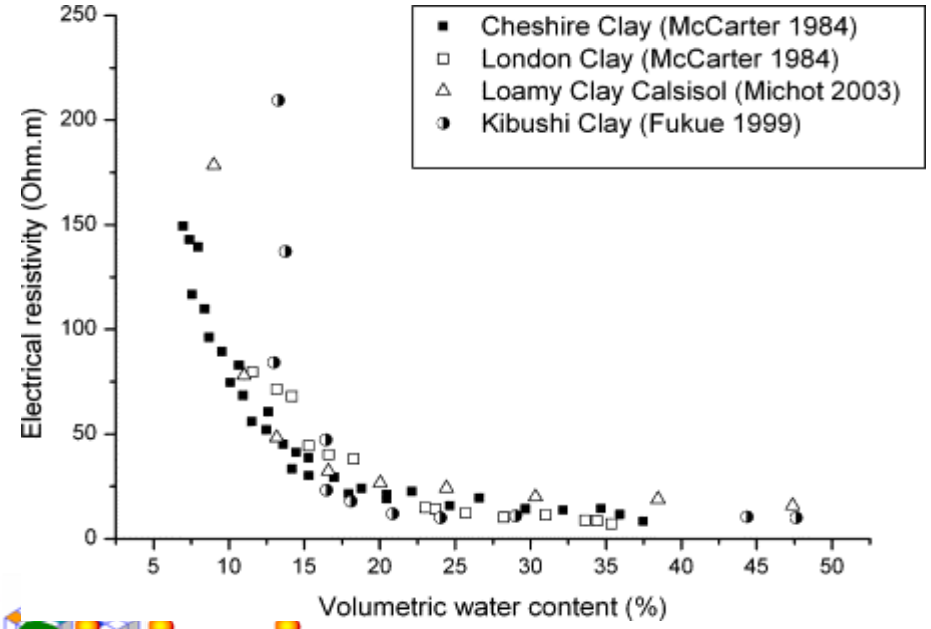
From geophysical parameters to soils characteristics

A) Physical expression
GPR: Complex Refractive Index Model (CRIM)

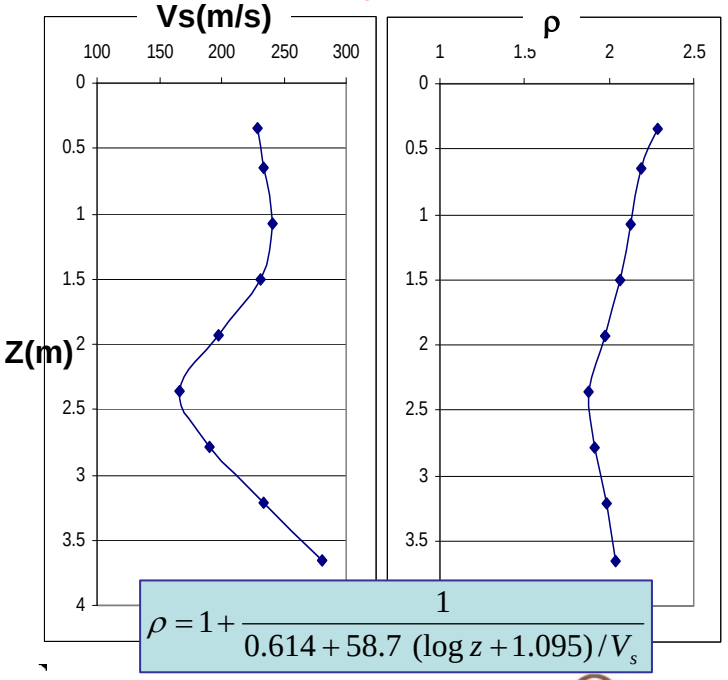
$$\varepsilon_r = \left(\theta\varepsilon_{r,w}^{\alpha} + (1-n)\varepsilon_{r,s}^{\alpha} + (n-\theta)\varepsilon_{r,a}^{\alpha}\right)^{\frac{1}{\alpha}}$$

θ: water content
εr: relative permittivity in water (w), soil (s) and air (a)
n: soil porosity
α: anisotropy factor

B) Correlation between geophysics and properties
Geoelectric: water content estimation from resistivity



C) Empirical expression
Seismic: estimating ρ from Vs values

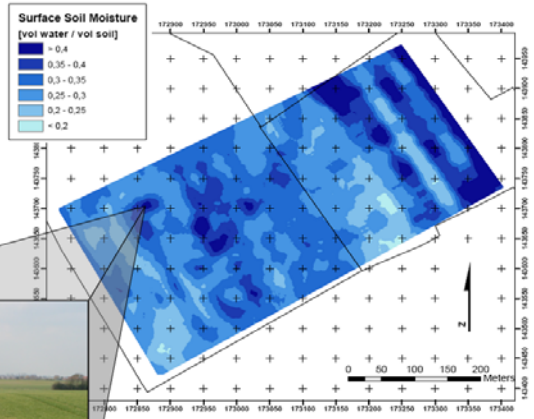


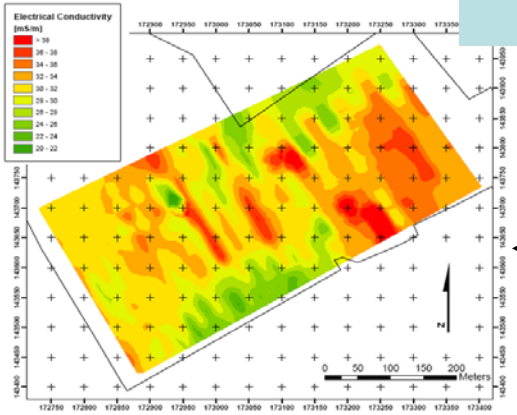
$$\rho = 1 + \frac{1}{0.614 + 58.7\ (\log z + 1.095)/V_s}$$

Retreiving water content using GPR
(Lambot et al., 2006)

Data processing

Full Waveform Inversion



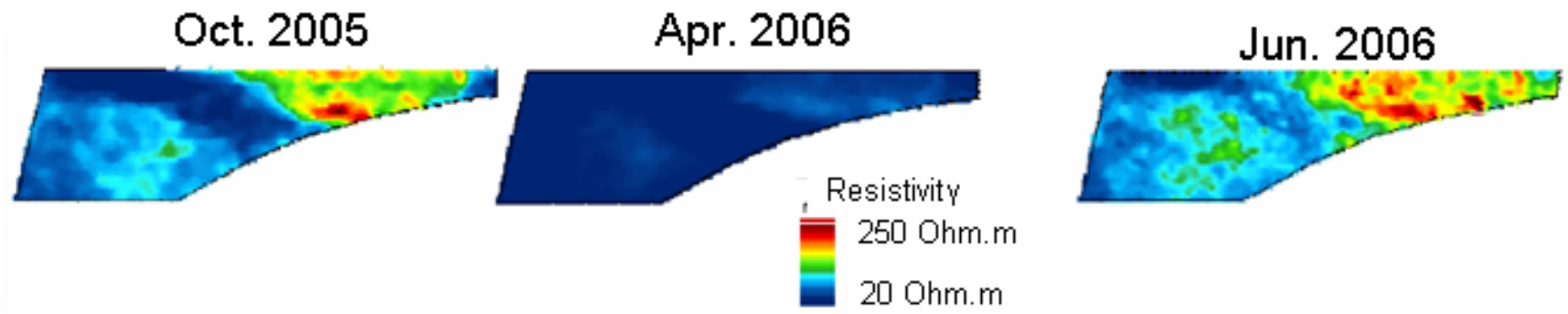


Water content seasonal effect with ERT

(Besson et al., 2006)

Data processing

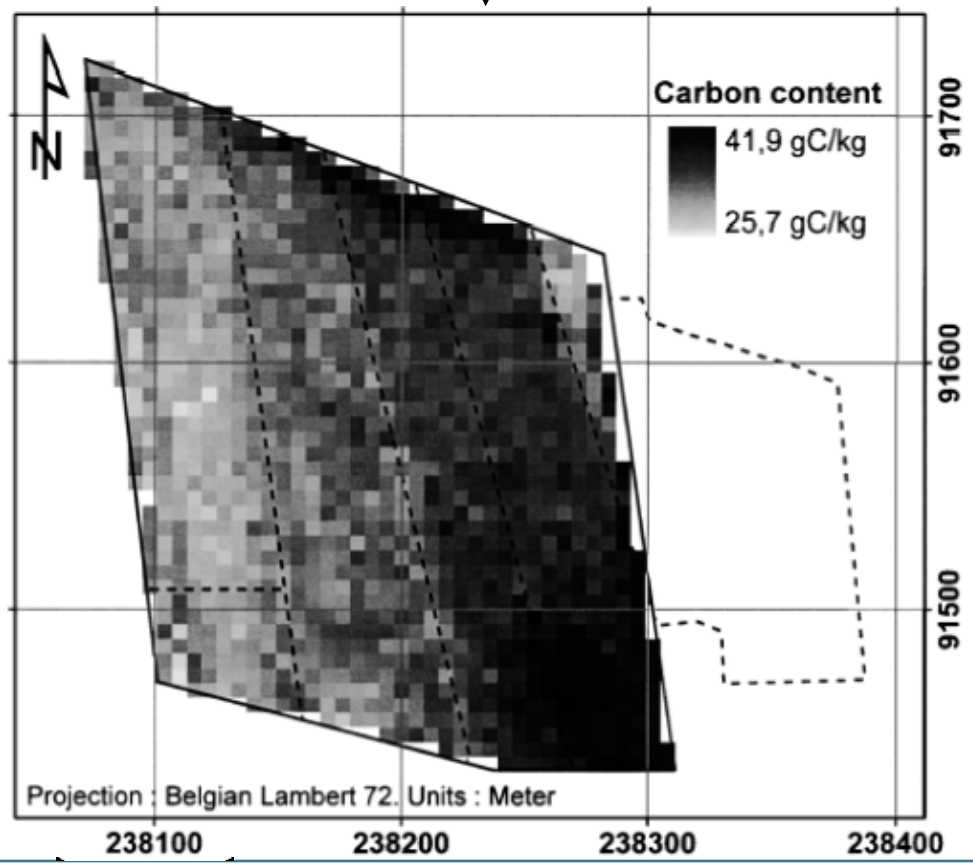
Data inversion



Mapping C content with hyperspectral
(Stevens et al., 2008)

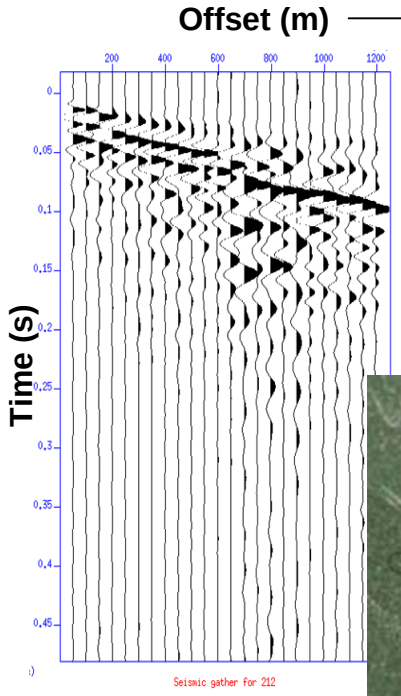
Data processing

Correlation with soils measurements



Soil thickness using SASW

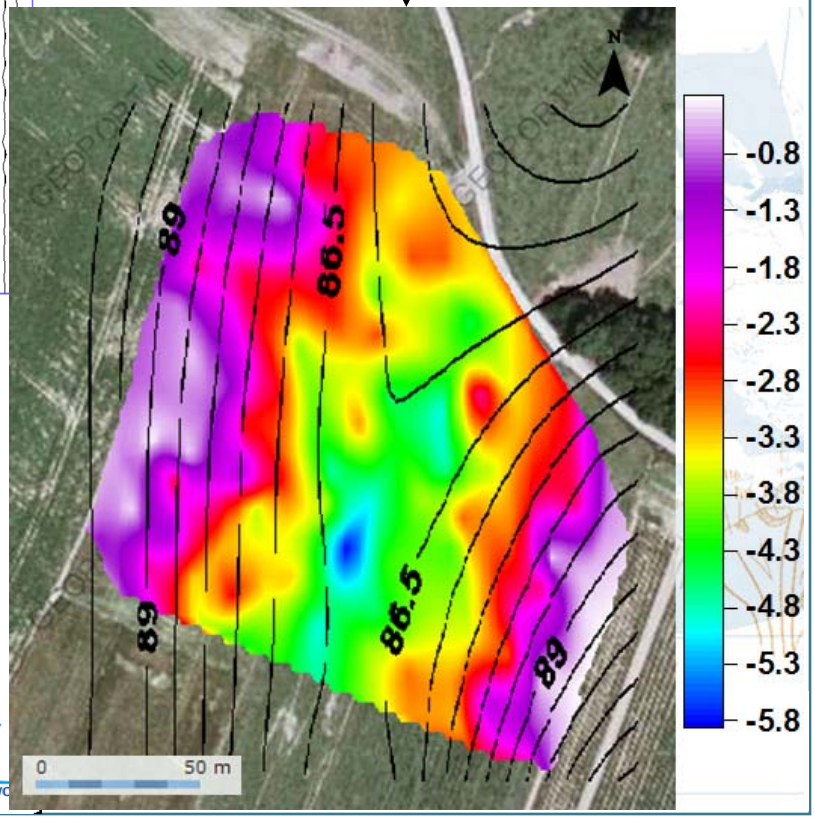
(Samyn et al., 2009)



Data processing

Spectral Analysis of Surface Waves

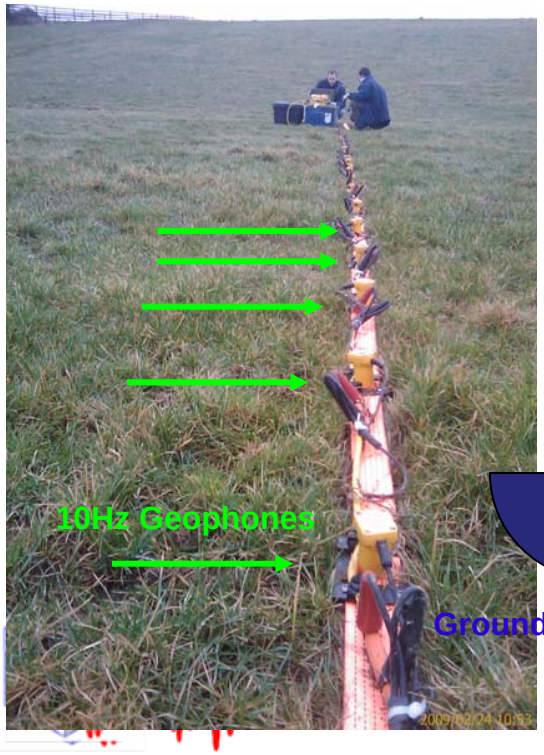
Correlation with penetrometer

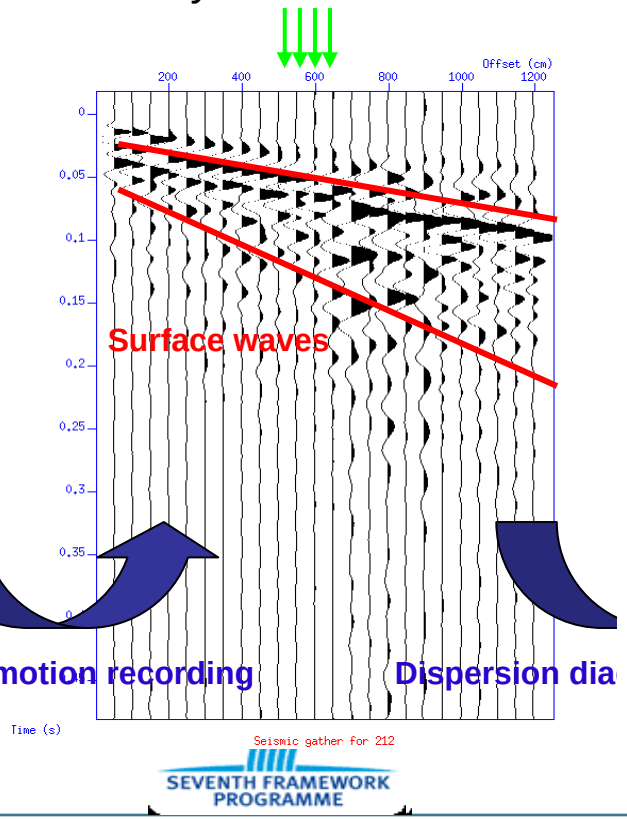


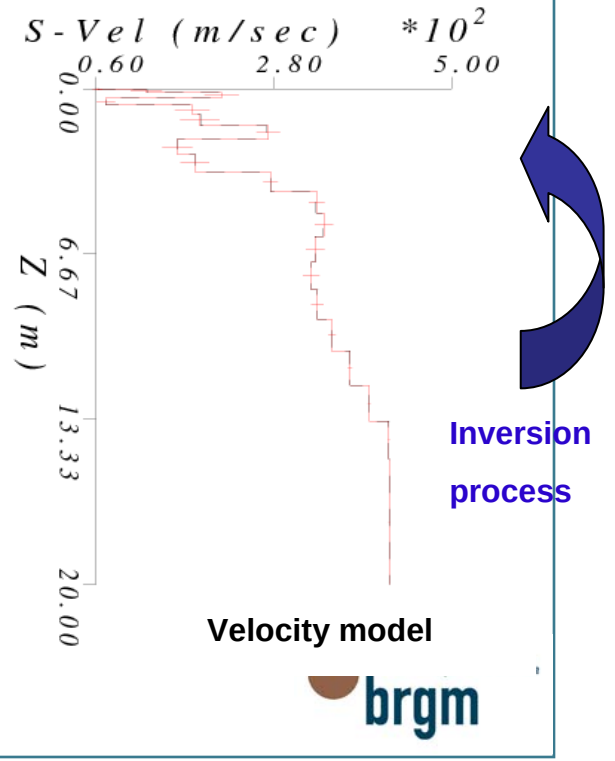
Seismic method: new advances for soil characterization

> Spectral analysis of surface waves (SASW)

- New type of multichannel seismic cable has been designed for soil investigation. It consists of 24 10Hz vertical geophones at fixed 0.5m intervals. The seismic cable is towed behind a vehicle)
- Based on dispersive character of surface waves (phase velocity depends on the frequency); The S-waves velocity model obtained is closely related to materials' stiffnesses







SEVENTH FRAMEWORK PROGRAMME

brgm

Methodology

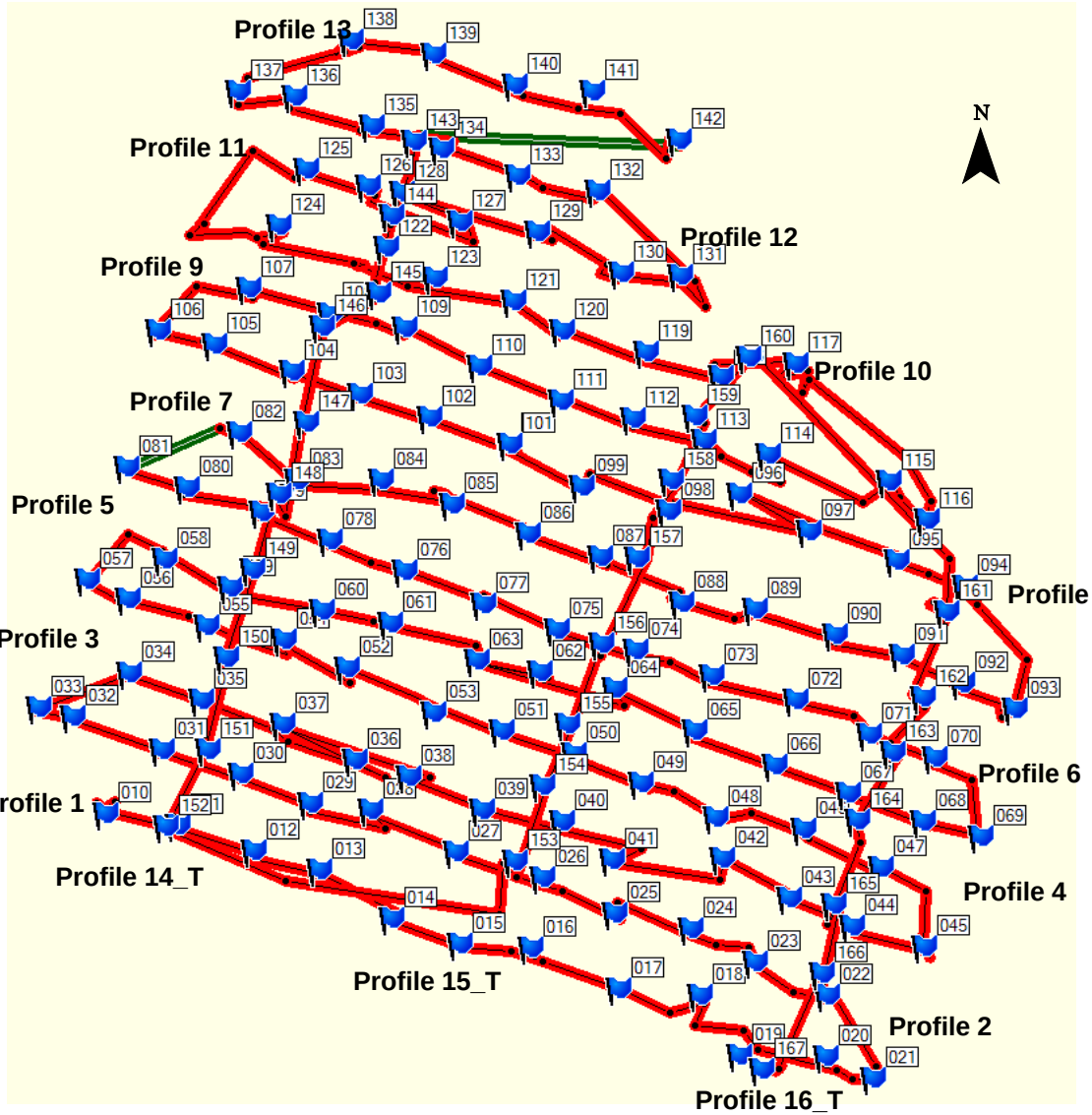
Seismic measurements

- **157 seismic shots were performed along a regular grid with measurmements every 12m**

-**13 sections in the slopes E-W direction**

-**3 transverse N-S sections**

- **Measurements cover a zone of 140mx150m i.e. 2.1 Ha**



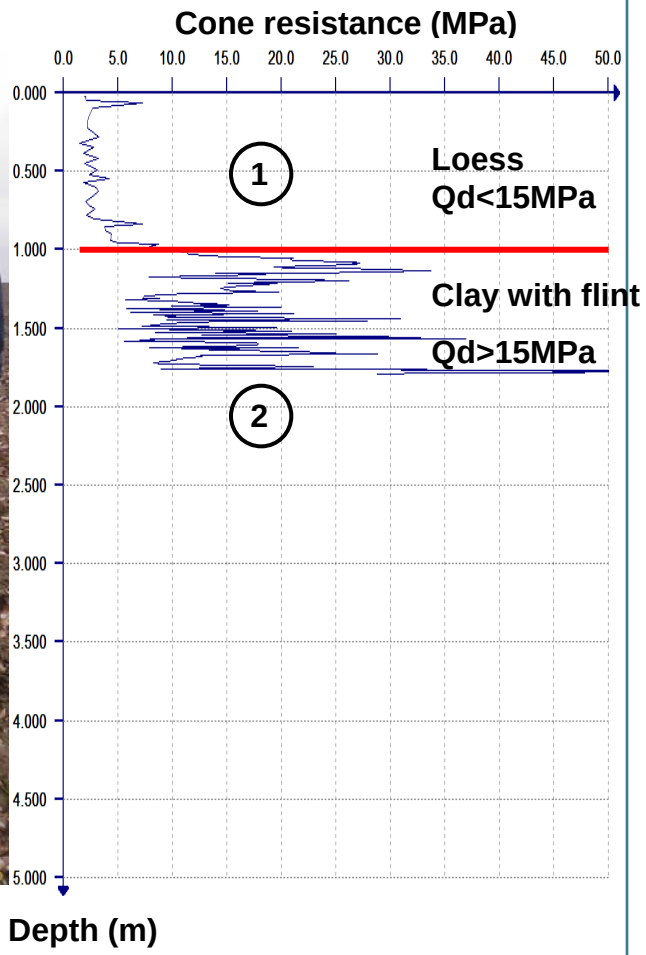
Methodology

Penetrometry measurements

> Cone resistance at different depths

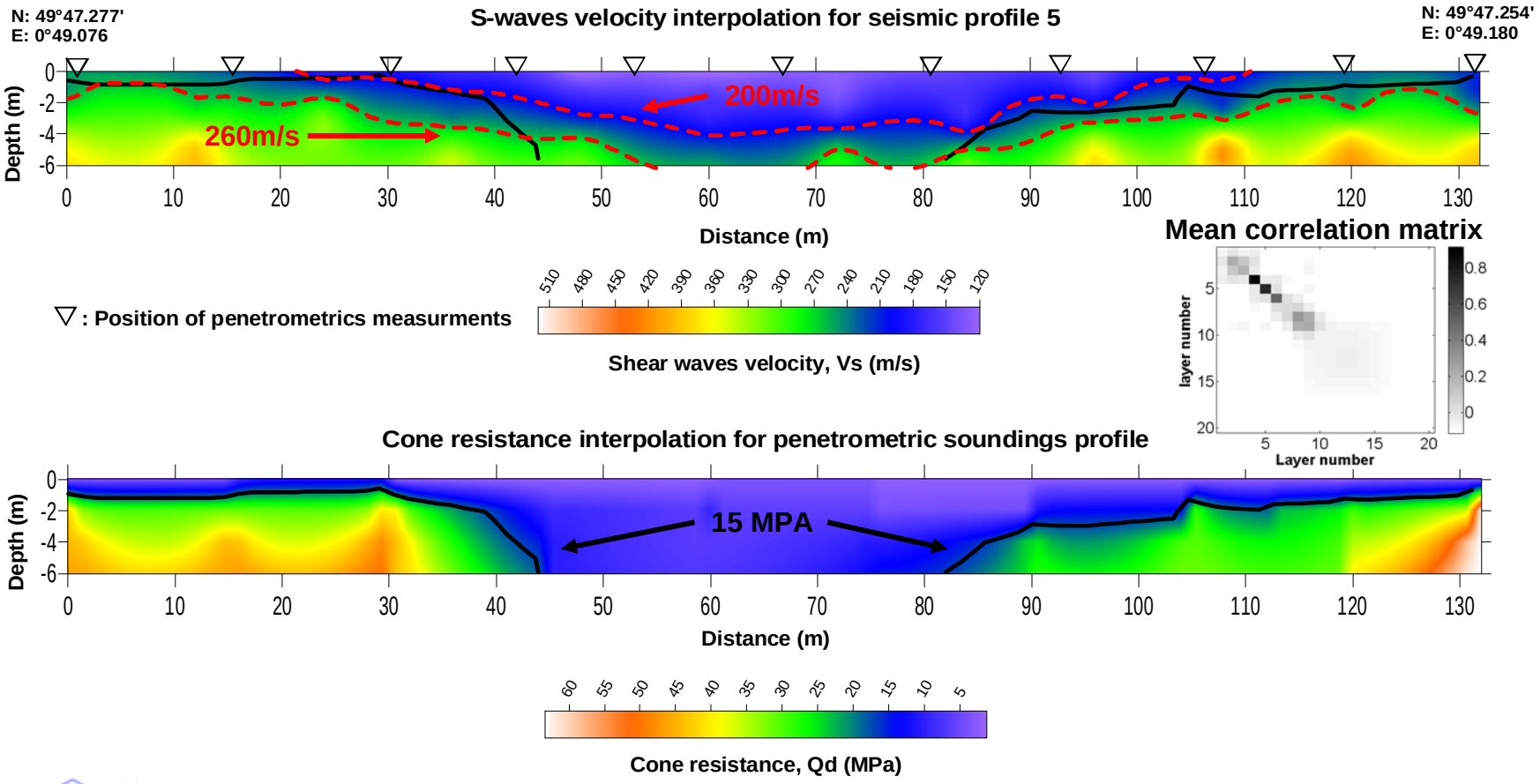
- **11 penetrometer measurements were performed along the profile 5**

- **Contact with clay at maximum 4 m and minimum 0.5 m deep**



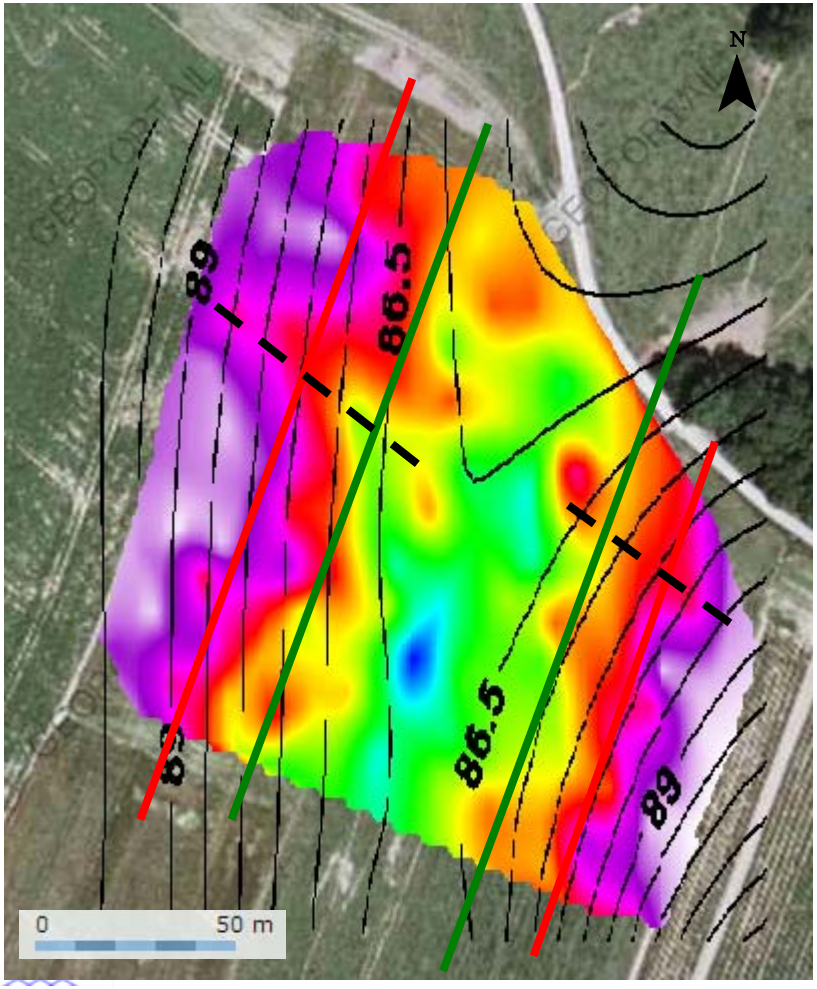
Results

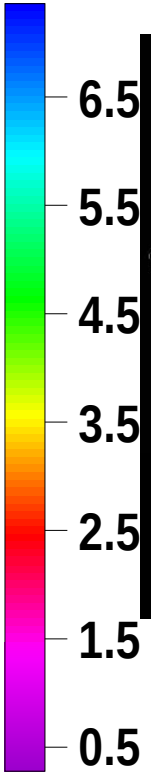
- **Identification of the loess/clay limit : Qd > 15 MPa ~ 230 m/s**
- **Interpolation 230 m/s limit was realized in 3D by Krigging technique**



Results

Soil depth mapping (loess thickness)



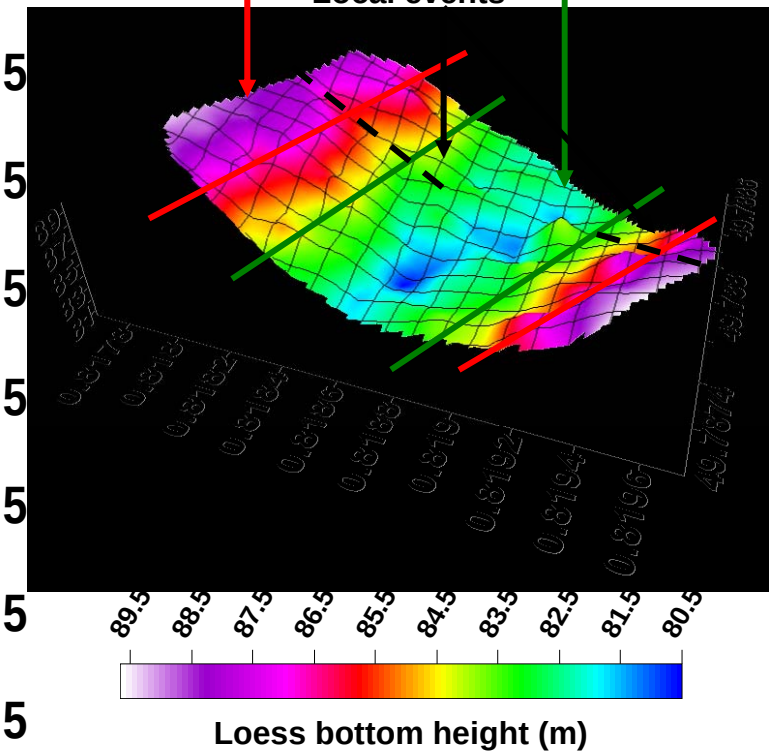


Loess thickness (m)

Important soil thickness

Outcropping clays

Local events



Conclusions

> Development of the DIGISOIL system

- State of the art leads to define methods, processing and inversion algorithms adapted to soil properties mapping
- First tests were successfully carried out and indicate a strong contribution of geophysical methods (GPR, geoelectric, seismic, Hs)

> Next steps

- Methods will be tested on 3 same sites to deliver multiparameter maps to e compared to field truth
- A reflexion will be carried out for using these maps in a DSM approach ➔ spatialization of mapped soil properties to the regional scale

Thank you for your attention !