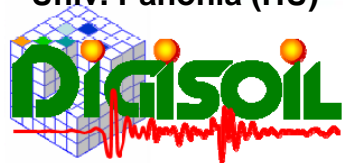# FP7-DIGISOIL

An integrated system of data collection technologies for mapping soil properties

G.Grandjean & DIGISOIL Team*

* BRGM, INRA (F), Univ. Louvain (BE), FZJ (DE), Univ. Firenze, Selex Galileo, JRC (IT), ABEM (SE), IGR (RO), Univ. Panonia (HU)

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)
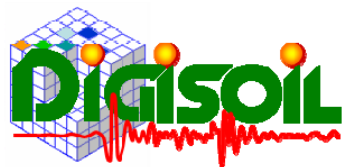
DIGISOIL's objectives

> **To develop, test and validate** the most relevant geophysical technologies for mapping soil properties (geoelectric, seismic, GPR/EMI, magnetic and airborne hyperspectral);

> **To establish correlations** 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;**

> **To evaluate the societal impact** of the developed techniques by investigating their relevance relative to the end-user needs, the technical feasibility and the cost effectiveness;

> **To produce an exploitation plan** 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.**
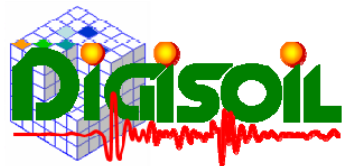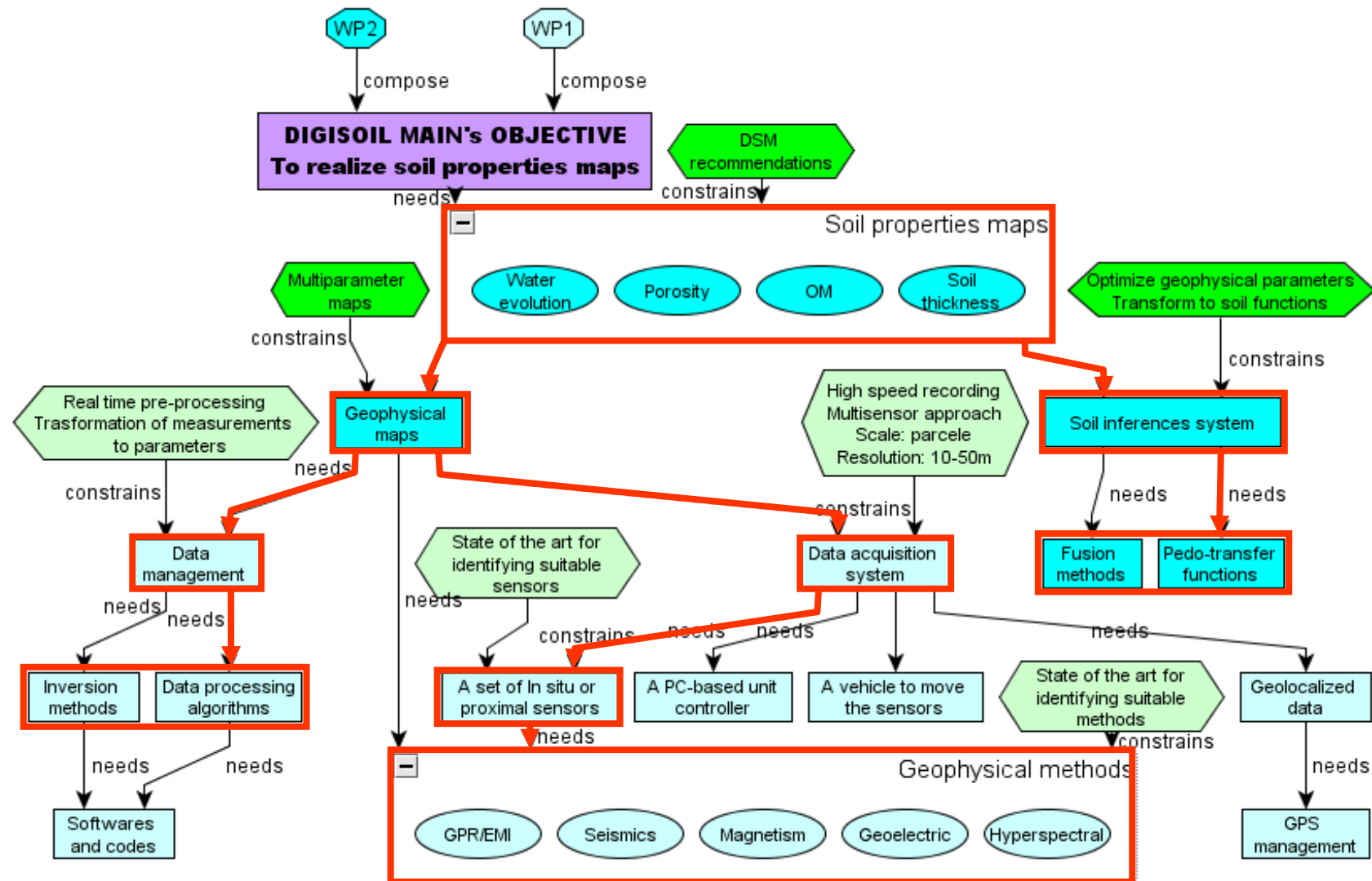
DIGISOIL strategy
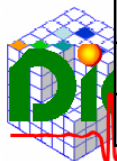Improvement of the classical DSM approach
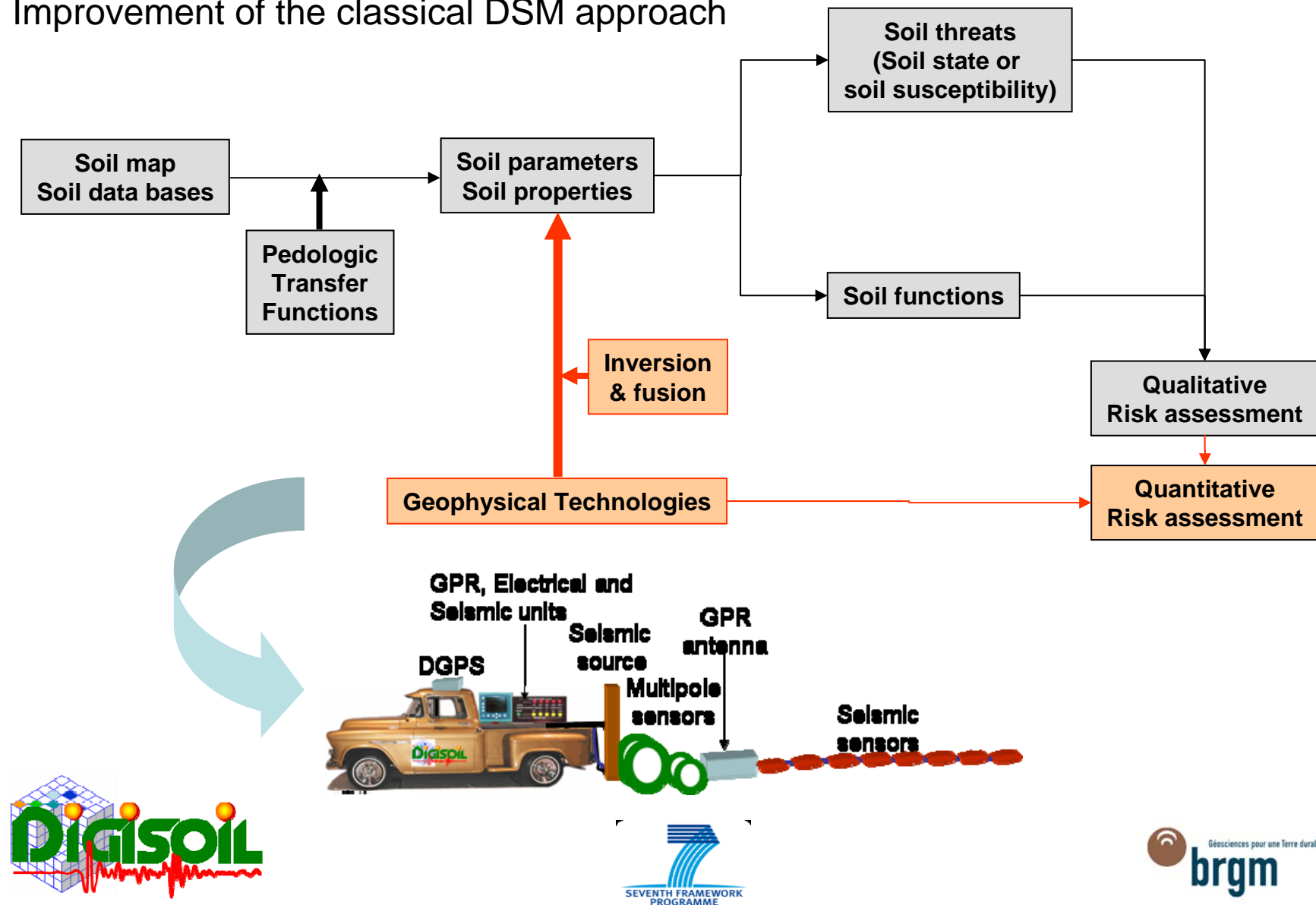
DIGISOIL's Concept: from Geophysical methods to soil properties

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
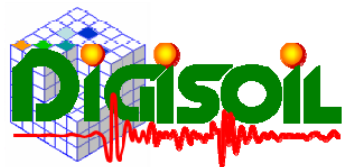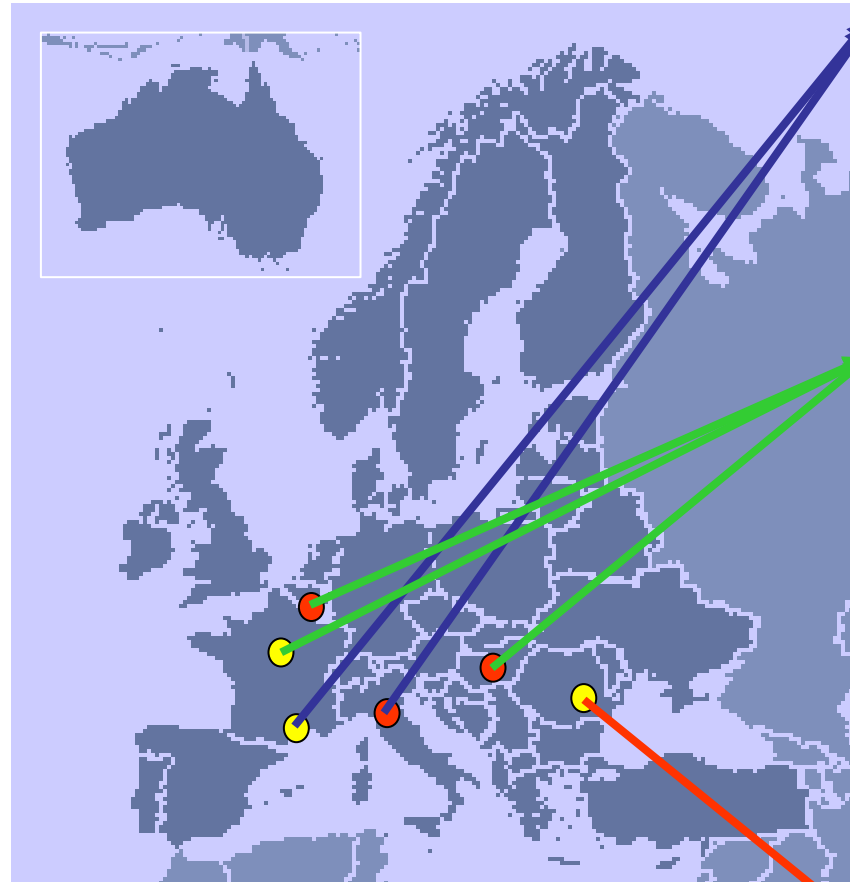
EROSION

C DECLINE / COMPACTION

SHALOW LANDSLIDES

DIGISOIL

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)

$$\varepsilon_r = \left(\theta \varepsilon_{r,w}^{\alpha} + (1-n)\varepsilon_{r,s}^{\alpha} + (n-\theta)\varepsilon_{r,a}^{\alpha} \right)^{\frac{1}{\alpha}}$$
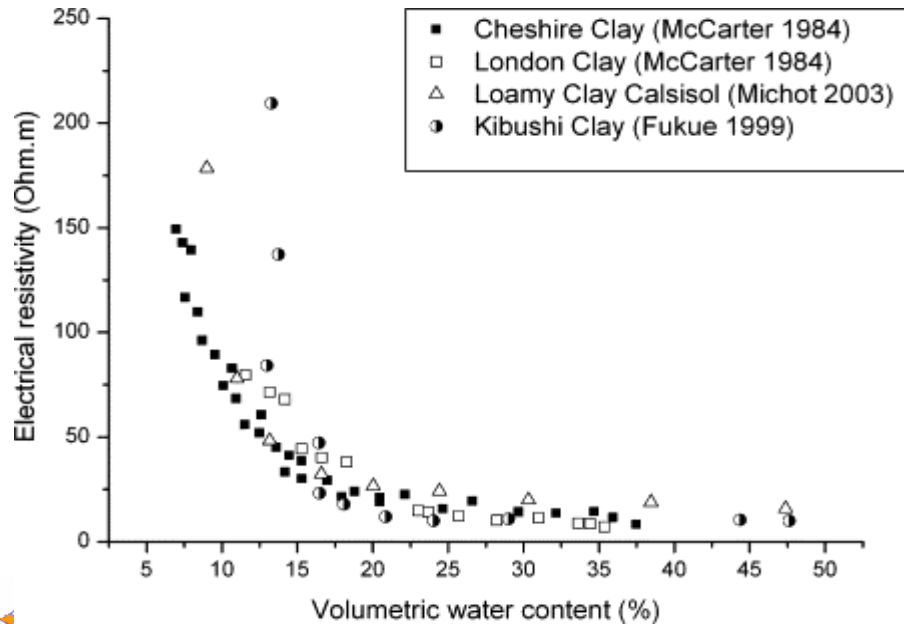
θ: water content
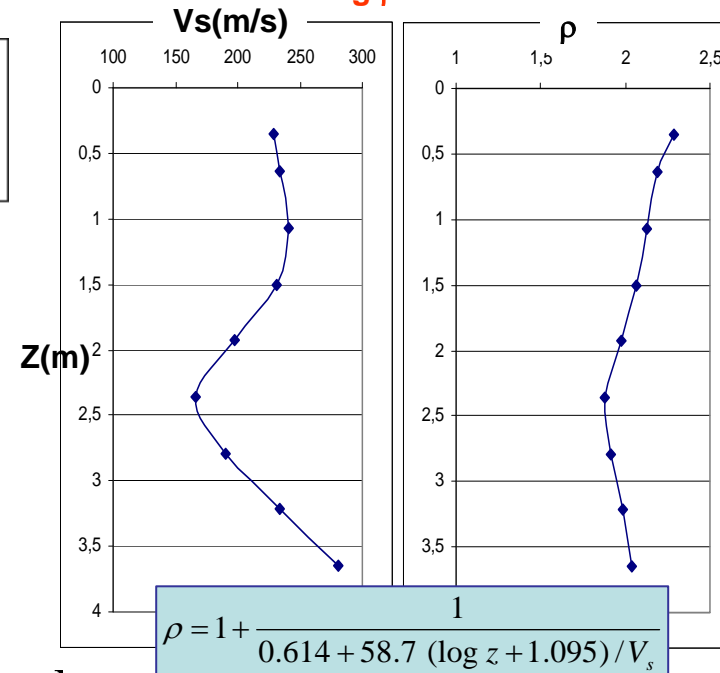εr: relative permittivity in water (w), soil (s) and air (a)
n: soil porosity
α: anisotropy factor

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

- ■ Cheshire Clay (McCarter 1984)
- □ London Clay (McCarter 1984)
- △ Loamy Clay Calsisol (Michot 2003)
- ◑ Kibushi Clay (Fukue 1999)

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 (Luxembourg)

Data processing

Full Waveform Inversion

Water Content (m³/m³)

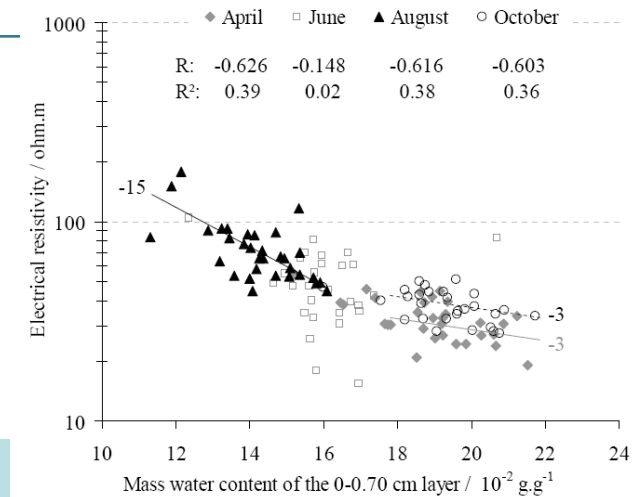|	
	< 0.05
	0.05 - 0.10
	0.10 - 0.15
	0.15 - 0.20
	0.20 - 0.25
	0.25 - 0.30
	> 0.30
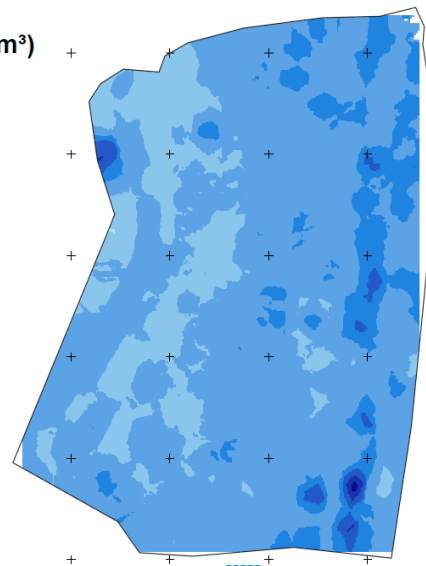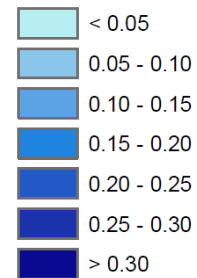
Water content seasonal effect with ERT (France)
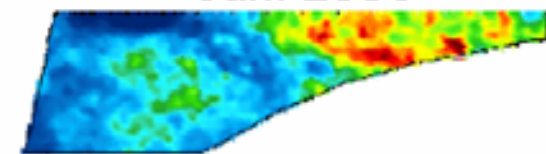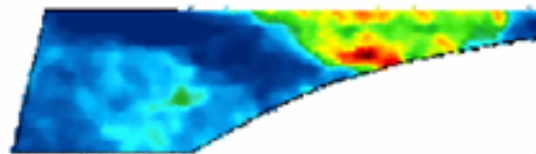

Data processing

Data inversion
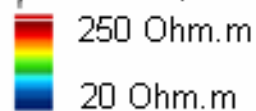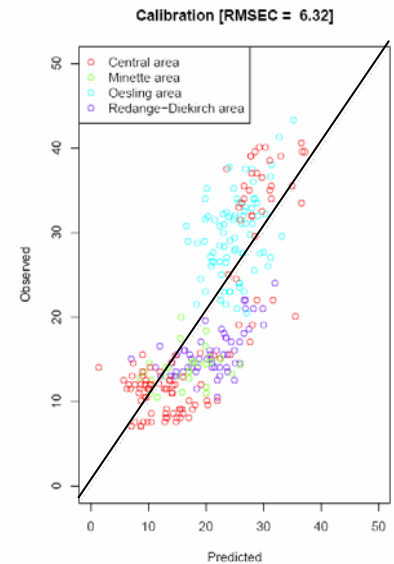

Oct. 2005   Apr. 2006   Jun. 2006

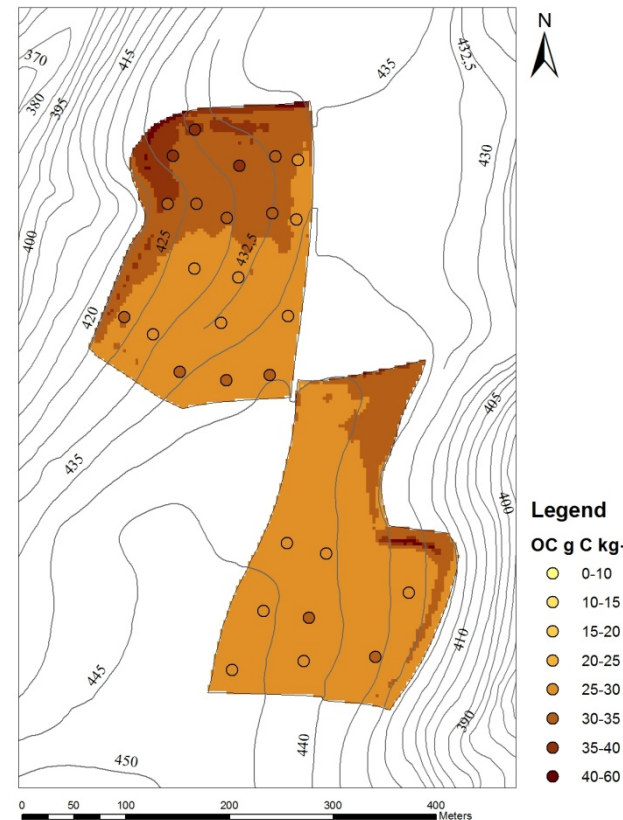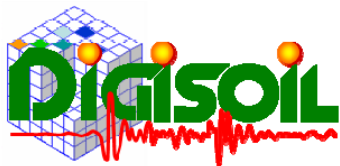Resistivity
250 Ohm.m
20 Ohm.m

Mapping C content with hyperspectral
(Luxembourg)

Data processing → Correlation with soils measurements

Calibration [RMSEC = 6.32]

- Central area
- Minette area
- Oesling area
- Redange-Diekirch area

SOC predictions using PLSR

Legend
OC g C kg-1
- 0-10
- 10-15
- 15-20
- 20-25
- 25-30
- 30-35
- 35-40
- 40-60

Mapping Clay content with Hs data
(Italy)

Total Clay mapping: preliminary results & validation

	Fieldspec				SIMGA			
	Index		Clay cont.		Index		Clay cont.	
	Mean	Stdev	Mean %	Stdev	Mean	Stdev	Mean %	Stdev
Field 1	1.12	0.01	**43.98**	0.39	1.14	0.11	**58.90**	5.68
Field 2	1.13	0.01	**51.44**	0.45	1.13	0.05	**51.44**	2.27
Field 3	1.12	0.02	**43.98**	0.78	1.16	0.07	**73.83**	4.45

$y = 1,06107 + 0,00134 \; x$
$R^2 = 0.662$

Linear Fit of indice BIERWITH

Fieldspec Band ratio $(1816*1911)/(1856)^2$

SUM ARGILLE
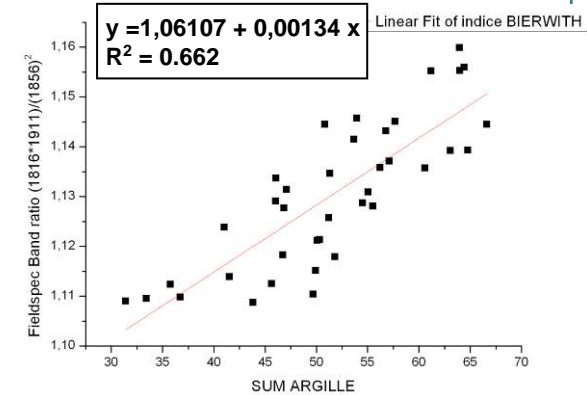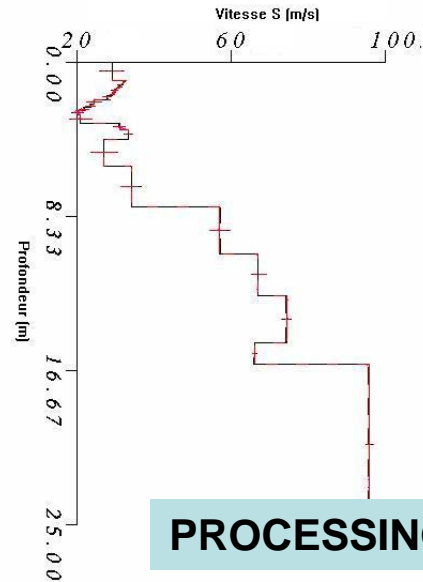
Clay Index = (2145 * 2283) / 2214^2
(ref. Illite & Montmor. absorption at 2215 nm)
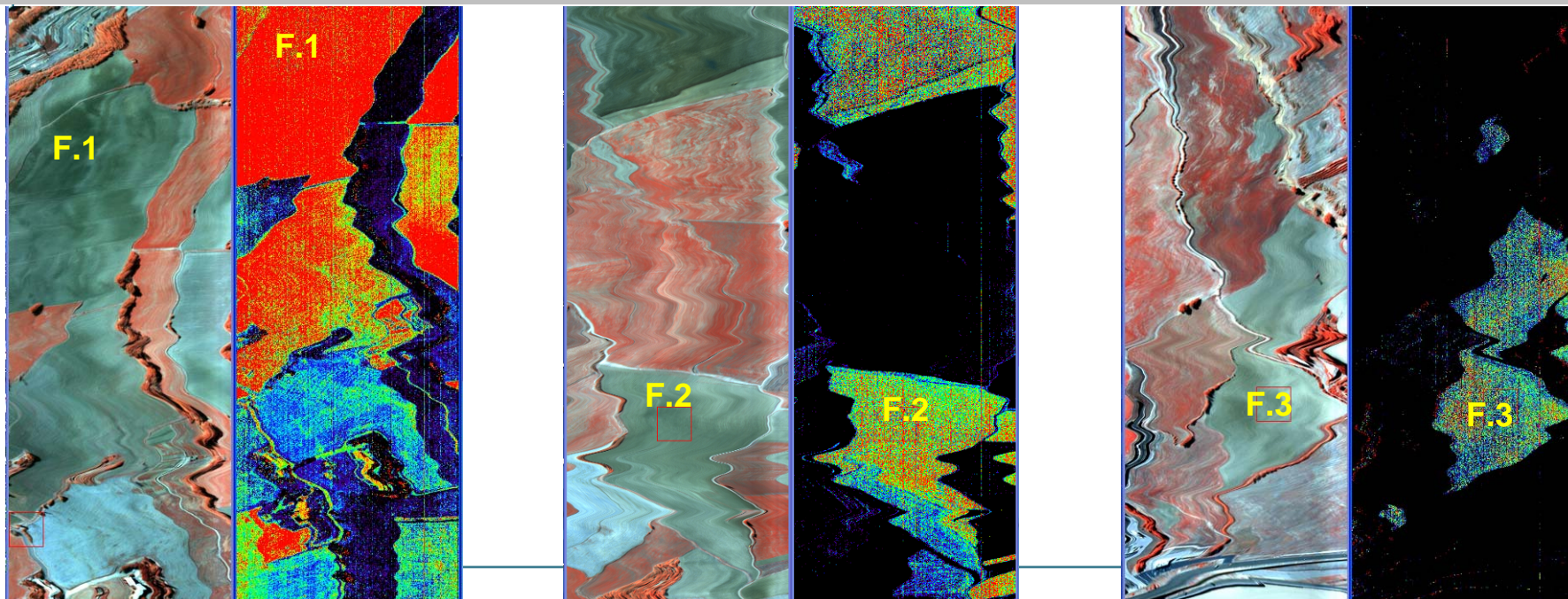
Soil thickness using SASW
(France)

SOIL PROP. MAPS
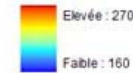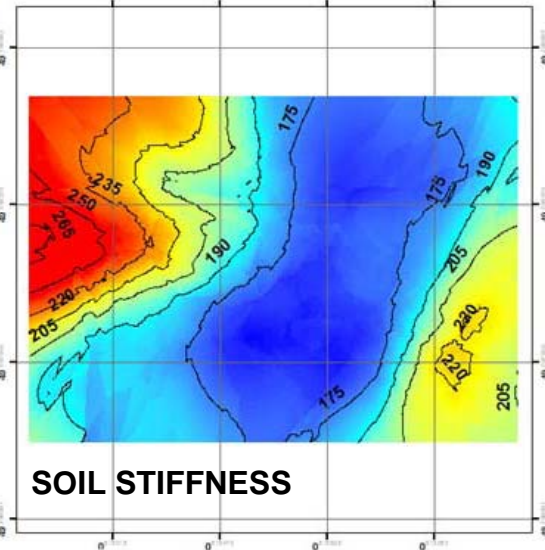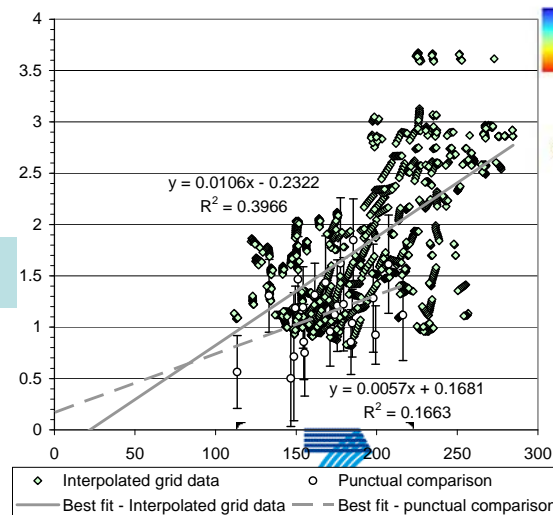
SENSORS

PROCESSING

Vitesse S (m/s)

Profondeur (m)

CALIBRATION

$y = 0.0106x - 0.2322$
$R^2 = 0.3966$

$y = 0.0057x + 0.1681$
$R^2 = 0.1663$

◇ Interpolated grid data   ○ Punctual comparison
— Best fit - Interpolated grid data   – – Best fit - punctual comparison

SOIL STIFFNESS

Elevée : 270
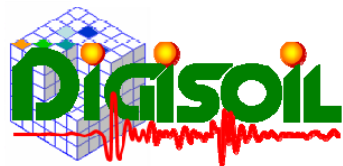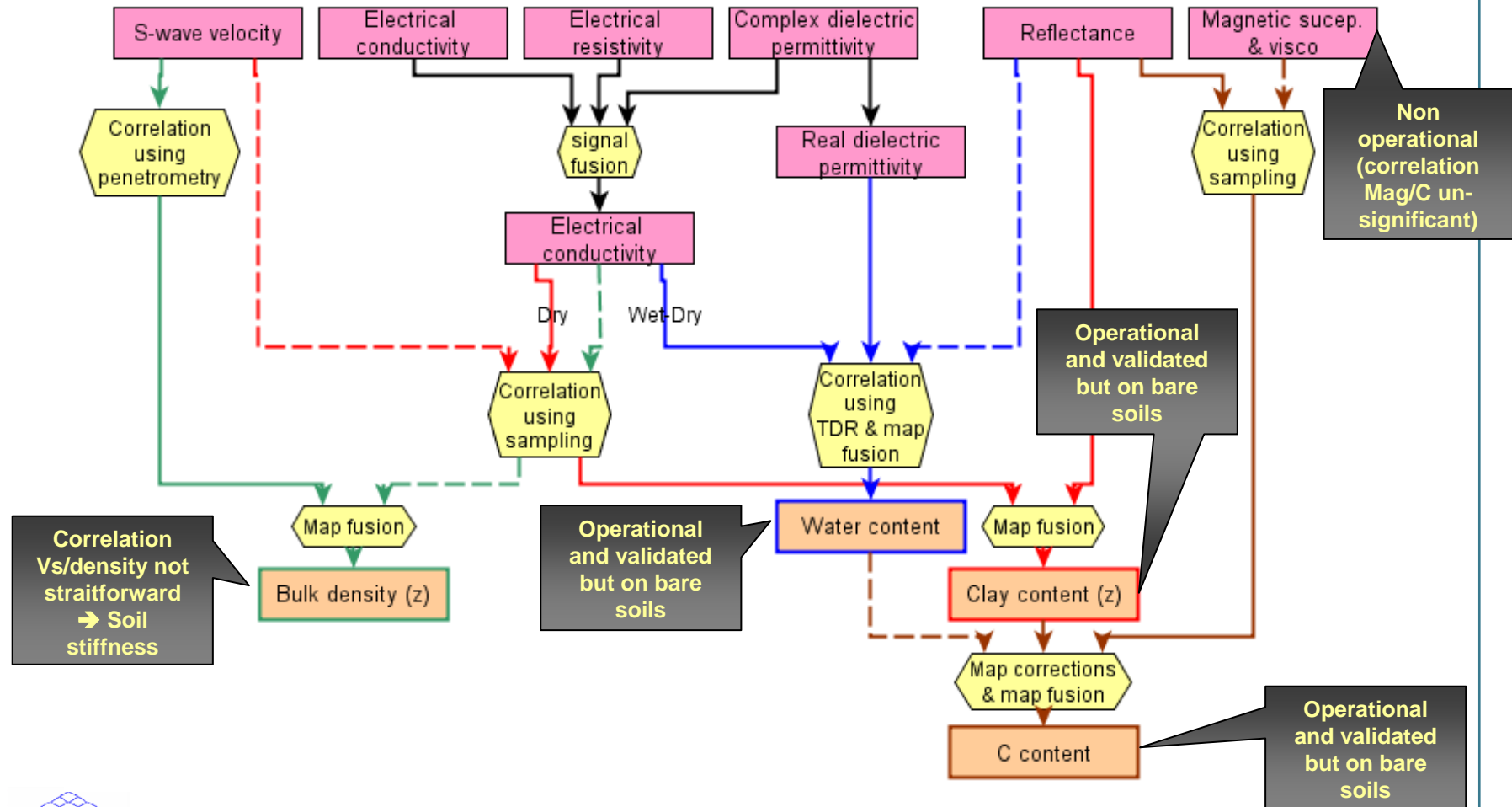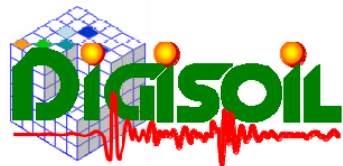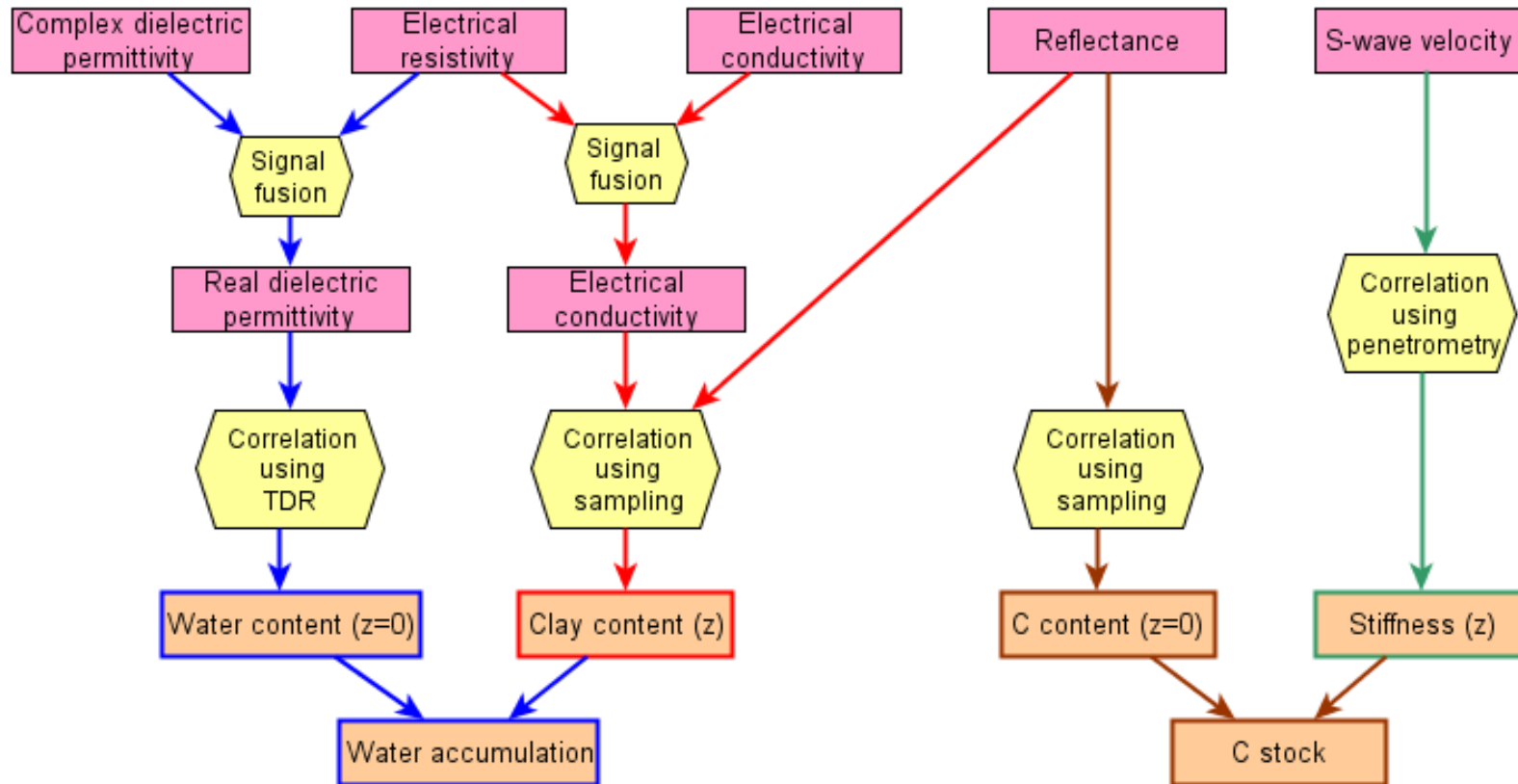Faible : 160

b)

c)

Elevée :6
Faible : 0

SOIL DEPTH

brgm
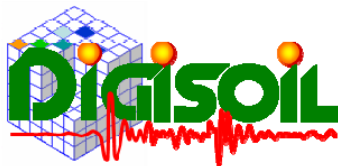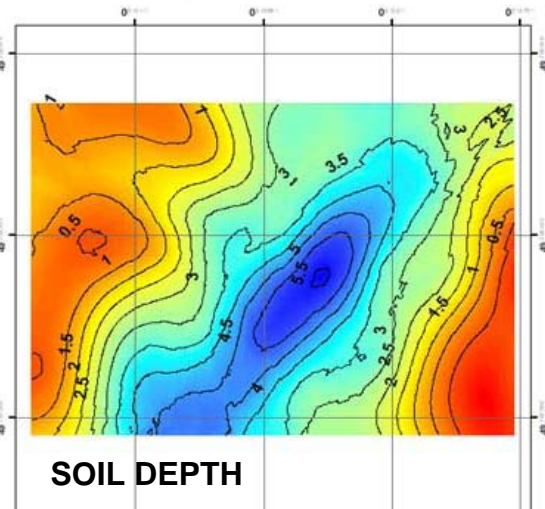
Current work: integrating interpretations in terms of soil properties ➔ identification of issues
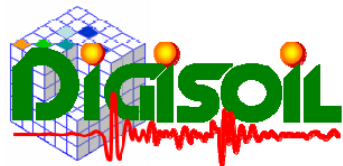
Foreseen operational outcomes

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 sites (Italy, Luxembourg, Hungary) to deliver multiparameter maps to be compared to field truth
- An evaluation will be conducted to identify and design optimal soil properties mapping services at European level

Thank you for your attention !
http://eusoils.jrc.ec.europa.eu/projects/Digisoil/
www.soiltechnologyresearch.eu