Public document

Scientific publications in European and international conferences – Contribution to the handbook with iSoil consortium

FP7 – DIGISOIL Project Deliverable D6.1-3

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N° FP7-DIGISOIL-D6.1-3
September 2011

The DIGISOIL project (FP7-ENV-2007-1 N°211523) is financed by the European Commission under the 7th Framework Programme for Research and Technological Development, Area "Environment", Activity 6.3 "Environmental Technologies".

Geoscience for a sustainable Earth
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With the collaboration of
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Synopsis

This document is a short note to present for the two periods of the DIGISOIL project:

- the list of publications done by DIGISOIL Consortium since the beginning of the project, and events to disseminate the project results, as requested by task 6.1.

- the collaboration with the iSoil project in terms of dissemination, and the preparation of a common Handbook, as requested by task 6.1

- the implication of Digisoil in professional conferences as requested by task 6.3

Contents

1. Scientific publications

Period: September 2008 – August 2011

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2. Contributions to the iSoil's handbook

2.1. INTRODUCTION

A key component of FP7 DIGISOIL and ISOIL projects lies in the development of guidelines for soil mapping, taking into account different scales and environments issues. Such guidelines, produced by the two consortiums, are also in phase with the European Committee for Standardization (CEN). The aim of such work is to give outline answers on how to handle important constraints in soil mapping such as costs, geomorphology, land use, land ownership, existing regulations and the hierarchical scale approach. All these items are scientifically addressed in the WPs of the two projects and are compiled in a series of documents that will be published in a handbook edited by the ISOIL group.

The contributions of DIGISOIL to this deliverable are the following:

- Grandjean, G., Samyn, K. and Bitri, A. Spectral analysis of surface waves (SASW);
- Galfagnoli, F., Chiarntini and S., Moretti, S. Contribution of hyperspectral data to digital soil mapping ;
- Besson, A., Cousin, I. and Seger, M. DC methods applied to soil properties mapping.
- Grandjean, G. and DIGISOIL Team. Overview of methods for soil characterization: application to a test site in Luxembourg.

The next section represents the first contribution on the use of SASW for digital soil mapping.

2.2. EXAMPLE OF CONTRIBUTION

Seismic Spectral Analysis of Surface Waves (SASW)

Gilles Grandjean, Kévin Samyn, Adnand Bitri

BRGM

Short Description of the method

The basic principle of all seismic methods is the controlled generation of elastic waves by a seismic source in order to obtain an image of the subsurface (Stark, 2008). The spectral analysis of surface waves (SASW) method is an *in situ*, non-destructive seismic technique used to evaluate the soil layers thickness and their associated shear waves velocity (Vs), closely related to soil stiffness. The exploitation of surface waves consists in analysing the dispersion behaviour of these waves, when propagating through the soil. After the seismic signal is emitted by hitting a hand-hammer on a small anvil, the propagating seismic waves are recorded along the landstreamer by a series of sensors called geophones. Each recorded signal is sampled by the seismic unit and recorded by a computer. The whole system is then moved to the next measurement point situated along a seismic line. A large area can be covered by repeating this operation along several parallel lines. To estimate soil stiffness variations with depth at each measurement point, three additional steps are needed: (1) determination of the experimental dispersion curve from field data, (2) inversion of this curve to obtain a vertical profile representing a 1D layered model of Vs values, and (3) conversion of Vs values featuring each layer into soil stiffness ones by using ancillary penetrometry data. The final products of such experiment consist of maps of soil stiffness and soil thickness at the parcel's scale. These maps can be used to analyse indicators of compaction or susceptibility to erosion.

Application of the method

Main applications are dedicated to mapping soil at the parcel's scale concerning the evaluation of compacted areas and bedrock depths since seismic waves are very sensitive to such properties. These soil properties can give indications about the soil susceptibility to erosion – when the bedrock depth decreases – and about the soil degradation due to compaction – when seismic velocities increase locally..

Sketch of the measuring system

The acquisition system is composed by:

A seismic source
- Normally a 10 Kg Hammer that strikes on an anvil for generating the seismic signal.,
- the generated is similar to a Ricker wavelet centered around 50 Hz

Seismic receivers
- Gathered along a seismic antenna of 24 geophones with central frequency of 10 Hz.
- The sensor spacing is 50 cm.

Recording unit
- This unit is used for the numerical sampling of signals
- A PC pilots the seismic acquisition software.

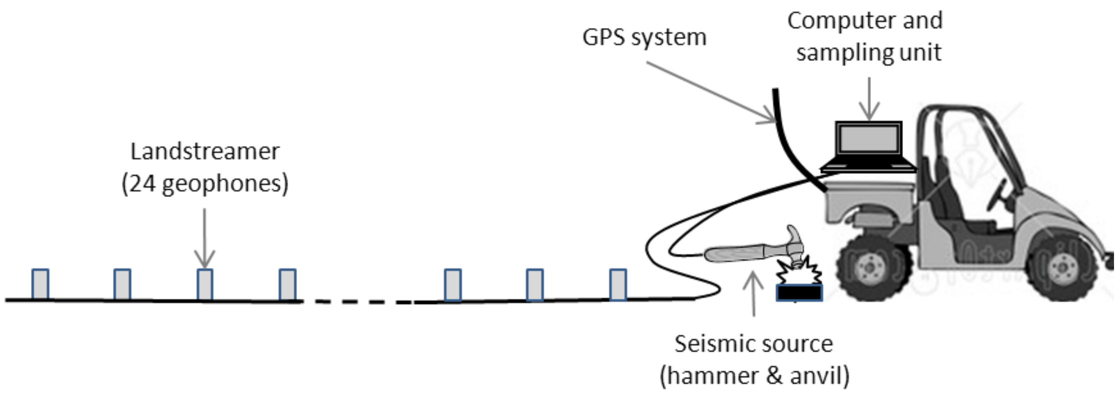


Figure 1: Schematic sketch of the measuring system.

Description of measurement steps

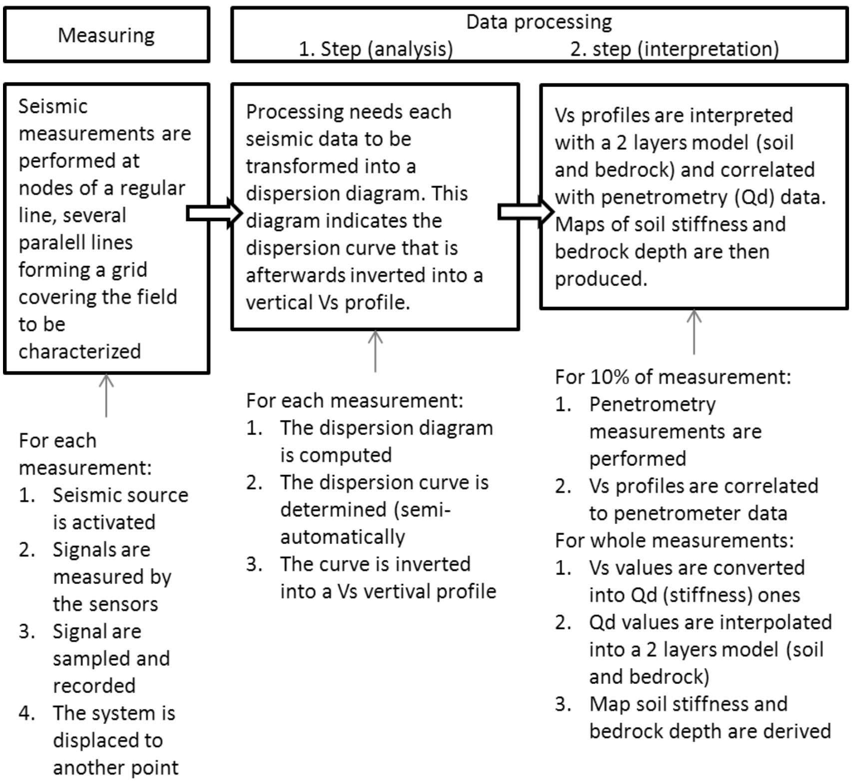
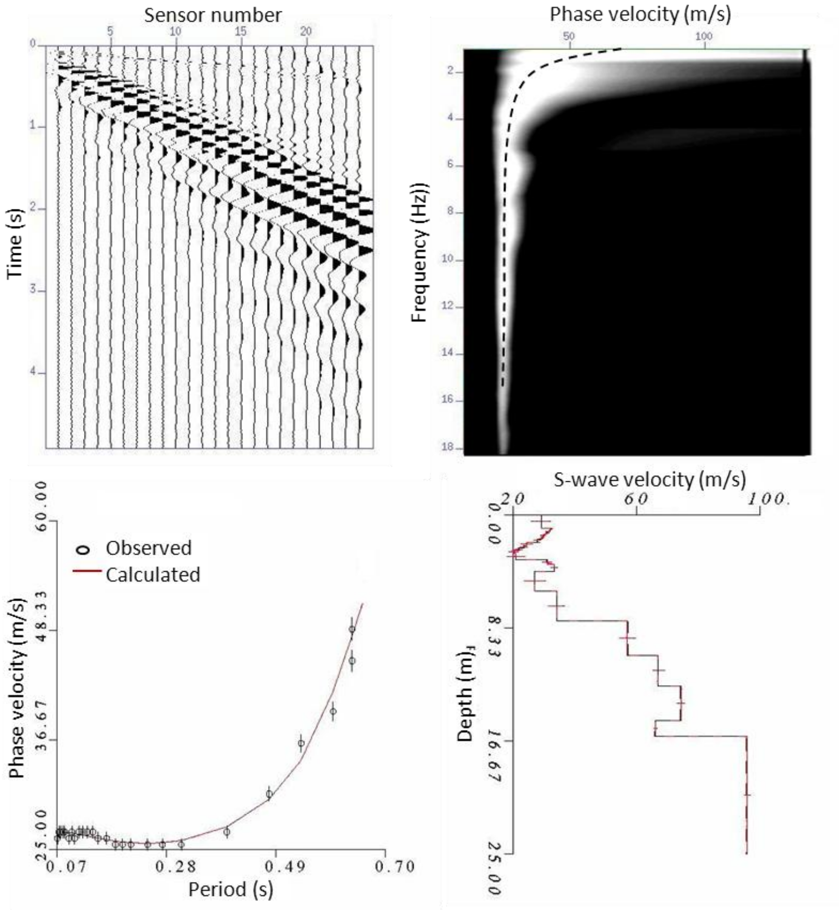


Figure 2: Illustration of the measuring and processing steps

Measurements are performed by the mobile system shown above (Fig.2). During data acquisition, it is moving stepwise from a single measurement point to the next along a defined transect. Successfully derived date sets allow the drawing of a cross section of the soil beneath the profile. By reiterating the measurement procedure along several parallel lines it becomes possible to cover a surface. The resolution of the method it related to the signal frequency, which depends on the quality of the seismic source, the sensor features and the mechanical properties of the soil. Several tests showed that a spatial sampling do not decrease the resolution in a great extend if the measurement spots are set around approximately 5 meter in distance along each transect, and parallel shifting of the seismic profile ranges between 5 to 10 m. The sampling time of the signal is typically set to 1 millisecond..



Firgure 3: Representation of a seismic shot, the related dispersion diagram indicating the dispersion curve (dashed line), the fit between observed and modelled curves and the inverted Vs profile

Descriptions of processing steps

The seismic processing is very complex since it involves different steps as shown in figure 4:

1. The analysis step consists in estimating the Vs vertical profile for each measurement. Seismic data are converted into dispersion diagrams according to Park et al., (1999). This computation is based on the summation in the frequency domain of slant-stacks derived from the seismic data. From this diagram, the dispersion curve is identified as the maximum values that are picked by using a semi-automatic procedure. Then, the curve is inverted according to Herrmann (2002) for producing the Vs vertical profile, i.e., the Vs variations with depth;
2. The aim of interpretation step is the derivation of a soil property maps from Vs vertical profile dataset. At around 10% points of the grid, penetrometer data (Qd) are acquired and correlated to Vs data. A conversion law is estimated in order to transform Vs into Qd data. Finally, the Qd dataset is interpolated spatially in order to produce maps at the parcel’s scale showing respectively the stiffness (Qd) variations in the soil layer and the bedrock depth. An exemple of such maps are shown in figure 5.

A detailed version of the SASW method can be found in Miller et al. (1999; Park et al., 1999; Grandjean and Bitri (2006). The following figure illustrates the different steps constituting the complete SASW workflow.

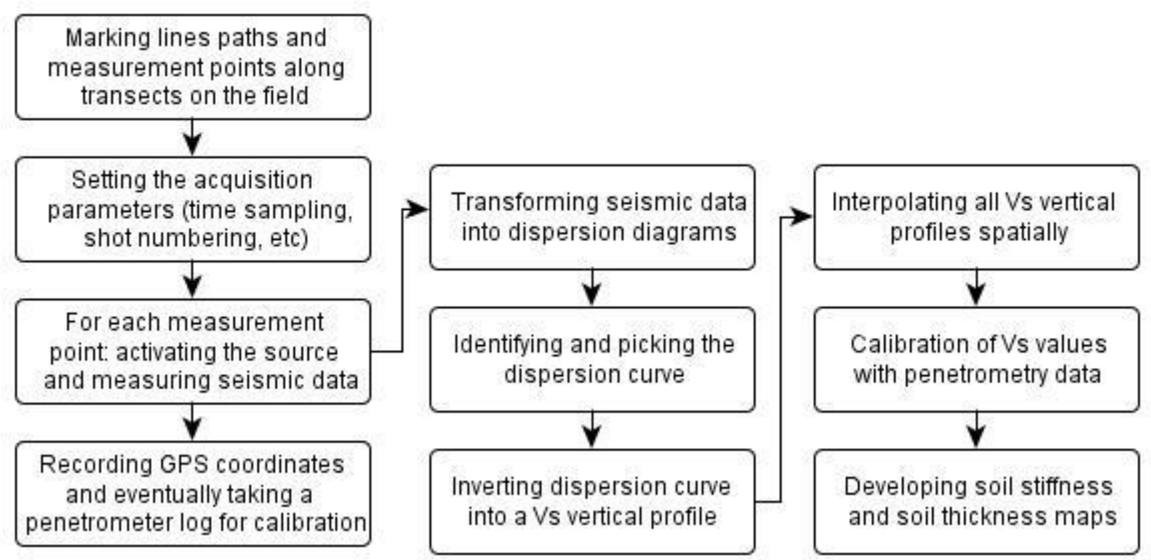


Figure 4: Workflow diagram of an SASW experiment

Output

Figure 5 shows an output of the method. Soil stiffness (left) and soil thickness (right) maps reveal the pedological context featuring the Normandie area (France). As it can be observed on highest topographic points, soil stiffness and thickness increases and decreases respectively. This can be interpreted as a consequence of erosion processes, transporting soil materials from the top of the hills down to the central domain.

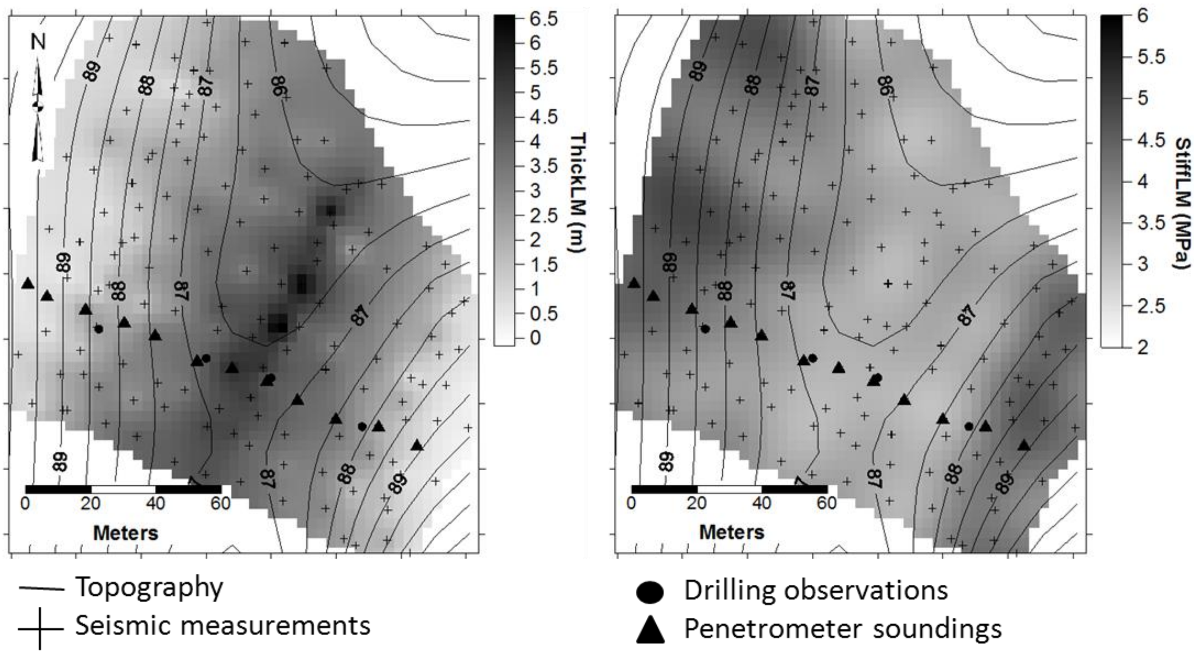


Figure 5: Example of soil thickness (left) and soil stiffness (right) maps.

Pro & cons

The SASW technique in combination with penetrometry allows the development of various distribution maps, eg. soil thickness, soil stiffness and bedrock depth maps, down to 2 till 3 m in depth at the catchment scale. It is possible to identify soil layers and the bedrock depth. The resolution depends on the available frequencies in the recorded signal. To achieve success in doing that measurements reliable equipment, in particular the seismic source and the seismic sensors (geophones) for high frequency recording, which can be moved quickly, is adapted. The sensors are thus coupled and united to allow a faster installation. The whole measurement device is towed behind a crawler type vehicle. The data are manually acquired and simultaneously referenced using a tracking GPS. Nevertheless, particular substrate types, like unconsolidated top layers (peat, humus etc.), can affect the measurements by limiting the transmission of high frequencies, and in the same way the resolution. Several other key characteristics emphasize the advantages of easy surface wave generation. First and probably foremost is the ease with which surface waves can be generated. The relative high-amplitude nature of surface waves (in comparison to body waves) permits their measurement in noisy areas without or just little impact on wave generation or propagation. Generally, no influence on the processing or interpretation of data is expected. This flexibility in data acquisition and the insensitivity to environmental noises allow the successful use of shear-wave velocity profiling in areas where other geophysical methods may be limited. The procedure is restricted by field features which could limit the surface wave propagation, e.g. in strong heterogeneous materials, in presence of rock boulders or due to strong topographic effects.

Estimated time and effort

Normal acquisition rates are about 50 measurements per hour. An area of one hectare in size can be covered in 4 hours using 5 m spacing between the measurement dots along each transect and a parallel shifting of 10 m of the seismic profiles. Such performances need two operators. The first pilots the acquisition and the second activates the seismic source. The processing time of one seismic shot takes about a few minutes, including seismic data processing and inversion of the dispersion curve. A basic knowledge of seismic processing is required in doing such works. The last processing steps take approximately half a day to generate the maps. For all data processing works, a PC-equipment containing seismic processing libraries and mapping tools is required.

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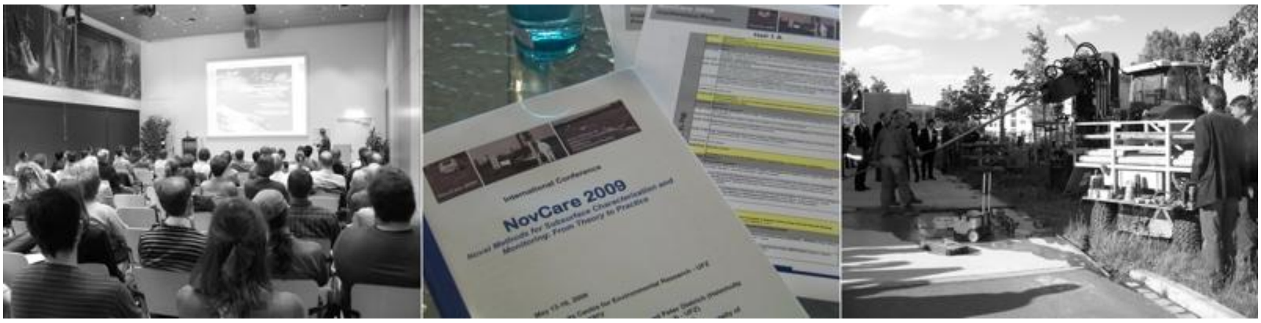
3. Professional conferences

During the 3 years of the project, 2 actions were performed to disseminate the results within professional conferences.

3.1. NOVCARE 2009

3.1.1. General scope

"To discuss the opportunities presented by newly-developed and refined field methods, novel applications of existing methods, and new concepts for subsurface characterization and monitoring, the First International Conference on "Novel Methods for Subsurface Characterization and Monitoring: From Theory to Practice (NovCare 2009)" was held at the Helmholtz Center for Environmental Research – UFZ in Leipzig, Germany from May 13-16, 2009. This conference, which provided researchers and practitioners an opportunity to exchange ideas on how to tackle the challenges of subsurface characterization and monitoring".



3.1.2. Session : hydro-geophysics: the non invasive characterization of the shallow subsurface

The characterization of the shallow subsurface in terms of its hydraulic and mechanical properties is a key step towards the solution of real-life problems in hydrology, hydrogeology, soil science and geotechnics. In particular, the presence and motion of water in the subsurface controls a number of phenomena of great environmental interests, such as contamination of water resources, catchment hydrology, floods and slope stability. The traditional characterization methods are inherently invasive (drilling and sampling) and in most cases do not allow for the space and time resolution needed for the monitoring of hydrological and environmental processes. For this reason, non invasive – geophysical – methods have been increasingly used to support the invasive techniques and fill the knowledge gap in space and time. This approach is conceptually similar to the one adopted for many years in the petroleum industry, with considerable success. However, the shallow subsurface requires specific investigation techniques that are not suitable for deeper applications. The development of such techniques has been very rapid over the past couple of decades. Ground-penetrating radar (GPR), electrical resistivity tomography (ERT) and spectral induced polarization (SIP) have seen the most widespread use to date. Of particular importance are the abilities of geophysical methods to describe two aspects of the shallow subsurface:

- static aspects, which do not change over time, principally related to physical and chemical properties of the geological medium;

- dynamic aspects, which do change over time in response to changes in fluid saturations and water chemistry.

The successful use of geophysical data for hydrologic, environmental and geotechnical investigations requires (1) that the collected geophysical data have a clear, identifiable and quantitative petrophysical relationship to environmental variables of interest; (2) that the resolution and sensitivity of geophysical methods in space and time is fully understood and is appropriate to constrain the process of interest; (3) that indirect measurements be incorporated into hydrologic models in the most effective way, e.g. as means to calibrate predictive models. In this talk, the general conceptual will be presented, together with specific applications to vadose zone and saturated zone characterization in both plain and mountain regions.

Presented paper:

Grandjean, G. and the DIGISOIL Team., 2009. First results of the DIGISOIL multi-sensor system for mapping soil properties. EGU 2009, Vienna, Austria; NOVCARE 2009, Leipzig, Deutchland.

3.2. CONSOIL 2010

3.2.1. General scope

"Strategies and techniques of soil investigation are to be developed further, the restoration and long term use of the ground beneath our feet secured. Even Salzburg is still confronted with underground explosives dropped in World War II. ConSoil 2010 in one of the two and a half days of thematic sessions will also address this problem of land mines and former military sites. On another front Salzburg is fiercely fighting the battle to keep control over quality ground water as public property."

3.2.2. Session SpS 4: Novel approaches for the integration of monitoring data into mapping

Friday, 24 September, 11.00 – 12.30 hrs. hall Papageno

Chairman: Peter Dietrich

Soil erosion, local and diffuse contamination, sealing, compaction are only some of the soil threats caused by human activities. As formulated in the European “Thematic Strategy for Soil Protection” soil degradation is a serious problem also in Europe. Property maps are required to on the first hand to improve the understanding and quantification of the worldwide issue of soil degradation, high-resolution soil and on the other hand to achieve the objectives of the “Thematic Strategy for Soil Protection” such as preventing further soil degradation, preserving soil functions and restoring degraded soils. Such maps will assist the specific protection of soil functions and the restoration of degraded soils as well as contribute towards sustainable land use, water and environmental management.

High-resolution soil property maps are one major prerequisite for the implementation of the Soil Thematic Strategy and the preparation of the planned Soil Directive. However, such maps are not available in the same resolution and level in detail in Europa. Conventional, sample-based soil property mapping is very time-consuming, cost-intensive, and the data collected are available only for discrete points in a landscape. Additionally, as laboratory analyses are expensive, many soil properties are estimated in the field by different soil surveyors, resulting in subjective, non-reproducible, and non-transferable data. Thus, sample-based soil mapping is not reasonably applicable for large areas. It could be recognized that currently available techniques for soil mapping still have deficiencies in terms of reliability and precision, the feasibility of investigation of large areas (e.g.catchments and landscapes) and the assessment of soil degradation threats at this scale.

Presented paper:

Grandjean, G., O. Cerdan, K. Samyn, G. Richard, I. Cousin, J. Thiesson, B. Van Wesemael, S. Lambot, F. Carré, R. Maftei, T. Hermann, T. Thörnelöf, L. Chiarantini, S. Moretti. DIGISOIL: a geophysical multi-sensor acquisition and processing system for mapping soil properties. CONSOIL 2010, Salzburg, Austria.

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