1 Publishable summary

iSOIL- Interactions between soil related sciences – Linking geophysics, soil science and digital soil mapping is a Collaborative Project (Grant Agreement number 211386) co-funded by the Research DG of the European Commission within the RTD activities of the FP7 Thematic Priority Environment.

The consortium consists of 19 partner; including 6 partners from research institutions, 7 universities and 5 SME's and the European Committee for Standardization. Partners origin from nine European countries.

One major prerequisite for the specific protection and restoration of soils, in addition to sustainable land use, water and environmental management, is the availability of high-resolution soil property maps. Usually, existing data bases for soils in Europe cannot provide such maps in sufficient resolutions. Furthermore, they are frequently inconsistent and based on different standards for soil mapping. Therefore, there is a strong demand for efficient technologies for (digital) soil mapping.

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. Various soil parameters can already be mapped using rapid, nearly non-destructive methods (geophysics, spectroscopy) for quasi-continuous 2D as well as 3D mapping of soil physical and hydrological properties. However, current techniques are deficient in terms of reliability and precision, the understanding of relationships between mapped soil parameters and relevant soil functions, the potential for upscaling to investigate large areas (e.g. catchments and landscapes) and the evaluation of soil degradation at such scales. In this context, new strategies and innovative methods have to be developed to generate high-resolution and accurate soil property maps and, on the other hand, to reduce the costs compared to traditional soil mapping.

The iSOIL project tackles these challenges by integrating the following main components: (i) high resolution, non-destructive geophysical (e.g. Electromagnetic Induction, EMI; Ground Penetrating Radar, GPR; magnetics, seismics) and spectroscopic (e.g., Near Surface Infrared, NIR) methods, (ii) mapping and modelling concepts of Digital Soil Mapping (DSM) and pedometrics, as well as (iii) optimised soil sampling with respect to profound soil scientific and (geo)statistical strategies. The objectives of iSOIL are the development of new, and the improvement of existing methods for spatial soil mapping including geophysical, spectroscopic and monitoring techniques. Maps of soil properties, functions and threats are relevant to and required by the "Thematic Strategy for Soil Protection" (COM(2006)231 final). iSOIL will develop, validate and evaluate necessary concepts and strategies for transferring measured physical parameter distributions into such spatial maps. This requires the combination and integration of different measuring techniques, of pedometrical and pedophysical approaches, enhanced DSM techniques, as well as subsequent modelling approaches. In addition to that it is necessary that structures of landscapes and different types of land use are taken into account using a hierarchical approach. The final aim of iSOIL is to provide techniques and recommendations for high resolution, affordable, and target-oriented soil mapping under conditions realistic for end-users.

Key component of the project is the development of cost- and time-efficient methodologies for mapping soils (mainly up to 2m depth) at an adapted resolution which are reasonably applicable for large areas. To achieve this, the advantages of geophysical survey methods and conventional soil mapping will be combined with the possibilities of pedometrical and DSM approaches.
The main structure of the project which includes seven work packages (WP) was derived from the background described above. The overall tasks and interactions between the work packages are visualised in Figure 1.

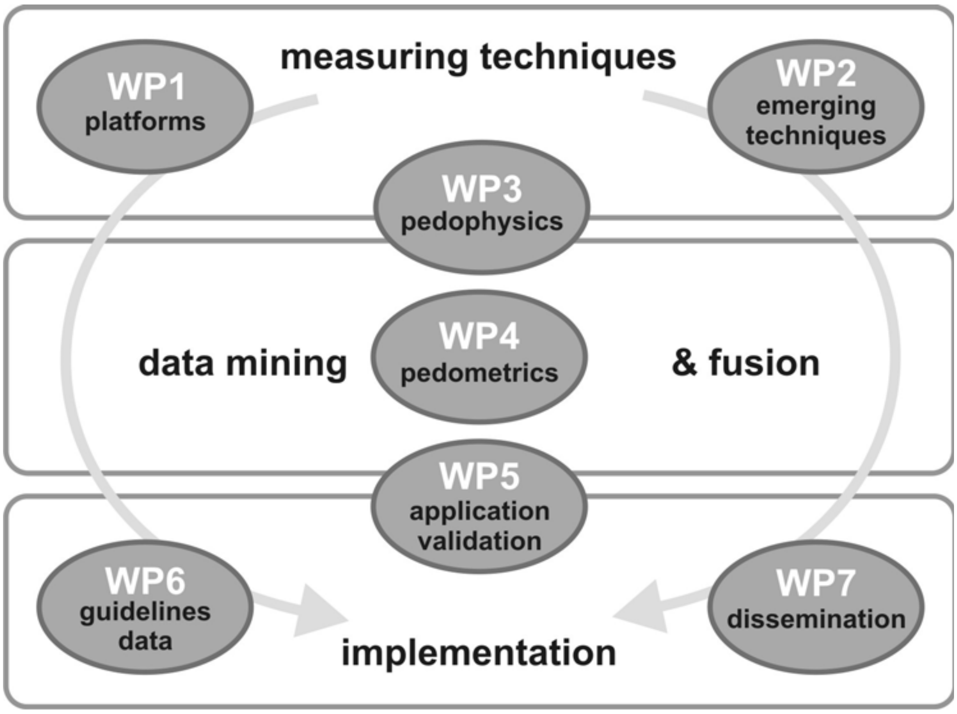

Figure 1: Relation of work packages to the overall tasks of iSOIL project

Objectives of WP1 and WP2 are the improvement of existing and the development of new techniques, including geophysics, spectroscopy and monitoring. This combination will yield the spatial distribution of soil parameters demanded by the "Thematic Strategy for Soil Protection" (COM(2006)231 final). Concepts and strategies for the transfer of measured physical parameter distributions into maps of soil functions are developed in WP3 in close cooperation with WP4 for the integrations in DSM.
Even by significantly increasing the speed of soil mapping with techniques developed and improved in WP1 and WP2, complete and detailed mapping of European soils at the landscape scale will not be feasible. Therefore, not only the relationship between geophysical data and the target soil properties, but also an optimised collection of data is addressed. This includes collecting data for derivation/verification of site specific features, as well as for establishing the relationships between direct (measured) parameters, indirect (derived) parameters, soil functions and threat indicators. Thus, in addition to digitally mapping soil properties, data interpretation, validation and the analysis of sensor and environmental data, as well as machine learning algorithms, are essential tasks in WP4. In terms of the expected impact of the project, it is necessary to demonstrate that the technologies developed in WP1-4 are capable of mapping soil functions, suitable for practical application (e.g. for the management of soil threats, precision farming), as well as affordable for end users. Therefore, validation and selected application plays an essential role in the overall project (WP5).

Another important aspect of the project is the ongoing dissemination of technologies and concept developments from WP1-5. For this purpose, guidelines will be written and published under the aegis of CEN, and results will be implemented in national and European soil databases (WP6). The current state of technologies and future perspectives will also be passed on to authorities, small and medium enterprises, and end users through workshops and special sessions at international conferences accompanying the entire project time (WP7).

Main results of the first reporting period

The integration of geophysical technologies into measuring platforms allows rapid, inexpensive and precise mapping of large areas with complementary parameters. The comparability of data of different sensor types, as well as the reproducibility of data, cannot be taken for granted. In particular, handling of sensors has to be carried out accurately, e.g. with a consistent calibration. One prerequisite for further data analysis is the qualitative and quantitative comparison of different geophysical properties. Reproducibility is one of the most important conditions for monitoring tasks. To successfully apply a sensor fusion approach, the performance of various sensors has to be known when used separately or simultaneously. Different sensor testing experiments were designed as a first step towards flexible and efficient mobile sensing.

A special focus in mobile sensing was put on EMI, GPR and γ-spectroscopy, since a combination of these methods seems highly promising for soil sensing. In addition, there is a need for further systematic studies of different sensors applied to different soils. Therefore, all measurements in WP1 are accompanied by sample-based soil mapping to determine and derive site-specific coefficients of geophysical transfer functions. A general agreement for the main three medium field sites was concluded with common activities from WP1, WP2 and WP3. These field sites are characterised by very different soil types, and they were selected according to the tasks of WP5 (model application) for calibration and validation, following a comprehensive list of meta data of several field sites. We compared sensor types, performed analyses of data quality, improved and tested emerging techniques, developed geophysical pedotransfer functions at the field and collected samples for further lab analyses. Concerning the emerging techniques to be studied in iSOIL, the development and the adaptation of the respective measuring strategies to *in situ* conditions was successful. Soil samples have been selected, partly collected and distributed to partners for relevant laboratory measurements that are needed to establish geophysical transfer functions (GPTFs). Trial GPTFs have been developed, linking geoelectrical and dielectric measurements, and for the description of spectral induced polarization spectra. We are working on pore-scale and pore-network models that can be used to derive links between soil parameters and geophysical responses.

We apply a hierarchical mapping approach with geophysical overview mapping, mapping of selected sub-plots with dense grids and point based measurements, as well as soil sampling for laboratory analysis according to newly developed Digital Soil Mapping approaches (WP4). Weighted Latin Hypercube Sampling, as developed by iSOIL, is the first sampling scheme that allows for weighing predictors (interpolated sensor data) according to their signal/noise ratio in terms of the kriging cross-validation error. Using regression approaches from data mining, such as support vector machines, allows for similar cross-validation results, but also offers the possibility to include multiple additional predictors such as terrain attributes into the mapping approach, and to extract non-linear relationships.

A key component in WP6 is the development of guidelines for soil mapping at different scales and environments and the development of guidelines for the use of different methods for field measurements in the context of soil mapping. During the reporting period the outline of the

handbook “Methods and Technologies for Mapping of Soil Properties, Function and Threat Risks” was fixed and responsibilities were discussed. The iSOIL consortium agreed that this handbook will provide guidelines or best practices on soil mapping depending on the aim of the end-user.
A prerequisite for the application of geophysical measurements for soil mapping are reproducible and reliable data. We started the procedure of the CEN Workshop of the European Committee for Standardization to establish a widely accepted voluntary standard for a best practice of one geophysical method, the electromagnetic induction measurement (EMI).

One important aspect of the work within iSOIL is the transfer of technologies, results and instruments to stakeholders, decision makers and users. Central parts for dissemination are workshops for stakeholders. Within the reporting period we organised two workshops for stakeholders, decision makers and end- users in Sofia (Bulgaria) and Graz (Austria) to give an introduction to the principles of soil property mapping, applied geophysical methods and emerging techniques for mapping. The Bulgarian and Austrian participants gave positive feedback and highlighted the informative character of this workshop. Since field surveys and scientific evaluation activities (validation of methods) will be conducted at the Fuhrberger Feld (Germany) in 2010, local stakeholders had to be informed at an early stage about the project. Therefore, a meeting was organised with stakeholders in the Fuhrberger Feld in June 2009.

Fig. 2: Impressions of the Workshop in Graz

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