ORIGINAL ARTICLE

iSOIL: exploring the soil as the basis for quality crop production and food security

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Abstract

Introduction The quality and safety of crops and derived products depend among other factors on the quality and safety of the soil. To control the quality and safety of the soil and adjust crop and soil management to meet the desired quality and safety standards, a profound knowledge of the soil is indispensable. At present the techniques available for soil mapping are too expensive, are at low resolution and are not suitable for precision farming applications. *Objective* The EU-funded project iSOIL aims to improve existing and develop new techniques and methodologies for sensor-based high-resolution digital soil mapping (DSM). *Methods:* In seven work packages the project members will develop and improve current methodologies for high-resolution DSM using geophysical, spectroscopic and monitoring techniques. *Results* The anticipated result of the project is a set of target-oriented techniques and guidelines for economically feasible high-resolution DSM. The anticipated results are illustrated by a gamma-ray soil mapping example. *Conclusion* The combination of geophysical methods and DSM techniques can provide a fast and cost-effective approach to create high-resolution digital soil property maps for large areas, but there is still some research necessary. These methods can be used for precision farming and will improve the production of crops at desirable quality and safety levels.

Introduction

During the production of food a lot of factors influence the quality and safety of crops and their derived products. The soil on which the crop is grown is a major building stone in securing the right quality and safety of crops (Oliver, 1997). Bad or uncontrollable soil conditions can lead to premature dying of crops, rotten products like tubers or maize that can lead to various soil or crop related diseases. Soil in a good condition that can provide enough nutrients and moisture to the crop can produce healthy crops with high yields, large nutritional contents and higher usable contents. By keeping the crop in a good condition it can also limit crop losses due to bad weather conditions, e.g., a nitrogen shortage in wheat can cause the crop to lay down easily during wind or heavy rains.

Apart from photosynthesis inputs all nutrients and trace metals that build a crop originate from the soil. Contaminated soil will therefore result in contaminated crops and animals. Possible contaminations that may pose health concerns are, e.g., heavy metals and radioactive material (Vera Tomé *et al*., 2002; Millis *et al*., 2004). Heavy metal contaminations originate from (former) factories or wastewater. Radioactive contamination can be the result of a nuclear accident such as Chernobyl (Papastefanou *et al*., 1999).

To secure and improve both quality and safety of soils implies that a farmer or food company need to know the soil characteristics, quality and contamination status of a soil. This will enable them to control or adjust crop production in such a way that the quality and safety standards for crop yield are met.

This need for low-cost high-resolution digital soil maps can at present only partially be answered (McBratney *et al*., 2003; Adamchuk *et al*., 2004). Traditional soil sampling techniques measure discrete points only and are labour-intensive, time consuming and very expensive. The resolution of the available data is not high enough to enable, e.g., global positioning system (GPS)-based precision farming. Different soil surveyors have different interpretations of the same soil characteristics resulting in subjective non-transferable maps. Soils are classified using national, non-comparable soil taxonomy systems instead of soil properties. The single soil sensor systems that are operational are bound to their measurement depth and sensitivity to the desired soil property.

As a result of these limitations there is a need for integration and improvement of current soil mapping techniques and for the development of new strategies and innovative methods to generate high-resolution soil property maps. At the same time these techniques should allow for a decrease in costs when compared with traditional soil mapping. The combination of geophysical methods and DSM techniques can provide a fast and cost-effective approach to create high-resolution digital soil property maps for large areas, but there is still some research necessary.

iSOIL

The need to improve the current soil mapping toolbox has been recognized by the EU as a result of the 'Thematic Strategy for Soil Protection' (EU, 2008). The EU-funded iSOIL project aims to develop new and improve existing methods for high-resolution DSM using geophysical, spectroscopic and monitoring techniques. The iSOIL consortium consists of 19 partners from nine countries and contains universities, research organizations and small- and medium-sized enterprises (Figure 1). The project started at June 1, 2008 and will finish at 30 November 2011. More information is available on http://www.isoil.info.

The project is structured in seven work packages (WP) (Figure 2). WP1 and WP2 apply the concept of mobile measuring platforms by integrating existing geophysical, spectroscopic and monitoring techniques (WP1) and exploring emerging technologies (WP2). WP3 tries to develop physically based transfer functions or so called constitutive models to establish site-specific relations between geophysical and soil parameters. WP4 will use the pedophysical relations found in WP3 together with geostatistical methods for DSM to derive digital soil property maps. Furthermore WP4 will optimize soil-sampling schemes for calibration of sensor data in WP1, WP2 and WP3. WP5 is responsible for validation of the derived techniques and exploring its uses in studying soil threats. WP6 will formulate guidelines and standardize technologies. WP7 is responsible for dissemination of the outcome to relevant end-users (WP7).

The anticipated result of the project is a set of target-oriented techniques and guidelines for economically feasible

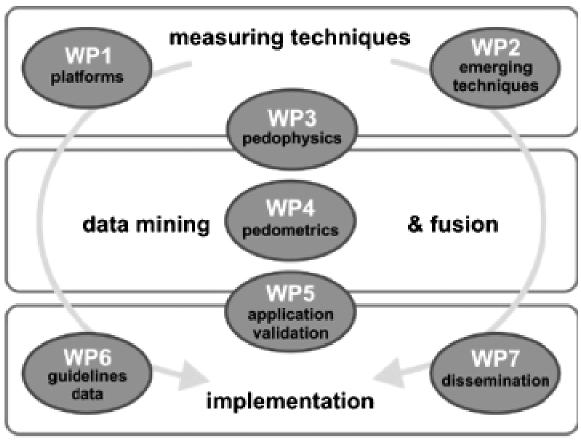

Figure 2 Relation of the work packages to the overall tasks of the iSOIL project.

Figure 1 Left: geographical distribution of iSOIL partners. Right: iSOIL partners at kick-off meeting, September 2008.

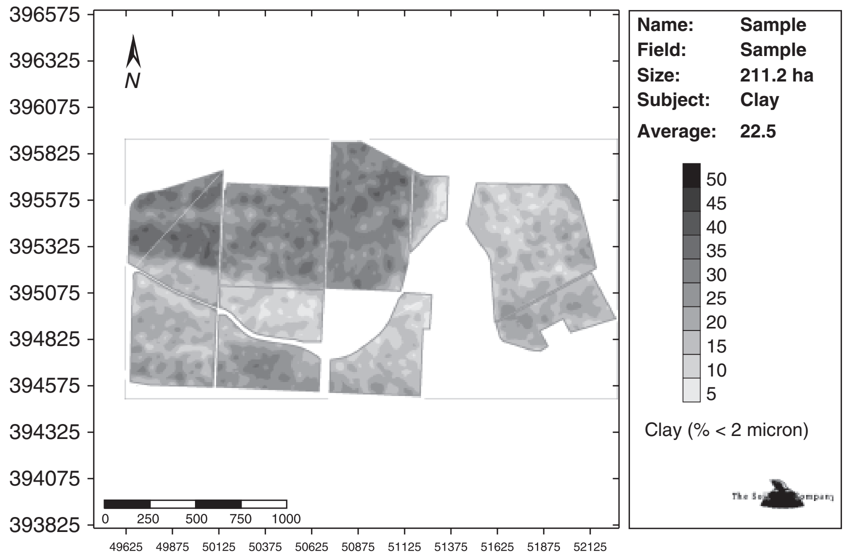

Figure 3 Clay map of the tillage layer derived using the γ ray sensor of The Soil Company.

Figure 4 Field measurement with γ ray soil sensor.

high-resolution DSM that can be used for, e.g., precision farming.

Example

To illustrate the future results of the iSOIL project and its applications in soil and food quality and security a single sensor system and its applications is presented. The Soil Company is one of the partners in the iSOIL consortium and operates a γ-ray soil sensor. This sensor measures the natural γ radiation emitted by radioactive daughter decay of three natural elements – potassium (K), thorium (Th) and uranium (U) – as well as the Chernobyl-related cesium (Cs) and the total amount of energy called total counts from within the top 30 cm of the Earth's surface. Maps prepared from radiometric surveys provide information about the soil parent materials as well as soil properties like clay and sand content of the tillage layer (Figure 3), average grain size, organic matter content, pH and several soil nutrients.

The sensor system consists of the sensor itself, a GPS and a laptop for data logging. This system is mounted on, e.g., a tractor and driven along the field with 6 kmh^{-1} at 10 m tramlines. (Figure 4) The measured signal is deconvoluted into the four elements and total counts. These elements are then calibrated to the desired soil properties using a few soil samples and a γ-soil property database that serves as a knowledge base (van Egmond *et al*., in preparation).

These soil property maps can be and are used in precision farming applications to safeguard the desired quality and safety of crops. Examples are, e.g., adjusting soil nitrogen levels to control the protein level in barley. Maize is sensitive to wet soil conditions caused by, e.g., compaction of the top- or subsoil. This causes maize plants to die before the crop is mature, posing a higher risk for crop diseases and decreasing yield. The soil, among other factors, influences the moisture content of cereals at harvest. High-grain moisture poses a high-moulding risk in storage. A shortage of nitrogen causes wheat to lay down during bad weather conditions.

Outreach and call for cooperation

The transfer of knowledge, technologies, results and instruments is one of the key objectives of the iSOIL framework. A key component of iSOIL will be the development of guidelines for soil mapping at different scales and environments using a set of various methods for field measurements. It is clear that end-users such as constructors, farmers, food companies, other problem owners and regulators have different interests. To meet the interests of potential end-users criteria such as price, availability, applicability, quality and velocity should be taken into account. The methods and strategies developed should be convincing for end-users to use the iSOIL methods.

To develop a product that is realistic and useful for end-users, it is important to identify and clarify the group of potential iSOIL end-users. Therefore our framework is open for collaboration with all potential end-users that are interested in this topic.

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