Soil sensing and yield improvement on marginal soils in Spain

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Abstract

Soil mapping provides information on the variation in physical characteristics of agricultural fields. For the EU Life+ project 'Crops for better soil' we developed a soil mapping tool consisting of a gamma spectrometer and GPR on a 4x4 car, which was able to map large and widespread areas fast and effectively. Without a direct translation to soil properties, the geophysical data serves as a first indication of the quality of the fields and proved to be an important base for communication between farmers and agronomists. The spatial information on local variation of soil properties provides a base for sound crop advise and selection of lands suitable for farming.

Keywords: Gamma spectrometry, GPR, Spain, soil properties, measurement campaign, communication

Introduction

The vast threat of soil erosion and the urgency to increase soil productivity to create sustainable incomes is a major issue in the Mediterranean region. As an answer to this, several Spanish, German and Dutch companies started the EU Life+ project 'Crops for Better Soil' (www.traditional-crops.com). The project aims to demonstrate that using organic farming techniques, crop rotation and the re-introduction of traditional crops improves the soil and increases yields of 400 hectares of marginal Spanish soils in a 5 year time span. Soil sensing techniques are used to provide detailed information on soil properties and to monitor improvement of the soils.

These 400 hectares are selected within 4 regions in Spain: Castilla la Mancha, Castilla y León, Aragón and Navarra. The first three are referred to as Guadalajara, Zamora and Zaragoza (figure 1). The regions and fields contain a range of different parent materials and geology thus presenting a representative subset of rainfed Spanish soils. Soils or fields are defined as marginal when they are rainfed, managed extensively and are often not or hardly profitable without subsidies. The size of the fields varies from over 25 hectares to less than 1 hectare. There are on average 6 farmers per region and farmers may have one or more fields in the project. One agronomist advises the farmers on the possibilities of traditional crops and organic management of the fields for each region.

The change to organic farming, the crop rotation and the use of crops that do not yet have a large market share, causes a lower income for the farmer during the first few years before the benefits of such an approach start to show in the yields. Therefore, a seed trading company buys the yields of the farmers each year to guarantee their income.

Objectives

The objective of the soil sensing techniques is to gather soil data that provides detailed and targeted information on the textural composition, structure and density of the soil. Because of the large variation in parent materials and soils, the differences between fields and the differences within fields are highly relevant. At present the mechanisation (eg. GPS aided variable rate application) is not available to the farmers for automated precision agriculture. However, the information will assist the agronomists and farmers in determining the suitability of the soil for certain selected (traditional) crops and in designing the crop rotation scheme. This will be primarily per field but may in some circumstances result in a within-field differentiation.

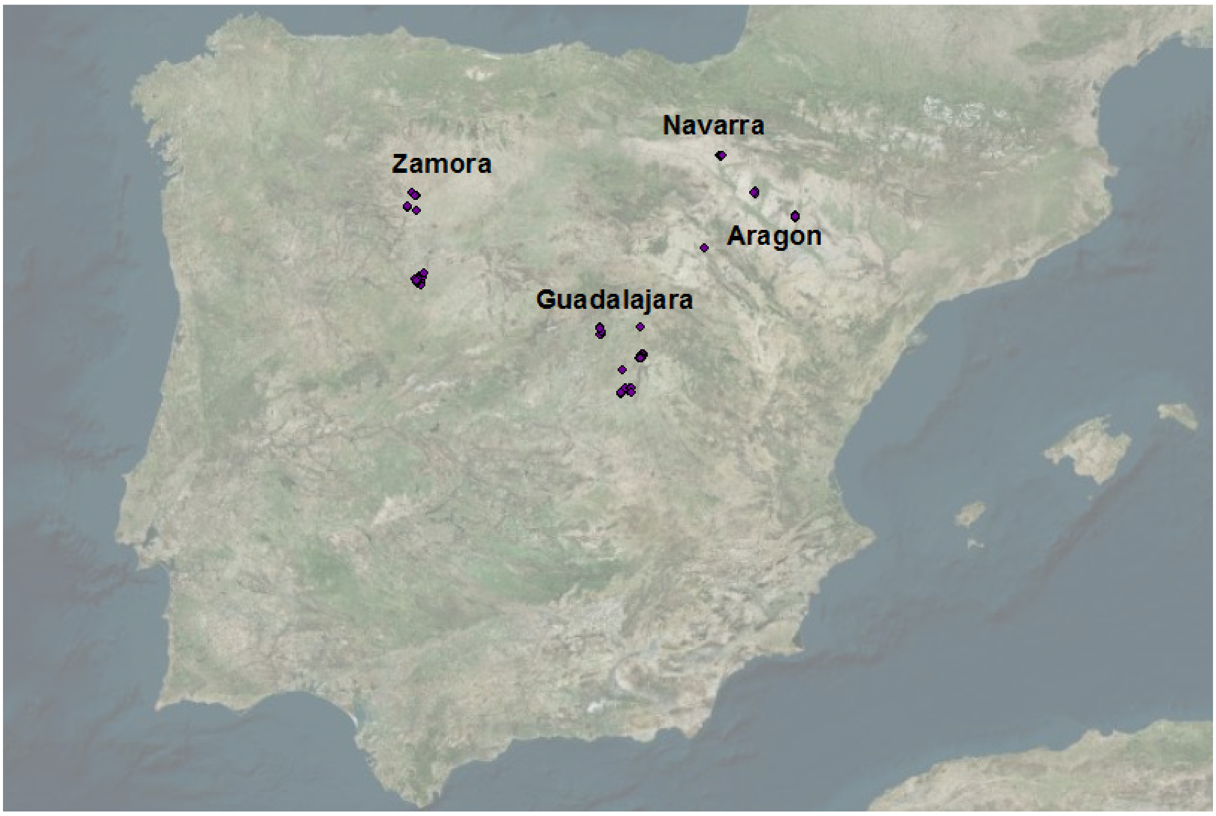

Figure 1. project fields in four regions in the central part of Spain. (source: Bing Aerial)

Moreover, the measurements aim to provide information on the improvement of soil fertility and structure and decrease of erosion in 5 years time.
The systems used have regularly been applied on large flat fields in the Netherlands (van de Klooster et al. (2011), van Egmond et al. (2010)). However, the stony Spanish soils provide completely different circumstances and most of the fields are small and are distributed over a wide area. To that end, the tools have been re-engineered for this project.

Materials and methods

The sensors employed were a MS-4000, 4 L CsI gamma spectrometer with full spectrum data analysis (FSA) (Hendriks et al., 2001), a 750 MHz air-coupled GPR and GPS on a 4x4 vehicle. The gamma spectrometer was mounted in a rugged steel casing in front of the car. The GPS was positioned on the roof and the GPR was towed on a custom-made cart behind the car. The system was powered by the car-engine and data was logged on a rugged field computer. Fields were scanned at 10 km/h in 5-15 m interval lines depending on apparent variation in geomorphology and gamma radiation. Soil samples of 0-20 cm depth were taken per 5 hectares. These were analysed on the concentration of radionuclides and on physical and chemical soil properties in the lab.


Figure 2. Measurement setup with a gamma spectrometer in front of the vehicle and GPR behind in a carriage the vehicle

Results

The designed hardware system operated well under the stony Spanish circumstances. Built-up time was small (5 minutes) which increased the number of hectares and fields that could be scanned per day.
The topsoil stoniness caused a decreased GPR reflection of the soil below, which proved visual interpretation of the GPR data difficult. Depth slices of GPR reflection, however, show clear patterns that are now verified in discussions with the farmers involved.
The results of the gamma spectrometer aim to deliver quantified properties of the soil such as clay content, stoniness and potentially soil quality. Correlations between soil lab data and lab data on radionuclide concentrations still have to be performed.
During the measurement campaign and in discussions with farmers the sensor data proved to be a good communication tool between farmers, agronomists and geophysicists. The data, in combination with regional knowledge, provided a good aid for differentiation in soil quality and suitability for various crops. In these discussions it was very helpful that the gamma-ray count rate data could be viewed real time during measurements. Many farmers recognised zones of good and poor production on-the-go. This increased their awareness that sensor data provide useful information for farming.
The knowledge of the farmers on organic farming and different crops is quite variable. Part of the aim of the project is to educate and aid farmers in applying organic farming and using different crops. Apart from maps of physical soil properties, additional maps will be made that assess the overall quality of the soil. These maps can be a useful tool for designing crop rotation schemes and for determining soil suitability for certain crops as well as for discussing ecological farming possibilities with the farmers. The data will therefore be used for educational as well as advisory purposes.

Example

Figure 3 shows the count rate maps of 6 fields of one farmer near Ejea de los Caballeros in Aragón. The differences between the fields are apparent. The southern fields (1, 2) are situated in a valley and have a much higher clay percentage, contain less stones, have a large rooting depth, and give a higher yield in moderate years. The 4 northern fields (3-6) are situated on flat hilltops (small mesetas). and have a lower clay percentage, a slightly higher sand percentage and a much higher stoniness than the southern fields. The top soil layer of the northern fields consists mostly of stones with some soil. In wet years these soils have better yields because of their good drainage properties. In dry years yields may be non-existent.

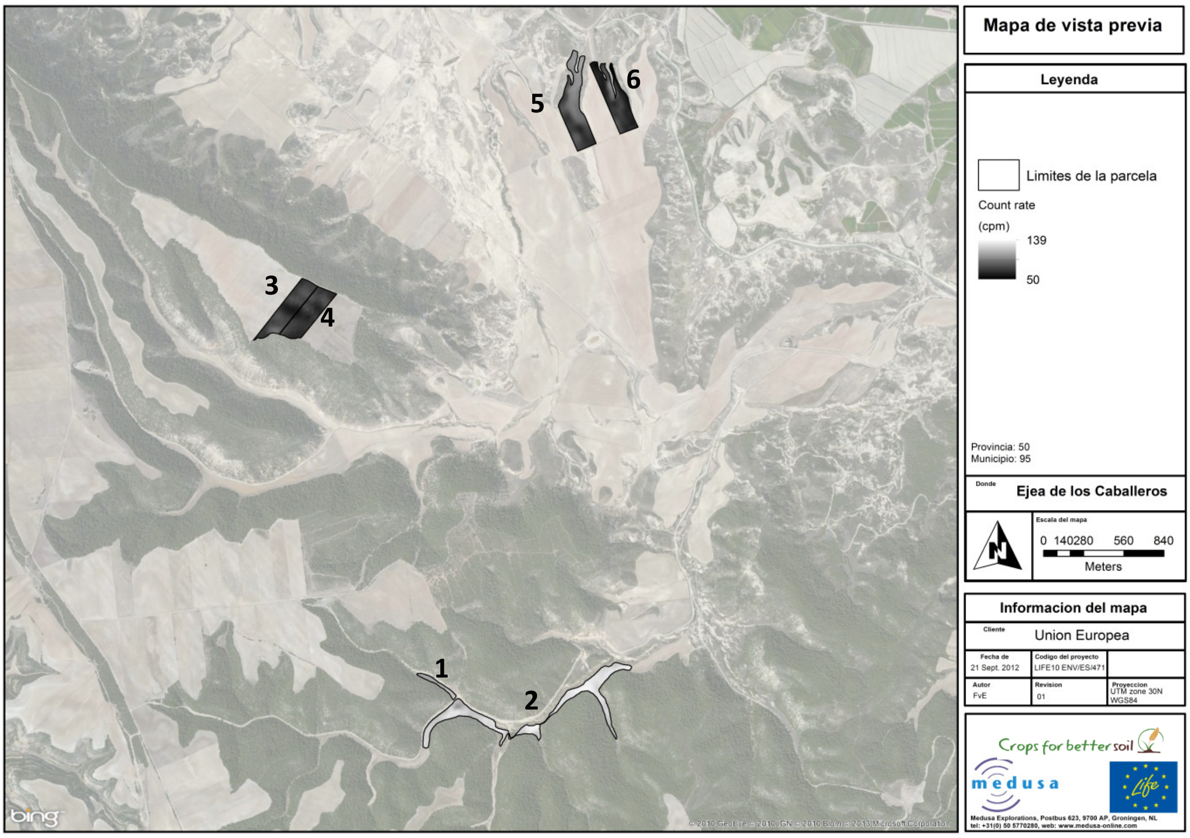

Figure 3. count rate (cpm) of 6 fields near Ejea de los Caballeros, Aragón, Spain.

Within most fields differences in count rate can be observed. This is most apparent in field 5. The northern part lies in a valley that consists of a different geological clay-rich layer. In discussions with the agronomist it was apparent that the choice of crops for fields 3-6 can be grouped and differs from what would be suitable for fields 1 and 2. Because of the large difference in properties within field 5, it is qualified as less suitable for every year farming. The local knowledge on differences in soil properties is partly known by the farmers, but visualisation of this data helps the farmers and agronomists to make decisions on semi-quantitative grounds.

Conclusions

Within the EU Life+ project `Crops for better soil´ Medusa Explorations has used a flexible, fast and robust sensor platform containing a GPR and a gamma spectrometer to measure the physical soil properties of 400 hectares of marginal Spanish soils. The designed sensor platform and sensors performed well. Gamma-ray data provided a fast and effective insight in the quality of the soil and proved to be a good quantitative communication tool for discussion with the farmers. An important aim of the project is to educate and aid farmers in applying organic farming and using different crops. The maps of geophysical data proved to be a useful semi-quantitative result to assist in the process of communication.

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