Preliminary analysis for soil organic carbon determination from spectral reflectance in the frame of the EU project DeSurvey

N. Richter, S. Chabrillat and H. Kaufmann

GeoForschungsZentrum Potsdam (GFZ), Section 1.4: Remote Sensing, Telegrafenberg, D-14473 Potsdam, Germany, email: nrichter@gfz-potsdam.de

ABSTRACT

This paper presents the concept of the GFZ hyperspectral remote sensing research project within DeSurvey. First we describe a preliminary analysis of laboratory experiments. These experiments were performed to study the influence of soil organic carbon (SOC) content, roughness and illumination on spectral reflectance. Then we present the design of field experiments that will be further used to test the transferability of reflectance models developed in the laboratory to field and subsequently to remote sensing scale. This work is in its very first stage. Following work includes the evaluation and improvement of the field and laboratory experiments and the investigation of other soil parameters such as soil organic matter and iron content.

Keywords: Hyperspectral remote sensing, DeSurvey, BRDF, soil properties, soil organic carbon

1 INTRODUCTION

The integrated EU project DeSurvey was started in March 2005 with the overall goal to develop a surveillance system for assessing and monitoring of desertification. Five test sites in southern Europe are selected to validate the DeSurvey system, and assess, monitor and forecast desertification and land degradation status. Subsequently, a compact set of integrated procedures for the assessment system will be delivered at EU and national scales. In the framework of the DeSurvey project, advanced remote sensing techniques are developed and tested to derive indicators related to soil surface parameters such as organic matter, organic and inorganic carbon, iron content, roughness status and the presence of biological crusts.

The main focus of the GFZ contribution in the DeSurvey project is to study desertification issues with support of hyperspectral imagery methods [1], [2]. Airborne remote sensing datasets recorded over well documented test areas in the Mediterranean region will be used to develop advanced information extraction procedures that allow the determination of relevant soil parameters (e.g. organic matter content) from hyperspectral data at first step, and extend it to available satellite imagery as a second step.

Our project objectives are:

- Development of a model for extraction of quantitative soil parameters such as soil organic carbon (SOC), iron content etc. from laboratory and field reflectance measurements and hyperspectral data [3], [4], [5].
- Setup of multi-scale field spectral (upscaling) experiments for transfer of models from the laboratory to remote sensing data as basis for the development of enhanced parameter extraction procedures for current and future spaceborne systems.
- Setup of laboratory and field experiments to study BRDF (Bidirectional Reflectance Distribution Function) effects over representative soil samples and selected test areas to obtain their directional spectral properties.

This paper presents the setups of laboratory and field experiments. Preliminary analysis of the laboratory measurements is shown.

Presented at the 1st International Conference on Remote Sensing and Geoinformation Processing in the Assessment of Land Degradation and Desertification, Trier, September 7-9 2005

2 LABORATORY EXPERIMENTS

2.1 Setup

Laboratory measurements are performed on soil samples from the Guadalentin area in SE-Spain, sampled and geochemically analyzed (organic and inorganic carbon, mineral composition) at the University of Trier. All samples are taken from crop fields representing catenas with different soil development status. Eight soil samples representing different organic carbon contents were chosen to simulate different surface roughness states and measure them under varying illumination angles (Figure 1). It was further attempted to extract the SOC from the spectra. The spectra have been taken with the ASD spectroradiometer *FieldSpec Pro FR* (www.asdi.com) from the University of Trier.

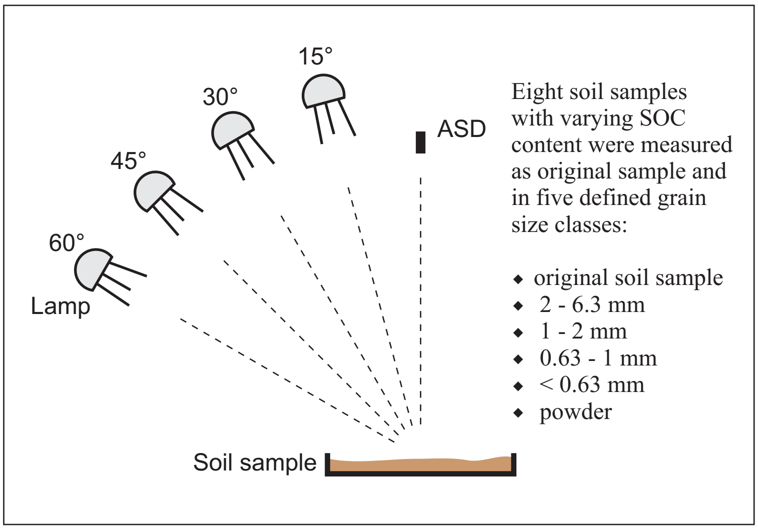

Figure 1: Laboratory experiment settings.

Variation of surface roughness states:

The influence of surface roughness states on reflectance was studied by measuring the spectra of the original sample and five different grain sizes of each soil sample. The grain sizes were retrieved through a sieving process separating the soil fractions starting at fine gravel level (2 – 6.3 mm) and down to homogenized samples in the fine sand level (crushed samples (powder)).

Variation of illumination angle:

The illumination angle of the light source was varied at four positions: 15°, 30°, 45°, 60°. In this laboratory setting the spectral measurements were taken with nadir-looking fiber optic of the ASD spectrometer.

Altogether 24 spectral measurements were taken per soil sample (six different roughness states at four illumination angles each). This results in 192 measurements total for the selected eight soil samples.

2.2 Preliminary analysis

The spectra are analyzed in terms of the influence of varying surface and illumination conditions for the determination of SOC.

The influence of the different surface roughness stages on the spectra is depicted in Figure 2. The surface reflectance of the sieved samples increases with decreasing grain size as can be expected [5]. It was further observed that with decreasing grain size the depth of absorption bands decreases. The high reflectance of the original soil sample might be due to different heights between the sample surface to the lamp and sensor.

The influence of varying illumination conditions is depicted in Figure 3. The variation of the illumination angle at the reflectance plays a major role on reflectance of rough surfaces having lots of shadow, i.e. shadowing is getting strongest with lower illumination. Here, grain size is small, with little shadow, and we observe that spectral reflectances are located at a similar level.

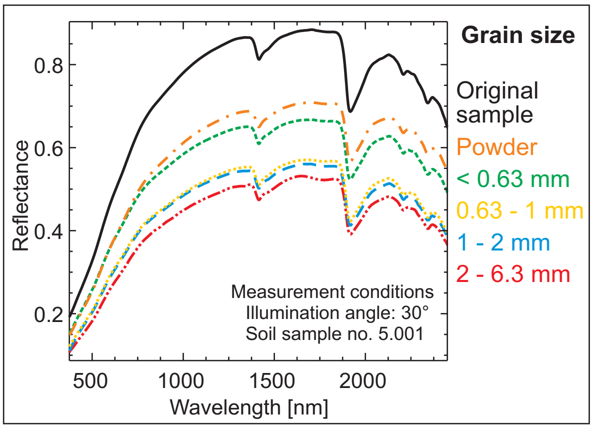

Figure 2: Variation of surface roughness states.

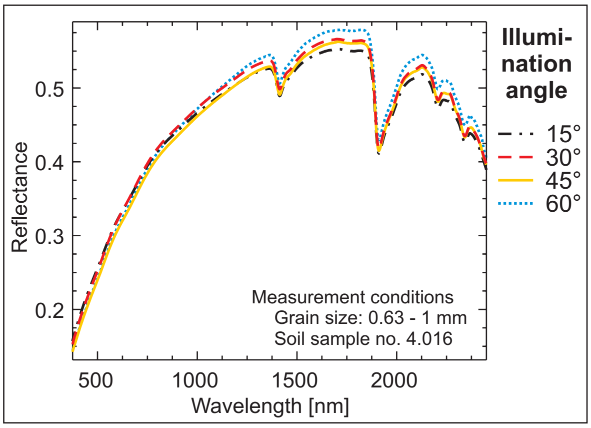

Figure 3:Variation of illumination angle.

Figure 4 depicts reflectance spectra of 5 soil samples with different SOC content. The direct extraction of SOC content from these spectra is difficult because of the influence in the same wavelength range of varying iron content. When there is few iron in the samples, the increase of the SOC content is associated with a decrease in the surface reflectance in the VNIR wavelength range and a general flattening of the spectra in this spectral region [5]. Here iron absorption bands at ~900 nm start to appear for samples of low SOC contents Then we observe that the influence of iron absorption bands increases significantly with decreasing SOC.

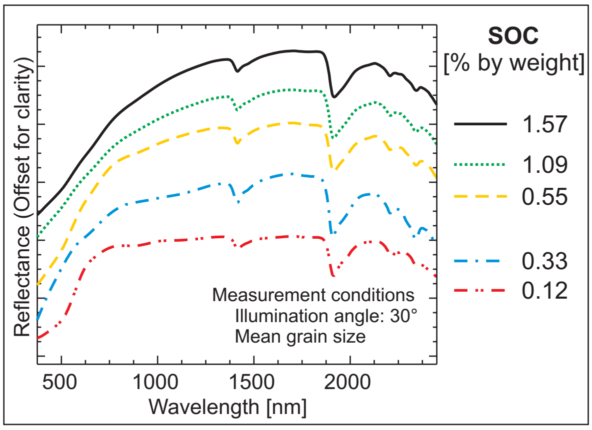

Figure 4: Soil organic carbon content. (The mean grain size spectra were generated by averaging the individual grain size spectra for one sample and illumination angle.)

3 FIELD EXPERIMENTS

A two-weeks field campaign in SE-Spain took place in July and August 2005. Three different types of semi-arid and arid ecosystems associated with the Cabo de Gata region, El Cautivo area, and Sierra de Gador mountains were chosen to perform the planned experiments (Figure 5). The Natural Parc Cabo de Gata – Nijar is geologically characterized by calcareous and volcanic rocks on which two different types of soil developed. El Cautivo is located within the Tabernas desert area. Lichens and different soil crust are typical for the calcareous rich soil in El Cautivo. The soils of the Sierra de Gador Mountains are based on calcareous and phyllitic rocks and show a high content in soil organic carbon.

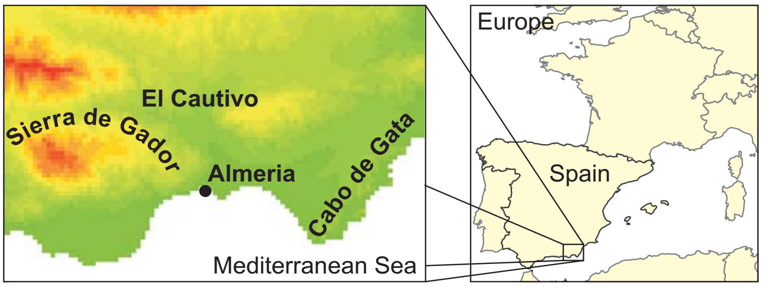

Figure 5: Study site.

In general, the whole area is characterized by a warm and very dry climate with average precipitation ranging from 100 to 500 mm and a low potential evapotranspiration.

3.1 BRDF Experiments

The BRDF experiment comprises spectral reflectance measurements of a 50 x 50 cm test area that are taken with the ASD field spectrometer every 30 min during the diurnal path of the sun (Figure 6). In the initial setup, measurements were acquired with a nadir-looking sensor. In theory, with increasing light angles, the nadir looking sensor records less energy, which will lead to a reduced signal-to-noise ratio and an increased noise in the spectra. This effect was not observed in this laboratory experiment with an artificial light source, but during the field BRDF experiment it was a limiting factor in terms of the daytime of measurements.

Due to technical problems with the field spectrometer during the campaign in SE-Spain, the BRDF experiment was performed in August 2005 in a bio-monitoring recultivation zone in the lignite mine Welzow-Süd near Cottbus, Germany. Undisturbed conditions, an unusual local dry climate and the lack of vegetation make this area ideal for the research on soil parameters. Land degradation processes take place on the area and are accurately measured and controlled throughout the years by different other research projects [6]. Currently, the experiment is re-designed to allow spectral measurements of the surface’s forward scattering at different sensor angles in the future.

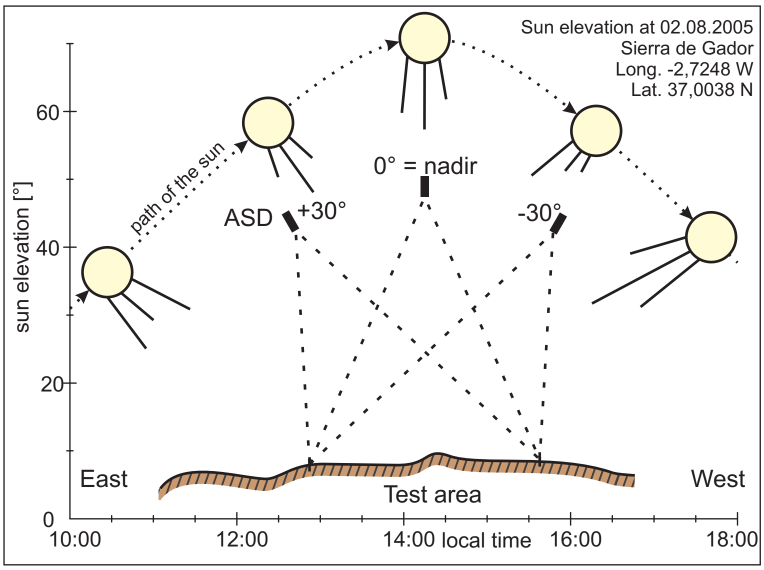

Figure 6: BRDF field experminent settings.

3.2 Upscaling Experiments

The upscaling experiment is designed to test the transferability of the laboratory models to remote sensing data. A 1 x 1m test area is measured with an ASD field spectrometer based on the defined measuring grid (Figure 8). The measurements are taken from 4 different heights to simulate different spatial resolutions (Figure 7). At each height level, the whole test area is measured with a varying number of spectra according to the grid indicated in parenthesis in Figure 7. For example at 30 cm measuring height, 64 spectral measurements are taken to cover the test area (Figure 9). When measuring from 2.50 m height only one spectra is needed (Figure 10). In addition, spectra of the detectable endmembers are recorded in the test area.

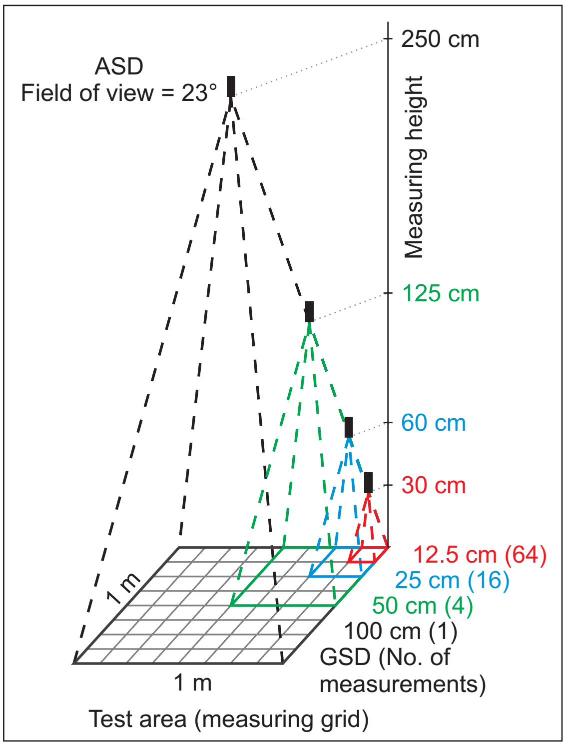

Figure 7: Upscaling field experiment settings.

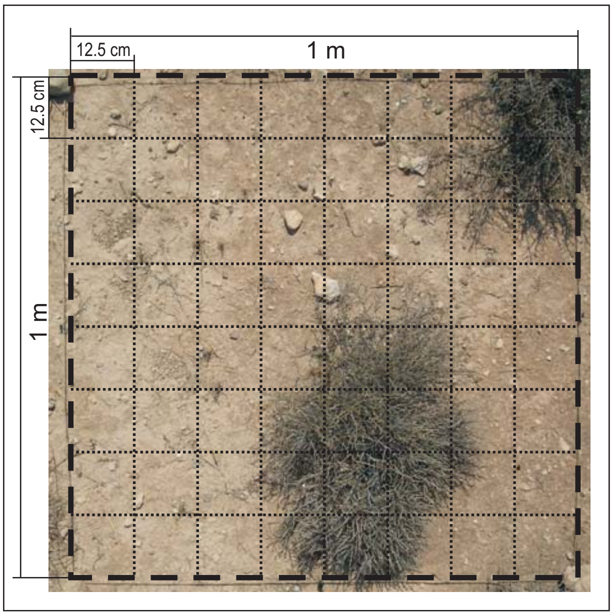

Figure 8: Test area on calcareous-rich soils in Cabo de Gata with indicated measuring grid.

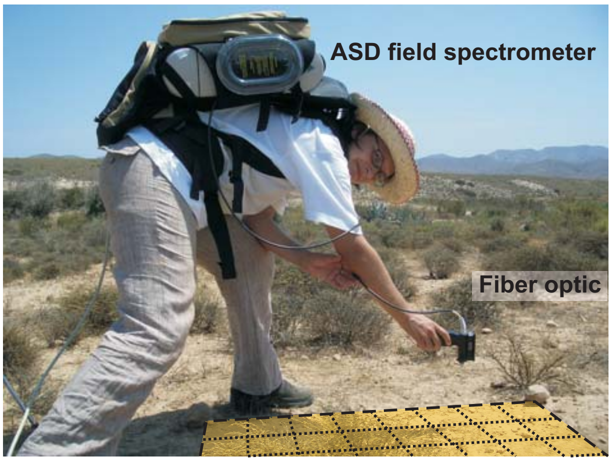

Figure 9: Cabo de Gata - taking spectra at the lowest measuring height (30 cm height -> ~12.5 cm GSD). The measuring grid of the test area is indicated.

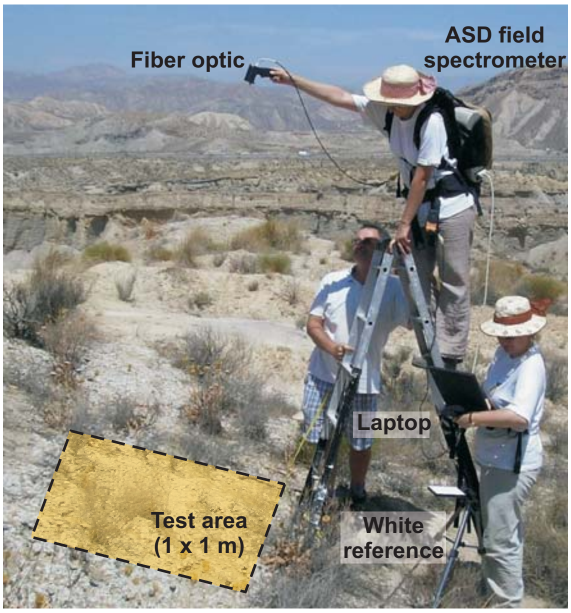

Figure 10: El Cautivo - a ladder is used to aquire spectra at 2.50 m measuring height (~100 cm GSD).

SUMMARY AND OUTLOOK

In the frame of the EU integrated project DeSurvey, first field experiments studying BRDF and upscaling effects have been designed and tested. Spectra of a laboratory experiment were analyzed in terms of the influence of roughness and illumination on spectral reflectance of different soil samples with varying SOC content. The strong influence of iron absorption made it difficult to extract SOC content directly from the spectra.

Following work include the evaluation and improvement of laboratory experiments and field experiments. Procedures will be developed to analyze the experiments measurements. Further the combined influence of the SOC and iron content of soil samples in their reflectance spectra will be studied and models are developed.

ACKNOWLEDGMENTS

The authors would like to thank the European Commission for funding the EU integrated project DeSurvey within the 6th Framework Programme: Global Change & Ecosystems (Project Contract N° 003950). Juan Puigdefabregas and DeSurvey participants are gratefully acknowledged for their intensive work toward the successful start of the project. We also would like to thank Thomas Jarmer from the University of Trier for providing us the soil samples, analytical data, laboratory facilities and his support in laboratory reflectance measurements. For their support during the field campaign in Spain this summer, we like to thank Paula Escribano and Cecilio Oyonarte-Gutierrez from the University of Almeria and Mónica García and Roberto Lázaro Suau from the CSIC-EEZA.

REFERENCES

[1] HILL, J., 2000: Semiarid land assessment: monitoring dry ecosystems with remote sensing. Encyclopedia of Analytical Chemistry. In: Meyers, R.A. (ed.): Encyclopedia of Analytical Chemistry, Chichester, pp. 8769-8794.

[2] HOSTERT, P., RÖDER, A., JARMER, T., UDELHOVEN, T. AND HILL, J., 2003: The potential of remote sensing and GIS for desertification monitoring and assessment. *Int. J. Remote Sens. 24 (20)*, pp. 4019-4034.

[3] BEN-DOR, E. AND BANIN, A., 1994: Visible and near-infrared (0.4-1.1µm) analysis of arid and semiarid soils. *Remote Sensing of Environment 48*, pp. 261-274.

[4] UDELHOVEN, T., HILL, J., SCHÜTT, B., IMESON, A. AND CAMMERAAT, L.H., 1998: A neural network approach for the identification of the organic carbon content of soils in a degraded semiarid ecosystem (Guadalentin, SE Spain) based on hyperspectral data from the DAIS 7915 sensor. In: Schaepmann, M., Schläpfer, D. and Itten, K. (eds.): *1st EARSeL Workshop on Imaging Spectroscopy*, pp. 437-444.

[5] BAUMGARDNER, M.F.; SILVA, L.F.; BIEHL, L.L. AND STONER, E.R., 1985: Reflectance properties of soils. Advances in Agronomy 38, pp. 1-44.

[6] HAUBROCK, S.; CHABRILLAT, S. AND KAUFMANN' H., 2005: Application of hyperspectral imaging for the Quantification of surface soil moisture in erosion monitoring and modeling. *4th EARSeL Workshop on Imaging Spectroscopy,* in press.