Scientific report for the STSM, COST Action ES1306

Tracing vertical transport of soil particles within the vertisol profile

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1. Introduction

Magnetic iron oxide, a black powder of a moderate prize, has been used as a soil erosion tracer within the research activities on various scales at the IAS-CSIC, Córdoba. Guzmán et al. (2010) showed that the tracer binds to soil aggregates and can be easily, and relatively cheaply, detected via its contrasting magnetic properties (magnetic susceptibility). They also conclude that the tracer is immobile in vertical direction during short term experiments.

Currently, based on long term monitoring of the tracer mobility on vertisols, the CSIC team has found indications of deep tracer percolation due to vertisols self-mulching. This opens new possibilities of studying vertical fluxes in vertic soils due to self-mulching, as well as a better understanding of the long-term behaviour of any sediment tracer in this kind of soils.

The purpose of the STSM, besides the gain of the experience related to use of the magnetite tracers, was to prepare a research framework to be able to analyse the vertical distribution of the magnetic traces within the soil profile.

2. The work carried out during the STSM

2.1. Theory of the magnetic susceptibility monitoring

The first days I was introduced into the magnetic susceptibility monitoring technique, including the instruments calibration. I learned how to utilize the measured values for the mass magnetic susceptibility estimation of the air dried soil samples. I got the basics about the magnetic susceptibility theory, commonly used magnetic tracers and the way of tracer and soil mixing.

Magnetic susceptibility system MS2 by Bartington Instruments (UK) was used for the analyses (fig. 1). The system consists of the magnetic susceptibility meter and the susceptibility sensors. For the small disturbed samples we used laboratory Dual Frequency Sensor MS2B and in the field the Surface Scanning Probe MS2D.

Fig. 1 Magnetic susceptibility system. Laboratory sensor (left), Surface scanning probe (right)

2.2. Experiments preparation

We prepared two experiments within the STSM framework

First task was to analyse the Surface Scanning Probe MS2D sensitivity to the vertical position and in-depth distribution of the magnetic tracer. According to the Bartington documentation the probe reaches only upper 15 mm of the soil profile. But we have shown that the detection limit lies beyond this limit. Another reason for the trial preparation is motivated by the fact that the same volumetric magnetic susceptibility come from different magnetite distributions within the soil profile.

We prepared 7 boxes with homogeneous soil of known magnetic susceptibility. The soil was taken from the top horizon at the IAS experimental plots. The soil was air dried at the temperature of 40°C and sieved to obtain particles bellow 2 mm in diameter. Background mass magnetic susceptibility of the soil was measured. Then we prepared three mixtures with different magnetite concentrations (fig. 2). The soil was packed into the paper boxes, each 27 mm thick, the same soil bulk density was maintained. Three boxes were filled with the soil-magnetite mixture, remaining four boxes contained blank soil without the tracer. We measured mass magnetic susceptibility of the individual boxes and then mass magnetic susceptibility of various combinations of the piles of the boxes mimicking various tracer distribution in the soil profiles. Altogether approximately 100 combinations were measured.

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Fig. 2 Dried and sieved soil mixed with the magnetite tracer. The darker mixtures denote higher magnetite concentration.

The second task was to study the vertisols self-mulching. The vertisol was collected from an experimental site in a commercial olive orchard called ‘La Conchuela’ nearby Córdoba, where the IAS team has been monitoring soil erosion and sediment transport since 1999. The soil was treated similarly to the previous soil samples. Vertisol contains significantly higher clay content, therefore it is prone to create very stable aggregates during the long drying process. We had to use 6 mm sieve to obtain sufficient amount of soil for the further experiments. Part of the soil was mixed with magnetite, the rest was placed loosely directly into the pots (fig. 3).

Fig. 3 Olive orchard on vertisols (left). Sieved vertisol in the pots during the wetting process (left).

Soil in the pots was let through the repeated cycles of saturation and drying to consolidate and to mimic the natural swelling–shrinking process. As the preparation of the soil samples and drying/wetting process takes a long time, we were not able to finish this experiment. In a near future the tracer will be applied on the top of the prepared soil samples and the magnetic susceptibility from the top will be monitored during additional drying/wetting cycles. With the use of the calibration data from the previous paper boxes experiments, we will analyse the vertical movement of the tracer.

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3. Main results

Results from the monitoring of the artificially stratified soil profiles with various positions of the magnetite tracer clearly shows that the Surface Scanning Probe reaches by far deeper than to 15 mm. The probe is very sensitive to the tracer close to the surface, the signal decreases exponentially with the depth. But still, we were able to detect the tracer even 10 cm below the surface, even though the measured mass magnetic susceptibility was only 2 % of the tracer susceptibility. An example of the decrease in magnetic susceptibility with the deeper position of the magnetic tracer is on fig. 4. The tests with various tracer concentrations and different layers combinations show the same trends.

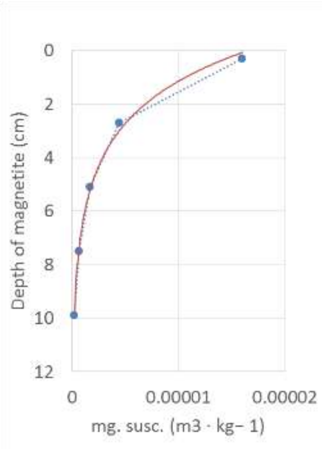

Fig. 4 Example of the decrease of the measured magnetic susceptibility with the depth of magnetic tracer.

At the moment we keep analysing the results in a quantitative manner to be able to estimate the vertical distribution of the tracer from the surface. We have measured enough combinations of the traces positions to be able to calibrate and validate the proposed procedure.

The method will be used during the vertisols experiment. We will keep measuring the magnetic susceptibility of the soil samples in the pots from the top. As the cracks will develop and the tracer will start to migrate into the cracks, we assume the magnetic susceptibility will decrease. Our aim is to relate the decrease in the magnetic susceptibility to the depth of the tracer percolation.

4. Contribution to the Action aims

The STSM stay at IAS CSIC contributes mainly to the aims of ES1306, Working Group 2 (in particular to increase knowledge of sediment connectivity mechanisms across a range of spatial and temporal scales). Our findings suggest a way how to trace also vertical soil movement and how to evaluate the soil profile connectivity.

On top of the STSM project we initiated a collaboration on studying local soil conservation management on vineyards. Farmers are introducing a sediment disconnecting feature called *acerpiados*, a cascades of small dry pools in the rows between the vine trees. Still within the STSM stay we ran initial numerical simulations of the storm water infiltration regime towards the vine root zone. This topic fits well into the objectives of WG2 and WG3.

The mission has helped to strengthen the IAS and CTU teams collaboration in further sediment connectivity research. Thanks to the STSM we have at least two open research questions on which we have been working.

5. Confirmation of the stay

The letter of confirmation by the host institution of the successful execution of the STSM is attached in a separate file.

6. Authorization to post the report at the Action website

I, David Zumr, hereby authorize the Action Committee to post the report at the COST Action website.

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