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Monitoring of the vertical distribution of the magnetite tracer in a shallow soil profile

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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. The tracer binds to soil aggregates and can be easily, and relatively cheaply, detected via its contrasting magnetic properties (e.g. magnetic susceptibility). Previous research indicates that the tracer is immobile in vertical direction during short term experiments, therefore only a little attention has been payed to the vertical extend of the tracer detectability. For studies related to tillage erosion, depth of deposited sediments after an erosion event, or for the description of the Vertisols self-mulching process, the position and distribution of the magnetite tracer within the soil profile is essential. Traditionally two methods to measure the magnetic susceptibility have been used: (i) laboratory analysis of soil samples; (ii) surface probe that integrates the magnetic signal from the shallow soil. But it is unclear into which depth does the surface probe detect the signal and how does the different distribution of the magnetic material affect the measurement of the probe.
A laboratory trial to find a methodology which will enable us to use the magnetic susceptibility monitoring from the surface to identify the depth of the buried tracer in the soil was set up. We prepared 7 boxes, each approximately 3 cm high, with homogeneous soil and three different magnetite concentrations. 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. Magnetic susceptibility was measured using the MS2B and MS2D sensors (Bartington Instruments, UK).
Results from the monitoring of the artificially stratified soil profiles with various positions of the magnetite tracer clearly shows that the MS2D surface scanning probe reaches by far deeper than to 15 mm as is commonly considered. 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. These results highlight the need to have a proper understanding of the distribution in the soil profile of the magnetic material, since different combinations of magnetic materials with different concentrations can results in similar readings by the probe.
For the case of soil tagging with magnetic iron oxides, the same amount of magnetite placed at different depths can provide different magnetic susceptibility values at the field that must be contrasted with laboratory measurements to quantify and normalize the results obtained. The research has been carried out within a STSM financed by COST Connecteur action ES1306 and grant no. TH02030428.