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A multi-tracer field experiment reveals macropore structures and its influence on solute leaching under two contrasting land uses

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Figure 1. From left to right: Preparation of the soil surface by mowing and vacuum cleaning. Ponded infiltration of the multi-tracer solution (Brilliant Blue and KBr). Excavation of vertical profile sections. Auger sampling within a profile along a 10 x 10 cm raster for vol. water content and XRF analysis. Vane shear strength measurement in the mid of each 10 x 10 cm raster. Core sampling for determining the soil hydraulic properties.

Introduction

Leaching of solutes below the root zone is a main source of potential groundwater pollution. In structured soils, preferential flow paths can have a significant influence on rapid leaching of solutes. The relative influence of the macropore network on solute leaching might differ between land uses. The objectives of the present study were (I) to map the macropore network with a dye tracer, (II) analyze the leaching behaviour of a conservative tracer (KBr), and (III) correlate it with physical soil properties (meachanical shear strength, bulk density) under two contrasting land use systems (grassland and cropland with wheat). By applying a new sampling scheme we were able to correlate physical and hydrological observations and reveal the relative influence of the macropore network, the soil texture, and the mechanical state of the soil on solute leaching.

Material and Methods

- Two analyzed land use systems: Grassland and cropland (wheat) at the UK Agricultural Experiment Station Spindletop Farm in Lexington/KY, USA
- Ponded infiltration (h = 25 mm) of 70 mm tracer solution (10 g L^{-1} KBr + 5 g L^{-1} Brilliant Blue) within an area of 1.1 x 0.6 m (Fig. 1)
- Excavation of 11 vertical profile sections per land use (width: 1.1 m, depth: 0.7 m, distance between the profile sections (z): 0.05 m)
- Mapping of stained areas (= macropore-influenced) by digital picture analysis (threshold approach)
- Every other profile: Small-scale sampling for vol. water content, bulk density, and Br^-
- Determination of Br^- concentrations and SiO_2 and Al_2O_3 concentrations (texture proxy) using X-ray fluorescence (Abderrahim et al., 2011)
- Determination of mechanical shear strength using vane shear test (Fig. 1)
- Determination of soil hydraulic properties by evaporation experiments (not shown)

Results

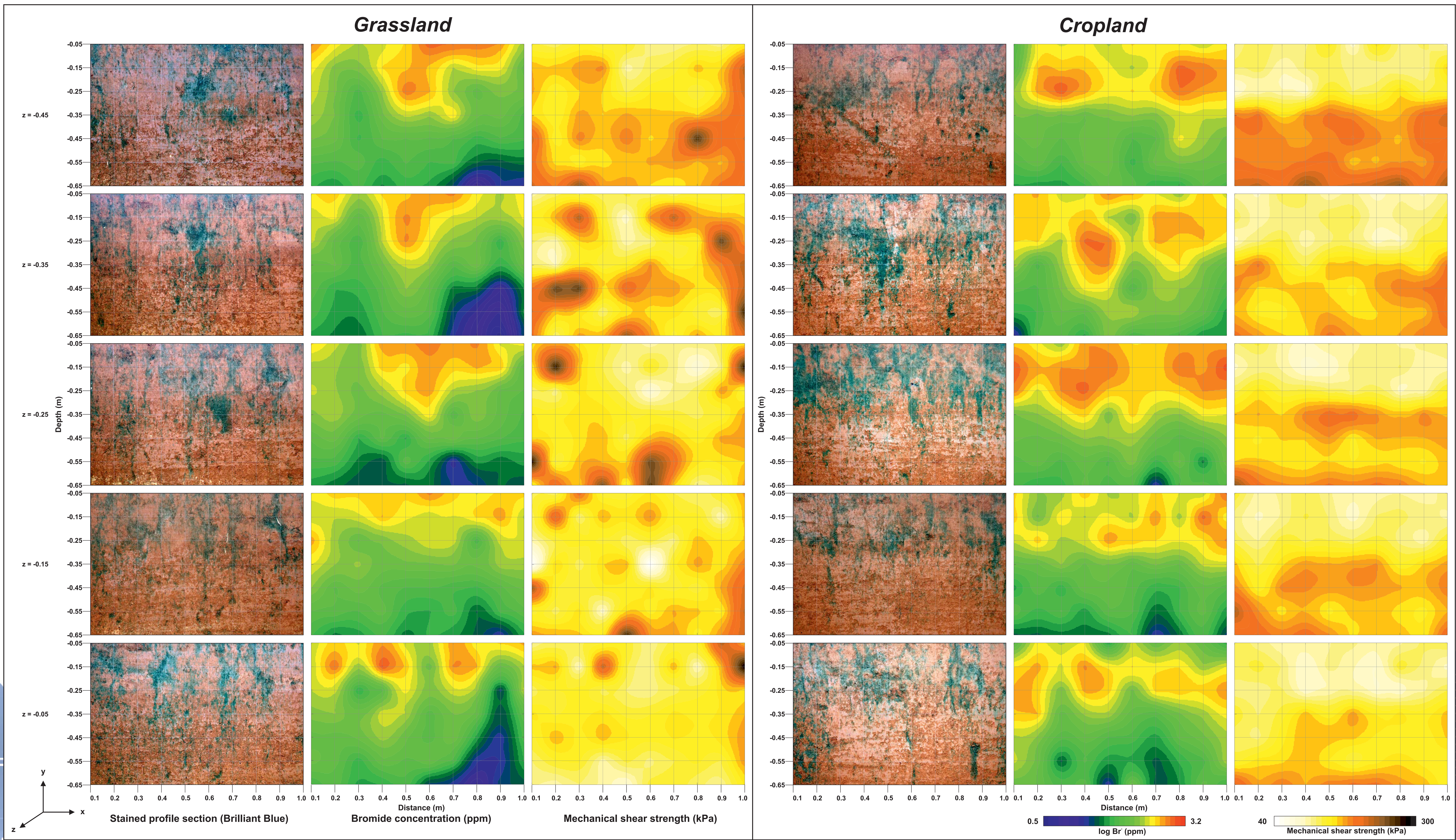

Figure 2. Results of the tracer infiltration experiment for grassland (left) and cropland (right). The stained areas in the profile sections (left section) denote soil areas that are influenced by preferential infiltration pathways (earthworm burrows and areas around plant roots). Bromide concentrations (mid section) indicate soil areas that were affected by the total solute transport process (macropores + matric flow). Informations about the mechanical state of the soil profiles are given by the shear strength (right section).

Key findings:

- Solute transport as indicated by the conservative tracer KBr distinctly differed between the analyzed land use systems (grassland and cropland; Fig. 2): Under cropland most of the tracer remained in the formerly tilled topsoil above the more compacted subsoil (indicated by the distinct difference in mechanical shear strength, Fig. 2), whereas grassland resulted in a patchy tracer distribution with most of the bromide remaining close to the soil surface.
- Conservative tracer displacement correlated with the spatial occurence of preferential flow paths and its surrounding as indicated by dye tracer in both land uses. Grassland inhibited a more developed macropore network throughout the analyzed profile depth.
- XRF signal intensities of SiO_2 can be used as a proxy for soil texture (sand content). This method allows a rapid estimation of general texture trends within a large number of samples. Bromide displacement depth increased with increasing sand contents (Fig. 3).

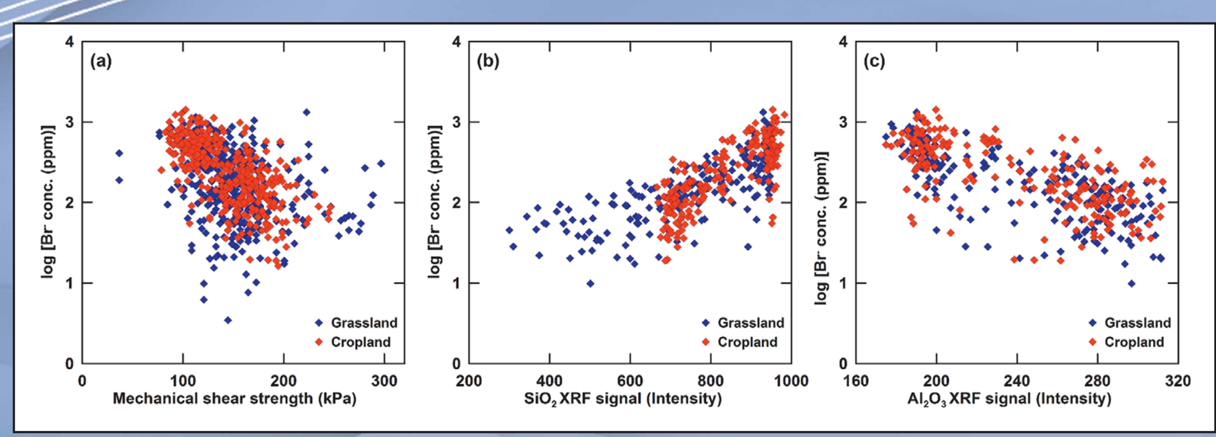

Figure 3. Observed Br^- concentrations at both land uses (grassland and cropland) as a function of (a) mechanical shear strength, and signal intensities of (b) SiO_2 and (c) Al_2O_3.

Reference: Abderrahim, H., L. Candela, I. Queralt, K. Tamoh, and A. Maslouhi, 2011. X-Ray Fluorescence Analysis for Total Bromide Tracking in the Vadose Zone: Results for Mnsara, Morocco. Vadose Zone J. 10: 1-5.