PROTEA: Automation of preferential flow analysis in the field using hybrid artificial intelligence methods

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Purpose and aims

The main goal of this project is to design and build an artificial intelligence-based tool to automate the detection and characterization of preferential flow in soils using a dataset of images of stained soil profiles. Specifically, the AI-based tool should be able to: 1) recognize and characterize preferential flow pathways, and 2) quantify the degree of preferential flow.

Potential research questions (RQ)

RQ1: What type of visual approach of AI can be used to classify efficiently different types of water flow in soils using a limited number of images? RQ2: What AI-based algorithm can be used to automatize the calculation of the degree of preferential flow?

PROTEA: Automation of preferential flow analysis in the field using hybrid artificial intelligence methods. This proposal is oriented to be developed as a master thesis project at the Department of Computing Science, Umeå University. The thesis will be co-supervised by Dr. Aida Bargués Tobella (Department of Forest Ecology and Management, Swedish University of Agricultural Sciences (SLU), Umeå, Sweden), Dr. Esteban Guerrero (Department of Computing Science, Umeå University (UMU), Umeå, Sweden), Dr. Tor. G Vågen and Leigh. A Winowiecki (World Agroforestry (ICRAF), Nairobi, Kenya).

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Background

Images of stained soil profiles showing a gradient in the degree of preferential flow. Preferential flow (PF) in soil describes a non-uniform flow mechanism in which water and solutes move through the vadose zone along preferred pathways, bypassing much of the porous soil matrix (Beven & Germann, 2013; Hendrickx & Flury, 2001). The occurrence of PF influences the residence time of water in the vadose zone, which in turn is linked to

groundwater recharge and the transport of nutrients and contaminants such as pesticides and trace metals. Hence, characterizing PF is critical for reliable prediction of water, solute, and particle transport in soils (Simunek et al., 2003). Dye tracing techniques constitute one of the most frequently used methods to quantify PF (Allaire et al., 2009). Dye tracing experimentation methodology involves several steps: a) applying a soluble dye at the soil surface, typically as a solution b) excavating the soil profile, c) taking a picture of the stained soil profile, and d) performing image analysis of the profile pictures to quantify the degree of PF. Whereas the first three steps (a-c) are reasonably straightforward to implement and require elementary equipment, the image analysis step (d) of stained soil profiles is complex and often constitutes a bottleneck of dye tracing experiments. Most hydrologists, ecohydrologists, and soil scientists often lack the expertise to perform complex image analysis, and therefore the quantification and characterization of PF from stained profiles is restricted to a narrow group of experts or limited to few simple calculations. Currently, artificial intelligence (AI)-based techniques are to a great extent a key underlying technology for the prediction and detection of data-driven phenomena. Some AI techniques (e.g. machine learning algorithms) rely on the mathematical manipulation of data such as images or videos, others use rule-based mechanisms, for example, considering policies, guidelines, or expert domain information. Roughly, the first type of AI mechanism, AI learning, is used when enough data is available, however in cases where data is scarce and inconsistent, reasoning approaches are suitable. AI mechanisms applied to dye tracing experiments (e.g. images of stained soil profiles) provide accurate results; the technique for applying the dye highly influences the data collection and its interpretation (Allaire et al., 2009). Then, the project aims at combining AI approaches of machine learning (e.g. image data analysis, pattern detection, etc.), and reasoning (e.g. answer-set, logic programming) to solve the aforementioned research questions.