



## Image analysis of dye stained patterns in soils

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Quality of surface water and groundwater is directly affected by flow processes in the unsaturated zone. In general, it is difficult to measure or model water flow. Indeed, parametrization of hydrological models is problematic and often no unique solution exists. To visualise flow patterns in soils directly dye tracer studies can be done. These experiments provide images of stained soil profiles and their evaluation demands knowledge in hydrology as well as in image analysis and statistics.

First, these photographs are converted to binary images classifying the pixels in dye stained and non-stained ones. Then, some feature extraction is necessary to discern relevant hydrological information. In our study we propose to use several index functions to extract different (ideally complementary) features. We associate each image row with a feature vector (i.e. a certain number of image function values) and use these features to cluster the image rows to identify similar image areas. Because images of stained profiles might have different reasonable clusterings, we calculate multiple consensus clusterings. An expert can explore these different solutions and base his/her interpretation of predominant flow mechanisms on quantitative (objective) criteria.

The complete workflow from reading-in binary images to final clusterings has been implemented in the free R system, a language and environment for statistical computing. The calculation of image indices is part of our own package `Indigo`, manipulation of binary images, clustering and visualization of results are done using either build-in facilities in R, additional R packages or the  $\text{\LaTeX}$  system.