Mapping spatial distribution of preferential flow using earthworm distribution models in combination with tracer infiltration patterns

Loes van Schaik*[(1)], Juliane Palm[(1)], Julian Klaus[(2)], Boris Schröder[(1,3)], Erwin Zehe[(2)]

•*contact: schaik@uni_potsdam.de*

(1) University of Potsdam, Institute of Earth and Environmental Sciences, Potsdam, Germany , (2) Technical University of Munich, Institute of Water and Environment, Germany

(3) Leibniz Centre for Agricultural Landscape Research (ZALF) e.V., Müncheberg, Germany

Funded by DFG

Biopore Project

Infiltration variability in the topsoil strongly determines the distribution of precipitation water to surface runoff, soil moisture storage and percolation towards groundwater. Preferential infiltration often takes place along macropores of biological origin, such as earthworm burrows and root channels. Previous research by Zehe and Flühler (2001) showed that earthworm presence was the main cause of preferential flow in the Weiherbach Catchment (Baden-Württemberg, Germany).

The aim of the Biopore project is therefore to link spatiotemporal earthworm distribution models with a preferential flow model to obtain an integrated eco-hydrological model.

Fig 1. Dye-tracer infiltration pattern, with macropores

Fig 2. *Lumbricus terrestris* earthworm in stained macropore at 90 cm soil depth

There are three different earthworm types which have different burrowing patterns. These result in varying infiltration patterns: from rapid deep vertical infiltration to a stronger diffuse distribution of water and solutes in the upper soil layers. Thus the spatial distribution of different ecological earthworm types can help us to understand the spatial variability in preferential infiltration patterns.

Here the relationships between infiltration patterns, macropores and abundance of different earthworm species are presented.

Weiherbach Catchment

The Weiherbach is an agricultural area with slightly undulating relief in the south-west of Germany . The area is covered with a Loess layer of up to 15 m thickness. The climate is semi-humid with 750-800 mm/yr average annual precipitation and an average annual runoff of 150 mm/yr. The average annual air temperature is 8.5 C.

The land-use is mainly agricultural, with tillage practices varying from reduced-tillage to conservational tillage.

The spatiotemporal distribution patterns of earthworms were modeled using soil properties (organic matter content, texture, soil moisture), and topography (slope, elevation) as predictors for earthworm occurrence, abundance and biomass.

Fig 3. Weiherbach Catchment with 16 measurement locations (●).

Measurements

At 16 locations in the Weiherbach Catchment (see Fig. 3) a set of measurements were performed in March 2010:
- dye tracer rainfall experiments with approx. 43 mm/h on 1 m^2;
- earthworm extraction using a mustard solution on 0.25 m^2 ;
- profile excavation: three vertical and three horizontal profiles;
- macropore counting and labeling in size groups (<2 mm, 2-6 mm, >6 mm) and stained or non-stained;
- additional descriptional data: local slope, topographical position, crop, tillage condition;
- soil physical measurements in different soil depths: texture, initial moisture content, temperature, porosity, bulk density, saturated conductivity.

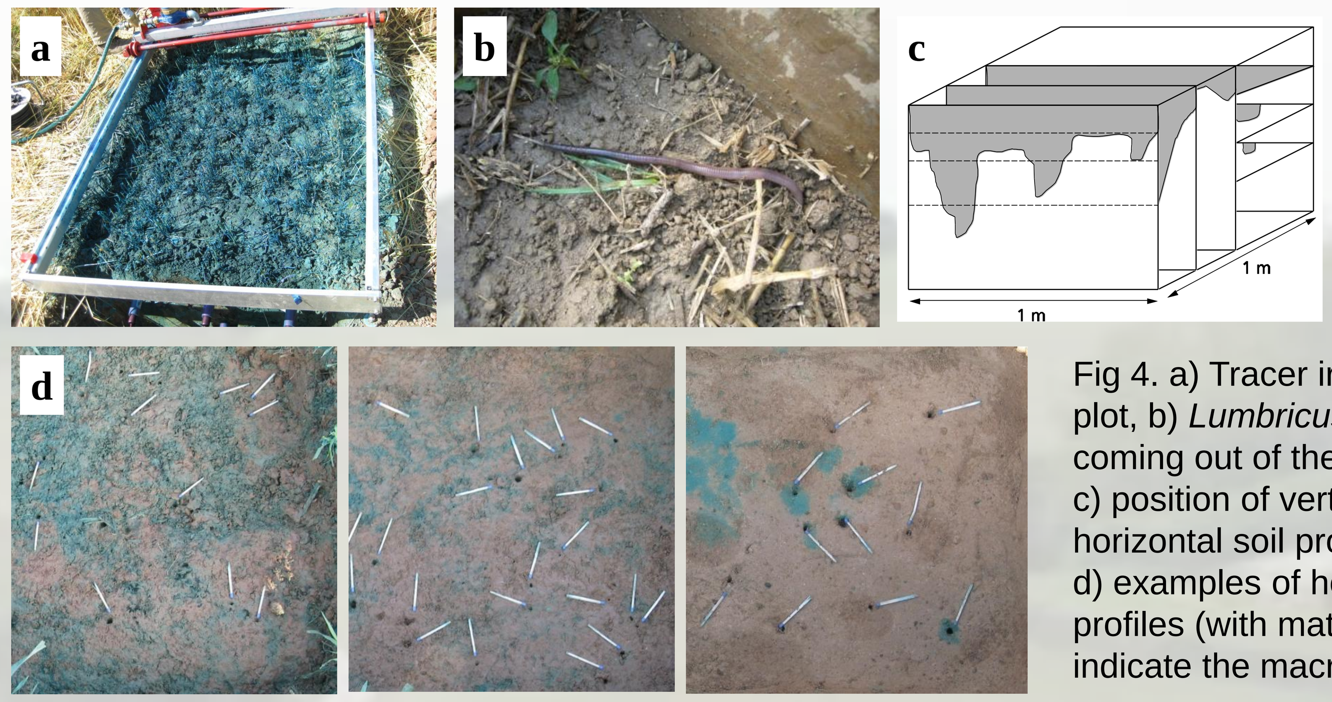

Fig 4. a) Tracer irrigated plot, b) *Lumbricus terrestris* coming out of the soil, c) position of vertical and horizontal soil profiles, d) examples of horizontal profiles (with matches to indicate the macropores).

Acknowledgements

We gratefully acknowledge the funding of the Biopore Project, which is provided by the DFG (grant no. SCHR 1000/3-1 and ZE 533/5-1). Furthermore we would like to thank Markus Morgner for his invaluable support in the field. The students (Teresa, Josephine, Silvio, Lina, Thorsten & Carolina) are also thanked for their efforts in the field.

Results and Discussion

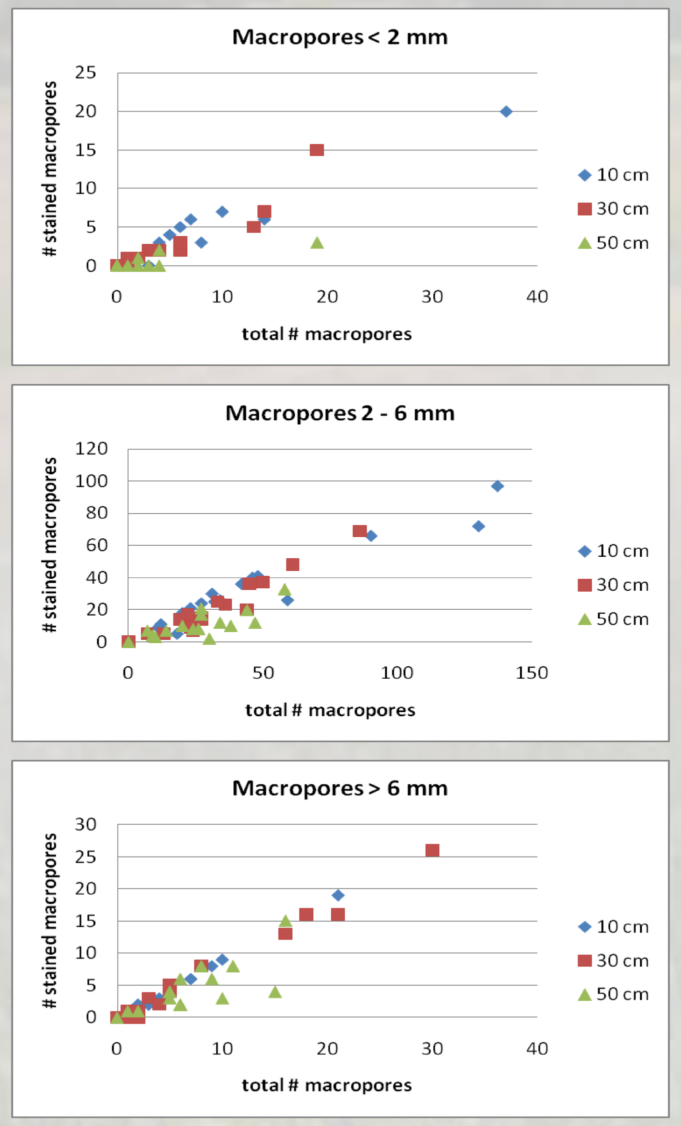

Fig. 5 Numbers of active macropores related to the total number of macropores, for different size classes and profile depths

Relationships earthworm types and different macropore classes (Table 1)

As can be expected of the different ecological earthworm types the correlation coefficients show that the endogeic worms are mainly correlated with the small sized macropores in 10 cm soil depth, while the Lumbricus terrestris is mainly correlated with the larger sized macropores (>6 mm) in all soil layers.

Table 1. Correlation coefficients for different earthworm types and macropore classes in various soil depths. Blue marked correlations are significant at $p < .050$ (Biomass = BM, number of worms = #, Endogeic = ENDO, Epigeic = EPI and Lumbricus Terrestris = LT).

	Macropores: 10 cm			30 cm			50 cm		
Earthworms:	<2	2-6	>6	<2	2-6	>6	<2	2-6	>6
BM_ENDO	.57	.32	.33	.08	.17	.38	.78	.37	.69
BM_EPI	-.09	.10	.17	-.12	.54	-.05	.07	.44	-.06
BM_LT	.11	.09	.78	.25	.32	.93	.60	.35	.83
#_ENDO	.66	.29	.40	.05	.15	.54	.79	.32	.81
#_EPI	-.07	.17	.20	-.10	.69	-.03	.17	.54	-.05
#_LT	.06	.29	.76	.21	.51	.79	.55	.49	.68

Macropore effectivity (Fig. 5)

The relationship between total number of macropores and active macropores is linear for the different pore sizes and also for the different soil depths. The strength of this relationship does decrease with depth (R^2> 0.9 for the first two soil layers and R^2 between 0.5 and 0.7 for 50 cm depth). Generally the relative amount of macropores which are stained decreases with depth.

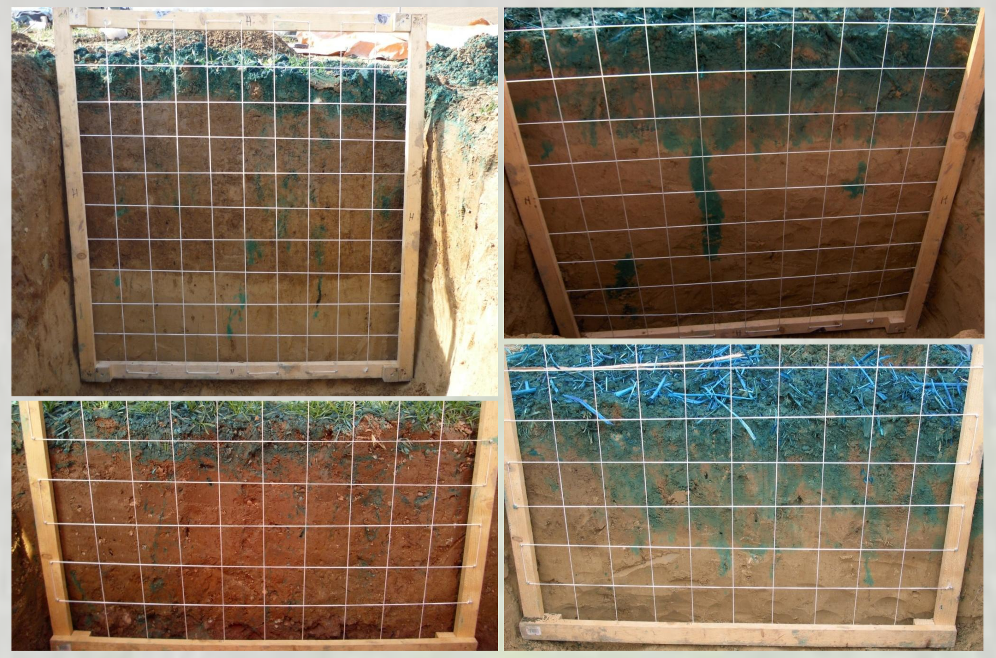

Fig. 6 Infiltration profiles showing a large variability in infiltration front at soil surface and infiltration from macropores to the matrix

Parameterisation of preferential flow (Fig. 6)

Due to the high rainfall intensity used for this study the stained infiltration patterns should be seen as potential preferential flow patterns. Under natural circumstances the matrix infiltration capacity in the topsoil strongly determines the distribution of rainfall to matrix or macropores. Also the interaction between macropores and matrix determines the effectivity of macropore flow over larger depths or distances. Thus the earthworm distribution models may be used to quantify the spatial distribution of potential preferential flow paths. The next important step is to take into account the transient distribution of infiltration to preferential flow paths under natural conditions, by explicit hydrological parameterisation of matrix and macropore characteristics (van Schaik et al, 2010).

Conclusions and Outlook

- The abundance and biomass of different earthworm types are correlated to different sizes of macropores in different soil depths;
- The amount of flow effective macropores is linearly related to the total number of macropores;
-The distribution of water to the macropores or matrix of course strongly depends on the matrix characteristics;

For the Weiherbach Catchment spatiotemporal distribution patterns of earthworms were modeled using soil properties (organic matter content, texture, soil moisture), and topography (slope, elevation). In future the results of the spatiotemporal distribution patterns of earthworms will be used as indicator for potential spatiotemporal occurrence of preferential flow. For the modelling of actual preferential flow occurrence however the matrix parameterisation using infiltration patterns and soil physical measurements however will have to be included.

References

-Van Schaik, N.L.M.B., Hendriks, R.F.A., van Dam, J.C. (2010) Use of dye-tracer infiltration patterns for the macropore parameterization of a physically based model (SWAP). Vadose Zone Journal 9 (1), p. 95–106.
- Zehe, E., Flühler, H. (2001): Slope scale variation of flow patterns in soil profiles. Journal of Hydrology 247, p.116-132.

For further information please keep an eye on the Biopore project website:
http://brandenburg.geoecology.uni-potsdam.de/users/schroeder/biopore/home.html