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Significance of earthworm burrows for runoff processes

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Introduction

The knowledge of runoff generation is a basic prerequisite for process-related hydrologic modelling and for an effective flood risk management. Nevertheless, the spatial variability of soils and site conditions make it difficult to identify the specific mechanisms of discharge generation at the plot scale or even at catchment scale. Apart from the approximate calculation of matrix flow, the Richards-equation is not adaptable to the turbulent macropore flow, which is the main process of subsurface flow along preferential pathways like earthworm burrows. Consequently the implementation and assessment of earthworm burrows in commonly used hydrologic models presents an unresolved problem. This study contributes to the knowledge of the main processes of discharge generation in differing landscapes, by analysing the significance of earthworm burrows.

Experimental Setup

Sprinkling-experiments[1] combined with multi-attribute soil analyses were performed in the Mesozoic Trier-Bitburger basin for different land use types (arable land, grassland, forest) and a number of different substrates (sandy and loamy/ clayey)[2]. The overall goal was to identify the key-predictors dominating the respective runoff process. For this purpose, the experimental setup included the survey of earthworm burrows in different layers and the classification of species.

Results and Discussion

Deep percolation was found to be the dominant process for sandy substrates, where infiltration and percolation was mainly a result of the high number of macropores due to the texture (Table 1). The relevance of earthworm burrows in these highly permeable substrates is negligible. The statistically verified non-correlation between the number of

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[1] Four 15-minute intervals of 10 mm precipitation in between four hours were applied to a 50 m² area. At the bottom of the plot, a trench was excavated (3 m wide, 1.5 m deep). Discharge from the trench front was recorded in three different depths (near surface, plough pan, lithological discontinuity) via notched steel sheets and gutters. Soil moisture at the beginning of the experiments: saturated field capacity (pF > 1.8).

[2] RSG: Brunic Arenosol, Endodystric (parent material: unconsolidated sand)
RSG: Haplic Planosol, Orthoeutric (parent material: loess loam above calcareous and clayey marls).

earthworm burrows and the saturated hydraulic conductivity (Ks) confirms this conclusion ($r_S = -0.40^*$).

In contrast to the sandy soils, earthworm burrows and an impermeable subsoil were the most important factors for the lateral subsurface flow that occurred in multilayered loamy to clayey soils. The correlation to the saturated hydraulic conductivity was found to be highly significant ($r_S = 0.76^{**}$).

Tab. 1: Runoff coefficients [%] (DP = Deep Percolation, SSF = Subsurface Flow, SOF = Saturated Overland Flow, HOF = Overland Flow, SW = Stagnic Water)

	DP	SSF	SOF	HOF	SW
Sandy substrate					
arable land 1	85			15	
arable land 2	89			11	
arable land 3	70			30	
grassland 1	61			39	
grassland 2	100				
grassland 3	100				
forest 1	98			2	
forest 2	100				
forest 3	100				
Loamy substrate					
arable land 1		17			83
arable land 2		21			79
arable land 3		40	15		45
grassland 1		23		42	35
grassland 2				59	41
grassland 3				50	50
forest 1		27			73
forest 2		70			30
forest 3		37	30		33

Comparing the different substrates, the overall quantity of burrows was much higher in the loamy substrate (Figure 1).

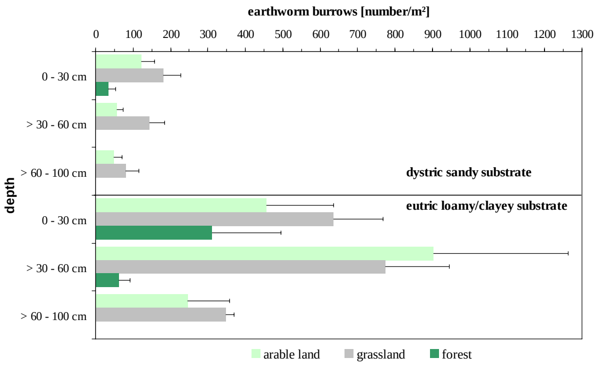

Figure 1: Number of earthworm burrows depending on land use and substrate conditions (n = 9).

However, both substrates showed similar relative macroporosity due to the land use: grassland > arable land > forest. Unlike agricultural land, forests are characterised by less earthworm abundance and the absence of the anecic ecological group (lower pH-values), and thus by a lack of earthworm burrows in the subsoils (Figure 2). The crucial preferential pathways under forests are pipes of decomposed tree roots.

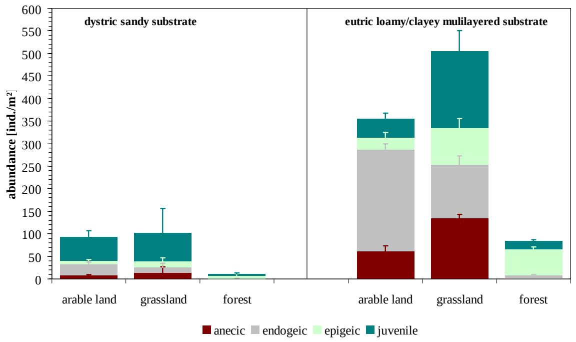

Figure 2: Abundance of ecological groups depending on land use and substrate conditions (n = 9).

Due to the findings, it is obvious to challenge some of the simplified approaches employed in process-related hydrologic models. These models often assess macroporosity without any site differentiation and generalise the influence of land use in a disputable sequence: forest > grassland > arable land (Table 2).

Table 2: Example of model-specific options to assess macropores in Topmodel, WASIM-ETH (Bronstert et al. 2001, modified)

land use	macropores [Vol.-%]
spring grain	1,0
vineyard	1,0
fruit	1,0
arable land	1,0
grassland	1,2
natural grassland	2,0
coniferous forest	2,0
mixed forest	2,2
deciduous forest	2,4

The more empirical approach by Scherrer (2004) relates the number of counted earthworm burrows observed to their hydraulic relevance (Tab. 3). For this purpose he multiplies the larger burrows by a factor five to weight their assumed major influence for infiltration.

Table 3: Assessment of macroporosity (Scherrer 2004, modified)

earthworm burrows/m^2	**hydraulic relevance**	**macroporosity**
0 - 40	low infiltration	low
40 - 70	critical range	moderate
70 - 150	normal infiltration	high
> 150	high infiltration	very high

According to this study, the mentioned classification scheme of Scherrer (2004) was not suitable to indicate the measured differences in runoff generation. Rather, it was essential to count all burrow diameter classes accurately, not only the largest ones. Certainly the burrow classes > 5 mm are the most straightforward to observe and measure, and the deep going (but predominantly vertically orientated) macropores of especially *L. terrestris* are important. However, the smaller burrows formed by endogeic species and juveniles outnumber the larger burrows. Nevertheless, in a soil physical point of view, they are still macropores (Figure 3).

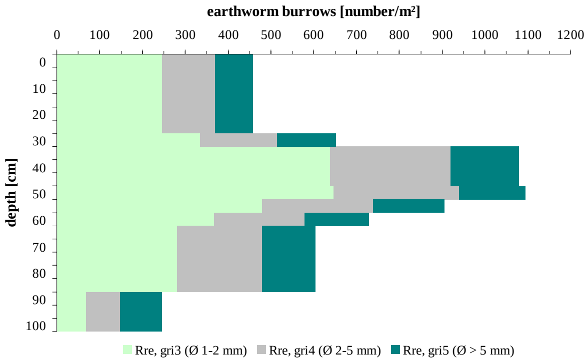

Figure 3: Example of vertically distributed earthworm burrow classes; arable land, loamy/clayey multilayered soil (n = 9)

These dense array of smaller burrows affect high infiltration and percolation capacities by building a continuous lateral pore-network which induces subsurface flow. Using tracer-marked sprinkling water it was possible to detect a remarkable mean subsurface flow velocity of around 80 m/d in an otherwise poorly permeable soil matrix.

Conclusions and Prospects

Earthworm burrows are the most relevant pores for infiltration, percolation and retention of heavy rainfall in soils without a high textural permeability. To benefit from deep macropored soils, it is necessary to promote land uses, that enhance the living conditions for earthworms as much as possible.

The development of a classification scheme to assess the hydraulic relevance of earthworm should be one objective of further research. In this case study, a number of < 300 burrows/m^2 indicates a limit for infiltration and percolation, and thus saturated overland flow occurred.

References

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