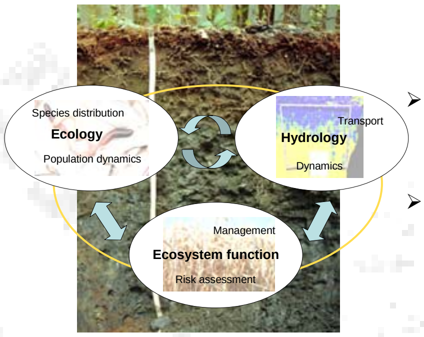
Linking spatial patterns of anecic earthworm populations, preferential flow pathways and agrochemical transport in rural catchments: an ecohydrological model approach

Juliane Palm [1]* , Julian Klaus [2] , Boris Schröder [1], Erwin Zehe [2]
[1] University of Potsdam, Institute of Geoecology; [2] Technical University of Munich, Institute of Water and Environment
* juliane.palm@uni-potsdam.de

Earthworms play an important role in soil and ecosystem functioning and are known as “ecosystem engineers”. Through their burrowing activity they modulate the soil structure, increase the pore space, effect filter function and soil aeration, transform soil and organic matter and provide nutrients for plants. Earthworm burrows are preferential flow pathways for water and solutes, especially the vertical burrows of anecic earthworm species such as *Lumbricus terrestris*. On one hand increased infiltration and preferential flow prevent surface runoff and soil erosion. But on the other hand, agrochemicals have the risk of being transported into deeper soil layers where their degradation is much slower. So this study combines earthworm ecology and soil hydrology to understand transport processes and to make predictions for land use management and risk assessment.

Aims of the project

- Modelling the spatial distribution and population dynamics of anecic earthworm populations (*Lumbricus terrestris*)
  - understanding and prediction of distributional patterns depending on soil properties, terrain, land use (hierarchical, multi-scale species distribution model[1])
  - understanding and prediction of population dynamics depending on soil properties, resource availability and disturbance (stage-structured matrix population model[2-4])
- Modelling related patterns of connective preferential flow pathways and space-time-pattern of infiltration and travel depth distribution of solutes
  - stochastic transport model depending on macropore distribution, initial and boundary conditions (CATFLOW[5, 6])



- Integrating both topics into an ecohydrological model applicable for catchment-scale risk assessment that may assist agro-chemical registration
- General research questions:
  - how do small-scale patterns regulate large-scale processes in rural landscapes?
  - how do feedbacks between earthworm engineering and transport characteristics affect the functioning of (agro-) ecosystems?

Design

- Study area: Weiherbach catchment in Kraichtal (Baden-Württemberg, Fig. 1)
- Loess soils with high erodibility and intensive agriculture
- Earthworm sampling takes place on different fields (land use, soil type, tillage practices), different scales (large scale and small scale variability) and at different times (spring, summer, fall)
- After extraction with mustard solution earthworms are identified, counted and weighted
- Measurement of soil related predictor variables (grain size, bulk density, pH, organic matter content, nutrients)
- Experimental measurements of infiltration capacity of the soil surface, maximum water fluxes in macroporous soil samples and infiltration rates of single earthworm burrows
- Continuous monitoring of air temperature and air humidity and in some fields also soil temperature and soil moisture
- Irrigation and transport experiments on field scale with tracers (Brilliant Blue, Bromide) and two different herbicides

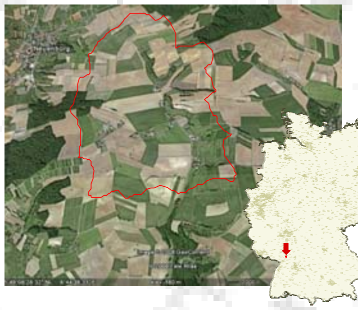
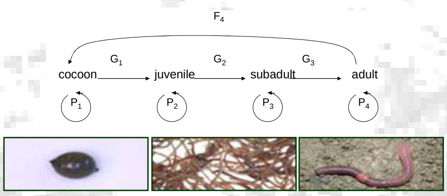


Fig. 1: Location and aerial photograph of Weiherbach catchment.

First results



$$M=\begin{pmatrix} P_1 & 0 & 0 & F_4(T) \\ G_1(T,\theta) & P_2 & 0 & 0 \\ 0 & G_2(T,\theta) & P_3 & 0 \\ 0 & 0 & G_3(T,\theta) & P_4 \end{pmatrix}$$

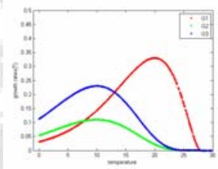


Fig. 2: Life cycle graph and transitions matrix for stage-structured population dynamic model. Fecundity and transitions probabilities depend on temperature and soil moisture (O'Neill functions)[4].

- A first approach of a stage-structured matrix model for *L. terrestris* was developed. Fecundity and transition probabilities depend on temperature and soil moisture, represented by means of the O`Neill function[4].
- A first tracer experiment with Brilliant Blue on a field with low anecic earthworm activity has shown strong connective flow pathways until depth of 1. 20 m.
- Former experiments in the Weiherbach catchment have shown great differences in pesticide transport between fields with and without earthworm burrows (Fig.3)
- Earthworm sampling on 30 different agricultural fields (150 plots) have shown that *Lumbricus terrestris* is present at nearly all sites but with high variability in abundance and biomass.
  - Fields with intensive land use over several years have a very low *L. terrestris* density and biomass, whereas fallows or former fallows are characterised by high biomass
  - Fields with organic fertilisers seem to exhibit a higher earthworm activity than those with mineral, but soil analysis will bring more details
- Small scale variability within the same field seems to be more relevant for the earthworm distribution. On the margin of the fields, earthworm activity is much higher than in the centre as the different numbers of casts at the soil surface show.

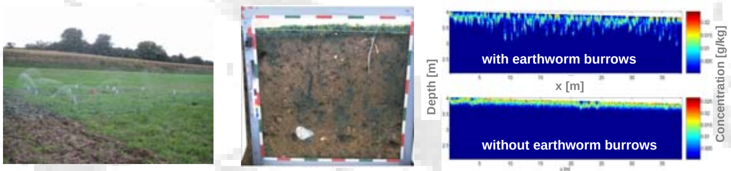


Fig. 3: Irrigation experiment with Brilliant Blue tracer in a vertical soil profile and the simulated transport of pesticides.

References:
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