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Ecohydrological modelling

Linking spatiotemporal earthworm models to preferential flow

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

B I O P O R E

DFG-Project 2007-2011



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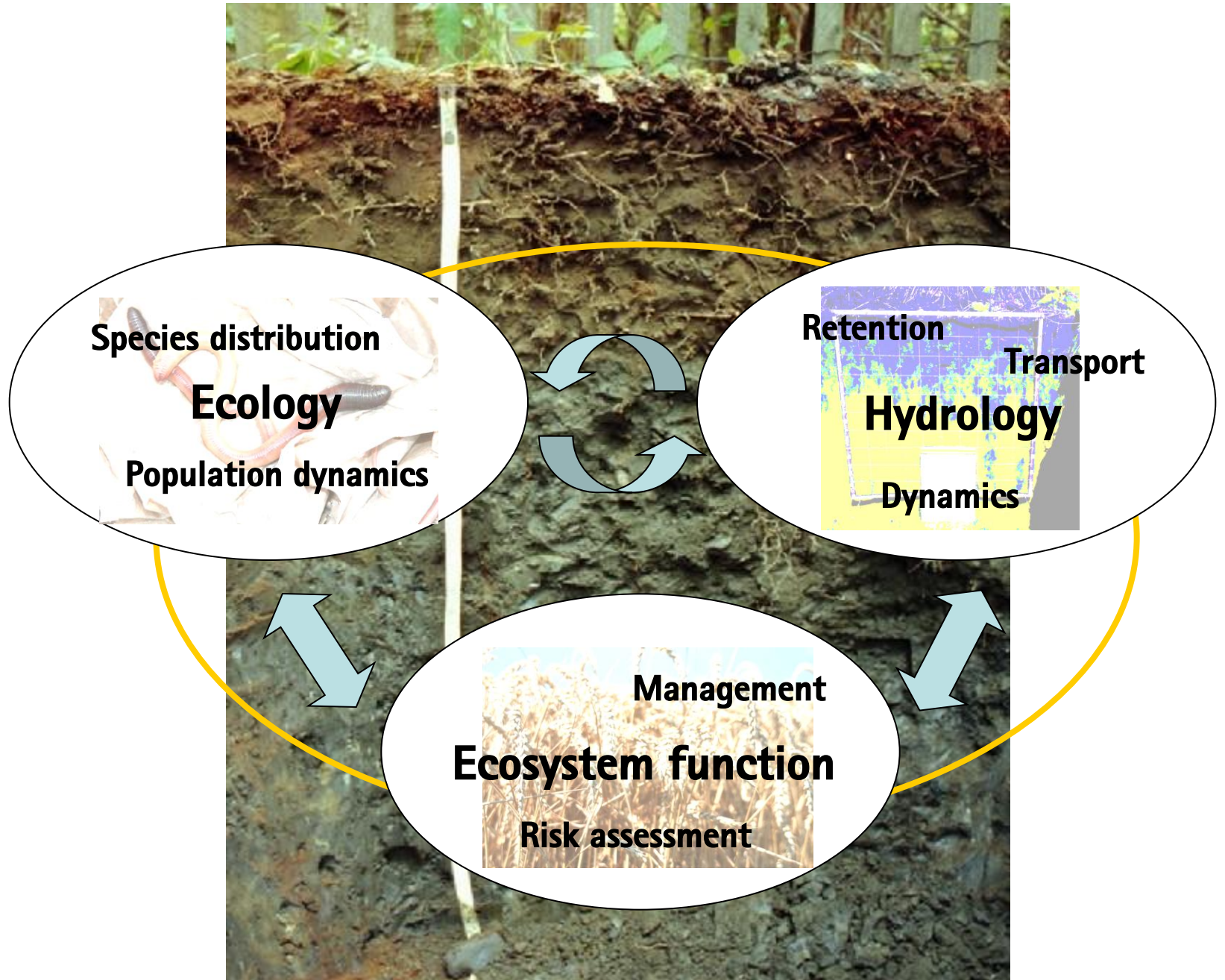
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Biopore



Aims

Integrated ecohydrological model linking

- **Spatiotemporal distribution patterns and population dynamics of anecic earthworms**
- **Spatiotemporal patterns of connective preferential flowpaths (i.e. earthworm burrows)**
- **Spatiotemporal patterns of transport and degradation of agrochemicals considering feedbacks between abiotic and biotic processes**

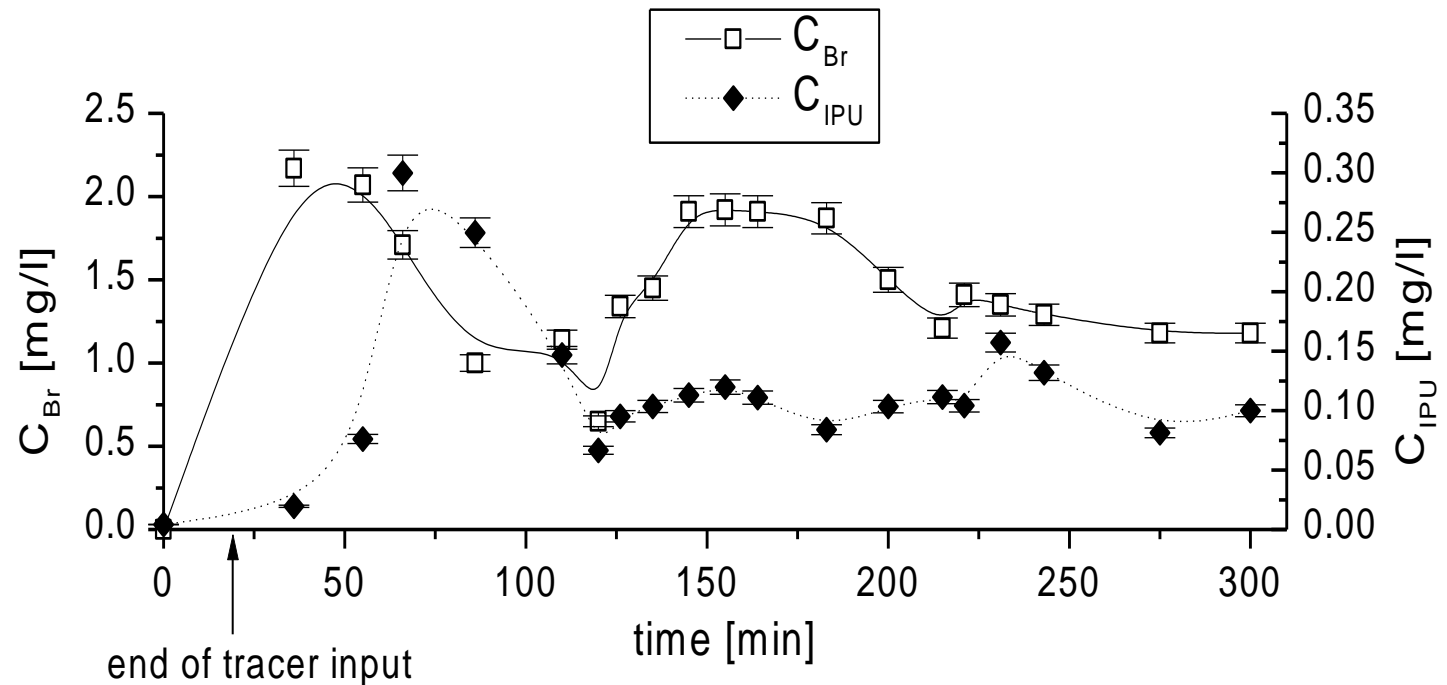
Preferential transport in agroecosystems

Weierbach catchment: tile-drained arable land (1000 m²)

- Isoproturon application
- in three phases, tracer pulse after 10 min

Fast breakthrough in 1.2 m depth

- Tracer: 20 min, IPU peak: 50 min



Preferential transport

Tracer experiments

- Earthworm burrows as transport pathways
- Fast transport: up to 340 $\mu\text{g}/\text{kg}$ into 1 m depth within 2 h



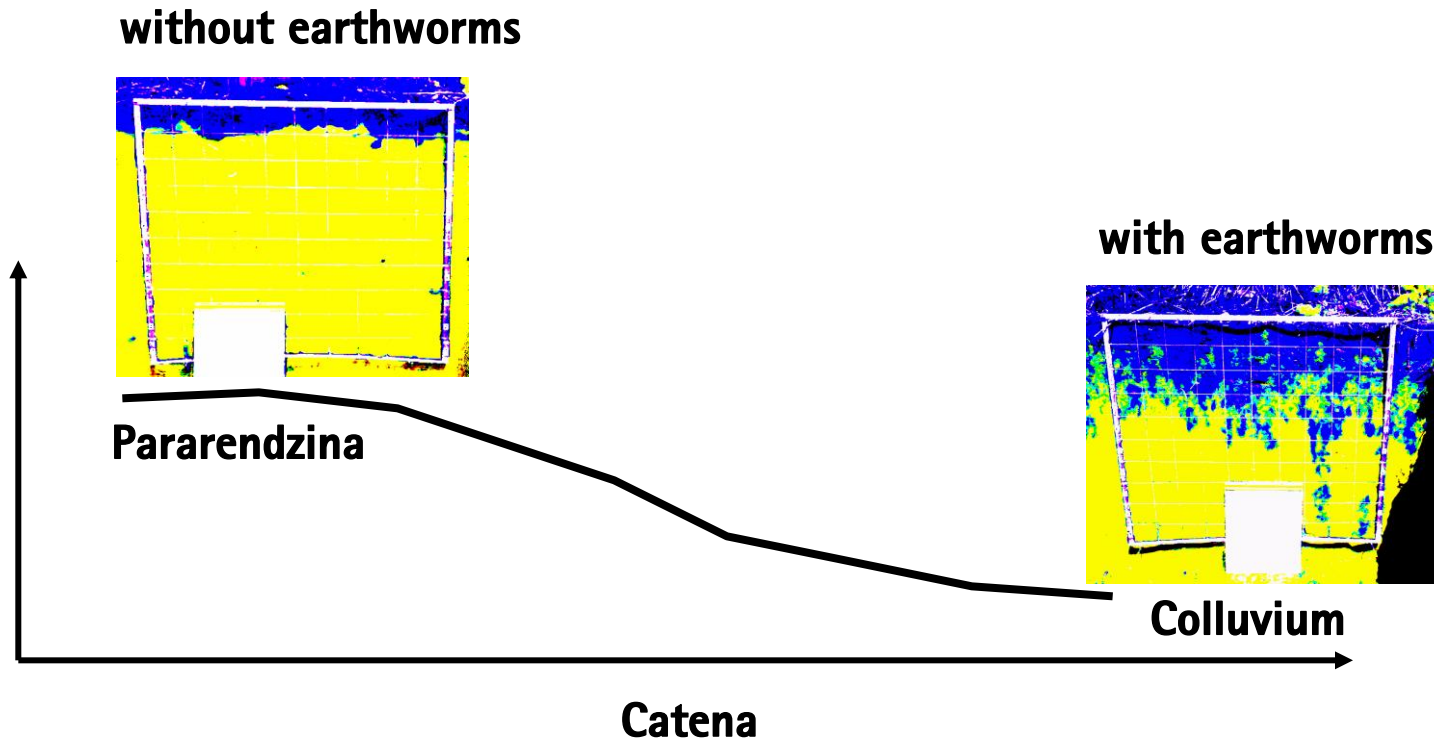
additional experiments in 2008/09

Zehe E, Flüher H, 2001. Slope scale distribution of flow patterns in soil profiles. J Hydrol 247: 116-132.

Spatial patterns on hillslope scale

Habitat preferences and erosion catena

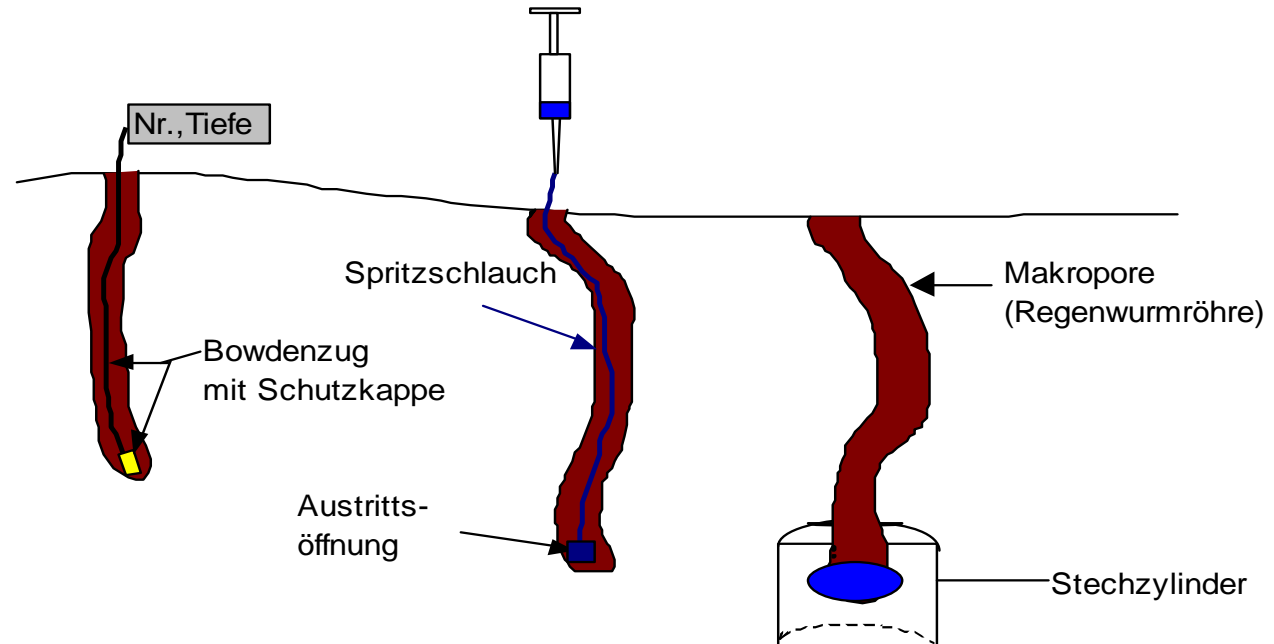
- spatial organisation of transport patterns
- patterns of biogenic structures control transport
- essential for mobility of pesticides



Transport and Environmental fate of pesticides

Experiments to investigate microbial IPU-degradation

- Top soil : 8-30 d
- Deeper soil layers (0,80 – 1 m) : depending on location
- Earthworm burrows : 15 d (first order decay, co-metabolic)
- Soil matrix : > 150 d



First synthetic modelling approach

1) Generation of realistic heterogeneous media

Soil matrix: turning bands

(mean $k_s = 10^{-6}$ m/s, Variance $\log(k_s) = 1$, range 3m/50 cm, Zehe et al., HESS 2006)

Macropores

- Density : Poisson-distributed (data: Zehe & Blöschl 2004)
- Length : Gaussian
- Burrowing activity : random walk
- Infiltration capacity : measurements

2) Simulation with CATFLOW

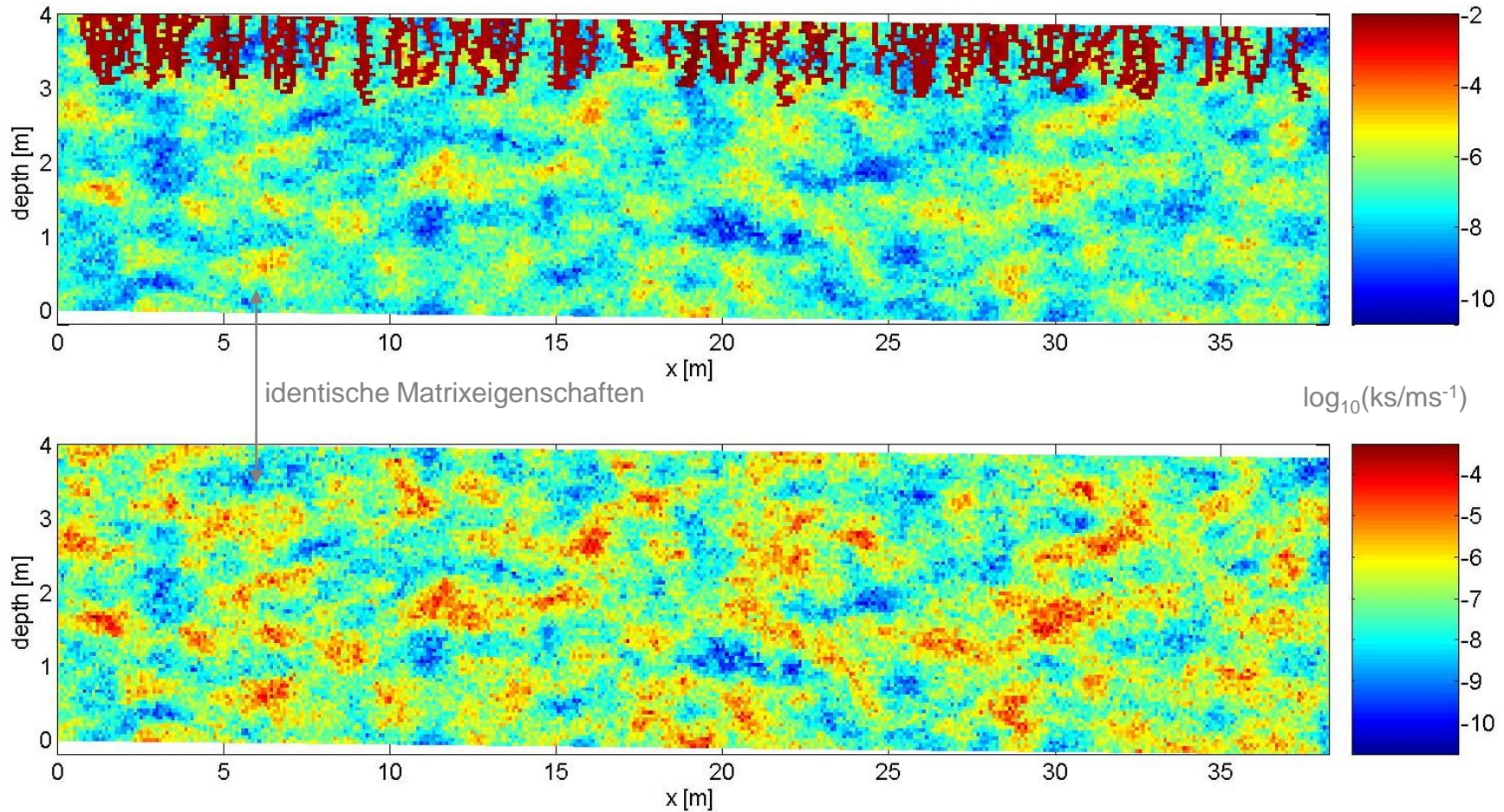
Erwin Zehe



First synthetic modelling approach

1) Generation of realistic heterogeneous media

Matrix properties are identical on both cases

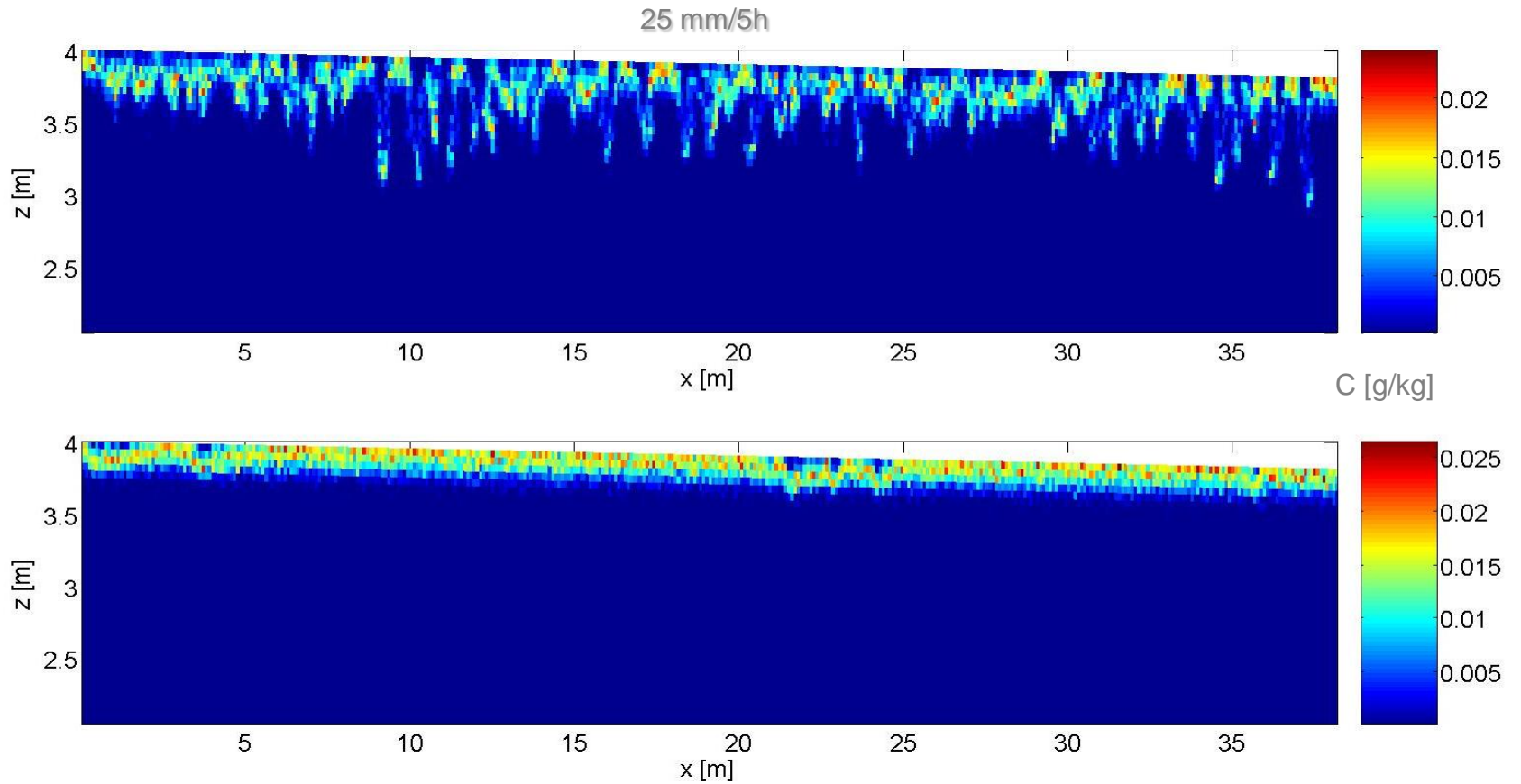


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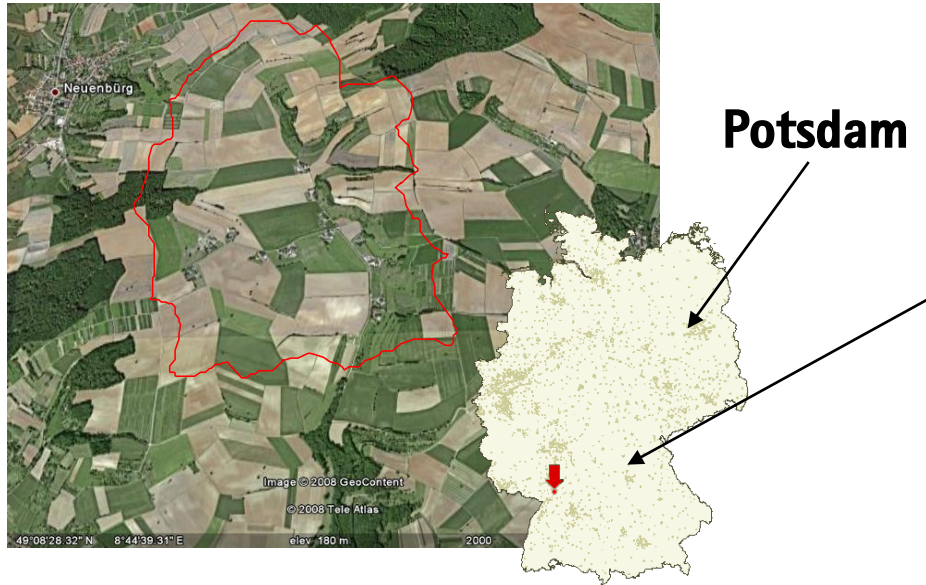
First synthetic modelling approach

2) Simulation with CATFLOW

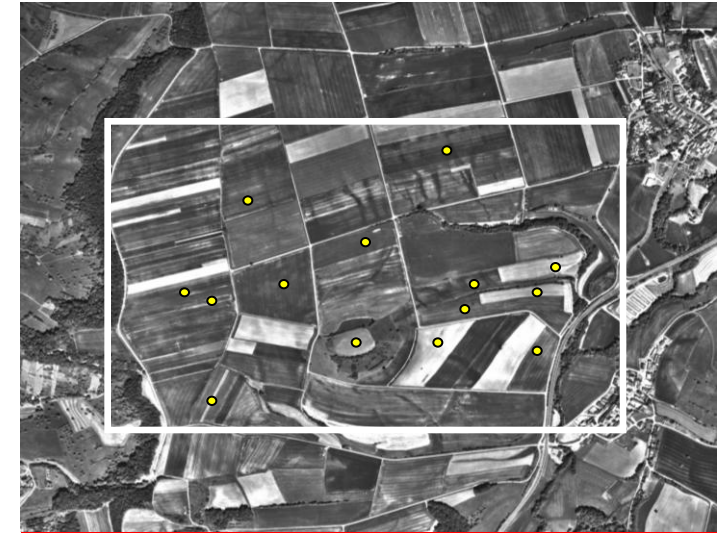


Two study sites

Weierbach



Hassberge



Loess soils with high erodibility and intensive agriculture.

Pelosoil soils with high clay content and extensive agriculture, partly nature reserve

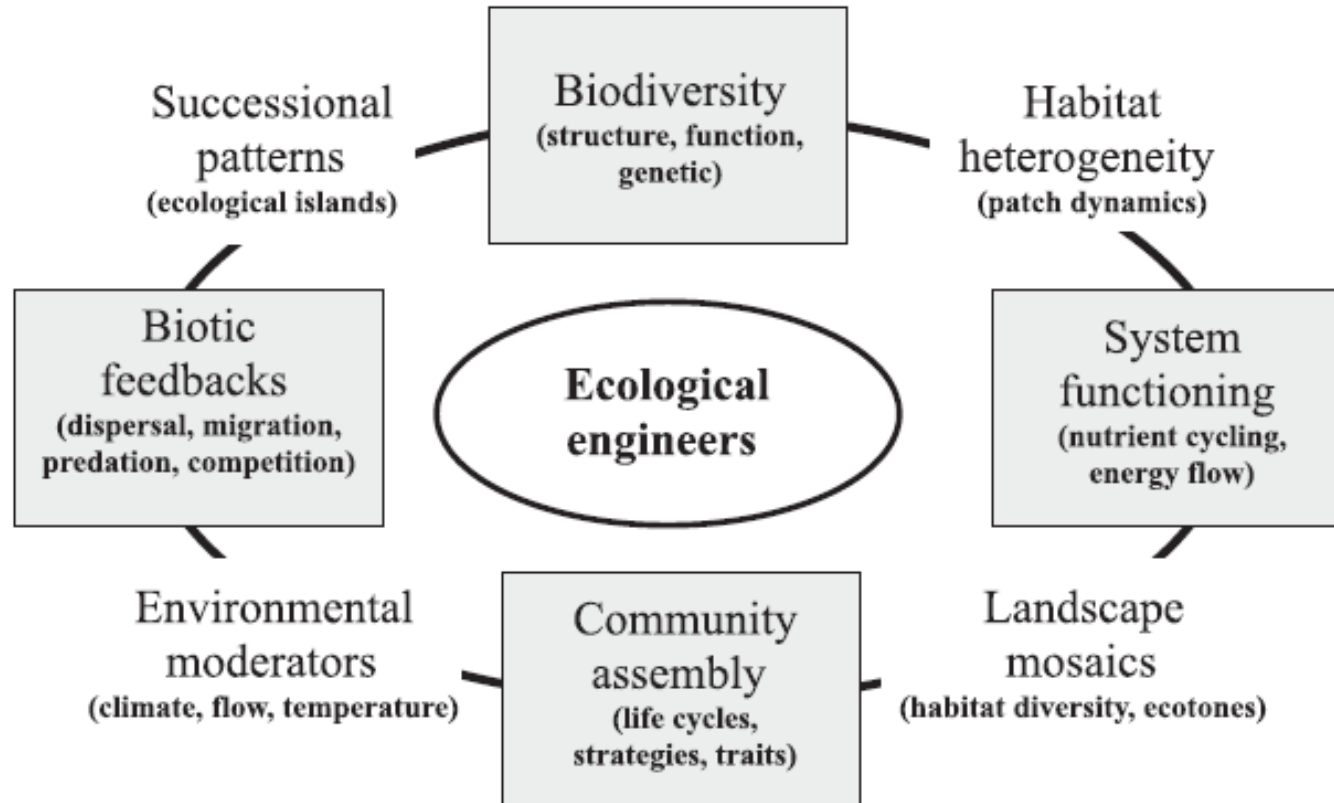
ECOSYSTEM ENGINEERS

Protagonists



Ecosystem engineers / ecosystem engineering

Abiotic and biotic effects of ecosystem engineers



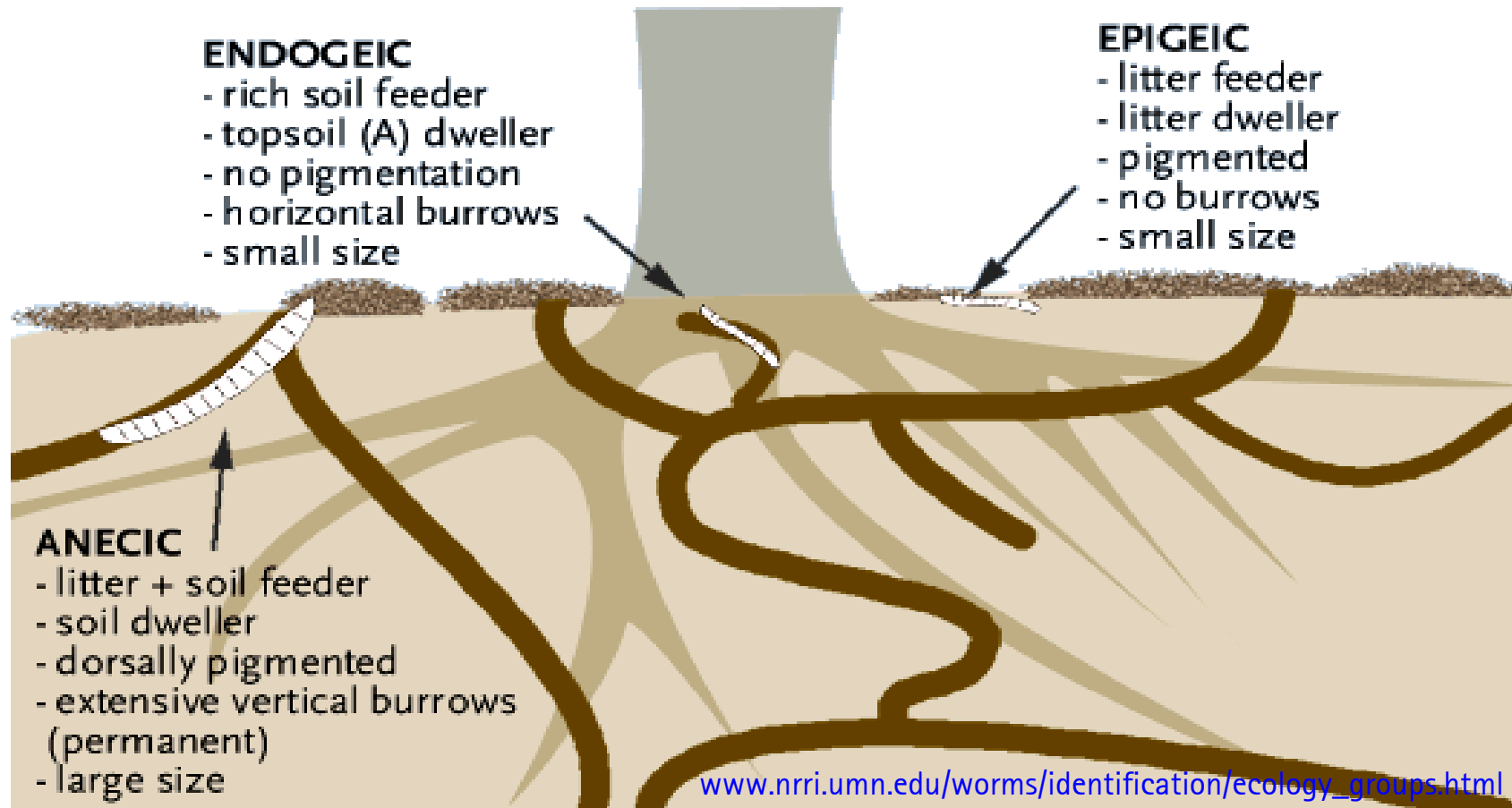
Ecosystem engineers are organisms that directly or indirectly modulate the availability of resources to other organisms by causing physical state changes in biotic or abiotic materials.

Jones CG, Lawton JH & Shachak M 1994. Organisms as ecosystem engineers. - *Oikos* 69: 373-386.

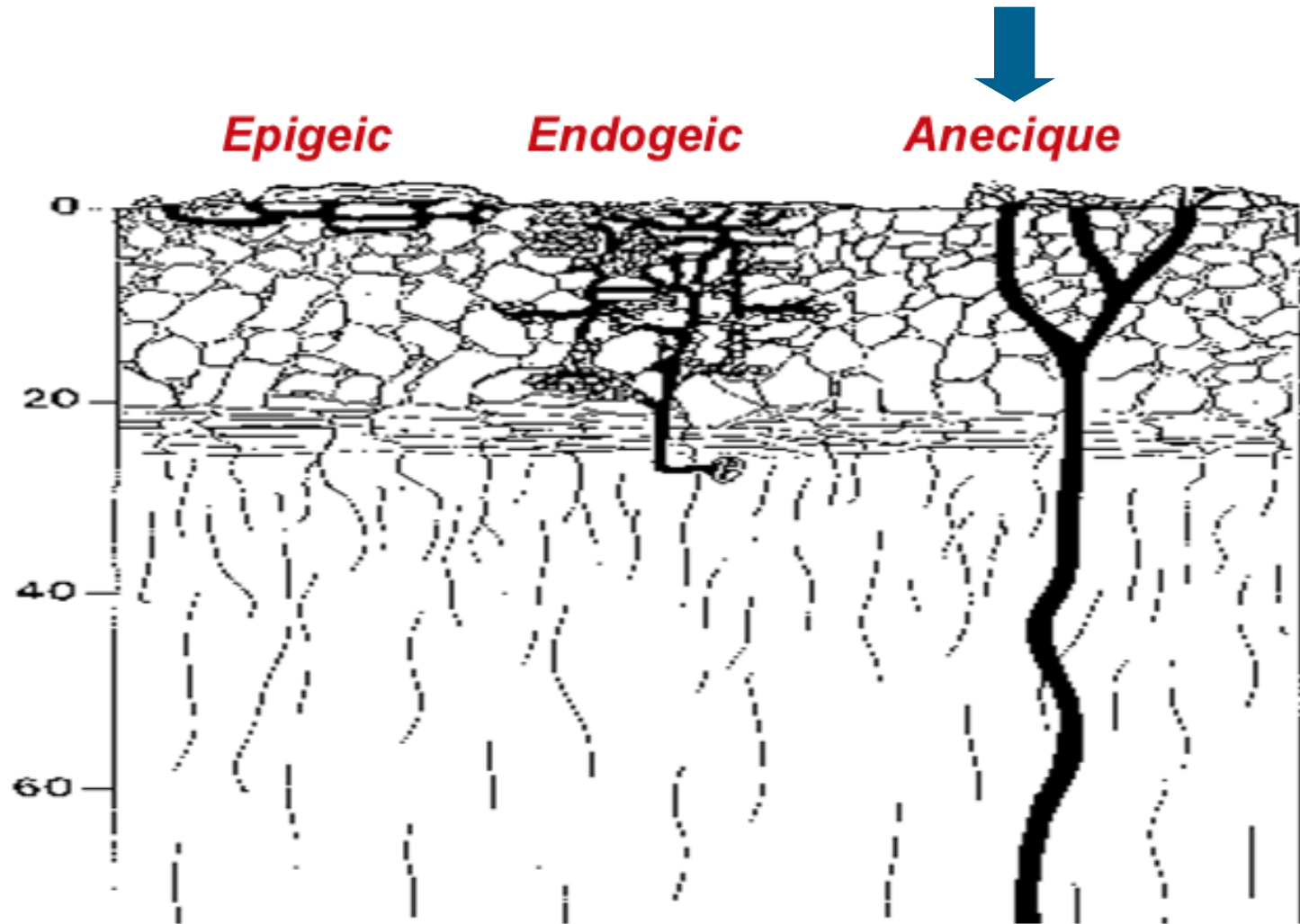
Robinson, C. T., Tockner, K. and Ward, J. V. 2002. The fauna of dynamic riverine landscapes. - *Freshwater Biology* 47: 661-678.

Crooks JA 2002. Characterizing ecosystem-level consequences of biological invasions: the role of ecosystem engineers. - *Oikos* 97: 153-166.

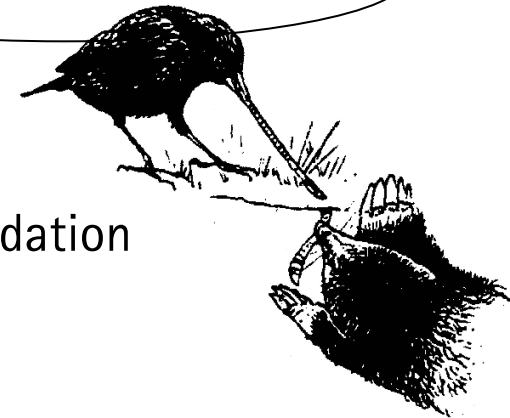
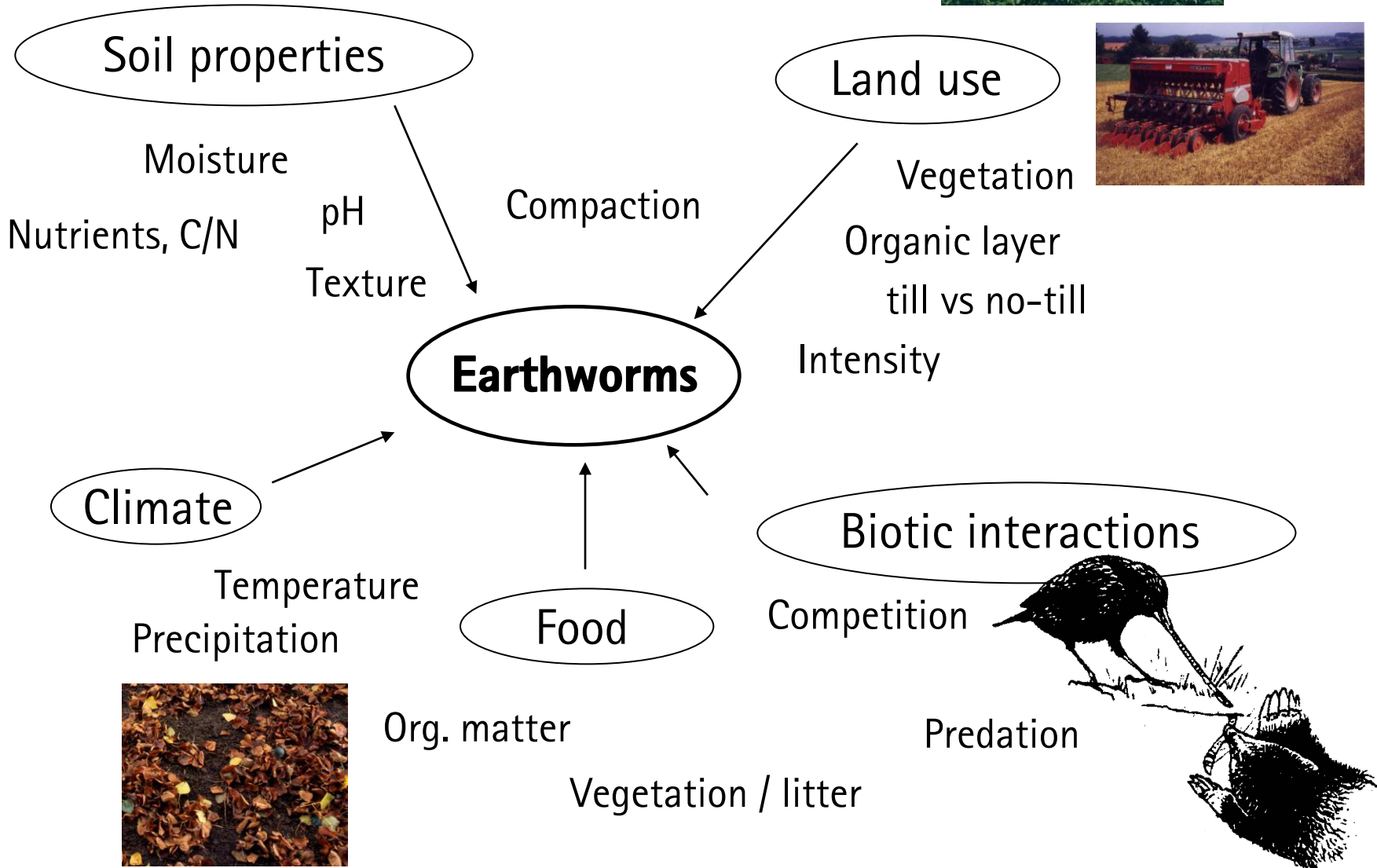
Life forms (Bouché 1975)



Earthworm functional types – different burrows



Habitat factors controlling earthworm distributions



Modules 1/3

A) Hierarchical, multi-scale earthworm distribution model

Understanding and prediction of distribution patterns depending on soil, terrain and land use parameters ...

... and observational data



Earthworm extraction with mustard solution on a 50 × 50 cm² plots (stratified random sampling)

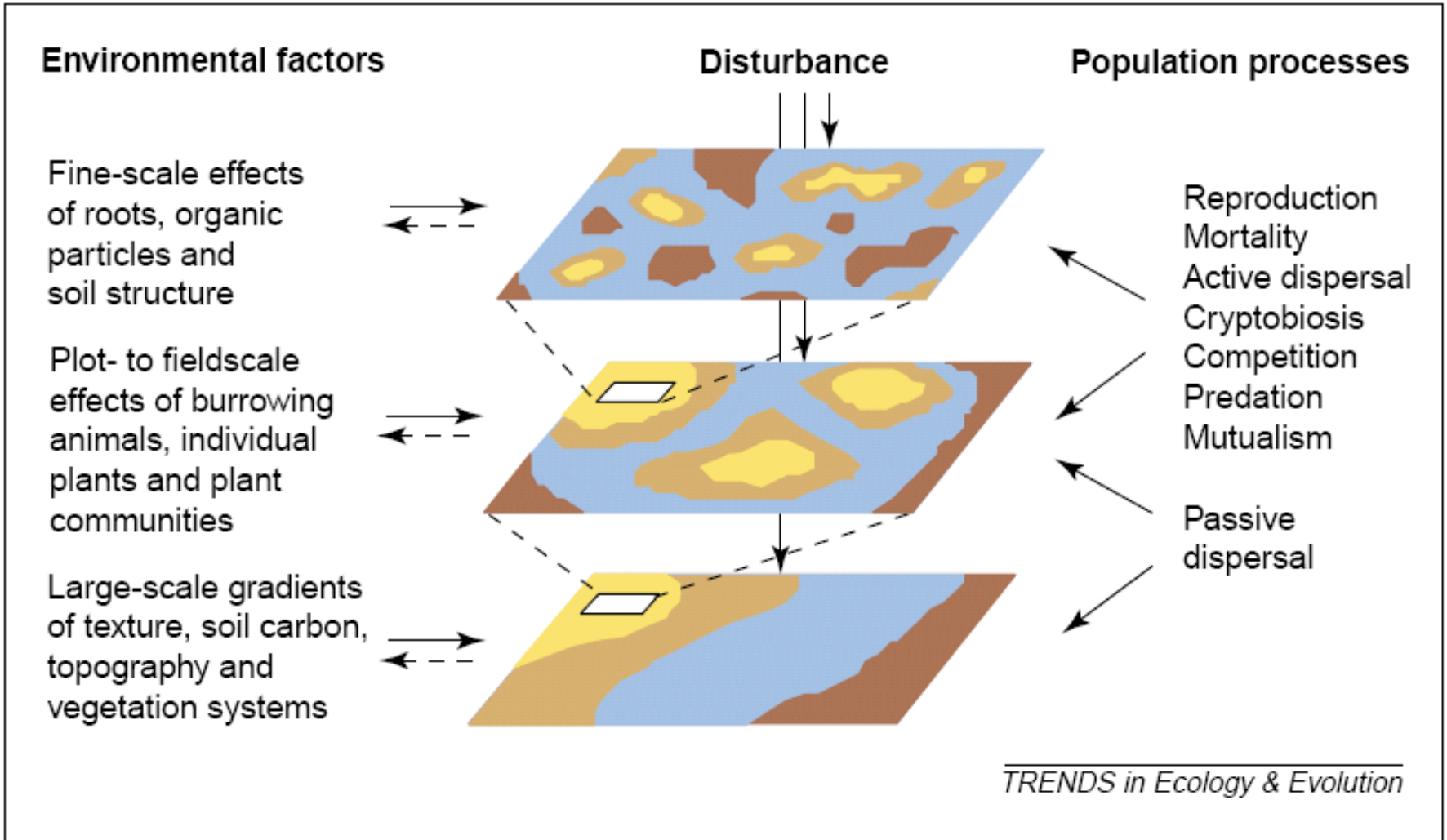


Counting macropores in different soil depths



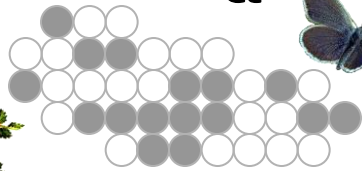
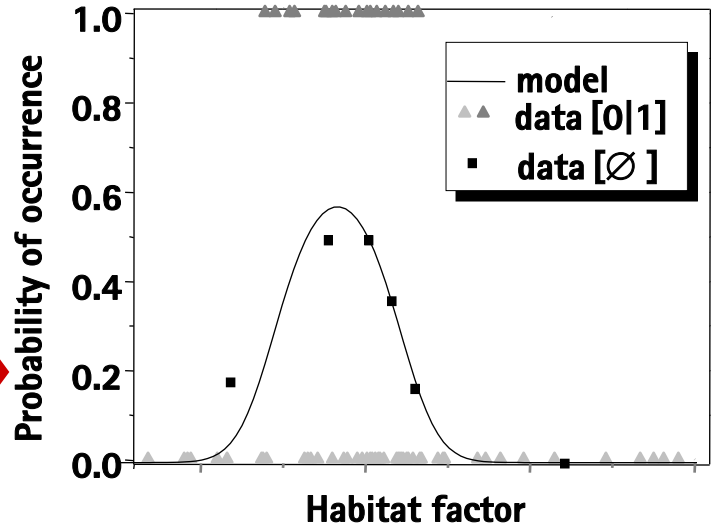
Unbalanced nested sampling design to analyse spatial heterogeneity

Multi-scale spatial distribution of soil organisms



Species distribution models / realised niche

SPECIES DISTRIBUTION



Presence/absence data
 Abundance data



$P < 0.2$
$0.2 < P < 0.5$
$0.5 < P < 0.8$
$P > 0.8$



	Habitat factors
Relevance	soil attributes
	disturbance frequency
	patch isolation
	land use

Independent data



Species distribution modelling – statistical methods

Standard /"Simple" methods

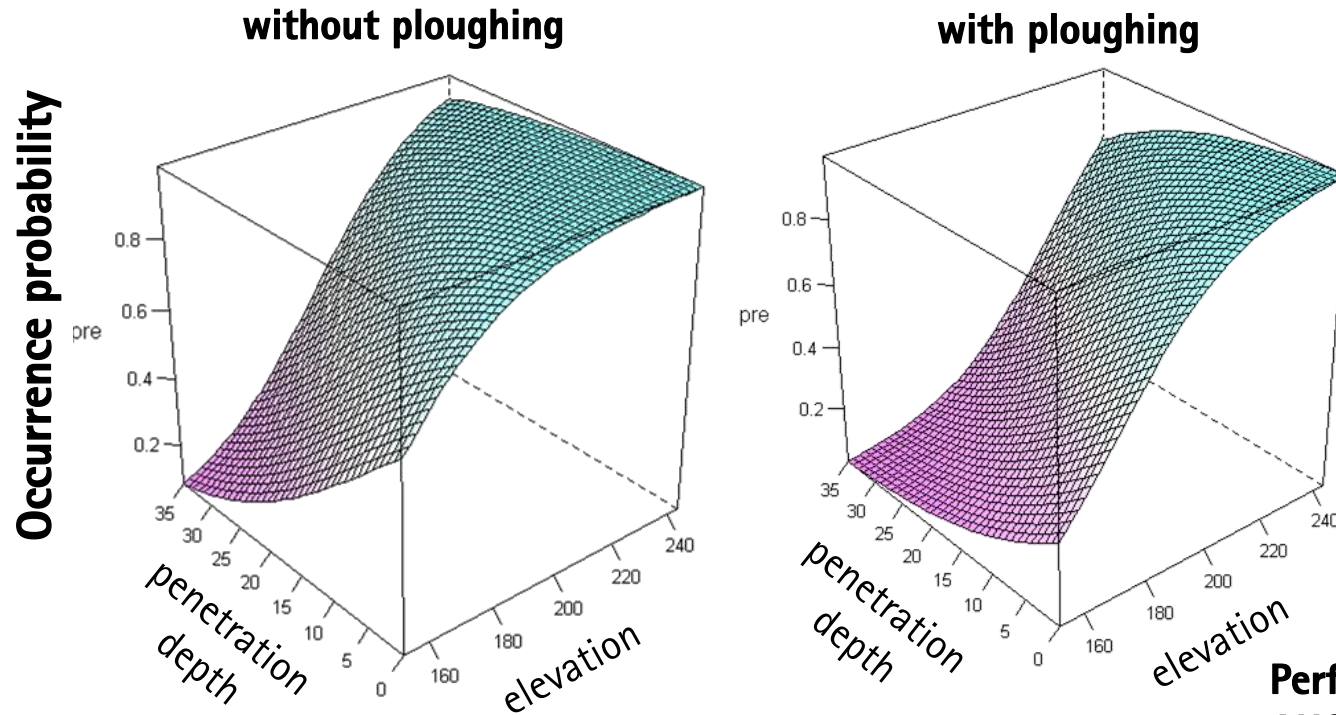
- **Generalised linear models GLM** ←
- **Generalised additive models GAM**
- **Classification and regression trees CART**

Ensemble forecasting methods (machine learning)

- **Random Forest RF**
- **Boosted Regression Trees BRT** ←
- **Multivariate adaptive regression splines MARS**

Several methods for variable selection, regularisation, multi-model inference
Internal validation via bootstrapping or crossvalidation or external
Check/controlling for residual spatial autocorrelation

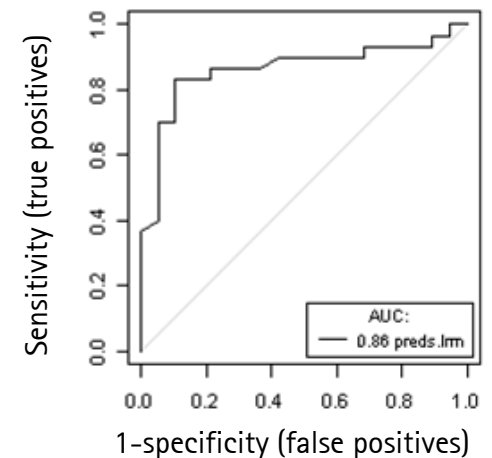
SDMs – first results (simple logistic regressions)

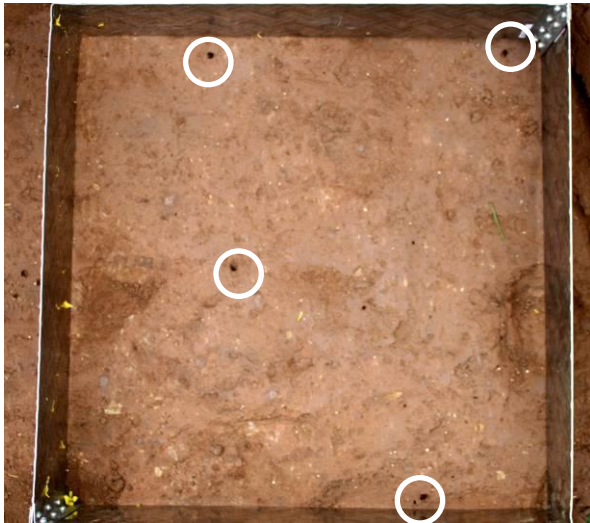


- Strong effect of land use practice (no-till > tillage)
- Low elevation = higher groundwater level
- Low penetration depth = soil compaction

Juliane Palm

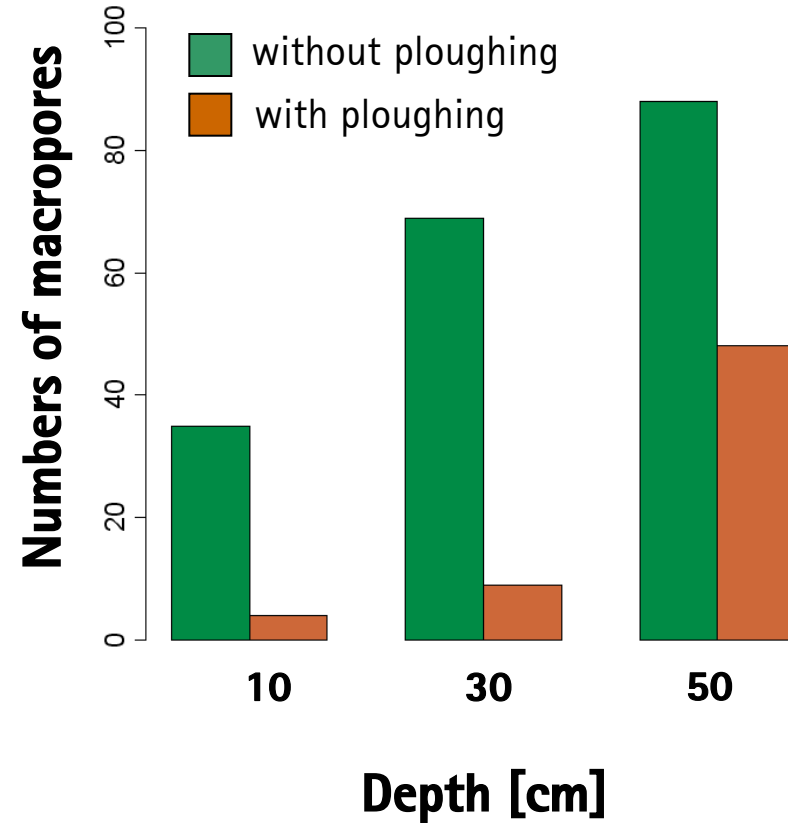
Performance: ROC-plot
AUC = 0.86, $R^2_N=0.43$





Juliane Palm

Macropores



Modules 2/3

Stage-structured population dynamic model

Understanding and prediction of population dynamics of anecic earthworms ...

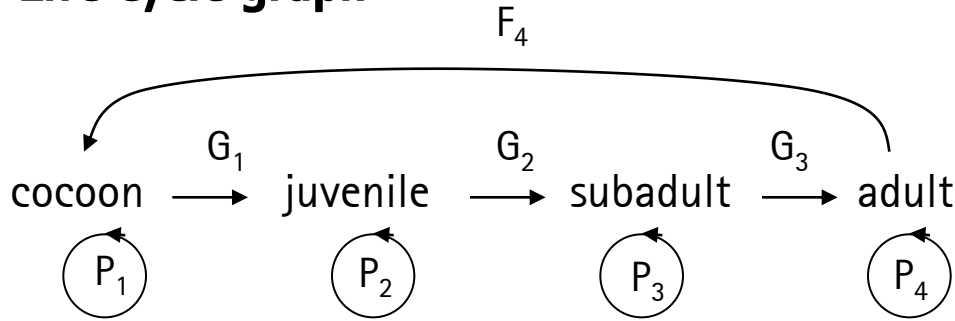
... depending on soil properties (temperature, moisture), resource availability and disturbance (land use)

... considering active and passive dispersal

Matrix population models (Klok et al. 1997; Pelosi et al. 2008), dynamic energy budget model (Jager et al. 2006)

Life cycle graph - stage-structured population model

Life cycle graph

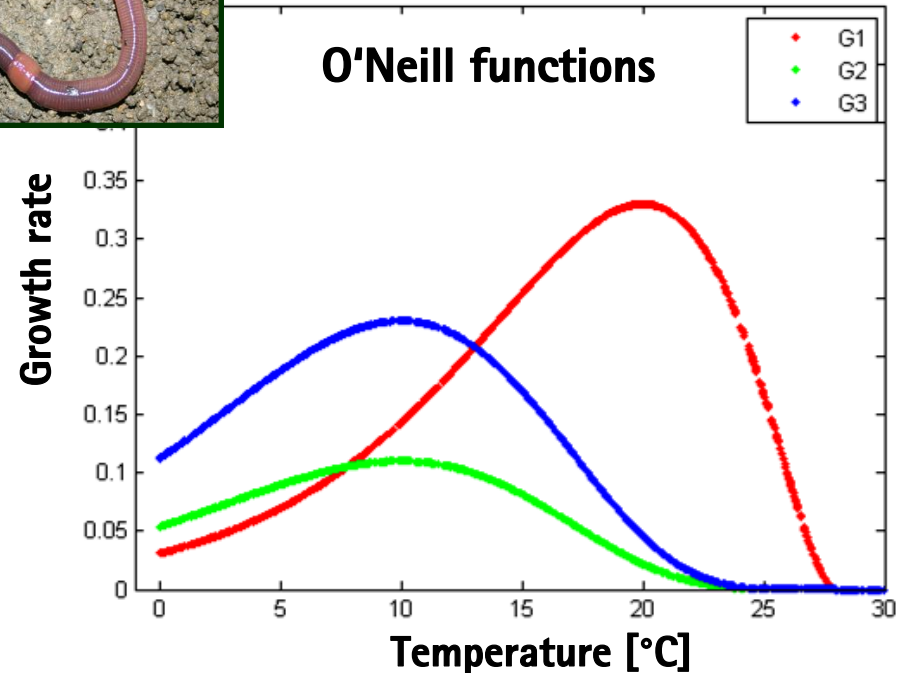


Transition matrix

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



O'Neill functions



Simulation model

$$n_{t+1} = M(T, \theta)_t \cdot n_t$$

Implementation: Anett Schibalski, Studienprojekt 2008



C) Stochastic transport model

Predicting infiltration, transport and sorption of tracers and pesticides ...

... depending on spatiotemporal distribution of connective macropores (earthworm burrows).

CATFLOW -> Erwin Zehe (Maurer 1997, Zehe & Flühler 2001)

Summary

Results from previous projects show

- a) Strong effects of earthworm burrows on transport of pesticides**
- b) Strong need for an integrated ecohydrological modelling approach**

Preliminary results show

- a) Importance of management (no-till) for earthworm distribution**
- b) Strong effect of soil moisture and temperature on earthworm abundance**
- c) High spatial and seasonal variability in earthworm abundances at both sites**
- d) Significant preferential flow at both study sites**

... still a long way to go ...

Gute Besserung, Erwin!



Thank you.



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... and the German Science Foundation DFG**

