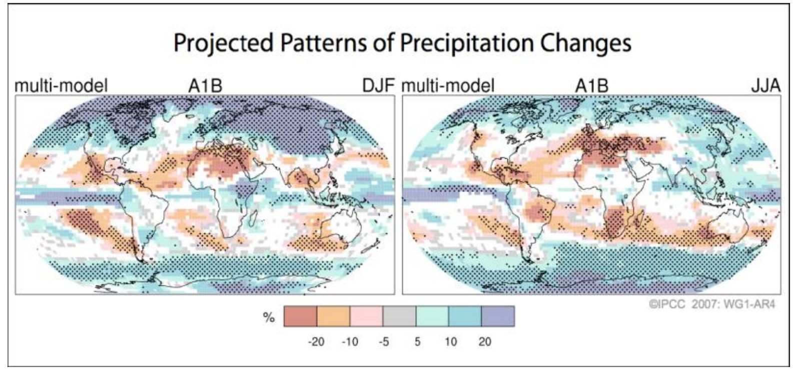
Patterns, processes and functions in ecohydrology
–
Integrating landscape ecological and hydrological models

Boris Schröder
University of Potsdam
ZALF Müncheberg
boris.schroeder@uni-potsdam.de

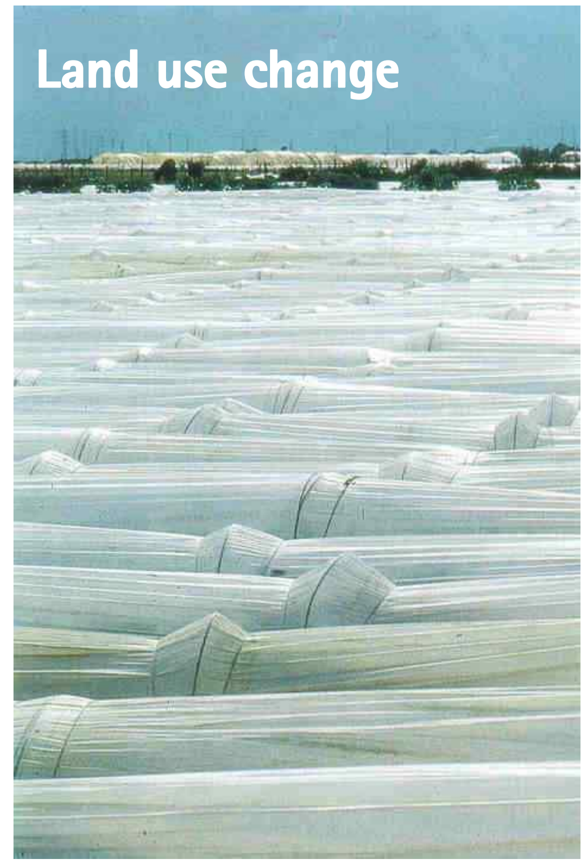
HydroEco 2011
3rd Interdisciplinary Conference
Vienna, 2-5 May 2011
Interactions between Ecology and Hydrology

Motivation



"The ongoing and predicted environmental change and its consequences for ecological systems and natural resources are key challenges of the 21st century."

UN – Environmental Programme



Key research questions

Where do we find which species?

Why? Underlying mechanisms?

How are these distributional patterns affected by environmental change?

Does this has an effect on the functioning of ecosystems?

Schröder B, 2008. Species in dynamic landscapes: Patterns, processes, and functions.

Key research questions

Where do we find which species?

Why? Underlying mechanisms?

How are these distributional patterns affected by environmental change?

Does this has an effect on the functioning of ecosystems?

Understanding the relationship between patterns, processes, and functions in dynamic landscapes

Schröder B, 2008. Species in dynamic landscapes: Patterns, processes, and functions.

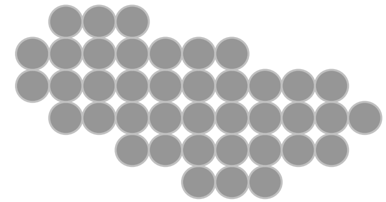
Key research questions

Where do we find which species?

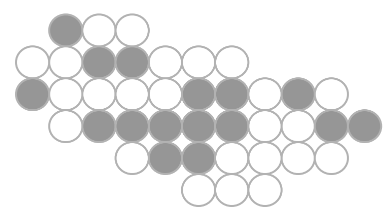
Why? Underlying mechanisms?

How are these distributional patterns affected by environmental change?

Does this has an effect on the functioning of ecosystems?



Understanding the relationship between patterns, processes, and functions in dynamic landscapes



Schröder B, 2008. Species in dynamic landscapes: Patterns, processes, and functions.

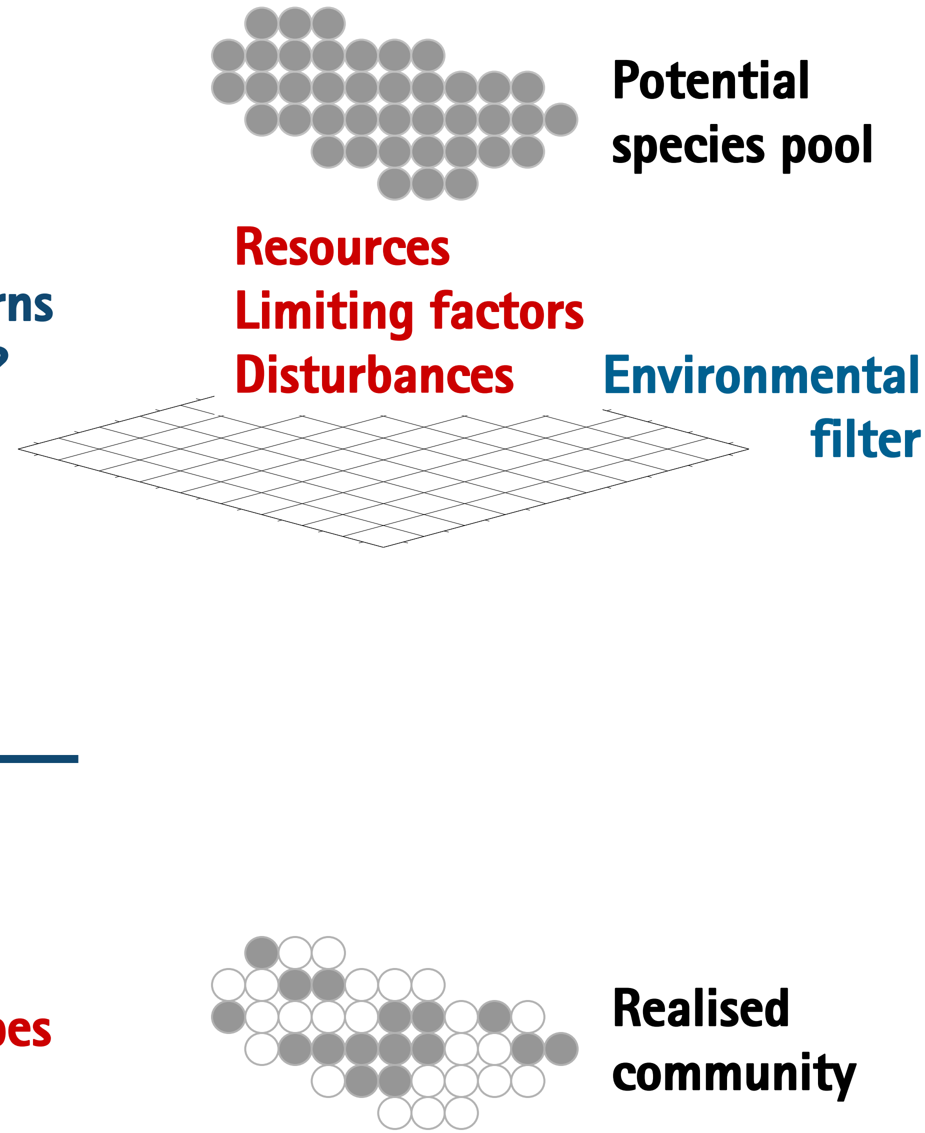
Key research questions

Where do we find which species?

Why? Underlying mechanisms?

How are these distributional patterns affected by environmental change?

Does this has an effect on the functioning of ecosystems?



Understanding the relationship between patterns, processes, and functions in dynamic landscapes

Schröder B, 2008. Species in dynamic landscapes: Patterns, processes, and functions.

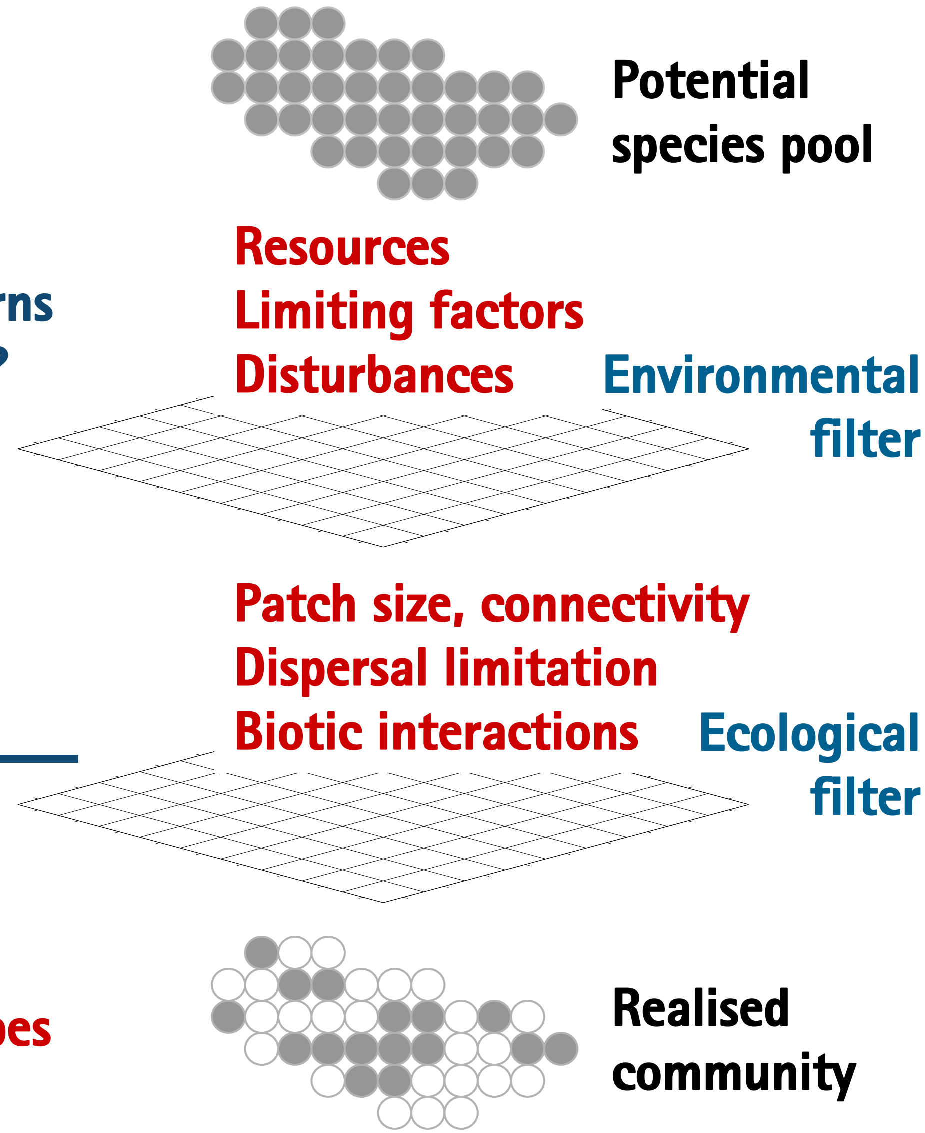
Key research questions

Where do we find which species?

Why? Underlying mechanisms?

How are these distributional patterns affected by environmental change?

Does this has an effect on the functioning of ecosystems?



Understanding the relationship between patterns, processes, and functions in dynamic landscapes

Schröder B, 2008. Species in dynamic landscapes: Patterns, processes, and functions.

OVERVIEW

Central research questions

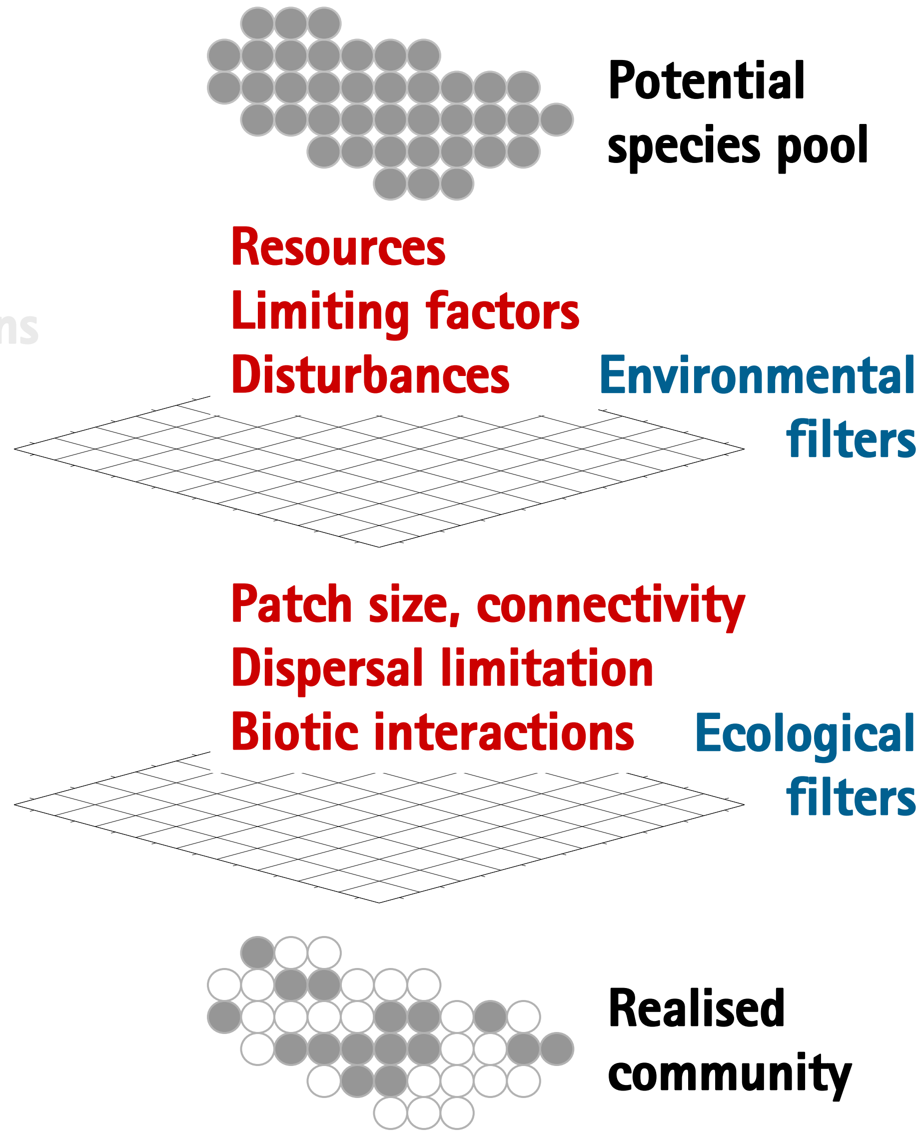
Where do we find which species?

Why? Underlying mechanisms?

How are these distributional patterns affected by environmental change?

How does this affect ecosystem functioning?

Environmental niche modelling /species distribution modelling for plants, birds, insects, ...

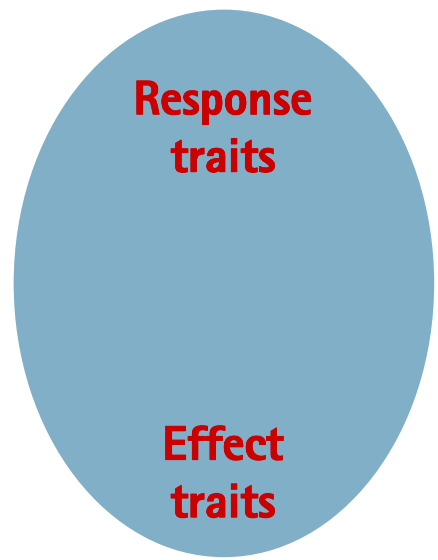


Schröder B, 2008. Species in dynamic landscapes: Patterns, processes, and functions.

Background

Species – Communities – Functional groups – Biodiversity

Response-and-effect framework
Species = characterised by properties
i.e. combination of "traits"

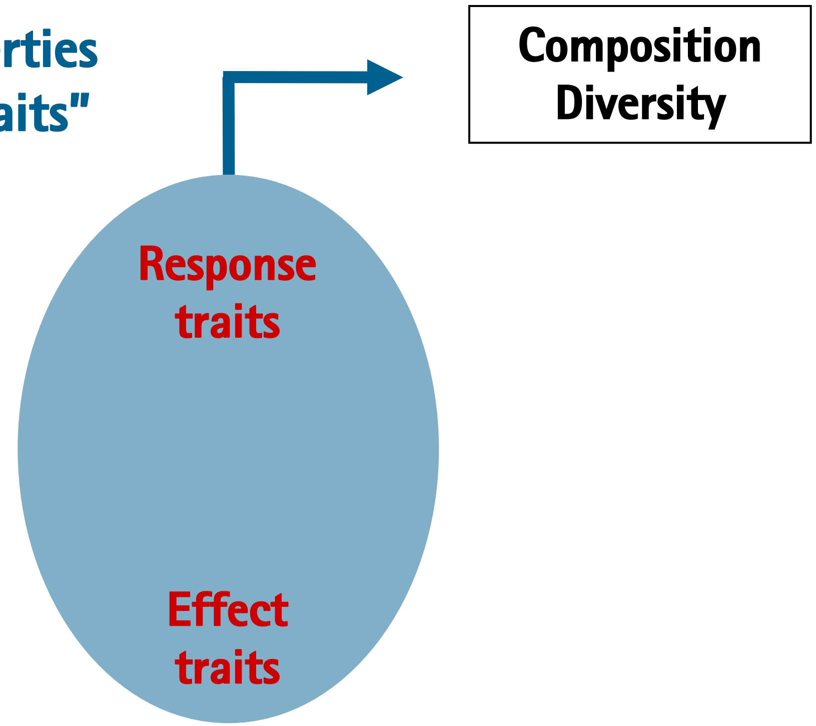


Lavorel S, Garnier E, 2002. Predicting changes in community composition and ecosystem functioning from plant traits revisiting the Holy Grail. Funct Ecol 16: 545-556.

Background

Species – Communities – Functional groups – Biodiversity

Response-and-effect framework
Species = characterised by properties
i.e. combination of "traits"

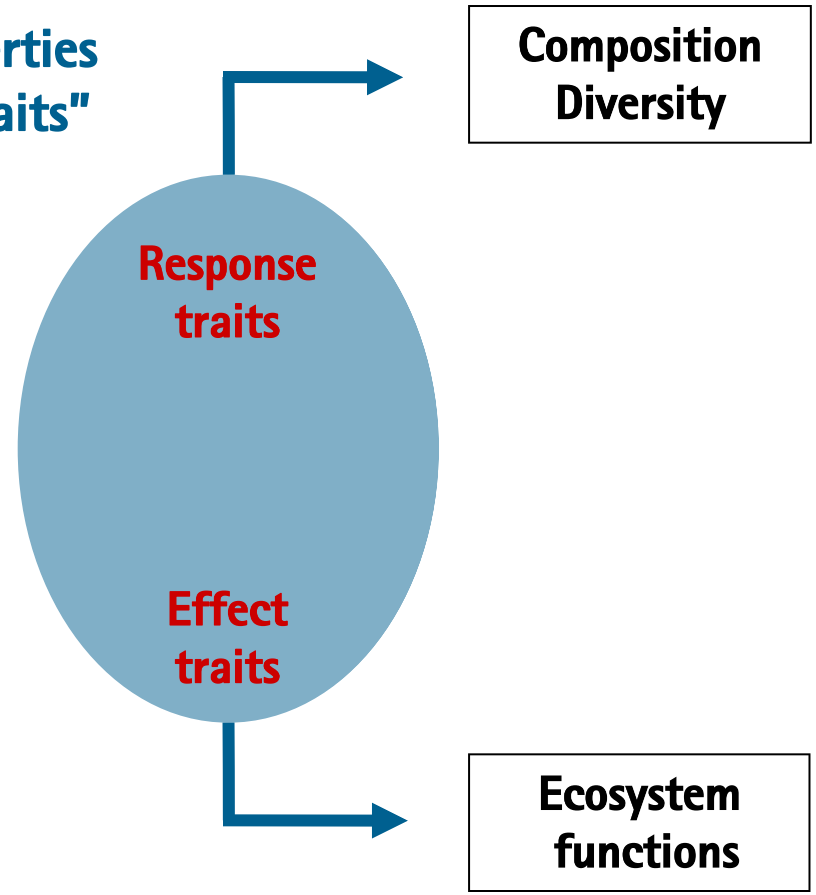


Lavorel S, Garnier E, 2002. Predicting changes in community composition and ecosystem functioning from plant traits revisiting the Holy Grail. Funct Ecol 16: 545-556.

Background

Species – Communities – Functional groups – Biodiversity

Response-and-effect framework
Species = characterised by properties
i.e. combination of "traits"

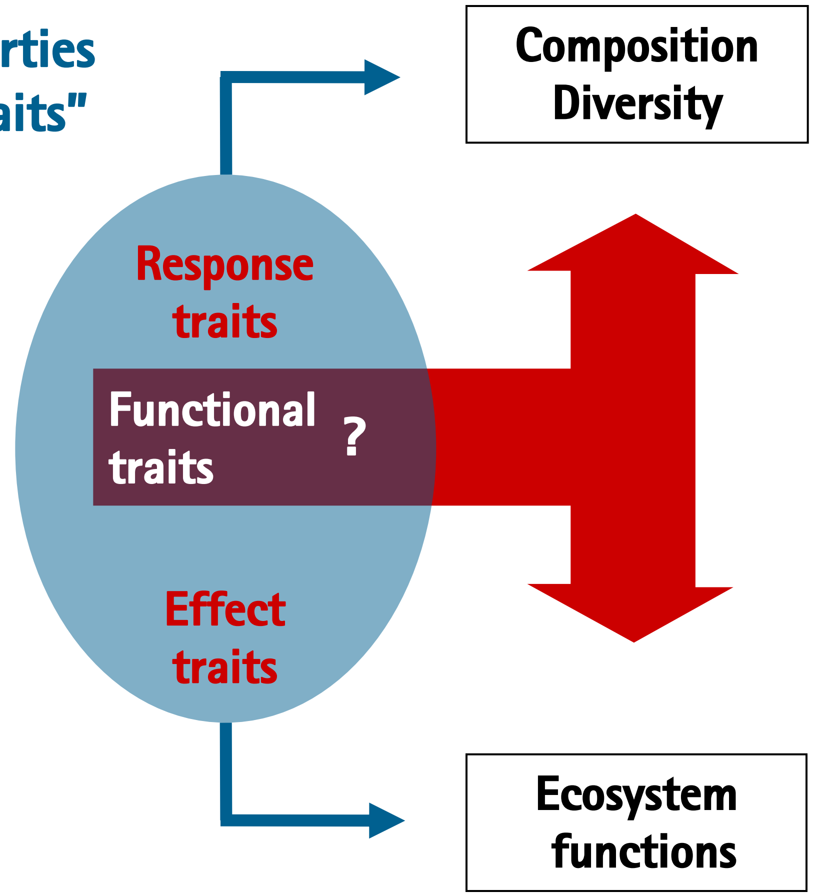


Lavorel S, Garnier E, 2002. Predicting changes in community composition and ecosystem functioning from plant traits revisiting the Holy Grail. Funct Ecol 16: 545-556.

Background

Species – Communities – Functional groups – Biodiversity

Response-and-effect framework
Species = characterised by properties
i.e. combination of "traits"



Lavorel S, Garnier E, 2002. Predicting changes in community composition and ecosystem functioning from plant traits revisiting the Holy Grail. Funct Ecol 16: 545-556.

Central research questions

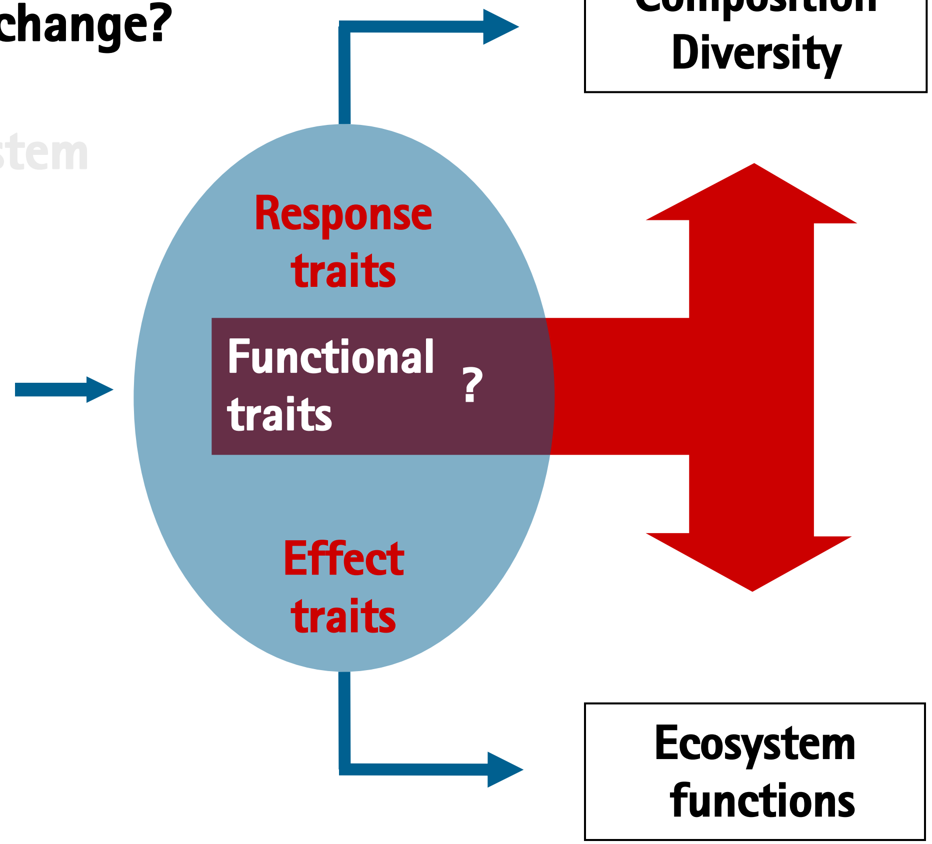
...

Move, adapt or die?

How are these distributional patterns affected by environmental change?

How does this affect ecosystem functioning?

Land use and cover change
x Climate change
x Biotic interactions



Aitken SN et al. 2008. Adaptation, migration or extirpation: climate change outcomes for tree populations. Evol Appl 1: 95–111.

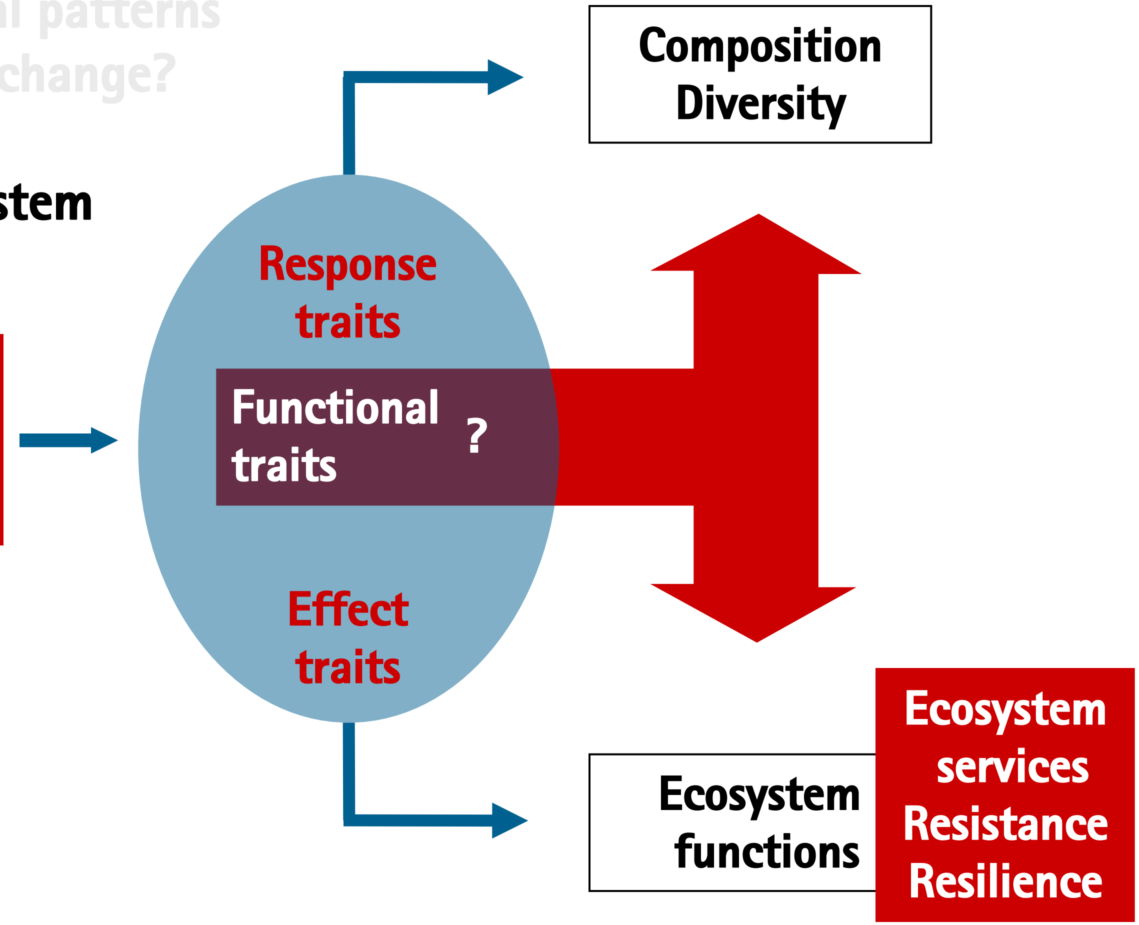
Central research questions

...

How are these distributional patterns affected by environmental change?

How does this affect ecosystem functioning?

Land use and cover change
x Climate change
x Biotic interactions



Outline – Key projects

(1) Landscape Ecology – MOSAIK

bmb+f

Management of dynamic landscapes – integrated landscape model

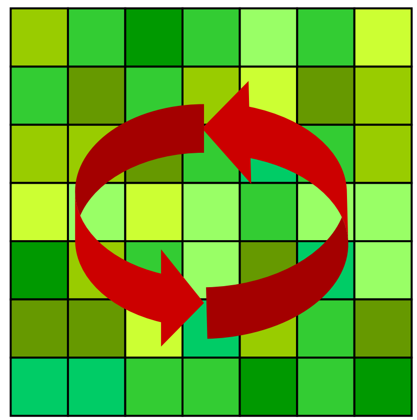
(2) Ecohydrology - BIOPORE

Deutsche Forschungsgemeinschaft DFG

Ecosystem engineers, preferential flow & environmental fate of pesticides

Universität Potsdam

zalf



Dynamic landscapes

Effects of management

Shifting mosaic of habitat quality

MOSAIK

MOSAIK Landscape model

Ecological and economic assessment of management systems for open landscapes

!

Nature Reserve Hohe Wann
50°03′ N 10°35′ E

Effect of different spatiotemporal disturbance regimes on distribution and survival of plant & animal species in a landscape?

?

MOSAIK

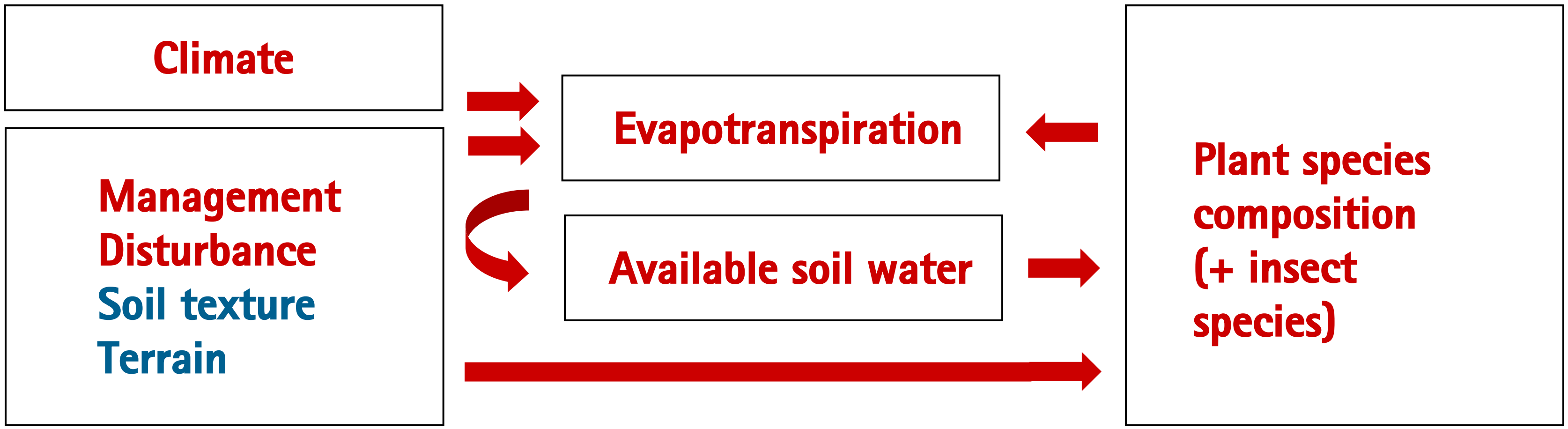
Main hypothesis

- less expensive
- severe but less frequent disturbance
- man-made mosaic cyclic
- temporary succession allowed

Infrequent rototilling can serve as a cost-effective alternative to annual mowing preserving biodiversity of open dry grasslands

- more expensive
- slight but frequent disturbance

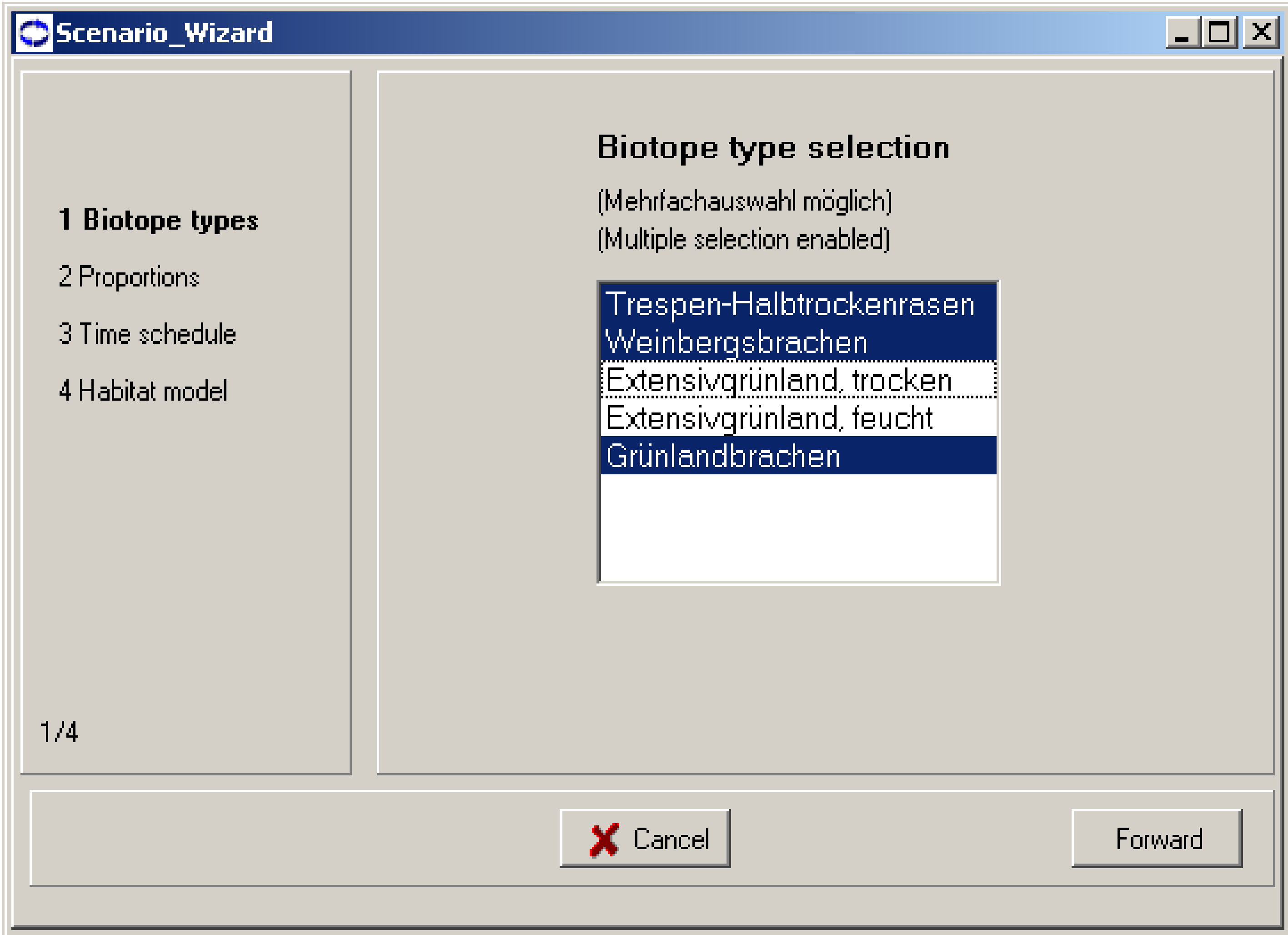
Landscape model – dynamic & static drivers



Schröder B 2006 Pattern, process, and function in landscape ecology and catchment hydrology….- Hydrol. Earth Syst. Sci. 10: 967-979.

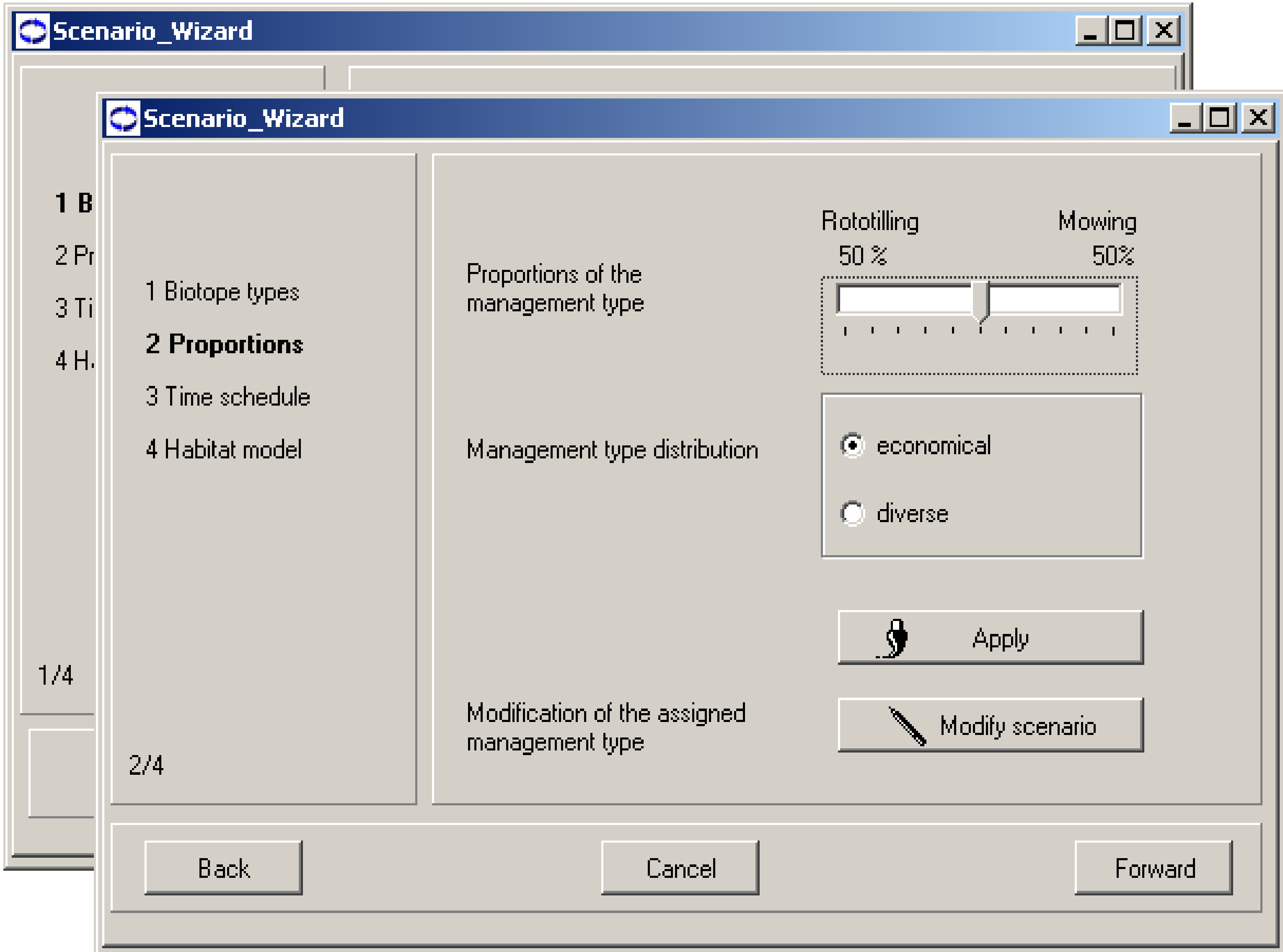
Management / Disturbance

Scenario generation

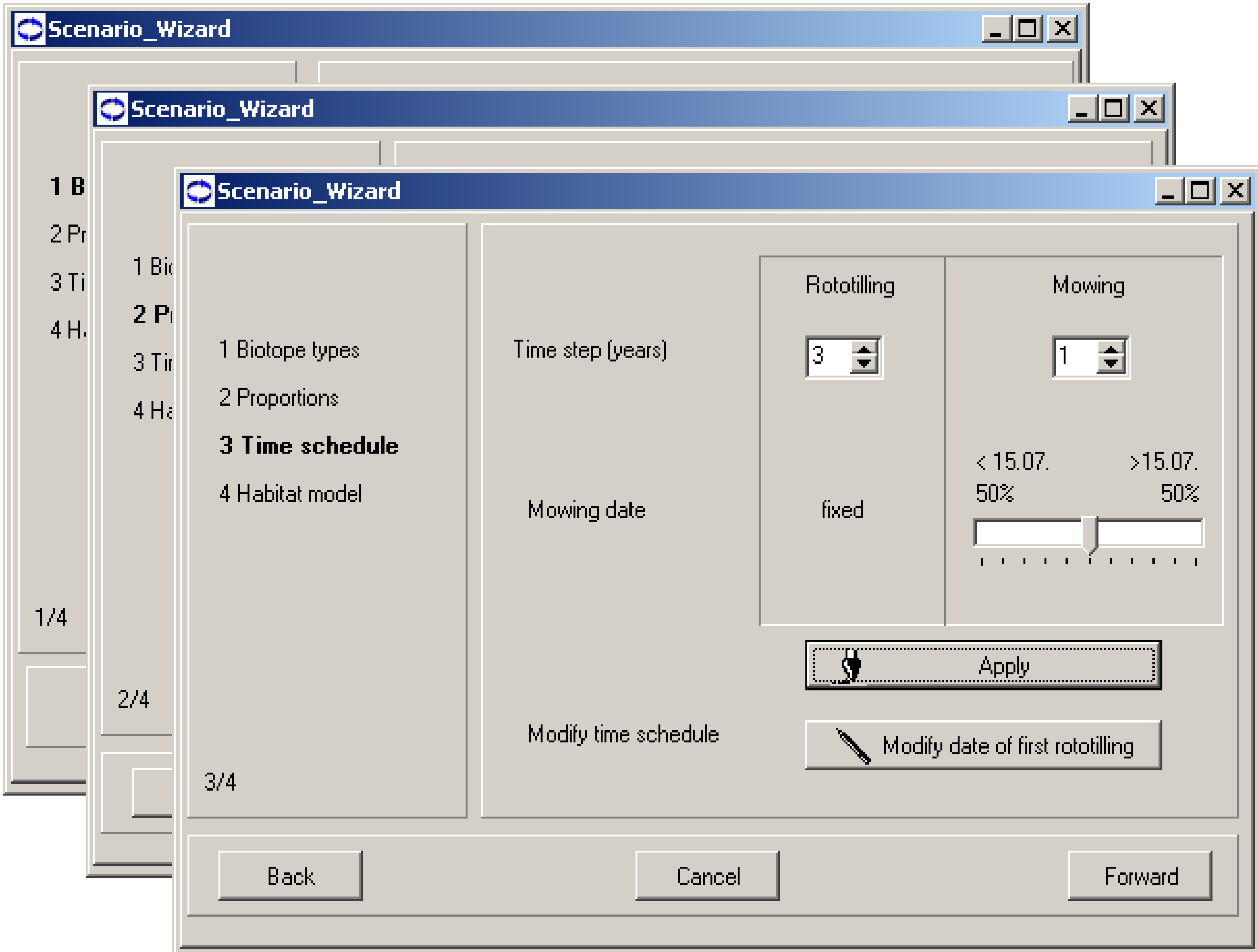


SCENARIOS

Scenario generation



Scenario generation



Schröder Hydrol Earth Syst Sci 2006
Schröder & Seppelt Ecol Model 2006
Rudner et al. Env Mod Softw 2007
Schröder et al. Biol Cons 2008

Abiotics

Modelling abiotic conditions – plant available water

Input data

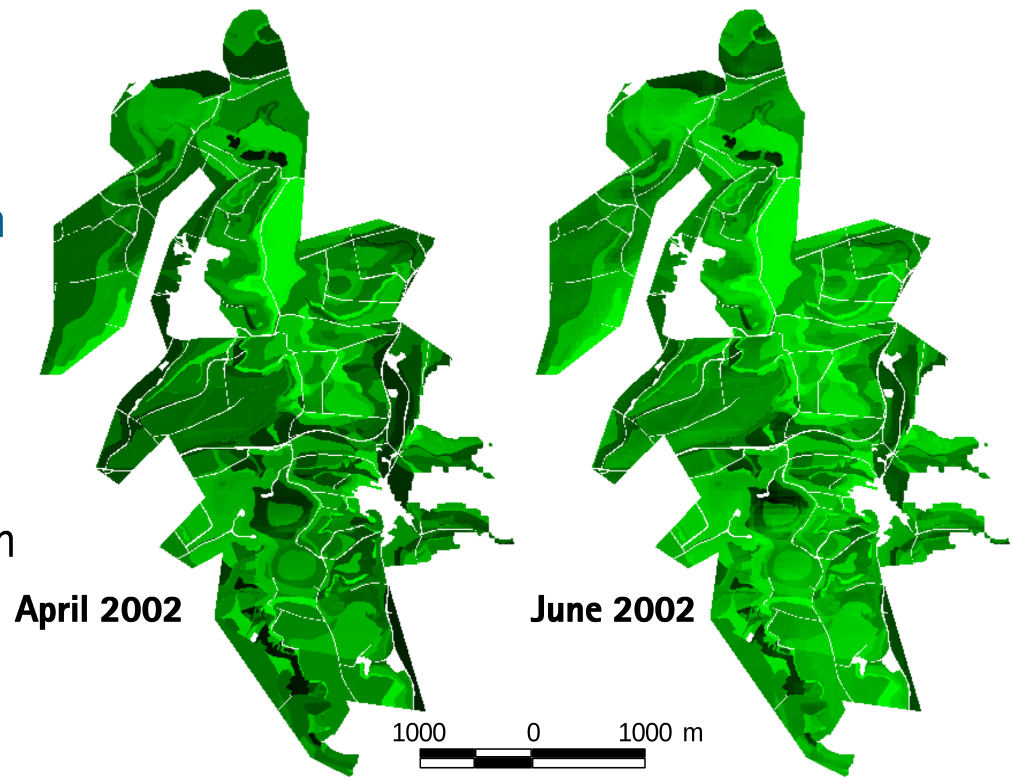
- daily agrometeorological data
- soil & terrain properties
- crop parameter

Model

- evapotranspiration
- soil moisture:
  simple water balance approach
  no lateral flow

Results

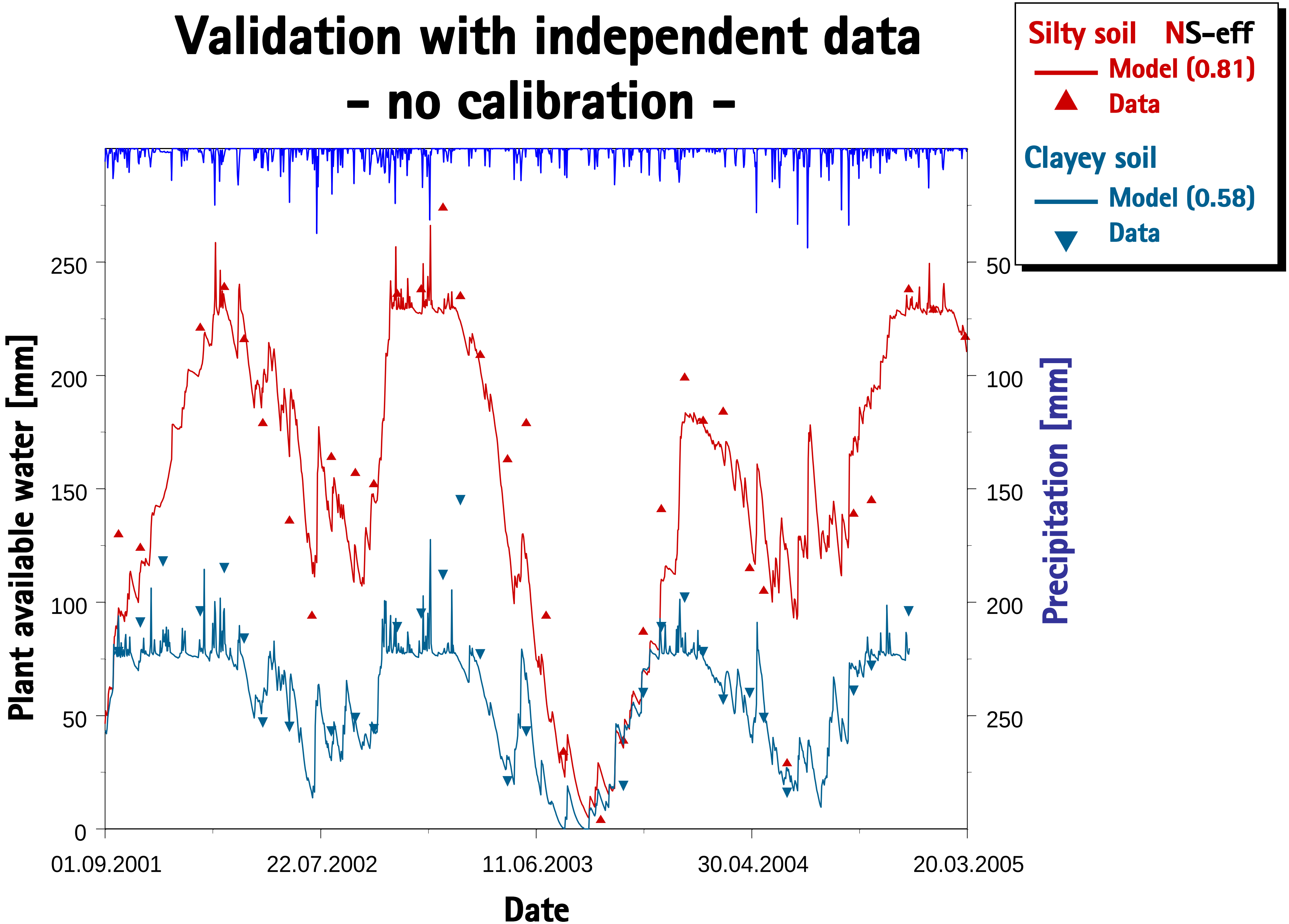
- spatially explicit and dynamic
  - pot. & act. evapotranspiration
  - plant available water
- time series of maps
  for vegetation period



Schröder, B. 2006. Pattern, process, and function in landscape ecology and catchment hydrology Hydrol Earth Syst Sci 10: 967-979.

ABIOTIC MODEL

Validation with independent data
– no calibration –



Schröder B, Rudner M, Biedermann R & Kleyer M 2008
A landscape model for quantifying the trade-off between conservation needs and economic constraints ... . Biol Cons

Biotics

Binzenhöfer et al. Biol Cons 2005
Hein et al. Basic Appl Ecol 2007
Hein et al. J Insect Cons 2007
Schröder Hydrol Earth Syst Sci 2006
Rudner et al. Env Mod Softw 2007
Binzenhöfer et al. Ecol Res 2008
Pagel et al. Ecol Appl. 2008
Schröder et al. Biol Cons 2008
Heisswolf et al. J Insect Cons 2009

KEY METHOD

Species distribution modelling | SDM – principle

Environmental Niche Modelling, Habitat modeling

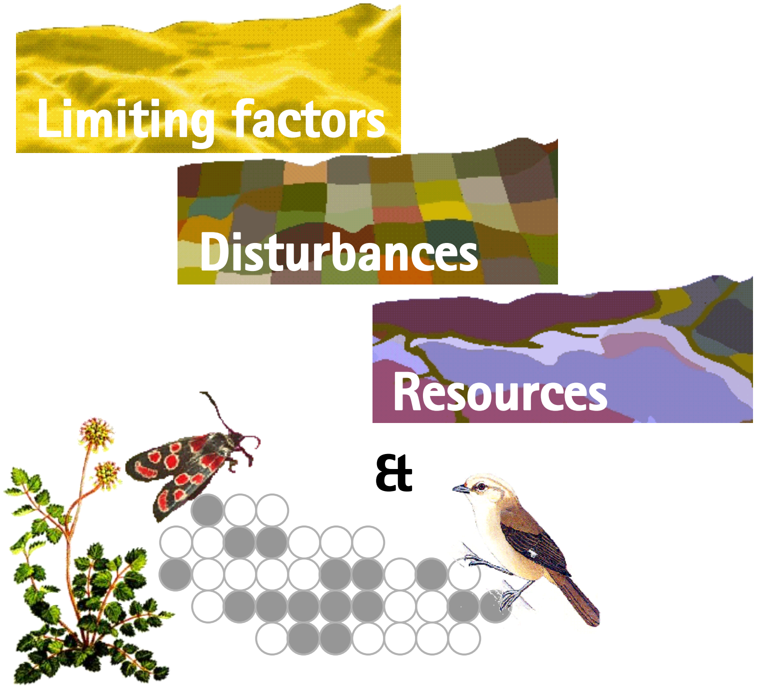
Hypotheses regarding species-habitat relationships

KEY METHOD

Species distribution modelling | SDM – principle

Environmental Niche Modelling, Habitat modeling

Hypotheses regarding species-habitat relationships



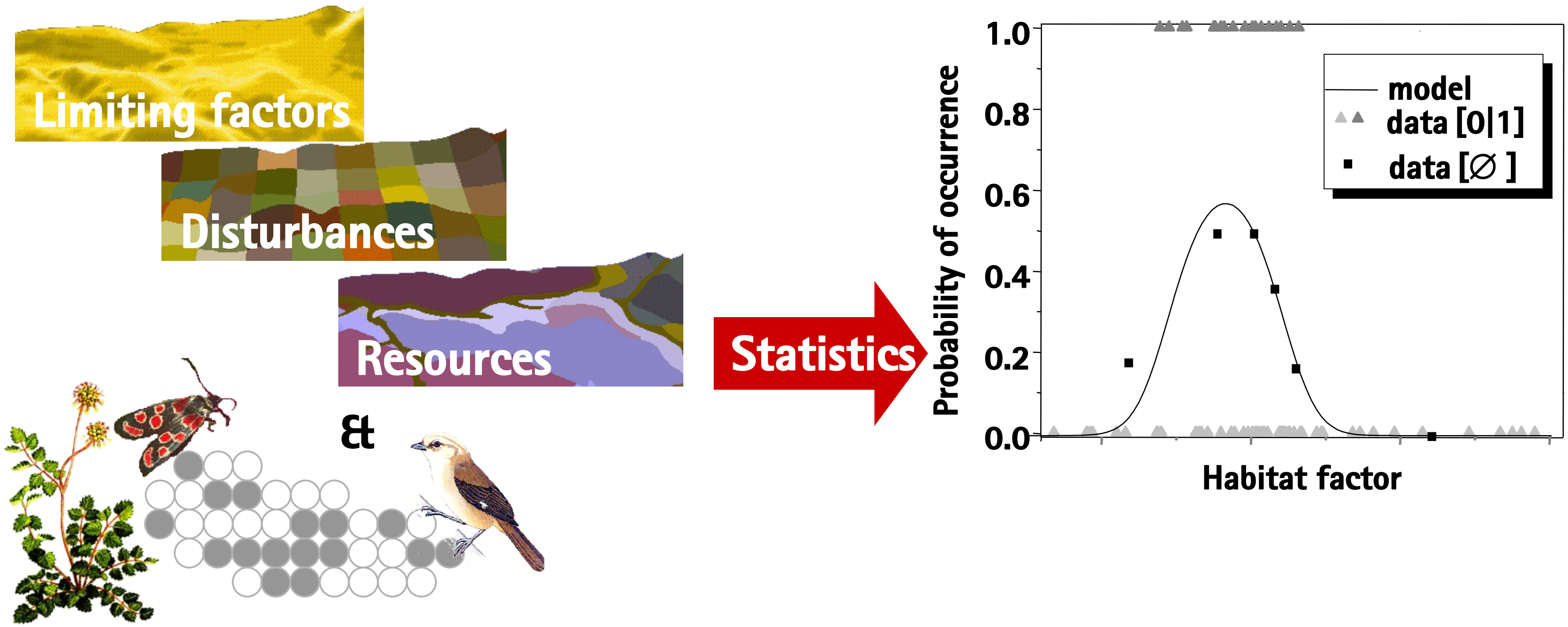
Presence-absence data

KEY METHOD

Species distribution modelling | SDM – principle

Environmental Niche Modelling, Habitat modeling

Hypotheses regarding species-habitat relationships



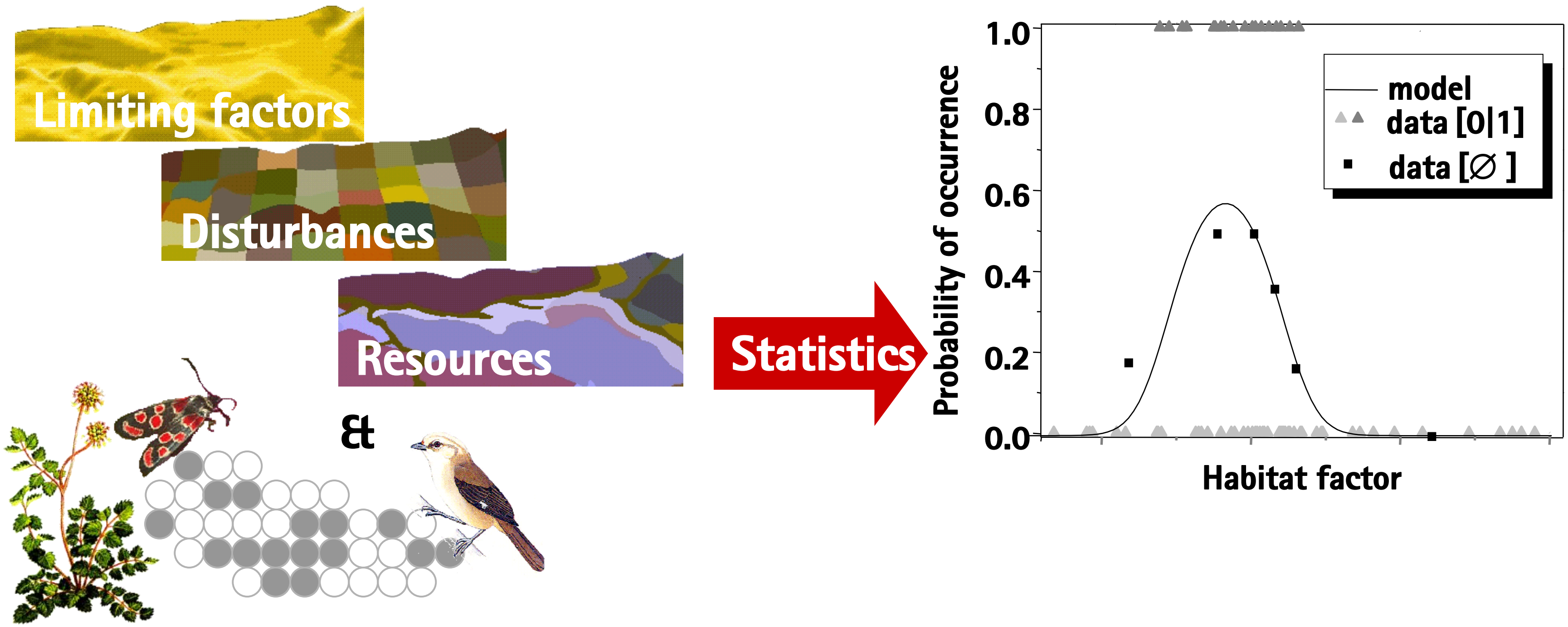
Presence-absence data

KEY METHOD

Species distribution modelling | SDM – principle

Environmental Niche Modelling, Habitat modeling

Hypotheses regarding species-habitat relationships



Presence-absence data

Explanation

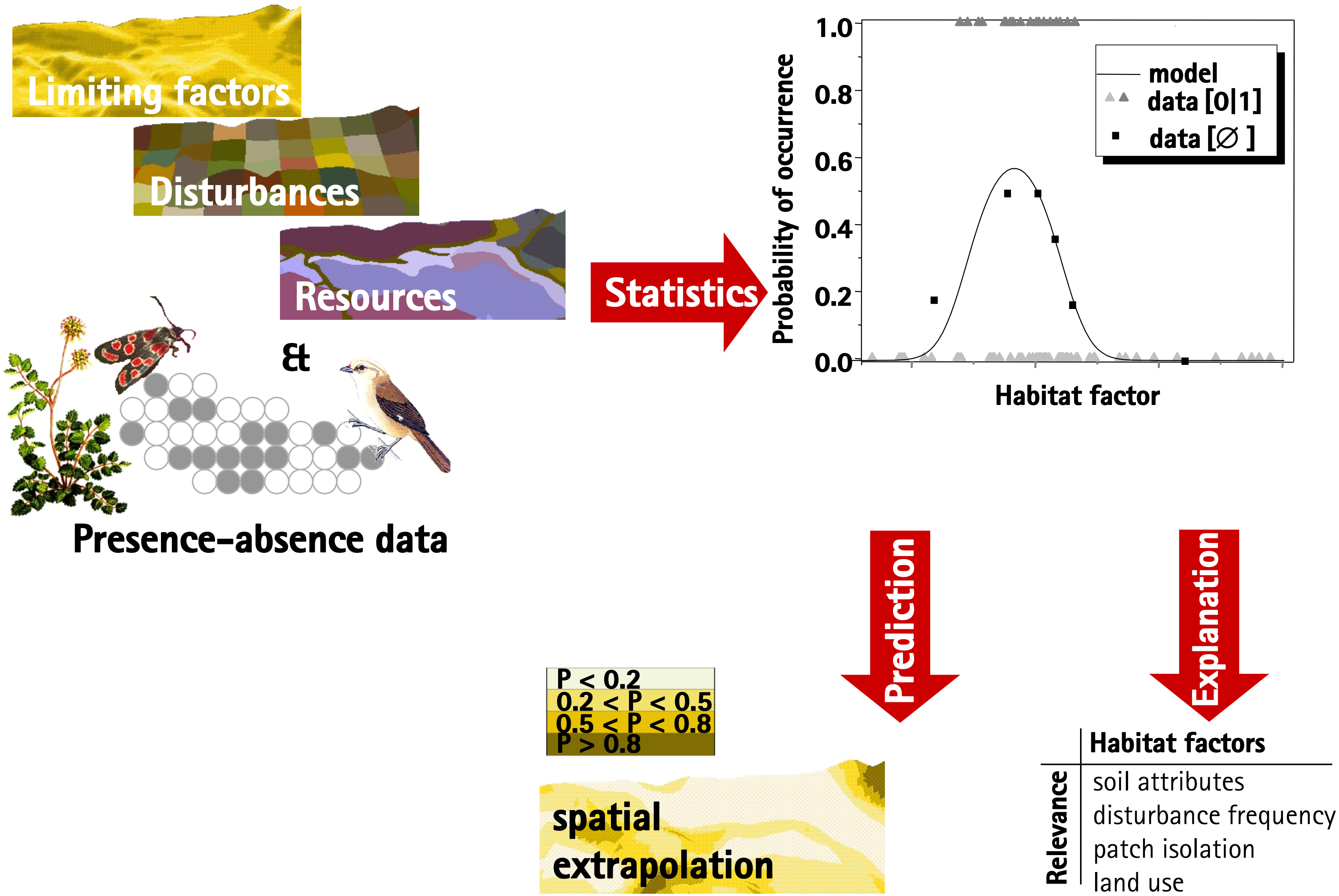
Relevance	Habitat factors
	soil attributes
	disturbance frequency
	patch isolation
	land use

KEY METHOD

Species distribution modelling | SDM – principle

Environmental Niche Modelling, Habitat modeling

Hypotheses regarding species-habitat relationships

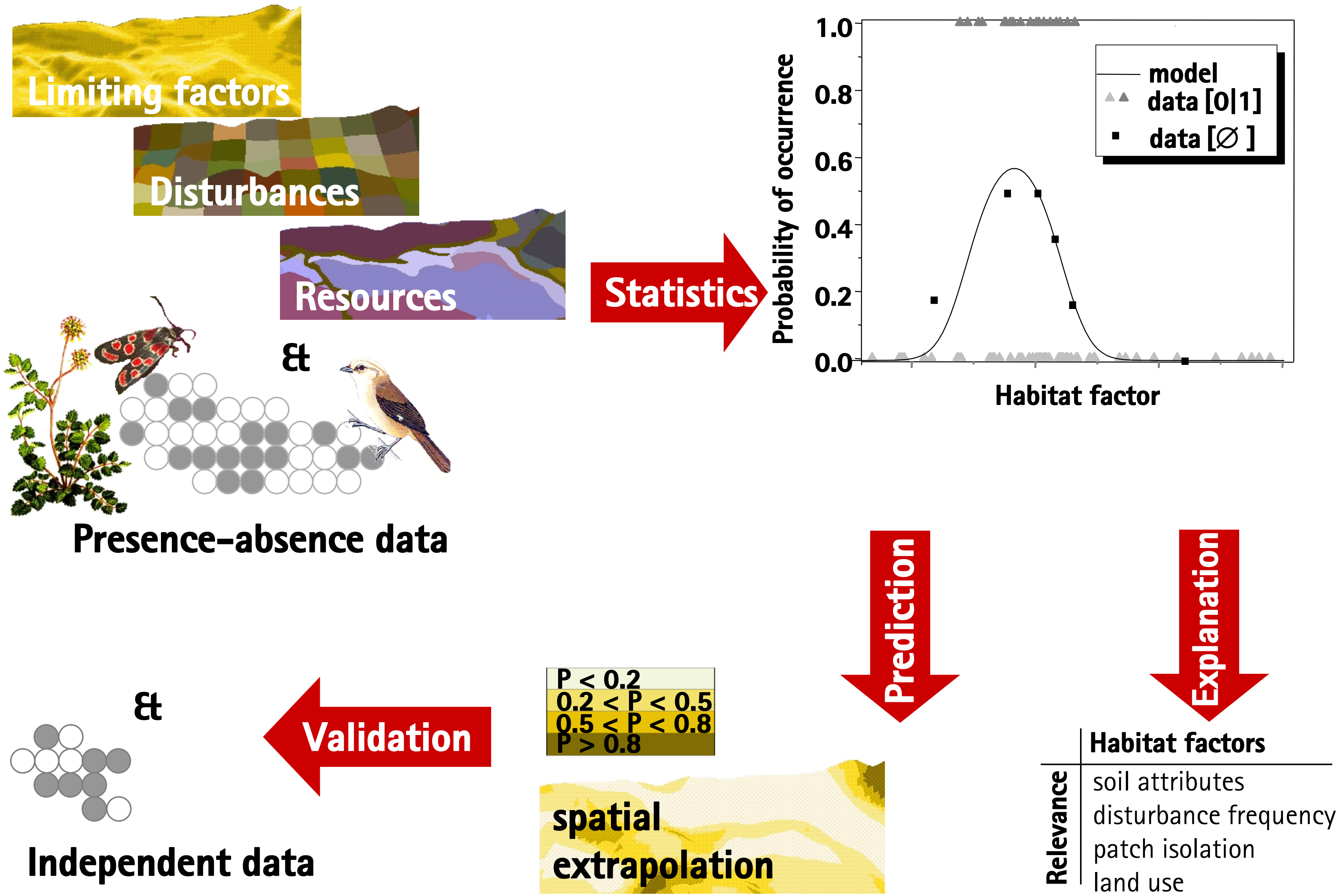


KEY METHOD

Species distribution modelling | SDM – principle

Environmental Niche Modelling, Habitat modeling

Hypotheses regarding species-habitat relationships



KEY METHOD

Species distribution modelling | SDM – principle

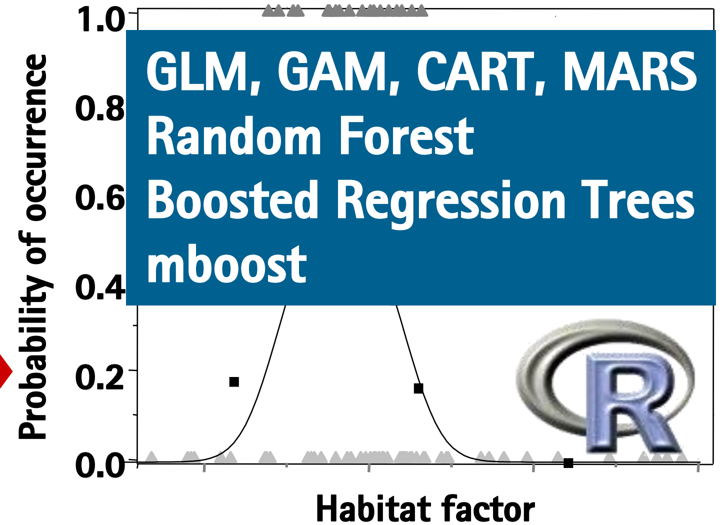
Environmental Niche Modelling, Habitat modeling

Hypotheses regarding species-habitat relationships

&

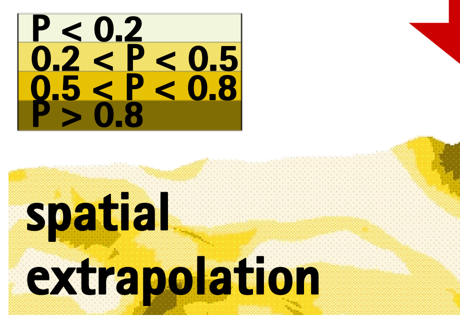
Presence-absence data

Statistics



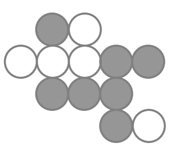
Prediction

Explanation



Validation

&



Independent data

	Habitat factors
Relevance	soil attributes
	disturbance frequency
	patch isolation
	land use

Biotic response: SDM performance

Logistic regression models with static and dynamic predictors

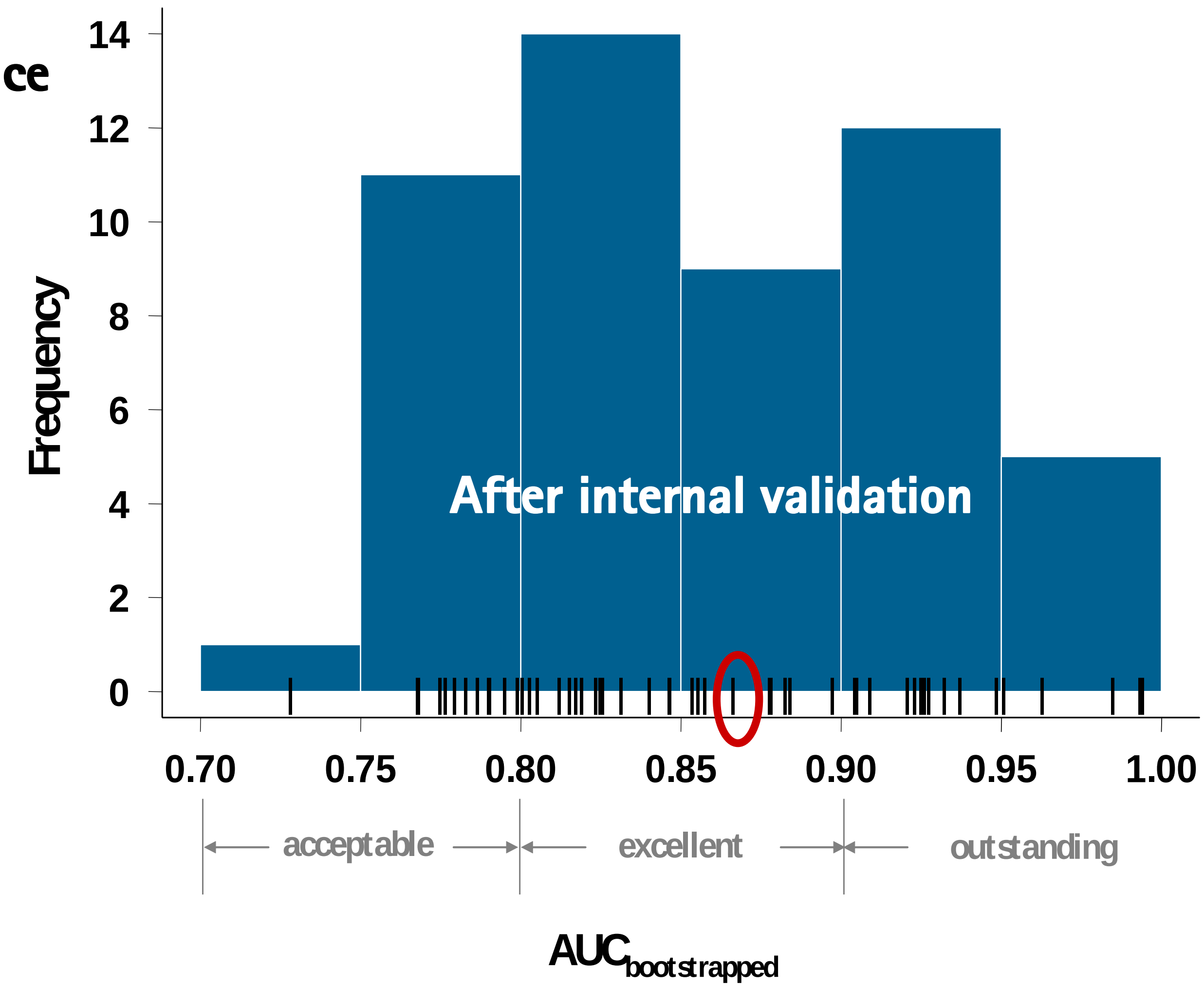
Predictor variable types
– examples : **significance**

Disturbance : 51/57
– time since last dist.
– dist. frequency

Ecohydrology : 15/57
– plant avail. water

Soil.static : 31/57
– field capacity
– CEC

Topography : 38/57
– slope
– potential insolation

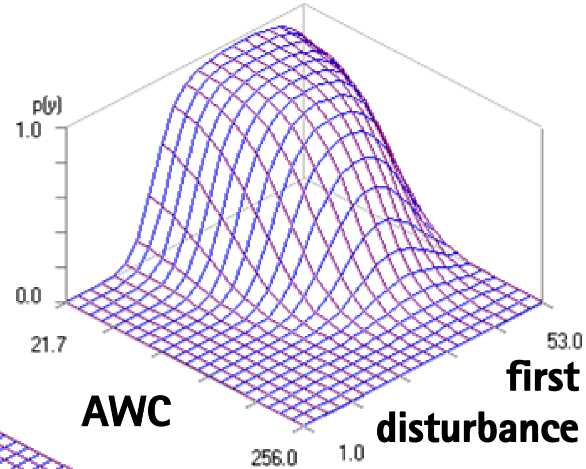


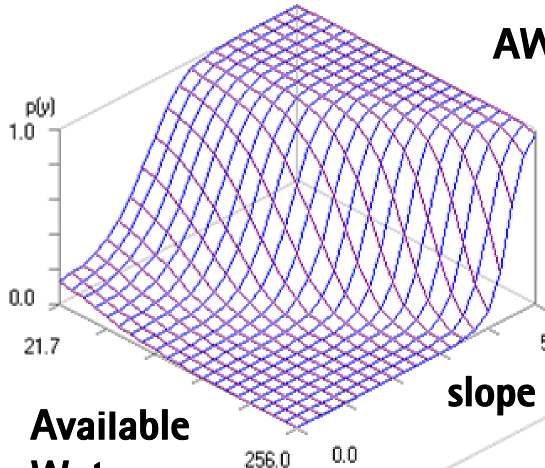
Rudner M, Biedermann R, Schröder B & Kleyer M 2007: Integrated grid based ecological and economic (INGRID) landscape model – a tool to support landscape management decisions, Env. Mod. Softw. 22, 177-187.

LANDSCAPE MODEL

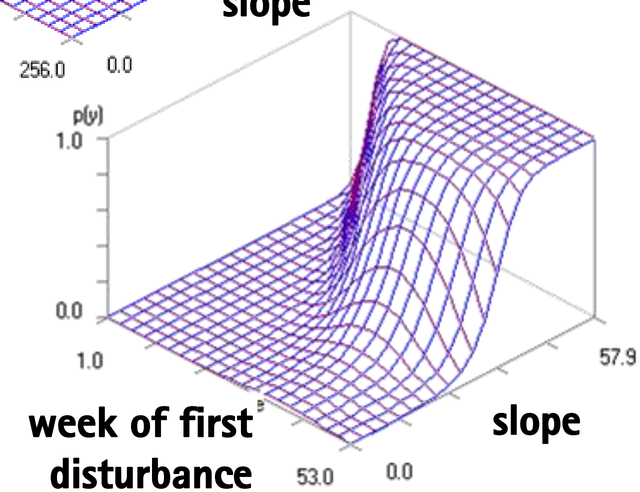
Response curves & suitability map

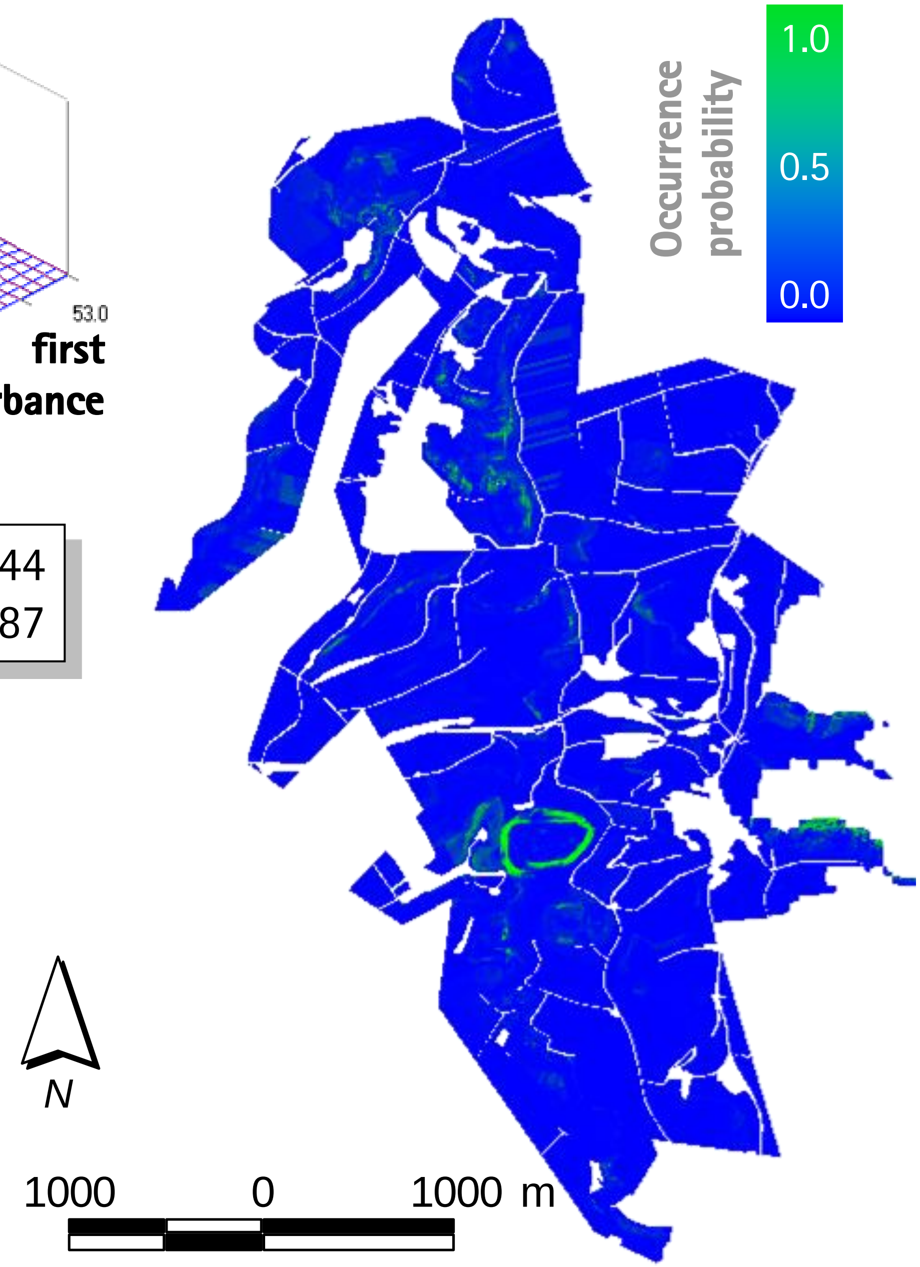
Thlaspi perfoliatum





$R^2_N = 0.44$
AUC = 0.87





Simulation

DYNAMIC LANDSCAPES

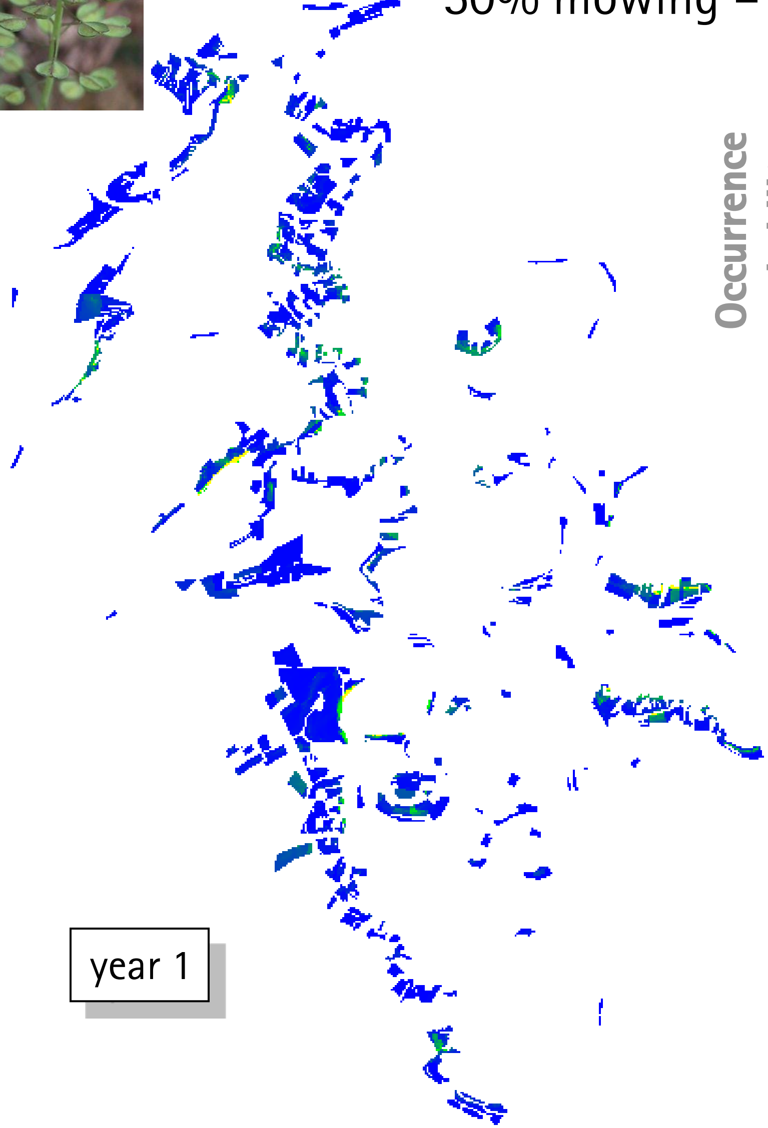
Thlaspi perfoliatum

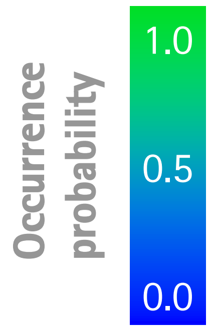
Shifting mosaic of habitat quality

Szenario 50(3)/50(1)

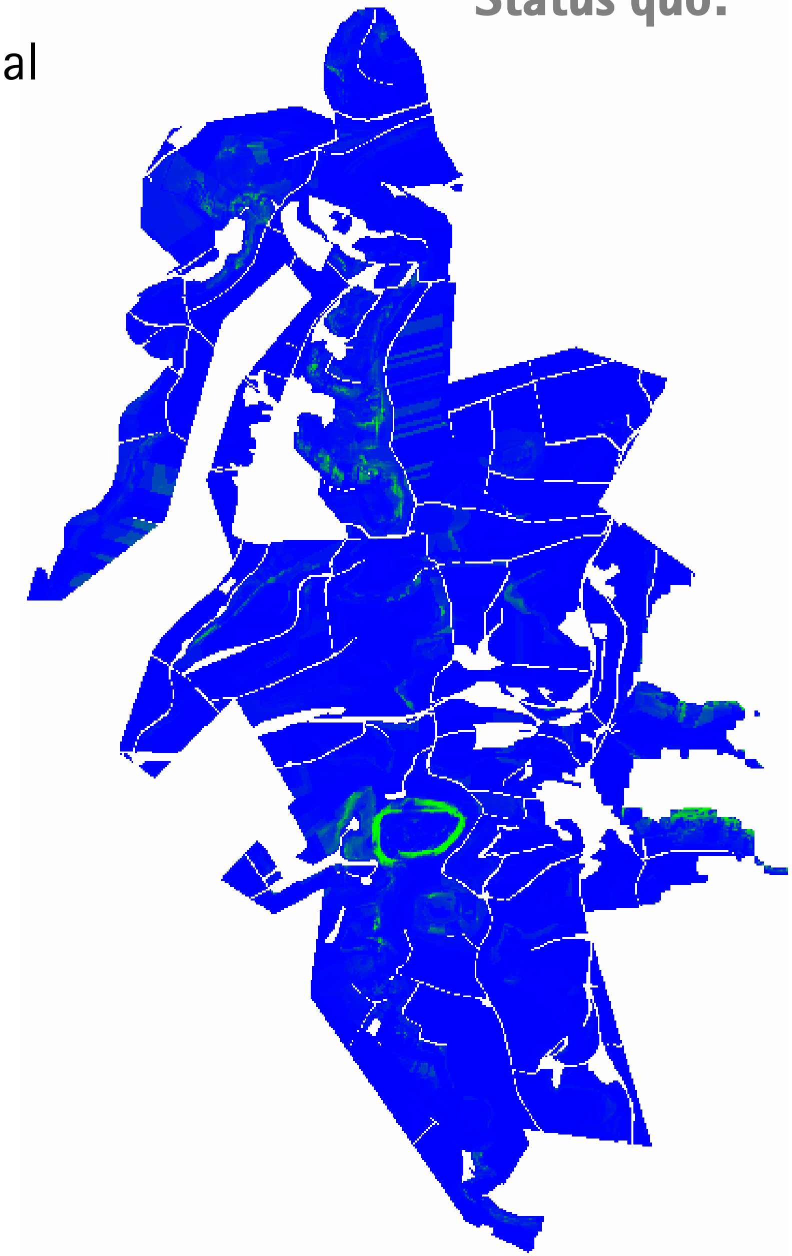
50% rototilling – tri-annual

50% mowing – annual





Status quo:

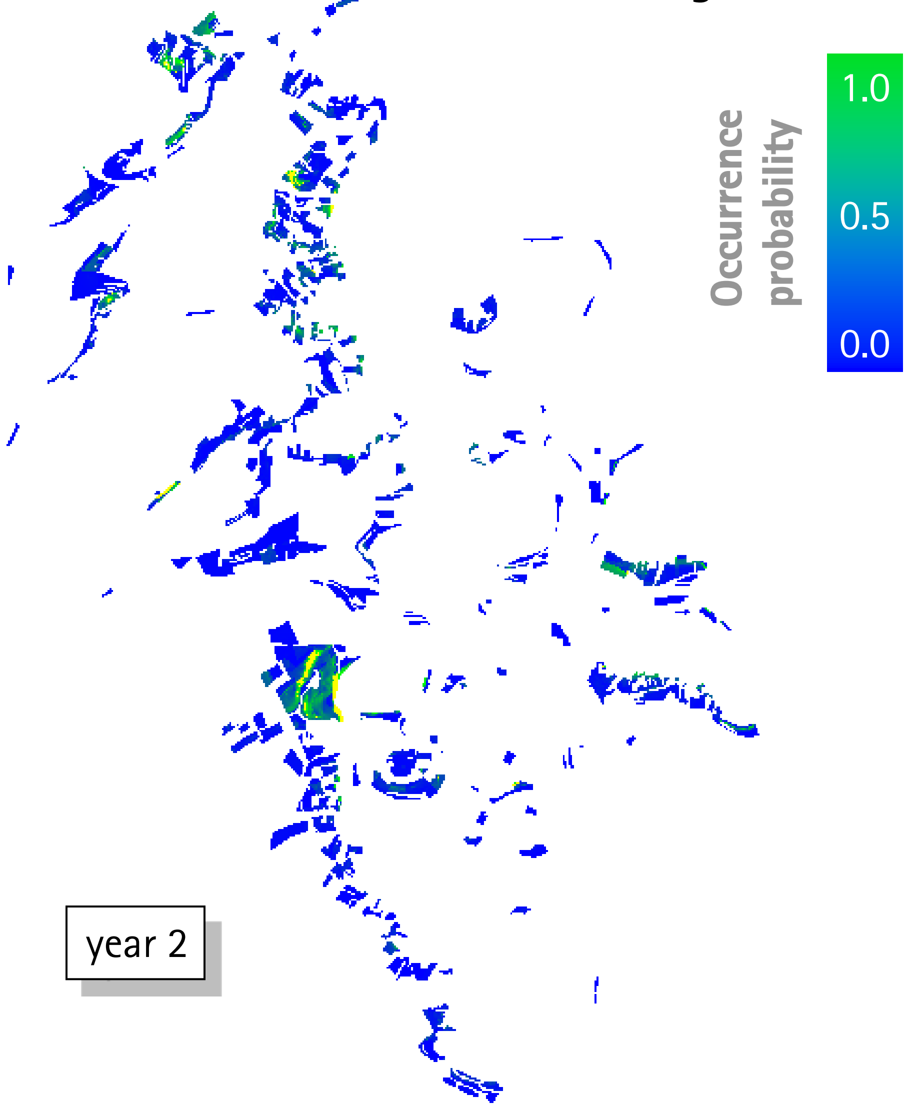


Shifting mosaic of habitat quality

Szenario 50(3)/50(1)

50% rototilling – tri-annual

50% mowing – annual



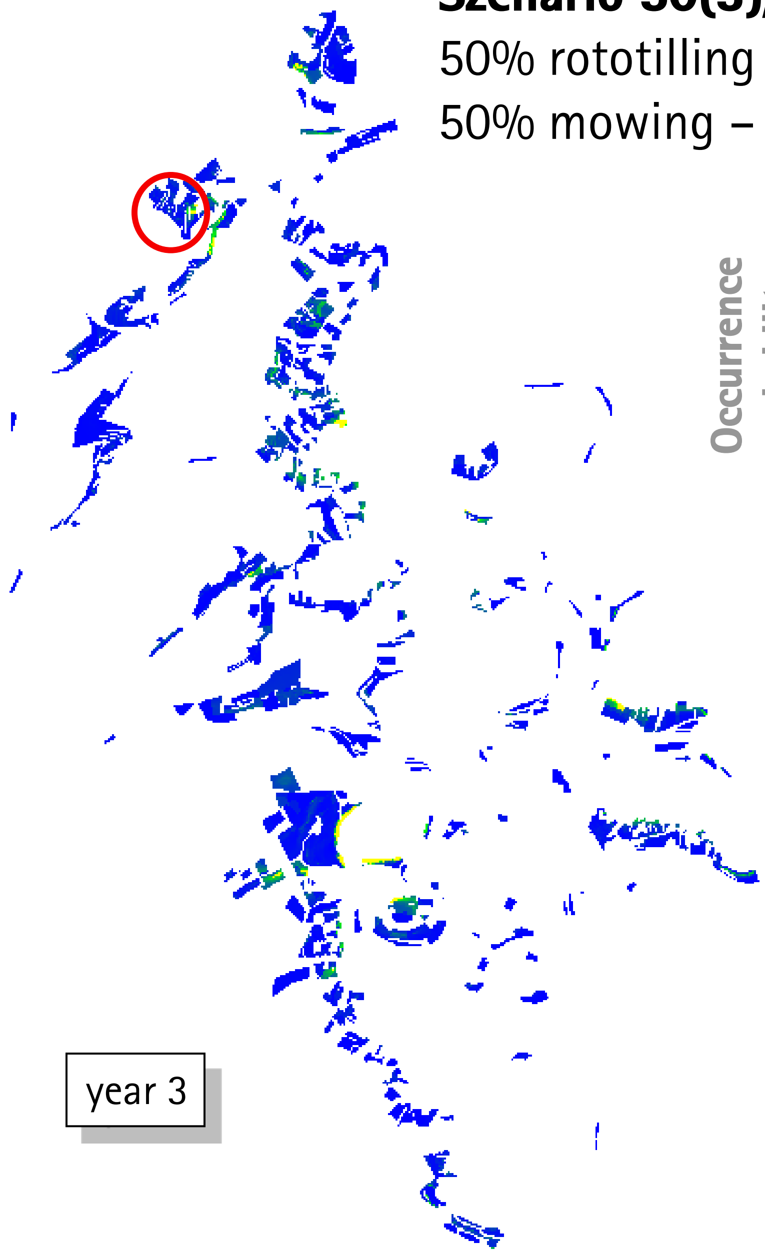
DYNAMIC LANDSCAPES

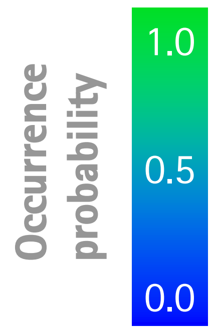
Shifting mosaic of habitat quality

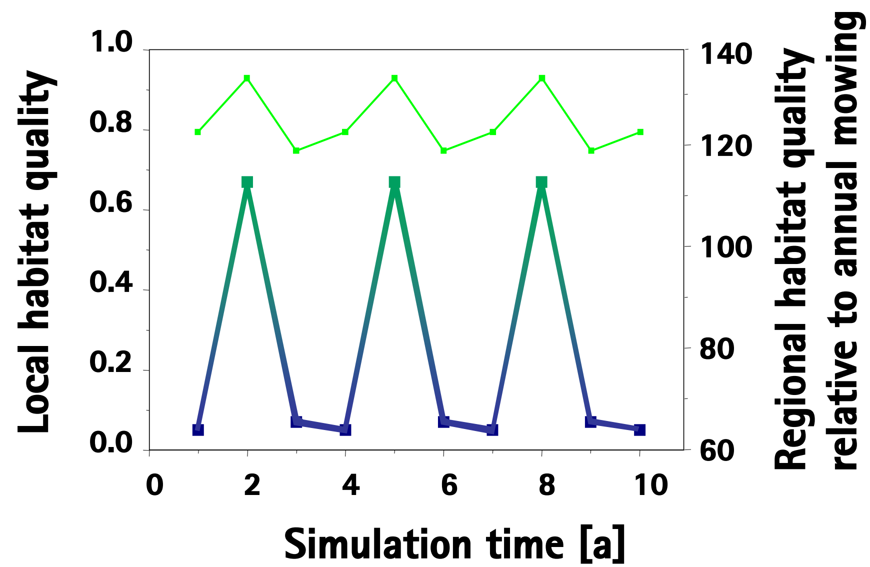
Szenario 50(3)/50(1)

50% rototilling – tri-annual

50% mowing – annual





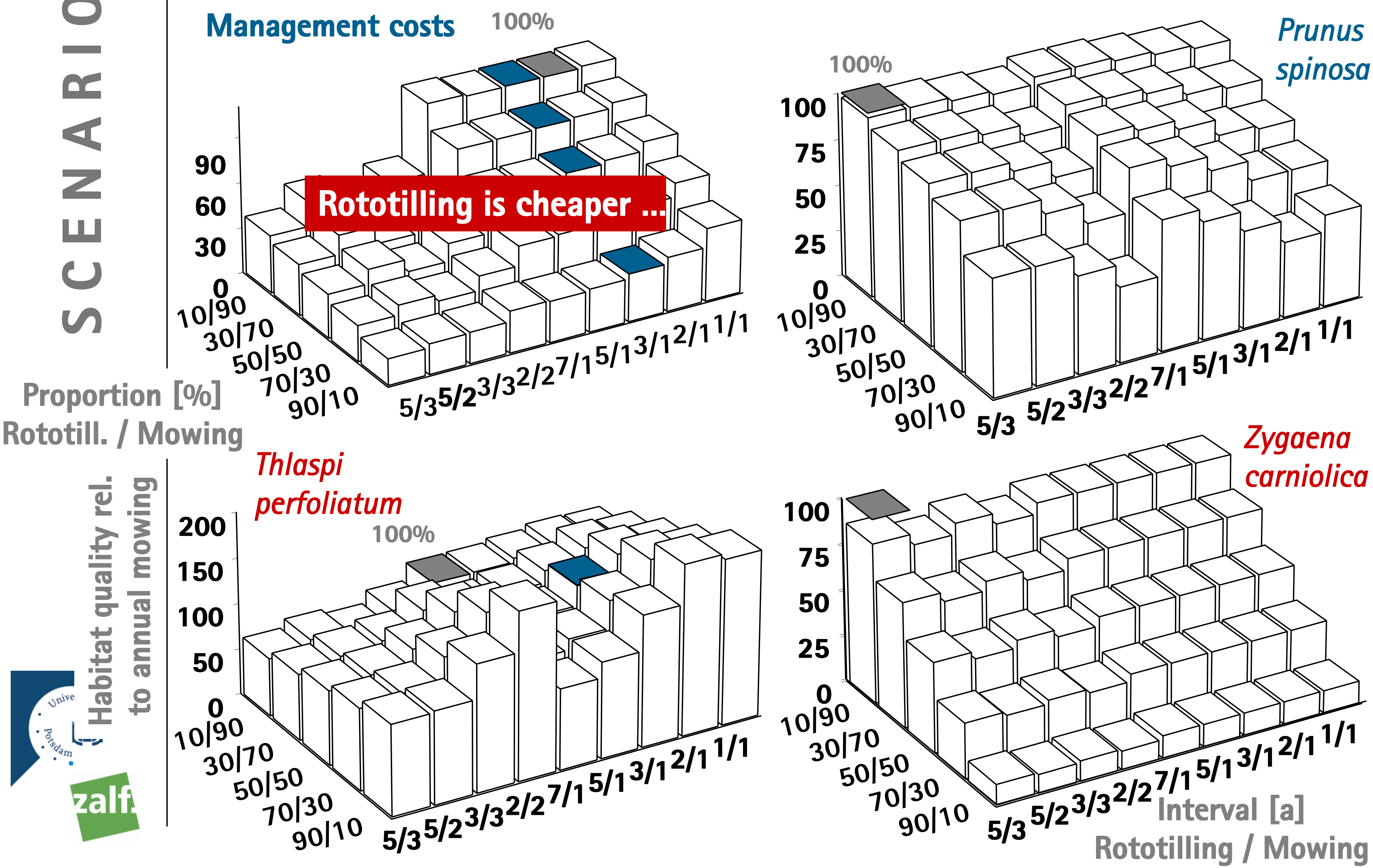


5

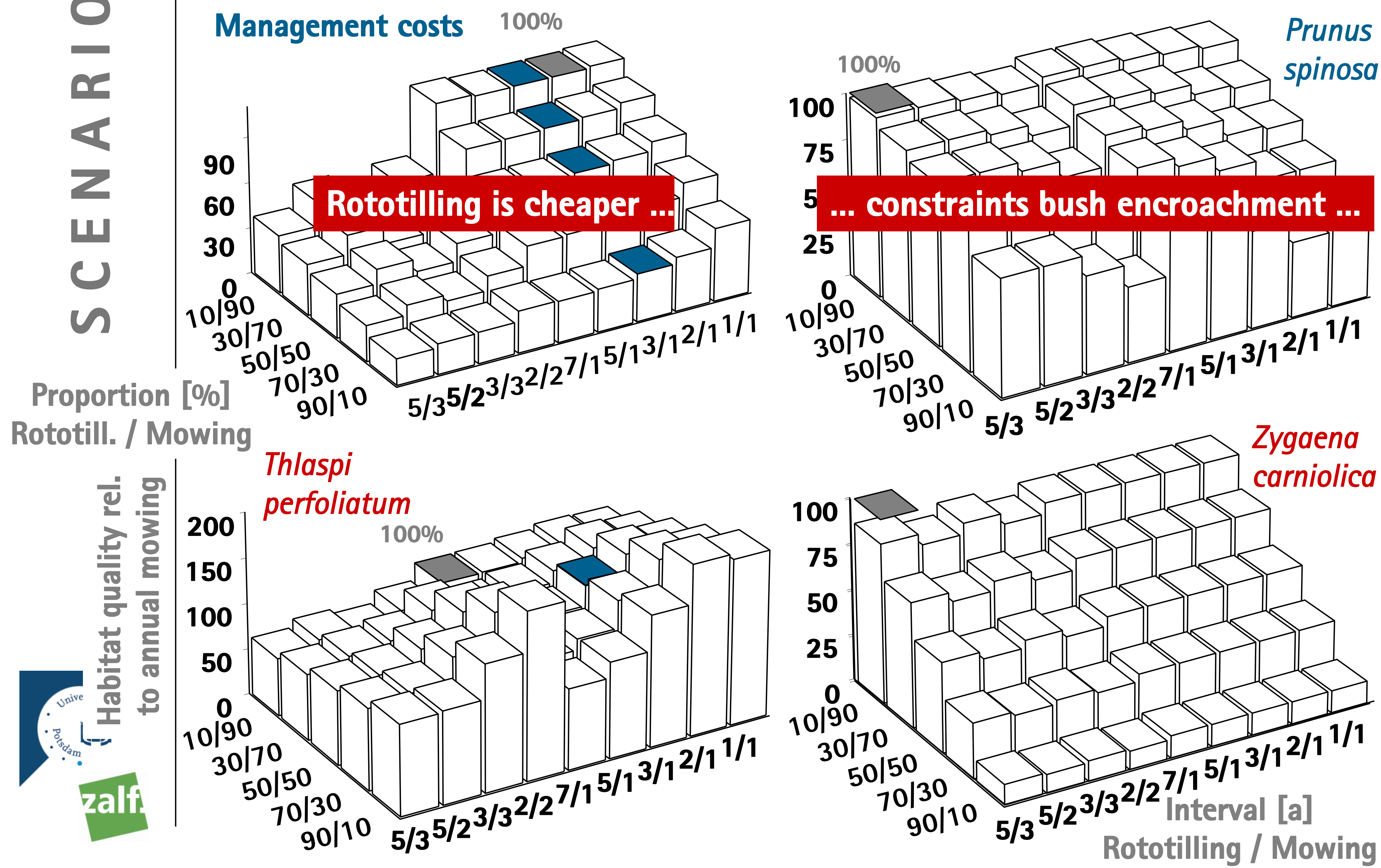
Comparison of scenarios

SCENARIOS

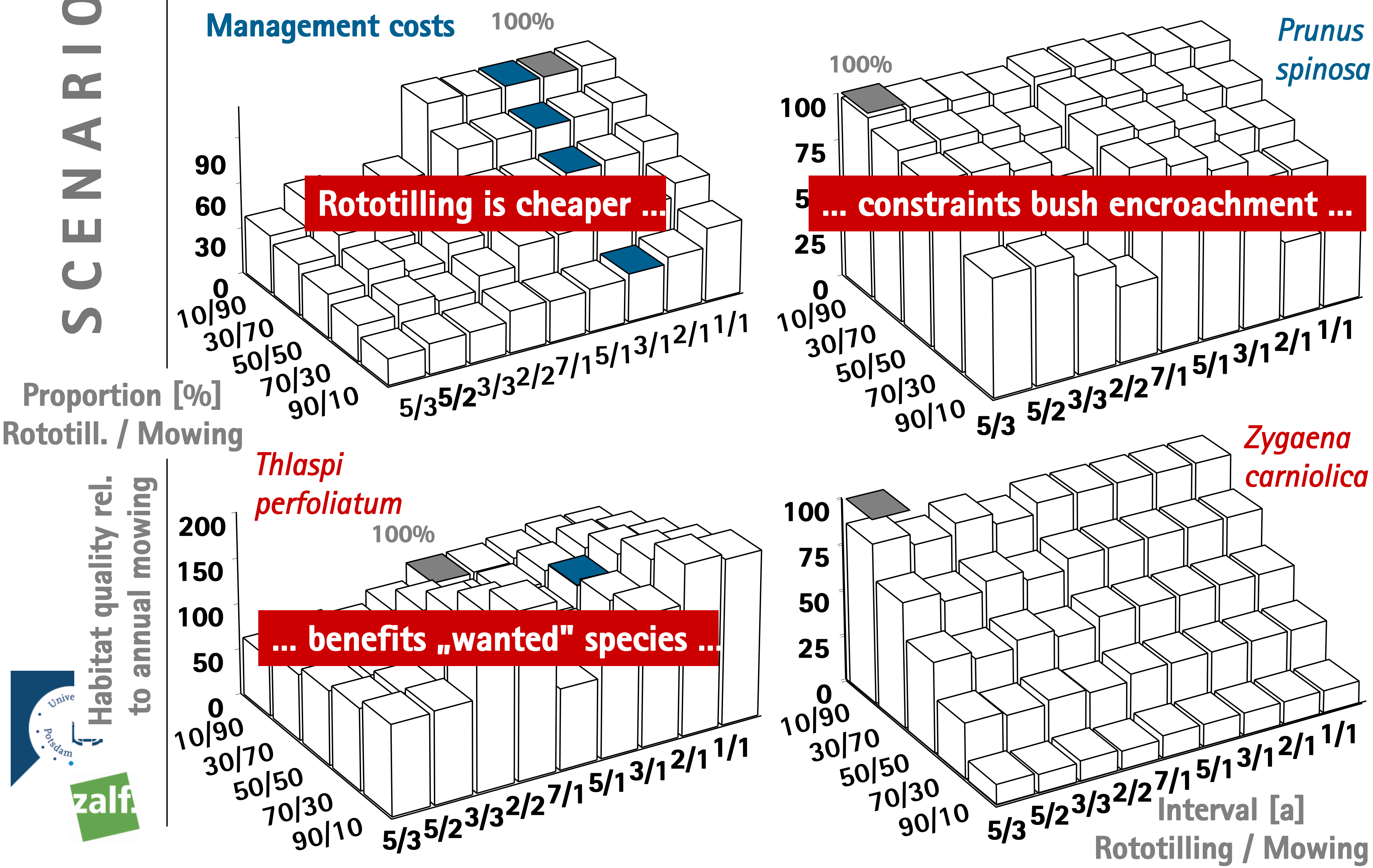
Effect of rototilling relative to annual mowing [%]



Effect of rototilling relative to annual mowing [%]

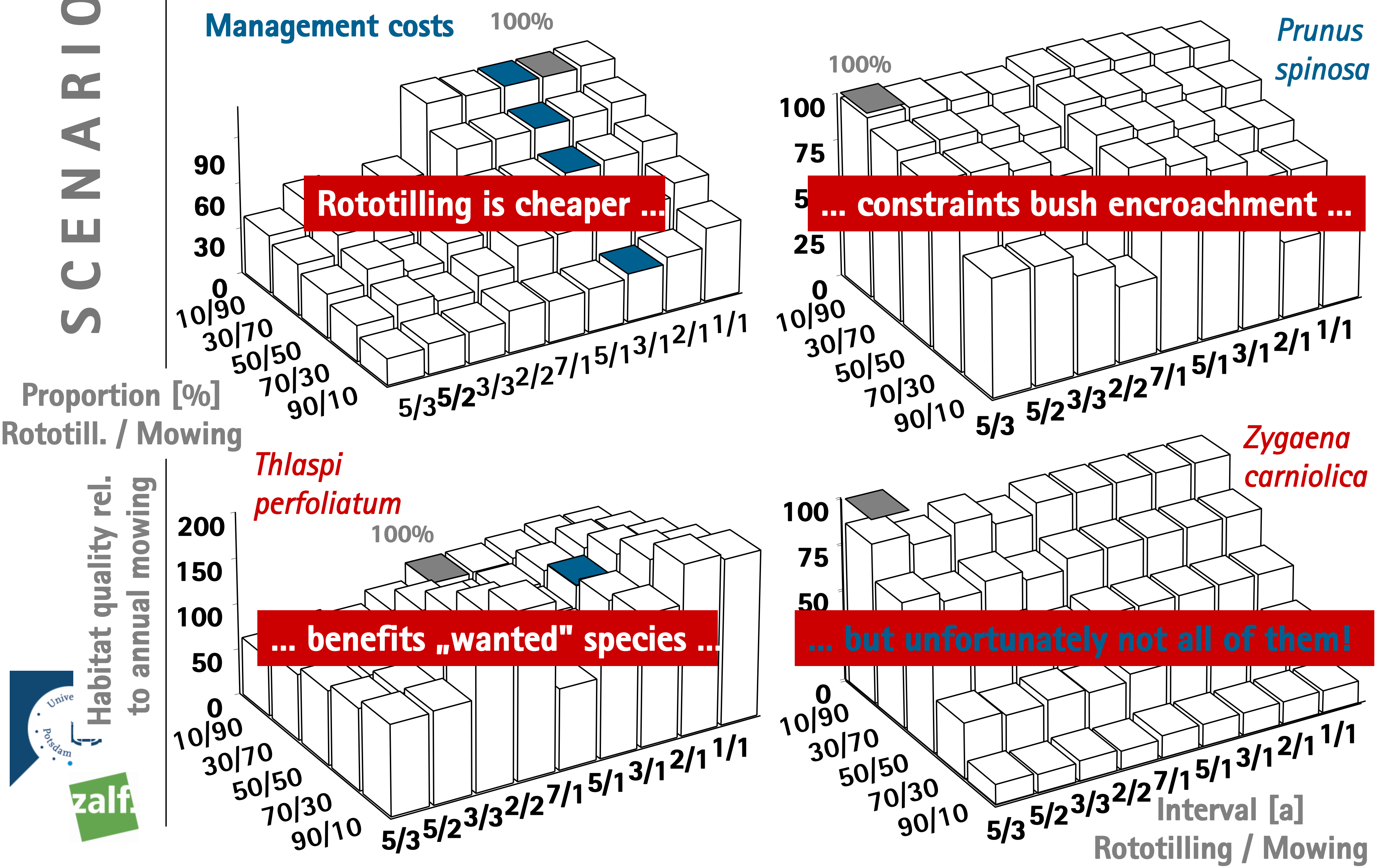


Effect of rototilling relative to annual mowing [%]



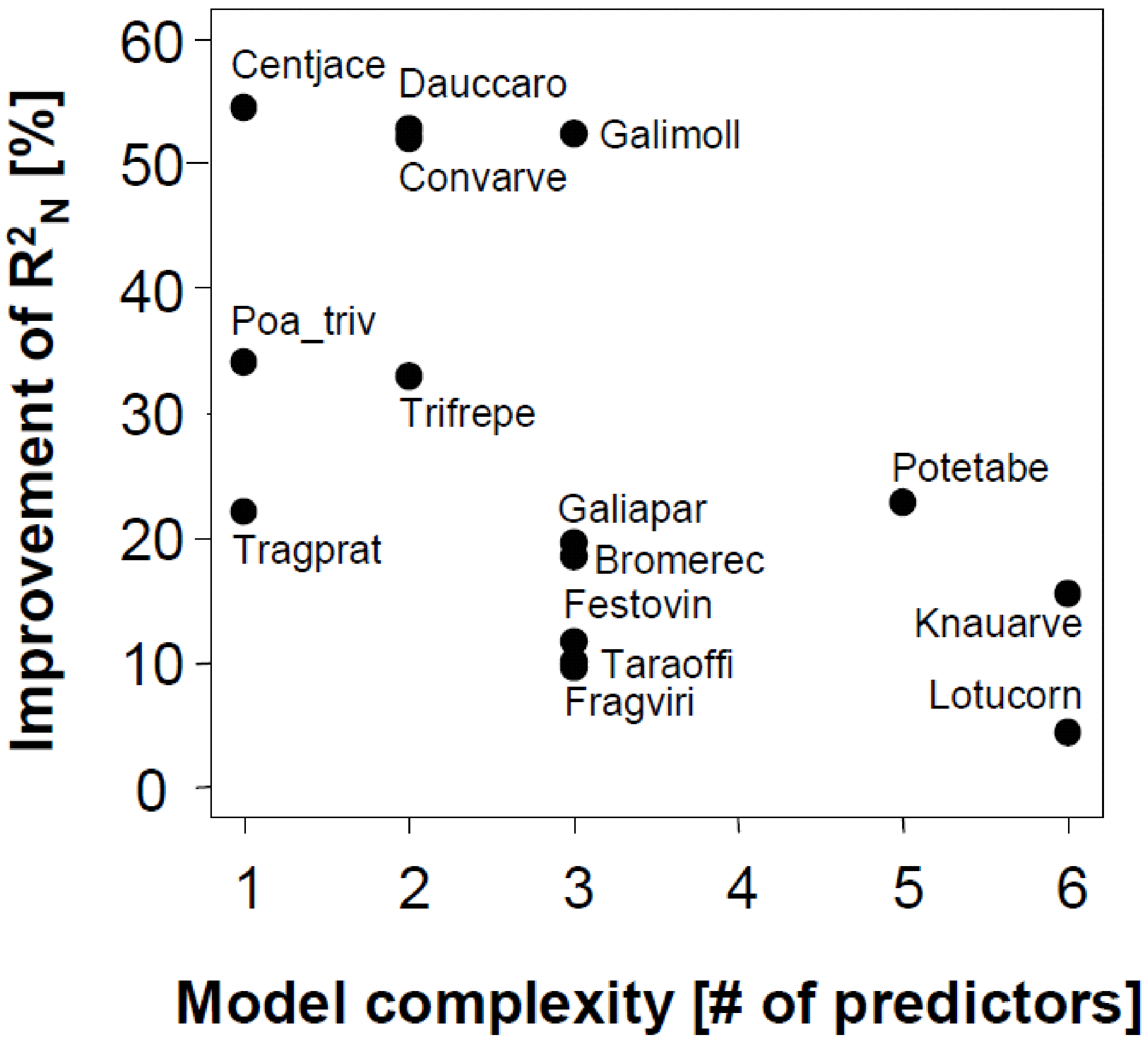
SCENARIOS

Effect of rototilling relative to annual mowing [%]



SUMMARY

Improvement due to ecohydrological predictors i.e. plant available water



Schröder, B. 2006. Pattern, process, and function in landscape ecology and catchment hydrology Hydrol Earth Syst Sci 10: 967-979.

ECOHYDROLOGY

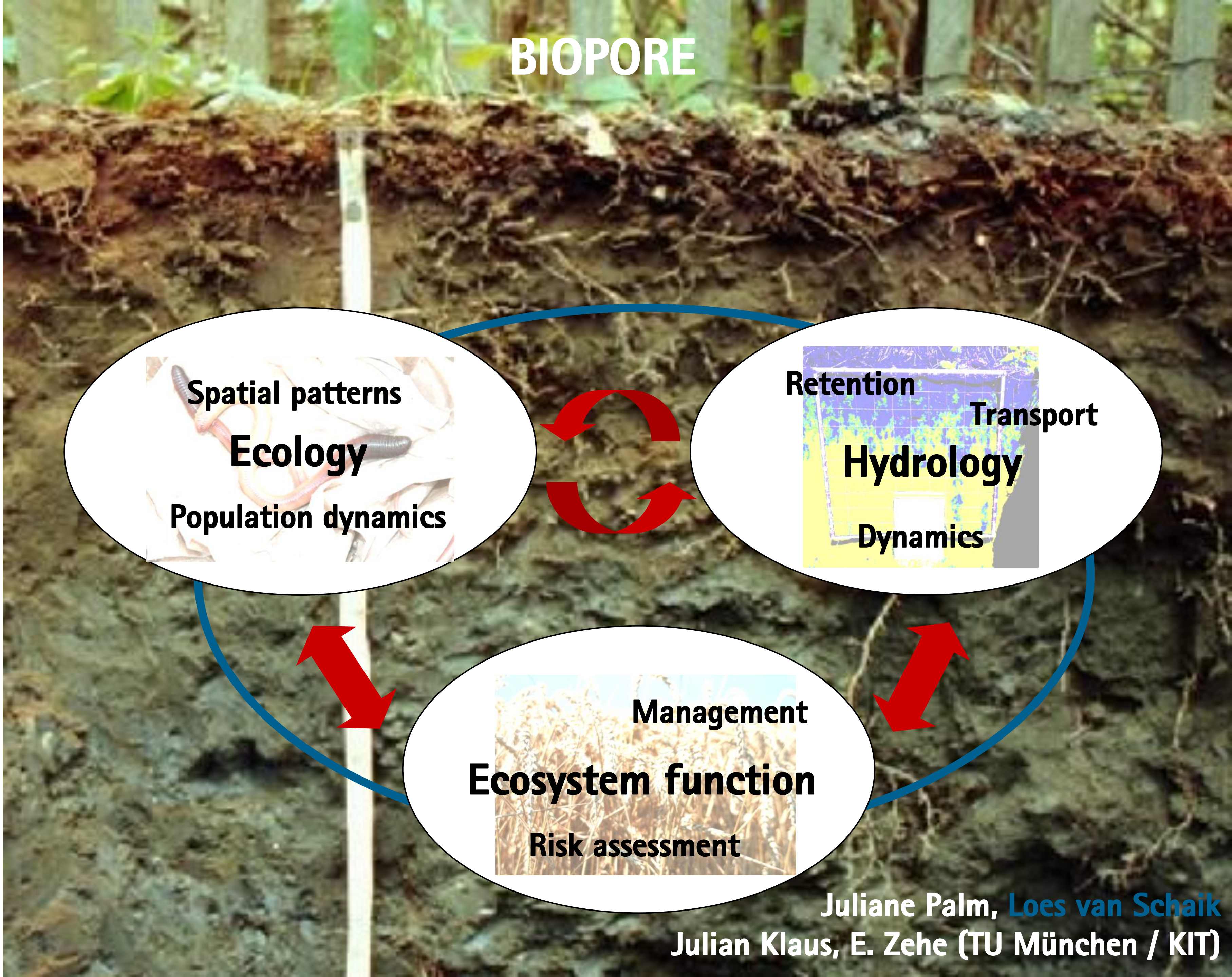
2007 - 2011

Deutsche Forschungsgemeinschaft DFG

KIT Karlsruhe Institute of Technology

Universität Potsdam

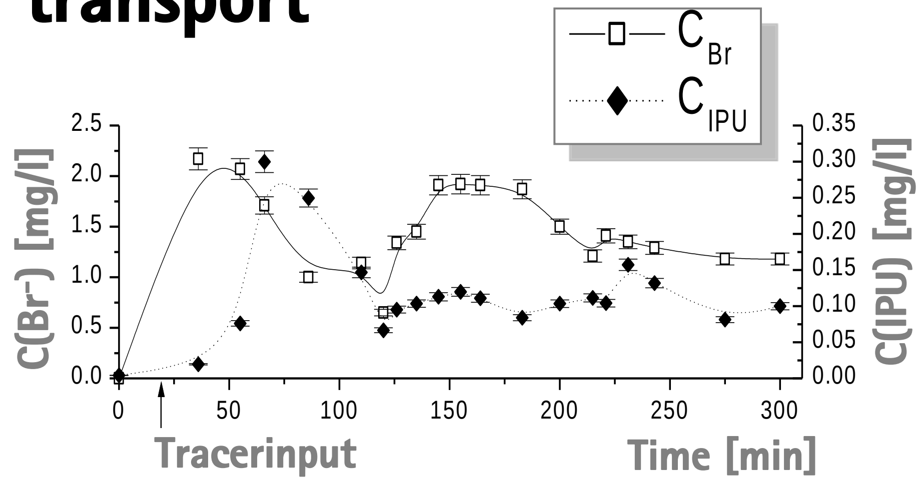
zalf



Preferential transport

Tracer experiments

- **Earthworm burrows as transport pathways**
- **Fast transport: up to 340 mg/kg Isoproturon into 1 m depth within 2 h**



Weiherbach catchment, Kraichgau

additional experiments in 2008/09/10

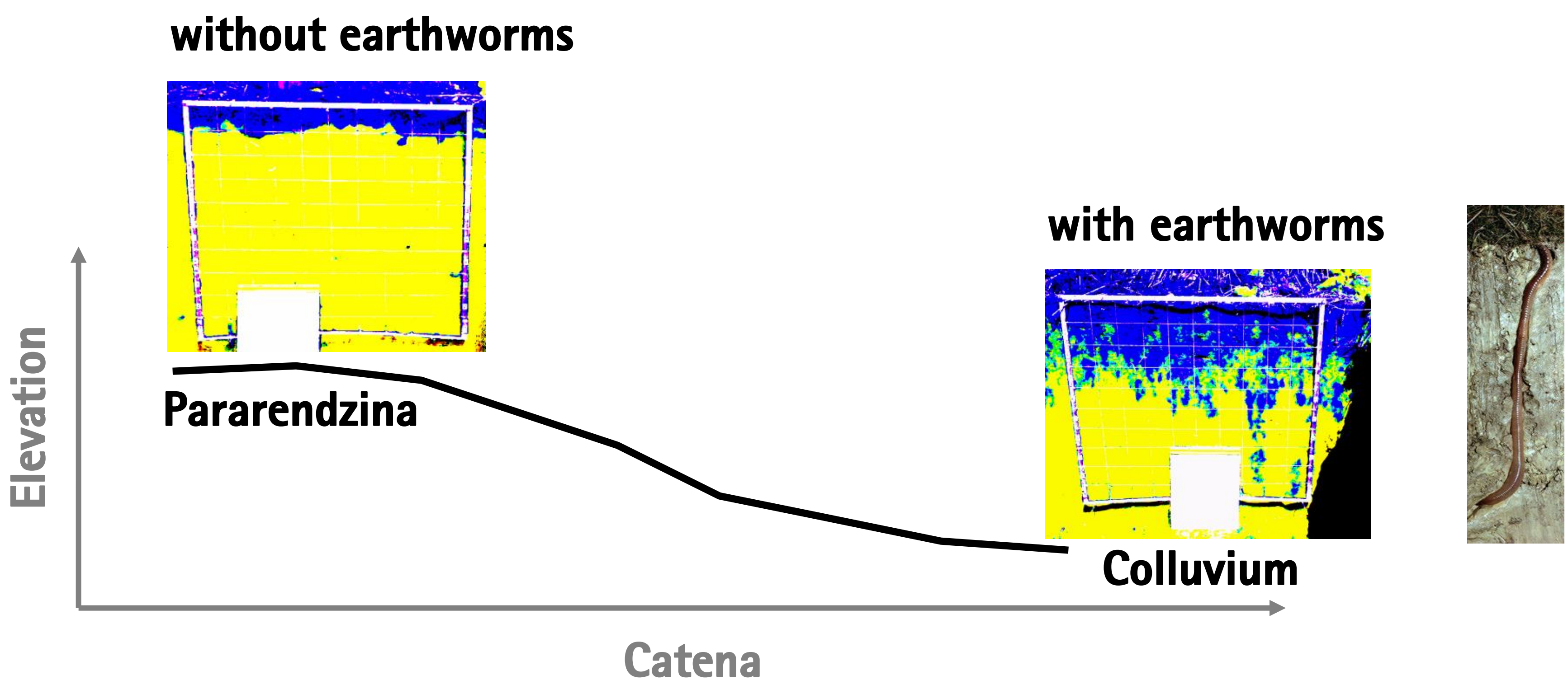
Loes van Schaik
Julian Klaus
Erwin Zehe

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

Spatial patterns at hillslope scale

Habitat preferences and erosion catena

- Spatial organisation of transport patterns
- Patterns of biogenic structures control transport
- Essential for mobility of pesticides

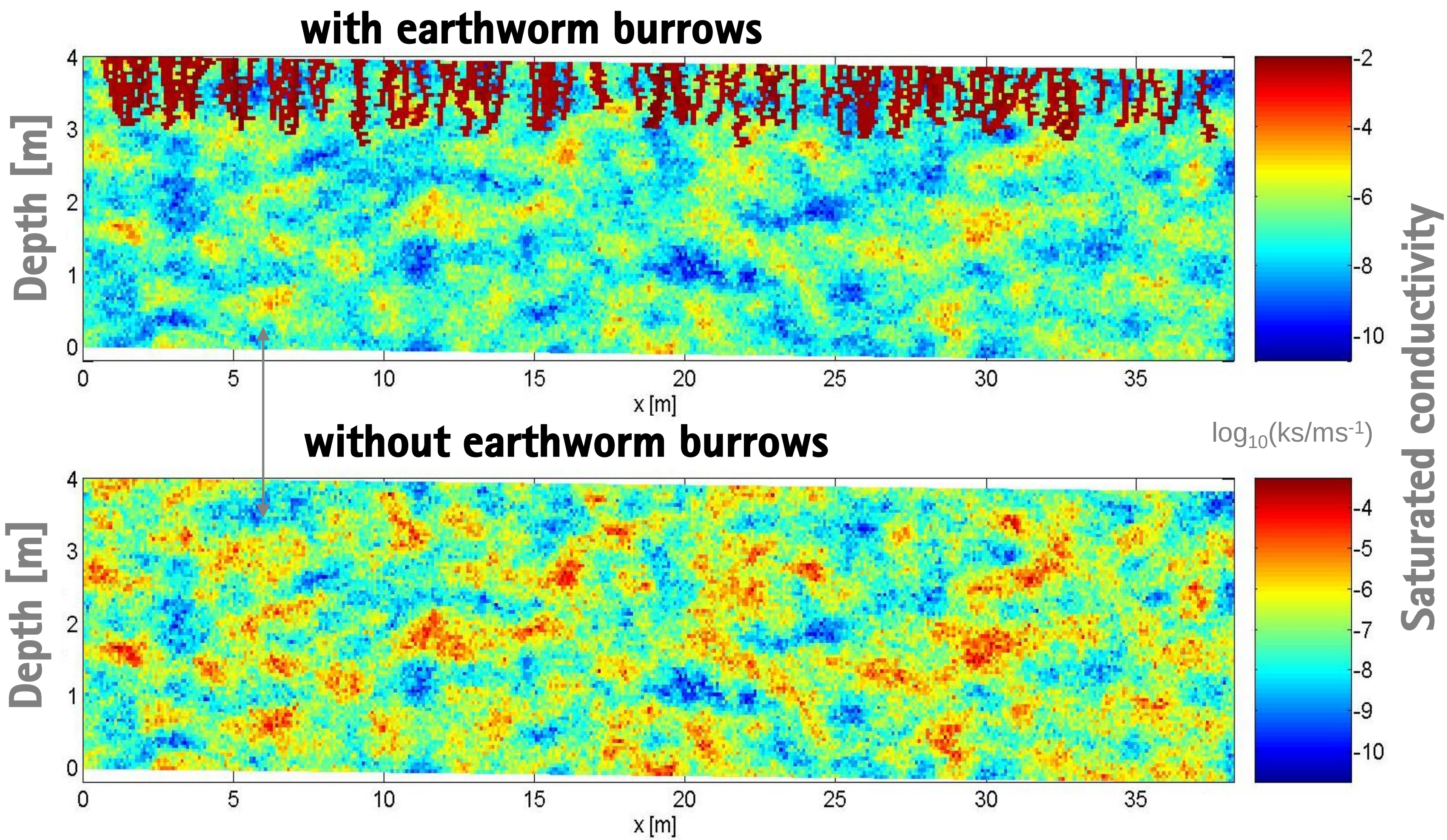


Zehe E, Flühler H, 2001. Slope scale distribution of flow patterns in soil profiles. J Hydrol 247: 116-132.

FIRST MODELS

Synthetic modelling approach

1) Generation of realistic heterogeneous media with identical matrix properties

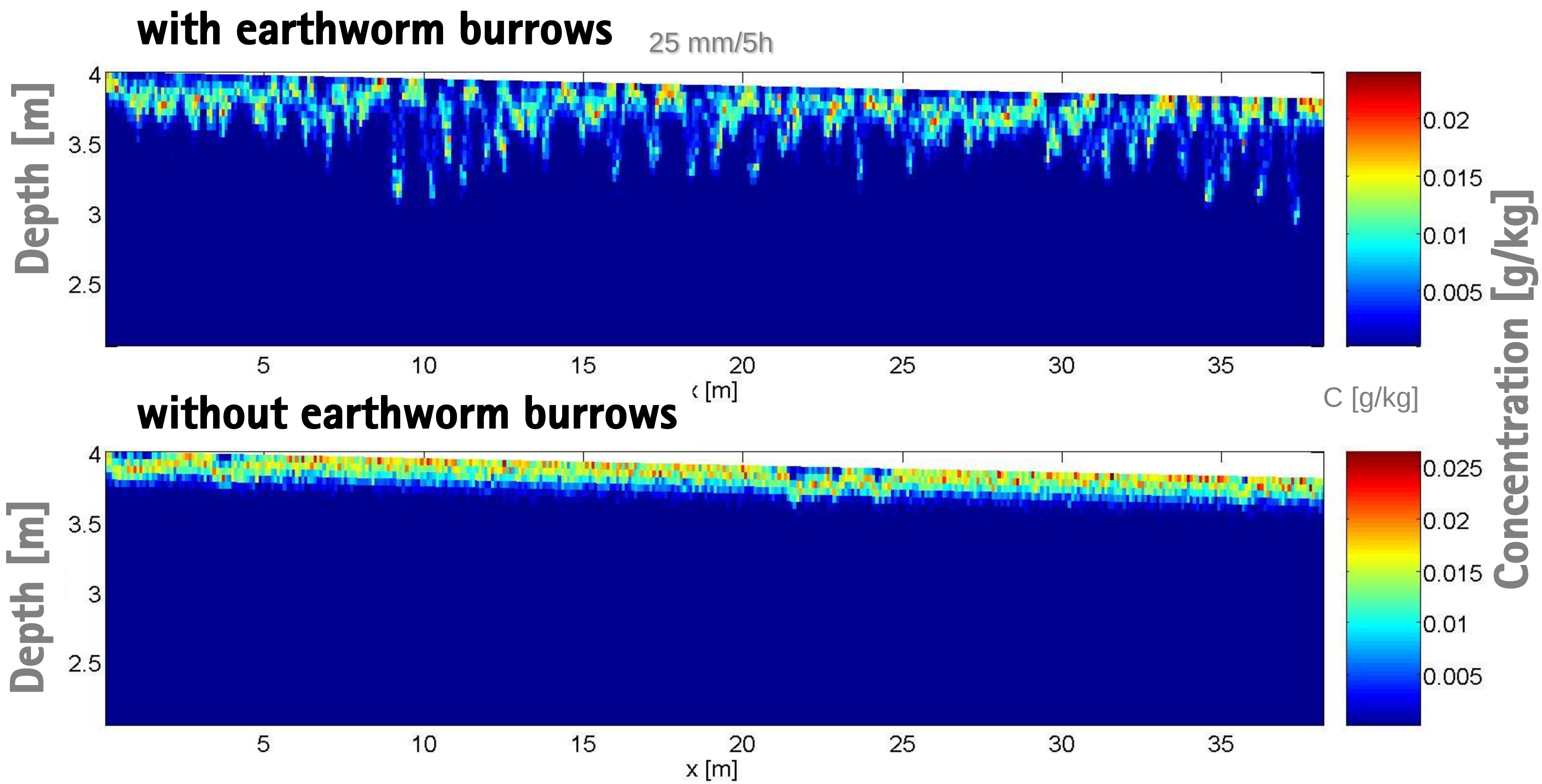


Erwin Zehe

Zehe E, Blöschl G, 2004. Predictability of hydrologic response at the plot and catchment scales .... Water Resour Res 40: W10202.

First synthetic modelling approach

2) Simulation with CATFLOW



Erwin Zehe
N Hartmann

Klaus J, Zehe E, Elsner M, Palm J, Schneider D, Schröder B, Steinbeiss S, van Schaik NLME, West S (in revision): Linking runoff generation and pesticide breakthrough at a tile drained field site.

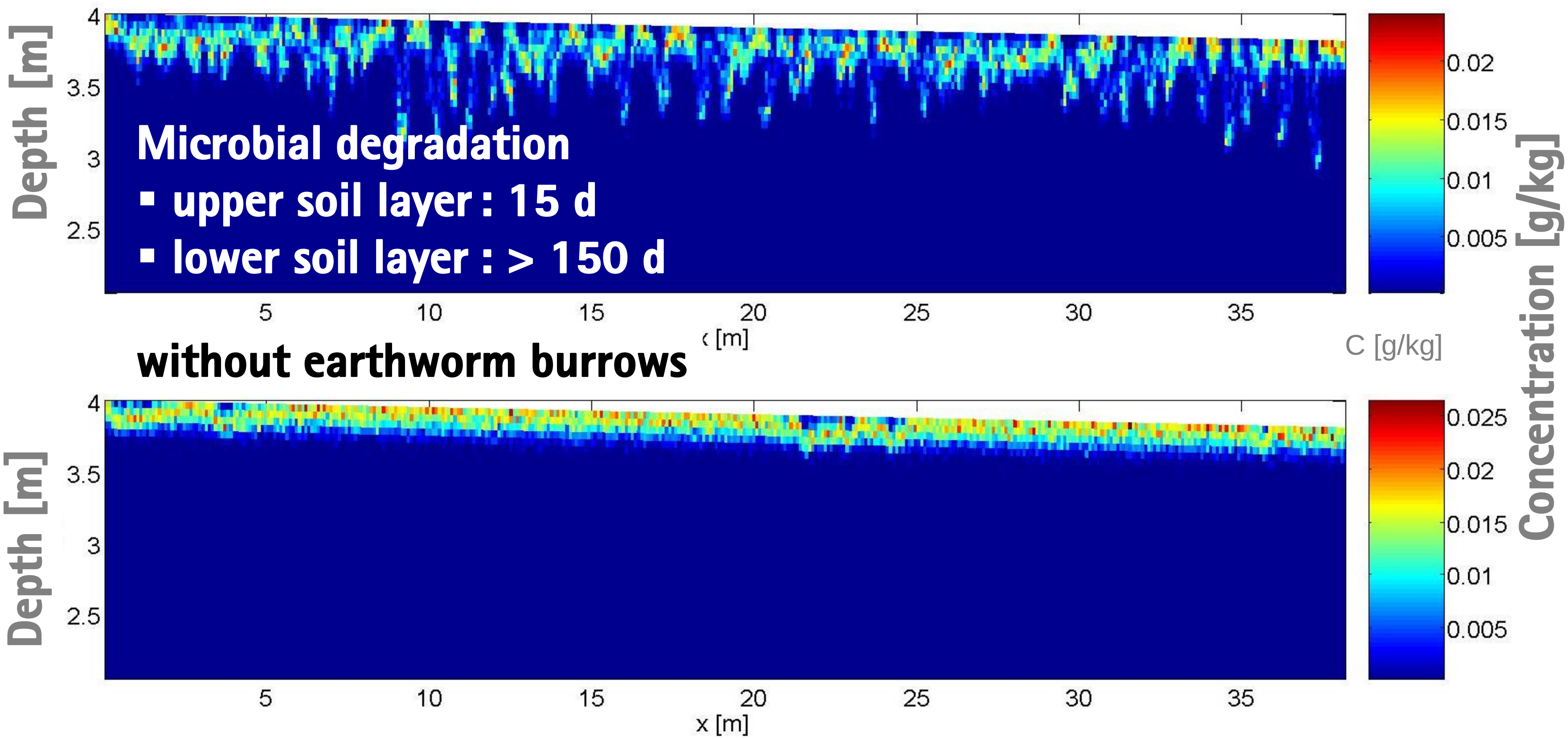
FIRST MODELS

First synthetic modelling approach

2) Simulation with CATFLOW

with earthworm burrows 25 mm/5h

without earthworm burrows



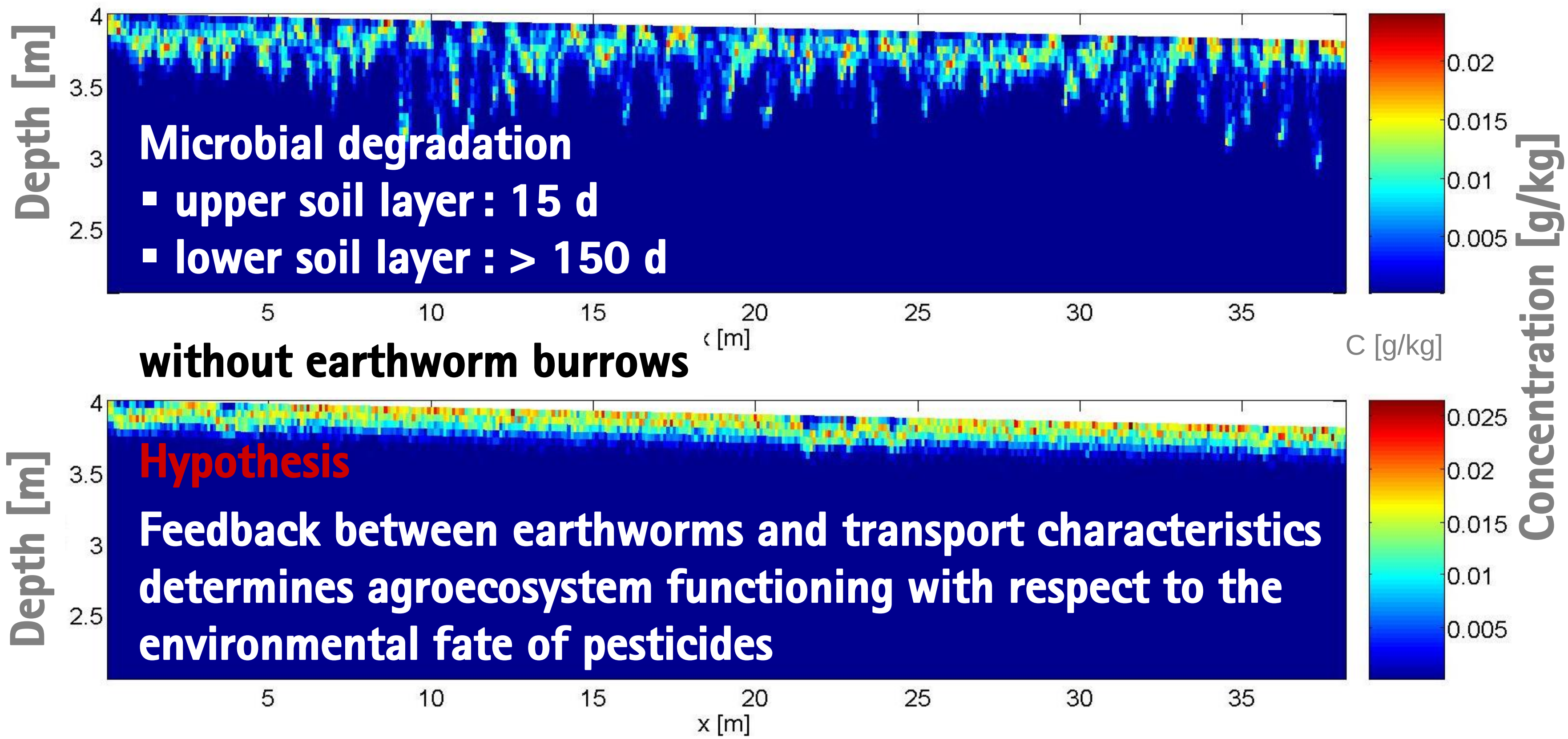
Erwin Zehe
N Hartmann

Klaus J, Zehe E, Elsner M, Palm J, Schneider D, Schröder B, Steinbeiss S, van Schaik NLME, West S (in revision): Linking runoff generation and pesticide breakthrough at a tile drained field site.

First synthetic modelling approach

2) Simulation with CATFLOW

with earthworm burrows



Microbial degradation

- **upper soil layer : 15 d**
- **lower soil layer : > 150 d**

Hypothesis

Feedback between earthworms and transport characteristics determines agroecosystem functioning with respect to the environmental fate of pesticides

Erwin Zehe
N Hartmann

Klaus J, Zehe E, Elsner M, Palm J, Schneider D, Schröder B, Steinbeiss S, van Schaik NLME, West S (in revision): Linking runoff generation and pesticide breakthrough at a tile drained field site.

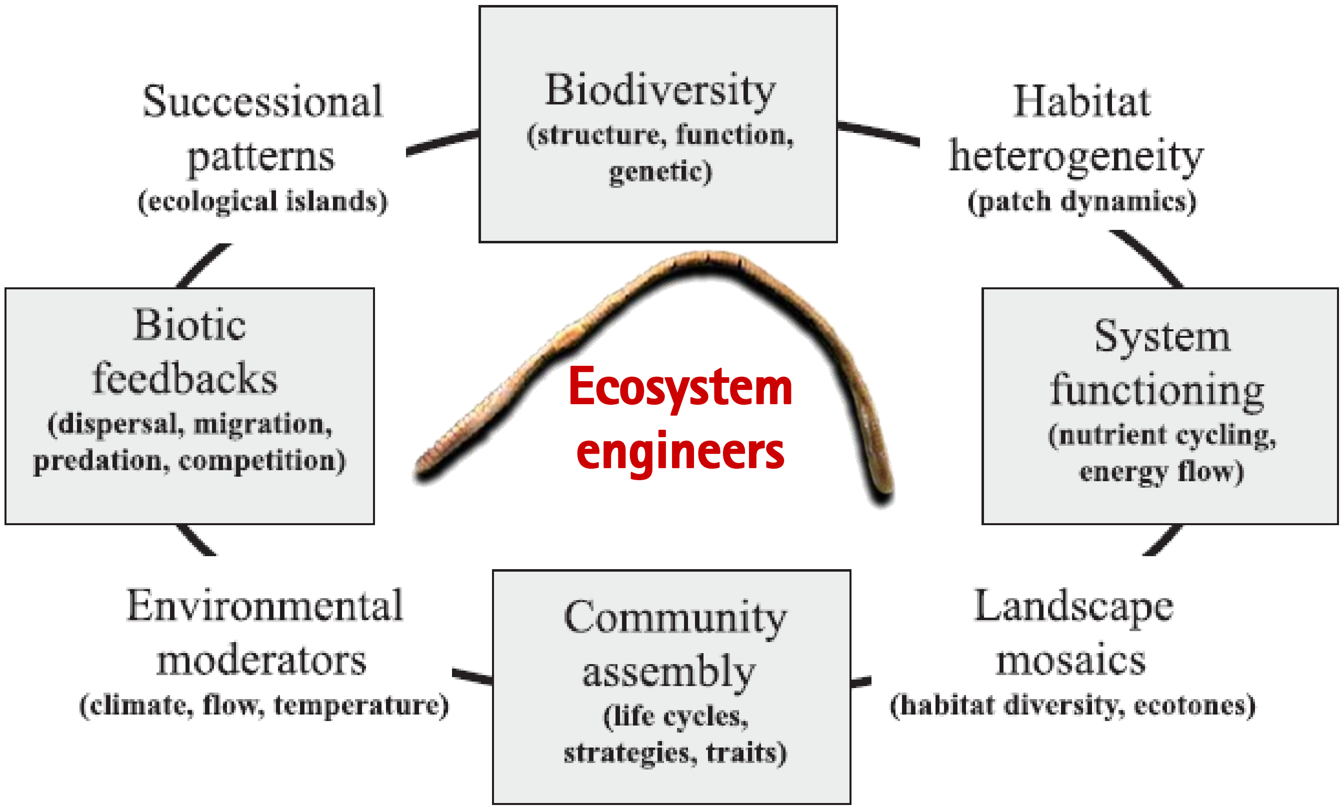
Ecosystem engineers / ecosystem engineering

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.

Ecosystem engineers / ecosystem engineering

Abiotic and biotic effects of ecosystem engineers



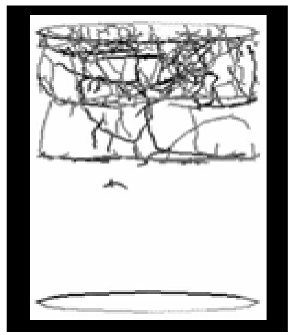
Ecosystem engineers are organisms that directly or indirectly modulate the availability of resources to other organisms by causing physical state changes in biotic or abiotic materials.

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

Earthworm ≠ Earthworm – three ecological life forms

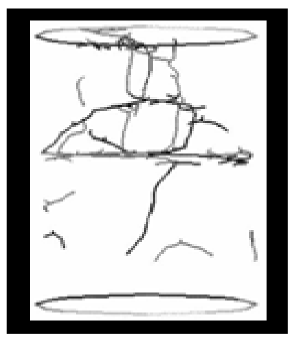
Epigeics

- Litter inhabitants
- No permanent burrow system



Endogeics

- Inhabitants of the mineral soil layer, max 40 cm
- Horizontal burrow system
- Pore diameter Ø 2-5 mm



Anecics

- Connect deeper soil layers with soil surface
- Vertical, straight burrows, 1- >2 m depth
- Pore diameter Ø 6-11 mm

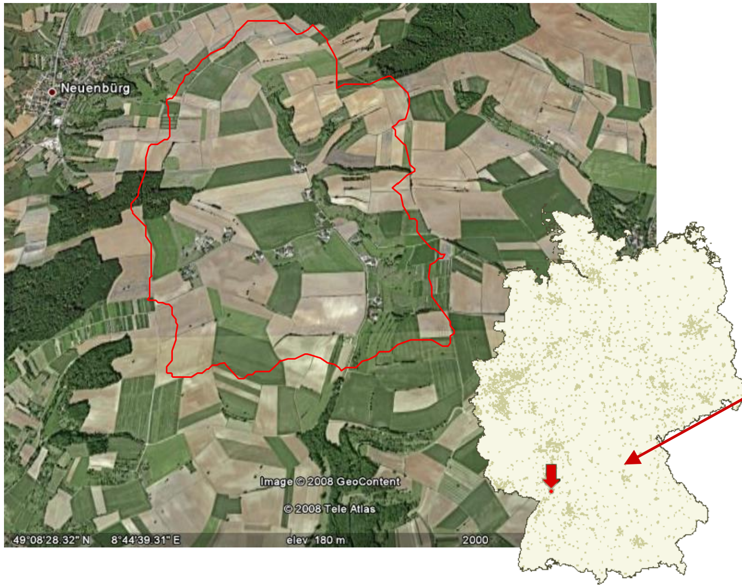
Bouché MB, 1975. Action de la faune sur les états de la matière organique dans les écosystèmes. In: Kilbertius G, O. R, A. M, Cancela da Fonseca JA (eds.), Humification et biodégradation. Pierron, pp. 157-168.

Photos Otto Ehrmann; Jegou et al. 2001 Geoderma 102, 123-137

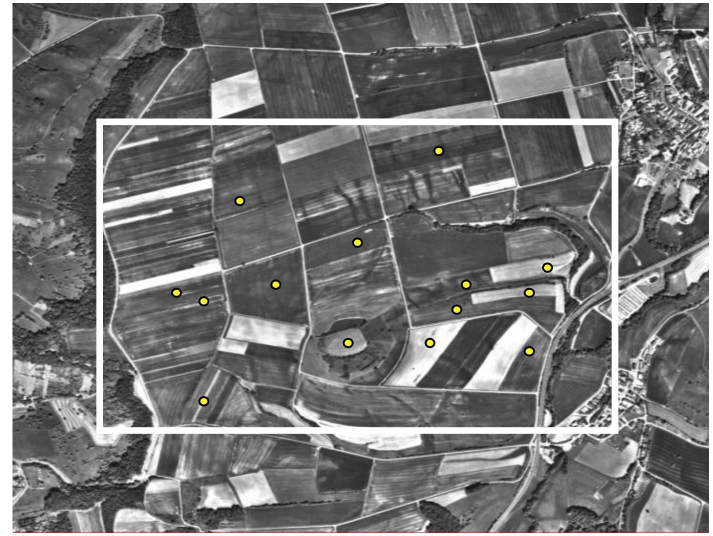
BIOPORE

Study sites

Weiherbach, Kraichgau



Hassberge, Unterfranken



Loess soil, high erodibility
and intensive agriculture

Clay soils and
low impact agriculture, nature reserves

BIOPORE

1 – Species distribution model for earthworms

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

... and observational data


Earthworm extraction with mustard
50 × 50 cm^2 plots
(stratified random sampling)

Detection of macropores in different soil depths

Nested Sampling Design for analysing spatial heterogeneity

Juliane Palm

Schröder B, 2008. Challenges of species distribution modelling belowground. J Plant Nutr Soil Sci 171: 325-337.

ECOLOGY

Habitat factors

controlling spatiotemporal distribution patterns of earthworms

Soil properties

Moisture

Nutrients, C/N

pH

Texture

Compaction

Land use

Vegetation

Organic layer

till vs no-till

Intensity

Earthworms

Climate

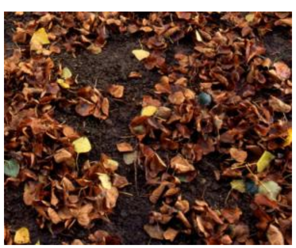
Temperature

Precipitation

Food

Org. matter

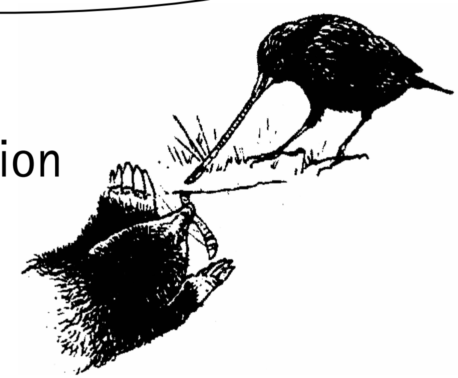
Vegetation / litter



Biotic interactions

Competition

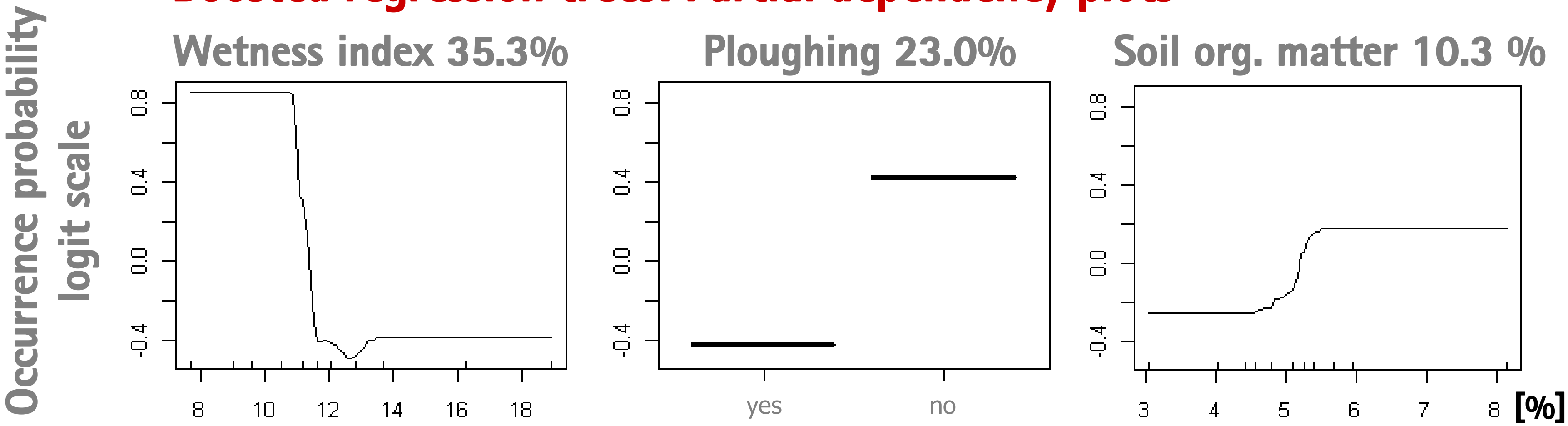
Predation



RESULTS

Species distribution models – *Lumbricus terrestris*

Boosted regression trees: Partial dependency plots



Further predictors (contribution)

Heat Load (9.2%)

pH value (6.5%)

Compaction (6.0%)

Juliane Palm

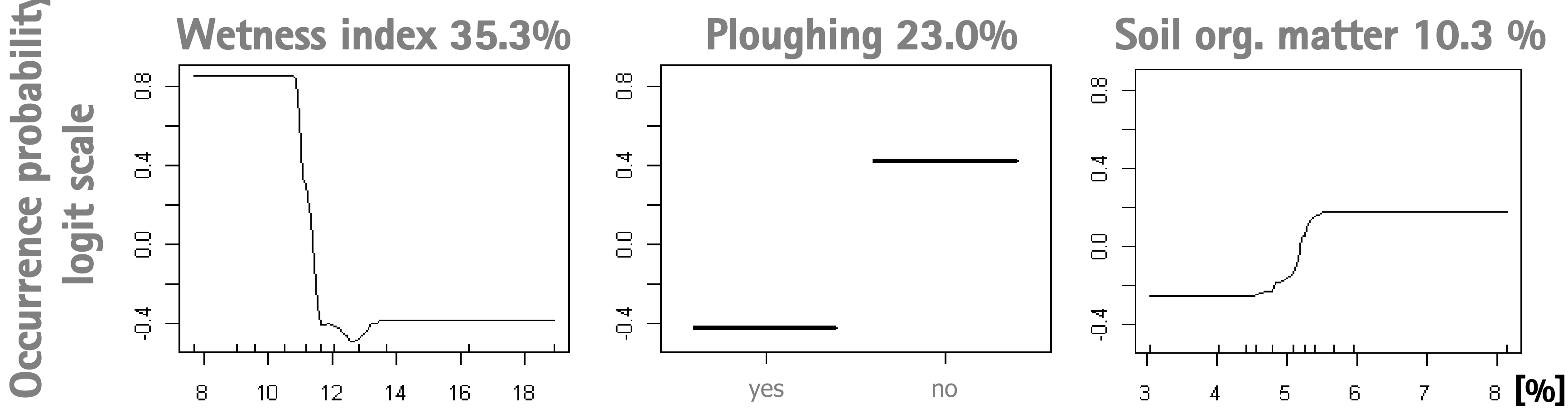
Higher occurrence probability in areas with low wetness index, no ploughing and higher soil organic matter content

Palm J, van Schaik, NLMB, Schröder B (2010): First results in modelling distribution patterns of anecic earthworms on catchment scale. Berichte der DBG, DBGPrints-Archiv No. 496

RESULTS

Species distribution models – *Lumbricus terrestris*

Boosted regression trees: Partial dependency plots



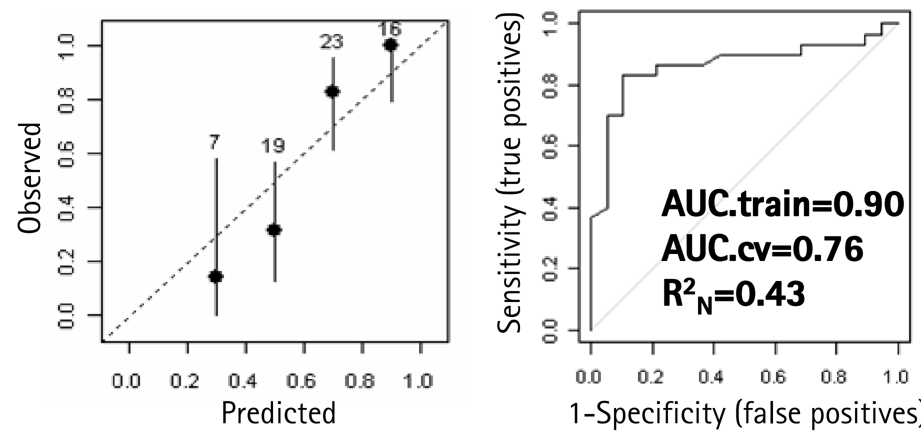
Further predictors (contribution)

Heat Load (9.2%)

pH value (6.5%)

Compaction (6.0%)

Model performance



Higher occurrence probability in areas with low wetness index, no ploughing and higher soil organic matter content

Good model performance after cross-validation

AUC = 0.5	: null model
$0.8 \leq AUC \leq 0.9$	: excellent
AUC = 1	: perfect classification

Juliane Palm

Palm J, van Schaik, NLMB, Schröder B (2010): First results in modelling distribution patterns of anecic earthworms on catchment scale. Berichte der DBG, DBGPrints-Archiv No. 496

BIOPORE

Anne Schneider

Outlook – Linking SDM with …

2) Population dynamic model

Understanding and prediction of spatial population dynamics of anecic earthworms

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

BIOPORE

Anne Schneider

Loes van Schaik
Julian Klaus
Erwin Zehe

Outlook – Linking SDM with ...

2) Population dynamic model

Understanding and prediction of spatial population dynamics of anecic earthworms

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

3) CATFLOW – water and matter transport model

Prediction of infiltration, transport & sorption of tracers & pesticides

... depending on spatiotemporal distribution of connective macropores, i.e. earthworm burrows

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

Klaus J, Zehe E, 2010. Modelling rapid flow response of a tile drained field site using a 2D-physically based model: assessment of "equifinal" model setups. Hydrol Proc 24: 1595-1609.

Klaus J, Zehe E, Elsner M, Palm J, Schneider D, Schröder B, Steinbeiss S, van Schaik NLME, West S (in revision): Linking Runoff generation and pesticide breakthrough at a tile drained field site. J Env Qual

Summary

Preliminary results show

- **Importance of land use (no-till) for earthworm distribution**
- **Strong effect of soil moisture & temperature on earthworm abundance**
- **High spatial & seasonal variability of abundances**
- **Preferential flow in both study sites**

SUMMARY

Summary – Species distribution models | SDMs

Species distribution modelling

- Understanding species-environment / diversity-environment relationships
- Generation of hypotheses
- Extrapolation and projection in space & time
- Towards mechanistic niche modelling
  – integration of processes and interactions (dispersal, population dynamics etc.)

Dormann et al. Ecography 2007
Dormann et al. Ecology 2008
Reineking & Schröder Ecol Model 2006
Schröder et al. JPNSS 2008
Schröder et al. Biol Cons 2008
Hothorn et al. Ecol Monogr 2011
Zurell et al. in submitted

Summary – Species distribution models | SDMs

Species distribution modelling

- Understanding species-environment / diversity-environment relationships
- Generation of hypotheses
- Extrapolation and projection in space & time
- Towards mechanistic niche modelling
  – integration of processes and interactions (dispersal, population dynamics etc.)

Dormann et al. Ecography 2007
Dormann et al. Ecology 2008
Reineking & Schröder Ecol Model 2006
Schröder et al. JPNSS 2008
Schröder et al. Biol Cons 2008
Hothorn et al. Ecol Monogr 2011
Zurell et al. in submitted

- Methods transferable to other geoecological sub-disciplines
  Prediction of ...
  – erosion
  – landslides
  – tree fall
  – sediment yield
  – flow regimes
  – soil properties (soil landscape modelling)

Märker et al. Geomorphology 2010
Vorpahl et al. ESPL submitted
Vorpahl et al. EcoMod submitted.
Vogt et al. Forest Ecol Manage 2006
Francke et al. Hydrol Proc 2008
Graeff et al. Hydrol Proc 2009
Häring et al. Geoderma submitted
Stang et al. in prep.

Conclusions

- Considering ecohydrological feedbacks is pivotal for dealing with the

  Impact of environmental change on ecological systems & natural resources

- Therefore, linking ecological & hydrological models is a key tool

- Understanding of mechanisms of process-pattern relationships is a pre-requisite for valid predictions and designing adaptation/mitigation strategies

Thanks to all collaborators and funding institutions

Thank you...

MOSAIK

Michael Kleyer, Robert Biedermann, University of Oldenburg
Michael Rudner, University of Freiburg
Elisabeth Obermaier, University of Würzburg
Hans Kögl, University of Rostock
Birgit Binzenhöfer, Josef Settele, ANL Laufen / UFZ Leipzig

BIOPORE

Erwin Zehe, Juliane Klaus, TU München / KIT Karlsruhe
Loes van Schaik, Juliane Palm, University of Potsdam
Anne Schneider, ZALF Müncheberg

OUTLOOK

Landscape management
in the face of sea level rise
COMTESS

NACHHALTIGES LANDMANAGEMENT

Bundesministerium für Bildung und Forschung

2011-2015

Universität Potsdam

zalf

COMTESS

Sea level rise – North Sea Region (Germany, Netherlands, Denmark)

Impossible to build up higher dikes (underlying peat)!

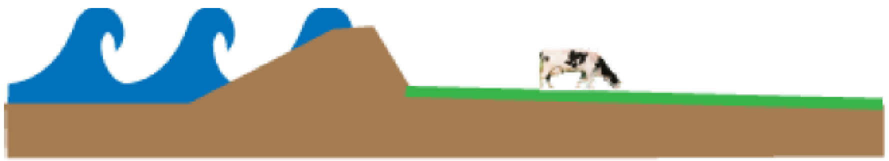
Second dike line?
Scenarios: BAU, water management, peat formation, bioenergy

Effects on ecosystem services and biodiversity? Trade-offs?

COMTESS-Scenarios

1) Trend, business-as-usual

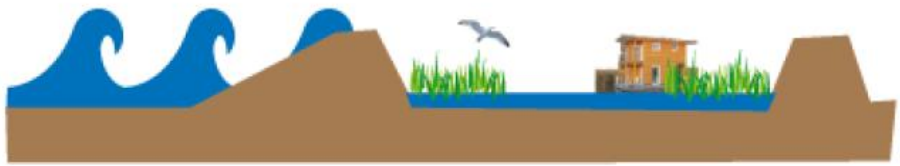
One single primary dike line
Dairy farming as usual



- **Increased inundations**
- **Increased costs for pumping for drainage**
- **Agricultural losses due to inundation in winter, salt water intrusion in summer**

COMTESS-Scenarios

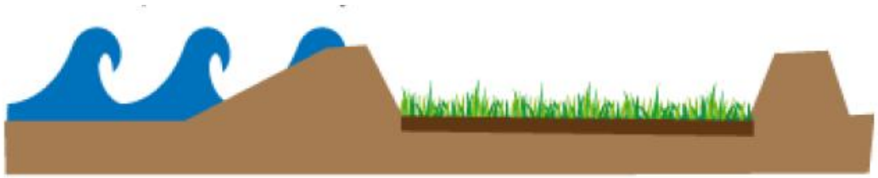
2) Two dike lines
water management



- **Poldering, prevention of subsurface salt water intrusion, retention of winter freshwater for agricultural use in summer**
- **reed grass as biofuel (BtL)**
  13 t dry matter/ha unmown *Phragmites*
  15 t dry matter/ha mown *Phragmites*

COMTESS-Scenarios

3) Two dike lines
Carbon sequestration by restoration of reed fens



- Reed fens, brackish water reeds, salt marshes
- Frequent inundation during storm tides
- Peat formation
- Tradeoff biomass vs. biodiversity

Universität Potsdam

zalf.

Torsten Hothorn

Thomas Kneib

Red kite

mboost

Unified framework

- boosted regression trees/environment
- non-stationarity
- spatial autocorrelation
- spatiotemporal variability

UNIFIED FRAMEWORK

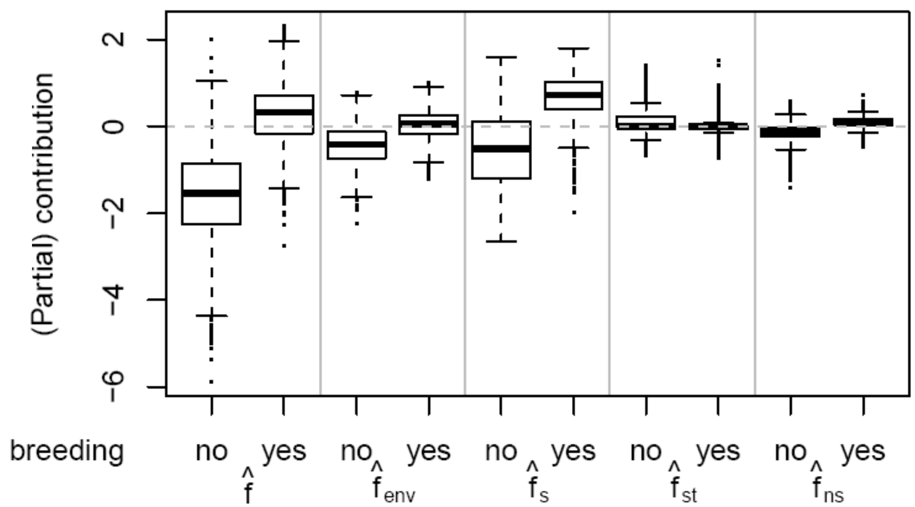
Decomposition of environmental, spatial and spatiotemporal components of distributions patterns

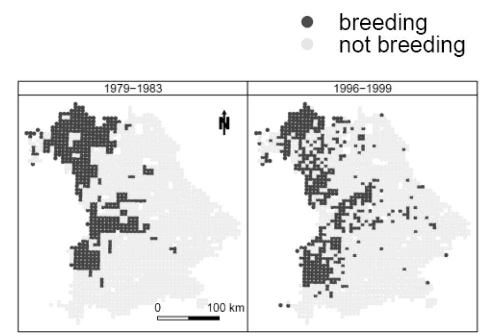
Unified framework basing on boosted regression trees

$$f(\mathbf{x}, s, t) = \underbrace{f_{\text{env}}(\mathbf{x})}_{\text{global}} + \underbrace{f_{\text{ns}}(\mathbf{x}, s) + f_{\text{s}}(s) + f_{\text{st}}(s, t)}_{\text{local}}$$

Total variability	~	Environment	non-stationary env. effects	spatial autocorrelation	spatio-temporal variability

Red kite in Bavaria





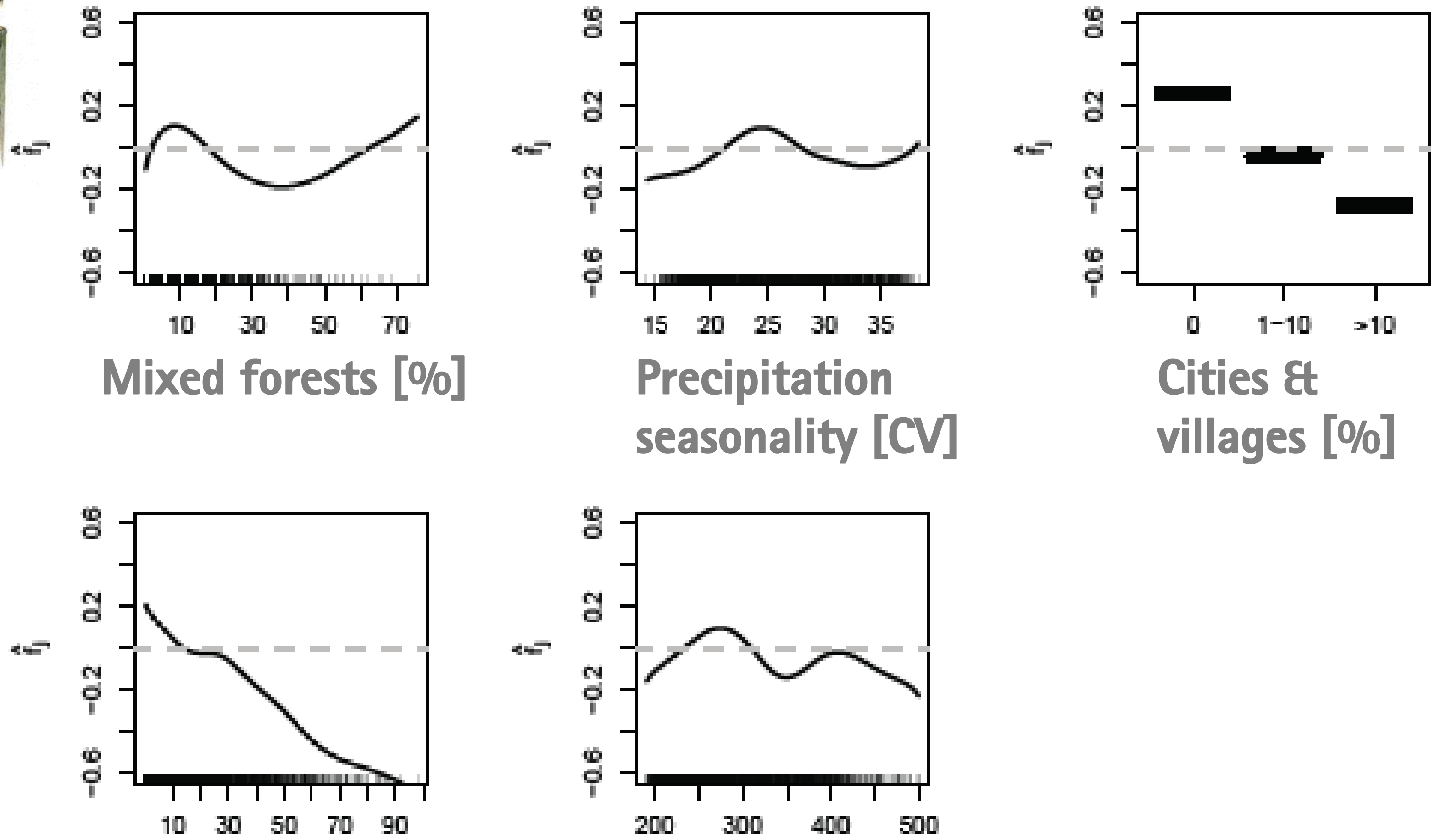
- CORINE
- FRAGSTATS
- WorldClim

7 predictors

Hothorn T, Müller J, Schröder B, Kneib T, Brandl R, 2011
Decomposing environmental, spatial, and spatiotemporal components of species distributions. Ecol Monogr 81: 329-347.

UNIFIED FRAMEWORK

Partial effects – environmental component f_{env}



Mixed forests [%]

Precipitation seasonality [CV]

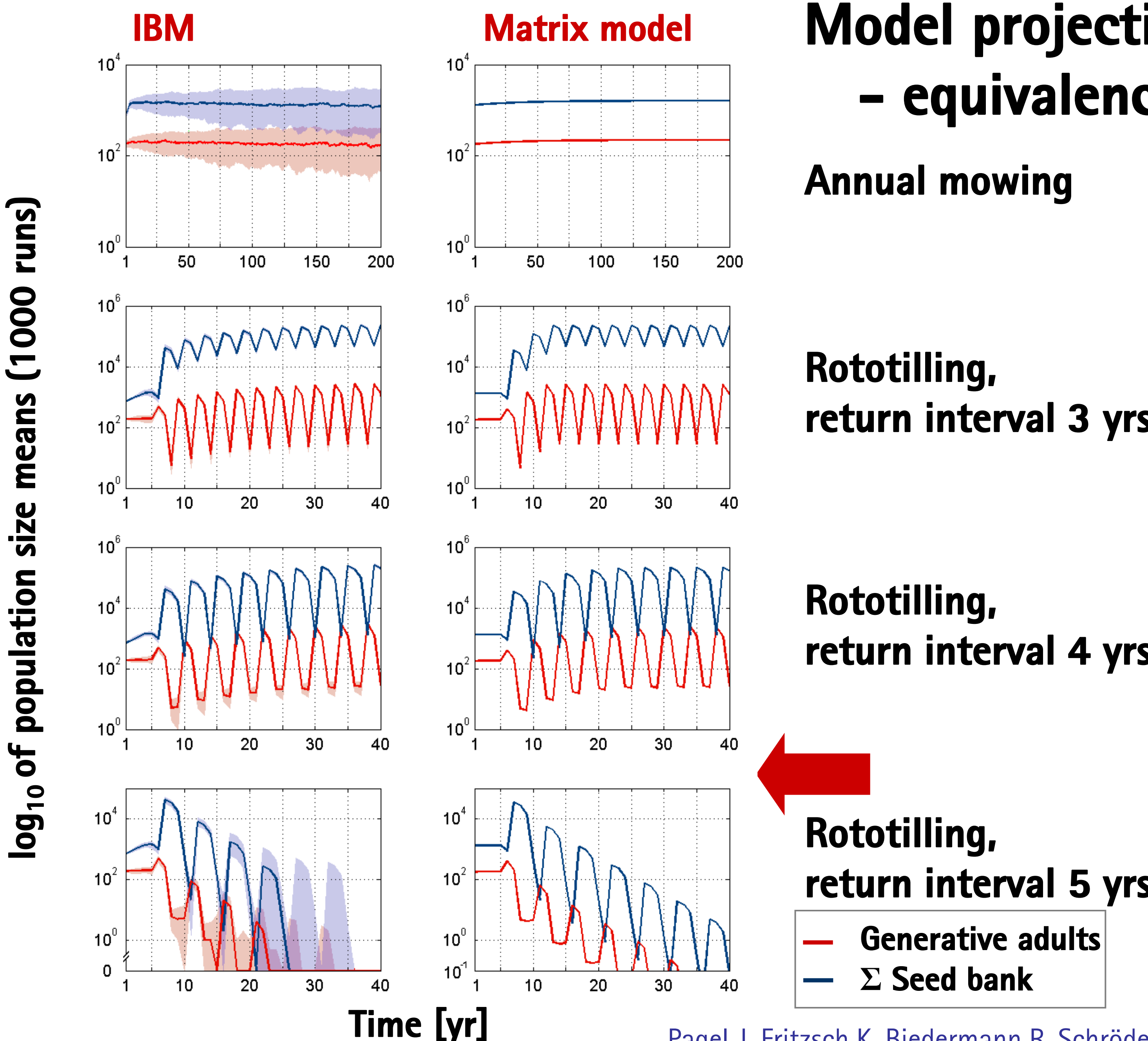
Cities & villages [%]

Coniferous forests [%]

Precipitation of wettest quarter [mm]

Hothorn T, Müller J, Schröder B, Kneib T, Brandl R, 2011
Decomposing environmental, spatial, and spatiotemporal components of species distributions. Ecol Monogr 81: 329-347.

Model projections – equivalence



Pagel J, Fritzsch K, Biedermann R, Schröder B (2008): Annual plants under cyclic disturbance regimes – better understanding through model aggregation. Ecol Appl 18: 2000-2015

Summary SDMs

Environmental niche modelling

- **Model-related uncertainty important**

Method
AUC

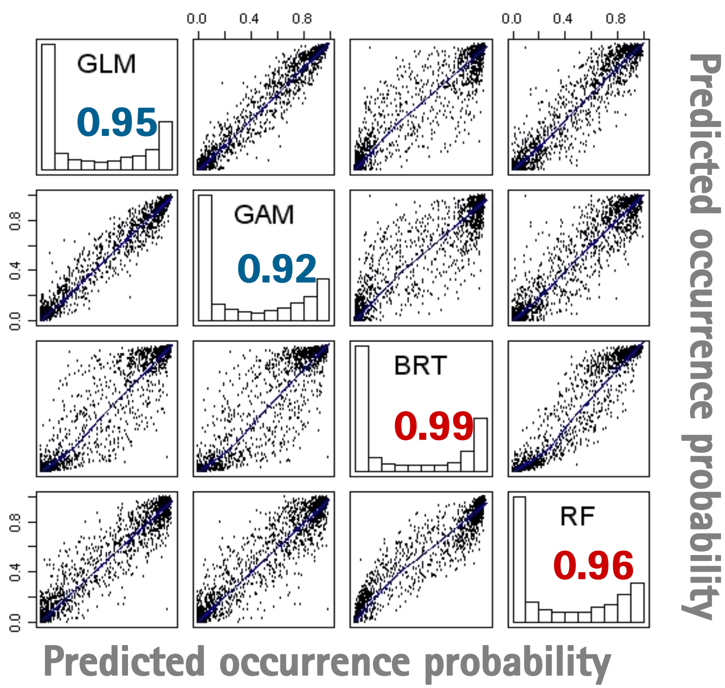


TABLE 1. ANOVA results for mean cross-validated area under curve (AUC) values.

Modeling step	df	SS100	*F*	*P*
Model type ⬅	2	7.64	111.3	<0.001
Data uncertainty	2	2.71	39.5	<0.001
Collinearity correction	2	0.89	13.0	<0.001
Variable selection method	2	0.19	2.7	0.075
Data uncertainty × collinearity correction	4	0.49	3.6	0.011
Collinearity correction × variable selection	4	0.53	3.9	0.007
Collinearity correction × model type	4	0.39	2.9	0.031
Residuals	60	2.06		

Note: SS100 refers to sum of squares (Type I) multiplied by 100 for easier presentation.

Dormann CF, Purschke O, García J, Lautenbach S, Schröder B, 2008. Components of uncertainty in species distribution analysis: a case study of the Great Grey Shrike *Lanius excubitor* L. Ecology 89: 3371-3386.

DISCUSSION

Survival in a changing environment – move, adapt or die?

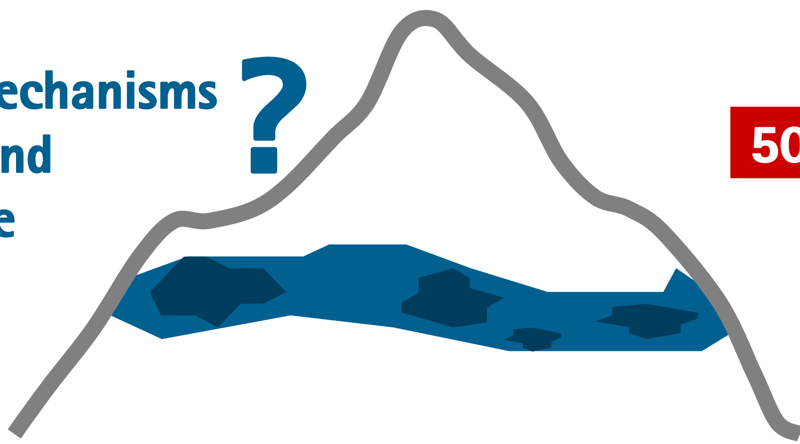
Mosaic cycle due to landscape management

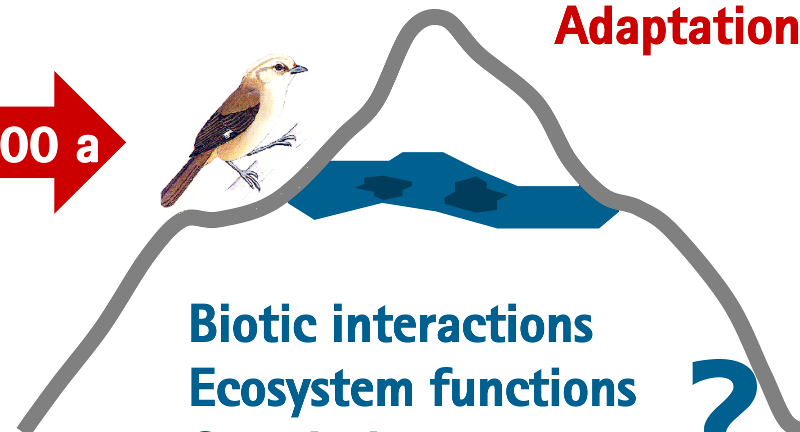

Persistence
Dispersal ?

Adaptation in situ
Local extinction ?

Dispersal
Adaptation ?

Different mechanisms at leading and trailing edge ?





Biotic interactions
Ecosystem functions
Correlation structures
Niche shifts ?

Range shift due to climate and land use change

Reflection

Phenomenological models

- pattern detection & description
- simple parameterisation
- very many species, diversity
- multiple scales

Process-based models

- process description
- laborious parameterisation
- only for single species (or funct. groups)
- often small scales

Reflection

Phenomenological models

- pattern detection & description
- simple parameterisation
- very many species, diversity
- multiple scales

- ... but no implementation of

Process-based models

- process description
- laborious parameterisation
- only for single species (or funct. groups)
- often small scales

- ... but explicit implementation of

- processes:
  - dispersal
  - adaptation
  - biotic interactions
- feedback mechanisms
- transient dynamics

Reflection

Phenomenological models

- pattern detection & description
- simple parameterisation
- very many species, diversity
- multiple scales

- … but no implementation of

Process-based models

- process description
- laborious parameterisation
- only for single species (or funct. groups)
- often small scales

- … but explicit implementation of

– processes:
  – dispersal
  – adaptation
  – biotic interactions
– feedback mechanisms
– transient dynamics

Phenomenological models:

- combination with funct. traits
- combination with process models

Process-based models:

- generalisation
- upscaling

Reflection

Phenomenological models

- pattern detection & description
- simple parameterisation
- very many species, diversity
- multiple scales

- … but no implementation of

Process-based models

- process description
- laborious parameterisation
- only for single species (or funct. groups)
- often small scales

- … but explicit implementation of

– processes:
  – dispersal
  – adaptation
  – biotic interactions
– feedback mechanisms
– transient dynamics

Phenomenological models:

- combination with funct. traits
- combination with process models

Process-based models:

- generalisation
- upscaling

Combination

SUMMARY

Research needs – SDMs

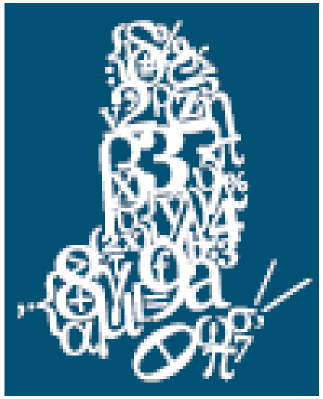
- **Transient dynamics** – no equilibrium!
- **Processes** – e.g. dispersal, (meta-)population dynamics
- **Interactions of drivers** – e.g. land use change x climate change
- **Biotic interactions** – e.g. competition, facilitation, predation
- **Adaptation** – e.g. behaviour, genotypes
- **Feedback mechanisms** – e.g. ecosystem engineers

Need to incorporate processes as first principles of population biology

---

But how much process detail do we need for valid predictions?
Which processes have the largest impact on SDM performance?

UPGradE



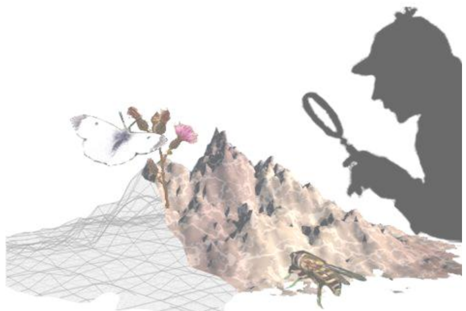
How much process detail do we need?

Integration of phenomenological & mechanistic approaches

INTEGRATION

Virtual world

Dynamic Model



Effects of transient dynamics and ecological processes on SDM prediction accuracy

Zurell et al. (2009) Ecography

Damaris Zurell

Zurell D, Jeltsch F, Dormann CF, Schröder B 2009 Static species distribution models in dynamically changing systems: How good can predictions really be? Ecography 32: 733-744

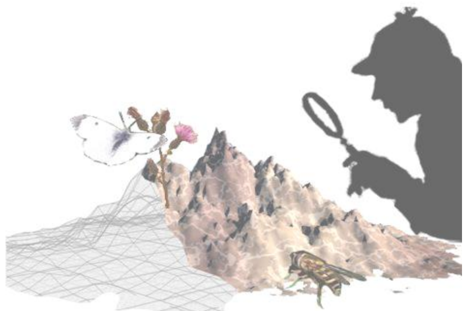
Zurell D et al. 2010 The virtual ecologist approach: simulating data and observers. Oikos 119: 622-635

INTEGRATION

Integration of phenomenological & mechanistic approaches

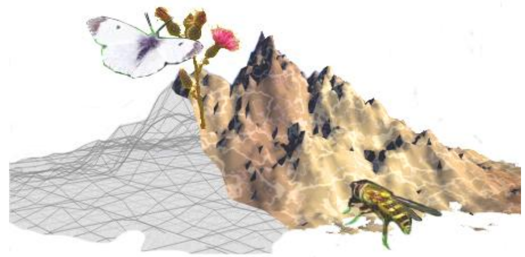
Virtual world

Dynamic Model



Effects of transient dynamics and ecological processes on SDM prediction accuracy

Zurell et al. (2009) Ecography



Virtual, tri-trophic host-parasitoid system, virtual landscape

Damaris Zurell

Zurell D, Jeltsch F, Dormann CF, Schröder B 2009 Static species distribution models in dynamically changing systems: How good can predictions really be? Ecography 32: 733-744

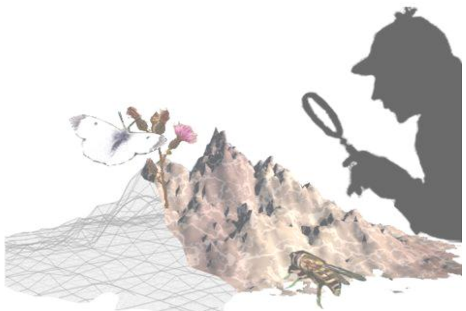
Zurell D et al. 2010 The virtual ecologist approach: simulating data and observers. Oikos 119: 622-635

INTEGRATION

Integration of phenomenological & mechanistic approaches

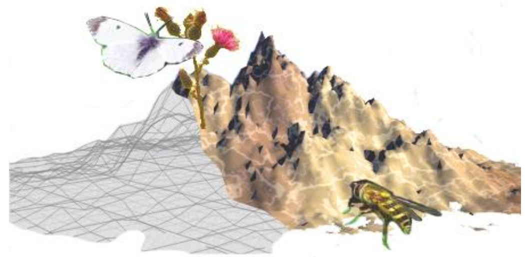
Virtual world

Dynamic Model



Effects of transient dynamics and ecological processes on SDM prediction accuracy

Zurell et al. (2009) Ecography



Virtual, tri-trophic host-parasitoid system, virtual landscape

Scenarios

Sampling by virtual ecologist

Damaris Zurell

Zurell D, Jeltsch F, Dormann CF, Schröder B 2009 Static species distribution models in dynamically changing systems: How good can predictions really be? Ecography 32: 733-744

Zurell D et al. 2010 The virtual ecologist approach: simulating data and observers. Oikos 119: 622-635

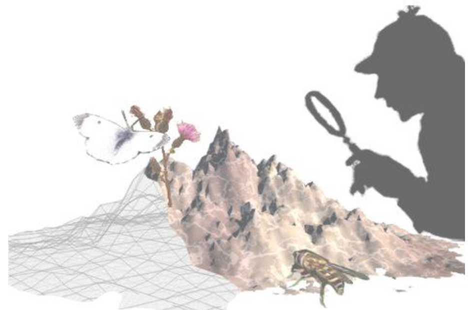
INTEGRATION

Integration of phenomenological & mechanistic approaches

Damaris Zurell

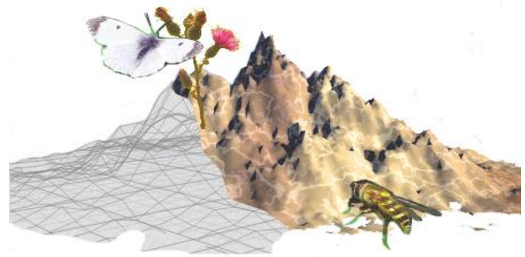
Virtual world

Dynamic Model



Effects of transient dynamics and ecological processes on SDM prediction accuracy

Zurell et al. (2009) Ecography

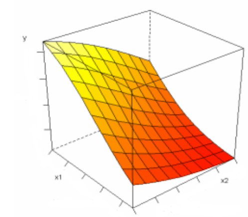


Virtual, tri-trophic host-parasitoid system, virtual landscape

Scenarios

Sampling by virtual ecologist

Training data



SDM

Zurell D, Jeltsch F, Dormann CF, Schröder B 2009 Static species distribution models in dynamically changing systems: How good can predictions really be? Ecography 32: 733-744

Zurell D et al. 2010 The virtual ecologist approach: simulating data and observers. Oikos 119: 622-635

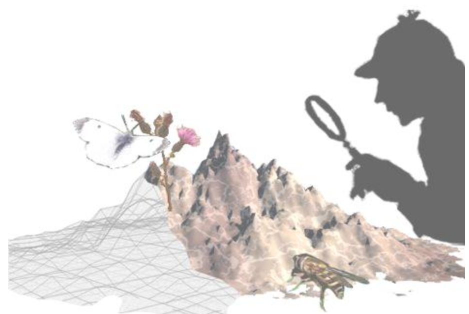
I N T E G R A T I O N

Integration of phenomenological & mechanistic approaches

Damaris Zurell

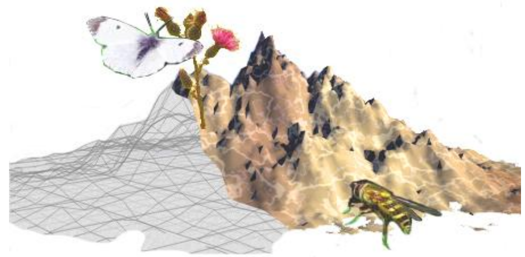
Virtual world

Dynamic Model



Effects of transient dynamics and ecological processes on SDM prediction accuracy

Zurell et al. (2009) Ecography



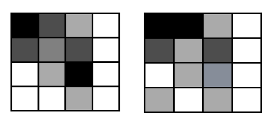
Virtual, tri-trophic host-parasitoid system, virtual landscape

Scenarios

Sampling by virtual ecologist

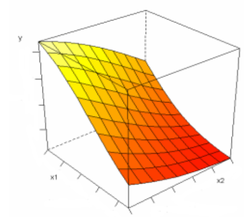
„Real" distribution

Training data



Pattern comparison

Extrapolation



SDM

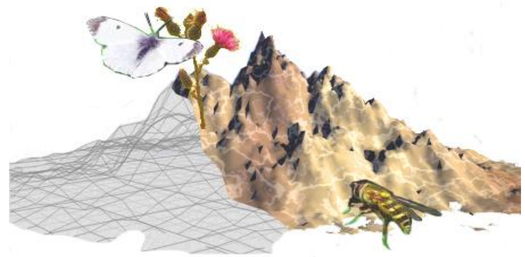
Zurell D, Jeltsch F, Dormann CF, Schröder B 2009 Static species distribution models in dynamically changing systems: How good can predictions really be? Ecography 32: 733-744

Zurell D et al. 2010 The virtual ecologist approach: simulating data and observers. Oikos 119: 622-635

INTEGRATION

Integration of phenomenological & mechanistic approaches

Virtual world



Virtual, tri-trophic
host-parasitoid system,
virtual landscape

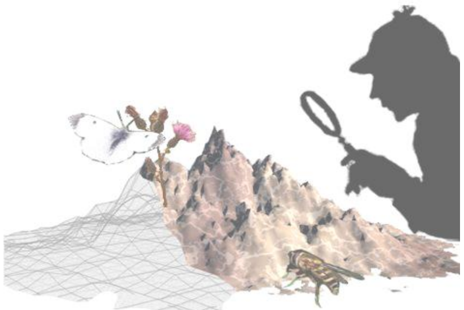
Scenarios

Sampling by
virtual ecologist

„Real“
distribution

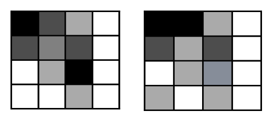
Training
data

Dynamic Model



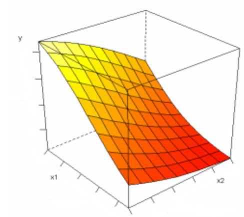
Effects of transient dynamics and ecological processes on SDM prediction accuracy

Zurell et al. (2009) Ecography



Pattern comparison

Extrapolation



SDM

Damaris Zurell

Importance of dispersal & population dynamics & interactions!

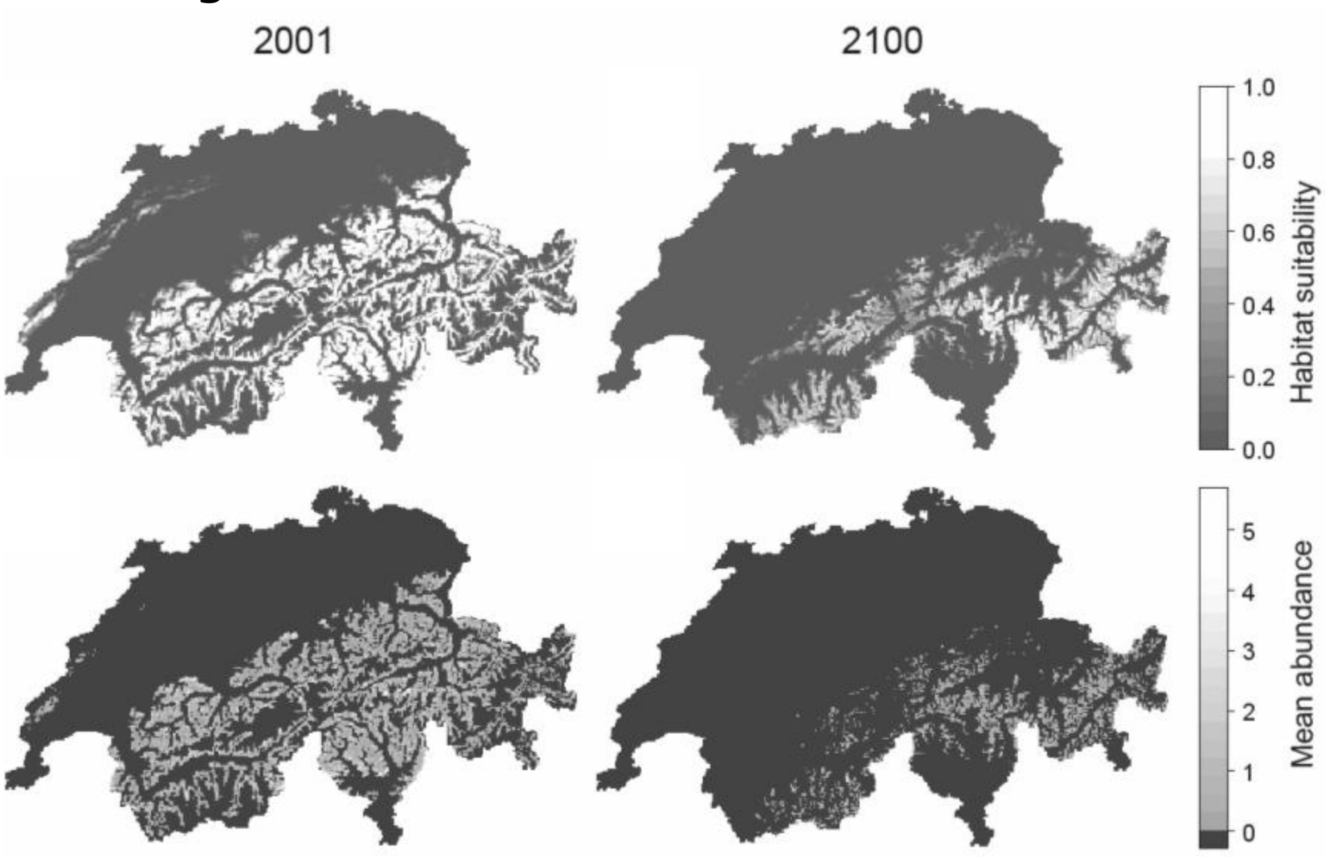
Zurell D, Jeltsch F, Dormann CF, Schröder B 2009 Static species distribution models in dynamically changing systems: How good can predictions really be? Ecography 32: 733-744

Zurell D et al. 2010 The virtual ecologist approach: simulating data and observers. Oikos 119: 622-635

INTEGRATION

Integrating SDM and process-based models

1. Bayesian logistic regression (posterior distribution of occ. probs.)
2. Habitat suitability map -> map of carrying capacity
3. IBM (birth, death, dispersal), inverse / pattern-oriented parameterisation
4. Prediction of abundance, habitat area, extinction risk, and altitudinal range shifts



SRES A2 + LUCC scenarios

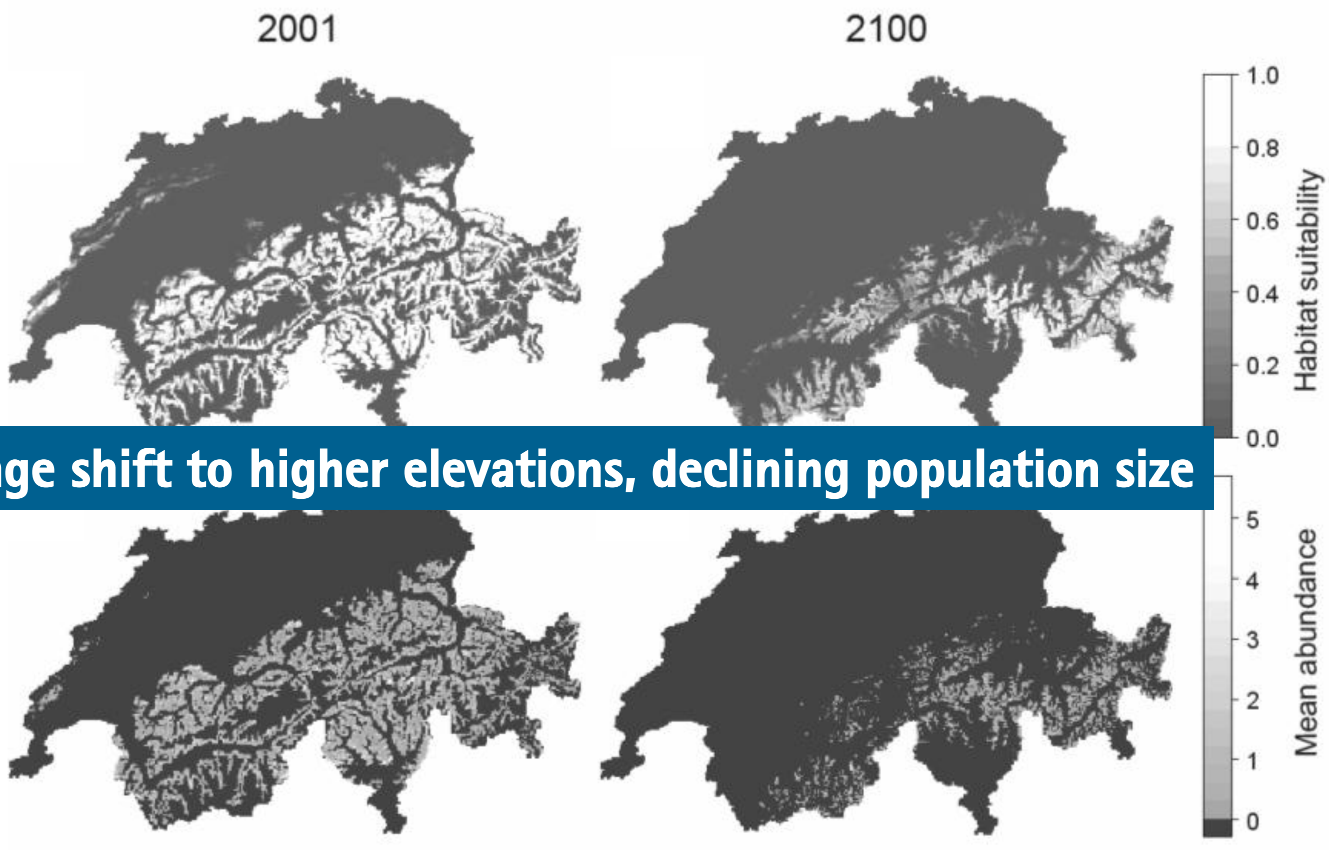
1000 IBM replicates

Damaris Zurell

Zurell D, Grimm V, Rossmanith E, Zbinden N, Zimmermann NE, Schröder B, in revisiion
Uncertainty in predictions of range dynamics: Black Grouse climbing the Swiss Alps

Integrating SDM and process-based models

1. Bayesian logistic regression (posterior distribution of occ. probs.)
2. Habitat suitability map -> map of carrying capacity
3. IBM (birth, death, dispersal), inverse / pattern-oriented parameterisation
4. Prediction of abundance, habitat area, extinction risk, and altitudinal range shifts



Range shift to higher elevations, declining population size

SRES A2 + LUCC scenarios

1000 IBM replicates

Damaris Zurell

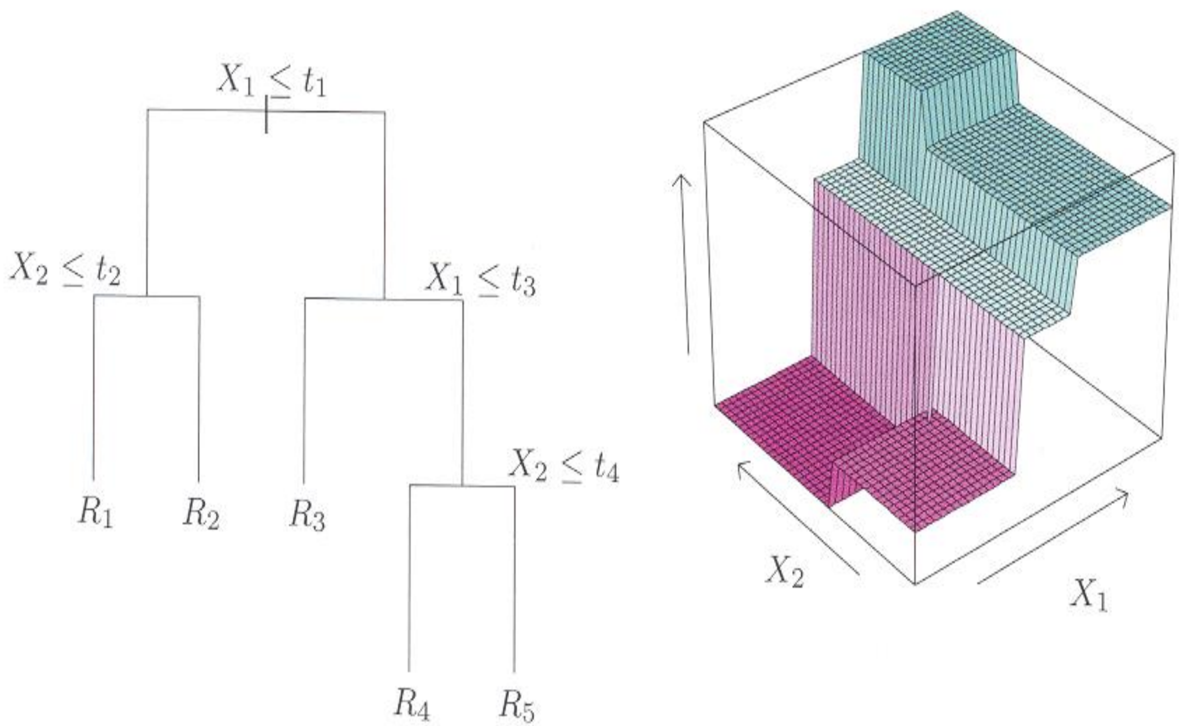
Zurell D, Grimm V, Rossmanith E, Zbinden N, Zimmermann NE, Schröder B, in revisiion
Uncertainty in predictions of range dynamics: Black Grouse climbing the Swiss Alps

Boosted regression trees | Stochastic gradient boosting

Combination of

A Classification and regression trees | CART

- powerful (variable selection, dealing with interactions)
- but inaccurate



Hastie, T., Tibshirani, R., Friedman, J.H., 2001. The elements of statistical learning, Springer, New York.

Boosted regression trees | Stochastic gradient boosting

Combination of

A Classification and regression trees | CART
- powerful (variable selection, dealing with interactions)
- but inaccurate

B Boosting algorithm
- idea: many rough rules of thumb instead of one single highly accurate rule
- ensemble prediction method
- sequential, i.e. penalized forward stage-wise (adding trees, reweighting data)

- avoid overfitting via crossvalidation
- avoid overfitting via simplification, i.e. backward stepwise elimination
- one of the best performing methods in recent model comparison (Elith et al.)

Random forests: similar idea; bagging = bootstrap aggregation of CARTs

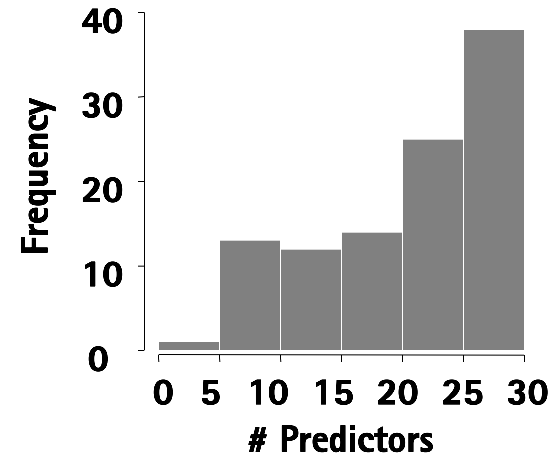
Elith et al. 2006 Ecography

METHODS

Boosted regression trees | BRTs

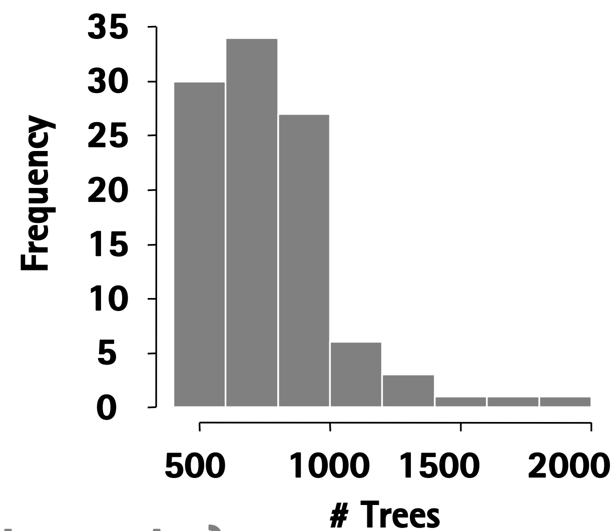
Parameters

- number of trees : ← crossvalidation
- number of predictors : ← simplification
- learning rate (weighting) : 0.01 (fixed)
- tree size (interactions) : 5 (fixed)



Final model(s)

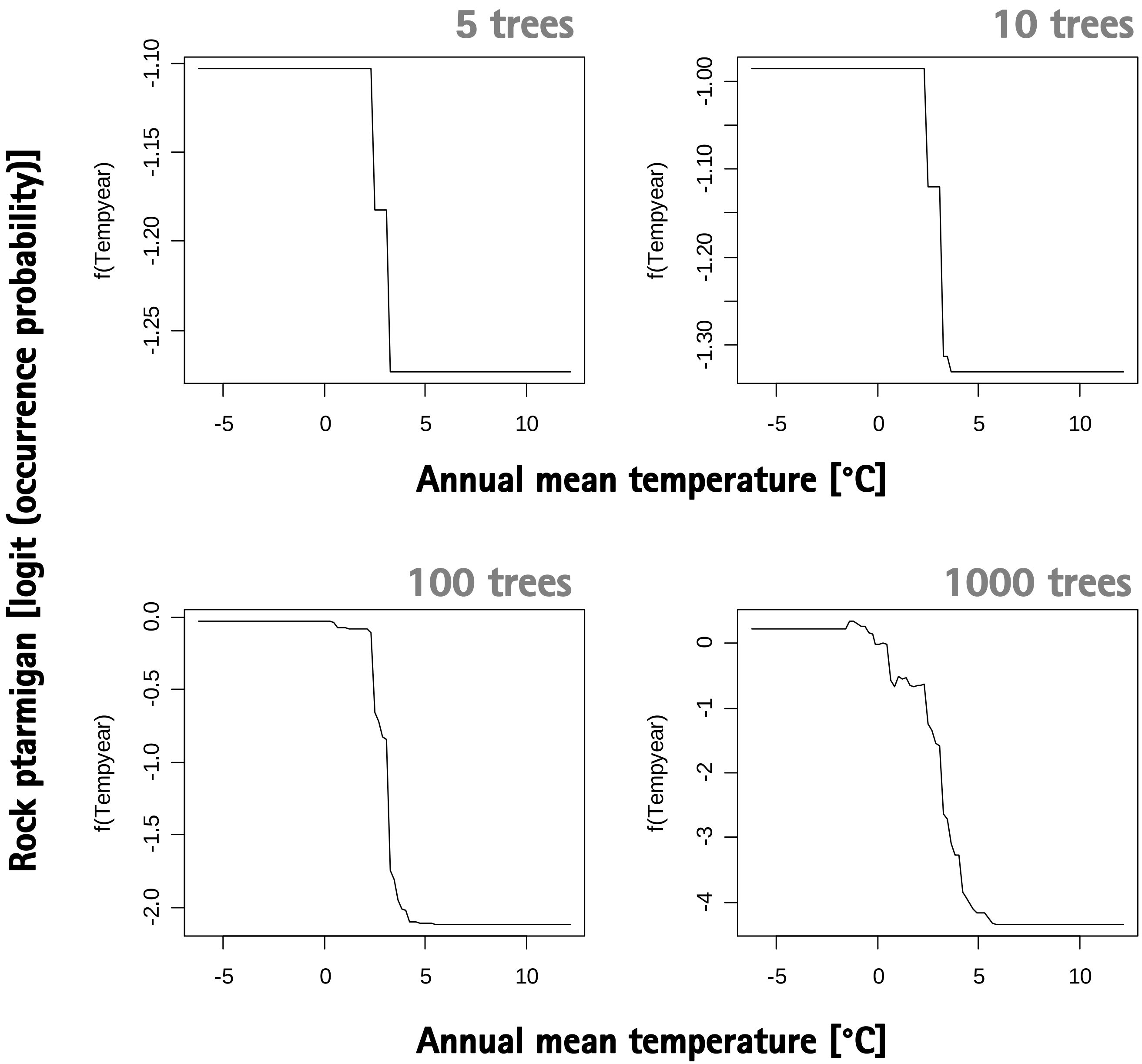
- hundreds .. thousands of trees
- prediction from weighted average
- contribution of predictors and response curves



- for binomial response (presence–absence of single species) and Poisson response (species number)

METHOD

Boosted regression trees | BRTs



cf. Elith & Leathwick 2008 J Appl Ecol

METHOD

Boosted regression trees | BRTs