Opportunities, challenges and limitations of Species Distribution Models (SDM):

Implications for decision-making in support of biodiversity conservation and sustainable land use

Herkt KMB (1), Barnikel G (1), Fahr J (1), Finckh M (2), García Marquez JR (3), König K (4), Oldeland J (2), Penner J (6), Röder M-O (6), Schmidt M (5), Sommer JH (3), Wegmann M (7)

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(7) Department of Remote Sensing, University of Würzburg, German Aerospace Center (DLR), German Remote Sensing Data Center (DFD), Germany

"Biodiversity of Africa - Observation and Sustainable Management for our Future!"
International Congress, 29 September – 3 October 2008, at Spier, RSA

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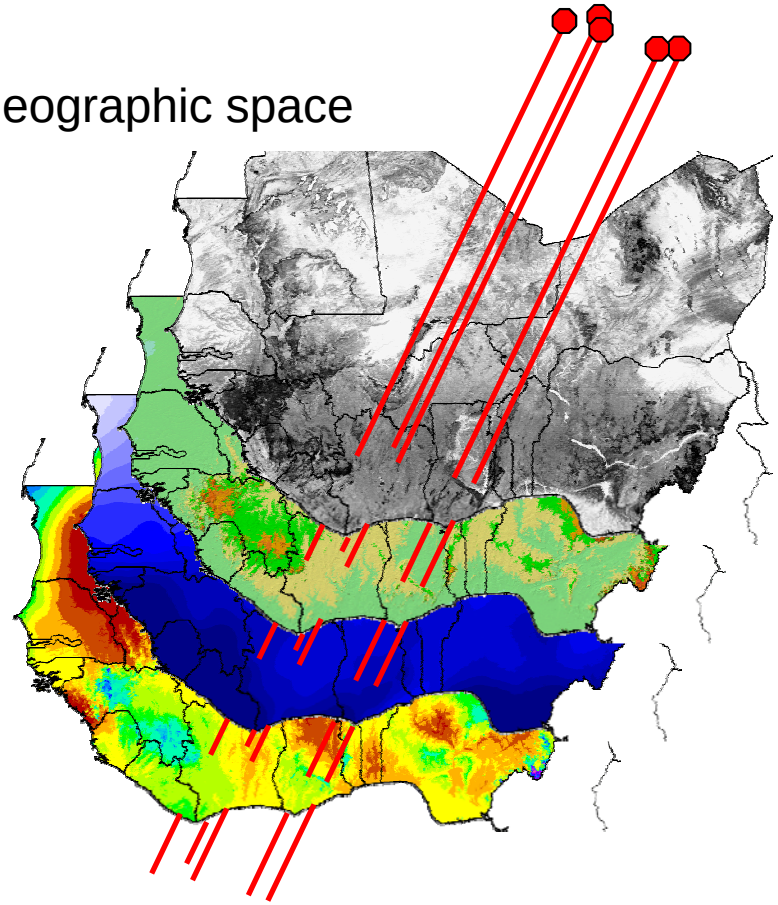
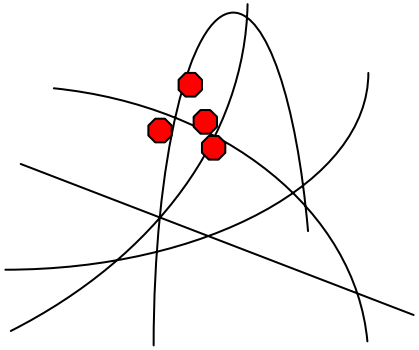
What is an SDM?

species localities

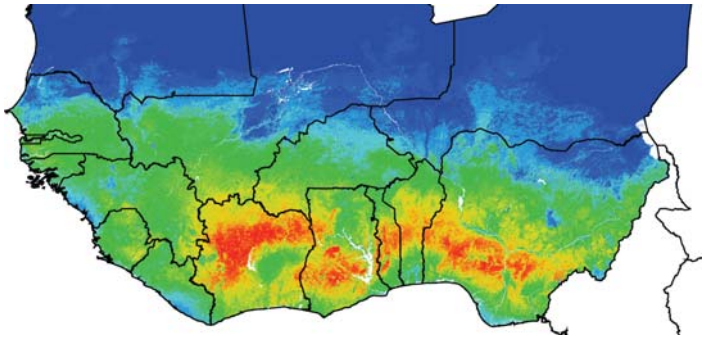
geographic space



n-dimensional ecological space



prediction into geographic space



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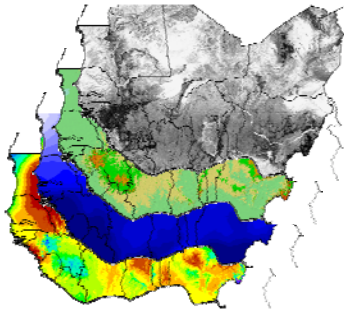
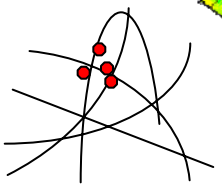
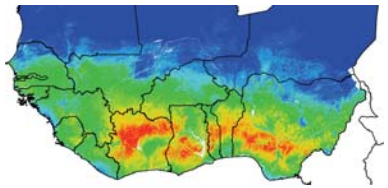
The complete workflow

research question







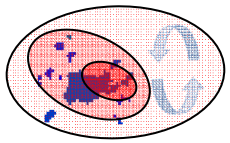
interim result

stochastic events

human land use

biotic interactions

dispersal



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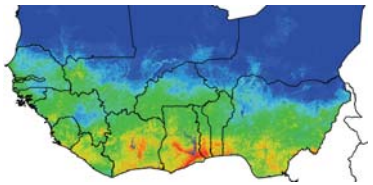

final result

APPLICATION FIELDS

- biodiversity conservation
- survey planning
- invasive species
- climate change
- ecological understanding
- ... others...

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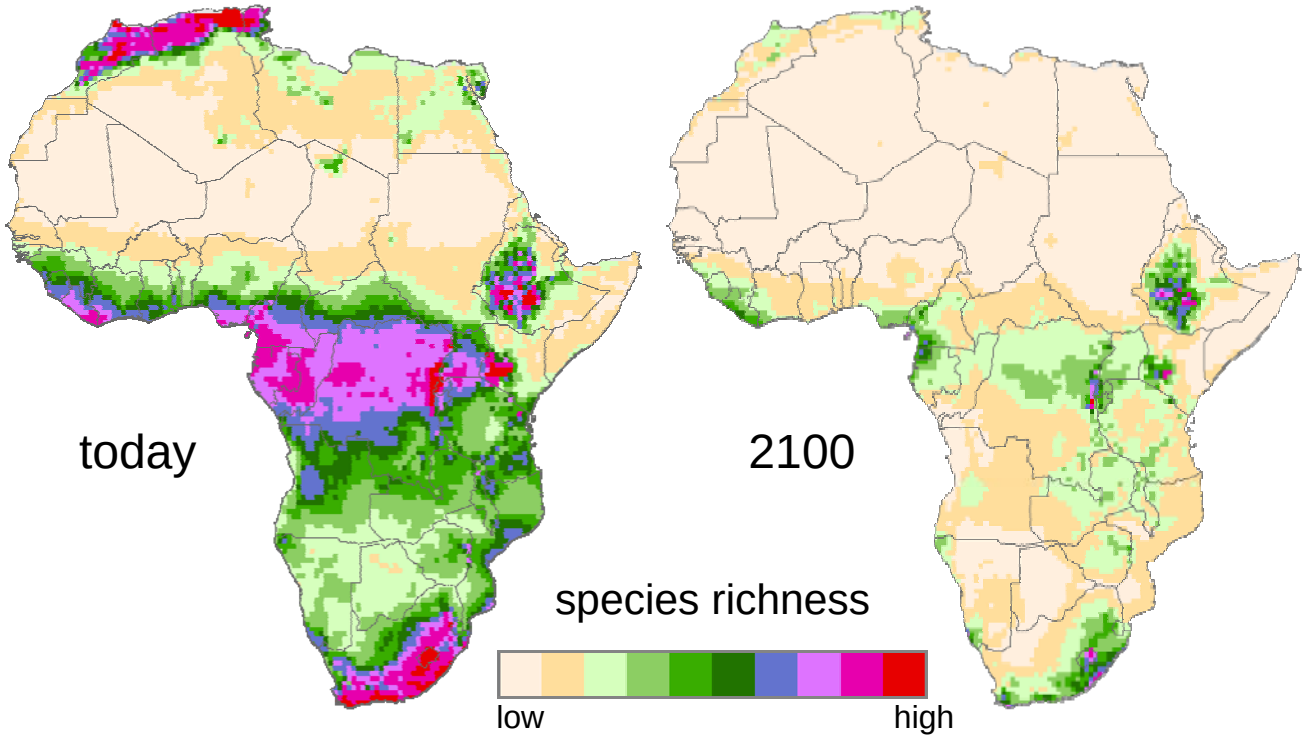
What are SDM good for?

Example 1: prepare for climate change

[BIOTA West / Sommer et al.]



HadCM3 climate model, IPCC A1FI Scenario, +4°C

Talk 2.10

What are SDM good for?

Example 2: identify biodiversity hotspots

also see Talk 4.1

Species richness in West Africa at 1 km^2

[BIOTA West; Penner et al.; Fahr et al.]

FIGURE REMOVED

FIGURE REMOVED

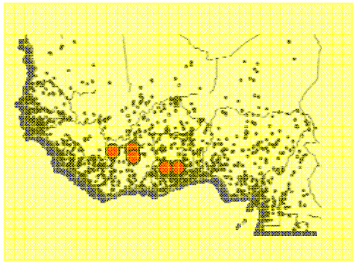
Amphibians

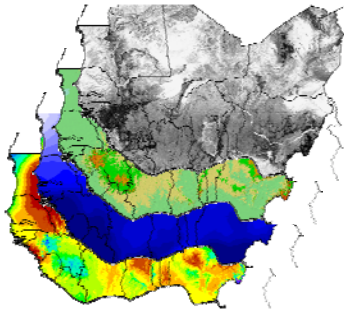
Bats

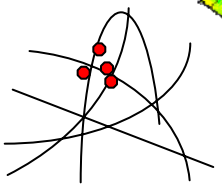
For another example (Conservation) see Talk 3.2

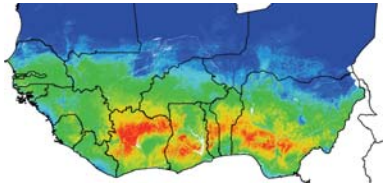
Selected challenges and solutions

research question









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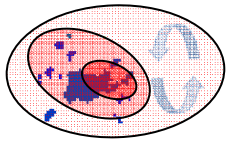

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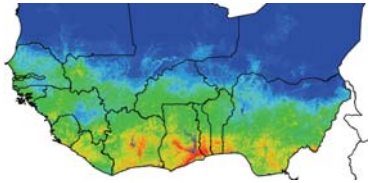

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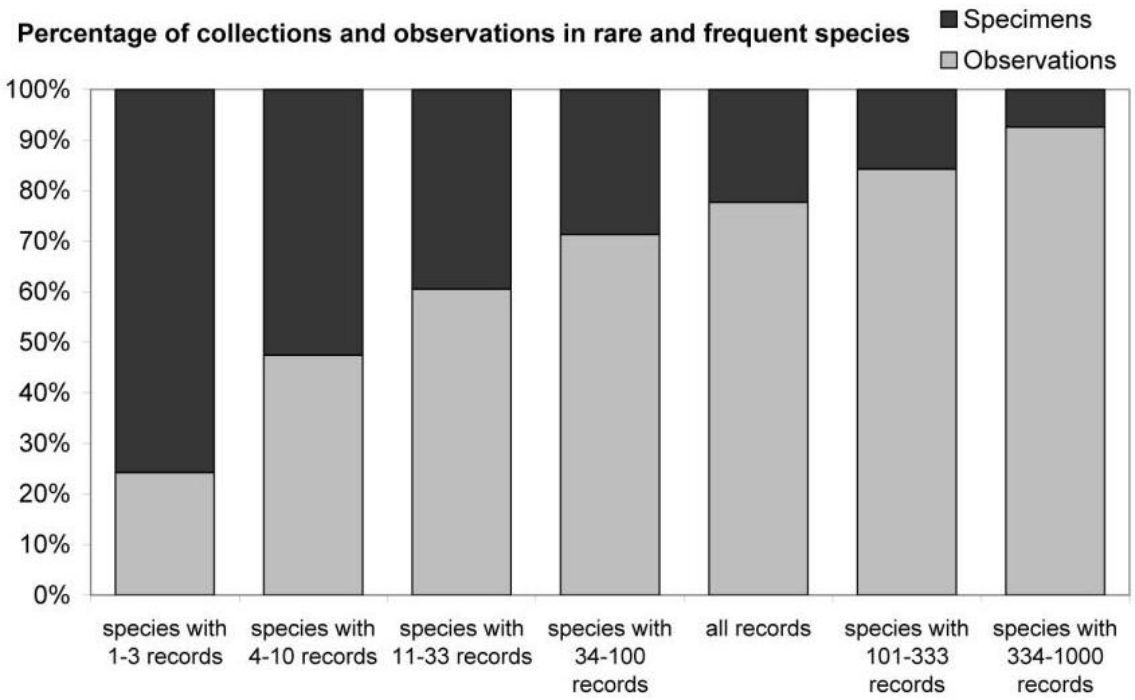
Species occurrence data

all good?

Observations: an untapped resource for SDM?



[BIOTA West / Schmidt et al.]

- **Availability**
- Sample Size
- Sampling Bias
  - → Spatial autocorrelation
- Accuracy
  - – geographic
  - – taxonomic

supports validation
(and possibly calibration)

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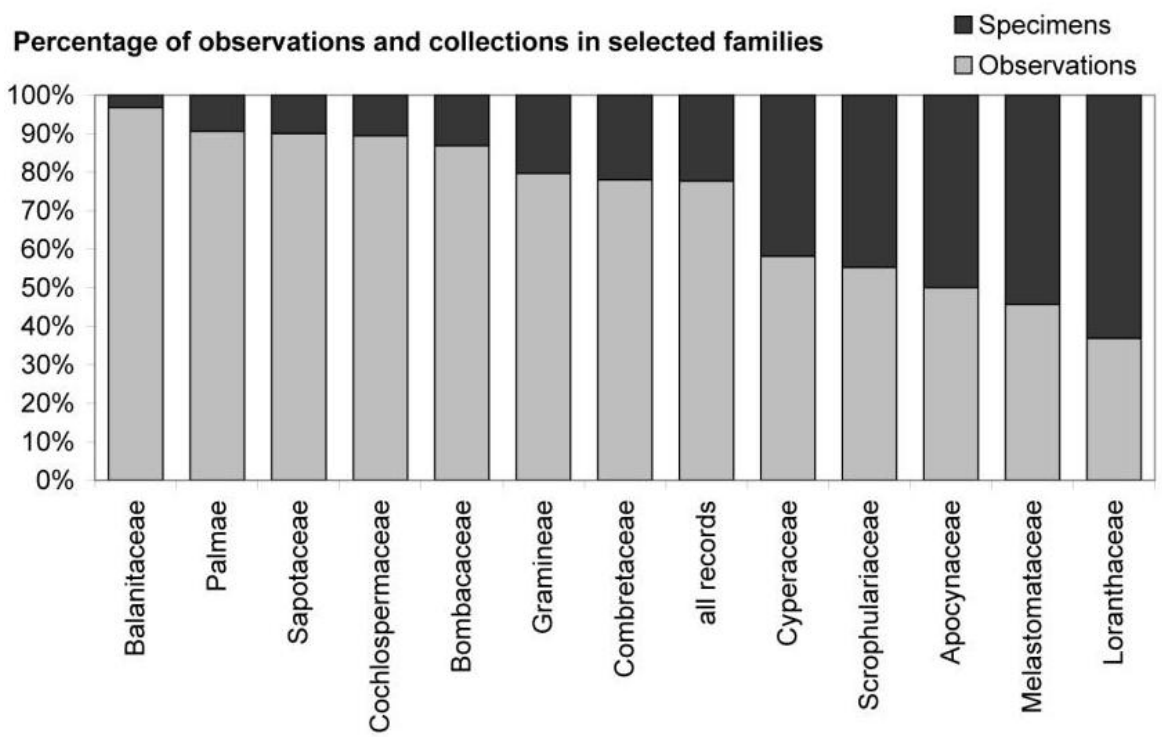

[BIOTA West / Schmidt et al.]

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Species occurrence data

all good?

Effect of targeted field survey on predicted distribution

- Availability
- Sample size
- Sampling Bias
  → Spatial autocorrelation
- Accuracy
  – geographic
  – taxonomic

FIGURE REMOVED

Species richness map of West African bats

BEFORE predicted distribution changes in under-sampled regions

[BIOTA West / Weber & Fahr]

Species occurrence data

all good?

Effect of targeted field survey on predicted distribution

- Availability
- Sample size
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FIGURE REMOVED

Species richness map of West African bats

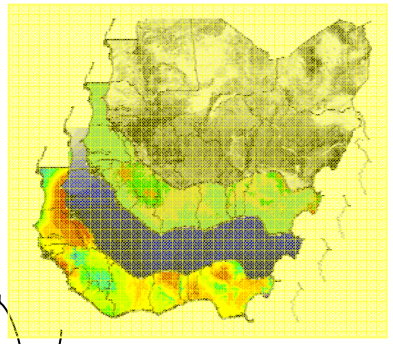
AFTER

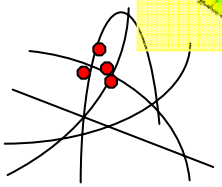
predicted distribution changes in under-sampled regions

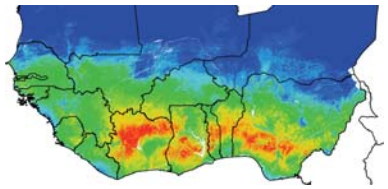
[BIOTA West / Weber & Fahr]

Selected challenges and solutions

research question







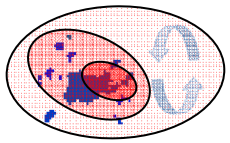
interim result

stochastic events

human land use

biotic interactions

dispersal



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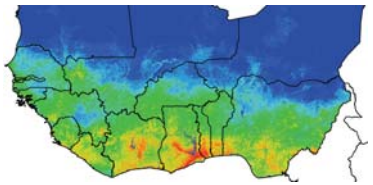

final result

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- ... others...

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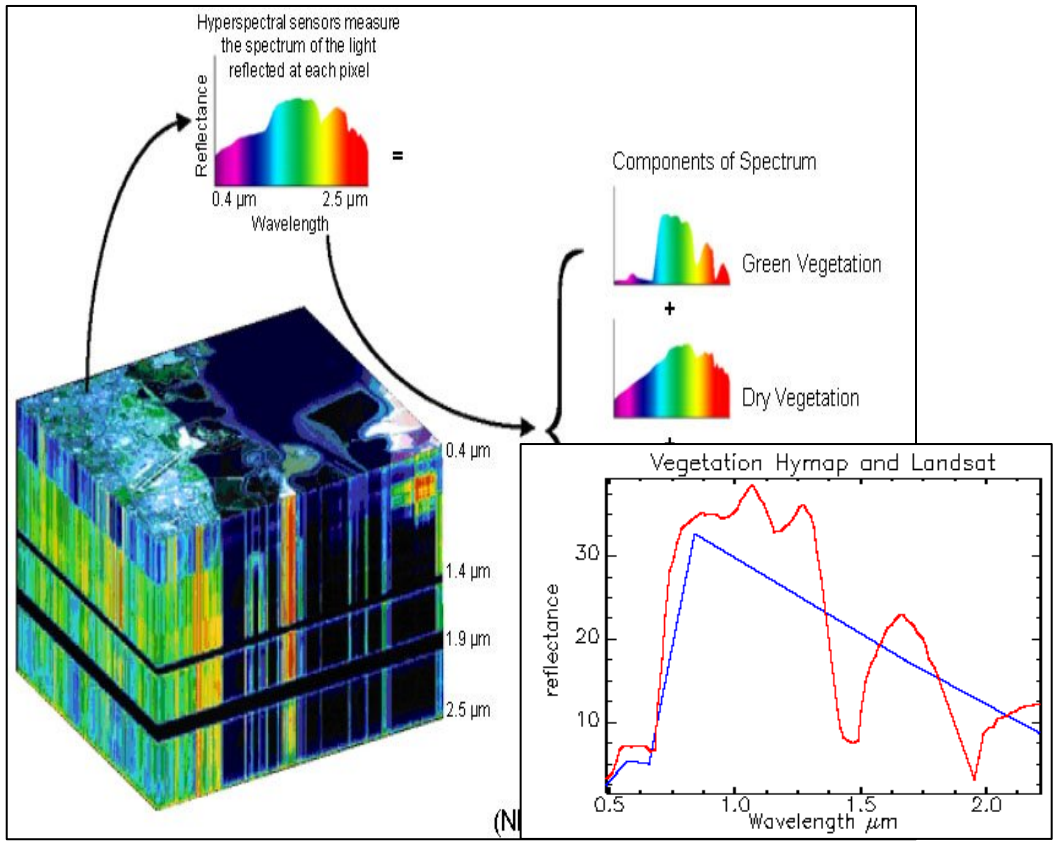
Environmental variables

spoilt for choice

Seeing the world through the eyes of a …

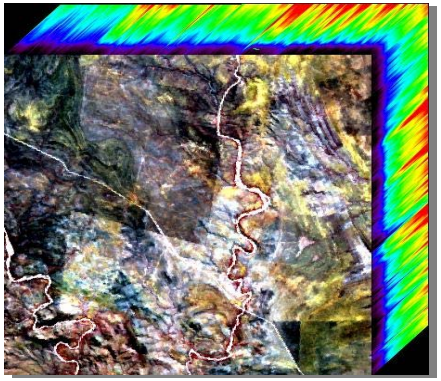


- Availability
  - – finer spatial res.
  - – time series
  - – hyperspectral
- Selection
  - → multicollinearity
- Transformation
- Consistency

Environmental variables

spoilt for choice

Seeing the world through the eyes of a …



e.g. CHRIS-Proba satellite data
32 / 64 channels
32 m / 17 m spat. res.
however: swath width only 14 km

extract spectral profiles
of surface features and indices,
e.g. NDVI

Inferring biodiversity from spectral heterogeneity (spectral variation hypothesis) → direct use

Inferring biodiversity from aggregated SDM: create new environmental variables from hyperspectral data → indirect use

- Availability
  - finer spatial res.
  - time series
  - hyperspectral
- Selection
  - → multicollinearity
- Transformation
- Consistency

[BIOTA Süd / Oldeland et al in prep.]

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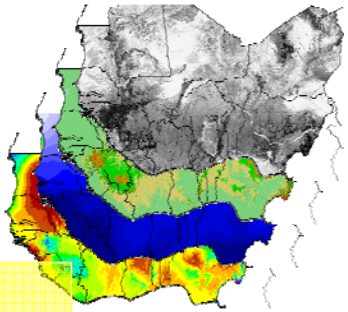
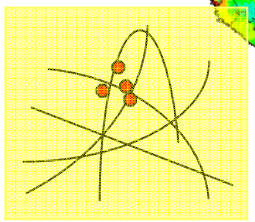
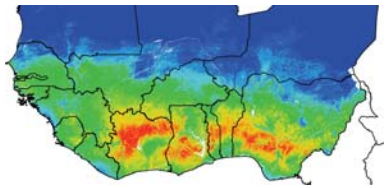
Selected challenges and solutions

research question







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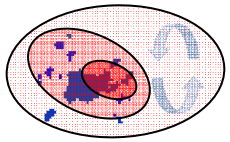

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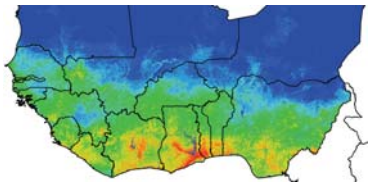

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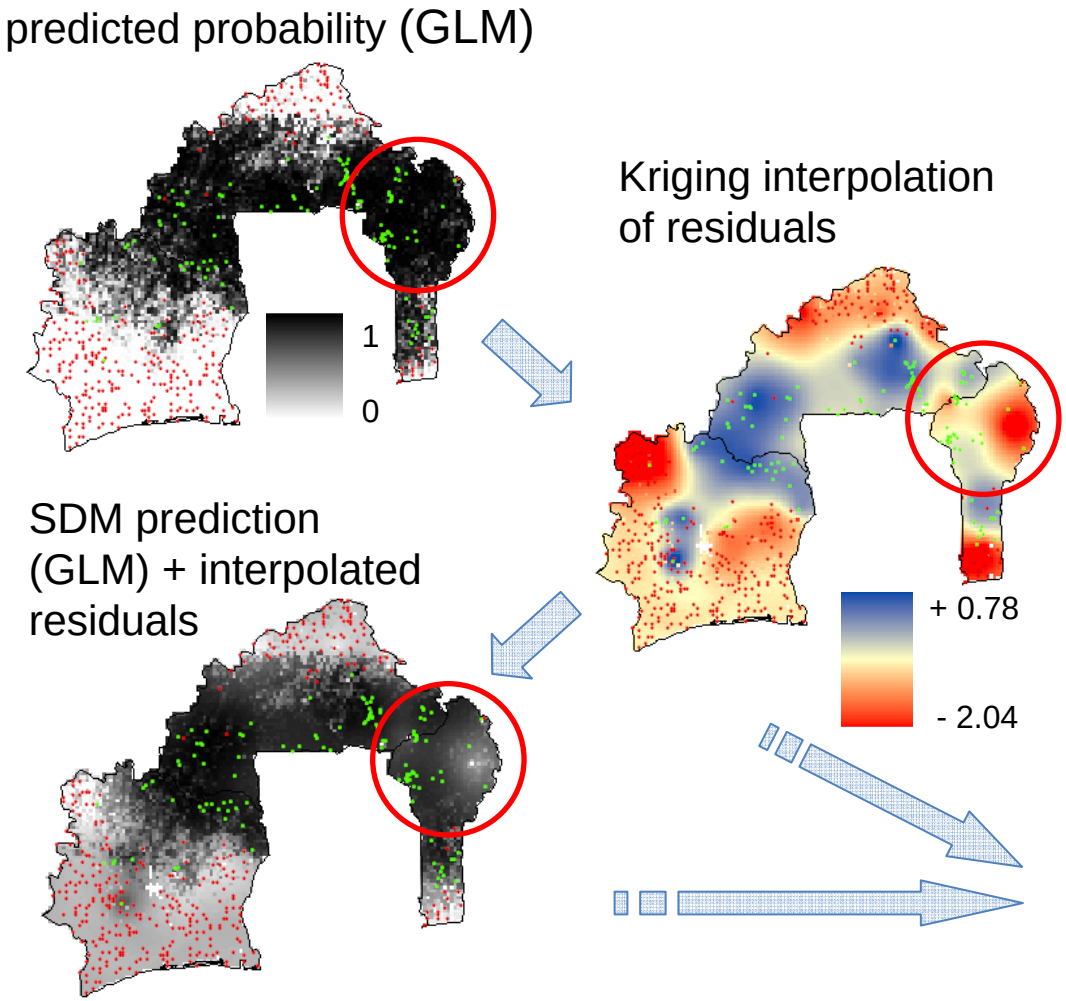
The statistical model

magic or math?



- Data assumptions
- Choosing model type
- Evaluating model quality
  - calibration / fit
  - discriminatory power
  - validation options

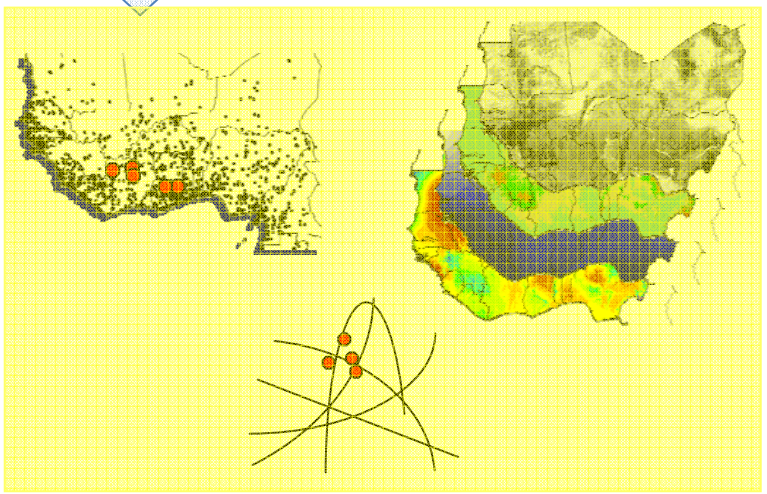
- Quantifying uncertainty

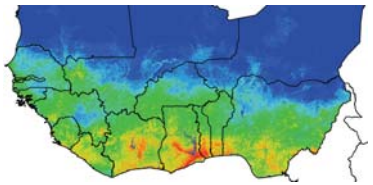
added value for decision-makers

[BIOTA West / García Marquez]

Selected challenges and solutions

research question





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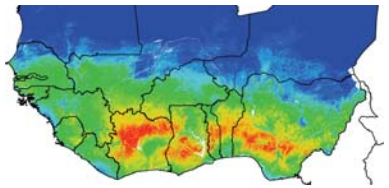

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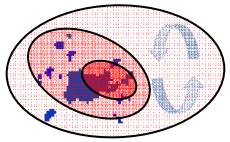


customization

An adequate framework

why bother?

FIGURE REMOVED

- Spatial extent
- **Spatial resolution**
- Temporal extent
- Temporal resolution

Species richness of bats; cell size ~ 1 km^2

FIGURE REMOVED

Expert knowledge required to capture a species' ecological niche at relevant scale

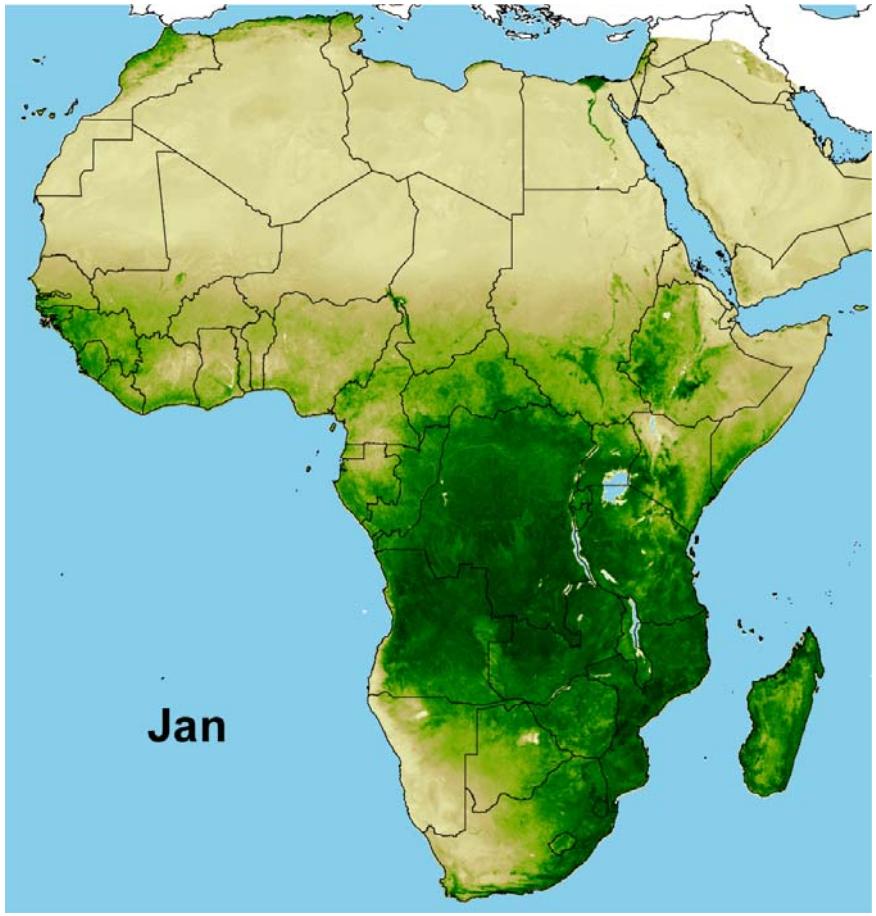
prevents decision-makers from using maps with false precision or over-prediction

Species richness of bats; cell size 0.5° (~ 3,000 km^2)

[BIOTA West / Fahr et al.]

An adequate framework

why bother?



[ADDS]

- Spatial extent
- Spatial resolution
- Temporal extent
- Temporal resolution

Do mobile species respond to seasonal greening of vegetation?

(AVHRR NDVI, decadal, monthly averages 1981 – 2005)

An adequate framework

why bother?

- Spatial extent
- Spatial resolution
- Temporal extent
- Temporal resolution

Monthly distribution models of *Eidolon helvum;*
Maxent; 8 environmental variables; n = 537

SDM provide evidence that some mobile species depend on seasonally shifting resources → important for decision-makers

[BIOTA West, Fahr et al.]

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DLR
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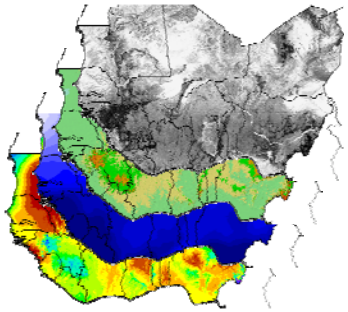
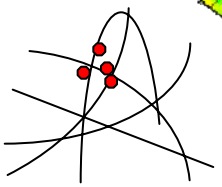
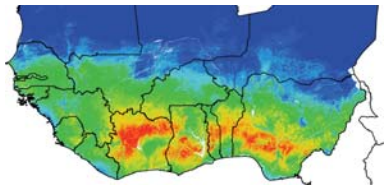
Selected challenges and solutions

research question







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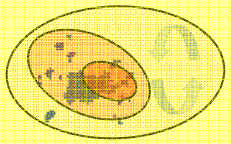

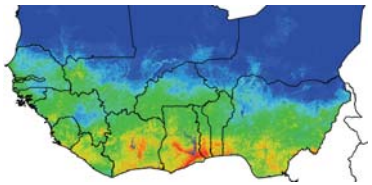

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customization

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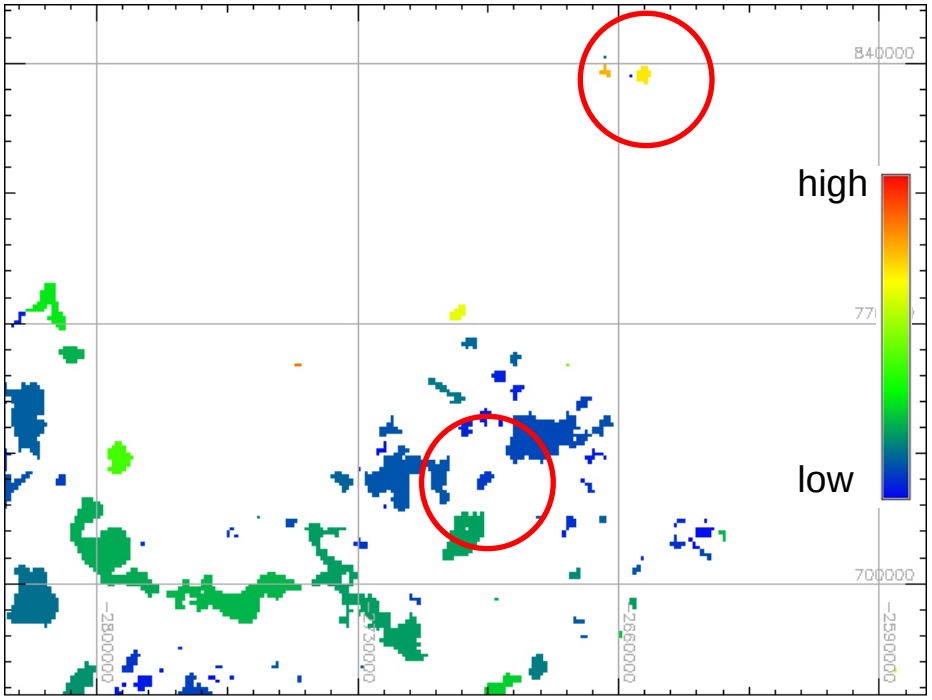
Enhancing results

let‘s get real

Talk 1.2

Predicted habitat patches evaluated with an „omnidirectional connectivity“ index



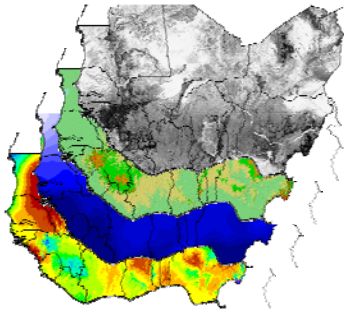
[BIOTA West, Wegmann]

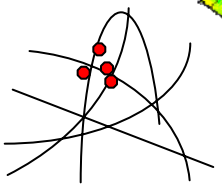
- Dispersal
  - biogeography
  - metapopulation / habitat fragmentation
- Human land use
- Stochastic events
- Biotic interactions

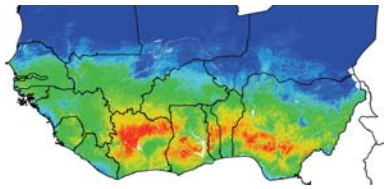
ensures that predicted distribution maps exclude unsustainable patches

Selected challenges and solutions

research question







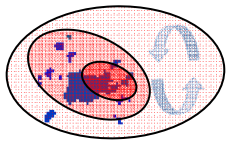
interim result

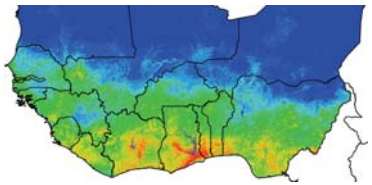
stochastic events

human land use

biotic interactions

dispersal





final result

APPLICATION FIELDS

- biodiversity conservation
- survey planning
- invasive species
- climate change
- ecological understanding
- ... others...

customization

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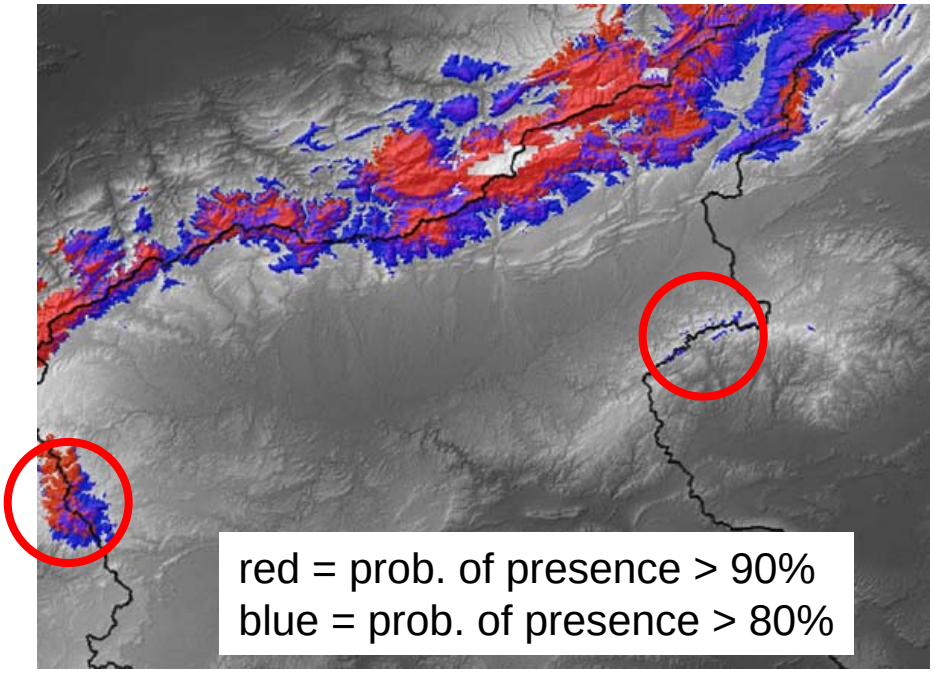
The application field

menu du jour ou à la carte?

Change of predicted presence area of *Alyssum spinosum* if temperature + 2.5° C



12 Climatic Variabels
ECHAM-REMO-LM-FOOT3DK
60 Geological / Soil Variabels
6 Topographical Variabels / DEM 30m

Variables actually used in tree construction:
ID367TMIN0 <= 6 °C
FROSTDAYS1 <= 140 days of frost
ID367TMAX0 <= 20.4 °C

- Ecological understanding
- Direction of future surveys
- **Climate change**
- Invasive species
- Biodiversity conservation

Climate change SDM should be based on abiotic variables only, as long as biotic interaction of target species are unknown - as done in this BIOTA project.

[BIOTA-Morocco]

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The application field

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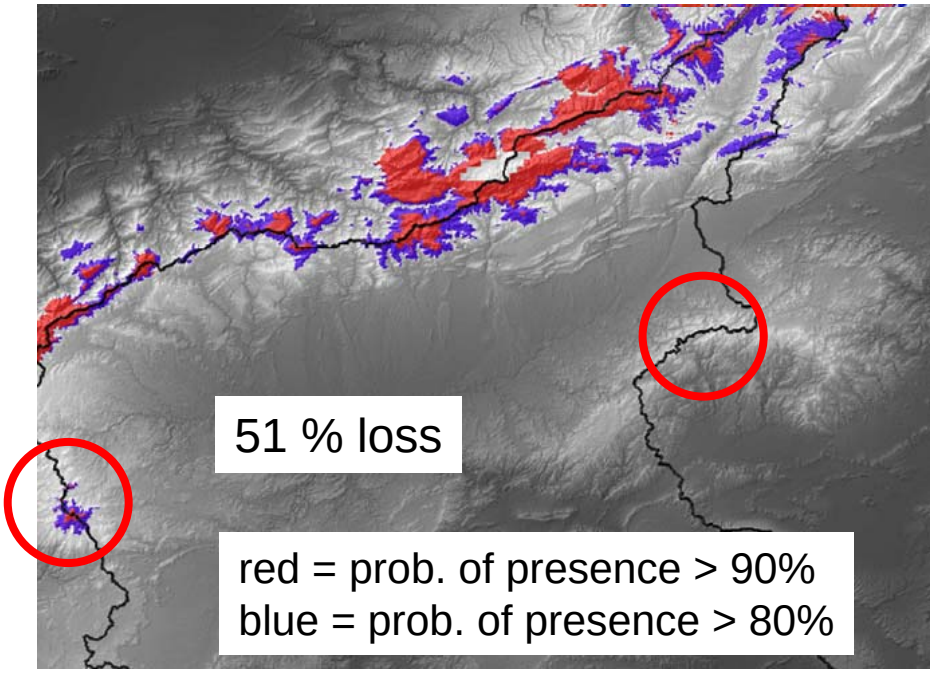

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Application Field

menu du jour ou à la carte?

FIGURE REMOVED

- Ecological understanding
- Direction of future surveys
- Climate change
- Invasive species
- Biodiversity conservation

Ordination analysis of SDM output (non-metric multidimensional scaling) for West African Red List Amphibians

SDM help undestand drivers of species richness, ecosystem functions and services

[BIOTA West, Penner]

The application field

menu du jour ou à la carte?

Conversion of SDM output from continuous probability values to binary prediction map

- Ecological understanding
- Direction of future surveys
- Climate change
- Invasive species
- Biodiversity conservation

FIGURE REMOVED

Threshold setting must (and can) be done depending on application field

- Presence *Rhinolophus maclaudi*
- Core habitat (predicted)
- Peripheral habitat (predicted)

[BIOTA-West, Fahr et al.]

Conclusions & Implications

- SDM create important new knowledge
- SDM stand to benefit from rapidly improving data
- SDM can be exploited particularly well by researchers with biological expert knowledge

- Understanding of model reliability and data quality issues is critical
- Always consider intended application of SDM
- Decision-makers should (and can) be supplied with robust information on uncertainties of SDM

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Outlook

- Need to improve integration of biotic interactions into SDM
- Improving „streaming“ data availability will enable SDM to support not only analysis but also observation tasks
- SDM would be a valuable contribution to any early warning system designed to detect threats to biodiversity (e.g. as in Scholes et al. 2008), especially if
  - a dynamic link was established between model predictions and remotely sensed land-cover change,
  - the user given the option to change the scale of analysis
  - if processing of interim results was done in response to the management objective

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