Spatio-temporal dynamics of malaria vector niche overlaps in Africa

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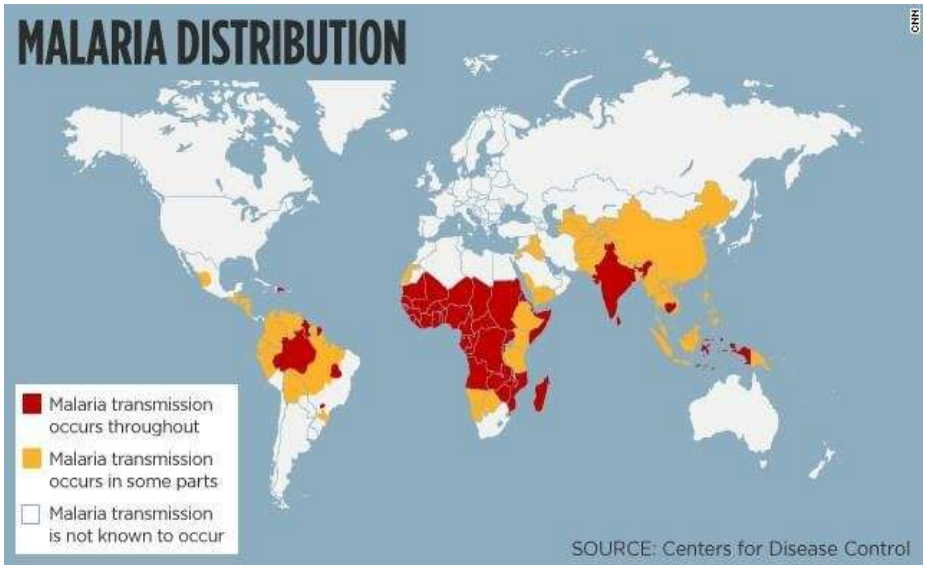
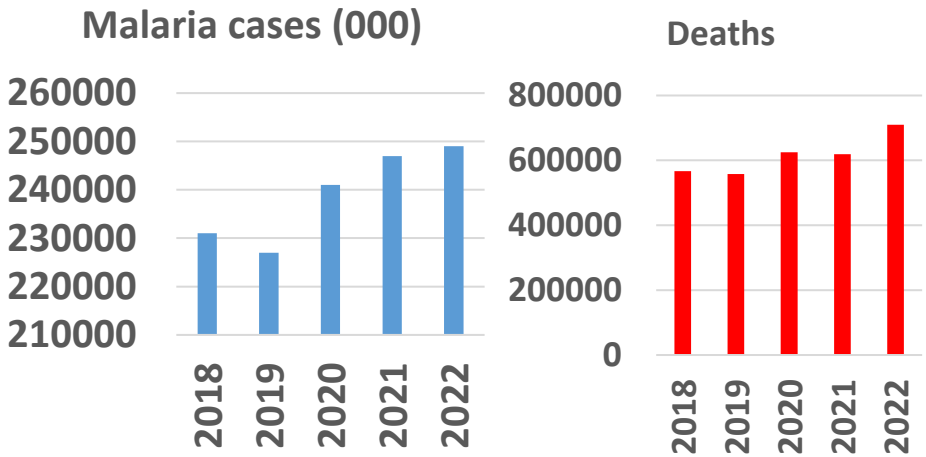
Background

- Malaria continues to be a life-threatening disease (WHO, 2023).



Trend in malaria incidences & related deaths



Sub-Saharan Africa

- **95% of the malaria cases**
- **Population at risk:** Infants, children < 5 years, pregnant women, HIV/AIDS, low immune people
- Children < 5 years (**80 % of deaths**)
- **Nigeria**, **DRC**, **Tanzania**, **Mozambique** accounting for over 50% of all malaria deaths worldwide.

- Malaria transmission by both primary and secondary malaria vectors

Primary Vectors

- 95% of transmissions
- Feed and rest indoors

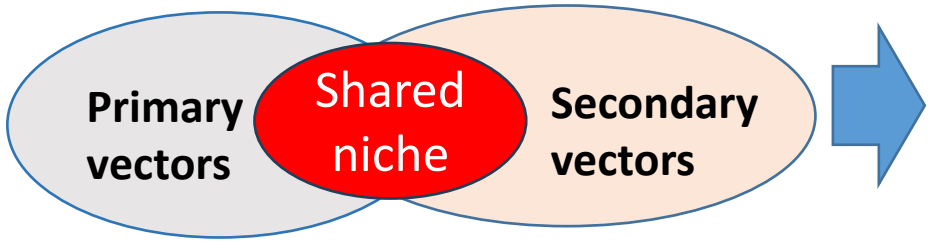
Secondary Vector

- 5% of transmissions
- Feed and rest outdoors

Implication on vector control

- Vector control Interventions (IRS & ITNs): on **secondary vectors**
  - Preservation of **secondary vector populations :** Assume primary role **eg An. *arabiensis***
  - ***Changing bionomics***

- **Vectors don't live in isolation : Share habitats**



- increased likelihood of **intensified, sustained & prolonged residual malaria transmission**

- Vectors are not static: spread to new habitats due to **climate change** & **adaptation, Transport** ; increased **shared habitats** and **spatial temporal dynamics**
- **Identification of niche overlaps is** critical in pinpointing regions at elevated risks of residual malaria transmission

- **Aim: modelling niche overlaps between primary and secondary malaria vector in Africa**

Methodology

- **Study Area**

Spatial and temporal data:

(a) Malaria vectors occurrence

- **Primary vectors:** *An. gambiae* complex & *funestus group*
- **Secondary vectors:** *An. pharaonsis* and *An. coustani*

Data sources:

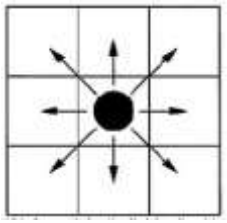
- (b) Environmental factors;

1	Temperature	8	Climate moisture index
2	Relative humidity	9	Cloud area fraction
3	Irrigation proximity	10	Wind speed
4	Elevation	11	Potential evapotranspiration
5	Build-ups proximity	12	Precipitation
6	NDVI	13	Solar radiation
7	Shrubs proximity	14	Surface water balance

Spatial and temporal scope: 1985 - 2021

Methodology: Key considerations

- **Diffusion process of vectors species**: vectors movement across landscape - in search for **mates/feed/aquatic habitats or by transport and wind (eg An. *Stephensi*).**



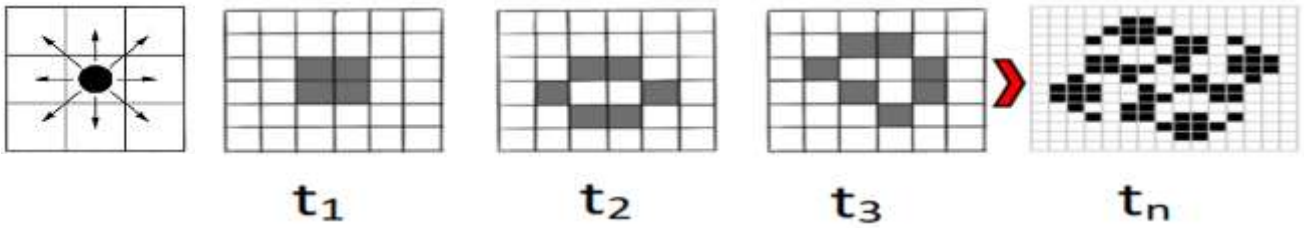
- Vectors initial (and subsequent) occurrence points informs their presence, in localities at subsequent time-steps

- **Adaptation to new habitats:** due to climatic changes & environmental changes

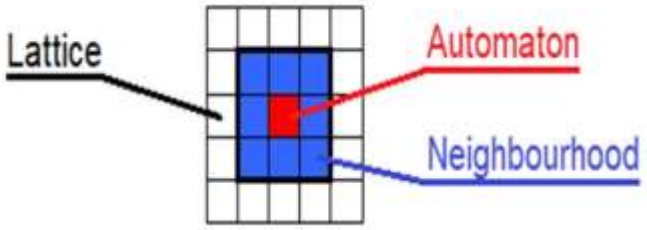
- Dynamics of species Distribution due to seasonality, LULC changes, climate change
- **Prior modeling approaches**: don't integrate vectors diffusion & spatio-temporal dynamics

Methodology: dynamic spatial-temporal modeling

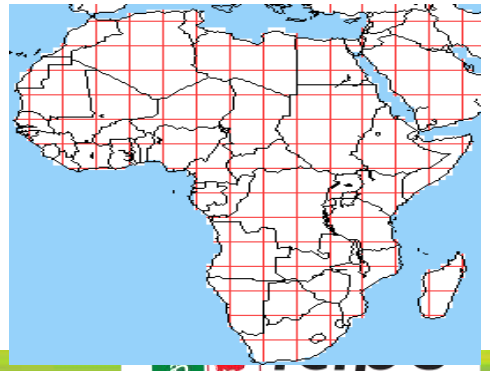
- Model informed by vectors' occurrences at every distinct timestep;- **account for diffusion, evolution and spatio-temporal dynamics involved.**
- **Spatio-temporal model: cellular automata**



- The model; $S_{ij}^{t+\Delta t} = f(S_{ij}^{t}, N_{ij}^{t}, T)$
  - S_{ij}^{t} the **state of cell(s)** at defined time t,
  - N_{ij}^{t} the **state of cells the neighborhood** of cell S_{ij}^{t};
  - T the **transition rules**; and Δt is the time-step.



- Inclusion of vector occurrence data reported at later time-steps in modelling



Methodology: Model implementation

a) Exploratory data analysis

Significance:

Cluster analysis
Correlation test

- Subset of predictor variables
- Informing formulation of transition rules

b) Model implementation

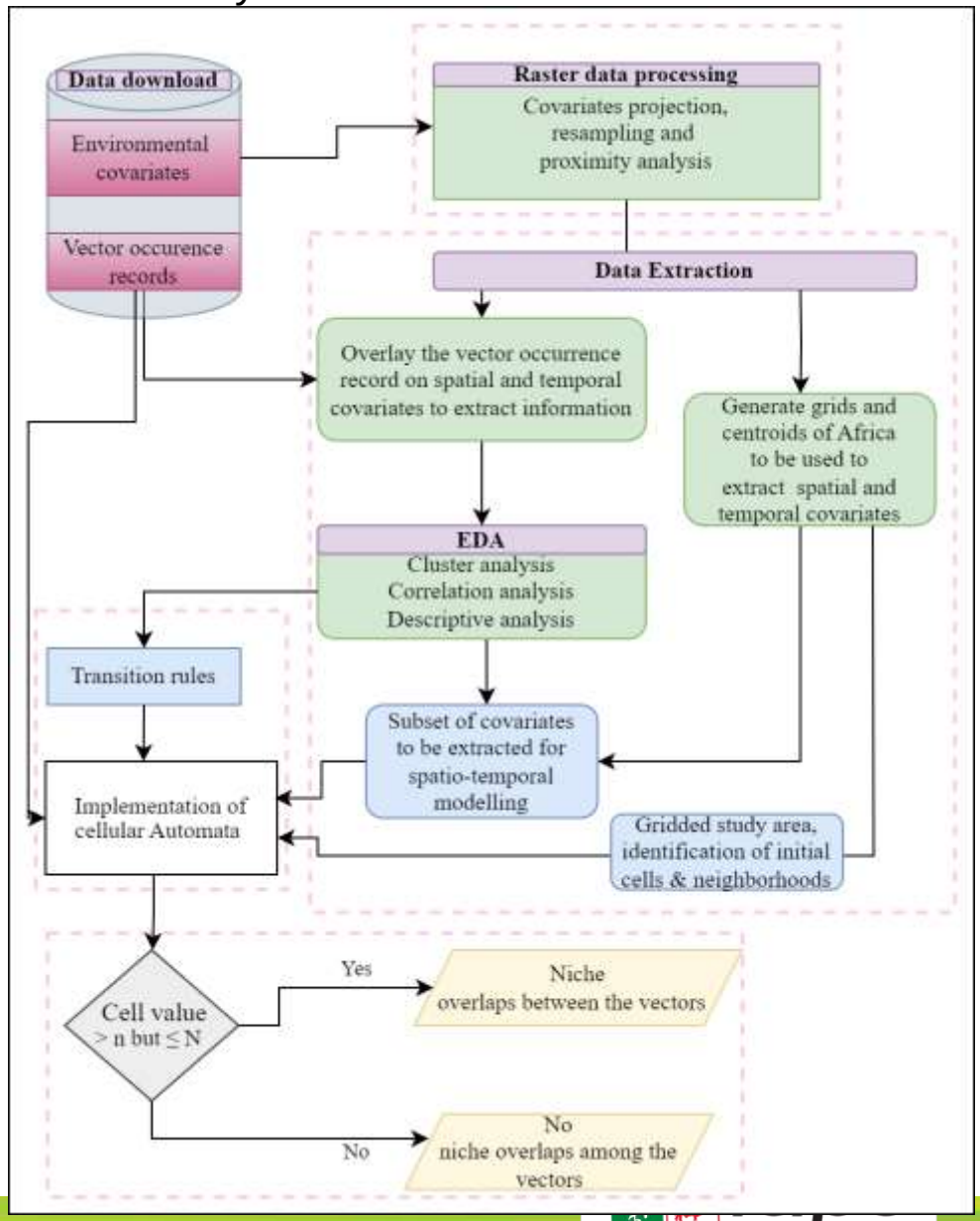
Descriptive statistics

- Formulation of **transition rules**
- Gridding area study
- Identification of initial cell & neighborhoods
- Model implementation & fine-tuning (1985-2017)

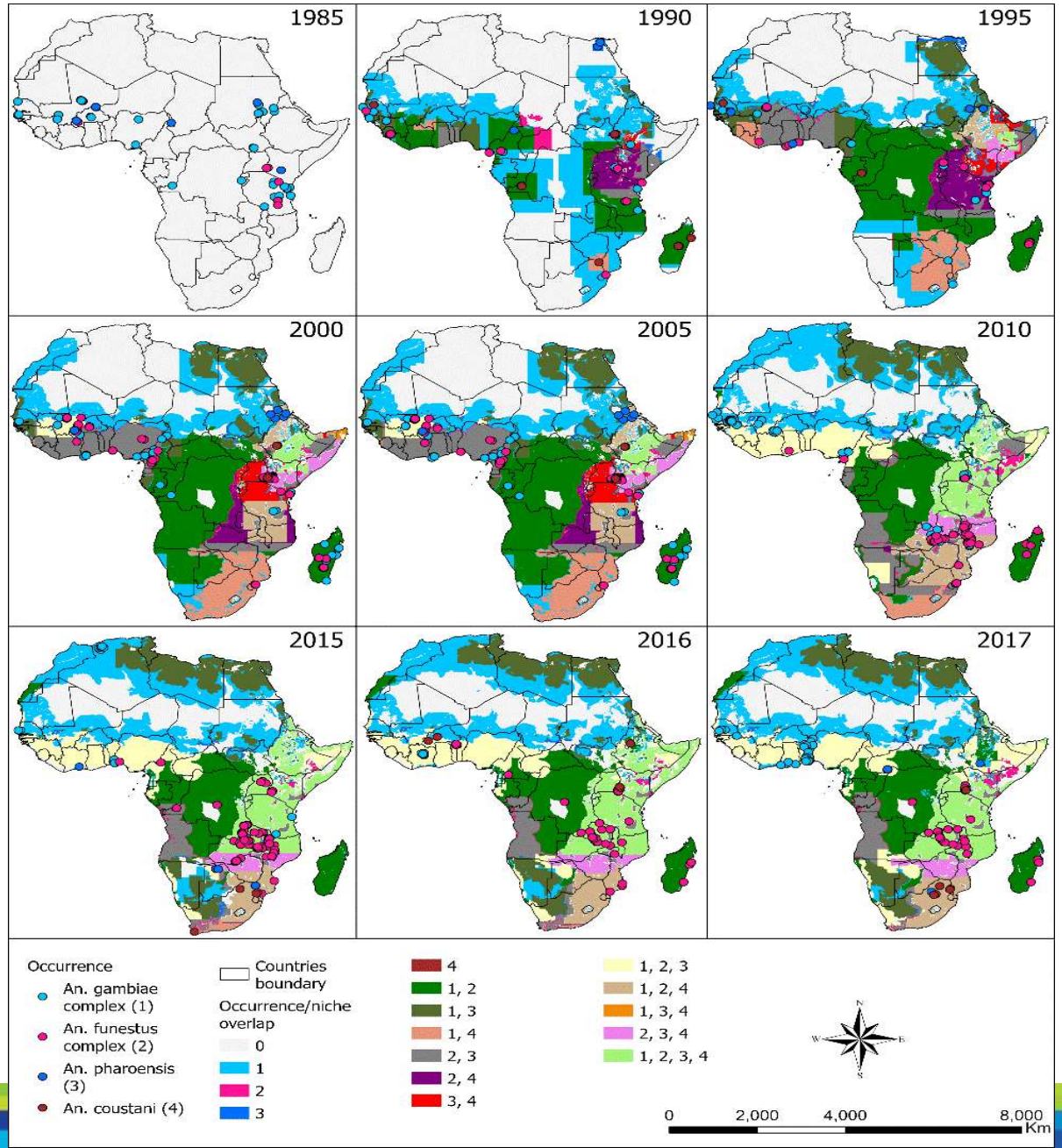
c) Model validation

- Spatial approach (2018-2021)

- Summary



Results: Model implementation



Vectors:

1. *An. gambiae complex*,
2. *An. funestus group*,
3. *An. pharoensis &*
4. *An. coustani*

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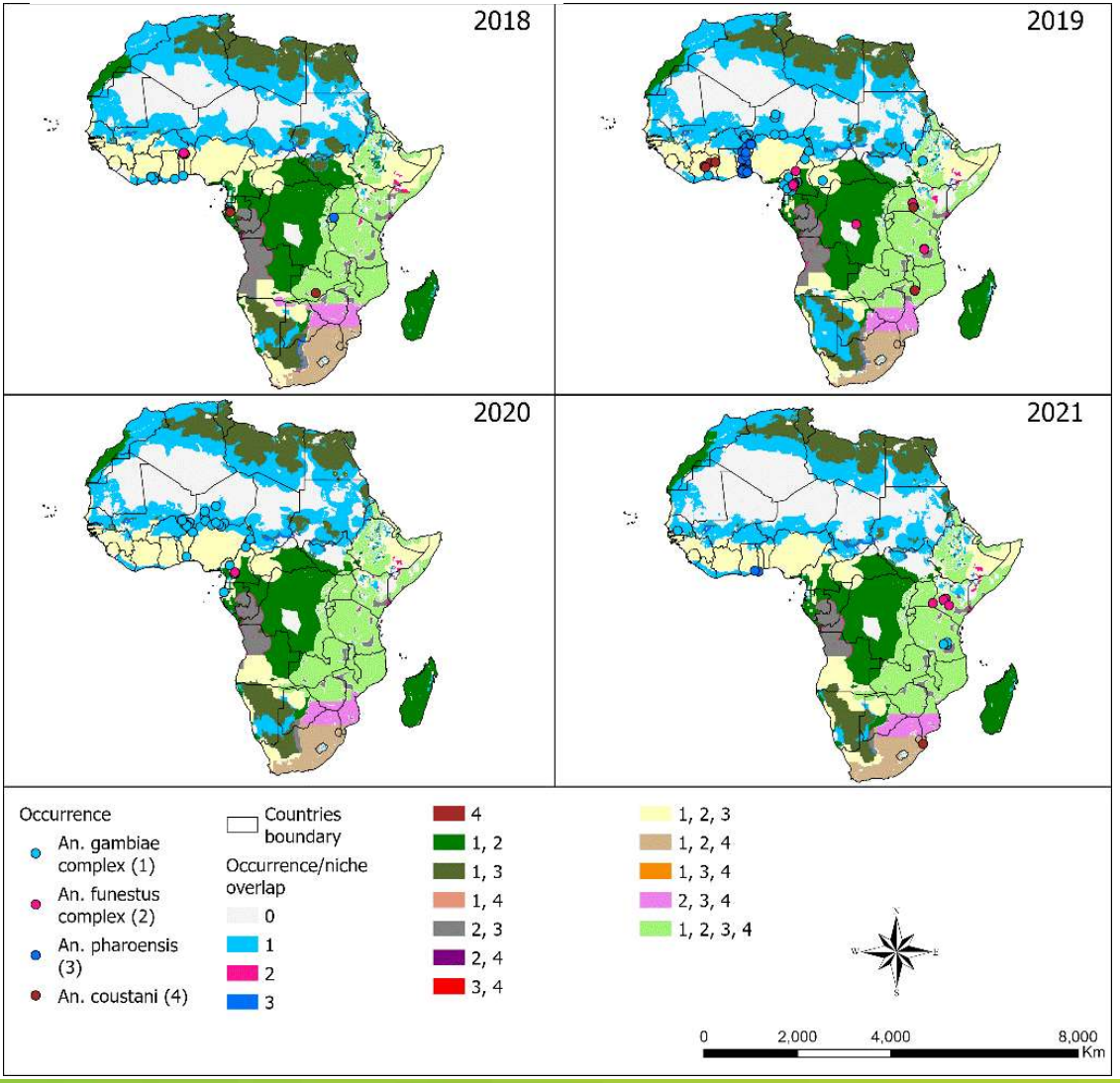
Results: Model validation

Vectors: *An. gambiae complex*, *An. funestus complex*, *An. pharoensis* & *An. coustani*

Model validation



Vectors:

1. *An. gambiae complex*,
2. *An. funestus group*,
3. *An. pharoensis* &
4. *An. coustani*

Accuracy; > 0.92.

Significance:

The niche overlaps, integrated with malaria parasites distribution highlight potential hotspots for sustained malaria transmissions

Nigeria, DRC, Uganda, Mozambique

Conclusion/Implications

- Knowledge of vector niche overlaps is key for strategic planning & implementing interventions tailored for local vectors factoring their bionomics.
- In Africa, extensive areas have niche overlaps between primary and secondary vectors: hence many areas are at:
  - **heightened risk** of sustained and prolonged malaria transmission.
  - **hotspots** for malaria persistence or resurfacing (**if malaria parasites present, persistent biting rates**)
- Habitats shared primary & secondary vectors should be priority focus, **using more target vector control strategies, aligned with their bionomics**
- **Dynamic spatial-temporal modeling approach**: Key for predicting the changing distributions and niche overlaps of malaria vectors and hence boosting surveillance efforts

Significant undertakings going forward:

- Incorporating additional primary and secondary vectors in our model, forecasting, and extension to non-malaria vectors
- Integrating our outputs with as **plasmodium parasite distribution**, **biting rates** and **updated data on interventions**

Donor Acknowledgement

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Thank you

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