Fine-scale spatial risk maps of incidence in Senegal

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map

Overview

- In 2023, many African countries began the tedious process of updating their National Strategic Plan for malaria.
- As part of this plan, country programs require to have a clear understanding of the spatial distribution of malaria and how it has changed over time.
- In elimination settings such as Senegal, the program do not run malaria surveys because there are too few cases. Instead, they only rely on their surveillance system-incidence.

The purpose of this work

was to explore the fine-scale heterogeneity of malaria transmission in Senegal to support decision making.

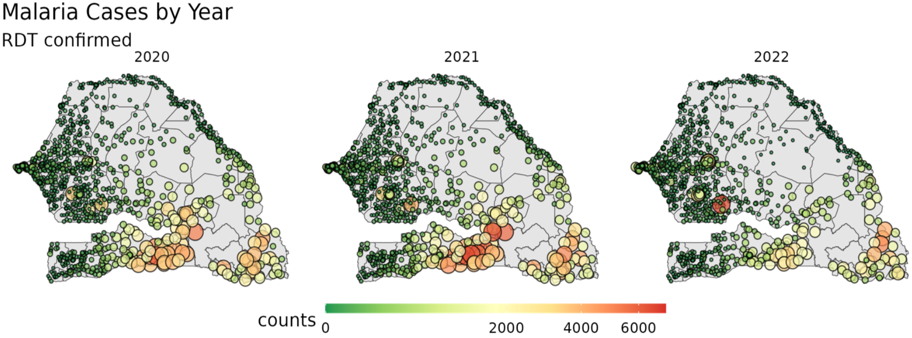
Data used: Routine Health Facility (HF) Data

Clinical case counts from HF can become a powerful data source for mapping disease burden especially in elimination settings. However, often there are **challenges with facility-based data**:

- challenge 1: missing information on HF catchments: unknown areal footprints and population denominators,
- challenge 2: uncertainties regarding treatment seeking rates: particularly urban/rural differences,
- challenge 3: missing information on the total set of facilities: e.g. private facilities may not report, and their locations and populations served may be unknown.

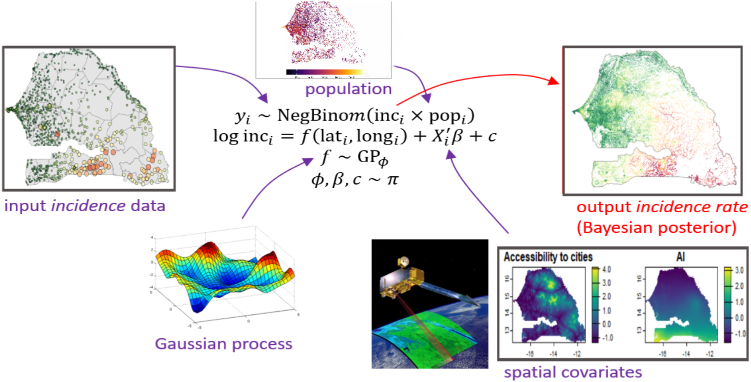
Data from DHIS2 used

- Number of malaria cases for all ages from 1251 health facilities.
- A total of 52.2 % of the health facilities was geolocated.

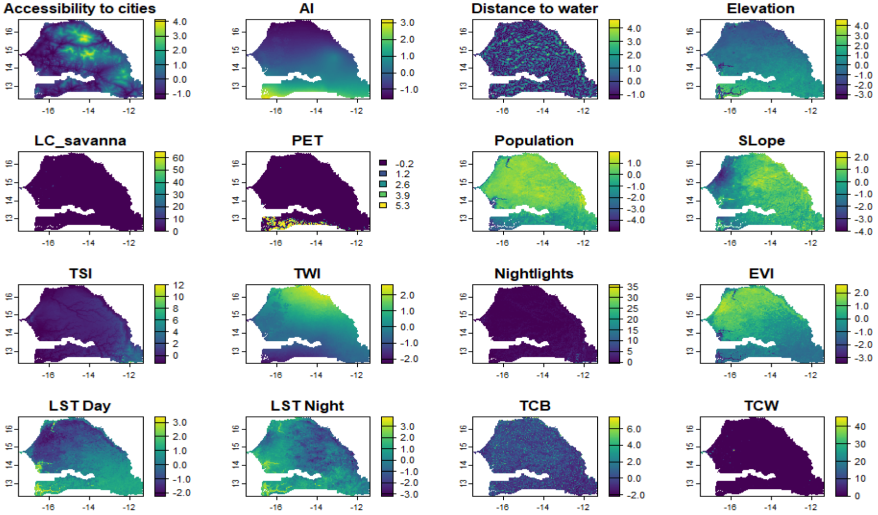


Geostatistical model

The model for incidence data combines spatial covariates with a spatial (Gaussian process) random effect: designed for measurements taken at known locations of negligible area (point-level data), and population denominator into a Negative binomial sampling distribution



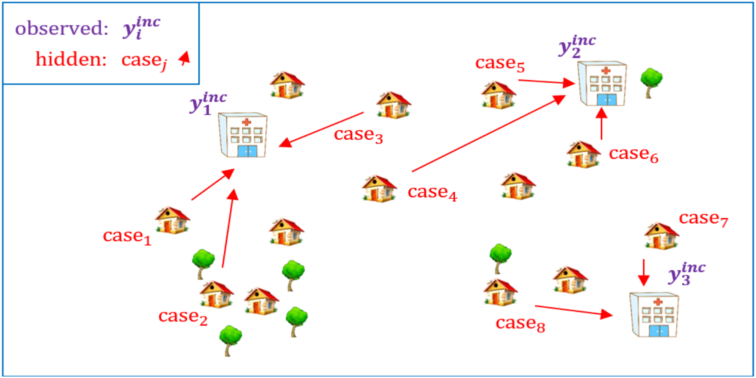
Environmental and socio-demographic covariates



AI: Aridity index; Elevation: Multi-error-removed improved-terrain; TWI: Topographic wetness index; PET: Potential evapotranspiration; TSI: Temperature suitability index for P.falciparum; Slope: Elevation as measured by the shuttle radar topography mission (SRTM); TCB & TCW: Tasselled cap brightness & wetness; LST: Land surface temperature.

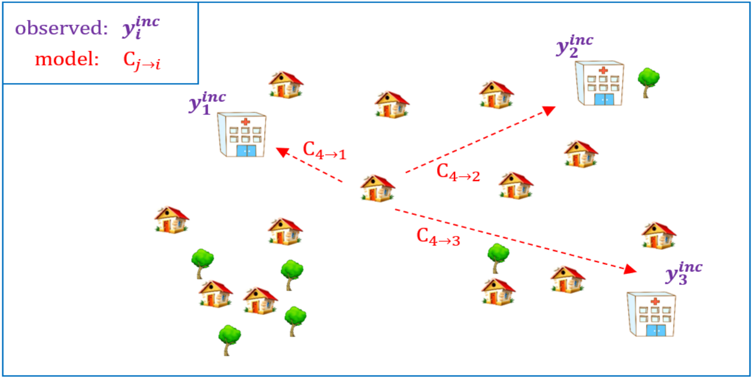
Catchment model (challenge 1)

- The greatest challenge with facility based case data is determining the catchment population associated with the case estimates.
- Evidence shows that people do not always attend the facility that is nearest.



Catchment model (challenge 1)

A catchment model assigns a probability ($C_{j \to i}$) that the people in each household (j) will seek treatment at each HF (i).



Catchment model (challenge 1)

- Some facilities may be preferred over others because of the relative cost of care or reputation.

- Individuals in pixel j who seek treatment, the proportion seeking treatment at HF i is modelled as proportional to the HF attractiveness M_i (a per-facility parameter) divided by the square of the travel time to that HF

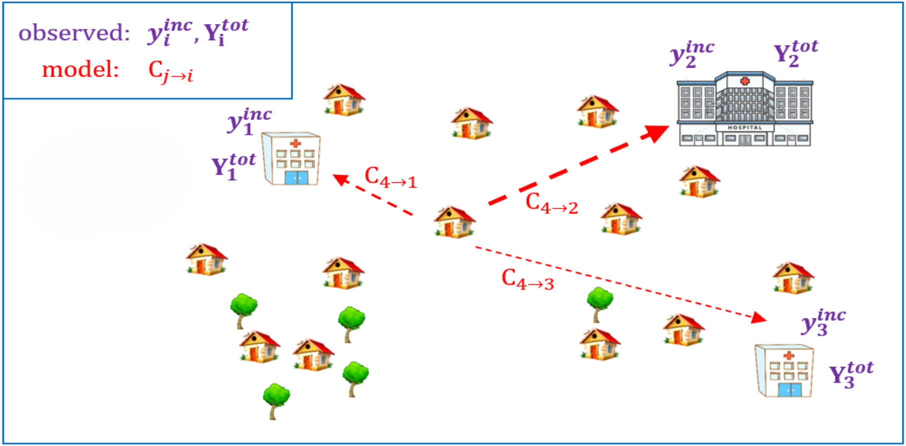
$$\tilde{C}_{\text{pixel}_j \to \text{HF}_i} := \begin{cases} t(\text{pixel}_j \to \text{HF}_i)^{-2} M_i & \text{if } t(\text{pixel}_j \to \text{HF}_i) \leq 180 \text{ mn} \\ 0 & \text{otherwise.} \end{cases}$$

The proportion seeking treatment at facility i was

$$C_{\text{pixel}_j \to \text{HF}_i} = \frac{\tilde{C}_{\text{pixel}_j \to \text{HF}_i}}{\sum_{k=0}^{N_{\text{HF}}} \tilde{C}_{\text{pixel}_j \to \text{HF}_k}}.$$

Catchment model (challenge 1)

To fit this model with 'masses' it's helpful to know the total number of cases (malaria + non-malaria) seen by each HF; but priors can be used to represent uncertainty if that information is unavailable



Geostatistical framework with catchment

catchment model (sum over pixels)

$$y_i^{\text{inc}} \sim \text{NegBinom}\left(\sum_j C_{j\to i} \times \text{inc}_j \times \text{pop}_j\right)$$

$$\log\left(inc_j\right) = f\left(\text{lat}_j, \text{long}_j\right) + X_j'\beta + c$$

$$f \sim \text{GP}_\phi$$

$$\phi, \beta, c, M_i \sim \pi$$

free parameters of the catchment model get their own priors

The expected incidence at each HF is obtained by summing the incidence over all pixels weighted by the catchment model.

Treatment seeking model (challenge 2)

- Generally we will want to allow for the possibility that not everyone with a fever will seek for a treatment.

- The proportion of the population at a given location (j) that would seek treatment for fever in the nearest formal healthcare system was modelled as in (Arambepola et al., 2021)

$$TS_j = \frac{\alpha}{1 + \exp\left(\sigma t(\text{pixel}_j \to \text{HF}_{\text{nearest}})\right)} + \beta; \quad (\alpha + \beta \leq 1),$$

where parameters α, σ and β were chosen based on the threshold values of the maximum and minimum possible treatment-seeking proportions.

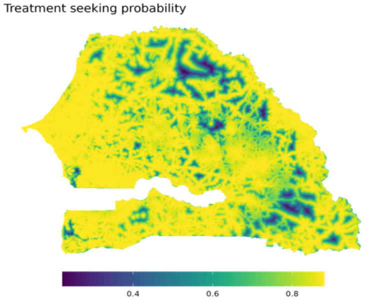
Geostatistical framework with treatment seeking adjustment (challenge 2)

$$y_i^{\text{inc}} \sim \text{NegBinom}\left(\sum_j C_{j\to i} \times \text{inc}_j \times \text{pop}_j \times TS_j\right)$$

treatment seeking probability map

$$\log\left(inc_j\right) = f\left(\text{lat}_j, \text{long}_j\right) + X_j'\beta + c$$

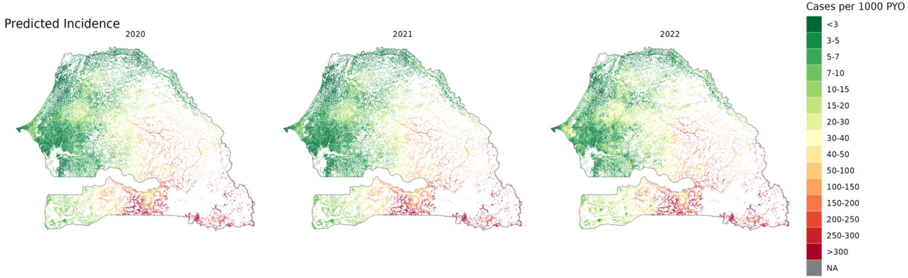
$$f \sim \text{GP}_\phi$$
$$\phi, \beta, c, M_i \sim \pi$$



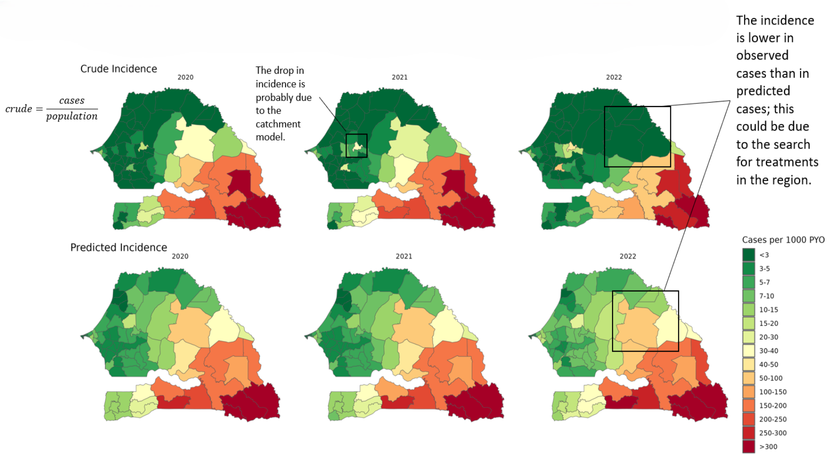
One way to do this is to introduce a previously estimated treatment seeking map (e.g. from DHS survey data).

Main result

- Prediction of malaria risk at 1 km of resolution in pixel level.
- Adjusted estimations from the model with catchment and treatment seeking to represent population level load.



Comparison between raw data and prediction by district



Use of the prediction maps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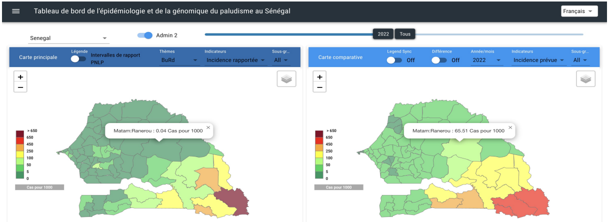

Model limitations

Data

–Challenge 3: Lack of consensus on a master facility list with validated GPS coordinates.

–Population remains stationary within the model framework.

Assumptions

–Our models are based on various assumptions (**stationary Gaussian field, linear predictor (non-linear effect of covariates excluded), simple 'gravity' model considered**).

–Our models aim to predict rather than explain, which implies a compromise between predictive performance and interpretability (e.g., the interpretation of covariate coefficients is not straightforward).

Conclusion

- A classical geostatistical framework was used and was extended by a catchment population and treatment seeking models.
- A series of annual 1km pixel risk maps were produced and presented to the Senegal NMCP.
- We further have developed a work about influential dominant covariates by pixel and admin level.
- Monthly risk maps work is in development.

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Thank you for your attention!