African Risk Prediction Model: Mapping the burden of typhoid fever in Africa

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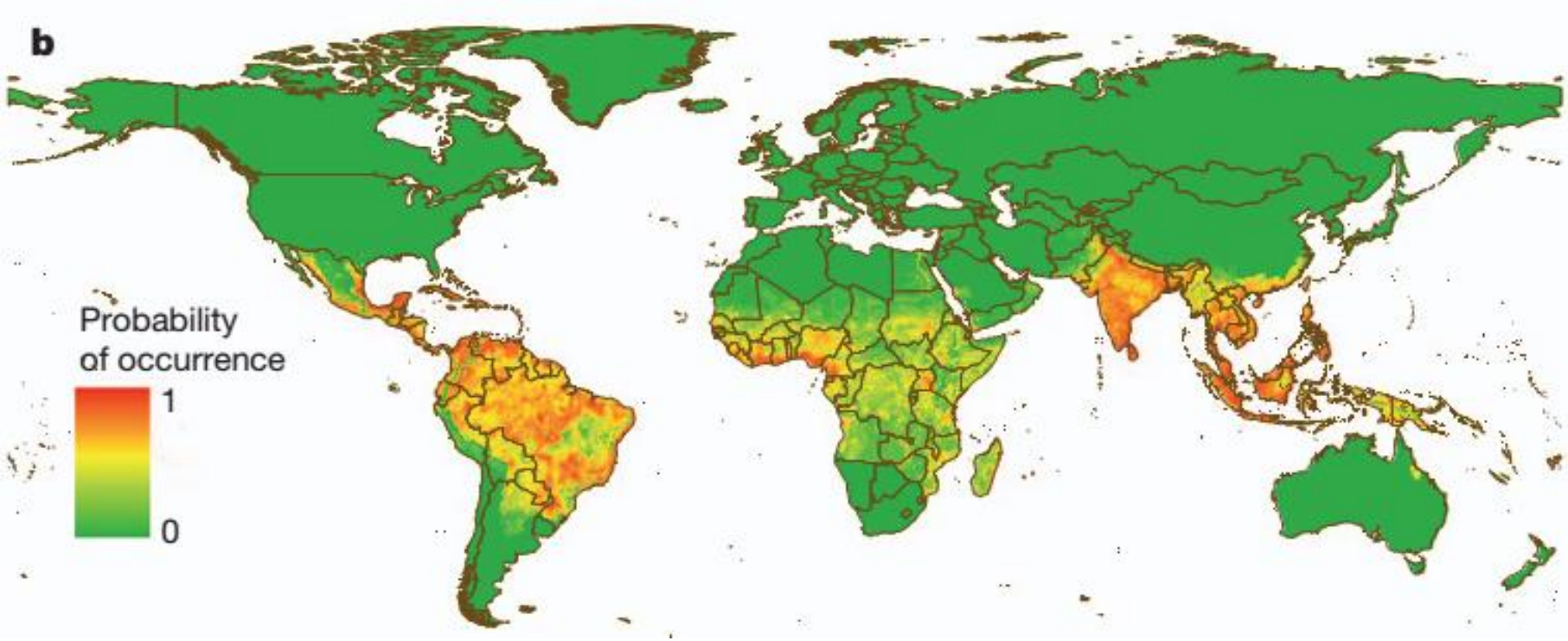
International Vaccine Institute

Topics

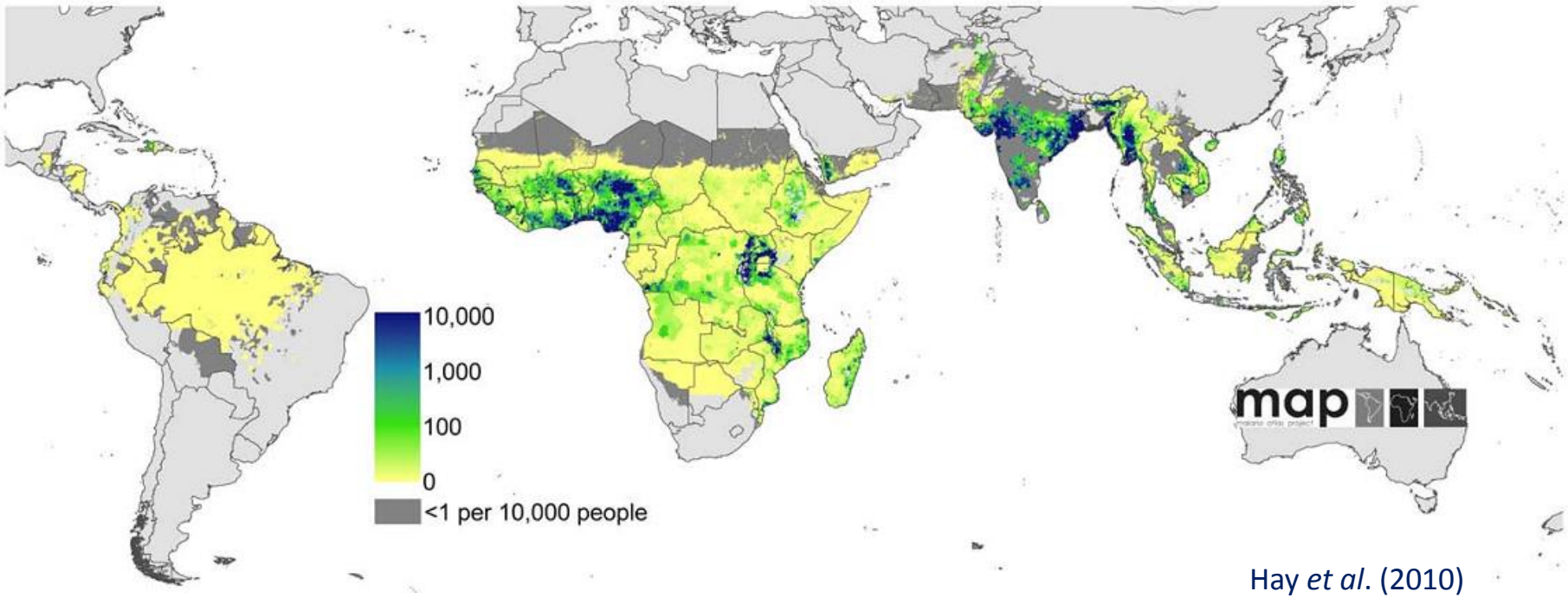
- Examples of disease burden maps
- Generating maps
- Mapping the burden of typhoid fever: model and input
- Typhoid occurrence and explanatory covariates
- Boosted regression tree model
- African map of probability of occurrence and annual incidence rate of typhoid fever

Example: probability of dengue occurrence



Bhatt *et al*. (2013)

Example: incidence of malaria transmission

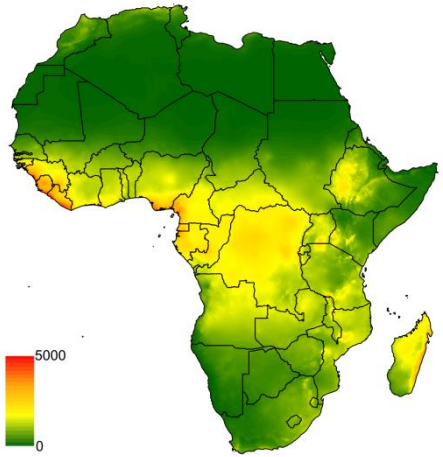


Hay *et al*. (2010)

Mapping the burden of a disease

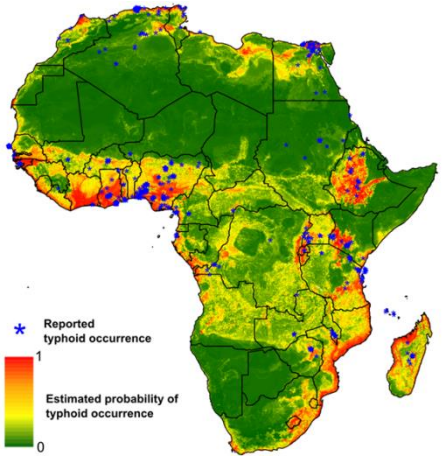
Disease occurrence points

Geospatial covariates

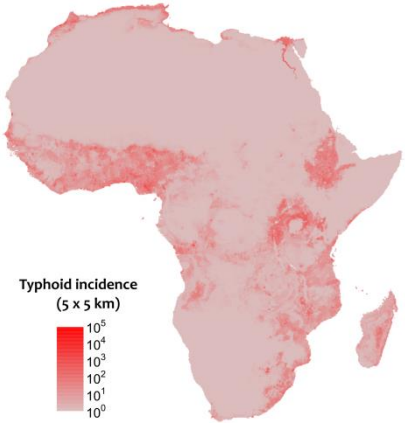


Model

Predicted probability of occurrence



Predicted incidence rate



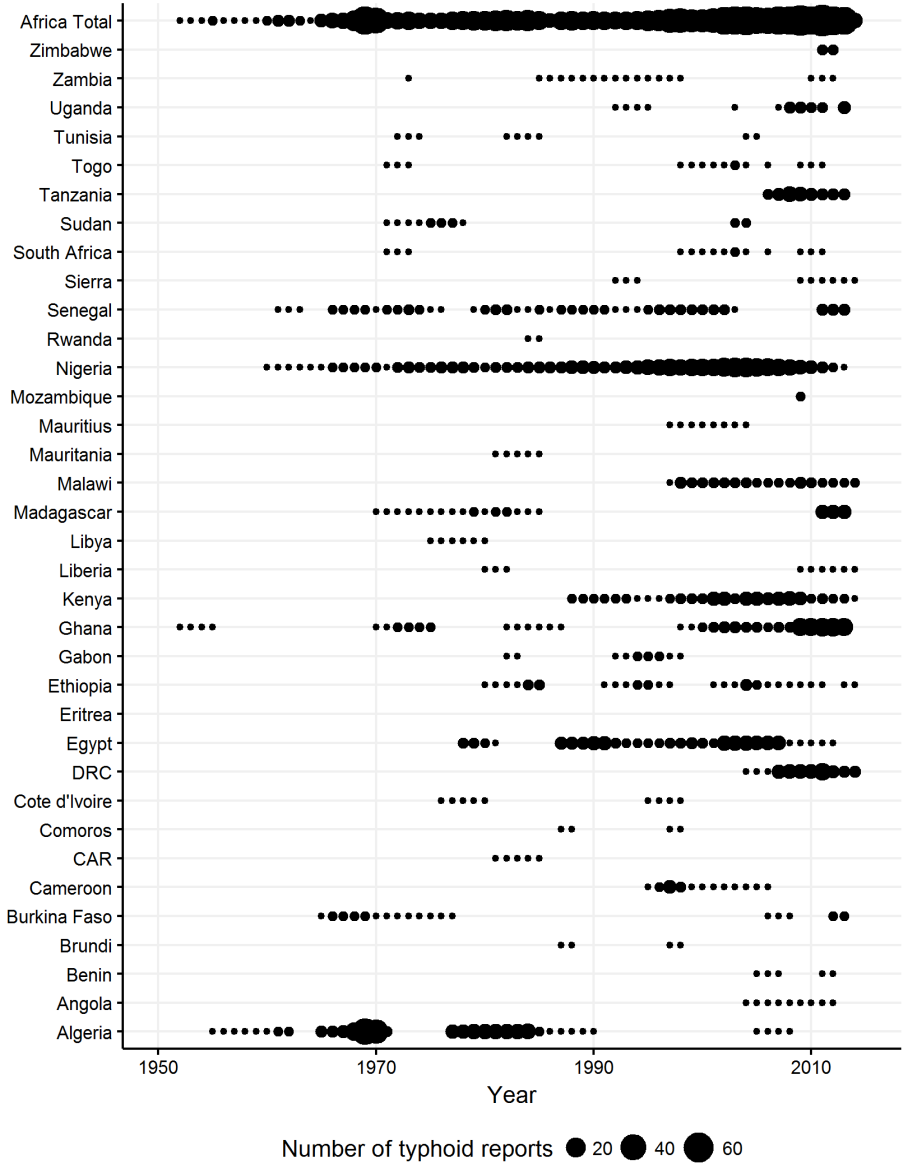
Mapping the burden of typhoid fever

- Data
  - Geo-referenced typhoid fever occurrence
  - Geo-referenced variables that potentially have influence on typhoid transmission
- Model
  - Boosted regression trees and Bayesian hierarchical model

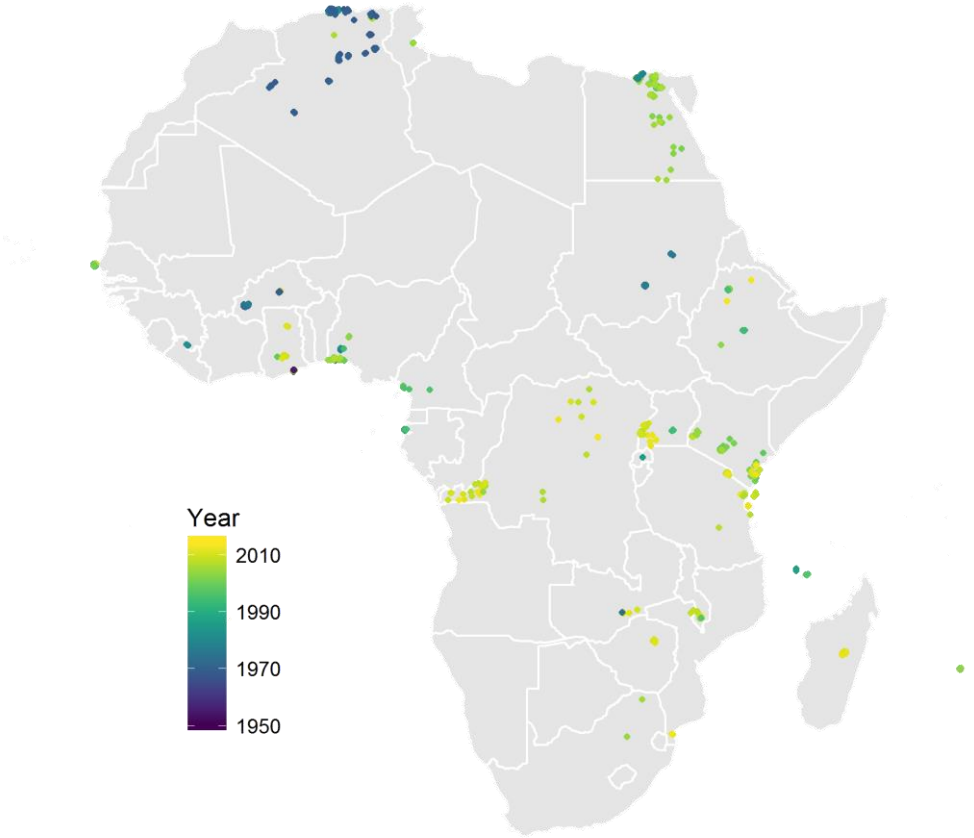
Identification of typhoid occurrence

- Review of records (PubMed, Embase, and ProMED)
- Blood culture confirmed typhoid fever
- Geographic coordinates using Google Maps
- The period of 1950-2015
- Typhoid occurrence standardized by year

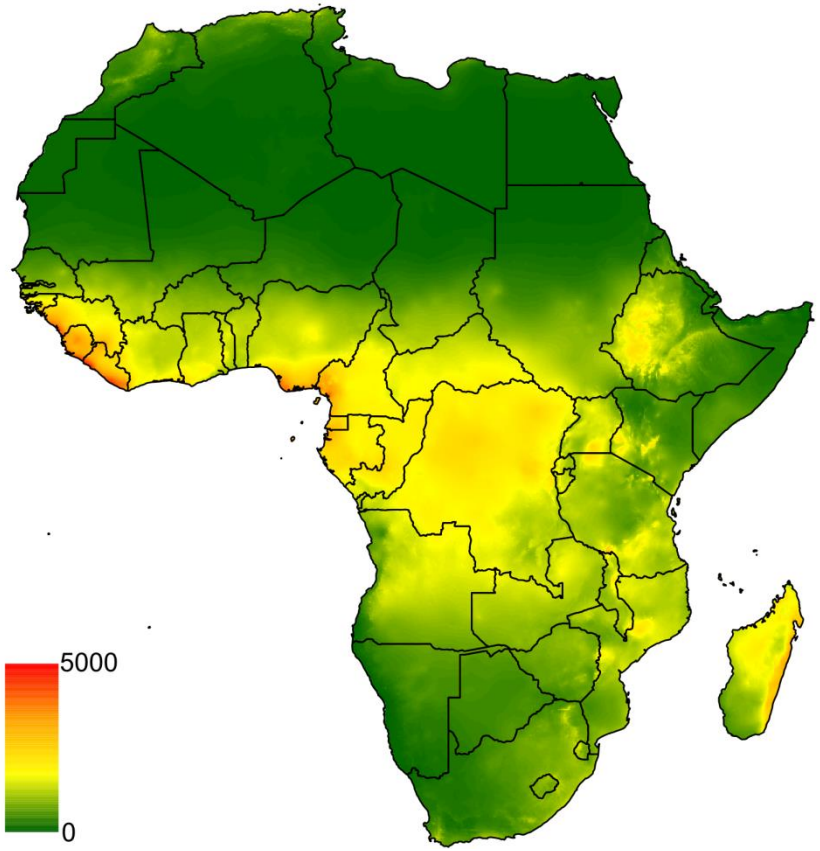
Typhoid reports by country and year



Blood culture confirmed typhoid (n=688)

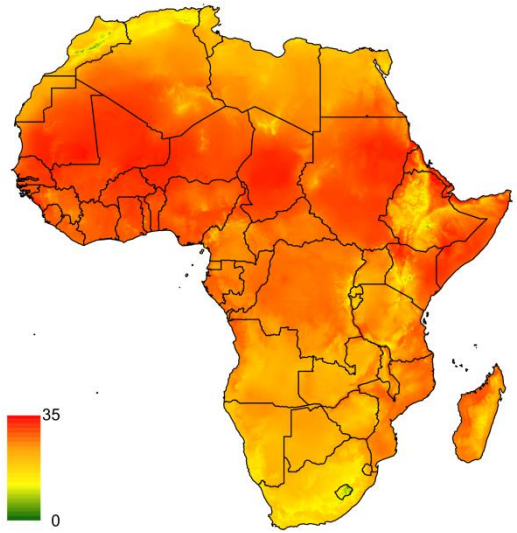


Explanatory covariate: annual precipitation

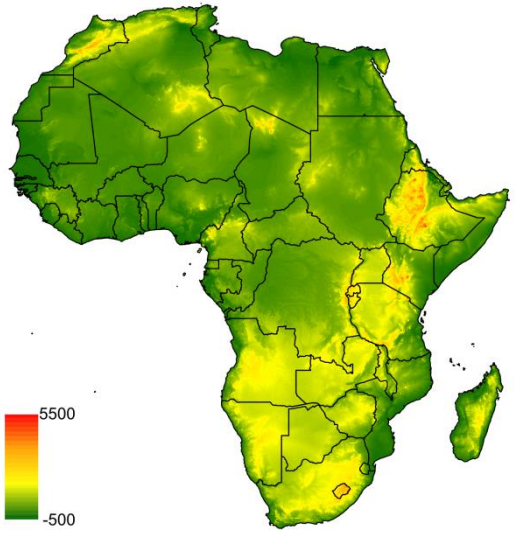


Additional covariates

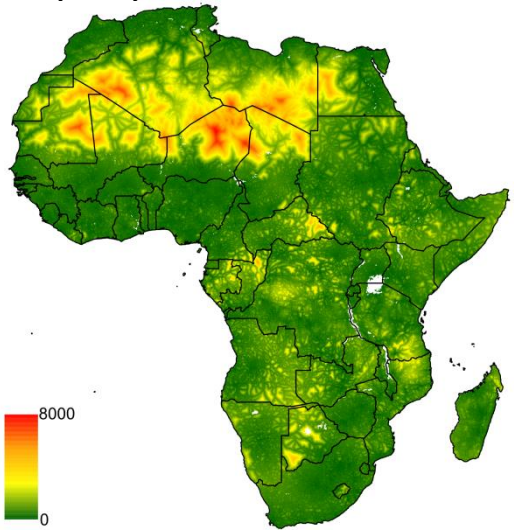
Annual mean temperature



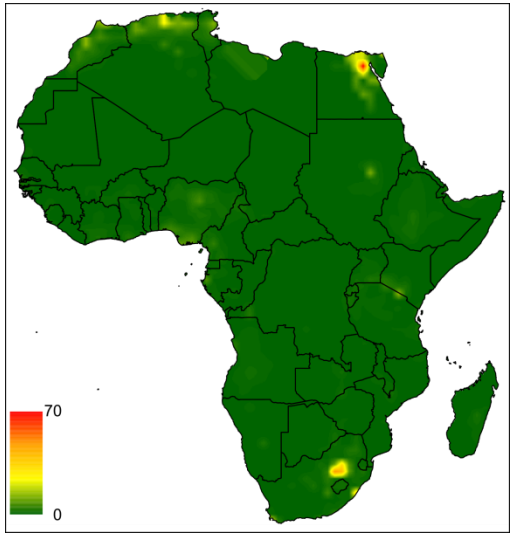
Altitude



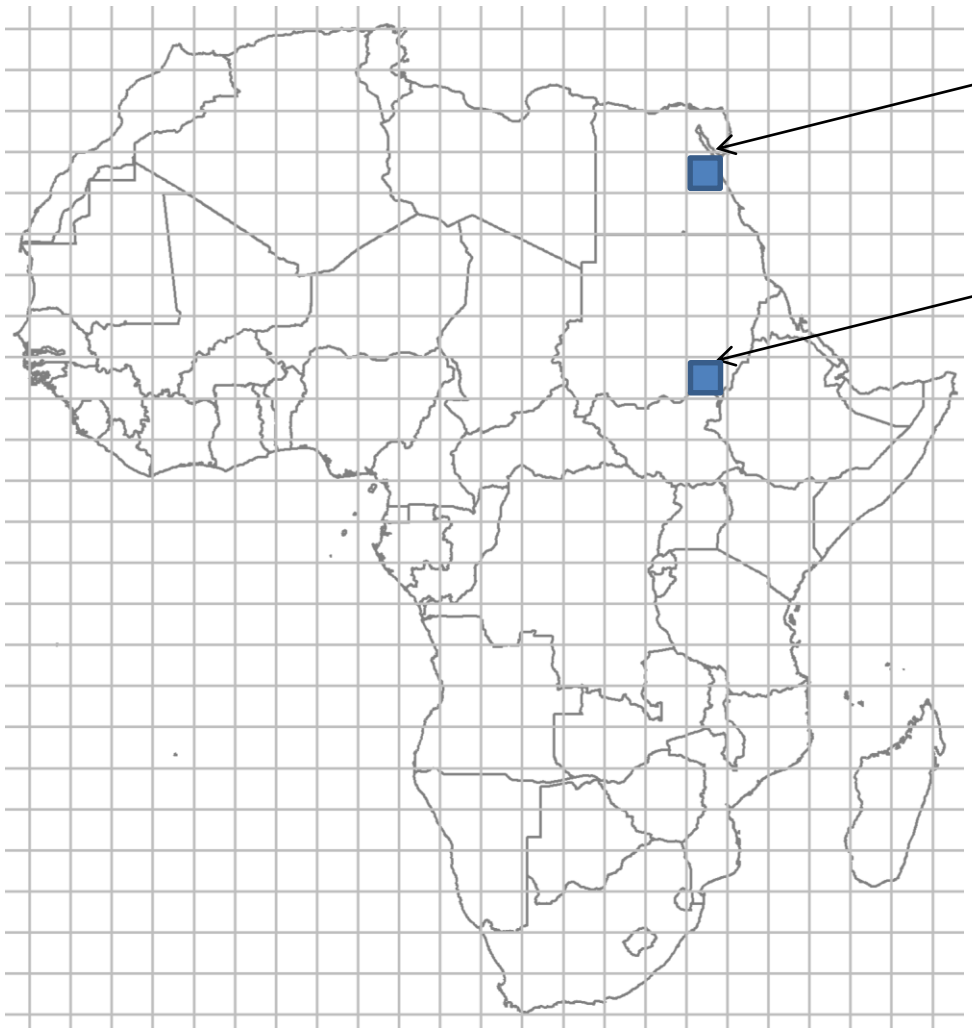
Travel time to the nearest settlement of 100,000 people



Gross cell product



Model inputs

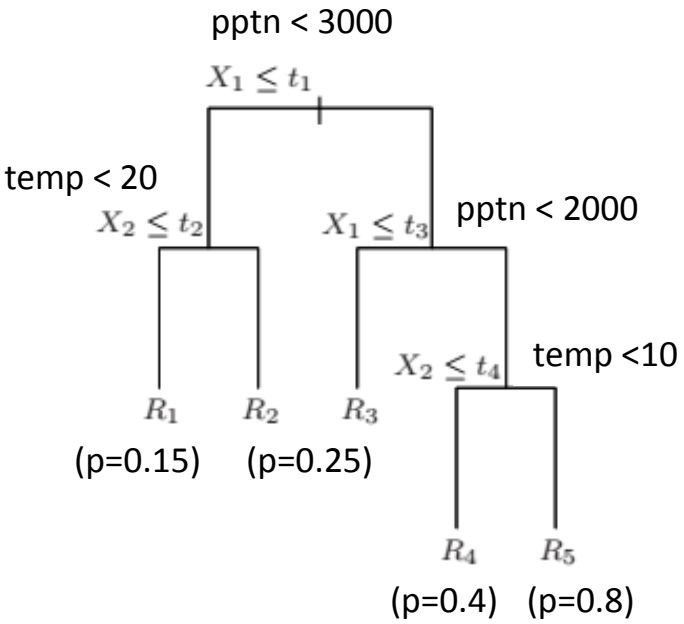


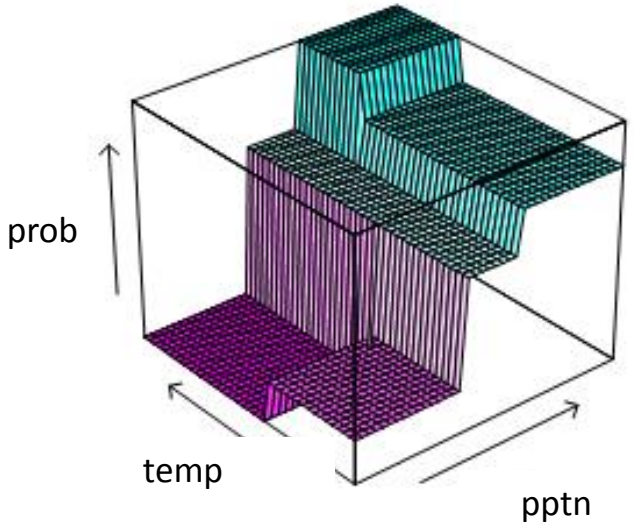
Cell#	TF?	pptn	temp	alt	…
56	YES	1500	10	5	

Cell#	TF?	pptn	temp	alt	…
180	NA	500	89	5	

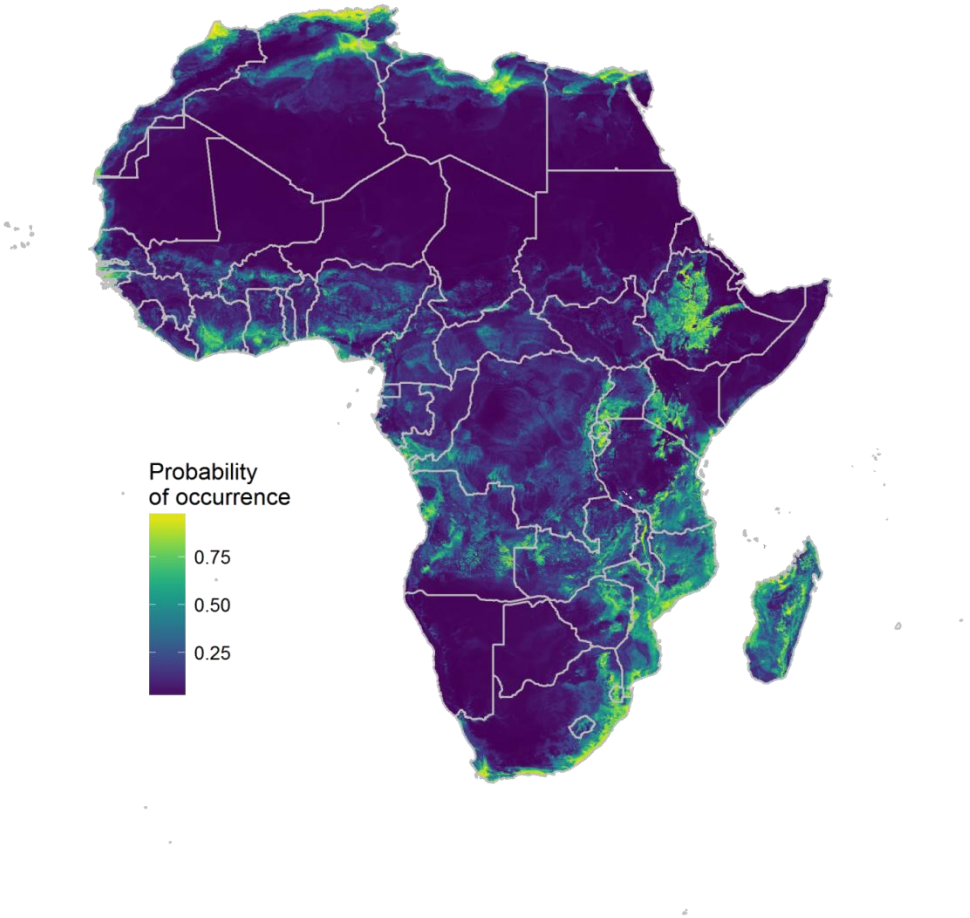
Boosted regression tree (BRT) model

An ensemble of (weak) decision tree

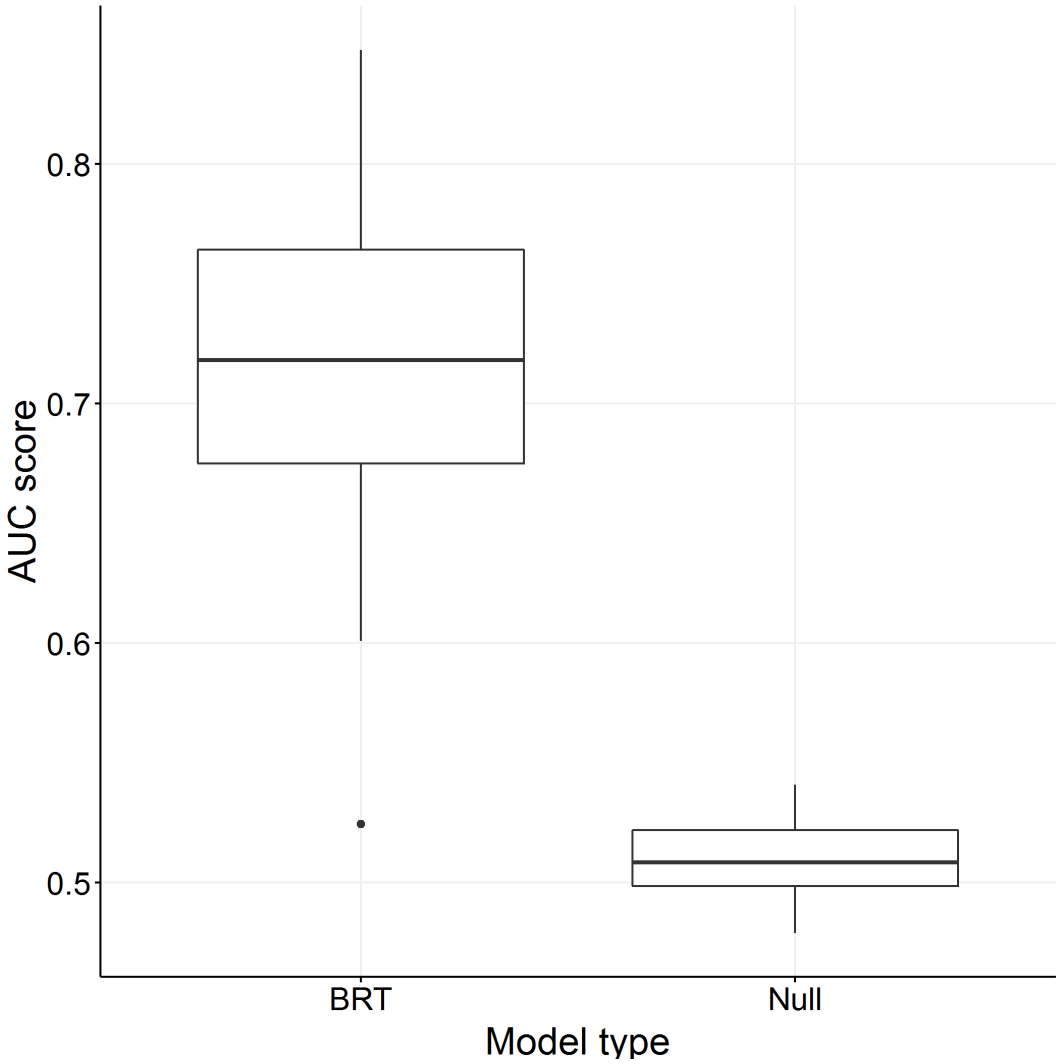




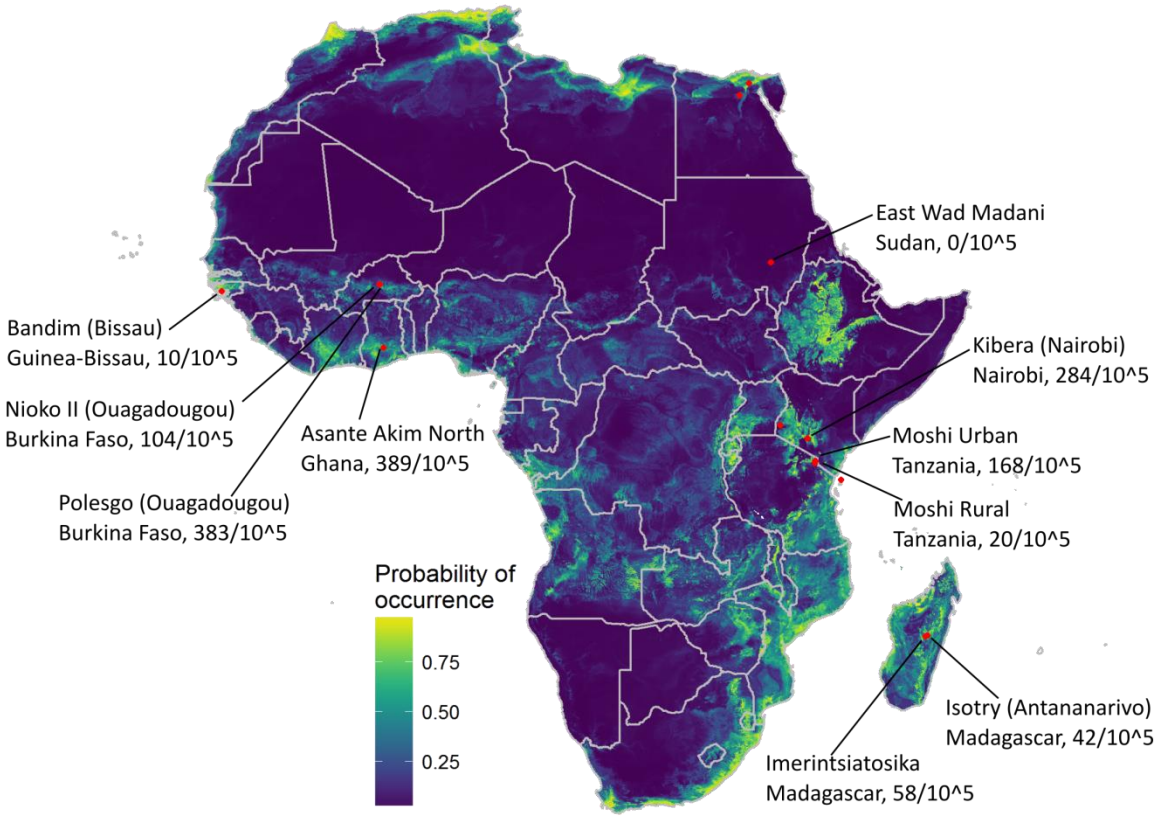
Predicted probability of typhoid occurrence



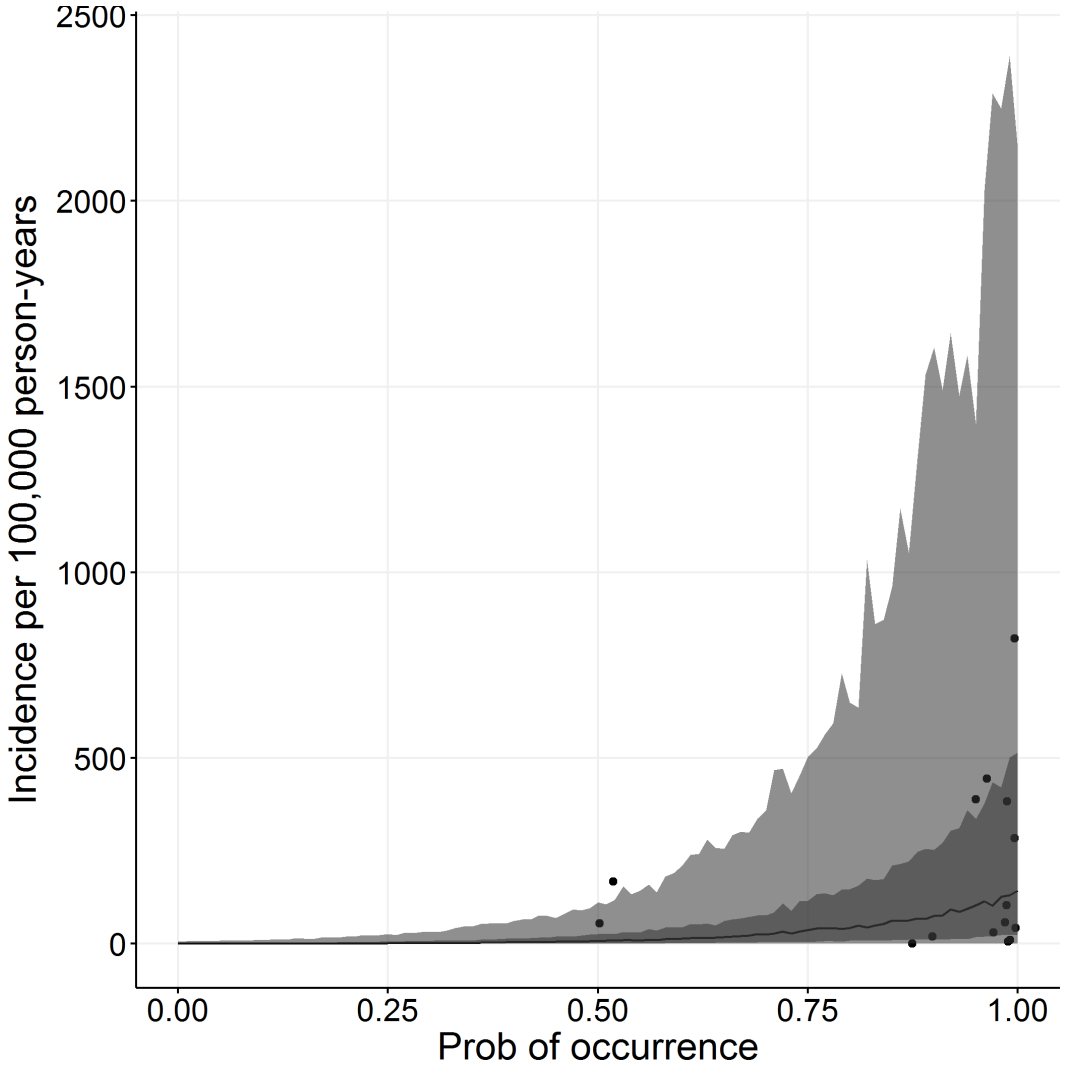
The prediction model evaluation via 10-fold cross validation



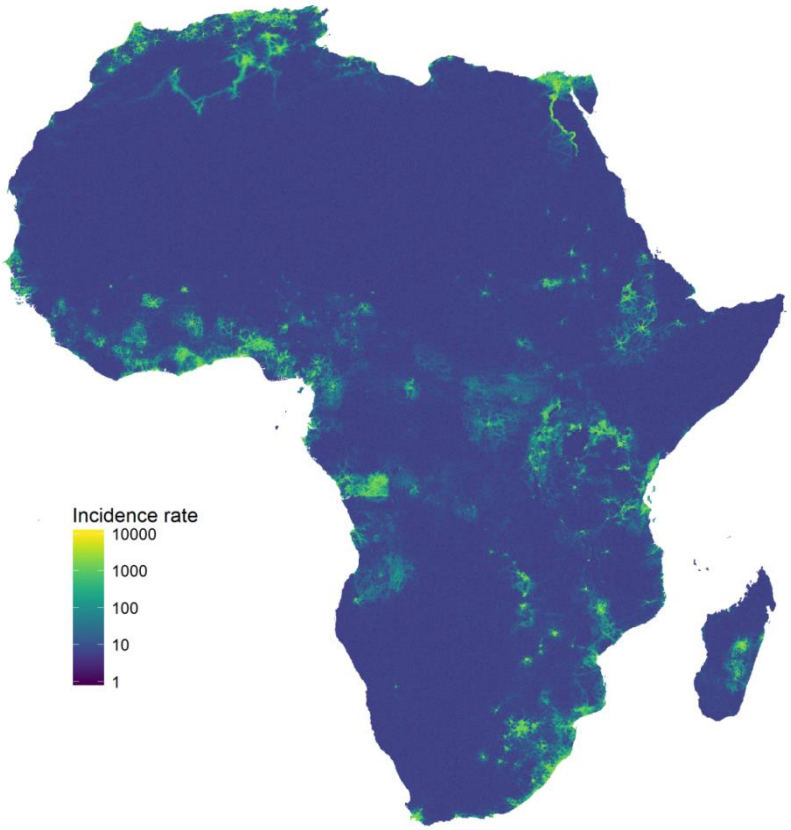
Predicted probability of typhoid occurrence overlaid with surveillance sites



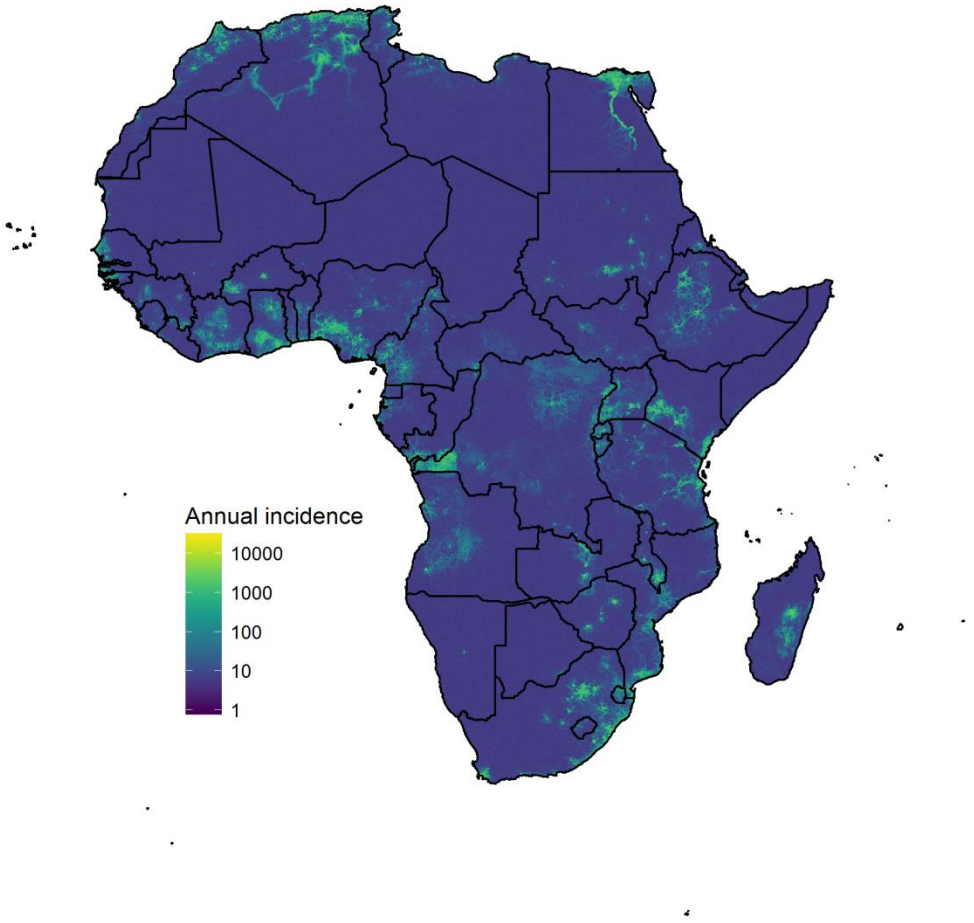
Incidence rate vs. probability of occurrence



Typhoid incidence rate in Africa (5 x 5 km)

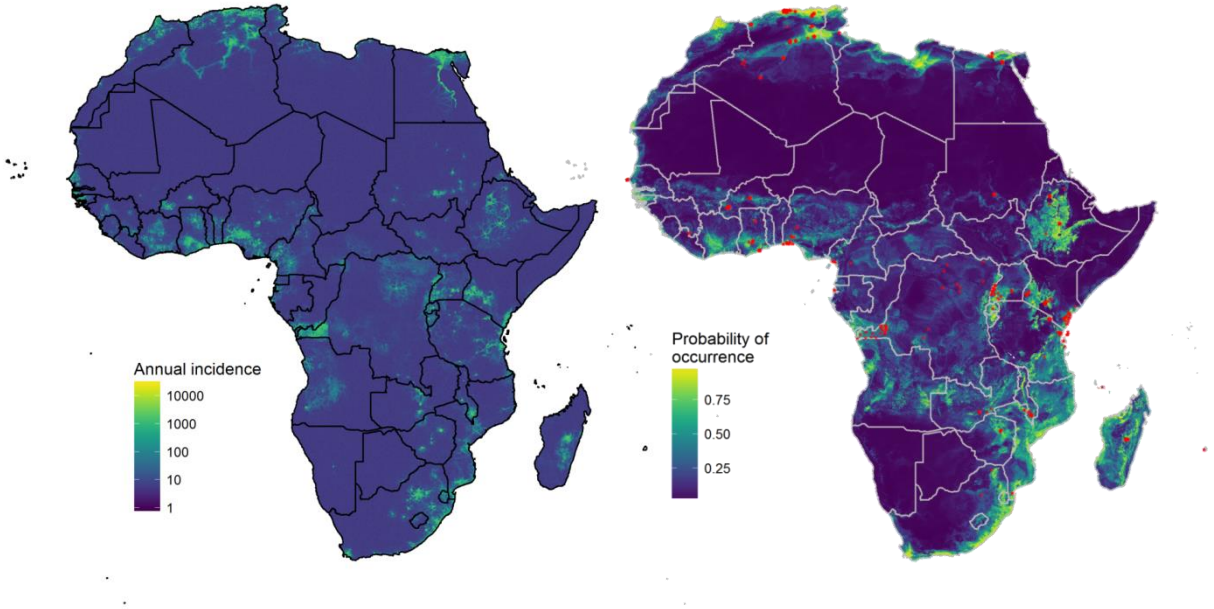


Annual incidence of typhoid in Africa (5 x 5 km)



Conclusion

- High-resolution (5 x 5 km) maps on the probability of occurrence and incidence rate of typhoid fever
- There appears to be a significant spatial heterogeneity in burden of typhoid fever
- More relevant covariates (e.g., access to clean water) synthesized and tested for the model



Acknowledgement

- IVI Epi Unit members: Florian Marks, Justin Im, Trevor Toy, Prerana Parajulee (IVI)
- David Pigott, Simon Hay (IHME, Univ. of Washington)
- Andy Tatem (Univ. of Southampton)

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Supplementary slides

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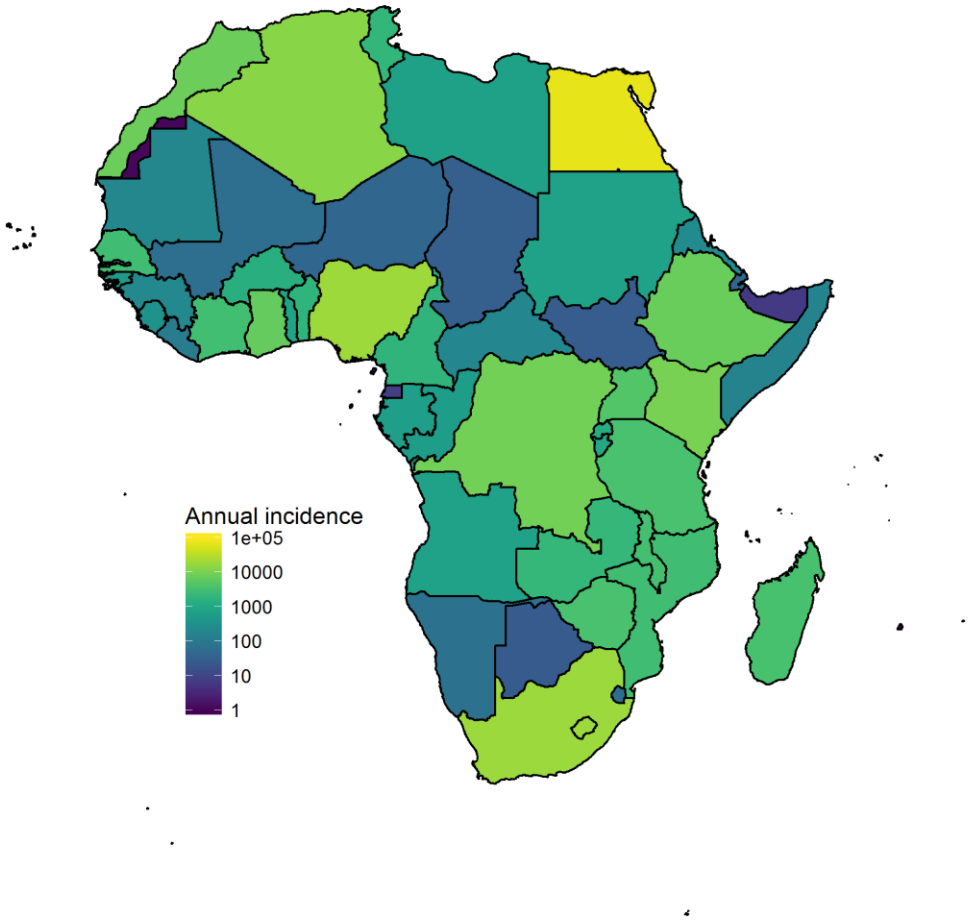
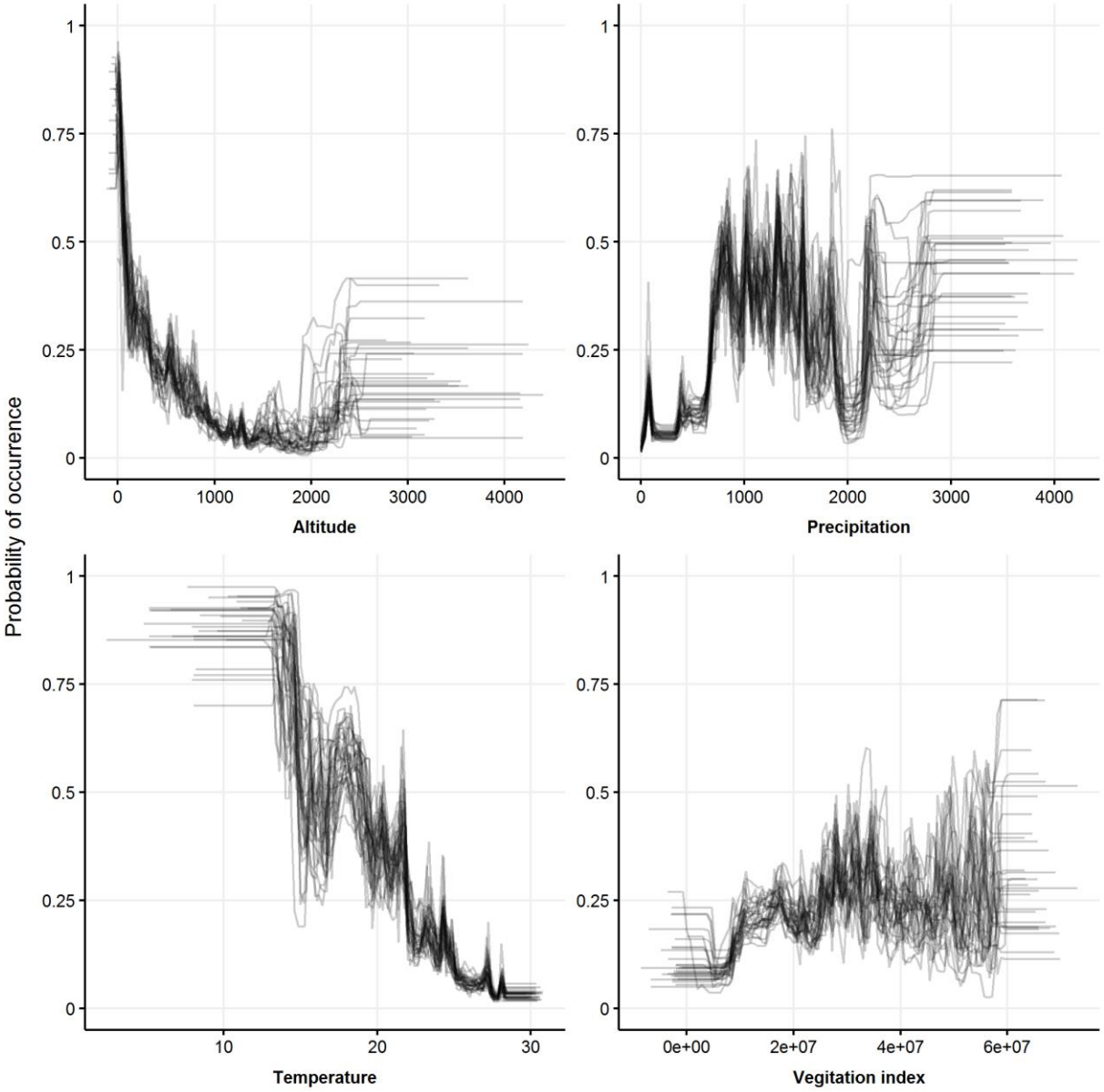
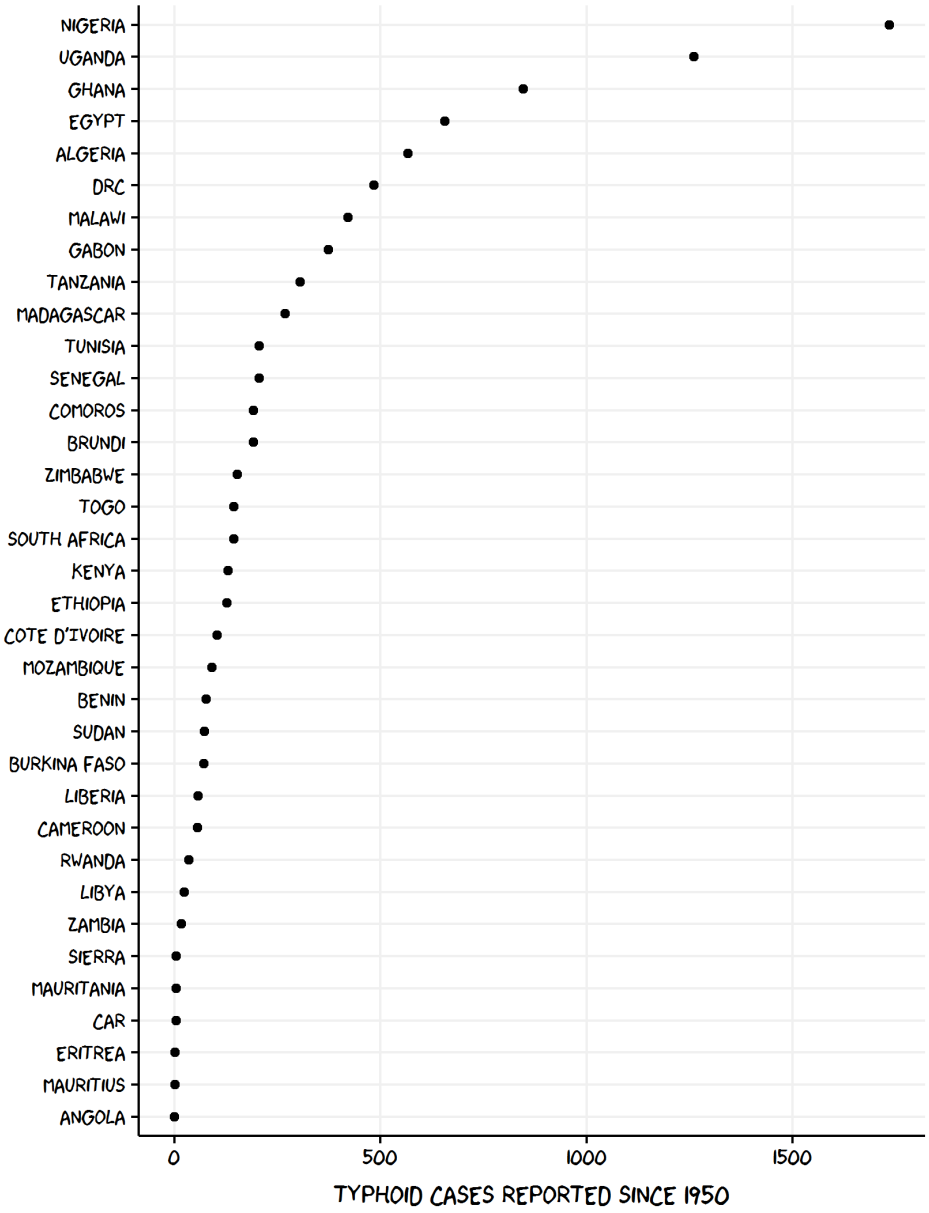
Annual incidence of typhoid in Africa by country



Partial dependency plots



Number of typhoid cases since 1950



Future work – Explanatory covariates

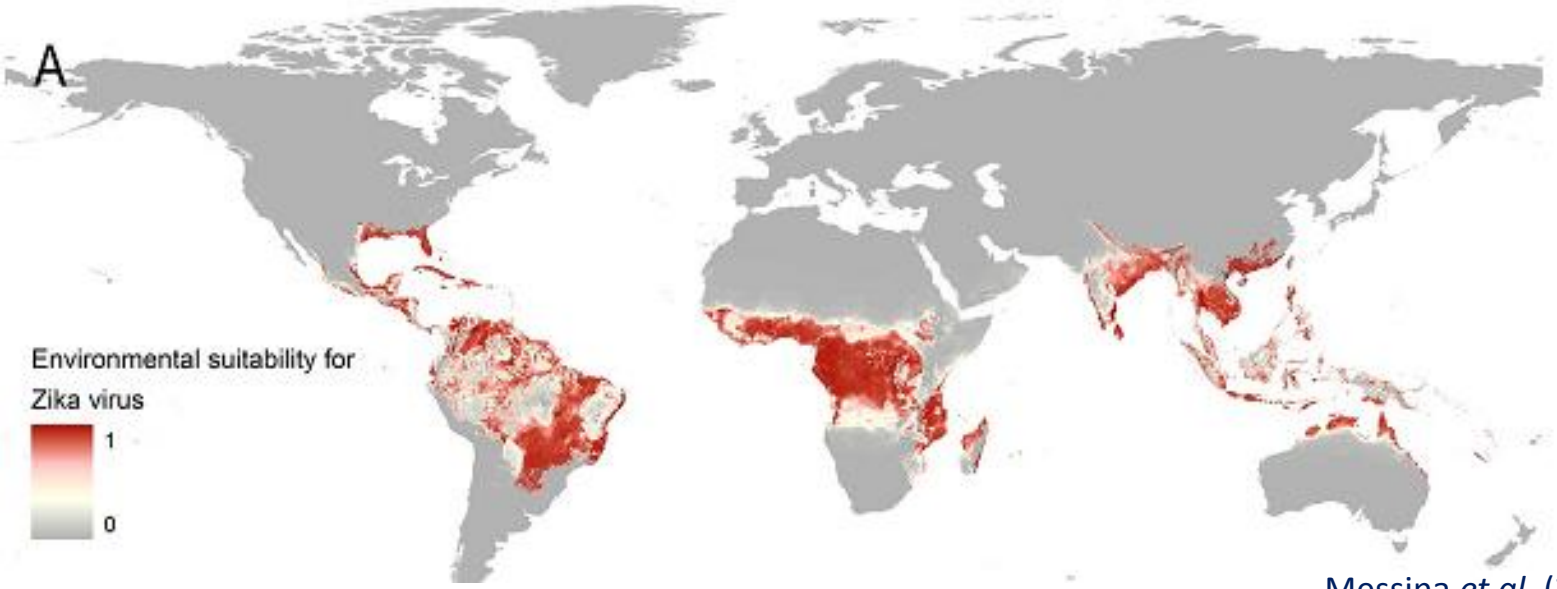
Percent Urban, Temperature, Vegetation, Population density, Rainfall, vapour pressure, agricultural land (percentage of), forested land, Increasing age, Age 12 years or younger

Variables that can be mapped across Africa – data available

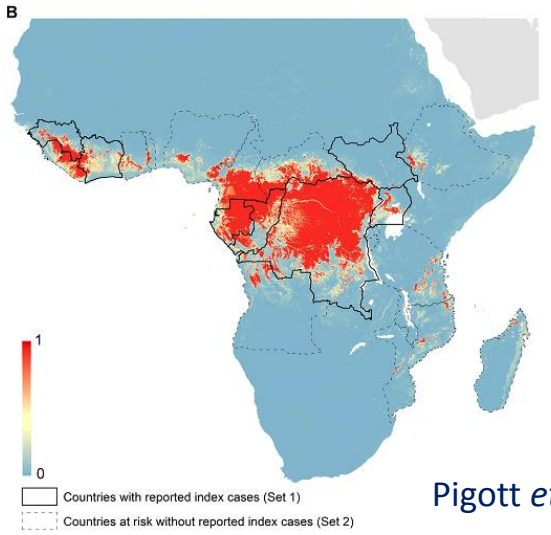
Total literacy rate, Housing density, Percent slum, House with open sewers, No water supply from municipal network, No toilet in the household, low income, owning mobile phone, Community latrine, Refrigerator in the home

Variables that can be mapped across Africa- data to be retrieved

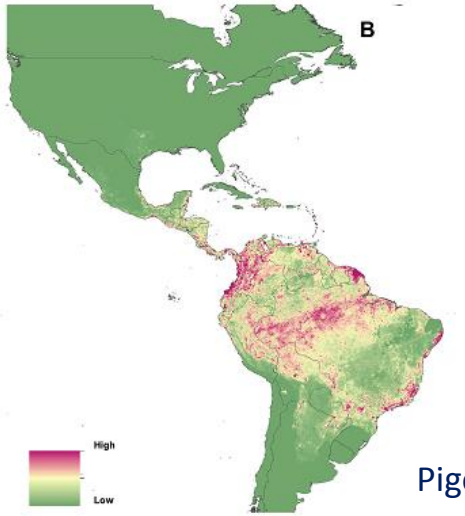
Many others: ZIKV, EBVD, Leishmaniases , …



Messina *et al*. (2016)

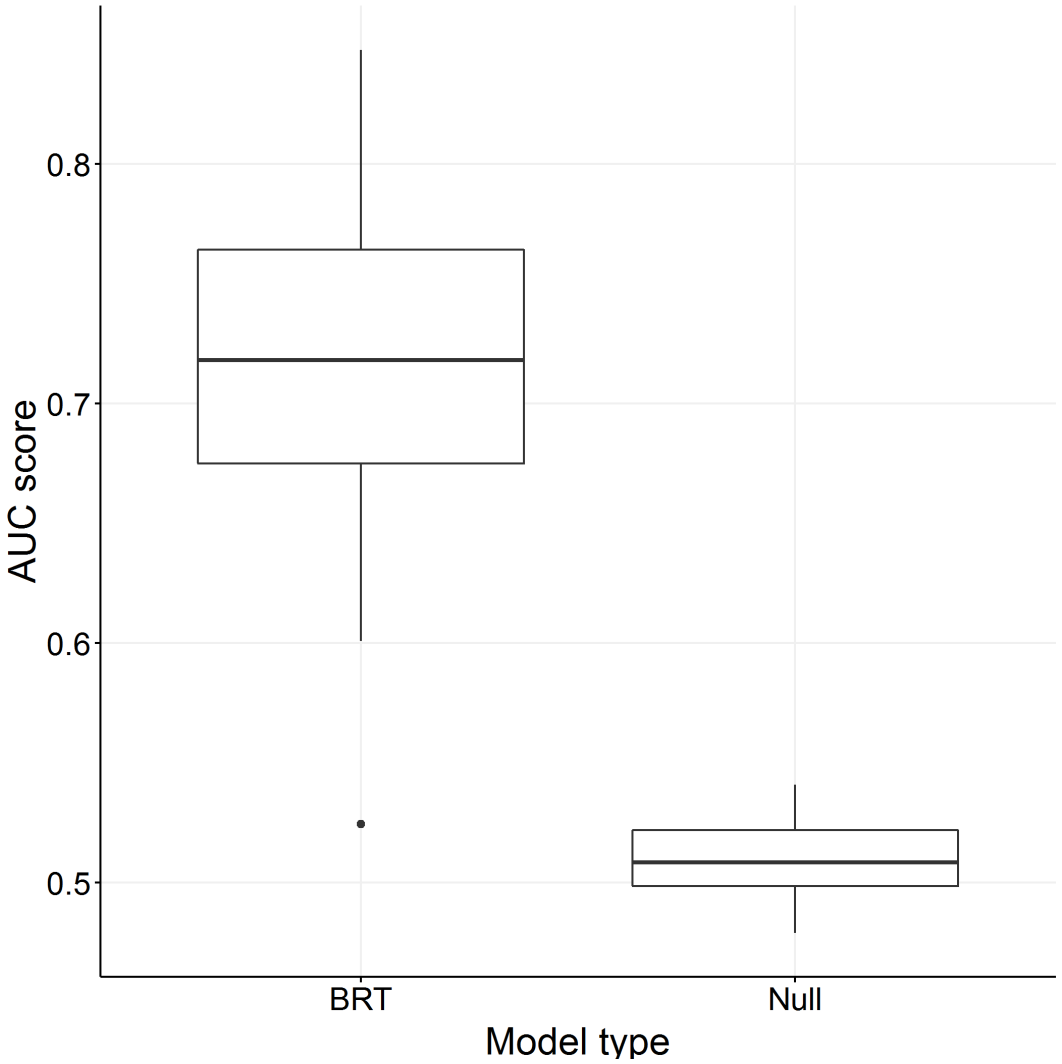


Pigott *et al*. (2016)

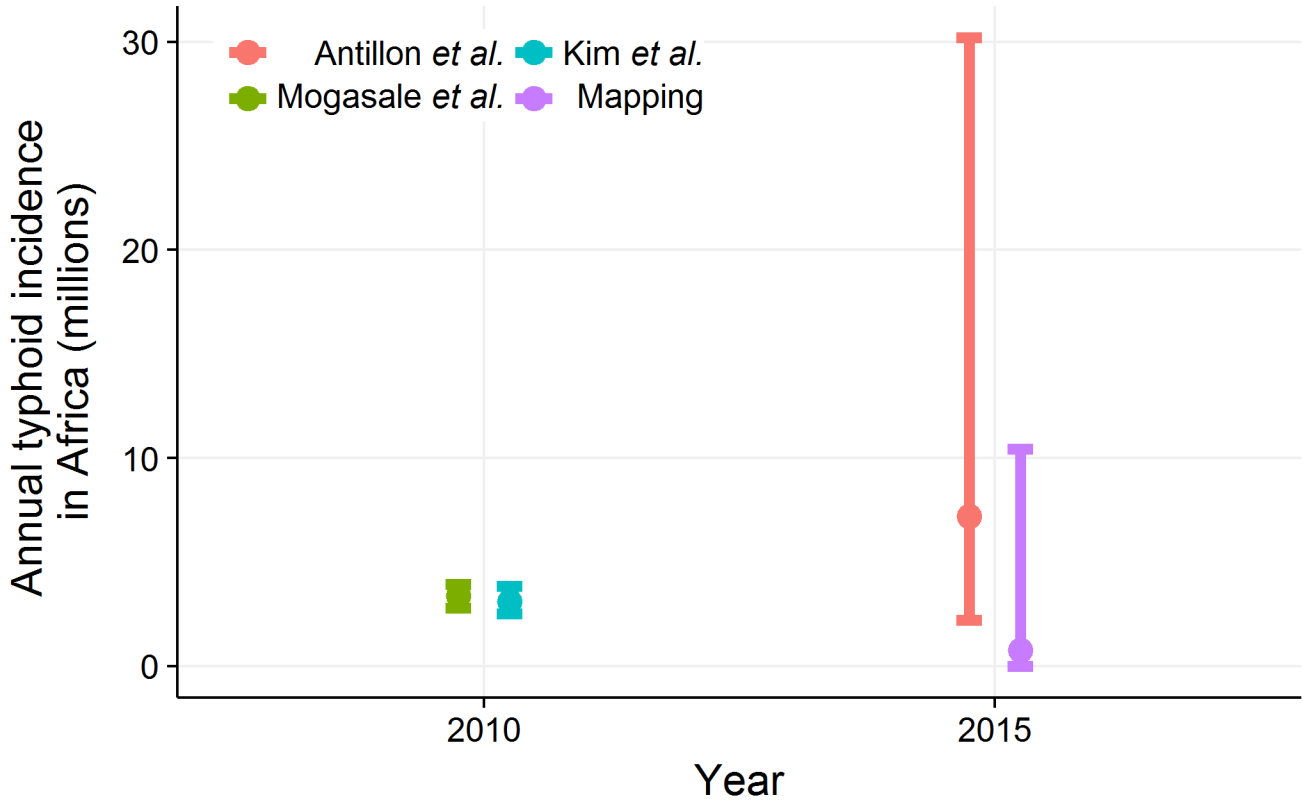


Pigott *et al*. (2014)

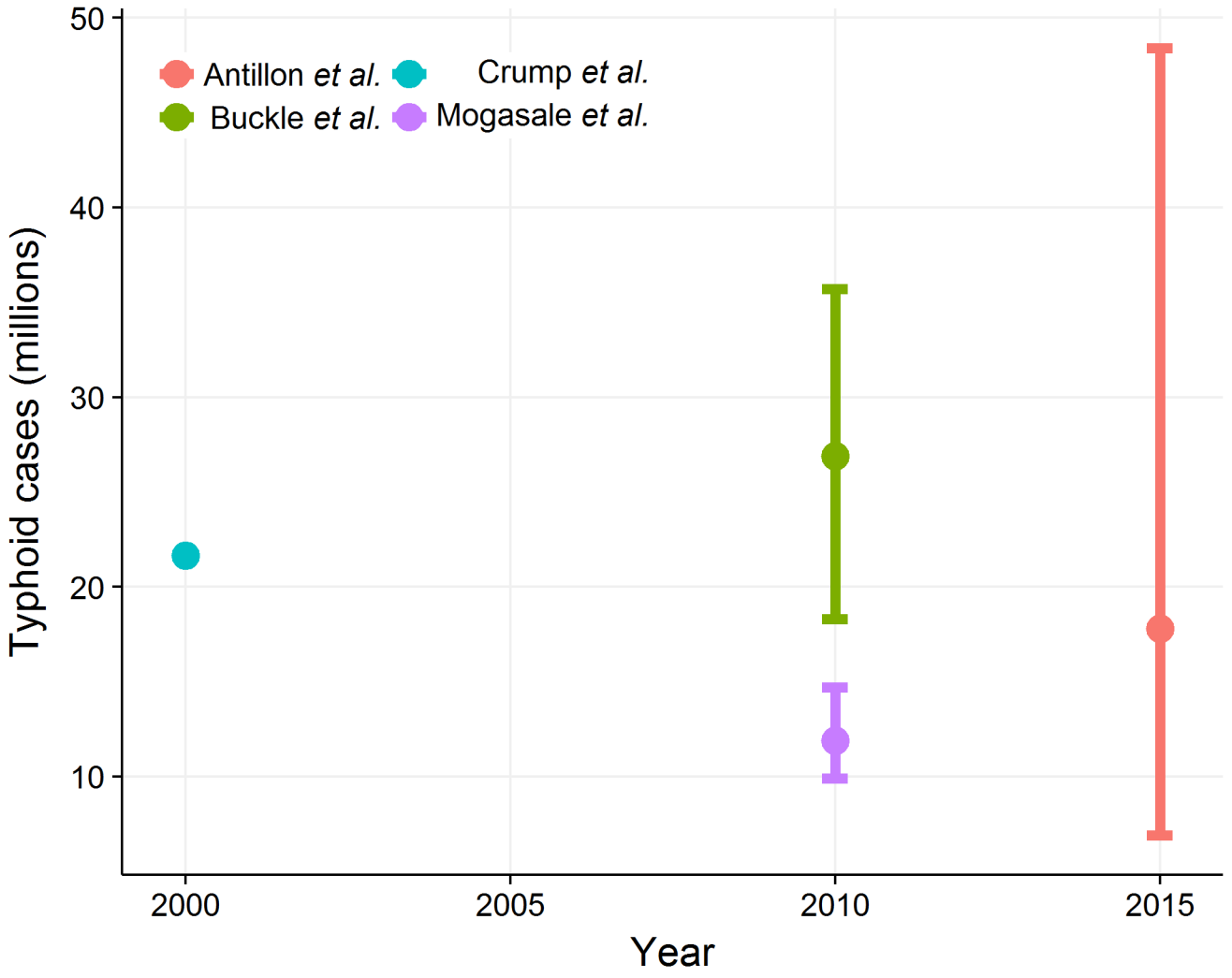
BRT model validation



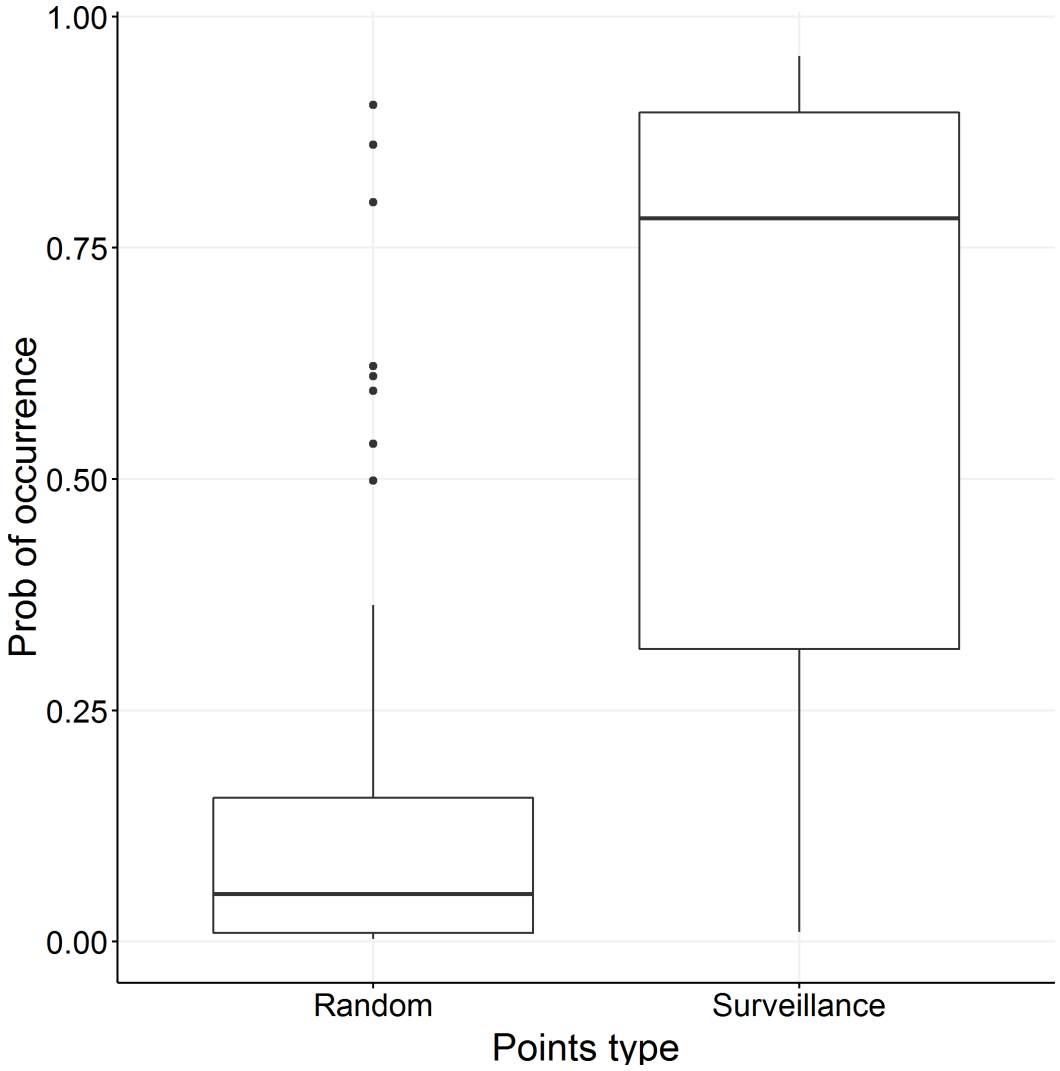
Comparison with the previous estimates



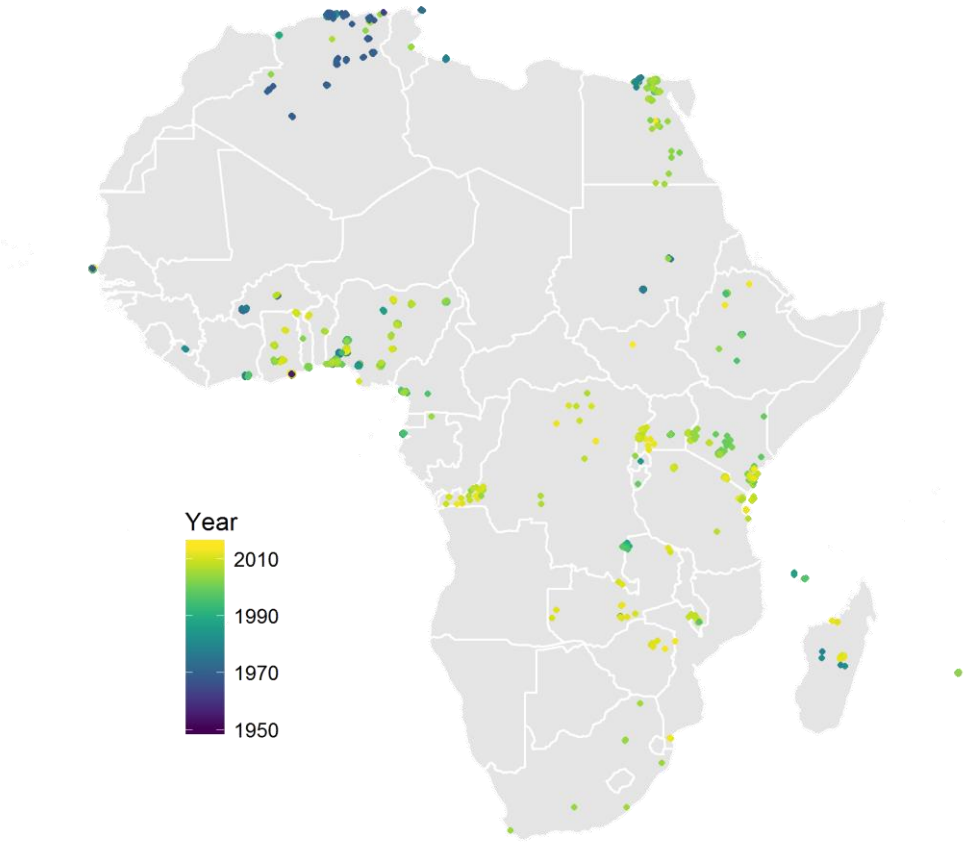
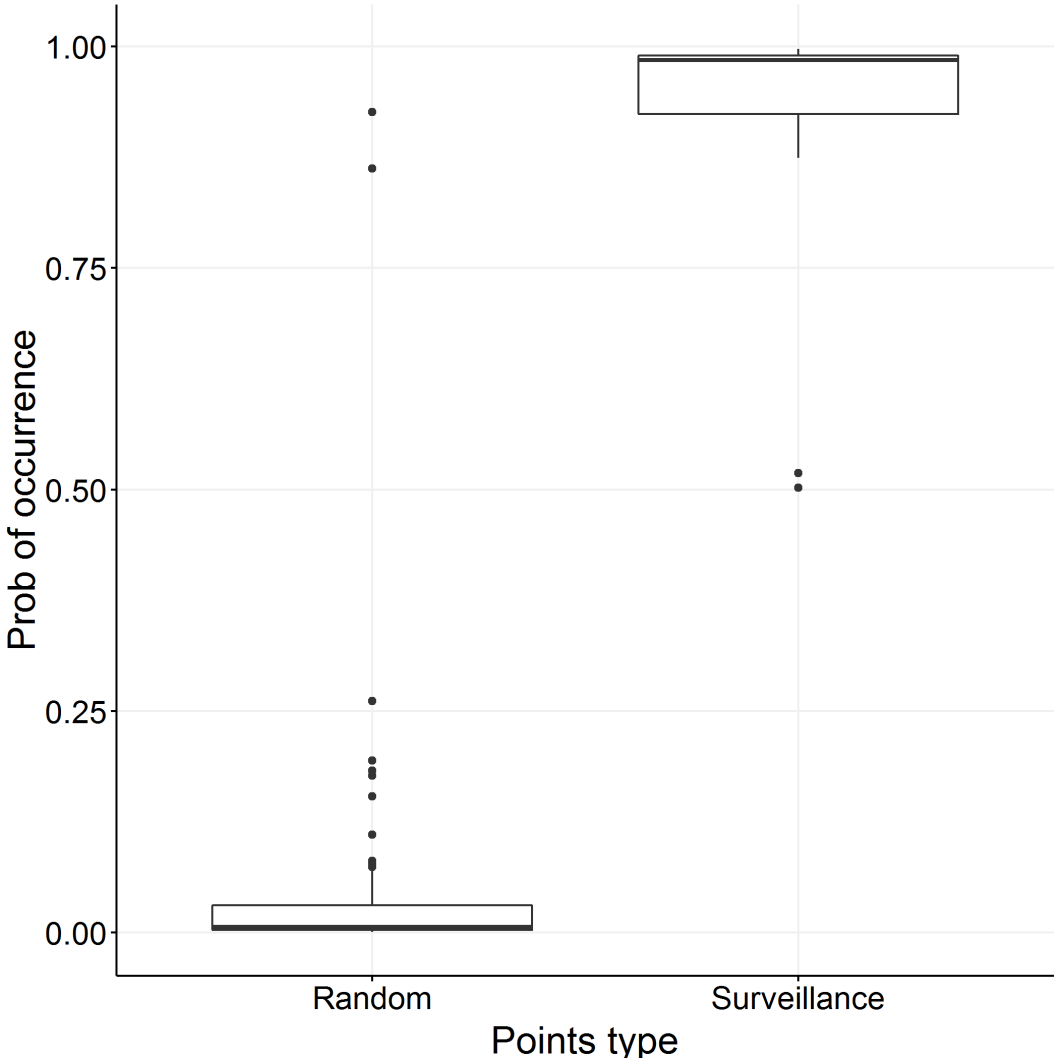
Estimates of typhoid burden already exist



Predicted probability of typhoid occurrence



Typhoid occurrences including clinically suspected (n=1523)



Surveillance sites are high-risk areas?