Predictive tools and modelling for mitigating arboviral threats

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LONDON SCHOOL of HYGIENE &TROPICAL MEDICINE

Overview

1. Understand
2. Estimate
3. Predict
4. Forecast

What developments enabled these and what would the next breakthrough look like?

What is a model and who are modellers?

Model 1

Model 2

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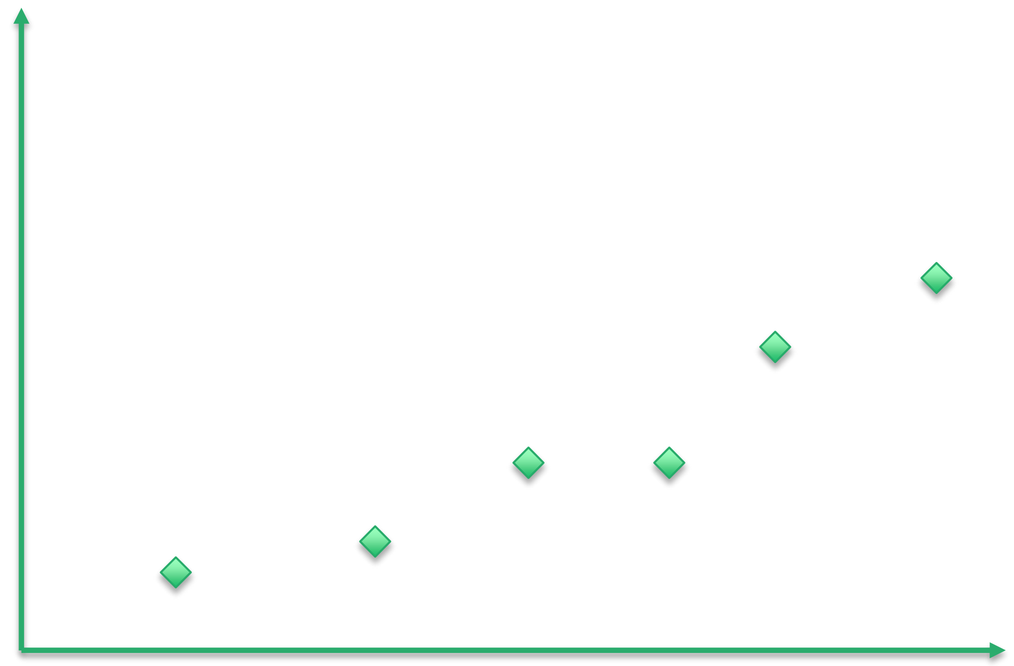

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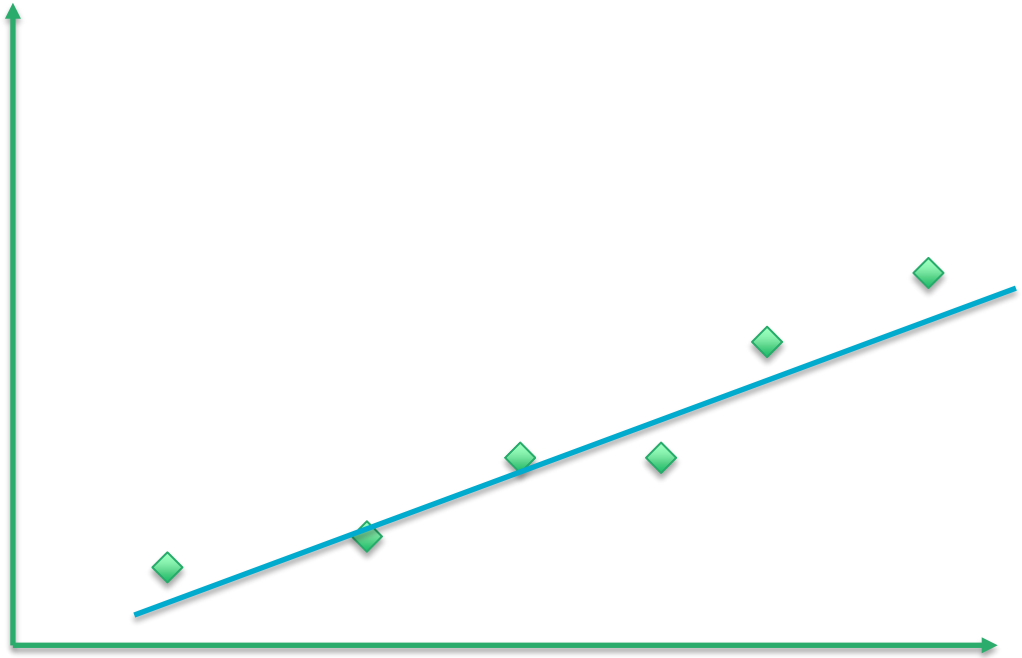

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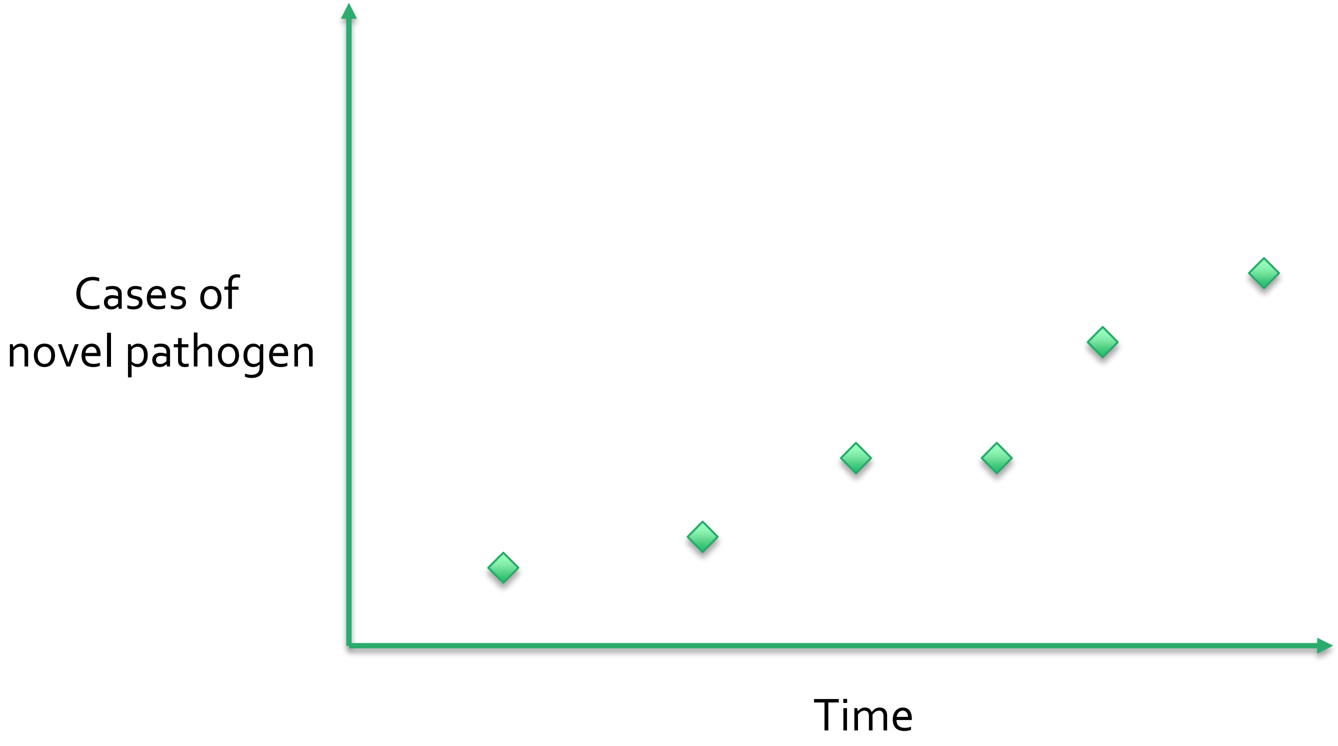

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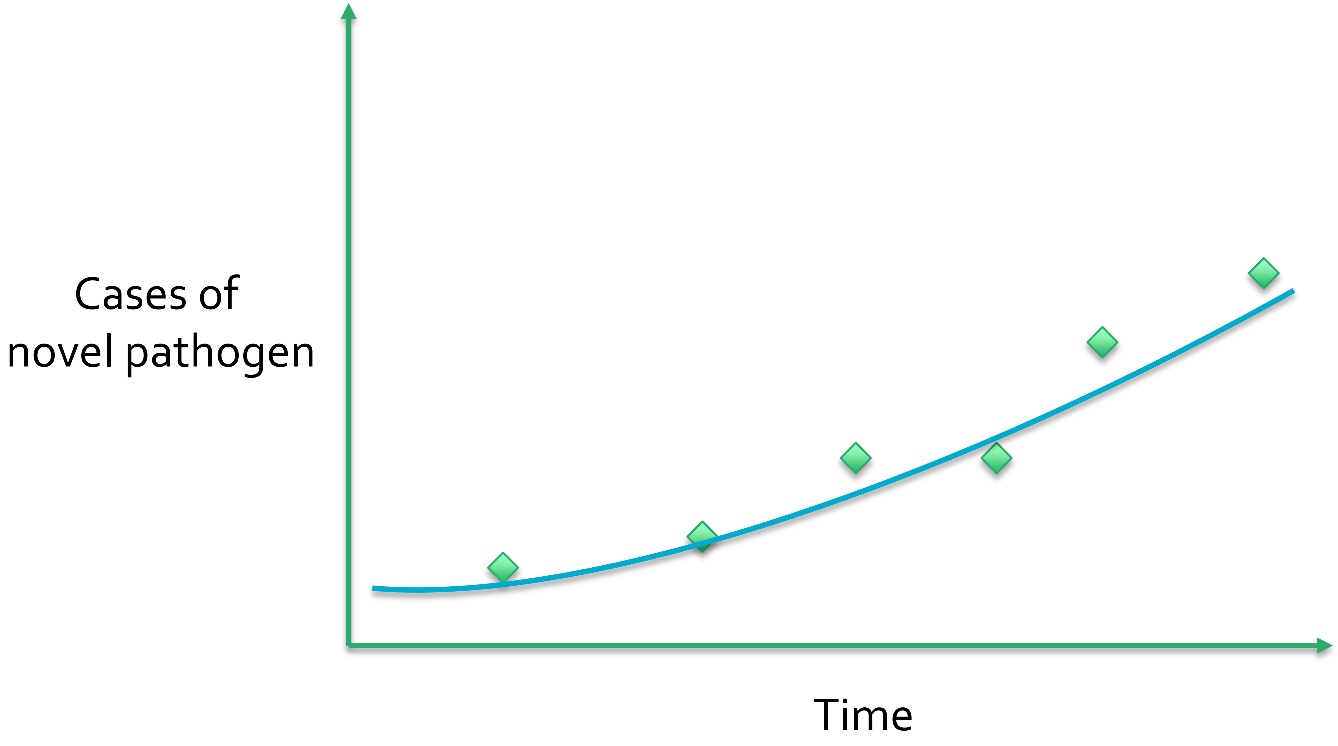

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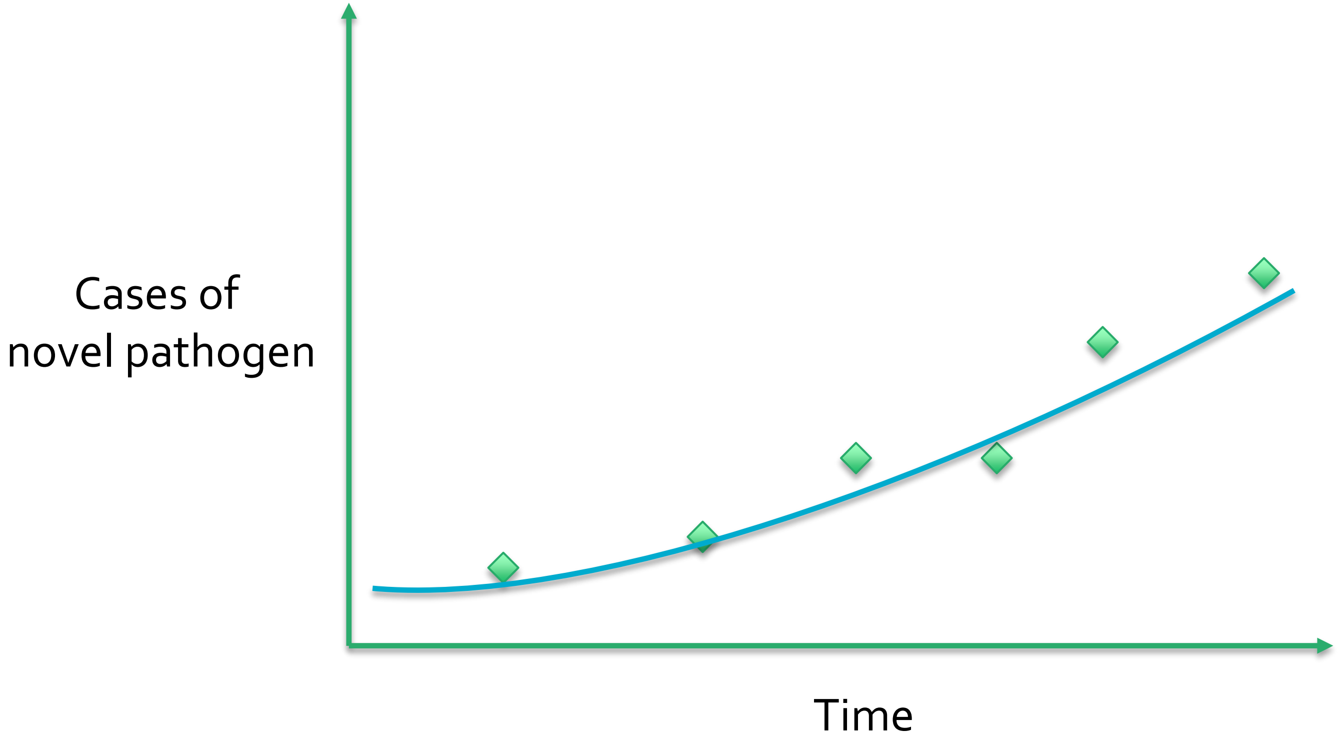


We all use "models"

Modelling is just a way of expressing those assumption and ideas in a mathematical form

Challenges of summarising a broad field

Mechanistic models

Review

Mathematical models for dengue fever epidemiology: A 10-year systematic review

Maíra Aguiar [a,b,c,*], Vizda Anam [a], Konstantin B. Blyuss [f], Carlo Delfin S. Estadilla [a], Bruno V. Guerrero [a], Damián Knopoff [a,e], Bob W. Kooi [d], Akhil Kumar Srivastav [a], Vanessa Steindorf [a], Nico Stollenwerk [a,b]

Aguiar et al. Phy. of Life Rev 2022

https://doi.org/10.1016/j.plrev.2022.02.001

Forecasting models

RESEARCH ARTICLE

A systematic review of dengue outbreak prediction models: Current scenario and future directions

Xing Yu Leung[1], Rakibul M. Islam[1], Mohammadmehdi Adhami[1], Dragan Ilic[1], Lara McDonald[1], Shanika Palawaththa[1], Basia Diug[1], Saif U. Munshi[2], Md Nazmul Karim[1*]

Leung et al. PLoS NTDs 2023

https://doi.org/10.1371/journal.pntd.0010631

Risk mapping models

A systematic review of the data, methods and environmental covariates used to map *Aedes*-borne arbovirus transmission risk

Ah-Young Lim[1,2*], Yalda Jafari[3,4], Jamie M. Caldwell[5], Hannah E. Clapham[6], Katy A. M. Gaythorpe[7], Laith Hussain-Alkhateeb[8,9], Michael A. Johansson[10], Moritz U. G. Kraemer[11], Richard J. Maude[3,4], Clare P. McCormack[7], Jane P. Messina[12,13], Erin A. Mordecai[14], Ingrid B. Rabe[15], Robert C. Reiner Jr[16,17], Sadie J. Ryan[18], Henrik Salje[19], Jan C. Semenza[20], Diana P. Rojas[15] and Oliver J. Brady[1,2]

Lim et al. BMC Infect. Dis.2023

https://doi.org/10.1186/s12879-023-08717-8

Models for improving understanding

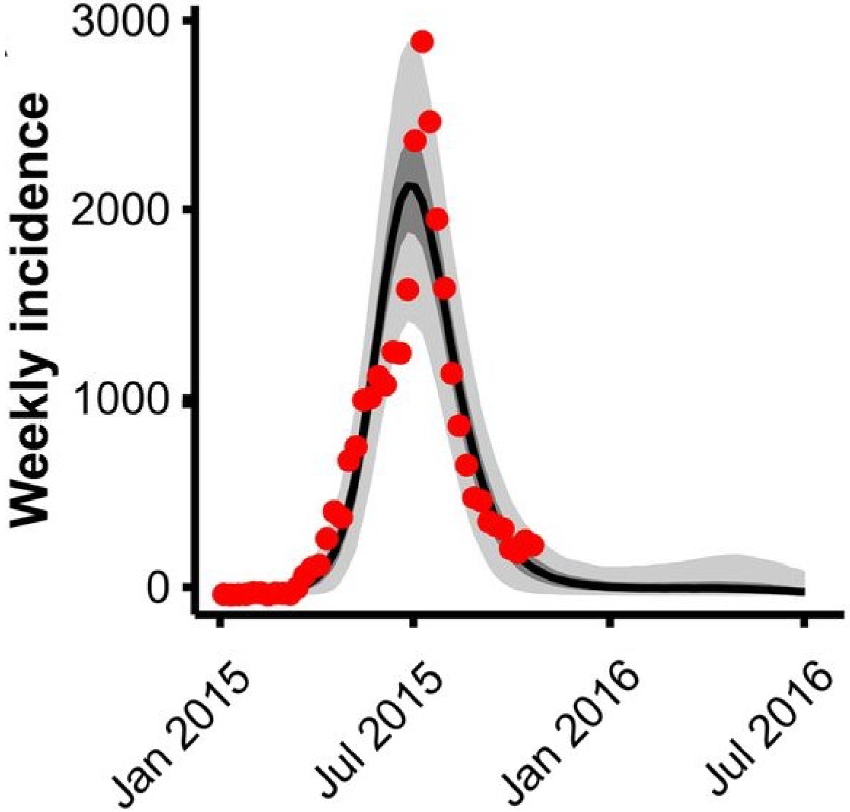
Using model to test hypotheses about:

- Immunity
- Climate
- Environment
- Origins of epidemics
- …

Usually using observational data

Models for improving understanding

Why did the Zika epidemic decline in Salvador, Brazil?



Netto et al. 2017 *mBio* https://doi.org/10.1128/mbio.01390-17

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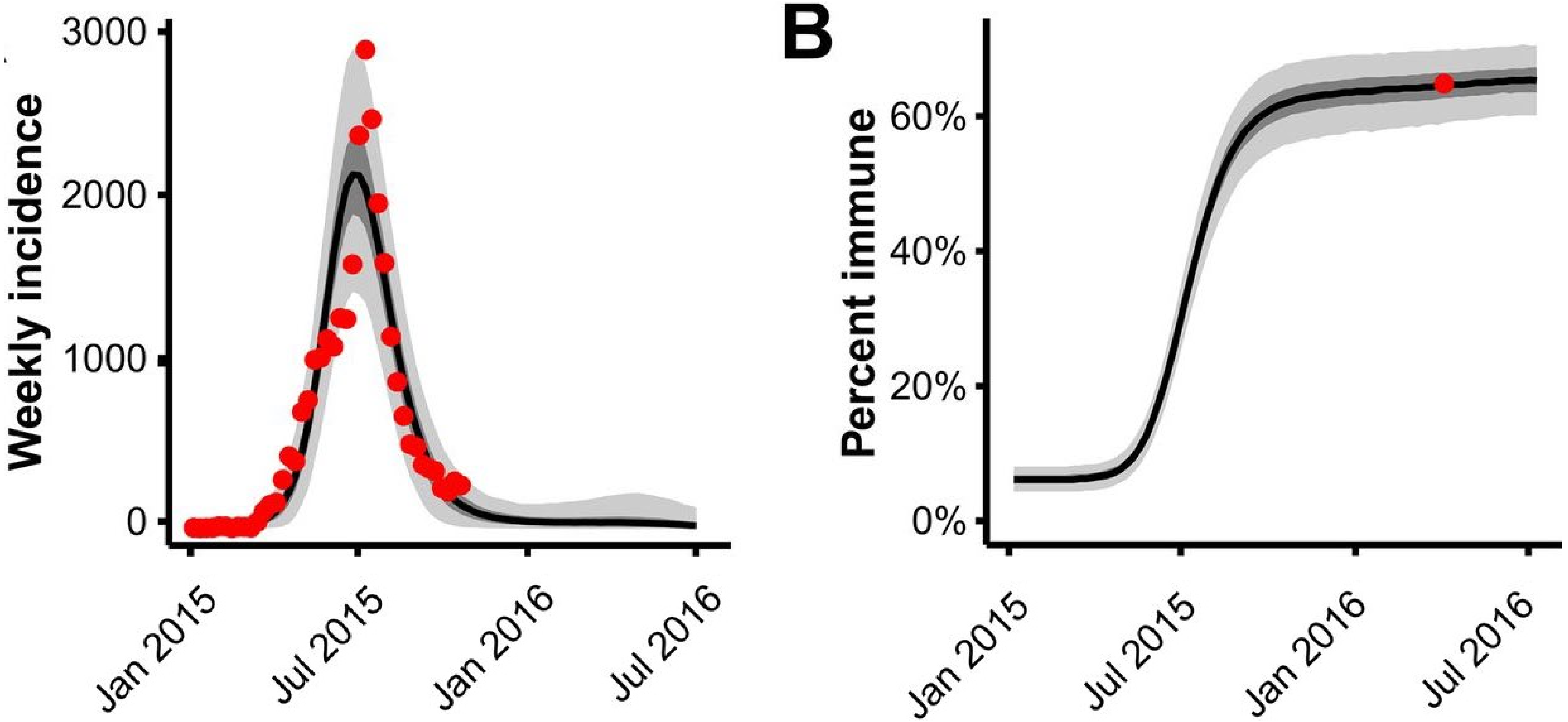

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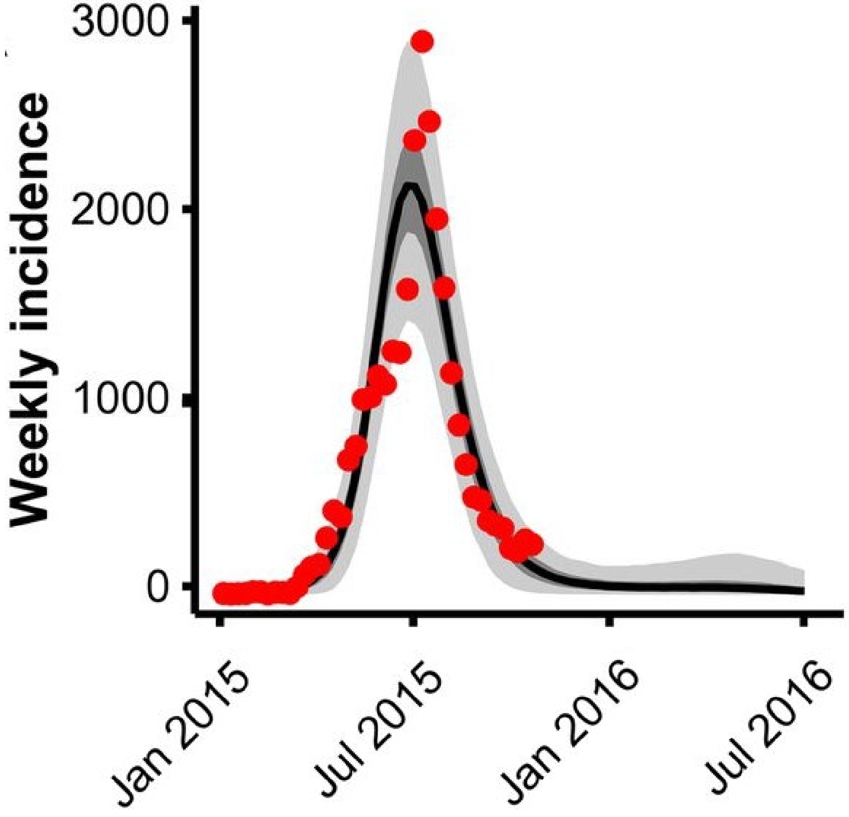

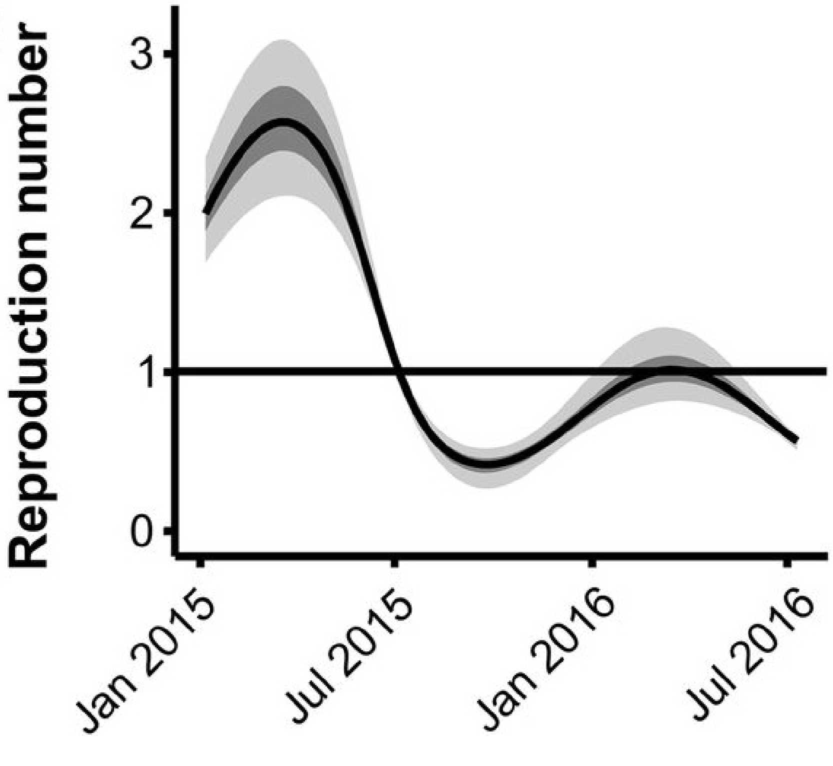

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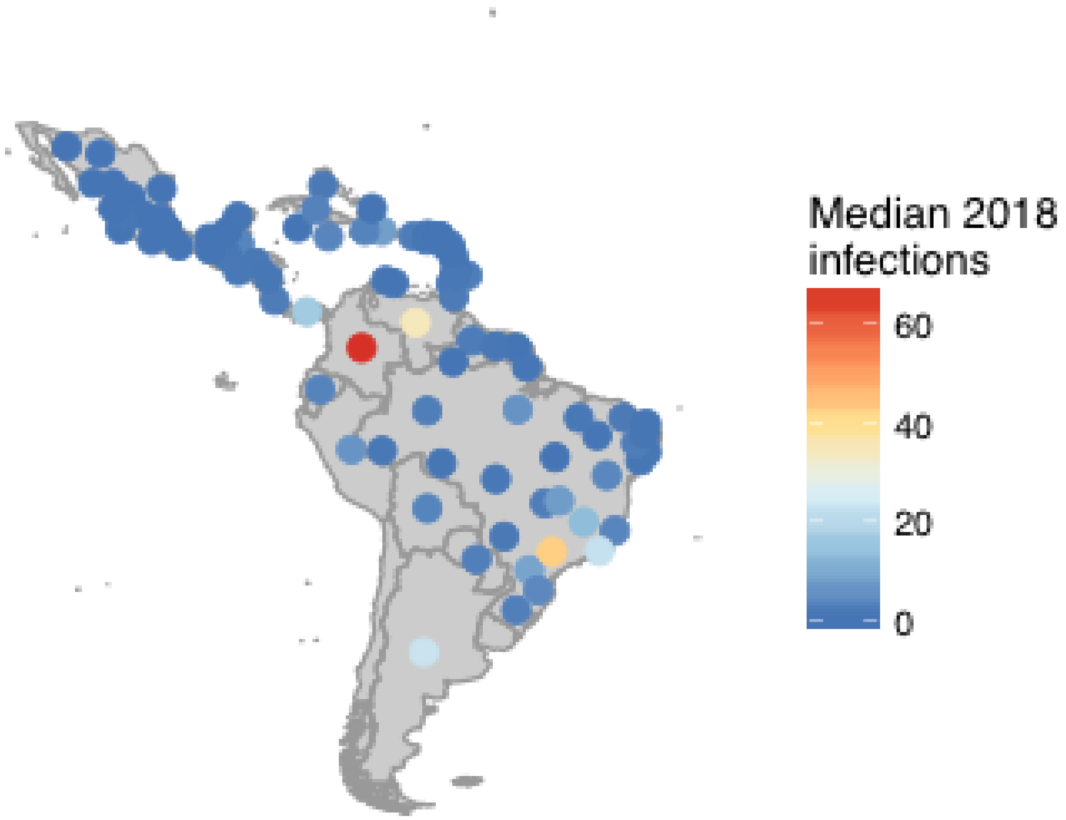
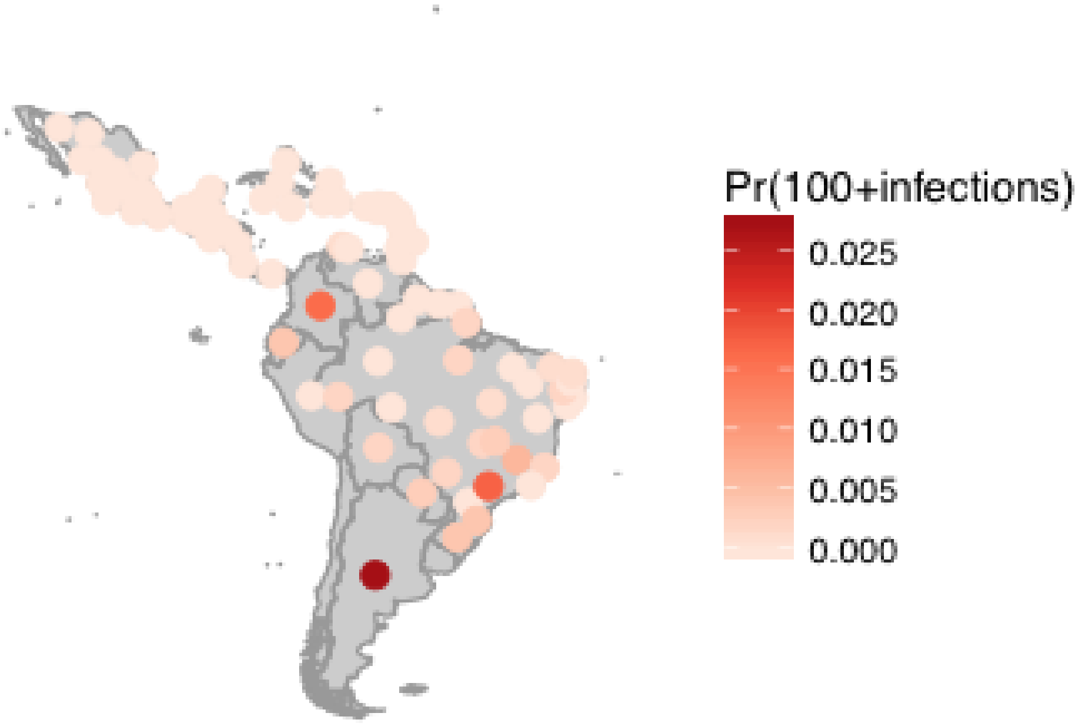
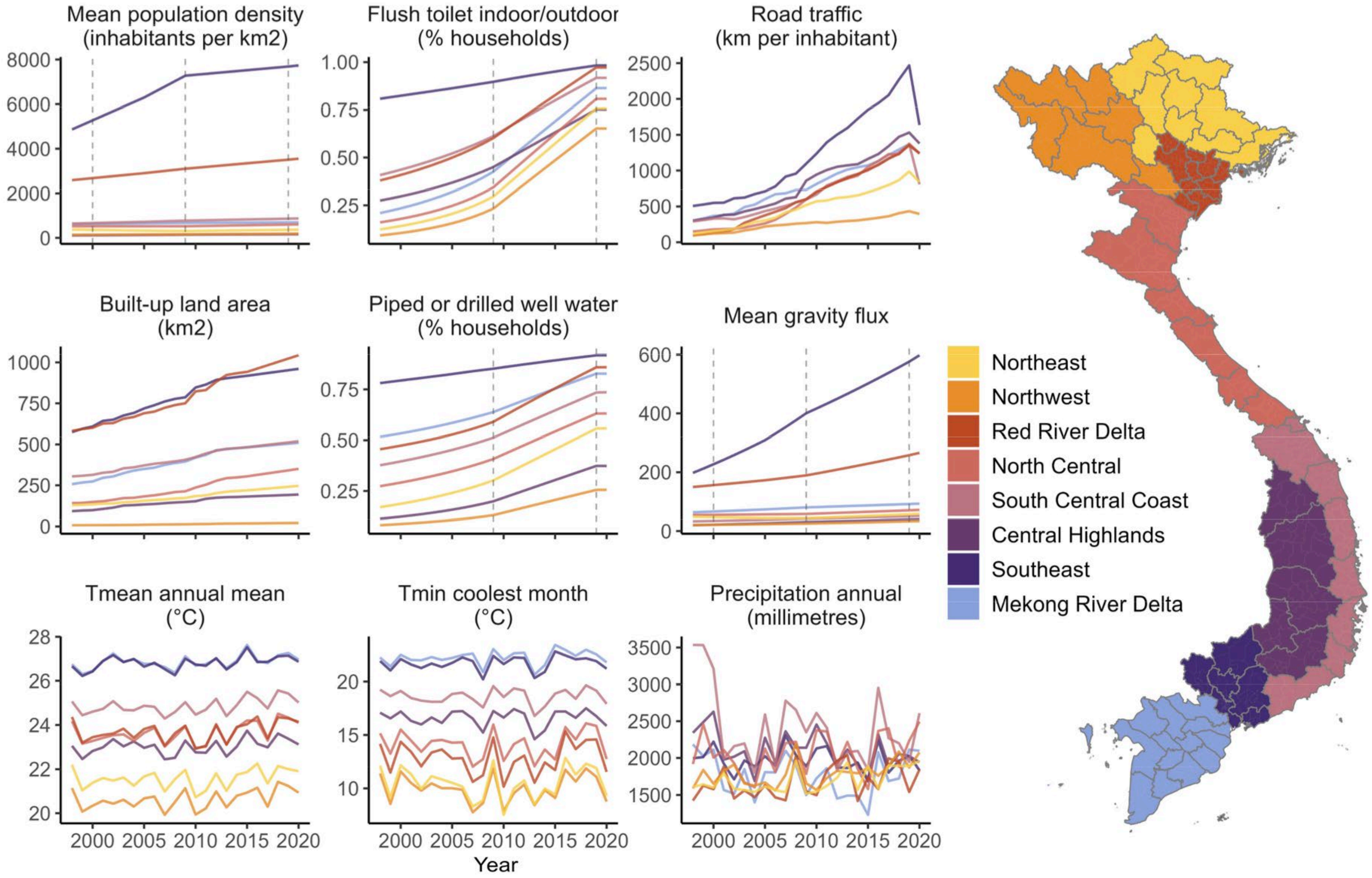




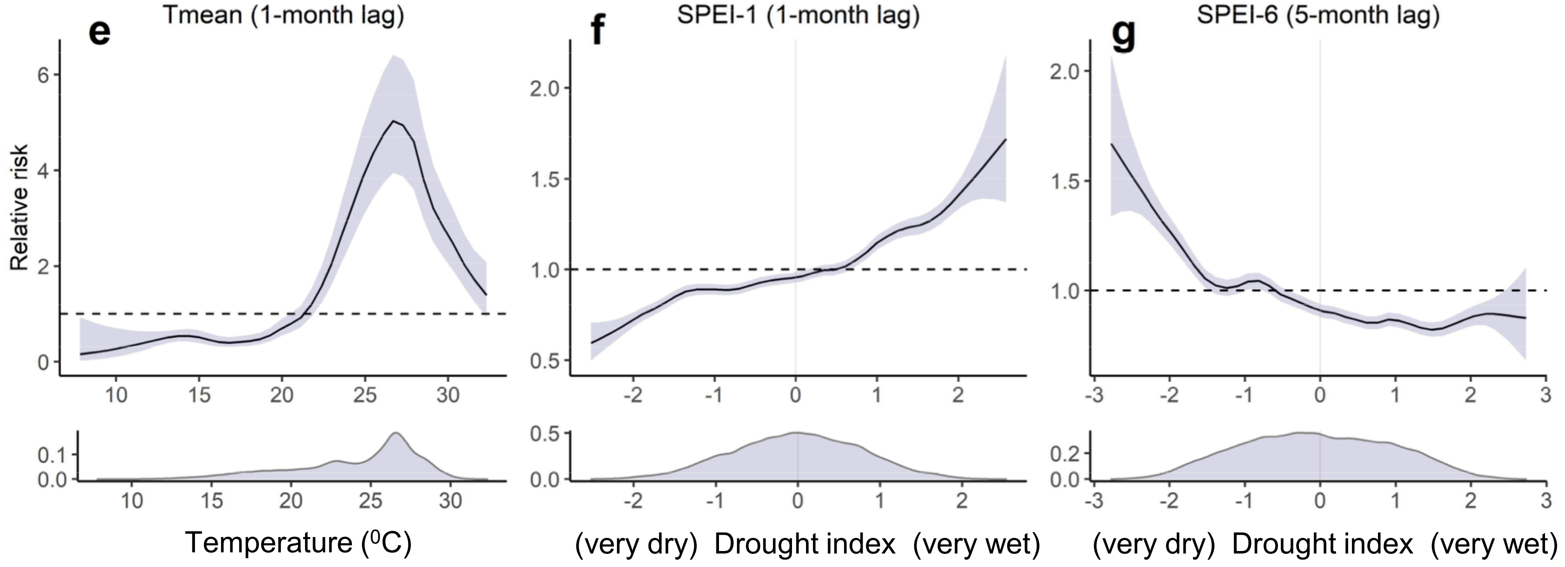
O'Reilly et al. 2018 *BMC Med* https://doi.org/10.1186/s12916-018-1158-8

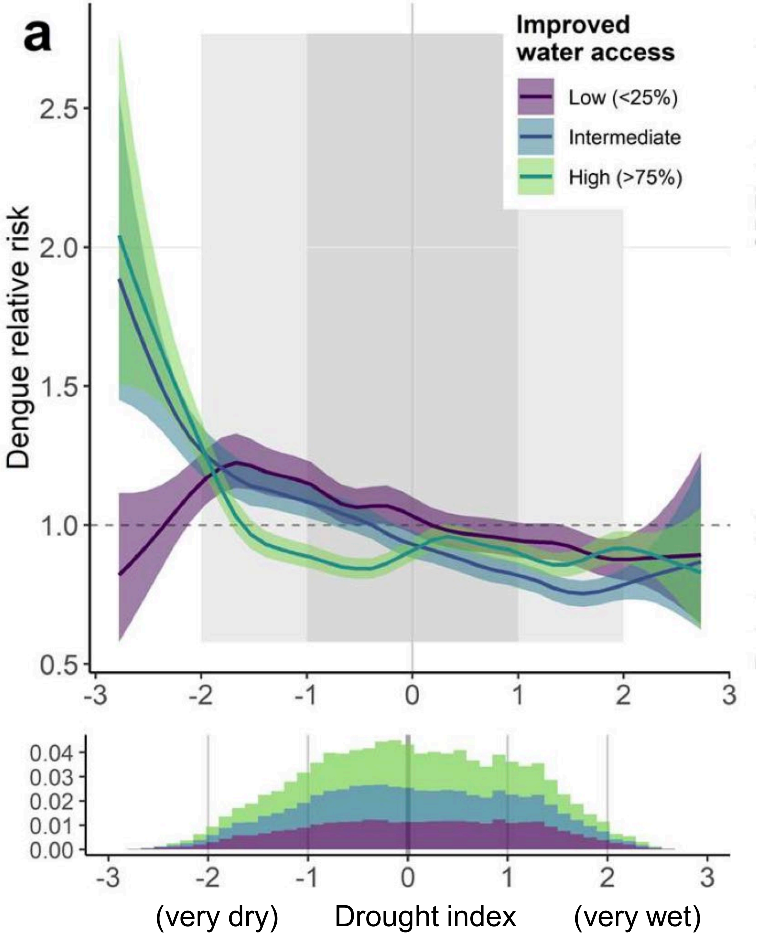
Models for improving understanding



Gibb et al. 2023 *Nat. Comms. In press*

Models for improving understanding





Gibb et al. 2023 *Nat. Comms. In press*

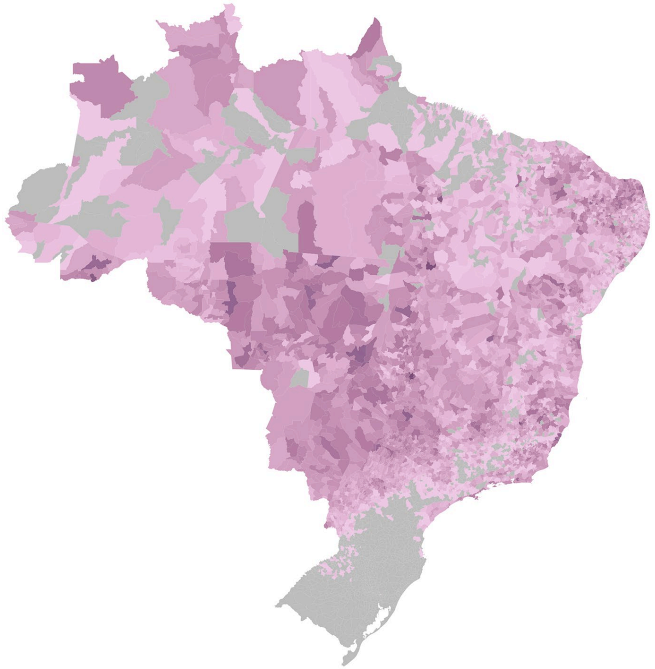
Models for improving understanding

Enabling factors:

– Higher spatial and temporal resolution data
  - Of cases
  - Of explanatory variables (infrastructure, human movement)

Future developments:

– Integration of causal inference methods into modelling
  - DAGs



Models for estimation

Can improve experimental estimates of epidemiological parameters or estimate relevant new parameters:

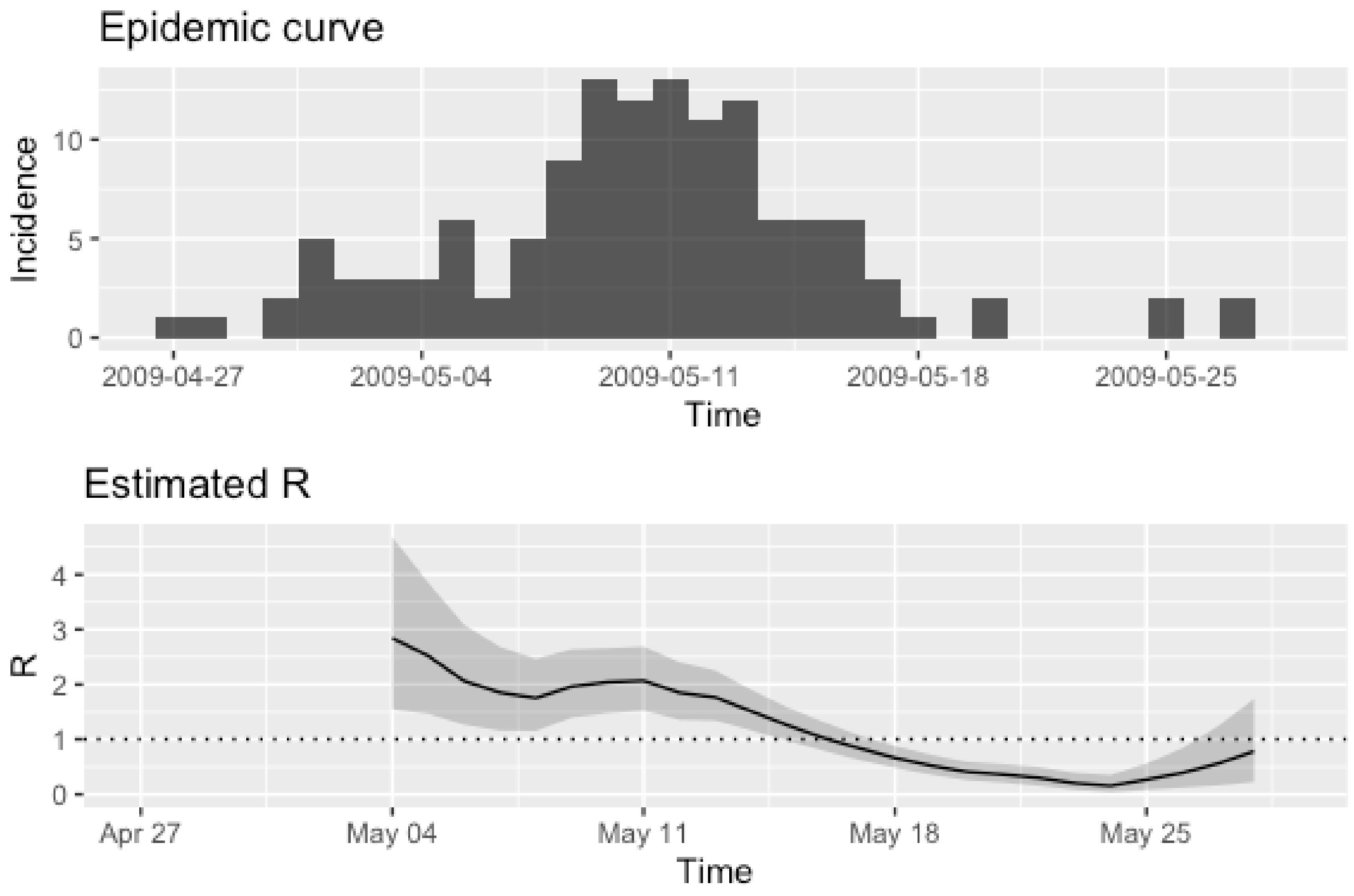
- Reproduction number
- Burden
- Effectiveness

Models fill the gap where experimental measurement is impractical or impossible

Models for estimation -Rt

Effective reproduction number (R_t)

- Number of new infections generated by the average infected individual
- Critical for outbreak management
- Difficult to directly measure
- Can be inferred from case data using models



Cori et al. EpiEstim vignette https://cran.r-project.org/web/packages/EpiEstim/vignettes/demo.html

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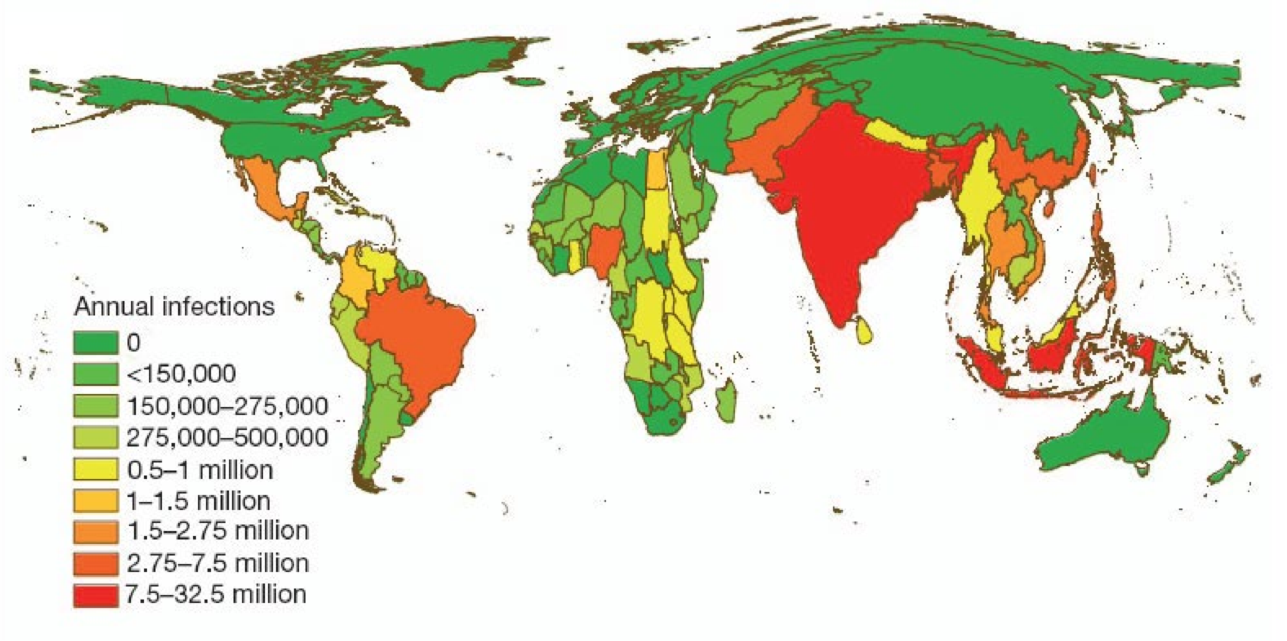
InfoDengue https://info.dengue.mat.br

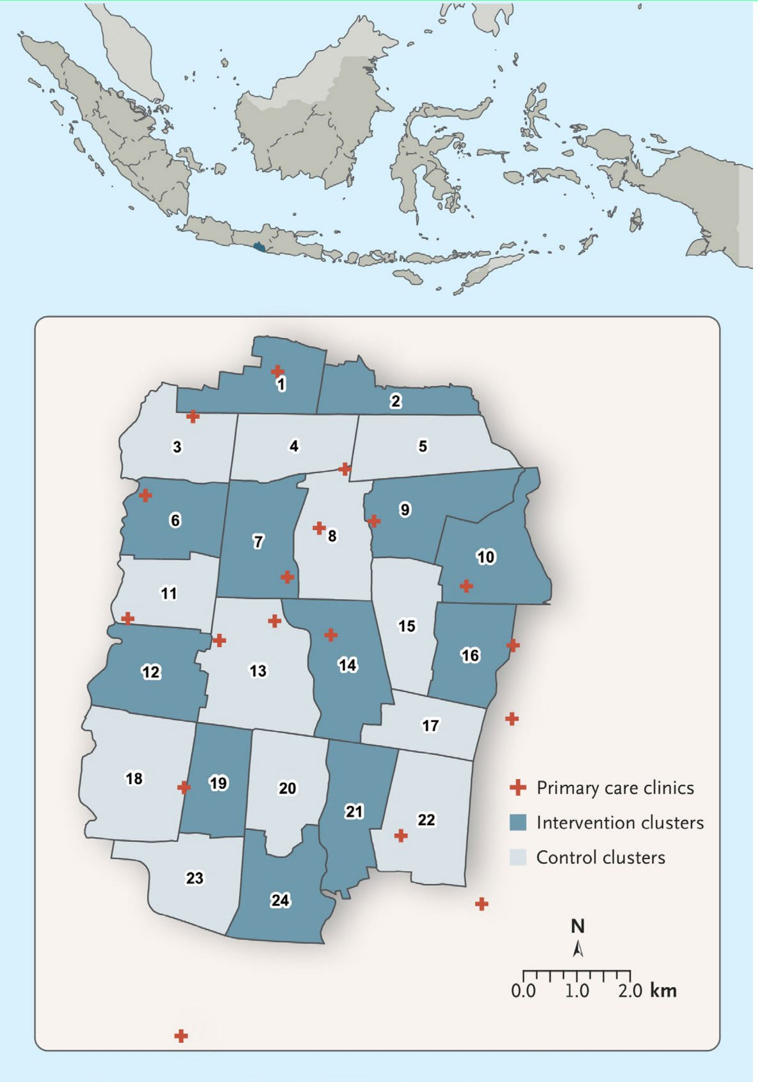
Models for estimation -Burden

- Measuring incidence of infections is expensive
- Data sparsity necessitates extrapolation
- Importance of different approaches

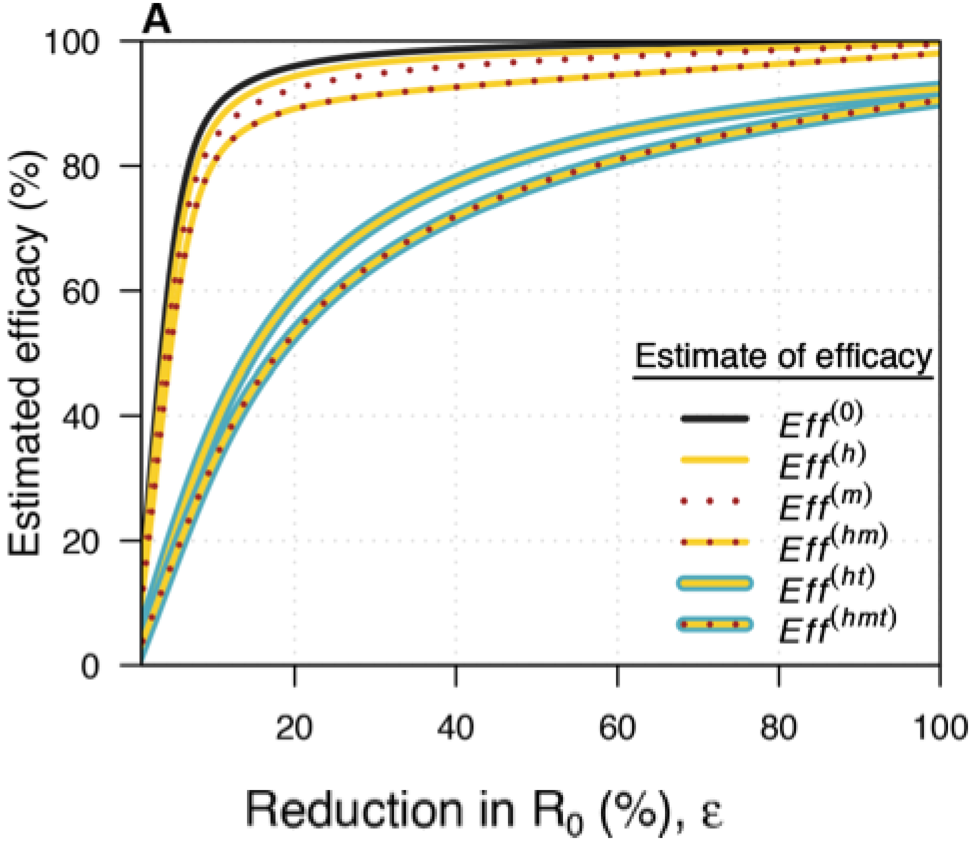


Bhatt et al. 2013 Nature https://doi.org/10.1038/nature12060

Models for estimation -Effectiveness



Utarini et al. *N Eng J Med*. 2021 10.1056/NEJMoa2030243



Cavany et al. 2023 *BMJ Glob. Health*
http://dx.doi.org/10.1136/bmjgh-2023-012169

Models for estimation

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Enabling factors:

- Accessibility and speed of computational methods
- Recognition of modelled estimates

Future developments:

- Integration across more disciplines
  - Routinely measuring effectiveness of vector control
  - Model-informed trial design
  - Targeted data collection to improve modelled estimates

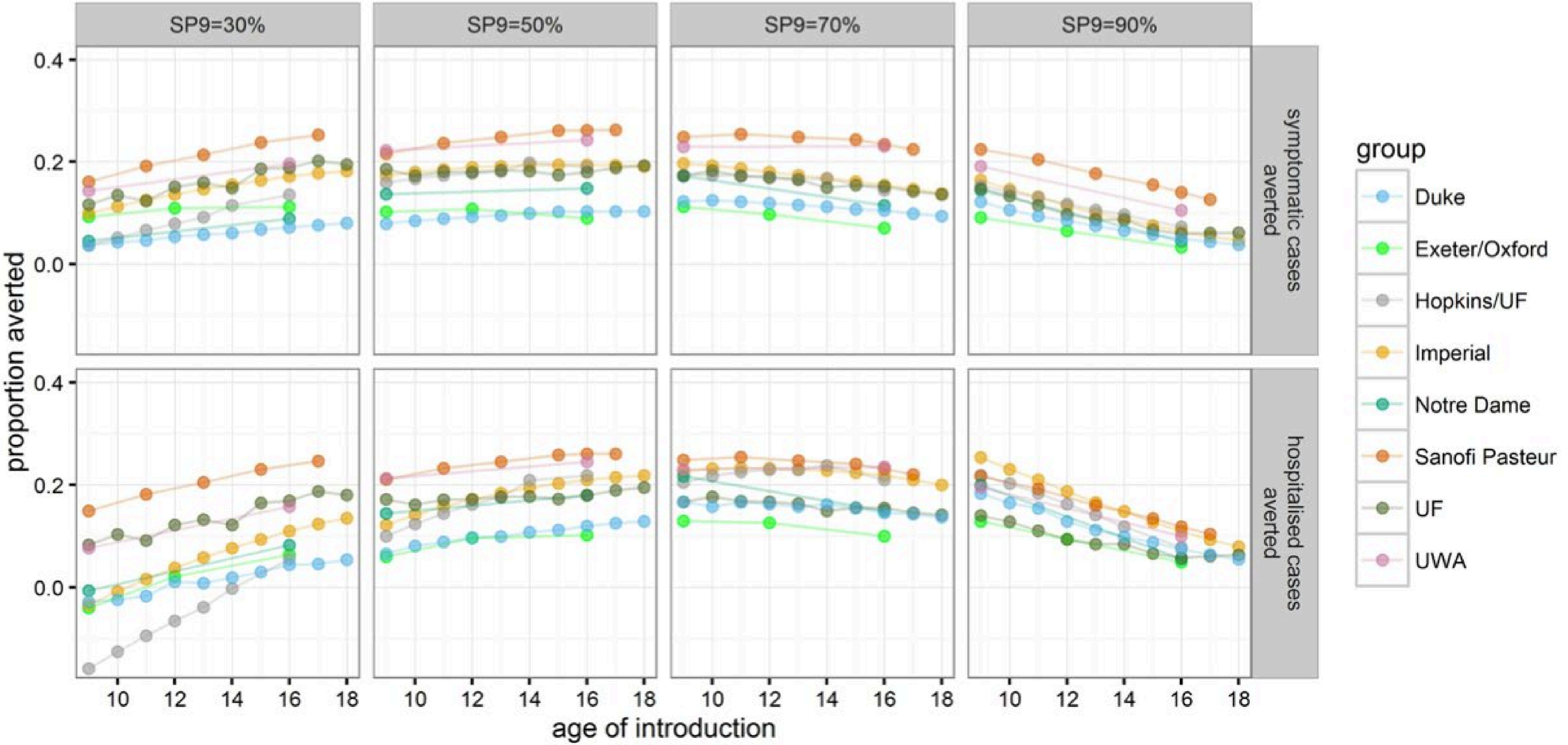
Models for prediction

Predicting the consequences of different intervention choices:

- Best long-term usage strategy for an intervention
- How to best combine interventions

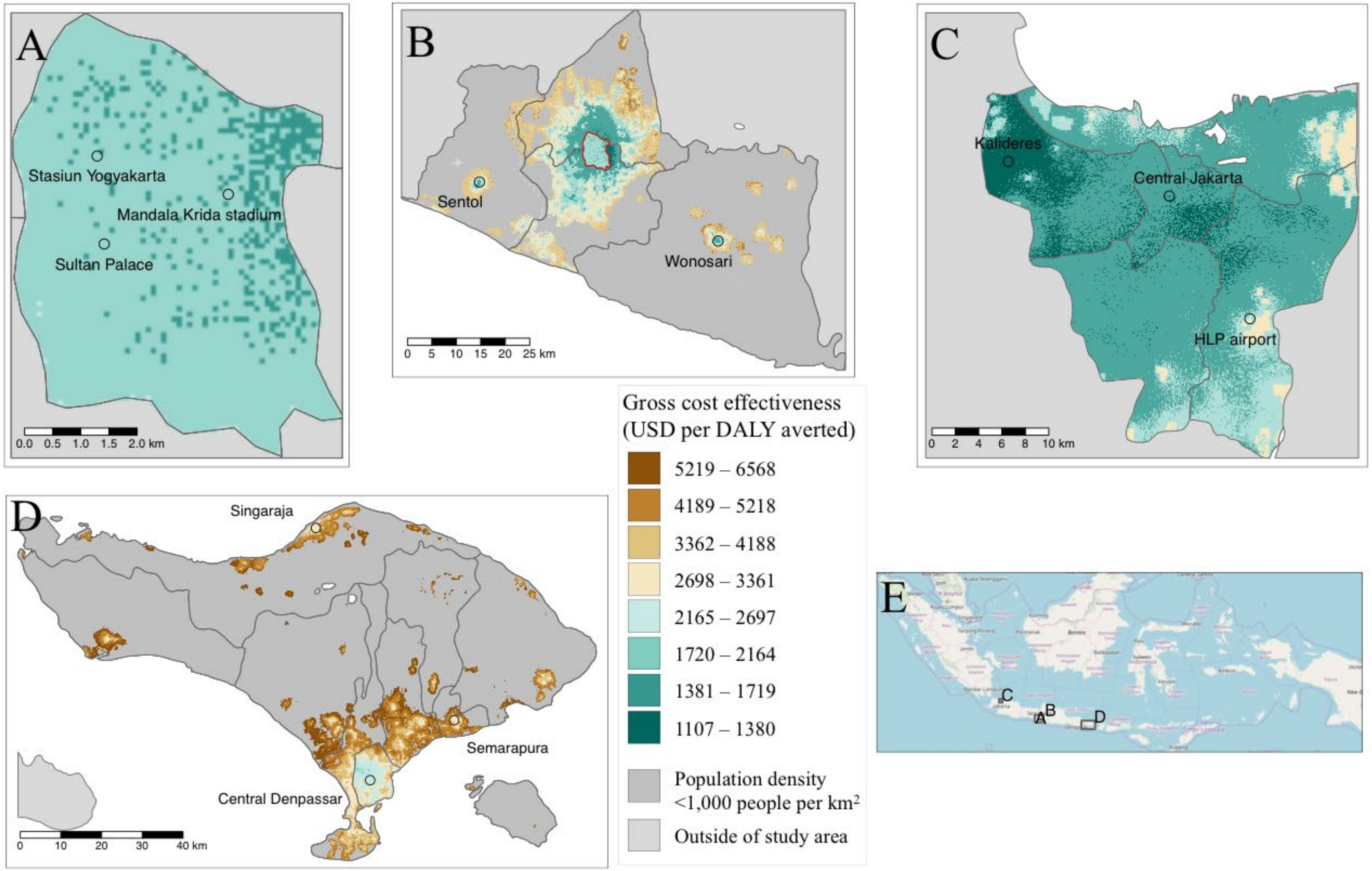
Increasingly critical piece of evidence needed for investment in new interventions

Models for prediction- Intervention strategy



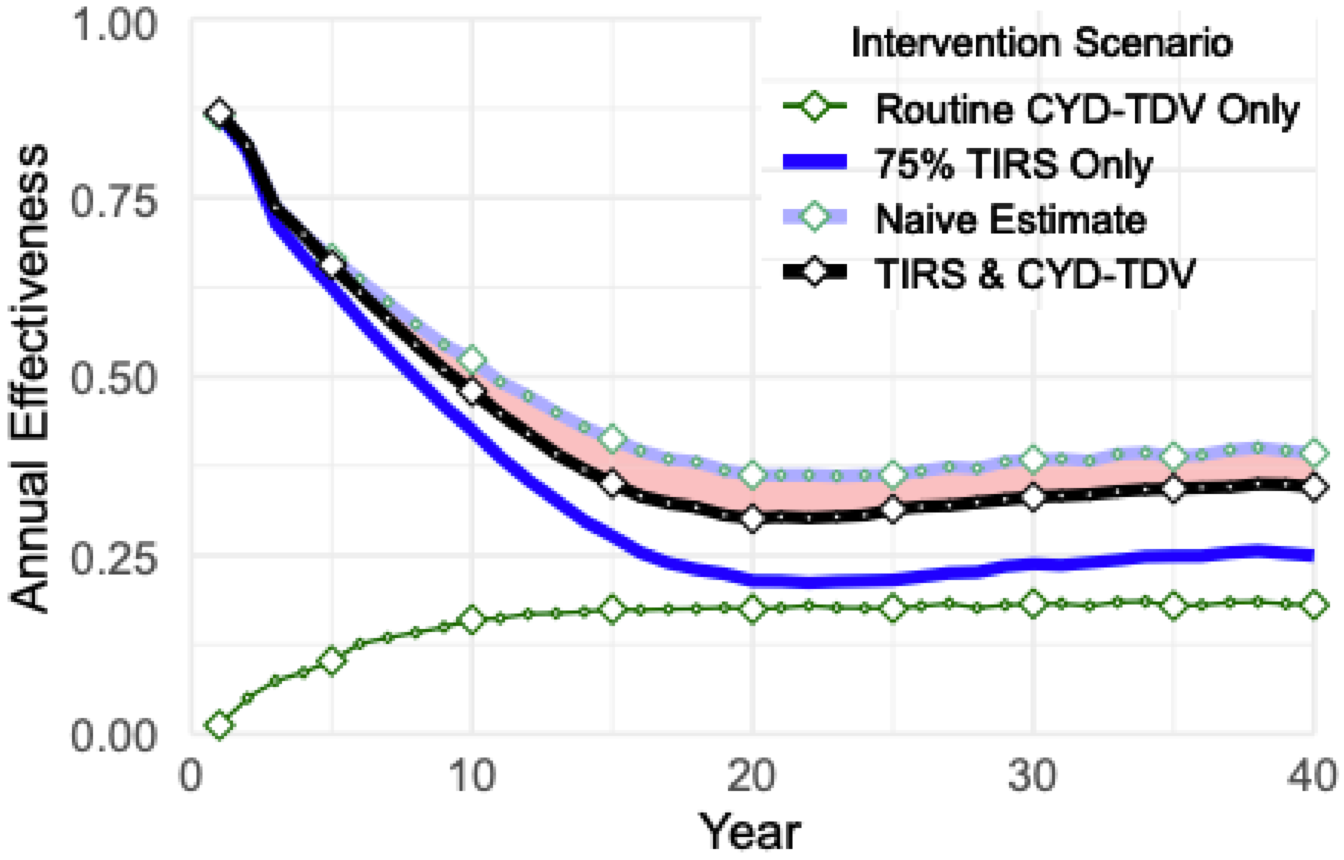
Flasche et al. *PLoS Med*. 2016 https://doi.org/10.1371/journal.pmed.1002181

Models for prediction- Intervention strategy



Brady et al. *BMC Med*. 2020 https://doi.org/10.1186/s12916-020-01638-2

Models for prediction- combining interventions



Hladish et al. *PNAS*. 2020 https://doi.org/10.1073%2Fpnas.1903496117

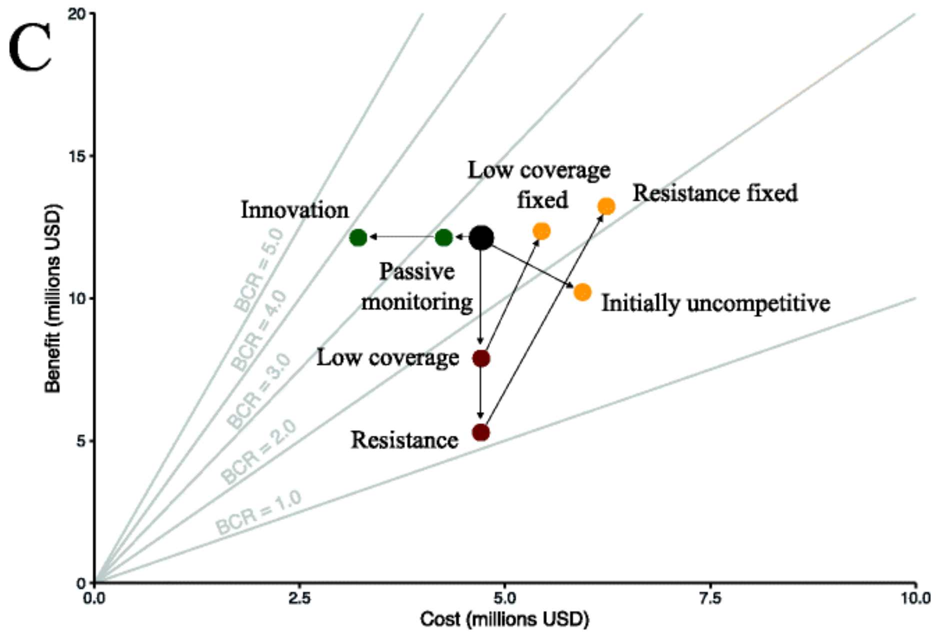
Models for prediction

Enabling factors:

- Good collaborations with intervention developers, governments and international health organisations
- Consensus among models

Future developments:

- More realistic and locally-relevant predictions to improve robustness



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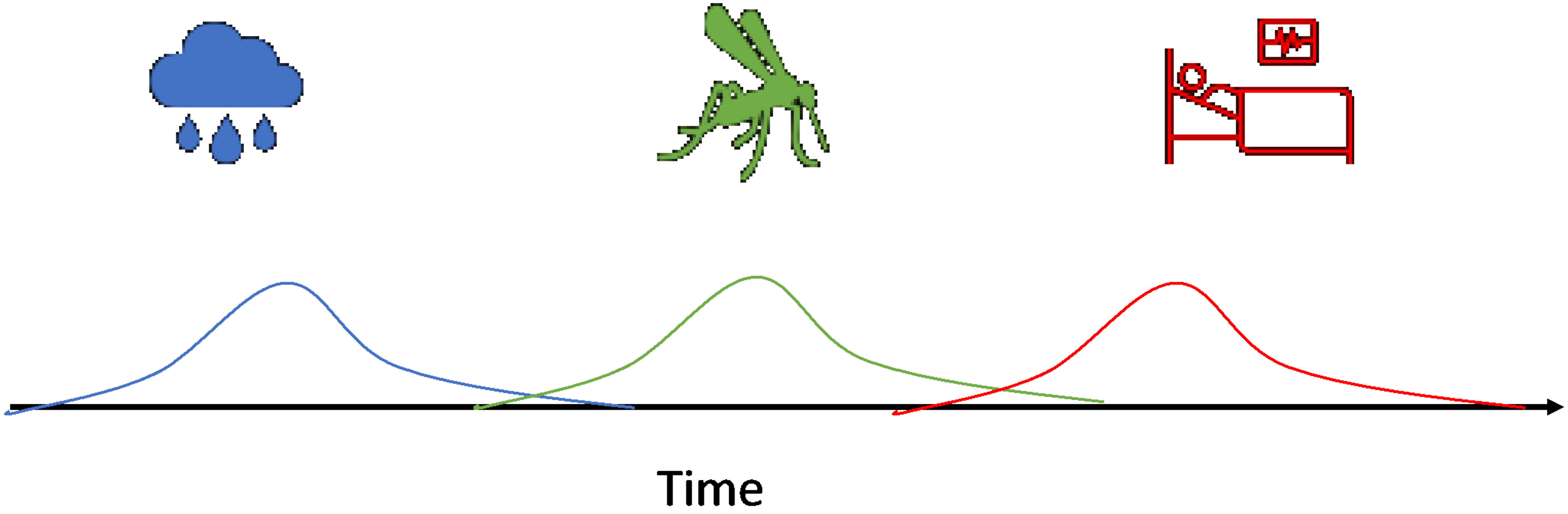
Models for forecasting



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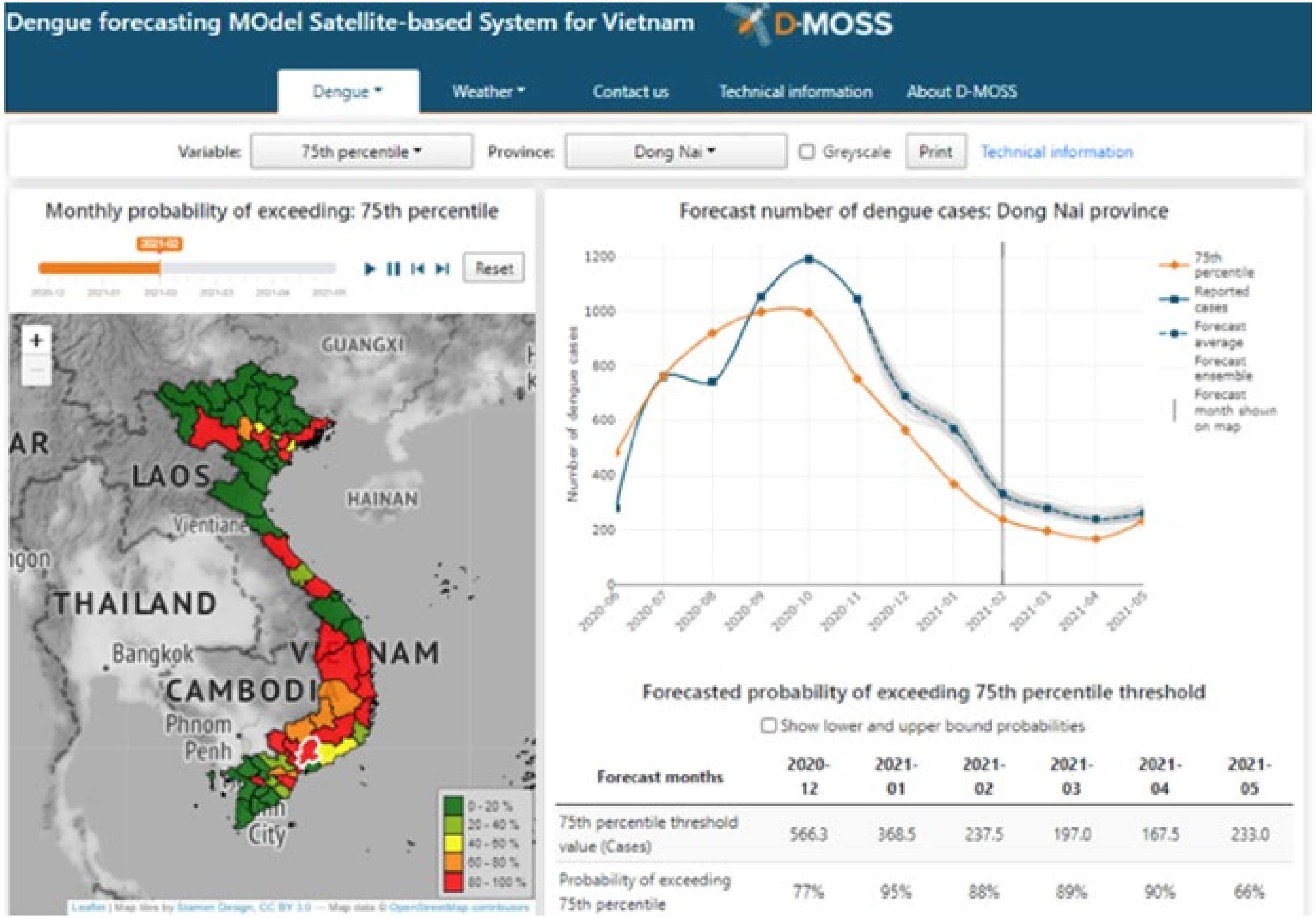
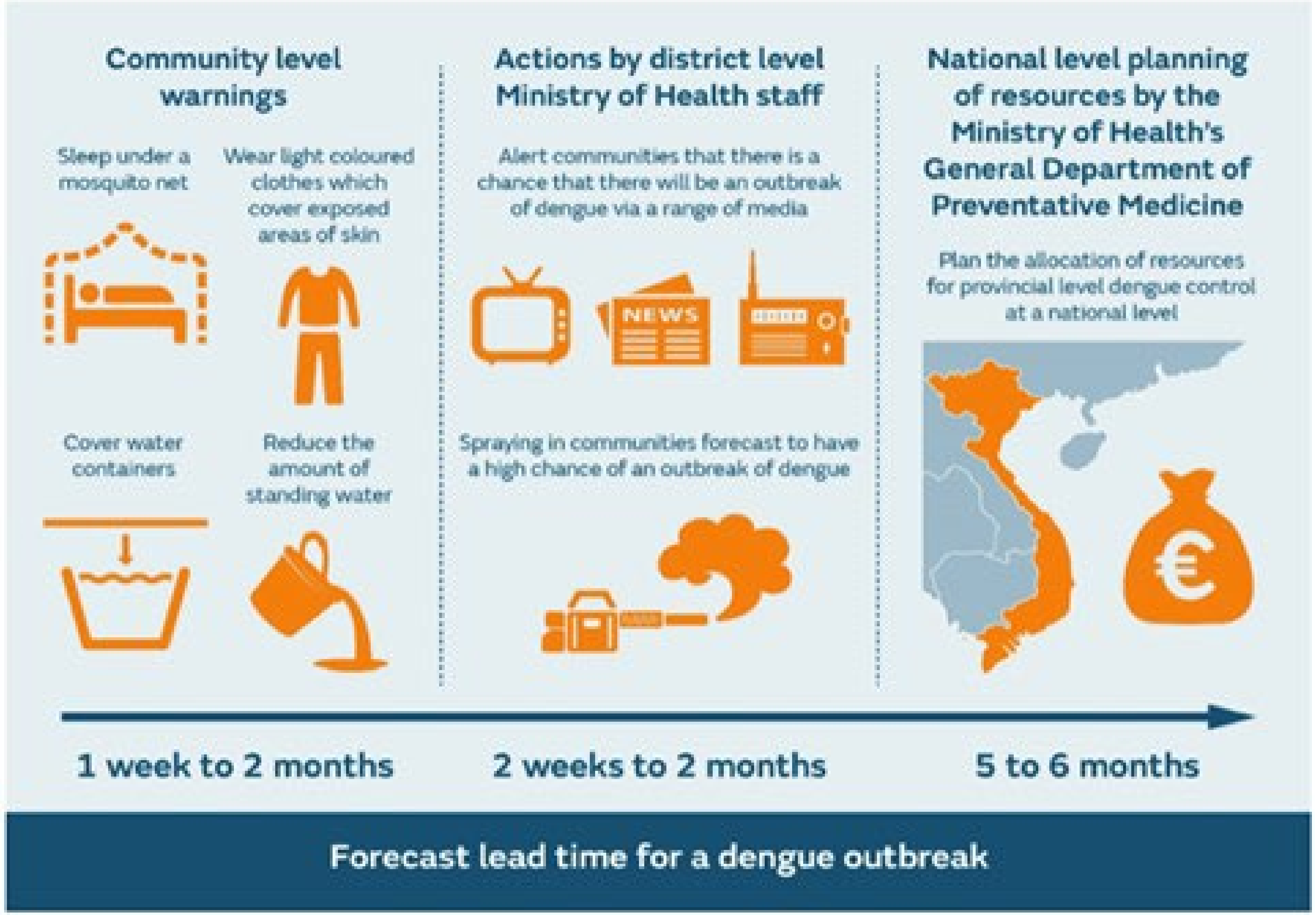


https://www.d-moss.org and Colon-Gonzalez et al. 2021 *PLoS Med* https://doi.org/10.1371/journal.pmed.1003542

Models for forecasting



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Models for forecasting

Enabling factors:

- Better understanding of drivers of arboviruses
- Efficient Bayesian inference methods
- More relevant approaches to validation developed with ministries of health

Future developments:

- More prospective evaluation of forecasts
- cRCT of forecast-informed outbreak prevention

Summary

Purpose	Enabling developments	Future opportunities
Understand	More abundant and detailed case data	Use of causal inference methods
Estimate	New answers to difficult questions and rapid and easy to use frameworks	Routine use of models in data dashboard and study design
Predict	Collaborations with intervention developers and between modelling groups	More specific and realistic predictions for context-specific decision making
Forecast	Capitalising on improved understanding of dynamics and closer collaboration with users	Better evaluation of operational performance and epidemiological effectiveness