

Bayesian spatio-temporal methods for small-area estimation of HIV indicators

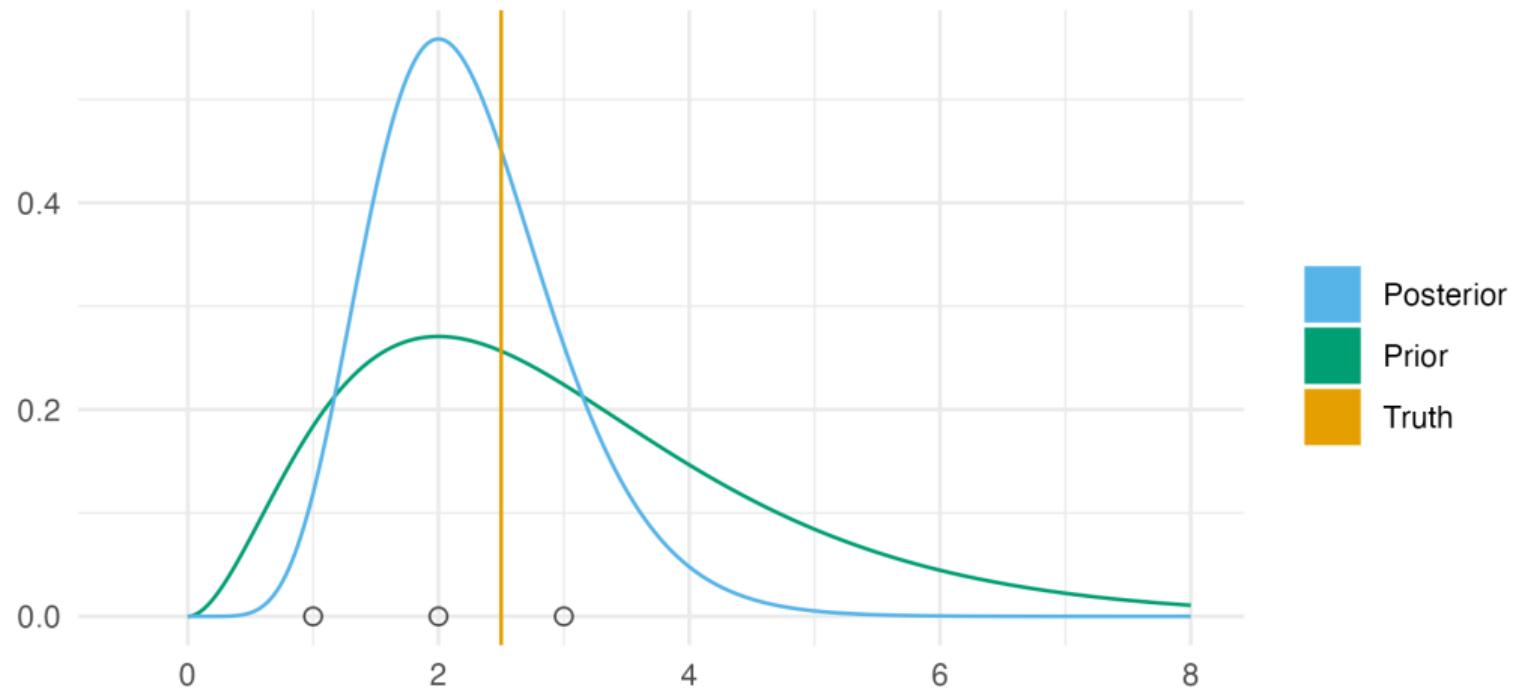
Adam Howes

Imperial College London

March 2023

Bayesian

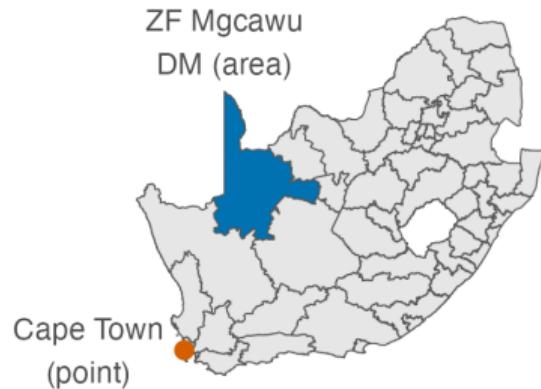
Use probability distributions for all unknowns



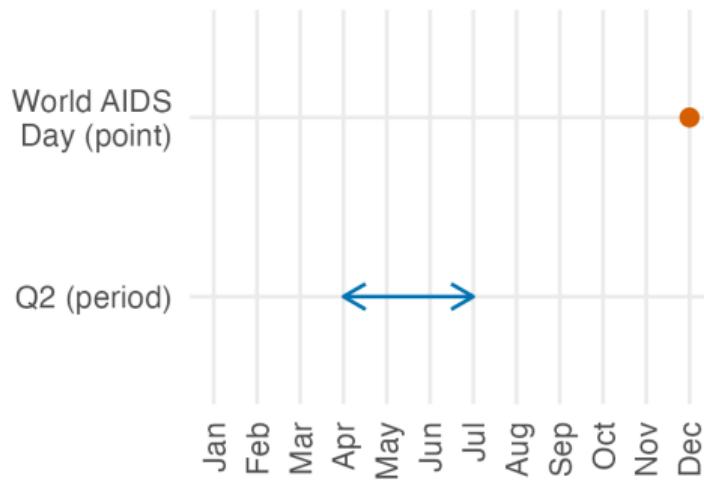
Spatio-temporal

Observed data has spatial and temporal location

A

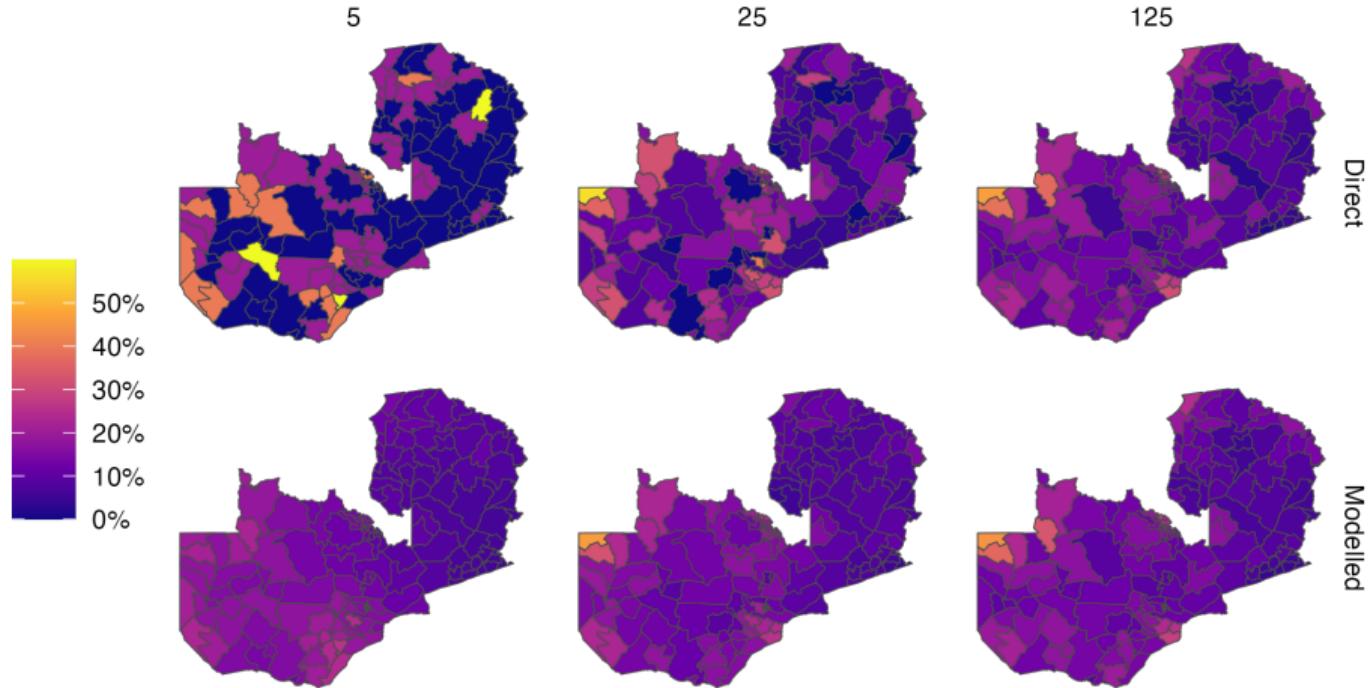


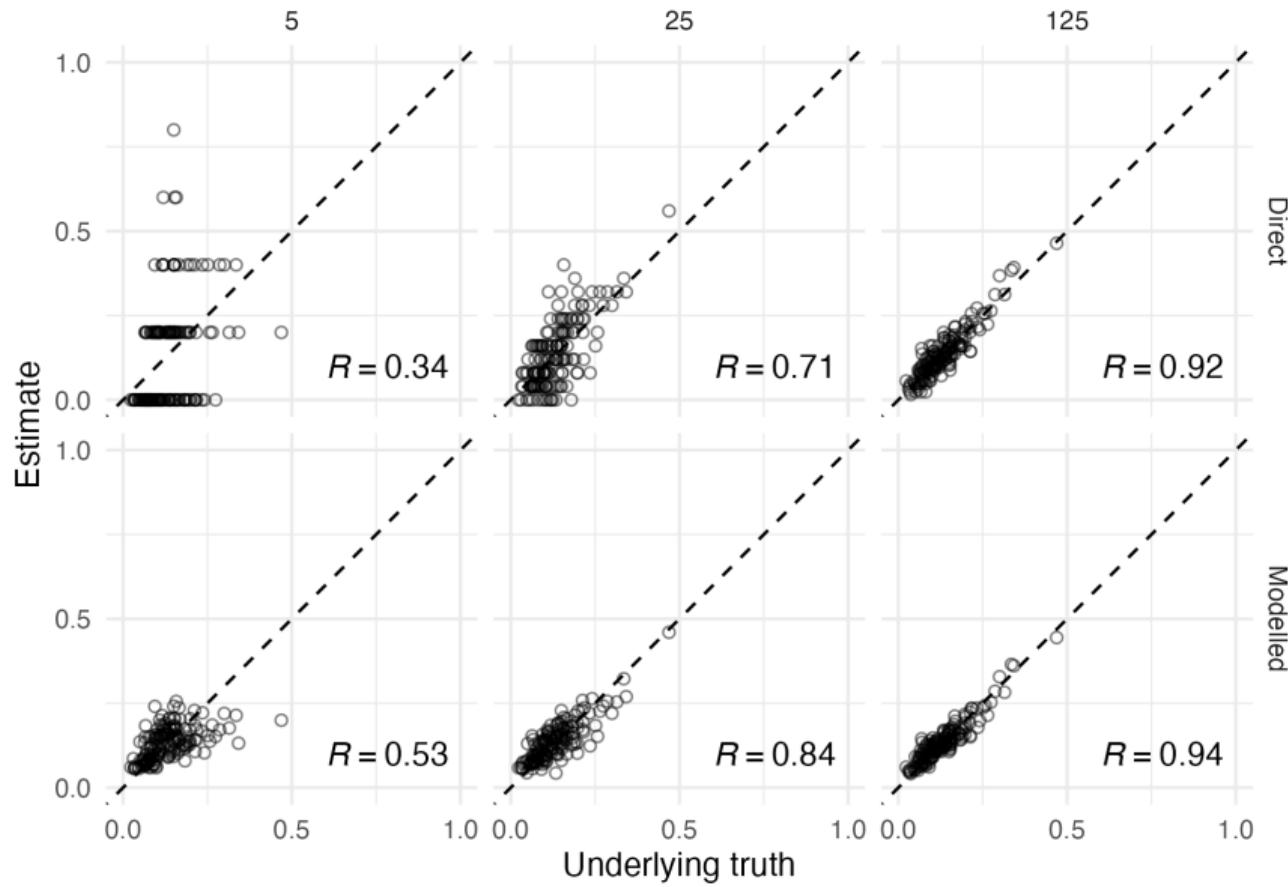
B



Small-area estimation

Sample size for demographic subgroups too small for precise direct estimates

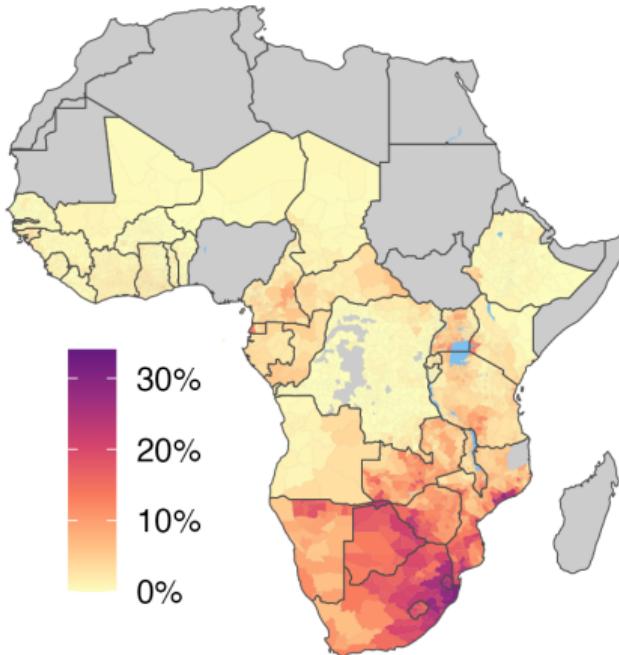
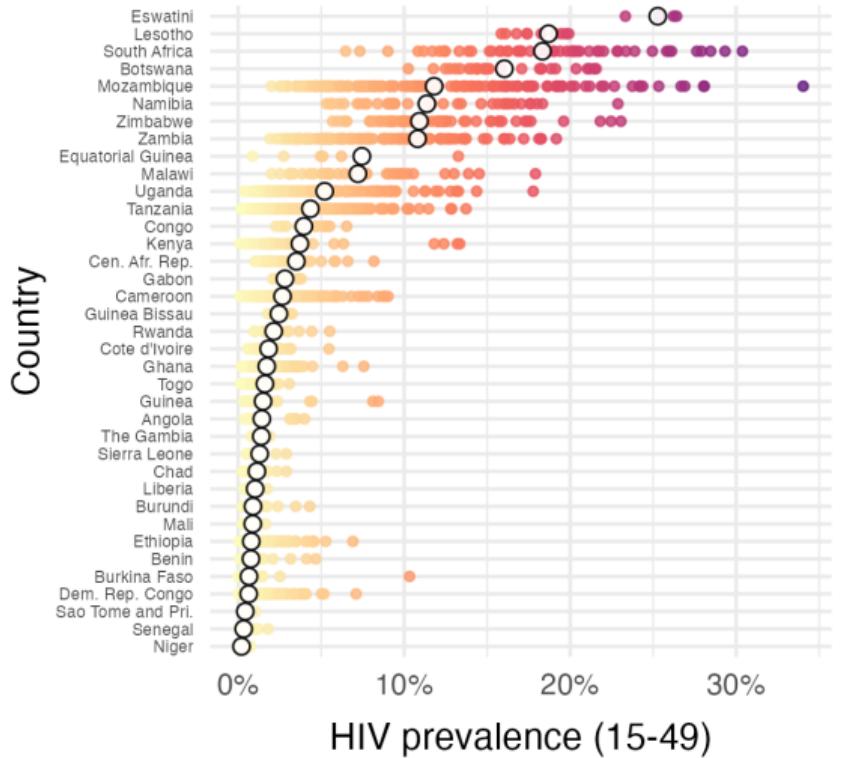




Toy example! But same principle applies to real models

e.g. Naomi¹ (Eaton et al. 2021; Esra et al. 2024).

¹See C.4 Simplified Naomi model description



Source: UNAIDS Naomi model estimates, 2023

Nearby things tend to be similar

Supposing prior correlation structure between observations!

Gaussian Markov random field model of Besag, York, and Mollié (1991):

Proportional to number of neighbours

Average of neighbours

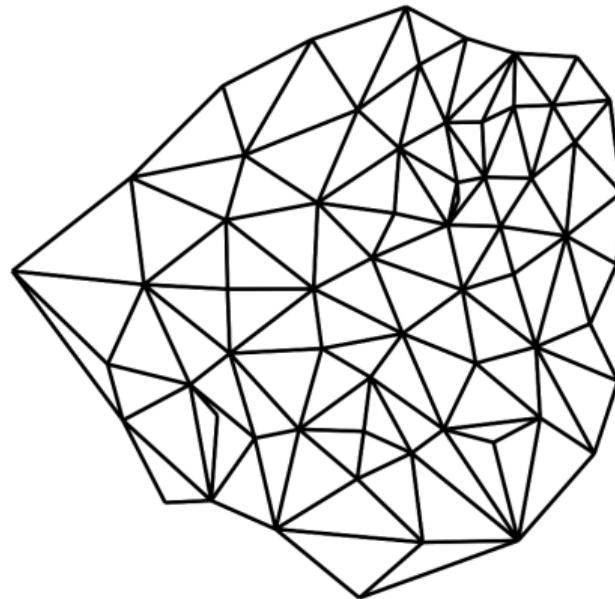
$$u_i | \mathbf{u}_{-i} \sim \mathcal{N} \left(\frac{1}{n_{\delta i}} \sum_{j:j \sim i} u_j, \frac{1}{n_{\delta i} \tau_u} \right)$$

ith full conditional

A



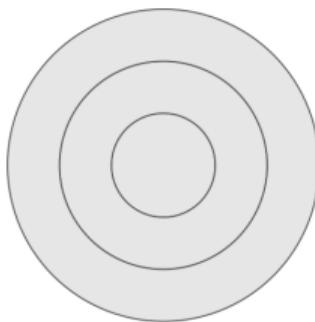
B



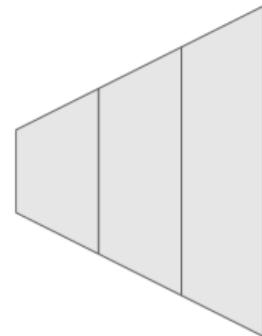
A



B



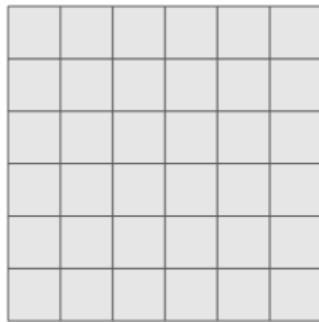
C



D



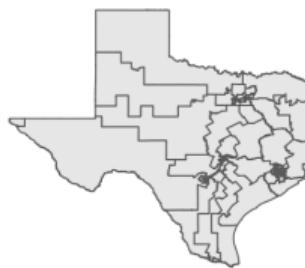
E

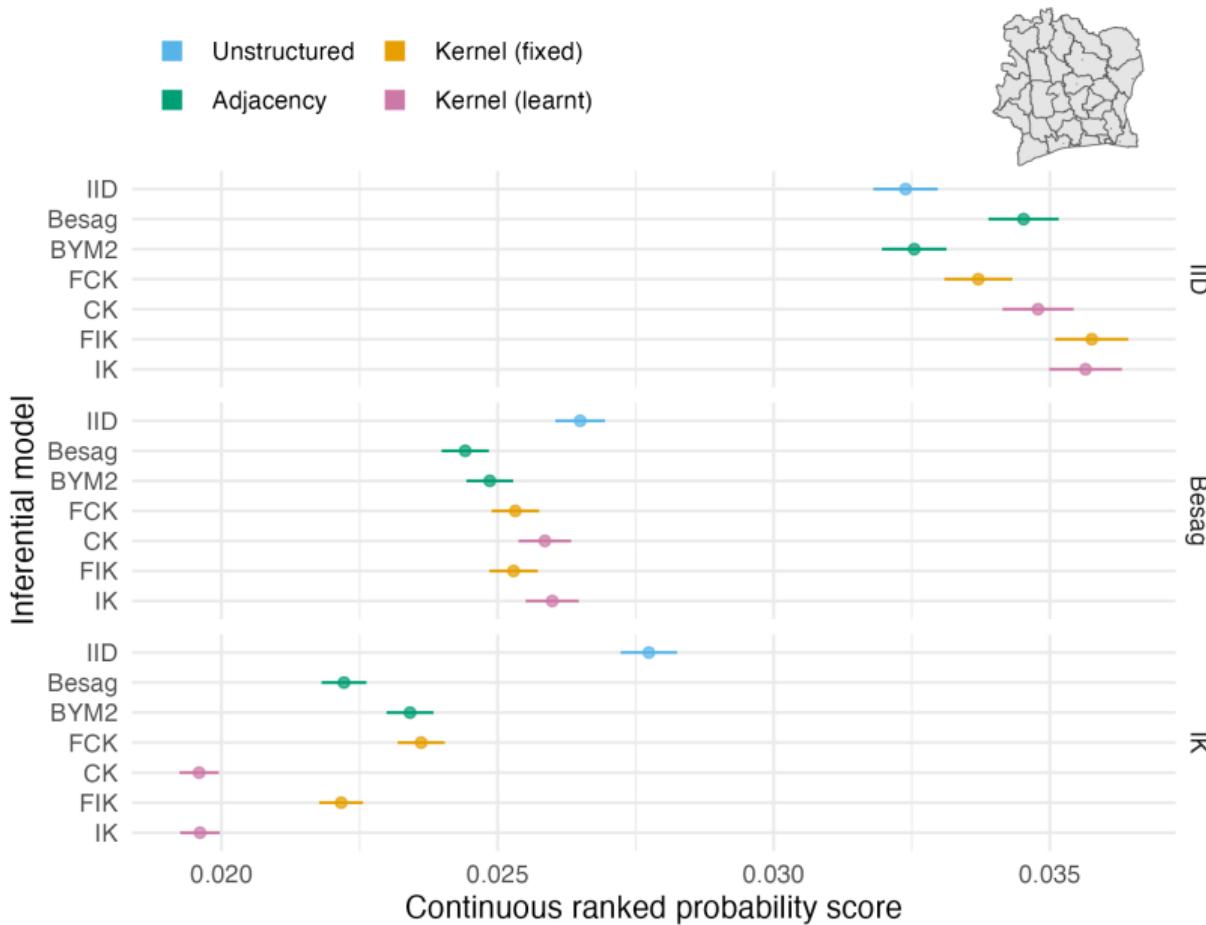


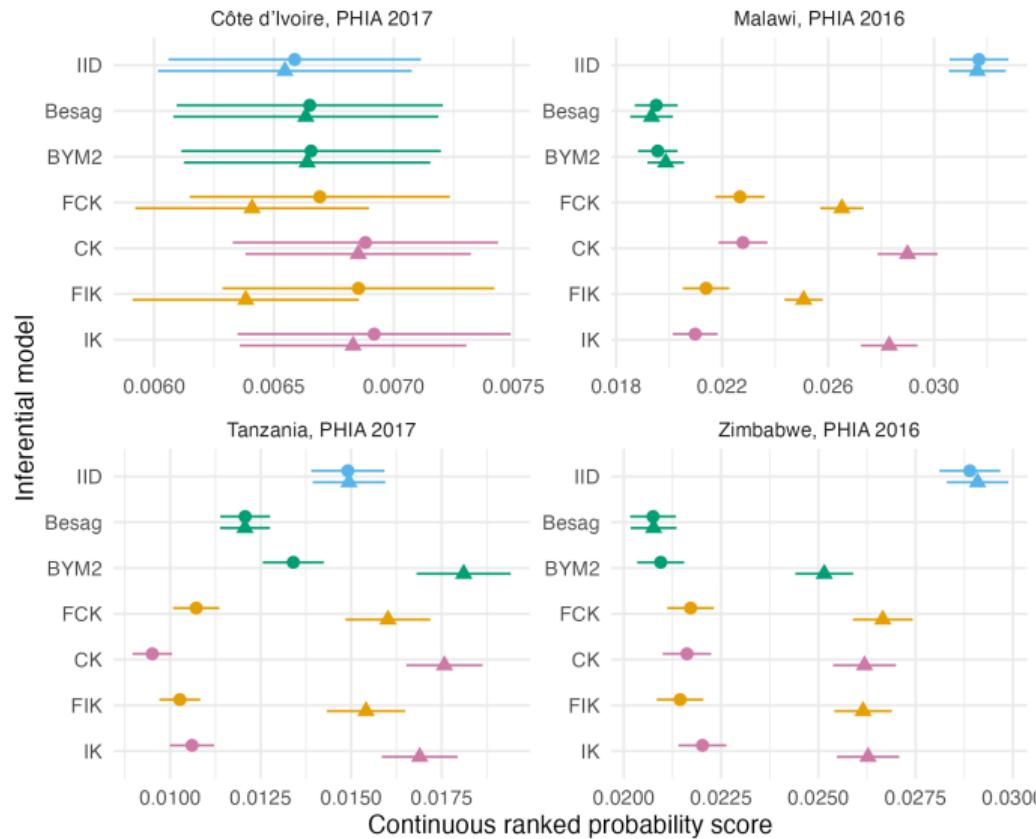
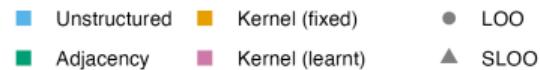
F



G

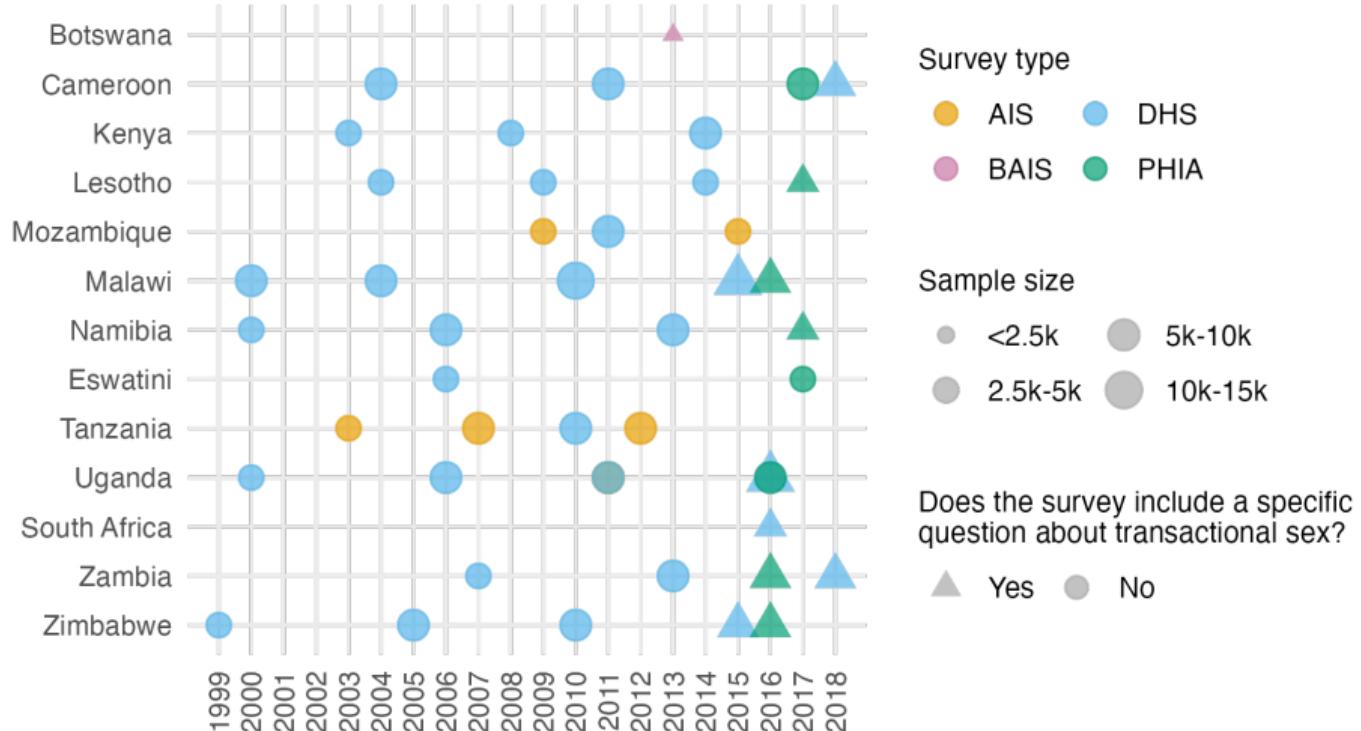




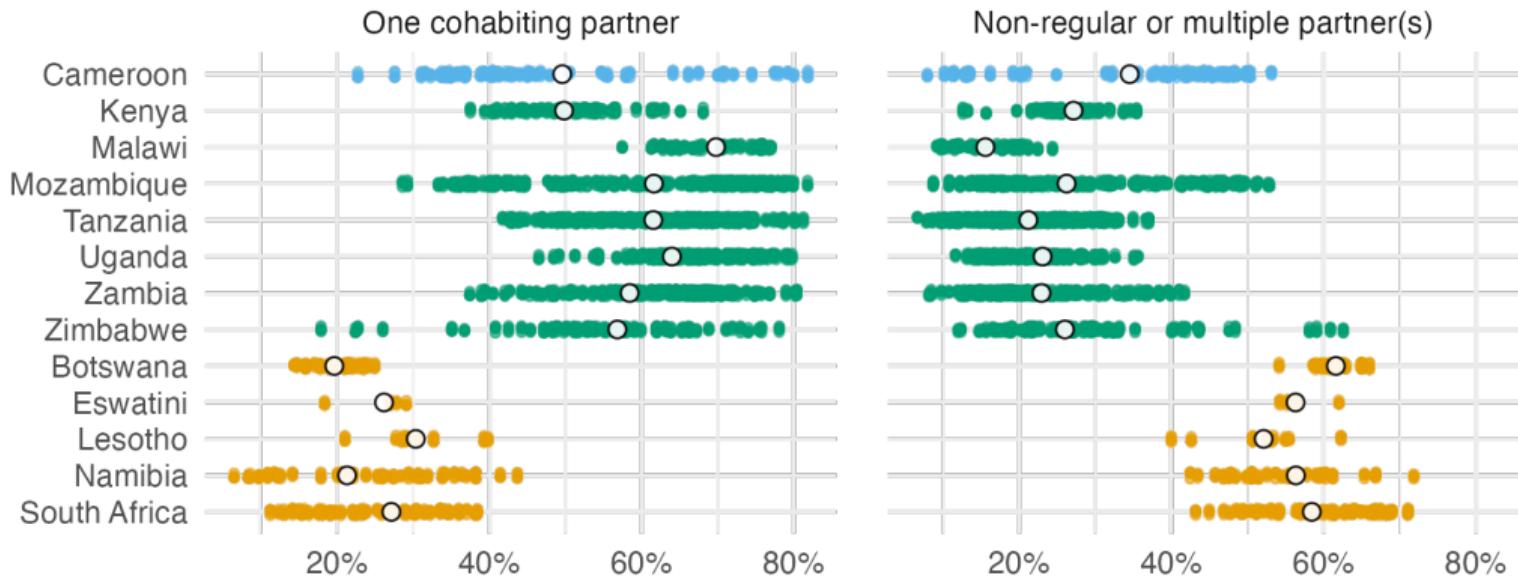


GLOBAL AIDS STRATEGY 2021-2026
**END INEQUALITIES.
END AIDS.**





Regions of sub-Saharan Africa ● Central ● Eastern ● Southern

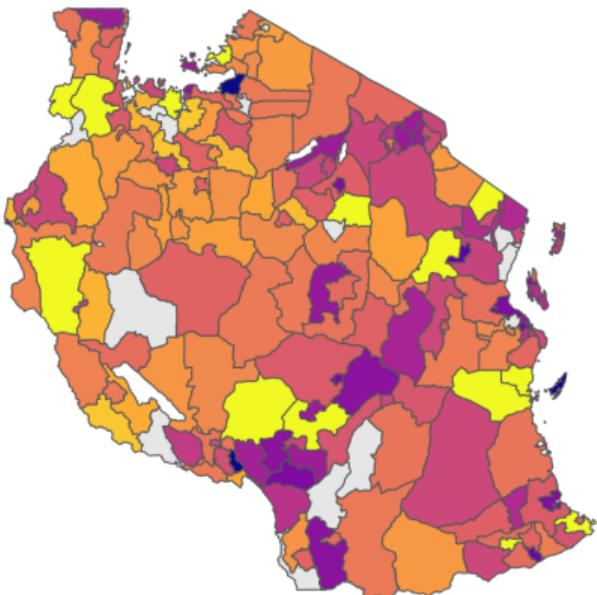


Not sexually active (not shown) + one cohabiting partner + non-regular or multiple partner(s) + FSW (not shown) = 100%

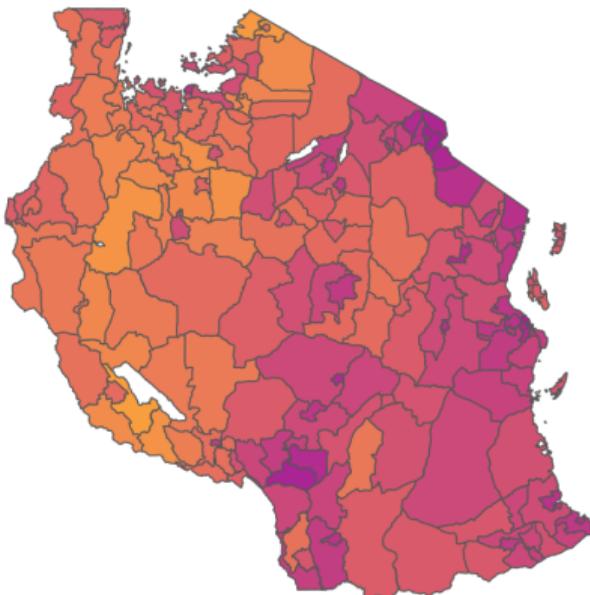
Proportion
of women
20-24
cohabiting
(2010)

100%
75%
50%
25%
0%

Direct

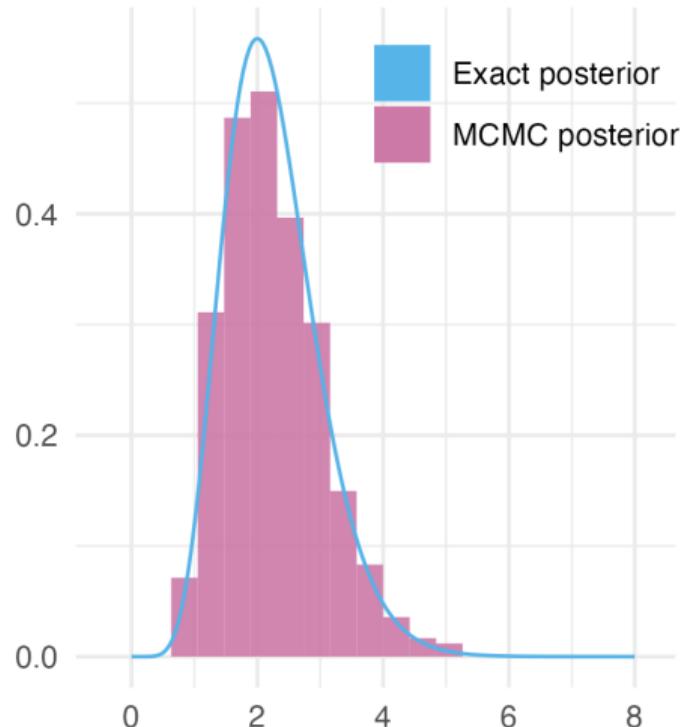
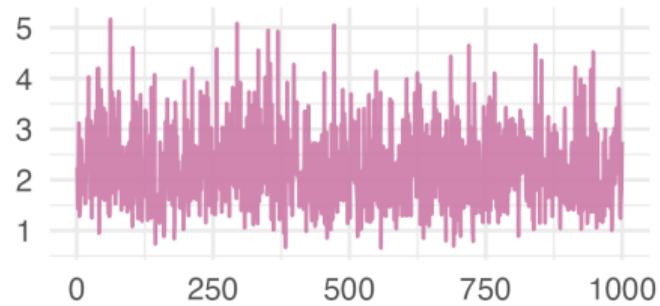
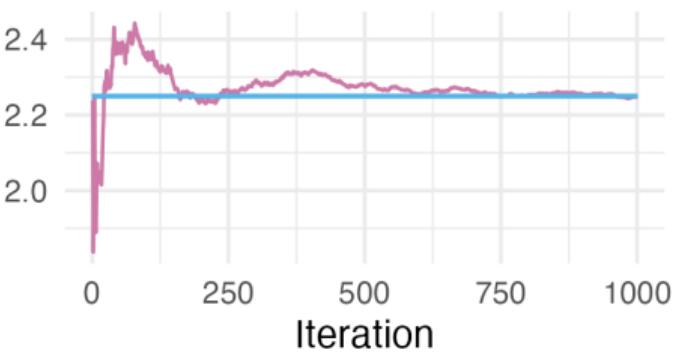


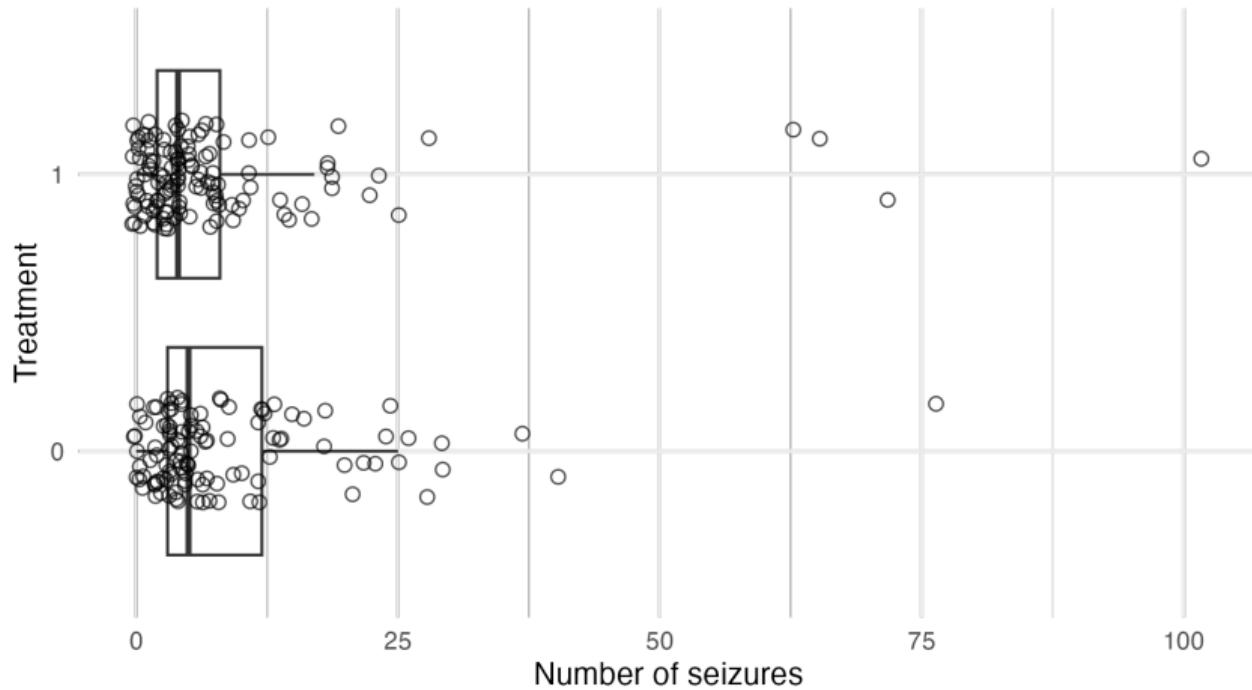
Modelled

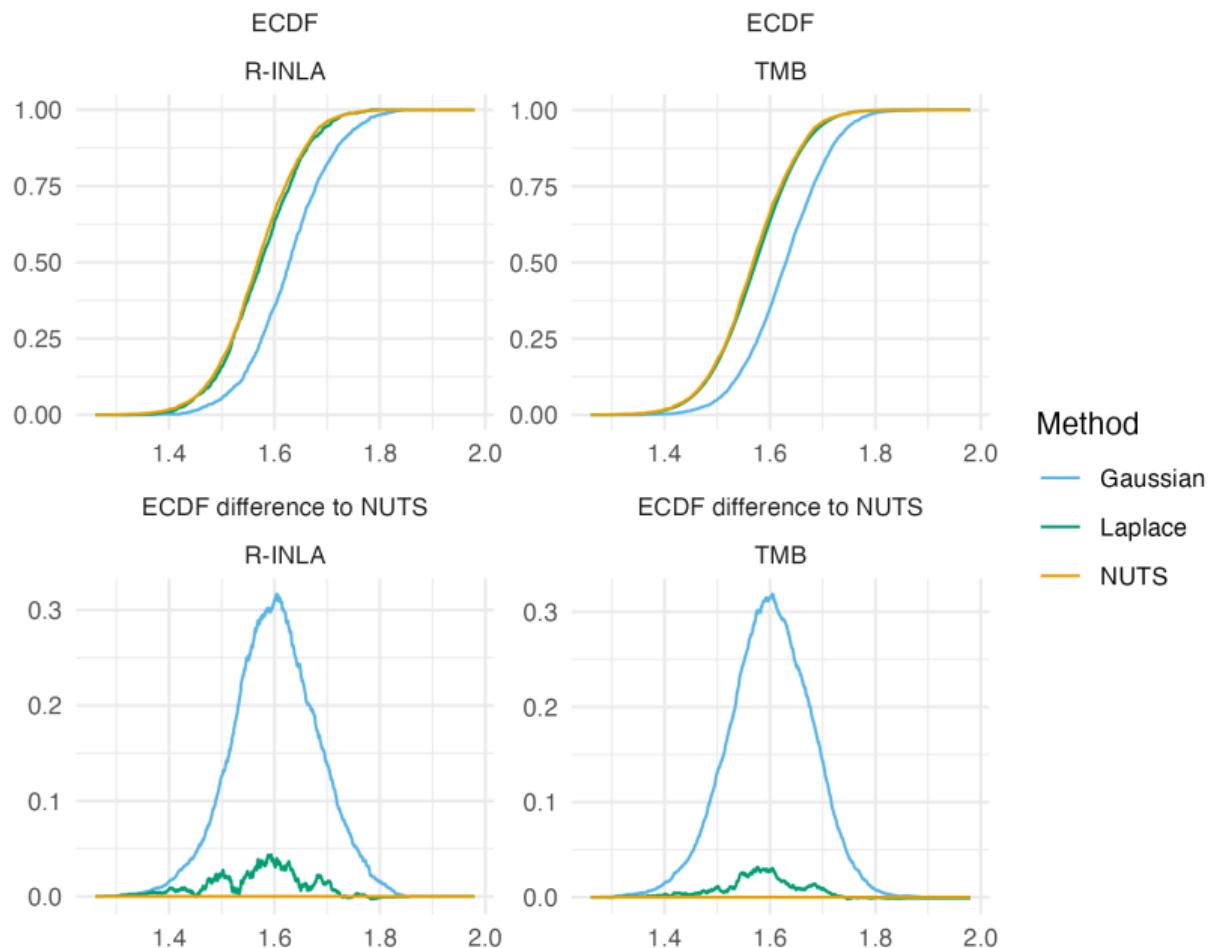


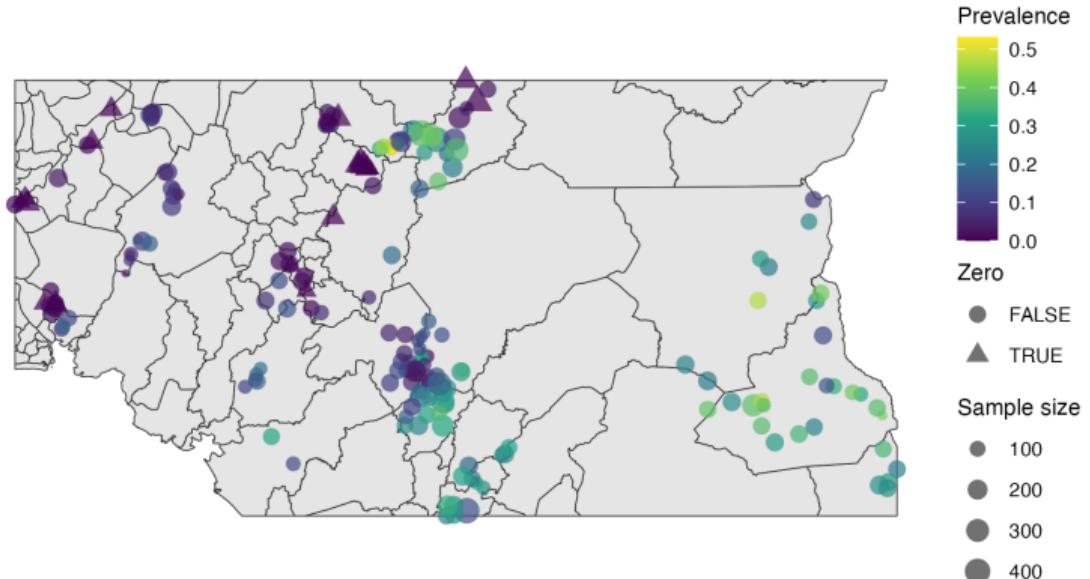
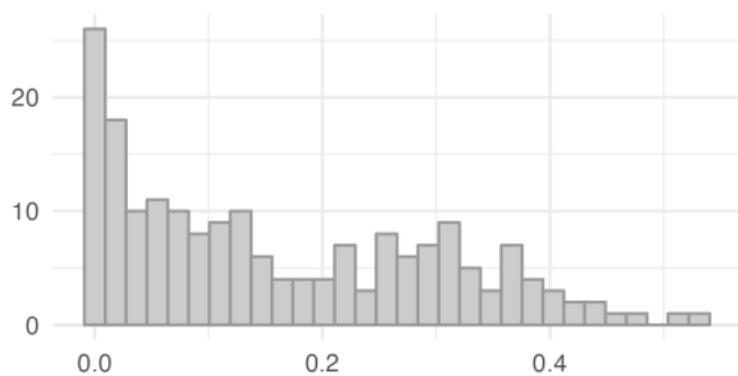
Since extended to include 1) males, 2) additional countries

See the sub-national HIV estimates in priority populations UNAIDS tool at
hivtools.unaids.org/shipp/

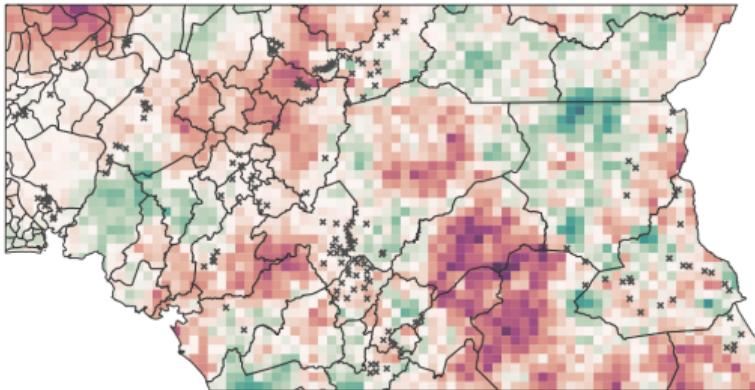
A**B****C**



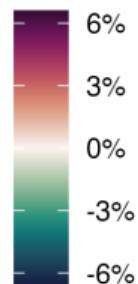


A**B**

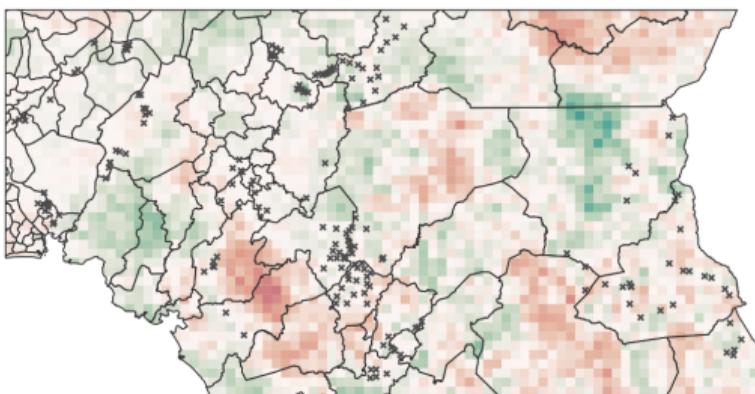
Gaussian



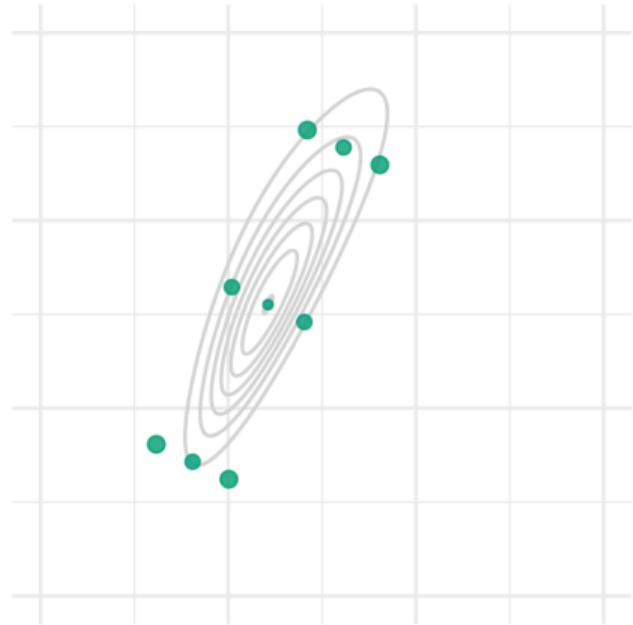
Prevalence
difference
to NUTS



Laplace

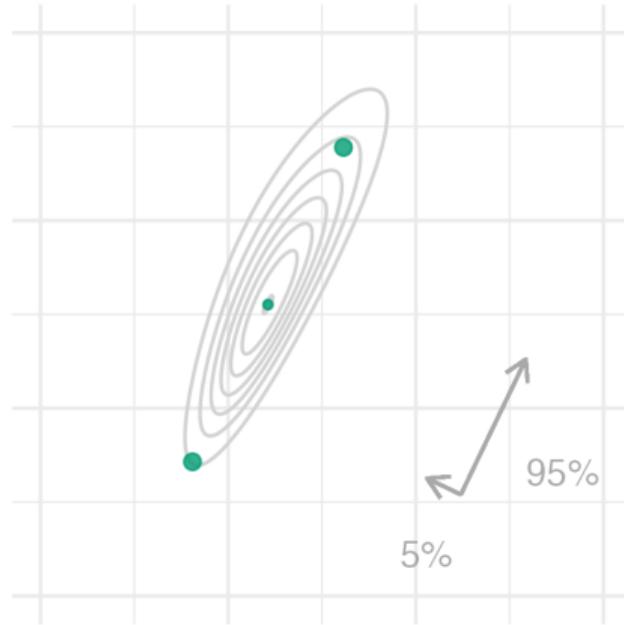


A

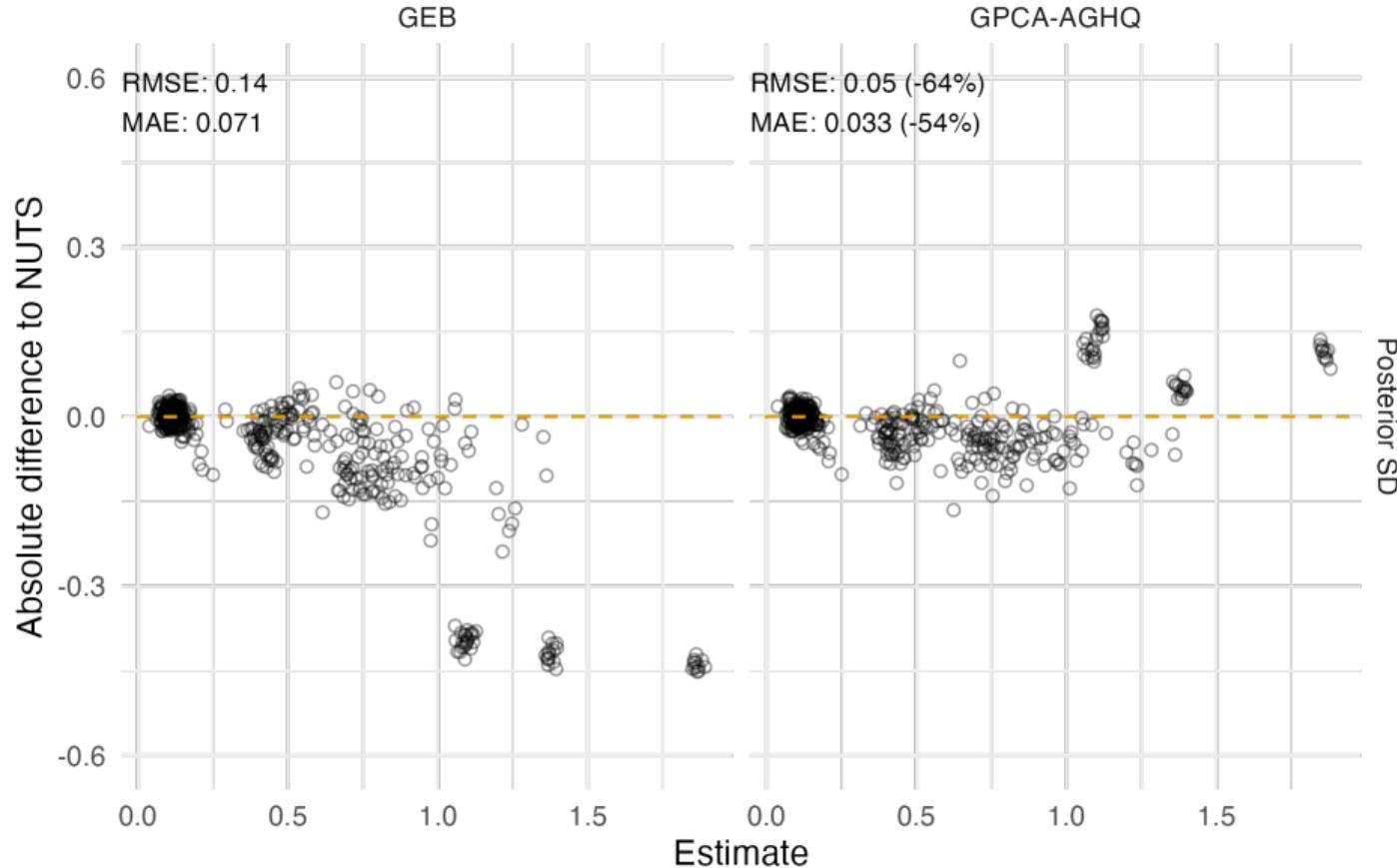


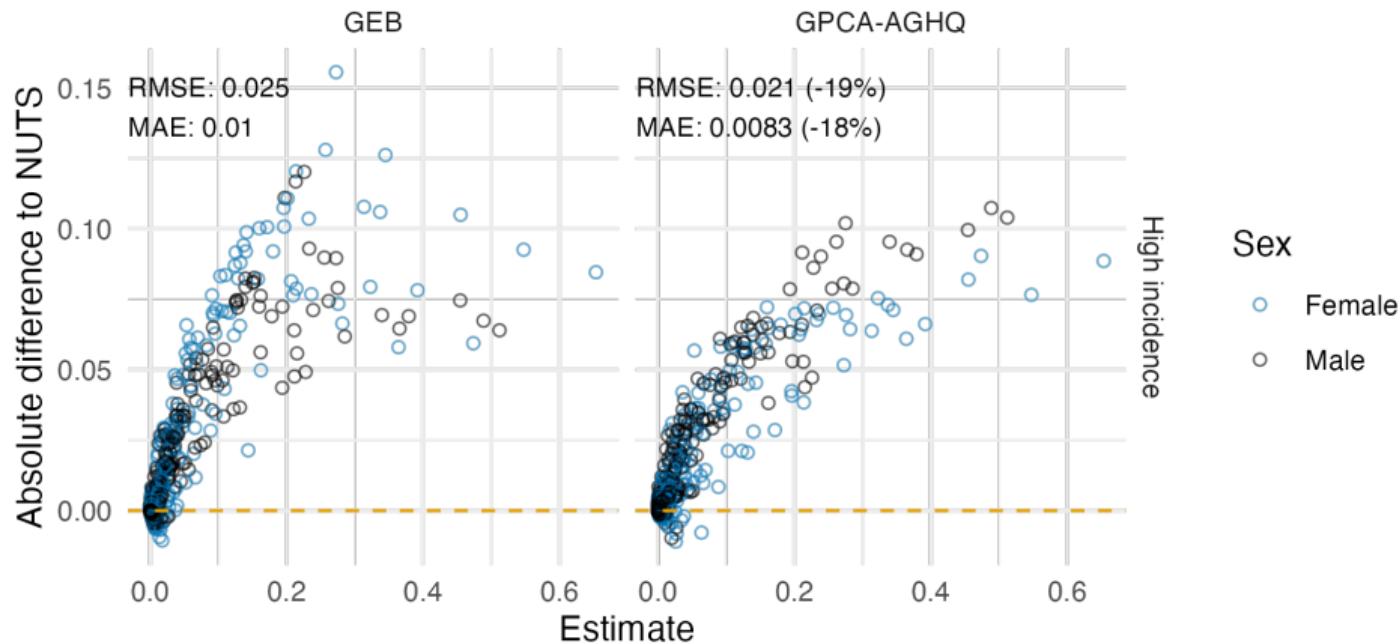
AGHQ (spectral)

B



PCA-AGHQ





Acknowledgements

Collaborator(s)	Affiliation
Jeff Eaton	Imperial, Harvard
Seth Flaxman	Oxford
Alex Stringer	Waterloo
HIV Inference Group	Imperial
Machine Learning and Global Health Network	Worldwide
StatML CDT	Imperial, Oxford

References I

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References II

Esra, Rachel, Mpho Mmelesi, Akeem T. Ketlogetswe, Timothy M. Wolock, Adam Howes, Tlotlo Nong, Matshelo Tina Matlhaga, Siphiwe Ratladi, Dinah Ramaabya, and Jeffrey W. Imai-Eaton. 2024. "Improved Indicators for Subnational Unmet Antiretroviral Therapy Need in the Health System: Updates to the Naomi Model in 2023." *JAIDS Journal of Acquired Immune Deficiency Syndromes* 95 (1S): e24–33.
<https://doi.org/10.1097/QAI.0000000000003324>.