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A zero-dose vulnerability index for equity assessment and spatial prioritization in low- and middle-income countries

Introduction

Many low- and middle-income countries (LMICs) continue to experience substantial inequities in vaccination coverage despite recent efforts to reach missed communities and reduce zero-dose prevalence. Geographic inequities in vaccination coverage are often characterized by a multiplicity of risk factors, which should be operationalized through data integration to inform more effective and equitable vaccination policies and programmes. Here, we explore approaches for integrating information from multiple risk factors to create a zero-dose vulnerability index to improve the identification and prioritization of vulnerable communities and understanding of inequities in vaccination coverage.

Methodology

Data

- Data on risk factors for zero dose and under-immunization, as well as vaccination coverage, were obtained from the most recent household survey conducted in six countries. These were Demographic and Health Surveys (DHS) conducted in the Democratic Republic of the Congo (DRC, 2013–14), Ethiopia (2016), India (2015–16), Pakistan (2017–18), Uganda (2016) and the Multiple Indicator Cluster Survey-National Immunization Coverage Survey (MICS-NICS) conducted in Nigeria in 2021.

Risk factors for zero dose and under-vaccination

- Antenatal care attendance
- Tetanus toxoid vaccination
- Skilled birth attendance
- Postnatal care
- Malaria prevalence
- Health insurance
- Malnutrition
- Travel time (health facility)
- Modern contraception

- Maternal education
- Household wealth
- Decision making

- Ethnicity
- Household size
- Religion
- Maternal age
- Birth quarter

- Rural population
- Conflict-affected population

Outcome indicators

- DTP1 vaccination
- DTP3 vaccination
- MCV1 vaccination

- Geospatial covariate data were also obtained from the respective surveys (surfaces were created using geospatial modelling and other approaches).

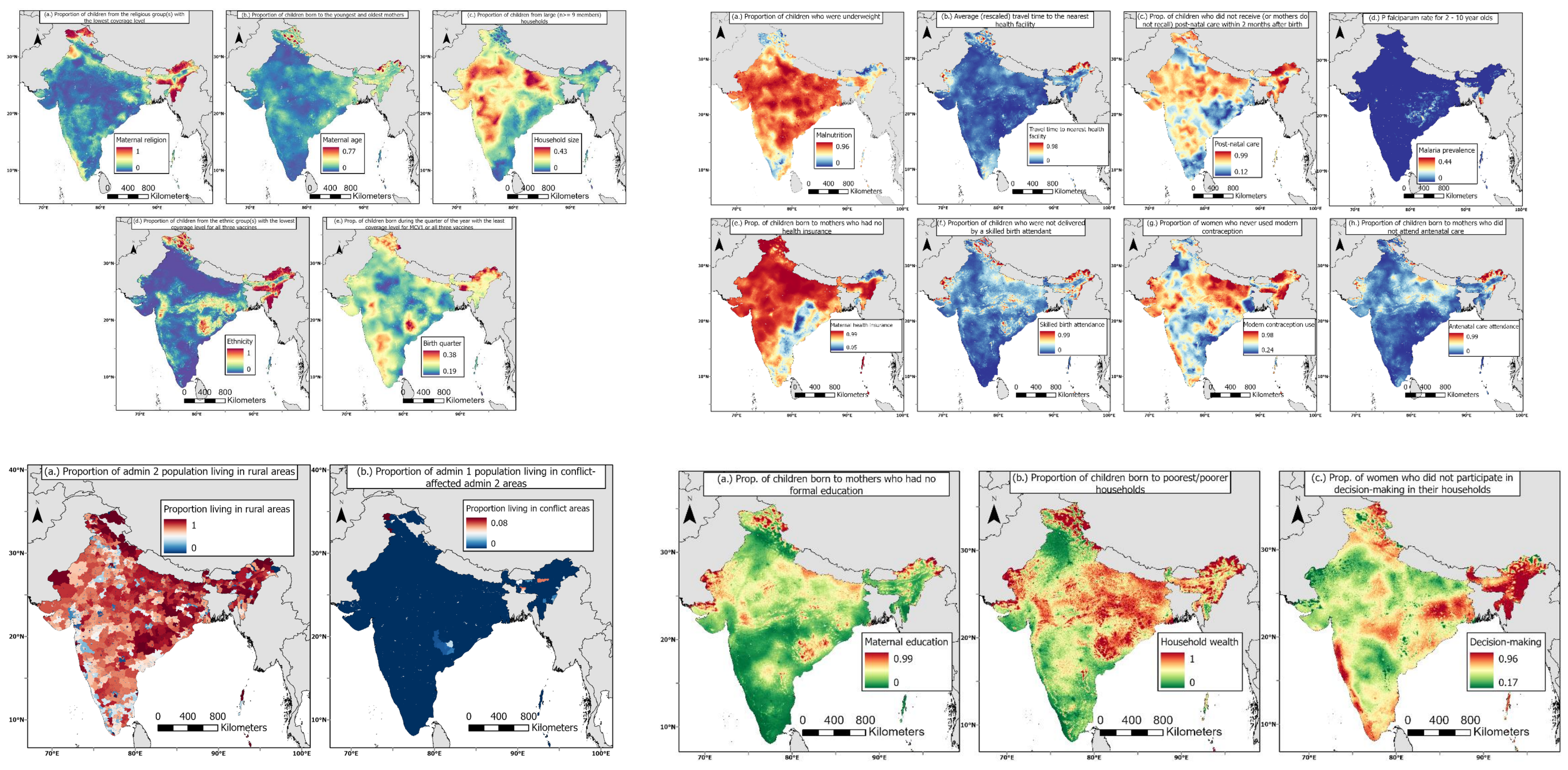

Fig. 1. Risk factors for zero dose and under-vaccination and vaccination coverage indicators considered in the study and corresponding 1x1 km gridded layers.

Geospatial modelling, prediction and validation

- We fitted Bayesian geostatistical models to model and predict the risk factors and vaccination coverage. The model can be expressed as:

$$Y(\boldsymbol{s}) \sim \text{Binomial}\big(m(\boldsymbol{s}), p(\boldsymbol{s})\big)$$
$$\text{logit}\big(p(\boldsymbol{s})\big) = \mathbf{x}(\boldsymbol{s})^T\boldsymbol{\beta} + \omega(\boldsymbol{s}) + \epsilon(\boldsymbol{s})$$

- The model was fitted using the INLA-SPDE approach. Predictions were obtained at 1x1 km resolution and aggregated to the district level through weighting using gridded population data.

Constructing the vulnerability index

To construct the index using the risk factors, we first rescaled/normalized these to a common scale ranging from 0 (lowest risk) to 100 (highest risk). We then considered five different approaches to construct the vulnerability index: **direct weighting** – assigns equal weights to the risk factors to create the index; **group-based weighting** – assigns the risk factors to groups, uses equal weights within groups to obtain group-specific indexes which are then combined to obtain the final index; **regression rank-based weighting I and II** – utilize information on vaccination coverage to rank the risk factors (based on their predictive R^2). The ranks are averaged over all three outcomes to obtain the weight for each risk factor (I), or quartile-based ranks are obtained for each covariate under each outcome, which are then averaged over all the outcomes to obtain the weight for each risk factor. **Factor analysis approach** – weights were generated for the risk factors using factor analysis. The approach enforces dimension reduction.

Results

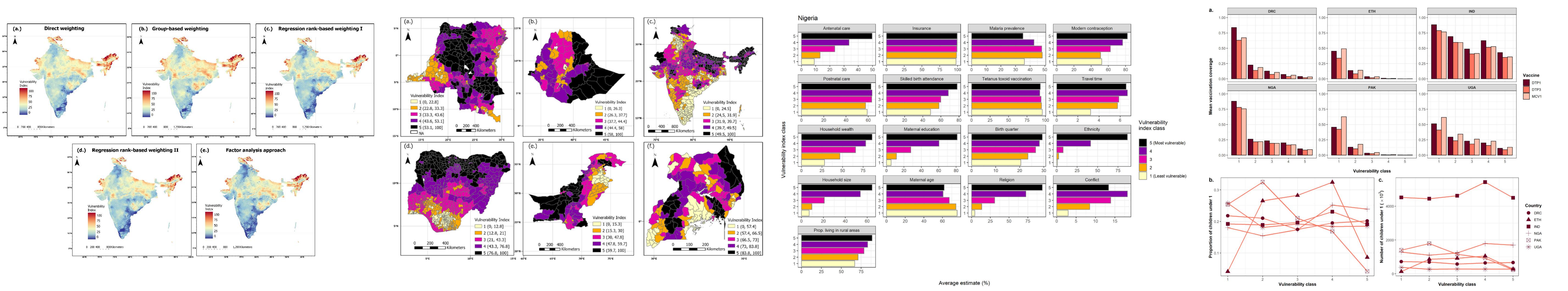

Fig. 2 (left – right): 1x1 km vulnerability index maps for India; District level vulnerability index maps for all six study countries; distributions of the risk factors within the vulnerability classes for Nigeria; and differences in vaccination coverage and under-1 populations among the vulnerability classes.

Summary and conclusion

- Different approaches for creating the index yielded similar results.
- The index had strong spatial patterns within countries.
- Vaccination coverage declined rapidly or gradually with increasing level of vulnerability.

Reference

C.E. Utazi *et al*: A zero-dose vulnerability index for equity assessment and spatial prioritization in low- and middle-income countries, *Spatial Statistics*, 57, 2023, https://doi.org/10.1016/ j.spasta.2023.100772.