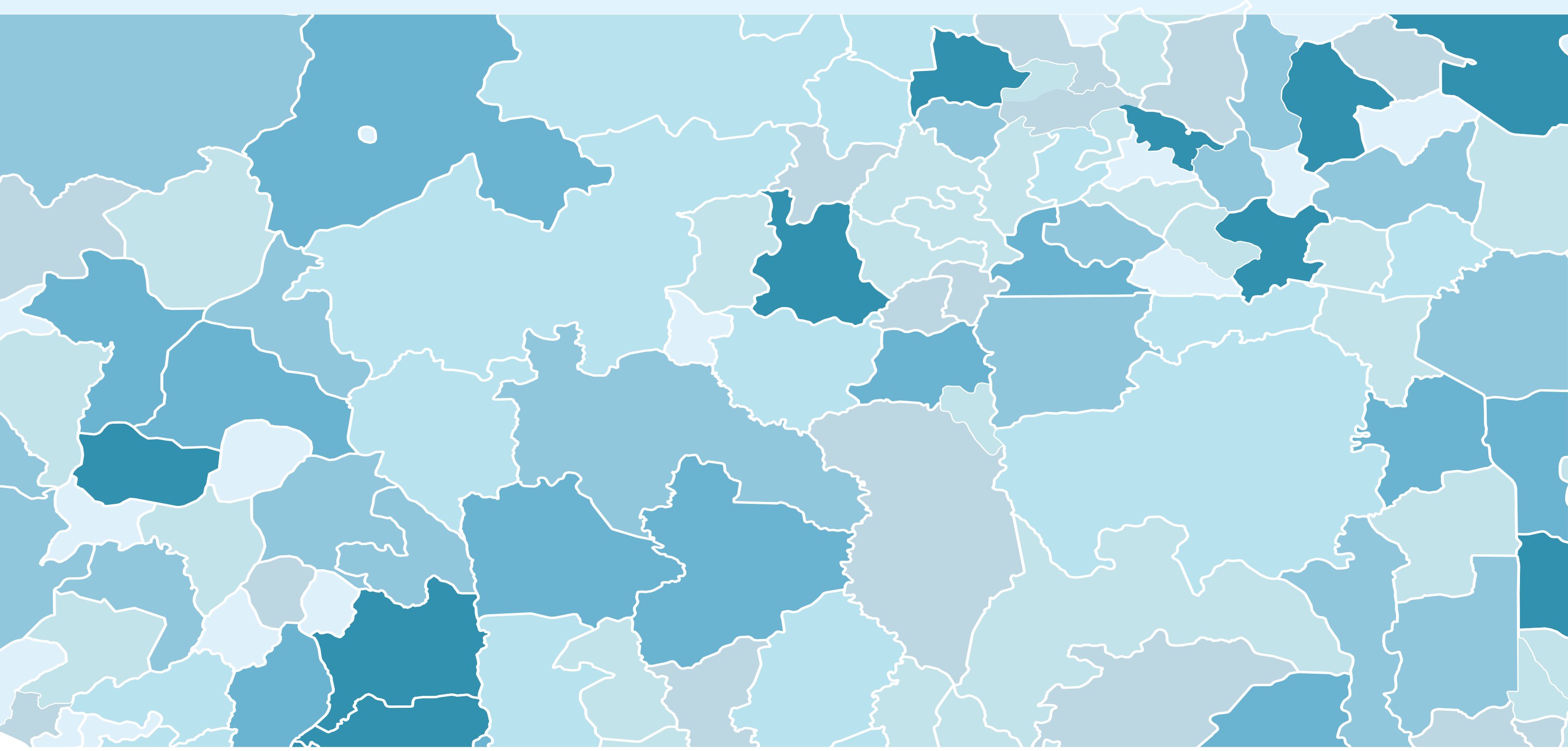
Explanatory Notes

Subnational under-five mortality trend series to 2019



United Nations Inter-agency Group for Child Mortality Estimation (UN IGME)
Member agencies: UNICEF, the WHO, the UN Population Division and
the World Bank Group

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The United Nations Inter-agency Group for Child Mortality Estimation (UN IGME), which is led by UNICEF and includes members of the World Health Organization (WHO), the United Nations Population Division, and the World Bank Group, was established in 2004 to advance the work on monitoring progress towards the achievement of child survival goals regarding child mortality. In 2020, UN IGME has been working on the first set of estimates of under-five mortality rates by subnational areas.

The methods used for the UN IGME subnational child mortality estimates are summarized in this document. Estimates by the UN IGME may differ from the official statistics by Member States, which may use alternative equally rigorous methods.

Subnational Estimation of Under-five Mortality: The BB8 Model

Estimating subnational variation in child mortality is of great importance to flag areas with high rates and to track progress towards targets such as the Sustainable Development Goals, which explicitly mention monitoring subnational child mortality. In the absence of vital registration systems, obtaining estimates at subnational levels—national level is denoted by Admin0, with increasingly granular subnational levels being denoted Admin1, Admin2, and so on—is a challenge, because the most reliable data come from household surveys, which are not generally designed to collect sufficient data to characterize under-five mortality rate (U5MR) at the Admin2 level, which is the level at which health interventions and decisions on resource allocation are typically made.

Subnational U5MR is estimated using a BetaBinomial sampling model with: 1. Cluster-level modeling, 2. Space-time smoothing, 3. Country-specific models, 4. Bayesian inference, 5. Overdispersion, 6. Benchmarking to UN IGME national estimates, 7 an HIV adjustment, and 8. Informative visualization. Hence, the model is referred to as BB8.

To overcome sparse data problems, U5MR is modeled at the cluster-level directly using a Bayesian space-time model. Subnational U5MR is estimated using household survey data from Demographic and Health Surveys (DHS), which typically use stratified two-stage cluster sampling with strata that are urban/rural crossed with some set of geographical (often Admin1) areas.

Mortality risk is assumed to be similar at locations that are close together because of shared risk factors, thus the risk of mortality is assumed to have spatial structure. The model contains spatial terms to account for such structure.

The betabinomial distribution is used in the model since it appropriately characterizes the binary outcome (non-death/death) distribution and has an additional parameter to accommodate overdispersion, also known as excess binomial variation.

For simplicity, we describe a model for deaths at a generic age. The model is,

$$Y_c \mid p_c \sim BetaBinomial(n_c, p_c, d), \quad \text{for} \quad c=1,\dots,C$$

where Y_c is the number of deaths out of n_c months at risk, and $p_c = p(s_c)$ is the probability of a death at location s_c for $c=1,\dots,C$ clusters. The parameter d allows for overdispersion and is related to the within-cluster correlation between the n_c different individuals in the same cluster.

The probability is modeled as,

$$p(s_c) = expit(\boldsymbol{\alpha} + S_{c[i]} + e_{c[i]})$$

where $S_{c[i]}$ and $e_{c[i]}$ are spatial and independent random effects, respectively, specified at the Admin2 level, which is indexed by i; the notation $c[i]$ here should be read as the Admin2 area i that cluster c resides in. Hence, all clusters in Admin2 area i receive the same random effects. The spatial terms are assumed to follow intrinsic conditional autoregressive (ICAR) model[1]. The latter is the most popular model for disease mapping in epidemiology, since it is straightforward to fit and has been shown in a multitude of studies to provide reliable estimates. The model is fit using the fast and accurate integrated nested Laplace approximation (INLA) approach[2].

Aggregation of the cluster probabilities to Admin2 area *i* is aided by the assumption of a constant spatial term within each Admin2 area. Specifically, the probability of a neonatal death in Admin2 area *i* is

$p_i = expit(\alpha + S_i + e_i)$

For the U5MR estimation over time, the model is more complex since it is necessary to consider how the risks change over time and with age, in addition to space.

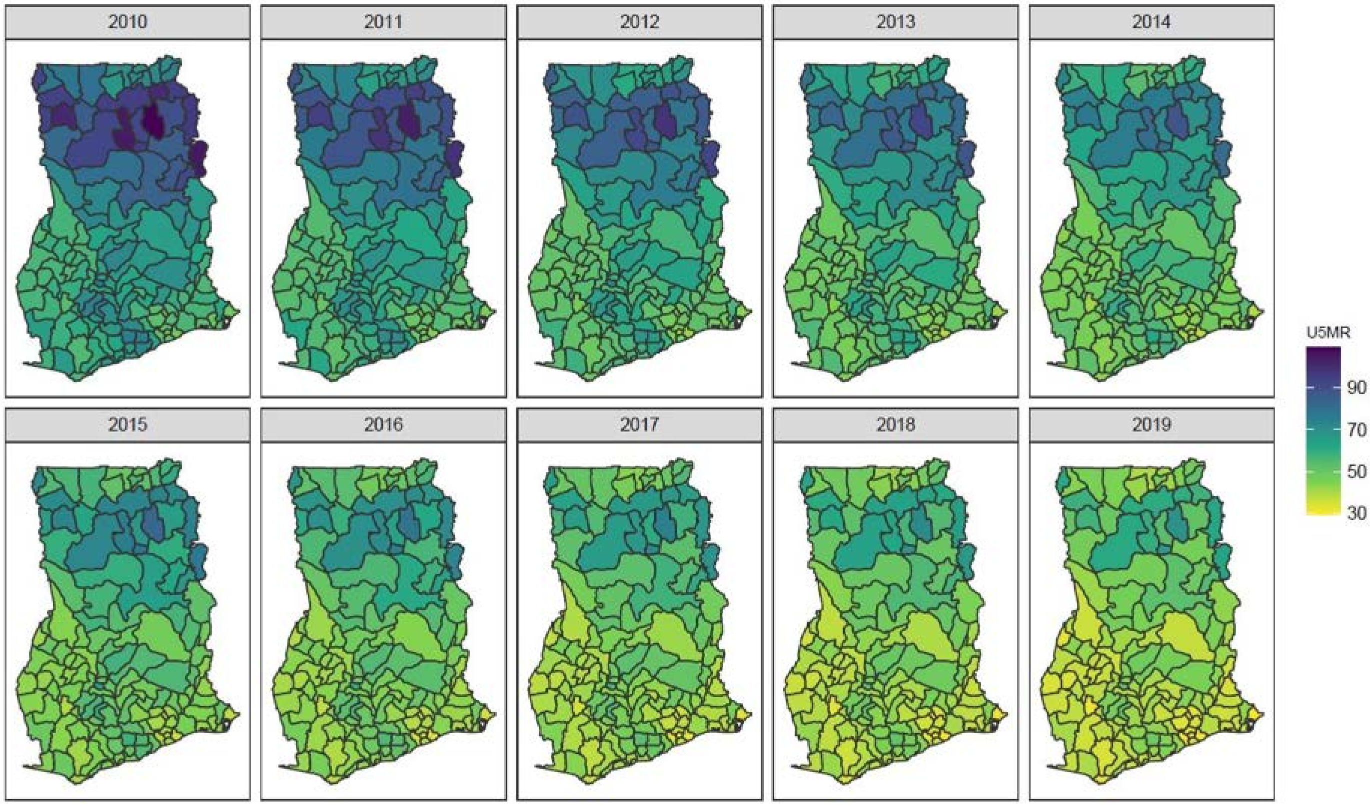
As with previous work[4,5], and as used by the DHS, a discrete hazards model is assumed with 6 hazards for each of the age groups (in months): 0-1, 2-11, 12-23, 24-35, 36-47, 48- 59. A flexible random walk of order 2 (RW2) as the main temporal term is also assumed, with separate random walks for the age groups 0-1, 2-11, 12-59. This model carries out local linear smoothing using the previous two time periods (which correspond to years in the model). For the main spatial term an ICAR model is assumed. We also assume a space-time interaction. Depending on the country, either a RW2 and ICAR model are combined, or an autoregressive of order 1 (AR1) model and an ICAR are combined. The RW2, ICAR and AR1 models are described in more detail elsewhere[6]. The interaction terms allow local deviations from the main spatial and temporal patterns.

Survey data are adjusted to account for mothers who have died from AIDS, and whose children are at greater risk of death using the same method used in the U5MR B3 model (See the explanatory notes 'Child and youth mortality trend series to 2019' for a description of the methods to generate national U5MR estimates with the B3 model (section 3) and a description of the HIV/AIDS adjustment (section 2.3)). In general, the B3 model uses more data (for example from censuses and vital registration systems, when available), thus the estimates are benchmarked to the B3 estimates at the national level, for consistency.

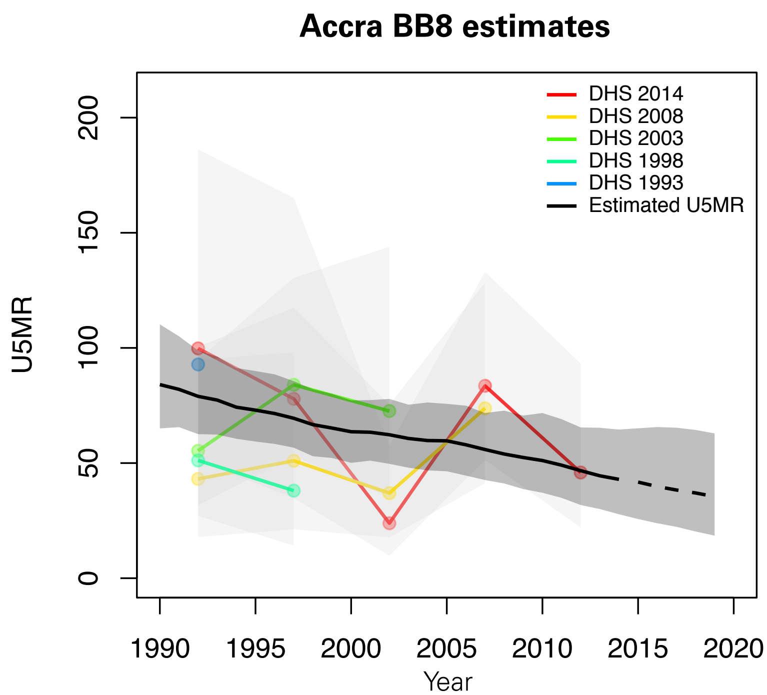
The model is fitted in the R programming environment using the SUMMER package. This link also contains vignettes that give full details on the space-time-age model.

There are numerous ways to present and visualize summaries of the Admin2 estimates over time. Figure 1 shows Admin 2 estimates and data three ways: the top panel shows Admin2 level U5MR estimates for Ghana 2010-2019 mapped for each year, the bottom-left panel shows the subnational data and estimates with uncertainty for Accra, and the bottom-right panel with a ridge plot showing U5MR in 2019 with uncertainty across all Admin2 areas of Ghana.

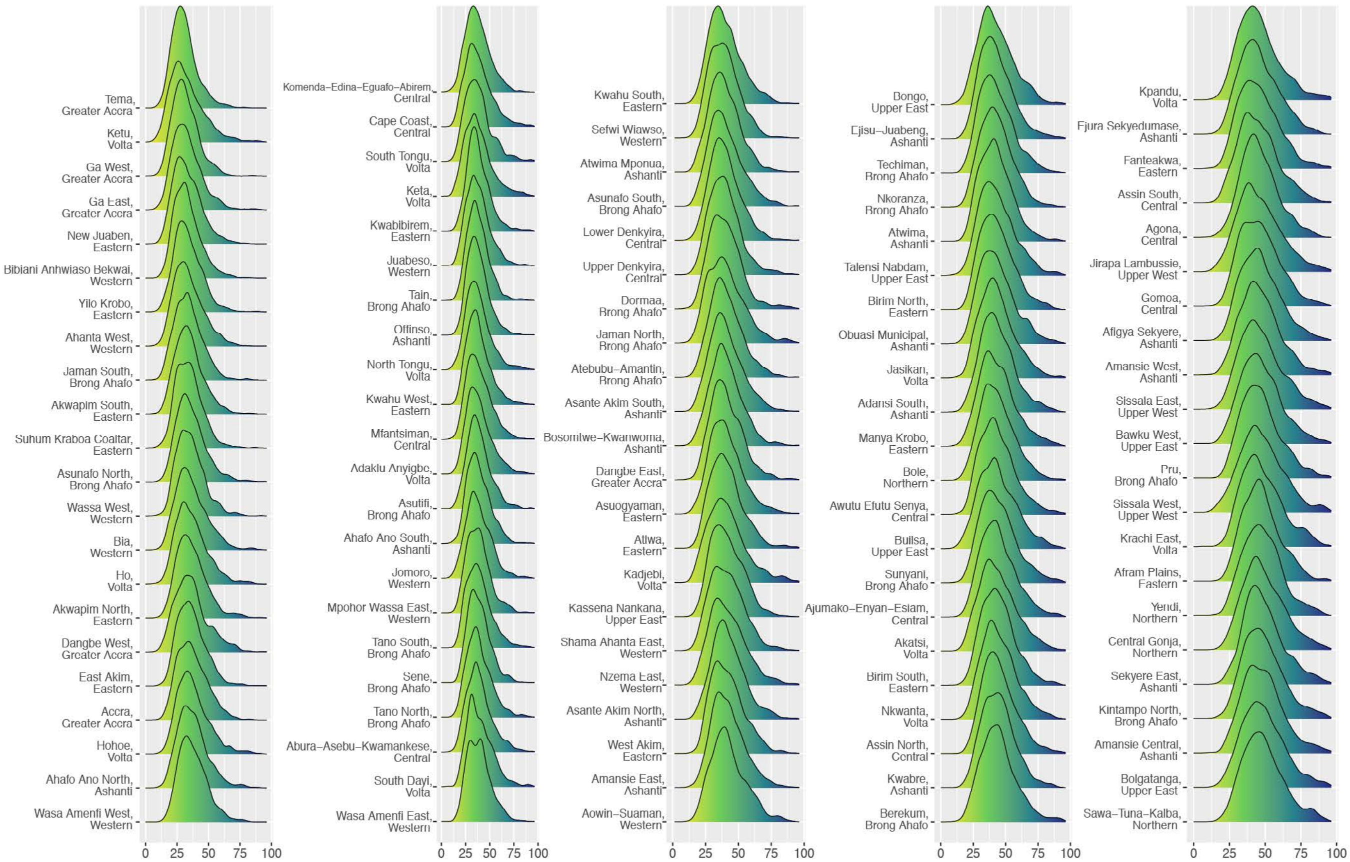
Figure 1: Subnational Admin2 area U5MR estimates for Ghana presented three ways.
1.1: Admin2 level U5MR estimates for Ghana 2010-2019 mapped by year



1.2: Subnational U5MR data and estimates with uncertainty for Accra



1.3: a ridge plot showing U5MR in 2019 with uncertainty across all Admin2 areas of Ghana.



References

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