

# Mapping the characteristics of un- and under-vaccinated children

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## Background

While there has been great success in increasing coverage of new childhood vaccines globally over the past decade, expanding routine immunisation services to reliably reach all children and communities has proven more challenging and certain populations remain un- or under-vaccinated in many low and middle income countries. Considering the high probability of transmission of vaccine-preventable diseases and occurrence of outbreaks among these populations, there have been continuous efforts in the health policy environment to design vaccination strategies and interventions that prioritize and target key at-risk groups. Policies and resource allocation decisions both globally and nationally regarding these marginalized populations need to be guided by the most current and robust evidence regarding their size, spatial distribution and other characteristics in countries of interest. The Equity Reference Group for Immunisation has identified remote-rural, conflict-affected and the urban poor as the most likely groups to be un- or under-vaccinated, and reaching each type of group to deliver vaccinations requires different strategies. However, estimates on how many children are in each group, their vaccination rates and relative distributions between and within countries have been scarce, limiting robust resource allocation, strategy design and targeting.

Here, we present outputs from the integration of a range of geospatial datasets to build a global subnational evidence base on the distributions and numbers of children not receiving vaccine doses. Given available data and capacity, we focus on children under 1 year of age in 2019 not receiving the first and third doses of the diphtheria, tetanus toxoids and pertussis (DTP1, DTP3) and also the first dose of the measles containing vaccine (MCV1). We explore where these children not receiving DTP1/DTP3/MCV1 reside, focussing on remote-rural, conflict-affected, and urban and peri-urban areas. Moreover, we look at the relative proportions and numbers of these key populations, both within and between countries.

## Data and research methods

Estimates of the number of children under the age of one, at the 1x1 km grid square scale, were obtained from WorldPop for 2019 (Worldpop, 2020). To estimate the numbers of un- and under-vaccinated children under the age of one, vaccination coverage (VC) rates for DTP1, DTP3, and MCV1, were obtained from the Institute for Health Metrics and Evaluation (IHME) (Sbarra A. et al, 2020), also for 2019, and the following calculation used:  $(1-VC) \times PU1$ , to estimate the numbers of un- and under-vaccinated children under the age of one at the grid square level. These were then summarised at the second subnational level (adm2), using the database of Global Administrative Areas (GADM) (GADM, 2020).

The GHS-SMOD Global Human Settlement Layer (Global Human Settlement Layer, 2020) was used to identify un- and under-vaccinated children under the age of one, living in urban and peri-urban areas. The rural grid square classification was then used, also from the GHS-SMOD Global Human Settlement Layer, along with estimates of travel-time to the nearest town/city of 50,000 people or more (Weiss et al (2018)), to define un- and under-vaccinated children under the age of one, living in remote-rural areas, defined as a travel-time of more than 180 minutes. These were also summarised at the second subnational level (adm2), using the GADM administrative boundaries. We then additionally explored

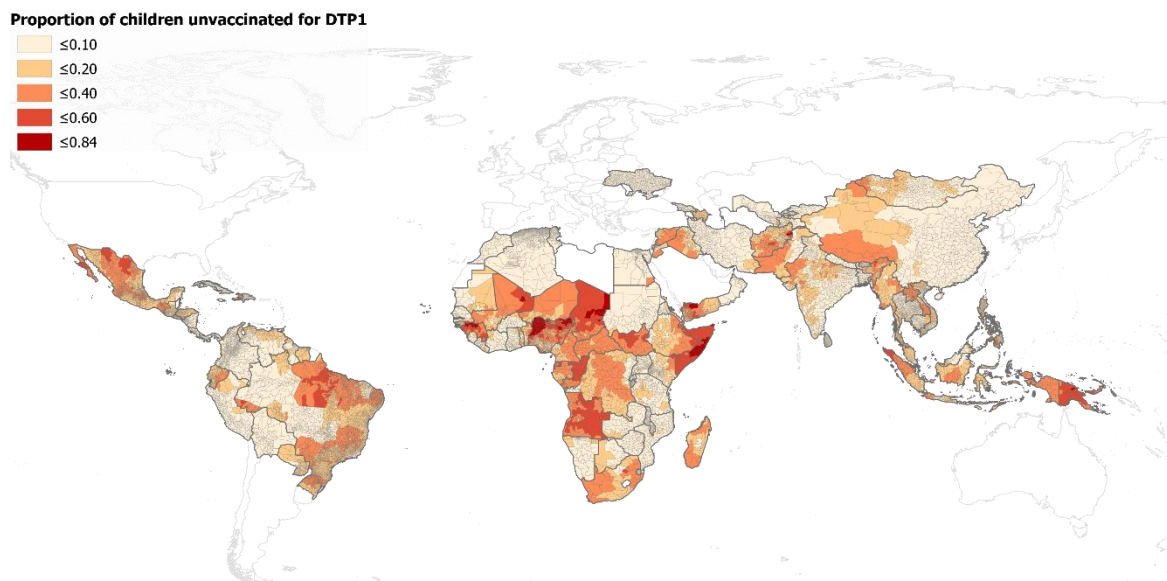
the numbers of unvaccinated children living in rural non-remote areas, within 0 to 60, 60 to 120, and 120 to 180 minute categories.

To estimate the numbers of un- and under-vaccinated children under the age of one living in conflict affected areas, we used geolocated conflict locations from the Armed Conflict Location & Event Data Project (ACLED) (ACLED, 2020), for conflicts resulting in violent deaths, two years prior to 2019, and resulting in at least one fatality. Conflict affected areas were defined at the adm2 level, using the GADM administrative boundaries. Through consultation with experts at GAVI and WHO, this was refined further, using a threshold of at least 30 fatalities per 1 million people and at least 300 fatalities per 1 million people, to establish broad and narrow definitions of conflict, respectively.

## Results

We found that substantial heterogeneities existed in 2019, both between and within countries, in terms of the breakdowns of the characteristics of the children not receiving DTP1/DTP3/MCV1 and their distributions. These differences varied by vaccine dose and the characteristics the population, though also in the spatial distributions of those unvaccinated.

Substantial spatial variations were found across the countries, with the vast majority clustered within small areas for some countries and more equally spread in others (figure 1). These distributions show strong similarities between the three vaccine-dose combinations examined. Differences were seen however, with those not receiving DTP1 more concentrated in urban areas than DTP3 and MCV1, and children not receiving MCV1 relatively more concentrated in conflict-affected areas.



*Figure 1. Proportions of children under 1 years of age in 2019 at administrative level 2 estimated to have not received (top) the first dose of the DTP vaccine.*

Based on both the broad and narrow definitions of conflict, we identified 51 or 32 countries respectively, with conflicted-affected districts, and around 6% (narrow definition) or 15% (broad definition) of children not receiving DTP1 living in conflicted affected settings in 2019. Table 1 shows the percentage breakdown of children not receiving DTP1/DTP3/MCV1, by category, for all countries experiencing conflict, based on the broad definition of conflict.

	PU1 in conflict (broad)	Unvaccinated PU1 in conflict (broad)	% unvaccinated PU1 in conflict (broad) from total unvaccinated	Unvaccinated PU1(% of total) in conflict (broad)			
				Urban	Peri-urban	Rural (remote)	Rural (non-remote)
DTP1	10,818,029	2,068,785	14.74	11.12	3.94	22.73	62.20
DTP3	10,818,029	3,851,618	16.55	11.31	3.87	22.69	62.13
MCV1	10,818,029	3,658,501	18.08	12.22	3.97	21.71	62.10

*Table 1. Estimated population under 1 year old (PU1) and proportions residing in the different settings studied.*

Over 11% of children that had not received DTP1/DTP3/MCV1 lived in remote-rural areas that are more than 3 hours travel time from the nearest town or city, while more than 19% live in urban areas and more than 7% in peri-urban areas, with the largest numbers of children living in remote-rural locations that have not received DTP1/DTP3/MCV1 in DR Congo and Ethiopia. However, across all countries, up to 60% of children that have not received DTP1/DTP3/MCV1 are estimated to live in settings other than urban, peri-urban or remote-rural, with around 40% of these estimated to be living within 1-hour of the nearest town or city.

## **Discussion**

The analyses outlined have focussed on quantifying and mapping un- and under-vaccinated children in specific settings across all low and middle income countries, bringing together a variety of disparate geospatial datasets to capture the distributions of children, vaccination coverage rates, urban and peri-urban areas, remote-rural locations, and conflict affected locations. Each of these datasets have their own strengths and weaknesses, and simple decisions have been made throughout in terms of how to define categories, presenting some uncertainty in the estimates produced.

Whilst the numbers presented are largely based on expert opinion derived thresholds to determine, e.g. what is classed as 'remote', how to define 'urban' or 'rural', and what level of conflict is significant, the datasets feeding into these decisions are typically continuous in nature and/or alternative sources are available, the choice of threshold naturally effects the estimates produced. For example, defining what is 'urban' or 'rural' represents an ongoing challenge, with a wide variety of datasets and definitions existing, and governments often establish their own definitions for census and other purposes, creating substantial inconsistencies between countries. There is however much scope in exploring the sensitivity of these definitions, involving the adjustment of threshold values, and comparison of alternative datasets, to examine how large an effect each has on the estimates of un- and under-unvaccinated children across all categories.

Future work could also examine the quantitative relationships between the different thresholds and definitions of urban, remote-rural, conflict, and vaccination coverage, to assess the sensitivity of the different definitions and threshold used with regards to vaccination coverage. As well as the incorporation of additional datasets, for example travel-time to the nearest facility, which may be a more relevant measure in assessing the effect of travel-time on vaccination coverage.

However, despite the inherent uncertainties in the definitions and thresholds adopted, we present the first global sub-national evidence base of estimates on the distributions and numbers of children not receiving vaccine doses, providing valuable guidance to better inform global vaccination strategies and interventions that prioritize and target those key at-risk groups.

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