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Geospatial disparities in maternal and newborn health indicators across 62 conurbations in 33 sub-Saharan African countries

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Abstract

Background: Maternal and perinatal mortality remains high in sub-Saharan Africa, where population growth in cities is outpacing healthcare services expansion. Urban maternal and newborn care is usually monitored through national urban-area averages, which may hide differences between cities. We examined variation in maternal and newborn healthcare across 62 conurbations (core cities and surrounding peri-urban areas).

Methods: We used Demographic and Health Survey data on 20,104 livebirths from surveys conducted after 2010 in 33 sub-Saharan African countries. We assessed six indicators of utilisation, content and continuity of care: at least one and at least four antenatal care visits, facility-based childbirth, caesarean section, postnatal check within 48 hours, and newborn weighing. We estimated indicators at conurbation and national urban levels, assessed continuity as the relative loss between successive stages of care, and summarised the patterns in a seven-category typology.

Results: Coverage varies widely between conurbations, including within countries: in 51 of 62 conurbations, the national urban average falls outside the conurbation confidence interval for at least one indicator. A first antenatal visit is near universal, but coverage falls between the first and fourth visits and between facility-based childbirth and postnatal check. Caesarean section rates range from 1% to 32%, and newborn weighing varies most. The typology classes 20 conurbations as high or highest coverage, five as consistently low and 37 as inconsistent.

Conclusions: Measuring maternal and newborn care at conurbation level and summarising it in a typology shows where urban care falls short. Targeting the specific gaps in each conurbation can guide health system action.

Plain language summary

Many women and babies in African cities still die from causes that could be prevented by good quality care during pregnancy, childbirth and the days after birth. Healthcare system planners usually rely on average figures for all urban areas in a country, which can hide large differences between cities. We used national household surveys to look at the care received by women and babies in 62 large urban areas, including their fast-growing surroundings, across 33 sub-Saharan African countries. Most women saw a health worker at least once during pregnancy and gave birth in a health facility, but many missed completing at least four checks with a provider during pregnancy visits or a check after birth. Coverage levels differed a lot between cities, even within the same country. Knowing where each city falls short can help target improvements where they are most needed.

Introduction

Historically, urban areas in sub-Saharan Africa (SSA) have enjoyed various advantages in economic development and health compared to rural areas [1–6]. This includes infrastructure, tarmacked roads, major health facilities, piped water, electricity, educational and financial institutions. Consequently, urban residents have historically exhibited better health outcomes than their rural counterparts, the so-called urban “health advantage” [1–6]. It partly drives rural-to-urban migration leading to population and geographic expansion of cities by incorporating neighbouring suburbs, towns and previously non-urban areas [2], giving rise to “conurbations” [7]. Two-thirds of the world’s population will live in urban areas by 2050 and the fastest rates of urbanisation are in Africa and Asia where about 90% of the additional 2.5 billion urban residents will reside [8]. Africa’s population will triple by 2050, and by 2100, the world’s biggest cities will be concentrated there [9].

However, the health and social service provision and planning in urban areas do not match the degree of urbanisation in SSA [3, 10]. Urban areas in this region are characterised by haphazard development, leading to growth of informal settlements. In 2020, 51% of the urban population in SSA lived in slums, ranging from 11% in Eswatini to 94% in South Sudan [11]. Poor sanitation, lack of access to clean water, long travel times to healthcare, financial and social barriers disproportionately affect residents of suburbs and peri-urban areas, with negative consequences on maternal health outcomes [12–15]. Wide socioeconomic disparities drive inequalities in healthcare coverage and outcomes, leaving urban areas with both the best and worst health outcomes; highly specialised private care is beyond the reach of the poor and overwhelmed public services are unable to meet growing demand.

Consequently, the urban health advantage is diminishing or reversing in parts of SSA. Neonatal mortality no longer differs between rural and urban areas in most SSA countries [16], and in Tanzania, it is higher in core urban areas [16, 17]. Gaps in child and adult mortality by residence are narrowing [4, 18]. These trends underscore the importance of better understanding health dynamics in urban settings.

This comes at a time when SSA disproportionately bears the highest maternal mortality ratio (MMR) globally at 454 deaths per 100,000 livebirths, accounting for 70% of all maternal deaths (182,000) in 2023. Despite a 40% reduction in MMR between 2000 and 2023, progress has slowed significantly since 2016 [19]. About 47% of the 3.04 million stillbirths occur in SSA, with a high perinatal mortality rate of 46.6 per 1,000 total births [20, 21]. MMR in urban hospitals can be high, as they treat complicated cases, receive late referral and cover large catchment areas [22–26].

Pregnant women access two broad kinds of maternal health services: planned outpatient care services such as antenatal care (ANC), and unscheduled urgent care including childbirth and management of obstetric complications. Ensuring that women and babies receive care across the full recommended continuum - covering pregnancy, childbirth through the postnatal period - is central to reducing maternal and newborn mortality [27, 28]. A functional urban health system must ensure that this range of services is available (acceptable, accessible and affordable) to all women within a high-quality "maternal health service package" [29]. Yet evidence from SSA consistently shows substantial drop-off across this continuum at national level [27, 28, 30]. A comprehensive picture of how this pattern varies across conurbations remains absent.

Several studies have assessed maternal healthcare utilisation in urban SSA, either by combining all urban areas into a single unit within a country [31], or analysing cities independently [4, 32]. Amouzou and colleagues assessed the coverage and inequalities of reproductive and child health indicators in 51 capital or large cities [4] showing that coverage inequalities are narrowing while capital cities lose their primacy, reflecting a gradual erosion of their advantage. However, the analysis did not disaggregate coverage by indicator and relied on country-specific urban definitions inadequate for multi-city comparison [33]. Similar analyses of the 38 most populated cities documented persistent wealth-related inequalities in maternal and newborn health coverage, characterising the urban poor as a heterogeneous population whose disadvantage is inadequately captured by city-level averages [34, 35]. Wong and colleagues assessed coverage and content of maternal care in 22 large African cities [32], finding no shared utilisation patterns across better performing cities.

Studies of individual cities offer further insights into the barriers women face [15, 36, 37]. Spatial and socioeconomic inequalities in caesarean section were seen in Dakar [38], and inter-district wealth-based disparities in maternal and child health coverage in Addis Ababa [39]. In Lusaka, inequalities concentrated in unplanned settlements [40], while in Bamako, coverage gains did not extend to content of care, with notable drop-off across the continuum [41]. In Dar es Salaam, the poorest faced high child mortality despite relatively high intervention coverage reflecting an urban penalty that persists even where provision seems adequate [42]. Collectively, these studies demonstrate that city-level

averages mask substantial intra-urban heterogeneity, populations in peri-urban areas and informal settlements remain disproportionately underserved, and gains in coverage guarantee neither optimal care continuity nor quality.

Despite this growing body of evidence, key gaps remain, mostly concerning how urban populations are defined and compared across space. Existing studies rarely document heterogeneity between cities within a country, and where variation is examined, analyses are typically confined to the largest or capital cities leaving the full extent of variation across SSA conurbations uncharacterised. This matters for policy: since city governments bear responsibility for health system performance in their jurisdictions, national governments can use city-level estimates to target resources and cities in similar policy environments can benchmark against each other. Studies also seldom treat the core city together with its peri-urban and suburban surrounding as a single functional unit - a conurbation. Commonly used boundary definitions are overly simplistic, and prone to misclassification [33], because historical administrative boundaries rarely align with where people live and seek care [43], whereas a conurbation-based approach better represents metropolitan populations and health system performance [33, 44, 45]. No study has presented conurbation-level and national urban estimates side by side to assess whether national averages conceal between-conurbation variation.

Two further gaps concern how these estimates can be interpreted and used. First, no study has traced the sequential loss in care continuity, from ANC through facility-based delivery to postnatal care, across multiple SSA conurbations, leaving the extent and pattern of drop-out at this scale uncharacterised. Second, city performance has so far been described only in broad categories [32]; a more granular descriptive typology could reveal patterns those categories obscure.

In this study, we used data from the most recent Demographic and Health Surveys (DHS) to estimate the coverage of six maternal and newborn indicators spanning utilisation, content and continuity of care across 62 conurbations in 33 SSA countries. This descriptive study had three objectives: to describe coverage across conurbations alongside national urban averages, to characterise loss along the continuum of care, and to summarise coverage patterns in a more granular typology than previously available. We show that coverage differs widely between conurbations, including within countries; that losses along the continuum of care are concentrated between the first and fourth antenatal visits and between facility-based childbirth and the postnatal check; and that inconsistency across indicators, rather than uniformly low coverage, is the most common pattern.

Results

Descriptive statistics

We included 33 countries and 62 conurbations (ranging from one to 11 conurbations per country; 13 countries had two or more conurbations). Eight surveys were conducted between 2012 and 2015, 16 between 2016 and 2020, nine between 2021 and 2024. The number of DHS clusters per conurbation ranged from six (Djougou and Lubumbashi) to 177 (Nouakchott). There were 20,104 live births across 2,556 clusters, ranging from 105 (Port Harcourt) to 876 (Cotonou) per conurbation.

Maternal and newborn indicators across 62 conurbations

Table 1 and **Supplementary Table 1** show the six indicators, characterised and compared across the 62 conurbations. Overall, ANC1+ had both the highest levels and the smallest variability across conurbations; the median across conurbations was 98% with 46 (74%) conurbations exceeding 95%. The lowest (71%) was in Maiduguri (Nigeria) and

the highest ~100% in four conurbations - Bobo-Dioulasso (Burkina Faso), Kumasi (Ghana), Lilongwe (Malawi), and Kitwe (Zambia). The median ANC4+ was substantially lower than ANC1+ at 72% (range 37% to 97%). The smallest relative drop in the ANC continuum, calculated as the percentage lost relative to the preceding indicator, was in Kumasi and Tamale (Ghana 3% each). One third of the conurbations (n=21) had a relative loss of more than 30% with the highest loss of 62% in Djougou (Benin).

FBC had a median of 94% across the conurbations. Three conurbations in Northern Nigeria had levels <50% (Sokoto, Kano and Maiduguri). The percentage of births by CS ranged from 1.4% to 32%, with a median of 11%. Levels ≤5% were present in nine of the 62 conurbations. CS rates were generally lower in West African conurbations than elsewhere, even where FBC was high, while East and Southern African conurbations showed higher and more variable CS rates. The median percentage of women receiving PNC48 was 72%, ranging from 22% in Cabinda (Angola) to 93% in Accra (Ghana). Newborns weighed showed the widest variability among the six indicators across the 60 conurbations where this indicator was measured; it ranged from 18% in Sokoto (Nigeria) to >95% in 14 conurbations, with a median of 91%.

PNC48 matched or exceeded FBC in only six conurbations. The largest difference was in Cabinda (Angola) where 88% of births occurred in a health facility but 22% of women reported PNC48 (75% relative loss). However, newborn weighing was at or above FBC levels in 21 of the 60 conurbations where this indicator was collected, and within 2% of FBC in 10 additional conurbations. The highest relative loss among conurbations with less than 10% missing data was in Aba (Nigeria), where 84% of births occurred in facilities but 51% of newborns were weighed (39% relative loss), with similar losses in Sokoto, Kano and Maiduguri. Nouakchott and Monrovia showed larger apparent losses, but over 30% of their responses were missing or "don't know" (**Supplementary Data 1**)

Typology of conurbations across indicators

Expanding the typology of Wong et al., [32] we classified conurbations into seven categories using five indicators (ANC1+, ANC4+, FBC, PNC48 and newborn weighed; CS was assessed separately) (**Table 2**). Eight conurbations had the highest coverage and were concentrated in West and Central Africa (Cameroon, Gabon, Burkina Faso, Ghana) and East Africa (Kenya, Ethiopia); no Southern African or Nigerian conurbations reached this category. Twelve conurbations had high coverage (all indicators medium or above), and five had low coverage with no indicator high or highest (Sokoto, Uyo, Abuja, N'Djamena, Maiduguri). Among these five, continuity of care was at or above the median in the majority, despite low absolute coverage levels. The remaining 37 conurbations had inconsistent coverage across the five indicators. Given that this was the category with the highest number of conurbations, we further examined the patterns of inconsistencies. In 23 of the 37, this was due to a single low-scoringindicator or pair (eleven low ANC4+, six low PNC48, six low FBC , and/or newborn weighed). The remaining 14 conurbations had two or more low scoring indicators alongside higher-scoring ones.

Table 2. Typology of conurbations across five key maternal and newborn health indicators. Conurbations are classified into seven categories based on the levels of five indicators in Table 1. Categories range from highest to lowest coverage, with four inconsistent sub-classes reflecting which specific indicator was relatively lower. ANC1+, at least one antenatal care visit; ANC4+, at least four antenatal care visits; FBC , facility-based childbirth; PNC48, postnatal check within 48 hours by a skilled provider; CS, caesarean section.

Category	Conurbation	Potential for improvement based on continuity and content (CS levels)
Highest coverage All indicators are high or highest levels (green in Table 1)	**Eight conurbations:** Douala, , Kumasi, Bafoussam, Libreville, Nairobi/Ruiru, Yaounde, Bobo-Dioulasso, Addis Ababa	Five of the eight conurbations had a >20% relative drop between FBC and PNC48
High coverage All indicators are medium or above, with at least one medium (a mix of green and blue in Table 1)	**12 conurbations:** Bulawayo, Abidjan, Maseru, Mombasa, Accra, Tamale, Dakar, Banjul, Ouagadougou, Lome, Cotonou, Zanzibar	Four of the 12 conurbations had a >20% relative drop between FBC and PNC48 Five of the 12 conurbations had a >5% relative drop between FBC and newborn being weighed
Inconsistent (low ANC4+) relative levels among the 5 indicators (green/ blue mixed with brown in Table 1), with **ANC4+** the only indicator low or lowest	**11 conurbations:** Niamey, Kigali, Windhoek, Lusaka, Kitwe, Kisumu, Bujumbura, Conakry, Johannesburg, Kampala, Djougou	Drop between ANC1+ and ANC4+ was the biggest issue. Followed by relative drop between FBC and PNC48 (5 conurbations) and FBC and newborn being weighed (one conurbation). One conurbation (Conakry) had both issues (PNC48 and newborn).
Inconsistent (low PNC48) relative levels among the 5 indicators (green/blue mixed with brown in Table 1) with **PNC48** the only indicator low or lowest	**Six conurbations:** Harare, Kinshasa, Mbuji-Mayi, Dar es Salaam, Maputo, Dire Dawa	Drop between FBC and PNC48 was the biggest issue in these conurbations (none of them had an issue with drop between FBC and newborn weight). One conurbation had CS ≤5% (Mbuji-Mayi).
Inconsistent (low FBC and/or newborn weighed) relative levels among the 5 indicators (green/blue mixed with brown in Table 1) with only **FBC** coverage and/**or newborn weighed** low or lowest	**Six conurbations:** Monrovia, Antananarivo, Enugu, Onitsha, Bamako, Ibadan	Low relative FBC rates (<80%) and/or high relative drop from FBC to newborn weighed.
Inconsistent: (**multiple low indicators)** relative levels among the five indicators (green/blue mixed with brown in Table 1)with two or more indicators low or lowest, not limited to FBC and newborn weighed	**14 conurbations :** Benguela, Cabinda, Huambo, Luanda, Malanje, Lubumbashi, Blantyre, , Lilongwe, , Aba, Kano, Nouakchott, Lagos, Port Harcourt, Freetown	Most conurbations had issues in both retention from ANC1+ to ANC4+ and from FBC to PNC48/newborn weighed. Half additionally had poor FBC levels. Five of these conurbations had CS ≤5%.
Low coverage: Low relative levels **on most** indicators, with none high or highest (mix of blue-brown in Table 1)	**Five conurbations:** Sokoto, Uyo, Abuja, N'Djamena, Maiduguri	Low level across multiple indicators. However, retention in ANC continuum was median or higher in three conurbations, in FBC -PNC48 continuum in four conurbations, and in FBC -newborn weighed in one.

Within-country variation between conurbations

We examined the levels across indicators between conurbations *within* countries and relative to national urban average using equiplots (**Supplementary Figure 1; Figure 1 shows Nigeria as an example**). Across all 62 conurbations, the national urban average fell outside the conurbation 95% confidence interval for at least one indicator in 51 conurbations (39 when requiring non-overlapping confidence intervals), and differed from the conurbation estimate by 10 percentage points or more in 34 conurbations. By indicator, the national urban average fell outside the conurbation

interval in 29 conurbations for ANC4+ and FBC, 27 for newborn weighed, 22 for PNC48, 19 for CS and 18 for ANC1+ (**Supplementary Table 1**).

In 16 of the 33 countries, there was minimal variation between conurbations and the national urban average across all indicators (**Supplementary Figure 1**). In Ethiopia, Addis Ababa had higher levels than Dire Dawa and the national urban average on most indicators. In Madagascar and Mozambique, the single included conurbation had higher levels than the national urban average in all indicators, as did Maseru in Lesotho on most indicators (**Supplementary Figure 1**). In Zimbabwe, the largest conurbation (Harare/Chitungwiza) had lower coverage than the included secondary conurbation (Bulawayo) and the national urban average across most indicators. In Nigeria, Lagos consistently had higher levels than the national urban average, but several secondary conurbations had higher levels across most indicators (**Figure 1**). In South Africa and Sierra Leone, the national urban average for ANC4+ was higher than the largest conurbation. Differences between conurbations in the same country reached up to 40 percentage points (ANC4+: 77% in Cotonou vs 37% in Djougou, Benin). Even where conurbations were similar, the national urban average could misrepresent them: in Ethiopia, FBC was 96% in both conurbations against a national urban average of 73% (**Supplementary Table 1**)

ANC1+ showed the least within-country variability, except in Ethiopia. Little within-country variability in the FBC and newborn weighed was observed, except in Angola, Benin, Chad, Ethiopia, and Madagascar. ANC4+ and PNC48 showed the highest within-country variability between conurbations (for example in Benin, Malawi, and Kenya).

Sensitivity analysis

Estimates were robust to the handling of missing and "don't know" responses (except newborn weighed in some conurbations), typology assignments were broadly stable (seven conurbations reclassified, all to a higher-coverage category; Supplementary Note 2), and estimates were closely concordant with aligned sampling-stratum estimates (**Supplementary Data 1 and 2; Supplementary Table 2; Supplementary Figure 2**). Across the conurbations aligned with a DHS sampling stratum, median absolute differences ranged from 0.2 to 0.9 percentage points by indicator and 95% confidence intervals overlapped in 27 to 30 conurbations per indicator; the few larger differences were in merged multi-town conurbations such as Benguela and Lobito, where the functional boundary and the sampling stratum enclose different populations. Full sensitivity analyses are in **Supplementary Note 1**.

Discussion

We estimated levels of six maternal and newborn indicators of utilisation, content and continuity of care for 62 conurbations across 33 SSA countries home to over 1.2 billion people. National urban averages concealed substantial variation between conurbations, including within the same country; therefore, the urban population of a country should not be assumed to be a single unit when planning maternal and newborn care. These findings offer a descriptive basis for identifying heterogeneity that may inform policy and research priorities for urban maternal and newborn health systems. We advanced previous analyses in several ways [4,32]. Conurbations combined core urban and peri-urban areas, defined from objective satellite data [44–46] to better capture the lived experiences of women seeking care in urban settings [25]. We included all SSA conurbations meeting data and sample size criteria, enabling comparisons across and within countries, and expanded an existing typology [32] to classify conurbations by coverage.

The spatial unit of analysis shapes which disparities become visible and whose experiences are counted. Women in peri-urban and suburban spaces are often obscured in national urban averages, yet our findings show that urban maternal and newborn care is far from uniform across conurbations. The national urban average therefore serves only as a contextual comparator, since some conurbations include DHS rural clusters that were functionally urban based on

satellite-imagery, reflecting women's lived experiences in these spaces. We unpack these patterns and their implications below.

Across the 62 conurbations, ANC1+ showed the highest, near-universal coverage and the least variability, consistent with evidence from across SSA [32,47,48]. Despite this, poor care continuity was evident: in about one-third of conurbations, coverage dropped by more than 30% (relative) between ANC1+ and ANC4+. This likely reflects the greater logistical and time demands of four visits, financial barriers, limited decision-making autonomy and late initiation of ANC [32,49,50].

PNC48 coverage fell below FBC in most conurbations, indicating gaps in the continuity of care between birth and the early postpartum period. For women who gave birth outside a facility, PNC48 depends on outpatient or community-based services and is more sensitive to both supply-and demand-side factors, including avoidance of care after previous negative experiences [51,52]. For women giving birth in a facility, a postnatal check before discharge is standard care; its absence most plausibly reflects deficiencies in the content and quality of facility-based care rather than suboptimal care-seeking. Although PNC48 does not distinguish checks before and after discharge, most women in these conurbations gave birth in facilities, so the relative drop from FBC is most likely driven by inadequate immediate postnatal care within facilities.

Newborn weighing diverged from PNC48: it remained at or near FBC level in about half of the conurbations, likely because weighing occurs at childbirth and requires no additional contact or provider time, whereas PNC48 requires a separate check in the ward. Together, these patterns point to gaps in the organisation of immediate postnatal care within health facilities, gaps that mostly disadvantage the woman.

Wide variations in CS rates, from potential underuse in ten conurbations with rates ≤5%, to levels suggestive of overuse in several conurbations, highlight the complexity of interpreting this indicator at population level, reflecting private sector availability, inequalities in access and affordability and differing clinical practices [53–56]. CS rates were generally lower in West African conurbations than in East and Southern Africa, even where FBC was high (Ghana being a notable exception), suggesting that operative capacity varies by region, independently of facility delivery rates. Cultural acceptability of CS may also play a role [57].

We expanded the three-category typology of Wong et al. [32], to add sub-categories within the "inconsistent" category, giving a more granular view of the specificity and direction of inconsistencies. Based on descriptive differences across conurbations, Kumasi (Ghana) and Douala (Cameroon) were among those with the highest coverage, while Sokoto and Maiduguri, both in Nigeria, had the lowest across all five indicators. Consistent with Wong et al., we found Cotonou and Accra among highest coverage-conurbations and N'Djamena among the lowest[32]. Secondary conurbations did not consistently have lower coverage than the largest or capital city in the same country.

One-third of conurbations fell into the highest- or high-coverage categories. Most are capital cities or among the largest urban areas in their countries, and about half are located in West Africa. What distinguishes these settings from others, including capital city status, health system investment, or national policy, warrants further investigation through an exemplar, context specific study [36].

However, differences in levels between conurbations across countries were more pronounced than differences between conurbations of different sizes within the same country. This suggests that national-level factors, such as health policies, financing (e.g., removal of user fees), and health system organisation, may play a larger role in shaping maternal health indicators, while city-specific characteristics, such as population size, lifestyle and environmental exposure, or capital city status appear less influential within a given country. This is further supported by our finding that, in some countries with multiple conurbations, the largest or capital city did not consistently have higher coverage

than secondary conurbations or the national urban average. These findings align with and extend those of Amouzou et al [4] on the erosion of the capital city advantage and suggest that national policies and health system strengthening efforts may be especially important for improving maternal health coverage across conurbations.

Abuja, Maiduguri, Sokoto, and Uyo (Nigeria), and N'Djamena (Chad) had low levels on most indicators, with none high or highest. The low levels in Maiduguri and Sokoto are consistent with the well-documented low uptake of maternal healthcare there, aggravated by conflict, displacement, and natural disasters [58–60]. The contrast between conurbations illustrates heterogeneity that would be invisible in national or regional estimates. N'Djamena, the only Chadian conurbation, showed similarly low levels, likely reflecting challenges within Chad's health system which has one of the highest MMRs globally at 748 deaths per 100,000 live births in 2023 [19].

A fundamental challenge in city-level analysis is defining what constitutes an urban area. No universally accepted definition exists: national definitions typically rest on population thresholds shaped by historical administrative boundaries, and vary across countries and over time [33]. Conventional DHS approaches delineate urban areas using the sampling stratum in which a city sits [33]. Although pragmatic, this can under- or overestimate a city's true extent since administrative and sampling boundaries rarely align with functional geography [33]. Advances in satellite imagery and geospatial data now allow urbanicity to be defined more objectively and comparably, explicitly accounting for suburbs, peri-urban zones, and neighbouring satellite towns [33,44,45]. This matters for analytical consistency and equity; populations in these transitional zones are functionally part of the city, even when they lie outside its administrative core. It is especially relevant for women of reproductive age, whose care-seeking frequently crosses administrative boundaries toward providers in the centre. In Kampala, Uganda, for example, 55% of women seeking obstetric care originate from the neighbouring suburbs and districts [43], so a city-boundary definition excluding these areas would misrepresent the population actually using urban health services.

For these reasons, we defined each conurbation as the core city together with its surrounding suburbs and satellite towns, a single, functionally integrated unit, or greater city region, using objective satellite-based classification irrespective of whether DHS coded some constituent clusters as rural. This is consistent with recent urban health studies and produces estimates that reflect the lived experiences of the populations studied, rather than artefacts of administrative boundary-drawing [15,36,37].

A related challenge concerns the minimum number of clusters and women needed for robust city-level estimates [35]. DHS surveys are designed primarily for regional-level inference, so sample adequacy varies across cities. Large conurbations, especially those coinciding with DHS sampling strata, such as Nairobi, have sufficient clusters by design, whereas smaller or more sparsely populated conurbations may be represented by a few clusters. Much of the existing literature has not treated sample size as an explicit inclusion criterion, often focusing on large cities without formal justification [38–42]. Where thresholds have been applied, they vary: Wong et al. restricted their analysis to cities with at least 1 million inhabitants with Lilongwe (Malawi) having a sample of just 14 clusters [32]. Using population size as a proxy for sample adequacy is pragmatic but imperfect, since cluster allocation depends on the national sampling design rather than city population alone. Moreover, a large cluster allocation does not guarantee representativeness if sampling fails to capture the geographic, socioeconomic, and demographic heterogeneity of a conurbation.

In the absence of formal guidelines, we adopted transparent, pragmatic thresholds: at least 10 clusters and more than 100 live births within the three-year recall period, reducing 167 candidate conurbations to 62. These thresholds are not derived from a formal power calculation, and establishing evidence-based minimum sample size remains an open question, one that affects not only city-level work but subnational analyses more broadly, particularly at finer levels such as admin-3 units which are below the DHS stratum [61]. Our group is pursuing this in a dedicated methodological

study, alongside work developing a data-driven framework to define conurbations more precisely and to assess how alternative urban definitions and geo-scrambling affect coverage estimates [62].

Strengths

To our knowledge, this is the first analysis to estimate maternal and newborn indicators for conurbations, defined as core cities with their peri-urban areas, across SSA and to present them alongside national urban averages, making visible the variation that those averages conceal. We included all eligible conurbations using inclusion criteria based on DHS cluster and live-birth sample sizes rather than population size alone. Conurbation estimates agreed closely with aligned with sampling-stratum estimates ,with differences confined to a few conurbations formed by merging adjacent urban areas, indicating that our findings are robust to this alternative spatial definition.

Our typology characterised each conurbation relative to all 62. Because this is a relative comparison, some conurbations necessarily fall into lower categories; to avoid labelling high absolute coverage as low because of small relative differences, we grouped conurbations with similar or near-universal coverage (e.g. ANC1+) together.

Estimates are based on data self-reported by women living in each conurbation at the time of the survey, which links care to where women live rather than where they seek it. This matters because indicators derived from routine facility data often include many women who do not live in the conurbation where they give birth [43] . We also shortened the recall period from five to three years to reduce recall bias [63] and aligned the definition of a skilled provider with local designations to improve the cross-country comparability of PNC48 estimates.

Limitations

Several limitations should be considered. First, the surveys span 2012 to 2024, so estimates for different countries reflect different points in time, up to twelve years apart. Because urban maternal health coverage in SSA is likely to have increased over this period, conurbations with older surveys may show lower coverage independently of health system differences. This affects between-country but not within-country comparisons, because a single survey year applies to all conurbations. Moreover, older and newer surveys were spread evenly across the higher- and lower-coverage groups, so survey timing does not explain results of the typology. A formal time trend analysis was beyond our scope and is recommended for future work.

Second, our estimates are subject to spatial imprecision. The DHS displaces cluster coordinates by up to 2km in urban and 5km in rural areas [64], so some clusters may sit just outside or just inside a conurbation boundary, and some surveys were matched to the urbanization surfaces to within ±2.5 years, given their five-year intervals [45,46]. This imprecision in boundary definition and geo-displacement is inherent to DHS-based urban analyses and remains an active methodological area; addressing it rigorously requires moving beyond pragmatic boundary definitions toward data-driven delineations [62].

Third, sample adequacy varied. We applied a pragmatic cut-off (clusters and live births) and present design-adjusted 95% confidence intervals, but some of the conurbations were not designed as sampling units and warrant cautious interpretation. However, this concern does not affect all 62 conurbations: 30 conurbations (48%) which directly correspond to DHS sampling regions are well powered, and our definition simply extends these regions to include peri-urban clusters. Of the rest, 21% substantially overlap with the sampling region, while 31% (19 conurbations) are at most at risk of under-sampling, either sharing a region with a large rural component or forming only a small fraction of it. For these, adding peri-urban clusters improves both sample size and representativeness.

Finally, missing and "don't know" responses were coded as non-receipt per DHS methodology, which could bias estimates downwards if missingness varied across surveys. Overall missingness was low, though "don't know" responses were more frequent for PNC48 and newborn weighing, likely reflecting recall bias and genuine lack of knowledge (e.g., a baby was removed from the mother for hours or days after birth). Sensitivity analyses confirmed that estimates and typology assignments were broadly robust. Only seven conurbations were reclassified, in all cases to a higher-coverage category, indicating that conservative coding may modestly underestimate coverage in a few settings, without altering the overall pattern.

Conclusion

This study provides a comprehensive picture of key maternal and newborn health service coverage, content, and continuity indicators across 62 conurbations in 33 SSA countries using conurbation boundaries that reflect rapid urbanisation. Measured at this scale, urban maternal and newborn care varied widely in ways that national urban averages did not reveal. The findings can help identify policies and interventions to improve accessibility, quality, and continuity of care in settings with rapidly expanding populations. The most common challenge across conurbations was not uniformly low coverage but inconsistency: most conurbations had high coverage on some indicators and low coverage on others, particularly ANC4+ and PNC48. National-level factors appear to matter more strongly than city size or capital city status, with several examples of capital cities having lower coverage than secondary conurbations or national urban averages. The intersection of national policies on universal access to healthcare and context-specific barriers and enablers at facility and community level will be critical to closing the gaps in continuity and content of care and improving survival and wellbeing of women and their babies in cities across SSA.

Methods

Study context

We conducted this study across 33 SSA countries (**Table 3**), all with a most recent standard DHS conducted since 2010 (range 2012-2024) and including 62 conurbations (**Figure 2**). In 2023, the MMR in these 33 countries ranged from less than 100 maternal deaths per 100,000 livebirths (Zambia and Mozambique) to over 500 (Benin, Chad, Liberia and Nigeria) (**Table 3**) [19]. The total population of the 33 countries in 2025 was 1.2 billion; ranging from 2.6 million people in Gabon to 241.2 million in Nigeria (**Table 3**) [65]. The characteristics of the 33 countries are summarised in **Table 3** based on 2023 MMR [19], total fertility rate from the most recent DHS [66] and 2025 population projections [65].

Table 3. Characteristics of 33 countries included in analysis. Countries are ordered alphabetically. Included DHS surveys were conducted between 2012 and 2024. MMR, maternal mortality ratio per 100,000 livebirths based on 2023 WHO estimates; TFR, total fertility rate from the most recent DHS report; mil, millions. DRC, Democratic Republic of the Congo.

ID	Country	Demographic and Health Survey year	Population in 2025 (mil)	Number of included conurbations	% of population in included conurbations	maternal mortality ratio (2023)	Total Fertility Rate
1	Angola	2015	38.35	5	34.95	183	6.2
2	Benin	2017	14.59	2	15.12	518	5.7
3	Burkina Faso	2021	23.76	2	18.71	242	4.4
4	Burundi	2016	14.22	1	10.24	392	5.5
5	Cameroon	2018	29.45	3	20.41	258	4.8
6	Chad	2014	20.68	1	9.78	748	6.4
7	Côte d'Ivoire	2021	32.28	1	21.29	359	4.3
8	DRC	2013	110.87	3	10.57	427	6.6
9	Ethiopia	2019	133.59	2	4.65	195	4.1
10	Gabon	2019	2.56	1	24.60	233	3.9
11	Gambia	2019-2020	2.78	1	1.44	354	4.4
12	Ghana	2022	34.73	3	30.15	234	3.9
13	Guinea	2018	14.89	1	18.18	494	4.8
14	Kenya	2022	56.93	3	20.58	149	3.4
15	Liberia	2019-2020	5.65	1	34.62	628	4.2
16	Lesotho	2023-2024	2.35	1	17.74	478	2.5
17	Madagascar	2021	32.33	1	9.20	445	4.3
18	Malawi	2015	21.85	2	14.21	381	4.4
19	Mali	2018	24.75	1	18.10	225	6.3
20	Mauritania	2019	5.23	1	22.09	381	5.2
21	Mozambique	2022-2023	35.11	1	8.33	99	4.9
22	Namibia	2013	3.05	1	14.22	139	3.6
23	Niger	2012	27.40	1	5.87	350	7.6
24	Nigeria	2018	241.17	11	28.56	993	5.3
25	Rwanda	2019-20	14.39	1	17.57	229	4.1
26	Senegal	2023	18.70	1	20.69	237	4
27	Sierra Leone	2019	8.71	1	13.82	354	4.2
28	South Africa	2016	64.37	1	20.51	118	2.6
29	Tanzania	2022	67.34	2	11.11	276	4.8
30	Togo	2013	9.60	1	32.07	349	4.8

31	Uganda	2016	50.63	1	13.28	170	5.4
32	Zambia	2018	21.49	2	9.66	85	4.7
33	Zimbabwe	2015	16.77	2	23.02	358	4
	Total		**1,200.55**	**62**	**17.65**		

Overall methodological approach

This is a cross-sectional geospatial study using secondary data from 33 SSA countries encompassing 62 conurbations, drawing on DHS surveys conducted between 2012 and 2024. All analyses are descriptive; confidence intervals are presented to convey precision of estimates rather than to support inferential comparisons between conurbations. We undertook a six-step process. First, we assembled and refined the boundaries of all conurbations in 2015 and 2020. Second, we reviewed and obtained data from each country's most recent DHS since 2010 and defined six key maternal and newborn care indicators across three dimensions: coverage of care (ANC1+, ANC4+, FBC), content of care (CS, PNC48 and newborn weighed), with continuity assessed as the relative loss between successive indicators. Third, we spatially linked the conurbation boundaries to DHS clusters to define the clusters falling within each conurbation. Fourth, we estimated the coverage of each indicator at two spatial scales: i) national urban level, combining all DHS clusters designated as urban within each country, and ii) conurbation level, for each of the 62 conurbations. This enabled both cross-country comparisons across all conurbations and within-country comparisons between conurbations and their respective national urban averages. Fifth, we developed a rule based descriptive typology of conurbations capturing relative performance across five indicators using five relative levels for each indicator . Finally, we assessed the robustness of coverage estimates and typology assignments to the handling of missing and "don't know" responses through sensitivity analyses comparing the standard DHS approach against a complete-case alternative.

Data

We assembled two key types of data, a) DHS data and b) conurbation boundaries.

1. Demographic and Health Surveys

We used secondary data from the most recent DHS conducted in SSA since 2010. DHS are nationally representative cross-sectional household surveys, initiated in 1984 to gather data on key socio-demographic and population health indicators across more than 90 low- and middle-income countries [66]. The survey sampling design has two stages, stratified by urban and rural residence and by administrative region. In the first stage primary sampling units, also called clusters, are selected while the second stage involves selection of households within the sampled clusters. A typical cluster contains approximately 100-300 households, from which 20–30 are randomly selected and surveyed. Each sampled cluster is geolocated using a global positioning system (GPS) coordinate. To protect the confidentiality, cluster coordinates are randomly displaced by up to 5 km for rural clusters and up to 2 km for urban clusters [64].

2. Boundaries of conurbations along functional urban areas

Conurbation boundaries were based on functional urban areas (FUA), also called metropolitan areas [44,45,67] comprising a high-density urban centre, the surrounding commuting zone and interconnected low-density areas [44,45,67] . The SSA FUAs (**Figure 2**) are defined using three datasets, urban centres and density from Global Human Settlement Layer -Settlement Model grid (GHS-SMOD); estimates of travel time to cities and pre-existing FUA boundaries for 31 European Union countries [44]. Based on the GHS-SMOD, an urban centre is first defined (contiguous

high-density cells with at least 1,500 people per km^2 or at least 0.5 km^2 of built-up area containing at least 50,000 inhabitants in total). Second, a commuting zone is then added around the urban centre determined based on the probability that each cell within each country is part of a commuting zone of an existing urban centre informed by baseline FUAs in 31 countries [44].

We also ensured that each conurbation covered peri-urban and suburban areas as defined by GHS-SMOD. Within ArcGIS Pro version 3.3.1 (ESRI Inc., Redlands, CA, USA), we overlaid the vector files of the conurbation and the GHS SMOD urbanization surfaces for 2015 and 2020 [68]. The GHS-SMOD gridded surface is derived from population distribution, built-up surfaces and the land surface based on satellite image and OpenStreetMap classified using the degree of urbanisation concept. We include the cells defined as sub-urban or peri-urban within the previously defined FUA boundaries. Suburbs and peri-urban areas represent a key urbanisation frontier where a large proportion of women who seek care in the urban centre reside. The end result was two boundaries for each conurbation - one for 2015 and one for 2020. Four urban areas were not part of the metropolis vector file and were digitised based on GHS-SMOD 2015 and 2020 incorporating the urban centre, peri-urban area and suburbs in ArcGIS Pro version 3.3.1 (ESRI Inc., Redlands, CA, USA).

Linking DHS clusters with conurbations

We used the GPS file attached to each survey to associate (spatially link) DHS clusters to conurbation boundaries, achieved by overlaying the vector files of clusters with that of the conurbation boundaries in ArcGIS Pro version 3.3.1 (ESRI Inc., Redlands, CA, USA). DHS surveys conducted closer to 2015 were linked to the 2015 conurbation boundaries, while those conducted closer to 2020, were linked to the 2020 conurbation boundaries. We included all clusters within the boundary of each conurbation irrespective of whether they had been classified urban or rural by the DHS. The designation of clusters as either urban or rural used by the DHS is derived from the national statistical offices and is often based on subjective criteria that are not comparable between countries, or are outdated [33]. Satellite-derived information, population density and built-up area data provide comparable, accurate, and continuous measures of the urban gradient [33]. Since our conurbation definition relied on objective and comparable satellite derived data, we included all clusters within the defined boundaries consistent with previous work in SSA [17,33].

Displacement of GPS coordinates of DHS clusters meant that some clusters near conurbation edges may have been marginally misclassified as inside or outside the defined boundaries [62]. In the context of this study, the effect of this displacement is not uniform across conurbations, as it depends on their spatial extent. For large conurbations whose size is comparable to or exceeds that of a DHS sampling region (the majority, see **Table 4**), displacement is unlikely to substantially affect coverage estimates, since misplaced clusters are still likely to fall within the correct boundary. For smaller conurbations, however, displacement poses a greater risk - clusters near boundaries may be incorrectly included or excluded, leading to biased coverage estimates. Coverage figures for smaller conurbations (**Table 4)** should therefore be interpreted with caution, as the cluster may not precisely represent the population of its assigned conurbation.

Inclusion and exclusion criteria

We considered for inclusion all 167 conurbations in SSA which had at least 300,000 inhabitants in 2020 (UN urban agglomeration population, based on national urban definitions) [8] across all 34 countries with a most recent standard DHS conducted since 2010. The final sample was arrived at through a sequential process of merging, exclusion, and sample size screening, as described below (**Figure 3**).

Merging of adjacent conurbations. Smaller urban areas (n=14) that were part of, or immediately adjacent to, larger conurbation where adjacency was defined as two adjoining conurbations, meaning women could reasonably attend facilities in either area easily were merged into a single larger conurbation. Examples included, Nairobi and Ruiru in Kenya, and Cotonou and Abomeyi-Calavi in Benin. This reduced the total to 153 conurbations in 34 countries.

Exclusion based on lack of geographic coordinates. Two conurbations in the Republic of the Congo (Brazzaville and Pointe-Noire) were excluded because the GPS coordinates of the DHS clusters were unavailable resulting in 151 conurbations in 33 countries.

Exclusion based on small sample size. No formal guidelines exist on the minimum number of clusters or individuals required for conurbation-level analysis. Common alternatives, such as including only capital or large cities, using population size as a proxy, or applying no threshold at all, lack empirical grounding and studies applying them are generally less transparent about this limitation. A representative sample size for estimating maternal health coverage depends on conurbation size, the proportion of the population living within it, fertility levels, and the indicator of interest. We therefore made a pragmatic decision to include conurbations with at least 10 clusters and more than 100 livebirths within the three-year recall period. Exceptions were made for five conurbations with six to nine clusters but with >100 livebirths; no conurbation had five or fewer clusters with >100 livebirths. This yielded a final sample of 62 conurbations across 33 SSA countries (**Table 4**). The threshold governs which conurbations are included, not the validity of their estimates, since precision is reported per conurbation through its design-based 95% confidence interval.

In the included sample, Angola (5) and Nigeria (11) had the most conurbations (**Table 4**). The 62 conurbations (**Figure 2**) had a combined population of 211.9 million (17.7% of the combined population of the 33 countries) in 2025 (**Table 3 and 4**). Five had a population below 0.5 million and 14 above 5 million (**Table 4**). The DHS sampling strata corresponded to the conurbations to varying degrees (**Table 4**): 30 (48%) matched to a conurbation directly and are considered representative; in 21% the names differed but the stratum still largely covered the urban area; 13% shared a name but included a substantial rural component; and in 18% the names differed and the conurbations formed only a small fraction of the stratum.

Table 4. Characteristics of 62 conurbations included in the analysis. Conurbations are ordered by country ID as in Table 3. The sampling stratum column indicates whether the conurbation corresponds to a DHS sampling stratum, with the percentage of the conurbation population classified as urban by the DHS shown in parentheses where applicable. The number of DHS clusters includes all clusters within the conurbation boundary, with the number classified as rural by the DHS shown in parentheses. Population estimates reflect 2025 projections from gridded surfaces. Asterisks denote conurbations where the name differs from the administrative unit used in the DHS. DHS, Demographic and Health Surveys; km², square kilometres.

ID	Country	Conurbation	Sampling stratum	Population (2025)	Geographical Size (km^2)	Number of DHS clusters (of which those classified as rural)	Live births in analysis sample
1	**Angola**	Huambo	No	665,889	215.71	9 (0)	118
2		Malanje	No	568,461	140.11	15 (2)	208
3		Luanda	Yes	10,149,167	2,006.14	68 (2)	701
4		Benguela and Lobito	Yes	1,293,483	330.00	13 (0)	168
5		Cabinda	Yes	728,082	191.74	25 (0)	238
6	**Benin**	Djougou	No*	110,484	467.00	6 (0)	126
7		Cotonou and Abomey-Calavi	Yes*	2,096,320	742.00	93 (18)	876
8	**Burkina Faso**	Bobo-Dioulasso	No*	920,817	208.70	24 (0)	205
9		Ouagadougou	Yes*	3,524,604	991.93	60 (10)	510
10	**Burundi**	Bujumbura	Yes*	1,456,294	253.30	37 (2)	350
11	**Cameroon**	Douala	Yes	3,186,707	401.30	44 (0)	303
12		Bafoussam/Mbouda	No*	328,336	657.68	15 (6)	143
13		Yaoundé	Yes	2,495,993	594.03	45 (1)	391
14	**Chad**	N'Djaména	Yes	2,022,728	316.68	49 (0)	607
15	**Côte d'Ivoire**	Abidjan	Yes	6,871,119	1,093.76	50 (5)	358
16	**Democratic Republic of the Congo**	Lubumbashi	No*	2,145,913	477.05	6 (0)	120
17		Mbuji-Mayi	No*	1,176,536	247.37	9 (0)	165
18		Kinshasa	Yes	8,401,315	648.02	35 (0)	526
19	**Ethiopia**	Addis Ababa	Yes	5,604,154	1,000.58	25 (0)	174
20		Dire Dawa	No	603,081	62.60	16 (1)	121
21	**Gabon**	Libreville	Yes	629,694	245.35	62 (0)	498
22	**Gambia**	Banjul	Yes	40,055	7.95	39 (0)	221
23	**Ghana**	Accra	Yes	6,794,757	1,990.84	52 (6)	287
24		Kumasi	No*	2,862,334	1,074.95	22 (2)	122
25		Tamale	No*	813,503	200.72	11 (0)	122
26	**Guinea**	Conakry	Yes	2,706,697	710.48	63 (0)	495
27	**Kenya**	Mombasa	Yes	2,191,255	926.81	64 (10)	303
28		Nairobi and Ruiru	Yes	8,765,281	1,317.13	99 (4)	426

29		Kisumu	No	756,869	527.44	23 (7)	159
30	**Lesotho**	Maseru	Yes	416,842	207.19	46 (5)	151
31	**Liberia**	Monrovia	Yes*	1,955,914	485.81	37 (2)	295
32	**Madagascar**	Antananarivo	Yes	2,974,911	1,094.17	62 (15)	466
33	**Malawi**	Lilongwe	No	1,898,632	929.47	14 (1)	147
34		Blantyre and Limbe	Yes	1,205,922	622.54	20 (2)	203
35	**Mali**	Bamako	Yes	4,479,146	766.33	56 (8)	765
36	**Mauritania**	Nouakchott	Yes	1,155,528	257.60	177 (0)	702
37	**Mozambique**	Maputo and Matola	Yes*	2,923,215	812.61	76 (6)	346
38	**Namibia**	Windhoek	Yes*	433,852	144.31	47 (0)	212
39	**Niger**	Niamey	Yes	1,607,597	366.80	49 (0)	562
40	**Nigeria**	Lagos and Ikorodu	Yes	18,810,055	2,839.37	61 (5)	476
41		Ibadan	Yes*	4,734,251	1,179.32	19 (0)	156
42		Port Harcourt	No	5,249,753	673.53	12 (4)	105
43		Sokoto	No	1,496,828	773.32	7 (2)	107
44		Abuja	Yes*	5,460,926	1,154.61	19 (2)	197
45		Ikot, Ekpene, Uyo	No*	4,745,512	2,389.14	18 (15)	116
46		Enugu	Yes	3,180,987	1,708.79	19 (3)	153
47		Kano	No	6,927,876	2,321.71	19 (4)	307
48		Nnewi, Onitsha, Umuahia, Owerri	Yes*	13,275,900	5,150.00	70 (28)	640
49		Maiduguri	No*	3,928,202	257.41	10 (0)	131
50		Aba	No*	1,079,238	508.63	11 (5)	109
51	**Rwanda**	Kigali	Yes	2,527,984	1,199.43	71 (23)	604
52	**Senegal**	Dakar and Rufisque	Yes	3,869,701	538.84	44 (2)	357
53	**Sierra Leone**	Freetown	Yes*	1,203,596	315.96	83 (1)	612
54	**South Africa**	Johannesburg, West Rand, Ekurhuleni	Yes*	13,199,329	6,047.86	58 (3)	113
55	**Tanzania**	Dar es Salaam	Yes	6,271,027	1,359.10	37 (0)	227
56		Zanzibar city	No*	1,213,172	425.20	33 (22)	321
57	**Togo**	Lomé	Yes	3,078,653	608.38	90 (8)	814
58	**Uganda**	Kampala	Yes	6,723,641	2,573.66	69 (8)	600
59	**Zambia**	Lusaka	Yes	1,452,682	827.21	47 (8)	421
60		Kitwe	Yes*	622,952	330.00	13 (0)	121

61	**Zimbabwe**	Harare and Chitungwiza	Yes*	3,189,194	1,624.10	50 (14)	422
62		Bulawayo	Yes	671,865	312.39	33 (0)	221
Total				211,874,811		2,556 (272)	20,104

Footnote: Yes- the stratum names differ from official conurbation names; however, a substantial proportion of the stratum covers the urban area of interest, No*- the stratum names differ from official conurbation and encompass a significant rural component*

Study Population

The study population comprised women of reproductive age (15-49 years) at the time of survey, residing in households located within DHS clusters in the selected conurbations, who had their most recent live birth in the 3 years preceding each survey.

Key maternal and newborn health indicators

We defined six indicators to capture three dimensions of care from pregnancy through childbirth and the immediate postnatal period: i) coverage of care (ANC1+, ANC4+, FBC); ii) content of care (CS, PNC48, and newborn weighed); and iii) continuity of care. The indicator definitions are presented in **Supplementary Note 3**. These indicators relate to the most recent livebirth in the three-year recall period and were harmonised into standardised definitions enabling comparison between conurbations in different countries (**Supplementary Note 3 and Supplementary Table 3**). Continuity of care was assessed by comparing coverage across successive indicators (e.g., ANC1+ versus ANC4+, FBC versus PNC48 and FBC vs newborn weighed) as described in the Statistical Analysis section).

Statistical analysis

Estimation of coverage

We estimated the level of each indicator as a percentage and its associated 95% confidence interval (CI) at two spatial scales corresponding to the two analytical levels of this study. First, we calculated the national urban estimate from clusters coded as urban by the DHS, for each survey and indicator, providing a cross-country comparator. Second, we repeated the procedure for observations within each of the 62 conurbations, enabling both cross-country comparisons across all conurbations and within-country comparisons between conurbations and their national urban averages. Of the 62 conurbations, 39 contained clusters coded as “rural” by the DHS, so these are not an exact subset of the DHS-classified urban national average (**Table 4**); these rural clusters represented only 10.6% of all clusters.

All estimates accounted for the DHS complex survey design, declared in Stata using svyset with the primary sampling unit (DHS cluster), stratum, and individual sampling weight. Conurbation estimates were obtained by subpopulation estimation (svy, subpop()) using an indicator for observations within the boundary, whether urban- or rural-coded. Analyses used Stata (V.15.0, Stata Corporation, College Station, TX).

Continuity of care

We assessed continuity of care using the relative loss between successive stages of the care pathway across two broad themes. Relative loss was calculated as the difference between the preceding and the subsequent indicator, divided by the preceding indicator and multiplied by 100. First, we assessed the loss during pregnancy care between ANC1+ and ANC4+. Second, the loss between care during and following childbirth was assessed by comparing the percentage of FBC with i) the percentage of women receiving a PNC48 and ii) the percentage of newborns who were weighed after birth.

Comparing indicator levels across conurbations

To compare the estimated level of each of the six indicators across conurbations, we treated all indicators except CS as ideally being as high as possible, approaching 100%. CS was therefore handled separately as described below. We structured the comparison at two levels: (i) within country comparing conurbations in the same country (where multiple were included) and comparing each conurbation with the national urban average; and ii) between-country, comparing conurbations across countries.

Caesarean section

CS was treated differently from the other indicators. There is no "optimal" CS rate: some caesarean sections are medically indicated while others are elective and not medically necessary, so higher rates do not imply higher-quality care and may reflect overuse. Population-level CS rates above 10% are not associated with reductions in maternal and neonatal mortality [54,55]. We therefore did not categorise high CS rates as low-performing. Instead, we flagged CS only where the population-level rate fell below 5%, a threshold below which access to necessary caesarean care is likely inadequate [53,56].

Comparison of conurbations with urban areas within a country

Building on the approach of Wong et al., we compared coverage levels of maternal health indicators among conurbations within the same country [32]: the largest or primary conurbation (often the capital) compared with other, secondary conurbations, and with the national urban average. To summarise this comparison across all conurbations, we counted, for each indicator, the conurbations whose 95% confidence interval excluded the national urban point estimate, and those whose estimate differed from it by 10 percentage points or more. As a conservative check that also accounts for uncertainty in the national urban estimate, we counted conurbations whose confidence interval did not overlap that of the national urban average. Because the national urban estimate shares a proportion of clusters with conurbations, these counts are descriptive rather than formal tests. Conurbation estimates of 100% without a confidence interval were excluded from the interval counts. Rather than positing a directional hypothesis, we examined whether coverage in the largest or capital conurbation differed from that in secondary conurbations and the national average. This comparison is descriptive and exploratory given the small number of paired conurbations within each country. We created equiplots in which differently coloured dots show the primary, and secondary conurbations and the national urban average for each indicator. Thirteen countries had two or more conurbations while the remaining 20 had a single conurbation each, and compared only with the national urban average. The national urban average serves as a contextual comparator rather than a like-for-like benchmark, as some conurbations include clusters classified as rural by the DHS but confirmed as functionally urban through satellite-derived data.

Typology of conurbations across indicators

We grouped conurbations by their relative coverage levels, starting from the three-category typology (low, medium, and high) of Wong et al., [32] , a descriptive approach that assesses the relative levels of each indicator across conurbations, using simple measures of distribution and dispersion (means, medians, outliers). For each indicator, we first computed the mean, median, minimum, and maximum across the 62 conurbations and then classified estimates into five levels using the median and the observed range and natural breaks in the distribution: (1) highest (dark green), near universal (≥95% for ANC1+, FBC and newborn weighed); about 90% or above for ANC4+ and PNC48) or, for continuity indicators, no loss; (2) high (light green), above the median; (3) medium (blue), around the median ; 4) low (light brown), below the median; and 5) lowest (dark brown), low outliers separated from the remaining conurbations by a clear gap in the distribution. For indicators with near-universal coverage in many conurbations (ANC1+, FBC and newborn weighed), the median lies within or close to the highest level, so levels 2 to 4 were defined by bands below 95%. We did not aim *a priori* for equal-sized categories (e.g., quintiles); instead we grouped conurbations with substantively similar levels together. Consequently, for indicators such as ANC1+ and FBC , the highest category includes many conurbations with essentially the same high coverage. CS was assessed differently: because no optimal population rate exists, high rates were not penalised, and rates of 5% or below were flagged as indicating inadequate access.

Such descriptive methods of assessing patterns, including by visual inspection, have previously been used in the reproductive and maternal health field to assess country coverage [69]. The larger sample size (62 conurbations versus 22 in Wong et al. [32]), allowed us to expand the typology to seven categories. One co-author (LB) drafted the expanded typology, and three co-authors (AS, FMG and PMM) independently verified the assignment of conurbations into the seven categories, before it was further developed iteratively in discussion. The expansion mainly allowed a clearer identification of reasons for inconsistency among conurbations in the middle (inconsistent) categories and secondarily, distinguished the highest-coverage conurbations from those in the next category.

The typology used five indicators (ANC1+, ANC4+, FBC , PNC48 and newborn weighed); CS and the continuity indicators were described alongside, but did not determine the category. The seven categories were: (i) *highest coverage*, where all indicators were at the high or highest levels (light or dark green); (ii) *high coverage*, where no indicator was at the low or lowest levels and at least one was at the medium level (a mix of green and blue); four inconsistent sub-classes, where at least one indicator was at the low or lowest levels (light or dark brown) and at least one at the high or highest levels (light or dark green): (iii) *inconsistent (low ANC4+)*, where ANC4+ was the only indicator at the low or lowest levels; (iv) *inconsistent (low PNC48),* where PNC48 was the only indicator at the low or lowest levels; (v) *inconsistent (low FBC and/or newborn weighed),* where only FBC and/or newborn weighed were at the low or lowest levels; and (vi*) inconsistent (multiple low indicators),* where two or more indicators were at the low or lowest levels, not limited to FBC and newborn weighed; and (vii) *low coverage*, where no indicator was at the high or highest levels and at least one was at the low or lowest levels (a mix of blue and brown, or all brown). No conurbation had ANC1+ as its only indicator at the low or lowest levels. Where an indicator was unavailable (newborn weighed in Ethiopia), categories were based on the remaining indicators. This typology is explicitly rule-based and descriptive; conurbations close to boundaries should be treated as broadly similar rather than meaningfully distinct, and assignments should not be interpreted as definitive rankings.

Sensitivity analysis

We conducted three sensitivity analyses: on the handling of missing and "don't know" responses, on their effect on typology assignments, and on the sensitivity of estimates to the extended urban definition (comparing the 30 conurbations aligned with an urban DHS stratum against their stratum estimates). Full methods and results are in **Supplementary Note 1**.

Declarations

Data availability

The data are available in a public, open access repository. The functional urban areas are available at European Union's space programme, Copernicus [44,45], DHS datasets are available from the DHS programme portal [66,70] while the urbanicity surfaces can be accessed at JRC Data Catalogue [46].

Code availability

No novel code or algorithms were developed for this study. Indicators were constructed by adapting the publicly available Stata code of the DHS Program[71] , harmonised across surveys as described in Supplementary Note 3 and Supplementary Table 3. Estimation used standard survey commands in Stata version 15.0 (svyset and svy with subpopulation estimation), and spatial linkage used standard overlay tools in ArcGIS Pro version 3.3.1, as described in the Methods.

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Author Contributions

PMM and LB conceptualized the study and developed the methodology. Software was developed by PMM LB, AS, LL, RO. Formal analysis was performed by PMM, AS, FMG,HM,ND, LL, PK. HFS, RO. Resources were provided by LB, PMM and AD with data curation handled by LL, MAO, NNR and P.M.M. PMM, LB and AS contributed to the original draft of the paper, while all authors participated in its review and editing. Visualization was performed by PMM, LB and AS. The project was supervised and administered by PMM, and LB with funding acquisition led by PMM, AD and LB. All authors approved the final paper.

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Ethical approval

The study is based on the use of DHS data, for which ethical approval was obtained from each country's national ethical committee. Our use of the DHS data as a secondary source was exempt from ethical approval according to the Institute of Tropical Medicine Antwerp Institutional Review Board. We received approval to download and analyse these data from the DHS program.

Competing interests

PMM is an Editorial Board Member for Communications Medicine but was not involved in the editorial review of, or the decision to publish this article. All other authors declare no competing interests.

References

1. Dye C. Health and Urban Living. *Science (1979)*. 2008;319:766–9. doi: 10.1126/science.1150198
2. Leon DA. Cities, urbanization and health. Int. J. Epidemiol. 2008;37.
3. WHO, UN-HABITAT. *Hidden cities: unmasking and overcoming health inequities in urban settings*. Word Health Organization, Centre for Health Development 2010.
4. Amouzou A, Melesse DY, Wehrmeister FC, *et al.* Erosion of the Capital City Advantage in Child Survival and Reproductive, Maternal, Newborn, and Child Health Intervention Coverage in Sub-Saharan Africa. *Journal of Urban Health*. Published Online First: 2024. doi: 10.1007/s11524-023-00820-0
5. Varzi AC. What is a City? *Topoi*. 2021;40:399–408. doi: 10.1007/s11245-019-09647-4
6. UN HABITAT. What is a city? 2020. https://unhabitat.org/sites/default/files/2020/06/city_definition_what_is_a_city.pdf (accessed 28 May 2025)
7. Cambridge Dictionary. conurbation. 2023. https://dictionary.cambridge.org/dictionary/english/conurbation (accessed 25 April 2023)
8. United Nations, Department of Economic and Social Affairs Population Division. World Urbanization Prospects The 2018 Revision (ST/ESA/SER.A/420). New York 2019.
9. Hoornweg D, Pope K. Population predictions for the world's largest cities in the 21st century. *Environ Urban*. 2017;29. doi: 10.1177/0956247816663557
10. Matthews Z, Channon A, Neal S, *et al.* Examining the 'Urban advantage' in maternal health care in developing countries. *PLoS Med*. 2010;7. doi: 10.1371/journal.pmed.1000327
11. UN-HABITAT. Population living in slums (% of urban population) - Sub-Saharan Africa. 2024. https://data.worldbank.org/indicator/EN.POP.SLUM.UR.ZS?locations=ZG&name_desc=false (accessed 2 September 2024)
12. Banke-Thomas A, Wong KLM, Olubodun T, *et al.* Geographical accessibility to functional emergency obstetric care facilities in urban Nigeria using closer-to-reality travel time estimates: a population-based spatial analysis. *Lancet Glob Health*. 2024;12:e848–58. doi: 10.1016/S2214-109X(24)00045-7
13. Macharia PM, Wong KLM, Beňová L, *et al.* Measuring geographic access to emergency obstetric care: a comparison of travel time estimates modelled using Google Maps Directions API and AccessMod in three Nigerian conurbations. *Geospat Health*. 2024;19. doi: 10.4081/gh.2024.1266
14. Banke-Thomas A, Avoka CKO, Gwacham-Anisiobi U, *et al.* Travel of pregnant women in emergency situations to hospital and maternal mortality in Lagos, Nigeria: A retrospective cohort study. *BMJ Glob Health*. 2022;7. doi:

10.1136/bmjgh-2022-008604

15. Grovogui FM, Dioubate N, Manet H, *et al.* Inequities in spatial access to childbirth care in the Grand Conakry conurbation, Guinea. *Nature Cities*. 2025;2:422–33. doi: 10.1038/s44284-025-00220-2
16. Norris M, Klabbers G, Pembe AB, *et al.* A growing disadvantage of being born in an urban area? Analysing urban-rural disparities in neonatal mortality in 21 African countries with a focus on Tanzania. *BMJ Glob Health*. 2022;7. doi: 10.1136/bmjgh-2021-007544
17. Macharia PM, Beová L, Pinchoff J, *et al.* Neonatal and perinatal mortality in the urban continuum: a geospatial analysis of the household survey, satellite imagery and travel time data in Tanzania. *BMJ Glob Health*. 2023;8. doi: 10.1136/bmjgh-2022-011253
18. Menashe-Oren A, Masquelier B. The shifting rural–urban gap in mortality over the life course in low- and middle-income countries. *Popul Stud (NY)*. 2022;76. doi: 10.1080/00324728.2021.2020326
19. WHO, UNICEF, UNFPA, *et al.* Trends in maternal mortality estimates 2000 to 2023. Geneva 2025.
20. Comfort H, McHugh TA, Schumacher AE, *et al.* Global, regional, and national stillbirths at 20 weeks' gestation or longer in 204 countries and territories, 1990–2021: findings from the Global Burden of Disease Study 2021. *The Lancet*. 2024;404:1955–88. doi: 10.1016/S0140-6736(24)01925-1
21. Abate BJ, Melesse AW, Brhan H, *et al.* Spatial variation, pooled prevalence, and factors associated with perinatal mortality in Sub-Saharan Africa, evidence from demographic and health surveys 2015–2023: a geospatial regression approach. *EClinicalMedicine*. 2025;81:103137. doi: 10.1016/j.eclinm.2025.103137
22. Zamané H, Sow HE, Kain DP, *et al.* Maternal Mortality at the Dori Regional Hospital in Northern Burkina Faso, 2014–2016. *International Journal of Maternal and Child Health and AIDS (IJMA)*. 2019;7. doi: 10.21106/ijma.263
23. Diallo A, Michalek IM, Bah IK, *et al.* Maternal mortality risk indicators: Case-control study at a referral hospital in Guinea. *European Journal of Obstetrics and Gynecology and Reproductive Biology*. 2020;251. doi: 10.1016/j.ejogrb.2020.05.066
24. Umar A. Maternal Mortality in the Main Referral Hospital in Angola, 2010–2014: Understanding the Context for Maternal Deaths Amidst Poor Documentation. *International Journal of MCH and AIDS (IJMA)*. 2016;5. doi: 10.21106/ijma.111
25. Birabwa C, Aduragbemi BT, Waiswa P, *et al.* Maternal health in cities: analysis of institutional maternal mortality and health system bottlenecks in Kampala City Uganda, 2016–2021. *J Glob Health Rep*. 2024;8. doi: 10.29392/001c.116248
26. Grovogui FM, Semaan A, Manet H, *et al.* Levels of in-facility maternal mortality, obstetric complications and stillbirths in three urban referral hospitals in Guinea: analysis of routine data from May 2021 to April 2023. *BMJ Glob Health*. 2026;11:e020317. doi: 10.1136/bmjgh-2025-020317
27. Alem AZ, Shitu K, Alamneh TS. Coverage and factors associated with completion of continuum of care for maternal health in sub-Saharan Africa: a multicountry analysis. *BMC Pregnancy Childbirth*. 2022;22. doi: 10.1186/s12884-022-04757-1
28. Singh K, Story WT, Moran AC. Assessing the Continuum of Care Pathway for Maternal Health in South Asia and Sub-Saharan Africa. *Matern Child Health J*. 2016;20. doi: 10.1007/s10995-015-1827-6
29. Friesen J, Georganos S, Haas J. Differences in walking access to healthcare facilities between formal and informal areas in 19 sub-Saharan African cities. *Communications Medicine*. 2025;5:41. doi: 10.1038/s43856-025-00746-5
30. Arroyave L, Neves P, Wehrmeister FC, *et al.* A novel maternal and newborn health composite indicator using national health surveys from low- and middle-income countries: Validation and association with infant mortality. *Public Health*. 2026;258:106397. doi: https://doi.org/10.1016/j.puhe.2026.106397

31. Riese S, Assaf S. DHS Analytical Studies No. 89 Inequity in Effective Coverage by Urban Poverty Status. 2024.
32. Wong KLM, Banke-Thomas A, Sholkamy H, *et al.* A tale of 22 cities: utilisation patterns and content of maternal care in large African cities. *BMJ Glob Health*. 2022;7. doi: 10.1136/bmjgh-2021-007803
33. Macharia PM, Pinchoff J, Taylor C, *et al.* Exploring the urban gradient in population health: insights from satellite-derived urbanicity classes across multiple countries and years in sub-Saharan Africa. *BMJ Glob Health*. 2023;8:e013471. doi: 10.1136/bmjgh-2023-013471
34. Blumenberg C, Costa JC, Ricardo LI, *et al.* Coverage, Trends, and Inequalities of Maternal, Newborn, and Child Health Indicators among the Poor and Non-Poor in the Most Populous Cities from 38 Sub-Saharan African Countries. *Journal of Urban Health*. Published Online First: 2023. doi: 10.1007/s11524-023-00806-y
35. Wehrmeister FC, Ferreira LZ, Amouzou A, *et al.* Identifying and Characterizing the Poorest Urban Population Using National Household Surveys in 38 Cities in Sub-Saharan Africa. *Journal of Urban Health*. Published Online First: 2024. doi: 10.1007/s11524-023-00805-z
36. Molenaar J, Beňová L, Abimbola S, *et al.* The richness of urban health realities lost in measurement monocultures. *BMJ Glob Health*. 2026;11:e023241. doi: 10.1136/bmjgh-2025-023241
37. Hounménou YSC, Avahoundjè EM, Semaan A, *et al.* Modeling Geographical Accessibility and Inequalities to Childbirth Services in the Grand Nokoué Metropolitan Area, Benin. *Journal of Urban Health*. 2025;102. doi: 10.1007/s11524-025-01000-y
38. Sy I, Sandie AB, Sylla EM, *et al.* Spatial and Socioeconomic Inequalities in Cesarean Section Deliveries in Urban Settings in Dakar, Senegal. *Journal of Urban Health*. Published Online First: 2024. doi: 10.1007/s11524-024-00835-1
39. Mekonnen W, Dechassa W, Melesse DY, *et al.* Inter-district and Wealth-related Inequalities in Maternal and Child Health Service Coverage and Child Mortality within Addis Ababa City. *Journal of Urban Health*. Published Online First: 2024. doi: 10.1007/s11524-024-00836-0
40. Jacobs C, Musukuma M, Hamoonga R, *et al.* Trends and Inequalities in Maternal and Newborn Health Services for Unplanned Settlements of Lusaka City, Zambia. *Journal of Urban Health*. Published Online First: 2024. doi: 10.1007/s11524-024-00837-z
41. Traoré M, Coulibaly D, Diawara F, *et al.* Trends in Coverage and Content of Maternal and Neonatal Care in Bamako, Mali. *Journal of Urban Health*. 2024;101:57–67. doi: 10.1007/s11524-024-00931-2
42. Kagoye S, Minja J, Ricardo L, *et al.* High Child Mortality and Interventions Coverage in the City of Dar es Salaam, Tanzania: Are the Poorest Paying an Urban Penalty? *Journal of Urban Health*. Published Online First: 2024. doi: 10.1007/s11524-023-00813-z
43. Birabwa C, Beňová L, van Olmen J, *et al.* Emergency Obstetric Care Access Dynamics in Kampala City, Uganda: Analysis of Women's Self-Reported Care-Seeking Pathways. *Glob Health Sci Pract*. 2024;12:e2400242. doi: 10.9745/GHSP-D-24-00242
44. Moreno-Monroy AI, Schiavina M, Veneri P. Metropolitan areas in the world. Delineation and population trends. *J Urban Econ*. 2021;125. doi: 10.1016/j.jue.2020.103242
45. Schiavina M, Moreno-Monroy AM, affenini L, *et al.* GHS-FUA R2019A - GHS functional urban areas, derived from GHS-UCDB R2019A, (2015), R2019A. European Commission, Joint Research Centre (JRC). 10.2905/347F0337-F2DA-4592-87B3-E25975EC2C95 PID:http://data.europa.eu/89h/347f0337-f2da-4592-87b3-e25975ec2c95. 2019.
46. Schiavina Marcello, Melchiorri Michele, Pesaresi Martino. GHS-SMOD R2023A - GHS settlement layers, application of the Degree of Urbanisation methodology (stage I) to GHS-POP R2023A and GHS-BUILT- S R2023A, multitemporal (1975–2030). European Commission, Joint Research Centre [Dataset] doi: 10.2905/JRC.SPX1FDR PID: http://data.europa.eu/89h/a0df7a6f-49de-46ea-9bde-563437a6e2ba. 2023.

47. Bobo FT, Asante A, Woldie M, *et al.* Evaluating equity across the continuum of care for maternal health services: analysis of national health surveys from 25 sub-Saharan African countries. *Int J Equity Health*. 2023;22. doi: 10.1186/s12939-023-02047-6
48. Pell C, Meñaca A, Were F, *et al.* Factors Affecting Antenatal Care Attendance: Results from Qualitative Studies in Ghana, Kenya and Malawi. *PLoS One*. 2013;8. doi: 10.1371/journal.pone.0053747
49. Camara BS, Benova L, Delvaux T, *et al.* Women's progression through the maternal continuum of care in Guinea: Evidence from the 2018 Guinean Demographic and Health Survey. *Tropical Medicine and International Health*. 2021;26. doi: 10.1111/tmi.13661
50. Mohan D, LeFevre AE, George A, *et al.* Analysis of dropout across the continuum of maternal health care in Tanzania: Findings from a cross-sectional household survey. *Health Policy Plan*. 2017;32:791–9. doi: 10.1093/heapol/czx005
51. Clarke-Deelder E, Opondo K, Oguttu M, *et al.* Immediate postpartum care in low- and middle-income countries: A gap in healthcare quality research and practice. *Am J Obstet Gynecol MFM*. 2023;5:100764. doi: 10.1016/J.AJOGMF.2022.100764
52. Sacks E, Finlayson K, Brizuela V, *et al.* Factors that influence uptake of routine postnatal care: Findings on women's perspectives from a qualitative evidence synthesis. *PLoS One*. 2022;17:e0270264-.
53. WHO, UNFPA, UNICEF, *et al.* Monitoring emergency obstetric care: a handbook. Geneva 2009.
54. World Health Organization (WHO). WHO Statement on Caesarean Section Rates. 2021. https://www.who.int/news-room/questions-and-answers/item/who-statement-on-caesarean-section-rates-frequently-asked-questions (accessed 22 April 2026)
55. World Health Organization (WHO). WHO statement on caesarean section rates. 2015. https://www.who.int/publications/i/item/WHO-RHR-15.02 (accessed 22 April 2026)
56. Cavallaro FL, Cresswell JA, França GV, *et al.* Trends in caesarean delivery by country and wealth quintile: cross-sectional surveys in southern Asia and sub-Saharan Africa. *Bull World Health Organ*. 2013;91. doi: 10.2471/blt.13.117598
57. Vigan AA, Dossou JP, Boyi C, *et al.* "To give life is a journey through the unknown": an ethnographic account of childbirth experiences and practices in Southern Benin. *Sex Reprod Health Matters*. 2023;31. doi: 10.1080/26410397.2023.2258478
58. Olubodun T, Ogundele OA, Michael TO, *et al.* Regional trends, spatial patterns and determinants of health facility delivery among women of reproductive age in Nigeria: A national population based cross-sectional study. *PLoS One*. 2024;19:e0312005-.
59. Chukwuma A, Ekhator-Mobayode UE. Armed conflict and maternal health care utilization: Evidence from the Boko Haram Insurgency in Nigeria. *Soc Sci Med*. 2019;226. doi: 10.1016/j.socscimed.2019.02.055
60. Tukur I, Cheekhoon C, Tinsu T, *et al.* Why women are averse to facility delivery in Northwest Nigeria: A qualitative inquiry. *Iran J Public Health*. 2016;45.
61. Wu Y, Dong Q, Xu J, *et al.* sae4health: An R Shiny Application for Small Area Estimation in Low- and Middle-Income Countries. *ArXiv*. Published Online First: 1 May 2025.
62. Libertini L, Grovogui FM, Yahaghi N, *et al.* Defining conurbation (extended urban area) boundaries for maternal healthcare applications in sub-Saharan Africa. 2025.
63. Ngandu NK, Manda S, Besada D, *et al.* Does adjusting for recall in trend analysis affect coverage estimates for maternal and child health indicators? An analysis of DHS and MICS survey data. *Glob Health Action.* 2016;9. doi: 10.3402/GHA.V9.32408

64. Burgert CR, Colston J, Roy T, *et al.* DHS Spatial Analysis Reports 7 Geographic displacement procedure and georeferenced data release policy for the Demographic and Health Surveys. 2013.
65. Tatem AJ. WorldPop, open data for spatial demography. Sci. Data. 2017;4.
66. Corsi DJ, Neuman M, Finlay JE, *et al.* Demographic and health surveys: A profile. *Int J Epidemiol*. 2012;41. doi: 10.1093/ije/dys184
67. Dijkstra L, Poelman H, Veneri P. The EU-OECD definition of a functional urban area", OECD Regional Development Working Papers, No. 2019/11. Paris 2019.
68. Schiavina M, Melchiorri M, Pesaresi M. GHS-SMOD R2022A - GHS settlement layers, application of the Degree of Urbanisation methodology (stage I) to GHS-POP R2022A and GHS-BUILT-S R2022A, multitemporal (1975–2030). European Commission, Joint Research Centre (JRC). Published Online First: 2022. doi: 10.2905/4606D58A-DC08-463C-86A9-D49EF461C47F
69. Da Silva ICM, Everling F, Hellwig F, *et al.* Does women's age matter in the SDGs era: Coverage of demand for family planning satisfied with modern methods and institutional delivery in 91 low- And middle-income countries. *Reprod Health*. 2020;17. doi: 10.1186/s12978-020-0903-6
70. The DHS Program. Demographic and Health Survey (DHS). https://dhsprogram.com/Methodology/Survey-Types/DHS.cfm (accessed 23 February 2026)
71. The DHS Program. DHS-Indicators-Stata: Stata code to produce Demographic and Health Survey indicators. GitHub. 2022. https://github.com/DHSProgram/DHS-Indicators-Stata (accessed 5 October 2026)

Table

Table 1 is available in the Supplementary Files section.

Figures

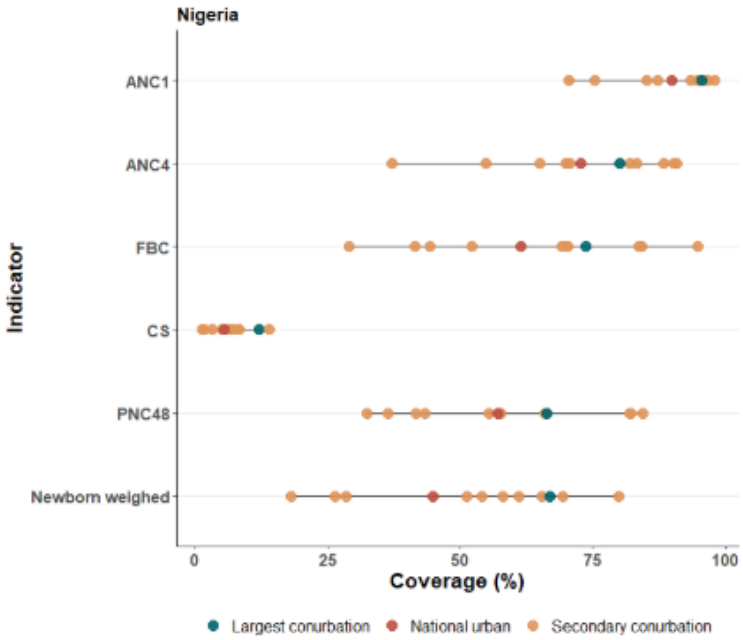


Figure 1

Equiplot comparing maternal and newborn health indicators estimates across conurbations in Nigeria and the national urban average. Each dot represents a point estimate for a single conurbation or the national urban average. The largest conurbation (Lagos) is shown in green, the national urban average in red, and secondary conurbations in orange. Equiplots for all other countries are shown in **Supplementary Figure 1**. ANC1+, at least one antenatal care visit; ANC4+, at least four antenatal care visits; FBC , facility-based childbirth; CS, caesarean section; PNC48, postnatal check within 48 hours by a skilled provider.

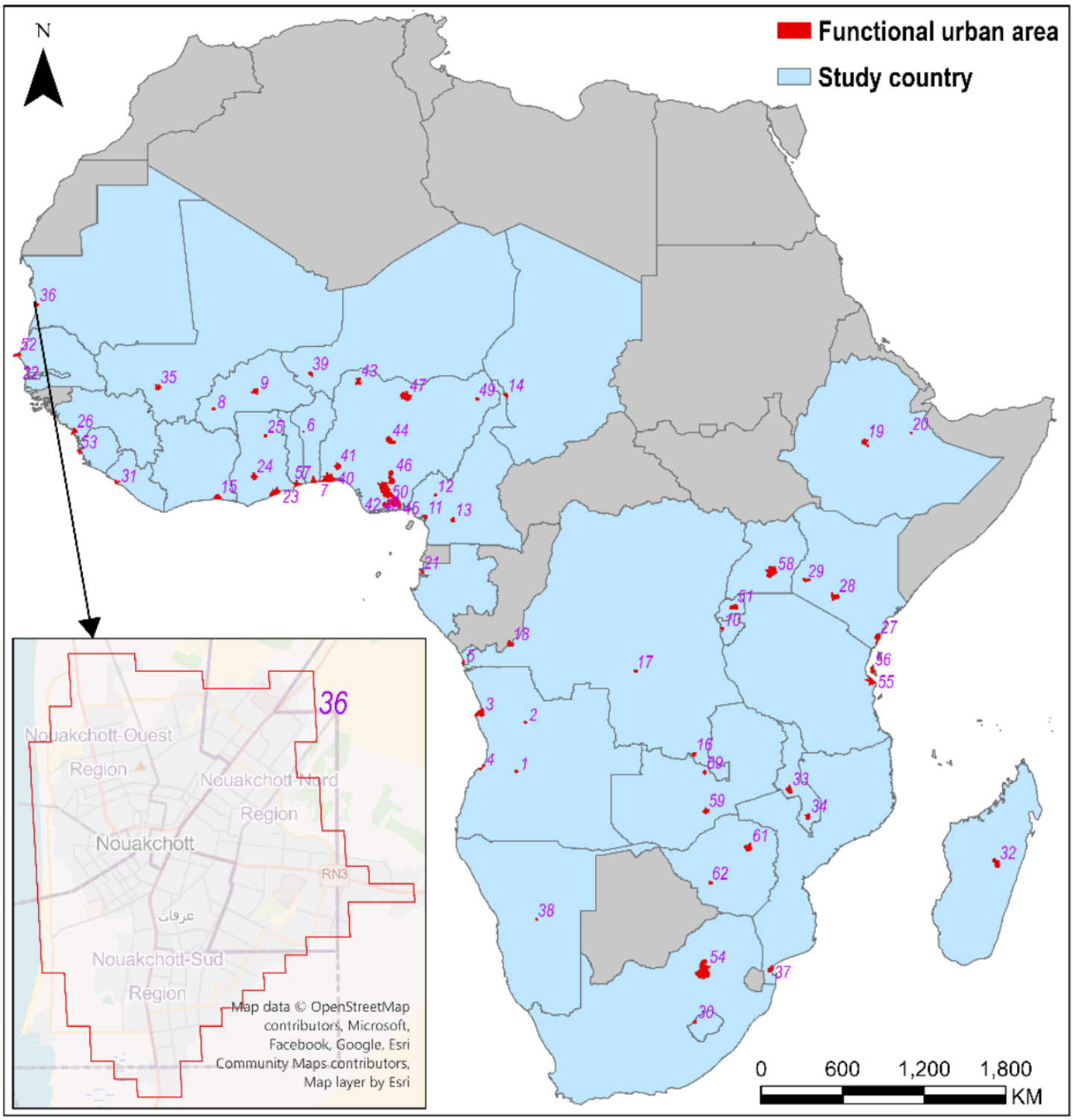


Figure 2

Spatial distribution of 62 conurbations across 33 sub-Saharan African countries included in the analysis. Conurbation boundaries, encompassing the urban core, peri-urban areas and suburbs, are shown in red. Study countries are shown in blue and excluded countries in grey (either lack recent DHS data or not in sub-Saharan African). Conurbation numbers (purple) correspond to IDs in Table 4. The inset shows conurbation 36 (Nouakchott, Mauritania). Detailed maps of each conurbation are provided in **Supplementary Figure 3**

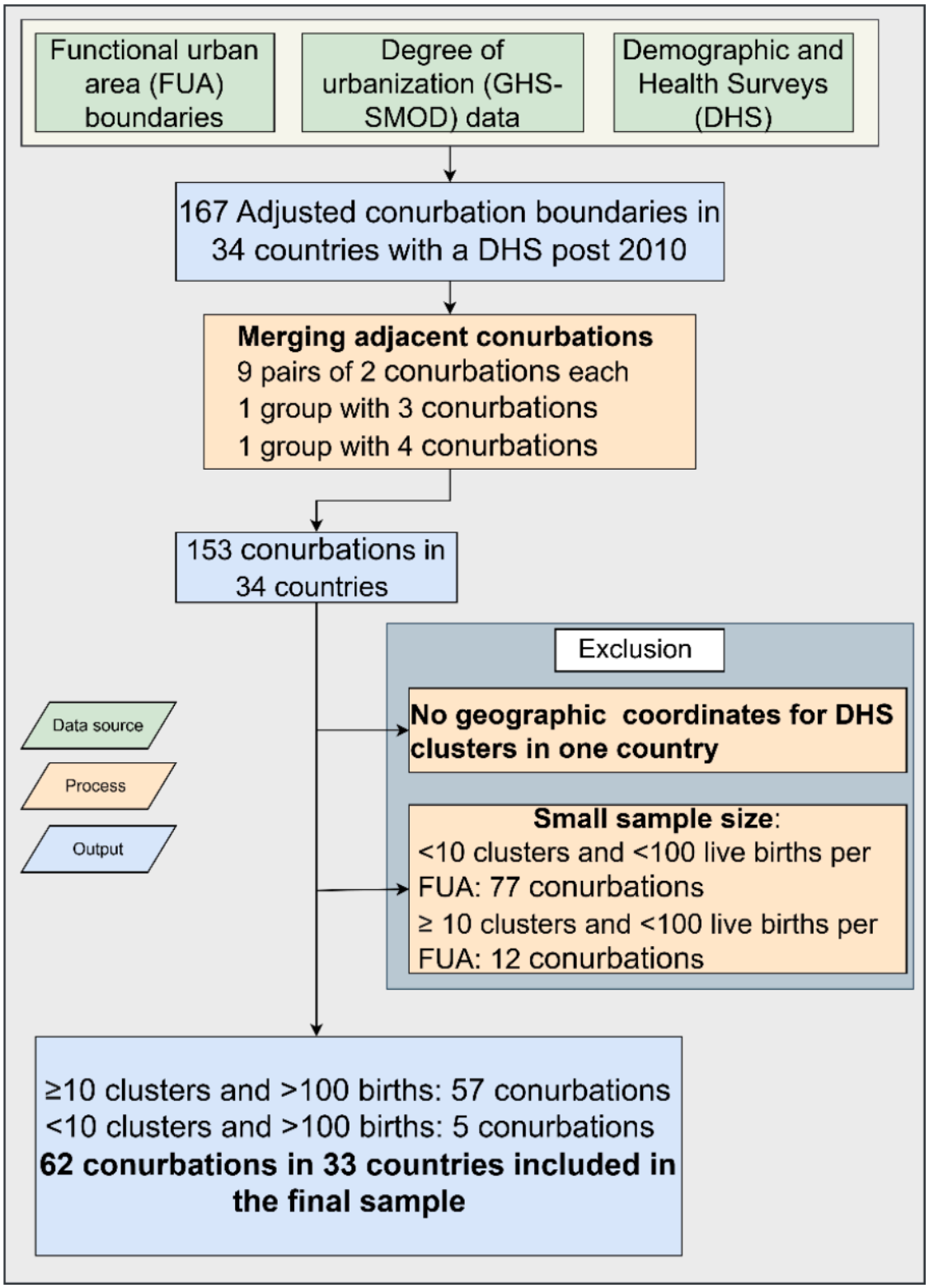


Figure 3

Flow chart showing the sequential process of conurbation inclusion and exclusion. Green boxes indicate data sources, orange boxes indicate analytical processes and blue boxes indicate outputs. Starting from 167 conurbations in 34 countries with a DHS conducted since 2010, adjacent conurbations were merged, then two rounds of exclusion applied; first for unavailability of DHS cluster geographic coordinates, then for insufficient sample size (fewer than 10 clusters or 100 livebirths). The final sample comprised 62 conurbations across 33 countries. FUA, functional urban area; GHS-SMOD, Global Human Settlement Layer Settlement Model grid; DHS, Demographic and Health Surveys.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementaryData1.xlsx
- Supplementaryinformation.pdf
- SupplementaryData2.xlsx
- Table1.docx