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Title

Model-Based Prioritisation of Local Government Areas for Maternal Mortality Reduction in Nigeria

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Abstract

Background

Nigeria continues to bear one of the world's highest maternal and neonatal mortality burdens, with the 2018 NDHS estimating a maternal mortality ratio (MMR) of 512 per 100,000 live births and United Nations inter-agency estimates suggesting it may have exceeded 1,047 per 100,000 by 2020. Efficient allocation of scarce resources requires transparent and reproducible

approaches for identifying high-burden Local Government Areas (LGAs). This study developed and validated a nationwide LGA-level prioritisation framework to support targeted interventions for Maternal and Neonatal Mortality Reduction Initiatives in Nigeria.

Methods

Four complementary approaches were implemented using routine health information, household survey, and operational data. These included: (1) ranking LGAs using four-year (2020–2023) cumulative and median routine maternal mortality ratios (MMR); (2) equal-weight composite risk scoring across multiple scenarios combining service-coverage, readiness, and mortality indicators; (3) projection of survey-derived service coverage indicators from 2018 to 2023; and (4) a survey-anchored mortality signal derived from pregnancy-related deaths using the 2018 sibling-history data. Cross-scenario convergence was used to identify consistently high-risk LGAs.

Results

Across methods, a consistent cluster of high-risk LGAs emerged, predominantly located in northern Nigeria. Routine MMR approaches identified substantial overlap in priority LGAs, while composite and projection analyses highlighted persistent service-coverage and readiness deficits. The survey-based pregnancy-related death approach produced a shortlist of 172 LGAs for initial programme implementation, closely aligning with patterns observed in the other methods.

Conclusions

Triangulation of routine, survey, and operational data provides a robust and defensible framework for subnational prioritisation of maternal and neonatal mortality interventions. This approach enables targeted investment in high-burden LGAs and offers a replicable model for evidence-based programme targeting in data-constrained settings.

Keywords: Geographic prioritisation, Local Government Areas, Maternal mortality, Neonatal mortality, Nigeria, DHIS2, NDHS

1 Background

Nigeria bears one of the world's highest maternal mortality burdens. The 2018 Nigeria Demographic and Health Survey (NDHS) estimated the maternal mortality ratio (MMR) at about 512 deaths per 100,000 live births, while recent United Nations inter-agency estimates suggest it may exceed 1,047 per 100,000 as of 2020 [1][2]. This rate is roughly double the sub-Saharan African average (531 per 100,000) and among the highest globally [2]. To put this in perspective, the lifetime risk of maternal death for a Nigerian woman is higher than for her counterpart in high-income countries and likely higher than for her average counterpart from other sub-Saharan African countries. Neonatal outcomes are similarly poor; the neonatal mortality rate (NMR) stands around 39 per 1,000 live births, one of the highest globally [1].

These high mortality levels persist despite the fact that most maternal and neonatal deaths are preventable with timely and effective care. Coverage of essential maternal and newborn interventions remains critically low: only about 58% of pregnant women receive the recommended minimum of four antenatal care visits, 43% of births are attended by a skilled health provider, and only 40% of mothers or newborns receive a postnatal check-up within two days of birth [1]. These gaps reflect persistent barriers particularly in the rural areas across the continuum of care, including delays in deciding to seek care, challenges in reaching facilities, and inadequacies in receiving prompt, high-quality treatment [3][4].

Crucially, this burden is not evenly distributed across the country [5]. Evidence points to a pronounced geopolitical divide across Nigeria's six geopolitical zones, with substantially worse outcomes in the Northwest, Northeast, and Northcentral geopolitical zones and in rural areas compared to urban settings [5]. This geographic concentration implies that uniform,

72 nationwide resource allocation risks diluting impact. Instead, more efficient gains may be
73 achieved through targeted prioritisation at the Local Government Area (LGA) level, where
74 health service delivery and administrative decisions are typically operationalised [6].

75 However, moving from national burden estimates to LGA-level targeting is constrained by data
76 limitations that constrain evidence-based decision-making. Nigeria's civil registration and vital
77 statistics (CRVS) system remains weak, with many deaths unregistered, particularly those
78 occurring outside health facilities, making complete mortality capture difficult [7]. Routine
79 health information systems, which serve as the primary source of reported maternal death data,
80 frequently under-report maternal deaths and fail to reflect deaths occurring in home or
81 community settings, limiting their usefulness for planning and accountability [8]. Meanwhile,
82 nationally representative surveys such as the Demographic and Health Survey (DHS), while
83 critical for understanding broad maternal and child health trends, are not designed to generate
84 reliable maternal mortality estimates at the LGA [5, 9, 10]. Taken together, these limitations
85 highlight that each available data source captures only part of the maternal mortality picture,
86 leaving specific gaps in the information needed for subnational prioritisation. In particular,
87 facility-based maternal death data overlook home deaths, while survey-based estimates are
88 infrequent and subject to recall bias. These gaps in the literature and surveillance capacity
89 underscore the need for innovative methods to triangulate multiple data sources and pinpoint
90 local maternal mortality "hotspots."

91 Recognising the urgent need to reduce Nigeria's high maternal and neonatal mortality burden,
92 recent national efforts have emphasised accelerated action in the Local Government Areas
93 (LGAs) with the greatest need[11]. Rather than dispersing limited resources across the entire
94 country, targeted prioritisation offers a more efficient approach for identifying high-risk LGAs
95 for focused attention. However, the effectiveness of such an approach depends on the
96 credibility of the LGA selection process. Historically, no standardised or transparent

methodology has existed for maternal mortality prioritisation at the LGA level in Nigeria, leaving room for decisions to be influenced by subjective judgment or unreliable data. This is the critical gap our study addresses.

This study documents a suite of four analytic approaches considered for identifying high-risk LGAs for maternal and neonatal mortality, the data and scoring rules underpinning each, and the shortlists produced. An evidence-based list of 172 priority LGAs was identified to guide strategic planning and resource prioritisation. This targeted approach is intended to maximise the impact of limited resources by concentrating health system improvements and innovative strategies where they are needed most. The findings illustrate how different analytic lenses can be used to guide public health decision-making and inform strategic planning for high-burden areas.

2 Methods

2.1 Study Setting

Nigeria has 774 LGAs that vary widely in health system capacity and maternal survival outcomes. Given the need to concentrate resources where the burden and risk are greatest, our analytics were conducted at the LGA level. We also conducted additional scenarios for a restricted 12-state high-burden frame (Nasarawa, Taraba, Kano, Bauchi, Borno, Gombe, Bayelsa, Niger, Katsina, Zamfara, Sokoto, and Kebbi) identified in programme diagnostics as the states with the poorest maternal-mortality performance. This dual-frame design allows us to report priorities under a national lens while stress-testing whether the same LGAs remain poor-performing when attention is focused on the highest-burden belt, aligning the analytics with near-term strategic planning and resource prioritisation

2.2 Data Sources

Multiple data sources were triangulated: routine, survey and operational datasets that capture maternal mortality and its proximal drivers.

Routine surveillance: Maternal mortality ratios (MMR) were obtained directly from the District Health Information System 2 (DHIS2) for the years 2020–2023. Data completeness and quality were assessed and are summarised in Table 1. LGAs with no reported maternal deaths or live births across all four years were excluded from the analysis. Extreme values were flagged as implausible if MMR exceeded 2,000 per 100,000 live births, a threshold chosen based on epidemiological plausibility: even in high-burden settings, population-level MMR rarely exceeds 1,200 per 100,000 live births, and higher values are likely due to reporting errors or very small denominators [12]. LGAs with implausible MMRs were documented but excluded from LGA-level summaries (cumulative and median MMR) to avoid undue influence on estimates

Table 1 DHIS2 maternal mortality ratio reporting, 2020–2023

Year	Proportion of LGAs reporting (%)	Proportion of LGAs with MMR $\geq$ 2,000 per 100,000 (%)
2020	61	3
2021	71	9
2022	70	8
2023	70	5

Household surveys: Maternal and service-coverage indicators were derived from the Nigeria Demographic and Health Survey (NDHS) 2018 microdata, which was the most recent dataset available at the time of this study. Using standard DHS definitions and design weights, we constructed LGA level for several key maternal indicators: These included the proportion of women with a recent live birth who had fewer than four antenatal contacts delivered without a skilled birth attendant, did not take iron–folic acid during pregnancy, did not receive at least

two IPTp-SP doses, did not sleep under an insecticide-treated net during pregnancy. Also, we constructed the proportions of those who received fewer than two tetanus-containing vaccine doses in pregnancy, were not tested for HIV during antenatal care and did not already know their status, did not receive a postnatal check within 48 hours, as well as the proportion of currently married women with unmet need for modern family planning. NDHS is not designed to produce observations in every LGA. Thus, using the cluster-to-LGA crosswalk, LGAs with no NDHS clusters were coded “no data” and excluded *a priori* from all survey-based analyses.

Operational readiness: Operational readiness indicators were derived from the 2024 National Primary Health Care Development Agency (NPHCDA) Health Facility Assessment and state Human Resources for Health (HRH) registries. These data were used to construct LGA-level measures of primary health care (PHC) facility density and skilled birth attendant (SBA) density. PHC facility density was defined as the number of functional PHC facilities per population within each LGA.

2.3 Maternal mortality and service-coverage indicators: definitions, justification, and scoring

The primary outcome was the MMR per 100,000 live births. To characterise proximal determinants of maternal death along the continuum of care and health-system readiness, a set of twelve LGA-level indicators was specified, spanning contact and content of care in pregnancy and childbirth, preventive interventions for malaria and tetanus, postpartum follow-up, family planning, and structural supply proxies (facility and workforce density). These indicators, together with the outcome, provided a coherent basis for triangulating mortality patterns with coverage and readiness gaps. The indicator list, scenario definitions, and banding cut-points were defined *a priori* and held constant across analyses. Full definitions and thresholds are provided in Table 2. All indicators were direction-aligned so that higher values denote higher risk. Each indicator was then banded into three performance categories, high (2),

164 medium (1), and low (0), using fixed, prespecified cut points. Cut-points were informed by
165 inspection of the empirical distribution of LGA-level values, including assessment of skewness
166 and clustering patterns. Thresholds were selected to preserve meaningful differentiation across
167 LGAs while limiting excessive concentration within a single band in highly skewed
168 distributions. This distribution-informed approach enhanced discriminatory capacity and
169 reduced the influence of extreme values on composite scoring. The resulting bands were used
170 for cartographic representation, transparent communication of performance levels, and as
171 categorical inputs in scenario-based composite analyses. Where composite models were used,
172 indicators contributed with equal weights, and scores were computed as the mean of
173 non-missing bands, with re-normalisation of the denominator when an indicator was not
174 available for a given LGA. Equal weighting is a commonly accepted practice in composite
175 indicator construction when there is no strong empirical or theoretical basis to favour one
176 indicator over another and helps to maintain transparency and reproducibility in policy-relevant
177 scoring frameworks [13][14]. The same scoring rules were applied identically in both the
178 national and restricted 12-state frames.

S/N	Indicator (LGA level) LGA-level indicators (source)	Definition	Direction of risk	Cut points: High (2) / Medium (1) / Low (0)	Justification for indicator selection
1	<4 ANC contacts [1]	% recent births to women with fewer than 4 ANC visits	Higher = worse	>50% / 30–50% / <30%	ANC is the platform for risk screening and preventive packages (IFA, IPTp, TT, HIV testing); low contact signals missed opportunities[1],[15].
2	Non-SBA delivery [1]	% of deliveries not by SBA	Higher = worse	>50% / 25–50% / <25%	SBA is the entry point to life-saving intrapartum and emergency obstetric care; strong predictor of maternal survival[1],[16].

3	No iron– folic acid [1]	% Preg. Women who did not receive FEFA during Pregnancy	Higher = worse	>40% / 20– 40% / <20%	IFA prevents maternal anaemia and adverse outcomes; low uptake marks weak ANC content [1],[17].
4	<2 IPTp– SP doses [1]	% Pregnant Women who did not receive SP/Fansidar (IPTp1)	Higher = worse	>70% / 30– 70% / <30%	Core malaria-in- pregnancy prevention; poor IPTp completion elevates maternal anaemia and adverse outcomes[1],[17]
5	No LLIN use in pregnancy [1]	Percentage of pregnant women who did not receive LLIN	Higher = worse	>60% / 40– 60% / <40%	ITN reduces malaria infection in pregnancy; complements IPTp as access/behaviour proxy[1],[18].
6	<2 tetanus doses [1]	% Preg women who did not receive TT	Higher = worse	<30% / 30– 49% / ≥50%	Critical to maintain MNTE; proxy for ANC functionality

		during pregnancy			and clean delivery readiness [1],[19].
7	No HIV test at ANC [1]	% pregnant women not tested/without result	Higher = worse	>50% / 20–50% / <20%	Universal ANC testing enables timely care; low testing increases maternal/infant risk[1],[20].
8	No PNC ≤48h [1]	% Preg. women who did not attend PNC	Higher = worse	>50% / 20–50% / <20%	Early PNC addresses concentrated postpartum risk (haemorrhage, sepsis, hypertension)[1],[21].
9	Unmet need [1]	% women with UNMET Need	Higher = worse	>35% / 20–35% / <20%	Prevents unintended/high-risk pregnancies; upstream lever on maternal deaths[1],[22].

10	PHC facility density[23]	PHCs per km ²	Lower = worse	<1.0 / 1.0–2.4 / ≥2.5	Structural access/readiness proxy affecting ANC/SBA/PNC use[24].
11	SBA density[23]	Skilled birth attendants per LGA	Lower = worse	<0.01 / 0.01–0.049 / ≥0.05	Workforce availability constrains intrapartum care and emergency response[25].
12	Routine MMR [26]	MMR from routine data (2020–2023)	Higher = worse	>683 / 512–682 / 150–511	Direct mortality signal for triangulation; communicates burden to stakeholders[27].

2.4 Analytic Approaches

Four complementary approaches were compared, ranging from direct use of routine MMR to statistical modelling that integrates survey and operational indicators. Approaches were implemented transparently to support programme decision-making under the maxim that models are tools for usefulness rather than proofs of truth [28].

2.4.1 Approach 1: MMR from DHIS2, 2020-2023

Two summaries for each LGA from routine systems were derived: a four-year cumulative MMR and a median annual MMR to reduce the influence of one-year spikes. For LGA l and year t , let $D_{l,t}$ be the reported maternal deaths and $B_{l,t}$ reported live births. Therefore, Cumulative MMR (2020-2023):

$$MMR_l^{cum} = \frac{\sum_{t=2020}^{2023} D_{l,t}}{\sum_{t=2020}^{2023} B_{l,t}} \times 100,000$$

Median-year MMR:

$$\widehat{MMR}_l = \text{median} \left\{ \frac{D_{l,2020}}{B_{l,2020}}, \frac{D_{l,2021}}{B_{l,2021}}, \frac{D_{l,2022}}{B_{l,2022}}, \frac{D_{l,2023}}{B_{l,2023}} \right\} \times 100,000$$

LGAs were ranked according to each summary to identify the poorest-performing areas. This approach reflects the locations where deaths were recorded.

2.4.2 Approach 2: Scenario analysis via composite risk scoring

This approach ranks LGAs using equal-weight composites of banded risk indicators under a set of prespecified scenarios that vary the sampling frame and the inclusion and summary form of routine MMR. Scenarios were designed to stress-test prioritisation against data-quality differences and modelling choices. To identify LGAs with persistently poor performance across the eight composite scenarios, a modal frequency analysis was conducted. Each LGA's appearances in the high-risk category across scenarios were counted, and an LGA was classified as "consistently high-risk" if it appeared in at least four of the eight scenarios. This threshold reflects recurrence in $\geq 50\%$ of model specifications, ensuring that consistently high-risk LGAs are identified independently of any single scenario or indicator configuration.

Indicator coding. For LGA l and indicator j , let $x_{l,j}$ denote the raw value (e.g., % without ANC4+, % non-SBA delivery, PHC facility density). All indicators were direction-aligned so

that larger values reflect higher risk. Each $x_{l,j}$ was then mapped to a three-level performance band by indicator-specific cut-points (Table 2) using a banding function $b_j(\cdot) \in \{0,1,2\}$ (low, medium, high):

$$r_{l,j} = b_j(x_{l,j}) \in \{0,1,2\}$$

Cross-scenario consensus. To identify places that underperform robustly, a modal consistency index was computed for each LGA:

$$M_l = \sum_{s=1}^8 \mathbf{1}\{l \in \mathfrak{B}_s\}$$

LGAs were classified as consistently high risk if $M_l \geq 4$, moderate risk if $M_l \in \{1,2,3\}$, and low risk if $M_l = 0$. Applying this rule yielded a core set of 132 LGAs that appeared in at least four of eight scenarios.

Scenario design. Eight scenarios were run (Figure 1): (S1) Routine-only, cumulative DHIS2/MPDSR MMR (2020–2023), national frame. (S2) Routine-only, median MMR (2020–2023), national frame. (S3) Composite with MMR (cumulative): 9 NDHS coverage indicators + 2 operational indicators + banded cumulative MMR; national frame. (S4) Composite with MMR (median): as S3, replacing cumulative with banded median MMR; national frame. (S5) As S3, 12-state frame (poorest-performing states). (S6) As S4, 12-state frame. (S7) Composite without MMR: 9 NDHS + 2 operational indicators; national frame. (S8) As S7, 12-state frame. S1-S2 provide mortality-only rankings from routine systems; S3-S6 test composites that include routine MMR (cumulative vs median) alongside survey and readiness signals; S7-S8 remove MMR to test robustness where routine data are uncertain. National vs 12-state frames evaluate whether priorities are stable when focusing on the highest-burden belt.

Scenarios	Description	Data Source(s)	Scenarios	Description	Data Source(s)
1 Cumulative MMR	Total MMR from 2020 to 2023	▪ DHIS2	2 Median MMR	Median MMR from 2020-2023	▪ DHIS2
3 SN_Cumulative	Composite using the Cumulative MMR in combination with 9 indicators from survey data (S) and 2 operational indicators from NPHCDA modelled on a sampling frame for all LGAs in the country (N)	▪ DHIS2 ▪ NDHS 2018 ▪ NPHCDA HF Assessment	4 SN_Median	Composite using the Median MMR in combination with 10 indicators from survey data (S) and 2 operational indicators from NPHCDA modelled on a sampling frame for all LGAs in the country (N)	▪ DHIS2 ▪ NDHS 2018 ▪ NPHCDA HF Assessment
5 SP_Cumulative	Composite using the Cumulative MMR in combination with 9 indicators from survey data (S) and 2 operational indicators from NPHCDA modelled on sampling frame that includes ONLY LGAs in 12 priority states (P)	▪ DHIS2 ▪ NDHS 2018 ▪ NPHCDA HF Assessment	6 SP_Median	Composite using the Median MMR in combination with 10 indicators from survey data (S) and 2 operational indicators from NPHCDA modelled on sampling frame that includes ONLY LGAs in 12 priority states (P)	▪ DHIS2 ▪ NDHS 2018 ▪ NPHCDA HF Assessment
7 SN	Composite using the 9 indicators from survey data (S) and 2 operational indicators from NPHCDA modelled on sampling frame that includes ONLY LGAs in 12 priority states (P) without MMR	▪ NDHS 2018 ▪ NPHCDA HF Assessment	8 SP	Composite using the 9 indicators from survey data (S) and 2 operational indicators from NPHCDA modelled on sampling frame that includes ONLY LGAs in 12 priority states (P) without MMR	▪ NDHS 2018 ▪ NPHCDA HF Assessment
9 Modal Estimate	▪ The 150 poorest-performing LGAs from each scenario were identified. ▪ The frequency of each LGA's appearance among the 150 poorest-performing LGAs across all scenarios was calculated. ▪ LGAs appearing 4-8 times were labelled as "high risk," those appearing 1-3 times as "moderate risk," and those that did not appear at all were labelled as "low risk."				
12 priority states: Nasarawa, Taraba, Kano, Bauchi, Borno, Gombe, Bayelsa, Niger, Katsina, Zamfara, Sokoto and Kebbi					

Figure 1. S1–S8 scenario definitions, data sources, and modal estimate for Bottom-150 LGAs

Selection size. The shortlist size was fixed *a priori* at $K = 150$ to balance depth of targeting with operational feasibility. With $N = 774$ LGAs nationally, this captures roughly the bottom quintile, large enough to encompass the principal high-risk clusters while avoiding dilution from mid-performing areas.

2.4.3 Approach 3: State-to-LGA proportional projection of 2023 coverage (NDHS 2018 and 2023)

The NDHS 2023-24 microdata were not yet available; therefore, projections were made for LGA-level coverage indicators to 2023 by applying state-level percentage changes observed between NDHS 2018 and NDHS 2023 to the 2018 LGA baselines.

Let $j = 1, \dots, 9$ index each coverage indicator used in the scenarios. Let $s(l)$ denote the state that contains LGA l . Define $C_{s,j}^{2018}$ and $C_{s,j}^{2023}$ as the design-weighted state estimates from NDHS 2018 and NDHS 2023, respectively, and $C_{l,j}^{2018}$ as the corresponding LGA estimate from NDHS 2018 (using the cluster-to-LGA crosswalk). For each state-indicator pair percentage change was computed

$$\Delta_{s,j} = \begin{cases} \frac{C_{s,j}^{2023} - C_{s,j}^{2018}}{C_{s,j}^{2018}}, & C_{s,j}^{2018} > 0 \\ 0, & \text{otherwise} \end{cases}$$

and projected each LGA's 2018 level forward to 2023 as

$$\hat{C}_{l,j}^{2023} = \text{clip}(C_{l,j}^{2018}(1 + \Delta_{s(l),j}), 0, 1)$$

The operator $\text{clip}(\cdot, 0, 1)$ constrains results to the $[0, 1]$ probability scale (0-100%). For indicators defined as “lack of” care we converted to the positive direction before applying $\Delta_{s,j}$, and then re-expressed the result in risk form for scoring.

This approach assumes that within a state each LGA experienced the same proportional change as the state aggregate between 2018 and 2023. It preserves LGA rank differences present in 2018 while updating levels to reflect the most recent state trend. The projected 2023 LGA coverage set $\{\hat{C}_{l,j}^{2023}\}$ was then used in the composite scenarios and for comparisons with routine MMR. These projections inherit the sampling uncertainty of the state estimates and do not incorporate LGA-specific shocks such as service expansions, staffing disruptions or insecurity, so they were used comparatively for ranking and banding rather than as precise point estimates.

2.4.4 Approach 4: NDHS 2018 maternal mortality analysis

This approach derives a direct, survey-anchored mortality signal from the pregnancy-related death (PRD) item in the NDHS 2018 sibling-history module. For each death of a woman aged 15–49 reported in the seven years before the interview, the survey records whether the death occurred during pregnancy, during childbirth, or within two months after the end of pregnancy (Yes/No). NDHS clusters were attributed to LGAs using the study crosswalk; PRD responses with non-missing status were then aggregated by LGA.

265 Let $\mathcal{L}$ denote the set of eligible LGAs (those with at least one PRD response). For each $l \in \mathcal{L}$,
 266 let N responses be indexed by $k = 1, \dots, N_l$. Define the PRD indicator

$$267 \quad y_{l,k} = \begin{cases} 1, & \text{if } PRD = \text{Yes for response } k \text{ in LGA } l, \\ 0, & \text{if } PRD = \text{"No"} \end{cases}$$

268 with the per-LGA response count

$$269 \quad N_l = \sum_{k=1}^{N_l} \mathbf{1}$$

270 The LGA-level PRD proportion (higher = worse) is

$$271 \quad \hat{p}_l = \frac{1}{N_l} \sum_{k=1}^{N_l} y_{l,k} \quad (N_l > 0)$$

272 LGAs with $N_l = 0$ were labelled “No Data” and excluded from ranking. Note that when
 273 $\sum_k y_{l,k} = 0$ and $N_l > 0$, then $\hat{p}_l = 0$ by definition.

274 LGAs were ranked nationally by $\hat{p}_l$ in descending order. Let τ_{150} denote the 150th order
 275 statistic (the value of $\hat{p}_l$ at the 150th rank when sorted descending) among $\{\hat{p}_l: l \in \mathcal{L}\}$. The
 276 shortlist applied the inclusive tie rule

$$277 \quad \mathfrak{B} = \{l \in \mathcal{L}: \hat{p}_l \geq \tau_{150}\},$$

278 so that all LGAs tied at the 150th boundary were included.

279 **2.5 Handling of Missing Data**

280 Missing data were handled using pre-specified exclusion rules. LGAs with no recorded births
 281 or deaths in DHIS2 over 2020–2023 were excluded from Approach 1. For NDHS-based
 282 approaches (2–4), LGAs with no survey clusters were coded “No Data” and excluded.
 283 Composite scores were re-normalised when indicators were missing. No imputation was
 284 performed.

2.6 Ethical Considerations

Secondary analysis of anonymised, publicly accessible survey data (NDHS) and routine programmatic data (DHIS2) does not require ethical approval. No individual-level identifiable information was used.

3 Results

Across all four approaches, prioritisation outputs converged on a geographically consistent set of high-risk LGAs. Routine mortality analyses identified stable clusters across years, particularly in the Northwest and Northeast. Composite scenario modelling confirmed persistent underperformance across service coverage and readiness indicators in these same areas.

Table 3 provides a comparative summary of the number and proportion of LGAs flagged across these approaches and scenarios, offering a high-level overview of emerging patterns prior to detailed reporting by approach.

298 *Table 3 Count and proportion n(%) of LGAs meeting prioritisation criteria by state across four approaches*

Geopolitical zones	State	Approach 1		Approach 2						Modal ≥ 4	Approach 3	Approach 4
		S1_Cu mMMR	S2_Me dMMR	S3_N_ Cum	S4_N_ Med	S5_P_ Cum	S6_P_ Med	S7_N_ NoMMR	S8_P_ oMMR		Pred20 23_MM R	PRD_Prop
North Central	Benue	12 (52%)	11 (48%)	3 (13%)	2 (9%)	0 (0%)	0 (0%)	2 (9%)	0 (0%)	1 (4%)	4 (17%)	1 (4%)
	FCT											
	Abuja	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
	Kogi	2 (10%)	2 (10%)	2 (10%)	1 (5%)	0 (0%)	0 (0%)	3 (14%)	0 (0%)	0 (0%)	1 (5%)	1 (5%)
	Kwara	1 (6%)	2 (12%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (6%)	0 (0%)	1 (6%)	1 (6%)	2 (12%)
North East	Nasara	4 (31%)	1 (8%)	0 (0%)	0 (0%)	5 (38%)	3 (23%)	0 (0%)	4 (31%)	3 (23%)	4 (31%)	2 (15%)
	wa					17 (68%)	14 (56%)	5 (20%)	15 (60%)	12 (48%)	9 (36%)	4 (16%)
	Niger	7 (28%)	8 (32%)	3 (12%)	4 (16%)	0 (0%)	0 (0%)	6 (35%)	0 (0%)	4 (24%)	5 (29%)	1 (6%)
	Plateau	6 (35%)	4 (24%)	7 (41%)	5 (29%)	0 (0%)	0 (0%)	4 (19%)	0 (0%)	0 (0%)	0 (0%)	9 (43%)
	Adama	2 (10%)	2 (10%)	1 (5%)	2 (10%)	0 (0%)	0 (0%)	6 (30%)	6 (30%)	2 (10%)	2 (10%)	11 (55%)
North West	Bauchi	0 (0%)	0 (0%)	0 (0%)	0 (0%)	6 (30%)	6 (30%)	2 (10%)	6 (30%)	2 (10%)	2 (10%)	11 (55%)
	Borno	5 (19%)	4 (15%)	12 (44%)	6 (22%)	18 (67%)	17 (63%)	5 (19%)	18 (67%)	13 (48%)	12 (44%)	13 (48%)
	Gombe	2 (18%)	4 (36%)	2 (18%)	2 (18%)	6 (55%)	8 (73%)	4 (36%)	4 (36%)	6 (55%)	4 (36%)	8 (73%)
	Taraba	5 (31%)	6 (38%)	4 (25%)	3 (19%)	12 (75%)	12 (75%)	6 (38%)	11 (69%)	9 (56%)	7 (44%)	5 (31%)
	Yobe	3 (18%)	4 (24%)	6 (35%)	5 (29%)	0 (0%)	0 (0%)	3 (18%)	0 (0%)	0 (0%)	0 (0%)	5 (29%)
North West	Jigawa	8 (30%)	10 (37%)	3 (11%)	5 (19%)	0 (0%)	0 (0%)	4 (15%)	0 (0%)	2 (7%)	5 (19%)	7 (26%)
	Kaduna	1 (4%)	1 (4%)	1 (4%)	1 (4%)	0 (0%)	0 (0%)	2 (9%)	0 (0%)	1 (4%)	0 (0%)	8 (35%)
	Kano	6 (14%)	7 (16%)	3 (7%)	3 (7%)	14 (32%)	14 (32%)	4 (9%)	16 (36%)	11 (25%)	9 (20%)	18 (41%)

South East	Katsina	14 (41%)	14 (41%)	6 (18%)	6 (18%)	21 (62%)	20 (59%)	4 (12%)	15 (44%)	19 (56%)	14 (41%)	14 (41%)
	Kebbi	1 (5%)	2 (10%)	2 (10%)	2 (10%)	16 (76%)	15 (71%)	4 (19%)	15 (71%)	8 (38%)	9 (43%)	10 (48%)
	Sokoto	4 (17%)	3 (13%)	5 (22%)	3 (13%)	17 (74%)	17 (74%)	7 (30%)	16 (70%)	11 (48%)	9 (39%)	5 (22%)
	Zamfara	4 (29%)	6 (43%)	8 (57%)	4 (29%)	13 (93%)	13 (93%)	7 (50%)	12 (86%)	11 (79%)	7 (50%)	4 (29%)
	Abia	5 (29%)	3 (18%)	3 (18%)	2 (12%)	0 (0%)	0 (0%)	5 (29%)	0 (0%)	2 (12%)	3 (18%)	3 (18%)
	Anambra	2 (10%)	4 (19%)	1 (5%)	3 (14%)	0 (0%)	0 (0%)	2 (10%)	0 (0%)	0 (0%)	1 (5%)	2 (10%)
	Ebonyi	2 (15%)	2 (15%)	0 (0%)	1 (8%)	0 (0%)	0 (0%)	1 (8%)	0 (0%)	0 (0%)	1 (8%)	2 (15%)
South South	Enugu	3 (18%)	2 (12%)	1 (6%)	5 (29%)	0 (0%)	0 (0%)	1 (6%)	0 (0%)	1 (6%)	2 (12%)	3 (18%)
	Imo	10 (37%)	13 (48%)	2 (7%)	5 (19%)	0 (0%)	0 (0%)	4 (15%)	0 (0%)	0 (0%)	3 (11%)	3 (11%)
	Akwa Ibom	11 (35%)	8 (26%)	2 (6%)	3 (10%)	0 (0%)	0 (0%)	1 (3%)	0 (0%)	1 (3%)	3 (10%)	3 (10%)
	Bayelsa	3 (38%)	3 (38%)	1 (12%)	1 (12%)	4 (50%)	5 (62%)	1 (12%)	3 (38%)	3 (38%)	4 (50%)	0 (0%)
	Cross River	0 (0%)	1 (6%)	4 (22%)	5 (28%)	0 (0%)	0 (0%)	6 (33%)	0 (0%)	0 (0%)	0 (0%)	1 (6%)
	Delta	8 (32%)	6 (24%)	7 (28%)	2 (8%)	0 (0%)	0 (0%)	9 (36%)	0 (0%)	2 (8%)	3 (12%)	5 (20%)
	Edo	2 (11%)	0 (0%)	11 (61%)	5 (28%)	0 (0%)	0 (0%)	12 (67%)	0 (0%)	1 (6%)	1 (6%)	4 (22%)
South West	Rivers	4 (17%)	4 (17%)	6 (26%)	8 (35%)	0 (0%)	0 (0%)	8 (35%)	0 (0%)	1 (4%)	3 (13%)	6 (26%)
	Ekiti	1 (6%)	3 (19%)	3 (19%)	5 (31%)	0 (0%)	0 (0%)	3 (19%)	0 (0%)	1 (6%)	1 (6%)	0 (0%)
	Lagos	7 (35%)	6 (30%)	4 (20%)	4 (20%)	0 (0%)	0 (0%)	7 (35%)	0 (0%)	3 (15%)	3 (15%)	1 (5%)
	Ogun	1 (5%)	0 (0%)	0 (0%)	1 (5%)	0 (0%)	0 (0%)	7 (35%)	0 (0%)	0 (0%)	0 (0%)	2 (10%)
	Ondo	1 (6%)	0 (0%)	3 (17%)	4 (22%)	0 (0%)	0 (0%)	8 (44%)	0 (0%)	0 (0%)	0 (0%)	5 (28%)
	Osun	0 (0%)	1 (3%)	13 (10%)	11 (27%)	0 (0%)	0 (0%)	14 (10%)	0 (0%)	1 (3%)	1 (3%)	0 (0%)
	Oyo	2 (6%)	2 (6%)	(39%)	(33%)	0 (0%)	0 (0%)	(42%)	0 (0%)	2 (6%)	2 (6%)	4 (12%)

Total	149	149	132	127	149	144	165	135	132	133	172
S1_CumMMR: scenario 1, routine DHIS2 cumulative MMR (2020–2023); S2_MedMMR: Scenario 2, routine DHIS2 median of annual MMRs (2020–2023); Pred2023_MMR: state-to-LGA projection of NDHS 2018→2023 coverage and predicted-MMR shortlist; S3_N_Cum / S4_N_Med / S7_N_NoMMR: Scenarios 3,4,7 composites on N (national) frame; include cumulative MMR, median MMR, or no MMR, respectively; S5_P_Cum / S6_P_Med / S8_P_NoMMR = Scenarios 5,6,8 composites on P (restricted 12-state) frame with the same MMR options; PRD_Prop: Approach 4, NDHS 2018 pregnancy-related death proportion (PRD “Yes” proportion) shortlist; Modal ≥ 4 = LGAs appearing in ≥ 4 of the 8 scenarios (S1–S8); Frames & eligibility: Bottom-150 lists are computed within their analysis frame (national vs 12-state) and are not directly comparable across frames. Survey-based approaches (A2, A3, A4) exclude LGAs not reached by NDHS; Selection rule: At rank 150, include all tied LGAs, so the pool may exceed 150. If fewer than LGAs meet the selection criterion, the pool may be smaller											

Our first approach directly identified high-burden LGAs using reported maternal mortality ratios from routine health information systems. LGAs with no reported maternal deaths or live births over 2020–2023 (12.5% of LGAs) were excluded, as were implausible outliers (annual MMR >2,000 per 100,000 live births, usually due to data errors or very small denominators). For the remaining LGAs (n = 677, 87.5%), two summary measures were calculated: a four-year cumulative MMR and a median annual MMR (to down-weight one-year spikes). LGAs were then ranked in descending order of risk by each measure.

Across the two metrics, 107 of 149 LGAs recur (about 71.8% of each Bottom-149 list), indicating a stable spatial pattern rather than single-year spikes. Recurring LGAs concentrate in the Northwest and, to a lesser extent, in the Northeast, with additional pockets in the North Central and in riverine southern states. Within the overlap set, the zonal split was Northwest 34 of 107 (31.8%), Northeast 13 (12.1%), North Central 20 (18.7%), South south 16 (15.0%), Southeast 18 (16.8%), and Southwest 6 (5.6%). States contributing the most recurring LGAs were Katsina (12), Imo (10), Benue (9), Jigawa (7), Kano (6), Akwa Ibom (6), and Delta and Niger (5 each). Differences between the cumulative and median MMR metrics were mainly at the margins, typically involving swaps within the same states, confirming that while some perimeter LGAs are sensitive to metric definition, the core geography of high routine MMR is robust.

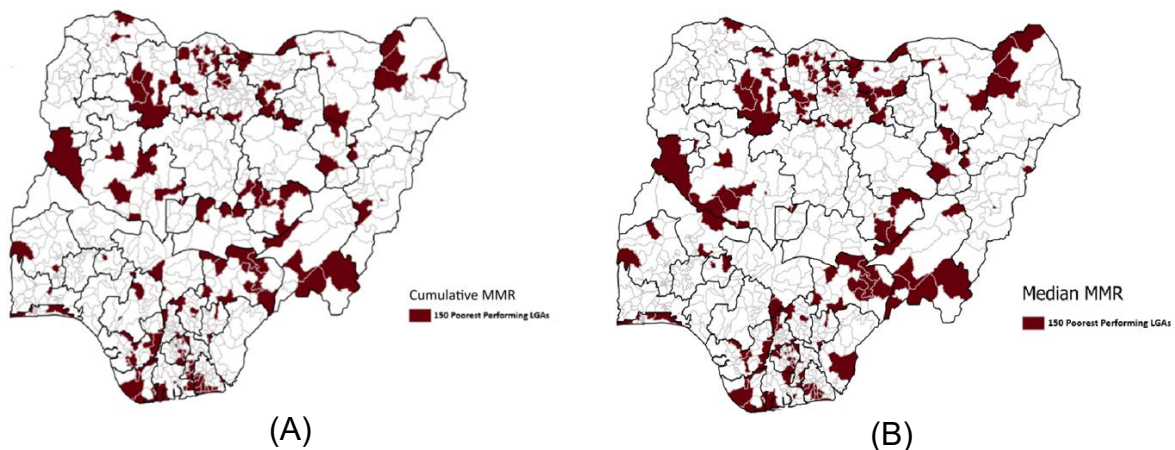
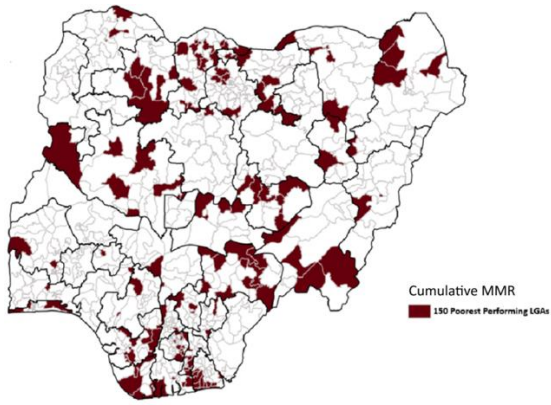


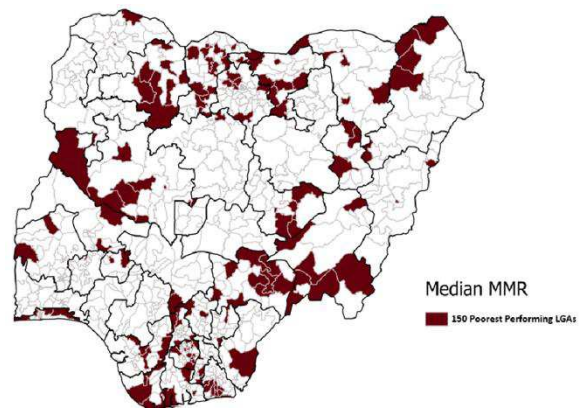
Figure 2. Maps show LGAs ranked among the Bottom-150 using DHIS2 data: (A) four-year cumulative MMR and (B) median of annual MMRs (2020–2023)

Approach 2 combined multiple data streams (routine MMR, survey coverage, and health system metrics) into integrated risk scores under a suite of eight scenarios. Each scenario produced a Bottom-150 LGA list under varying assumptions (for example, inclusion or exclusion of MMR; national versus 12-state frame) (Figure 3). Across the eight composite scenarios, the Bottom-150 outputs showed strong internal consistency and broad alignment with Approach 1: states with many LGAs in the routine DHIS2 shortlists (S1_CumMMR, S2_MedMMR) generally also had many LGAs selected in the composite scenarios (S3–S8) and in the Modal ≥ 4 column (Table 3). As shown in Figure 3, each scenario produced Bottom-150 lists with a similar geographic pattern, with risk clusters reappearing across analyses.

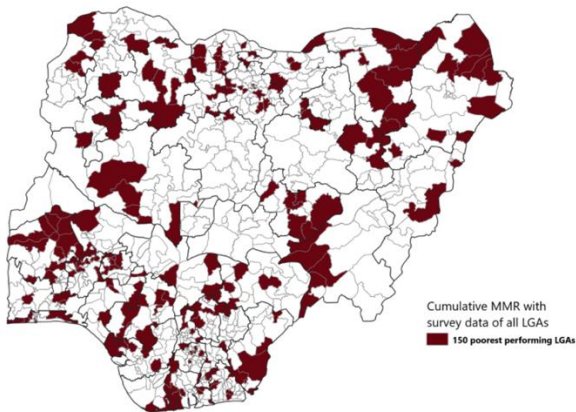
This yielded 132 LGAs that met the Modal ≥ 4 threshold, representing the consensus high-risk cohort across the composite models. Geographically, these 132 LGAs were heavily concentrated in northern Nigeria, particularly within the Northwest and Northeast zones. Katsina had the highest number of flagged LGAs (19 of 34, 56%), followed by Zamfara (11 of 14, 79%), Borno (13 of 27, 48%), Sokoto (11 of 23, 48%), Taraba (9 of 16, 56%), Kebbi (8 of 21, 38%), Gombe (6 of 11, 55%), and Kano (11 of 44, 25%). In contrast, southern states contributed relatively few LGAs to this modal shortlist: no southern state had more than three LGAs meeting the Modal ≥ 4 criterion. Bayelsa and Lagos each had 3 LGAs (38% and 15% of their LGAs, respectively), while Delta had 2 (8%), and all other southern states had 0 or 1 modal LGA. Figure 4 shows the frequency of LGA appearance across scenarios (≥ 4), highlighting clusters that closely mirror the high-risk regions identified in Figure 2.



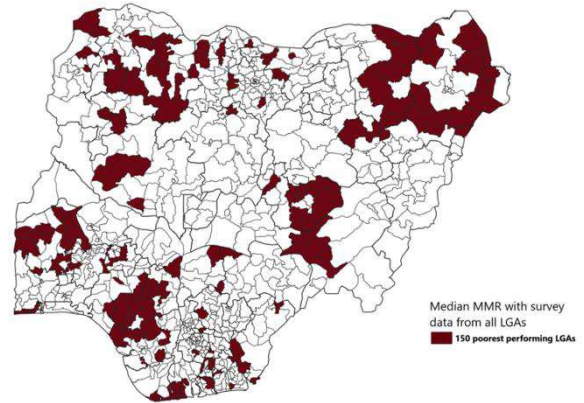
(I)



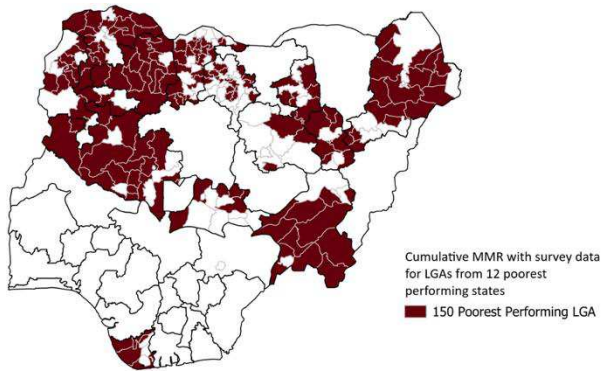
(II)



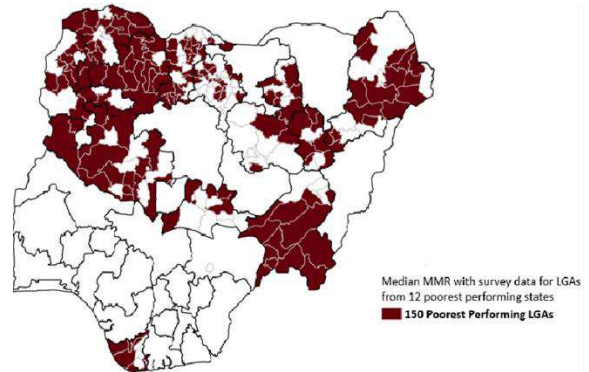
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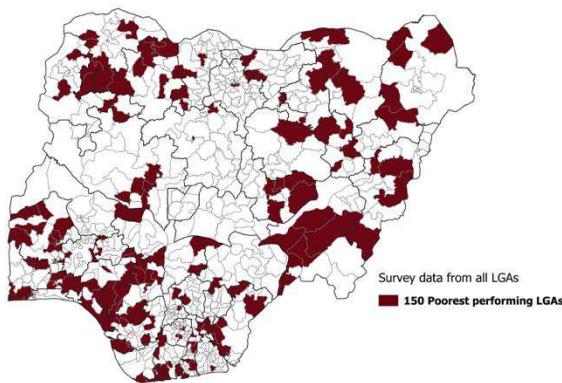
(IV)



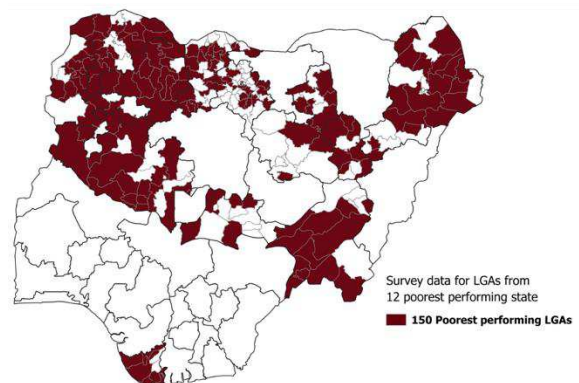
(V)



(VI)



(VII)



(VIII)

Figure 3. Spatial distribution of the 150 poorest-performing LGAs across eight prioritisation scenarios. Panels show LGAs ranked in the Bottom-150 under: (I) cumulative MMR only; (II) median annual MMR only; (III) cumulative MMR plus survey indicators for all LGAs; (IV) median MMR plus survey indicators for all LGAs; (V) cumulative MMR plus survey indicators restricted to LGAs in the 12 poorest-performing states; (VI) median MMR plus survey indicators restricted to the 12 poorest-performing states; (VII) survey indicators only for all LGAs; and (VIII) survey indicators only for LGAs in the 12 poorest-performing states.

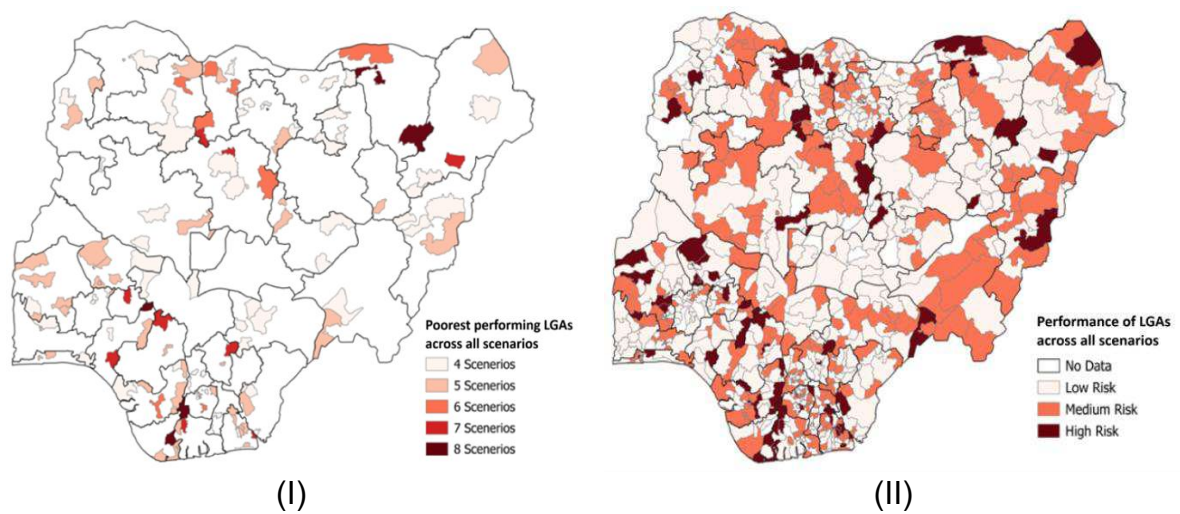


Figure 4. Modal performance of LGAs across eight composite prioritisation scenarios. (I) Map of LGAs appearing in the Bottom-150 list in at least four scenarios. (II) Composite risk classification showing overall LGA performance across all scenarios. LGAs are categorised as high risk, medium risk, low risk, or no data based on their frequency of appearance in the Bottom-150 lists.

Approach 3 used population-based survey data to identify LGAs with severe gaps in maternal health service coverage. We projected nine core maternal and newborn health indicators from the 2018 NDHS to 2023 using state-level trends, constraining all estimates within plausible bounds. The resulting 2023 coverage profiles showed substantial geographic variation, with large, spatially coherent clusters of low-coverage LGAs. These clusters are illustrated in Figure

5 and reflect areas with consistently low levels of ANC, skilled birth attendance, and related services.

Many of the LGAs with projected low coverage were located in the northern zones, particularly Borno (12 LGAs, 44%), Katsina (14 LGAs, 41%), Kebbi (9 LGAs, 43%), Zamfara (7 LGAs, 50%), Gombe (4 LGAs, 36%) and Taraba (7 LGAs, 44%). Several other northern states had smaller but notable numbers of affected LGAs, while a few such as Kaduna, Adamawa, and Yobe showed very limited or no representation. In the southern zones, most states contributed few LGAs, though some exceptions existed – for example, Bayelsa (4 LGAs, 50%), Delta (3 LGAs, 12%), and Rivers (3 LGAs, 13%).

Overall, the projection-based coverage gaps showed broad geographic congruence with the high-mortality belts identified in Approach 1, although the alignment varied across states. The largest clusters of low-coverage LGAs occurred in the northern regions where routine MMR was also persistently high, while many LGAs in southern and selected central states showed relatively stronger coverage and did not appear within the severe-gap clusters. Thus, Approach 3 produced a risk distribution (Figure 5) that largely mirrors the patterns observed in Approaches 1 and 2, with the most pronounced coverage deficits concentrated in northern Nigeria.

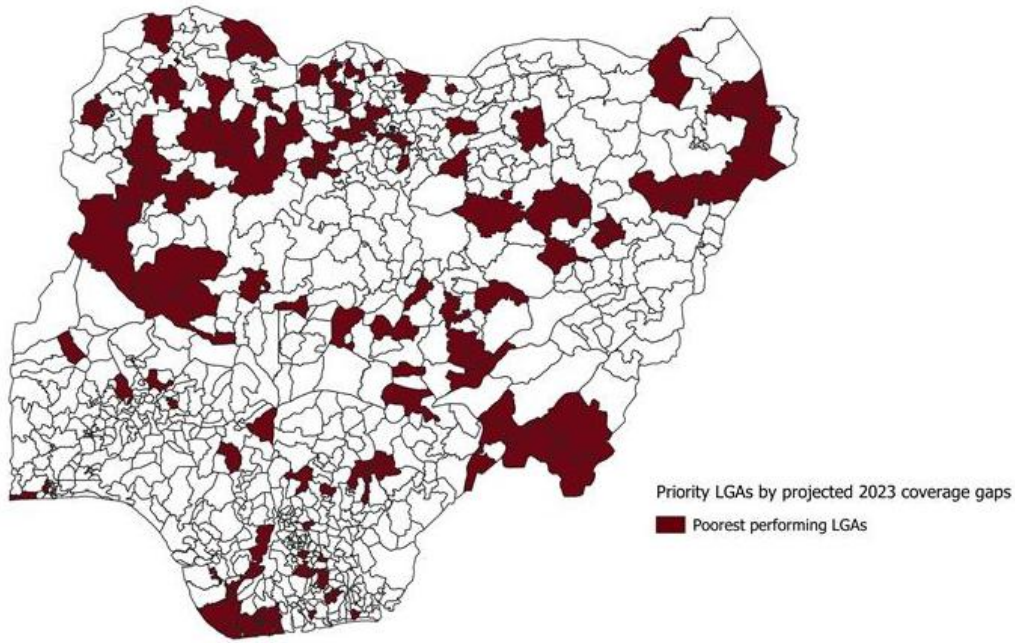


Figure 5. Priority LGAs identified through projected 2023 maternal and newborn health coverage gaps

Approach 4 provided a direct survey-based mortality signal by ranking LGAs on the proportion of adult female deaths that were pregnancy-related, using the NDHS 2018 sibling-history module. Each LGA's metric was the percentage of reported sister deaths (ages 15–49) attributable to maternal causes (during pregnancy, childbirth, or within 42 days postpartum). LGAs with high pregnancy-related death (PRD) proportions were prioritised, reflecting a heavy underlying maternal mortality burden relative to their population. This NDHS-derived ranking produced a shortlist from which the programme selected 172 LGAs for initial targeting. Figure 6 presents the mapped distribution of these LGAs, based primarily on the PRD analysis with minor programme adjustments.

The spatial pattern of high-PRD LGAs closely mirrors those identified in Approaches 1–3, with a strong concentration in northern Nigeria. The Northwest zone accounts for approximately 38 percent of all selected LGAs, and the Northeast for about 30 percent. State-level patterns also reveal substantial internal clustering: Gombe had 8 of its 11 LGAs (73%)

390 flagged, Borno had 13 of 27 (48%), Kebbi had 10 of 21 (48%), Sokoto had 5 of 23 (22%), and
391 Taraba had 5 of 16 (31%). Southern states showed far lower representation: Bayelsa had no
392 high-PRD LGAs, Lagos had only 1 of 20 (5%), and most states in the Southeast and South
393 South zones contributed fewer than three.

394 Figure 7 summarises this zonal distribution of PRD-identified LGAs, illustrating the sharp
395 north–south gradient in survey-based maternal mortality risk. The bar chart reinforces the
396 dominance of the Northwest and Northeast in contributing to the national high-risk pool and
397 provides a clear visual counterpart to the mapping in Figure 6.

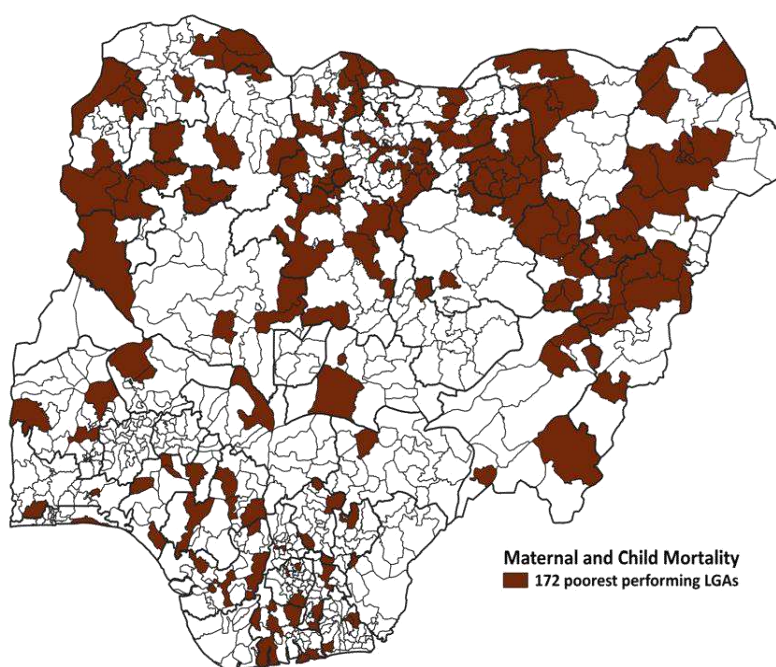


Figure 6 Map of the 172 LGAs identified through the final prioritisation process, derived from the Approach 4 (PRD proportion) shortlist with additional review.

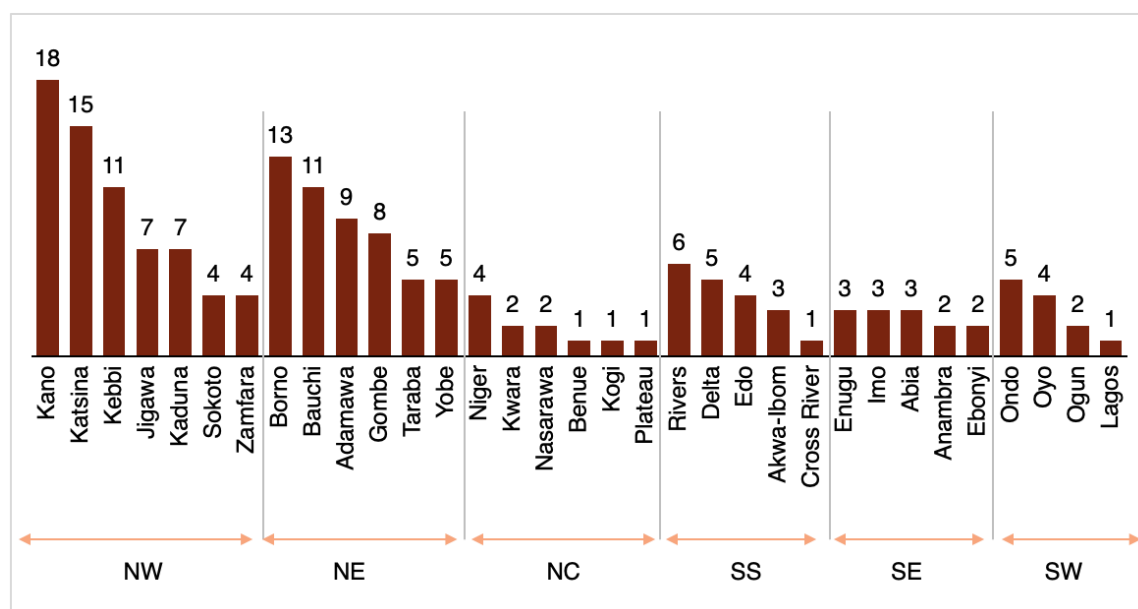


Figure 7 Final priority LGAs (n = 172) by geopolitical zone. List of LGAs is reported in Appendix B.

404 Across the four analytic approaches, there was substantial overlap in the LGAs prioritised.
405 Routine MMR data (Approach 1) first identified LGAs with high cumulative or median MMR;
406 107 of the 149 LGAs in the cumulative MMR shortlist also appeared in the median MMR
407 shortlist, indicating a large, shared core between the two routine metrics. Many of these LGAs
408 also reappeared in the composite risk analysis (Approach 2), the coverage-gap projections
409 (Approach 3), and the NDHS pregnancy-related death (PRD) shortlist (Approach 4).

410 The overlap is evident at both the state and LGA level. Several LGAs feature in three or more
411 approaches, including Obi Ngwa (Abia), Alimosho (Lagos), Ido-Osi (Ekiti), Akwanga and
412 Karu (Nasarawa), Nafada and Akko (Gombe), Bagwai and Bichi (Kano), Charanchi and
413 Batsari (Katsina), Irepodun (Kwara and Osun), Kanam and Langtang South (Plateau), Akuku
414 Toru (Rivers), Dange Shuni and Gada (Sokoto), Gashaka, Donga, Ibi and Karim-Lamido
415 (Taraba), and Gusau, Talata Mafara, Anka and Maru (Zamfara) (Tables 4, 12–14). At state
416 level, Borno, Gombe, Jigawa, Kano, Katsina, Kebbi, Sokoto, Taraba, Yobe and Zamfara each
417 have multiple LGAs selected by all four approaches. Other states with repeated appearance
418 across at least three approaches include Benue, Niger, Nasarawa, Plateau, Delta, Rivers, Abia,
419 Akwa Ibom, Imo and Lagos.

420 By contrast, many southern states have either no LGAs or only one or two LGAs prioritised
421 across the four methods, and these tend to appear in only one or two approaches. Taken
422 together, Table 3 and Appendix C show that the approaches repeatedly highlight a common set
423 of LGAs, particularly in the northern zones, with only a smaller number of LGAs unique to a
424 single method.

4 Discussion

This study provides a comprehensive and methodologically rigorous LGA-level assessment of maternal mortality risk currently available in Nigeria, integrating routine surveillance data, population-based survey estimates, service coverage gaps and health-system readiness indicators within a unified prioritisation framework. By design, each of the four analytical approaches offered a distinct perspective on maternal risk, yet their outputs demonstrated remarkable convergence, consistently identifying a similar cluster of high-burden LGAs. The convergence observed across independent analytic approaches strengthens confidence that identified hotspots reflect genuine geographic inequities rather than artefacts of measurement.

Our findings reinforce longstanding evidence of a pronounced north–south divide in maternal health outcomes in Nigeria. Concentration of high-risk LGAs in northern regions underscores the need for geographically targeted investment rather than uniform national strategies.

A major methodological contribution of this work lies in its explicit triangulation framework, designed for data-constrained settings where no single source provides a complete or unbiased account of maternal mortality [10, 29]. In Nigeria, civil registration remains incomplete, routine facility data are affected by under-utilisation, misclassification and under reporting and survey estimates are periodic [9]. Rather than privileging any one dataset, we treated each as a partial signal and systematically examined their areas of intersection. By applying four independent analytic approaches in parallel and assessing convergence across them, we reduced reliance on any single measurement system. This structured triangulation represents a replicable model for subnational maternal mortality surveillance in contexts where data fragmentation is the norm.

Geographically, the prioritised LGAs were heavily clustered in Nigeria’s northern regions, reflecting the country’s well-documented north–south divide in maternal health outcomes [30–

32]. Every approach consistently found the Northwest and Northeast zones to harbour the largest share of high-mortality LGAs. In the final NDHS-based prioritization list, roughly 38% of all selected LGAs fell in the Northwest and 30% in the Northeast. By contrast, the entire southern half of the country contributed relatively few priority LGAs – many southern states had no high-risk LGA at all, or at most one or two. The spatial pattern is striking in several northern states (for example, Gombe, Borno, Kebbi), nearly half or more of all LGAs were flagged as high-risk, whereas in many southern states (e.g. Bayelsa or Lagos) virtually none were flagged. This pronounced gradient aligns with national survey evidence showing maternal mortality ratios in parts of the North up to an order of magnitude higher than in the South [33]. This shows that maternal deaths in Nigeria are not uniformly distributed but rather concentrated in distinct geographic belts of disadvantage. Consequently, any serious effort to reduce the national burden must focus intensively on these high-mortality clusters in the North.

Amid the strong agreement among methods, Approach 4 (survey-based PRD proportion) emerged as the most practical and informative basis for guiding final LGA selection. This approach offered a direct mortality signal anchored in the nationally representative 2018 NDHS sibling-history data. By ranking LGAs on the proportion of all adult female deaths that were pregnancy-related, it provided an intuitive measure of maternal risk grounded in actual outcomes rather than in proxy indicators. An area with a very high PRD proportion, meaning a large share of women's deaths are related to pregnancy, is a clear warning sign for intervention. The appeal of this metric lay in its epidemiological directness and relative immunity to the under-reporting biases that can affect routine facility data. The NDHS sibling method enabled comparable estimates across the country, likely capturing maternal deaths even in communities with weak health information systems [34]. Equally important, the PRD-based ranking showed close convergence with the other Approaches' results, reinforcing that this survey-derived measure was flagging the very same hotspots identified by poor service

coverage and high facility-reported MMR. On this basis, the PRD metric was used to define the final shortlist of priority LGAs. Although the original plan was to focus on the bottom 150 LGAs, the shortlist was expanded to 172 to include LGAs with similar risk metrics near the cutoff. This expanded list, representing roughly 20% of all LGAs in the country, encompasses areas accounting for an estimated 55% of maternal deaths, highlighting the disproportionate burden borne by a concentrated set of localities.

In practical terms, using the NDHS mortality signal as the principal guide combined analytical rigor with clarity for decision-makers: it anchored the prioritisation in a credible, nationally vetted data source and distilled the risk into a single, actionable indicator. Therefore, the PRD-ranking output was adopted, with only minor adjustments for on-the-ground feasibility, to define the final priority areas. The final rollout list of 172 LGAs was drawn directly from the NDHS-derived shortlist, essentially mapping Nigeria's maternal mortality hotspots as identified by Approach 4. Because this list closely mirrored the patterns from Approaches 1–3, the choice of Approach 4 provided both a defensible evidence base and operational simplicity in targeting the LGAs of greatest need.

From a policy perspective, this data-driven prioritisation has important implications for maternal health strategy in Nigeria and beyond. First, it operationalises the principle of evidence-based resource allocation: by funnelling investments to the worst-affected LGAs, Nigeria can make more efficient progress toward national targets and global commitments like SDG 3.1, which calls for a dramatic reduction in maternal mortality and an end to geographic disparities by 2030 [35]. Focusing on the identified LGAs is especially crucial, as these areas currently drive the national death toll; improvements here will disproportionately boost Nigeria's overall performance on maternal health indicators. This targeted approach aligns with Nigeria's RMNCAEH+N strategy, which emphasises concentrating interventions where need is greatest, and with the equity objectives of the WHO's Ending Preventable Maternal

Mortality framework [36, 37]. By clearly defining a high-burden subset of LGAs, this prioritisation framework provides a practical template for accountability: it enables policymakers to track whether intensified support in these locales indeed accelerates mortality reductions.

In a broader sense, the methods and findings from this prioritisation exercise can guide other high-burden countries in transparently identifying their own maternal mortality hotspots. Concentrating efforts in these hotspots is not only imperative for saving lives in the near term, but also for setting countries on a realistic path toward achieving more equitable and sustainable maternal health outcomes at the national level. This prioritisation enables more efficient allocation of scarce resources, supports accountability, and aligns with national and global maternal health strategies. The framework is replicable and adaptable for other high-burden countries seeking to operationalise equity-focused resource allocation.

4.1 Limitations

This study has several limitations that should be considered when interpreting the findings. First, routine maternal mortality data from DHIS2 are affected by longstanding challenges such as incomplete reporting, variable data quality, misclassification of maternal deaths, and low facility utilisation in many LGAs. Although we mitigated these issues by excluding implausible values and triangulating with independent data sources, some residual bias is possible. Second, the NDHS 2018 survey is not designed to produce LGA-representative estimates; several LGAs lacked survey clusters and were therefore excluded from survey-based analyses. For LGAs with NDHS data, sibling-history-based pregnancy-related death estimates carry sampling uncertainty, particularly in areas with small numbers of recorded deaths. Third, our projection of service-coverage indicators from 2018 to 2023 relies on state-level growth patterns applied uniformly to LGAs within each state. This assumption may mask

important sub-state heterogeneity, including local shocks such as insecurity, service expansions, or workforce disruptions. Fourth, although the triangulation of four analytical approaches increased the robustness of prioritisation, all methods remain dependent on existing datasets that may not fully capture informal care-seeking, community deaths, or emerging shifts in maternal-health behaviours.

Finally, because this prioritisation was conducted for programme design rather than for formal epidemiological estimation, the shortlist reflects a pragmatic balance between analytical precision and operational feasibility. As Nigeria expands investments in maternal and neonatal health, future prioritisation can be refined with improved vital registration, enhanced subnational surveys, and strengthened routine information systems.

5 Conclusion

A multi-source, analytically transparent prioritisation framework can effectively identify maternal mortality hotspots at subnational level. In Nigeria, convergence across routine, survey, and operational data highlights a concentrated burden in northern LGAs and provides a defensible basis for targeted action in high-burden LGAs. This approach strengthens evidence-based decision-making, supports equity-focused investment, and offers a scalable model for other countries confronting similar data constraints. Continued improvements in data quality, surveillance, and routine monitoring will further enhance future prioritisation cycles and programme impact.

Abbreviations

ANC Antenatal Care

DHIS2 District Health Information System, Version 2

EPMM	Ending Preventable Maternal Mortality
FEFA	Iron–Folic Acid Supplementation
HF	Health Facility
HRH	Human Resources for Health
IPTp-SP	Intermittent Preventive Treatment in Pregnancy with Sulfadoxine– Pyrimethamine
LGA	Local Government Area
LLIN	Long-Lasting Insecticidal Net
SDG	Sustainable Development Goals
MMR	Maternal Mortality Ratio
MPDSR	Maternal and Perinatal Death Surveillance and Response
NDHS	Nigeria Demographic and Health Survey
NMR	Neonatal Mortality Rate
NPHCDA	National Primary Healthcare Development Agency
PNC	Postnatal Care
PRD	Pregnancy-Related Death
RMNCAEH+N	Reproductive, Maternal, Newborn, Child, Adolescent and Elderly Health plus Nutrition
SBA	Skilled Birth Attendant

TT Tetanus Toxoid (vaccine)

543

544 **Declarations**

545 **Ethics approval and consent to participate**

546 Not applicable.

547 **Consent for publication**

548 Not applicable.

549 **Availability of data and materials**

550 The datasets used and analysed in this study are not publicly available due to restrictions
551 imposed by the data custodians. Routine health service data were obtained from the District
552 Health Information System (DHIS2) managed by the National Primary Health Care
553 Development Agency (NPHCDA), and access requires institutional approval. Survey-derived
554 indicators were generated from the Nigeria Demographic and Health Survey (NDHS 2018),
555 which is accessible upon request from The DHS Program (<https://dhsprogram.com>).

556 **Competing interests**

557 The authors declare that they have no competing interests.

558 **Funding**

559 No specific funding was received for this work.

560 **Authors' contributions**

561 **Chijioke Kaduru** conceptualised the overall analytical framework and design, defined the
562 prioritisation logic, identified relevant indicators and weighting structures, translated
563 policymakers' needs into technical specifications, contributed to the interpretation of findings

and their policy implications, and supervised the project delivery. **Olamide Akeboi** led the data management and analysis across all four methodological approaches, produced the visualisations, and drafted the first full version of the manuscript. **Marvellous Oni** supported the analytical process, contributed to data cleaning and geospatial analysis, and generated the maps used in the prioritisation outputs. **Dupsy Akoma, Ifeoma Ezenyi, Bola Lukman Solanke, Ehimario Igumbor** critically reviewed and edited the manuscript. **Obiageli Onwusaka** critically reviewed the manuscript, provided programmatic inputs, and coordinated engagement with key stakeholders throughout the prioritisation process. **Dayo Adeyanju, Muntaqa Umar-Sadiq, Iniofon Inyang, and Linda Ugalahi** critically reviewed and edited the manuscript. They also provided programmatic context to the analytical process

All authors approved the final manuscript and agreed to be accountable for all aspects of the work.

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