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Persistent Spatial Inequalities in Contraceptive Use in Nigeria: A Bayesian Spatio-Temporal model Evidence from Demographic Health Survey Data from 2003 to 2024

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Abstract

Introduction

Contraceptive use remains unevenly distributed across Nigeria despite ongoing reproductive health interventions. This study assessed the spatio-temporal distribution and determinants of contraceptive use among women of reproductive age in Nigeria.

Methods

Data from the 2003, 2008, 2013, 2018, and 2024 Nigeria Demographic and Health Surveys involving 127,865 women aged 15-49 years were analyzed. Bayesian spatio-temporal conditional autoregressive models were fitted using the Integrated Nested Laplace Approximation (INLA) approach. Spatial, temporal, and nonlinear effects were modeled, and posterior exceedance probabilities were estimated.

Results

Overall prevalence of contraceptive use increased from 14.5% in 2003 to 20.7% in 2024, with a pooled prevalence of 16.0%. Contraceptive use was significantly associated with education ($\chi^2 = 13192.019$, $p < 0.001$) also wealth index, residence, marital status, and region were all significantly associated with increase prevalence of contraceptive use. Women with higher education had over four times higher odds of contraceptive use (OR = 4.10; 95%CI: 3.79-4.43), while women from the richest households had significantly higher odds of use (OR = 2.78; 95% CI: 2.55-3.03). Significant spatial heterogeneity persisted across states ($\sigma = 0.54$), with southern states showing higher exceedance probabilities of contraceptive prevalence above the national average.

Conclusion

Although contraceptive use improved over time, substantial spatial and socioeconomic inequalities remain across Nigeria. Targeted reproductive health interventions should prioritize underserved northern and rural communities to reduce persistent disparities in contraceptive use.

Keywords: Spatial Distribution, Contraceptive, Bayesian Model, Generalized Linear model, Africa

Introduction

Family planning remains a critical component of reproductive health programs globally, contributing to improved maternal and child health outcomes through birth spacing, prevention of unintended pregnancies, and reduction of maternal mortality (1). The adoption of modern contraceptive methods has been widely recognized as one of the most cost-effective public health interventions for improving reproductive health and socio-economic development in low- and middle-income countries. Modern contraceptive methods include oral pills, implants, injectables, intrauterine devices, and barrier methods that help regulate fertility and promote reproductive autonomy(1). Choosing the right method depends on each individual's health, preferences, and needs. Health workers have a duty to advise so people can identify appropriate contraceptive methods that will work for them.

Based on global statistics as at 2025, out of 1.9 billion women of reproductive age (15-49 years) worldwide, 1.1 billion have a need for family planning; of these, 874 million are using modern contraceptive methods, and 164 million have an unmet need for contraception¹. Despite this record and global efforts to improve access to family planning services, contraceptive use remains relatively low in many developing countries, particularly in Sub-Saharan Africa². Nigeria, the most populous country in Africa, continues to experience low contraceptive prevalence rates compared with global averages. For instance, evidence from the Nigeria Demographic and Health Survey indicates that the contraceptive prevalence rate for any method was about 14.6% in 2008, with modern contraceptive use estimated at approximately 9.7%³.

Over time, some improvements in contraceptive uptake have been observed. However, overall levels remain low and unevenly distributed across different socio-economic and geographic groups. Studies show that modern contraceptive use among women of reproductive age increased

from about 8.25% in 2003 to approximately 12.01% in 2018, yet substantial inequalities persist across wealth groups, educational levels, and regions⁴.

An important characteristic of contraceptive use in Nigeria is its strong geographic disparity. Evidence suggests that national averages often conceal substantial sub-national heterogeneity in contraceptive behaviour. For example, some states have extremely low contraceptive prevalence rates of less than 1%, while others record prevalence levels as high as 40%, reflecting major inequalities in reproductive health outcomes across the country⁵.

Recent spatial analyses have further demonstrated that contraceptive use in Nigeria exhibits significant spatial clustering patterns. Areas with high contraceptive prevalence are mostly located in southern parts of the country, while northern states tend to exhibit low prevalence levels⁶. These geographic disparities are often associated with differences in socio-economic status, educational attainment, cultural norms, and access to reproductive health services.

Although several studies have examined determinants of contraceptive use in Nigeria, many have relied on conventional regression techniques that do not fully account for spatial dependence and temporal dynamics. Ignoring spatial autocorrelation may lead to biased estimates and incomplete understanding of geographic inequalities. Bayesian hierarchical spatio-temporal models provide a robust framework for analyzing such patterns by incorporating spatial random effects and temporal trends simultaneously.

Based on the availability of multiple waves of the Nigeria Demographic and Health Survey (DHS), there is an opportunity to investigate the evolution of contraceptive use across states over time using advanced spatial modelling techniques. Adequate understanding of persistent spatial inequalities in contraceptive use is essential for designing targeted family planning interventions and reducing reproductive health disparities across Nigeria.

Method

Data source

This study used secondary data obtained from multiple rounds of the Nigeria Demographic and Health Survey (NDHS) conducted in 2003, 2008, 2013, 2018, and 2024. The NDHS is a nationally representative household survey designed to collect information on population, health, and socio-

economic indicators, including reproductive health and contraceptive use among women of reproductive age.

Each survey employed a stratified two-stage cluster sampling design. In the first stage, enumeration areas (EAs) were selected as primary sampling units using probability proportional to size. In the second stage, households were systematically selected within each cluster. This sampling approach ensures that the survey is representative at both national and sub-national levels, the survey collected data from 36 administrative units and the Federal Capital Territory (FCT).

Across the survey waves, data were collected from women aged 15-49 years. For the purpose of this study, only respondents with complete information on contraceptive use and relevant explanatory variables were included in the analysis. The dataset provides a large nationally representative sample suitable for examining temporal trends and spatial variation in contraceptive use across Nigeria.

The NDHS data collection procedures, including sampling design, questionnaire structure, and field implementation protocols, have been described in detail in the official DHS reports for each survey year. The datasets used in this study are publicly available upon request from the DHS Program. <https://dhsprogram.com/methodology/survey/survey-display-636.cfm>

Variables

Dependent variable

The outcome variable in this study is current contraceptive use among women of reproductive age (15-49 years), derived from the DHS contraceptive method variable.

A binary variable was constructed as:

$$Y_{it} = \begin{cases} 1, & \text{if a woman is currently using any contraceptive method} \\ 0, & \text{Otherwise} \end{cases}$$

Women who reported using any modern or traditional contraceptive method at the time of the survey were classified as users, while those not using any method were classified as non-users.

This binary outcome was modeled using a binomial likelihood within a Bayesian hierarchical framework.

Independent variables

The explanatory variables included socio-economic, demographic, and reproductive characteristics known to influence contraceptive use. These comprised household wealth index (poorest to richest), educational attainment (no education, primary, secondary, higher), place of residence (urban/rural), and marital status.

Reproductive factors such as current age, age at first sexual intercourse, and number of children ever born were also included to capture life-course and fertility-related influences. In addition, temporal variation was accounted for using survey year, while geographic differences across states were incorporated to capture regional disparities in contraceptive use. The interaction between space and time was further considered to allow for state-specific changes over time.

Statistical model

Let $i = 1, 2, \dots, 37$ index states and $t = 1 \dots T$ index survey years.

Let Y_{it} = number of women using contraception in state i at time t

N_{it} = total number of women

$Y_{it} \sim \text{Binomial}(N_{it}, p_{it})$

$E(Y_{it}) = N_{it}p_{it}$

$\text{logit}(p_{it}) = \log\left(\frac{p_{it}}{1-p_{it}}\right)$

$\text{logit}(p_{it}) = \alpha + \beta^T X_{it} + f_1(\text{Agefirst sex}_{it}) + f_2(\text{CurrentAge}_{it}) + f_3(\text{ChildrenEverBorn}_{it}) + u_{it}$

where:

α = intercept

X_{it} = fixed covariates (wealth, residence, marital status)

f_1, f_2, f_3 = smooth nonlinear effects

u_i = spatial effect

γ_t = temporal effect

δ_{it} = space time interaction

Spatial Dependence structure

Let $W = (w_{ij})$ be the adjacency matrix:

$$w_{ij} = \begin{cases} 1, & \text{if states } i \text{ and } j \text{ are neighbors} \\ 0, & \text{otherwise} \end{cases}$$

$$d_i = \sum_j w_{ij}$$

Conditional distribution

The intrinsic CAR model specifies:

$$u_i | u_{-i} \sim N\left(\frac{1}{d_i} \left(\sum_{j \sim i} u_j, \frac{1}{\tau_u d_i} \right)\right)$$

Mean=average of neighboring states

Variance decreases as number of neighbors increases.

Joint Distribution

The joint distribution of spatial effects is:

$$u \sim N(0, \tau^{-1} Q^{-1})$$

where

$$Q = D - W$$

D diagonal matrix with entries d_i

Q=precision matrix

Because Q is singular, this defines an intrinsic CAR(ICAR) model.

The CAR prior enforces $u_i \approx u_j$ for neighboring regions

Thus, it captures spatial clustering, similar contraceptive behaviour in nearby states and unobserved regional influences

Temporal effect

$$\gamma_t - \gamma_{t-1} \sim N(0, \tau^{-1} \gamma)$$

This ensures smooth temporal evolution.

$$\delta_{it} \sim N(0, \tau^{-1} \delta)$$

Captures state-specific deviations over time

$$p(\theta|Y) \propto \prod p(Y_{it}|p_{it}) \times p(u|\tau_u) \times p(\gamma|\tau_\gamma) \times p(\delta|\tau_\delta) \times p(\theta)$$

this model is estimated using Integrated Nested Laplace Approximation (INLA), which provide accurate and computationally efficient Bayesian Inference for latent Gaussian models.

Ethnical Consideration

The data is already in public domain therefore Human Ethics and Consent to Participate declarations: not applicable.

Result

Descriptive Characteristics of the Study Population

Table 1 displayed the distribution of contraceptive use based on socio-demographics variables. The Contraceptive use increased with higher educational attainment, ranging from 5.0% among women with no education to 40.8% among women with higher education ($\chi^2=13192.019$, $p<0.001$). Also, contraceptive use has a strong positive association across different wealth index, increasing from 4.8% among women in the poorest households to 38.2% among those in the richest households ($\chi^2=12446.506$, $p<0.001$). Place of residence has significant association with contraceptive use, with urban women reporting a high prevalence of use (26.5%) compared with rural women (10.8%) ($\chi^2=5235.328$, $p<0.001$). Concerning marital status, women living with partners had the highest contraceptive use (29.5%), whereas divorced women had the lowest prevalence (6.8%) of contraceptive use with ($\chi^2=673.358$, $p<0.001$). Regional disparities were evident across Nigeria. The highest prevalence of contraceptive use was observed in the South-west region (35.6%), followed by the South-east (28.4%) and South-south (27.4%), while the North-west region recorded the lowest prevalence (6.8%) with ($\chi^2=10172.297$, $p<0.001$). Finally, the findings indicate that there is significant association between contraceptive use and considered Sociodemographics variables.

Table 1: Descriptive Characteristics by Contraceptive use

Variable	Non-user (%)	User (%)	Chi-square	p-value
Education				
No education	56,883 (95.0)	2,966 (5.0)	13192.019	<0.001
Primary	19,069 (83.1)	3,876 (16.9)		
Secondary	26,033 (72.4)	9,906 (27.6)		
Higher	5,406 (59.2)	3,726 (40.8)		
Wealth Index				
Poorest	29,895 (95.2)	1,505 (4.8)	12446.506	<0.001
Poorer	26,673 (92.2)	2,272 (7.8)		
Middle	21,703 (84.7)	3,913 (15.3)		
Richer	17,441 (75.8)	5,564 (24.2)		
Richest	11,679 (61.8)	7,220 (38.2)		

Residence				
Urban	31,215 (73.5)	11,273 (26.5)		
Rural	76,176 (89.2)	9,201 (10.8)	5235.328	<0.001
Marital Status				
Never married	1,947 (80.0)	488 (20.0)		
Married	99,516 (84.4)	18,440 (15.6)		
Living with partner	2,644 (70.5)	1,107 (29.5)		
Widowed	1,285 (90.0)	143 (10.0)		
Divorced	1,109 (93.2)	81 (6.8)		
Separated	889 (80.5)	215 (19.5)	673.358	<0.001
Region				
North Central	21,635 (86.0)	3,514 (14.0)		
North East	25,326 (91.5)	2,340 (8.5)		
North West	32,650 (93.2)	2,386 (6.8)		
South East	9,053 (71.6)	3,592 (28.4)		
South South	9,801 (72.6)	3,705 (27.4)		
South West	8,926 (64.4)	4,937 (35.6)	10172.297	<0.001

Table 2 show that, the mean age of the respondents was 30 years and standard deviation of 6.94, with a median age of 29 years and an age range of 15 to 49 years. The mean age at first sex was 17 years with standard deviation of 3.08 it ranges from 7 to 41 years. Respondents had a mean of 4 children ever born (SD = 2.57), with a median of 4 children and a range of 1 to 18 children.

Table 2: Summary statistics of Age, and Children Ever born

Variable	Mean	SD	Median	Minimum	Maximum
Current age	30	6.94	29	15	49
Age at first sex	17	3.08	16	12	41
Children ever born	4	2.57	4	1	18

Contraceptive Prevalence by year

Table 3 revealed that the total number of women included in the study across the five DHS survey years is 127,865. In total, 20,474 women reported contraceptive use, giving a prevalence of 16%. The prevalence of contraceptive use varied across survey years, decreasing slightly from 14.5% in 2003 to 12.9% in 2008, before increasing progressively to 14.9% in 2013, 16.1% in 2018, and reaching the highest prevalence of 20.7% in 2024. The 2024 survey recorded both the highest number of contraceptive users (5,764) and the highest prevalence of contraceptive use during the study period.

Table 3: Prevalence of Contraceptive by Year

Year	Sample Size	Users	Prevalence (%)
2003	6,029	875	14.5
2008	28,647	3,695	12.9
2013	31,482	4,684	14.9
2018	33,924	5,456	16.1
2024	27,783	5,764	20.7
Total	127,865	20,474	16

Spatial Distribution of Observed (Raw) Contraceptive Prevalence

Figure 1 displayed spatial distribution of contraceptive use from 2003. The result revealed substantial geographic disparities across Nigeria, with higher prevalence levels observed in several southern and North-central states, whereas lower prevalence was in the North-west and North-east states. The highest prevalence categories (50-70%) were observed in a few states, while most states recorded prevalence of contraceptive use which is below 40%, indicating likelihood of spatial heterogeneity in contraceptive use across the country.

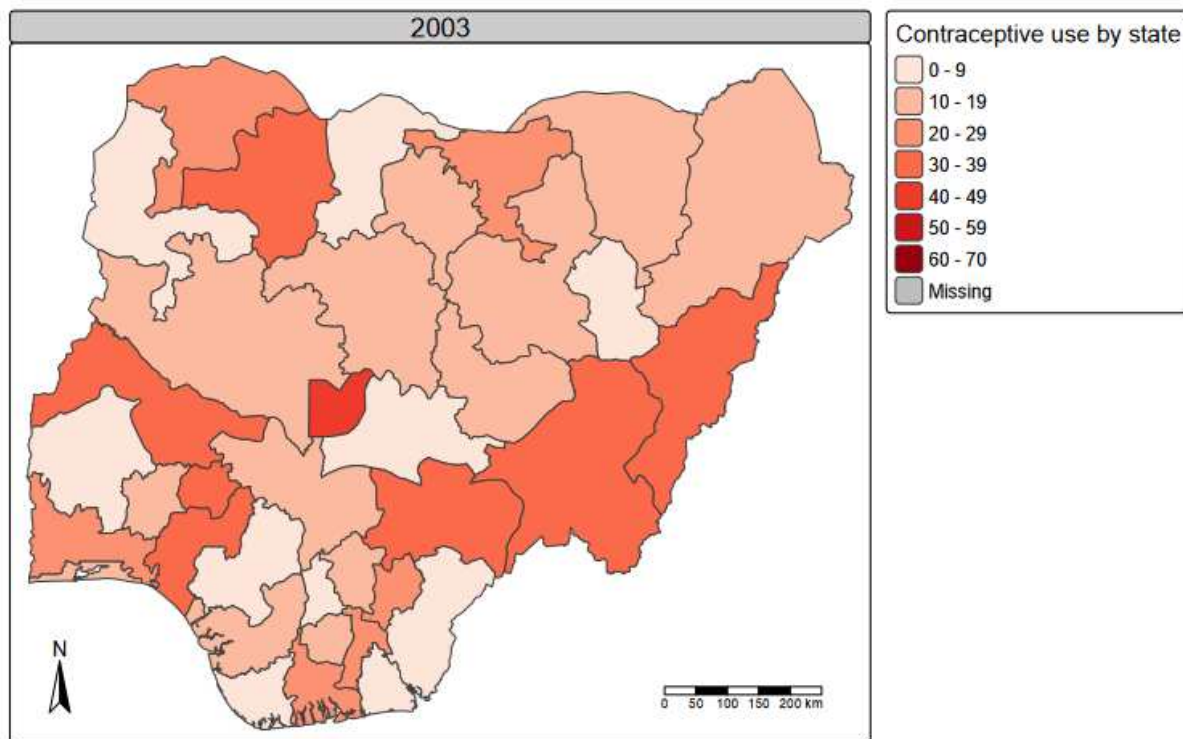


Figure 1: State-level crude prevalence by year

Fixed Effects model

In table 4 shows that Women from wealthier households had significantly higher odds of contraceptive use compared with women from the poorest households. The odds of contraceptive use increased progressively across wealth-index categories, with women from the richest households having 2.8 times higher odds of contraceptive use compared to the poorest (OR = 2.78; 95% CI: 2.55-3.03). For Educational attainment the result showed a strong positive association with contraceptive use. Women with higher education are four times more likely to use contraceptive compared with women with no education (OR = 4.10; 95% CI: 3.79-4.43). Place of residence also show significant association with contraceptive use, as rural women are less likely to use contraceptive compared to urban women (OR = 0.90; 95% CI: 0.86-0.94). Based on marital status, widowed, divorced, and separated women were less likely to use modern contraceptive

compared to women that are never married, while women living with partners showed no statistically significant difference since the credible interval included one.

Table 4: Posterior OR and 95% Credible Intervals

Variable	Odds Ratio (OR)	SD	95% CI
Wealth Index			
Poorer	1.21	0.037	1.12 - 1.30
Middle	1.68	0.037	1.56 - 1.81
Richer	2.12	0.039	1.97 - 2.29
Richest	2.78	0.043	2.55 - 3.03
Education			
Primary	2.14	0.031	2.01 - 2.27
Secondary	2.91	0.031	2.74 - 3.09
Higher	4.1	0.04	3.79 - 4.43
Residence			
Rural	0.9	0.022	0.86 - 0.94
Marital Status			
Married	0.85	0.058	0.76 - 0.96
Living with partner	1.04	0.069	0.91 - 1.19
Widowed	0.35	0.11	0.28 - 0.44
Divorced	0.48	0.135	0.37 - 0.63
Separated	0.65	0.099	0.54 - 0.79

Non-Linear model

The random effects results table 5 indicated varying levels of heterogeneity across the modeled components. The nonlinear effect of age at first sex exhibited very high precision ($\tau = 2182$) and a very small standard deviation ($\sigma = 0.021$), which implies an almost flat and highly smooth effect (See figure 2). Current age also demonstrated a smooth nonlinear pattern with relatively high precision ($\tau = 368$, $\sigma = 0.052$). However, children ever born showed greater variability of ($\tau = 45$, $\sigma = 0.149$), which implies moderate nonlinear fluctuations in modern contraceptive use based on number of children ever-born by a woman. The spatial random effect revealed geographic variation in contraceptive use across Nigerian states with $\tau = 3.4$, and $\sigma = 0.54$, which suggests the presence of residual spatial inequalities after adjusting for observed covariates. The temporal effect had extremely high precision and a near-zero standard deviation ($\tau = 21636$, $\sigma = 0.007$), indicating minimal unexplained temporal variation across survey years. On contrary, the space-time

interaction term exhibited relatively large variability ($\tau=2.23$, $\sigma=0.67$), suggesting considerable heterogeneity in temporal changes across states over time.

Table5: Hyperparameters (Precision Parameters)

Random Effect	Precision (τ)	SD (σ)
Age at First Sex	2182	0.021
Current Age	368	0.052
Children Ever Born	45	0.149
State (Spatial)	3.4	0.54
Year (Temporal)	21636	0.007
Space–Time Interaction	2.23	0.67

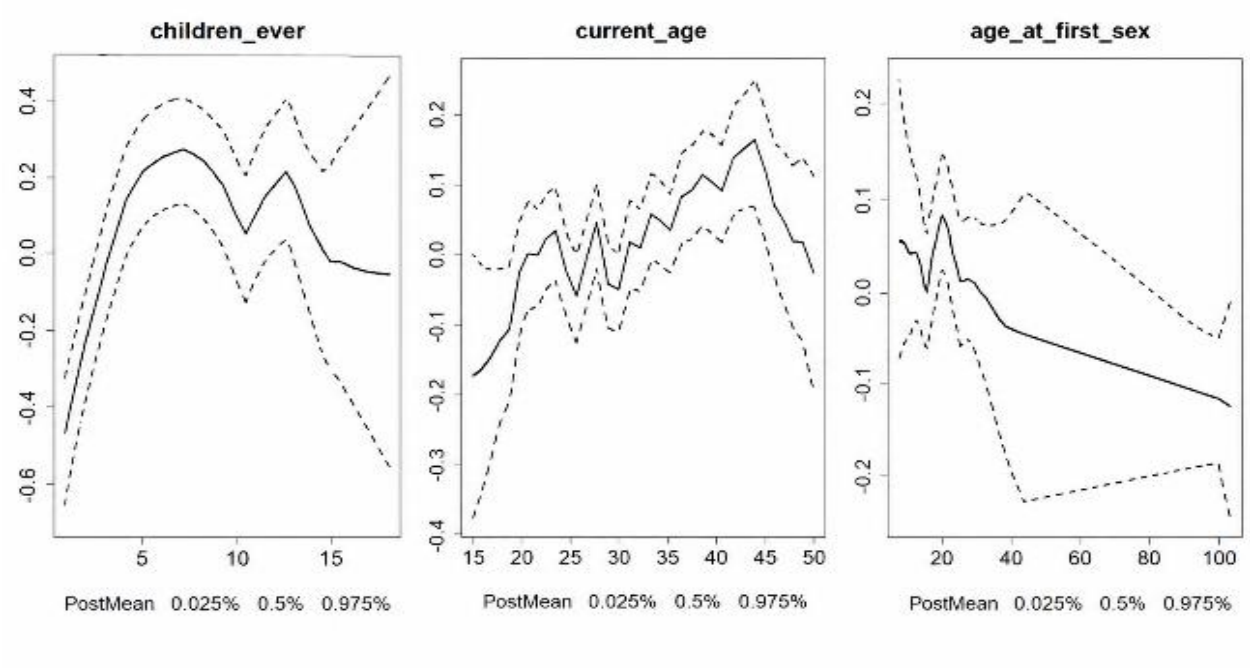


Figure 2: Non-linear Variables model plot

Smoothed Prevalence

Figure 3 shows the smoothed prevalence maps of contraceptive use from the Bayesian INLA model which revealed persistent spatial inequalities in contraceptive use across different state in Nigeria between 2003 and 2024. Higher smoothed prevalence estimates were consistently observed in several southern states as raw prevalence indicated earlier, particularly in the South-

West and parts of the South-South, whereas lower prevalence was seen in many northern states. As time increases, the spatial pattern exhibits gradual improvement in contraceptive use across different states, with the 2024 map indicating a broader expansion of moderate-to-high prevalence areas compared with earlier survey years. The smoothed estimates also demonstrated reduced random fluctuation and clearer spatial clustering relative to the raw prevalence maps, suggesting that the Bayesian spatial model effectively captured the underlying spatial effect impact on contraceptive use in Nigeria.

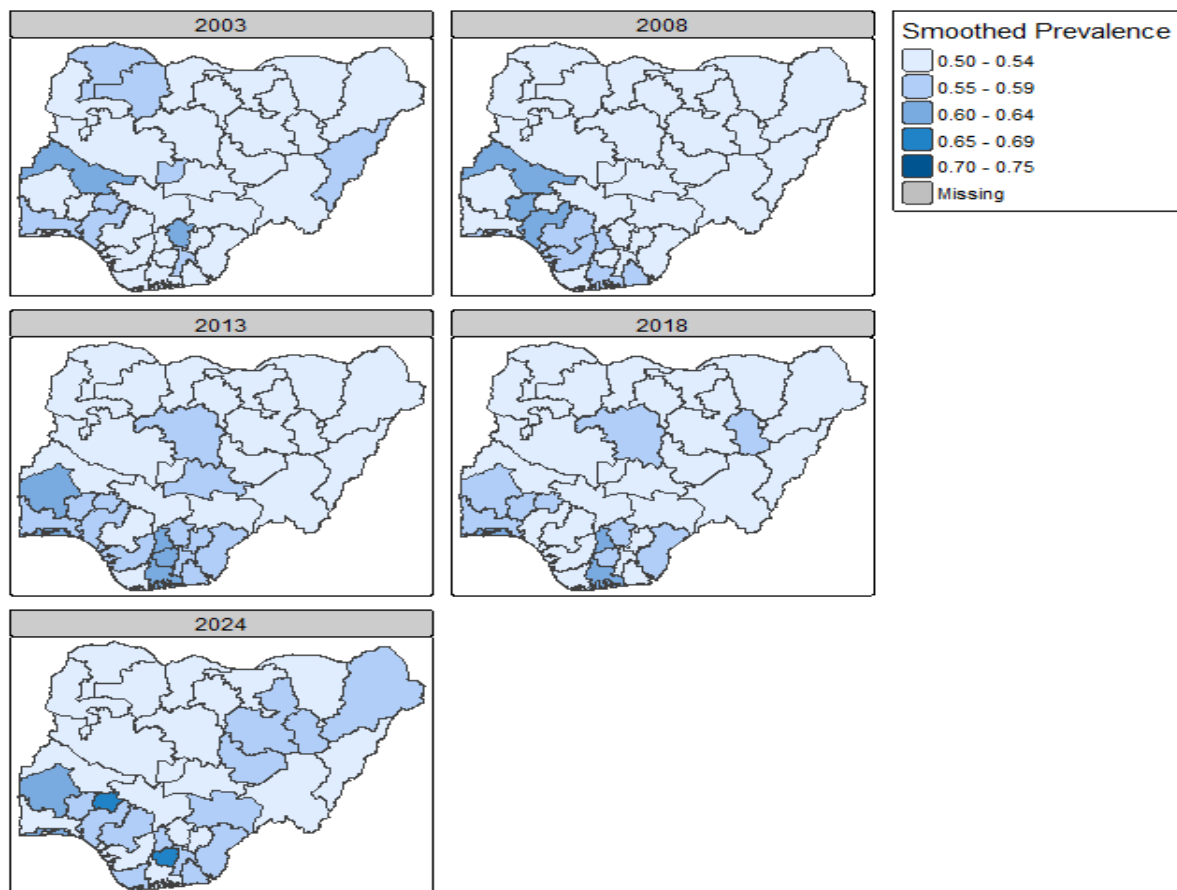


Figure 3: Smooth Prevalence by Year

Change in prevalence over Time

Figure 4 show the state-level change map which revealed significant geographic heterogeneity in contraceptive use prevalence between 2003 and 2024, with changes ranging approximately from - 0.2 to 0.5. A lot of states, particularly in southern Nigeria, recorded marked increases in

contraceptive prevalence, with some states showing improvements exceeding 0.4 in absolute terms. However, a few northern states experienced little improvement and some slight declines, with negative changes approaching -0.2. In Overall, the spatial distribution of change indicates that although contraceptive uptake improved nationally over the study period, the magnitude of progress remained uneven across states, which revealed persistent regional disparities in contraceptive use across Nigeria.

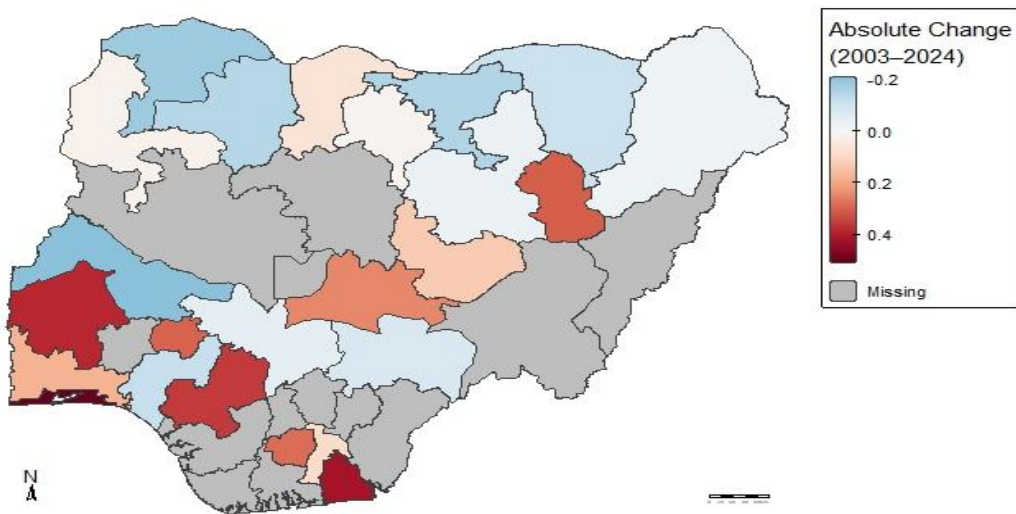


Figure 4: Prevalence change between 2003 to 2024

Figure 5 displayed the categorical change across states which highlight substantial spatial variation in contraceptive use prevalence changes across Nigeria between 2003 and 2024. A lot of states were classified as stable, particularly across some parts of southern and North-central Nigeria, while several northern states experienced declines in contraceptive use prevalence over the study period. High improvement states were scattered across both northern and southern regions, whereas moderate improvements were observed in few states. Overall, the map demonstrates that

changes in contraceptive uptake were spatially heterogeneous, with evidence of both progress and persistent regional inequalities across Nigerian states.

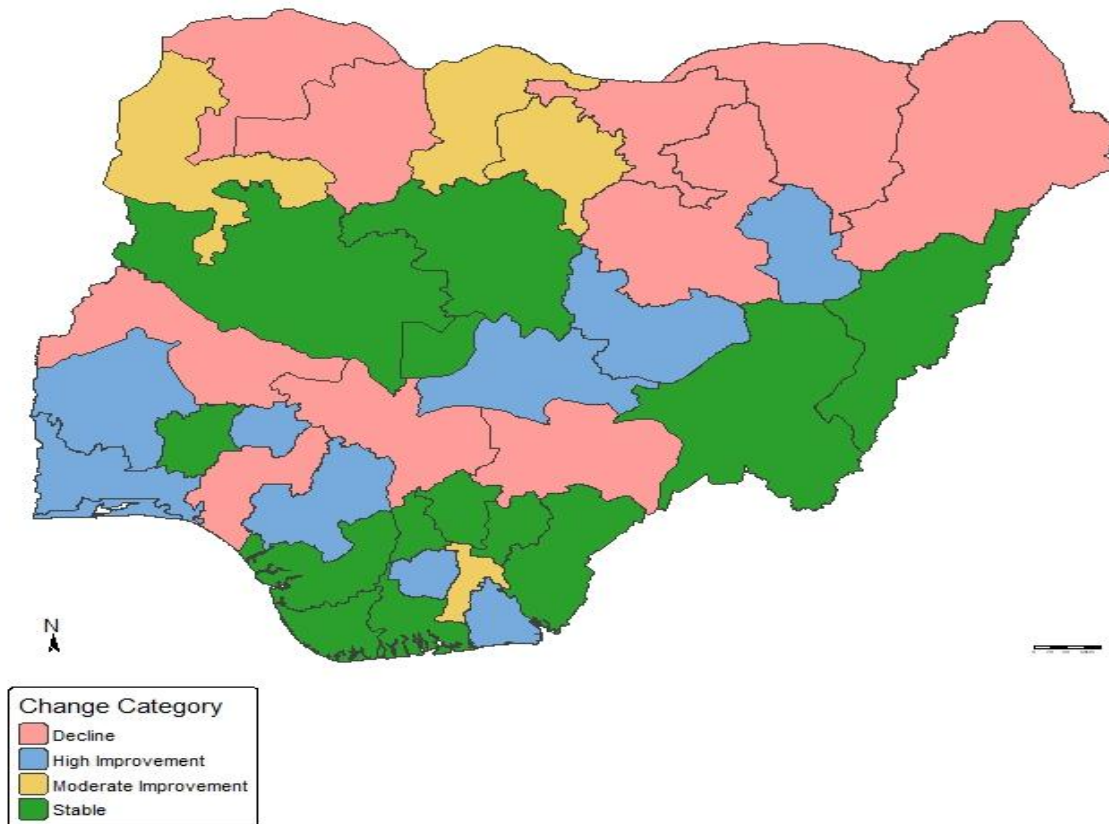


Figure 5: categorical change in prevalence from 2003 to 2024 by state

Posterior Exceedance Probabilities

Figure 6 displayed the result of posterior exceedance probability map which revealed marked spatial disparities in the likelihood of contraceptive prevalence exceeding the national average across Nigeria. Several states, particularly in southern Nigeria and parts of the North-East, exhibited high exceedance probabilities ranging from 0.6 to 1.0, indicating a high certainty that contraceptive use prevalence in these states was above the national mean. However, many states in northern and central Nigeria showed lower exceedance probabilities below 0.3, suggesting a low probability of exceeding the national average prevalence. Therefore, this result provided additional evidence of persistent spatial inequalities in contraceptive use across the country.

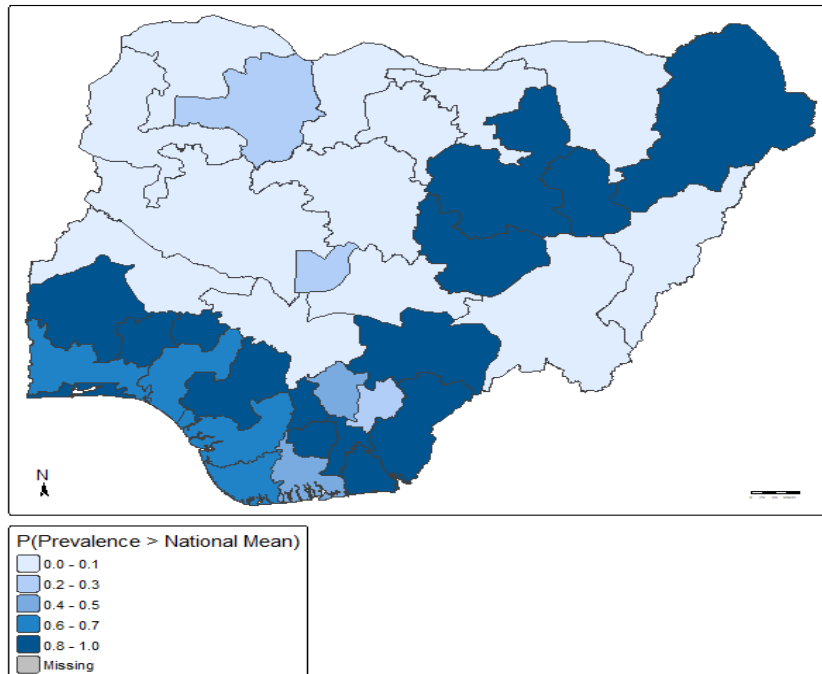
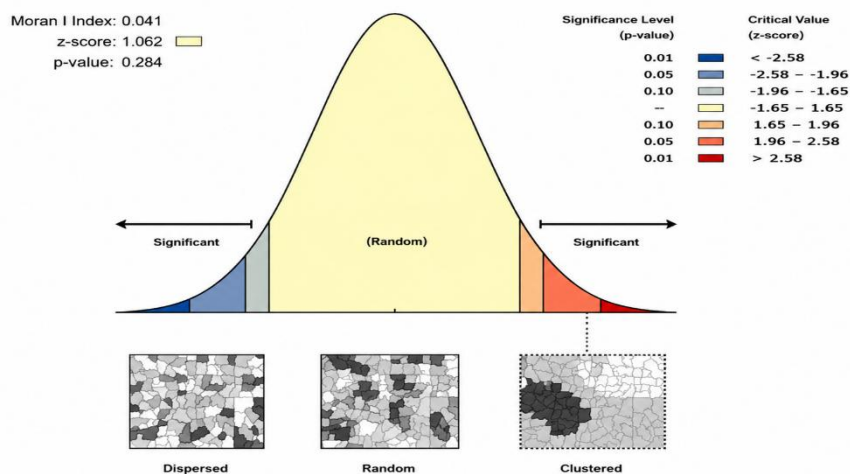


Figure 6: Posterior Exceedance Probabilities by State

Model Diagnostics

In figure 7, the Moran's I statistic for the model residuals was positive but not statistically significant ($I=0.041$, $pvalue=0.284$), this implies that the Bayesian spatial model is sufficiently captured the underlying spatial and geographic dependence in contraceptive use across states.



Given the z-score of 1.06217420167, the pattern does not appear to be significantly different than random.

Figure 7: Moran I plot of residuals

Discussion of Findings

This study examined the spatio-temporal distribution and determinants of contraceptive use among women in Nigeria using nationally representative DHS data from 2003 to 2024. The findings showed substantial spatial, socioeconomic, and temporal inequalities in modern contraceptive use across the states. The results show that the contraceptive prevalence increased from 14.5% in 2003 to 20.7% in 2024, suggesting gradual improvement over the two-decade period. This upward trend aligned with previous studies conducted in Nigeria and other sub-Saharan African countries, which reported increasing contraceptive uptake due to improved awareness, expansion of reproductive health programs, and greater access to family planning services^{7,8}. Nevertheless, the observed prevalence remains below the targets recommended for achieving universal reproductive health coverage under the Sustainable Development Goals.

This study found strong socioeconomic inequalities in contraceptive use. Women with higher educational attainment are more likely to use contraceptive compared with women without formal education. Specifically, women with higher education had approximately four times greater odds of contraceptive use. This finding agrees with previous evidence that education improves women's reproductive autonomy, knowledge of family planning methods, and healthcare utilization^{9,10}. Educated women are more likely to understand contraceptive benefits, negotiate reproductive decisions, and access modern healthcare services. Similarly, household wealth was strongly associated with contraceptive uptake, with women from the richest households more likely to use contraceptive compared to women from poorer households. This pattern has been widely reported in sub-Saharan Africa and reflects persistent financial and structural barriers to reproductive healthcare among disadvantaged populations¹¹.

Place of residence also showed significant disparities, as rural women are less likely to use contraceptive than urban women. This finding aligns and supports earlier Nigerian studies reporting that urban areas benefit from better healthcare infrastructure, greater media exposure, and improved access to reproductive health services¹². On contrary, rural populations often face shortages of health facilities, limited access to contraceptive commodities, transportation barriers, and cultural resistance to family planning. The observed rural-urban inequality therefore highlights the continuing need for geographically targeted interventions.

Significant regional disparities were also observed across Nigeria, with southern regions consistently demonstrating higher prevalence of contraceptive use than northern regions. The South West recorded the highest prevalence, whereas the North West exhibited the lowest levels of contraceptive use. This north-south divide has been documented in previous Nigerian demographic studies and is often linked to differences in female education, sociocultural norms, religion, fertility preferences, and healthcare access^{13,12}. However, this present study extends previous evidence by demonstrating that these disparities persist even after adjusting for important demographic and socioeconomic factors within a Bayesian spatial modeling framework.

The nonlinear random effects further revealed important demographic patterns. The effect of current age demonstrated a smooth nonlinear relationship with contraceptive use, suggesting that uptake varies across reproductive age groups rather than changing linearly. Similarly, the effect of children ever born indicated moderate variability, implying that Children ever-born play an important role in shaping contraceptive behavior. Women with larger family sizes may increasingly adopt contraception after achieving desired fertility. These findings are consistent with fertility transition theories and previous reproductive health studies in developing countries¹⁴.

One of the major strengths of this study lies in the spatial modeling component. The spatial random effects revealed substantial residual geographic variation in contraceptive use across Nigerian states, even after accounting for observed covariates. This suggests that unmeasured contextual factors such as local health policies, cultural practices, service availability, and community norms continue to influence contraceptive uptake. The smoothed prevalence maps generated using the Bayesian INLA approach provided clearer and more stable spatial patterns than crude prevalence estimates by reducing random fluctuations and borrowing strength across neighboring states and time periods. This represents an important methodological contribution because most previous Nigerian studies relied primarily on classical regression approaches without accounting for spatial dependence.

The exceedance probability analysis provided further insight into the geographic distribution of contraceptive use. Several southern states demonstrated high posterior probabilities of exceeding the national average prevalence, whereas many northern states had very low probabilities. Unlike conventional prevalence mapping, exceedance probabilities provide probabilistic evidence for identifying priority intervention areas and are increasingly recognized as valuable tools in spatial

epidemiology¹⁵. The application of exceedance probability mapping in contraceptive use research within Nigeria remains limited, making this study particularly relevant for evidence-based reproductive health planning.

The temporal random effect suggested minimal unexplained temporal variation after accounting for covariates and spatial structure. However, the significant space-time interaction indicated that temporal changes in contraceptive use varied considerably across states. This finding implies that improvements in contraceptive uptake have not occurred uniformly throughout the country. While some states experienced substantial gains between 2003 and 2024, others showed stagnation or decline. This heterogeneity underscores the importance of subnational policy approaches rather than relying solely on national strategy.

The findings of this study contribute significantly to the existing body of knowledge in several ways. First, the study provides one of the few comprehensive Bayesian spatio-temporal analyses of contraceptive use in Nigeria covering more than two decades of DHS surveys. Second, it demonstrates the importance of accounting for spatial dependence and nonlinear demographic effects in reproductive health research. Third, the study reveals persistent subnational inequalities that are often masked by national-level estimates. Finally, the integration of exceedance probability mapping provides a novel framework for identifying states with consistently high or low contraceptive prevalence, thereby supporting geographically targeted public health interventions.

Overall, the study highlights that despite gradual national improvements in contraceptive use, substantial spatial and socioeconomic inequalities persist across Nigeria. Paying attention to these disparities will require sustained investments in female education, poverty reduction, rural healthcare access, and culturally sensitive family planning programs targeted toward underserved regions, particularly northern Nigeria.

Conclusion

This study revealed substantial spatial, temporal, and socioeconomic inequalities in contraceptive use across Nigeria between 2003 and 2024. Although contraceptive use prevalence improved nationally over the study period, however; important regional disparities persisted, with consistently higher prevalence observed in southern states compared with many northern states. Education, household wealth-index, place of residence, and marital status were significant

determinants of contraceptive use, while the Bayesian spatio-temporal INLA model demonstrated considerable residual spatial heterogeneity across states. The findings highlight the importance of geographically targeted and equity-focused family planning interventions, particularly in underserved regions. Furthermore, the application of Bayesian spatial modeling provided more stable and reliable estimates than crude prevalence methods, offering valuable evidence for reproductive health planning and policy formulation in Nigeria.

Abbreviations

DHS: Nigeria Demographic and Health Surveys

INLA: Integrated Nested Laplace Approximation

AIC: Akaike Information Criterion

WAIC: Watanabe Akaike Information Criterion

BIC: Bayesian Information Criterion

Ethics approval and consent to participate

The data is already in public domain therefore Human Ethics and Consent to Participate declarations: not applicable

Consent for publication

Not Applicable

Availability of data and materials

All data supporting the findings of this study are available within the paper.

The datasets used in this study are publicly available upon request from the DHS Program.
<https://dhsprogram.com/methodology/survey/survey-display-636.cfm>

The supplement material could be assessed here

<https://drive.google.com/file/d/1bqkuLQko1TsZSgw0mVB9QZMJaxg7PFpI/view?usp=sharing>

Competing Interests

No conflict of interest.

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Authors' contributions

O.D.M: Conceptualisation, methodology, data curation, formal analysis, software, validation, visualisation, data verification, writing - original draft.

Z.N.J: Methodology, supervision, validation, data verification, data interpretation, writing - review & editing.

V.G.K: Literature review, data interpretation, validation, writing - review & editing.

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