Applied Spatial Analysis and Policy
https://doi.org/10.1007/s12061-022-09497-5

Spatially Varying Intergenerational Changes in the Prevalence of Female Genital Mutilation/Cutting in Nigeria: Lessons Learnt from a Recent Household Survey

Chibuzor Christopher Nnanatu[1,2] · **Adeniyi Francis Fagbamigbe**[3,4] · **Emmanuel Afuecheta**[5] · **Chigozie Edson Utazi**[1]

Received: 1 June 2021 / Accepted: 6 December 2022

Abstract

Considering the concerted investments in anti-female genital mutilation/cutting (FGM/C) campaigns championed by the Nigerian government and non-governmental organizations, research findings suggest that reduction in intergenerational (mother-to-daughter) prevalence of FGM/C in Nigeria has been very slow. What can we learn from the 2018 Nigerian Demographic and Health Survey (2018 NDHS) about the roles of the key drivers of mother-to-daughter FGM/C prevalence in Nigeria? Here, drawing upon the 2018 NDHS dataset, we provided a context-specific study on the geographical patterns and the enabling factors of intergenerational trends in FGM/C among Nigerian women aged 15 – 49 years and their daughters aged 0 – 14 years. Using Bayesian semi-parametric *geo-additive* regression model, we simultaneously controlled for the effects of individual-level, community-level and unobserved geographical factors. We learnt that although there has been an overall decline in mother-to-daughter prevalence of FGM/C, the practice persists in Nigeria largely due to geographical location and social norm related factors – risk was high among daughters of circumcised women and daughters of women who supported the continuation of FGM/C. We identified Kano, Kaduna, Imo and Bauchi states as the hotspots and there was an increased risk of FGM/C among daughters of women who lived in the neigbouring states of Jigawa and Yobe. Daughters of circumcised women were about 2.7 times more likely to be cut. We recommend the development of tailored community-level interventions targeting circumcised women in the hotspot states and their neighbours to ensure a total eradication of female circumcision in Nigeria by the year 2030.

Keywords FGM/C abandonment · Social norms · Bayesian geo-additive regression · Nigeria · Spatial random effects · Mother-to-daughter changes

✉ Chibuzor Christopher Nnanatu
cc.nnanatu@soton.ac.uk

Extended author information available on the last page of the article

Published online: 20 December 2022

Introduction

Female genital mutilation/cutting or female circumcision (FGM/C, henceforth) is a global health and human rights concern that is prevalent in over 30 countries of the world but concentrated mainly in Africa and the Middle East (WHO, 2020). The practice which is defined as all forms of non-medical injuries to the external female genitalia, has no justifiable benefits but comes with huge and often life-changing health consequences, ranging from shock to newborn deaths (Abd El-Naser et al., 2011; Alsibiani & Rouzi, 2010; Dirie & Lindmark, 1992; Toubia, 1994). Globally, it is estimated that about 200 million women and girls alive today have experienced various forms of FGM/C including some 20 million Nigerian women and girls (28TOOMANY, 2018, Kandala et al., 2020). FGM/C has been targeted for elimination in line with the Sustainable Development Goals (SDGs) of zero harmful practices against women and girls by the year 2030 (Kandala et al., 2020). As a result, efforts to end FGM/C are on top gear in prevalent countries around the world including Nigeria.

Currently, there are a number of anti-FGM/C intervention programmes aimed at accelerating a total eradication of FGM/C in Nigeria with a mix of legal /policy and advocacy strategies (28TOOMANY, 2018; Briggs, 1998; Mberu, 2017; Nnamdi, 2018). In 2015, the Nigerian government passed into law the Violence against Persons (Prohibition) Act, 2015 (VAPP Act). The 2015 VAPP Act criminalises FGM/C and other forms of gender-based violence in Nigeria with perpetrators liable for up to 4 years imprisonment or two hundred thousand Naira in fine or both if convicted, with a provision for the reintegration of FGM/C victims into the society (NAPTIP, 2015; Nnamdi, 2018). In addition, prior to the passage of the 2015 VAPP act, there was the 2013/2017 National Policy and Plan for Action for Elimination of FGM/C in Nigeria (28TOOMANY, 2018, Kandala et al., 2020; Nnamdi, 2018). Advocacy interventions are mainly carried out by the civil society organizations (CSOs) who have continued to mobilize people against FGM/C, turning cutters into anti-FGM/C campaigners. The groups often partner with the media, traditional/community leaders, political and religious leaders to ensure a grassroot dissemination of anti-FGM/C messages at federal and state levels aimed at increasing anti-FGM/C awareness and bring about attitudinal changes (Briggs, 1998).

However, a recent study by Fagbamigbe et al. in 2021 using household surveys from 14 African countries identified Nigeria and two other African countries (Niger and Mali) as having the lowest percentage reduction in mother-to-daughter FGM/C ratio and called for context-specific studies focusing on these identified countries (Fagbamigbe et al., 2021). In addition, recent estimates provided by the 2018 Nigerian Demographic and Health Surveys (2018 NDHS) show that the national prevalence of FGM/C among Nigerian women aged 15 – 49 years stood at 20% in 2018 with most of the cuttings (86%) carried out before age 5 (National Population Commission - NPC and ICF, 2018). Although this represents approximately 5% decline from the 25% prevalence reported in 2013 NDHS, this raises concerns about the slow pace of FGM/C practice abandonment given the huge investments in intervention programmes in Nigeria (Kandala et al., 2020; Nnanatu et al., 2021). This calls for an urgent total evaluation of the existing intervention programmes within the country.

In the context of Nigeria, the prevalence of FGM/C among women and girls varied geographically across the 36 states and the federal capital territory (FCT) (National Population Commission - NPC and ICF, 2018; Gayawan & Lateef, 2019; Kandala et al., 2020; Nnanatu et al., 2021). In particular, a recent study by Gayawan and Lateef in 2019 using 2013 NDHS data, found that FGM/C among women aged 15 – 49 years has persisted in Nigeria largely due to the support for the continuation of the practice which varied geographically with respect to demographic and socioeconomic characteristics (Gayawan & Lateef, 2019). Women who lived in most of the southern states whose highest level of education was either primary or secondary school were more likely to support the continuation of FGM/C than their counterparts in the northern Nigeria states. However, another recent study by Nnanatu et al. in 2021 which focused on FGM/C prevalence among girls aged 0 – 14 years in Nigeria using six (6) successive waves of the NDHS data and Multiple Indicator Cluster Surveys (MICS) between 2003 and 2016/17 found that FGM/C varied geographically with a possible shift in the practice from the southern states to the northern states (Nnanatu et al., 2021). Similarly, they found that social norm factors such as a woman's FGM status and her support for the continuation of the practice are the key challenges to FGM/C abandonment in Nigeria.

Until recently, most studies on FGM/C have focused on the trends of the practice among women aged 15 – 49 years with a very little interest on the trends among girls aged 0 – 14 years (Briggs, 1998; Kandala et al., 2020; Mberu, 2017; Nnanatu et al., 2021). Moreover, apart from the recent study on the enabling factors of FGM/C in the next generation of women in Africa (Fagbamigbe et al., 2021), studies have always explored changes among women and girls independently of each group, whereas the much needed context-specific studies on changes in mother-to-daughter FGM/C prevalence among mothers aged 15 – 49 years and their daughters aged 0 – 14 years are yet to be explored. In this study, we aimed to fill this gap in the literature in the context of Nigeria.

Intuitively, the daughters of women who received anti-FGM/C interventions are expected to be less likely to be circumcised. This therefore suggests that intergenerational (mother to daughter) changes in FGM/C could be used as a proxy measure of the impacts of the existing anti-FGM/C interventions in Nigeria, and elsewhere. Thus, in this study, using a class of flexible structured additive regression (STAR) models, also known as semi-parametric *geoadditive* regression models implemented within a robust Bayesian hierarchical regression modelling framework (Brezger & Lang, 2006; Failed, 2003; Kandala et al., 2019, 2021; Kneib & Hennerfeind, 2013; Nnanatu et al., 2021), we investigated the geographical patterns of mother-to-daughter FGM/C prevalence in Nigeria whilst drawing upon the most recent 2018 NDHS data. The statistical modelling approach allowed us to explicitly account for the inherent spatial autocorrelation due to shared geographical characteristics and possible spatial independence due to spatial heterogeneity within the data. In addition, the models allowed us to simultaneously control for the effects of other linear and non-linear covariates (e.g., mother's age). We expect that the findings from this study would provide more reliable statistical evidence that could highlight 'hotspots' of intergenerational FGM/C prevalence in Nigeria, and possibly suggest why change is not happening at the expected pace. Specifically, we aim to identify:

1) The geographical patterns of intergenerational (mother-to-daughter) shifts in the prevalence of FGM/C in Nigeria with respect to the spatial locations across the 37 spatial units (36 states and the FCT).
2) The enabling individual-level/community-level factors of mother-to-daughter FGM/C prevalence in Nigeria.

Materials and Methods

Data Source, Sample Design and Data Availability

The data used in this study were obtained from the 2018 NDHS implemented by the National Population Commission (NPC) in selected Enumeration Areas (EAs) across the 36 states and the Federal Capital Territory (FCT; Fig. 1). The NDHS which is usually conducted once every five years covers important research areas such as fertility, awareness and use of family planning methods, maternal and child health, disability, female genital mutilation/cutting, domestic violence, the

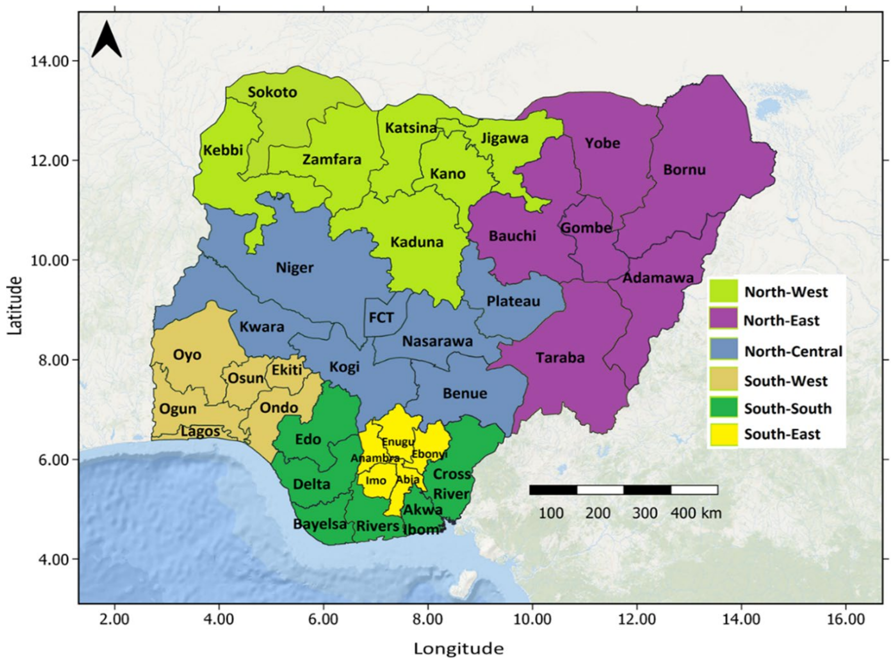

Fig. 1 Map of Nigeria showing the 36 states and the federal capital territory (FCT), and the six (6) geo-political zones of the country (Authors Drawings)

prevalence of malaria, amongst others (National Population Commission - NPC and ICF, 2018).

The 2018 NDHS involved a two-stage stratified cluster sampling strategy. The primary sampling units are based on the EAs in the 774 local government areas (LGas) across the 36 states and the FCT. In the first stage, 1400 EAs were selected with probability proportional to the number of households in the EA (size of the EA). The list of all the households in the selected EAs then formed the sampling frame for the second sampling stage. An equal probability systematic sampling was employed in the second stage and a fixed number of 30 households were selected in every cluster so that 42,000 households were selected in all. Finally, women aged 15 – 49 years across a total of 1,389 clusters were interviewed, and respondents who have living daughters aged 0 – 14 years were also asked about the FGM/C status and circumstances of their daughters FGM/C. See the 2018 NDHS report for more details on the sampling strategies (National Population Commission - NPC and ICF, 2018).

The datasets utilised for our purposes comprised 14,681 Nigerian girls aged 0 – 14 years and their 8,291 mothers aged 15 – 49 years out of which 8277 (99.8%) women reported their FGM/C status. Data were downloaded from the DHS website on https://dhsprogram.com/.

Methodology

The research objectives outlined above were addressed using semi-parametric geo-additive regression models, while simultaneously adjusting for spatial clustering and spatial independences including other key explanatory variables. Model parameter estimation rely on a Bayesian statisticalinference framework via Markov chain Monte Carlo (MCMC) techniques (Fahrmeir & Lang, 2001; Failed, 2003; Green, 2001; Utazi et al., 2018).

Outcome Variable

For each dataset (daughter or mother), the outcome y is a binary variable which represents whether a girl (or her mother) has experienced FGM/C or not with $y = 1$ if cut and $y = 0$ if uncut.

Explanatory Variables

The explanatory variables employed in this study in both descriptive analysis and Bayesian geoadditive regression modelling are presented in Table 1. These include a girl and her mother's current age, type of place of residence (rural–urban), region of residence, mother and her husband/partner's highest educational level, household wealth quintile, religion, ethnicity, and support for FGM/C continuation. For the models fitted to the girls' data, we included the mother's FGM/C status variable $fgm \in \{Cut, Notcut\}$ as a covariate within the modelling framework to test the

Table 1 Description of the explanatory variables included in our models

Variable	Description	Scale of measurement	Fixed/random/smooth
Region	The geopolitical region in which a girl's mother lives	Nominal: North Central, North East, North West, South South, South East & South West	Fixed effect
AgeM	Current age (in years) of a girl's mother at the time of the survey	Numerical: 15 – 49; Ordinal: 15 – 19, 20 – 24, 25 – 29, 30 – 34, 35 – 39, 40 – 44, 45 – 49	Smooth function (numerical), fixed effect (ordinal)
AgeD	A girl's current age at the time of the survey	Numerical: 0 – 14	Smooth function
Residence	The type of place of residence where a girl's mother lives	Nominal: Urban, Rural	Fixed effect
SexOfHH	The gender of the head of a girl's household	Nominal: Male, Female	Fixed effect
Ethnicity	The ethnic group of a girl's mother	Nominal: Hausa/Fulani, Yoruba, Igbo, Other	Fixed effect
Religion	The religious group which a girl's mother belonged to	Nominal: Islam, Christian, Other	Fixed effect
EducM	Highest educational level attained by a girl's mother	Ordinal: No Education, Primary, Secondary, Higher	Fixed effect
EducP	Highest educational level attained by the husband/partner of a girl's mother	Ordinal: No Education, Primary, Secondary, Higher	Fixed effect
Wealth	The wealth quintile class of a girl's household	Ordinal: Poorest, Poorer, Middle, Richer, Richest	Fixed effect
NumOfCutS	Number of circumcised sisters	Numerical: 0 – 9	Smooth function
Support	Whether a girl's mother supports FGM/C continuation or not	Ordinal: Continued, Stopped, Depends, Don't Know	Fixed effect
RequiredByReligion	Whether FGM/C is a woman's religious obligation	Ordinal: No, Yes, Don't know	Fixed effect
State	The state of residence of a girl's mother including the FCT	Numerical: 1 – 37	Smooth (correlated), random (uncorrelated)

potential influence of a woman's FGM/C status on the likelihood of her daughter being subjected to the practice.

Statistical Modelling and Data Analysis

Descriptive and Bivariate Analyses

First, we calculated the weighted bivariate association between FGM/C prevalence among girls and their mothers with respect to the key baseline characteristics using the *itable* and *svy* commands for performing Pearson's Chi-square test of idependence in STATA version 16 (Stata Statistical Software, 2009. 2009).

Test for Clustering

We assessed local and global clustering patterns of FGM/C among Nigerian girls aged 0–14 years and their mothers aged 15 – 49 years using Moran's I test (Hongfei et al., 2007). A clustered outcome is indicated by significantly positive Moran's I statistics, while a dispersed outcome is indicated by a significantly negative Moran's I statistics. These were implemented in R statistical programming software version 4.0.2 using *moran.test()* and *moran.mc()* functions available in the ***spdep*** package.

Bayesian Hierarchical Geo-Additive Logistic Regression Model

We used Bayesian semi-parametric *geo-additive* hierarchical regression models of the form,

$$g(p_i) = \eta_i = f_1(x_{i1}) + \cdots + f_p(x_{ip}) + z_i^{'}\boldsymbol{\gamma} + \boldsymbol{f_{spat}}(\boldsymbol{s_i}) \tag{1}$$

where p_i is the probability of undergoing FGM/C by subject (woman or her daughter) i and $g(p_i)$ is an appropriate link function such that $p_i = g^{-1}(\eta_i)$; $f_1(.), \ldots, f_p(.)$ are the non-linear (not necessarily smooth) functions of continuous covariates $x_{i1}, \ldots, x_{ip}$ (e.g., mother's age, girl's age, etc.); $f_{spat}(s_i)$ is the (non-parametric) function of the spatial covariates $s_i \in \{1, \ldots, S\}$ corresponding to the consecutively labelled geographical location identifiers for the 36 Nigerian states (*State*) and the FCT, that is, $S = 37$, and which accounts for the random effects of the geographical locations; $z_i^{'}s$ are the usual fixed effects linear and categorical variables (e.g., Educational level, Wealth index, etc.) with the coefficients vector $\boldsymbol{\gamma}$**.** Specifically, we used a logit link function within the full model given in Eq. (2).

$$\begin{aligned} logit(p_i) = \log\left(\frac{p_i}{1-p_i}\right) = \eta_i = f(AgeM) + f(AgeD) + f(NumOfCutS) \\ + Residence + EducM + Religion + SexOfHH + Ethnicity \\ + Wealth + Support + fgm + f_{str}(State_i) + f_{unstr}(State_i) \end{aligned} \tag{2}$$

where $\log\left(\frac{p_i}{1-p_i}\right)$ is the log odds of undergoing FGM/C.

Furthermore, variants of the model described in Eq. (2) were explored separately for each of the girls' and mothers' datasets. All models were implemented in R statistical programming software version 4.0.2 (R Core Team 2019) using R2BayesX, the R interface of BayesX – a popular statistical software for fitting various classes of generalized additive mixed models (Umlauf et al., 2015). Note that the *full* (or *adjusted*) model specified in Eq. (2) included all the key covariates as well as the spatial random effects f_{spat} which was decomposed into a spatially correlated (f_{str}) and spatially independent (f_{unstr}) random effects such that the total spatial random effect $f_{spat} = f_{str} + f_{unstr}$. In addition, we tested reduced models containing only the spatial random effects without the covariates (*unadjusted spatial* model) as well as models which contained other covariates but with no spatial random effects *(unadjusted* model, henceforth) in which the mother's age was modelled as a categorical variable for ease of exposition. For a fully Bayesian inference, samples were then drawn from the joint posterior distribution of the parameters $\boldsymbol{\theta} = (\boldsymbol{f}, \boldsymbol{\tau}^2, \boldsymbol{\gamma})$ given the data $\boldsymbol{y}$ in Eq. (3),

$$\pi\left(\boldsymbol{f}, \boldsymbol{\tau}^2, \boldsymbol{\gamma} | \boldsymbol{y}\right) \propto \pi(f, \tau, \gamma) \times L\left(\boldsymbol{y}, f_1, \ldots, f_p, \gamma\right) \tag{3}$$

where $\boldsymbol{f} = (f_1, \ldots, f_p)'$ is the vector of the smooth function's parameters; $\boldsymbol{\tau}^2$ is the corresponding vector of variance parameters; $\pi(f, \tau, \gamma)$ and $L(.)$ are the joint prior distribution of the parameters and the joint likelihood function of the data given the parameters; respectively. Note that f and τ are generic terms representing $\{f_1, \ldots, f_p, f_{str}, f_{unstr}\}$ and $\{\tau_1, \ldots, \tau_p, \tau_{str}, \tau_{unstr}\}$, respectively. The parameters γ and $f_j (j = 1, 2, \ldots, p)$ were assigned uniform prior and a mulriplicative Gaussian prior distribution, respectively (Fagbamigbe & Nnanatu, 2021; Nnanatu et al., 2021). Markov Random Field (MRF) prior distribution was assigned to the correlated spatial random effects. Thus, for $s = 1, \ldots, S$,

$$f_{str}(s) | f_{str}(r), r \neq s \sim N\left(\sum_{r \sim s} \frac{f_{str}(r)}{N_s}, \frac{\tau^2_{str}}{N_s}\right) \tag{4}$$

where N_s is the number of states that share border with state s, and $r \sim s$ denotes that state r is a neighbour of state s. Thus, the (conditional) mean of $f_{str}(s)$ is the average of functions of the neighbouring states, where τ_{str} is a variance parameter (Besag et al., 1991; Rue, 2001). A zero-mean independent and identically distributed Gaussian priors were assigned to the uncorrelated (unstructured) spatial effect $f_{unstr}(s)$ such that

$$f_{unstr}(s) | \tau_{unstr} \sim N\left(0, \tau^2_{unstr}\right), \tag{5}$$

where τ_{unstr} is a smoothing parameter. Inverse gamma-distributed hyperpriors were assigned to the τ parameters, that is, $\pi\left(\tau^2\right) \sim IG(a, b)$, where a and b are hyperparameters with $a > 0$ and $b > 0$ for joint posterior propriety.

Finally, samples were then drawn from the posterior distribution specified in Eq. (3) based upon iteratively weighted least squares (IWLS) MCMC sampling schema (Brezger & Lang, 2006; Fahrmeir & Lang, 2001). We carried out sensitivity analysis with different combinations of the hyperparameter values, however, the BayesX default choices of $a = b = 0.001$, provided no worse fit throughout. For these models, all functions were centred on zero for identifiability. MCMC convergence diagnostics were based on visual inspection of the trace plots and autocorrelation function plots of the posterior samples (Green, 2001). In addition, estimates of the deviance information criterion (DIC) were used to assess model fits such that models with smaller DIC values were believed to show better fit (Spiegelhalter et al., 2002). Results based on the *adjusted* and *unadjusted* models are presented as posterior odds ratios (PORs) using graphs, tables and maps, however, only the results from the best fit models are discussed further. The PORs are obtained by taking exponents of the posterior estimates of the linear predictors $\widehat{\eta}$ specified in Eq. (2), that is, $\text{POR} = \exp(\widehat{\eta})$.

Results

Descriptive Statistics

Results from the weighted bivariate association analyses between FGM/C prevalence and baseline characteristics of women and their daughters are presented in Table 2. Overall, FGM/C prevalence among Nigerian girls aged 0 – 14 years included in our study stood at 31.1%, while that of their mothers aged 15 – 49 years stood at 35.5% (N = 8277) representing a 4.4% decline (Table 2).

Unadjusted bivariate association between between a girl's FGM/C status and her mother's characteristics were found to be high if her mother lived in the northwestern region (51.2%), was a younger mother aged 15 – 19 years (50.4%), lived in rural area (37.3%), are Hausa/Fulani (49.1%), Islam (42.3%), uneducated mother (44.1%), and came from the poorest household (44.9%). On the other hand,, high unadjusted association between FGM/C status and background characteristics were obtained among women wholived in southwestern regions (54.8%), were older women aged 44 – 49 years (44.0%), lived in urban areas (41.7%), are Yoruba (61.5%), were Christian (39.6%), attained up to secondary school (40.7), and from richer household (41.4%)., However, with respect to a woman's beliefs about the practice of FGM/C, high levels of association with FGM/C status were obtained for both women versus their daughters among women who believed that FGM/C is a religious obligation (45.5% versus 59.5%) and women who supported the continuation of the practice (56.4% versus 75.3%). This further suggests that the persistence of FGM/C in Nigeria is mainly due to social norm factors where individuals feel compelled to conform with the expectations of the social class within one's community or risk social exclusion (Mackie & LeJeune, 2009; Shell-Duncan et al., 2018). Note that the weighted FGM/C prevalence presented here is different from that reported in the report of the 2018 NDHS (National Population Commission - NPC and ICF, 2018) because our analyses considered only women with living daughters for our purposes.

Table 2 Bivariate association ofa woman's baseline characteristics and the FGM/Cstatus of the woman and her daughter

Characteristics	Percentage of cut girls			Percentage of cut women		
	n	%	p-value	*n*	%	*p*-value
Region						
North Central	1,753	18.2	0.000	1,024	29.7	0.000
North East	3,421	30.7		1,826	10.8	
North West	4,327	51.2		2,259	38.5	
South East	2,050	18.9		1,166	53.6	
South South	1,470	7.8		918	34.7	
South West	1,660	17.5		1,084	54.8	
AgeM						
15–19	221	50.4	0.000	206	39.1	0.000
20–24	1,307	43.8		955	34.3	
25–29	2,818	32.1		1,647	31.4	
30–34	3,390	30.0		1,708	32.7	
35–39	3,242	27.5		1,607	36.5	
40–44	2,279	26.9		1,267	38.8	
45–49	1,424	31.2		887	44.0	
Residence						
Urban	5,794	23.1	0.000	3,364	41.7	0.000
Rural	8,887	37.3		4,913	30.6	
SexOfHH						
Male	13,086	32.1	0.000	7,229	34.6	0.000
Female	1,595	22.0		1,048	43.2	
Ethnicity						
Hausa/Fulani	6,047	49.1	0.000	3,202	33.8	0.000
Yoruba	1,769	21.3		1,128	61.5	
Igbo	2,409	17.0		1,397	49.4	
Others	4,456	14.4		2,550	18.0	
Religion						
Islam	8,708	42.3	0.000	4,656	33.2	0.000
Christian	5,876	12.8		3,572	39.6	
Others	97	2.1		49	9.3	
EducM						
No Education	6,563	44.1	0.000	3,442	31.4	0.000
Primary	2,677	25.4		1,495	39.2	
Secondary	4,174	20.6		2,547	40.7	
Higher	1,267	10.0		793	31.4	
EducP						
No Education	4,978	45.4	0.000	2,616	32.7	0.000
Primary	2,159	27.8		1,179	42.8	
Secondary	4,348	22.8		2,509	36.9	
Higher	2,097	20.6		1,245	30.8	
Don't Know	131	52.4		71	45.9	

Table 2 (continued)

Characteristics	Percentage of cut girls			Percentage of cut women		
	n	%	p-value	*n*	%	*p*-value
Wealth						
Poorest	3,537	44.9	0.000	1,877	28.7	0.000
Poorer	3,003	38.3		1,635	34.4	
Middle	2,932	30.8		1,640	37.9	
Richer	2,828	24.5		1,668	41.4	
Richest	2,381	13.5		1,457	35.8	
RequiredByReligion						
No	11,112	24.0	0.000	6,307	32.5	0.000
Yes	2,970	59.5		1,630	45.5	
Don't Know	599	21.9		340	42.6	
Support						
Continued	3,977	75.3	0.000	2,156	56.4	0.000
Stopped	9,357	10.0		5,371	24.9	
Depends	1,217	31.5		667	39.6	
Don't Know	130	15.4		83	48.2	
Total	**14,681**	**31.1**		**8,277**	**35.5**	

Geographical Variations in Prevalence of FGM/C

The prevalence of FGM/C among girls aged 0–14 and their mothers aged 15 – 49 years varied geographically across the 36 Nigerian states and the FCT with a shift in intergenerational (mother–daughter) prevalence from the southern sates to the northern states (Fig. 2).

Specifically, when compared to that of their mothers, FGM/C prevalence among girls indicated a huge decline in most of the southern states showing between 20 to 95% decline apart from Imo State where FGM/C prevalence among girls was almost as high as that of their mothers (~75%). However, FGM/C prevalence among girls in Kaduna state was about 1.3 times higher than that of their mothers (~81% versus ~61%). Similarly, higher FGM/C prevalence was found among girls who lived in Kano (~51%), Jigawa (62%), Yobe (~60%) and Bauchi (~41%) states than that of their mothers.

Moran's I Test for Spatial Clustering

Moran's I statistics for spatial clustering test found the existence of local spatial clusters in Kano, Kaduna and Jigawa states with Moran's I test statistics of 0.16, p-value = 0.01. In addition, Moran's I Monte Carlo simulations with 1000 samples returned a significant Moran's I test statistics of 0.16 with p-value = 0.02 which further confirmed that indeed FGM/C exhibited positive spatial clustering among the Northern states in Nigeria.

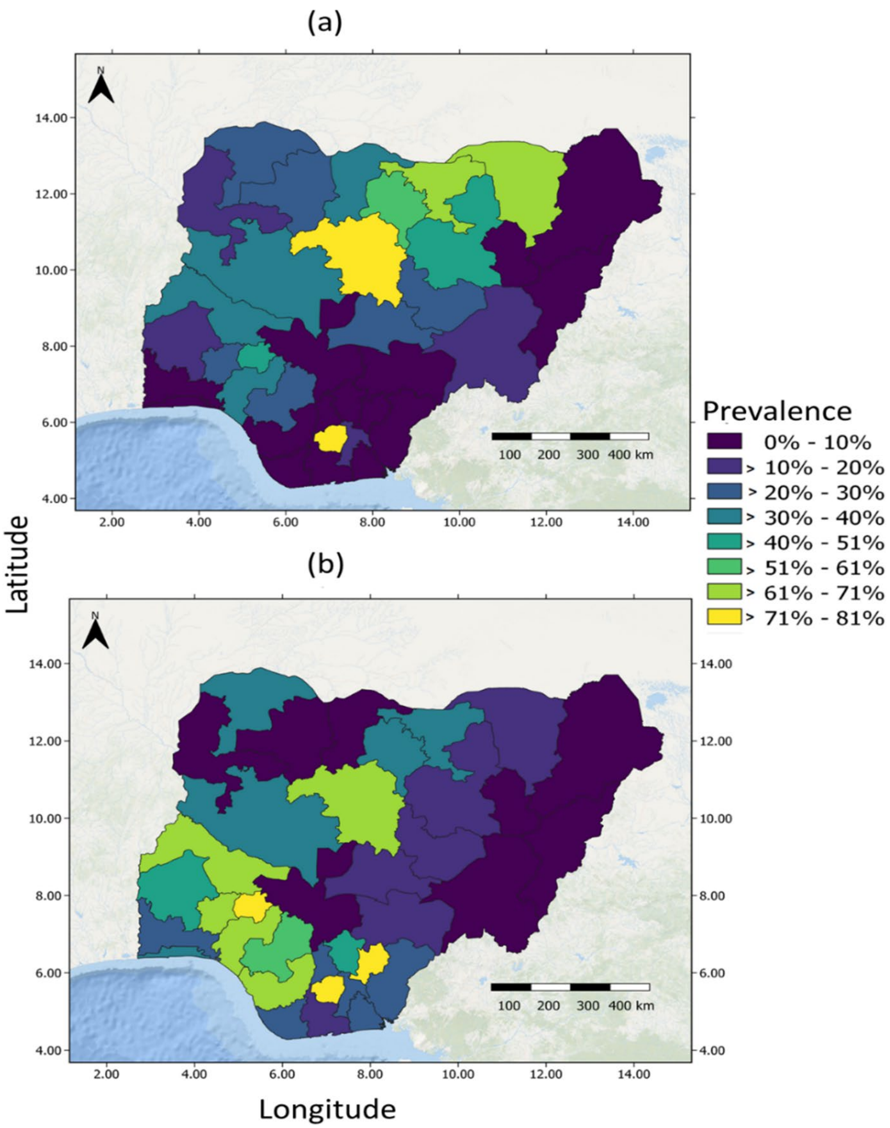

Fig. 2 Spatial distribution of the prevalence of female genital mutilation/cutting among (**a**) girls (0 – 14 years) and their (**b**) mothers (15 – 49 years) across the 36 states in Nigeria and the federal capital territory (FCT)

Bayesian Hierarchical Geo-Additive Logistic Regression

Posterior Estimates of the Adjusted and Unadjusted Odds Ratio (POR)

The Bayesian hierarchical geo-additive model results are presented in Table 3 as posterior odds ratios (PORs). Again, there are some contrasting results with respect

Table 3 Unadjusted and adjusted Posterior odds ratio (POR) of FGM/C among Nigerian girls and their mothers based on the covariates-unadjusted and adjusted models

Variable	Level	Unadjusted POR (95% CI)		Adjusted POR (95% CI)	
		Girls	Women	Girls	Women
Region	North-Central	*Reference*			
	North-East	3.01 (1.60, 5.16)	0.26 (0.21, 0.31)	0.85 (0.18, 3.27)	0.12 (0.03, 0.46)
	North-West	1.78 (1.01, 3.13)	0.77 (0.64, 0.94)	1.07 (0.31, 3.23)	0.58 (0.22, 1.71)
	South-East	2.20 (0.65, 7.36)	3.89 (2.97, 5.26)	0.70 (0.07, 4.64)	6.99 (1.20, 42.2)
	South-South	1.39 (0.57, 3.45)	3.84 (3.13, 4.78)	0.72 (0.11, 3.81)	4.74 (1.02, 25.1)
	South-West	1.46 (0.77, 2.87)	1.60 (1.28, 2.02)	1.15 (0.28, 4.47)	4.67 (1.13, 24.6)
AgeM	15 – 19	*Reference*			
	20 – 24	0.12 (0.02, 0.63)	0.73 (0.51, 1.04)	Not applicable	–
	25 – 29	0.04 (0.01, 0.25)	0.69 (0.49, 1.00)	–	–
	30 – 34	0.02 (0.00, 0.13)	0.76 (0.53, 1.10)	–	–
	35 – 39	0.02 (0.00, 0.12)	0.96 (0.67, 1.40)	–	–
	40 – 44	0.03 (0.00, 0.14)	0.95 (0.66, 1.39)	–	–
	45 – 49	0.04 (0.01, 0.24)	1.32 (0.92, 1.94)	–	–
Residence	Rural	*Reference*			
	Urban	0.62 (0.46, 0.87)	1.29 (1.17, 1.42)	0.72 (0.50, 1.05)	0.92 (0.81, 1.05)
SexOfHH	Female	*Reference*			
	Male	0.65 (0.33, 1.20)	–	0.62 (0.33, 1.14)	–
Ethnicity	Fulani	*Reference*			
	Hausa	0.92 (0.56, 1.45)	1.19 (0.99, 1.43)	0.92 (0.57, 1.43)	1.07 (0.90, 1.27)
	Other	0.53 (0.31, 0.90)	0.56 (0.44, 0.70)	0.58 (0.32, 0.98)	0.64 (0.50, 0.81)
	Igbo	0.34 (0.11, 1.23)	1.26 (0.90, 1.70)	0.42 (0.11, 1.75)	1.12 (0.75, 1.61)
	Kanuri/Beriberi	1.39 (0.47, 4.32)	0.58 (0.39, 0.85)	1.06 (0.38, 3.67)	0.70 (0.46, 1.06)
	Yoruba	0.39 (0.18, 0.84)	5.27 (3.92, 7.25)	0.38 (0.14, 0.96)	2.68 (1.93, 3.63)

Table 3 (continued)

Variable	Level	Unadjusted POR (95% CI)		Adjusted POR (95% CI)	
		Girls	Women	Girls	Women
Religion	Islam	*Reference*			
	Catholic	0.84 (0.38, 1.93)	1.36 (1.11, 1.68)	1.00 (0.43, 2.49)	1.12 (0.86, 1.43)
	Other	0.16 (0.01, 6.35)	0.29 (0.13, 0.54)	0.45 (0.01, 15.33)	0.44 (0.19, 0.96)
	Other Christian	1.12 (0.68, 1.90)	1.00 (0.85, 1.18)	1.31 (0.74, 2.37)	0.90 (0.75, 1.09)
EducM	Higher	*Reference*			
	No education	0.45 (0.18, 1.06)	1.29 (1.04, 1.58)	0.60 (0.24, 1.52)	1.65 (1.32, 2.04)
	Primary	0.42 (0.16, 1.01)	1.52 (1.26, 1.82)	0.49 (0.19, 1.27)	1.50 (1.21, 1.84)
	Secondary	0.45 (0.20, 0.96)	1.25 (1.03, 1.48)	0.50 (0.22, 1.19)	1.34 (1.12, 1.61)
EducP	Higher	*Reference*			
	No education	1.03 (0.62, 1.68)	–	1.02 (0.61, 1.75)	–
	Primary	0.83 (0.46, 1.46)	–	0.85 (0.48, 1.46)	–
	Secondary	0.87 (0.54, 1.39)	–	0.85 (0.54, 1.35)	–
Fgm (mother)	Not cut	*Reference*			
	Cut	3.70 (2.62, 5.21)	–	2.66 (1.83, 3.81)	–
Support	Continued	*Reference*			
	Depends	0.46 (0.31, 0.70)	0.44 (0.38, 0.52)	0.38 (0.25, 0.61)	0.33 (0.27, 0.40)
	Don't know	17.9 (1.29,287.0)	0.24 (0.15, 0.38)	33.9(1.04, 115.35)	0.19 (0.12, 0.30)
	Stopped	0.50 (0.38, 0.66)	0.13 (0.12, 0.15)	0.48 (0.34, 0.68)	0.13 (0.11, 0.14)
Wealth	Middle	*Reference*			
	Poorer	0.54 (0.36, 0.83)	0.85 (0.74, 0.97)	0.60 (0.38, 1.01)	0.92 (0.79, 1.06)
	Poorest	0.60 (0.40, 0.93)	0.83 (0.73, 0.96)	0.71 (0.44, 1.16)	1.00 (0.85, 1.18)
	Richer	1.37 (0.85, 2.29)	0.78 (0.68, 0.91)	1.41 (0.83, 2.31)	0.97 (0.83, 1.15)
	Richest	1.48 (0.83, 2.65)	0.56 (0.48, 0.65)	1.57 (0.88, 2.80)	0.97 (0.79, 1.17)
DIC	**-**	**1786.71**	**13,560.36**	**1704.53**	**11,603.78**
pD	**-**	**32.58**	**30.98**	**52.96**	**63.81**

DIC deviance information criterion, *pD* effective number of parameters, *CR* credible interval, *POR* posterior odds ratio to a girl's likelihood of undergoing FGM/C and that of her mother. For example, results based on the *adjusted* model indicate that there was no significant effect of region of residence on a girl's likelihood of cutting. This constrasted with that of their mothers where the likelihood of undergoing FGM/C was significantly high among women who lived in the southern regions of the country.

There were no significant effects of religion, the type of place of residence (urban–rural), and houswhold wealth quintine on a girl and her mother's likelihood of being cut. A Yoruba girl was less likely to be cut than her Fulani counterparts in contrast to that of their mum where a Yoruba woman was about 2.68 more likely to be cut than her Fulani counterparts. The likelihood of cutting a girl is not significantly impacted upon by the gender of the head of the household.

In terms of education, a girl's likelihood of undergoing FGM/C is not significantly impacted by the highest level of education of her mother or that of her mother's partner/husband. This is in contrast to that of their mothers where the likelihood FGM/C was highest among women who had no education and decreases as the highest level of education increases.

With respect to a woman's FGM/C status and her support for the continuation of FGM/C in Nigeria, daughters of circumcised women were about 2.7 times more likely to be cut than their counterparts whose mothers were not circumcised. Also, there was a lower likelihood of FGM/C among girls and their mothers who do not want FGM/C to continue compared with that of their counterparts who supported the continuation of the practice.

Mother to Daughter Geographical Variations in the Likelihood of FGM/C

The posterior estimates of the spatial (total, uncorrelated and correlated) effects on the likelihood of experiencing FGM/C among girls and their mothers along with the corresponding 95% credible interval significance maps based on the *adjusted* model are shown in Figs. 3 and 4, respectively. Except for the correlated spatial effects maps, the effects of the total and uncorrelated spatial effects on the likelihood of FGM/C showed a general decrease in daughters than their mothers (Fig. 3). Although, in theory the correlated and uncorrelated spatial effects are the decomposed components of the total spatial effects, each of these effects are estimated independently probabilistically hence the total effects maps may not necessarily be identical to the correlated and uncorreated effects maps combined.

For the 95% credible interval significance maps in Fig. 4, white (coded -1) indicates states with statistically significant low risk of FGM/C (bothlower (2.5%) and upper (97.5%) bounds estimates are less than zero). Also, grey (coded 0) indicates states where the spatially adjusted risk of FGM/C was not statistically significant, while the states under the black areas (coded 1) are identified as having statistically significant high risk of FGM/C.

Results based on the total spatial random effects (f_{spat}, top), indicate that there were significantly high intergenerational FGM/C risk in Kano, Kaduna, Bauchi, and Imo (both women and girls total spatial effects maps). However, when decomposed into spatially correlated and uncorrelated random effects, the correlated risk

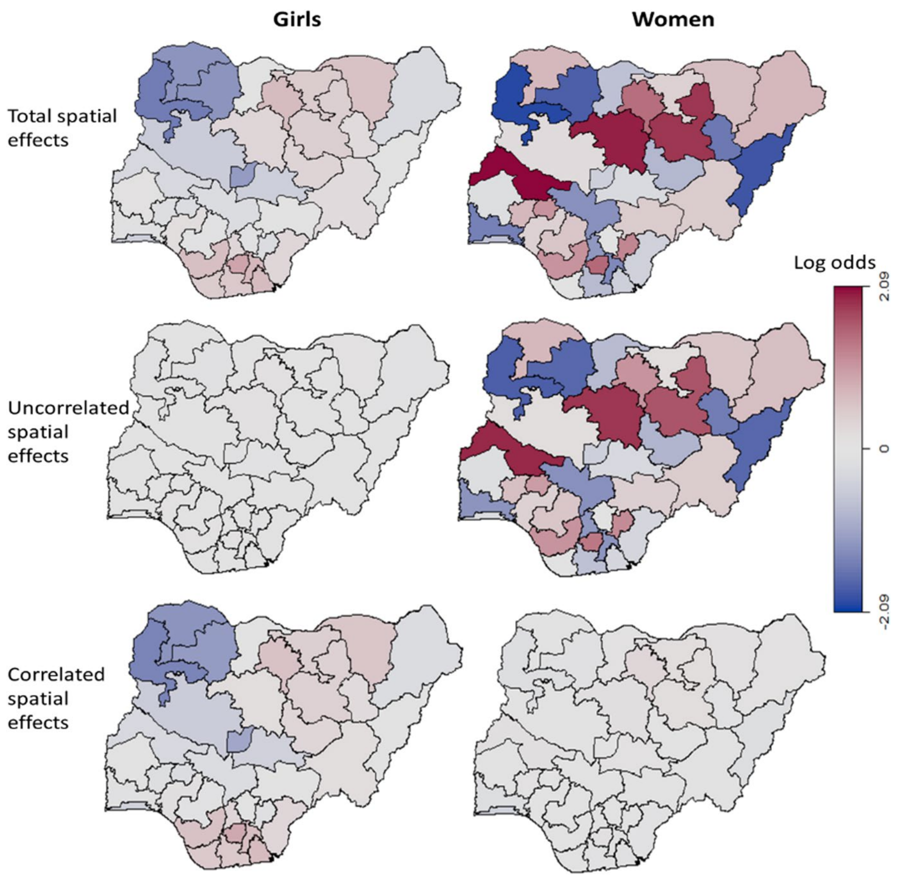

Fig. 3 Spatial distribution of the risk (likelihood) of female genital mutilation/cutting among girls (0 – 14 years) (left) and their mothers aged 15 – 49 years (right) across the 36 states in Nigeria and the federal capital territory (FCT). Maps show the log odds ($log(\frac{p_i}{1-p_i})$) of FGM/C based on total spatial effects (f_{spat}, top), uncorrelated and correlated spatial effects

of girls FGM/C across the high-risk states remained statistically significant apart from Imo State which is no longer statistically significant. Across the 37 geographical units, the uncorrelated risk of FGM/C among girls was not statistically significant. In contrast, among women, the correlated risk of FGM/C was not statistically significant (grey), while the uncorrelated effects remained significant across the initially identified high risk states.

Non-Linear Effects of Age (Mother & Daughter) on the Likelihood of Undergoing FGM/C

A girl's likelihood of undergoing FGM/C increased with her age (Fig. 5a). Higher likelihood of cutting among found among girls aged 11 years or more.

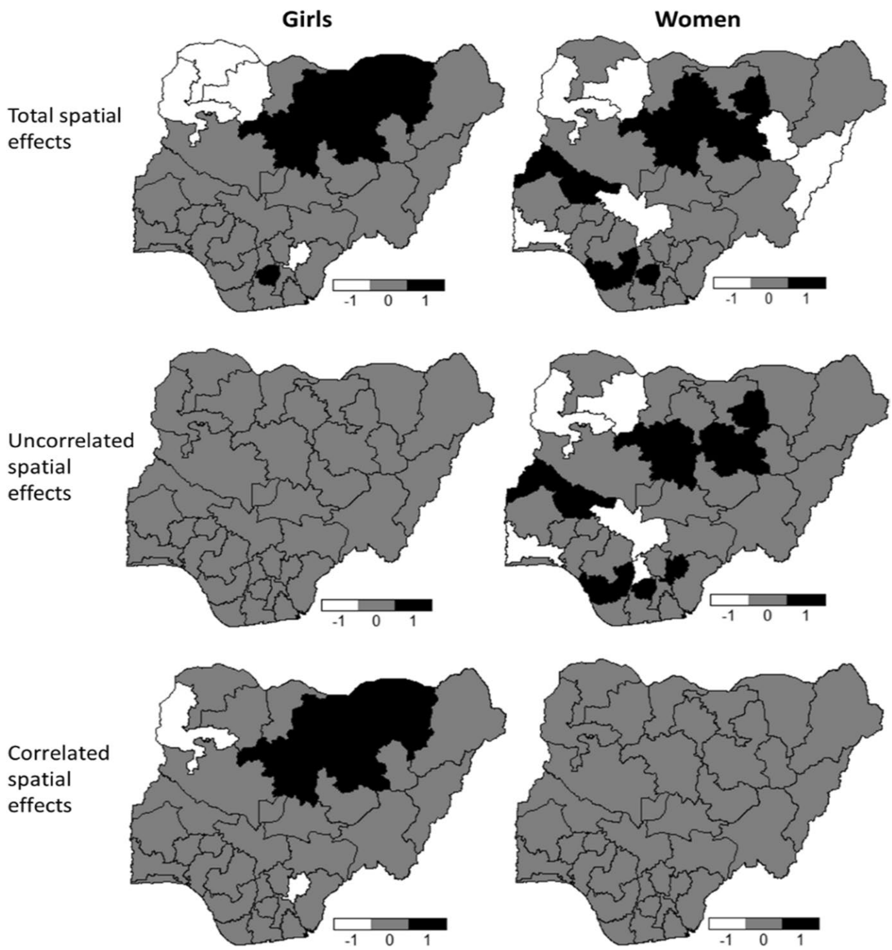

Fig. 4 95% credible interval significance maps for the estimated risk (likelihood) of female genital mutilation/cutting among girls (0 – 14 years) (left) and their mothers aged 15 – 49 years (right) across the 36 states in Nigeria and the federal capital territory (FCT). Maps show the statistical significance of the estimated risks of FGM/C based on 95% credible interval for total spatial effects (f_{spat}, top), uncorrelated spatial effects (f_{unstr}, middle) and correlated spatial effects (f_{str}, bottom). White corresponds to states with significantly low risk, black corresponds to states with significantly high risk, and grey corresponds to states where the risk of FGM/C was not statistically significant

Similarly, a girl's likelihood of cutting increased as the number of her circumcised sisters increased (Fig. 5b). Daughters of younger mothers (aged 15 – 19 years) have higher likelihood of cutting (Fig. 5c). Among women themselves, a woman's likelihood of cutting was higher if she was aged 45 – 49 years (Fig. 5d), thus, indicating that older women were more likely to have experienced FGM/C than the younger women.

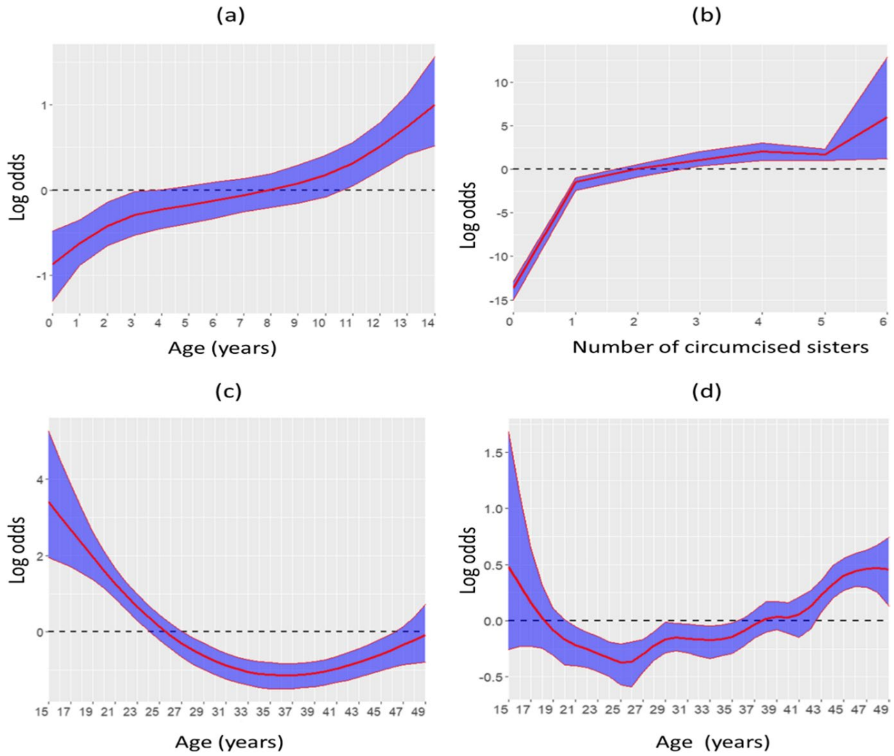

Fig. 5 Nonlinear effects of (**a**) a girl's age on her likelihood of undergoing FGM/C (**b**) number of circumcised sisters on a girl's likelihood of undergoing FGM/C (**c**) mother's age on her daughter's likelihood of being cut, and (**d**) woman's age on her own likelihood of being cut. The central red lines are the means while the blue band represents the 95% credible intervals

Predicted Changes in Mother to Daughter Prevalence in FGM/C

The predicted spatial distribution of the intergenerational prevalence in FGM/C among Nigerian girls and their mothers is shown in Fig. 6a and b. The predicted prevalence across the 36 states in Nigeria and the FCT was calculated as the back-transformed posterior estimates of the linear predictor defined in Eq. (2), with $p_k = \exp\left(\eta_k\right)/(1 + \exp(\eta_k))$ averaged over all girls (or their mothers) in spatial location (state) k, for $k = 1, \ldots, 37$. Figure 6a presents the predicted prevalence, the uncertainties in the prevalence estimates were quantified using the deviance maps (Fig. 6b). The deviance was calculated using

$$D(\theta) = 2\sum \left\{ y_i \log\left(\frac{y_i}{\hat{\theta}}\right) + \left(n_i - y_i\right)\log\left(\frac{n_i - y_i}{n_i - \hat{\theta}}\right)\right\}$$

where y_i and $\hat{\theta}$ are the logit transformed observed value and the fitted values corresponding to the ith observation, respectively. Thus, the deviance maps

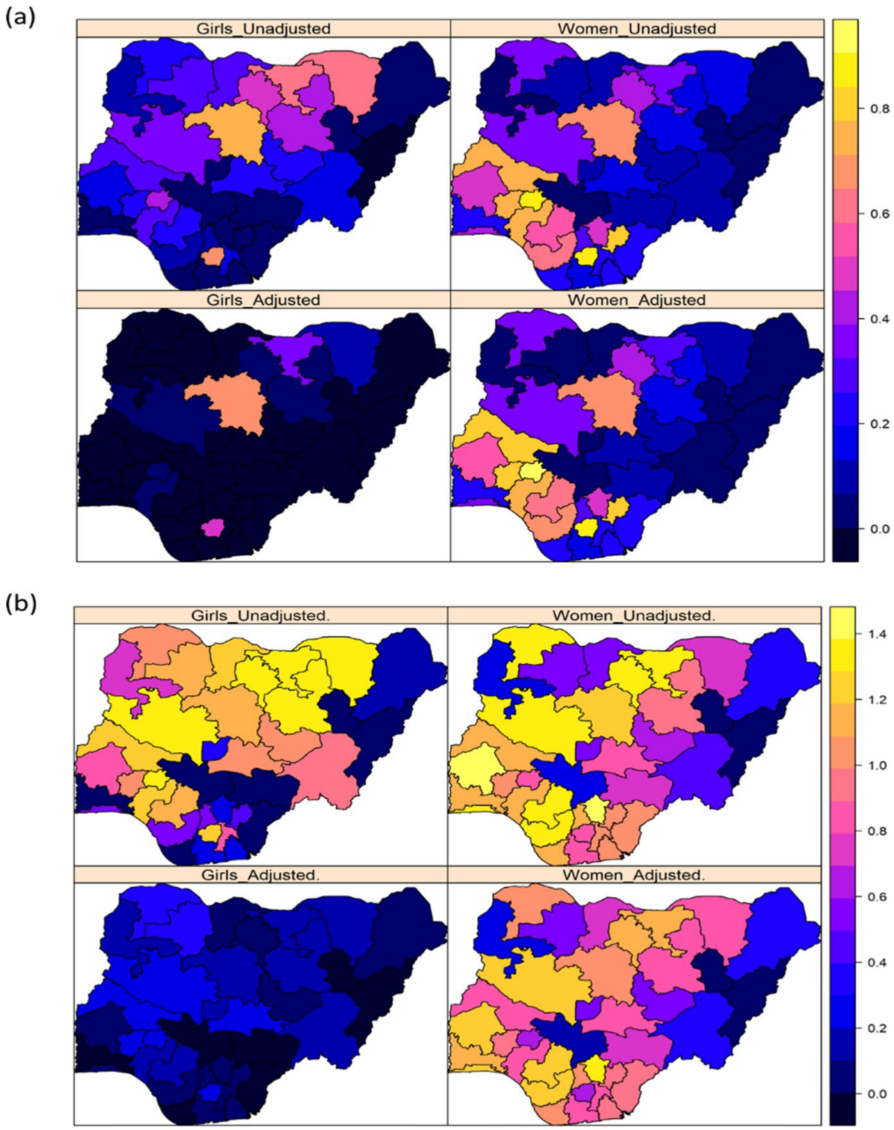

Fig. 6 Spatial distributions of the posterior estimates of (**a**) unadjusted (top) and adjusted (bottom) prevalence of female genital mutilation/cutting among girls (left) and their mothers (right) and the corresponding (**b**) deviance of the predicted posterior prevalence across the geographical regions of Nigeria.

present the average discrepancies between the fitted and the logit transformed observed values among all observations within a given state, such that the deviance for the jth state is obtained as.

$D(\theta)^{(j)} = \frac{1}{n_j}\sum_k D_k(\theta)$, for$k = 1, \dots, n_j$; where $D_k(\theta)$ and n_j are the deviance value of the kth observation and number of observations in the jth state, respectively.

In general, Fig. 6 shows that the predicted prevalence of FGM/C among girls and their mothers varied geographically across regions and states in Nigeria. When compared with that of their mothers, FGM/C prevalence predictions based on the *adjusted* model (Fig. 6a, bottom left), show a drastic reduction among girls in almost all the southern states (mostly less than 15%) apart from Imo state. Highest prevalence of ~ 65% was predicted for Kaduna State (Fig. 6a bottom left). In addition, FGM/C prevalence was slightly higher in Jigawa and Yobe states for girls unlike their mothers where higher prevalence was predicted for more southern sates than the northern states. The deviance maps show less deviation from the predicted FGM/C prevalence among girls than that of their mothers (Fig. 6b, bottom), maybe because the sample size of the girl's data is about 1.8 times larger than that of their mothers (14,681 versus 8277), thereby, giving rise to less variability.

Discussion

The several years of interventions both legal and advocacy (e.g., (28TOOMANY, 2018, Kandala et al., 2020; Briggs, 1998; Mberu, 2017; Nnamdi, 2018)) aimed at a total abandonment of female genital mutilation/cutting (FGM/C) in Nigeria mean that a proportional change in attitude towards the practice is expected. However, recent estimates showed that the change has been happening at a snail's pace, thereby, raising concerns as to whether Nigeria is still on track to attaining the sustainable development goal (SDG) of stamping out FGM/C in Nigeria by the year 2030. In this study, we investigated changes in the intergenerational (mother to daughter) prevalence of FGM/C in Nigeria, as a 'proxy' measure of the impacts of the various forms of interventions currently underway in the country. We drew upon the 2018 Nigerian Demographic and Health Survey (2018 NDHS) data. For our purposes, we focused on women and their living daughters aged 0 – 14 years only and employed a class of flexible Bayesian hierarchical *geo-addiive* regression modelling framework which allowed us to simulataneous account for the effects both linear and non-linear covariates as well as unobserved effects of geographical locations on mother-to-daughter trends in FGM/C in Nigeria.

Overall, the results suggest a significant decline in intergenerational trends in FGM/C prevalence in Nigeria especially across most of the states in southern Nigeria apart from Imo state where prevalence has remained high among mothers and their daughters. Specifically, our models predicted 15% prevalence among girls who lived in Ebonyi state which represents a 60% decline from the 75% prevalence predicted for their mothers. Such significant decline in the prevalence of the practice could be attributed to the anti-FGM/C interventions which were mostly concentrated in the southern states – women who benefited in one way or the other from the several years of interventions in these states were most likely to have converted to anti-FGM/C campaigners. On the other hand, FGM/C prevalence among girls who lived in Kaduna state was similarly high to that of their mothers. While this finding indicates a potential shift in the practice from southern states to northern states, thus, suggesting constrasting impacts of the existing anti-FGM/C campaigns within the southern and northern states. It also raises an important question on how effective the existing interventions within the northern states have been. In particular, is the design and implementation strategies currently being adopted by these interventions robust enough to account for any perculiarities within the affected states?

Analyses of bivariate association between baseline characteristics and FGM/C prevalence showed contrasting results between a girl and her mother. However, after adjusting for unobserved effects of geographical locations using Bayesian hierarchical geo-additive regression models, we found no significant influence of a woman's region of residence, type of place of residence (rural–urban), religion and gender of head of household on her daughter's likelihood of being cut. Also, the effects of highest level of education and household wealth on a girl's likelihood of being cut were not statistically significant, suggesting that the interventions which targeted the poor, uneducated, rural women, especially within the southern states, have made huge positive impacts on the abandonment of the practice. On the other hand, we found significantly high likelihood of FGM/C among daughters of younger women aged 15 – 19 years, daughters of circumcised women, and daughters of women who had at least 3 circumcised daughters, thus supporting the notion that FGM/C is a social norm (Mackie, 1996; Mackie & LeJeune, 2009; Shell-Duncan et al., 2011, 2018).

Findings from this study are to a large extent in agreement with those of recent studies (Fagbamigbe et al., 2021; Kandala et al., 2020; Nnanatu et al., 2021). In particular, Nnanatu et al. (2021) found significant spatio-temporal variations in the prevalence of FGM/C among 0–14 years old girls in Nigeria. However, the observed intergenerational geographical shifts in FGM/C prevalence in Nigeria might be a consequence of a disproportionate design and implementation of intervention programmes within the states in the northern region as most interventions may have largely been focused on the FGM/C hotspots previously identified across the southern states (Nnanatu et al., 2021). The higher likelihood of undergoing FGM/C found among daughters of circumcised women; daughters of women who supported the continuation of FGM/C in Nigeria, and daughters of women who have more than two circumcised daughters, together further suggest that the practice of FGM/C in Nigeria persists due to social norm (Mackie & LeJeune, 2009). This is because in a community where FGM/C is a social norm, it is often viewed as a prerequisite to being accepted into a social class largely due to the fear of social exclusion or being ostracized for not conforming (Shell-Duncan et al., 2011).

The statistical modelling approach employed in this study allowed us to explicitly model potential spatial autocorrelation and spatial independence within the observed data while simultaneously accounting for key linear and non-linear covariates. To the best of our knowledge, this is the first attempt to evaluate spatial variations in integernational (mother to daughter) trends in the prevalence of FGM/C in the context of Nigeria, using Bayesian hierarchical geo-additive regression model. By simultaneously controlling for other individual- and community-level factors, the approach served a 'proxy' measure of the impacts of anti-FGM/C intervention programmes in Nigeria. However, despite the various strengths of the approach utilised in the study, two key limitations of the study were identified. Firstly, given that the 2018 NDHS data utilised in this study were based on self-reporting by the respondents, there are risks of recall bias in that some respondents may have forgotten details of events that happened many years ago. However, while it is possible that some women might not accurately recall whether they were circumcised or not, the rate of recall bias on the FGM/C statuses of their daughters aged 0 – 14 years is most likely to be negligible. Secondly, the awareness of the existence of the 2015 VAPP act along with the punishments therein for the violators could lead to underreporting. For example, some women may intentionally lie about the FGM/C statuses of their daughters for the fear of prosecution.

In conclusion, we learnt that although there has been an overall decline in mother-to-daughter prevalence of FGM/C in Nigeria, women who supported the continuation of FGM/C, and women who had up to three circumcised daughters were more likely to have their daughters circumcised than their counterparts. This, in addition to the finding that the daughters of circumcised women were about 2.7 times more likely to be circumcised than their counterparts with uncircumcised mothers suggest that the intergenerational prevalence of FGM/C in Nigeria has largely persisted due to social norm related factors. Also, we learnt that geographical location plays a significant role in that states which share boundaries with the high-risk states are likely to experience a rapid increase in the practice, as the case with Jigawa and Yobe states, neighbours to the FGM/C high-risk states of Kano and Bauchi, where we found an increased risk of FGM/C among girls aged 0–14 years compared with that of their mothers. Thus, we now know where and how intergenerational change is happening. Our findings further reiterate the importance of approaching anti-FGM/C interventions based on the social convention theory such that a sustainable abandonment of the practice would require an entire community making public declarations to reject the continuation of the practice (Shell-Duncan et al., 2011). Such moves will in no doubt accelerate FGM/C abandonment in Nigeria and raise hope of meeting the SDGs of total eradication of FGM/C by the year 2030. Finally, there is need for a study that would seek to explain these intergenerational trends despite the intervention efforts that are currently underway in the affected states.

Acknowledgements The authors would like to thank DHS for making the data used in the various analyses available.

Authors' Contributions *Conceptualization*: Chibuzor Christopher Nnanatu; *Methodology*: Chibuzor Christopher Nnanatu, Adeniyi Francis Fagbamigbe, Chigozie Edson Utazi; *Formal analysis and investigation*: Chibuzor Christopher Nnanatu, Adeniyi Francis Fagbamigbe, Chigozie Edson Utazi, Emmanuel Afuecheta; *Writing—original draft preparation*: Chibuzor Christopher Nnanatu; *Writing—review and editing:* Chibuzor Christopher Nnanatu, Adeniyi Francis Fagbamigbe, Chigozie Edson Utazi, Emmanuel Afuecheta; *Resources:* Chibuzor Christopher Nnanatu; *Supervision:* Chibuzor Christopher Nnanatu, Chigozie Edson Utazi.

Data Availability The data analysed in this study are available on request from the DHS website on https://dhsprogram.com/.

Code availability The main R software package utilised in this study is available here: https://cran.r-project.org/web/packages/R2BayesX/R2BayesX.pdf.

Declarations

Ethics Approval Not Applicable (secondary data with no individual identifications used).

Consent to Participate Not Applicable.

Consent for Publication All authors have read and approved the publication of the final copy of the manuscript.

Conflicts of Interest/Competing Interests Authors declared no conflicts of interests.

References

28TOOMANY (2018). Nigeria: The Law and FGM.

Abd El-Naser, T., Farouk, A., El-Nashar, A.E.-R., & Mostafa, T. (2011). Sexual side effects of female genital mutilation/cutting May Be type dependent: a hospital-based study. *J Obstet Gynecol, 1*(2), 65–74.

Alsibiani, S. A., & Rouzi, A. A. (2010). Sexual function in women with female genital mutilation. *Fertility and Sterility, 93*(3), 722–724.

Besag, J., York, J., & Mollié, A. (1991). Bayesian image restoration, with two applications in spatial statistics. *Annals of the Institute of Statistical Mathematics, 43*, 1–20. https://doi.org/10.1007/BF00116466

Brezger, A., & Lang, S. (2006). Generalized Structured Additive Regression based on Bayesian P-Splines. *Computational Statistics and Data Analysis, 50*, 967–991.

Briggs, L. A. (1998). Female circumcision in Nigeria: Is it not time for government intervention? *Health Care Analysis, 6*(14).

Dirie, M., & Lindmark, G. (1992). The risk of medical complications after female circumcision. *East African Medical Journal, 69*(9), 479–482.

Fagbamigbe, A. F., Morhason-Bello, I. O., Kareem, Y. O., & Idemudia, E. S. (2021). Hierachical modelling of the factors associated with the practice and perpetuation of female genital mutilation in the next generation of women in Africa. *PLoS ONE, 16*(4), e0250411.

Fagbamigbe, A. F. & Nnanatu, C. C. (2021). Modelling the spatial distribution and the factors. *Spatial Demography*, 1–28.

Fahrmeir, L., & Lang, S. (2001). Bayesian Inference for Generalized Additive Mixed Models Based on Markov Random Field Priors. *Journal of the Royal Statistical Society C, 50*, 201–220.

Kammann, E. E. & Wand, M. P. (2003). Geoadditive Models. *Journal of the Royal Statistical*.

Gayawan, E., & Lateef, R. S. (2019). Estimating geographic variations in the determinants of attitude towards the practice of female genital mutilation in Nigeria. *Journal of Biosocial Science, 5*(51), 645–657.

Green, P. J. (2001). A primer in Markov Chain Monte Carlo. In *Complex Stochastic Systems*. Chapmann and Hall, p. 1–62.

Hongfei, L., Calder, C., & Cressie, N. (2007). Beyond Moran's I: Testing for spatial dependence based on the spatial autoregressive model. *Geographical Analysis, 39*, 357–375.

Kandala, N. B., Nnanatu, C. C., & Atilola, G. E. A. (2019). A Spatial Analysis of the Prevalence of Female Genital Mutilation/Cutting among 0–14-Year-Old Girls in Kenya. *International Journal of Environmental Research and Public Health, 6*(21), 4155.

Kandala, N.-B., Atilola, G., Nnanatu, C. C., Ogundimu, E., Mavatikua, L., & Komba, P. (2020). *"Female genital mutilation/cutting in Nigeria: Is the practice declining? A descriptive analysis of successive* *demographic and health surveys and multiple indicator cluster surveys (2003–2017)".Evidence to End FGM/C: Research to Help Girls and Women Thriv*. Population Council.

Kandala, N.-B., Nnanatu, C., Atilola, G., Komba, P., Mavatikua, L., Moore, Z., & Matanda, D. (2021). Analysing normative influences on the prevalence of female genital mutilation/cutting among 0–14 years old girls in Senegal: A spatial Bayesian hierarchical regression approach. *International Journal of Environmental Research and Public Health, 18*(7), 3822.

Kneib, T., & Hennerfeind, A. (2013). Bayesian Semiparametric Multi-State Models. *Statistical, 8*, 169–198.

Mackie, G. (1996). Ending footbinding and infibulation A convention account. *American Sociological Review, 61*, 999–1017.

Mackie, G. & LeJeune, J. (2009). Social dynamics of abandonment of harmful practices. In *A New Look at the Theory; Innocenti Working Paper No. 2009–06*. UNICEF Innocenti Research Centre.

Mberu, B. (2017). *"Female genital mutilation cutting in Nigeria: A scoping Review". Evidence. Evidence to End FGM/C: Research to Help Women Thrive*. Population Council.

NAPTIP (2015). *National agency for prohibition of trafficking in persons*. 2015 Violence Against Persons (Prohibition) Act 2015. https://www.naptip.gov.ng/wp-content/uploads/2017/05/Violence-Against-Persons-Prohibition-Act-2015-1.pdf. Accessed 17 Feb 2021

National Population Commission - NPC and ICF (2019). *Nigeria Demographic and Health Survey 2018 - Final Report*. NPC and ICF, Abuja, Nigeria.

U. S. Nnamdi (2018). *The law and FGM in Nigeria*.

Nnanatu, C., Atilola, G., Komba, P., Mavatikua, L., Moore, Z., Matanda, D., Obianwu, O., & Kandala, N.-B. (2021). Evaluating changes in the prevalence of female genital mutilation/cutting among 0–14 years old girls in Nigeria using data from multiple surveys: A novel Bayesian hierarchical spatio-temporal model. *PLoS ONE, 16*(2), e0246661.

R Core Team (2019). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing.

Rue, H. (2001). Fast sampling of Gaussian Markov Random fields with applications. *Journal of the Royal Statistical Society B, 63*, 325–338.

Shell-Duncan, B., Wander, K., Hernlund, Y., & Moreau, A. (2011). Dynamics of change in the practice of female genital cutting in Senegambia: Testing predictions of social convention theory. *Social Science and Medicine, 73*, 1275–1283.

Shell-Duncan, B., Moreau, A., Wander, K., & Smith, S. (2018). The role of older women in contesting norms associated with female genital mutilation/cutting: A factorial focus group analysis. *PLoS ONE, 13*, e0199217.

Spiegelhalter, D. J., Best, N. G., Carlin, B. P., & van der Linde, A. (2002). Measures of model complexity and fit. *Journal of the Royal Statistical Society B, 65*, 583–639.

Stata Statistical Software (2009). Sata Corp.

Toubia, N. (1994). Female circumcision as a public health issue. *New England Journal of Medicine, 331*(11), 712–716.

Umlauf, N., Adler, D. & Kneib, T. (2015). Structured additive regression models: An R interface to BayesX. *Journal of Statistical Software*, *63*(21).

Utazi, C. E., Afuecheta, A. O., & Nnanatu, C. C. (2018). Bayesian latent process spatiotemporal regression model for areal count data. *Spatial and Spatio-Temporal Epidemiology, 25*(37), 25.

WHO (2020). *Fact Sheets on Female Genital Mutilation*.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Authors and Affiliations

Chibuzor Christopher Nnanatu[1,2] · **Adeniyi Francis Fagbamigbe**[3,4] · **Emmanuel Afuecheta**[5] · **Chigozie Edson Utazi**[1]

[1] WorldPop, School of Geography and Environmental Science, University of Southampton, Southampton SO17 1BJ, UK

[2] Department of Statistics, Nnamdi Azikiwe University, PMB 5025, Awka, Nigeria

[3] Department of Epidemiology and Medical Statistics, Faculty of Public Health, College of Medicine, University of Ibadan, Ibadan, Nigeria

[4] Health Data Science Group, Division of Population and Behavioural Sciences, School of Medicine, University of St Andrews, St Andrews, UK

[5] Department of Mathematics and Statistics, King Fahd University of Petroleum & Minerals, Dhahran, Saudi Arabia