

Evidence to  
**End FGM/C**



Research to Help Girls and Women Thrive

MODELING AND MAPPING OF GIRLS'  
FEMALE GENITAL MUTILATION/CUTTING  
IN THE CONTEXT OF ECONOMIC, SOCIAL,  
AND REGIONAL DISPARITIES:  
KENYA DEMOGRAPHIC AND HEALTH  
SURVEYS 1998 – 2014

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# MODELING AND MAPPING OF GIRLS' FEMALE GENITAL MUTILATION/CUTTING IN THE CONTEXT OF ECONOMIC, SOCIAL, AND REGIONAL DISPARITIES: KENYA DEMOGRAPHIC AND HEALTH SURVEYS 1998 – 2014

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**The Evidence to End FGM/C: Research to Help Girls and Women Thrive generates evidence to inform and influence investments, policies, and programs for ending female genital mutilation/cutting in different contexts.**

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## Acronyms

FGM/C	Female Genital Mutilation/Cutting
KDHS	Kenya Demographic and Health Survey
DHS	Demographic and Health Survey
HIV	Human Immunodeficiency Virus
AIDS	Acquired Immune Deficiency Syndrome
UNICEF	United Nations International Children's Emergency Fund
DfID	Department for International Development (United Kingdom)
ARP	Alternative Rites Program
PATH	Program for Appropriate Technology for Health
NGO	Non-Government Organisation
KM	Kaplan-Meyer
SAE	Small Area Estimation
WHO	World Health Organisation
INLA	Integrated Nested Laplace Approximation
P-Splines	Penalised Spline
MRF	Markov Random Field
GRF	Gaussian Random Field
DIC	Deviance Information Criterion
OR	Odds Ratio
CrI	Credible Interval

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## Executive Summary

### Background

Important evidence gaps remain in our understanding of why FGM/C practice is sustained, changes, or abandonment does not start. This study is part of larger research, in three phases, seeking to differentiate individual and community factors in FGM/C abandonment in Kenya, using multilevel and spatial analyses.

The exploration of FGM/C as a practice potentially maintained by both individual factors and collective social norms rests on several assumptions that can be examined empirically with the increasingly rich body of survey data now available. The sampling strategy of DHS and MICS surveys lends itself to multilevel modelling techniques for simultaneous estimation of effects specific to individual respondents as well as communities. Multilevel models are a rich and important approach for expanding our understanding FGM/C factors using DHS or MICS data.

FGM/C persists from generation to generation within families, and understanding mothers' and daughters' FGM/C status concordance or discordance with multivariate analysis can provide powerful insights into the relative influence of various factors. This study began with analysis of the new (2014) Kenya DHS (KDHS) data because of huge declines in FGM/C that are not fully understood. An analytical method for multilevel and successive/consecutive DHS data analysis was developed to investigate the effects of individual and community factors associated with changes in FGM/C prevalence, using a statistical approach for censored data, a technique known as survival analysis. Survival analysis can provide powerful insights into the relative influence of factors such modernisation (measured by education and socio-economic status), media exposure, and autonomy in decision-making (through questions on who makes healthcare decisions). DHS and MICS surveys do not generate data directly measuring social norms, social interactions, and influence; however, analysis of spatial effects for FGM/C prevalence and mother and daughter concordance can be interpreted to reflect the influence of the immediate social environment, capturing the influence of the proximate population that may constitute an individual's or family's reference group.

Spatial analysis methods provide a powerful means of weighing community factors, mediated through social norms, versus individual factors influencing FGM/C practice. The collection of repeated survey data can, with appropriate caution, begin to help identify causal trends.

### Objectives of the study

The aim of this research study is analysis of successive household data for estimating and revealing trends, similarities, and differences in geographic patterns for the burden of FGM/C and related risk factors among girls ages 14 and younger in Kenya. This study is intended to contribute to a deeper understanding of the recent burden of FGM/C among the girls within this very young age group, and to enhance knowledge of the geographic distribution of this practice over time. The report can inform current elimination efforts by helping identify girls at risk, campaign and intervention planning and targeting, as well as monitoring future progress. This report also provides recommendations to assist national partners in planning interventions.

### Methods

It was initially assumed that the most straightforward approach for estimating trends would be to rely on data from all four DHS surveys in Kenya on percentages of circumcised women ages 15 to 49. This approach provides no information about recent trends, however. As a result, this report draws upon the data collected from mothers about their daughters. This modification, however, led



to complications because of the differences in questions among DHS surveys about daughters' circumcisions. In 1998 and 2003, information was collected only for the eldest daughter. In 2008, information was collected on the numbers of daughters circumcised, with no age restriction, and details of the most recent cutting. In 2014, information was collected for all daughters 14 years old and younger. These differences may distort trends, but advanced Bayesian geo-additive modeling techniques addressed this problem, as well as revealing sub-national county FGM/C loci of activity.

## **Key findings**

This study's primary findings are presented in terms of national trends; regional, county and district trends; age at cutting; and underlying socio-economic and cultural predictors:

### **National trends**

The prevalence of FGM/C in girls and women ages 15 to 49 years was estimated at 37.6 percent in 1998, 32.2 percent in 2003, 27.1 percent in 2008-2009, and 21 percent in 2014. As reported by KDHS, these national averages often hide marked variations in prevalence in different parts of the country. In 1998 overall national prevalence in Kenya was 37.6 percent, but in counties it ranged from 38 percent in Kajiado and 43.3 percent in Taita Taveta to 75.1 percent in Nyamira and 75.9 percent in Kisii.

### **Provincial, county and district trends, descriptive and predicted**

The trends for observed rates of FGM/C for the 16-year period of 1998 to 2014 are illustrated in maps throughout this report. Counties with persistently high levels of FGM/C are Garissa, Kisii, Mandera, Nyamira, and Wajir. Data were collected from different age groups, and overall trends point to a slight decrease in FGM/C from 2003 to 2014; throughout the 11-year period, however, three counties experienced consistently higher FGM/C rates than in 2003. From 2003 to 2014, Nyamira and Samburu counties reduced their rates. In Isiolo County, lower rates observed in 2003 trended higher in 2008 and 2014: What might have explained this upward trend?

Predictions for 1998 and 2014 show that the proportion of FGM/C practice *is* largely around the national average ( $\leq 25\%$ ) across the country, but within that range important variance exists. The practice of FGM/C among girls persists, with rates similar to FGM/C risk patterns observed in 1998, despite a decade-long investment in abandonment programmes. No notable decline could be observed in the North Eastern province. The lack of any substantial reduction in FGM/C during the two decades spanning 1998 to 2014 is supported by an examination of precision maps of the standard deviations of the predicted posterior.

### **Age at cutting**

Age at cutting varies by region and ethnic group, with cutting at a much younger age among Muslims and women without university education. More significantly, their daughters are cut much earlier, at age 10 or before majority age. Women who avoided FGM/C at girlhood can undergo the practice quite late.

In both urban and rural areas, risk of FGM/C appears to be similar through the age of five, but beyond age five it seems to occur much earlier in urban than rural areas (log rank test,  $P < 0.001$ ).

FGM/C practice continues in rural areas among older age groups, up to 20 years of age, whereas in urban areas the practice stops by age 15. 'Sewn closed' or 'stitched up' FGM/C type occurs earliest, just after birth, followed by more severe FGM/C, with the most severe forms that include flesh removal often visited upon girls much earlier than other FGM/C types (log rank test,  $P < 0.001$ ).

### **Socio-economic and cultural predictors of cutting**

Existing studies point to a steady decline in the observed FGM/C prevalence in successive years, yet great variations exist within each survey year in provincial and ethnic prevalence estimates. Factors such as geographic location were adjusted. Statistically, daughters of women with no education are 3.5 times more likely to be cut than those of educated mothers (95% CI=2.00–4.16); girls of Muslim mothers are 4.36 times more likely to have undergone FGM/C (95% CI=2.72–7.01) than those of mothers from other religions. Girls within the Kisii ethnic group are 6.97 times more likely to be subjected to FGM/C (95% CI=5.82, 8.35). Finally, unlike their wealthier peers, girls from poorer households and living in rural areas are 24 percent more likely to undergo FGM/C (95% CI=1.07, 1.43).

## **Key recommendations**

This report represents a first step in an ongoing process that uses evidence from statistical modelling to inform change efforts. Future modelling work based on forthcoming 2018 data is required for a valuable 2014 comparator. As the prevalence of FGM/C continues to decline, efforts at accelerating abandonment will need to be focused on loci where the practice remains. This should allow deployment of further intervention efforts best suited and adapted to local conditions. This is more likely to effectively contribute to the realisation of total elimination of FGM/C in Kenya's context. Designing varied activities for abandonment campaigns and defining targeted populations are recommended, using rough county epidemiological data, which serve as a baseline for future impact analysis. Analysis of multiple successive cross-sectional household data inevitably points to the type of information that may be issued to better understand and address FGM/C practices. It also identifies the need for additional longitudinal design data, which may be collected in a future project. There are also many unknown factors for why FGM/C prevalence is changing or remains stagnant. These additional data will need to draw on broader conceptual models and hypotheses-based behaviour change theories.

This report makes four critical recommendations:

- First, further investigation should examine why there has been little change in the decline of FGM/C prevalence in Mandera, Wajir, and Garissa counties in northeastern Kenya.
- Second, detailed longitudinal studies of girls' FGM/C incidence, intentions, health risks and psychological consequences, and attitudes are essential at fixed sentinel sites in Kenya.
- Third, an in-depth study is needed to examine how the seasonality of FGM/C and social and economic contexts may become a control option for Kenya.
- Fourth, a future study could explore daughters' cutting by whether her mother was cut, to provide an inter-generational measure of change. More importantly, when strong campaigns against FGM/C exist, a concern always exists that underreporting will increase. A future study could compare FGM/C prevalence for the same birth cohort in the four KDHS surveys; one example would be to compare women ages 30 to 34 in 1998 with women ages 40 to 44 in 2008, and to determine the extent to which the estimates would prove similar if reporting propensity remains constant.

# Introduction

## Background

A significant body of academic research has focused on the development of theoretical models of behaviour change that may afford insights into the dynamics of changes in FGM/C. These models fall broadly under two main paradigms: 1) individual-centred decision-theoretic models such as modernisation theory and 2) relational models that account for the influence of social norms within a reference community. FGM/C as a practice potentially maintained by both individual factors and collective social norms rests upon several assumptions that can be examined empirically with the increasingly rich body of survey data now available. Recent analyses of nationally representative survey data have, in several instances, been designed to investigate the effects of community norms associated with FGM/C, not of individual and household characteristics, but have been hampered by methodological limitations. The sampling strategy of DHS and MICS surveys lends itself to multilevel modelling techniques for simultaneous estimation of effects specific to individual respondents as well as those common to communities. In the first stage of sampling, clusters are selected from enumeration areas. In the second stage, a random sample of households is selected, and all women ages 15 to 49 are asked to respond to the survey. Characteristics common to a cluster, or in some instances larger geographic areas such as regions, estimate effects of the community, while simultaneously estimating individual and household effects. Community effects are interpreted as the influence of social norms. Several analysts have used hierarchical models, also known as multilevel models.

DHS data<sup>1</sup> provide a powerful means of weighing community factors, mediated through social norms, versus individual factors influencing FGM/C practice. Repeated survey data in several countries can, with appropriate caution, help identify causal trends. Hayford (2005) posits that if parents know that other girls competing for husbands have undergone FGM/C, they will be likely to circumcise their daughters<sup>2</sup>. Her analysis reveals, at the individual level, that women with more education are less likely to have FGM/C performed on their daughters, consistent with modernisation theory predictions. Controlling for socio-economic characteristics, however, even more variation in daughters' FGM/C status is explained by community effects, consistent with the hypothesis community FGM/C norms exert an important influence on marriage markets. In another study, community rather than individual characteristics largely explained FGM/C variation<sup>3</sup>. For Muslim women, but not those of other religions, FGM/C is highly correlated, suggesting the importance of collective norms for a religious obligation. In Egypt, a multilevel analysis revealed a robust association between individual measures of socio-economic status, exposure to social media, and women's empowerment with the likelihood of a daughter's undergoing FGM/C<sup>4</sup>. Community effects point to an important role for social norms, however. While controlling for a mother's own educational attainment, the average educational attainment of her age cohort has a significant influence on her daughter's risk of FGM/C, suggesting norm change may be influenced by community changes in women's educational opportunities.

Multilevel models are a rich and important approach for expanding our understanding of FGM/C factors using DHS or MICS data. Each of these studies struggle with a methodological challenge,

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<sup>1</sup> Kandala NB, N Nwakeze, S Kandala. 2009. Spatial distribution of female genital mutilation in Nigeria. *American Journal of Tropical Medicine and Hygiene* 81(5): 784-792; Achia T. 2014. Spatial modelling and mapping of female genital mutilation in Kenya. *BMC Public Health* 14: 276-90

<sup>2</sup> Hayford S. 2005. Conformity and change: community effects on female genital cutting in Kenya. *Journal of Health and Social Behavior* 46(2): 121-140

<sup>3</sup> Hayford, SR and J Trinitapoli. 2011. Religious differences in female genital cutting: a case study from Burkina Faso. *Journal for the Scientific Study of Religion* 50(2): 252-271

<sup>4</sup> Modrek S and J Liu. 2013. Exploration of pathways leading to the decline of female genital cutting in Egypt. *BMC Public Health*

however, of analysing the important outcome variable: daughters' FGM/C status. The DHS and MICS surveys collect information on daughters' current FGM/C status, which is different from final FGM/C status: A girl who is not cut may still be cut in the future. Statistically, this is referred to as censoring. The Hayford studies handle censoring by combining current FGM/C status with responses on intention to have a daughter cut in the future. When the DHS and MICS revised the FGM/C module in 2010, the question on intent was dropped because it was considered unreliable. Hence, this correction method is no longer possible. The Modrek and Liu study in Egypt handled censoring by analysing data on daughters ages eight and older only. They excluded data on younger girls because of censoring. This is a very crude correction technique.

This study proposes an analytical method for multilevel analysis using a statistical approach for censored data, a technique known as survival analysis<sup>5</sup>. Survival analysis can provide powerful insights into the relative influence of factors such modernisation (measured by education and socio-economic status), media exposure, and autonomy in decision-making (through questions on who makes healthcare decisions). Moreover, spatial analysis methods, such as those in analyses of Nigeria and Kenya DHS data<sup>6</sup>, provide a powerful means of weighing community factors, mediated through social norms, versus individual factors influencing FGM/C practice. Repeated survey data in several countries can, with appropriate caution, help identify causal trends. These methods have been developed for analysis and documentation of this study.

This study begins by analysing the new (2014) KDHS data because of the huge FGM/C declines not fully understood; these findings will be useful for other research projects. The development of innovative analytical techniques for multilevel analysis of daughters' FGM/C status allows testing of predictions of leading theories on behaviour change, and allows identification of factors of change.

Multilevel and successive or consecutive DHS data analysis investigated the effects of individual and community factors associated with changes in FGM/C prevalence. FGM/C is passed from generation to generation within families, and understanding mother and daughter FGM/C status concordance or discordance with multivariate analysis can provide powerful insights into the relative influence of factors such modernisation (measured by education and socio-economic status), media exposure, and autonomy in decision-making (through questions on who makes healthcare decisions). DHS and MICS do not elicit data directly measuring social norms, social interactions, and influence; however, the analysis of spatial effects of the prevalence of FGM/C and mother and daughter concordance can be interpreted to reflect the influence of the immediate social environment, capturing the influence of the proximate population that may constitute an individual's or family's reference group.

According to KDHS, the prevalence of FGM/C in girls and women (ages 15 to 49 years old) was estimated in 1998 at 37.6 percent, at 32.2 percent in 2003, at 27.1 percent in 2008-09, and at 21 percent in 2014. The simplest way of estimating trends is to use data from all four KDHSs on the percentages of women ages 15 to 49 who are circumcised. This approach provides no information about recent trends, however. Thus, this report emphasises data collected from mothers about their daughters, but which is complicated by variations in successive DHS surveys in the questions on daughters' circumcisions. In 1998 and 2003, information was collected only for the eldest daughter. In 2008, information was collected on the number of daughters circumcised, with no age restriction, and details of the most recent cutting. In 2014, information was collected for all daughters 14 years old and younger. These differences may distort trends, but advanced techniques address this problem.

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<sup>5</sup> University of Washington has a Center for Social Science Statistics that specializes in innovative survival analysis techniques.

<sup>6</sup> Kandala et al 2009; Achia 2014

The only datasets produced thus far on FGM/C prevalence in Kenya relate to eight large provinces<sup>7</sup> (Shell-Duncan et al 2017). Aggregated regional prevalence conceals important spatial variations of FGM/C practice in counties. In 1998 Kenya's overall national FGM/C prevalence was 37.6 percent, but the range of FGM/C in counties varied from 38 percent in Kajiado and 43.3 percent in Taita Taveta to 75.1 percent in Nyamira and 75.9 percent in Kisii (Figure 7). This study examined prevalence for each of the 47 counties in Kenya (Figure 1). A county is still a large unit for analysis, but disaggregation to the county level does represent a considerable advance over the use of the larger provincial unit, and this analysis provides the first robust county information on FGM/C among girls 14 years old and younger.

KDHS data contain geographic or spatial information, such as the counties where circumcised girls reside, information on their mothers, and on their households and communities. Understanding space, place, and geography related to the practice and occurrence of FGM/C is essential because FGM/C practice is present in diverse educational, socio-economic, and religious groups, and rural and urban communities.

In most countries in Africa, studies have found significant spatial patterns, separate from the effects of individual factors such as female education and demographic characteristics, that indicate associations with economic disadvantage and communities' remoteness (Kandala et al 2009). It is also possible to look further at community variables that might explain these spatial patterns (*ibid*). A better understanding of the geographic patterns in FGM/C outcomes and their influences are necessary for programmes and policies that seek to improve girls' reproductive health outcomes.

Historically, variations in FGM/C rates have been associated with individual social and economic factors such as education and religion. By contrast, geographic patterns other than rural or urban, and province, have been overlooked. This report begins with a simple analysis of geographic variation in Kenya, followed by a more detailed analytical approach. Previous research on FGM/C, including descriptive reports (Shell-Duncan et al 2017), tends to examine only socio-economic, demographic, and health determinants in specific contexts and have generally failed to incorporate spatial aspects in the study of FGM/C. Population level socio-economic variables and health resources encapsulated in previous research hardly explain the variations in FGM/C rates. There is abundant evidence, however, that aggregate FGM/C rates in many developing countries mask spatial variations and that understanding these spatial patterns may lead to identification of other important determinants of child health. Moreover, as a social norm, FGM/C often leads to concentration of the population in specific regions and ethnic groups.

This report is based on spatial patterns of FGM/C, and goes beyond previous research in the field. Previous studies traditionally have not treated factors like auto-correlation in the data, non-linear, and time varying covariates effect as well as small samples. Certain aspects have not been considered—for example, geographic location and its effects on outcomes—raising the question whether those studies can be generalised at all, given their reliance on the independence of random components for context (county or province). Most studies derive their conclusions from limited statistical analysis, and in so doing lose sight of the need to control factors that may have significant effects on girls' FGM/C—physical environments in which children live and their potential impacts on the risk of being circumcised. Furthermore, many findings represented in these studies provide national statistics, and they cannot be extrapolated or extended to a particular county.

Several methodological shortcomings in prior FGM/C research cast doubt on the extent to which their findings can be generalised. These studies' conclusions tend to rest upon limited statistical analysis. Such studies fall short of controlling the factors that potentially affect child health.

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<sup>7</sup> Before Kenya's new Constitution was enacted in 2013, Kenya was administratively divided into eight provinces, but the Constitution decentralised administration into 47 smaller counties.

Our approach has several advantages over these studies, which use logistic models with constant-fixed effects of covariates and fixed (or random) districts (provinces) effects or standard two level multilevel modelling with unstructured spatial effects.

With such models, it is assumed that the random components at the contextual level (county or province) are mutually independent, even though in practice this assumption is not actually implied by these approaches, so correlated random residuals could also be specified (Langford et al 1999). Borgoni and Billari (2003) point out that the independence assumption has an inherent problem of inconsistency: If the location of the event matters, it makes sense to assume that areas close to each other are more similar than areas far apart.

KDHS and MICS data are based on a random sample from Kenyan provinces. The structured component introduced herein allows this study to 'borrow strength' from neighbors to cope with the sample variation of the district or province effect and obtain estimates for areas that may have inadequate sample sizes or be un-sampled. Several models in this study emphasise the differences that can be found by adopting this approach in a spatial context and the possible bias involved with the violation of the independent assumption between aggregated spatial areas. Some of these models have a spatial and random component that reflect spatial heterogeneity globally and relative homogeneity among neighbouring counties, while some do not. A failure to account for the posterior uncertainty in the spatial location (county or province) would overestimate the precision of the prediction of FGM/C risks in un-sampled districts.

To address these shortcomings, rates of FGM/C were linked with geographic locations, which meant using all FGM/C cases processed in each county and province of Kenya, and accounting for the influence of such important factors as dependence of random component and geographic location on outcomes. The Bayesian geo-additive model is a key method adopted in this report, necessary to account for the space and time effects on the FGM/C rate. It also assists in explaining heterogeneity in FGM/C prevalence as influenced by child, household, and environmental factors. The aim is to provide mean county estimates of FGM/C, and to do this, model parameters were estimated using a combination of advanced statistical software including the Integrated Nested Laplace Approximation (INLA) algorithm for inference, implemented in R project version 3.3.2 using R-INLA library, and BayesX software. The underlying predictors related to household, maternal, and environmental factors were controlled in the model, including type of residence, religion, ethnicity, age of household head, and wealth index. County effects were incorporated to allow for structured (spatial and temporal) and unstructured heterogeneity of FGM/C rates, using a convolution prior. An assumption of additional flexibility in the model allowed for effects of non-linear predictors. KDHS survey years defined the temporal effect in the model.

Geo-coded repositories of county and provincial prevalence for girls' FGM/C were assembled, to be used in novel model-based geo-statistical frameworks to predict FGM/C intensity in 1998 and 2014 in each of the 47 counties and eight regions (provinces) used for sub-national planning (Figure 1). Incorporation of geographic information system (GIS) information may provide useful insights of FGM/C's distribution and give policymakers vital information for more effectively directing their intervention planning.

This approach adds significant value because disaggregation to counties represents a considerable advance over the use of provinces. By providing the first robust county information on FGM/C among girls ages 14 and younger, this approach will be of immediate importance and potential benefit to the categories of girls at risk of FGM/C, and to policymakers and programmers pursuing national and sub-national interventions.



**Figure 1:** Map of Kenya showing 47 counties defined when the new constitution was adopted in 2013; provincial divisions and subsequent data masked much of FGM/C's heterogeneity; a much clearer national picture will be seen with county sub-divisions, especially helping to identify loci of FGM/C practice

## Aims of the study

The study's overall goal is to analyse successive household data to emphasise trends, similarities, and differences in geographic patterns in FGM/C burden and related risk factors among girls 14 years old and younger in Kenya. The datasets used are the nationally representative KDHS surveys from 1998 to 2014. Multivariate spatial Bayesian approaches and innovative statistical methods of disease mapping and hotspot analysis addressed the research problem.

The specific aims of the study are:

1. To assess availability, applicability, use, and quality of successive KDHS data when measuring the burden of FGM/C over time in Kenya;
2. To examine small area variation in FGM/C prevalence and a wide range of purported traditional and emerging risk factors among girls 14 and younger in Kenya;
3. To identify and develop appropriate statistical models to facilitate synthesis of successive KDHS data and generate a complete and smooth temporal and geographic FGM/C variation;
4. To assesses the accuracy and robustness of the modelling and predictions techniques (in 2 and 3 above) by using a number of validation procedures;
5. To make policy recommendations on strategies for resource allocation that can be used to eliminate the practice of FGM/C and related health and socio-economic burdens associated with FGM/C in these settings; and
6. To identify promising areas and issues that can be advanced in any future research on this important topic.

## Research design and methods

### Research design

Several recent data sources, largely from nationally representative household surveys including KDHS 1998, 2003, 2008 and 2014, are examined and analysed in this study. The Demographic Health Surveys (DHS) are periodic cross-sectional health surveys funded by USAID's (US Agency for International Development) Bureau for Global Health. DHS includes modules on demographics and household affluence, fertility, reproductive health, maternal and child health, nutrition, and HIV/AIDS knowledge and practice (DHS 1990-2004). The core questionnaire for households collects data from adult women (ages 15 to 49) and men from nationally representative probability samples of households. Surveys allow for an optional additional series of questions about FGM/C to be added to the women's questionnaire (Yoder et al 2004, Creel 2001). The module on FGM/C includes three sections: 1) whether the woman underwent FGM/C or not, and details about the event, 2) whether one daughter underwent FGM/C or not, and details about that event, and 3) the woman's opinion about the continuation of the practice. Since 2000, UNICEF's Multiple Indicator Cluster Surveys (MICS) have used a similar module to collect information on FGM/C in selected countries (Yoder et al 2004, Creel 2001). This study draws on data from the core household questionnaire as well as the module on FGM/C administered to women ages 15 to 49 years.

The 2008-2009 KDHS survey had no age restrictions for daughters, while the 2014 KDHS survey focused on daughters ages 14 and younger. KDHS 1998 and 2003 collected information on circumcision among eldest daughters. Some socio-demographic and socio-economic factors associated with FGM/C are also included in the data. Respondents' ages at the time of survey were also included as an indicator of participant's birth cohort. Other predictor variables included gender, ethnicity, education (no education versus primary, matric and tertiary education), household wealth, and place of residence or locality (rural versus urban). Further details on the methods, objectives, organisation, sample design, and questionnaires in KDHS from 1998 to 2014 are described elsewhere (*ibid*), and the findings of a descriptive analyses of these data are presented elsewhere (Shell-Duncan et al 2017).

The main exposure variables to be investigated include girls' geographic location, i.e. rural or urban, and administrative county or province of residence. Geographic location can be viewed as a proxy measure for many unmeasured factors such as cultural norms. Such spatial factors might illustrate how much, if anything, can be learned from detailed exploratory analyses and the extent to which datasets can be strategically used to inform resource allocation and national and local policies for eradicating FGM/C in Kenya.

### Methods

To account for possible spatial dependence in the data, models were used that require both GIS and lattice data for different levels of administrative areas. GIS data for enumeration areas are available in these datasets, and the polygon shape files at appropriate levels are available from various sources. Thus, geo-statistical models accounted for dependence of prevalence of neighbouring areas. Data were also aggregated at the appropriate administrative boundaries (county and province) to enable lattice spatial modelling. The geographic patterns of FGM/C and other factors' potential effects are explored within a simultaneous, coherent regression framework designed to control both spatial dependence and the complex sampling design, allowing analysis of any residual variations in FGM/C risk not accounted by well-known risk factors. A full Bayesian approach, coupled with Markov Chain Monte Carlo (MCMC) techniques, were employed for inference and model checking (see Appendix 2 for more detailed modelling explanation). A wide variety of sources were utilised including the nationally representative household surveys,



so statistical models were designed and developed to examine data from each survey year and combined datasets to visualize FGM/C outcomes by interpolating values across space and time. Only by combining many data sources in a single model can the importance of each data source be determined and missing values addressed.

## **Why survival analysis techniques and spatial analysis to model time to female genital mutilation/cutting (FGM/C)**

### **Description of survival datasets and background variables**

The data included a total population of 20,259 girls ages 14 and younger. This population dataset was obtained from successive KDHS surveys: 1,590 in 1998, 1,577 in 2003, 4,703 in 2008, and 12,388 in 2014. Data were confined to a cohort exposed to FGM/C from birth. Across Kenya, nearly three fourths of girls are cut between the ages of five and nine. The average age of cutting varies according to different areas and communities, however (Shell-Duncan et al 2017), and this variation must be accounted in any attempt to assess potential FGM/C risk for girls in this part of the world. This study analysed risk of FGM/C from birth to the age or period at which girls were exposed to cutting (in years), following reporting by the girl's mother in the various KDHS surveys. For girls not yet subjected to FGM/C at the time of data collection, reference to 'time' means time from birth to the period at which data were available. The variable status indicates that time refers either to FGM/C (1) or end of study (0). Possible explanatory variables for FGM/C include mother's education, religion, ethnicity, household socio-economic status, region or district of residence, as well as rural or urban location. These variables were recorded in all KDHS (1998-2014). The datasets were first analyzed by Shell-Duncan et al and form Part I (descriptive analysis) of this consultancy.

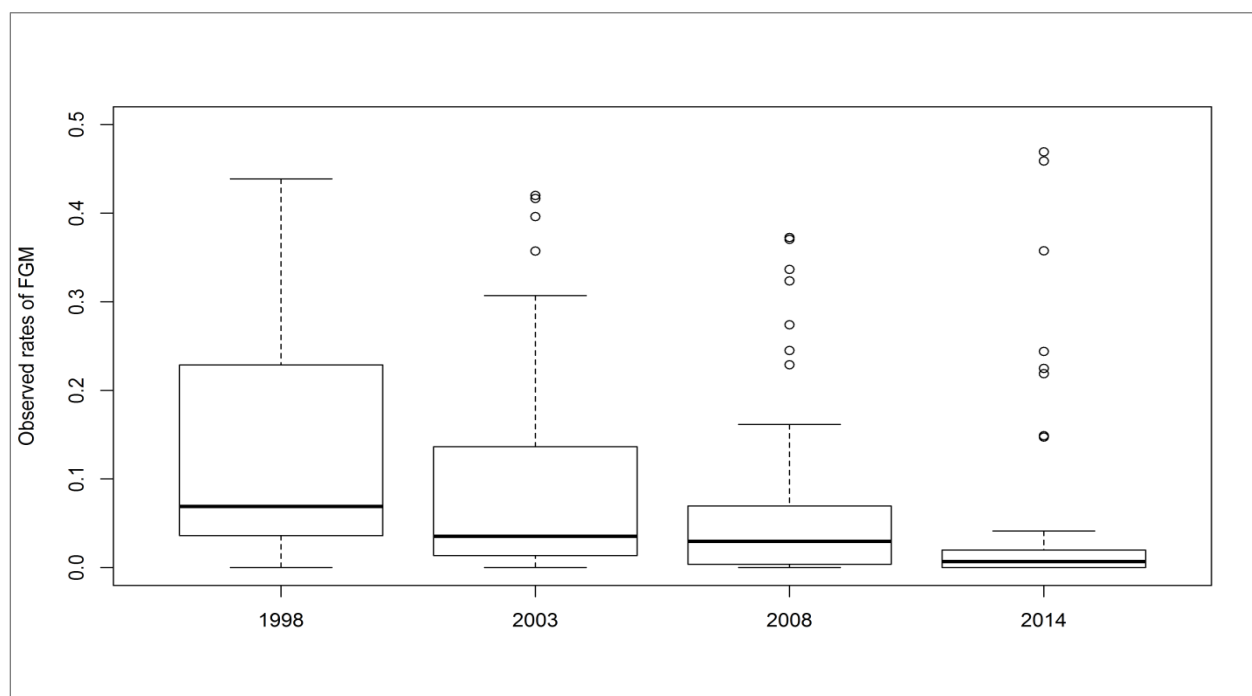
The data on girls' ages at cutting can be described as *survival data*, but in this case the 'endpoint' relates not to death, but to FGM/C. From engineering applications, the term 'failure' is commonly used for the end point to denote analysis of data on the time until an event occurs (death, failure, or, in this case, FGM/C). At any one point in time, the data include observations in one of the following three categories: 1) those on whose behalf the event (FGM/C) has occurred, 2) those for whom the event (FGM/C) has not yet occurred but is likely at some point in the future, and 3) those for whom the event (FGM/C) has not occurred and may never occur. Survival analysis is a method allowing analysts to include information on girls who are not cut at the time data collection occurs. Duration or survival data cannot generally be analysed by conventional methods such as linear regression, primarily because some durations (age of girl at circumcision) are usually right-censored, that is, the endpoint of interest (FGM/C, in this case) has not occurred during the period of observation and all that is known about the duration is that it exceeds the observation period. In the present dataset, this applies to all girls who had not undergone FGM/C, and these girls' observations or status is 0. Another reason why conventional linear regression is not appropriate is that survival times tend to have positively skewed distributions: Through age 14, most FGM/C events may occur close to birth (left negatively skewed) or close to age 14 (right positively skewed). A third reason is that time-varying covariates, such as the time of year when FGM/C is performed, could not be handled. The appendix provides descriptions of the methods specifically developed for survival data and their extension to hierarchical Bayesian spatial analysis.

More detailed description of datasets and background variables that were used in the survival and spatial descriptive analysis are described elsewhere (Shell-Duncan 2017). This, as well as a list of the datasets for each of the four KDHS surveys and detailed list of FGM/C specific variables for each survey, can be found elsewhere (*ibid*).

## Key Findings

### National trends: Mapping girls' FGM/C from 1998 to 2014, and key findings of the descriptive spatial analysis on girls' FGM/C

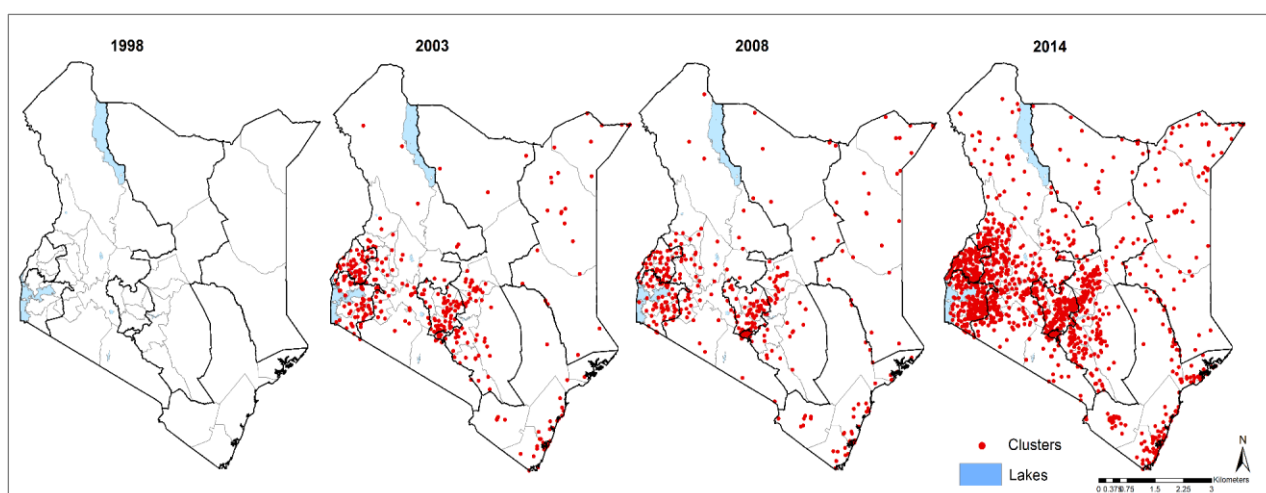
According to KDHS, FGM/C prevalence in girls and women (ages 15 to 49) was estimated at 37.6 percent in 1998, 32.2 percent in 2003, 27.1 percent in 2008-09, and at 21 percent in 2014. This section provides a detailed descriptive analysis, followed by a more advanced statistical analysis of the FGM/C prevalence in Kenya during this overall period.



**Figure 2:** Boxplots of observed FGM/C rates in Kenya from 1998 to 2014; KDHS 2008-2009 had no age restrictions, while KDHS 2014 focused on daughters 14 years old and younger; KDHS 1998 and 2003 collected information on circumcision among eldest daughters

Figure 2 shows that observed rates of FGM/C decreased from 1998 to 2014. As discussed, however, the 2008-2009 KDHS survey had no age restrictions for daughters while KDHS 2014 focused on daughters 14 years old and younger. KDHS 1998 and 2003 collected information on circumcision among eldest daughters. These inconsistencies in reporting and recording of ages may have affected the observed decline of FGM/C during the 16-year period.

The advanced statistical analysis (multivariate Bayesian models) discussed in this report will be able to account for this inconsistency in age reporting of daughters, investigating whether it affects the observed trend of FGM/C decline.



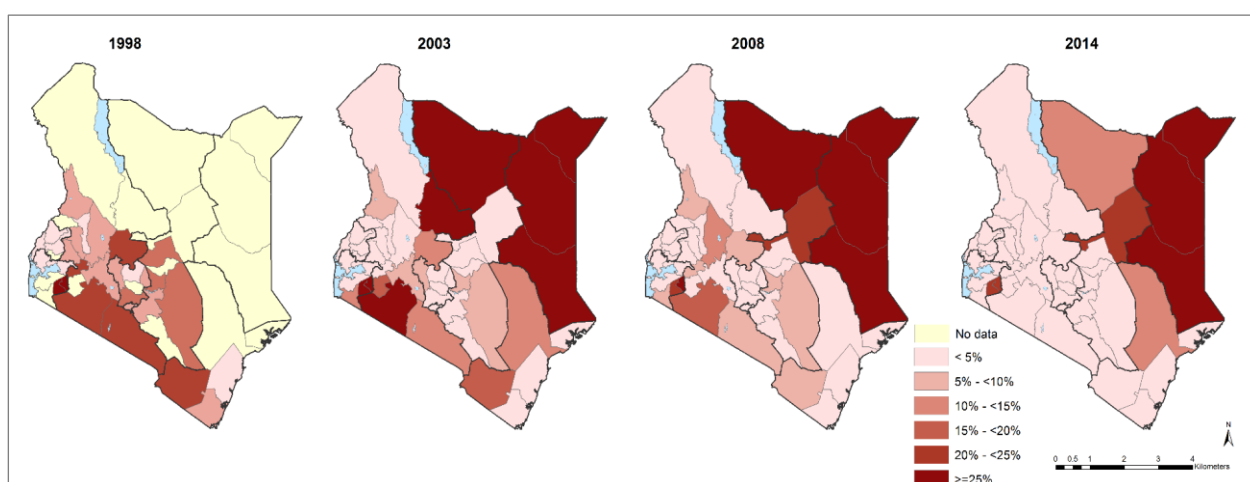
**Figure 3:** Distribution of clusters sampled in KDHS 1998, 2003, 2008-2009 and 2014—red points show the clusters (blue represents water bodies in Kenya); Kenya is divided into 47 counties and 8 regions (provinces); cluster coordinates for 1998 KDHS not collected

Groupings of household clusters were not geo-referenced in KDHS 1998 and therefore are not displayed. The number of survey clusters increased from 2003 to 2014. The distribution of clusters has an impact on the observed rates in each survey year and affects estimates of the various models, so robust statistical models will account for the cluster representation in each survey year.

## Regional, county and district trends, descriptive and predicted

### Descriptive key findings: Observed prevalence of FGM/C among girls, by region and county

This section illustrates the empirical spatial and temporal trends of FGM/C rates from 1998, 2003, 2008-2009, and 2014 KDHS data. The following section then provides a detailed survival and modelling of the KDHS 2008 and from 1998 to 2014 to illustrate the proposed methodologies. The third part of the report extends the analysis to present multivariate spatial results of the most recent (2014) KDHS data and combined 1998 to 2014 KDHS data.

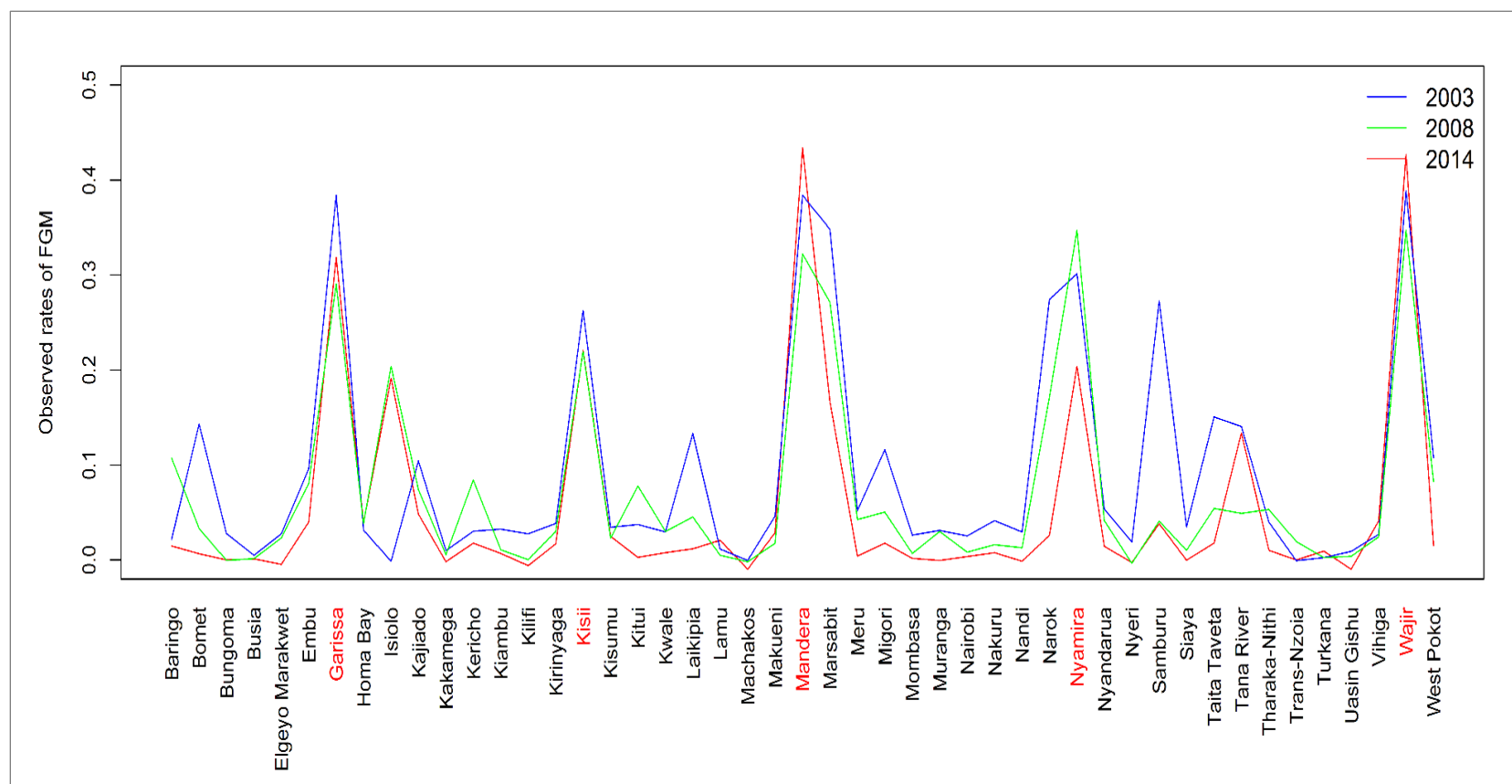


**Figure 4:** Observed county rates of FGM/C among circumcised daughters in four consecutive DHS surveys—1998, 2003, 2008-09 and 2014

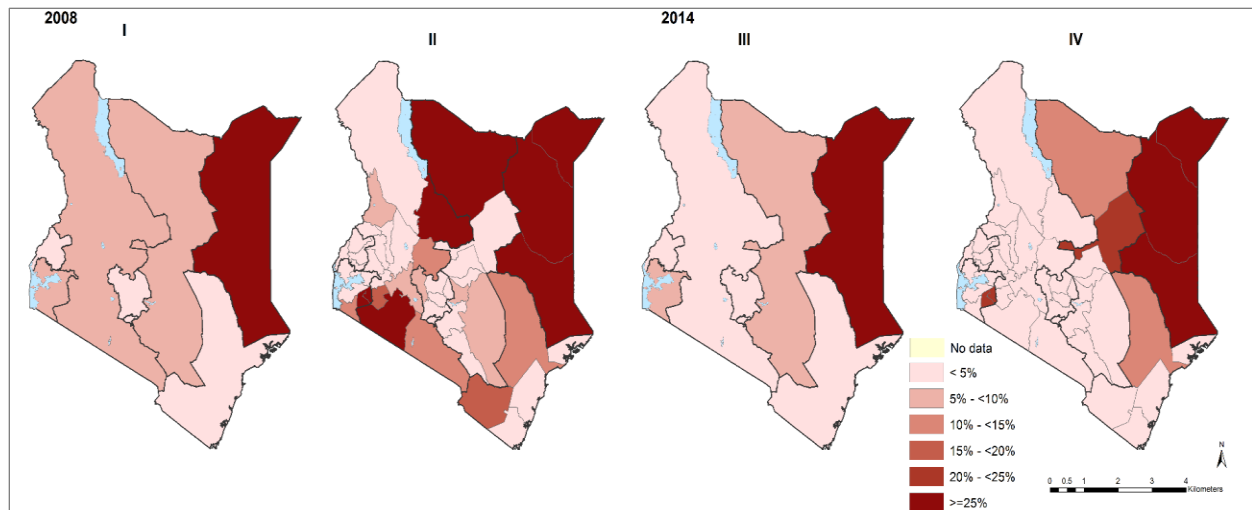
KDHS 1998 was not conducted in North Eastern province and other northern counties. The 2008-2009 KDHS had no age restrictions, while 2014 KDHS survey focused on daughters up to 14 years old. KDHS 1998 and 2003 collected information on circumcision among eldest daughters.

Observed rates of FGM/C decrease from 2008 to 2014, but with no observed decrease in rates in North Eastern province. During the 16-year period, higher FGM/C rates ( $\geq 25\%$ ) were observed consistently in the northeastern region except in 1998, when data were not collected. Eastern province exhibits higher observed FGM/C rates for both 2003 and 2008, with a marked decrease in rates observed in 2014; meanwhile, observed rates shift from lower rates to higher rates from 2008 to 2014. Some counties in Eastern province with rates below five percent in 2003 had observed FGM/C rate increases in 2008 and 2014 from 15 to 20 percent.

Figure 5 (following page) clearly shows the trend of the observed FGM/C rates during the 16-year period illustrated in the various maps of Figure 4. Counties showing persistent high levels of FGM/C were Garissa, Kisii, Mandera, Nyamira, and Wajir. Rates of FGM/C from KDHS 1998 were not analogous with the rates in the other survey years because it did not include all regions in the country. The trend decreases slightly from 2003 to 2014, although the data were collected from different age groups. For counties with observed higher FGM/C rates in 2003, apparently, Garissa, Kisii, Mandera, and Wajir remained consistently among counties with higher observed FGM/C rates throughout the 11-year period. From 2003 to 2014, however, Nyamira and Samburu counties achieved reduced rates. Isiolo county, on the other hand, presents an example of change from lower observed FGM/C rates in 2003 ( $<20.0\%$ ) to higher rates in 2008 ( $<20.0\%$ ) and 2014 (21.9%).



**Figure 5:** Trends of rates of FGM among girls by year of survey at county level for KDHS 2003, 2008-2009 and 2014: Note that the line graph above does not suggest a follow up period on continuous scale on the x-axis; the x-axis is counties in alphabetical order and the line does not mean they are continuous but rather they are from different survey years



**Figure 6:** Variation of the observed rates of FGM/C at both regional (province) and county levels in 2008 and 2014— maps I and II show rates of FGM/C in 2008, and maps III and IV in 2014 at provincial and county levels, respectively

Looking at both county and provincial levels, Figure 6 shows consistent higher observed FGM/C rates in North Eastern province, while the county map of observed FGM/C rates in 2008 displays a clearer and better picture of the geographic location of affected girls' populations, since the provincial map averages out county rates.

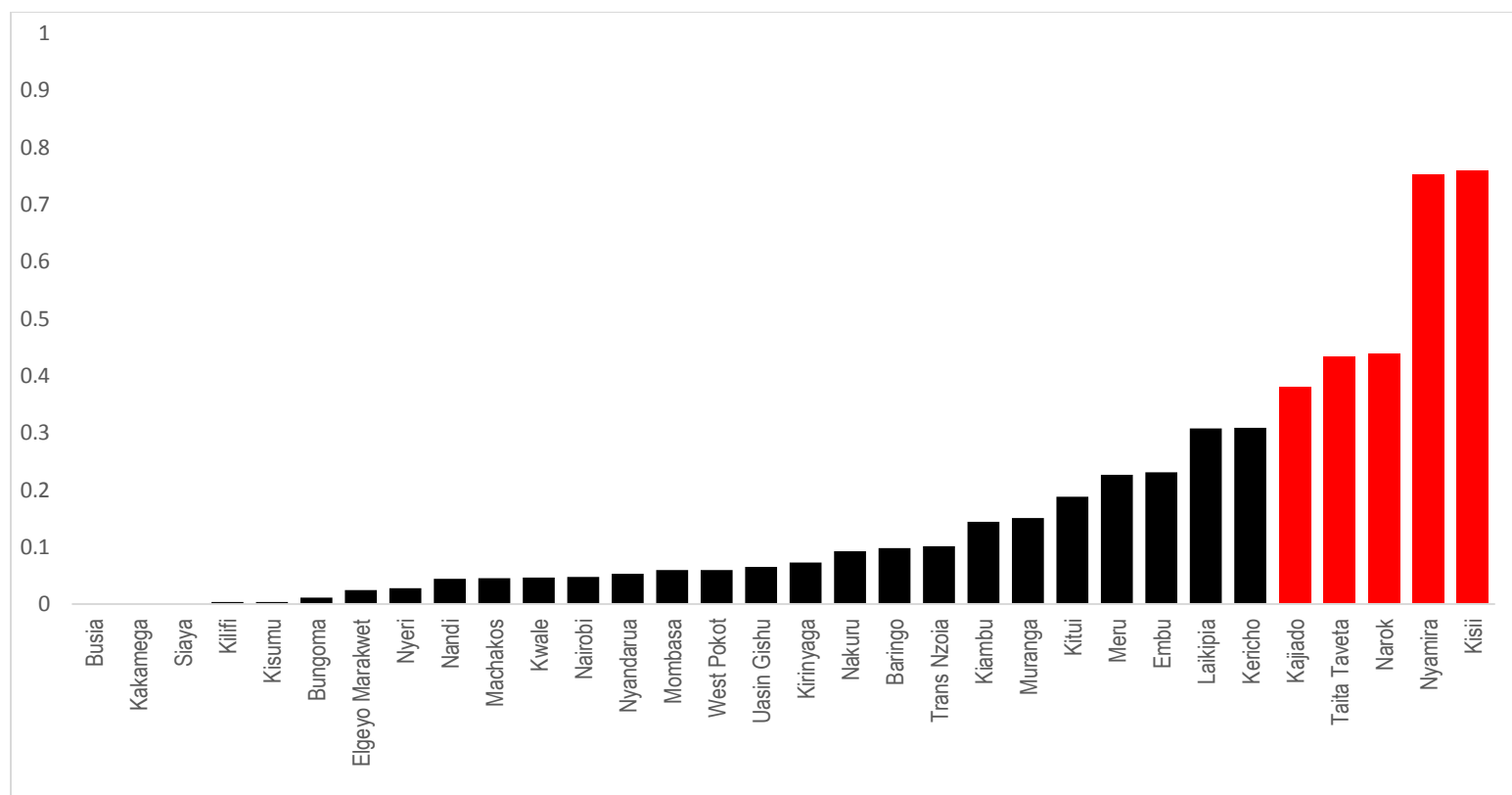


Figure 7: Observed county rates of FGM/C among circumcised daughters in 1998 KDHS. National FGM/C prevalence is 37.6%

In 1998, observed FGM/C rates appear higher than the national average of 37.6 percent in Kajiado (38.0%), Taita Taveta (43.3%), Narok (43.8%), Nyamira (75.1%), and Kisii (75.9%) counties.

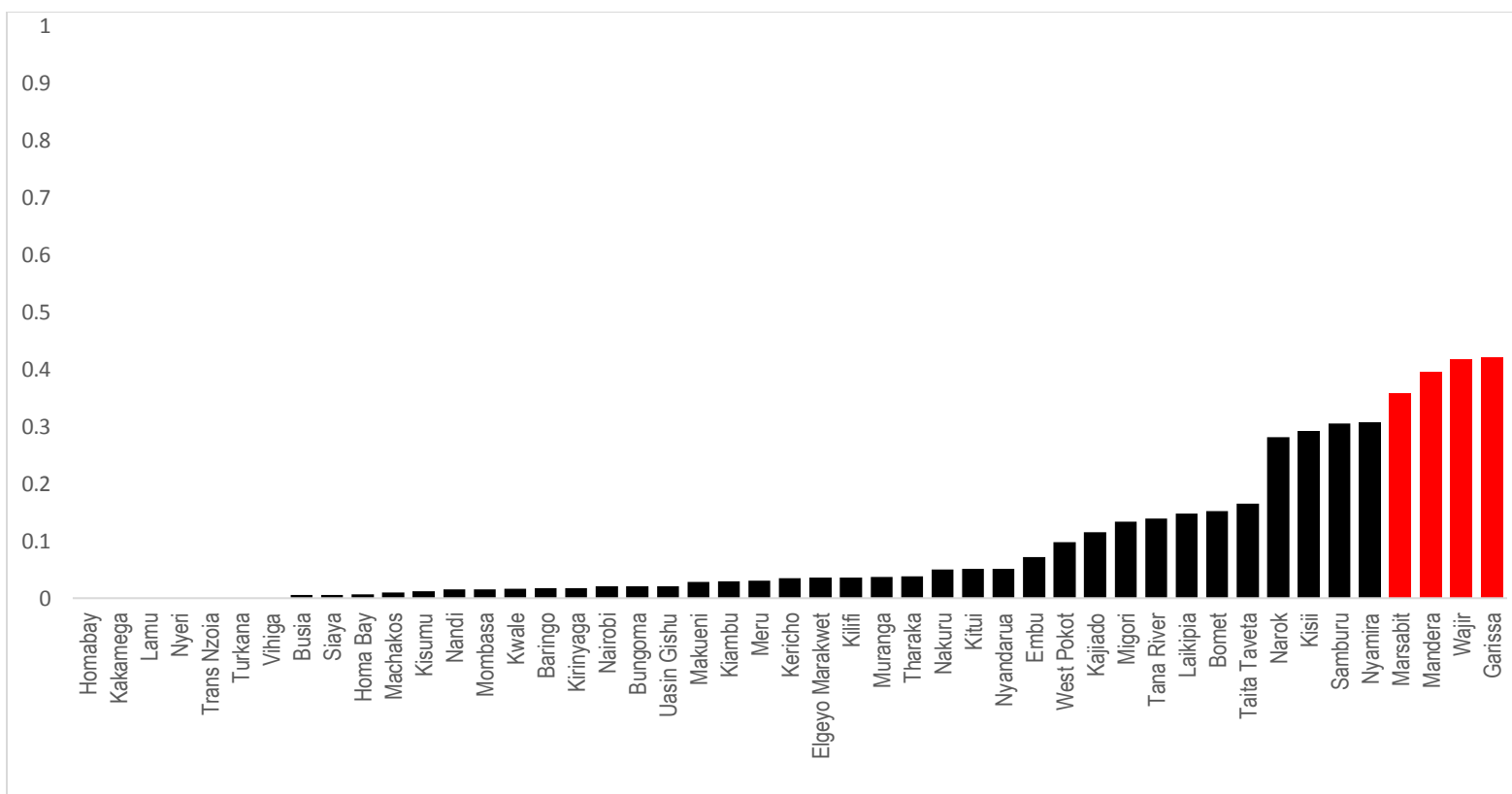


Figure 8: Observed county rates of FGM/C among circumcised daughters in 2003 KDHS. National FGM/C prevalence is 32.1%

In 2003, counties with higher observed FGM/C rates than the national average of 32.1 percent were Marsabit (35.7%), Mandera (39.6%), Wajir (41.7%), and Garissa (42.0%).



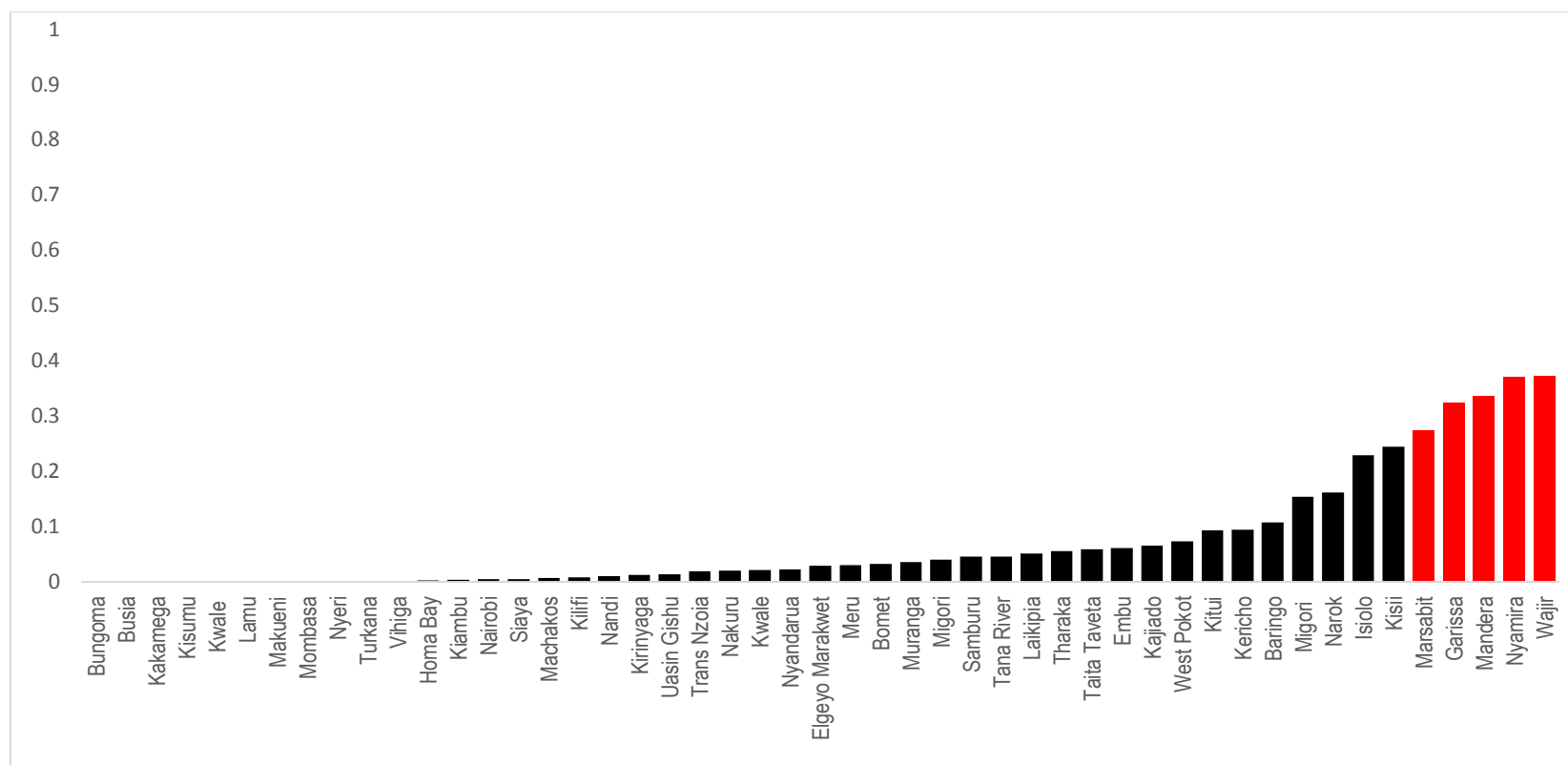


Figure 9: Observed rates of FGM among circumcised daughters in 2008 KDHS. National FGM/C prevalence is 27.1%

In 2008, counties with higher observed FGM/C rates than the national average of 27.1 percent were Marsabit (27.4%), Garissa (32.4%), Mandera (33.6%), Nyamira (37.0%), and Wajir (37.3%).

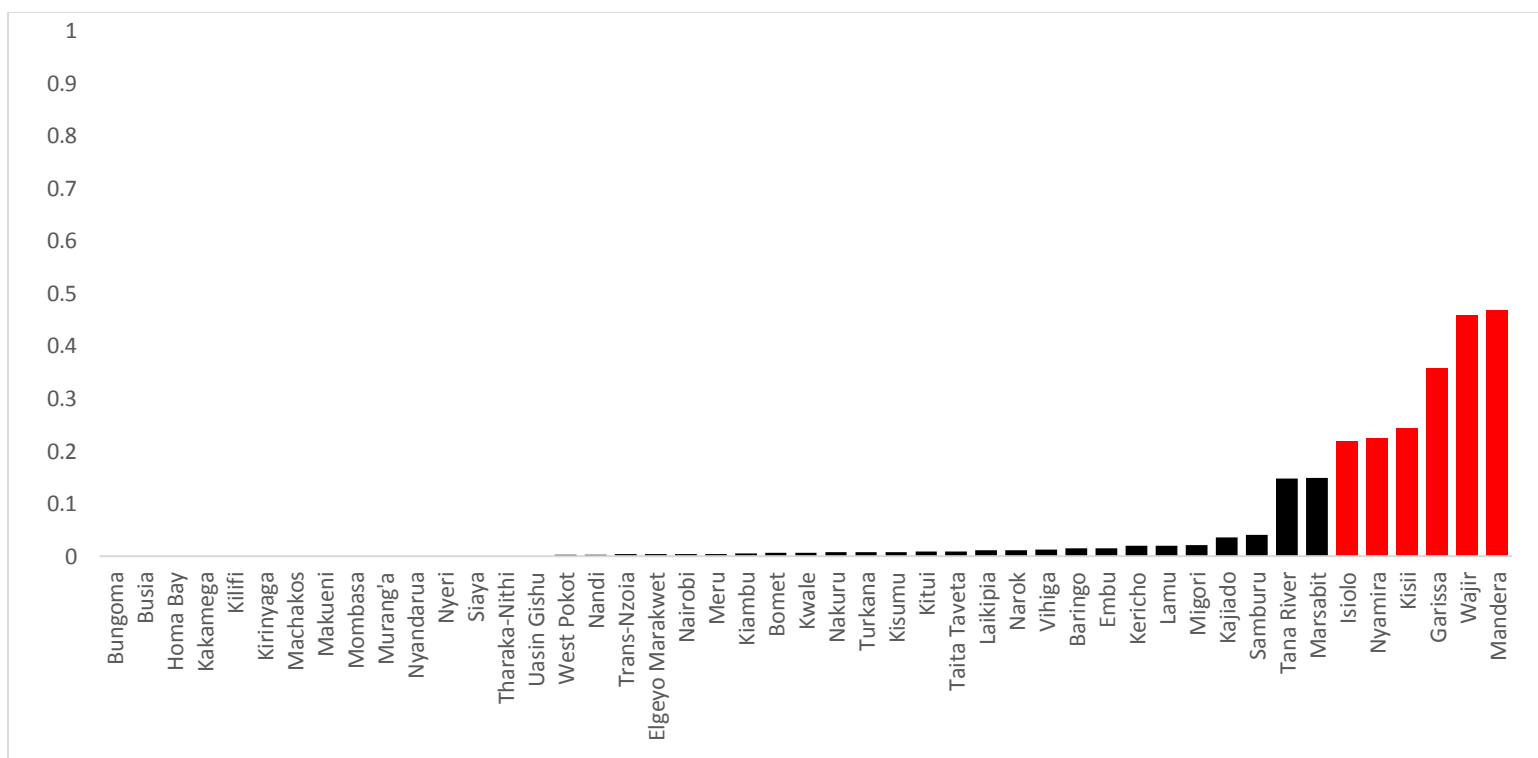


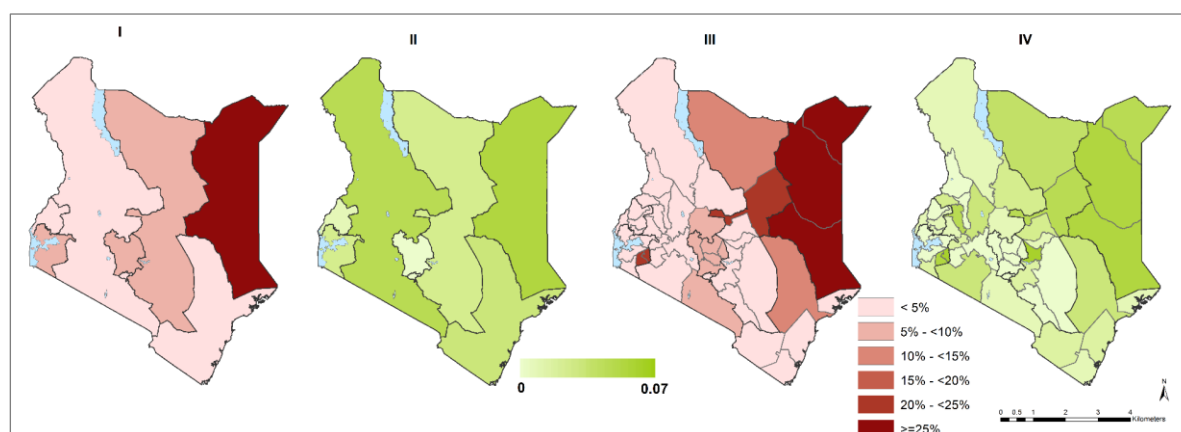
Figure 10: Observed county rates of FGM/C among circumcised daughters in 2014 KDHS. National FGM/C prevalence is 21.0%

In 2014, in addition to Isiolo (21.9%), Nyamira (22.5%) and Kisii (24.4%) counties, Mandera, Wajir, and Garissa counties remained with higher observed FGM/C rates than the national average of 21.0%—for 11 years (from 2003).

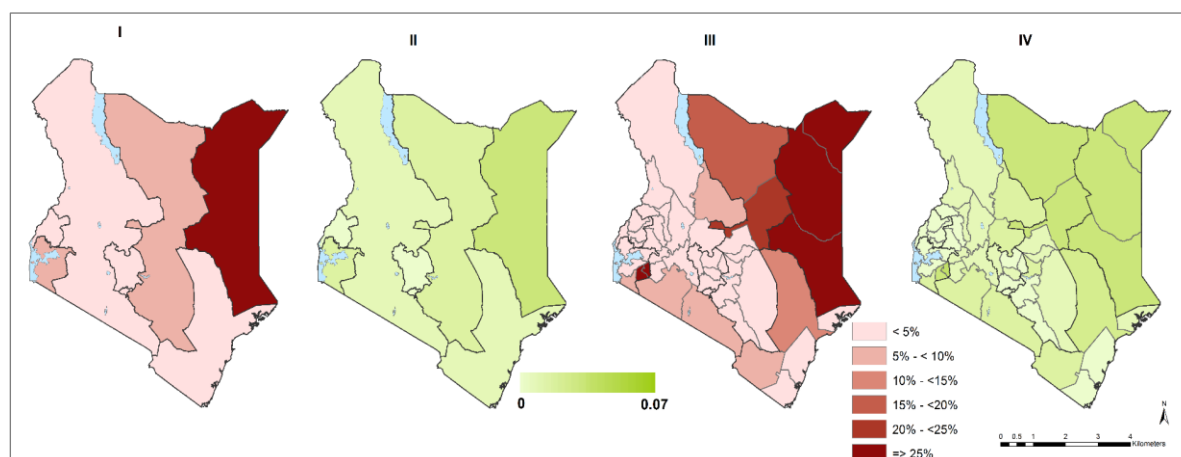
### Multivariate findings: Models predicted FGM/C among girls at provincial and county levels

Recent advances in disease mapping and availability of sub-national (county) data permit identification and analysis of successive KDHS data sources of girls' FGM/C status for proper and advanced modelling of the data to inform policy.

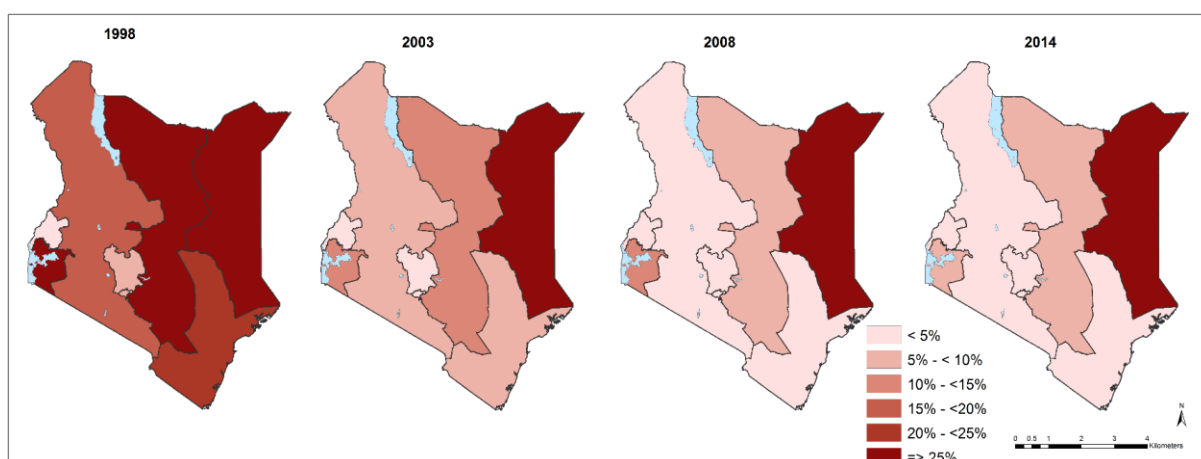
Geo-statistical models account for dependence of prevalence of neighbouring areas, with data aggregated at appropriate provincial and county administrative boundaries to enable lattice spatial modelling. The geographic patterns of FGM/C and possible effects of other factors are explored within a simultaneous, coherent regression framework, which simultaneously controls for spatial dependence and the complex sampling design. The resulting maps are residual maps free from random errors and represent unobserved spatial factors either not measured in the surveys or capturing the effects of cultural norms.



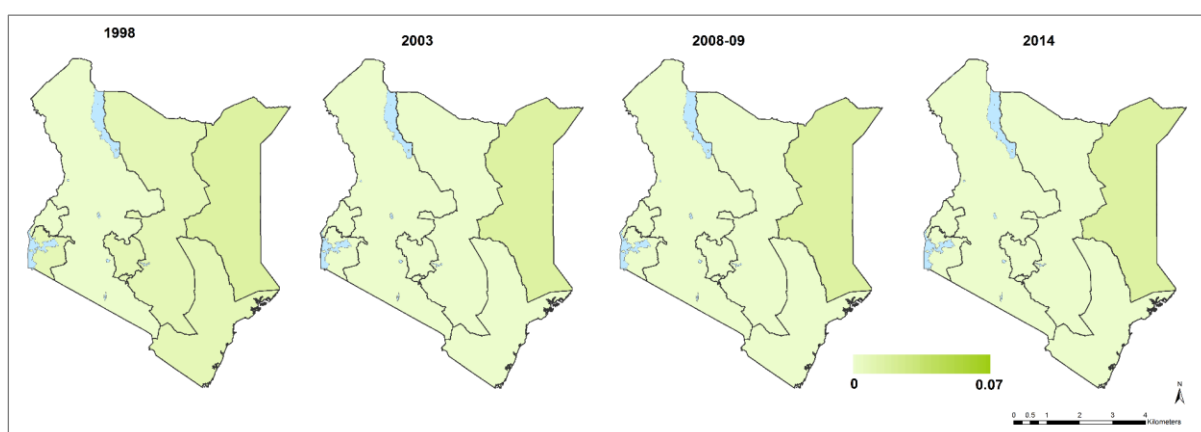
**Figure 11:** Predicted FGM/C prevalence and standard deviation around the mean using KDHS 2014: I=Mean provincial prevalence, II=Standard deviation around the mean at provincial level, III=Mean county prevalence, and IV=Standard deviation around the mean at county level indicating error margin



**Figure 12:** Pooled predicted FGM/C prevalence and standard deviation around the mean using KDHS dataset 1998 to 2014: I=Mean provincial prevalence, II=Standard deviation around the mean at provincial level, III=Mean county prevalence, and IV=Standard deviation around the mean at county level

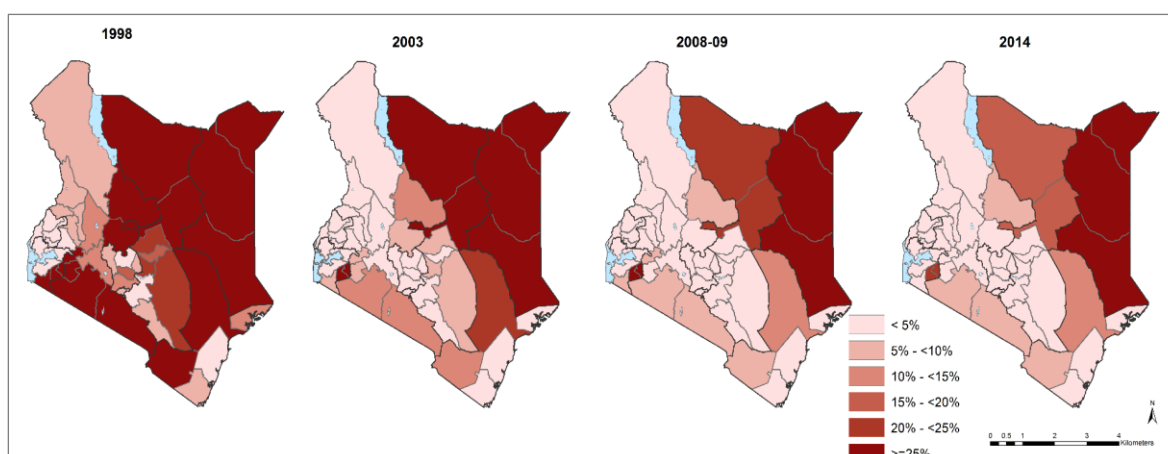


**Figure 13:** Predicted provincial FGM/C prevalence in Kenya 1998 to 2014 derived from spatial-temporal regression model



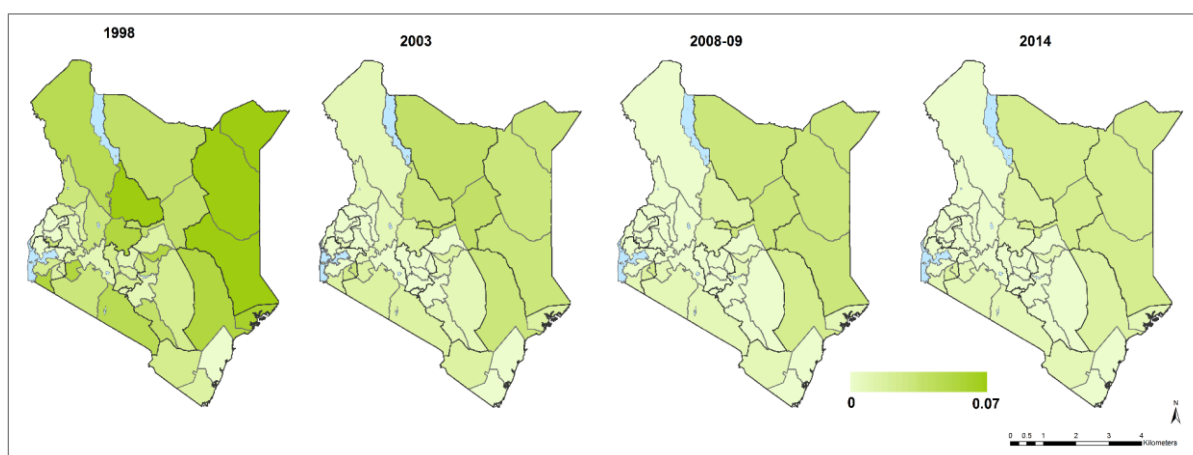
**Figure 14:** Standard provincial deviations of the predicted posterior mean among girls in Kenya from KDHS survey datasets 1998 to 2014 derived from spatial-temporal regression model

In 1998, overall national predicted FGM/C among girls was 38 percent, and almost all regions had a predicted FGM/C prevalence above 25 percent, among all age groups. Few regions had FGM/C prevalence among girls below the national average of 38 percent (Figure 21). Despite the fact FGM/C data were not collected in the 1998 survey, our model was able to predict high prevalence ( $\geq 25\%$ ) in the un-sampled regions of the northeast. By 2014 the modelled data from household surveys and distribution data suggested a very different pattern of FGM/C prevalence (Figure 21). The national predicted FGM/C prevalence was 21 percent, and most regions had predicted FGM/C prevalence estimates below 21 percent of their populations. Only three counties in the northeast had a prevalence in excess of 25 percent: Mandera, Wajir, and Garissa. The patchwork of prevalence in 2008 (Figure 21) was improved considerably, and was decreased considerably, possible a result of successful interventions that provided a very different pattern of improved spatial coverage by 2014 (Figure 21). By 2014 national predicted FGM/C was below 21 percent, and lowest prevalence was in the central region of Kenya including Nairobi. No province by 2014 had predicted FGM/C prevalence over 25 percent, except the North Eastern province.



**Figure 15:** Predicted county prevalence of FGM among girls in Kenya from KDHS survey datasets from 1998 to 2014 derived from spatial-temporal regression model

Further research is needed to explain why and how FGM/C persists in Kisii, given decades of interventions, and how and why the practice has begun to show recent (2014) decline among the Maasai in Narok.



**Figure 16:** Standard county deviations of the predicted posterior mean among girls in Kenya KDHS survey dataset from 1998 to 2014 derived from spatial-temporal regression model

In 1998, the overall national predicted FGM/C among girls was 38 percent and almost all districts had a predicted FGM/C prevalence above 25 percent, among all age groups. Few districts had FGM/C prevalence among girls below the national average of 38 percent (Figure 23). By 2014 the modelled data from household surveys and distribution data suggested a very different pattern of FGM/C prevalence (Figure 23). National predicted prevalence was 21 percent, and most counties had predicted prevalence estimates below 21 percent. Only three counties in the northeast had prevalence over 25 percent: Garissa, Mandera, and Wajir. Conversely, 43 counties still had overall predicted prevalence below 20 percent. The patchwork of prevalence in 2008 (Figure 23) was improved considerably to provide a very different pattern of improved spatial coverage by 2014 (Figure 23). By 2014 national predicted FGM/C was below 21 percent and lowest prevalence was in the central counties including Nairobi. No counties by 2014 had predicted FGM/C prevalence over 25 percent except Garissa, Mandera, and Wajir.

## Age at cutting: Findings of the descriptive survival analysis on FGM/C girls' FGM/C in 2008

KDHS questionnaires have included a number of questions FGM/C of women and their daughters. A detailed list of the questionnaire's various iterations is provided in Shell-Duncan et al (2017). Since the data are timed to event data, statistical techniques were used to bring the data into the survival analysis form using a combination of statistical software (STATA and BayesX). Before fitting any survival models, the data were declared as being of the form of 'survival time'.

In the 2008 KDHS, 8,444 women reported 523 cuttings of their girls, with a median and inter-quarter (IQR) survival time of eight years (7 years to 10 years). If the incidence rate of FGM/C (i.e. hazard function) could be assumed to be constant, it would be estimated as 0.11 per year, or in other words, the probability of occurrence of FGM/C (number of new cases of FGM/C) per population at risk (girls) in a year could be estimated at 11 percent per year.

Table 1 shows the median and inter-quarter (IQR) survival time in years of the predictors of FGM/C among girls in Kenya using KDHS 2008. Median survival time appears to be similar in both urban and rural areas, consistent with the result of KM survival curve. Median and inter-quarter (IQR) survival time is higher for Protestants, at 10 years (8 years to 13 years), and Roman Catholics, at eight years (7 years to 10 years), compared with Muslim girls at 10 years (9 years to 14 years). Similarly, median and inter-quarter (IQR) survival time is higher for 15-year old girls from the Kalenjin ethnic group (13 years to 17 years), the Kikuyu ethnic group, at eight years (7 years to 10 years), and Muslim girls at 15 years (13 years to 16 years), compared with girls from other ethnic groups that cut (Taita/Taveta). Median survival time is higher in Central and Rift Valley provinces.

**Table 1:** Median and inter-quarter (IQR) survival time (years) of predictors of FGM/C among girls in Kenya using KDHS 2008 dataset

Predictors	Level	Median	IQR
Residence	Rural	7 years	(6, 9)
	Urban	8	(7, 10)
Education (Higher Education	No education	7	(6, 9)
	Primary	10	(8, 13)
	Secondary	8	(7, 10)
	Higher Education	9	(7, 9)
Religion	Muslim	7	(6, 8)
	Protestant	10	(8, 13)
	Other	7	(6, 10)
	Roman Catholic	10	(9, 14)
Ethnicity	Kalenjin	15	(13, 17)
	Kamba	8	(5, 10)
	Kikuyu	15	(13, 16)
	Kisii	9	(8, 10)
	Luhya	0	(0, 0)
	Luo	0	(0, 0)
	Maasai	13	(12, 15)
	Meru/Embu	13	(12, 15)
	Mijikenda/Swahili	7	(1, 12)
	Somali	7	(6, 7)
	Taita/Taveta	1	(1, 3)
Wealth index	Poorest	7	(6, 9)
	Poor	9	(7, 12)
	Middle	10	(7, 12)
	Richer	8	(6, 10)
	Richest	7	(6, 9)

Predictors	Level	Median	IQR
Province	Nairobi	7	(6, 8)
	Central	15	(14, 16)
	Coast	5	(1, 7)
	Eastern	9	(7, 12)
	Nyanza	9	(8, 10)
	Rift Valley	15	(12, 16)
	Northeastern	7	(6, 7)
Type of flesh removed	Flesh removed	9	(7, 12)
	Nicked	7	(6, 9)
	Genital	7	(7, 8)
	Unknown	8	(6, 10)

The Kaplan-Meier estimator of the survivor functions for the key socio-economic factors associated with FGM/C (place of residence, region, religion, ethnicity, mother's education, household wealth, type of cutting) are plotted one at a time for descriptive purposes (in figures 17 through 24 in the appendix).

Multivariate analysis using Cox regression and Bayesian geo-additive models investigated these key socio-economic factors' effects on girls' survival. Descriptive analyses are presented in maps and Kaplan Meier curves for 2008 only because that survey had no age restrictions, while KDHS 2014 focused on daughters 14 and younger. All future KDHS data will be restricted to girls 14 and younger, so the 2014 data will be used as a baseline for future rounds of data. Examining survival curves for girls over age 14 is readily practicable by looking at the 15 to 19-year old age cohort in the women's questionnaire. The disadvantage is, perhaps, that it mixes self-reporting with reports on daughters, but it is more current data, regardless.

The risk of FGM/C appears to be similar in both rural and urban areas until age five, but after age five FGM/C seems to occur earlier in urban areas (log rank test,  $P < 0.001$ ). FGM/C seems to continue in rural areas in older age groups until age 20, whereas in urban areas the practice stops at age 15.

The pattern of cutting seems to differ remarkably in Nairobi from other regions before age five, as Nairobi appears to be cutting much earlier than other regions. In general, however, FGM/C seems to occur more rapidly in the northeast than other provinces (log rank test,  $P < 0.001$ ). What is striking is how late cutting can occur in Rift Valley and Central provinces. Data from other African countries indicates cutting almost never occurring after age 15. Kenya may be an outlier. Further examination of the 2014 data is warranted to investigate whether women in the 15 to 49 age range were cut at age 15 or older; this would mean that for Kenya alone, censoring even in the 15 to 19 age range would be a concern.

FGM/C seems to occur prior to age five for girls with mothers without education, rather than for girls with educated mothers. Mothers with university education, however, have their daughters cut much later (8 years of age) than mothers from lower educational backgrounds (log rank test,  $P < 0.001$ ). A study by Modrek and Liu (2013) on FGM/C in Egypt found that education rates in a woman's birth cohort, independent of her education alone, has a significant effect on daughters' FGM/C risk and that educational investments had a profound negative effect on FGM/C rates a generation later. It would be good to explore this hypothesis with the Kenya data in future research so secular changes and trends in women's education can be identified. This hypothesis could also be explored in relation to the modernisation theory. Education can also radically alter social networks, and this would fit with social norms theory; they are not mutually exclusive predictions.

FGM/C seems to occur at much younger age among Muslim girls than in other religions. Mothers with no religion appear to effect FGM/C for their girls at a much later age (8 years) than among religions (log rank test,  $P < 0.001$ ). Data also suggest that FGM/C patterns do not differ between Protestants and Catholics; therefore, these two groups are combined for the multivariate analysis. FGM/C occurs later among Christians (Catholic, Protestant, others) than other groups (Muslim, traditional religion). What is important about Kenya is that some Christian churches have been advocating for FGM/C abandonment for several decades, and longer periods. It would be interesting to explore trends in prevalence of Christianity over time, as charismatic Christian churches have become hugely powerful in Kenya.

FGM/C seems to occur sooner for Somali girls than other ethnicities (log rank test,  $P < 0.001$ ). FGM/C seems to occur earlier in girls from the poorest household than in other socio-economic backgrounds (log rank test,  $P < 0.001$ ). These results can be contextualised to fit modernisation theory predictions.

'Sewn closed' occurs earliest, followed by other FGM/C forms (flesh removed, nicked) (log rank test,  $P < 0.001$ ). FGM/C also seems to have occurred at much younger age among girls than for their mothers' cohort (log rank test,  $P < 0.001$ ). These results confirm that FGM/C is now occurring at earlier ages.

## **Socio-economic and cultural predictors of cutting**

### **Key findings of the multivariate spatial-temporal binomial regression analysis on girls' FGM/C 1998-2014, adjusted for spatial location**

Typically, national household surveys are designed to be precise at national and regional levels and rarely at lower levels, such as counties or districts. Therefore, simply aggregating survey data to provide county or district estimates of an outcome of interest will lead to values of low precision. District estimates, however, are more important to planners, for accelerating policy interventions, optimising inputs, and improving intervention coverage. Small Area Estimation (SAE) methods address the problem of reliable estimates of a variable at those units under conditions where the information available for the variable, on its own, is insufficient for valid estimates (Rao 2003, BIAS 2007). Hierarchical spatial and temporal SAE techniques with a fully Bayesian geo-additive regression approach (Banerjee et al 2004, Best et al 2005, Fahrmeir and Lang 2001, Kaman and Wand 2003, Wand 2003) have estimated girls' FGM/C prevalence by region and county for 1998, 2003, 2008 and 2014.

Details of model procedures and accuracy metrics are presented in Appendix 1. The data-driven, modelled predictions of the prevalence of girls' FGM/C for the survey years are shown in Figure 4 (for regions) and Figure 5 (for counties). Sensitivity of county predictions is shown in Figures 6 and 7, as provincial and county standard deviations of predicted means, respectively.

Maps of predicted mean prevalence of FGM/C in girls show decreases from 1998 to 2014, with higher rates in North Eastern, Rift Valley, and Nyanza provinces, consistently lowest rates in Nairobi and Western provinces (Figure 19). County estimates reveal consistently high FGM/C in Kisii, Mandera, Wajir, Garissa, Marsabit, Isiolo, and Tana River counties ( $\geq 25\%$ ). The counties showing marked FGM/C decrease ( $< 5\%$ ) include Nyamira, Migori, Narok, Kajiado, Taita Taveta, and Samburu (15% to 20%). Although Nyamira is next to Kisii, a locus of the practice, prevalence in Nyamira has decreased. Looking at the descriptive data, Narok was once a high prevalence area, and that prevalence has decreased in recent years, while Kajiado County, next to Narok, shows an even earlier drop in prevalence. The standard deviations of the mean estimates are shown in Figure 21, showing the reliability of the predicted mean.



Kenya has great ethnic and cultural diversity, as reflected in the differing FGM/C rates across ethnic groups, as well as counties. Somalis who live predominantly in the northeastern counties of Mandera, Wajir, and Garissa practice FGM/C at a rate of over 90 percent. The next highest prevalence is among the Kisii, consistently over 90 percent as well. The Luhya and Luo have the lowest rates, less than five percent.

The results of the covariates from the spatial-temporal Bayesian logistic regression are shown in Table 1 and Table 2, for KDHS 2014 and KDHS 1998-2014, respectively, representing the effects of education investments, income, and ethnicity after removing the common effects of spatial location. These estimates represent the likelihood of FGM/C for girls after no investment in mothers' education. Rural girls are at higher risk of FGM/C than girls in urban areas. Increased education is associated with lower FGM/C risk for girls. Muslim girls have a significantly higher likelihood of FGM/C than girls from other religious communities. Kisii, Somali, Maasai, Taita-Taveta, Samburu, Boran, Gabbra, Kuria, Orma, and Rendille ethnicities have markedly higher risks. Older household heads are associated with higher FGM/C risk. Poor communities are associated with higher FGM/C risk than relatively wealthier communities.

For those familiar with the multilevel modelling framework, this report's spatial analysis, as in multilevel modelling, is able to separate individual characteristics (like woman's education) from community characteristics (location in terms of community FGM/C prevalence, education of mother's age cohort, women's autonomy in an age cohort). The spatial analysis has the advantage of accounting for respondents with geographic proximity.

**Table 2:** Spatial regression model outputs (Odds ratios (OR) and credible intervals (CrI)) of the predictors of FGM/C among girls in Kenya using KDHS 2014 dataset

Predictors	Level	Odds ratio	Credible interval
Residence (rural area as reference)	Urban areas	0.93	(0.89,0.96)
Education (higher Education as reference)	No education	3.53	(2.99,4.16)
	Primary	1.49	(1.32,1.69)
	Secondary	1.10	(1.05,1.17)
Religion (Roman Catholic as reference)	Muslim	4.36	(2.72,7.01)
	Protestant	1.05	(0.76,1.45)
	Other	0.44	(0.36,0.53)
Ethnicity (Embu as reference)	Kalenjin	1.37	(0.11,16.3)
	Kamba	1.34	(0.11,16.4)
	Kikuyu	0.31	(0.21,0.44)
	Kisii	6.97	(5.82,8.35)
	Luhya	0.84	(0.45,1.57)
	Luo	0.40	(0.13,1.23)
	Maasai	4.99	(2.90,8.60)
	Meru	0.71	(0.35,1.44)
	Mijikenda/Swahili	0.21	(0.09,0.50)
	Somalia	6.08	(3.86,9.57)
	Taita/Taveta	2.68	(1.24,5.80)
	Other	4.67	(3.05,7.14)
Wealth index (middle as reference)	Poorest	1.24	(1.07,1.43)
	Poor	1.02	(0.88,1.17)
	Richer	0.93	(0.78,1.12)
	Richest	0.55	(0.34,0.89)
Age of household head	Age (years)	1.02	(1.02,1.03)

After adjusting for all other factors (fully adjusted model) including geographic location, the likelihood of FGM/C among girls remained statistically significantly higher for those of mothers with no education, Muslim mothers, from Kisii and Somali ethnic groups, and poorer households, and in rural communities. Girls of mothers with no education were 3.5 times more likely to be

circumcised than those with mothers with education (95% CI=2.00–4.16); girls from Muslim mothers were 4.36 times more likely to have undergone FGM/C (95% CI=2.72–7.01) than those from other religions; while 6.97 times more likely to be from the Kisii ethnic group (95% CI=5.82, 8.35). Girls from poorer households were 24 percent more likely to undergo FGM/C (95% CI=1.07, 1.43) than wealthier counterparts. These results speak strongly to a modernisation perspective, not just in the traditional formulation, but in reduced barriers for women, both of which have occurred in Kenya: Policy reform for girls' education, the relentless work of many Christian churches to end FGM/C, and economic development—a powerful story in Kenya these data support strongly.

**Table 3:** Spatial regression model outputs (odds ratios (OR) and credible intervals (CrI)) of predictors of FGM/C in Kenya for all datasets combined, 1998-2014

Predictors	Level	Odds ratio	Credible interval
Residence (rural as reference)	Urban areas	0.85	(0.82,0.88)
Education (higher education as reference)	No education	5.93	(5.21,6.75)
	Primary	2.33	(1.76,3.08)
	Secondary	1.22	(1.01,1.47)
Religion (Roman Catholic as reference)	Muslim	3.00	(2.18,4.12)
	Other	0.69	(0.44,1.08)
	Protestant	1.13	(0.95,1.34)
Ethnicity (Embu as reference)	Kalenjin	2.46	(1.03,5.84)
	Kamba	1.45	(1.32,1.59)
	Kikuyu	0.28	(0.21,0.37)
	Kisii	3.08	(2.37,4.00)
	Luhya	0.15	(0.11,0.20)
	Luo	0.31	(0.23,0.42)
	Maasai	1.25	(1.19,1.31)
	Meru	0.57	(0.43,0.76)
	Mijikenda/Swahili	0.26	(0.23,0.29)
	Somalia	4.62	(3.48,6.13)
	Taita/Taveta	1.32	(0.97,1.78)
	Other	3.20	(2.42,4.24)
Wealth index (middle as reference)	Poor	1.16	(0.95,1.41)
	Poorest	1.42	(1.18,1.72)
	Richer	0.90	(0.73,1.12)
	Richest	0.72	(0.54,0.95)
Age of household head	Age (years)	1.04	(1.03,1.04)

The results of the combined 1998-2014 KDHS fully adjusted model including geographic location did not alter the likelihood of FGM/C among girls. Despite this, with the combined data, a larger sample size and more precision of the estimated likelihood of FGM/C among girls remained statistically higher for girls with mothers with no education, girls of Muslim mothers, girls from the Kisii and Somali ethnic groups, and girls from poorer households in rural communities.

**Table 4:** Spatial-temporal regression model outputs (Odds ratios (OR) and credible intervals (CrI)) of predictors of FGM/C in Kenya for all KDHS survey years 1998-2014; county spatial effects controlled in analysis

Predictors	Level	Odds ratio	Credible interval
Residence (rural as reference)	Urban areas	0.92	(0.87,0.97)
Education (higher education as reference)	No education	9.50	(8.31,10.87)
	Primary	2.82	(2.35,3.37)
	Secondary	1.56	(1.35,1.81)
Religion (Roman Catholic as reference)	Muslim	2.98	(2.16,4.11)
	Protestant	0.92	(0.77,1.09)
	Other	0.69	(0.65,0.72)
Ethnicity (Embu as reference)	Kalenjin	0.47	(0.38,0.58)
	Kamba	1.25	(1.01,1.55)
	Kikuyu	0.31	(0.13,0.70)
	Kisii	3.60	(2.71,4.78)
	Luhya	0.06	(0.05,0.08)
	Luo	0.05	(0.04,0.07)
	Maasai	2.15	(1.62,2.87)
	Meru	0.46	(0.18,1.16)
	Mijikenda /Swahili	0.26	(0.09,0.76)
	Somalia	4.25	(3.53,5.12)
	Taita/Taveta	1.45	(1.30,1.62)
	Other	2.32	(0.98,5.45)
Wealth index (middle as reference)	Poorest	1.13	(1.01,1.28)
	Poor	1.26	(1.04,1.52)
	Richer	0.89	(0.82,0.96)
	Richest	0.66	(0.61,0.72)
Age of household head	Age (years)	1.04	(1.04,1.05)

After adding the time dimension in the prediction model (spatial-temporal model), the results of combined 1998-2014 KDHS fully adjusted model including the geographic location and 16-year span, a better picture develops of the magnitude of the effects of FGM/C factors for girls. Again, with the combined data, larger sample size and much more precision for the estimation, the likelihood of FGM/C among girls remains higher in girls with mothers of no education, girls of Muslim mothers, girls from the Kisii and Somali communities, and girls from poorer households in rural communities, confirming the validity and robustness of these estimation methods. This model predicted FGM/C during the 16-year span with much precision, and in areas with no 1998 data, as shown in Figure 23. Ethnic Somali are different from any other ethnic group in Kenya because they identify with the greater Somali communities in Somalia and Ethiopia.

The investigation into FGM/C prevalence among girls using advanced statistical techniques of Bayesian spatial analysis has several advantages to conventional methods. We investigated whether the inconsistencies between surveys have affected the observed trends of FGM/C during the 16-year period. From the results of the predicted county FGM/C prevalence, we noted that the inconsistencies between surveys have indeed affected the observed trends of FGM/C during the 16-year period. Such data have largely been descriptive and excessively interpretative.

## Conclusions

The claims about decreases in FGM/C during this period in Kenya have proven hard to substantiate in the absence of robust analytical evidence. This report has argued that such a claim is best tested if a more accurate analytical approach to national FGM/C prevalence is used. A sub-national analysis can inform decision-making processes for specificity and needed FGM/C interventions.

This report conveys current state of knowledge on the prevalence of the practice, based on a spatial analysis of KDHS household data. Such data lend no support, however, for general decline in the prevalence of the practice. Instead, spatial analysis shows a significant degree of geographic variations for both prevalence decrease and increase in some counties in Kenya. The prevalence of FGM/C in the northeastern region remains at the same levels observed in 1998. This report assembles geo-coded repositories of county and provincial or regional prevalence of girls' FGM/C, using the data in novel model-based geo-statistical frameworks to predict FGM/C intensity in 1998 and 2014 for each of the 47 counties and eight regions (provinces), for sub-national planning.

Predictions for 1998 and 2014 show that FGM/C practice is largely around the national average ( $\leq 25\%$ ) across the country, with some important variances. FGM/C appears not to have changed significantly despite a decade's investment in abandonment programmes (Figures 19 and 21) and remains similar to patterns of FGM/C risk observed in 1998 (Figure 7).

There is a steady decline in observed FGM/C prevalence in successive years, however, with great variations within each survey year in regional and ethnic prevalence estimates. No notable declines are observed in the northeastern region. Age at cutting varies for regions and ethnic groups, with cutting much younger among Muslims and mothers without higher education. More significant is the difference in age at cutting for women and daughters with the latter much earlier (before age 10 for the majority). The lack of any substantial reduction in FGM/C over the two decades spanning 1998 to 2014 is supported by an examination of precision maps of the standard deviations of the predicted posterior (figures 22 and 24).

## Limitations of the Study

This study has at least three limitations. First, it does not investigate direct associations between FGM/C prevalence and geography (county) or contextual socio-economic factors—for example, asset index and educational attainment. Any such links appear to be incidental. This lack of direct causation between location and socio-economic status is a major limitation in the KDHS surveys.

The second limitation relates to the survey data. KDHS relies on self-reported evidence for FGM/C status derived from each household. The datasets were derived from participants' responses, without any independent assessment of individual girls by health professionals. There is, therefore, a small chance such self-reported data may involve an element of bias and risk of misclassification.

The third limitation relates to the measurement of socio-economic variables such as household wealth. Wealthiest (fifth quintile) households have, per household, fewer children than less well-off households, which generates a relatively small sample of young children from these wealthiest families. Additionally, more detailed measures of household poverty are not available.

Notwithstanding these limitations, this report's findings give some support to those who advocate sub-national (county) decentralised policies for Kenyan children, and these findings can enable policymakers to focus interventions on worst-affected areas and age groups. This study should stimulate the need for further investigation to develop greater longitudinal datasets on girls' FGM/C.

In addition, identifying and understanding environmental factors that can reasonably be associated with county differences in FGM/C prevalence would represent a significant investigation of the correlation between environment and FGM/C practices in Kenya.

## Recommendations

This report's primary recommendations call for research to inform and facilitate national planning and targeted interventions as follows:

1. **Investigate the reason for little change in the decline of FGM/C prevalence in Mandera, Garissa, Wajir, Kisii, and Narok counties:** To implement this recommendation, future research will involve the correct examination of data on: FGM/C practice, changing attitudes towards FGM/C, FGM/C cultural norms, and FGM/C laws and legal obedience, FGM/C interventions, alongside household economic data. The present exploratory report should form the substrate for any such enquiry by academics and partners. That additional piece of research should then focus on norms and practices among the Kisii, Maasai, and Somalis.

Additionally, appropriate qualitative methods should be developed to collect primary data to understand the multiplicity of reasons that may co-exist in individual perceptions for why the practice sustains in families and communities, and to explore how these reasons may overlap, contradict, or change over time.

2. **Establish detailed investigations to longitudinally study girls' FGM/C incidence, intentions, attitudes, health, and psychological consequences at fixed sentinel sites across Kenya:** This should involve monitoring practice of FGM/C over time in loci identified, such as Kisii, Narok, Garissa, Mandera, and Wajir using sentinel sites.

3. **Study daughters' cutting according to whether mothers are cut, to understand inter-generational change:** When strong campaigns against FGM/C exist, a concern always exists that underreporting will increase. A future study could compare FGM/C prevalence for the same birth cohort of women in the four KDHS surveys: One example would be to compare women ages 30 to 34 in 1998 with women ages 40 to 44 in 2008, and to determine the extent to which the estimates would prove similar if reporting propensity remains constant.

4. **Study in-depth the seasonality of FGM/C and socio-economic impacts as a control option in Kenya**

More detailed investigation on seasonality and the social and economic backgrounds against which FGM/C occurs involves both novel and less conventional methodologies including various data sources, to broaden the view of the environment at both child and community levels. Given the limitations of spatial analysis when the database is a household survey, an important message emerging from this research is that a detailed spatial analysis to support census data and other official data sources would be worthwhile. Armed with such data sources, future research could then uncover more detailed and precise spatial structures, which are deemed relevant for analytical and policy purposes.

## Appendix 1

### Kaplan-Meier (KM) curves of age at cutting on FGM/C in girls in KDHS 2008

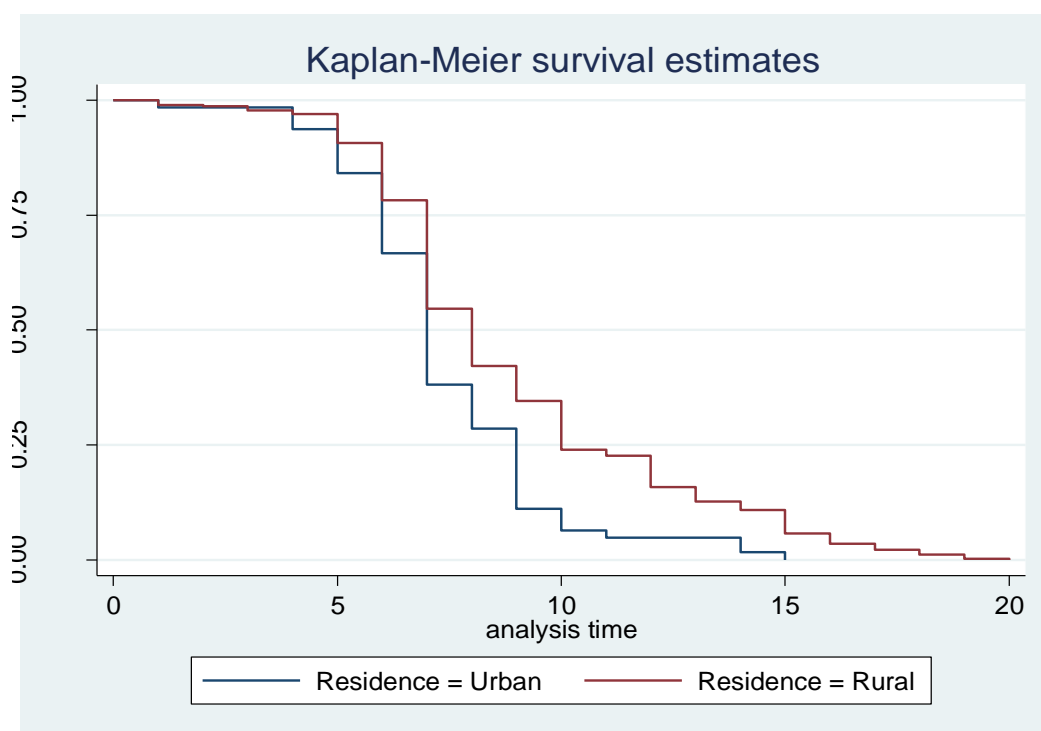


Figure 17: Kaplan-Meier survival curves of time to cutting by place of residence in 2008.

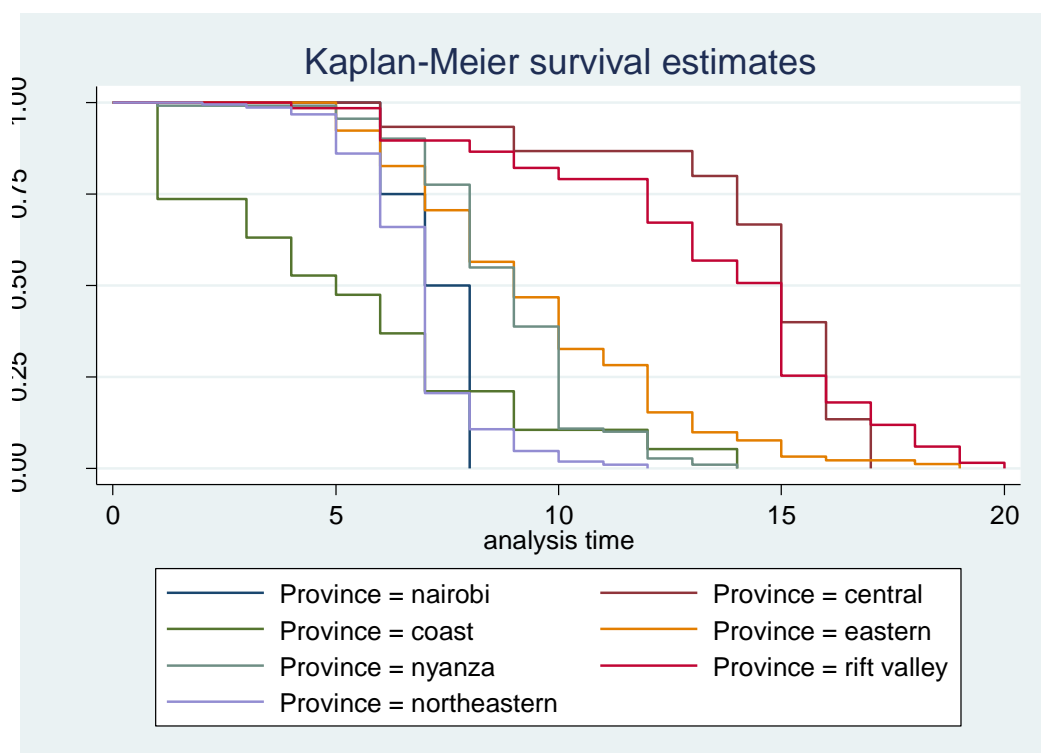


Figure 18: Kaplan-Meier survival curves of time to cutting by region of residence in 2008

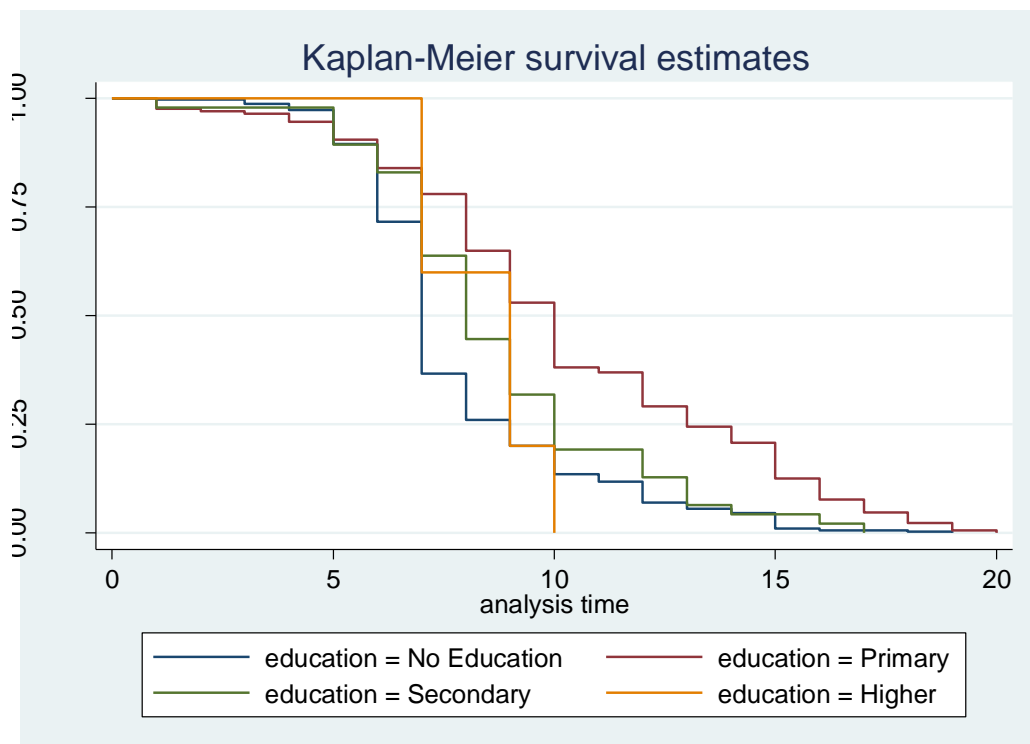


Figure 19: Kaplan-Meier survival curves of time to cutting by mother's education in 2008

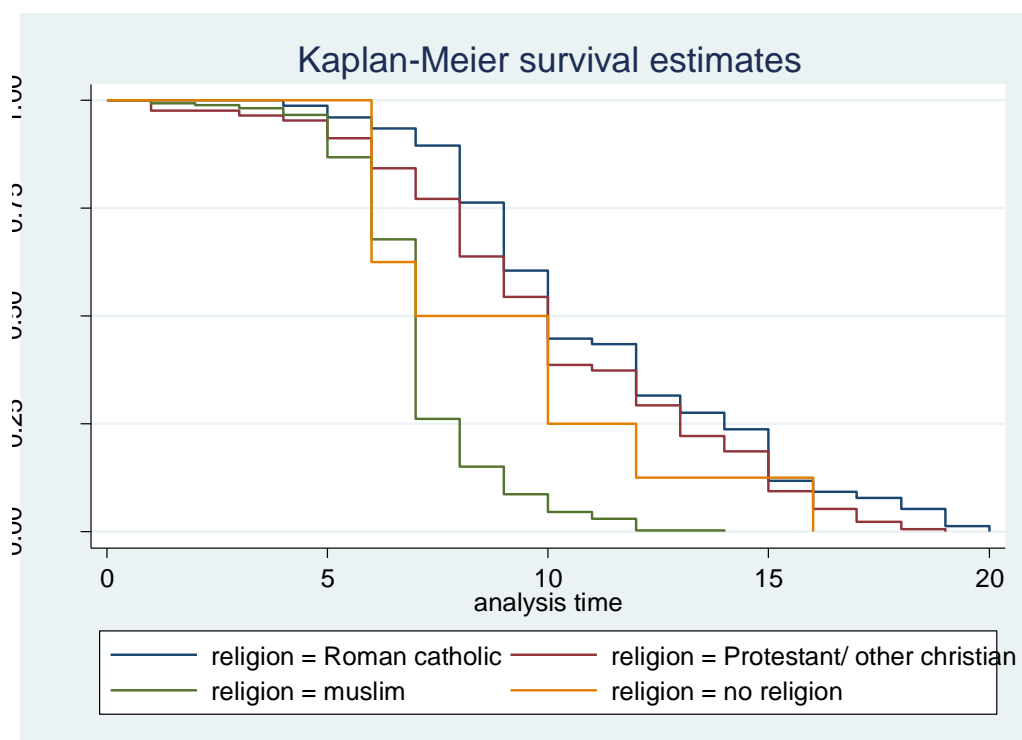


Figure 20: Kaplan-Meier survival curves of time to cutting by religion in 2008



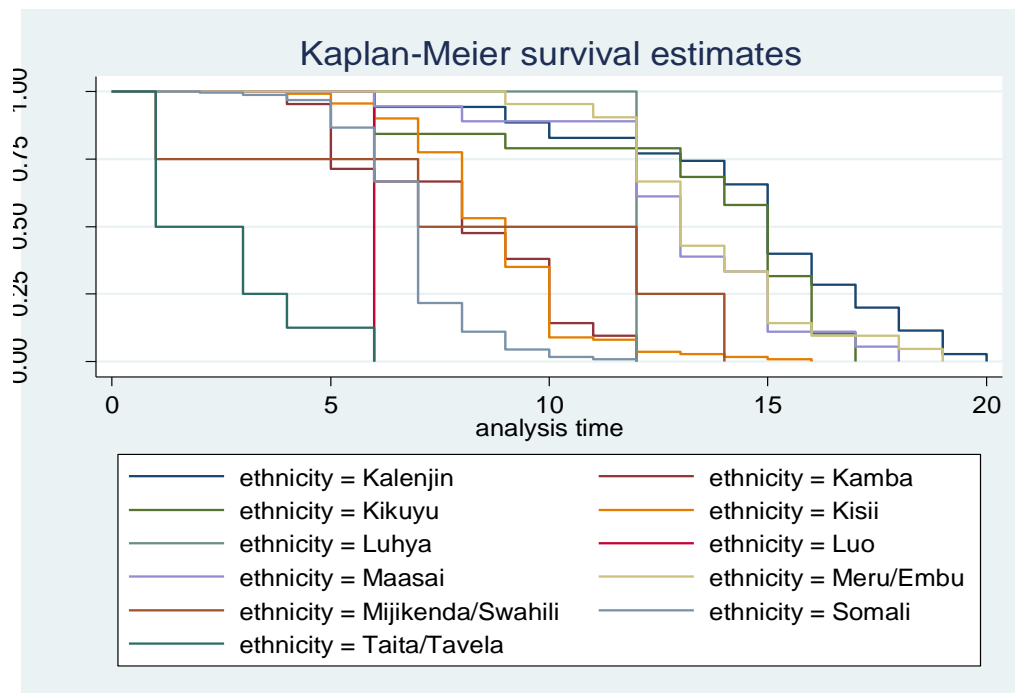


Figure 21: Kaplan-Meier survival curves of time to cutting by ethnicity in 2008

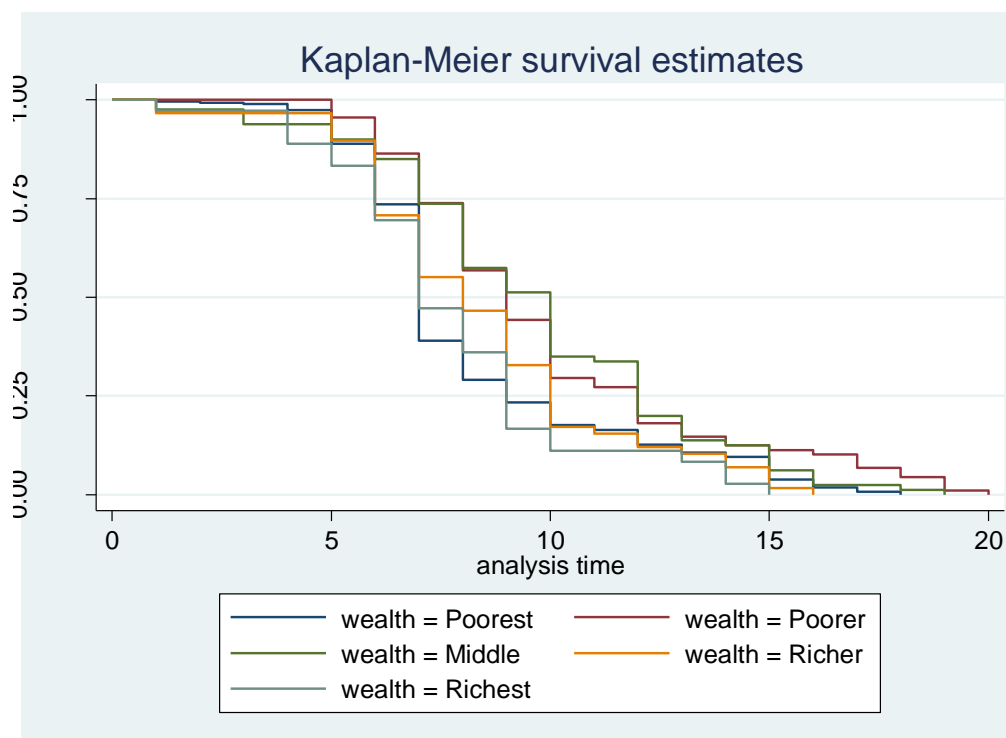


Figure 22: Kaplan-Meier survival curves of time to cutting by household wealth in 2008

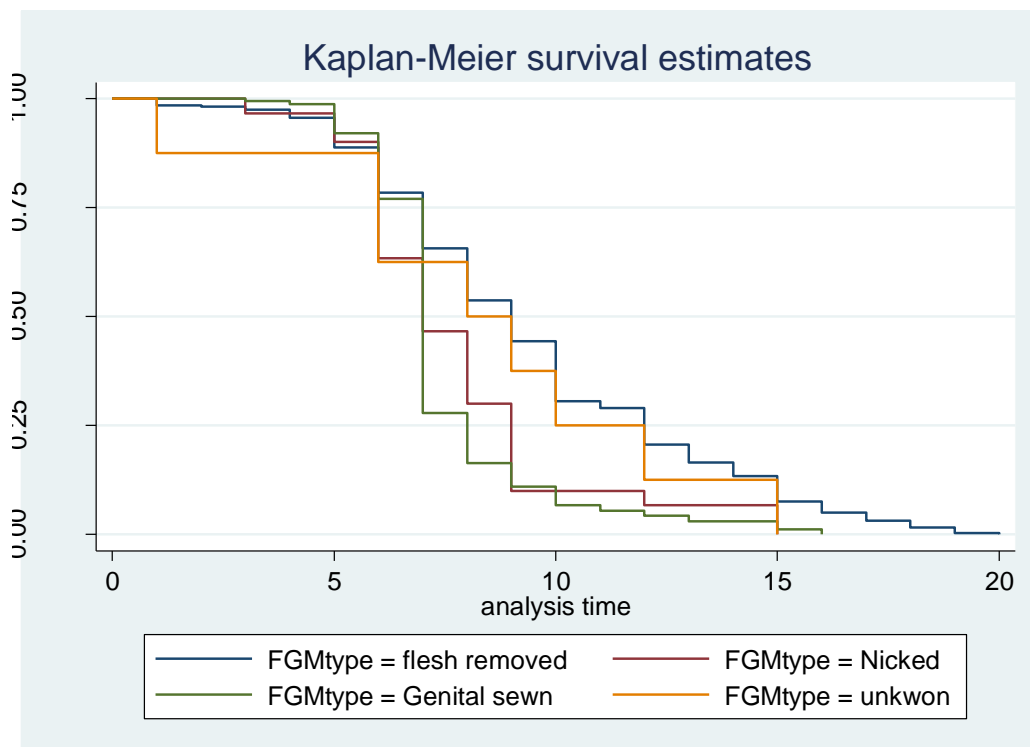


Figure 23: Kaplan-Meier survival curves of time to cutting by type of FGM/C in 2008

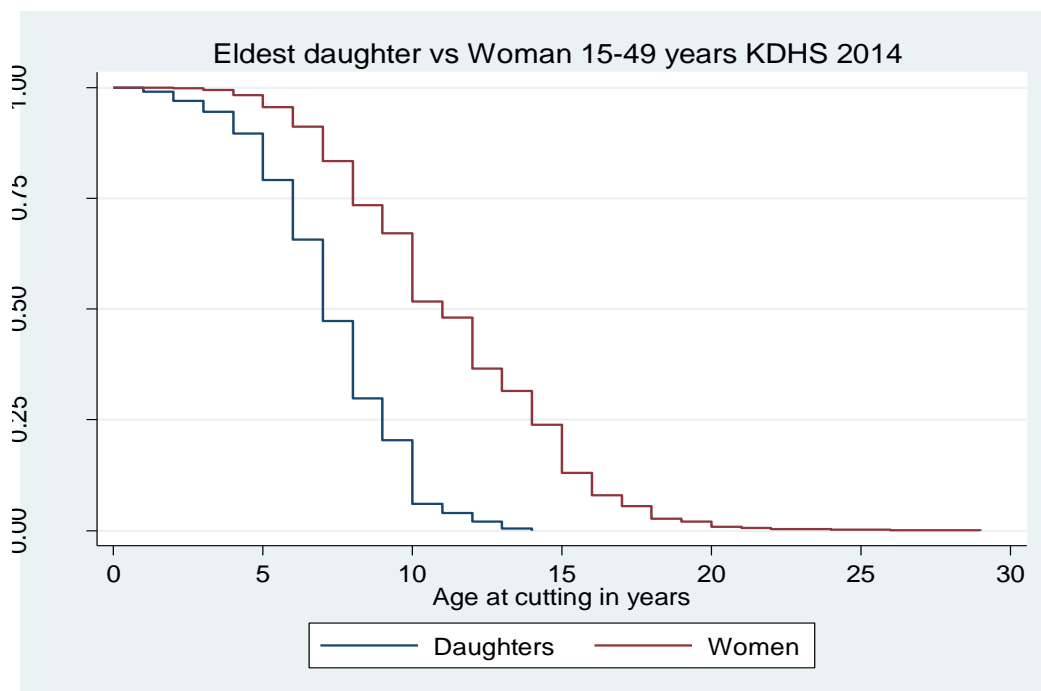


Figure 24: Kaplan-Meier survival curves of time to cutting of daughter compared to women in 2014

## Appendix 2

### Statistical Analysis

The 1998 to 2014 of the Kenya DHS include geographical information that allows us to examine spatial effects along with individual sociodemographic factors that may influence the risk of FGM/C among daughters. These factors are explored within a simultaneous, coherent regression framework, using a geo-additive, semi-parametric mixed model that simultaneously controls spatial dependence and possibly nonlinear or time effects of covariates and the complex sampling design (Kandala et al 2009).

Historically, variations in prevalence of FGM/C have been related to household socio-economic factors (such as education, age, income). By contrast, geographical associations with prevalence have been neglected. In this report, we begin with a simple analysis of geographical variation of FGM/C in Kenya followed by a more detailed approach to the data.

First, a conventional logistic regression analysis will be carried out to document regions' differences in the variations of the observed FGM/C rates using dummies variables for the regions. A map of observed FGM/C prevalence will be produced from the raw data. We also tested the bivariate and multivariate associations of well-known socioeconomic correlates of FGM/C. From this initial analysis, we identified the association between socio-economic and demographic factors and FGM/C while showing the regions' differences in the prevalence of FGM/C and the variation across them in the correlates.

Second, we then used flexible methods to model spatial determinants of FGM/C and to allocate these spatial effects to structured and unstructured (random) components. This modelling draws on Bayesian geo-additive methods of spatial statistics, taking advantage of advances in Geographic Information Systems (Fahrmeir and Lang 2001). The modelling of the two components is done jointly in one estimation procedure that thereby simultaneously identifies socioeconomic determinants, and the spatial effects that are not explained by these socioeconomic determinants while accounting for the complex sampling scheme. In this way, we are able to identify regional patterns of FGM/C that are either related to left-out socioeconomic variables that have a clear spatial pattern or point to spatial (possibly cultural or environmental) processes that account for these spatial patterns.

#### **Data structures**

Nested data in survey studies is often the rule rather than the exception. Here the data structure is retrospective birth, health and survival information including self-reported history of the FGM/C practice, typically about more than one child from each sampled woman. Health and survival information of women and their children are nested within family, the clustering of families living within regions. In fact, heterogeneity is often present and frequently the available predictor variables do not explain this heterogeneity sufficiently (Draper 2000, Pfeffermann 1996). With recent computational advances in statistics it is becoming increasingly straightforward to describe such heterogeneity with mixture models that employ unobserved predictors in a Bayesian hierarchical structure.

#### **Sample design**

Kenya was divided in eight administrative regions in 2010, with the regions subdivided into 47 counties. Through stratified clustered sampling and draws, in the 2014 KDHS, survey respondents were from 377

clusters (158 urban and 219 rural) in the 47 counties of the eight regions. In total, 8,000 households were drawn at random for a representative national sample of 12,000 women ages 15 to 49 and 3,400 men ages 15 to 59. Response rates were 93.7 percent for women and 86 percent for eligible men. One cannot assume, however, that the clusters in each region are fully representative of their region, as the surveys only attempted to generate a fully representative national sample. Consequently, the spatial analysis will be affected by some random fluctuations. Some of this random variation can be reduced by relaxing the independence assumption between neighbouring states. Such spatial analysis should preferably be applied to census data, where there is higher clustering at the highly disaggregated sub-national level and the precision of the spatial analysis would be much higher. Unfortunately, most censuses do not collect FGM/C data and often the full dataset is not, in any case, available for such analyses. Hence, analysis of KDHS household survey data is the only feasible way to evaluate FGM/C spatial variation.

We assessed the likely impact of the neglect of hierarchical structure and geographical location in analyses of the KDHS data that ignore correlation structure and dependence in the data. The neglect of the geographical location where the respondent lives leads to underestimation of standard errors of the fixed effects that inflates the apparent significance of the estimates (Kandala et al 2009, Bolstad and Manda 2001). Our analysis includes this correlation structure and accounts for the dependence of neighbouring communities (regions) in the model. The model also permits 'borrowing strength' from neighbouring areas to obtain estimates for areas that may, on their own, have inadequate sample sizes. This gives more reliable estimates of the fixed effect standard error.

It is worth mentioning some advantages of our approach over existing ones using, say, logistic models with constant-fixed effects of covariates and fixed (or random) district effects or standard two level multilevel modelling with unstructured spatial effects. With such models, it is assumed that the random components at the contextual level (counties) are mutually independent, even though, in practice, this assumption is not actually implied by these approaches, so correlated random residuals could also be specified (Langford et al 1999). Borgoni and Billari (2003) pointed out that the independence assumption has an inherent problem of inconsistency: If the location of the event matters, it makes sense to assume that areas close to each other are more similar than areas that are far apart. Also, KDHS data are based on a random sample of regions. That is, the structured component introduced here allows us to 'borrow strength' from neighbours to cope with the sample variation of the regional effect and obtain estimates for areas with inadequate sample sizes or be un-sampled. We will try several models to highlight the differences that can be found by adopting this approach in a spatial context and possible bias involved with the violation of the independent assumption between aggregated spatial areas. Some of these models have a spatial and random component that reflect spatial heterogeneity globally and relative homogeneity among neighbouring regions, while some will not. A failure to account the posterior uncertainty in the spatial location (district or state) would overestimate the precision of the prediction of FGM/C risks in un-sampled districts. We also performed a sensitivity analysis of the various prior assumptions of the spatial effects.

## **Bayesian Geo-Additive Regression Models**

Spatial analyses of FGM/C often are confined to using region-specific dummy variables to capture the spatial dimension. Here, we go a step further by exploring regional patterns of FGM/C and, possibly nonlinear, effects of other factors within a simultaneous, coherent regression framework using a geo-

additive semi-parametric mixed model. Because the predictor contains usual linear terms, nonlinear effects of metrical covariates and geographic effects in additive form, such models are also called geo-additive models. Kammann and Wand (2003) proposed this type of model within an empirical Bayesian approach. Here, we apply a fully Bayesian approach as suggested in Fahrmeir and Lang (2001), which is based on Markov priors and uses MCMC techniques for inference and model checking.

Classical linear regression models of the form

$$y_i = w_i' \gamma + \varepsilon_i, \quad \varepsilon_i \sim N(0, \sigma^2), \quad (1)$$

for observations  $(y_i, w_i)$ ,  $i = 1, \dots, n$ , on a response variable  $y$  and a vector  $w$  of covariates assume that the mean  $E(y_i | w_i)$  can be modeled through a *linear predictor*  $w_i' \gamma$ . In our application to FGM and in many other regression situations, we are facing the following problems: First, for the *continuous covariates* in the data set, the assumption of a strictly linear effect on the response  $y$  may not be appropriate. In our study, such covariate is the respondent's age. Generally, it will be difficult to model the possibly nonlinear effect of such covariates through a parametric functional form, which has to be *linear* in the parameters, prior to any data analysis.

Second, in addition to usual covariates, geographical small-area information was given in the form of a location variable  $s$ , indicating the region, department or community where individuals or units in the sample size live or come from. In our study, this geographical information is given by the regions in Kenya. Attempts to include such small-area information using region/department-specific dummy-variables would in our case entail more than 30 dummy-variables for the departments and nine dummies for the regions and using this approach we would not assess spatial inter-dependence. The latter problem cannot also be resolved through conventional multilevel modeling using uncorrelated random effects (Kandala et al 2009). It is reasonable to assume that areas close to each other are more similar than areas far apart, so that spatially correlated random effects are required.

To overcome these difficulties, we replace the strictly linear predictor,  $\eta_i = x' \beta + w_i' \gamma + \varepsilon_i$

with a logit link function with dynamic and spatial effects,  $\Pr(y=1|\eta) = e^\eta / (1 + e^\eta)$ , and a geo-additive semi-parametric predictor  $\mu_i = h(\eta_i)$ :

$$\eta_i = f_1(x_{i1}) + \dots + f_p(x_{ip}) + f_{spat}(s_i) + w_i' \gamma + \varepsilon_i \quad (2)$$

Where  $h$  is a known response function with a logit link function,  $f_1, \dots, f_p$  are non-linear smoothed effects of the metrical covariates (respondent age), and  $f_{spat}(s_i)$  is the effect of the spatial covariate  $s_i \in \{1, \dots, S\}$  labelling the region in Kenya. Covariates in  $w_i$  are usual categorical variables such as gender and urban or rural residence. Regression models with predictors as in (2) are sometimes referred to as geo-additive models. The observation model (2) may be extended by including interaction  $f(x)w$  between a continuous covariate  $x$  and a binary component of  $w$ , say, leading to so called varying coefficient models, or by adding a nonlinear interaction  $f_{1,2}(x_1, x_2)$  of two continuous covariates.

In a further step, we may split up the spatial effect  $f_{spat}$  into a spatially correlated (structured) and an uncorrelated (unstructured) effect

$$f_{spat}(s_i) = f_{str}(s_i) + f_{unstr}(s_i)$$

A rationale is that a spatial effect is usually a surrogate of many unobserved influences, some of them may obey a strong spatial structure and others may be present only locally. By estimating a structured and an unstructured effect, we aim at separating between the two kinds of factors.

As a side effect, we are able to assess to some extent the amount of spatial dependency in the data by observing which one of the two effects is larger. If the unstructured effect exceeds the structured effect, the spatial dependency is smaller and vice versa. It should be noted that all functions are centred about zero for identification purpose, thus fixed effects parameters automatically include an intercept term  $\mathbb{1}_0$ .

In a Bayesian approach, unknown functions  $f_j$  and parameters  $\gamma$  as well as the variance parameter  $\sigma^2$  are considered as random variables and have to be supplemented with appropriate prior assumptions. In the absence of any prior knowledge we assume independent diffuse priors  $\gamma_j \propto \text{const}$ ,  $j=1, \dots, r$  for the parameters of fixed effects. Another common choice is highly dispersed Gaussian priors.

Several alternatives are available as smoothness priors for the unknown functions  $f_j(x_j)$ , see Fahrmeir and Lang (2001), Fahrmeir, Kneib and Lang (2004). We use Bayesian P(enalized) – Splines, introduced by Eilers and Marx in a frequentist setting. It is assumed that an unknown smooth function  $f_j(x_j)$  can be approximated by a polynomial spline of low degree. The usual choices are cubic splines, which are twice continuously differentiable piecewise cubic polynomials defined for a grid of  $k$  equally spaced knot  $p$  on the relevant interval  $[a, b]$  of the  $x$ -axis. Such a spline can be written in terms of a linear combination B-spline basis functions  $B_m(x)$ , i.e.

$$f(x) = \sum_{m=1}^l \beta_m B_m(x) \quad (3)$$

These basis functions have finite support on four neighbouring intervals of the grid, and are zero elsewhere. A comparably small number of knots (usually between 10 and 40) is chosen to ensure enough flexibility in combination with a roughness penalty based on second order difference of adjacent B-spline coefficients to guarantee sufficient smoothness of the fitted curves. In our Bayesian approach this corresponds to second order random walks

$$\beta_m = 2\beta_{m-1} - \beta_{m-2} + u_m, \quad (4)$$

with Gaussian errors  $u_m \sim N(0, \tau^2)$ . The variance parameter  $\tau^2$  controls the amount of smoothness, and is also estimated from the data. More details on Bayesian P-Splines can be found in Lang and Brezger (2004). Note that random walks are the special case of B-Splines of degree zero.

We now turn our attention to the spatial effects  $f_{str}$  and  $f_{unstr}$ . For the spatially correlated effect  $f_{str}(s)$ ,  $s = 1, \dots, S$ , we choose Markov random field priors common in spatial statistics (Besag et al 1991). These priors reflect spatial neighbourhood relationships. For geographical data one usually assumes that two sites or regions  $s$  and  $r$  are neighbours if they share a common boundary. Then a spatial extension of random walk models leads to the conditional, spatially autoregressive specification

$$f_{str}(s) | f_{str}(r), r \neq s \sim N\left(\sum_{r \in \partial_s} f_{str}(r) / N_s, \tau^2 / N_s\right) \quad (5)$$

where  $N_s$  is the number of adjacent regions, and  $r \in \mathcal{N}_s$  denotes that region  $r$  is a neighbour of region  $s$ . Thus the (conditional) mean of  $f_{str}(s)$  is an average of function evaluations  $f_{str}(s)$  of neighbouring regions. Again the variance  $\sigma^2_{str}$  controls the degree of smoothness.

For a spatially uncorrelated (unstructured) effect  $f_{unstr}$  a common assumption is that the parameters  $f_{unstr}(s)$  are i.i.d. Gaussian

$$f_{unstr}(s) | \sigma^2_{unstr} \sim N(0, \sigma^2_{unstr}) \quad (6)$$

Variance or smoothness parameters  $\sigma^2_j, j=1, \dots, p, str, unstr$ , are also considered as unknown and estimated simultaneously with corresponding unknown functions  $f_j$ . Therefore, hyper-priors are assigned to them in a second stage of the hierarchy by highly dispersed inverse gamma distributions  $p(\sigma^2_j) \sim IG(a_j, b_j)$  with known hyper-parameters  $a_j$  and  $b_j$ . Standard choices for the hyperparameters are  $a = 1$  and  $b = 0.005$  or  $a = b = 0.001$ . Jeffrey's non-informative prior is closer to the later choice, and since practical experience shows that regression parameters depend on the choice of hyperparameters, we have investigated in our application the sensitivity to this choice.

Since some regions in Kenya may not have many neighbors, we have investigated the sensibility of the choice of Markov Random Field (MRF) prior with other priors such as Gaussian random field (GRF) priors, but the resulting maps from the two priors did not differ much. Therefore, we considered the MRF prior for the spatial effects. For model choice, we routinely used the Deviance Information Criterion (DIC) developed in Spiegelhalter et al (2001) as a measure of fit and model complexity. Before commenting on the substantive results, it is important to point out this model had the best fit after evaluation of the fit criteria using Deviance Information Criteria (DIC).

The model assumes that  $f_1(\cdot)$ ,  $f_2(\cdot)$  and  $f_{str}$  are nonlinear effects and spatial effects were the same in all the country. This was confirmed by prior separate analyses of the non-linear effects in other countries, which were found to be remarkably similar.

Quite clearly, the methods used here are able to identify more subtle socioeconomic and spatial influences on FGM than reliance on linear models with regional dummy variables. As such, they are useful for diagnostic purposes to identify the need to find additional variables that can account for this spatial structure. Moreover, even if the causes of spatial structures are not fully explained, one can use this spatial information for campaigns to eliminate the practice of FGM/C and planning purposes, which is gaining increasing importance in policy circles that attempt to focus the allocation of public resources to the most at high risk population.

Multivariate Bayesian geo-additive regression models were used to evaluate the significance of the POR determined for the fixed effects and spatial effects between prevalence of FGM/C in Kenya. Each factor was looked at separately in unadjusted models using conventional logistic regression models. Next, fully adjusted multivariate Bayesian geo-additive regressions analyses were performed to look again for a statistically significant correlation between these variables, but this time further controlling for any influence from individual (age), ethnicity, education and religious factors. A  $P$ -value of  $<0.05$  was considered indicative of a statistically significant difference.

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