Unravelling Factors Influencing Demand for Modern Contraception and Evaluating Coverage Progress since 2015 in Ethiopia, Kenya, and Nigeria: Insights from Multilevel and Geostatistical Modelling

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Abstract

Introduction

The United Nations established the Sustainable Development Goals (SDGs) in 2015 to enhance global development. In this study, we examine an SDG indicator: the percentage of women aged 15-49 whose family planning needs are met by modern contraception (mDFPS). We evaluate both the factors influencing its coverage and its progress since 2015.

Methods

We used nationally representative survey data (Demographic and Health Surveys (DHS) and Performance Monitoring for Action (PMA)) from Ethiopia, Kenya, and Nigeria. We assessed individual and community-level predictors of mDFPS. We also computed mDFPS coverage across countries and subnational areas, assessing coverage changes from the SDGs onset to the most recent period with data using a Bayesian model-based geostatistical approach. Additionally, we assessed whether the subnational areas exceeded the minimum recommended WHO mDFPS coverage of 75%. Coverage assessment and mapping were done at pixel (5 x 5 km) and sub-national levels.

Results:

Varied individual and community-level determinants emerged, highlighting the countries' uniqueness. The results indicate mDFPS stagnation in most administrative areas across the three countries. Geographic disparities persisted over time, favouring affluent regions. Ethiopia and Nigeria showed minimal mDFPS improvement, while Kenya exhibited increased coverage. Mean posterior change, 95% credible intervals (CI) and exceedance probabilities (EP) were: Ethiopia 5.68% (95% CI: [-38.07, 49.44], EP = 0.61), Kenya 10.19% (95% CI: [-17.72, 39.33], EP = 0.80), and Nigeria 1.98% (95% CI: [-17.72, 39.33], EP = 0.58). None of the sub-national areas in Ethiopia and Nigeria exceeded the WHO-recommended coverage in their latest survey. While 9 out of 47 counties in Kenya in 2022 exceeded the WHO mDFPS coverage recommendation.

Conclusion:

The study unveils demographic, geographic, and socioeconomic mDFPS disparities, signalling progress and stagnation across administrative areas. The findings offer policymakers and governments insights into targeting interventions for enhanced mDFPS coverage. Context-specific strategies can address local needs, aiding SDG attainment.

Keywords: Sustainable Development Goals, mDFPS, women, modern contraception, DHS, spatial, geostatistical

Introduction

The United Nations member states adopted the Agenda 2030 for Sustainable Development Goals (SDGs) in 2015. The agenda has 17 goals building on the Millennium Development Goals (MDGs) to stimulate action toward shared sustainable prosperity. The use of modern contraceptive methods falls under SDG 3.7, which states that "*by 2030, countries should ensure universal access to sexual and reproductive health (SRH) care services for family planning, information, and education, and the integration of reproductive health into the national strategies and programmes*" (United Nations 2019). Several indicators track this goal, one of which is indicator 3.7.1, which measures the percentage of women of reproductive age (15-49 years) who have their demand for family planning satisfied with modern contraceptive methods (mDFPS) (United Nations 2019).

Globally, an estimated 1.1 billion women of reproductive age needed family planning to postpone or avoid getting pregnant in 2020 (United Nations Department of Economic and Social Affairs 2020). However, only 851 million had access to and used modern contraceptives, and an additional 85 million used traditional contraception methods. Modern contraception methods are defined as any product or medical procedure that prevents pregnancy from occurring as a result of sexual intercourse (Hubacher and Trussell 2015). Among those women who were using contraception in 2020, 90% of them were using a modern method (United Nations Department of Economic and Social Affairs, 2020). Modern contraceptive methods are considered more effective at preventing pregnancy than traditional methods, and many health facilities encourage their use (Sully et al., 2020). Sub-Saharan Africa (SSA) has the lowest proportion of modern contraceptive use among all women of childbearing age, with just 22.0 % (95% CI: [21.8, 22.2]) (Boadu 2022). In 2020, among women who wanted to postpone pregnancy, only 55% were using modern contraceptives in SSA. In addition, most countries with lower than 50% mDFPS were from the region (Cahill et al. 2018; United Nations Department of Economic and Social Affairs 2020).

Women who can make informed decisions about their sexual relations, contraceptive use and reproductive health are more likely to use modern contraceptives to meet their family planning needs (Alomair et al., 2020). In turn, meeting the demand for family planning with modern contraception methods empowers women to prevent unintended and high-risk pregnancies, thereby lowering the risk of maternal and under-five mortality (Conde-Agudelo and Belizán, 2000; Sully et al., 2020). Additionally, modern contraception reduces the risk of early childbearing and allows women to achieve their educational goals. Thus, access to and use of modern contraception can improve women's health and educational opportunities, hence improving women's chances of paid labour employment (Bloom et al., 2014; Onarheim, Iversen, and Bloom, 2016).

Since the inception of the SDGs in 2015, it has been imperative that countries track their progress within different demographic, social, economic, and geographical groups to ensure that no one is left behind (Alhassan and Madise, 2021; United Nations, 2019). Countries can identify disparities in access to modern contraceptives and other services by monitoring this progress. They can then use this information to address these disparities and ensure that all women of reproductive age can access the necessary information and services to achieve their desired family planning needs with modern contraception methods (United Nations, 2019).

The current analysis focuses on Ethiopia, Kenya, and Nigeria, with Nigeria and Ethiopia being the most populous nations in Africa and Kenya ranking seventh (World Bank 2023). Kenya ranks among the top countries in SSA regarding the modern contraceptive use prevalence rate (mCPR) among married women, at 56.9%. Ethiopia, on the other hand, has a moderate mCPR rate of 40.5%, whereas Nigeria has one of the lowest prevalence rates among married women in SSA, at 12% (Boadu, 2022; Ethiopia Central Statistical Agency (CSA), 2020; KNBS and

ICF, 2023; National Population Commission (NPC) [Nigeria] and ICF, 2019). In terms of the proportion of mDFPS among married women, coverage was 64.9% in Ethiopia, 74.7% in Kenya, and 33.9% in Nigeria (Ethiopia Central Statistical Agency (CSA) 2020; KNBS and ICF 2023; National Population Commission (NPC) [Nigeria] and ICF 2019; United Nations Department of Economic and Social Affairs 2020).

In addition, there is an unequal distribution of modern contraceptive use among various categories within these countries. Adolescents (ages 15 to 19), economically disadvantaged women, women with limited education (below secondary school level), and rural residents have lower utilisation rates (Ahinkorah et al. 2021; Blumenberg et al. 2020; Bolarinwa et al. 2021). Although the predictors of modern contraceptive utilisation have been investigated, there needs to be more literature regarding the predictors of mDFPS (Alhassan and Madise 2021). Hypothesising that similar factors influence the adoption of modern contraception and mDFPS, this study seeks to investigate these factors and evaluate and compare the progress in mDFPS coverage since 2015 in the three countries.

Methods

Data sources

The study used data from Demographic and Health Surveys (DHS) and Performance Monitoring for Action (PMA) from three countries, namely Ethiopia, Nigeria and Kenya (Ethiopia Central Statistical Agency (CSA) 2020; KNBS and ICF 2015, 2023; National Population Commission (NPC) [Nigeria] and ICF 2014; Zimmerman et al. 2017). The DHS is a nationally representative, cross-sectional survey that provides data on various health indicators, including family planning. PMA surveys cover a subset of the variables included in the DHS and are done in selected administrative areas in each country. DHS data, collected closer to the inception of the SDGs in 2015, was utilised. For more recent data where DHS was unavailable, the PMA survey data was utilised. Data from Ethiopia was obtained from the 2016 DHS survey and the 2019 PMA survey, excluding the 2019 mini-DHS survey due to the absence of necessary questions for calculating mDFPS (Ethiopia Central Statistical Agency (CSA) 2017; Zimmerman et al. 2017). Kenya data was analysed using the DHS for 2014 and 2022 (KNBS and ICF 2015, 2023). Nigeria's data analysis relied on the 2013 and 2018 DHS surveys (National Population Commission (NPC) [Nigeria] and ICF 2014, 2019).

The outcome of interest was defined as a binary variable (Yes/No): where women 15-49 years old who needed family planning and were using modern contraception methods to satisfy that need were considered to have demand for family planning satisfied with modern contraception methods (Yes); the need for family planning was defined as fecund women who either needed to space or limit childbearing (Alhassan and Madise 2021; Ewerling et al. 2018). By choosing to use mDFPS instead of just modern contraception prevalence, we were able to restrict the analysis to individuals with a demand for contraception, making it easier to track the progress of SDG indicator 3.7.1 (Alhassan and Madise 2021; Ewerling et al. 2018). Modern contraceptive methods include pills, condoms (male and female), injectables, hormonal implants, patches, diaphragms, spermicidal agents (foam/gel) and emergency contraception.

Statistical analysis

We adjusted exploratory statistics, percentages for complex survey design (Lumley 2004).

Multilevel modelling

Using the latest DHS survey datasets for each country, we used a multilevel Bayesian logistic model to fit the data to explore factors associated with the outcome of interest. Multilevel models were used because of the hierarchical nature of the data's sampling framework (Equation 1) (Stephenson et al. 2007). All Women from sampled households in enumeration areas (clusters) are selected for inclusion. The enumeration areas are, in turn, located in administrative areas (counties, regions or states). The independent variables included in the

adjusted models were selected based on the literature, to allow within and between country comparison (Ewerling et al. 2018; Stephenson et al. 2007). The following variables were included in the multilevel model: place of residence (rural versus urban), age category, respondent's level of education, household head gender, wealth quintile, marital status and religion.

Equation 1:

$$logit(P(x_{kji})) = \beta_0 + \beta_1 \boldsymbol{X}_{k:(j:i)} \ldots + region_i + cluster_{j:i}$$
$$\mathrm{i} = 1, \ldots, n_c; \mathrm{j} = 1 \ldots, n_h; \mathrm{k} = 1, .., n_w$$

Where the indices are defined for region i, cluster j and individual k. Index ji denotes that cluster j is nested within a region i. Similarly, index $k:(j:i)$ denotes that individual k is nested within a cluster (whereupon the cluster is also nested within a region i). The vector $\boldsymbol{X}$ denotes the covariates, and βs are the coefficients for the covariates.

Geostatistical modelling

A model-based Bayesian geostatistical logistic model to derive and assess the geographical variation in coverage for mDFPS (Equation 2) (Lindgren and Rue 2015) was also used in the study. The variables used to adjust for confounding in these models were informed by the variables identified in the multilevel modelling stage and the literature. We included the variables in the analysis based on the availability of the spatial raster data of those variables for the countries of interest. The raster data included in the geostatistical models were women's education years, population density, probability of seeking care at health facilities, poverty rate and mean parity (WorldPop 2023).

Equation 2:

$$logit(P(x_i)) = \beta_0 + \beta_1 \boldsymbol{X}_i + \cdots + S(x_i)$$

Where the vector $\boldsymbol{X}$ denotes covariates and βs are coefficients for the covariates conditional on the true prevalence $\boldsymbol{P}(\boldsymbol{x_i})$ at location $\boldsymbol{S}(\boldsymbol{x_i})$, $\boldsymbol{i}$ = 1, …, n, where the number of positive results is $\boldsymbol{x_i}$ out of $\boldsymbol{N_i}$ with a binomial distribution**.** $\boldsymbol{S}(.)$ is a spatial random effect that follows a zero-mean Gaussian process with the Matérn covariance function.

The geostatistical models were fit to two time points, at the start and end, to allow comparison in the coverage of mDFPS between the two-time points to assess progress. Posterior samples were drawn based on the models to calculate sub-national-level mDFPS estimates and 95% credible intervals (CI) for each sub-national area. In addition, the predicted posterior samples were used to estimate the mean posterior change (MPC) of the outcome of interest between the years on which the geostatistical models were based to assess the change (progress) in coverage of mDFPS. Given the available data, we quantified how likely it was for the coverage of mDFPS to be above the recommended WHO minimum coverage of 75% (United Nations 2019) for each sub-national area (region, state or county), set as threshold $\boldsymbol{t}$. This was achieved by quantification of the exceedance probability (EP) presented in Equation 3. An EP close to 1 indicates that the prevalence of the outcome was above $\boldsymbol{t}$, EP close to 0 indicates that the prevalence was likely below $\boldsymbol{t}$. An EP value of around 0.5 indicated that the prevalence was equally likely to be below or above $\boldsymbol{t}$, hence the high uncertainty (Lindgren and Rue 2015). Equation 3 was also used to calculate EPs for MPC between the two time periods to assist in assessing if there was an improvement in coverage between the two times. In this case, the threshold $\boldsymbol{t}$ in Equation 3 was set to zero (Blangiardo, Cameletti, and Baio 2013).

Equation 3:

$$EP = Probability(P(\boldsymbol{x_i} > \boldsymbol{t} \mid data))$$

For each country, we generated coverage of the outcome, and EP maps at 5 by 5 km pixel-, sub-national-, and national levels to influence decision-making at various administrative levels. These maps show areas where coverage is the lowest or highest. These maps and tables would enable program implementers to appreciate where progress is lagging and to prioritise health interventions in areas that need them most while maintaining support where coverage is already good (Khundi et al. 2021). R programming software version 4.2.1 was utilised for data management, and the Bayesian models were fitted using the INLA R package (Lindgren and Rue 2015).

Results

The Ethiopia DHS 2016 survey had 5,312 women aged 15 – 49 who expressed a desire for family planning. The sample was drawn from 606 clusters. Similarly, the Ethiopian PMA 2019 survey included 3,396 women, sampled from 265 clusters. The 2014 Kenya DHS had 7,840 women with a demand for family planning, selected from 1,549 clusters. The 2022 Kenyan DHS survey comprised 8,911 women with a demand for family planning, drawn from 1,662 clusters. The 2013 Nigerian DHS encompassed 11,464 women with data on the demand for family planning, sampled from 887 clusters, while the 2018 survey included 12,243 women with a demand for family planning, drawn from 1,376 clusters.

Respondent characteristics and mDFPS coverage

According to the latest DHS surveys Ethiopia 2016, Kenya 2022 and Nigeria 2018, the majority of respondents were rural residents in Ethiopia (80.99%) and Kenya (59.75%) while in Nigeria rural residents were slightly less (46.27%). About 20% of respondents were aged 15-24, Ethiopia (23.31%), Kenya (24.12), and Nigeria (20.42%). Refer to Table 1 for more details on the characteristics of the respondents.

The crude mDFPS coverage was 61.35% (in 2016 DHS) and 62.41% (in 2019 PMA) in Ethiopia, 70.81% (in 2014 DHS) and 74.59% (in 2022 DHS) in Kenya, while in Nigeria, it was 38.82% (in 2013) and 35.66% (in 2018). Urban residents had higher coverage of mDFPS coverage in all countries: Ethiopia (78.17%), Kenya (75.66%) and Nigeria (40.46%). Refer to Table 2 for more details on mDFPS coverage. The unadjusted weighted sub-national level estimates of the mDFPS coverage are in supplemental Figures S1 to S3.

Multilevel modelling

The results of the multilevel Bayesian logistic model varied between countries. This analysis was based on the latest DHS from each of the three countries for easier comparison between countries. In Ethiopia and Nigeria, women residing in rural areas had significantly lower odds of mDFPS compared to women residing in urban areas. In Ethiopia, the OR was 0.59 (95% CI: [0.42, 0.82]), implying 41% lower odds of mDFPS among rural women. In Nigeria, the OR was 0.88 (95% CI: [0.78, 0.99]), signifying 12% decreased odds of mDFPS among rural women. But in Kenya, the OR of mDFPS was not significantly different between rural and urban residents; (OR: 0.91, 95% CI: [0.78, 1.06]). Detailed information is presented in Table 3.

In Ethiopia, women with secondary school or higher level of education did not have significantly different odds of mDFPS when compared to women with primary school education and no education (OR: 1.09, 95% CI: [0.85, 1.38]) and (OR: 1.14, 95% CI: [0.92, 1.41]). However, in Kenya, only women with no education had lower odds of mDFPS (OR: 0.40, 95% CI: [0.31, 0.50]) versus women with a secondary school or higher-level education. Similarly, in Nigeria, only women who did not have any education had lower odds of mDFPS (OR: 0.51, 95% CI: [0.44, 0.59]) (Table 3). These findings suggest that the relationship

between education level and mDFPS varies across the three countries, with education being positively associated with higher mDFPS in Kenya and Nigeria but not in Ethiopia.

In terms of marital status, women who had never been in a union had higher odds of mDFPS compared to those who were in a union in Kenya (OR: 1.41, 95% CI: [1.16, 1.72]) and Nigeria (OR: 1.51, 95% CI: [1.21, 1.87]), but not in Ethiopia (odds ratio: 0.80, 95% CI: 0.53, 1.20). Furthermore, women who were no longer in a relationship had higher odds of mDFPS compared to those who were in a union: Ethiopia (OR: 3.18, 95% CI: [2.15, 4.78]), Kenya (OR: 2.00, 95% CI: [1.64, 2.44]), and Nigeria (OR: 2.19, 95% CI: [1.74, 2.77]) (Table 3). These findings highlight the importance of considering household dynamics, wealth, and marital status in understanding and addressing modern contraceptive use in the respective countries.

In comparison with Muslim women, those who identified themselves as Orthodox, Roman Catholic or Protestants had higher odds of mDFPS. Women with a parity of 3-4 did not have significantly different odds of mDFPS to those with a parity of none in Ethiopia and Nigeria, while in Kenya they had lower odds of mDFPS (OR: 0.38, 95% CI: [0.29, 0.49]). Women with a parity of 1-2 had higher odds of use in Ethiopia (OR: 1.49, 95% CI: [1.22, 1.82]), while women with a parity of five or more had lower odds of mDFPS in Ethiopia (OR: 0.64, 95% CI: [0.53, 0.77]) and Kenya (OR: 0.78, 95% CI: [0.67, 0.90]). Furthermore, in all three countries, there were substantial residual variation at both the cluster level and the regional, county, or state level, after accounting for the confounding variables (Table 3). This indicates that levels of mDFPS were likely to vary within the countries, suggesting the influence of additional factors not captured in the analysis.

Geostatistical modelling

The results of the Bayesian geostatistical logistic regression based on the latest survey are presented in Table 4. The implemented models were adjusted to account for spatial confounding by their definition (Equation 2). Notably, in these models, an increase in women's education years was consistently associated with higher odds of mDFPS in all three countries. The highest odds were observed in Nigeria (odds ratio: 8.49, 95% CI: [5.03, 14.35]), followed by Kenya (OR: 2.63, 95% CI: [1.79, 3.65]), and Ethiopia (OR: 2.69, 95% CI: [1.39, 5.11]). The results of the Bayesian geostatistical model for the first survey are in the supplementary Table S3.

The predicted posterior samples of the proportion of mDFPS from the geostatistical models were used to map the adjusted mDFPS of the three countries between the two time periods (Figures 1 - 3). The adjusted predicted posterior proportion of mDFPS for Ethiopia was 39.85% (95% CI: [4.51, 83.01]) in 2016 and 46.28% (95% CI: [7.15, 85.99]) in 2019. In Kenya, the adjusted predicted proportion for 2014 was 30.19% (95% CI: 2.59, 80.24) and 44.16 % (95%CI: [9.35, 80.24]) in 2022. In Nigeria, the proportion of mDFPS was 17.91 % (95% CI: [1.24, 61.29]) in 2013, and it was 23.08 % (95% CI: [1.80, 56.24]) in 2018. These estimates provide insights into the changing proportion of mDFPS in the respective countries over time.

The pattern of mDFPS coverage was similar between the two time periods for all three countries, with some exceptions (Figures 1 - 3). Sidama was the only region in Ethiopia identified in 2016 as having an EP of greater than or equal to 0.90, surpassing 75% WHO recommended coverage. In Kenya, in 2014, seven counties (Embu, Kiambu, Kirinyaga, Machakos, Murang'a, Nairobi and Nyeri) had an EP of greater than or equal to 0.9 that they exceeded the 75% WHO recommended coverage, while in 2022 there were only seven (Embu, Kiambu , Kirinyaga, Machakos, Murang'a, Nyandarua, Nyeri), with an additional two counties (Nairobi and Tharaka-Nithi) that had an EP of above 0.8. In Nigeria, none of the states had an EP probability greater than or equal to 0.9 in either survey year in 2013 and 2018.

In addition, the geostatistical predictive posterior samples from the geostatistical models were used to calculate the mean posterior change (MPC) in the proportion of mDFPS between the two time periods for each included country. The MPC was calculated overall for the country and at the sub-national level (Table 5, Supplementary material Tables S1 & S2). A probability of exceedance (EP) was also calculated, interpreted as the probability that the MPC between the first and the second period was greater than zero; in other words, to assess whether mDFPS coverage improved in the second period. The overall national level 95% CI of the absolute change in the proportion of mDFPS for the three countries were as follows: Ethiopia: 5.68% (95% CI: [-38.07, 49.44], EP = 0.61); Kenya: 10.19% (95% CI: [-17.72, 39.33], EP = 0.80) and Nigeria: 1.98% (95% CI: [-26.48, 34.49], EP = 0.58).

Kenya had the biggest absolute national change in the estimated percentage change of mDFPS coverage between the two periods. It also had a high probability that the absolute difference was greater than zero; suggestive of huge improvements. The EP of the change of mDFPS being greater than zero was closer to 0.60 for Ethiopia and Nigeria. This suggests that the level of mDFPS in Ethiopia and Nigeria slightly improved.

At the sub-national level, in Ethiopia, only one region, Gambela, had a high EP probability (0.90) that the change in mDFPS coverage proportion improved in the second period of 2019 compared to 2016 (Table 5). In Kenya, the counties that had an EP of 0.9 or more probability of improving in mDFPS were 22 counties (Baringo, Bomet, Bungoma, Elgeyo-Marakwet, Homa Bay, Isiolo, Kajiado, Kericho, Kilifi, Kisumu, Laikipia, Mandera, Migori, Nakuru, Narok, Nyandarua, Taita Taveta, Trans Nzoia, Turkana, Vihiga, Wajir, West Pokot) between the year 2022 compared to 2014 (Table S1). While in Nigeria, the states with an EP of 0.9 or more probability of improving in mDFPS were 8 (Adamawa, Buachi, Gombe, Jigawa, Kano, Katsina, Kebbi and Sokoto) between the years 2018 compared to 2013 (Table S2). Conversely, the areas that had a very low EP probability (<= 0.1) of improvement in coverage of mDFPS were likely to have had a reversal in coverage of mDFPS in the later period (Table 5 and Supplementary material Tables S1 & S2).

Discussion

The results from multilevel modelling varied among the three countries, except for a few determinants, emphasising the uniqueness of each country. For instance, in Ethiopia, women without an education or with primary-level education had similar odds of mDFPS as those with secondary or higher-level education. In Kenya and Nigeria, women without an education had lower odds of mDFPS. This suggests that education may not contribute to mDFPS uptake inequality in Ethiopia compared to Kenya and Nigeria. In all three countries, women from well-to-do households had higher odds of mDFPS, highlighting that household wealth remains an important determinant of inequality (Adegbosin et al. 2019; Ahmed et al. 2010). Muslims consistently had lower odds of mDFPS than women from other denominations; this provides an opportunity for tailored interventions to improve this population's access and use of modern contraception. For instance, a review of the factors that influence the use of sexual reproductive health services among Muslim women reported that Muslim women prefer being seen by female service providers (Alomair et al. 2020).

In all three countries, geographic variations in the proportion of mDFPS were observed. The pattern of geographic variation was similar for the first and second periods, with a higher proportion of mDFPS seen in the relatively affluent sub-national areas. The analysis results investigating whether there was an improvement in the proportion of mDFPS, show that both Ethiopia and Nigeria had modest improvements. In contrast, Kenya increased its coverage of mDFPS between the two periods; 22 out of the 47 states improved coverage of mDFPS over the two periods, with 9 counties likely to have exceeded the minimum WHO recommendation threshold. In the sub-national analysis in Ethiopia, Gambela region (out of 12 regions) was

identified as the only region that may have experienced a significant increase in its mDFPS coverage. In Nigeria, eight (out of 36 states) were identified as potentially increasing mDFPS coverage, all from the northern region. In Ethiopia and Nigeria, most administrative areas had only slight improvements or stagnated in mDFPS coverage. It should be noted that even in communities where improvements were registered, the level of coverage of mDFPS was still below the WHO target even after these improvements. This can be seen on the exceedance maps of the WHO recommended 75% coverage that barely changed between the two periods.

The current analysis results indicate that demographic, geographic, and socioeconomic factors are important in determining who has greater coverage of mDFPS. These findings are consistent with previous studies that have analysed data on mDFPS (Alhassan and Madise 2021; Stephenson et al. 2007). The geospatial analysis identified areas that still need to meet the WHO mDFPS coverage target. The geospatial analysis of changes in the coverage of mDFPS between the two time periods identified regions that have experienced either an increase or a decline and those that have been stagnant. These findings can guide targeted interventions that can address the unique needs of local communities instead of generalised interventions that local evidence does not drive (Ahmed et al. 2019; Ewerling et al. 2018; Olakunde et al. 2022; Yesuf, Birhanu, and Nigatu 2020).

Administrative areas with declining or stagnant mDFPS coverage should be prioritised for interventions to improve the situation. In areas that have shown progress, efforts should be sustained to maintain and accelerate the gains made (Sully et al. 2020). Even though we are advocating for interventions to increase the level of coverage of mDFPS, the rights of the individual and the couples and communities must be respected as enshrined in the 1994 International Conference on Population and Development (ICPD) conference (Hardee et al. 2014). It is important to acknowledge that some women may not start using modern contraceptive methods soon, even if they have an unmet need for modern contraception methods due to reasons such as perceived low risk of pregnancy or perceived cultural, social, or health concerns and preference for traditional methods (Cleland, Harbison, and Shah 2014; Senderowicz and Maloney 2022). On the other hand, it's worth noting that a portion of the unmet need for contraceptives may reflect a desire for modern contraception use, making these individuals more likely to adopt it when made available and accessible (Cleland et al., 2014; Curtis and Westoff, 1996).

Studies carried out in various settings consistently underscore the considerable impact that enhanced accessibility to modern contraceptive methods can make on their adoption (Bongaarts 2014; Cleland et al. 2014). Promoting family planning and ensuring access to the preferred contraceptive methods for women and couples is crucial in securing the autonomy and well-being of women, as well as supporting the health and development of communities (Cleland et al. 2006). However, access alone is insufficient as multiple barriers exist to adopting and using modern contraceptive methods. For example, unmarried women may face stigma when accessing care, and young people may avoid youth-unfriendly family planning services. Additionally, some women may decide not to use modern contraception methods due to fear of perceived side effects, even if they are available. (Choi, Fabic, and Adetunji 2016).

Access and utilisation of modern contraceptive products can also be affected by pandemics, conflicts and climatic emergencies (Namasivayam et al. 2017; Svallfors and Billingsley 2019). Amidst the COVID-19 pandemic spanning 2019 to 2022, the availability of Sexual and Reproductive Health and Rights (SRHR) services was hindered by travel restrictions implemented to mitigate the spread of the virus (Otieno et al. 2021). The limitations in movements meant women could not access modern contraceptives at their preferred locations and when they needed them. The Ebola pandemic in Guinea, Liberia, Nigeria, and Sierra Leone

from 2013 to 2016 also decreased the availability and use of modern contraceptives (Bietsch, Williamson, and Reeves 2020).

Women living in areas with ongoing conflict or climatic catastrophic events have reduced usage of modern contraception (Namasivayam et al. 2017; Svallfors and Billingsley 2019). In general, conflicts and climate change events can pose significant challenges to countries in meeting the demand for family planning services among women. When such events occur, the health system may be overwhelmed and unable to provide the necessary services that enable women to access and use modern contraception methods (Svallfors and Billingsley 2019). These challenges can have a particularly profound negative effect in regions and countries with already vulnerable healthcare infrastructure, like most countries in the SSA region (Gesesew et al. 2021; United Nations Department of Economic and Social Affairs 2020).

In Ethiopia, the Tigray region (and other regions such as Amhara, Afar and Oromia) has been at war since November 2020 until the time of writing this paper. Since the data analysed in this work was from a pre-conflict period, the situation is likely to have changed (Gesesew et al. 2021). The Afar, Oromia, Somali and Harari regions are prone to drought and were also identified as having low mDFPS coverage in this analysis (Bahru et al. 2019; Hirvonen, Sohnesen, and Bundervoet 2020; IFRC 2021). Similarly, in Kenya, most counties (Garisa, Isiolo, Mandera, Marsabit, Tana River, Samburu, Turkana and Wajir) with a history of drought were also identified as having a low coverage of mDFPS. When communities live in resource-constrained conditions, they prioritise survival and hence have low utilisation of health services (Lindvall et al. 2020; WHO 2018).

Furthermore, the northern Kenyan counties also face conflicts as communities are forced to fend for scarce resources. This results in displaced communities, further exacerbating the issues of health service utilisation (IFRC 2021). To promote the use of modern contraception methods in such areas, it is necessary to take a holistic approach that addresses the challenges caused by conflict and climate change shocks (Rawat et al. 2022).

In Nigeria, the northern states have been at war since 2009 (Ojeleke et al. 2022); our analysis shows that most of the northern states have low coverage of mDFPS. The region is also predominantly Muslim (Sinai et al. 2017). Our analysis and work from elsewhere show that Muslim women have lower odds of modern contraception use than women from Christian-based religions in the SSA (Alomair et al. 2020). In addition, misconceptions about modern contraception methods discourage women from using these methods in northern Nigeria. Some documented misconceptions include the belief that modern contraception can affect a woman's ability to bear children and can cause cancer (Hutchinson et al. 2021). Work being done by humanitarian organisations can be alluded to as having helped to improve the level of mDFPS between the two time periods in the northern states, but there is more work that needs to be done to improve healthcare services in the region (ICRC 2019; WHO 2023). Overall, Nigeria is one of the countries in SSA with a low modern contraception prevalence rate. In 2017, the HP Plus initiative identified insufficient domestic funding as one of the challenges affecting Nigeria's family planning programmes (Health Policy Plus (HP+) Project Nigeria 2017).

Study strengths and limitations

The study had several strengths. Firstly, we employed a multilevel modelling approach to identify the disparities in mDFPS coverage driven by demographic, geographic, and socio-economic factors. This modelling process helped us identify the cluster and regional-level residual variance, indicating the presence of spatial variation. To account for this, we performed a spatial analysis using geostatistical models. This enabled us to calculate the adjusted proportion of mDFPS for each administrative area and determine the exceedance probability of each area, highlighting areas which exceeded the WHO mDFPS coverage

minimum target of 75%. Additionally, our analysis of two time periods, which corresponded to a before and after period, allowed us to assess the progress made and identify areas that have stalled or retrogressed in their mDFPS coverage. The methods used in this study can be replicated for other SDG indicators to identify underserved communities, assisting policymakers and governments in directing their efforts more effectively.

Our research also had certain limitations. Despite our efforts, we could not find nationally representative data from 2015, when the UN established the SDG goals. Instead, we used the data that was closest to 2015. Similarly, for the latest year, we relied on the most recent data available for these countries. Thus, the time between the assessment years was different among the included countries, affecting the comparability of the results between the three countries. A complete spatial-temporal approach was impossible due to limited available data, which only spanned two time points. It is hard from this analysis to tell the actual reasons why the proportion of mDFPS reduced or improved in the areas that it did; hence, further studies are required in these areas. Despite these limitations, our analysis provides valuable evidence and fills an essential gap in the available literature.

Conclusion

Our analysis utilised multilevel modelling, geospatial analysis and comparison of data from three countries over two time periods. The results showed the presence of demographic, geographic and socio-economic disparities in the mDFPS, and that some areas have made progress while others have retrogressed but the majority have remained stagnant. The majority of sub-national level areas have mDFPS that are below the WHO recommendation of 75%. Our findings will be important in providing valuable insights for policymakers and governments on how they can effectively target their interventions to improve uptake of modern contraception among women who have a demand for it. By providing much-needed evidence, this analysis contributes to countries' efforts to assess their progress in meeting the SDG indicator 3.7.1.

List of abbreviations

CI, CI, DHS, EP, ICPD, mDFPS, MDG, MPC, OR, OR, PMA, SDG, SRH, SRH, SRH, SSA, UN, WHO

Data availability statement

Data may be obtained from DHS website after registration.

Ethics statements

This analysis utilized data from DHS and PMA surveys. The surveys were approved by the relevant ethics committees in each country; Ethiopia's National Research Ethics Review Committee (NRERC), Kenya's National Review Board (NERB), and Nigeria National Health Research Ethics Committee of Nigeria (NHREC). Before each interview informed consent was obtained.

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Table 1: Characteristics of respondents based on the latest DHS data. Both counts and percentages were weighted to adjust for the survey design.

Characteristic	Ethiopia (year: 2016)	Kenya (year:2022)	Nigeria (year: 2018)
	N = 6,3561	**N = 9,490**	**N = 12,331**
Residence			
Urban	1,208 (19.01%)	3,819 (40.25%)	6,625 (53.73%)
Rural	5,148 (80.99%)	5,671 (59.75%)	5,705 (46.27%)
Age groups			
15-24	1,482 (23.31%)	2,289 (24.12%)	2,517 (20.42%)
25-34	2,917 (45.89%)	3,777 (39.80%)	4,880 (39.58%)
35-49	1,957 (30.80%)	3,424 (36.08%)	4,933 (40.01%)
Level of education			
Secondary or higher	799 (12.56%)	5,261 (55.44%)	7,339 (59.52%)
Primary	1,931 (30.38%)	3,859 (40.66%)	2,053 (16.65%)
No education	3,626 (57.05%)	370 (3.90%)	2,939 (23.83%)
Sex of household head			
Male	5,357 (84.29%)	6,296 (66.34%)	10,347 (83.91%)
Female	999 (15.71%)	3,194 (33.66%)	1,984 (16.09%)
Wealth index			
Poorest	970 (15.26%)	1,344 (14.17%)	1,339 (10.86%)
Poorer	1,263 (19.87%)	1,725 (18.17%)	1,771 (14.36%)
Middle	1,326 (20.87%)	1,797 (18.93%)	2,395 (19.42%)
Richer	1,294 (20.36%)	2,188 (23.06%)	3,253 (26.38%)
Richest	1,503 (23.65%)	2,436 (25.67%)	3,573 (28.98%)
Marital status			
In union	5,949 (93.60%)	7,089 (74.70%)	10,337 (83.83%)
Never in union	138 (2.18%)	1,394 (14.69%)	1,624 (13.17%)
Formerly in union	269 (4.23%)	1,007 (10.62%)	369 (2.99%)
Religion group			
Islam	1,883 (29.63%)	363 (3.82%)	5,077 (41.17%)
Orthodox	2,896 (45.57%)		
Roman Catholic		1,863 (19.64%)	1,458 (11.83%)
Other	79 (1.24%)	372 (3.92%)	45 (0.37%)
Other christians	1,497 (23.56%)	6,891 (72.62%)	5,750 (46.63%)
Parity group			
None	552 (8.68%)	948 (9.99%)	1,440 (11.68%)
1-2	1,807 (28.42%)	3,837 (40.43%)	2,991 (24.26%)
3-4	1,598 (25.14%)	2,999 (31.60%)	3,301 (26.77%)
5+	2,399 (37.75%)	1,706 (17.98%)	4,598 (37.29%)

Table 2: Coverage of demand for family planning satisfied with modern methods (mDFPS) by characteristics of respondents based on latest DHS data. Both counts and percentages were weighted to adjust for survey design.

	Ethiopia (year: 2016)	Kenya (year:2022)	Nigeria (year: 2018)
Overall mDFPS	61.35%	74.59%	35.66%
Residence			
Urban	78.17%	75.66%	40.46%
Rural	57.40%	73.87%	30.08%
Age groups			
15-24	65.51%	67.99%	32.57%
25-34	63.18%	78.04%	37.47%
35-49	55.47%	75.19%	35.44%
Level of education			
Secondary or higher	76.64%	74.79%	42.00%
Primary	64.13%	77.09%	35.54%
No education	56.50%	45.64%	19.90%
Sex of household head			
Male	61.69%	75.98%	35.25%
Female	59.53%	71.85%	37.76%
Wealth index			
Poorest	43.41%	65.55%	18.70%
Poorer	53.37%	76.64%	26.77%
Middle	60.67%	76.22%	33.53%
Richer	67.32%	74.87%	39.72%
Richest	75.09%	76.66%	44.14%
Marital status			
In union	60.58%	74.72%	33.88%
Never in union	63.14%	69.33%	43.51%
Formerly in union	77.46%	80.96%	50.77%
Religion group			
Islam	42.64%	54.96%	28.62%
Orthodox	70.73%		
Roman Catholic		73.97%	37.83%
Other	27.07%	67.06%	15.97%
Other christians	68.54%	76.19%	41.47%
Parity group			
None	68.47%	56.14%	42.23%
1-2	72.47%	78.28%	36.03%
3-4	66.03%	78.57%	39.45%
5+	48.23%	69.54%	30.63%

Table 3: Table of adjusted odds ratios (aOR) for demand for family planning satisfied by modern contraception methods (mDFPS) in Ethiopia, Kenya and Nigeria using Bayesian logistic regression (Equation 1) based on latest DHS data

	Ethiopia (year: 2016)	Kenya (year: 2022)	Nigeria (year: 2018)
	aOR (95% CI)	**aOR (95% CI)**	**aOR (95% CI)**
Residence (urban)			
Rural	0.59 (0.42, 0.82)	0.91 (0.78, 1.06)	0.88 (0.78, 0.99)
Age groups (35-49 years)			
15-24 years	1.06 (0.81, 1.37)	0.92 (0.77, 1.1)	0.75 (0.64, 0.88)
25-34 years	1.18 (0.98, 1.40)	1.2 (1.05, 1.36)	0.98 (0.88, 1.08)
Level of education (Secondary or higher)			
No education	1.09 (0.85, 1.38)	0.40 (0.31, 0.50)	0.51 (0.44, 0.59)
Primary	1.14 (0.92, 1.41)	1.06 (0.94, 1.21)	0.89 (0.79, 1.00)
Household head sex (Male)			
Female	0.62 (0.52, 0.74)	0.73 (0.65, 0.82)	0.82 (0.73, 0.93)
Wealth index (Richest)			
Poorest	0.23 (0.17, 0.32)	0.73 (0.58, 0.92)	0.49 (0.4, 0.61)
Poorer	0.4 (0.29, 0.54)	1.11 (0.89, 1.38)	0.56 (0.47, 0.66)
Middle	0.55 (0.4, 0.74)	1.12 (0.92, 1.37)	0.77 (0.67, 0.89)
Richer	0.74 (0.55, 0.99)	1.05 (0.89, 1.24)	0.94 (0.84, 1.06)
Marital status (In union)			
Never in union	0.80 (0.53, 1.20)	1.41 (1.16, 1.72)	1.51 (1.21, 1.87)
Formerly in union	3.18 (2.15, 4.78)	2.00 (1.64, 2.44)	2.19 (1.74, 2.77)
Religion group (Islam)			
Other	0.64 (0.3, 1.33)	1.81 (1.32, 2.48)	0.97 (0.47, 1.89)
Orthodox	1.91 (1.55, 2.35)		
Roman Catholic		2.07 (1.6, 2.67)	1.35 (1.13, 1.62)
Other Christians	1.77 (1.38, 2.28)	2.19 (1.72, 2.78)	1.45 (1.28, 1.65)
Parity groups (3-4)			
None	1.09 (0.80, 1.50)	0.38 (0.29, 0.49)	0.92 (0.72, 1.17)
1-2	1.49 (1.22, 1.82)	0.89 (0.77, 1.03)	0.86 (0.76, 0.97)
5+	0.64 (0.53, 0.77)	0.78 (0.67, 0.9)	0.98 (0.88, 1.10)
Cluster-level variance	0.47 (0.35, 0.62)	0.10 (0.04, 0.17)	0.20 (0.15, 0.27)
Regional/county/state-level variance	0.80 (0.28, 1.92)	0.15 (0.07, 0.27)	0.32 (0.19, 0.53)

Table 4: Adjusted odds ratios (aOR) for demand for family planning satisfied with modern contraception methods in Ethiopia (PMA), Kenya (DHS) and Nigeria (DHS) based on the latest health surveillance survey using Bayesian geostatistical logistic regression (Equation 2).

Characteristic	Ethiopia (year: 2019)	Kenya (year: 2022)	Nigeria (year: 2018)
	aOR (95% CI)	**aOR (95% CI)**	**aOR (95% CI)**
Women education years	2.69 (1.39, 5.11)	2.63 (1.79, 3.65)	8.49 (5.03,14.35)
Population density	1.00 (0.89, 1.13)	1. 06 (0.97, 1.08)	1.06 (1.01, 1.12)
Mean parity	0.72 (0.66, 0.79)	0.94 (0.90, 0.99)	0.93 (0.90, 0.96)
Probability seeking care at a health facility	1.77 (0.75, 4.23)	0.52 (0.25, 1.05)	1.20 (0.92, 1.56)
Percentage of people living below a one USA dollar[1]		0.32 (0.18, 0.57)	1.17 (0.48, 2.83)

[1]Percentage of people living below US $1-dollar variable was not available for Ethiopia, PMA: Performance Monitoring for Action, DHS: Demographic Health Survey.

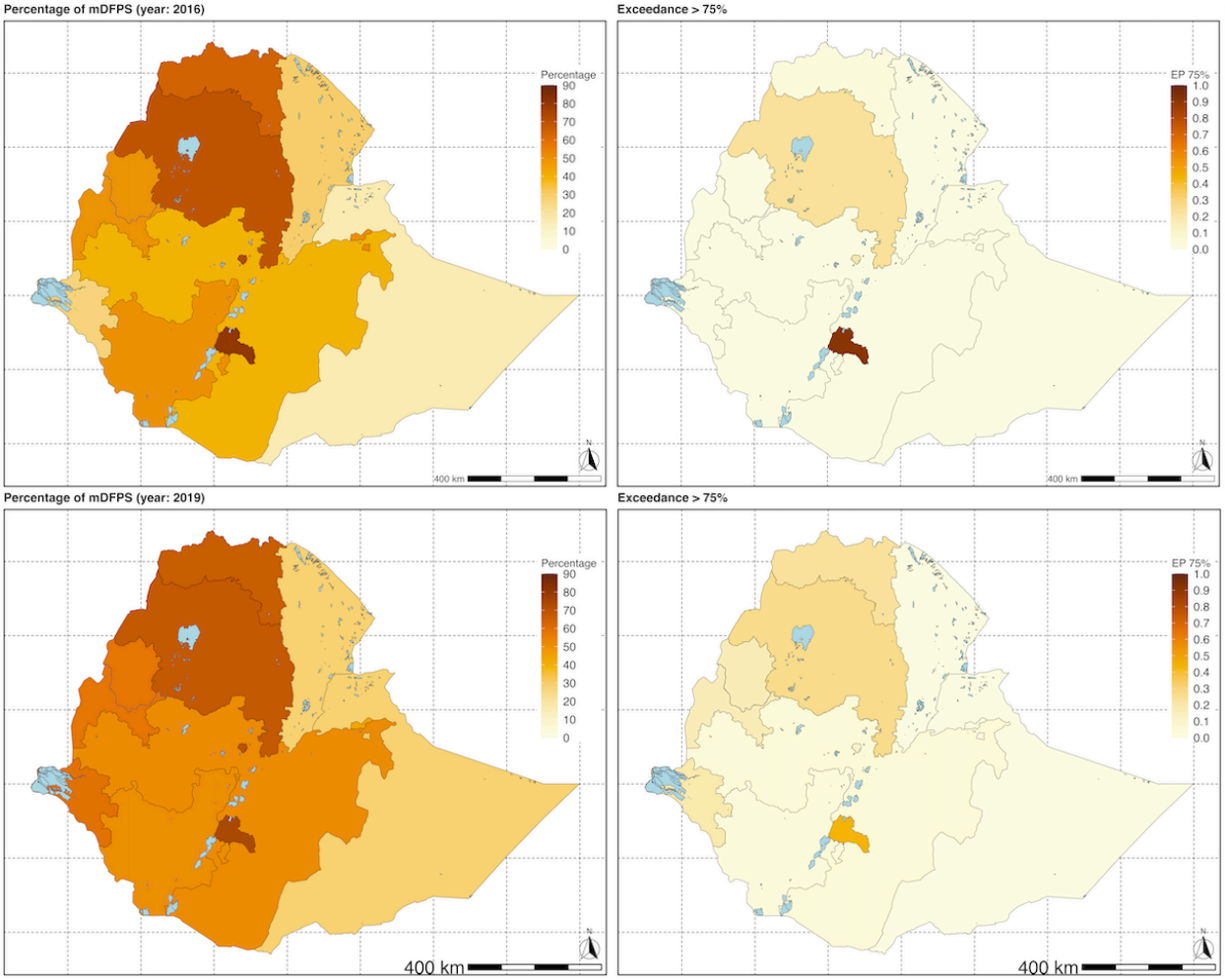

Figure 1: Proportion of demand for family planning satisfied with modern contraception methods (mDFPS) for Ethiopia. Estimates based on adjusted Bayesian geostatistical models. ***Top left panel:*** Map of the predicted proportion of demand for family planning satisfied with modern contraception methods (mDFPS) in Ethiopia in 2016 (DHS). ***Top right panel:*** The likelihood or certainty that the estimated mDFPS exceeds the 75% threshold (SDG target of mDFPS). ***Bottom left panel:*** Map of the predicted proportion of mDFPS in Ethiopia in 2019 (PMA). ***Bottom right panel:*** The likelihood or certainty that the estimated mDFPS exceeds the 75% threshold (SDG target of mDFPS).

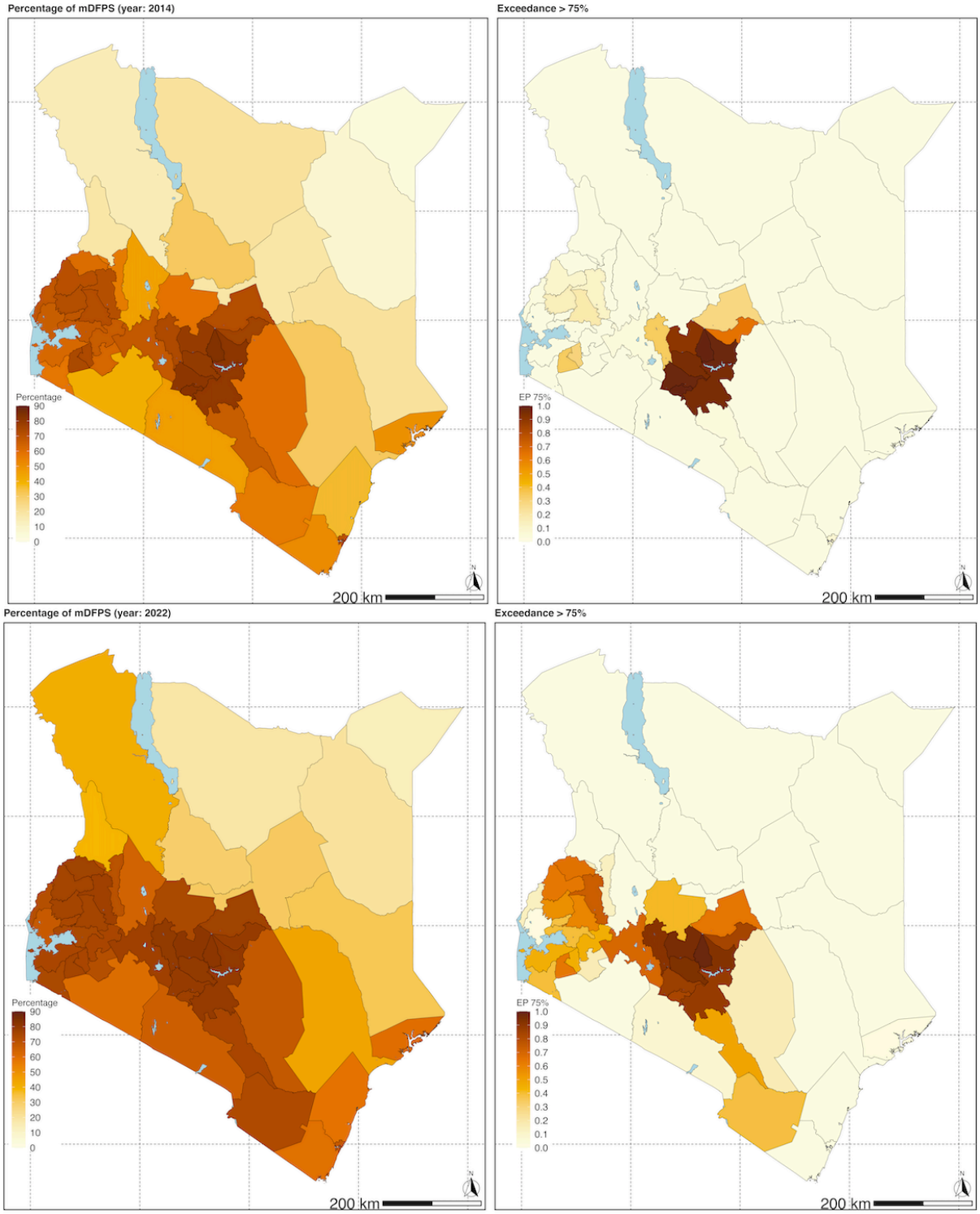

Figure 2: Proportion of demand for family planning satisfied with modern contraception methods (mDFPS) for Kenya. Estimates based on adjusted Bayesian geostatistical models.
Top left panel: Map of the predicted proportion of demand for family planning satisfied with modern contraception methods (mDFPS) in Kenya in 2014 (DSHS). ***Top right panel:*** The likelihood or certainty that the estimated mDFPS exceeds the 75% threshold (SDG target of mDFPS). ***Bottom left panel:*** Map of the predicted proportion of mDFPS in Kenya in 2022 (DHS). ***Bottom right panel:*** The likelihood or certainty that the estimated mDFPS exceeds the 75% threshold (SDG target of mDFPS)

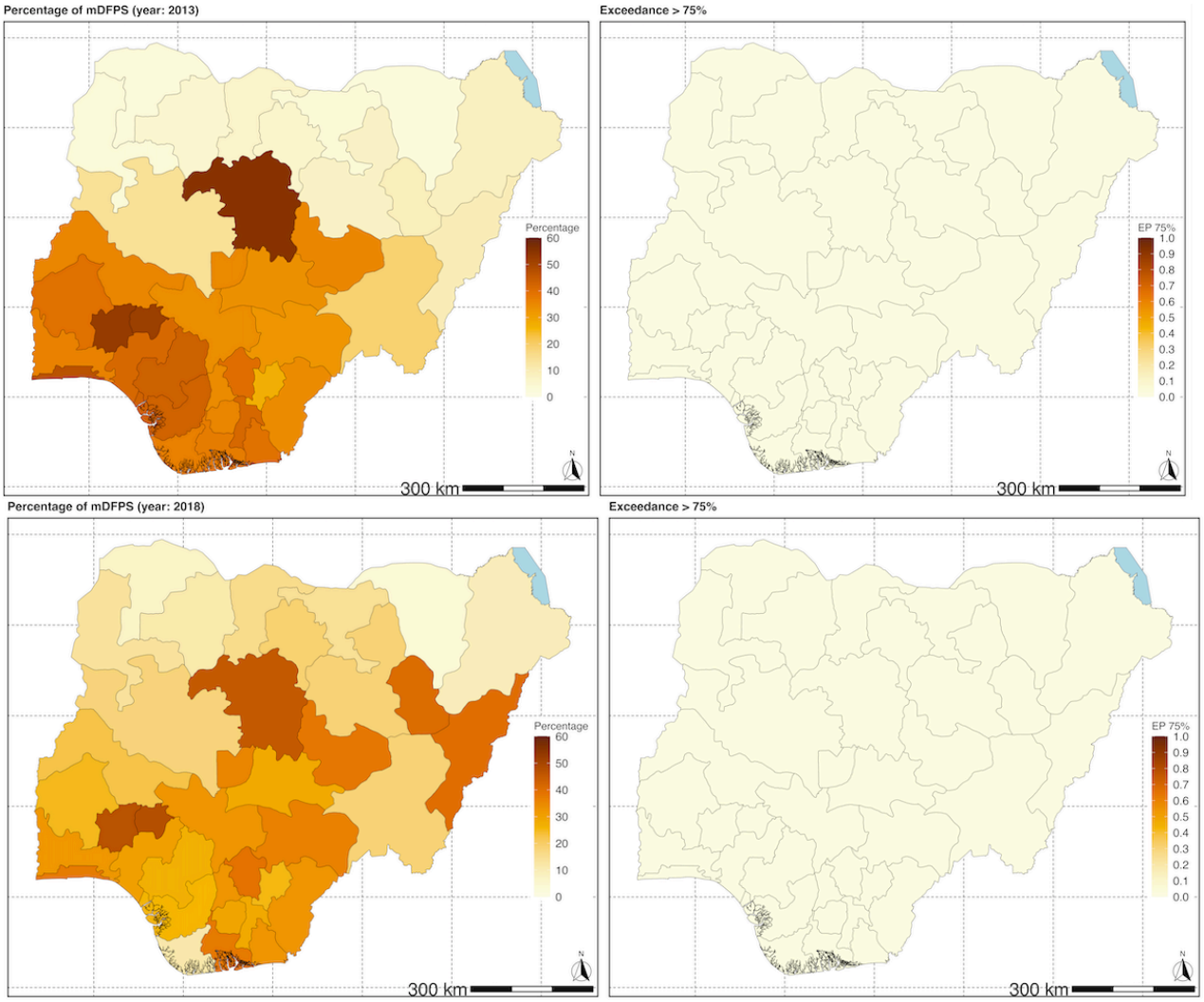

Figure 3: Proportion of demand for family planning satisfied with modern contraception methods (mDFPS) for Nigeria. Estimates based on adjusted Bayesian geostatistical models. ***Top left panel:*** Map of the predicted proportion of demand for family planning satisfied with modern contraception methods (mDFPS) in Ethiopia in 2013 (DHS). ***Top right panel:*** The likelihood or certainty that the estimated mDFPS exceeds the 75% threshold (SDG target of mDFPS). ***Bottom left panel:*** Map of the predicted proportion of mDFPS in Ethiopia in 2018 (DHS). ***Bottom right panel:*** The likelihood or certainty that the estimated mDFPS exceeds the 75% threshold (SDG target of mDFPS).

Table 5: Table showing Ethiopia's regional proportion of mDFPS (2016-2019) with 95% credible intervals (CI), mean posterior change (MPC), percentage change, and exceedance probability of increase of greater than zero of mDFPS from 2016 to 2019. Estimates based on adjusted Bayesian geostatistical models.

Region	% mDFPS 2019 (95% CI)	% mDFPS 2016 (95% CI)	Mean posterior change (MPC) in mDFPS (95% CI)	Probability of increase of mDFPS from 2016 to 2019
Addis Ababa	70.1 (60.3, 77.96)	72.76 (67.58, 77.59)	-3.25 (-11.22, 4.79)	0.32
Afar	28.26 (7.14, 65.32)	29.57 (10.41, 58.47)	0.24 (-38.42, 41.93)	0.47
Amhara	67.71 (40.8, 87.27)	69.1 (52.22, 82.88)	-2.01 (-30.16, 23.65)	0.46
Benishangul Gumz	57.88 (25.78, 86.09)	49.55 (34.64, 67.01)	11.35 (-25.81, 39.55)	0.68
Dire Dawa	43.53 (29.76, 62.09)	50.31 (41.64, 60.98)	-6.76 (-23.46, 14.14)	0.33
Gambela	59.31 (25.57, 86.48)	27.09 (11.31, 49.16)	32.98 (-3.84, 61.54)	0.90
Harari	30.86 (21.97, 44.91)	51.77 (44.62, 59.06)	-20.35 (-32.21, -4.84)	0.01
Oromia	51.61 (23.76, 79.28)	39.81 (21.47, 67.33)	7.52 (-29.16, 43.73)	0.63
Sidama	73.55 (56.86, 85.58)	80.54 (72.45, 86.84)	-10.4 (-27.49, 3.37)	0.35
Snnp	50.92 (27.42, 76.86)	49.79 (32.95, 69.96)	2.81 (-27.77, 32.63)	0.53
Somali	28.12 (4.67, 64.82)	16.2 (2.71, 52.3)	9.62 (-29.95, 49.84)	0.69
Tigray	66.35 (42.85, 84.99)	64.02 (48.59, 75.23)	3.06 (-23.39, 27.42)	0.58

Supplementary material

Table S1: Table showing Kenya's county-level proportion of mDFPS (2014-2022) with 95% credible intervals (CI), mean posterior change (MPC), percentage change, and exceedance probability of increase of greater than zero of mDFPS from 2014 to 2022 Estimates based on adjusted Bayesian geostatistical models.

County	% mDFPS 2022 (95% CI)	% mDFPS 2014 (95% CI)	Mean posterior change (MPC) in mDFPS (95% CI)	Probability of increase of mDFPS from 2014 to 2022
Baringo	63.76 (52.49, 73.8)	44.8 (33.91, 55.63)	18.96 (3.21, 33.81)	0.98
Bomet	71.7 (63.87, 78.39)	63.1 (55.27, 70.14)	8.52 (-1.11, 18.52)	0.93
Bungoma	76 (69.11, 81.68)	71.03 (64.64, 76.78)	5.58 (-3.59, 14.16)	0.87
Busia	71.5 (64.05, 77.84)	68.44 (61.16, 74.93)	2.62 (-6.28, 11.85)	0.62
Elgeyo-Marakwet	70.73 (62.44, 78.04)	56.12 (46.59, 64.18)	17.69 (4.83, 28.41)	0.98
Embu	80.49 (72.83, 86.41)	81.71 (75.69, 86.68)	-1.12 (-9.74, 7.07)	0.42
Garissa	32.25 (15.99, 51.64)	20.44 (9.13, 38.5)	9.03 (-13.47, 31.92)	0.79
Homa Bay	74.55 (66.94, 81.55)	62.38 (53.25, 70.36)	12.18 (0.33, 23.42)	0.96
Isiolo	30.84 (18.16, 48.06)	18.36 (8.87, 32.33)	11.82 (-6.13, 30.49)	0.88
Kajiado	65.4 (49.74, 78.27)	46.44 (32.36, 60.5)	17.14 (-3.6, 36.47)	0.93
Kakamega	75.5 (68.97, 81.07)	72.1 (66.13, 77.56)	3.19 (-5.06, 11.33)	0.78
Kericho	74.63 (67.75, 80.51)	66.65 (59.38, 73.25)	7.77 (-1.79, 17.1)	0.92
Kiambu	78.74 (71.97, 84.1)	80.99 (75.52, 85.47)	-2.16 (-10.37, 5.58)	0.36
Kilifi	58.33 (43.23, 72.42)	36.62 (24.44, 49.64)	20.77 (0.61, 39.42)	0.96
Kirinyaga	81.44 (76.14, 86.1)	84.15 (79.63, 87.86)	-2.18 (-9.13, 3.86)	0.32
Kisii	75.85 (70.11, 80.71)	74 (68.76, 78.96)	0.99 (-6.91, 8.33)	0.60
Kisumu	74.1 (66.98, 80.23)	67.52 (60.61, 73.2)	6.8 (-2.11, 15.76)	0.91
Kitui	67.73 (51.04, 81.44)	59.93 (43.57, 73.32)	7.08 (-13.05, 27.64)	0.70
Kwale	59.81 (47.49, 71.61)	52.03 (40.07, 64.62)	7.39 (-11.14, 26.11)	0.77
Laikipia	73.91 (62.13, 82.62)	58.42 (48.08, 67.62)	13.62 (-0.64, 28.01)	0.92
Lamu	59.73 (41.89, 74.58)	50.05 (36.43, 66.23)	5.6 (-13.24, 23.65)	0.70
Machakos	79.56 (71.4, 85.98)	80.43 (74.08, 85.64)	-0.37 (-9.36, 8.58)	0.49
Makueni	74.92 (64.9, 83.04)	66.39 (56.42, 75.36)	9.31 (-5.06, 22.32)	0.80
Mandera	13.54 (5, 28.86)	2.85 (0.61, 9.77)	10.26 (-0.25, 25.91)	0.97
Marsabit	18.68 (8, 36.34)	20.34 (9.03, 39.8)	-1.42 (-22.91, 18.83)	0.46
Meru	76.5 (67.61, 84.29)	72.27 (63.6, 80.68)	4.45 (-7.64, 15.28)	0.70
Migori	74.03 (65.67, 81.01)	57.71 (49.01, 66.16)	15.83 (3.43, 27.64)	0.99
Mombasa	67.55 (60.47, 73.93)	70.53 (63.8, 76.31)	-2.11 (-10.92, 6.33)	0.36
Murang'a	80.07 (73.24, 85.41)	79.59 (73.88, 84.33)	0.85 (-7.36, 8.34)	0.58
Nairobi	77.24 (72.31, 81.74)	82.66 (78, 86.3)	-5.14 (-11.32, 0.8)	0.11
Nakuru	77.02 (68.7, 83.64)	68.12 (59.72, 75.77)	7.84 (-3.35, 18.94)	0.90
Nandi	75.66 (68.75, 81.42)	72.22 (66.11, 78.38)	3.27 (-5.86, 11.8)	0.77
Narok	60.61 (47.84, 71.98)	41.09 (30.07, 55.1)	16.41 (-1.48, 34.06)	0.95

County	% mDFPS 2022 (95% CI)	% mDFPS 2014 (95% CI)	Mean posterior change (MPC) in mDFPS (95% CI)	Probability of increase of mDFPS from 2014 to 2022
Nyamira	74.66 (68.63, 79.72)	73.63 (68.39, 78.77)	0.74 (-7.18, 8.2)	0.58
Nyandarua	80.05 (72.74, 86.11)	73.59 (66.56, 80.25)	6.8 (-3.17, 16.17)	0.90
Nyeri	81.2 (74.05, 86.95)	78.99 (72.67, 84.59)	2.37 (-6.52, 10.79)	0.70
Samburu	29.23 (17.36, 45)	31.38 (19.8, 46.8)	2.56 (-16.46, 20.8)	0.56
Siaya	67.27 (58.15, 74.65)	66.21 (58.38, 72.63)	1.13 (-9.85, 11.38)	0.56
Taita Taveta	73.03 (56.85, 84.65)	56.62 (39.61, 72.63)	16.27 (-5.19, 36.21)	0.91
Tana River	43.91 (26.02, 62.07)	31.29 (17.36, 48.36)	12.99 (-11.93, 36.39)	0.78
Tharaka-Nithi	79.17 (69.95, 85.33)	76.33 (68.75, 82.74)	1.82 (-8.78, 12.15)	0.62
Trans Nzoia	76.35 (69.22, 82.47)	61.11 (53.1, 68.74)	15.23 (3.89, 25.32)	0.99
Turkana	41.59 (24.5, 62.26)	14.81 (6.39, 30.37)	25.97 (4.32, 48.79)	0.97
Uasin Gishu	77.01 (70.43, 82.36)	71.21 (64.61, 77.32)	4.24 (-5.17, 13.2)	0.81
Vihiga	74.22 (68.7, 79.04)	68.95 (62.79, 73.71)	5.48 (-2.53, 13.51)	0.91
Wajir	20.14 (8.83, 38.6)	7.78 (2.85, 19.53)	11.54 (-2.55, 30.41)	0.93
West Pokot	38.22 (24.42, 53.34)	18.2 (10.74, 29.77)	17.71 (1.9, 34.18)	0.98

Table S2: Table showing Nigeria's state-level proportion of mDFPS (2013-2018) with 95% credible intervals (CI), mean posterior change (MPC), percentage change, and probability exceedance probability of increase of greater than zero of mDFPS from 2013 to 2018. Estimates based on adjusted Bayesian geostatistical models.

State	% mDFPS 2018 (95% CI)	% mDFPS 2013 (95% CI)	Mean posterior change (MPC) in mDFPS (95% CI)	Probability of increase of mDFPS from 2013 to 2018
Abia	28.59 (21.92, 36.29)	41.68 (34.75, 49.01)	-12.88 (-23.14, -2.65)	0.04
Adamawa	39.86 (26.59, 54.36)	9.56 (4.78, 18.67)	31.15 (16.54, 46.38)	0.99
Akwa Ibom	32.58 (25.6, 40.52)	39.57 (32.33, 46.91)	-7.86 (-17.61, 2.18)	0.17
Anambra	32.32 (25.24, 39.5)	34.78 (28.33, 42.64)	-3.55 (-12.97, 6.12)	0.27
Bauchi	18.44 (11.07, 29.3)	7.27 (3.47, 14.69)	7.63 (-1.22, 19.77)	0.89
Bayelsa	11.56 (6.88, 18.4)	36.79 (29.04, 45.52)	-25.12 (-34.49, -15.55)	0.01
Benue	36.3 (25.97, 48.15)	32.2 (22.53, 43.01)	5.33 (-9.73, 20.26)	0.67
Borno	9.32 (2.42, 20.96)	8.16 (2.77, 18.36)	-0.13 (-10.11, 12.88)	0.56
Cross River	32.47 (23.35, 43.63)	34.49 (24.79, 44.03)	2.09 (-13.61, 17.87)	0.51
Delta	25.35 (17.54, 35.03)	42.95 (33.88, 53.08)	-19.7 (-32.33, -5.82)	0.01
Ebonyi	25.07 (17.73, 33.53)	27.07 (21.25, 34.01)	-2.99 (-12.43, 7.19)	0.35
Edo	26.66 (18.64, 36.81)	43.23 (34.08, 52.94)	-16.54 (-29.36, -3.11)	0.01
Ekiti	47.74 (40.14, 55.97)	52.05 (45.05, 59.74)	-5.36 (-16.24, 5.49)	0.19
Enugu	39.08 (30.9, 48.21)	39.89 (32.69, 47.33)	-0.35 (-11.69, 11.36)	0.48
FCT - Abuja	35.72 (27.3, 44.83)	34.92 (25.39, 45.88)	-0.47 (-12.7, 11.73)	0.51
Gombe	40.61 (30.58, 52.05)	9.25 (5.02, 15.95)	30.64 (19.04, 42.64)	1.00
Imo	29.12 (22.79, 36.01)	35.6 (29.3, 42.39)	-6.27 (-15.28, 2.78)	0.18
Jigawa	14.64 (8.46, 24.16)	3.33 (1.46, 7.6)	10.99 (3.91, 21.02)	0.99
Kaduna	45.01 (32.93, 57.93)	55.32 (41.96, 67.48)	-6.69 (-24.47, 11.03)	0.32
Kano	18.87 (11.68, 28.72)	5.83 (3.05, 10.53)	11.79 (4.24, 21.52)	0.95
Katsina	15.8 (9.01, 25.72)	6.53 (3.27, 12.77)	8.37 (0.18, 18.61)	0.92
Kebbi	13.66 (5.99, 27.49)	3.32 (1.16, 8.7)	8.12 (0.81, 22.12)	0.93
Kogi	32.41 (21.81, 45.44)	33.97 (24.14, 45.05)	-0.55 (-16.48, 15.3)	0.44
Kwara	22.57 (11.57, 41.12)	35.72 (22.03, 53.42)	-13.98 (-32.67, 6.09)	0.16
Lagos	37.48 (28.39, 47.4)	46.98 (38.1, 56.03)	-9.26 (-21.58, 3.53)	0.12
Nassarawa	28.63 (18.89, 40.6)	33.45 (22.96, 46.44)	-5.18 (-20.17, 9.95)	0.33
Niger	18.12 (8.96, 33.89)	14.33 (7.17, 26.58)	2.92 (-10.5, 19.47)	0.64
Ogun	32.16 (22.32, 44.77)	36.09 (26.22, 47.55)	-3.64 (-17.97, 11.05)	0.35
Ondo	30.29 (21.93, 40.68)	41.37 (31.84, 51.67)	-11.12 (-24.55, 3.00)	0.11
Osun	46.88 (38.17, 55.93)	52.78 (45.39, 60.76)	-6.1 (-17.59, 4.95)	0.22
Oyo	24.9 (14.58, 38.54)	39.78 (28.5, 53.6)	-14.56 (-31.07, 1.34)	0.10
Plateau	38.15 (26.66, 50.16)	35.07 (24.37, 47.49)	2.04 (-14.29, 18.26)	0.59
Rivers	37.76 (30.05, 47.11)	37.37 (29.77, 45.89)	1.14 (-10.09, 13.38)	0.53
Sokoto	7.00 (2.56, 15.8)	2.9 (1.03, 7.88)	3.2 (-2.2, 12.73)	0.86
Taraba	18.38 (9.27, 34.48)	18.77 (10.57, 30.76)	1.48 (-12.82, 18.45)	0.59
Yobe	4.11 (1.63, 10.35)	2.51 (0.83, 7.58)	1.34 (-3.47, 8)	0.73
Zamfara	11.23 (4.86, 23.47)	5.32 (2.37, 11.48)	5.71 (-2.88, 18.22)	0.86

Table S3: Adjusted odds ratios (aOR) for demand for family planning satisfied with modern contraception methods in Ethiopia (DHS), Kenya (DHS) and Nigeria (DHS) based on the using Bayesian geostatistical logistic regression (Equation 2). Based on the first survey.

Characteristic	Ethiopia (year: 2016)	Kenya (year: 2014)	Nigeria (year: 2013)
	aOR (95% CI)	aOR (95% CI)	aOR (95% CI)
Women education years	2.25 (1.32, 3.83)	3.43 (2.10, 6.47)	10.83 (6.12,19.83)
Population density	1.15 (1.07, 1.24)	1. 05 (0.99, 1.12)	1.09 (1.03, 1.15)
Mean parity	0.68 (0.64, 0.72)	0.84 (0.81, 0.88)	0.89 (0.86, 0.92)
Probability seeking care at a health facility	1.06 (0.59, 1.88)	0.63 (0.28, 1.56)	1.58 (1.18, 2.11)
Percentage of people living below a one USA dollar[1]		0.27 (0.12, 0.80)	2.11 (0.85, 5.23)

[1]Percentage of people living below US $1-dollar variable was not available for Ethiopia

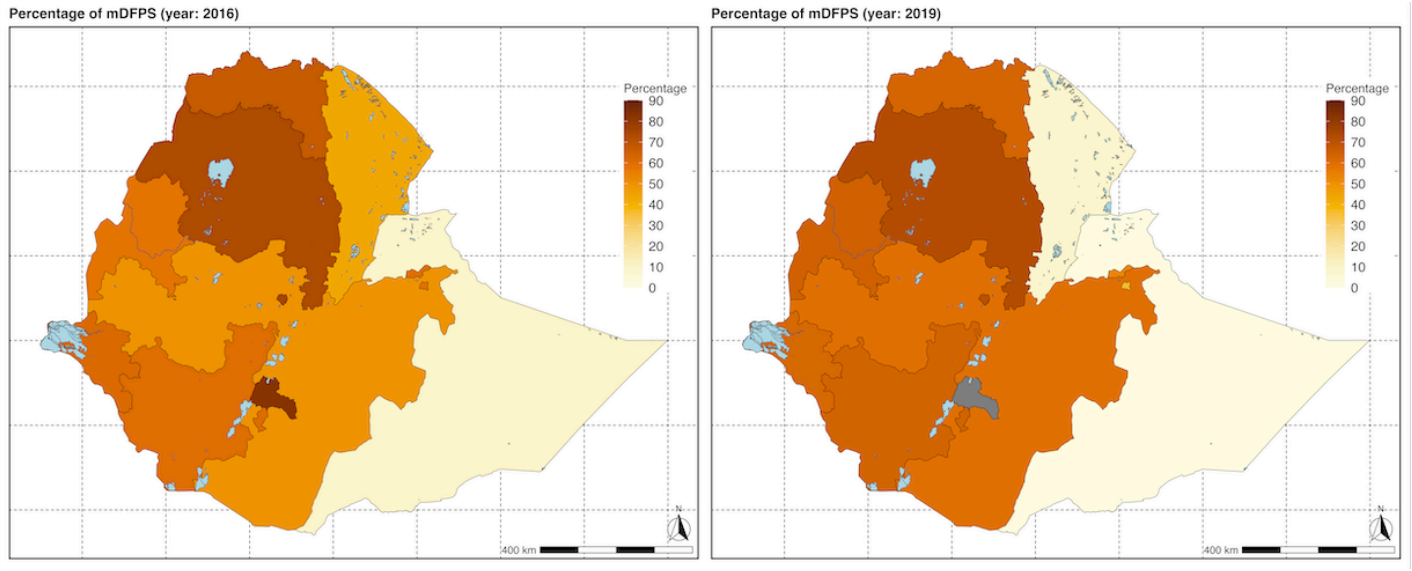

Figure S1: Percentage of demand for family planning satisfied with modern contraception methods (mDFPS) for Ethiopia. Estimates based on unadjusted weighted averages. ***Top left panel:*** Map of the percentage of demand for family planning satisfied with modern contraception methods (mDFPS) in Ethiopia in 2016 (DHS). ***Top right panel:*** Map of the crude percentage of mDFPS in Ethiopia in 2019. Note: data was not collected in Sidama in 2019 (PMA).

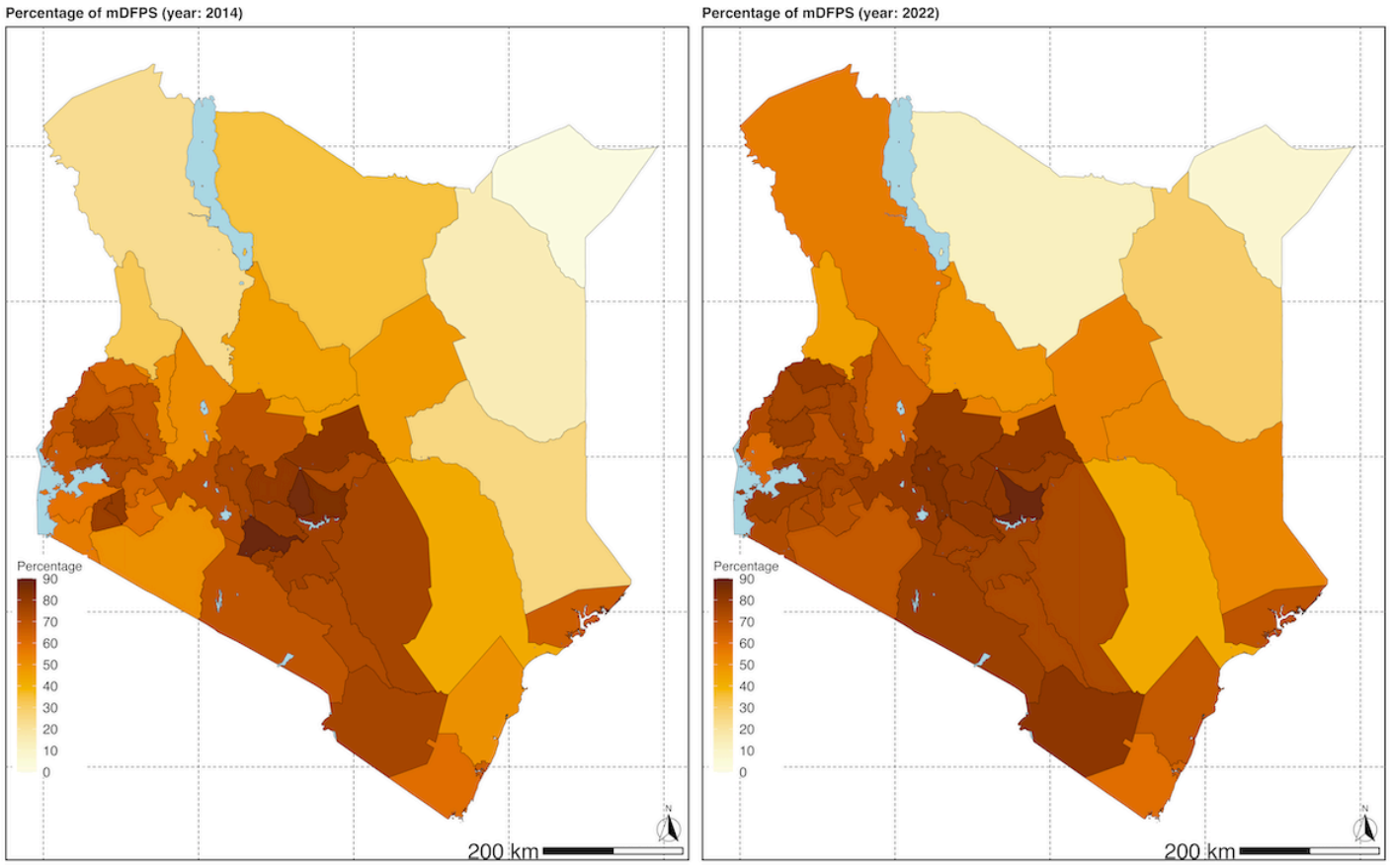

Figure S2: Percentage of demand for family planning satisfied with modern contraception methods (mDFPS) for Kenya. Estimates based on unadjusted weighted averages. ***Top left panel:*** Map of

the percentage of demand for family planning satisfied with modern contraception methods (mDFPS) in Kenya in 2014 (DHS). ***Top right panel:*** Map of the crude percentage of mDFPS in Ethiopia in 2022 (DHS).

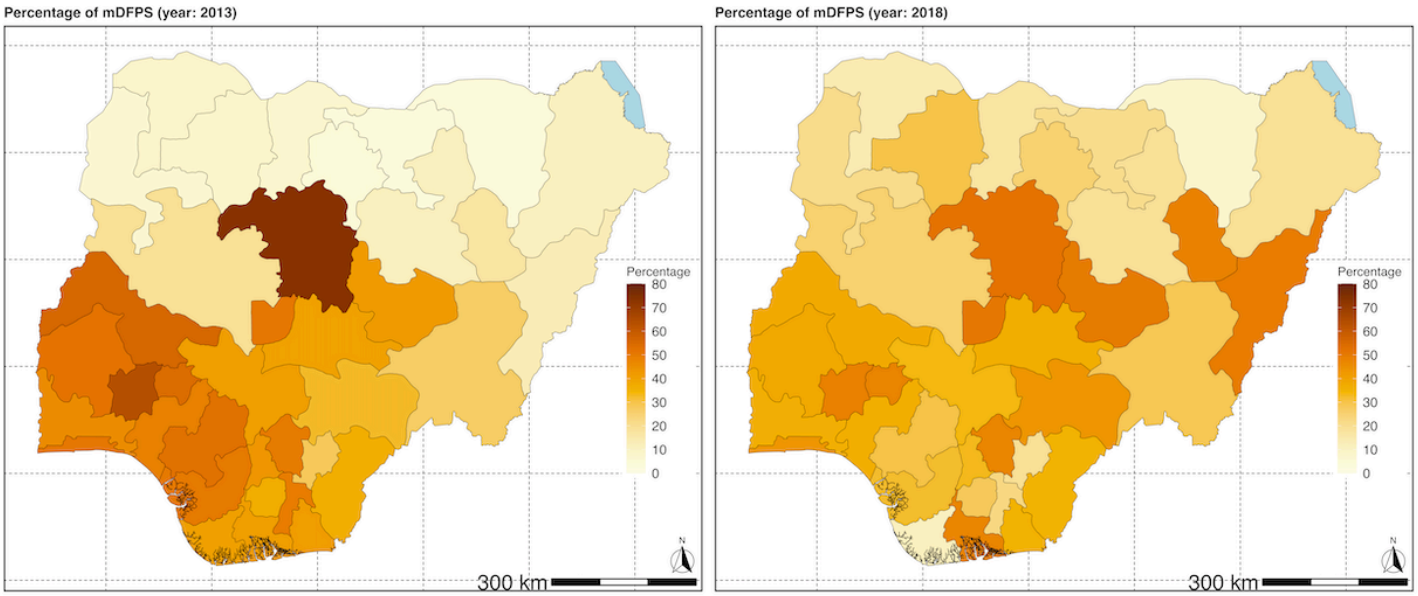

Figure S3: Percentage of demand for family planning satisfied with modern contraception methods (mDFPS) for Nigeria. Estimates based on unadjusted weighted averages. ***Top left panel:*** Map of the percentage of demand for family planning satisfied with modern contraception methods (mDFPS) in Nigeria in 2013 (DHS). ***Top right panel:*** Map of the crude percentage of mDFPS in Nigeria in 2018 (DHS).