ISA Journal of Medical Sciences (ISAJMS)

Homepage: https://isapublisher.com/isajms/

Volume 3, Issue 2, March-April, 2026 ISSN: 3049-1746

Machine Learning-Based Prediction of Unmet Need for Family Planning Among Reproductive-Age Married Women in Nigeria

Esther I. Aikulola-Bolaji[1] & Ayo S. Adebowale[2]

[1]*Department of Epidemiology and Medical Statistics, Faculty of Public Health, University of Ibadan, Ibadan, Nigeria*
[2]*Population and Health Research Entity, Faculty of Humanities, NorthWest University, Mafikeng, South Africa*

Received: 25.03.2026 | **Accepted:** 09.04.2026 | **Published:** 23.04.2026

***Corresponding Author:** Esther I. Aikulola-Bolaji

DOI: *10.5281/zenodo.19711699*

Abstract **Review Article**

Background: Unmet Need for Family Planning (UMFP) remains a public health concern in developing countries, particularly in Nigeria, where women who want to stop or delay childbearing are not using contraception. Although, previous studies identified factors influencing UMFP, limited evidence exists on how these factors are prioritised and used to predict the probability of UMFP. This study prioritised factors influencing UMFP and predicted its probability among married women of reproductive age in Nigeria.

Methodology: This cross-sectional study used 2003, 2008, 2013, 2018 and 2024 rounds of Nigerian Demographic and Health Survey (NDHS), which applied two-stage cluster sampling. Sub-samples extracted were 3,651 (2003), 17,316 (2008), 18,600 (2013), 19,318 (2018) and 16,111 (2024) currently married women of reproductive age. Logistic regression identified significant factors influencing UMFP,while dominance analysis ($\Delta R^2 \geq 0.10$) priortised their relative contributions. Decision trees, random forest, support vector machine and KNN models were trained on 2003-2018data and tested on 2024. Model performance was assessed using F1-score, precision, accuracy, recall and AUC. Decomposition analysis examined contributors to changes in UMFP. All analyses were conducted at $\alpha_{0.05}$.

Result: Standardised prevalence of UMFP increased from 29.3% (2003) to 36.0% (2024). Of 21 identified significant factors, dominant factors were Number of Surviving Children (NSC) with ΔR^2 ranging from 0.43-0.49, age (ΔR^2: 0.33- 0.39), ideal number of children (ΔR^2: 0.17-0.33), religion (ΔR^2: 0.16-0.33), and wealth index (ΔR^2: 0.10-0.19). Random Forest (AUC=76.2%; 95% CI=75.0-77.1). Highest predicted probability of UMFP was observed among women who live in the urban areas, belong to Yoruba ethnic group, in the rich wealth quintile, and practicing Christianity ($p_{2003/2024}$=81.2%, $p_{2008/2024}$=90.0%, $p_{2013/2024}$=81.2%, and $p_{2018/2024}$=97.2%).The rise in UMFP (rate=1.43) was mostly attributed to women's NSC and religion.

Conclusion: Targeted, parity- sensitive and religiously responsive interventions are essential t reduce UMFP in Nigeria.

Keywords: Dominance analysis, Unmet need for Family Planning, Random Forest model, Women of reproductive age.

INTRODUCTION

Background of the study

Increased adoption of family planning is crucial to improving sexual and reproductive health of women globally. The World Health Organization (WHO, 2022) defines family planning has a process that allows individuals and couples to anticipate and attain their desired number of children and the spacing and timing of their births. It is achieved through use of various family planning methods and the treatment of involuntary infertility. On the other hand, unmet need for family planning refers to sexually active women who desire to stop or delay childbearing but are not employing any effective method to prevent conception (WHO, 2022).

Globally, out of 1.9 billion women of reproductive age, approximately 57.9% of women of reproductive age globally have a unmet need for family planning (UN, 2022). This shows at least one in ten married women in most regions of the world has an unmet need for family planning. The highest proportion of unmet need for family planning is concentrated in developing regions. In sub-Saharan(SSA) Africa, nearly 37% of all women of reproductive age have an unmet need for contraception (UNDESA, 2022).

Nigeria's rapid population growth poses significant challenges to economic development, healthcare, and education. Family planning is crucial in addressing these challenges. However, despite many interventions, robust commitment and huge financial outlays invested by the Nigerian government to generate demand for contraception at low cost, and the present policy in place for subsidised family planning in government health facilities (Federal Ministry of Health; National Family planning communication Plan, 2020). In Nigeria, married women of reproductive aged 15-49 still has one of the highest (20%) unmet needs in SSA counties (NPC/ICF, 2019).

The realisation of the SDG goal (UN, 2021) to ensure universal access to sexual and reproductive healthcare services, including family planning, information and education, and the integration of reproductive health into national strategies and programs by 2030 becomes indeterminate in Nigeria. Numerous studies (Meskel et al., 2021; Kraft et al., 2020; Phiri et al., 2023; Oyinlola et al., 2024). Therefore, prioritising factors of unmet needs for family planning and predicting its probability among married women of reproductive age in Nigeria is essential for effective policy interventions and future strategies to addressing the problem of unmet need for family planning with peculiarity to Nigeria.

Problem Statement

Globally, as the world population hits 8 billion, Nigeria is ranked as the sixth most populous country and projected to be the world's fourth most populous nation by 2050 with an estimated 375 million population if the current growth rate is sustained (UN, 2022). The rapidly increasing population growth is evident in the current total fertility rate of 4.8 children per woman with over 200 million people (UNDESA, 2022). Teenage pregnancy is considerably high in Nigeria despite the health issues associated with child pregnancy. It remains a huge challenge in Nigeria despite its negative effects on adolescent girl child, over 23% of teenagers aged 15-19 years have begun childbearing with teenage pregnancy rate estimated as 19% (NPC/ICF, 2019). Its consequences can be severe, leading to adverse pregnancy outcomes and posing challenges to health and socioeconomic advancement in later part of life (Okoli et al., 2022).

In the past few decades, Nigeria has consistently reported high level of teenage pregnancy ranging from 25.2% in 2003 (NPC/ICF, 2003), to about 15% in 2023 (UNFPA, 2023). The most recent national data reported high age-specific fertility rate (106 births per 1000 women) for teenage girls aged 15-19 years (NPC/ICF, 2019) which was higher than what was obtained in some sub-Saharan African countries like Kenya (56.31), Ghana (58.24), Ethiopia (69.9), and South Africa (51.56) (World Bank, 2024). The high level of unmet needs for family planning in Nigeria was one of the primary reasons for the high prevalence of teenage pregnancy (19%), unintended pregnancy (24%), abortion (4.6%), and high-risk

pregnancy outcomes obtainable in the country (NPC/ICF, 2019).

Globally, 121 million unintended pregnancies occur yearly with 61% of the pregnancies ending up in abortion (UN, 2022). In Nigeria, high fertility rate and fertility behaviour among sexually active women characterized by high birth rates and unmet need for family planning increases the rate of unwanted or mistimed pregnancies. More worrisome is that 1 in 5 pregnancies each year are unplanned with more than half ending up in abortion (UN, 2022). More than 400,000 women in Nigeria die due to childbirth and complications related to unplanned pregnancies yearly (Adefalu *et al*., 2018; WHO, 2022). Among married women in Nigeria, 40% have an unwanted pregnancy in their lifetime and 14% have an unwanted pregnancy in the past 5years (NPC/ICF, 2019). Numerous studies have demonstrated the benefits of well-spaced births for both mother and child (Conde-Agudelo et al., 2007; Dim et al.,2013; Ewemade et al.,2019). Nigeria's fertility behaviour is of short birth interval, the estimated median birth interval in Nigeria is 30.9 months. Twenty-five per cent of non-first births occur within 2 years after the preceding birth. Almost 4 in 10 births (38%) occur between 24-35 months after the previous birth. (NPC/ICF, 2019). Relatable pregnancy risk outcomes among married women would have been significantly reduced if the unmet need for family planning had not occurred. Access to family planning services among married women in Nigeria is complex and multi facets.

Economic factors such as poverty and financial inaccessibility also influences unmet need for family planning (Envuladu et al., 2021; Ezenwaka et al., 2020). For instance, Nigeria contributes three million to global extreme poverty (Poverty and Prosperity Report, 2022) with about half (107 million) of the population living in extreme poverty (Nigeria Poverty Assessment, 2022). Sadly, this may affect unmet needs for family planning causing inability to access and afford family planning due to cost of transportation to family planning center, and payment for commodities. In the case of emergency sex among couples this financial inadequacy can lead to unaffordability of contraceptive and increase unmet needs for family planning. Earlier research, (Adebowale et al., 2022; Ukoji et al., 2022) in Nigeria, another study in in Spain (Wietzke, 2020), have established that there is a relationship between national or individual wealth and their fertility rate.

Thus, unsatisfied family planning is one of leading cause of high fertility among married women of reproductive age in Nigeria (UNDESA, 2022). Therefore, married women in Nigeria face significant challenges in experiencing satisfied family planning services. Hence, addressing the unmet need for family planning is not just a matter of sexual and reproductive health, but also a strategic imperative for Nigeria's sustainable development.

Objectives of the Study

This study prioritised factors of UMFP and predicted its probability among married women of reproductive age in Nigeria.

The specific objectives are to:

1. Examine the socio-demographic factors influencing UMFP among married women of reproductive age in Nigeria.
2. Identify the optimal predictors of UMFP among married women of reproductive age
3. Determine the best supervised model for predicting UMFP among married women of reproductive age
4. Prioritise the predictors of UMFP in order of relative importance among married women of reproductive age
5. Estimate the probability of UMFP based on dominant characteristics among married women of reproductive age in Nigeria.

Significance of the Study

This study prioritised factors of unmet needs for family planning and predicted its probability among married women of reproductive age in Nigeria. The application of dominance analysis and machine learning algorithms provided a focused understanding of the primary predictors of unmet

need for family planning among married women aged 15-49 in Nigeria. Additionally, it identified the determinants of unmet need for family planning, focusing specifically on the United Nations SDG Indicator 3.7.1, which pertains to family planning uptake. The United Nations has set a target for all countries to achieve universal access to sexual and reproductive health-care services, including family planning, by 2030. Prioritizing dominant predictors of unmet need for family planning is essential for prediction of unmet need which is critical to high parity women, uncontrolled fertility, and rapid population growth in Nigeria.

This statistical technique exhibits limitations in reporting the linear relationship and correlation of diverse factors that influence unmet needs. It assumes linearity which might not always be evident in reporting major association between variables. Regression analysis may not clearly capture the complex relationships between variables and in case of multiple predictors, coefficients can be difficult to interpret. Thus, does not identify the key predictors of unmet needs for Family planning in Nigeria (Azen and Budescu, 2006; Guttmacher Institute, 2015). This leaves a critical gap in the detailed comparison of the relative importance of one predictor of unmet need over another predictor with comprehensive consideration of all additional contributors among married women. Thus, this study fills this gap by reporting unmet needs for family planning predictions using both dominance analysis and Machine learning techniques (MLT). This study provided an explicit understanding of the most significantly dominant predictor of unmet need for family planning among the study population. This study also adopted (MLT), to identify the optimal predictors, determine the best supervised model for predicting unmet need for family planning.

However, integrating the application of both dominance analysis to prioritize predictors of UMFP and MLT for predicting the probability of UMFP remains a grey areas for research. This study addressed these gaps and limitations of the previous studies by using MLT to identify the optimal predictors, and to further determine the best fit model of unmet need for family planning, while dominance analysis to prioritize the predictors of unmet need family planning in order of relative importance among married women of reproductive age. Overall, thus reduced the usual large number of associated factors of unmet need for family planning and enhance focus for prediction of unmet needs among women of reproductive age in Nigeria. Findings from this study allow more accurate, interpretable predictions that can guide targeted family planning strategies, counseling quality improvements, and supply-chain interventions for married women mostly at risk of unmet need. The end goal is to alleviate UMFP in Nigeria and improve the use of family planning.

This study contributes to the set target for all countries to achieve universal access to sexual and reproductive health-care services, including family planning, by 2030 (UN, 2022) and the achievement of the 27% modern contraceptive prevalence rate earmarked for 2030 up from the 15% mCPR recorded in 2024 (NPC/ICF, 2025).

Research Gap

Despite decades of family planning programming, Nigeria continues to exhibit substantial levels of unmet need for family planning among married women. This undermines national plans to reduce fertility and maternal deaths. National survey reports from the Nigeria DHS indicate that about 21% of married women had an unmet need in the 2024 survey, highlighting persistent gaps between fertility preferences and contraceptive use. This national estimate reports unmet need fell from 20.2% in 2008 to 16.1% in 2013, but then increased to 18.9% in 2018 and 21% in 2024 (NPC/ICF, 2004; 2009; 2014; 2019; 2025). These fluctuating national figures point to a knowledge gap in understanding the changing dynamics and the drivers of unmet need for family planning in Nigeria. This study focused on the integrating ML algorithms to maximize predictive accuracy with dominance analysis variance techniques to prioritize determinants of unmet needs among married women aged 15-49. These findings is essential to reporting accurate, interpretable predictions that guide targeted family planning programs.

Unfortunately, there hasn't been substantial evidence indicating a significant decline in unmet need for family planning in Nigeria over the past decade when compared to other regions. Several past studies (Fagbamigbe *et al*., 2015; Sekoni and Oladoyin 2016; Okigbo *et al*. 2017; Bello *et al*., 2022) focused on population-level or regionally estimates. Some others studies (Mandiwa *et al*., 2018; Jain *et al*., 2020; Odusina *et al*.2020; Olika *et al*., 2021; Fadeyibi *et al*., 2022) on the individual-level socio-economic and behavioral characteristics of married women that determine family planning decision-making. Other studies, (Austin et al., 2015; Asresie *et al*., 2020; Cheng *et al*., 2022; Kassim & Ndumbaro, 2022) examined national trends of family planning. These studies were limited in investigating disparities in subgroups that drive unmet need. The prediction of unmet need presents a cost-effective means to address these challenges, not only improving maternal and child health but also impacting socioeconomic indicators positively on a global scale.

In terms of analysis technique, past studies conducted in SSA countries used different classes of regression model to identify the determinants of unmet need for family planning (Fagbamigbe et al., 2018; Teshale, 2022; Mamuye et al., 2022; Adebowale and Palamuleni, 2023). Findings from these studies were limited to reporting variation, correlation, and association of characteristics of women and unmet-need for family planning. Regression approach has several limitations as it assume linearity, in case of multiple factors, coefficients can be difficult to interpret. For instance, prevalence of unmet need from local studies are higher than national estimates with several studies reporting unmet need at (>30–45%). A study in University of Portharcourt teaching hospital (Oriji et al., 2023) unmet needs for family planning was 31.4%, another study in Ilesha teaching Hosipital (Uthman et al., 2018) unmet needs for family planning was 58.2%. Mohammed et al., (2018) in plateau state community unmet needs for family planning was 56%, and among Niger Delta University undergraduates (Isa et al., 2015), unmet needs for family planning was 48%. Notably, smaller facility-based studies offer rich contextual detail but suffer from limited external validity. These studies relied on cross-tabulations or multivariable logistic regression which may have excluded complex, non-linear interactions among predictors that could be exploited for precision. This methodological gap suggests machine learning approaches which can model high-order interactions and non-linearity.

Machine learning techniques are underutilized for predicting unmet need among married women. Beyond predictive capacity, there is limitation in research using variable relative importance and contribution of each predictor to unmet need at the population level (kino et al.,2021; Dey et al., 2022; Kebede et al., 2023; Yehuala, 2024; Melaku et al., 2025; Adem & Legesse, 2025). Dominance analysis techniques fills this gap by providing a principled way to rank predictors and to attribute explained variance among the characteristics of women in the study population (Azen & Budescu, 2003; Luo & Azen 2018). Information from these socioeconomic and demographic predictor will not only serve analytical purpose but will be useful for public health intervention with focus on subgroup that are at high risk of unmet need either currently or those predicted to have unmet need.

These is not only predictive on who will have unmet need but interpretive to public health by reporting which determinants of unmet need matter most, and by how much they contribute to unmet need for family planning. This fills a clear methodological gap and findings from these study is essential to reporting accurate, interpretable predictions that can guide targeted family planning programs, counseling, quality improvements, and supply chain interventions for married women most at risk of unmet need and younger sub population of women in Nigeria.

METHODOLOGY

Research Design

This study utilised data from 2003 to 2024 Nigeria Demographic and Health Survey (NDHS). The NDHS is a cross-sectional study design which employs a two-stage cluster sampling technique for sample selection. This survey was conducted to

gather comprehensive information on various demographic and health indicators in Nigeria.

Data Collection Method

To accomplish the research goals, the study used 2003 to 2024 Nigeria Demographic and Health Survey (NDHS) dataset with approval from the DHS program through an online request via (archive@dhsprogram.com). Data collected were highly comparable over time because of the standardization in sampling procedures, data collection methodologies and coding. The number of women aged 15-49 years interviewed for these year periods used in the study were 7620, 33385, 38948, 41821, 39050 respectively (NPC/ICF, 2004, 2009, 2014, 2019 and 2025). These samples are fairly representative of the whole nation. For the purpose of this study, this group of women were narrowed down to those who are fecund and currently married. The sub-samples for this study were extracted. The analyses were based on this secondary data which were assessed on the DHS program's data repository of the data originators.

Data Analysis Technique

The analysis for this study was conducted using the Women dataset (Individual recode, IR) from 2003, 2008, 2013, 2018 and 2024 Nigeria Demographic and Health Survey (NDHS). The data were be requested, extracted and cleaned for analysis using R. Sample weights were applied to adjust for differences in the probability of selection and to ensure the findings are representative of the population. To examine socio-demographic factors influencing UMFP among married women of reproductive age 15-49 in Nigeria, chi-square test was done to show association, adjusted logistics regression was done, and significant variables were identified. This tool does the job of estimating the effect of each independent variable on the log odds of the dependent outcome while controlling for the confounding variable. This provided a systematic and robust understanding of significant factors influencing UMFP.

Thereafter, to identify the optimal predictors of UMFP among married women of reproductive age from the significant variables, the variable feature importance tool of four supervised machine learning model (decision tree, random forest, support vector machines (SVMs), and k-nearest neighbors) was employed. This was done to enhance interpretability and ensure that model insights are not biased by overfitted to a single algorithm. Thus, for the objective comparison of the predictive strength of these machine learning models the performance and evaluation metrics tool was used to determine the best model for predicting UMFP. The 2024 dataset was used as the test data set while all the previous survey rounds (2003, 2008, 2013, 2018) served as the train dataset.

The accuracy of each MLT algorithm reflects overall correctness, the deviation between the train and test dataset indicates the extent of error in predictions; and patterns of overfitting reveals if the model generalises well. The precision to deduce the correctness among the predicted positives, recall shows the coverage of actual positives, F1 scores indicates the balance between the precision and recall and lastly AUC-ROC measures the overall ability of the model clearly indicating the model of best fit for the prediction of unmet need for family planning. Further analysis was done using dominant analysis to pioritise the predictors of UMFP in order of relative importance.

The variable feature tool and dominance may seem similar, but for their purpose of this study was different. The variable feature importance tool highlights predictor that contributes to model predictive accuracy while dominance analysis break down variance explained to ranks predictors of UMFP by their relative importance. The variance explained in this study is the proportion of variation in UMFP that is accounted for by the predictors measured by R^2. It shows how the predictors of UMFP explains differences in among currently married women.

The end goal of this study to estimate probability of UMFP based on dominant characteristics among

married women of reproductive age in Nigeria. This was achieved using the best fit model from the performance metrics (random forest model) and the dominant predictors (prioritised predictors of UMFP in order of relative importance). The probablity of UMFP was deduced by holding the dominant predictors constant at number of surviving children ≥5; high fertility desire, ideal no of Children ≥5; the advanced reproduce aged women, Age (35-49), as these categories exhibited higher unmet needs, estimates on probability of UMFP was done across the categories of ethnicity, religion, residence and wealth.

RESULTS

Table 4.1j to 4.1i presents the adjusted distribution of married women age 15-49 according to their background characteristics from 2003 to 2024. Age of women was statistically significantly with unmet need for family planning. Compared with women aged 15-24 years, those aged 25-34 years had significantly lower odds of having unmet need in 2024 (OR = 0.63; 95% CI: 0.56–0.72, p<0.001), while women aged 35-49 years were more likely to report unmet need (OR = 1.04; 95% CI: 0.88–1.21, p<0.001). The number of surviving children was statistically significantly to unmet need for family planning. In 2024, women with three to four surviving children had higher odds of unmet need compared with those with none or two (OR = 1.41; 95% CI: 1.14–1.74, p<0.001), while women with five or more surviving children were twice likely to have higher odds of having unmet need (OR = 1.57; 95% CI: 1.81–2.00, p<0.001).

Educational attainment was statistically significantly with unmet need for family planning. In 2024, women with primary education (OR = 1.18; 95% CI: 1.03–1.35, p<0.05) and those with secondary education (OR = 1.15; 95% CI: 1.01–1.31, p<0.001) had significantly higher odds of unmet need compared with women with no education. Similar pattern was observed across the survey rounds.

In 2024, across survey years, women in all regions, had higher odds of having unmet needs for family planning compared with those in the North-Central region. Conversely, in 2018, the odds of having unmet need was significantly higher in the South-South (OR = 1.90; 95% CI: 1.64–2.20, p<0.001) and South-West (OR = 1.46; 95% CI: 1.21–1.75, p<0.001). In 2003, women from middle-income households had lower odds of unmet need compared with the poor category (OR = 0.99; 95% CI: 0.77–1.28, p<0.05), but this was not sustained in 2024 (OR = 1.24; 95% CI: 0.11–1.38, p<0.05). In 2024, women with low family planning information from the media were more likely to report unmet need compared with those with no information on family planning on media (OR = 1.31; 95% CI: 1.18–1.45, p<0.05).

Table 4.1j Adjusted Logistic Regression of Unmet Needs for Family Planning according to Demographic Characteristics, 2003 - 2024

Demographic Characteristics	2003	2008	2013	2018	2024
	OR(C.I)	OR(C.I)	OR(C.I)	OR(C.I)	OR(C.I)
Age					
15-24(RC)	1.00	1.00	1.00	1.00	1.00
25-34	0.83 (0.61-1.13)	0.81 (0.70-0.92)^	0.75 (0.66-0.86)*	0.70 (0.62-0.79)*	0.63 (0.56-0.72)*
35-49	1.08 (0.72-1.61)	1.30 (1.09-1.55)^	1.19 (1.00-1.42)	1.32 (1.13-1.54)^	1.04 (0.88-1.21)

Age at First Cohabitation					
0-17	1.00	1.00	1.00	1.00	1.00
18 -24	1.29 (1.01-1.65)+	0.88 (0.79-0.98)+	1.11 (1.00-1.23)+	1.02 (0.92-1.13)	1.09 (0.99-1.21)
25+	0.91 (0.58-1.44)	0.68 (0.57-0.82)*	0.78 (0.65-0.94)+	0.71 (0.61-0.83)*	0.80 (0.68-0.93)^
Age At First Sexual Intercourse					
0-14	1.00	1.00	1.00	1.00	1.00
15-17	0.94 (0.66-1.34)	1.09 (0.95-1.25)	0.94 (0.76-1.15)	0.91 (0.83-1.00)	1.08 (0.97-1.21)
18-24	1.04 (0.70-1.53)	1.16 (0.98-1.36)	0.77 (0.62-0.96)+	0.88 (0.78-0.99)+	1.05 (0.92-1.20)
25+	1.12 (0.83-1.52)	1.02 (0.90-1.17)	0.85 (0.70-1.02)	0.85 (0.66-1.10)	1.08 (0.83-1.41)
Partners Age					
15-24	1.00	1.00	1.00	1.00	1.00
25-34	0.90 (0.51-1.59)	0.69 (0.55-0.87)^	1.06 (0.83-1.35)	0.91 (0.71-1.17)	1.05 (0.81-1.36)
35+	0.63 (0.35-1.15)	0.64 (0.51-0.82)*	0.91 (0.70-1.17)	0.92 (0.71-1.19)	0.95 (0.73-1.24)
Ideal Number of Children					
0-2	1.00	1.00	1.00	1.00	1.00
3-4	1.08 (0.47-2.49)	0.83 (0.66-1.05)	1.01 (0.73-1.40)	1.04 (0.85-1.27)	0.97 (0.81-1.16)
5+	0.51 (0.22-1.15)	0.52 (0.42-0.65)*	0.71 (0.52-0.97)+	0.64 (0.53-0.77)*	0.64 (0.54-0.76)*
Number of Surviving Children					
0-2	1.00	1.00	1.00	1.00	
3-4	1.32 (0.87-1.98)	1.43 (1.19-1.73)*	1.31 (1.07-1.60)^	1.18 (0.96-1.44)	1.41 (1.14-1.74)^
5+	1.66 (0.99-2.79)	1.53 (1.22-1.93)*	1.39 (1.09-1.79)^	1.51 (1.23-2.00)*	1.57 (1.18-2.00)^
Sex of House Head					
Male	1.00	1.00	1.00	1.00	
Female	0.83 (0.52-1.32)	1.09 (0.90-1.31)	1.14 (0.96-1.36)	1.10 (0.94-1.29)	0.99 (0.84-1.16)

***p<0.001;^p<0.01; +p<0.05**

Table 4.1k Adjusted Logistic Regression of Unmet Needs for Family Planning according to Socioeconomic Characteristics, 2003 - 2024

Socioeconomic Characteristics	**2003**	**2008**	**2013**	**2018**	**2024**
	OR(C.I)	**OR(C.I)**	**OR(C.I)**	**OR(C.I)**	**OR(C.I)**
No of Unions					
Once(1)	1.00	1.00	1.00	1.00	1.00
1+	1.02 (0.87–1.11)	1.02 (0.90-1.14)	1.06 (0.94-1.20)	1.11 (1.00-1.24)	0.93 (0.81-1.07)
Highest Educational Status					

No education	1.00	1.00	1.00	1.00	1.00
Primary	1.05 (0.83–1.32)	0.97 (0.86-1.11)	1.21 (1.07-1.38)^	1.15 (1.02-1.30)+	1.18 (1.03-1.35)+
Secondary	1.08 (0.80–1.46)*	1.08 (0.92-1.26)	1.29 (1.11-1.50)^	1.25 (1.10-1.42)^	1.15 (1.01-1.31)+
Tertiary	0.84 (0.49–1.42)*	0.90 (0.69-1.17)	1.26 (0.98-1.63)	1.10 (0.91-1.35)	0.97 (0.80-1.17)
Partner Education					
No education	1.00	1.00	1.00	1.00	1.00
Primary	0.72 (0.22–2.33)	1.02 (0.90-1.15)	0.95 (0.84-1.08)	0.96 (0.85-1.09)	1.04 (0.90-1.20)
Secondary	0.89 (0.28–2.89)*	0.98 (0.86-1.13)	1.00 (0.88-1.14)	0.96 (0.86-1.08)	1.09 (0.96-1.23)
Tertiary	0.79 (0.24–2.61)*	0.99 (0.82-1.18)	0.97 (0.82-1.15)	1.01 (0.87-1.17)	1.16 (1.00-1.35)
Don't know	0.85 (0.26–2.76)	0.93 (0.54-1.58)	0.81 (0.51-1.28)	1.29 (0.97-1.71)	1.11 (0.81-1.53)
Family Type					
Monogamy	1.00	1.00	1.00	1.00	1.00
Polygamy	1.36 (1.04–1.77)+	1.11 (1.01-1.22)+	1.02 (0.93-1.12)	0.96 (0.88-1.05)	1.14 (1.04-1.25)^
Region					
North-Central	1.00	1.00	1.00	1.00	1.00
North-East	0.86 (0.65–1.13)	0.90 (0.78-1.03)	0.84 (0.73-0.97)+	0.76 (0.67-0.86)*	1.17 (1.03-1.32)+
North-West	0.58 (0.42–0.81)^	1.08 (0.91-1.27)	0.56 (0.47-0.66)*	0.46 (0.40-0.53)*	1.26 (1.10-1.45)^
South-East	1.51 (0.85–2.70)	1.16 (0.85-1.60)	0.76 (0.54-1.07)	1.14 (0.89-1.47)	1.28 (0.96-1.72)
South-South	1.11 (0.78–1.59)	1.75 (1.48-2.06)*	1.09 (0.93-1.28)	1.90 (1.64-2.20)*	1.53 (1.26-1.84)*
South-West	0.75 (0.49–1.16)	1.24 (1.00-1.55)	0.89 (0.72-1.10)	1.46 (1.21-1.75)*	1.43 (1.14-1.78)^
Residence					
Urban	1.00	1.00	1.00	1.00	1.00
Rural	0.84 (0.68–1.03)*	0.99 (0.88-1.10)	1.04 (0.93-1.16)	0.97 (0.89-1.06)	0.94 (0.85-1.03)
Ethnicity					
Hausa/Fulani	1.00	1.00	1.00	1.00	1.00
Igbo	0.66 (0.37–1.18)*	0.98 (0.75–1.28)	1.02 (0.77–1.34)	0.91 (0.71–1.18)*	1.34 (1.10-1.63)^
Yoruba	1.20 (0.73–1.97)	1.05 (0.85–1.29)*	1.04 (0.84–1.28)	1.25 (1.02–1.54)+	0.79 (0.70-0.89)*
Others	1.22 (0.93–1.60)*	1.05 (0.94–1.19)	0.99 (0.88–1.13)*	1.01 (0.90–1.14)	0.89 (0.70-1.14)
Religion					
Christianity	1.00	1.00	1.00	1.00	1.00
Islam	1.24 (0.94–1.66)*	0.71 (0.62-0.82)*	0.78 (0.69–0.88)*	0.88 (0.79–1.00)+	0.81 (0.71-0.92)^
Trad/Others	0.87 (0.66–1.15)	0.79 (0.58-1.08)	0.76 (0.54–1.07)	0.72 (0.48–1.08)	0.89 (0.57-1.41)
Working Status					
Working	1.00	1.00	1.00	1.00	1.00
Not Working	0.99 (0.91–1.08)	0.96 (0.87-1.05)	1.01 (0.92-1.11)	1.03 (0.94-1.12)	0.95 (0.87-1.03)

***p<0.001;^p<0.01; +p<0.05**

Table 4.1l Adjusted Logistic Regression of Unmet Needs for Family Planning according to Socioeconomic Characteristics, 2003 - 2024

Socioeconomic Characteristics	2003	2008	2013	2018	2024
	OR(C.I)	OR(C.I)	OR(C.I)	OR(C.I)	OR(C.I)
Wealth Quintile					
Poor	1.00	1.00	1.00	1.00	1.00
Middle	0.99 (0.77-1.28)	1.20 (1.07-1.34)^	1.21 (1.08-1.36)^	1.17 (1.06-1.30)^	1.24 (1.11-1.38)*
Rich	1.06 (0.80-1.41)	1.43 (1.25-1.65)*	1.14 (0.99-1.31)	1.28 (1.14-1.43)*	1.25 (1.10-1.42)^
Partners Desire For Children					
Both want same	1.00	1.00	1.00	1.00	1.00
Partner want more	1.13 (0.89-1.43)	1.04 (0.94-1.16)	0.98 (0.89-1.09)	1.08 (0.99-1.18)	0.83 (0.76-0.90)*
Partnerwant fewer	1.03 (0.61-1.73)	1.24 (0.97-1.58)	1.01 (0.80-1.28)	1.45 (1.24-1.70)*	1.02 (0.87-1.20)
don't know/other	1.01 (0.79-1.28)	1.10 (0.99-1.22)	1.15 (1.03-1.28)+	1.35 (1.20-1.52)*	0.99 (0.88-1.11)
Currently Reside with Husband					
Yes	1.00	1.00	1.00	1.00	1.00
No	0.87 (0.75–1.01)	0.85 (0.73–0.98)+	1.16 (0.99-1.37)	1.27 (1.09-1.47)^	1.24 (1.06-1.46)^
Visit Health Facility and discussed FP					
No	1.00	1.00	1.00	1.00	1.00
Yes	0.90 (0.80–1.02)	0.94 (0.90–1.02)	0.92 (0.77-1.09)	0.84 (0.77-0.92)*	0.86 (0.77-0.95)^
Visited by Field Worker and Discussed FP					
No	1.00	1.00	1.00	1.00	1.00
Yes	0.87 (0.73–0.92)	0.88(0.79-0.94)	0.91(0.89-0.97)	1.14 (0.99-1.32)	1.14 (0.99-1.32)
Gender Prefrence					
No Preference	1.00	1.00	1.00	1.00	1.00
Male Preference	0.73 (0.65–0.82)*	0.94 (0.91–0.97)	1.03 (0.91-1.16)	1.17 (1.04-1.30)^	1.31 (1.18-1.45)*
Female Preference	0.87 (0.66–1.15)	0.86 (0.66–1.12)	0.97 (0.87-1.07)	1.09 (0.99-1.19)	1.15 (1.04-1.26)^
FP information Media					
No Info	1.00	1.00	1.00	1.00	1.00
Low Info	1.06 (0.76–1.47)	1.20 (0.99–1.45)	1.03 (0.91-1.16)	1.17 (1.04-1.30)^	1.31 (1.18-1.45)*
High Info	0.99 (0.71–1.39)	1.28 (0.92–1.76)	0.97 (0.87-1.07)	1.09 (0.99-1.19)	1.15 (1.04-1.26)^
Knows FP Source					
Know a Source	1.00	1.00	1.00	1.00	1.00
Knows no Source	0.83 (0.68–1.01)*	0.88 (0.80-0.98)+	1.02 (0.93-1.12)	0.88 (0.80-0.96)^	1.07 (0.99-1.17)
FP Awarness					
No	1.00	1.00	1.00	1.00	1.00
Yes	1.01(0.76-1.47)	1.14 (0.87–1.50)	1.07 (0.95–1.20)	1.00 (0.88–1.12)	1.00 (0.89-1.13)
Women Empowerment					
Low	1.00	1.00	1.00	1.00	
Medium	0.99 (0.62–1.60)	1.10 (1.01-1.21)+	1.03 (0.84–1.26)	1.50 (1.28–1.76)	1.15 (1.05-1.25)^
High	1.02 (0.82–1.25)	1.07 (0.98–1.17)	1.11 (1.00–1.22)	1.33 (1.18–1.50)	1.34 (1.03-1.74)+

***p<0.001;^p<0.01; +p<0.05**

4.3 Determination of the Best Supervised Model for Predicting UMFP

Table 4.3. a. Machine Learning Tools indicating Model of Best-Fit for 2003-2018

Model Name	Accuracy	Precision	Recall	F1-Score	AUC (%)
Training data 2003					
Logistic Regression	0.7558	0.7618	0.9747	0.8552	74.42
Decision Tree	0.7649	0.7718	0.9688	0.8591	75.49
Random Forest	0.7929	0.8002	0.9599	0.8728	77.29
Support Vector Machine (SVM)	0.7583	0.7600	0.9840	0.8577	73.83
K-Nearest Neighbour (KNN)	0.7750	0.7861	0.9562	0.8628	76.50
Test data 2024					
Logistic Regression	0.7266	0.7357	0.9623	0.8339	72.66
Decision Tree	**0.7374**	**0.7387**	**0.9776**	**0.8415**	**73.22**
Random Forest	0.7363	0.7536	0.9363	0.8351	73.13
Support Vector Machine (SVM)	0.7316	0.7308	0.9874	0.8400	70.16
K-Nearest Neighbour (KNN)	0.7359	0.7457	0.9557	0.8377	73.59
Training data 2008					
Logistic Regression	0.7258	0.7324	0.9690	0.8342	71.58
Decision Tree	0.7210	0.7328	0.9570	0.8300	72.13
Random Forest	0.7643	0.7641	0.9676	0.8539	76.27
Support Vector Machine (SVM)	0.7248	0.7271	0.9819	0.8355	71.28
K-Nearest Neighbour (KNN)	0.7451	0.7580	0.9430	0.8405	73.91
Test data 2024					
Logistic Regression	0.7374	0.7448	0.9613	0.8393	72.34
Decision Tree	0.7371	0.7427	0.9660	0.8398	73.22
Random Forest	**0.7393**	**0.7552**	**0.9387**	**0.8370**	**73.87**
Support Vector Machine (SVM)	0.7312	0.7328	0.9807	0.8388	72.12
K-Nearest Neighbour (KNN)	0.7282	0.7492	0.9302	0.8300	72.68
Training data 2013					
Logistic Regression	0.7580	0.7657	0.9736	0.8572	75.63
Decision Tree	0.7461	0.7461	1.0000	0.8546	73.34
Random Forest	0.7875	0.7899	0.9742	0.8725	78.98
Support Vector Machine (SVM)	0.7580	0.7665	0.9717	0.8570	75.27
K-Nearest Neighbour (KNN)	0.7703	0.7840	0.9553	0.8612	77.12
Test data 2024					
Logistic Regression	0.7353	0.7368	0.9782	0.8405	73.51
Decision Tree	0.7132	0.7132	1.0000	0.8326	70.78
Random Forest	**0.7382**	**0.7451**	**0.9620**	**0.8398**	**73.66**
Support Vector Machine (SVM)	0.7348	0.7367	0.9776	0.8402	73.19
K-Nearest Neighbour (KNN)	0.7215	0.7380	0.9450	0.8288	71.15
Training data 2018					
Logistic Regression	0.7580	0.7657	0.9736	0.8572	72.55
Decision Tree	0.7461	0.7461	1.0000	0.8546	70.94
Random Forest	0.7875	0.7899	0.9742	0.8725	74.97
Support Vector Machine (SVM)	0.7580	0.7665	0.9717	0.8570	70.99
K-Nearest Neighbour (KNN)	0.7703	0.7840	0.9553	0.8612	69.66
Test data 2024					

Logistic Regression	0.7353	0.7368	0.9782	0.8405	71.39
Decision Tree	0.7132	0.7132	1.0000	0.8326	72.07
Random Forest	**0.7382**	**0.7451**	**0.9620**	**0.8398**	**76.23**
Support Vector Machine (SVM)	0.7348	0.7367	0.9776	0.8402	72.04
K-Nearest Neighbour (KNN)	0.7215	0.7380	0.9450	0.8288	70.96

Table 4.3a above presents the result for best fit model evaluation and selection for 2003, 2008, 2013, 2018 and 2024. In each of the survey years, the performance of five machine learning tools (logistic regression, decision tree, random forest, support vector machine, k-nearest neighbor) was evaluated using the train-test split metrics such as accuracy, precision, recall, F1-score, and AUC-ROC curve. This enabled the selection of the best-fit model in predicting unmet need for family planning. Across the survey years except in 2003, Random forest performed best with the highest training accuracy (73.87%, 73.66% and 76.23%) and F1-score (0.8370, 0.8398, and 0.8114) respectively. However, in the test data for 2003, decision tress accuracy was highest (73.22%) higher than random forest (73.13%) indicating a better generalization. Overall, random forest consistently had the highest training performance and was the best-fit model based on test performance and generalization ability across the survey years, particularly in 2008, 2013 and 2018. This suggests that complex models capture data and offers a better predictive stability.

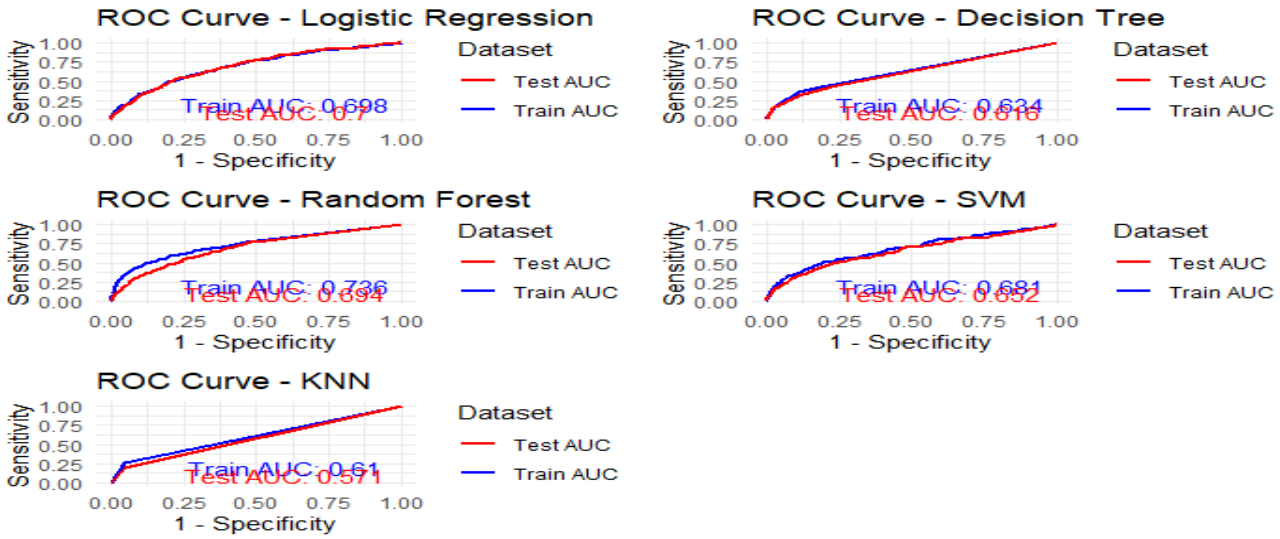

Fig 4.6a ROC (Receiver Operating Characteristic) curves for different machine learning models: Logistic Regression, Decision Tree, Random Forest, SVM, and KNN for 2003 and 2024

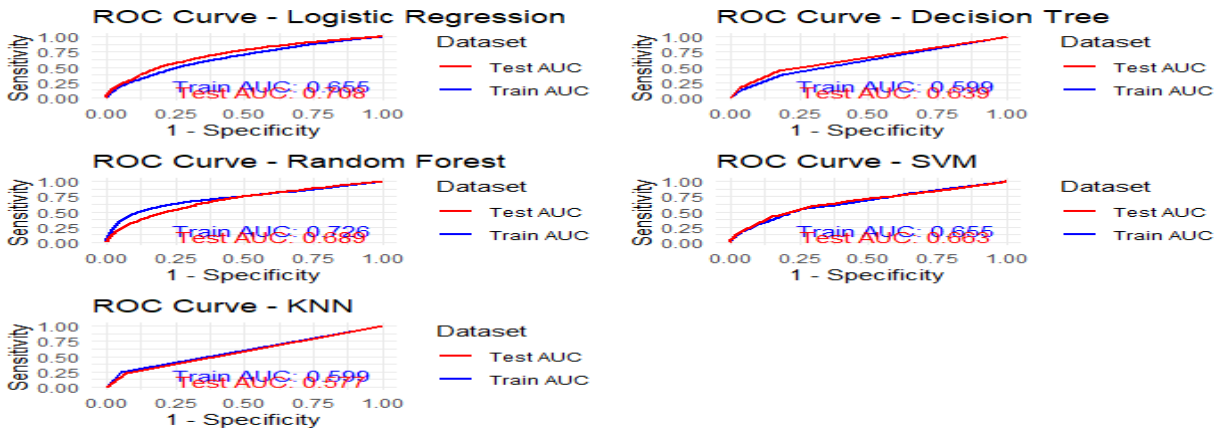

Fig 4.6b ROC (Receiver Operating Characteristic) curves for different machine learning models: Logistic Regression, Decision Tree, Random Forest, SVM, and KNN for 2008 and 2024

4.4 Prioritization of Predictors of UMFP in Order of Relative Importance

Table 4.4a Ranked Dominant Predictors of Unmet Need for Family Planning

2Rank	Ranked Dominant Predictors of UMFP							
	2003 &2024		2008 &2024		2013 & 2024		2018 & 2024	
	Predictors	Average Contribu-tion	Predictors	Average Contribu-tion	Predictors	Average Contribu-tion	Predictors	Average Contribu-tion
1	**No of surviving children**	0.48	**No of surviving children**	0.49	**No of Surviving Children**	0.43	**No of Survivin g Children**	0.45
2	Ideal number of children	0.33	Age of respondent	0.38	Age of respondent	0.39	Age of respondent	0.35
3	Age of respondent	0.28	Religion	0.31	Religion	0.32	Religion	0.33
4	Ethnicity	0.23	Ideal number of children	0.26	Ethnicity	0.25	Ideal number of children	0.28
5	Religion	0.16	Wealth Index	0.18	Ideal number of children	0.17	Wealth Index	0.19

6	Wealth Index	0.10	Ethnicity	0.11	Wealth Index	0.11	Ethnicity	0.12
7	Visited HF & discussed FP	0.08	Partner's age	0.09	Age at First cohabitation	0.07	Currently resides with husband	0.09
8	Sex of household head	0.05	Knows FP source	0.06	Education	0.05	Age at First cohabitation	0.06
9	Residence	0.02	Age at First cohabitation	0.04	FP info on media	0.03	Education	0.04
10	Region	0.0	Residence	0.01	Residence	0.00	Partner's desire for children	0.01

Table 4.4a presents the ranking of dominant predictors based on their contribution to unmet need for family planning among married women of reproductive age from 2003 to 2024 in Nigeria. The scores quantify the relative importance of each predictor to unmet need among the study population. This table also reports predictors' relative contributions and shifts in importance over time. Across the survey years, the number of surviving children (0.49, 0.49, 0.43, 0.45) is the strongest predictor of unmet need for family planning. Its contribution has remained high and even increased slightly over time, and at its peak in 2013, reflecting a strong link between fertility experience and demand for family planning as childbearing experience remains the strongest determinant.

Age was consistently observed as a key factor as it ranked second in 2003, 2008, and 2018, but was not a dominant predictor in 2003: thus, its high contribution (0.38, 0.39, 0.35) suggests age-related differences of married women affect the unmet need for family planning across age groups. On the other hand, religion was reported as a key predictor. In terms of ethnicity, it slightly increased dominance in 2008 (0.26) compared to 2003 (0.23), indicating the impact of sociocultural influences on unmet need for family planning. In summary, age, religion, ideal number of children, wealth were dominant predictors of unmet need for family planning has they are all above the threshold (0.10), but fluctuated in rank over time.

Other variables such as residence, age at first cohabitation, was a low-ranking but persistent predictors, while residing with husband reported a declining dominance from 2003 through to 2013, while education emerged as a relevant predictor in 2018, though low-ranked. In conclusion, the number of surviving children, age, ideal number of children, religion, and wealth are the strongest predictors. Conversely, consistently lower-ranked factors (residence, age at cohabitation, ethnicity, currently residing with husband) may have a minimal but direct impact on unmet need for family planning among MWRA, as they were below the threshold of dominance (0.10), though were repeatedly persistent predictors across the survey years.

Fig 4.10 Trend of Dominant Predictors of UMFP from 2003 to 2024

Fig 4.10 shows the trend of dominant predictors of UMFP from 2003 to 2008. The dominance scores of

top predictors for unmet need for family planning show a clear hierarchy in terms of their relative importance. The number of surviving children remained the most dominant predictor, reporting about 50% of the total dominance score in 2003 and about 40% in other years. Indicating that the number of living children a woman has strongly influences the probability of experiencing unmet need for family planning. Age was reported as the second most important predictor in 2008, 2013, and 2018, showing a significant increase from previous years to nearly 30% in 2018, suggesting that age-related factors became more critical in determining unmet need for family planning.

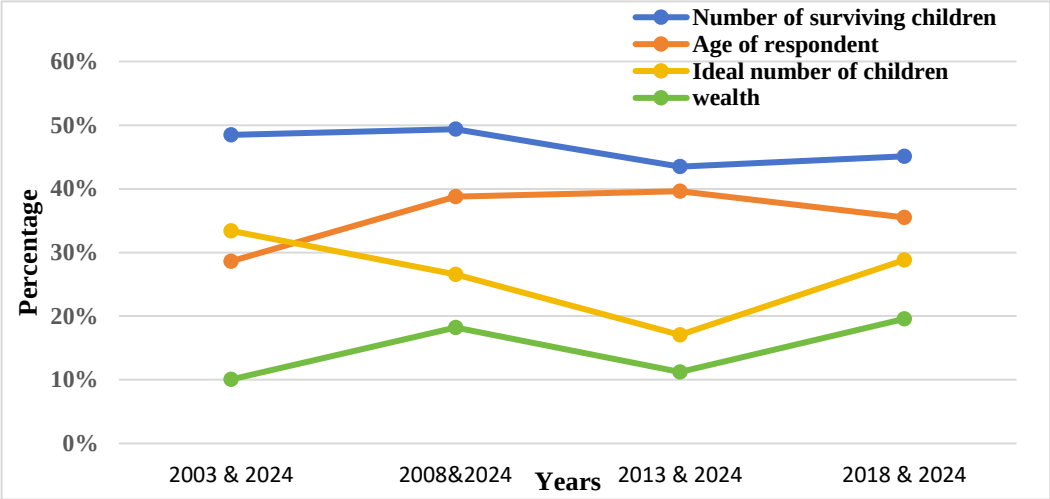

Fig 4.10 Trend of Dominant Predictors of UMFP from 2003 to 2024

4.5 Estimated Probabilities of Unmet Need for Family Planning

Table 4.5a Predicted Proportion of UMFP among Married Women of Reproductive Age by Residence Using the Best-Fit Model (Random Forest Model) and Dominant Predictors (2003-2024)

Residence	Dominant Predictors (No of surviving children ≥5; Ideal no of Children ≥5; Age (35-49); Wealth(rich)									Pro. of UMFP (%)
	Ethnicity			Religion			Wealth			
	Yoruba	Igbo	Hausa/ Fulani	Christianity	Islam	Trad/ others	Poor	Mid	Rich	Total
	✓	-	-	✓	-	-	✓	-	-	55.8
	✓	-	-	-	-	✓	✓	-	-	52.8

Urban	✓	-	-	✓		-	-	✓	-	**79.4(2)**
	-	-	✓	-	-	✓	✓	-	-	50.2
	✓	-	-	-	-	✓	-	✓	-	65.2
	✓	-	-	✓	-	-	-	-	✓	**81.2(1)**
	✓	-	-	-	-	✓	-	-	✓	63.4
	-	-			-	-	-	-	✓	53.6
	-	✓	-	✓		-	-	-	✓	**68.8(3)**
Rural	✓	-	-			✓	✓			50.6
		✓	-	✓			✓			56
	✓	-	-	✓				✓		57.4
	-	✓	-	✓				✓		**66.4(3)**
	✓		-	✓					✓	**82.2(1)**
	✓	-		-		✓			✓	54.2
	-	-	✓	✓					✓	62.6
		✓		✓					✓	**71.0(2)**

Table 4.5b Predicted Proportion of UMFP among Married Women of Reproductive Age by Residence Using the Best-Fit Model (Random Forest Model) and Dominant Predictors (2008-2024)

Residence	**Dominant Predictors (No of surviving children ≥5; Ideal no of Children ≥5; Age (35-49); Wealth**									**Pro. of UMFP (%)**
	Ethnicity			**Religion**			**Wealth**			
	Yoruba	**Igbo**	**Hausa/ Fulani**	**Christianity**	**Islam**	**Trad/ others**	**Poor**	**Mid**	**Rich**	**Total**
	✓			✓			✓			62.8
		✓		✓			✓			64.8

Urban	✓			✓				✓		57.8
		✓		✓				✓		58
	✓			✓					✓	**90 (1)**
	✓				✓				✓	58.2
	✓					✓			✓	53.6
			✓	✓					✓	**78.6(3)**
			✓		✓				✓	63.8
			✓			✓	✓			51.2
		✓		✓					✓	**88.8(2)**
Rural	✓			✓			✓			57.6
	✓			✓				✓		**65.6(3)**
		✓		✓				✓		63.4
	✓			✓					✓	**83.4(1)**
			✓	✓					✓	64.6
		✓		✓					✓	**81.4(2)**
			✓			✓	✓			50.5

Table 4.5c Predicted Proportion of UMFP among Married Women of Reproductive Age by Residence Using the Best-Fit Model (Random Forest Model) and Dominant Predictors (2013-2024)

Residence	**Dominant Predictors (No of surviving children ≥5; Ideal no of Children ≥5; Age (35-49); Wealth**									**Pro. of UMFP (%)**
	Ethnicity			**Religion**			**Wealth**			
	Yoruba	**Igbo**	**Hausa/ Fulani**	**Christianity**	**Islam**	**Trad/ others**	**Poor**	**Mid**	**Rich**	**Total**
	✓			✓			✓			52.2

Urban	✓			✓				✓		61.2
		✓		✓				✓		54.6
	✓			✓					✓	**81.2 (1)**
	✓					✓			✓	59.8
			✓	✓					✓	56.4
		✓		✓					✓	**76.2(2)**
		✓		✓				✓		**68.8 (3)**
			✓			✓	✓			52.1
Rural	✓			✓			✓			65.4
		✓		✓			✓			63.2
	✓			✓	✓			✓		53.2
		✓		✓				✓		**69.4(3)**
	✓			✓					✓	**80.4(1)**
			✓	✓					✓	58.2
		✓		✓					✓	**76.2(2)**
			✓			✓	✓			51.2

Table 4.5d Predicted Proportion of UMFP among Married Women of Reproductive Age by Residence Using the Best-Fit Model (Random Forest Model) and Dominant Predictors (2018-2024)

Residence	**Dominant Predictors (No of surviving children ≥5; Ideal no of Children ≥5; Age (35-49); Wealth**									**Pro. of UMFP (%)**
	Ethnicity			**Religion**			**Wealth**			
	Yoruba	**Igbo**	**Hausa/ Fulani**	**Christianity**	**Islam**	**Trad/ others**	**Poor**	**Mid**	**Rich**	**Total**
Urban	✓			✓			✓			76.8
	✓				✓		✓			56
			✓	✓			✓			62.6
		✓		✓			✓			65
	✓			✓				✓		**90.6(3)**

	✓				✓			✓		73.6
	✓					✓		✓		81.2
		✓		✓				✓		90.8
	✓			✓					✓	**97.2(1)**
	✓				✓				✓	86.4
	✓					✓			✓	60.8
			✓	✓					✓	84.4
			✓			✓	✓			53.4
		✓		✓					✓	**91.6(2)**
Rural	✓			✓			✓			82.2
	✓				✓		✓			54.4
	✓					✓	✓			50.4
			✓	✓			✓			72.2
		✓		✓			✓			74.6
	✓			✓				✓		84
	✓				✓			✓		57.4
			✓	✓				✓		81
		✓		✓				✓		**92.8(3)**
	✓			✓					✓	**95.8(1)**
	✓				✓				✓	78.8
	✓					✓			✓	67
			✓			✓	✓			50.1
			✓	✓					✓	82.6
		✓		✓					✓	**95.6(2)**

Table 4.5a to 4.5d presents the predicted proportion of unmet need for family planning among married women of reproductive age group in Nigeria from 2003 to 2024, stratified by the residence type (rural and urban residence), using the best-fit model (Random Forest) with prioritized predictors from the dominant analysis result. These prioritized dominant predictors include number of surviving children (fixed at 5 children), age (woman aged 35- 49 years), ethnicity (Yoruba, Igbo, Hausa/Fulani), and religion (Christianity, Islam, Traditional/others), wealth (poor, middle, rich) as the most dominant predictors. These predictions report persistence and variation in the patterns of unmet need for family planning across different subgroups of Nigerian women. The results consistently highlight Yoruba and Igbo women particularly those affiliated with Christianity having the highest predicted unmet need, while Hausa/Fulani women, regardless of residence or religion, displayed the lowest unmet need across all years.

In the 2003-2018 estimates, the highest predicted unmet need was observed among Yoruba women who lived in rural area and practised Christianity (81.2%), likewise their counter parts who lived in the urban area (80.7%). This was followed closely by Igbo women who are Christians but lives in the rural area (79.4%) and their counterparts in the urban

setting (80.0%). By contrast, the lowest predictions were recorded among Hausa/Fulani women in the rural area practicing traditional or other religions (23.5%) and their counterparts who are Muslims (29.2%). The 2008-2018 predictions, observed the same pattern, rural Yoruba Christians had the highest unmet need (95.0%), with an increase compared to the earlier survey round. Similarly, Igbo women who lived in urban setting and are Christians remained very high at 84.0%, while their counterparts who lived in rural areas predicted 82.2% probability of having unmet needs for family planning.

In contrast, Hausa/Fulani women in rural who are Muslims were (31.2%) and Hausa/Fulani women in urban practicing traditional or other religions were (29.8%) consistently represented the lowest unmet need. By 2013-2018, although the levels of unmet need among some groups appeared to moderate, the general pattern persisted. Yoruba women who reside in the rural area and are Christians continued to record a high unmet need (82.8%), while their counterparts who are practicing traditional or other religions registered 65.8%. Igbo Christians women in the urban area were predicted to experience high unmet need for family planning with 80.6% and their rural counterpart at 76.4%.

On the other hand, Hausa/Fulani women in the urban area who practise traditional/other religion had the lowest unmet need for family planning predictions at 32.8% and their counterpart who are Muslims residing in the rural area had 37.2% probability of have unmet need for family planning. Across the three periods, two striking findings emerge. First, the highest prediction overall was among Yoruba women who live in the rural area and practised Christianity in 2008-2018 (95.0%), while the lowest prediction was consistently among Hausa/Fulani women who reside in the urban area and practised the traditional/other religion in 2003-2018 (23.5%). The Hausa/Fulani women in the urban area practising traditional/other in 2008–2018 (29.8%) was also the lowest. Second, unmet need among Yoruba and Igbo women has remained persistently high across time, particularly among Christians, while Hausa/Fulani women have maintained relatively low levels of unmet need irrespective of survey wave, residence, or religion.

This comparison suggests that cultural and religious contexts play a stronger role than residence alone in shaping unmet need for family planning. Moreover, while overall levels fluctuate slightly across years, the structural disparities between Yoruba/Igbo and Hausa/Fulani populations remain stable, pointing to the need for more culturally tailored interventions. In summary, the predicted UMFP proportions underscore that age, number of surviving children, ethnicity, and religion, are critical predictors of UMFP among Yoruba and Igbo married women who are Christians, as they experience the highest predicted UMFP across the survey years. This highlights the need for targeted interventions addressing socio-cultural.

DISCUSSION

This study provides comprehensive evidence that unmet need for family planning among married women aged 15 to 49 in Nigeria using five waves of Demographic and Health Survey data from 2003 to 2024. The findings reveal that unmet need is shaped by demographic, socioeconomic, cultural and empowerment-related factors. Consistent with findings from the National Population Commission and ICF International reports and prior sub-Saharan African studies, high parity, older age, ideal family size, wealth, religion, ethnicity were central predictors of unmet need, reinforcing arguments by John Bongaarts and John Cleland on fertility preferences shaping contraceptive demand. In this study, Number of surviving children emerged as the most dominant predictor, with higher parity women consistently demonstrating greater unmet need, reflecting a critical tension where women wishing to stop childbearing encounter substantial barriers to contraceptive use. Age ranked second in importance, with women aged 35 to 49 facing significantly elevated unmet need as their fertility preferences shift toward limitation, yet health systems remain inadequately adapted to serve this changing demand. Ideal number of children and wealth emerged as additional critical determinants, illuminating how

fertility norms and economic constraints jointly shape contraceptive access. Poorer women face compound disadvantages including limited affordability, reduced physical access to facilities, weaker media exposure, and diminished household autonomy, suggesting poverty alleviation strategies must integrate with reproductive health interventions. The persistence of higher predicted UMFP among wealthy Yoruba women living in urban areas and practicing Christianity, thus, targeting parity-sensitive and religiously responsive interventions is essential to effectively reduce UMFP in Nigeria.

Methodologically, the integration of dominance analysis and machine learning feature importance tools provided a robust framework for prioritizing intervention targets, quantifying relative contribution of each predictor to explained variance in unmet need. Integration of dominance analysis with machine learning feature importance ranking provided a robust framework for prioritizing intervention targets, quantifying relative contribution of each predictor to explained variance in unmet need. The consistency of key predictors across diverse analytical techniques strengthens confidence in their policy relevance, suggesting number of surviving children, age, ideal family size, and wealth represent genuine structural drivers. These findings support a shift toward predictive analytics in reproductive health monitoring, enabling proactive service delivery and facilitating resource allocation to geographic areas and population subgroups with highest predicted need.Random Forest consistently demonstrated superior predictive stability alignong with ensemble learning theory adavanced by Leo Bremian.

CONCLUSION

This study concludes that unmet need for family planning in Nigeria is a multidimensional challenge rooted in demographic transitions, socioeconomic inequities, and persistent cultural barriers. The dominance of number of surviving children, age, ideal family size, and wealth as predictors points to structural drivers that demand targeted, equity focused interventions particularly for high parity, older, and economically disadvantaged women. Ultimately, reducing unmet need requires moving beyond one size fits all programs toward culturally competent strategies that address the specific needs of diverse ethnic and religious communities, while strengthening postpartum counseling, male involvement, and rural service delivery to bridge the gap between fertility intentions and contraceptive use.

Recommendations

Based on the findings from this study, the following recommendations are made:

i. Strengthen interventions for women with large family size. Postpartum and women with more children should be prioritized for family planning counseling and uptake through strengthened postnatal and community-based programs.

ii. Implement region- and culture-specific interventions in Northern Nigeria, with active engagement of religious and traditional leaders to address cultural barriers to contraceptive use.

iii. Integrate predictive analytics into family planning programming. The predictive models (e.g., random forest) should be embedded into national health information systems to identify and target high-risk women more efficiently.

iv. Promote policies that address access to Family planning programs among older women with more children, alongside religiously sensitive interventions.

Contributions to Knowledge

i. Unlike prior studies with numerous determinants UMFP over the years, this study identified optimal predictors of UMFP and ranked dominant factors by relative importance.

ii. The use of machine learning to determine the best-fit model to predict UMFP improved understanding of key drivers of UMFP over 20 years, enabling a more targeted family planning strategies in Nigeria

iii. Applying dominance analysis introduced a rigorous method for ranking predictors, enhancing interpretability, generalisability and robustness for large Public health dataset.

iv. The study highlighted persistent cultural disparities, particularly the higher burden of unmet need in Southern Nigeria and among christian women, informing religious sensitive interventions.

v. It developed a policy-relevant predictive and explanatory framework that can be integrated into Nigeria's reproductive health systems for evidence-based planning and targeted interventions.

REFERENCES

Abdulai, M., Kenu, E., Ameme, D., Bandoh, D., Tabong, P., Lartey, A., Noora, C., Adjei, E., & Nyarko, K. (2020). Demographic and socio-cultural factors influencing contraceptive uptake among women of reproductive age in Tamale Metropolis, Northern Region, Ghana. *Ghana Medical Journal*, *54*(2), 64–72. https://doi.org/10.4314/gmj.v54i2s.11

Abdulrazaq, A. G., Kabir, S., Mohammad, N. S., & Suleiman, I. H. (2014). The effect of educational intervention on family planning knowledge, attitudes, and practices among married women in a military barrack in northern Nigeria. *African Journal of Reproductive Health*, *18*(1), 93–101.

Adedini, S. A., Omisakin, O. A., & Somefun, O. D. (2019). Trends, patterns and determinants of long-acting reversible methods of contraception among women in sub-Saharan Africa. *PLOS ONE*, *14*(6), e0217574. https://doi.org/10.1371/journal.pone.0217574

Aduloju, O. P., Akintayo, A. A., Adefisan, A. S., & Aduloju, T. (2021). Utilization of Long-Acting Reversible Contraceptive (LARC) Methods in a tertiary hospital in southwestern Nigeria: A Mixed Methods Study. *The Journal of Obstetrics and Gynecology of India*, *71*(2), 173–180. https://doi.org/10.1007/s13224-020-01386-6

Agadjanian, V. (2013). Religious Denomination, Religious Involvement, and Modern Contraceptive Use in Southern Mozambique. *Studies in Family Planning*, *44*(3), 259–274. https://doi.org/10.1111/j.1728-4465.2013.00357.x

Agyei-Baffour, P., Boahemaa, M. Y., & Addy, E. A. (2015). Contraceptive preferences and use among auto artisanal workers in the informal sector of Kumasi, Ghana: A discrete choice experiment. *Reproductive Health*, *12*(1), 32. https://doi.org/10.1186/s12978-015-0022-y

Ahinkorah, B. O. (2020). Predictors of modern contraceptive use among adolescent girls and young women in sub-Saharan Africa: A mixed effects multilevel analysis of data from 29 demographic and health surveys. *Contraception and Reproductive Medicine*, *5*(1), 32. https://doi.org/10.1186/s40834-020-00138-1

Ahmed, M., & Seid, A. (2020). Association between Exposure to Mass Media Family Planning Messages and Utilization of Modern Contraceptive among Urban and Rural Youth Women in Ethiopia. *International Journal of Women's Health*, *Volume 12*, 719–729. https://doi.org/10.2147/IJWH.S266755

Ajzen, I. (1991). The theory of planned behavior. Organizational behavior and human decision processes, 50(2), 179-211.

Akamike, I. C., Okedo-Alex, I. N., Eze, I. I., Ezeanosike, O. B., & Uneke, C. J. (2020). Why does uptake of family planning services remain sub-optimal among Nigerian women? A systematic review of challenges and implications for policy. *Contraception and Reproductive Medicine*, *5*(1), 30. https://doi.org/10.1186/s40834-020-00133-6

Akilimali, P., Anglewicz, P., Engale, H. N., Kurhenga, G. K., Hernandez, J., Kayembe, P., & Bertrand, J. (2018). Differences in family planning outcomes between military and general populations in Kinshasa, Democratic Republic of the Congo: A cross-sectional analysis. *BMJ Open*, *8*(12), e022295. https://doi.org/10.1136/bmjopen-2018-022295

Akinyemi, J. O., Dipeolu, O. I., Adebayo, A. M., Gbadebo, B. M., Ajuwon, G. A., Olowolafe, T. A.,

Adewoyin, Y., & Odimegwu, C. O. (2022). Social consequences of COVID-19 on fertility preference consistency and contraceptive use among Nigerian women: Insights from population-based data. *Contraception and Reproductive Medicine*, *7*(1), 14. https://doi.org/10.1186/s40834-022-00181-0

Aleni, M., Mbalinda, S. N., & Muhindo, R. (2020). Birth Intervals and Associated Factors among Women Attending Young Child Clinic in Yumbe Hospital, Uganda. *International Journal of Reproductive Medicine*, *2020*, 1–11. https://doi.org/10.1155/2020/1326596

Aliyu, A. A. (2018). Family Planning Services in Africa: The Successes and Challenges. In Z. O. Amarin (Ed.), *Family Planning*. InTech. https://doi.org/10.5772/intechopen.72224

Amoah, E. J., Hinneh, T., & Aklie, R. (2023). Determinants and prevalence of modern contraceptive use among sexually active female youth in the Berekum East Municipality, Ghana. *PLOS ONE*, *18*(6), e0286585. https://doi.org/10.1371/journal.pone.0286585

Angko, W., Arthur, E., & Yussif, H. M. (2022). Fertility among women in Ghana: Do child mortality and education matter? *Scientific African*, *16*, e01142. https://doi.org/10.1016/j.sciaf.2022.e01142

Ashore, A., Erkalo, D., & Prakash, R. (2022). Dual contraceptives and associated predictors in HIV positive women: A case–control study. *Reproductive Health*, *19*(1), 168. https://doi.org/10.1186/s12978-022-01475-x

Asresie, M. B., Fekadu, G. A., & Dagnew, G. W. (2020). Contraceptive use among women with no fertility intention in Ethiopia. *PLOS ONE*, *15*(6), e0234474. https://doi.org/10.1371/journal.pone.0234474

Ayala-Marín, A. M., Iguacel, I., Miguel-Etayo, P. D., & Moreno, L. A. (2020). Consideration of Social Disadvantages for Understanding and Preventing Obesity in Children. *Frontiers in Public Health*, *8*, 423. https://doi.org/10.3389/fpubh.2020.00423

Babalola, S., John, N., Ajao, B., & Speizer, I. (2015). Ideation and intention to use contraceptives in Kenya and Nigeria. *Demographic Research*, *33*, 211–238. https://doi.org/10.4054/DemRes.2015.33.8

Babalola, S., Oyenubi, O., Speizer, I. S., Cobb, L., Akiode, A., & Odeku, M. (2017). Factors affecting the achievement of fertility intentions in urban Nigeria: Analysis of longitudinal data. *BMC Public Health*, *17*(1), 942. https://doi.org/10.1186/s12889-017-4934-z

Bado, A. R., Badolo, H., & Zoma, L. R. (2020). Use of Modern Contraceptive Methods in Burkina Faso: What are the Obstacles to Male Involvement in Improving Indicators in the Centre-East and Centre-North Regions? *Open Access Journal of Contraception*, *Volume 11*, 147–156. https://doi.org/10.2147/OAJC.S274570

Bekele, D., Surur, F., Nigatu, B., Teklu, A., Getinet, T., Kassa, M., Gebremedhin, M., Gebremichael, B., & Abesha, Y. (2020). Knowledge and Attitude towards Family Planning Among Women of Reproductive Age in Emerging Regions of Ethiopia. *Journal of Multidisciplinary Healthcare*, *Volume 13*, 1463–1474. https://doi.org/10.2147/JMDH.S277896

Bertrand, J. T., Ross, J., Sullivan, T. M., Hardee, K., & Shelton, J. D. (2020). Contraceptive Method Mix: Updates and Implications. *Global Health: Science and Practice*, *8*(4), 666–679. https://doi.org/10.9745/GHSP-D-20-00229

Beyene, G. A. (2019). Prevalence of unintended pregnancy and associated factors among pregnant mothers in Jimma town, southwest Ethiopia: A cross sectional study. *Contraception and Reproductive Medicine*, *4*(1), 8. https://doi.org/10.1186/s40834-019-0090-4