

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

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## Abstract

### 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 ( $\Delta R^2 \geq 0.10$ ) prioritised their relative contributions. Decision trees, random forest, support vector machine and KNN models were trained on 2003-2018 data 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  $\Delta R^2$  ranging from 0.43-0.49, age ( $\Delta R^2$ : 0.33- 0.39), ideal number of children ( $\Delta R^2$ : 0.17-0.33), religion ( $\Delta R^2$ : 0.16-0.33), and wealth index ( $\Delta R^2$ : 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 to 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 as 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 an 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). Also, a multi-country study in SSA reported 23.7% unmet need for family planning among women (Teshale, 2022). African countries bear 20% of unmet need for family planning compared to 10% in the world (UNDESA, 2022). In developing countries approximately 257 million women have unmet needs for family planning, with about 17% of them married and wish to delay, space, or limit their fertility but aren't using any form of 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).

have shown several socio-economic and demographic factors at individual, household and community levels associated with unmet need for family planning in Nigeria and other countries.

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 5 years (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).

## Literature Review

In the last three decades, rapid progress has been made in reducing unmet need for family planning across the world. Unmet need for family planning in developed nations of the world declined from 10.7% to 9.3% between 1990 and 2010 (UNDESA, 2022). Globally, about 257 million women have unmet need for family planning (UMFP) and 84% live in low- and middle-income countries (UNFPA, 2022). Although the population of women of reproductive age experienced a 46% increase between 1990 and 2021. (UNDESA, 2022), UMFP still experienced a decrease from 15.4% in 1990 to 9.8% in 2019 and 9.4% in 2021 (UN, 2022). In developing nations, unmet need for family planning declined from 16.5% to 12.8% among married women between 1990 and 2010 (UNDESA, 2022). In Africa, there was also a noticeable decline from 26.4% to 23.2% at the same period. (UNDESA, 2022). Although, regional disparities exist across Africa, Middle Africa and Western Africa experienced very little change in unmet need for family planning from 26.3% to 26.1% in Middle Africa and 24.9% in 1990 to 25.4% in 2010 (Alkema et al., 2013).

Within the same time period, other regions in Africa experienced noticeable decline in unmet need for family planning from 23.6% to 14.9% in Northern Africa. In Asia, unmet need for family planning reduced from 14.6% in 1990 to 11% in 2010, same was reported in Latin America and the Caribbean with 16.9% in 1990 to 10.4% in 2010 (Alkema et al., 2013). The number of married women having an unmet need for family planning between 2010 and 2015 remained at 15 million women in developed nations, but in developing nations, the number grew from 131 million women to 138 million women. (Alkema et al., 2013). According to the Demographic and Health Survey conducted in 37 countries in sub-Saharan Africa, SSA has the highest unmet need for family planning of 23% among married women. However, UMFP varies from nation to nation with Zimbabwe

having the lowest rate (10%) while the highest rate (38%) is reported in Sao Tome and Principe and Angola (Phiri et al., 2023). In South Africa, Ghana, Kenya and Nigeria UMFP is 20%, 30%, 14%, 19% respectively (World Family Planning UN, 2022). In Nigeria, the trend of UMFP was 18%, 20%, 16% and 19% from 2003 to 2018 respectively (NPC/ICF, 2019). However, within age group, the youngest age group (15-19) reported a decrease in UMFP from 13.1% in 2013 to 12.2% in 2018. Similar pattern was found among the next older age group (20-24), UMFP reduced from 16.6% to 16.1% around the same period (NPC/ICF, 2019).

## Determinants Unmet Need for Family Planning

Many studies have shown that there are a number of socioeconomic, demographic factors which may be associated with unmet need for family planning among fecund women. Some of the demographic factors identified are: age of respondents, age at first cohabitation, age at first sexual intercourse, partners age, number of surviving children and sex of house head (Ejembi *et al.*, 2015; Ibisomi 2014; Oyediran *et al.*, 2002). Socio-economic factors identified by literature include level of education, no of unions, region, wealth, place of residence, family type etc (Ejembi *et al.* 2015; Odewale, Oiadusun, and Amoo 2016; Sekoni and Oladoyin 2016; Okigbo *et al.* 2017) In 2021, an estimated 257 million women aged 15 to 49 worldwide have unmet need or has expressed desire to postpone or prevent pregnancy (United Nations Population Fund, 2022).

Several studies in sub-Saharan Africa (Ahinkorah et al., 2020, Mulenga et al., 2020, Gahungu et al., 2021), particularly in developing countries has suggested some level of association between unmet need for family planning and religion. While many studies could not find association of unmet need with religion. In assessing regional differences in unmet need for contraception among women of reproductive age in Kenya using the Kenya

Demographic and Health Survey. Wafula (2015) found association between unmet need for contraception and religious affiliation of respondents. Protestant married women had the lowest unmet need irrespective of their region. Roman Catholic married women had the highest unmet need. In low unmet need zone, Muslim married women had the highest unmet need. His findings also showed that, regardless of location, Catholic married women had the greatest unmet need for family planning.

In a multi-stage stratified study conducted to address unmet need and religious barrier towards the use of family planning among 70,016 currently married in India. The findings of the study shows that about 9% of Muslim women in India have unmet need for family planning due religious resistance. Patra & Singh (2015) also found religious opposition against family planning was found higher among older women 10.3, 10.7 and 10.1 per cent among 35-39, 40-44 and 45-49 respectively.

In another study conducted in Mali on women's healthcare decision-making and unmet need for contraception among 6593 married women of reproductive age using the Mali Demographic Health Survey. Ameyaw et al (2022) found that unmet needs were highest among those with no religious affiliation (39.7) followed by traditional worshipers (32.3). The Christians and Muslims had nearly equal level of unmet need for family planning with a prevalence rate of 26.2 and 26.9 respectively. The binary logistic regression analysis revealed that those without any religious affiliation are likely to report unmet need for contraception compared to Muslim women (AOR=1.53, CI=1.07-2.19).

Similarly, a cross-sectional study (Teshale, 2022) conducted in nineteen countries in sub-Saharan Africa using their demographic and health surveys (DHS) conducted between 2015 and 2020 to assess the factors associated with unmet need for family planning. A weighted sample of 175, 820 married women

of reproductive age. This study used a multilevel multinomial logistic regression model for assessing these factors. Findings reported both individual and community level factors to be associated with unmet need for family planning among respondents. Unmet need for contraception was found to be significantly influenced by place of residence. The odd of unmet need was higher among women living in urban centers compared to their counterparts living in the rural areas. Several other studies conducted in Nigeria has shown the link between women's place of residence and unmet need for family planning. These studies conducted in different part of Nigeria demonstrated the significant contribution of place of residence and unmet need for family planning. (Michael et al., 2021; Ekholuenetale et al., 2021; Undelikwo et al., 2023)

### **Studies that used Dominance Analysis and Machine Learning Algorithm**

In a study conducted in Ethiopia on predicting unmet need for family planning in Ethiopia using machine learning methods by (Kebede et al., 2023) used nationally representative PMA 2019 data, among 5,819 women aged 15-49. The study compared machine learning models such as logistic regression, decision tree, support vector machine, K-Nearest Neighbors, AdaBoost, and random forest. The random forest model was the best fit and proceeded to use SHAP to rank predictors. The findings from these study reported random forest achieved AUC 0.78, accuracy 0.72, sensitivity 0.79, specificity 0.64. The strongest positive contributors to unmet need were husband/partner disapproval, larger household size, low respondent education, residence in Amhara, and no facility delivery in the most recent birth. In Bangladesh, a study on factors associated with post-natal care utilization among high-order birth mothers was conducted using dominance analysis (Shabuz et al., 2025). The study analyzed a nationally representative survey of about 1,740 mothers. Dominance analysis was

employed to partition the variance explained by demographic, socioeconomic predictors. Results indicated that mass-media exposure, wealth quintile, educational attainment, and facility delivery had the largest dominant contributions, surpassing the effects of age and parity. Although, the study focused on postnatal care, the findings have implications on family planning, as these determinants strongly align with drivers of family planning demand and postpartum contraception uptake.

Similarly, a study in Bangladesh investigated whether education and living standards influence barriers to healthcare access among women using a dominance analysis approach (Akter et al., 2023). Using a nationally representative Demographic and Health Survey dataset conducted comprising 19,345 sexually active women, this study identified household wealth and spousal education as the most dominant factors explaining barriers to healthcare, ahead of demographic variables such as age and residence. These barriers such as cost, permission, and distance are closely linked with family planning. Another study on explainable machine learning for modeling the predictors of unintended pregnancy by (Agarwal et al., 2024) using 29,757 women pooled weighted sample from 2005, 2011 and 2016 Rwanda Demographic Health Survey women. Random Forest model, Logistic Regression, Naïve Bayes, Linear/Quadratic Discriminant, SVM. random forest performed best and SHAP was used for model interpretability. The findings reported that top drivers of unintended pregnancy was unmet need for contraception, children ever born, ideal number of children, marital status, age, parity, educational attainment, wealth, and residence.

In a study conducted in East Africa on used machine learning algorithms to predict non-use of modern contraception among married women in East Africa (Yehuala et al., 2024) using 92,564 women 15-49 currently in union from pooled Demographic and Health Survey

from several countries of East Africa. Multiple machine learning algorithms were employed and XGBoost was reported best with as accuracy of 98.7%, further interpretation was with SHAP. The findings from this study reported non-use clustered among women with no or low education, ages 25-29, rural residence, not knowing how to use a method, and limited media exposure. In a cross-sectional study on predictors of informed contraceptive choice in six sub-Saharan African countries by (Melaku et al., 2025). Pooled weighted sample of 23,822 women from Demographic Health Survey was used. The study compared different tree-based machine learning models and identified the best-performing model as random forest model, using SHAP values and partial dependence plots for interpretability. Findings revealed that provider counseling quality, media exposure, educational attainment, method availability by source, and household wealth were the strongest predictors of informed contraceptive choice.

### 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; Olike *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; Adebawale 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 (Orijii *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. The study captured a snapshot of the population at a specific point in time, allowing for the examination of associations and characteristics within that period. This NDHS datasets provided a rich source of data for the study, enabling the exploration of key research questions and the analysis of important trends related to demographic and health factors in Nigeria. Analytical approach was used to achieve the study objectives.

### 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](mailto: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. Background and reproductive characteristics such as age, level

of education, religion, region, satisfied family planning, ethnicity, wealth quintile, media exposure, and fertility preference were controlled. 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 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 prioritise 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 probability of UMFP was deduced by holding the dominant predictors constant at number of surviving children  $\geq 5$ ; high fertility desire, ideal no of Children  $\geq 5$ ; 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 4.1a presents the percentage distribution of the demographic characteristics of participants in 2003, 2008, 2013, 2018 and 2024 NDHS. A total of 16,111 married women of reproductive age were extracted in 2024, 19,318 in 2018, 18,600 in 2013 and 17,316 in 2008 and 3,651 in 2003. Table 4.1 reveals the distribution of participants across three age groups: 15-24, 25-34, and 35-49. In all three-survey years, the age group 25-34 was the most populous, comprising 42.1% in 2003 and 44.3% in 2024. The mean age of the participants rose minimally from 28.8 years in 2003 to 30.0 years in 2024. The distribution by age at first cohabitation a significant majority of respondents cohabited before the age of 18, with the percentages being 65.5% in 2003, 47.0% in 2024.

Table 4.1b presents the percentage distribution of women of reproductive age by socioeconomic characteristics in 2003, 2008, 2013, 2018 and 2024 NDHS. In 2003, the proportion of women who married more than once, increased consistently from 81.3% in 2003 to 92.0% in 2024. For educational attainment of respondent, in 2003 the data showed that 54.6% of the women had no formal education, this pattern was sustained across other survey years. With respect to family type, monogamy was more pronounced across the years than polygamy, with 6 in 10 women practising monogamy in all survey rounds except in 2024 which was higher (72.0%).

Table 4.1c presents the percentage distribution of women of reproductive age by socioeconomic characteristics in 2003, 2008, 2013, 2018 and 2024 NDHS. In terms of wealth quintile, respondents were classified into different wealth quintiles: "Poor," "Middle," and "Rich.", about half of the respondent were poor from 45.2% in 2003 to 49.0% in 2024. Across the survey years,

women whose partner wanted more children were the highest from 32.8% in 2008 to 41.1% in 2024. Majority of the respondents resided with their partner from 91.3% in 2003 to 90.0% in 2024.

**Table 4.1a Demographic Characteristics of Married Women of Reproductive age 15-49 years in Nigeria, 2003-2024**

Characteristics	2003	2008	2013	2018	2024
	N=3651	N=17316	N=18600	N=19318	N=16111
	n (%)				
<b>Age</b>					
15-24	1143(31.3)	5153(29.8)	5474(29.4)	5388(27.9)	4260(26.4)
25-34	1536(42.1)	7381(42.6)	8076(43.4)	8417(43.6)	7137(44.3)
35-49	972(26.6)	4782(27.6)	5050(27.2)	5513(28.5)	4714(29.3)
<b>Mean age ±S.D</b>	<b>28.8 ± 8.1</b>	<b>29.1 ± 8.0</b>	<b>29.1 ± 7.9</b>	<b>29.5 ± 7.8</b>	<b>30.0 ± 7.7</b>
<b>Age at First Cohabitation</b>					
0-17	2390(65.5)	10847(62.6)	11295(60.7)	10844(56.1)	7576 (47.0)
18 -24	1040(28.5)	5105 (29.5)	5758 (31.0)	6282 (32.5)	6270 (38.9)
25+	221 (6.1)	364 (7.9)	1547 (8.3)	2192 (11.3)	2265 (14.1)
<b>Mean age ±S.D</b>	<b>16.8 ± 4.3</b>	<b>17.3 ± 4.4</b>	<b>17.5 ± 4.5</b>	<b>18.1 ± 4.9</b>	<b>18.9 ± 5.1</b>
<b>Age At First Sexual Intercourse</b>					
0-14	438 (12.0)	2367 (13.7)	769 (4.1)	4112 (21.3)	2438 (15.1)
15-17	610 (16.7)	5052 (29.2)	2242 (12.1)	9098 (47.1)	7419 (46.0)
18-24	581 (15.9)	3252 (18.8)	2335 (12.6)	5613 (29.1)	5795 (36.0)
25+	2022(55.4)	6645 (38.4)	13254(71.3)	493 (2.6)	459 (2.8)
<b>Mean age ±S.D</b>	<b>16.7 ± 3.3</b>	<b>16.7 ± 3.1</b>	<b>17.5 ± 3.1</b>	<b>16.6 ± 3.0</b>	<b>17.1 ± 3.0</b>
<b>Partners Age</b>					
15-24	123 (3.4)	645 (3.8)	667 (3.6)	536 (2.8)	451 (2.8)
25-34	1047(29.0)	5014 (29.5)	5380 (28.9)	5435 (28.1)	4119 (25.6)
35+	2442(67.6)	11341(66.7)	12553(67.5)	13347(69.1)	11541(71.6)
<b>Mean age ±S.D</b>	<b>40.1 ± 11.1</b>	<b>39.7 ± 11.0</b>	<b>40.1 ± 11.9</b>	<b>40.1 ± 10.5</b>	<b>40.7 ± 10.2</b>
<b>Ideal Number of Children</b>					
0-2	33 (1.0)	507 (3.5)	257 (1.5)	655 (3.5)	769 (4.9)
3 to 4	507 (16.1)	2646 (18.0)	3104 (18.2)	3685 (19.6)	3988 (25.5)
5+	2603(82.8)	11518(78.5)	13682(80.3)	14492(77.0)	10891(69.6)
<b>Number of Surviving Children</b>					
0-2	297 (31.3)	1652 (33.0)	1526 (32.2)	1481 (26.7)	1577 (29.5)
3 to 4	250 (26.3)	1493 (29.8)	1357 (28.7)	1720 (31.0)	1780 (33.3)

5+	402 (42.4)	1860 (37.2)	1850 (39.1)	2340 (42.2)	1997 (37.3)
<b>Parity</b>					
0-2	1442(39.5 )	6653 (38.4)	7335 (39.4)	7410 (38.4)	6609 (41.0)
3 to 4	875 (24.0)	4356 (25.2)	4589 (24.7)	5050 (26.1)	4489 (27.9)
5+	1334(36.5 )	6307 (36.4)	6676 (35.9)	6858 (35.5)	5013 (31.1)
<b>Sex of House Head</b>					
Male	3406(93.3 )	15885(91.7 )	17029(91.6 )	17817(92.2 )	14531(90.2 )
Female	245 (6.7)	1431 (8.3)	1571 (8.4)	1501 (7.8)	1580 (9.8)

**Table 4.1b Distribution of Socioeconomic Characteristics of Married Women of Reproductive age 15-49 years in Nigeria, 2003-2024**

Characteristics	2003	2008	2013	2018	2024
	N=3651	N=17316	N=18600	N=19318	N=16111
	n (%)	n (%)	n (%)	n (%)	n (%)
<b>No of Unions</b>					
Once(1)	2951(81.3 )	14606(84.8 )	15943(86.9 )	17046(88.2 )	14818(92.0 )
1+	678 (18.7)	2616 (15.2)	2404 (13.1)	2272 (11.8)	1293 (8.0)
<b>Highest Educational Status</b>					
No education	1992(54.6 )	9557 (55.2)	9734 (52.3)	9681 (50.1)	7780 (48.3)
Primary	827 (22.7)	3630 (21.0)	3584 (19.3)	2932 (15.2)	1844 (11.4)
Secondary	687 (18.8)	3352 (19.4)	4262 (22.9)	5385 (27.9)	4914 (30.5)
Tertiary	145 (4.0)	777 (4.5)	1020 (5.5)	1320 (6.8)	1573 (9.8)
<b>Partner Education</b>					
No education	1522(41.9 )	7667 (44.7)	7764 (41.7)	7502 (38.8)	6604 (41.0)
Primary	870 (24.0)	3409 (19.9)	3368 (18.1)	2750 (14.2)	1589 (9.9)
Secondary	804 (22.1)	4213 (24.5)	4997 (26.9)	6180 (32.0)	5048 (31.3)
Tertiary	413 (11.4)	1752 (10.2)	2282 (12.3)	2584 (13.4)	2648 (16.4)
Don't know	23 (0.6)	122 (0.7)	189 (1.0)	302 (1.6)	222 (1.4)
<b>Family Type</b>					
Monogamy	2305(63.4 )	11071(64.4 )	12048(65.2 )	13190(68.5 )	11587(62.0 )
Polygamy	1328(36.6 )	6128 (35.6)	6430 (34.8)	6075 (31.5)	4495 (38.0)
<b>Region</b>					
North-Central	607 (16.6)	3166 (18.3)	2836 (15.2)	3468 (18.0)	5440 (33.8)

North-East	903 (24.7)	4144 (23.9)	4221 (22.7)	4209 (21.8)	3259 (20.2)
North-West	1198(32.8)	5341 (30.8)	6604 (35.5)	6415 (33.2)	3191 (19.8)
South-East	289 (7.9)	1165 (6.7)	1140 (6.1)	1691 (8.8)	1449 (9.0)
South-South	289 (7.9)	1652 (9.5)	1939 (10.4)	1679 (8.7)	1464 (9.1)
South-West	365 (10.0)	1848 (10.7)	1860 (10.0)	1856 (9.6)	1308 (8.1)
<b>Residence</b>					
Urban	1221(33.4)	4193 (24.2)	5421 (29.1)	6005 (31.1)	5721 (35.5)
Rural	2430(66.6)	13123(75.8)	13179(70.9)	13313(68.9)	10390(64.5)
<b>Ethnicity</b>					
Others	1348(37.0)	6829 (39.6)	7246 (39.0)	6766 (35.0)	5945 (36.9)
Yoruba	342 (9.4)	1719 (10.0)	1612 (8.7)	1758 (9.1)	1225 (7.6)
Hausa/Fulani	1558(42.8)	7243 (42.0)	8324 (44.8)	8777 (45.4)	7225 (44.8)
Igbo	393 (10.8)	1439 (8.4)	1418 (7.6)	2017 (10.4)	1716 (10.7)
<b>Religion</b>					
Christianity	1284(35.2)	6328 (36.8)	6352 (34.2)	6743 (34.9)	5462 (33.9)
Islam	2302(63.1)	10544(61.3)	11948(64.2)	12432(64.4)	10556(65.5)
Trad/Others	64 (1.8)	337 (2.0)	300 (1.6)	143 (0.7)	93 (0.6)
<b>Working Status</b>					
Not Working	1389(38.2)	6568 (38.2)	6286 (33.9)	6670 (34.5)	6908 (42.9)
Working	2247(61.8)	10646(61.8)	12235(66.1)	12648(65.5)	9203 (57.1)

**Table 4.1c Distribution of Socioeconomic Characteristics of Married Women of Reproductive age 15-49 years in Nigeria, 2003-2024**

Characteristics	2003	2008	2013	2018	2024
	N=3651	N=17316	N=18600	N=19318	N=16111
	n (%)	n (%)	n (%)	n (%)	n (%)
<b>Wealth index</b>					
Poor	1651(45.2)	9316 (53.8)	9315 (50.1)	9704 (50.2)	7891 (49.0)
Middle	751 (20.6)	3329 (19.2)	3640 (19.6)	3920 (20.3)	3109 (19.3)
Rich	1249(34.2)	4671 (27.0)	5645 (30.3)	5694 (29.5)	5111 (31.7)
<b>Partner's desire for children</b>					
Both want same	1204(33.1)	5128 (29.7)	5765 (31.0)	6929 (35.9)	6291 (39.0)
Husband wants more	1162(31.9)	5652 (32.8)	7882 (42.4)	9287 (48.1)	6618 (41.1)

	)				
Husband wants fewer	104 (2.9)	406 (2.4)	558 (3.0)	904 (4.7)	839 (5.2)
Don't know	1169(32.1)	6052 (35.1)	4395 (23.6)	2198 (11.4)	2363 (14.7)
	)				
<b>Currently Reside with Husband</b>					
Yes	3313(91.3)	15545 (90.6)	16733 (90.5)	17573 (91.0)	14496 (90.0)
No	316 (8.7)	1609 (9.4)	1760 (9.5)	1745 (9.0)	1615 (10.0)
<b>Visit Health Facility and discussed FP</b>					
No	3304(90.6)	15866 (92.6)	16555 (90.0)	14953 (77.4)	13428 (83.3)
Yes	341 (9.4)	1265 (7.4)	1849 (10.0)	4365 (22.6)	2683 (16.7)
<b>Visited by Field Worker and Discussed FP</b>					
Yes	252 (6.9)	1323(7.6)	1732 (9.3)	1108 (5.7)	1194 (7.4)
No	3399(93.0)	15993( 92.3)	16868 (90.7)	18210 (94.2)	14917 (92.6)
<b>Gender Preference</b>					
No Preference	2270(62.4)	11811 (68.4)	12889 (69.3)	13183 (68.2)	10712 (66.5)
Male Preference	386 (10.6)	1586 (9.2)	2188 (11.8)	2234 (11.6)	2388 (14.8)
Female Preference	981 (27.0)	3863 (22.4)	3523 (18.9)	3901 (20.2)	3011 (18.7)
<b>FP information Media</b>					
No	2296(62.9)	12029 (69.5)	13359 (71.8)	13436 (69.6)	11237 (69.7)
Low	1088(29.8)	4559 (26.3)	4622 (24.8)	5346 (27.7)	3520 (21.8)
High	267 (7.3)	728 (4.2)	619 (3.3)	536 (2.8)	1354 (8.4)
<b>Knows FP Source</b>					
Know a Source	1125(31.1)	5400 (32.1)	8884 (48.7)	14282 (73.9)	10744 (66.7)
Knows no Source	2497(68.9)	11442 (67.9)	9351 (51.3)	5036 (26.1)	5367 (33.3)
<b>FP Awareness</b>					
No	2297(62.9)	11595(67.0)	16202 (87.0)	12441 (64.4)	11237 (69.7)
Yes	1354(37.0)	5721 (33.0)	2398(13.0)	6877 (35.6)	4874 (30.3)
<b>Women Empowerment</b>					
Low	2640(72.3)	10437 (60.3)	10582 (56.9)	10004 (51.8)	7128 (44.2)
Medium	1011(27.7)	6879 (39.7)	7689 (41.3)	8822 (45.7)	8680 (53.9)
High	0 (0.00)	0 (0.00)	0 (0.00)	492 (2.5)	303 (1.9)

Tables 4.1d to 4.1f presents the distribution of married women age 15-49 according to their background characteristics from 2003 to 2024. Unmet need for family planning was significantly associated with age of women across all survey years ( $p < 0.001$ ). Younger women aged 15-24 years consistently reported the lowest levels of unmet need 20.8% in 2003 and 18.2% in 2003. The highest unmet need

was reported among women aged 35-49 years, increasing from 40.8% in 2003 to 43.4% in 2024. Partner's age was statistically significant with unmet need ( $p < 0.001$ ). In 2024, women married to younger men aged 15-24 years had the lowest unmet need (20.6%), compared with 36.5% among those whose partners were 35 years and above. Unmet need for family planning increased with the number of surviving children ( $p < 0.001$ ). Women with 0-2 surviving children reported the lowest unmet need (16.9%, 21.6%), women with five or more children recorded the highest level (44.4%, 49.2%) in 2003 and 2024 respectively. The association between ideal number of children and unmet need was significant ( $p < 0.001$ ). In 2024, women who reported an ideal of 0-2 children had an unmet need of

36.5%, compared with 30.8% among those who desired five or more children, same pattern was observed across survey rounds. Education was significantly related to unmet need for family planning ( $p < 0.001$ ). In 2024, unmet need was lowest among women with no education (27.6%) and highest among those with secondary education (39.0%). Significant regional differences were observed ( $p < 0.001$ ). In 2024, unmet need was lowest in the North-Central (24.9%) but highest in the South-West (47.3%). These disparities reflect cultural, religious, and service-delivery differences across Nigeria's regions. Unmet need for family planning was significantly associated with ethnicity ( $p < 0.001$ ). In 2024, Hausa/Fulani women reported the lowest (25.2%), while Yoruba women recorded the highest (49.4%). The Igbo and others ethnic groups also reported relatively high levels of unmet need (40.7% and 37.5%) respectively. Wealth was a significant factor ( $p < 0.001$ ). Across the survey rounds respectively, unmet need was lowest among women in poor married women (22.8%, 25.1%, 20.7%, 22.8%, 27.5%) and highest among women in the richest quintile.

**Table 4.1d Distribution of Married Women aged 15-49 years according to Unmet Needs for Family Planning by Demographic Characteristics**

Demographic Characteristics	2003		2008		2013		2018		2024	
	UMFP 949 (25.9%)	$\chi^2_{value}$	UMFP 5005 (28.9%)	$\chi^2_{value}$	UMFP 4733 (25.4%)	$\chi^2_{value}$	UMFP 5541 (28.7%)	$\chi^2_{value}$	UMFP 5354 (33.2%)	$\chi^2_{value}$
<b>Age</b>										
15-24	197(20.8)	146.0*	1113(22.6)	527.4*	1020(21.6)	526.4*	918(16.6)	1278.2*	975(18.2)	813.6*
25-34	365(38.5)		1891(37.8)		1839(38.9)		2063(37.2)		2057(38.4)	
35-49	387(40.8)		1983(39.6)		1874(39.6)		2560(46.2)		2322(43.4)	
<b>Age At First Cohabitation</b>										
0-17	571(60.2)	20.9*	3043(60.8)	17.3*	2613(55.2)	102.8*	2729(49.3)	149.8*	2270(42.4)	73.08*
18-24	325		1588		1742		2094		2305(43)	

	(34.2)		(31.7)		(36.8)		(37.8)		.1)	
25+	53 (5.6)		374 (7.5)		378 (8.0)		718 (13.0)		2306(43 .1)	
<b>Age At First Sexual Intercourse</b>										
0-14	99 (22.6)	15.0 ^	659 (27.8)	27.6 *	260 (33.8)	151. 6*	1187 (28.9)	39.0*	784 (32.2)	10.7 8+
15-17	170(27 .9)		1498 (29.7)		731 (32.6)		2439 (26.8)		2412(32 .5)	
18-24	183(31 .5)		1041 (32.0)		694 (29.7)		1773 (31.6)		2017(34 .8)	
25+	497(24 .6)		1807 (27.2)		3048 (23.0)		140 (28.4)		141 (30.7)	
<b>Partners Age</b>										
15-24	20 (16.3)	25.3 *	166 (25.7)	122. 0*	122 (18.3)	86.0 *	101(18.8 )	340.2 *	93 (20.6)	202. 7*
25-34	221(21 .1)		1162 (23.2)		1164(21. 6)		1076(19. 8)		1046(25 .4)	
35+	689(28 .2)		3578 (31.5)		3447( 27 .4)		4364(32. 7)		4215(36 .5)	
<b>Ideal Number of Children</b>										
0-2	12 (36.4)	30.1 *	185 (36.5)	53.1 *	83 (32.3)	94.9 *	225 (34.3)	226.2 *	281 (36.5)	102. 0*
3-4	186(36 .7)		892 (33.7)		980 (31.6)		1404 (38.1)		1571(39 .4)	
5+	655(25 .2)		3180 (27.6)		3215 (23.5)		3750 (25.9)		3350(30 .8)	
<b>Number of Surviving Children</b>										
0-2	297(16 .9)	234. 6*	1623 (21.0)	588. 1*	1526 (18.1)	606. 4	1481(17. 6)	1100. 0*	1577(21 .6)	954. 6*
3-4	250(25 .4)		1464 (29.6)		1357 (26.0)		1720(30. 9)		1780(37 .6)	
5+	402(44 .4)		1827 (41.7)		1850(37. 2)		2340(43. 8)		1997(49 .2)	
<b>Parity</b>										
0-2	243(16 .9)	164. 7*	1389 (20.9)	460. 7*	1322 (18.0)	444. 3*	1327 (17.9)	875.5 *	1431(21 .7)	775. 5*
3-4	200(22 .9)		1223 (28.1)		1171 (25.5)		1448 (28.7)		1626(36 .2)	
5+	506(37 .9)		2393 (37.9)		2240 (33.6)		2766 (40.3)		2297(45 .8)	
<b>Sex of House Head</b>										
Female	99(40. 4)	28.3 *	496 (34.7)	25.1 *	537(33.9 )	64.0 *	614(40.9 )	118.9 *	649 (41.1)	48.6 *
Male	846(24 .9)		4509 (28.4)		4201(24. 7)		4927(27. 7)		4705(32 .4)	

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

**Table 4.1e Distribution of Married Women aged 15-49 years according to Unmet Needs for Family Planning by Socioeconomic Characteristics, 2003 - 2024**

<b>Socioeconomic Characteristics</b>	<b>2003</b>		<b>2008</b>		<b>2013</b>		<b>2018</b>		<b>2024</b>	
	<b>UMFP 949 (25.9%)</b>	$\chi^2_{value}$	<b>UMFP 5005 (28.9%)</b>	$\chi^2_{value}$	<b>UMFP 4733 (25.4%)</b>	$\chi^2_{value}$	<b>UMFP 5541 (28.7%)</b>	$\chi^2_{value}$	<b>UMFP 5354 (33.2%)</b>	$\chi^2_{value}$
<b>No of Unions</b>										
Once(1)	753(25.5)	2.4	4124 (28.2)	20.0*	397 (24.9)	14.1*	4786 (28.1)	26.0*	4880(32.9)	7.44^
1+	193 (28.5)		851 (32.5)		685 (28.5)		755 (33.2)		474 (36.7)	
<b>Highest Educational Status</b>										
No education	426 (21.4)	49.3*	2466 (25.8)	105.2*	1997 (20.5)	273.7*	2168(22.4)	381.9*	2144 (27.6)	224.7*
Primary	260 (31.4)		1173 (32.3)		1137 (31.7)		1048(35.7)		728 (39.5)	
Secondary	219 (31.9)		1133 (33.8)		1329 (31.2)		1902(35.3)		1918 (39.0)	
Tertiary	44 (30.3)		233 (30.0)		270 (26.4)		423(32.0)		564 (35.9)	
<b>Partner Education</b>										
No education	312 (20.5)	41.3*	1978 (25.8)	67.6*	1607(20.7)	171.8*	1671(22.3)	248.7*	1793 (27.2)	191.4*
Primary	261 (30.0)		1037 (30.4)		946 (28.0)		898 (32.7)		597 (37.6)	
Secondary	237 (29.5)		1334 (31.7)		1506 (30.1)		2057(33.3)		1926 (38.2)	
Tertiary	127 (30.8)		570 (32.5)		635(27.8)		820 (31.7)		966 (36.5)	
Don't know	7 (30.4)		38 (31.1)		39(20.6)		95(31.5)		72 (32.4)	
<b>Family Type</b>										
Monogamy	603 (31.2)	0.1	3157 (29.5)	1.36	3077 (25.1)	0.4	3860 (27.3)	8.05^	3861 (25.3)	0.28
Polygamy	341 (34.0)		1799 (29.4)		1615 (25.5)		1657 (29.3)		1478 (28.5)	
<b>Region</b>										
North-Central	202 (33.3)	142.5*	855 (27.0)	310.0*	898 (31.7)	613.1*	1084(31.3)	1082.6*	1353 (24.9)	451.1*
North-East	220 (24.4)		972 (23.5)		1027 (24.3)		1023(24.3)		1001 (30.7)	
North-West	188 (15.7)		1409 (26.4)		1099 (16.6)		1150(17.9)		1112 (34.8)	
South-East	99		377		313		594		592	

	(34.3)		(32.4)		(27.5)		(35.1)		(40.9)	
South-South	123 (42.6)		717 (43.4)		779(40.2 )		825 (49.1)		677 (46.2)	
South-West	117 (32.1)		675 (36.5)		617(33.2 )		865 (46.6)		619 (47.3)	
<b>Residence</b>										
Urban	582(24.0)	16.3*	3585 (32.4)	33.6*	3208 (24.3)	29.0*	3477(26.1)	137.8*	3086 (29.7)	164.3*
Rural	367(30.1)		1360 (27.8)		1525 (28.1)		2064(34.4)		2268 (39.6)	
<b>Ethnicity</b>										
Hausa/Fulani	441 (32.7)	111.9*	1884 (24.9)	105.4*	1520(18.3)	419.5*	1773 (20.2)	706.0*	1819 (25.2)	448.0*
Igbo	122(31.0)		471 (32.7)		406(28.6 )		723 (35.8)		698 (40.7)	
Yoruba	115(33.6)		602 (35.0)		540 (33.5)		828 (47.1)		605 (49.4)	
Others	441(32.7)		2101 (30.8)		2267 (31.3)		2217 (32.8)		2232 (37.5)	
<b>Religion</b>										
Christianity	465 (36.2)	108.1*	2171 (34.3)	146.1*	2193 (34.5)	423.0*	2598 (38.5)	496.3*	2302 (42.1)	298.6*
Islam	468 (20.3)		2702 (25.6)		2463 (20.6)		2897 (23.3)		3018 (28.6)	
Trad/Others	16 (25.0)		98 (29.1)		77 (25.7)		46 (32.2)		34 (36.6)	
<b>Working Status</b>										
Working	659(29.3)	33.4*	3250 (30.5)	35.4*	3401 (27.8)	111.0*	4124 (32.6)	275.6*	3388 (36.8)	124.1*
Not Working	286(20.7)		1727 (26.3)		1300 (20.7)		1417 (21.2)		1966 (28.5)	

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

**Table 4.1f Distribution of Married Women aged 15-49 years according to Unmet Needs for Family Planning by Socioeconomic Characteristics, 2003 - 2024**

Socioeconomic Characteristics	2003	$\chi^2_{value}$	2008	$\chi^2_{value}$	2013	$\chi^2_{value}$	2018	$\chi^2_{value}$	2024	$\chi^2_{value}$
	UMFP 949 (25.9%)		UMFP 5005 (28.9%)		UMFP 4733 (25.4%)		UMFP 5541 (28.7%)		UMFP 5354 (33.2%)	
<b>Wealth Index</b>										
Poor	376 (22.8)	21.7*	2334 (25.1)	167.3*	1930(20.7)	220.1	2209 (22.8)	371.6*	2170 (27.5)	237.0*
Middle	193 (25.7)		1018 (30.6)		1086(29.8)		1225 (31.3)		1146 (36.9)	
Rich	380		1653		1717(30)		2107		2038	

	(30.4)		(35.4)		.4)		(37.0)		(39.9)	
<b>Partners Desire For Children</b>										
Both want same	344 (28.6)	9.1 <sup>+</sup>	1509 (29.4)	22.1 *	1572(27 .3)	82.1 *	2089 (30.1)	123. 0*	2297 (36.5)	81.7 *
Partner want more	290 (25.0)		1524 (27.0)		1744(22 .1)		2361 (25.4)		1952 (29.5)	
Partner want fewer	33 (31.7)		145 (35.7)		164 (29.4)		340 (37.6)		321 (38.3)	
Don't know/other	280 (24.0)		1799 (29.7)		1253(28 .5)		751 (34.2)		784 (33.2)	
<b>Currently Reside with Husband</b>										
Yes	809(24. 4)	40.5 *	4403 (28.3)	24.3 *	4150(24 .8)	38.6 *	4874(27 .7)	85.3 *	4704 (32.5)	39.8 *
No	129(40. 8)		550(34. 2)		556 (31.6)		667 (38.2)		650 (40.2)	
<b>Visit Health Facility and discussed FP</b>										
Yes	133(39. 0)	33.0 *	422 (34.2)	13.2 *	555 (30.0)	22.6 *	1267(29 .0)	0.3	4459 (33.2)	0.0
No	815(24. 7)		4529 (28.3)		4130(24 .9)		4274(28 .6)		895 (33.4)	
<b>Visited by Field Worker and Discussed FP</b>										
Yes	77(36.7 )	31.6 *	269 (1.53)	18.0 *	471 (25.3)	20.8 *	390(35. 2)	24.3	4932 (33.1)	2.6
No	872(25. 5)		4736 (27.3)		4262(22 .9)		5151(28 .3)		422 (35.3)	
<b>Gender Preference</b>										
Female Preference	127(32. 9)	15.1 ^	489 (30.8)	12.3 ^	543 (24.8)	0.7	678 (30.3)	3.8	877 (36.7)	21.8 *
Male Preference	272(27. 7)		1184 (30.6)		909 (25.8)		1125(28 .8)		1040 (34.5)	
No Preference	548(24. 1)		3318 (28.1)		3281(25 .5)		3738(28 .4)		3437 (32.1)	
<b>FP information Media</b>										
High Info	89(33.3 )	21.0	229 (31.5)	82.6 *	170 (27.5)	71.0 *	165 (30.8)	65.2 *	503 (37.1)	15.2 *
Low Info	319(29. 3)		1546 (33.9)		1386(30 .0)		1754(32 .8)		1212 (34.4)	
No Info	541(23. 6)		3230 (26.9)		3177(23 .8)		3622(27 .0)		3639 (32.4)	
<b>Knows FP Source</b>										
Know a Source	394 (35.0)	70.8 *	1871 (34.6)	128. 1*	2075(22 .2)	102. 7*	1186(23 .6)	87.7 *	1692 (31.5)	10.6 ^
Knows no Source	544 (21.8)		2995 (26.2)		2552(28 .7)		4355(30 .4)		3662 (34.1)	
<b>FP Awareness</b>										

Yes	408(30.1)	19.2*	1827 (33.4)	83.7	773(32.2)	66.9	2224(32.3)	69.8*	1715 (35.2)	12.0 <sup>^</sup>
No	541(23.6)		3178 (26.9)		3960(24.4)		3317(26.7)		3639 (32.4)	
<b>Women Empowerment</b>										
Low	855(25.4)	31.1	2752 (26.4)	24.1	2330(22.0)	154.6*	2319 (23.2)	320.0*	1933 (27.1)	230.7*
Medium	94 (33.2)		2253 (32.8)		2292(29.8)		3017 (34.2)		3274 (37.7)	
High	0 (0.0)		0 (0.0)		111 (33.7)		205 (41.7)		147 (48.5)	

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

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)
<b>Age</b>					
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-	0.75 (0.66-	0.70 (0.62-	0.63 (0.56-

		0.92)^	0.86)*	0.79)*	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)
<b>Age at First Cohabitation</b>					
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)^
<b>Age At First Sexual Intercourse</b>					
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)
<b>Partners Age</b>					
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)
<b>Ideal Number of Children</b>					
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)*
<b>Number of Surviving Children</b>					
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)^
<b>Sex of House Head</b>					
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&lt;0.001; ^p&lt;0.01; +p&lt;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)
<b>No of Unions</b>					
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)
<b>Highest Educational Status</b>					
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)
<b>Partner Education</b>					
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)
<b>Family Type</b>					
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)^
<b>Region</b>					
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)^
<b>Residence</b>					
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)

<b>Ethnicity</b>						
Hausa/Fulani	1.00	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)	
<b>Religion</b>						
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)	
<b>Working Status</b>						
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 4.11 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)
<b>Wealth Quintile</b>					
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)^
<b>Partners Desire For Children</b>					
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)*
Partner want 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)
<b>Currently Reside with Husband</b>					
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)^
<b>Visit Health Facility and discussed FP</b>					
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)^
<b>Visited by Field Worker and Discussed FP</b>					
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)
<b>Gender Preference</b>					
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)^
<b>FP information Media</b>					
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)^
<b>Knows FP Source</b>					
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)
<b>FP Awareness</b>					
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)
<b>Women Empowerment</b>					
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

Fig 4.1a - 4.1c presents the random forest variable importance graph using the mean decrease accuracy (MDA) and the mean decrease impurity (MDI) metric. It measures how much the model accuracy falls when variable values are randomly shuffled. It shows the impact of the model prediction performance, interaction of predictors, and the non-linear effects, unlike mean decrease impurity (MDI) that only shows how a feature is used in splits. MDI indicates which key variables have the greatest influence on the model's ability to split the data in a way that

reduces classification errors. When there is a correlated or categorical features with many levels, MDA reports an unbiased estimate. A high MDA shows variable (feature) is a strong predictor of unmet need for family planning among MWRA.

Table 4.2a presents the random forest variable importance, it highlights the key predictors of UMFP among married women of reproductive age across the 2003, 2008, 2013, 2018, and 2024 NDHS surveys using the mean decrease accuracy (MDA) scores. Across the survey years, the number of living children was the

most important variable with its MDA highest from 42.25 in 2003 to 103.25 in 2024 respectively. Other top key variables varied by year however, closely followed are ideal number of children (49.84), age (58.74), which were reported significant scores across the years. Notably, in later years, the impact of age at first cohabitation (30.20 in 2018), (37.65 in 2024), ethnicity (36.82 in 2024) was

observed. Wealth (41.87), religion (40.6), became a strong predictor in 2024. Unlike family planning information on the media, which was of average importance in earlier years, 2003 and 2013. Variables such as gender preference, partner desire for children, age at first sex, reported lower scores over time.

**4.3 Determination of the Best Supervised Model for Predicting UMF**

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

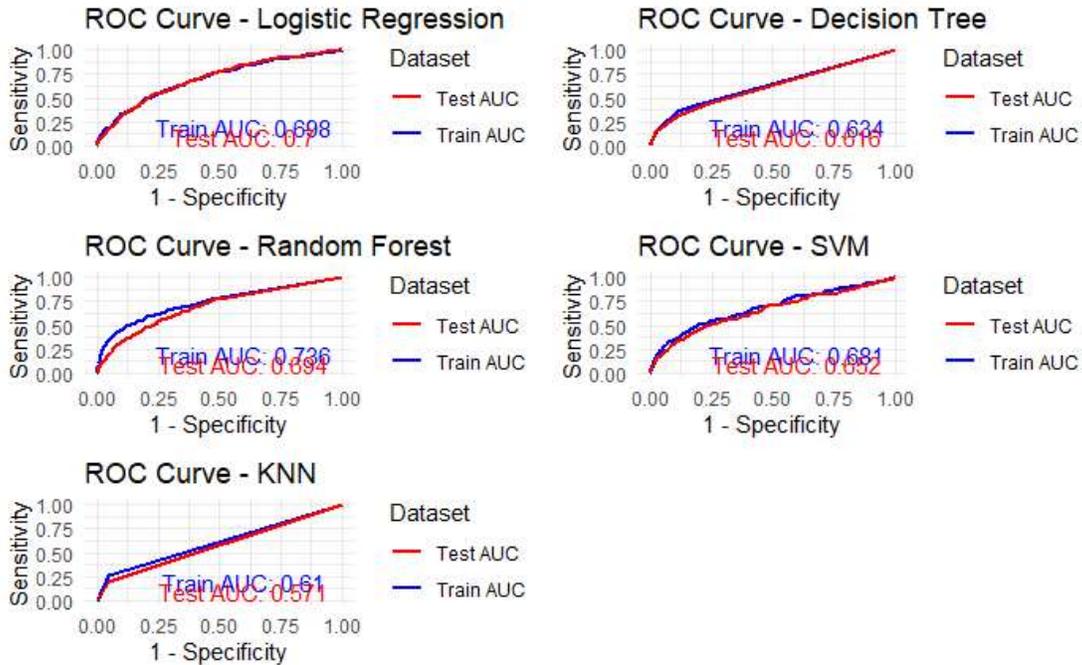
Model Name	Accuracy	Precision	Recall	F1-Score	AUC (%)
<b>Training data 2003</b>					
Logistic Regression	0.7558	0.7618	0.9747	0.8552	74.42
Decision Tree	0.7649	0.7718	0.9688	0.8591	75.49
Random Forest	0.7929	0.8002	0.9599	0.8728	77.29
Support Vector Machine (SVM)	0.7583	0.7600	0.9840	0.8577	73.83
K-Nearest Neighbour (KNN)	0.7750	0.7861	0.9562	0.8628	76.50
<b>Test data 2024</b>					
Logistic Regression	0.7266	0.7357	0.9623	0.8339	72.66
<b>Decision Tree</b>	<b>0.7374</b>	<b>0.7387</b>	<b>0.9776</b>	<b>0.8415</b>	<b>73.22</b>
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
<b>Training data 2008</b>					
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
<b>Test data 2024</b>					
Logistic Regression	0.7374	0.7448	0.9613	0.8393	72.34
Decision Tree	0.7371	0.7427	0.9660	0.8398	73.22
<b>Random Forest</b>	<b>0.7393</b>	<b>0.7552</b>	<b>0.9387</b>	<b>0.8370</b>	<b>73.87</b>
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
<b>Training data 2013</b>					
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
<b>Test data 2024</b>					
Logistic Regression	0.7353	0.7368	0.9782	0.8405	73.51

Decision Tree	0.7132	0.7132	1.0000	0.8326	70.78
<b>Random Forest</b>	<b>0.7382</b>	<b>0.7451</b>	<b>0.9620</b>	<b>0.8398</b>	<b>73.66</b>
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
<b>Training data 2018</b>					
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
<b>Test data 2024</b>					
Logistic Regression	0.7353	0.7368	0.9782	0.8405	71.39
Decision Tree	0.7132	0.7132	1.0000	0.8326	72.07
<b>Random Forest</b>	<b>0.7382</b>	<b>0.7451</b>	<b>0.9620</b>	<b>0.8398</b>	<b>76.23</b>
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

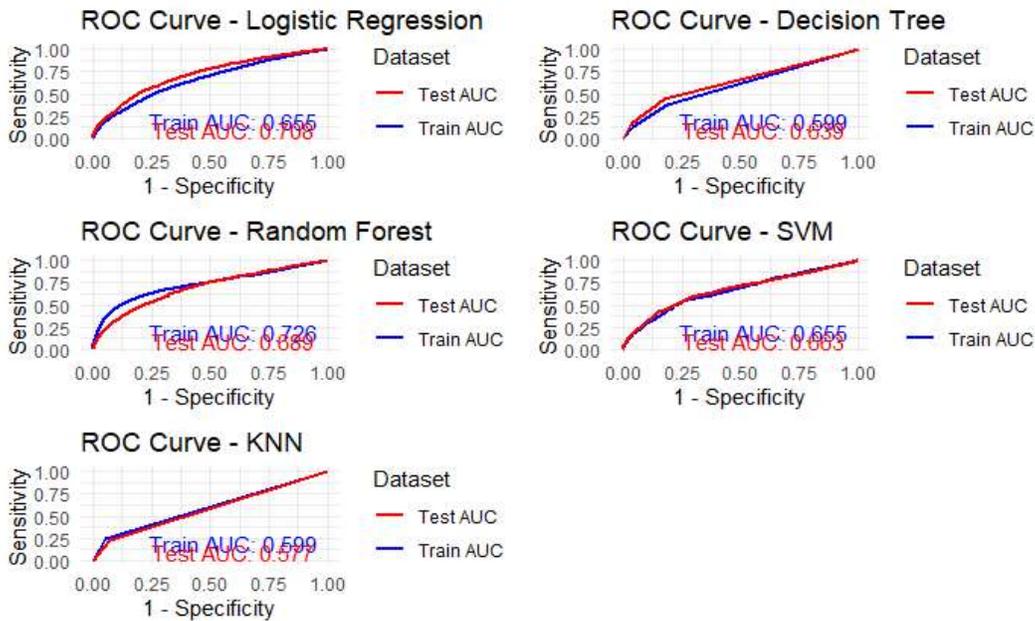
Table 4.3a above presents the result for best fit model evaluation and selection for 2003, 2008, 2013, 2018 and 2024. In each of the survey years, the performance of five machine learning tools (logistic regression, decision tree, random forest, support vector machine, k-nearest neighbor) was evaluated 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

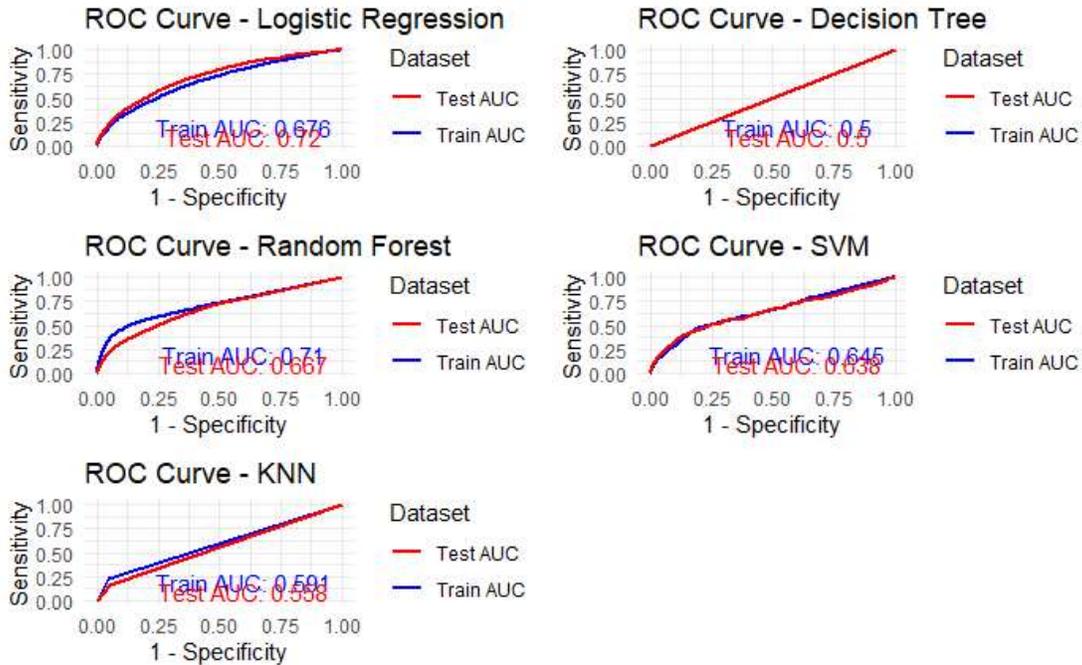
highest training accuracy (73.87%, 73.66% and 76.23%) and F1-score (0.8370, 0.8398, and 0.8114) respectively. However, in the test data for 2003, decision tree accuracy was highest (73.22%) higher than random forest (73.13%) indicating a better generalization. Overall, random forest consistently had 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.



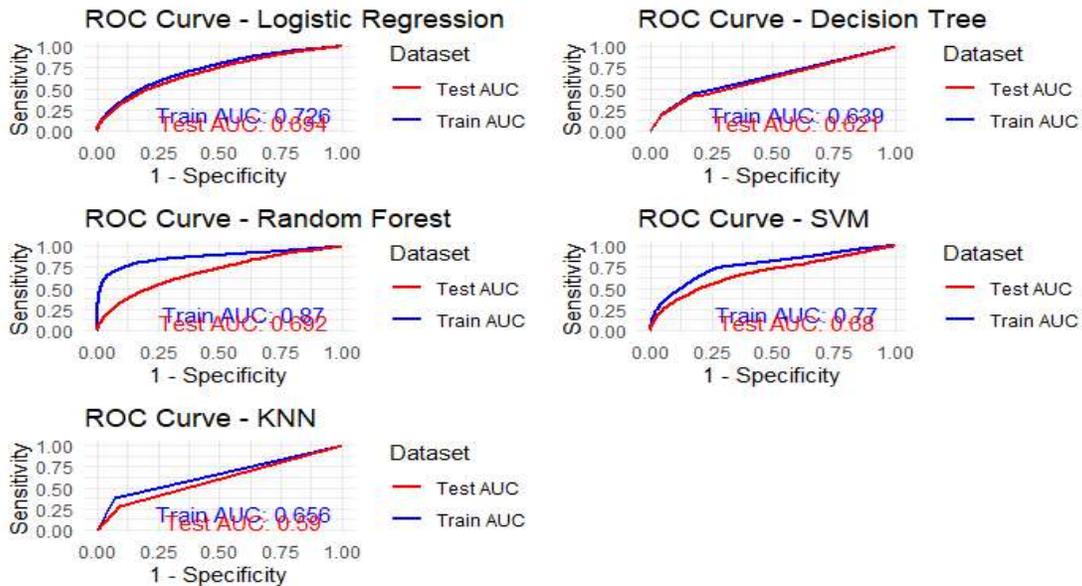
**Fig 4.6a** ROC (Receiver Operating Characteristic) curves for different machine learning models: Logistic Regression, Decision Tree, Random Forest, SVM, and KNN for 2003 and 2024



**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



**Fig 4.6c ROC (Receiver Operating Characteristic) curves for different machine learning models: Logistic Regression, Decision Tree, Random Forest, SVM, and KNN for 2013 and 2024**



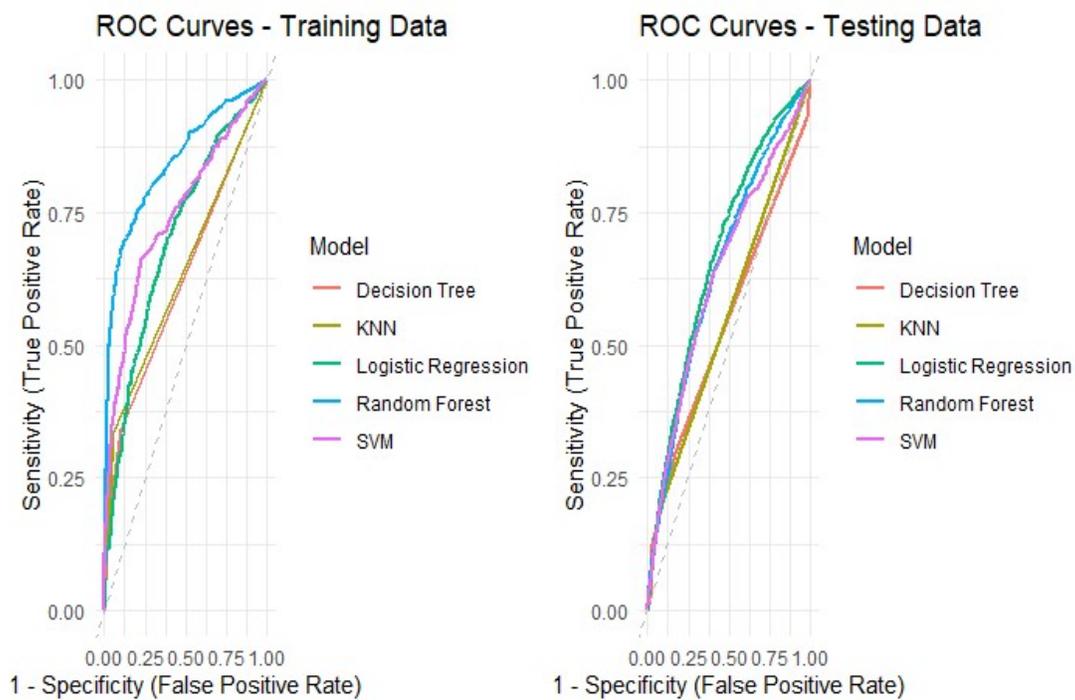
**Fig 4.6d ROC (Receiver Operating Characteristic) curves for different machine learning models: Logistic Regression, Decision Tree, Random Forest, SVM, and KNN for 2018 and 2024**

Fig 4.6a - Fig4.6d presents the receiver operating characteristic(ROC) curves that

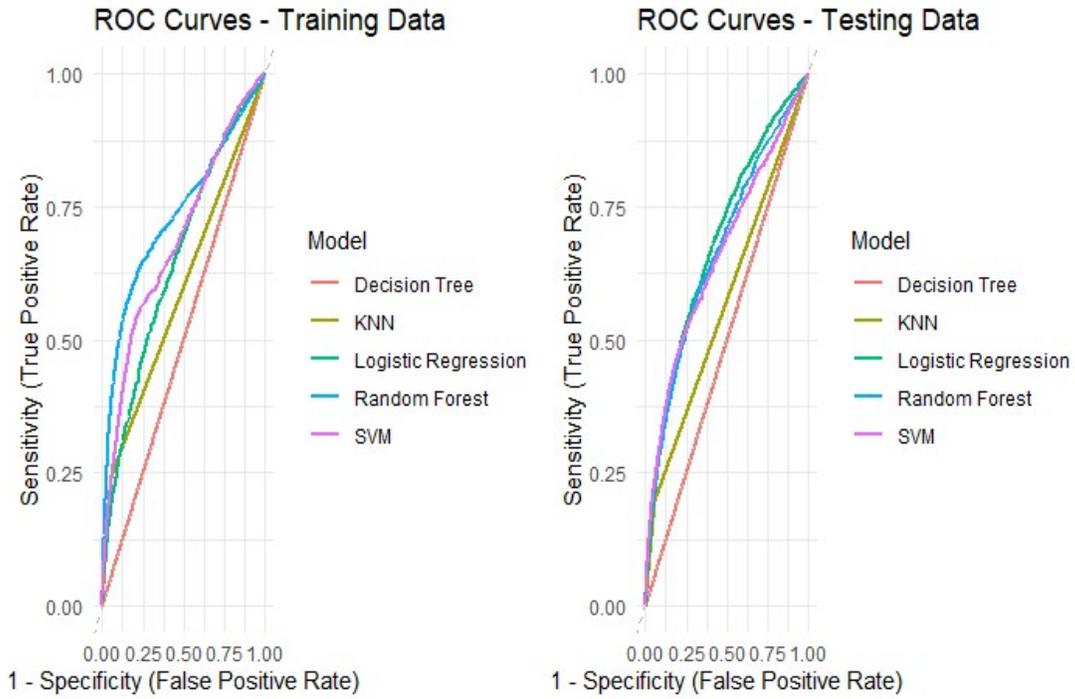
display a visual assessment of the classification of five machine learning models (logistic regression, decision tree, random forest, support vector machine (SVM), k-nearest neighbor (KNN)) over the survey years (2003 to 2024). The area under the curve (AUC) serves as a critical metric for evaluating model performance. When the

ROC curve is near-perfect, it implies an exceptional AUC close to 1.0. For training data, in all the years, random forest showed the highest ROC curve and AUC values closer to 1, best for stronger generalization in later years of the survey. This indicates that the model generalizes well without significant over fitting. The random forest model shows a Train AUC of 0.741 and a Test AUC of 0.733 slightly lower.

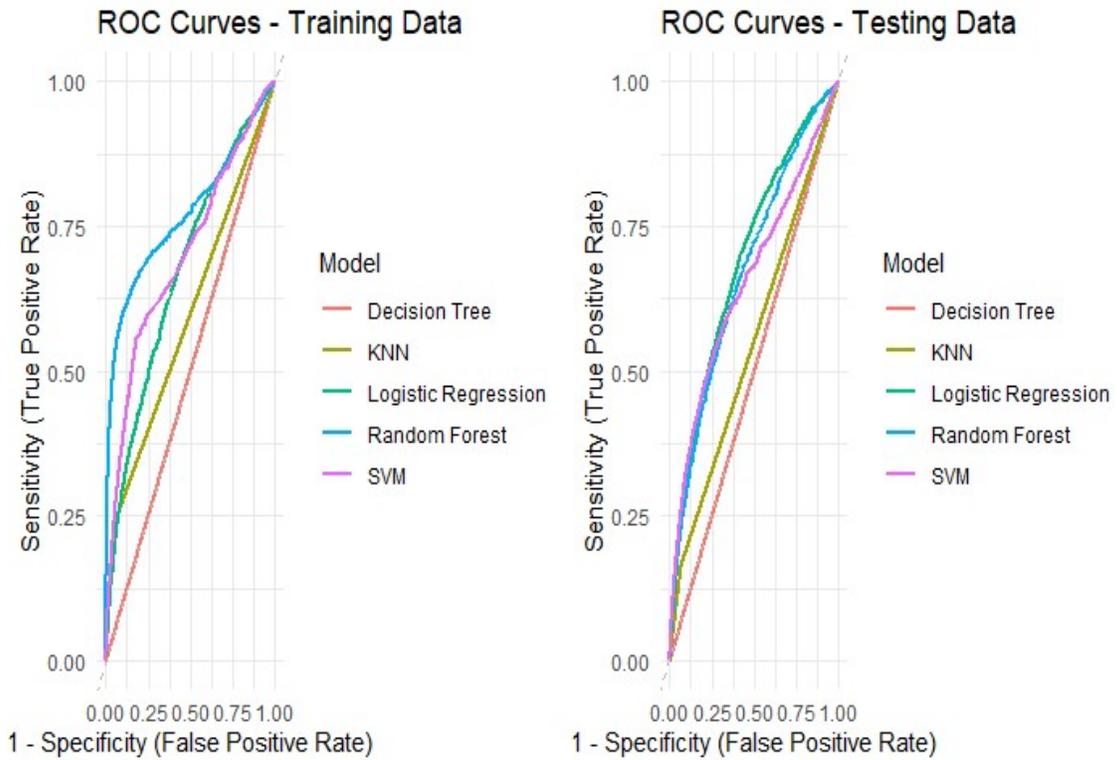
This suggests that the model performs well on both datasets without severe over fitting. Random forest model is known for its robustness in high-dimensional spaces, which is likely why it is achieving a good balance between training and test performance. In conclusion, Random Forest model is the most suitable and shows a good balance between train and test performance, followed closely is Logistic Regression, the Decision Tree appears to under fit, and KNN suffers from moderate over fitting.



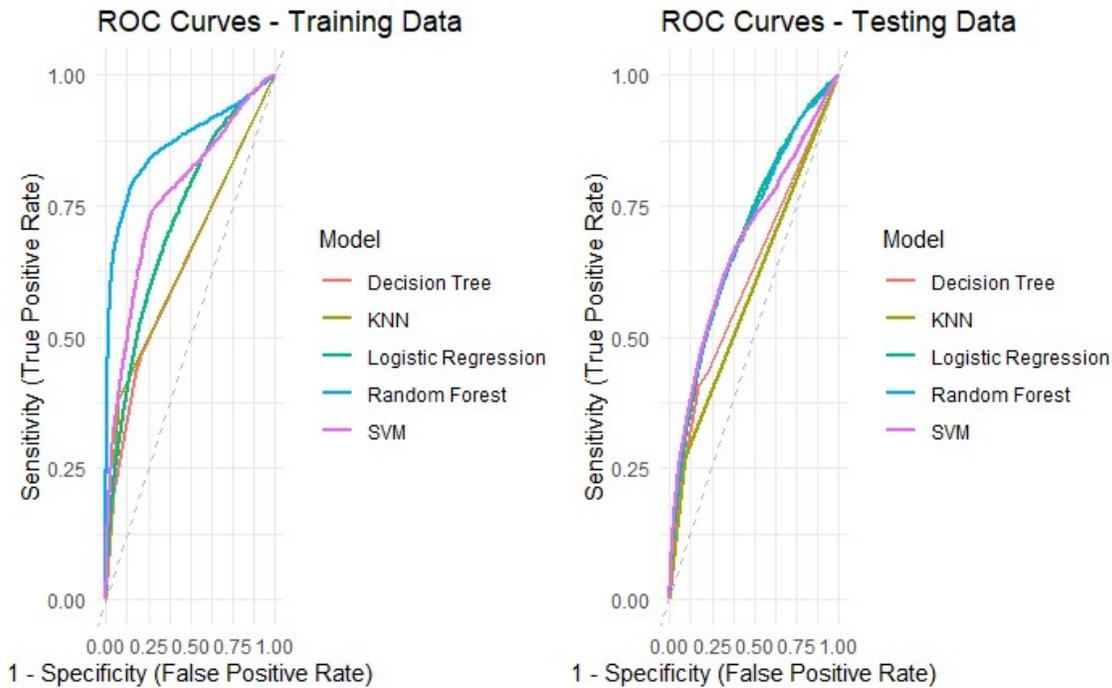
**Fig 4.7a Combined ROC for all MLT for performance metrics 2003 and 2024**



**Fig 4.7b Combined ROC for all MLT for performance metrics 2008 and 2018**



**Fig 4.7c Combined ROC for all MLT for performance metrics 2013 and 2024**



**Fig 4.7d Combined ROC for all MLT for performance metrics 2018 and 2024**

**Fig 4.7d Combined ROC for all MLT for performance metrics 2018 and 2024**

Fig 4.7a - Fig 4.7d presents the combined receiver operating characteristic (ROC) curves that provide a visual aggregated evaluation of five machine learning models (logistic regression, decision tree, random forest, support vector machine (SVM), k-nearest neighbor (KNN)) over the survey years (2003 to 2024). This graph collectively shows the models' discriminatory ability using both the training and test splits. In all the survey years, the combined ROC curve maintained a similar pattern for the training data. On the training data, the random forest model had the highest AUC and classification strength, which is visible in its prominent curve and high AUC. In 2018 graph shows the gap between other model and random forest narrowed, maintaining random forest model as stronger predictive model even on the training data. However, logistic regression remained consistent with a reliable accuracy, while

decision tree and KNN showed only marginal effects.

Similarly, in 2024, the random forest still showed a strong performance, with its reliability in generalization in both test data and training data. It had a near perfect AUC curve even, Decision tree and KNN had weakness in curves indicating a limited effectiveness in classification compared with other models. Overall, across the survey years, the combined ROC confirms random forest to be the best performing model when prioritizing classification power on the training data, while logistic regression is the second best. Random Forest model remains is the best-fit performing model mainly because of its generalization, balance, and stability. It is the most reliable choice when over-fitting is concerned.

**4.4 Prioritization of Predictors of UMFP in Order of Relative Importance**

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

Rank	Ranked Dominant Predictors of UMFP							
	2003 &2024		2008 &2024		2013 & 2024		2018 & 2024	
	Predictors	Average Contribution	Predictors	Average Contribution	Predictors	Average Contribution	Predictors	Average Contribution
1	No of surviving children	0.48	No of surviving children	0.49	No of Surviving Children	0.43	No of Surviving 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 as 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.

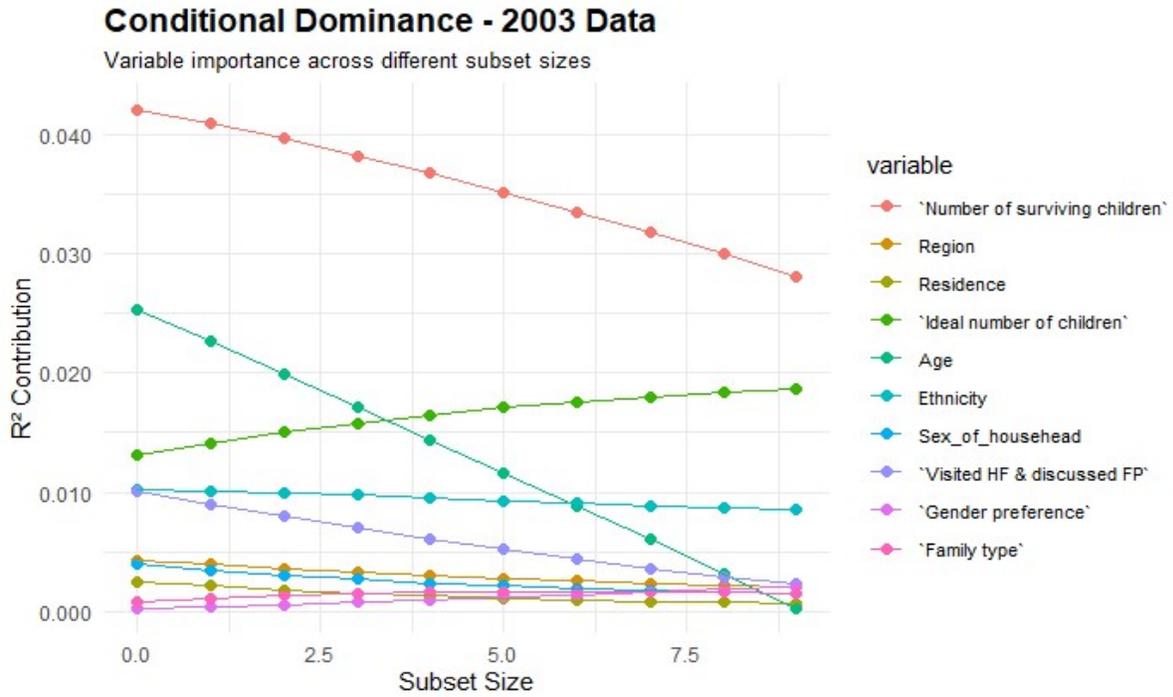


Fig 4.8a Conditional Dominance of Predictors of UMFP 2003 and 2024

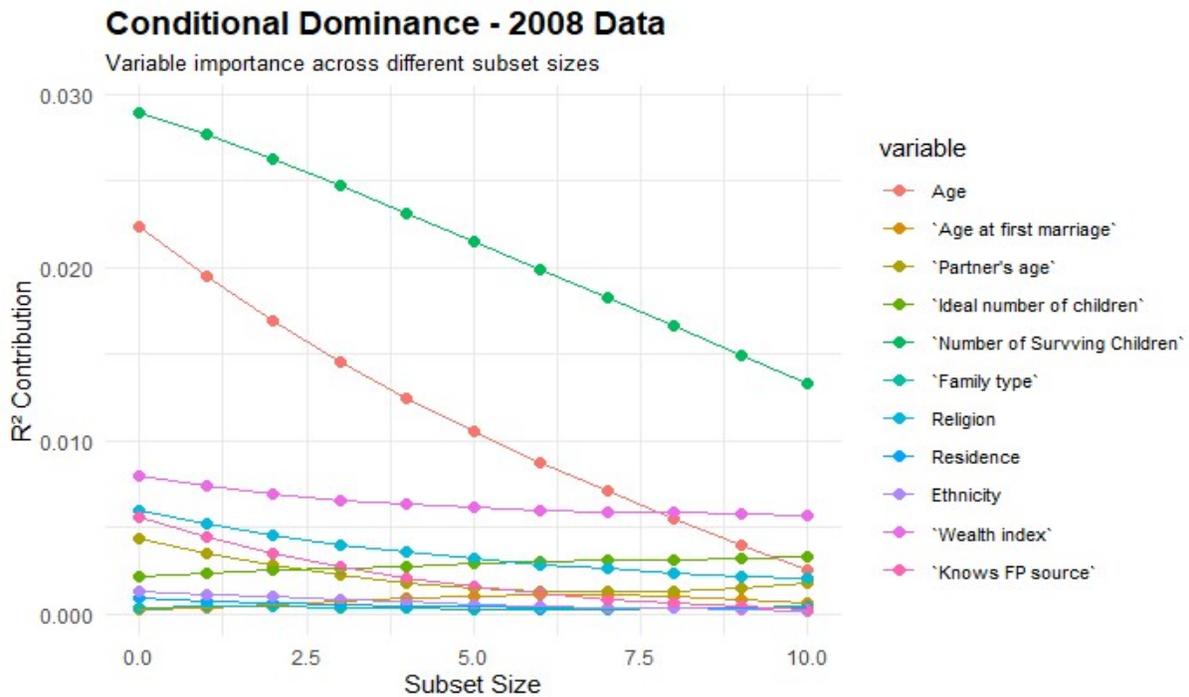


Fig 4.8b Conditional Dominance of Predictors of UMFP 2008 and 2024

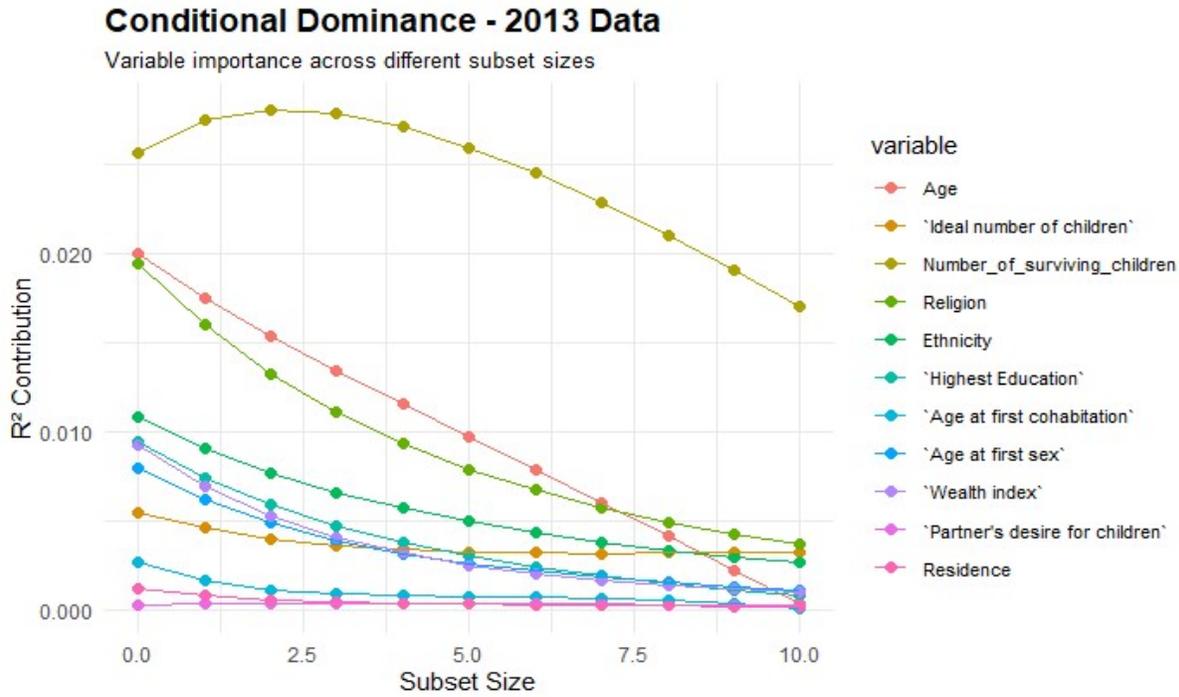


Fig 4.8c Conditional Dominance of Predictors of UMFP 2013 and 2024

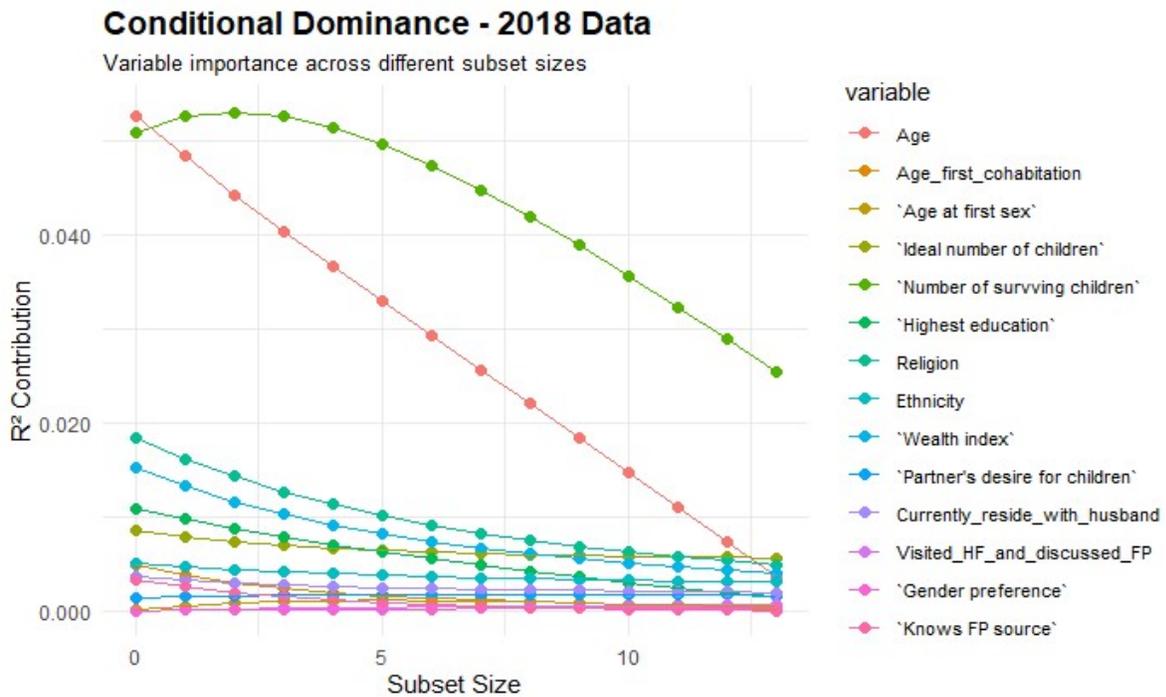


Fig 4.8d Conditional Dominance of Predictors of UMFP 2018 and 2024

Fig 4.8a - Fig 4.8d above present conditional dominance Chart that shows the dominant predictors of unmet needs for family planning among MWRA from 2003 to 2024. These charts illustrate the predictors that most conditionally contribute to explaining UMFP among married women from 2003 to 2024. In all the years, the number of surviving children was consistently observed to have the highest conditional dominance. Other variables like ethnicity, religion, and age also had strong

conditional contributions, mostly in 2013 and 2018. This reaffirms that over time, the most conditional predictor of unmet needs for family planning among married women in Nigeria is fertility or cultural factors.

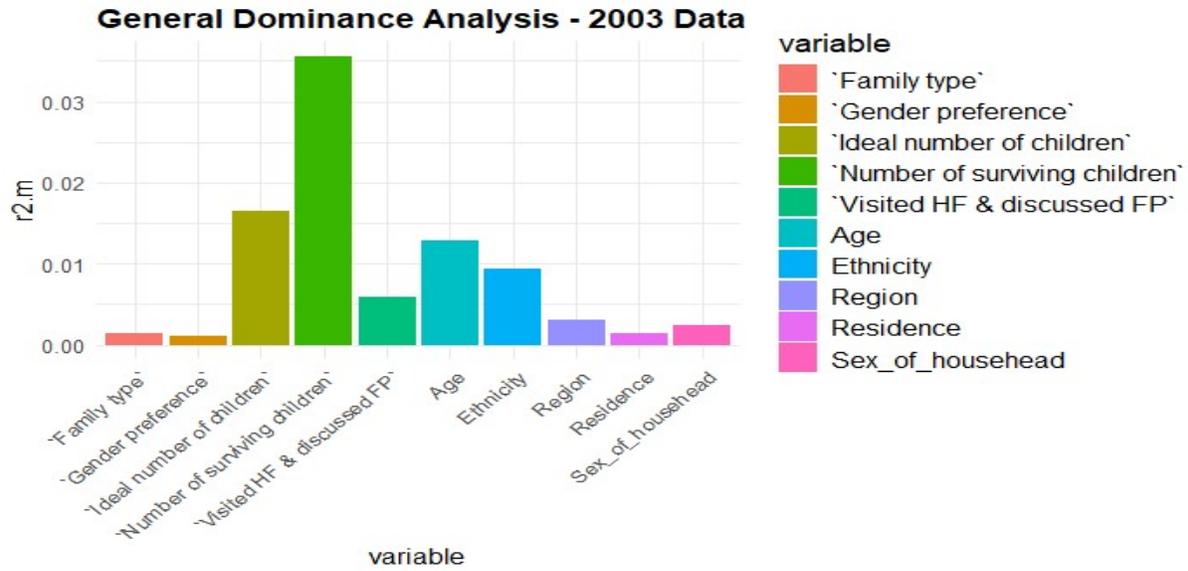


Fig 4.9a General Dominance of Predictors of UMFP 2003 and 2024.

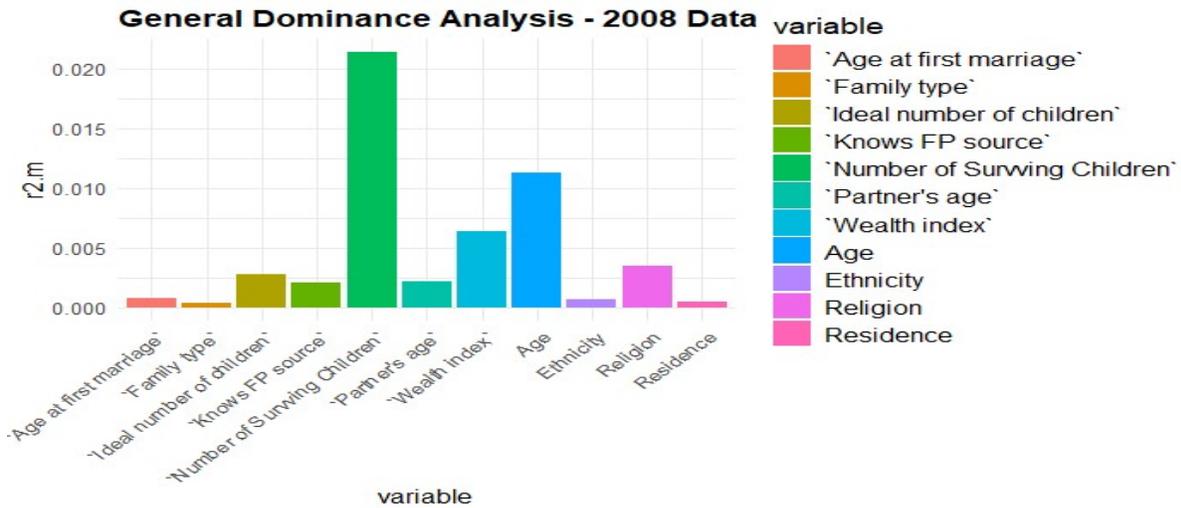


Fig 4.9b General Dominance of Predictors of UMFP 2008 and 2024.

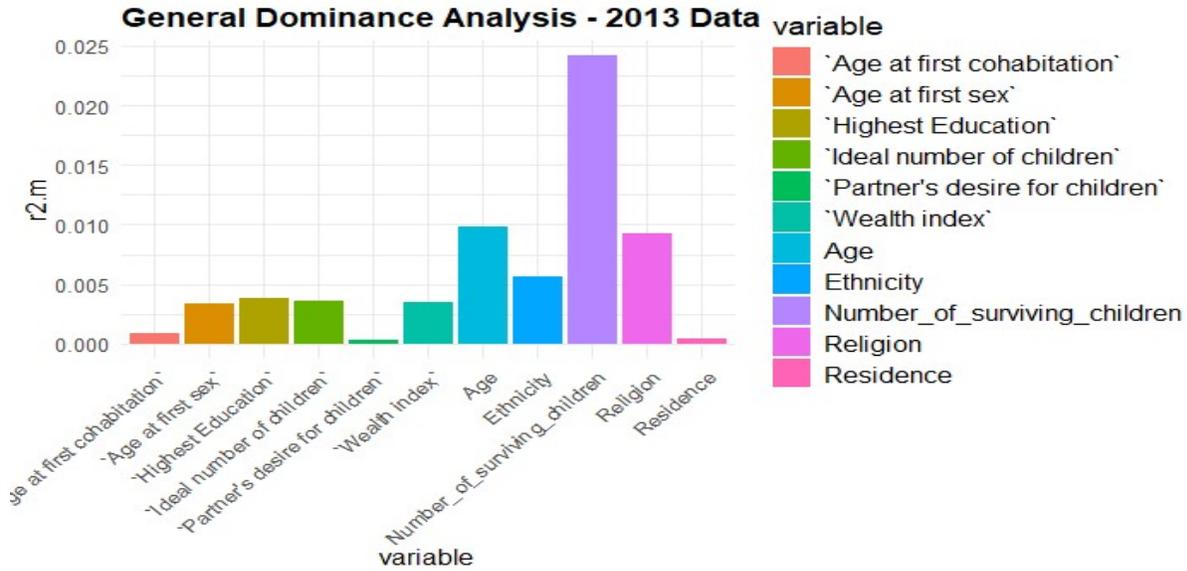


Fig 4.9c General Dominance of Predictors of UMFP 2013 and 2024.

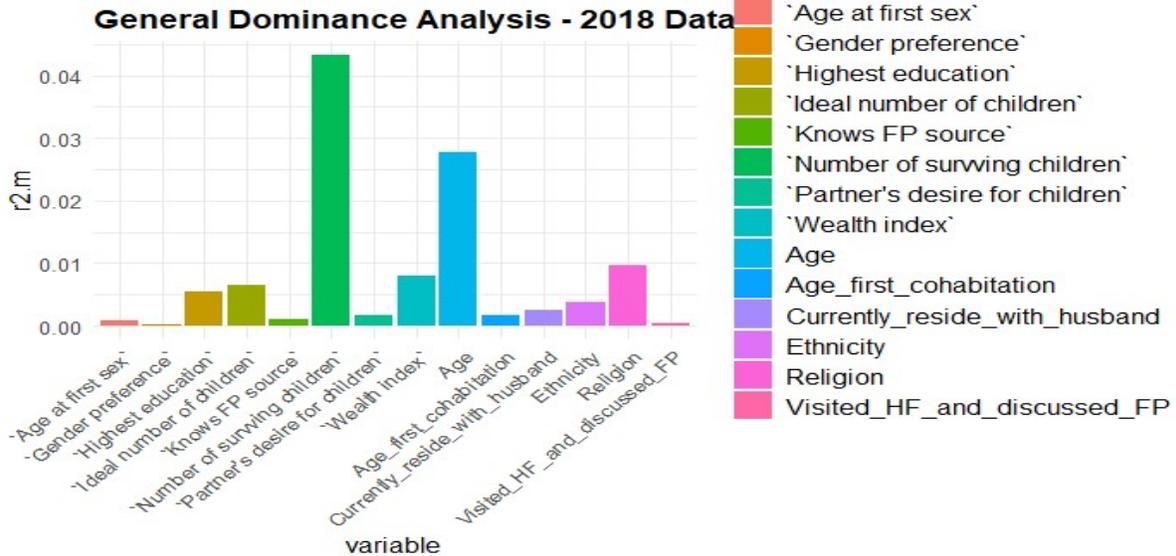


Fig 4.9d General Dominance of Predictors of UMFP 2018 and 2024

Fig 4.9a - Fig 4.9d present a general Dominance Chart that shows the dominant predictors of unmet needs for family planning among MWRA from 2003 to 2024. These charts identify the most influential predictors of UMFP among married women from 2003 to 2024. In all the years, number of surviving children consistently ranked as the most dominant predictor. Over time, the idea of children, religion, age and wealth also gained prominence in 2013 and 2018. This general dominance chart indicates that fertility history

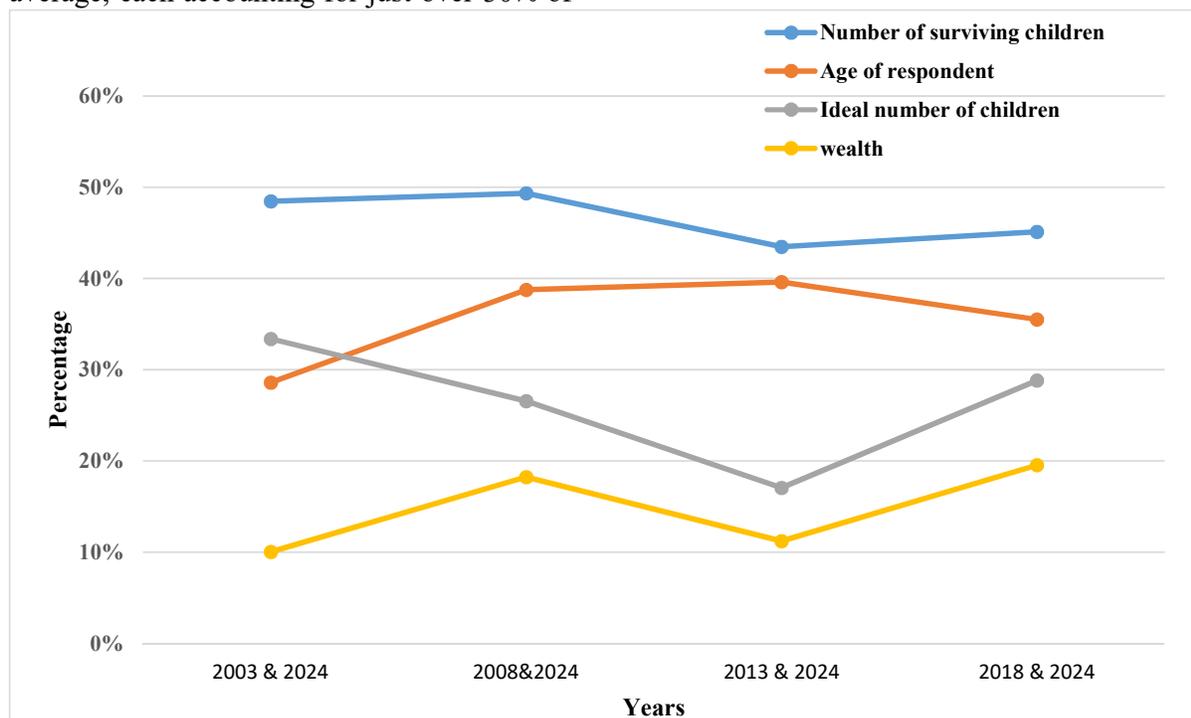
remains the top driver while demographic and cultural factors grow in importance.

**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. Other predictors had less dominant roles, age and ideal number of children contributed average, each accounting for just over 30% of

the total score. Indicating that while cultural and religious contexts matter, they were less influential than demographic characteristics. Wealth had the lowest dominance scores, although slightly showed increase in 2018 compared to previous years. Overall, the trend reports the dominant influence of number of surviving children and age, ideal number of children, wealth over other predictors in shaping 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 $\geq 5$ ; Ideal no of Children $\geq 5$ ; Age (35-49); Wealth(rich)									Pro. of UMFP (%)
	Ethnicity			Religion			Wealth			
	Yoruba	Igbo	Hausa/ Fulani	Christianity	Islam	Trad/ others	Poor	Mid	Rich	

<b>Urban</b>	✓	-	-	✓	-	-	✓	-	-	55.8
	✓	-	-	-	-	✓	✓	-	-	52.8
	✓	-	-	✓		-	-	✓	-	<b>79.4(2)</b>
	-	-	✓	-	-	✓	✓	-	-	50.2
	✓	-	-	-	-	✓	-	✓	-	65.2
	✓	-	-	✓	-	-	-	-	✓	<b>81.2(1)</b>
	✓	-	-	-	-	✓	-	-	✓	63.4
	-	-			-	-	-	-	✓	53.6
	-	✓	-	✓		-	-	-	✓	<b>68.8(3)</b>
<b>Rural</b>	✓	-	-			✓	✓			50.6
		✓	-	✓			✓			56
	✓	-	-	✓				✓		57.4
	-	✓	-	✓				✓		<b>66.4(3)</b>
	✓		-	✓					✓	<b>82.2(1)</b>
	✓	-		-		✓			✓	54.2
	-	-	✓	✓					✓	62.6
		✓		✓					✓	<b>71.0(2)</b>

**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	
	✓			✓			✓	✓		62.8
		✓		✓			✓			64.8

<b>Urban</b>	✓			✓				✓		57.8
		✓		✓				✓		58
	✓			✓					✓	<b>90 (1)</b>
	✓					✓			✓	58.2
	✓						✓		✓	53.6
			✓	✓					✓	<b>78.6(3)</b>
			✓			✓			✓	63.8
			✓				✓	✓		51.2
		✓		✓					✓	<b>88.8(2)</b>
<b>Rural</b>	✓			✓				✓		57.6
	✓			✓					✓	<b>65.6(3)</b>
		✓		✓					✓	63.4
	✓			✓					✓	<b>83.4(1)</b>
			✓	✓					✓	64.6
		✓		✓					✓	<b>81.4(2)</b>
			✓				✓	✓		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 $\geq 5$ ; Ideal no of Children $\geq 5$ ; Age (35-49); Wealth									Pro. of UMFP (%)
	Ethnicity			Religion			Wealth			
	Yoruba	Igbo	Hausa/ Fulani	Christianity	Islam	Trad/ others	Poor	Mid	Rich	
<b>Urban</b>	✓			✓				✓		52.2
	✓			✓					✓	61.2
		✓		✓					✓	54.6

	✓			✓					✓	<b>81.2 (1)</b>
	✓					✓			✓	59.8
			✓	✓					✓	56.4
		✓		✓					✓	<b>76.2(2)</b>
		✓		✓				✓		<b>68.8 (3)</b>
			✓			✓	✓			52.1
<b>Rural</b>	✓			✓			✓			65.4
		✓		✓			✓			63.2
	✓			✓	✓			✓		53.2
		✓		✓				✓		<b>69.4(3)</b>
	✓			✓					✓	<b>80.4(1)</b>
			✓	✓					✓	58.2
		✓		✓					✓	<b>76.2(2)</b>
			✓			✓	✓			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	
	✓			✓			✓			76.8
	✓				✓		✓			56
			✓	✓			✓			62.6
		✓		✓			✓			65
<b>Urban</b>	✓			✓				✓		<b>90.6(3)</b>
	✓				✓			✓		73.6
	✓					✓		✓		81.2

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

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 aligning with ensemble learning theory advanced by Leo Breiman.

### 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. The superior performance of machine learning approaches, especially Random Forest, offers a pathway for integrating predictive analytics into national reproductive health systems to enable early identification of at risk populations. 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, generalizability 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

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