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Artigo de Investigação

RELATIONSHIP BETWEEN FERTILITY RATES AND UNMET NEED FOR FAMILY PLANNING IN THE NILE BASIN COUNTRIES (1990-2023): A POPULATION GEOGRAPHY STUDY

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ABSTRACT – High Total Fertility Rates (TFR) in the Nile Basin countries remain a significant demographic and public health challenge. This study examines whether higher TFR is associated with higher unmet need for family planning across 11 Nile basin countries over the period 1990-2023. We conducted an ecological, cross-national analysis using country-level data aggregated over the study period, drawing on publicly available sources from the World Bank, the United Nations Population Division, and the Global Religious Futures database. The study employed Pearson correlation analysis and Principal Component Analysis (PCA) with Varimax rotation to assess the strength and underlying structure of these relationships. A strong and statistically significant positive correlation was found between TFR and unmet need for family planning across the region ($r = 0.93$, $p < 0.0001$), with a coefficient of determination of $r^2 = 0.86$, indicating that differences in unmet need may contribute to 86% of the cross-national variation in TFR in 2023. This association was especially pronounced in countries such as Kenya, Rwanda, Ethiopia, Eritrea, Egypt, and Uganda. PCA revealed a three-factor solution collectively explaining 78.74% of the total variance across the analytical variables; the first factor, on which unmet need for family planning was among the variables with notable loadings ($\lambda = 0.59$), accounted for 38.2% of this total variance. These findings underscore the critical importance of addressing unmet need for family planning as a central strategy for managing population growth in the Nile Basin. Targeted interventions, particularly in underserved rural areas, are essential to reduce TFR and advance reproductive health equity across the region.

Keywords: Correlation analysis; family planning; spatial distribution; total fertility rate; unmet need.

RESUMO – RELAÇÃO ENTRE AS TAXAS DE FERTILIDADE E AS NECESSIDADES NÃO SATISFEITAS DE PLANEAMENTO FAMILIARES NOS PAÍSES DA BACIA DO NILO (1990-2023): UM ESTUDO DA GEOGRAFIA DA POPULAÇÃO. As elevadas taxas de fecundidade total (TFT) nos países da bacia do Nilo continuam a representar um desafio demográfico e de saúde pública significativo. Este estudo examina se uma TFT mais elevada está associada a uma maior necessidade não satisfeita de planeamento familiar em 11 países da bacia do Nilo, no período de 1990-2023. Realizámos uma análise ecológica transnacional utilizando dados a nível nacional agregados ao longo do período do estudo, com base em fontes publicamente disponíveis do Banco Mundial, da Divisão de População das Nações Unidas e da base de dados *Global Religious Futures*. O estudo empregou a análise de correlação de Pearson e a Análise de Componentes Principais (ACP) com rotação *Varimax* para avaliar a força e a estrutura subjacente destas relações. Foi encontrada uma correlação positiva forte e estatisticamente significativa entre a TFT e a necessidade não satisfeita de planeamento familiar em toda a região ($r = 0,93$; $p < 0,0001$), com um coeficiente de determinação de $r^2 = 0,86$, indicando que as diferenças na necessidade não satisfeita explicam 86% da variação transnacional da TFT em 2023. Esta associação foi especialmente pronunciada em países como o Quénia, Ruanda, Etiópia, Eritreia, Egito e Uganda. A ACP revelou uma solução de três fatores que, coletivamente, explicam 78,74% da variância total entre as variáveis analíticas; o primeiro fator, no qual a necessidade não satisfeita de planeamento familiar se encontrava entre as variáveis com cargas fatoriais notáveis ($\lambda = 0,59$), explicou 38,2% desta variância total. Estas descobertas realçam a importância crucial de abordar a necessidade não satisfeita de planeamento familiar como uma estratégia central para a gestão do crescimento populacional na bacia do Nilo. As intervenções direcionadas, especialmente em zonas rurais carenciadas, são essenciais para reduzir a TFT e promover a equidade em saúde reprodutiva em toda a região.

***Palavras-chave*:** Análise de correlação; planeamento familiar; distribuição espacial; taxa de fecundidade total; necessidade não satisfeita.

HIGHLIGHTS

- Correlation between fertility and unmet need in the Nile basin countries.
- Ongoing challenges in ensuring equitable access to reproductive health services.
- Positive correlation was found between fertility and unmet needs.
- Unmet needs accounted for 38.2% of the variance in fertility rates.

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1. INTRODUCTION

The unprecedented pace of population growth in the Nile basin countries – comprising Burundi, the Democratic Republic of the Congo, Ethiopia, Eritrea, Kenya, Rwanda, South Sudan, Sudan, Uganda, Egypt, and Tanzania –poses formidable obstacles to the attainment of sustainable development goals (Abbas & Hamdi, 2022; El-Fadel *et al.*, 2003; Nahas *et al.*, 2025). Demographic projections forecast a dramatic escalation in the region's population, from 556 million in 2020 to an estimated 1 044 million by 2050 (Elmoughazi, 2025; Younis Elsary & Elmoughazi, 2026), with the Democratic Republic of the Congo anticipated to reach 197 million inhabitants by 2050, thus becoming the most populous nation within the basin. This demographic surge, particularly when it surpasses the rate of economic advancement, accentuates the imperative for robust and effective family planning interventions (Bokhari, 2024; Heuveline, 2001; McNamara, 1991).

Current demographic analyses indicate that several Nile Basin countries have exceeded the population size that their available resources and economic capacity can optimally sustain, underscoring the urgency of recalibrating population policies in line with resource availability and development targets (Kemei, 2024; Mandavilli, 2024). Fertility indicators serve as essential metrics for the formulation of evidence-based policies and strategic planning to address the evolving needs of the Nile Basin populace. The prevalence of unmet needs for family planning remains a critical determinant of elevated Total Fertility Rates (TFR) in the region. Empirical studies have documented substantial unmet needs for modern contraceptive methods among postpartum women in Sub-Saharan Africa, frequently resulting in unintended pregnancies and persistently high TFR (Vahdaninia, 2021). Addressing these gaps is indispensable for moderating population growth and enhancing reproductive health outcomes.

Over recent decades, the implementation of family planning programs has been instrumental in precipitating fertility decline across Africa. Longitudinal analyses indicate that the adoption of contraceptive methods has significantly contributed to this trend (Garenne, 2018), although persistent barriers – particularly in rural locales with limited access to services –continue to impede progress. Evidence from analogous contexts, such as rural Pakistan, demonstrates that exposure to family planning initiatives can profoundly influence reproductive choices and health care utilization, suggesting the potential efficacy of similar interventions in the Nile Basin (Khan & Wang, 2021). Fertility patterns within the reproductive age cohort of 15 to 34 years exhibit notable homogeneity (Beaujouan, 2023; Sobotka, 2004), with education emerging as the predominant socioeconomic variable driving fertility reduction (Bongaarts, 2020). Women in this demographic not only display higher TFR but also face heightened susceptibility to pregnancy-related health risks compared to older women.

Age-specific fertility rates (ASFRs) decline markedly with advancing age beyond the peak reproductive years (20-29), a pattern observed irrespective of urban or rural residence (Murray *et al.*, 2018). Socioeconomic inequities and environmental stressors –including rapid urbanization, land degradation, and industrial pressures in arid environments – further complicate the demographic landscape of the Nile Basin (Hamdi *et al.*, 2026). Analyses of the growth-poverty-inequality nexus reveal pronounced disparities in access to family planning services, as evidenced by spatial data spanning two decades (Lin *et al.*, 2022). Rectifying these inequities is essential to ensure universal and equitable access to reproductive health care. While notable progress has been achieved in expanding family planning coverage (Sharan *et al.*, 2011), substantial challenges persist, necessitating sustained efforts to fulfil the reproductive health needs of the population.

The influence of contraceptive utilization and access to safe abortion services on TFR is profound. Increased availability and uptake of these services have been shown to contribute significantly to fertility decline in Sub-Saharan Africa (Singh *et al.*, 2017). The reliability of contraceptive supply chains and the quality-of-service delivery environments are pivotal in shaping contraceptive use patterns (Wang, 2012). In the context of the Nile Basin, strengthening these dimensions is critical to addressing the persistent unmet need for family planning. A substantial body of literature elucidates the broader ramifications of family planning and fertility dynamics in Sub-Saharan Africa. Family planning is recognized as a cornerstone for achieving international development targets, including the Millennium Development Goals, by directly impacting maternal and child health, poverty alleviation, and gender equity (Cleland *et al.*, 2006).

Addressing the unmet need for family planning is vital for reducing TFR and advancing women's health and empowerment (Casterline & Sinding, 2004). Effective family planning programs, underpinned by governmental commitment and international collaboration, have demonstrated the capacity to yield significant demographic and socioeconomic dividends, including economic growth, enhanced educational attainment, and improved health indicators (Bongaarts, 2011; Cohen, 2000). The Sustainable Development Goals (SDGs) explicitly advocate for universal access to sexual and reproductive health care, encompassing

comprehensive family planning services (Islam, 2024). This commitment is intended to empower women to make informed decisions regarding contraceptive use, tailored to their individual circumstances. Despite ongoing initiatives, global projections indicate that the unmet demand for family planning will remain above 10% until at least 2030 (Nsashiyi *et al.*, 2024), although some regions may experience reductions (Kebede *et al.*, 2023).

Modern contraceptive modalities encompass female sterilization, oral contraceptive pills, intrauterine devices (IUDs), injectable contraceptives, implants, condoms, and diaphragms (Anderson & Johnston, 2023; Thakur *et al.*, 2023), while traditional methods include periodic abstinence, withdrawal, and prolonged breastfeeding. The unmet need for family planning constitutes a significant determinant of TFR (Adeokun, 1983; Agbana *et al.*, 2023). To effectively promote contraceptive uptake, policy frameworks must address both demand- and supply-side barriers. Comprehensive strategies should incorporate educational interventions within schools and communities to enhance awareness of pregnancy risks, underscore the health and familial benefits of contraception, and dispel pervasive misconceptions regarding its adverse effects (Ahinkorah *et al.*, 2023; Soucy *et al.*, 2023).

The principal objectives of this study are threefold: (i) to investigate TFR and their spatiotemporal patterns across the Nile Basin countries from 1990 to 2023, with particular attention to regional disparities; (ii) to assess the unmet needs for family planning methods, analyzing their distribution, variability, and influence on TFR among the constituent countries; and (iii) to elucidate the correlation between TFR and unmet needs for family planning, quantifying the strength and significance of this relationship through rigorous statistical analysis. A nuanced understanding of the multifaceted determinants of fertility in the Nile Basin – including unmet family planning needs, economic disparities, and access to reproductive health services – will enable policymakers to devise targeted interventions to manage population growth and optimize health outcomes in the region.

2. MATERIALS AND METHODS

2.1 Study area

The study area comprises the 11 Nile Basin countries interconnected by the Nile River, which stretches 6695km across approximately 35º latitude, from 4° South to 31° North (fig. 1).

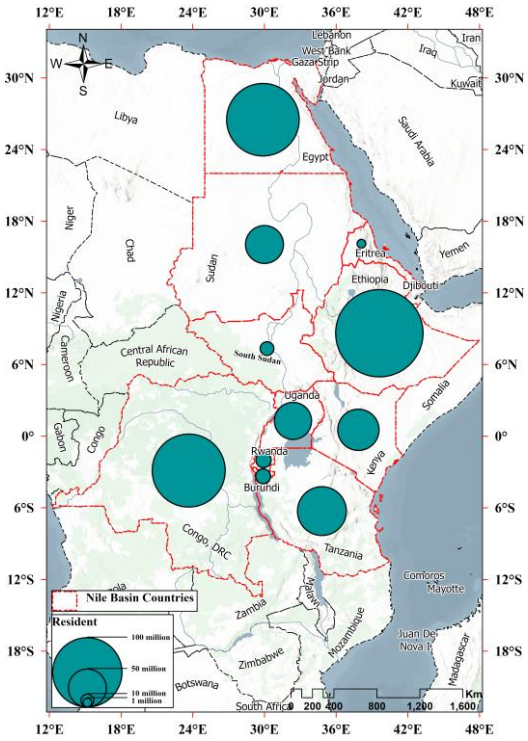

Fig. 1 – Resident population size of the Nile Basin countries, 2023.

Fig. 1 – Dimensão da população residente dos países da Bacia do Nilo, 2023.

Source: United Nations Population Division Data Portal, 2024

This vast latitudinal range results in significant climatic, cultural, and demographic diversity, transitioning from the tropical headwaters in the south to the arid Mediterranean region in the north (Lin *et al.*, 2022).

As illustrated in (fig.1), the region exhibits stark contrasts in population size, with each circle's area scaled directly to the absolute population of the corresponding country. Three nations, Egypt, Ethiopia, and the Democratic Republic of Congo, form the demographic heavyweights of the basin, each exceeding 100 million inhabitants.

A secondary tier comprises Tanzania and Kenya, with populations in the range of 50 to 100 million, followed by Sudan, which occupy intermediate population scales. Uganda represents a moderately populated state within the basin, while Rwanda, Burundi, and South Sudan have comparatively smaller populations.

Eritrea remains the least populous riparian state, with fewer than 5 million residents. This pronounced demographic asymmetry, as visually conveyed through the proportional symbols in (fig.1), underscores the highly uneven pressures on shared water resources, infrastructure, and governance frameworks across the basin's riparian states.

2.2 Data collection

This study adopts a quantitative approach in which fertility is operationalized specifically as TFR, rather than other fertility-related indicators such as the crude birth rate, age-specific fertility rate (ASFR), or fecundity rate (Hauer *et al.*, 2013). TFR is defined as the average number of children a woman would have over her reproductive lifespan if she experienced the prevailing age-specific fertility pattern observed in the population.

In this study, TFR is computed by aggregating ASFRs across the reproductive age range (15-49 years) using standard demographic procedures, and all subsequent analyses and interpretations of refer to TFR unless otherwise stated (Hauer & Schmertmann, 2020; Rallu & Toulemon, 1994).

Data were compiled from multiple authoritative sources. Demographic indicators – including TFR, family planning metrics, and population projections – were obtained from the United Nations Population Division Data Portal (United Nations Population Division, 2024).

Sociocultural and religious variables were sourced from the Pew Research Center's Global Religious Futures Project (Pew Research Center, 2024).

Socioeconomic and health-related development indicators were drawn from the World Bank's World Development Indicators database (World Bank, 2024), while governance and fragility metrics were obtained from the Fragile States Index (The Fund for Peace, 2024). Integrating these sources provides a cross-sectional, multi-source framework for examining fertility determinants across the Nile Basin countries.

2.3 Data Analysis

Data processing and statistical analyses were conducted using the *Statistical Package for the Social Sciences* (SPSS), a widely adopted tool for quantitative research in demographic and public health studies. Both descriptive and inferential statistical techniques were employed to rigorously examine the determinants of women's fertility in the Nile Basin countries, following current methodological standards in the field (Alemu *et al.*, 2024).

2.3.1. Total Fertility Rate

The TFR is defined as the average number of children a woman would have if she experienced the current age-specific TFR throughout her reproductive years (typically ages 15-49) (Murray et al., 2018). It is mathematically derived by aggregating these age-specific rates:

$$\mathrm{TFR} = \sum_{a=15}^{49} \mathrm{ASFR}_a \times i \tag{1}$$

Where:

ASFR_a = Age-Specific TFR for age group a

i = Width of the age interval (usually 5 years)

2.3.2. Age-Specific Fertility Rate

The Age-Specific Fertility Rate (ASFR) for a given age cohort constitutes the foundational metric for fertility analysis and is calculated as follows (Yasmeen & Mahmood, 2014):

$$\text{ASFR}_a = \frac{\text{Number of live births to women aged } a}{\text{Number of women aged } a} \quad (2)$$

2.3.3. Pearson Correlation coefficient

The Pearson correlation coefficient is utilized to quantify the strength and direction of the linear relationship between two continuous variables, such as unmet need for family planning and TFR (Asmamaw & Negash, 2022).

This statistical metric evaluates how changes in one variable correspond to changes in another, providing a standardized value that indicates whether the association is positive, negative, or neutral. By calculating this coefficient, the analysis determines the degree to which these demographic indicators move in tandem across the study's observations.

2.3.4. Principal Component Analysis

Principal Component Analysis (PCA) is a multivariate statistical technique widely used to reduce the dimensionality of datasets by transforming a set of correlated observed variables into a smaller number of uncorrelated components, known as principal components.

In demographic and fertility research, PCA is frequently applied to summarize the main dimensions of variation in the observed variables, thereby facilitating the interpretation of complex data structures (Aylie *et al.,* 2020; Kellow, 2006; Krishnan, 2010). PCA seeks linear combinations of the observed variables that maximize the variance explained.

The first principal component is defined as:

$$PC_1 = a_{11}X_1 + a_{12}X_2 + \cdots + a_{1p}X_p \quad (3)$$

Where:

PC_1 = first principal component

$a_{1\text{j}}$ = coefficient (loading) for variable X_j in the first component

X_j = observed variable j

p = total number of observed variables

The coefficients $a_{1\text{j}}$ are chosen so that the variance of PC_1 is maximized, subject to the constraint that the sum of the squared coefficients equals one:

$$\sum_{j=1}^{p} a_{1j}^2 = 1 \quad (4)$$

These equations form the analytical foundation for the quantitative assessment of TFR, its determinants, and the relationship with unmet needs for family planning in the Nile Basin countries (Alie *et al.*, 2022; Asmamaw & Negash., 2022).

To elucidate the underlying structure of components influencing TFR in the Nile Basin countries, PCA was conducted using the demographic, socioeconomic, and health-related variables listed. The suitability of the data for this analysis was confirmed by a Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy of 0.81, indicating that the correlation matrix was appropriate for components extraction.

The rotation process converged after five iterations, yielding a final solution of three principal components that collectively summarized the variance in the dataset. Variables exhibiting significant cross-

loadings were excluded from the final rotated component matrix to ensure distinct components definitions. Figure 2 depicts a visualization of the working method and methodology of the study.

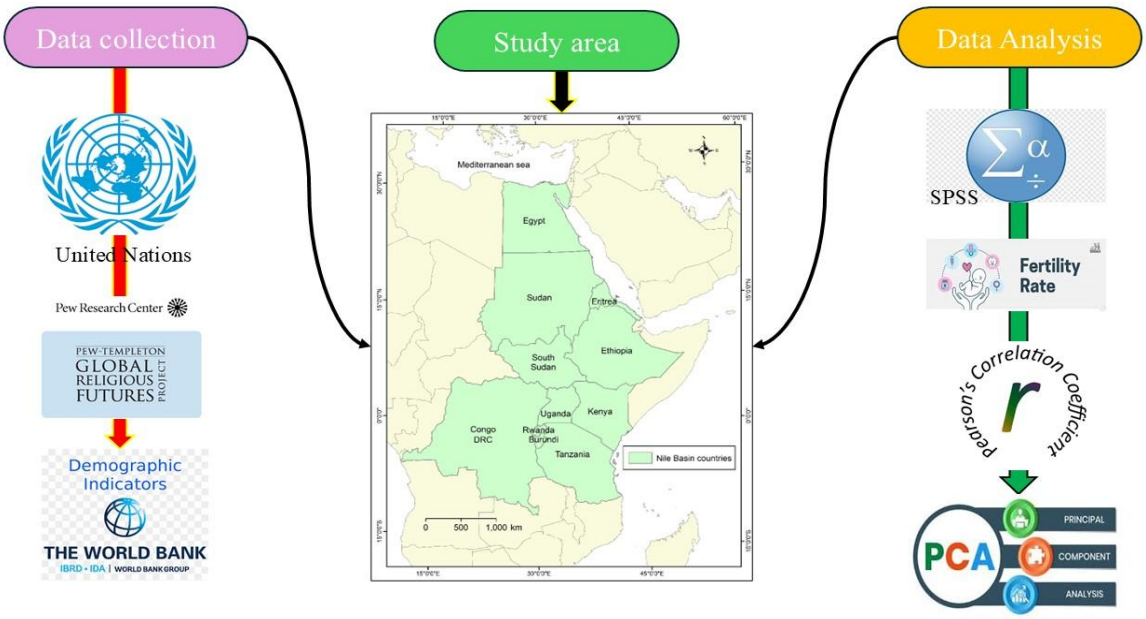

Fig. 2 – Overall flowchart of research method.

Fig. 2 – Fluxograma geral do método de investigação.

Source: Authors

3. RESULTS

3.1 Statistical analysis of fertility determinants

PCA was conducted to identify the main dimensions associated with TFR in the Nile Basin countries, as presented in table I. The analysis incorporated demographic, socioeconomic, and health-related variables, with particular attention to unmet need for family planning.

The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was 0.81, indicating that the correlation structure of the data was suitable for component extraction (Kaiser, 1974).

Components with eigenvalues greater than 1.0 were retained in accordance with the Kaiser criterion (Kaiser, 1960), and Varimax rotation with Kaiser normalization was applied to improve the interpretability of the solution (Kaiser, 1958).

Six variables were excluded from the rotated component matrix due to substantial cross-loadings, defined as secondary loadings exceeding 0.32 or a difference between primary and secondary loadings of less than 0.10. The PCA yielded three named components with eigenvalues exceeding 1.0, collectively explaining 78.74% of the total variance.

The first component, *Socioeconomic Development and Reproductive Health*, explained 38.21% of the variance and loaded strongly on female labour force participation; Christian religious affiliation; cause of death by communicable diseases and maternal and nutritional conditions; Gross Domestic Product (GDP) *per capita*; female employment in agriculture; women's autonomy in reproductive decision-making; maternal mortality ratio; unmet need for family planning; and the proportion of female contributing family workers. The second component, *Women's Empowerment and Healthcare Access*, accounted for 22.28% of the variance and was defined by adult female literacy rate; prenatal care coverage; the Women's Empowerment Index; births attended by skilled health staff; contraceptive prevalence; and female age at first marriage. The third component, *Adolescent Fertility and Rurality*, explained the remaining 18.25% of variance and loaded on the proportion of teenage mothers; rural population share; adolescent fertility rate; and female industrial employment.

Component scores were used to characterise the relative position of each country along the three identified dimensions, with positive scores indicating alignment with the dominant pattern of the component and negative scores indicating divergence from it.

For *Socioeconomic Development and Reproductive Health*, positive scores were observed across most Nile Basin countries, with the exception of Egypt and Sudan, where labour force participation and economic indicators were less consistent with the regional pattern. For *Women's Empowerment and Healthcare Access*, positive scores were recorded in Kenya, Uganda, Rwanda, Tanzania, Egypt, and the Democratic Republic of Congo, reflecting comparatively higher levels of female education, healthcare utilisation, and contraceptive uptake in those countries. For *Adolescent Fertility and Rurality*, positive scores were found in Rwanda, Kenya, Ethiopia, Burundi, South Sudan, and Egypt, indicating that rural residence and adolescent reproductive characteristics contributed more strongly to fertility variation in these settings.

Table I – Rotated principal component structure of variables associated with total fertility rate in the Nile Basin countries, 2023.

Quadro I – Estrutura rotacionada dos componentes principais das variáveis associadas à taxa de fecundidade total nos países da Bacia do Nilo, 2023.

#	Item	Component		
		1	2	3
		Socioeconomic Development and Reproductive Health	**Women's Empowerment and Healthcare Access**	**Adolescent Fertility and Rurality**
1	Labor force, female (% of total labor force)	0.97		
2	Christianity	0.89		
3	Cause of death, by communicable diseases and maternal, prenatal and nutrition conditions (% of total)	0.86		
4	GDP *per capita* (current US$)	0.81		
5	Employment in agriculture, female (% of female employment)	0.78		
6	Women making their own informed decisions regarding sexual relations, contraceptive use and reproductive health care (% of women age 15-49)	0.66		
7	Maternal mortality ratio (per 100 000 live births)	0.64		
8	Unmet need for family planning: Any modern method (% of married women ages 15-49)	0.59		
9	Contributing family workers, female (% of female employment)	0.57		
10	Literacy rate, adult female (% of females ages 15 and above)		0.95	
11	Pregnant women receiving prenatal care (%)		0.90	
12	Women's Empowerment Index (WEI)		0.78	
13	Births attended by skilled health staff (% of total)		0.76	
14	Contraceptive prevalence, any method (% of married women ages 15-49)		0.76	
15	Age at first marriage, female		0.70	
16	Teenage mothers (% of women ages 15-19 who have had children or are currently pregnant)			0.86
17	Rural population (% of total population)			0.73
18	Adolescent fertility rate (births per 1000 women ages 15-19)			0.56
19	Employment in industry, female (% of female employment)			0.39

Source: Authors

3.2 Geographic and demographic patterns

Figure 3 illustrates the spatial distribution of TFR and unmet needs for family planning across the Nile Basin countries in 2023. The spatial distribution of TFR in 2023, as depicted in the thematic map (fig. 3a), categorizes the Nile Basin countries into three classes based on the average number of children born per woman.

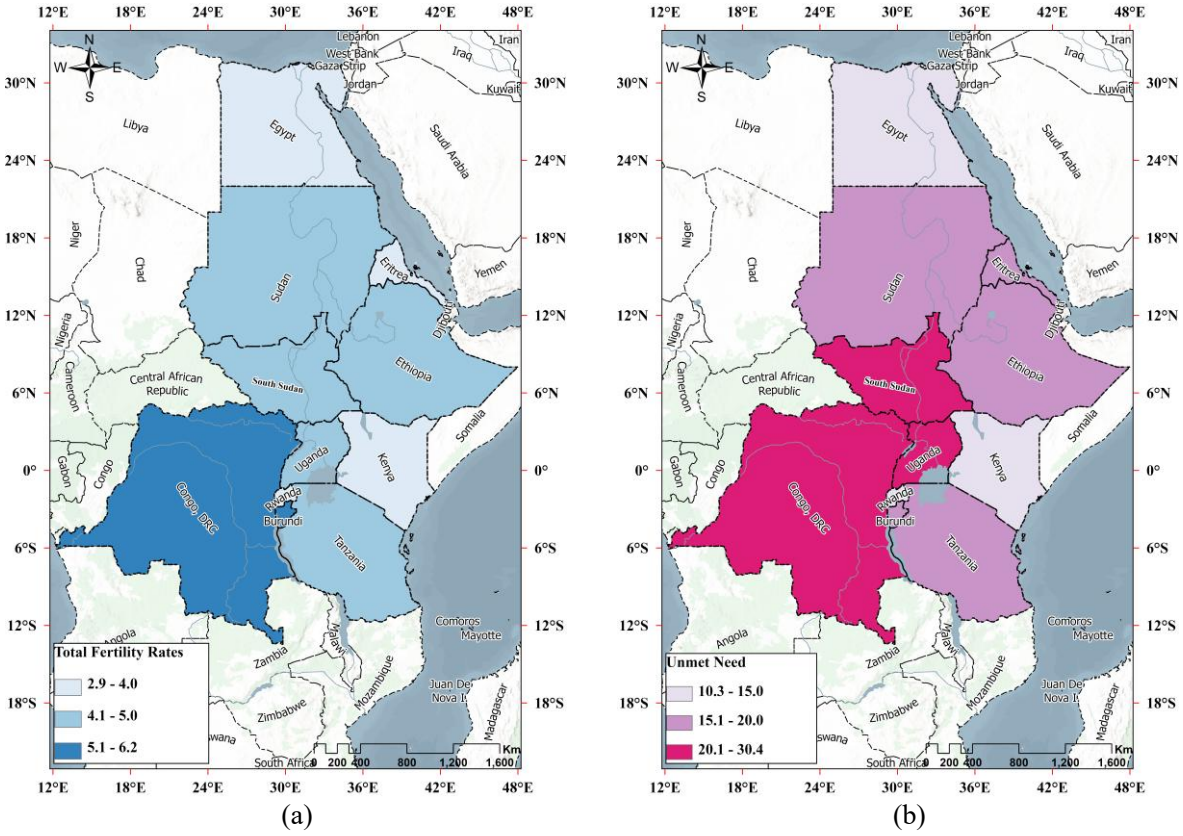

Fig. 3 – (a) Spatial distribution of TFR and (b) unmet needs for family planning tools in the Nile Basin countries, 2023.

Fig. 3 – (a) Distribuição espacial da TFR e (b) necessidades não satisfeitas de ferramentas de planeamento familiar nos países da Bacia do Nilo, 2023.

Source: United Nations Population Division Data Portal, 2024

Egypt, Eritrea, Kenya and Rwanda, shaded in light blue, exhibit the lowest TFR (2.9-4.0), reflecting advanced progress in family planning and demographic transition. Countries such as Sudan, South Sudan, Ethiopia, Uganda, and Tanzania fall into the medium category (4.1-5.0), shaded in medium blue. The highest TFR (5.1-6.2), represented in dark blue, is observed in the Democratic Republic of Congo and Burundi. This north-south gradient aligns with established demographic transition theory, wherein countries with more advanced socioeconomic development tend to have lower TFR.

The second thematic map (fig. 3b) illustrates the unmet need for family planning, also classified into three categories. Egypt, Kenya and Rwanda, shaded in light purple, report the lowest levels of unmet need (10.3-15.0), indicative of better access to reproductive health services and effective family planning programs. Countries including Sudan, Eritrea, Ethiopia, Burundi, and Tanzania occupy the medium range (15.1-20.0), represented in medium purple. Meanwhile, the highest levels of unmet need (20.1-30.4), shown in dark magenta, are found in the Democratic Republic of Congo, South Sudan, and Uganda.

These findings highlight significant disparities in access to contraceptive and family planning services across the region. A visual inspection of the two maps suggests a broadly consistent spatial pattern, whereby countries with higher TFR tend to report greater unmet need for family planning; this descriptive observation is supported by the strong and statistically significant positive correlation documented in the quantitative analysis ($r = 0.93$, $p < 0.0001$; see Section 3). Notably, the Democratic Republic of the Congo exhibits both

the highest TFR and the greatest unmet need, while South Sudan and Uganda report the highest unmet need alongside medium TFR levels.

3.3 Spatial association between total fertility and unmet need

The bivariate spatial analysis (fig. 4) reveals a pronounced north-south dichotomy in the relationship between TFR and unmet need for family planning across the Nile Basin countries in 2023.

A distinct "high-burden" cluster is evident in the central and southern equatorial regions, encompassing the Democratic Republic of Congo, South Sudan, Uganda, and Tanzania. In these nations, depicted in magenta, high TFR spatially coincides with elevated levels of unmet need, suggesting that the inability to access contraceptive services remains a primary driver of rapid population growth in this sub-region. Conversely, the northern and eastern territories specifically Egypt, Sudan, Eritrea, Ethiopia, and Kenya demonstrate a contrasting pattern characterized by relatively lower unmet need and moderate-to-low TFR, shown in cyan. This distribution reflects the varying degrees of success in national family planning programs, with Egypt exhibiting the most advanced demographic transition. Burundi emerges as notable exception, depicted in turquoise. This nation display relatively lower unmet need but persistent higher fertility, indicating that factors other than service access, such as desired family size or cultural norms, may be sustaining fertility levels in these specific contexts.

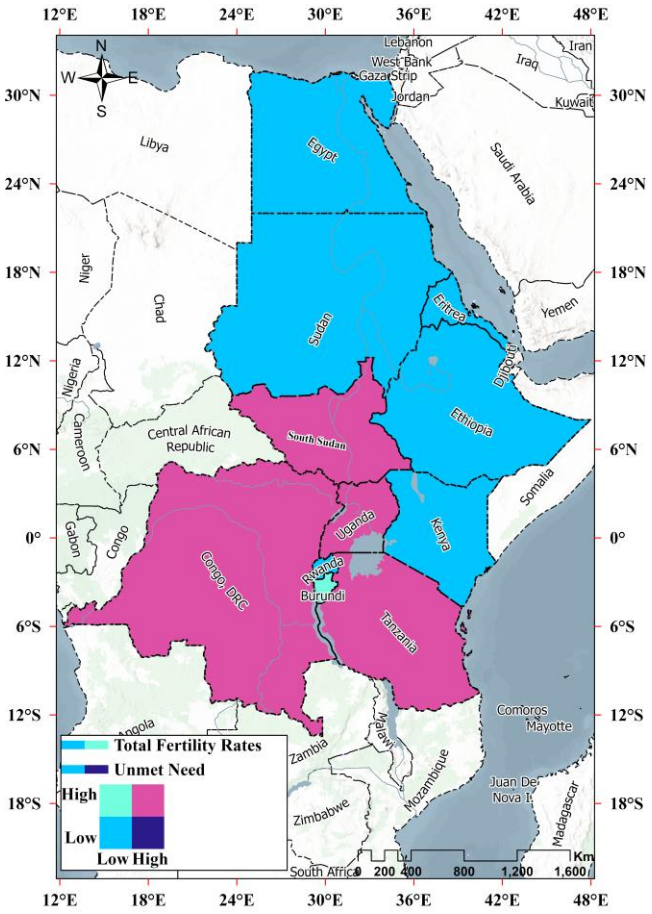

Fig. 4 – Spatial relationship between TFR and unmet need for family planning in the Nile Basin countries, 2023.

Fig. 4 – *Relação espacial entre as TFT e a necessidade não atendida de planeamento familiar nos países da Bacia do Nilo, 2023.*

Source: Authors

3.4 Comparative Analysis of TFR and unmet family planning needs in the Nile Basin (1990-2023)

Table II delineates the mean and standard deviation (SD) of unmet needs for family planning methods and women's TFR across the Nile Basin countries from 1990 to 2023. The data reveal pronounced heterogeneity in both TFR and unmet needs for family planning throughout the region.

TFR remain markedly elevated in countries such as the Democratic Republic of the Congo (6.54 ± 0.18) and Burundi (6.37 ± 0.76), signifying persistently high birth rates over the study period. Similarly, South Sudan (6.22 ± 1.39) and Uganda (6.11 ± 0.87) exhibit substantial fertility levels, indicating that reproductive health interventions have yet to yield significant reductions in these contexts. In contrast, Egypt (3.41 ± 0.42) demonstrates the lowest TFR among the Nile Basin countries, reflecting the effectiveness of comprehensive family planning policies and sustained fertility decline.

The extent of unmet needs for family planning methods also varies considerably. The Democratic Republic of the Congo reports the highest unmet need (33.29 ± 1.24), followed by Uganda (26.69 ± 2.89) and Tanzania (23.20 ± 1.93). These elevated levels of unmet need are closely associated with higher TFR, underscoring persistent barriers to accessing reproductive health services.

Conversely, Egypt's unmet need (12.08 ± 2.60) is the lowest in the region, suggesting more robust access to family planning and contributing to its lower TFR.

At the aggregate level, the Nile Basin exhibits a mean TFR of 5.42 ± 0.75 and an unmet need of 22.11 ± 2.50, both of which substantially exceed global averages (World TFR: 2.64 ± 0.24; World unmet need: 14.68 ± 1.31). These disparities highlight the significant reproductive health challenges confronting the Nile Basin countries relative to global trends.

The variability in unmet needs, as indicated by the SD, is particularly pronounced in Kenya (21.52 ± 6.05) and Rwanda (20.66 ± 5.57), reflecting inconsistent access to modern family planning methods. In contrast, South Sudan (23.14 ± 0.40) and the Democratic Republic of the Congo (33.29 ± 1.24) display minimal variability, indicative of persistently high and uniform levels of unmet need.

Table II – TFR and unmet family planning needs across Nile Basin countries (1990-2023).

Quadro II – TFT e necessidades de planeamento familiar não satisfeitas nos países da bacia do Nilo (1990-2023).

Countries	TFR (Mean ± SD)	Unmet Needs (Mean ± SD)
Burundi	6.37 ± 0.76	21.99 ± 1.17
Democratic Republic of Congo	6.54 ± 0.18	33.29 ± 1.24
Ethiopia	5.69 ± 1.12	21.76 ± 4.84
Eritrea	4.92 ± 0.79	19.12 ± 2.28
Kenya	4.57 ± 0.83	21.52 ± 6.05
Rwanda	5.14 ± 1.05	20.66 ± 5.57
South Sudan	6.22 ± 1.39	23.14 ± 0.40
Sudan	5.18 ± 0.50	19.68 ± 1.00
Uganda	6.11 ± 0.87	26.69 ± 2.89
Egypt	3.41 ± 0.42	12.08 ± 2.60
Tanzania	5.42 ± 0.45	23.20 ± 1.93
Nile Basin	5.42 ± 0.75	22.11 ± 2.50
World	2.64 ± 0.24	14.68 ± 1.31

Source: United Nations Population Division Data Portal, 2024

3.5 Correlation between TFR and unmet needs for family planning in the Nile Basin (1990-2023)

Table III presents the results of a correlation analysis examining the relationship between TFR and unmet needs for family planning methods in the Nile Basin countries from 1990 to 2023.

The analysis demonstrates a consistently strong and statistically significant association between these two variables across the region. R values range from 0.55 to 0.99, with all corresponding p-values indicating high statistical significance ($p < 0.001$). The findings reveal that in nearly all Nile Basin countries, higher levels of unmet need for family planning are closely linked to elevated TFR. For instance, Eritrea ($r = 0.99$, $p = 0.000$) and Kenya ($r = 0.99$, $p = 0.000$) exhibit near-perfect correlations, suggesting that inadequate access to modern contraceptive methods is a primary factor sustaining high TFR in these contexts. Similarly, Sudan ($r = 0.99$, $p = 0.000$) and Uganda ($r = 0.91$, $p = 0.000$) also display very strong associations, further emphasizing the critical role that unmet contraceptive needs play in maintaining high birth rates.

South Sudan stands out as having the lowest, yet still significant, correlation ($r = 0.55$, $p = 0.001$). This result suggests that while unmet need for family planning remains an important determinant of fertility, other influences such as cultural norms, socio-political dynamics, or health system limitations may also be shaping fertility patterns in this country. When considering the aggregate data, both the Nile Basin as a whole (r =

0.99, p = 0.000) and the global context (r = 0.97, p = 0.000) confirm the broader trend that unmet needs for family planning are a major driver of elevated TFR. These high correlation coefficients at both regional and global levels underscore the importance of expanding access to family planning services as a strategy for fertility reduction.

Table III – Correlation of TFR with unmet needs for family planning methods in the Nile Basin Countries (1990-2023).

Quadro III – Correlação da TFT com as necessidades não satisfeitas de métodos de planeamento familiar nos países da bacia do Nilo (1990-2023).

Countries	r	p-value
Burundi	0.85	0.000
D. R. Congo	0.76	0.000
Ethiopia	0.99	0.000
Eritrea	0.99	0.000
Kenya	0.99	0.000
Rwanda	0.98	0.000
South Sudan	0.55	0.001
Sudan	0.99	0.000
Uganda	0.91	0.000
Egypt	0.95	0.000
Tanzania	0.97	0.000
Nile Basin	0.99	0.000
World	0.97	0.000

Source: United Nations Population Division Data Portal, 2024

Figure 5 illustrates the association between unmet need for family planning and TFR in 2023 across the Nile Basin countries. The scatterplot indicates a pronounced positive relationship between these two variables, consistent with the Pearson correlation coefficient of 0.93 (p < 0.0001) and a 95% confidence interval ranging from 0.73 to 0.98, confirming that the association is statistically significant and robust.

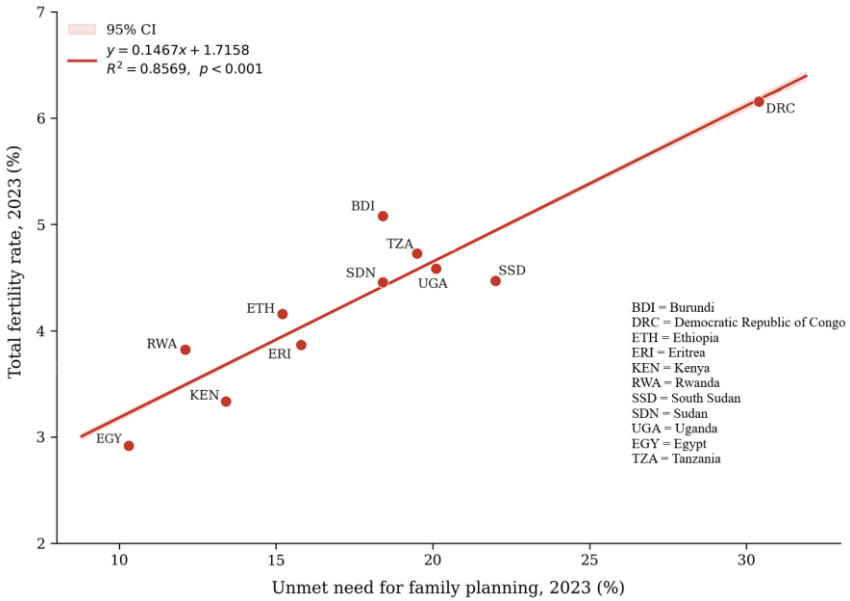

Fig. 5 – Scatterplot of unmet needs family planning with TFR.

Fig. 5 – Diagrama de dispersão das necessidades não satisfeitas de planeamento familiar com TFT.

Source: United Nations Population Division Data Portal, 2024

The strength of this relationship is further supported by the coefficient of determination (r^2 = 0.86), which indicates that 86% of the variation in TFR across countries can be explained by differences in unmet need for family planning in 2023. This implies a strong linear association, although it is not a near-perfect fit; therefore, the statement that unmet need is strongly associated with almost all fertility variation should be moderated accordingly.

Countries such as the Democratic Republic of the Congo and South Sudan, which report some of the highest levels of unmet need, also exhibit persistently high TFR. Conversely, nations like Egypt, where access to family planning services is more widespread, demonstrate lower TFR and reduced unmet need. The spatial patterns observed in the scatterplot reinforce the critical role of reproductive health services in shaping demographic trends.

4. DISCUSSION

4.1. Regional evidence on TFR-unmet need link

Despite decades of research on fertility and family planning in sub-Saharan Africa, significant knowledge gaps persist regarding the persistence and drivers of high TFR in the Nile Basin countries. While the association between unmet need for family planning and elevated fertility is well recognized, few studies have systematically quantified the strength and consistency of this relationship across the entire Nile Basin over an extended period (Ainsworth *et al.*, 1996). Much of the existing literature focuses on national or subnational trends, often neglecting the comparative, cross-country perspective essential for understanding regional disparities and informing coordinated policy responses (Bongaarts, 2020; Wildeman *et al.*, 2023). Recent studies have also highlighted the need to disentangle the effects of unmet need from other determinants such as education, socioeconomic status, and health system access, yet comprehensive, multivariate analyses remain scarce (Alie *et al.*, 2022).

This study addresses these gaps by providing a robust, region-wide analysis of the correlation between TFR and unmet need for family planning across 11 Nile Basin countries from 1990 to 2023. The results reveal a strong and statistically significant positive correlation ($r = 0.93$, $p < 0.0001$) between TFR and unmet need for family planning. The first principal component of the PCA, which was heavily loaded by unmet need and related reproductive health indicators, accounted for 38.21% of the total variance in the multivariate dataset, underscoring the centrality of this dimension within the overall structure of fertility determinants. This finding is consistent with recent evidence from sub-Saharan Africa, where unmet need for contraception remains high –often between 20% and 30% – and is closely linked to elevated fertility, particularly in countries with limited access to reproductive health services (Alayande *et al.*, 2023; Alemu *et al.*, 2024).

The observed regional decline in TFR, especially in Kenya, Rwanda, Ethiopia, Eritrea, Egypt, and Uganda, aligns with previous studies documenting the impact of expanded education and increased contraceptive use among women (Ainsworth *et al.*, 1996; Bongaarts, 2020). For example, recent analyses in Ethiopia and Egypt have shown that improvements in female education and targeted family planning programs are associated with both reduced unmet need and lower TFR (Abdelsalam *et al.*, 2021; Getachew & Kibret, 2025). However, the persistence of high fertility and unmet need in countries such as DRC, Burundi, South Sudan, Sudan, Uganda, and Tanzania underscores ongoing barriers to contraceptive access and use, echoing findings from recent multi-country studies in the region (Baranon *et al.*, 2024; Turner & Götmark, 2023).

The magnitude of the correlation found in this study is notably higher than that reported in some earlier research, which often identified weaker associations between unmet need and fertility decline, particularly when controlling for confounding factors such as education and socioeconomic status. For instance, Casterline & El-Zeini (2014) noted that fertility decline in sub-Saharan Africa is only weakly associated with trends in unmet need, suggesting that other factors such as desired family size and cultural norms play substantial roles. However, more recent studies using updated datasets and advanced statistical methods have reported stronger links, particularly in contexts where family planning programs have been effectively implemented (Alie *et al.*, 2022; Kraft *et al.*, 2022).

4.2. Country heterogeneity and multidimensional determinants

Country-specific patterns further illustrate the complexity of these relationships. In Ethiopia, for example, a reduction in unmet need has not always translated into a proportional decline in fertility, likely due to uneven implementation of family planning programs and persistent regional disparities (Teferi & Schröders, 2023). In contrast, Egypt, Eritrea, and Rwanda have demonstrated more consistent progress, with well-integrated family planning policies leading to both lower unmet needs and reduced fertility. These findings are supported by recent national surveys and program evaluations, which highlight the importance of comprehensive, context-specific interventions (Aly & Aly, 2023; Zalak & Goujon, 2017).

The PCA conducted in this study revealed that unmet need, along with socioeconomic status, health system access, and cultural norms, constitutes a principal dimension of the fertility landscape, with the three extracted components collectively accounting for nearly 79% of the total variance in the multivariate dataset.

This multidimensional perspective is supported by recent research emphasizing the interplay between individual, household, and community-level factors in shaping reproductive behavior (Alie *et al.*, 2022; Wildeman *et al.*, 2023). For example, studies have shown that women with higher levels of education, greater autonomy, and better access to health services are less likely to have unmet needs and more likely to achieve their desired family size (Bongaarts, 2011; Gausman *et al.*, 2023).

Importantly, the persistence of high fertility and unmet need in countries like the Democratic Republic of Congo and South Sudan highlights the urgent need for tailored policy interventions that address local demographic, economic, and infrastructural conditions (Baranon *et al.*, 2024; Turner & Götmark, 2023). Recent systematic reviews and meta-analyses have called for the expansion of family planning services, targeted outreach to underserved populations, and the integration of reproductive health education into broader development programs (Chaurasia, 2023; Nsashiyi *et al.*, 2024). Addressing these challenges is essential for achieving the Sustainable Development Goals related to health, gender equality, and poverty reduction (Islam, 2024).

4.3. Study limitations

This study is subject to several important limitations that should be considered when interpreting its findings. The analysis is based on cross-sectional averages spanning a long period (1990-2023); using averages may yield different results than when the median is applied, which means that year-to-year changes, policy impacts, and temporal trends within individual countries may be obscured (Hamdi *et al.*, 2025). Such an approach increases the risk of ecological fallacy and aggregation bias, as it does not capture within-country variations or short-term fluctuations. Furthermore, the study does not sufficiently control for confounding variables such as education, urbanization, economic status, health system quality, and cultural factors, all of which are known to influence both TFR and unmet need for family planning. While the PCA incorporates multiple variables, the interpretation and control of these confounders remain limited, and a regression-based approach would be required to formally quantify the independent contribution of any single variable to variation in TFR.

Another significant limitation relates to data quality and consistency. The study draws data from multiple reputable sources, including the United Nations, World Bank, and Pew Research Center, but differences in definitions, data collection methods, and reporting standards across countries and years may affect the comparability and reliability of the results. Issues such as underreporting, missing data, or inconsistencies in national surveys are not fully addressed, which could impact the robustness of the conclusions, in addition to factors related to the climate and geographic character of each region and the extent of its influence on the population (Hamdi *et al.*, 2024).

5. CONCLUSION

This study establishes a strong and statistically significant positive association between TFR and unmet need for family planning across the Nile Basin countries from 1990 to 2023 ($r = 0.93$, $p < 0.0001$). The PCA identifies unmet need as a central dimension of the fertility landscape in the region, with the first principal component – heavily characterized by unmet need and related reproductive health indicators – accounting for 38.21% of the total variance in the multivariate dataset. While notable progress has been made in countries such as Kenya, Rwanda, and Egypt – where declines in both indicators reflect successful policy implementations – nations like the Democratic Republic of Congo, Uganda, and Sudan continue to experience persistently high levels of both fertility and unmet need. These disparities highlight the critical role of equitable access to reproductive health services in shaping demographic outcomes.

However, the findings also indicate that reducing unmet need alone is insufficient for lowering TFRs, as the relationship is mediated by broader socioeconomic and structural factors. The multidimensional analysis reveals that female labour force participation, maternal health indicators, and cultural contexts are integral components of the fertility landscape. Consequently, effective interventions must go beyond the provision of contraceptives to encompass comprehensive development strategies, including improvements in women's education, economic empowerment, and health infrastructure. Future research should prioritize

longitudinal and spatially disaggregated approaches to better capture local nuances and inform targeted, context-specific policies that can sustain fertility transitions across the region.

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