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Aster Beyene Negesse

asterbeyene116@gmail.com

Dilla University

Selamawit Serka Mojo

Hawassa University

Tesfaye Tekleselassie Gashawbeza

Dilla University

Awoke Derese Fenta

Dilla University

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Spatial Distribution and Multilevel Determinants of Fertility among Married Women in Ethiopia: Evidence from the 2016 Ethiopian Demographic and Health Survey

Aster Beyene Negesse^{1*}, Selamawit Serka Mojo², Tesfaye Tekleselassie Gashawbeza¹, Awoke Derese Fenta¹

¹ Dilla University, Dilla, Ethiopia

² Hawassa University, Hawassa, Ethiopia

***Correspondence:**

Aster Beyene Negesse

Dilla University, Dilla, Ethiopia

Email: asterbeyene116@gmail.com

Abstract

Background: Fertility remains a key demographic and public health issue in Ethiopia, with marked spatial variation across regions. Understanding its distribution and determinants is essential for targeted reproductive health interventions. This study aimed to examine the spatial distribution and determinants of fertility among married women in Ethiopia.

Methods: A secondary analysis was conducted using data from the 2016 Ethiopian Demographic and Health Survey (EDHS), including 9,305 married women aged 15–49 years. Spatial analysis was used to identify clustering and hotspot areas of fertility. A multilevel mixed-effects negative binomial regression model was fitted to identify individual-, household-, and contextual-level determinants of the number of living children. Model fit was assessed using log-likelihood, AIC, and BIC.

Results: Fertility showed significant spatial variation, with hotspots in SNNPR, Oromia, Somali, Gambela, and Benishangul-Gumuz, and cold spots in Addis Ababa, Dire Dawa, Harari, and parts of Amhara. The negative binomial model showed better fit than the Poisson model, confirming overdispersion. About 88.3% of between-region variation was explained by covariates, although a small residual heterogeneity remained. Rural residence was associated with higher fertility (IRR

= 1.09; 95% CI: 1.03–1.15). Education showed a strong inverse dose–response relationship with fertility. Age at first birth and contraceptive use were negatively associated with fertility. Women in female-headed households had lower fertility. In contrast, working women and women from richer households had slightly higher fertility. Religious differences were observed, with lower fertility among Orthodox women and higher fertility among Protestant women compared with Muslim women. Discordance in fertility preferences and higher husband education were also associated with higher fertility.

Conclusion: Fertility in Ethiopia exhibits significant spatial clustering and is influenced by demographic, socioeconomic, and contextual factors. The findings suggest that fertility reduction strategies should prioritize hotspot regions through targeted interventions focusing on female education, improved access to family planning, delayed childbearing, and male involvement in reproductive health programs.

Keywords: Fertility; Spatial distribution; Hotspot analysis; Kriging interpolation; Multilevel negative binomial regression; Ethiopia; EDHS.

Introduction

Fertility remains a key determinant of population growth and a major public health concern globally. Although fertility has declined over recent decades, substantial regional disparities persist, particularly in sub-Saharan Africa [1,2,26]. According to United Nations estimates, the global total fertility rate declined from 3.3 births per woman in 1990 to 2.3 in 2021; however, sub-Saharan Africa continues to record the highest fertility levels worldwide [1]. High fertility contributes to rapid population growth and places considerable pressure on health systems, education services, and broader socioeconomic development [1–3,25]. Persistent inequalities in sexual and reproductive health services continue to influence fertility outcomes and reproductive choices globally, as highlighted by UNFPA reports.

Ethiopia, the second most populous country in Africa, has undergone a gradual demographic transition; however, fertility remains relatively high compared with many developing countries. The 2016 Ethiopian Demographic and Health Survey (EDHS) indicates marked disparities in fertility across regions, place of residence, and socioeconomic groups [3]. These disparities have

important implications for maternal and child health, household welfare, and national development planning.

Empirical studies in Ethiopia have identified multiple determinants of fertility, including women's educational attainment, age at first birth, contraceptive use, religion, household wealth status, employment status, and partner-related characteristics [5–8]. In general, lower education, early initiation of childbearing, limited access to reproductive health services, and disadvantaged socioeconomic conditions are associated with higher fertility levels [5–7]. Fertility behavior is also influenced by cultural norms, fertility preferences, and household decision-making dynamics [6–8].

Beyond individual and household factors, fertility exhibits substantial geographic variation. Such spatial heterogeneity is driven by differences in socioeconomic development, access to health services, cultural practices, and community-level norms. Identifying spatial clustering and hotspot areas of high fertility is essential for guiding geographically targeted reproductive health interventions and efficient resource allocation. Previous studies in Ethiopia have also reported significant spatial variation in reproductive health outcomes, highlighting the importance of spatial analytical approaches [9].

Given the hierarchical structure of EDHS data, where individuals are nested within communities and regions, conventional regression models may produce biased estimates due to clustering effects. Multilevel modeling provides a robust framework for accounting for unobserved heterogeneity at different levels while simultaneously examining individual- and contextual-level determinants [10]. In addition, fertility is a count outcome that often exhibits overdispersion; therefore, the negative binomial regression model is more appropriate than standard linear or Poisson models [11,12].

However, evidence integrating spatial analysis with multilevel mixed-effects count regression to jointly examine fertility patterns and determinants in Ethiopia remains limited. To the best of our knowledge, no previous study has simultaneously applied spatial analysis and multilevel mixed-effects negative binomial regression using EDHS data to investigate fertility among married women in Ethiopia.

Therefore, this study aimed to examine the spatial distribution and determinants of fertility among married women in Ethiopia using the 2016 EDHS. Specifically, spatial analytical techniques were

employed to identify clustering and hotspot areas of fertility, while multilevel mixed-effects negative binomial regression was used to assess individual- and contextual-level determinants. The findings are expected to inform geographically targeted reproductive health policies and contribute to reducing fertility disparities in Ethiopia.

2.1 Study Setting, Data Source, and Sampling Design

This study was based on secondary data obtained from the 2016 Ethiopian Demographic and Health Survey (EDHS) [4]. Ethiopia is located in the Horn of Africa in East Africa, between 3° and 15° north latitude and 33° and 48° east longitude. The country has diverse topographic and climatic conditions, ranging from highland areas exceeding 4,000 meters above sea level to lowland regions such as the Danakil Depression. The EDHS is a nationally representative survey implemented by the Central Statistical Agency (CSA) of Ethiopia in collaboration with ICF International and is designed to collect standardized demographic, health, and socioeconomic data across the country.[4]

The survey employed a stratified, two-stage cluster sampling design based on the 2007 Population and Housing Census frame [4]. In the first stage, 645 enumeration areas (EAs) were selected using probability proportional to size (PPS), and in the second stage, 28 households per cluster were selected using systematic random sampling. A total of 16,650 households were successfully interviewed, yielding a 98% response rate. From these households, 15,683 women aged 15–49 years completed individual interviews, and for this study, 9,305 married women were included after excluding clusters without geographic coordinates. Sampling weights were applied to account for unequal probability of selection and to ensure national representativeness.[4]

Data source and extraction

The datasets used for this study are publicly available in the DHS Program repository (https://www.dhsprogram.com/data/dataset_admin) to all registered users, downloaded with permission. After reviewing and understanding the details of the EDHS data structure and dataset types, we selected the recommended dataset type for fertility status. Data on fertility status of married women and its potential explanatory variables (individual and community-level variables) were extracted.

Inclusion and Exclusion Criteria

This study included married women of reproductive age (15–49 years) from the 2016 Ethiopian Demographic and Health Survey (EDHS), consistent with the standard definition used for family planning and reproductive health indicators [1]. Women younger than 15 years and older than 49 years were excluded from the study. In addition, only women from enumeration areas (EAs) with available geographic coordinate information were included in the spatial analysis, while women from clusters without geographic coordinates were excluded.

Study Variables

The study considered fertility status, measured by the number of children ever born to married women aged 15–49 years, as the outcome variable.

Table 1 Description of explanatory variables included in the analysis. Explanatory variables were selected based on previous literature and their availability in the 2016 Ethiopian Demographic and Health Survey (EDHS). The variables included individual-, household-, and community-level characteristics potentially associated with the number of children ever born among married women in Ethiopia.

Table 1. Description of study variables

Outcome variable	Number of children ever born
Individual-level variables	Mother's age, mother's educational level, mother's age at first birth, mother's current work status, religion, ever had a terminated pregnancy, current use of contraception, media exposure (heard about family planning on radio, heard about family planning on television and read about family planning in pamphlets/leaflets)
Household-level variables	Wealth index, sex of household head, husband's educational level, ownership of land
Community-level variables	Region, place of residence

Spatial Analysis

Spatial analysis was conducted to assess the geographic distribution, clustering patterns, and hotspot areas of fertility among married women in Ethiopia. Geographic coordinate data (longitude and latitude) obtained from the 2016 Ethiopian Demographic and Health Survey (EDHS) were

used for the spatial analysis. Spatial analyses and mapping were performed using ArcGIS software [12,13].

Global spatial autocorrelation analysis was performed using Global Moran's I statistics to determine whether fertility distribution was clustered, dispersed, or randomly distributed across Ethiopia [10].

$$I = \frac{n}{W} \frac{\sum_i \sum_j \omega_{ij} (x_i - \bar{x})(x_j - \bar{x})}{\sum_i (x_i - \bar{x})^2}$$

Where: n is the total number of observations, ω_{ij} represents the spatial weight between locations i and j , x_i and x_j denote observed fertility values at locations i and j , $\bar{x}$ is the mean fertility value, and W is the sum of all spatial weights.

A statistically significant positive Moran's I value indicates spatial clustering of fertility, whereas a negative value indicates spatial dispersion [10].

Hotspot analysis was conducted using Getis-Ord Gi* statistics to identify areas with significantly high and low fertility rates. Ordinary Kriging interpolation was also applied to predict fertility distribution in unsampled areas based on observed fertility values from sampled clusters [14,15].

Spatial scan statistical analysis was further conducted using SaTScan software to identify statistically significant hotspot clusters of high fertility areas [12]. The most likely and secondary clusters were identified using log-likelihood ratio (LLR) tests and Monte Carlo simulation [12]. Statistical significance was declared at p -value < 0.05 .

Multilevel Count Regression Analysis

Multilevel count regression models are statistical approaches used to analyze count or discrete outcome variables such as the number of children ever born per woman [16,17]. In this study, the outcome variable was the number of children ever born to married women, which was expressed as count data. Data management and statistical analyses were performed using Stata 16 and R statistical software.

Different count regression models were fitted to identify the most appropriate model for the data. Initially, the Poisson regression model was fitted under the assumption of equidispersion, where the mean and variance of the outcome variable are equal [18].

$$Y_i \sim \text{Poisson}(\mu_i)$$

The logarithmic link function for the Poisson regression model was expressed as:

$$\log(\mu_i) = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \dots + \beta_p X_{pi}$$

Where: Y_i represents the number of children ever born for the i^{th} woman, μ_i denotes the expected fertility count, β_0 is the intercept, β_p are regression coefficients, and X_{pi} are explanatory variables.

Because fertility data commonly exhibit over-dispersion, the Negative Binomial regression model was also fitted [19,20].

$$\text{Var}(Y_i) = \mu_i + \alpha \mu_i^2$$

Where: $\text{Var}(Y_i)$ is the variance of the outcome variable, μ_i represents the mean fertility count, and α is the dispersion parameter.

If the over-dispersion parameter (α) was significantly greater than zero, the Negative Binomial regression model was considered more appropriate than the Poisson regression model [19,20].

Furthermore, because the EDHS data have a hierarchical structure in which women are nested within clusters and regions, multilevel count regression models were employed to account for clustering effects and regional heterogeneity [15,16].

$$\log(\mu_{ij}) = \beta_0 + \beta X_{ij} + u_j$$

Where: μ_{ij} denotes the expected fertility count for woman i in cluster j , X_{ij} indicates explanatory variables, β_0 is the intercept, β denotes fixed-effect coefficients, and u_j represents the random effect for cluster or region,

Model comparison was performed using Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), and log-likelihood statistics [21,22]. The model with the lowest AIC and BIC values and highest log-likelihood value was selected as the best-fitting model.

Both bivariable and multivariable multilevel count regression analyses were conducted. Variables with p-value <0.20 in the bivariable analysis were entered into the multivariable analysis. In the final model, variables with p-value <0.05 were considered statistically significant determinants of fertility. The strength of association was reported using Adjusted Incidence Rate Ratios (AIRR) with 95% confidence intervals.

3. Results

3.1 Socio-demographic and reproductive characteristics

Table 2 presents the socio-demographic and reproductive characteristics of the 9,305 women included in the study. The majority of respondents resided in rural areas (74.5%), and more than half had no formal education (57.9%). Islam (42.9%) and Orthodox Christianity (36.5%) were the predominant religions. The largest age group was 25–29 years (22.9%), and the mean age at first birth was 19.0 years (SD = 3.8).

Most households were male-headed (81.8%), and 10.7% of women reported a history of terminated pregnancy. About 18.7% of respondents were currently using contraception, while 30.1% had media exposure. Approximately 32.2% were currently working. Regarding household wealth status, 29.0% belonged to the poorest quintile and 27.9% to the richest quintile. More than half (52.3%) did not own land. In terms of fertility preferences, 40.2% reported that both partners desired the same number of children, while 26.6% reported that husbands desired more children.

Table 2. Socio-demographic characteristics of married women in Ethiopia, EDHS 2016

Region	Frequency	Percent
Tigray	935	10.0
Afar	858	9.2
Amhara	1,114	12.0
Oromia	1,250	13.4
Somali	744	8.0
Benishangul-Gumuz	791	8.5
SNNPR	1,198	12.9
Gambela	669	7.2

Harari	568	6.1
Addis Ababa	625	6.7
Dire Dawa	553	5.9

Residence

Urban	2,369	25.5
Rural	6,936	74.5

HOUSEHOLD-LEVEL VARIABLES

Sex of household head

Male	7,613	81.8
Female	1,692	18.2

Wealth index

Poorest	2,695	29.0
Poorer	1,443	15.5
Middle	1,310	14.1
Richer	1,258	13.5
Richest	2,599	27.9

Owns land

Does not own	4,862	52.3
Alone only	1,534	16.5
Jointly only	2,814	30.2

Both alone and jointly	95	1.0
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INDIVIDUAL-LEVEL VARIABLES

Educational level

No education	5,390	57.9
Primary	2,574	27.7
Secondary	826	8.9
Higher	515	5.5

Religion

Catholic	57	0.6
Muslim	3,991	42.9
Orthodox`	3,400	36.5
Protestant	1,731	18.6
Traditional	71	0.8
Other	55	0.6

Currently using contraception

No	7,563	81.3
Yes	1,742	18.7

Media exposure

No	6,500	69.9
Yes	2,805	30.1

Currently working

No	6,305	67.8
Yes	3,000	32.2

Husband's desire for children

Both want same	3,737	40.2
Husband wants more	2,472	26.6
Husband wants fewer	603	6.5
Don't know	2,493	26.8

Husband's education

No education	4,176	44.9
Primary	2,935	31.5
Secondary	1,145	12.3
Higher	963	10.3
Don't know	86	0.9

Spatial analysis

Spatial Distribution of Fertility Status Among Married Women in Ethiopia

Figure 1 shows the spatial distribution of fertility among married women in Ethiopia based on the 2016 Ethiopian Demographic and Health Survey (EDHS). Substantial geographic variation was observed, with higher fertility concentrations in parts of Oromia, SNNPR, Somali, Gambela, and Benishangul-Gumuz regions.

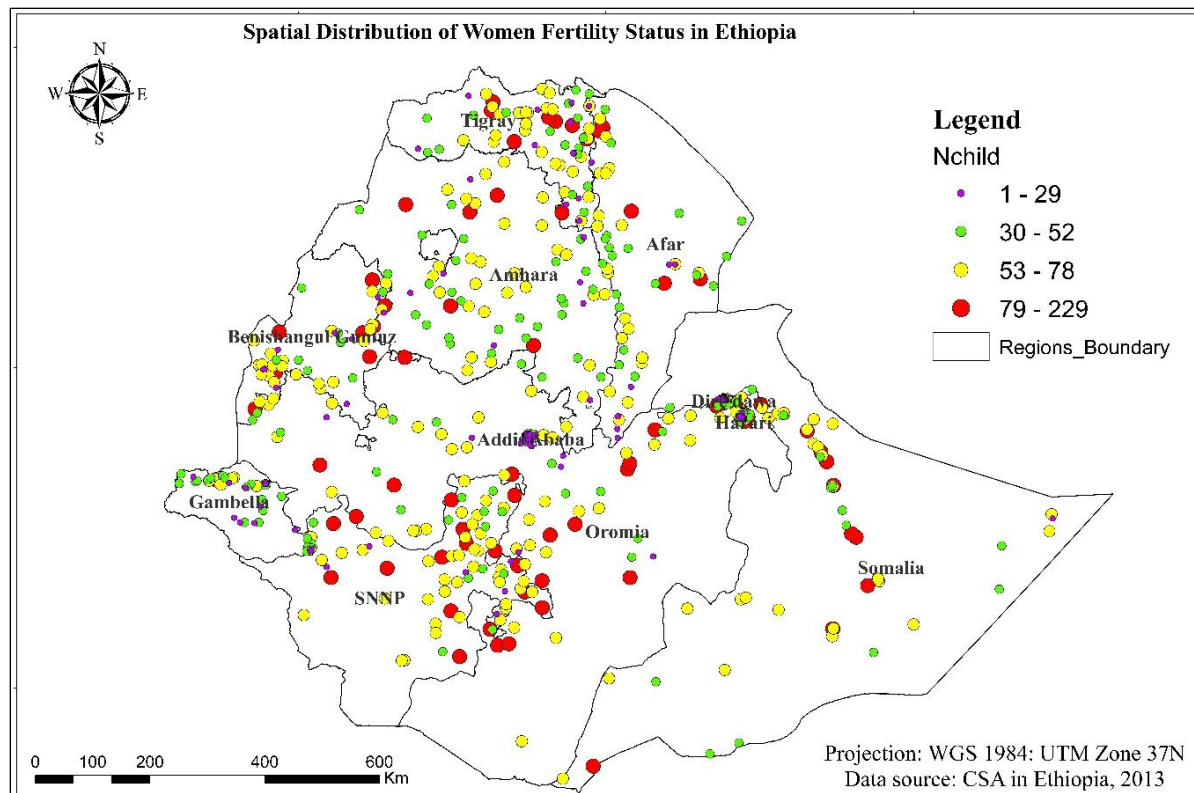


Figure 1. Spatial distribution of fertility among married women in Ethiopia, 2016

Global Spatial Autocorrelation of Fertility

Figure 2 shows the Global Moran's I spatial autocorrelation analysis of fertility among married women in Ethiopia. The analysis revealed significant spatial clustering (Moran's $I = 0.773$, $z\text{-score} = 25.61$, $p < 0.001$), indicating a non-random spatial pattern. The positive Moran's I value suggests that neighboring areas tend to exhibit similar fertility levels, confirming spatial dependence across the study area.

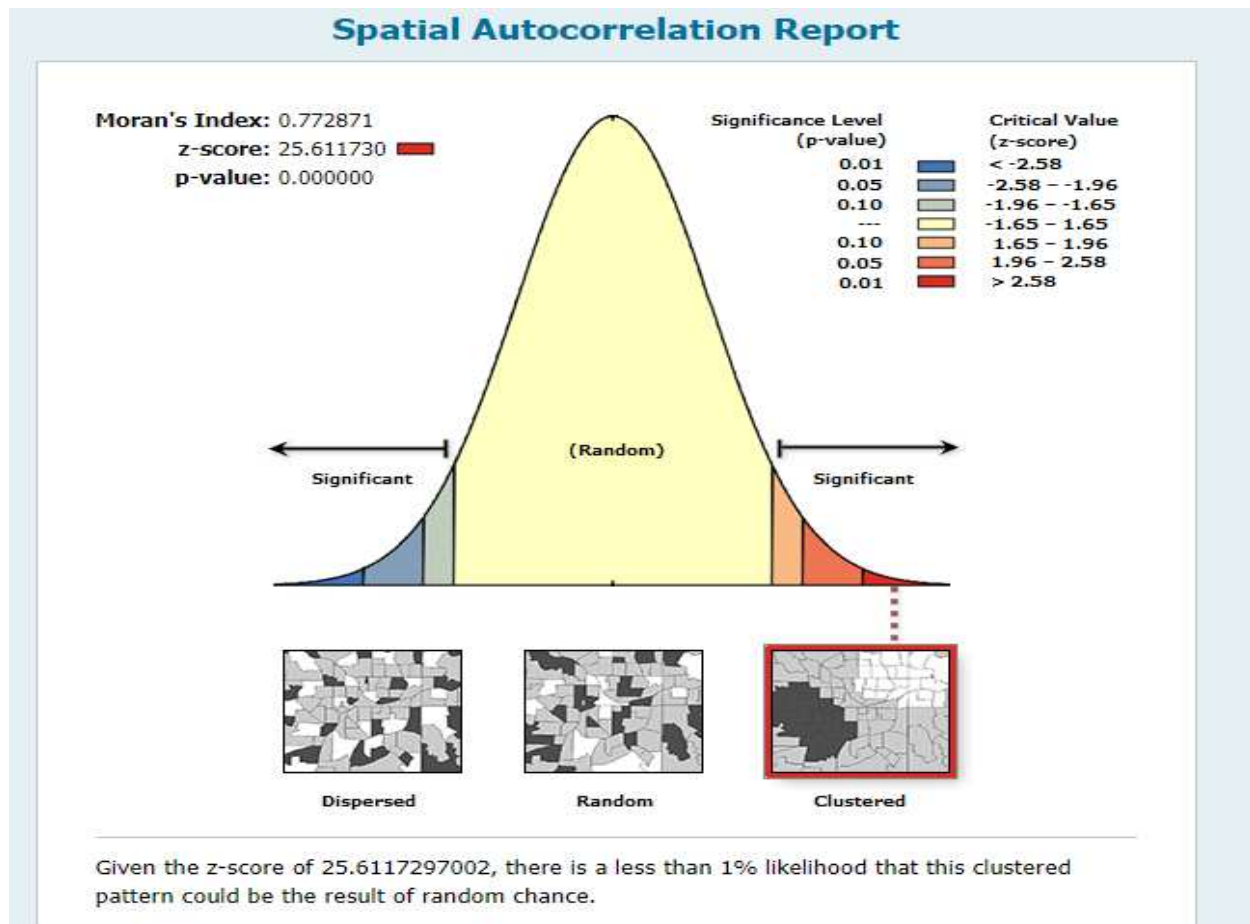


Figure 2. Global Moran's I spatial autocorrelation of fertility among married women in Ethiopia, 2016.

Hotspot Analysis of Fertility

Figure 3 shows the Getis-Ord Gi hotspot analysis of fertility among married women in Ethiopia. Significant spatial clustering was observed, with high-fertility hotspots primarily concentrated in the Southern Nations, Nationalities and Peoples' Region (SNNPR) and parts of Oromia, and additional clusters in Somali, Gambela, and Benishangul-Gumuz regions. In contrast, low-fertility cold spots were observed in Amhara, Addis Ababa, Dire Dawa, Harari, and parts of central Ethiopia, indicating marked geographic variation in fertility across the country.

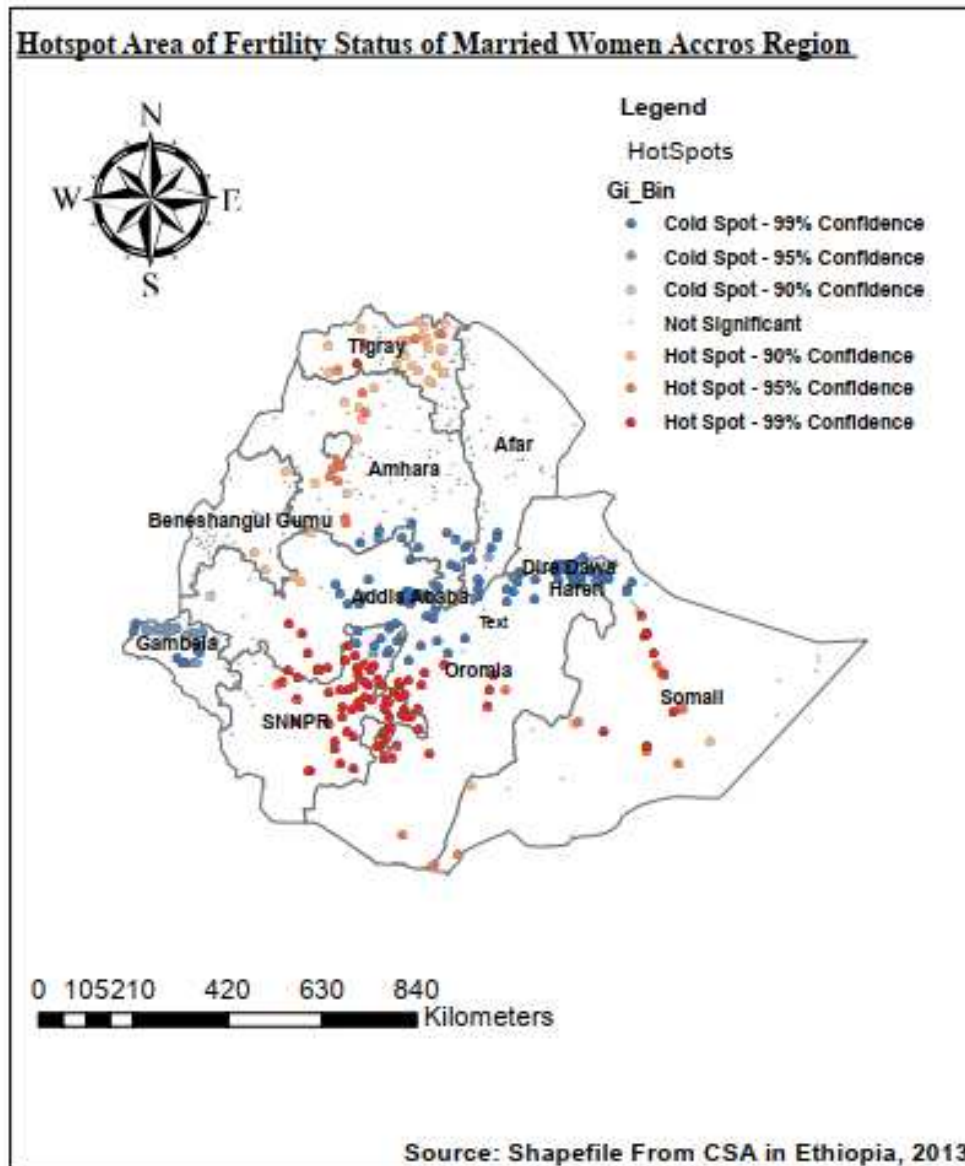


Figure 3. Hotspot and cold spot analysis of fertility among married women in Ethiopia, 2016.

Spatial Interpolation of Fertility

Figure 4 shows the ordinary kriging interpolation map of fertility among married women in Ethiopia. The map demonstrates considerable spatial variation in fertility across the country, with high predicted fertility concentrated in the southern, southwestern, and southeastern regions. In contrast, low predicted fertility was observed in Addis Ababa, Dire Dawa, Harari, Afar, and parts of northern Ethiopia. These findings suggest that fertility is geographically clustered rather than randomly distributed.

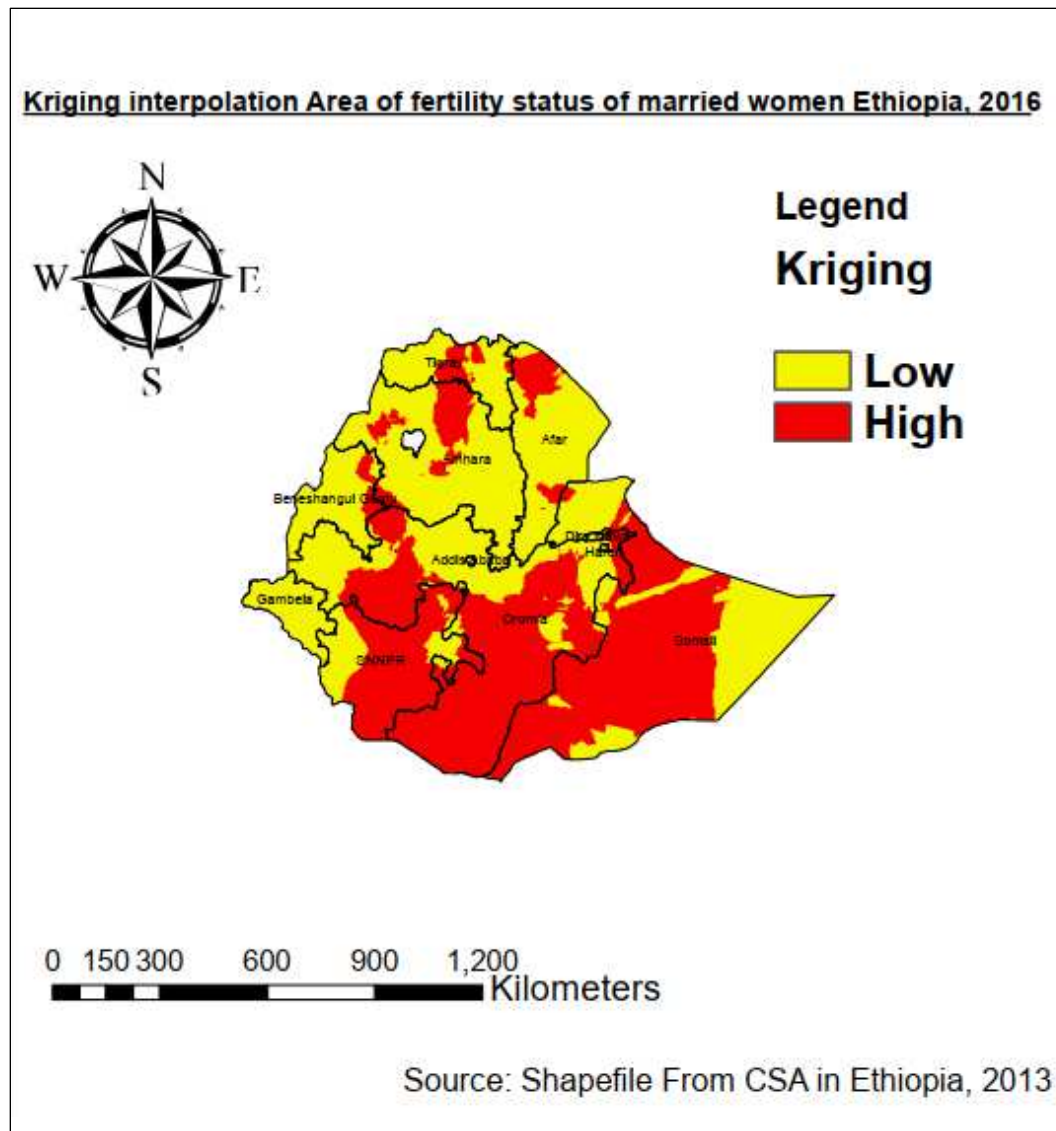


Figure 4. Spatial interpolation of fertility among married women in Ethiopia, 2016

Multilevel Count Regression Analysis

Model Comparison

Table 3 presents the model comparison using log-likelihood, Akaike Information Criterion (AIC), and Bayesian Information Criterion (BIC) to assess model fit. The results show that the multilevel Negative Binomial model fits the data better than the multilevel Poisson model. The Negative Binomial model had lower AIC (38,422.9) and BIC (38,615.63) values, along with a higher log-likelihood (-19,191.93), indicating superior model performance. Therefore, it was selected as the final model for subsequent analyses.

Table 3. Model comparison for multilevel Poisson and multilevel negative binomial regression models

Model	Log-likelihood	AIC	BIC
Multilevel Poisson	-19338.34	38728.68	38914.28
Multilevel Negative Binomial	-19184.45	38422.9	38615.63

Intercept model

Table 4 presents the results of the null multilevel negative binomial model. The model estimated an average of 3.18 living children per woman ($p < 0.001$). The regional random intercept variance was 0.0415 (SE = 0.0181), indicating significant variation in fertility across regions. The intraclass correlation coefficient (ICC = 0.068) shows that 6.8% of the total variation in the number of living children is attributable to regional differences, suggesting a modest degree of regional clustering and supporting the use of a multilevel modeling approach.

Table 4. Intercept only model

Parameter	Estimate	Std. Error	Z	p-value	95% CI
Fixed effect (Intercept)	3.176	0.197	18.66	<0.001	2.813 – 3.586
Region variance (σ^2_{uo})	0.0415	0.0181			0.0177 – 0.0975
ICC (Region)	0.068				
Log likelihood	-				
	20349.297				

Factors Associated with Fertility among Married Women

Table 5 presents the results of the multilevel mixed-effects negative binomial regression model identifying factors associated with the number of living children among married women in Ethiopia. Women in rural areas had a higher expected number of living children than urban women (IRR = 1.09; 95% CI: 1.03–1.15). Fertility showed a strong inverse association with education. Compared with women with no education, those with primary (IRR = 0.63), secondary (IRR =

0.51), and higher education (IRR = 0.47) had significantly lower expected numbers of living children, indicating a clear dose–response relationship.

Regarding religion, Orthodox women had lower fertility, while Protestant women had higher fertility compared with Muslim women. Women from female-headed households also had lower fertility (IRR = 0.92).

Each additional year in age at first birth was associated with a 4% reduction in fertility (IRR = 0.96), while contraceptive use was associated with lower fertility (IRR = 0.95). Working women had slightly higher fertility (IRR = 1.04). Women from richer households had higher fertility (IRR = 1.12), whereas media exposure was not statistically significant.

Husband-related factors were also important. Compared with concordant fertility preferences, both forms of spousal disagreement (husband wanting fewer or more children) were associated with higher fertility (IRR $\approx$ 1.11). Husband’s primary and higher education were also associated with higher fertility, while secondary education was not statistically significant.

At the regional level, variance decreased from 0.0415 in the null model to 0.0049 in the adjusted model, indicating that 88.3% of the between-region variation in fertility was explained by the included covariates, although a small residual heterogeneity remained.

Table 5. Results of multilevel mixed-effects negative binomial regression model

Category	Variable	IRR / Estimate	95% CI	p-value
Residence	Urban (Ref.)	1.00		
	Rural	1.09	1.03–1.15	0.02
Woman’s education	No education (Ref.)	1.00		
	Primary	0.63	0.61–0.65	<0.000
	Secondary	0.51	0.47–0.54	<0.000
	Higher	0.47	0.43–0.52	<0.000
Religion	Muslim (Ref.)	1.00		
	Orthodox	0.94	0.90–0.98	0.002
	Protestant	1.07	1.02–1.12	0.008
	Other religions	1.01	0.92–1.11	0.819
Sex of household head	Male (Ref.)	1.00		
	Female	0.92	0.88–0.95	<0.000

Category	Variable	IRR / Estimate	95% CI	p-value
Age at first birth	—	0.96	0.957–0.964	<0.000
Contraceptive use	No (Ref.)	1.00		
	Yes	0.95	0.92–0.99	0.008
Mother working	No (Ref.)	1.00		
	Yes	1.04	1.01–1.07	0.011
Wealth index	Poorest (Ref.)	1.00		
	Poorer	0.98	0.94–1.03	0.466
	Middle	1.01	0.97–1.06	0.601
	Richer	1.12	1.07–1.17	0.000
	Richest	1.04	0.99–1.11	0.122
Media exposure	No (Ref.)	1.00		
	Yes	0.99	0.95–1.03	0.546
Husband's desire	Same desire (Ref.)	1.00		
	Don't know	0.99	0.96–1.03	0.654
	Wants fewer	1.11	1.06–1.18	<0.001
	Wants more	1.11	1.08–1.15	<0.001
Husband's education	No education (Ref.)	1.00		
	Primary	1.17	1.01–1.36	0.038
	Secondary	1.08	0.93–1.27	0.315
	Higher	1.19	1.02–1.40	0.030

Random effects

Parameter	Estimate
Region-level variance (random intercept)	0.0049
Variance (residence slope)	2.36e–07
Variance (wealth index slope)	0.00076

Discussion

This study examined the spatial distribution and determinants of fertility among married women in Ethiopia using spatial analysis and multilevel mixed-effects negative binomial regression. The results demonstrated significant spatial clustering and geographic variation in fertility, with clear concentrations of high- and low-fertility areas. Hotspots were identified in SNNPR, Oromia,

Somali, Gambela, and Benishangul-Gumuz regions, while cold spots were observed in Addis Ababa, Dire Dawa, Harari, and parts of Amhara. This pattern reflects persistent regional disparities in education, socioeconomic conditions, and access to reproductive health services [9,26]. The multilevel model confirmed overdispersion and better fit of the negative binomial specification. Although 88.3% of between-region variation was explained by covariates, a small residual heterogeneity remained [4].

Rural residence was associated with higher fertility, while education showed a strong inverse dose–response relationship, likely operating through delayed marriage, improved autonomy, and contraceptive use [4,5,23]. Religious differences were also observed, with lower fertility among Orthodox women and higher fertility among Protestant women compared with Muslim women [4,7]. Age at first birth and contraceptive use were inversely associated with fertility [3,6,7]. Women in female-headed households had lower fertility, possibly reflecting greater autonomy and economic constraints.

Higher fertility was observed among working women and those from richer households, reflecting context-specific socioeconomic dynamics in low- and middle-income settings. Husband-related factors were important; discordance in fertility preferences and higher husband education were associated with higher fertility, reflecting household decision-making dynamics and resource availability. Overall, these findings support geographically targeted and context-specific fertility reduction strategies focusing on female education, improved access to family planning, delayed childbearing, and greater male involvement in reproductive health programs.

Strengths and Limitations

Strengths

This study has several strengths. It used nationally representative data from the 2016 Ethiopian Demographic and Health Survey (EDHS), which enhances the generalizability of the findings. The integration of spatial analysis with a multilevel mixed-effects negative binomial regression model provides a comprehensive approach to examining both geographic variation and individual- and contextual-level determinants of fertility. In addition, the use of spatial analytical techniques enabled the identification of fertility hotspots and cold spots, which are useful for geographically

targeted reproductive health interventions. Finally, the application of a multilevel count model appropriately accounted for clustering and overdispersion in the data, improving the robustness of the estimates.

Limitations

This study has several limitations. Due to the cross-sectional nature of the data, causal relationships between explanatory variables and fertility cannot be established. In addition, important contextual and cultural factors that may influence fertility were not available in the dataset and could not be included in the analysis, which may contribute to the remaining unexplained regional variation. There is also a possibility of recall and reporting bias in self-reported fertility and reproductive history data. Finally, although spatial clustering was identified, the analysis does not capture temporal changes in fertility patterns over time.

Conclusion

This study demonstrated that fertility among married women in Ethiopia is geographically clustered and varies substantially across regions. Spatial analysis identified fertility hotspots in SNNPR, Oromia, Somali, Gambela, and Benishangul-Gumuz, and cold spots in Addis Ababa, Dire Dawa, Harari, and parts of Amhara.

The multilevel mixed-effects negative binomial regression model showed that place of residence, educational attainment, religion, sex of household head, age at first birth, contraceptive use, women's employment status, household wealth, husband's fertility preference, and husband's education were significantly associated with fertility. Most of the between-region variation was explained by the included covariates, although a small residual heterogeneity remained.

These findings suggest that fertility reduction strategies in Ethiopia should prioritize hotspot regions through targeted interventions focusing on female education, improved access to family planning, delayed childbearing, and male involvement in reproductive health programs.

Policy Implications

The identification of fertility hotspots highlights the need for region-specific reproductive health interventions. Government agencies and development partners should prioritize hotspot regions

by expanding access to family planning services and reproductive health education. Particular attention should be given to improving girls' educational attainment, delaying age at first marriage and first birth, and increasing community awareness regarding family planning. Additionally, the significant influence of husbands' fertility preferences suggests that male involvement should be integrated into reproductive health programs to enhance their effectiveness.

Ethics and Declarations

Ethics approval and consent to participate

This study is based on secondary data from the 2016 Ethiopian Demographic and Health Survey (EDHS). Ethical approval for the EDHS was obtained by the DHS Program from relevant institutional review boards, and permission to use the dataset was granted upon request. The data used in this study contained no personal identifiers, ensuring participant confidentiality. Therefore, additional ethical approval was not required for this secondary data analysis.

Consent for publication

Not applicable.

Availability of data and materials

The dataset used in this study is publicly available upon reasonable request from the Demographic and Health Surveys (DHS) Program at <https://dhsprogram.com>.

Competing interests

The author(s) declare that they have no competing interests.

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Authors' contributions

The author(s) contributed to the study as follows: conceptualization and study design, data analysis, interpretation of results, and manuscript writing and revision. All authors read and approved the final manuscript.

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Abbreviations

AIC: Akaike Information Criterion, BIC: Bayesian Information Criterion, CI: Confidence Interval, EDHS: Ethiopian Demographic and Health Survey, Gi*: Getis-Ord Gi* statistic, ICC: Intraclass Correlation Coefficient, IRR: Incidence Rate Ratio, Moran's I: Global Moran's Index, NB: Negative Binomial, SD: Standard Deviation, SNNPR: Southern Nations, Nationalities, and Peoples' Region, DHS: Demographic and Health Survey, LLR: Log-Likelihood Ratio, GIS: Geographic Information System.

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