

Socio-demographic and contextual drivers of insecticide-treated net (ITN) utilization among women of reproductive age in Togo: a Bayesian multilevel analysis of the 2017 Togo Malaria Indicator Survey

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Abstract

Background: Insecticide-treated nets (ITNs) are a cornerstone of malaria prevention in sub-Saharan Africa. Despite wide-scale distribution, gaps between ITN ownership and utilization persist, particularly among women of reproductive age who are at high risk of malaria infection. This study aimed to identify the determinants of ITN utilization among women of reproductive age in Togo using data from the 2017 Togo Malaria Indicator Survey (TMIS).

Methods: This study analyzed data from the nationally representative 2017 Togo Malaria Indicator Survey (TMIS), which included 4,225 women aged 15–49 years residing in households owning at least one ITN. Weighted descriptive statistics and Rao–Scott Chi-square tests were used to summarize ITN use and explanatory variables. A Bayesian multilevel logistic regression model was employed using the *brms* R package to identify determinants of ITN utilization, accounting for the hierarchical data structure and survey design. Model performance was assessed using the Leave-One-Out Information Criterion (LOOIC) and Bayesian R^2 .

Results: Overall, 72.8% (95% CI: 70.2–75.5) of women reported sleeping under an ITN the previous night. Utilization varied significantly by age, marital status, education, household wealth, and region. Age, education, marital status, and exposure to ITN messages were significant predictors at individual level: widowed women had over sixfold higher odds of ITN use compared to never-married women (aOR = 6.61; 95% CrI: 1.81–25.38), and exposure to ITN messages more than doubled the odds of use (aOR = 2.25; 95% CrI: 1.44–3.55). At the household level, female-headed households had 40% lower odds of ITN use (aOR = 0.60; 95% CrI: 0.37–0.95), and medium-sized households (4–6 members) had lower utilization (aOR = 0.35; 95% CrI: 0.19–0.61). At the community level, rural residence tripled the odds of ITN use (aOR = 3.23; 95% CrI: 1.21–8.70), and women living in Savanes had eighteen times higher odds compared to Lomé Commune (aOR = 18.10; 95% CrI: 3.53–100.4). Random-effects modeling indicated that 16.5% and 61.5% of the variance were attributable to cluster- and household-level factors, respectively.

Conclusion: ITN utilization among women of reproductive age in Togo is relatively high but uneven. Use is shaped by socio-demographic, household, and community-level factors. Strengthening behavior-change communication, targeting urban and female-headed households, and addressing barriers among adolescents and educated women could improve equitable utilization and accelerate malaria control efforts.

Background

Malaria remains a critical public health challenge globally, with sub-Saharan Africa bearing the highest burden [1]. In 2023 alone, an estimated 263 million malaria cases and 597,000 malaria-related deaths were reported worldwide, of which the African Region accounted for 94% of all cases (246 million) and 95% of all deaths (569,000) [2]. Among these, the most vulnerable populations are pregnant women and children under five years of age, who together represent the majority of malaria-related morbidity and mortality [1–3]. Malaria during pregnancy, in particular, is associated with serious health consequences, including maternal anemia, low birth weight, preterm delivery, and elevated risks of maternal and neonatal mortality [4–6].

Togo, a malaria-endemic country in West Africa, continues to face a substantial burden, with the entire population at risk. In 2022, the country recorded more than two million malaria cases and over 3,400 related deaths, with *Plasmodium falciparum* accounting for more than 95% of infections [6,7]. Malaria is the leading cause of outpatient consultations (33%), hospital admissions (20%), and nearly one in ten hospital deaths [8]. To address this burden, the Togolese government, through the National Malaria Control Program (PNLP), has prioritized prevention, including the free distribution of insecticide-treated nets (ITNs) via mass campaigns, antenatal clinics, routine immunization programs, and seasonal malaria chemoprevention (SMC) [3,9]. In September 1, 2025, Togo incorporated the R21/Matrix-M malaria vaccine into its national immunization schedule (EPI), targeting children from five months old with a four-dose schedule (5, 6, 7 months, plus a booster at 15 months) [10]. Since 2004, six national ITN distribution campaigns have been implemented, with the latest in 2020 reaching over 80% of households. The current national strategic plan (2023–2026) aims to reduce malaria incidence and mortality in alignment with the WHO Global Technical Strategy for Malaria 2016–2030, through strengthened prevention, diagnosis, treatment, surveillance, and community engagement, while enhancing health system capacity [11,12].

ITNs are among the most effective malaria prevention tools, recommended by the WHO as a dual physical and chemical barrier against mosquitoes [13]. As part of the Roll Back Malaria initiative, mass ITN distribution campaigns have been conducted across sub-Saharan Africa, targeting high-risk groups such as pregnant women and children [14]. Despite high levels of ownership in sub-Saharan Africa, utilization is influenced by a range of factors. Socio-demographic determinants such as age, education, marital status, household wealth, and family size [15,16]. Behavioral determinants, including malaria knowledge, self-efficacy, and social norms, also play a critical role, as do environmental and housing conditions [15,17]. Moreover, these determinants vary geographically and hierarchically, highlighting the need for analytical approaches that account for both contextual effects and spatial clustering. Unlike traditional frequentist approaches, Bayesian methods offer greater flexibility in modeling complex data structures and integrating diverse sources of information [18–21].

In Togo, ITN ownership remains high but consistent utilization is lagging. Although ITN ownership in Togo is high, utilization among eligible individuals remains suboptimal even within households owning at least one net, indicating behavioral and intra-household allocation barriers [22]. This gap highlights the need to move beyond measuring ownership to understanding the underlying drivers of use. Yet, few studies in Togo have comprehensively assessed how individual, household, and community factors interact to shape ITN use, particularly among women of reproductive age, who have their central role in household health decisions.[5,6,23].

This study therefore examines the socio-demographic and contextual drivers of ITN utilization among women of reproductive age in Togo using nationally representative data from the 2017 Togo Malaria Indicator Survey. By applying Bayesian multilevel logistic regression, it explores determinants

across individual, household, and community levels while accounting for geographic variation. The findings aim to provide evidence to guide context-specific and geographically tailored interventions to support malaria control and elimination efforts in Togo.

Materials and Methods

Study setting

Togo is a West African country bordered by Ghana to the west, Benin to the east, Burkina Faso to the north, and the Gulf of Guinea or Atlantic Ocean to the south (Figure 1). As of 2022, its population was estimated at approximately 8,095,498, with a density of 143 inhabitants per square kilometer [24]. Administratively, the country is divided into six health regions, forty-three health districts, and 944 peripheral health units. The national health system follows a three-tier pyramidal structure: the central level (policy and strategic planning), the intermediate level (six health regions), and the peripheral level (district health services providing primary care to communities) [7]. The climate ranges from humid tropical conditions along the southern coast to semi-arid conditions in the northern savannahs. These climatic differences contribute to variations in malaria transmission intensity, with higher transmission typically observed during the rainy season and in areas with inadequate housing and environmental conditions [25].

The map was generated using QGIS version 3.44. Togo's administrative boundary shapefiles were obtained from the GADM database of Global Administrative Areas (<https://gadm.org>, version 4.1, downloaded 2025-06-25), a publicly available resource providing high-resolution administrative boundary data for all countries worldwide.

Data source

Data for this study were drawn from the 2017 Togo Malaria Indicator Survey (TMIS), a nationally representative household survey conducted by the National Institute of Statistics and Economic and Demographic Studies (INSEED) in collaboration with ICF International, with support from the MEASURE DHS Program, USAID, and The Global Fund [22].

The survey was conducted from September 16 to November 17, 2017 using standardized, pre-tested questionnaires adapted from Roll Back Malaria Monitoring and Evaluation Reference Group (MERG) guidelines. Three questionnaires were administered: a household questionnaire (socioeconomic and housing characteristics, mosquito net ownership and use), a women's questionnaire (sociodemographic factors, reproductive history, malaria prevention practices, ITN use), and a child health module (malaria testing among children aged 6–59 months). Data were collected through face-to-face electronic interviews in local languages by trained interviewers under strict quality control measures. The TMIS 2017 achieved a 98% household response rate, ensuring a high level of data completeness and reliability [22].

Study design and sampling technique

This study is a secondary data analysis based on cross-sectional data from the 2017 Togo Malaria Indicator Survey (TMIS). The TMIS, implemented as part of the global Roll Back Malaria initiative, follows standardized Demographic and Health Surveys (DHS) Program methodology [26,27]. It was designed to generate nationally and regionally representative estimates of malaria-related indicators, including insecticide-treated net (ITN) ownership and use, intermittent preventive treatment in pregnancy (IPTp), and treatment-seeking behavior for childhood fever [22].

The survey employed a two-stage stratified cluster sampling design, using the 2010 General Population and Housing Census as a sampling frame. In the first stage, 171 enumeration areas (EAs) were selected with probability proportional to size, stratified by urban and rural residence across Togo's six health regions. In the second stage, 30 households were systematically selected from each EA, yielding a sample of 5,130 households (1,800 urban and 3,330 rural).

The present analysis focuses on women of reproductive age (15-49 years), a key demographic for malaria prevention programs, particularly ITN utilization. Of the eligible population, 4,674 women were successfully interviewed 1,589 from urban areas and 3,085 from rural areas [22]. These participants provided detailed information on socio-demographic characteristics, household environment, malaria prevention practices, and ITN access and use.

Study population

The study population comprised women of reproductive age (15-49 years) enumerated in the 2017 Togo Malaria Indicator Survey (TMIS). This group is critical for malaria control due to their biological vulnerability and their central role in household health and child protection through insecticide-treated net (ITN) use [3].

Women were included in the analysis if they were usual residents of the household or had slept there the night before the survey and resided in a household with at least one ITN. Those with missing or incomplete information on ITN ownership, utilization, or key sociodemographic variables were excluded to ensure analytic validity.

Study variables and measurements

Outcome variable

The primary outcome was insecticide-treated net (ITN) utilization, defined according to WHO MERG guidelines as whether a woman slept under an ITN the night before the survey. In the 2017 TMIS, this was captured by variable HML20 and coded as a binary measure: 1 = Yes (slept under an ITN) and 0 = No (did not). Women coded “1” were classified as ITN users, and those coded “0” as non-users [27].

Explanatory variables

Explanatory variables were classified into three hierarchical levels individual, household, and community/cluster following the study’s conceptual framework and previous literature [16,28–31]. All variables were operationalized according to DHS standard definitions [32].

The variables were chosen to reflect multi-level determinants of ITN utilization. At the individual level, women’s sociodemographic characteristics (age, education, marital status, parity, pregnancy status) and behavioral attributes (malaria knowledge, exposure to ITN-related messages) capture both biological vulnerability and awareness, which strongly influence ITN use. At the household level, characteristics of the household head (sex, age), economic status (wealth quintile), and environmental factors (household size, sleeping rooms, beds) represent resources and living conditions that shape access to and distribution of ITNs. The DHS wealth quintile is a composite, asset-based measure constructed using principal component analysis of household ownership of durable goods, housing characteristics, and access to utilities, and serves as a proxy for long-term socioeconomic status rather than direct income. At the community/cluster level, contextual factors (region, urban–rural residence, altitude) account for spatial and ecological variations in malaria transmission and service access. Together, these variables address the nested structure of the 2017 TMIS data and allow for examination of individual, household, and community influences on ITN utilization within a Bayesian multilevel modeling framework. Table 1 summarizes the variables, their DHS codes, definitions, and categorizations.

Table 1. Summary of explanatory variables by hierarchical level and category, TMIS 2017

Level	Category	Variable (DHS code)	Operational definition	Type	Coding / Categories
Level 1 – individual	Socio-demographic	Women's Age Group (V013)	Age in completed years, grouped in 5-year intervals	Categorical	15–19, 20–24, 25–29, 30–34, 35–39, 40–44, 45–49
		Educational Level (V106)	Highest level of education attained	Categorical	No education, Primary, Secondary, Higher
		Marital Status (HV115)	Current marital status	Categorical	Never married, Married, Widowed, Divorced/Separated
		Total Children Ever Born (V201)	Total number of children ever born	Categorical	0, 1–2, 3–4, ≥5
		Pregnancy Status (V213)	Currently pregnant	Binary	Yes, No
	Behavioral	Knowledge: Mosquito bites transmit malaria (S111B)	Knows mosquito bites as main route of malaria transmission	Binary	Yes, No
		Knowledge: ITN protects against malaria (S113B)	Knows ITNs protect against malaria	Binary	Yes, No
		Exposure to ITN messages (S116A)	Heard/seen ITN-related message in past 6 months	Binary	Yes, No
Level 2 – Household	Socio-demographic	Sex of Household Head (V151)	Gender of household head	Binary	Male, Female
		Age of Household Head (V152)	Age of household head, grouped	Categorical	<30, 30–44, 45–59, ≥60
	Economic	Wealth Quintile (V190)	Asset-based wealth index	Categorical	Poorest, Poorer, Middle, Richer, Richest
	Environmental	Number of Household Members (HV009)	Total usual members in household	Categorical	1–3, 4–6, ≥7
		Rooms Used for Sleeping (HV216)	Number of rooms used for sleeping	Categorical	1, 2–3, ≥4
		Beds in Household (SH109A)	Number of beds available	Categorical	0–1, 2–3, ≥4
Level 3 – Community/Cluster	Spatial/Contextual	Region (V024)	Health region of residence	Categorical	Lomé Commune, Maritime, Plateaux, Centrale, Kara, Savanes
		Place of Residence (V025)	Urban or rural classification	Binary	Urban, Rural
		Cluster Altitude (V040)	Altitude of enumeration area	Categorical	<200 m, 200–499 m, ≥500 m

Data processing and statistical analysis

The women's individual recode (IR), household recode (HR), and household member recode (PR) files from the 2017 TMIS were merged to link women's individual information with household and malaria-related variables. Continuous variables were categorized to enhance interpretability, and missing data were managed in accordance with DHS recommendations [33]. The analytic sample was restricted to women aged 15–49 years who were de facto household members (hv103 = 1) and lived in households with at least one ITN.

To ensure national representativeness, all analyses incorporated DHS sampling weights (v005), adjusted for strata (v022) and primary sampling units (v021). This adjustment accounted for the two-stage cluster sampling design and unequal probabilities of selection [3,34]. Weighted descriptive statistics were used to summarize socio-demographic, behavioral, household, and community-level characteristics, as well as ITN utilization. Prevalence estimates were reported with 95% design-based confidence intervals. Associations between ITN utilization and explanatory variables were examined using the Rao–Scott Chi-square test of independence, which adjusts the standard Chi-square to reflect survey design effects [35]. Statistical significance was assessed at the 5% level. The selection of explanatory variables for multivariable modeling was guided by a conceptual framework and prior literature [16,28–31] rather than by statistical significance in bivariate analyses.

All analyses were performed in R version 4.5.1, and the analysis code is publicly available (see Availability of Data and Materials).

Bayesian statistical approach

To account for the hierarchical structure of the TMIS data, where women (level 1) were nested within households (level 2) and households within survey clusters (level 3), a three-level Bayesian multilevel logistic regression model was employed. This approach was selected because it appropriately captures intra-household and intra-cluster correlations, allows the incorporation of prior information, and provides full posterior distributions for parameters, offering a more intuitive assessment of uncertainty than traditional frequentist methods [18,36–38]. Five models were estimated sequentially: a null model with no covariates but including cluster variables (Model 0); models including individual-level (Model 1), household-level (Model 2), and community-level (Model 3) variables separately; and a fully adjusted model with all explanatory variables (Model 4). Random intercepts were specified at the household (v002) and cluster (v021) levels to account for unobserved heterogeneity. The model formulation was:

$$\text{logit}[P(Y_{ijk} = 1)] = \alpha + u_{0j} + v_{0k} + \sum \beta_k X_{kijk}, \quad u_{0j} \sim N(0, \sigma u^2), \quad v_{0k} \sim N(0, \sigma v^2)$$

where Y_{ijk} denotes ITN use by woman i in household j within cluster k , and X_{kijk} represents population level covariates. The Bernoulli likelihood with a logit link was used to model the binary outcome. In Bayesian inference, all unknown parameters are treated as random variables, and uncertainty is expressed in terms of probability. Posterior inference combines the likelihood function (information from the observed data) with prior distributions (information about parameters before observing the data) [18]. In this study, weakly informative priors were used: Normal(0,10) for fixed effects and the intercept, and Half-Cauchy(0,2.5) for random-effect standard deviations [20,37]. These priors provided gentle regularization while allowing the data to dominate the posterior distribution [37]. Posterior samples were generated using Hamiltonian Monte Carlo (HMC), an efficient simulation method that exploits gradient information to improve exploration of parameter space and reduce autocorrelation compared with traditional MCMC methods [18]. To further enhance efficiency, the No-U-Turn Sampler (NUTS) was applied, automatically determining optimal trajectory lengths and improving convergence [39]. The model was implemented in R using the brms package interfaced with Stan [40]. Four Markov Chain Monte Carlo (MCMC) chains were run with 4,000 iterations each, including 1,000 warm-up samples. Convergence was assessed through Rhat values (≤ 1.01), effective sample sizes (ESS), and inspection of trace plots [38]. A higher ESS indicated better mixing of the chains and more reliable posterior estimates. Fixed-effect estimates were reported as adjusted odds ratios (aORs) with 95% credible intervals (CrIs). Random effects were summarized using the intra-class correlation coefficient (ICC), the median odds ratio (MOR), and the proportional change in variance (PCV). The ICC quantified the proportion of total variance attributable to differences between clusters, providing evidence of clustering in ITN utilization. The MOR expressed cluster heterogeneity on the odds ratio scale, while the PCV measured the proportion of variance explained after inclusion of explanatory variables [18]. Model comparison and selection were evaluated using the Leave-One-Out Information Criterion (LOOIC) and Bayesian R^2 statistic (marginal and conditional) [41,42]. Lower LOOIC indicated better predictive performance. Bayesian R^2 statistic summarized variance explained by fixed effects alone and by the model. Before modeling, multicollinearity was assessed using the generalized (adjusted) variance inflation factor (VIF), with $VIF < 5$ considered acceptable [43–45].

Results

Characteristics of the study population

A total of 4,674 women participated in the 2017 TMIS; 4,225 met eligibility criteria, resulting in a weighted sample of 4,007. The population was predominantly young, with 34.6% aged 15–24 years and 18.4% aged 25–29 years. Most were married (74.9%), and over half had at least one child. Education levels were low, with 34.5% having no formal schooling and only 3.1% attaining higher education. At the time of the survey, 8.2% were pregnant. Malaria knowledge was high (84.5% knew mosquitoes transmit malaria; 71.8% knew ITNs protect against malaria), but ITN message exposure in the past six months was low (17.6%). At the household level, 76.2% were male-headed, most with heads aged 30–44 years (43.5%). Wealth distribution was balanced across quintiles. Nearly half had 4–6 members (45.3%), 2–3 sleeping rooms (50.0%), and 2–3 beds (51.6%). At the community level, 61.9% lived in rural areas; Plateaux (27.5%) and Lomé Commune (21.0%) had the highest representation (Table 2).

Prevalence and ITN utilization

In this nationally representative sample of women from households with at least one ITN, 72.8% (95% CI: 70.2–75.5) reported sleeping under an ITN the night before the survey. However, utilization varied across individual, household, and community characteristics (Table 2). At the individual level, ITN utilization was lowest among adolescents aged 15–19 years (66.9%) and highest among women aged 25–29 years (79.8%, $p < 0.001$). Married and widowed women had higher coverage (75.6% and 82.5%, respectively) than never-married women (62.8%, $p < 0.001$). At the household level, ITN use differed by sex of household head ($p < 0.001$), age of household head ($p = 0.027$), and wealth quintile ($p < 0.001$). Women in male-headed households reported 75.0% coverage compared with 65.9% in female-headed households. Utilization showed a socioeconomic gradient, from 85.0% among the poorer quintile to 62.4% among the richest quintile. At the community level, ITN use was significantly higher in rural areas (79.6%) than in urban areas (61.9%, $p < 0.001$). Marked regional differences were observed ($p < 0.001$): Savanes had the highest prevalence (88.1%), whereas Lomé Commune had the lowest (55.6%). Utilization increased with altitude, from 67.3% in clusters < 200 m to 83.6% in clusters ≥ 500 m ($p < 0.001$).

Table 2. Weighted distribution of women and ITN utilization by individual, household, and community characteristics, and Rao–Scott χ^2 test results, TMIS 2017 (N = 4,007)

Variable	Weighted Frequency	Weighted % (95% CI)	% ITN Use (95% CI)	χ^2 (df), p-value
Individual-level				
Age group (years)				47.37 (6), p < 0.001 ***
15–19	649	16.2 (14.8–17.6)	66.9 (62.3–71.6)	
20–24	658	16.4 (15.1–17.8)	67.8 (62.7–72.9)	
25–29	737	18.4 (16.9–19.8)	79.8 (76.3–83.3)	
30–34	651	16.3 (15.0–17.5)	76.5 (72.2–80.7)	
35–39	602	15.0 (13.7–16.4)	74.1 (69.3–78.8)	
40–44	401	10.0 (8.8–11.2)	69.6 (64.1–75.1)	
45–49	310	7.7 (6.8–8.7)	73.6 (68.1–79.1)	
Educational level				44.67 (3), p < 0.001 ***
No education	1,383	34.5 (30.5–38.5)	78.3 (74.5–82.1)	
Primary	1,255	31.3 (29.0–33.7)	71.9 (68.2–75.6)	
Secondary	1,243	31.0 (28.3–33.7)	69.2 (65.6–72.7)	
Higher	126	3.1 (2.4–3.9)	58.9 (48.2–69.6)	
Marital status				64.03 (3), p < 0.001 ***
Never married	799	19.9 (18.2–21.7)	62.8 (57.5–68.1)	
Married	3,003	74.9 (73.0–76.9)	75.6 (72.9–78.2)	
Widowed	93	2.3 (1.8–2.9)	82.5 (74.0–91.1)	
Divorced/Separated	112	2.8 (2.2–3.4)	64.1 (52.9–75.4)	
Children ever born				49.81 (3), p < 0.001 ***
0	910	22.7 (20.8–24.6)	64.4 (59.7–69.1)	
1–2	1,127	28.1 (26.7–29.6)	73.8 (70.5–77.1)	
3–4	937	23.4 (21.7–25.1)	74.4 (71.1–77.7)	
≥5	1,033	25.8 (23.6–27.9)	77.9 (74.0–81.8)	
Pregnancy status				3.09 (1), p = 0.069 ns
No	3,678	91.8 (90.8–92.9)	72.5 (69.8–75.2)	
Yes	328	8.2 (7.1–9.2)	76.9 (72.3–81.5)	
Knows mosquitoes as malaria vector				0.07 (1), p = 0.817 ns
No	623	15.5 (13.6–17.5)	72.4 (68.3–76.6)	
Yes	3,384	84.5 (82.5–86.4)	72.9 (70.1–75.8)	
Knows ITN against malaria				10.33 (1), p = 0.041 *
No	2,878	71.8 (69.0–74.6)	74.2 (71.1–77.4)	
Yes	1,129	28.2 (25.4–31.0)	69.3 (65.4–73.3)	
Exposed to ITN messages				21.01 (1), p < 0.001 ***
No	3,302	82.4 (80.4–84.4)	71.4 (68.5–74.3)	
Yes	705	17.6 (15.6–19.6)	79.6 (76.1–83.2)	
Household-level				
Sex of household head				32.11 (1), p < 0.001 ***
Male	3,052	76.2 (73.9–78.4)	75.0 (72.3–77.8)	
Female	955	23.8 (21.6–26.1)	65.9 (61.2–70.6)	
Age of household head				14.63 (3), p = 0.027 *

<30	482	12.0 (10.4–13.7)	76.1 (71.1–81.0)
30–44	1,745	43.5 (41.1–46.0)	74.6 (71.4–77.8)
45–59	1,238	30.9 (28.9–33.0)	71.2 (67.4–75.1)
≥60	542	13.5 (11.8–15.2)	67.8 (62.6–73.1)
Wealth quintile			185.94 (4), p < 0.001 ***
Poorest	772	19.3 (15.9–22.7)	82.0 (77.4–86.6)
Poorer	818	20.4 (17.4–23.5)	85.0 (81.1–88.9)
Middle	845	21.1 (17.9–24.3)	71.6 (66.5–76.6)
Richer	782	19.5 (16.7–22.3)	63.0 (57.6–68.5)
Richest	790	19.7 (16.6–22.8)	62.4 (56.5–68.3)
Household size			10.83 (2), p = 0.070 ns
1–3	800	20.0 (18.0–21.9)	74.9 (70.8–78.9)
4–6	1,816	45.3 (42.8–47.8)	74.3 (71.0–77.6)
≥7	1,391	34.7 (32.3–37.1)	69.8 (65.5–74.0)
Number of rooms in household			7.02 (2), p = 0.217 ns
1	1,246	31.1 (28.7–33.5)	72.8 (69.2–76.3)
2–3	2,003	50.0 (47.5–52.4)	74.2 (70.9–77.6)
≥4	758	18.9 (17.0–20.8)	69.3 (63.7–75.0)
Number of beds in household			9.46 (2), p = 0.08 ns
0–1	427	10.6 (9.3–12.0)	77.8 (73.3–82.4)
2–3	2,069	51.6 (49.2–54.0)	73.4 (70.2–76.5)
≥4	1,511	37.7 (35.2–40.2)	70.8 (66.7–74.8)
Community-level			
Region			239.41 (5), p < 0.001 ***
Lomé Commune	842	21.0 (18.3–23.7)	55.6 (50.5–60.7)
Maritime	718	17.9 (15.5–20.4)	69.2 (63.0–75.4)
Plateaux	1,103	27.5 (23.6–31.5)	80.0 (74.0–86.0)
Centrale	411	10.3 (8.8–11.7)	70.4 (63.5–77.3)
Kara	467	11.7 (9.7–13.6)	79.7 (73.8–85.7)
Savanes	466	11.6 (10.4–12.8)	88.1 (82.6–93.5)
Residence			157.80 (1), p < 0.001 ***
Urban	1,527	38.1 (34.7–41.6)	61.9 (57.8–66.0)
Rural	2,479	61.9 (58.4–65.3)	79.6 (76.2–83.0)
Cluster altitude			89.83 (2), p < 0.001 ***
<200 m	2,304	57.5 (51.0–64.0)	67.3 (63.2–71.4)
200–499 m	1,486	37.1 (30.5–43.6)	79.9 (76.0–83.7)
≥500 m	217	5.4 (1.7–9.1)	83.6 (76.4–90.7)

Weighted frequencies, percentages, and 95% confidence intervals account for the DHS survey design (weights, strata, and clusters). χ^2 = Rao–Scott adjusted chi-square test for survey data. Significance codes: *** p < 0.001, ** p < 0.01, * p < 0.05, · p < 0.1, ns = not significant.

Determinants of ITN use from Bayesian hierarchical analysis

Random Effects, heterogeneity measures, and model fit

Table 3 summarizes the random effects, heterogeneity measures, and model fit statistics across the five sequential models. The results demonstrate progressive changes in variance components and model performance as covariates at different levels were introduced.

Model 0 (Null model): The empty model revealed substantial variation in ITN use at both the cluster and household levels. Cluster-level variance was 3.06 (95% CrI: 2.13–4.37), while household-level variance was 6.30 (95% CrI: 4.67–8.35). Intra-class correlation coefficients (ICCs) indicated that 24.2% of the variance was attributable to clusters and 49.5% to households. Median odds ratios (MORs) further highlighted heterogeneity, with women moving between clusters having 5.29 times higher odds of ITN use, and moving between households increasing the odds by 10.84. These findings confirm strong contextual effects, particularly at the household level.

Model 1 (Individual-level predictors): Adding individual-level variables slightly increased the cluster-level variance to 3.49 (95% CrI: 2.37–5.02) and household-level variance to 7.78 (95% CrI: 5.76–10.49). ICCs were 23.8% (clusters) and 53.3% (households). Negative proportional change in variance (PCV) values at both levels (–12.9% and –23.6%) indicated that individual factors explained little of the contextual variability. MORs remained high (5.89 clusters; 14.14 households), implying that unmeasured contextual factors still strongly influence ITN utilization.

Model 2 (Household-level predictors): Introducing household-level covariates reduced cluster-level variance to 2.28 (95% CrI: 1.49–3.39) and household-level variance to 7.02 (95% CrI: 5.15–9.36). ICCs were 18.1% (clusters) and 55.5% (households). PCV showed that household factors explained 25.5% of cluster-level variation. MORs declined (4.22 clusters; 12.47 households), indicating a reduction in contextual heterogeneity after accounting for household-level factors.

Model 3 (Community-level predictors): Including community-level factors further reduced variance, with cluster-level variance falling to 1.96 (95% CrI: 1.28–2.89) and household-level variance to 6.55 (95% CrI: 4.88–8.76). Cluster ICC declined to 16.4%, and PCV indicated that community characteristics explained 36.5% of between-cluster variation. MORs declined further (3.77 cluster; 11.47 household), suggesting that geographic and contextual factors partially account for clustering in ITN use.

Model 4 (Full model, all levels): In the fully adjusted model, cluster-level variance increased to 2.49 (95% CrI: 1.59–3.80) and household-level variance to 9.36 (95% CrI: 6.76–12.81). ICCs were 16.5% for clusters and 61.5% for households. MORs indicated that moving to another cluster increased the odds of ITN use by 4.49, while moving to another household increased odds by 18.29. PCV values suggested that covariates explained part of the cluster-level variance (+19.1%), but household-level heterogeneity remained substantial (–48.4%).

Model fit and diagnostics: Model fit improved progressively across specifications, with the lowest LOOIC observed for the full model (3501.6 ± 73.6), indicating the best predictive performance. Bayesian R^2 increased from 0.00 (null model) to 0.16 (full model, marginal) and from 0.51 to 0.57 (conditional), showing that fixed and random effects together explained a moderate share of variance in ITN use. Convergence diagnostics confirmed model stability ($R\text{-hat} = 1$; Bulk-ESS and Tail-ESS > 1000 for all parameters). Multicollinearity was not detected, with generalized VIF values all < 5 (range: 1.03–2.86; mean: 1.54) (See Supplementary file A).

Table 3. Random effects, heterogeneity measures, and model fit statistics for Bayesian multilevel logistic regression of ITN utilization among women of reproductive age, TMIS 2017

Measure	Model 0 (Null)	Model 1	Model 2	Model 3	Model 4 (Full)
Random effects & heterogeneity					
Variance Cluster	3.06 (2.13-4.37)	3.49 (2.37-5.02)	2.28 (1.49-3.39)	1.96 (1.28-2.89)	2.49 (1.59-3.80)
Variance Household	6.30 (4.67-8.35)	7.78 (5.76-10.49)	7.02 (5.15-9.36)	6.55 (4.88–8.76)	9.36 (6.76–12.81)
ICC Cluster (%)	24.2 (18.9-30.6)	23.8 (18.4-30.2)	18.1 (13.1-24.0)	16.4 (11.9-21.8)	16.5 (11.6-22.1)
ICC Household (%)	49.5 (43.2-55.8)	53.3 (46.8-59.5)	55.5 (48.7-62.0)	55.4 (48.8-61.8)	61.5 (54.8-68.1)
MOR Cluster	5.29 (4.03-7.37)	5.89 (4.34-8.49)	4.22 (3.21-5.79)	3.77 (2.95-5.05)	4.49 (3.32-6.42)
MOR Household	10.84 (7.88-15.72)	14.14 (9.86-21.96)	12.47 (8.76-18.51)	11.47 (8.25-16.83)	18.29 (11.92-30.34)
PCV Cluster (%)	–	–12.9 (–89.7 to +32.7)	+25.5 (–25.4 to +57.2)	+36.5 (–7.3 to +63.1)	+19.1 (–42.2 to +54.3)
PCV Household (%)	–	–23.6 (–85.3 to +17.9)	–11.9 (–68.0 to +26.2)	–4.3 (–55.6 to +29.5)	–48.4 (–129.6 to +3.2)
Model fitness					
LOOIC	3630.4 (±71.7)	3555.2 (±72.0)	3600.4 (±73.1)	3622.4 (±71.9)	3501.6 (±73.6)
Bayesian R^2 (Marginal)	0.00 (0.00-0.00)	0.03 (0.01-0.05)	0.05 (0.03-0.08)	0.08 (0.04-0.12)	0.16 (0.11-0.21)
Bayesian R^2 (Conditional)	0.51 (0.47-0.55)	0.54 (0.50-0.58)	0.52 (0.49-0.56)	0.51 (0.47-0.55)	0.57 (0.52-0.61)

Note: σ^2 = variance of random intercepts; ICC = intraclass correlation coefficient; MOR = median odds ratio; PCV = proportional change in variance; LOOIC = leave-one-out information criterion; Bayesian R^2 (marginal) = proportion of variance explained by fixed effects; Bayesian R^2 (conditional) = proportion explained by both fixed and random effects.

Fixed effects (association measure)

Model comparison based on the Leave-One-Out Information Criterion (LOOIC) identified the fully adjusted model (Model 4; LOOIC = 3501.6 ± 73.6) as the best-fitting specification. The fixed effects from this model are presented in Table 4.

At the individual level, age, education, marital status, knowledge, and exposure to ITN messages influenced ITN use. Compared to women aged 15–19 years, those aged 40–44 years had 38% lower odds of ITN use (aOR = 0.62, 95% CrI: 0.41–0.94), while women aged 45–49 years had 1.73 times higher odds (aOR = 1.73, 95% CrI: 1.17–2.58). Women with higher education were less likely to use ITNs compared with those without formal education (aOR = 0.68; 95% CrI: 0.49–0.93). Marital status showed a strong association: married women (aOR = 2.21, 95% CrI: 1.04–4.79) and widowed women (aOR = 6.61, 95% CrI: 1.81–25.38) had higher odds of ITN use than never-married women. Women who knew mosquitoes transmit malaria were 1.57 times more likely to use ITNs than those who did not (aOR = 1.57; 95% CrI: 1.00–2.50). Exposure to ITN messages was strongly associated with utilization, increasing the odds more than twofold (aOR = 2.25; 95% CrI: 1.44–3.55).

At the household level, women in female-headed households were less likely to use ITNs (aOR = 0.60, 95% CrI: 0.37–0.95). Household size was also important: those from medium-sized households (4–6 members) had markedly lower odds of ITN use compared with smaller households (1–3 members) (aOR = 0.35, 95% CrI: 0.19–0.61).

At the community level, contextual differences were pronounced. Women in rural areas were more than three times as likely to use ITNs compared with those in urban settings (aOR = 3.23, 95% CrI: 1.21–8.70). Regional disparities were also substantial: women in Savanes had 18-fold higher odds of ITN use compared with those in Lomé Commune (aOR = 18.10, 95% CrI: 3.53–100.4), while women in Plateaux also had significantly higher odds (aOR = 5.10, 95% CrI: 1.34–21.25). Detailed outputs from Bayesian multilevel binary logistic regression models (models 0–3) is provided in supplementary file B

Table 4. Results of model 4 (Full model) with individual-, household-, and community-level variables from Bayesian multilevel binary logistic regression of ITN utilization among women of reproductive age, TMIS 2017

Fixed effect	Estimate	SE	aOR	95% CrI	Rhat	Bulk-ESS	Tail-ESS
β0 (intercept)	0.01	0.76	1.01	0.23-4.54	1.00	6177	7982
Age group							
15–19 (ref)	—	—	1.00	—	—	—	—
20–24	-0.23	0.36	0.80	0.39-1.62	1.00	9071	9174
25–29	-0.38	0.27	0.69	0.41-1.16	1.00	13099	10101
30–34	0.07	0.23	1.08	0.68-1.70	1.00	13739	10408
35–39	0.40	0.22	1.49	0.97-2.28	1.00	14036	10550
40–44*	-0.48	0.21	0.62	0.41-0.94	1.00	12046	9780
45–49*	0.55	0.20	1.73	1.17-2.58	1.00	11805	9978
Educational level							
No education (ref)	—	—	1.00	—	—	—	—
Primary	0.17	0.34	1.18	0.61-2.28	1.00	10073	9471
Secondary	-0.21	0.25	0.81	0.50-1.33	1.00	10014	9482
Higher*	-0.39	0.17	0.68	0.49-0.93	1.00	11022	9309
Marital status							
Never married (ref)	—	—	1.00	—	—	—	—
Married*	0.79	0.39	2.21	1.04-4.79	1.00	7220	8315
Widowed*	1.89	0.68	6.61	1.81-25.38	1.00	9121	9592
Divorced/Separated	0.32	0.54	1.37	0.48 – 4.04	1.00	8608	9414
Children ever born							
0 (ref)	—	—	1.00	—	—	—	—
1–2	0.27	0.32	1.31	0.71-2.47	1.00	10427	9579
3–4	-0.11	0.22	0.90	0.58-1.39	1.00	9746	9963
≥5	0.07	0.17	1.07	0.76-1.50	1.00	12064	10121
Pregnancy status							
No (ref)	—	—	1.00	—	—	—	—
Yes	-0.40	0.32	0.67	0.36-1.25	1.00	12886	10364
Knows mosquitoes as malaria vector							
No (ref)	—	—	1.00	—	—	—	—
Yes*	0.45	0.23	1.57	1.01-2.50	1.00	12798	9665
Knows ITN against malaria							
No (ref)	—	—	1.00	—	—	—	—
Yes	-0.20	0.20	0.82	0.55-1.21	1.00	11061	9518
Exposed to ITN messages							
No (ref)	—	—	1.00	—	—	—	—
Yes*	0.81	0.23	2.25	1.44-3.55	1.00	11598	10179
Sex of household head							
Male (ref)	—	—	1.00	—	—	—	—
Female*	-0.52	0.24	0.60	0.37-0.95	1.00	10025	9374
Age of household head							
<30 (ref)	—	—	1.00	—	—	—	—

30–44	0.05	0.34	1.06	0.53-2.07	1.00	6898	8198
45–59	-0.08	0.37	0.93	0.45-1.92	1.00	6793	8261
≥60	-0.31	0.41	0.73	0.32-1.63	1.00	6442	8370
Wealth quintile							
Poorest (ref)	—	—	1.00	—	—	—	—
Poorer	-0.54	0.43	0.58	0.25-1.33	1.00	7701	8937
Middle	0.08	0.25	1.09	0.66-1.77	1.00	8843	8788
Richer	0.31	0.23	1.36	0.88-2.14	1.00	9382	9452
Richest	-0.42	0.22	0.65	0.43-1.00	1.00	9530	9228
Household size							
1–3 (ref)	—	—	1.00	—	—	—	—
4–6*	-1.06	0.30	0.35	0.19-0.61	1.00	8397	8827
≥7	-0.12	0.18	0.89	0.62-1.26	1.00	10099	9222
Number of rooms in household							
1 (ref)	—	—	1.00	—	—	—	—
2–3	-0.32	0.31	0.73	0.40-1.32	1.00	8798	8996
≥4	-0.21	0.17	0.81	0.58-1.14	1.00	9348	9345
Number of beds in household							
0–1 (ref)	—	—	1.00	—	—	—	—
2–3	-0.11	0.36	0.90	0.45-1.80	1.00	8763	9375
≥4	0.26	0.20	1.29	0.89-1.91	1.00	9518	9459
Region							
Lomé Commune (ref)	—	—	1.00	—	—	—	—
Maritime	0.55	0.63	1.73	0.49-5.80	1.00	5163	7520
Plateaux*	1.63	0.70	5.10	1.34-21.25	1.00	4464	6026
Centrale	0.47	0.83	1.60	0.33-8.21	1.00	4657	6836
Kara	0.93	0.78	2.53	0.55-12.02	1.00	4609	6585
Savanes*	2.90	0.85	18.10	3.53-100.4	1.00	4602	6536
Residence							
Urban (ref)	—	—	1.00	—	—	—	—
Rural*	1.17	0.51	3.23	1.21-8.70	1.00	5973	7532
Cluster altitude							
<200 m (ref)	—	—	1.00	—	—	—	—
200–499 m	0.51	0.58	1.66	0.53-5.11	1.00	7053	7986
≥500 m	-0.12	0.41	0.89	0.40-1.97	1.00	6716	8636

Note: Model 0 is the null model, a baseline specification without covariates. Model 1 includes only individual-level variables. Model 2 adds household-level variables, while Model 3 incorporates community-level variables. Model 4 is the final model, simultaneously adjusted for individual, household, and community-level variables.

* denotes statistical significance at the 95% credible interval (CrI), meaning the posterior distribution of the adjusted odds ratio (aOR) does not include 1. ref = reference category.

Discussion

This study examined determinants of insecticide-treated net (ITN) utilization among women of reproductive age in Togo using nationally representative data from the 2017 TMIS. Applying Bayesian multilevel logistic regression, we found that ITN use is shaped by factors at the individual, household, and

community levels, confirming that both personal attributes and broader contextual conditions influence net use [6].

Overall, 72.8% of women in households owning at least one ITN reported sleeping under a net the night before the survey, indicating that nearly three in four women reported sleeping under a net the night before the survey. This is encouraging progress and reflects the impact of national ITN distribution campaigns implemented prior to the 2017 survey [3,12]. However, utilization remains below the World Health Organization (WHO) target of 80% coverage among at-risk populations [11]. Subgroup differences were evident: adolescents reported the lowest coverage, consistent with studies in West Africa showing that younger age groups are less likely to prioritize malaria prevention [28,46]. Married and widowed women, as well as those with higher parity, demonstrated greater ITN use, suggesting that caregiving responsibilities strengthen preventive behaviors [16,34]. Notably, women without formal schooling reported higher ITN use (78.3%) than those with higher education (58.9%), a paradox observed in Ghana, Nigeria, and Malawi and possibly related to differences in housing, perceived risk, or uptake of alternative prevention methods among educated groups [15,31,47]. Similarly, ITN use was highest among the poorest households and lowest among the richest, demonstrating the equity benefits of free distribution campaigns that disproportionately improve access among disadvantaged groups [15]. This suggests that ITN promotion must not only target women with limited education but also address complacency and substitution behaviors among wealthier and more educated groups. Women who had received ITN-related messages reported higher use. This finding aligns with evidence from Ethiopia and Nigeria, where behavior change communication significantly improved ITN utilization [17,30].

The fixed-effects results provided insights into which specific individual, household, and community characteristics were most strongly associated with ITN utilization. At the individual level, age, marital status, education, malaria knowledge, and recent exposure to ITN messages were important predictors. Older age groups showed mixed effects: women aged 40–44 were less likely to use nets, while those aged 45–49 were more likely compared with adolescents. This life-course pattern mirrors evidence from Ghana and Nigeria, where ITN use fluctuates across stages of adulthood, reflecting shifts in household roles, perceived vulnerability, and health-seeking behaviors [28,30]. Marital status also played a decisive role: married and widowed women were more likely to use ITNs than their never-married counterparts, a finding consistent with studies in Ethiopia and Malawi, where women in unions benefit from household decision-making dynamics and a stronger focus on child and maternal health [17,47]. Education demonstrated a paradoxical effect. Women with higher education had significantly lower odds of ITN use compared to those with no education, diverging from multi-country evidence that typically identifies education as a facilitator of preventive practices [15]. This anomaly may reflect urban residence patterns among educated women, who often adopt alternative preventive measures such as screened housing, insect repellents, or air conditioning. Knowledge of malaria transmission was positively associated with ITN use, underscoring the importance of basic health literacy in shaping protective behavior. Similarly, exposure to ITN-related messages more than doubled the likelihood of utilization, consistent with multilevel analyses from East Africa showing that communication campaigns substantially improve preventive practices [48]. By contrast, knowledge of ITN protection against malaria was not significantly associated with use, contradicting findings from Nigeria and Ethiopia [17,48]. A plausible explanation is knowledge saturation in Togo, where awareness levels are already high, reducing its discriminating power. Instead, cultural perceptions, discomfort during hot seasons, and irregular use may explain the persistence of non-utilization despite awareness.

At the household level, two factors sex of household head and household size were important determinants. Women in female-headed households had significantly lower odds of ITN use compared to those in male-headed households. Similar results have been documented in Ghana and Nigeria, where female heads often experience financial constraints or competing priorities that reduce the likelihood of consistent ITN use [28,31]. Larger household size was also negatively associated with utilization, as women in households of 4–6 members were substantially less likely to use ITNs than those in smaller households. This supports findings from Ethiopia and Malawi showing that competition for limited nets within larger families undermines equitable access [17,47]. In many West African settings, limited numbers of nets are commonly shared among household members, with priority often given to young children and pregnant women perceived as most vulnerable, leaving other adult women inconsistently protected [15,16]. Overcrowded sleeping arrangements and discomfort related to heat further discourage sustained ITN use, particularly in larger families [14, 17]. Moreover, households facing economic hardship may prioritize immediate subsistence needs such as food, education, and healthcare over replacing damaged or insufficient nets despite free distribution campaigns [15]. Together, these socio-cultural and economic dynamics illustrate that ownership alone does not guarantee equitable utilization within households. Interestingly, wealth quintile did not significantly predict ITN utilization, in contrast to studies from Nigeria and other African contexts that have documented socioeconomic gradients [15]. This lack of association in Togo may reflect the success of universal free distribution campaigns, which have narrowed wealth-based inequities [3]. At the same time, wealthier households may reduce their reliance on ITNs by investing in alternative structural or chemical prevention methods.

At the community level, both region and rural–urban residence strongly influenced ITN utilization. Women living in rural areas were over three times more likely to use ITNs than their urban counterparts, a pattern consistent with findings from Tanzania and Malawi where lower perceived malaria risk and reliance on structural protections diminish ITN use in cities [47,48]. Regional disparities were striking, with women in Savanes and Plateaux significantly more likely to use ITNs than those in Lomé Commune. This reflects both higher transmission intensity in the northern regions and targeted distribution strategies that prioritize high-burden areas [25,49]. Similar regional effects have been reported in Ghana and Nigeria, where geographic context and program intensity drive pronounced differences in coverage and utilization [28,30]. Averages can mask local heterogeneity and that district-level mapping is necessary to identify true hotspots and coldspots for targeted interventions.

Random-effects results (ICC, VPCs, and MORs) indicated that a substantial proportion of the variance in ITN utilization was attributable to household and cluster contexts rather than individual characteristics alone. In other words, ITN use was clustered within households and enumeration areas, reflecting shared living conditions, access to nets, and exposure to information. Similar findings have been reported across other African settings, where multilevel analyses demonstrated that a considerable share of the variation in ITN use is explained at the household and community

levels [28,47,50]. This clustering underscores the need for programmatic efforts that extend beyond individual behaviour change to address intra-household allocation, local distribution practices, and community-level determinants. In practice, this calls for complementing universal ITN distribution with strategies that promote equitable allocation within households, strengthen community outreach, and tailor messaging toward groups with lower uptake particularly adolescents, urban residents, female-headed households, and more educated women.

These findings should be interpreted alongside recent advances in Togo's malaria control programme. Since 2017, the country has scaled up seasonal malaria chemoprevention in high-transmission areas, established sentinel surveillance, and most recently initiated nationwide rollout of the R21/Matrix-M malaria vaccine for young children (September 2025) [10,12,51]. These interventions create opportunities for integrated approaches that combine ITN distribution, chemoprevention, vaccination, and real-time surveillance. Nonetheless, sustaining equitable ITN use remains essential to maximize collective protection and to prevent widening disparities among underserved groups [52].

Strengths and Limitations

This study has several strengths. It used nationally representative data from the 2017 Togo Malaria Indicator Survey, allowing generalizability of findings to women of reproductive age across the country. The use of a Bayesian multilevel modeling approach accounted for the hierarchical structure of the data and provided robust estimates of both fixed and random effects, while simultaneously quantifying uncertainty through credible intervals. The inclusion of variables at the individual, household, and community levels offered a comprehensive understanding of the multi-level determinants of ITN utilization.

However, some limitations must be acknowledged. First, the analysis relied on self-reported ITN use the night before the survey, which may be subject to social desirability or recall bias. Second, the cross-sectional design precludes establishing causal relationships between determinants and ITN utilization. Third, some potentially relevant factors such as cultural norms, perceptions of malaria risk, and seasonal variations in ITN use were not captured in the TMIS dataset. Despite these limitations, the study provides important insights into both individual and contextual influences on ITN use in Togo.

Conclusion

This study, based on nationally representative data from the 2017 Togo Malaria Indicator Survey, revealed that while ITN utilization among women of reproductive age living in households with at least one net was relatively high, marked disparities persist across geographic, socioeconomic, and household contexts. These inequalities, particularly among adolescents, urban residents, women in female-headed households, and those with higher education underscore that ownership alone does not guarantee equitable use. Since 2017, Togo has strengthened malaria control and these advancements complement but do not replace the central role of ITNs as the foundation of malaria prevention. Sustaining high ITN utilization will require continuous efforts to ensure equitable access, promote consistent use, and tailor interventions to populations and regions with lower coverage. For policy and practice, the findings emphasize the need for a more equity-oriented and integrated malaria control strategy linking ITN promotion with vaccination, chemoprevention, and behavior-change communication supported by rigorous monitoring and adaptive program design to address emerging challenges and sustain progress toward malaria elimination in Togo.

Abbreviations

aOR: Adjusted Odds Ratio; CI: Confidence Interval; CrI: Credible Interval; DHS: Demographic and Health Survey; ESS: Effective Sample Size; HMC: Hamiltonian Monte Carlo; ICC: Intra-class Correlation Coefficient; ITN: Insecticide-Treated Net; LOOIC: Leave-One-Out Information Criterion; MCMC: Markov Chain Monte Carlo; MIS: Malaria Indicator Survey; MOR: Median Odds Ratio; PCV: Proportional Change in Variance; TMIS: Togo Malaria Indicator Survey; WHO: World Health Organization.

Declarations

Ethics approval and consent to participate

Ethics approval was not required for this study as it involved the analysis of publicly available secondary data. The DHS Program, however, reports that written and verbal informed consent was obtained from all participants by the Institutional Review Board of Inner-City Fund (ICF) International and the Bioethics Committee for Health Research (BCRS) of Togo [53]. All procedures adhered to ethical standards for human research, in accordance with the Declaration of Helsinki. Permission to access and analyze the dataset was granted by the DHS Program.

Consent to publication

All authors have approved the submission of the final copy for publication.

Availability of data and materials

The datasets supporting the findings of this study are available from the Measure DHS repository. Specifically, the 2017 Togo Malaria Indicator Survey (TMIS) dataset can be accessed at <https://dhsprogram.com/data/available-datasets.cfm> upon request and approval from the DHS Program. The

analysis code used in this study will be made available at <https://github.com/TCHAKONDO/R-Code-for-Bayesian-Multilevel-Analysis-of-ITN-Utilization-in-Togo-TMIS-2017-/tree/main>.

Competing interests

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Authors' contributions

Samadou Tchakondo conceived and designed the study, performed data analysis, interpreted the findings, and drafted the manuscript. Muthuperumal Prakash supervised the study, guided the methodological framework, and critically revised the manuscript for important intellectual content. Smaila Alidou contributed to the analytical approach and provided technical and statistical guidance during data analysis. Komi Selassi Gayi, Ayao Sangénis Assogba, Yendouname Kandjoni, Richard Sagacity Tugbeh, and Kezia Angeline J assisted in data interpretation, literature review, and manuscript editing. All authors read and approved the final version of the manuscript.

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Figures

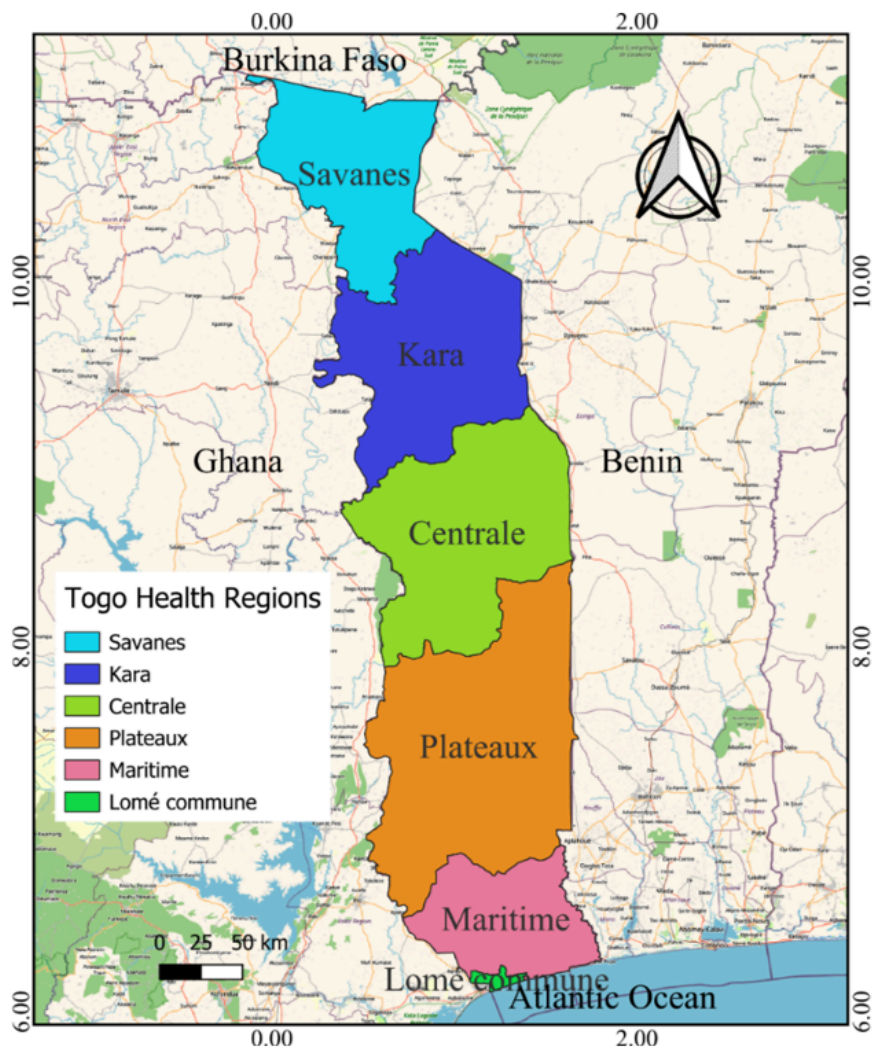


Figure 1

Togo administrative map showing health regions, TMIS 2017.

The map was generated using QGIS version 3.44. Togo's administrative boundary shapefiles were obtained from the GADM database of Global Administrative Areas (<https://gadm.org>, version 4.1, downloaded 2025-06-25), a publicly available resource providing high-resolution administrative boundary data for all countries worldwide.