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Mapping of access and usage of insecticide-treated nets in Nigeria

Faith Eshofonie[1*], Osafu Augustine Egbon[2] and Ezra Gayawan[1]

Abstract

Background Malaria remains a major public health challenge in Nigeria with children under five years of age and pregnant women possessing the highest risk. Preventive efforts including indoor residual spraying (IRS) and insecticide-treated nets (ITN) have been implemented over the years but issues such as limited funding, low net coverage, and cultural barriers have hindered progress. This study analyses ITN ownership and usage trends across Nigeria to assess local-level variations and differences based on household size.

Methods This study used data from the Nigeria Demographic and Health Survey (NDHS) and the Nigeria Malaria Indicators Survey (NMIS) to analyse access and usage trends over seven distinct years (2003, 2008, 2013, 2018, 2010, 2015, and 2020). A Bayesian spatio-temporal model was applied to capture variations in access and usage. The model was estimated using Integrated Nested Laplace Approximation (INLA).

Results The results highlight significant geographic and temporal variations in access to and use of bed nets, with notable disparities between northern and southern regions. For women of reproductive age, access to bed nets increased over time, particularly in northern states; however, usage remained generally low, especially in the south. Pregnant women exhibited similar patterns, with higher access in northern states but low usage overall, particularly in the southern regions. For children under five, usage increased in some northern states but remained low in the south, creating a clear north–south divide. Additionally, bed net availability at the household level remains low overall.

Conclusions The study underscores the need for targeted public health interventions to address regional disparities in access and use of bed nets in Nigeria. Promoting consistent use of bed nets through tailored awareness campaigns and overcoming cultural barriers will be crucial in reducing malaria burden.

Keywords Malaria, Insecticide-treated nets, Bayesian, Spatio-temporal modeling

Background

Malaria has remained a formidable public health challenge where in 2022, about 249 million cases were reported with about 94% occurring in the WHO African Region [1]. Nigeria (27%), DR Congo (12%), Uganda (5%) and Mozambique (4%) accounted for nearly half of all cases while, in terms of deaths, Nigeria (31.1%), DR Congo (11.6%), Niger (5.6%) and Tanzania (4.4%) reported more than half of all deaths [1]. Thus, Nigeria is a foremost country for malaria, where the disease disproportionately affects vulnerable populations such as children under five years of age and pregnant women, because these populations have weakened immune system [2, 3]. About 60% of annual outpatient visits in the country is due to malaria with about 95% annual child death [4–6]. The prevalence of congenital malaria in

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Nigeria varies widely throughout the country, affecting all geopolitical zones [7, 8], and the risk of malaria transmission persists year-round, particularly in the northern and northeastern regions where climatic conditions favor mosquito breeding and transmission [9]. In light of this ongoing crisis and as recommended by the World Health Organization (WHO), various strategies have been implemented to combat malaria, focusing on vector control interventions, chemopreventive therapies and chemoprophylaxis, treatment, and community education [4, 10]. Among the most effective preventive measures are indoor residual spraying (IRS) and the widespread use of insecticide-treated nets (ITNs). IRS involves the application of long-lasting insecticides to the interior walls of homes, effectively killing mosquitoes that come into contact with treated surfaces [11]. On the other hand, ITNs do not only act as a physical barrier against mosquito bites but also possess inherent insecticidal properties, making them vital tools in the fight against malaria [12]. Studies by Pryce and colleagues [13] reported that the use of ITN is capable of reducing mortality from all causes by 17% among children and reduce the incidence of uncomplicated episodes of *Plasmodium falciparum* malaria by almost a half.

Despite a notable increase in the usage of ITNs, especially among children, this increase has not correlated with a significant reduction in malaria incidence particularly in Nigeria [14–16]. This discrepancy raises important questions about the ITNs as a standalone intervention. Findings suggest that greater reductions in malaria morbidity and improved health outcomes for children may be achieved when ITNs are used in combination with IRS, surpassing the protection offered by either method alone [17]. In addition, the resurgence of malaria is significantly driven by inadequate funding, leading to low net coverage and usage, as well as the declining effectiveness of standard nets [18]. This underscores the need for integrated strategies to enhance malaria control efforts. A deeper understanding of the complexities surrounding ITN ownership and usage is required. The relationship between ITN ownership and actual usage in different Nigerian geographies remains underexplored, particularly among children and pregnant women [19], who are advised by the WHO to sleep under an ITN as early as possible in their pregnancies ideally before conception to safeguard both maternal and fetal health [20].

Furthermore, the distribution of ITNs across different demographics and geographic clusters adds another layer of complexity to malaria prevention. Understanding how ITNs are allocated among households, particularly regarding ownership and availability relative to the number of household members is crucial for effective intervention strategies. Previous research has largely focused on the presence of at least one ITN per household, often overlooking the critical issue of whether households have an adequate number of nets to meet their needs [21, 22]. This is particularly pressing in Nigeria, where overall ownership rates of mosquito nets remain low [23]. In addition to availability issues, misconceptions and cultural barriers significantly hinder the effective use of ITNs [24]. In regions like Anambra and Rivers states, fears of adverse health effects, such as vomiting blood or skin irritation, contribute to low usage rates [25]. Another Nigerian study reported that attitude towards the use of ITN can be influenced by the number of messages recalled from the information, education and communication (IEC) and behaviour change communication (BCC) interventions that are used during or following mass distribution of nets to encourage correct use, and that this is better off in the northern states [26]. Another study in Abraka, Nigeria identified that regular use of ITN depends on the level of awareness among students of a tertiary institution but that the awareness of the ITN itself relies on the roles played by health workers during net distribution [27]. Other obstacles include discomfort from heat, low mosquito activity, fear of chemicals, and difficulties in hanging nets, as well as cultural preferences for alternative prevention methods [25].

Socioeconomic factors also play some critical roles in access to and utilization of ITNs. Household income, education, and family size all influence a family's ability to afford and maintain enough nets [28]. Research from Cross River and Bauchi states reveals that wealthier, urban households and those with more educated heads of household are more likely to own bed nets [29]. A study by [30] found that literacy, better economic status, marital experience, and employment contributed positively to the use of ITN, while ignorance, poverty, and cultural beliefs were negative contributors. These findings underscore that malaria prevention efforts must address not only the availability of nets but also deeply rooted cultural perceptions and misinformation, which vary widely across Nigeria's diverse regions. Geospatial mapping of ITN ownership and usage over time could be a useful approach to understanding the complexities and changes in these important issues across different Nigerian landscape and can serve as a basis for identifying location-specific cultural or other barriers.

This study employs a spatio-temporal modeling approach to combine and analyse ITN data collected as part of the Nigeria Demographic and Health Survey (NDHS) conducted in years 2003, 2008, 2013, and 2018 and Nigeria Malaria Indicators Survey (NMIS) conducted in years 2010, 2015, and 2020, focusing on ownership (access) and usage trends of bed nets (treated and untreated) across Nigeria. This dual focus is essential; while treated nets provide enhanced protection through insecticides, untreated nets still offer a basic physical barrier against mosquito bites. Identifying patterns and changes over time will reveal how bed net access varies geographically and demographically, among vulnerable groups such as pregnant women and children under five. Bed net availability relative to household size was analysed within specific geographic clusters to assess whether households are adequately equipped to combat malaria through this medium. This broader perspective will guide policymakers in enhancing malaria control efforts, ensuring equitable access to protective measures, ultimately reducing malaria in Nigeria, one of the world's most affected countries.

Methods

Data source

This study utilized data from the NDHS and NMIS. The NDHS conducted in 2003, 2008, 2013, and 2018 provides extensive information on maternal and child health, focusing on female respondents aged 15–49 and their children below age five years. The data provide national estimates of key health indicators for rural and urban populations across the six geopolitical zones, the 36 states, and the Federal Capital Territory (FCT) (Fig. 1). Similarly, the NMIS, conducted in 2010, 2015, and 2021, capture vital health metrics relevant to malaria, anaemia and other related health indicators within the same geographical framework. Both surveys utilize the 2006 Population and Housing Census of Nigeria as their sampling frame, where enumeration areas serve as the primary sampling units (PSUs). They employ a two-stage stratified design, starting with selection of clusters followed by the systematic selection of households, ensuring a representative sample.

Variables of interest

The key variables in this analysis include: Access to bed nets in the households, which refers to whether bed nets are available in the respondent's household; children's bed net usage, indicating whether a child under the age of five slept under a bed net the previous night; respondent's bed net usage, which refers to whether the respondent personally used a bed net the previous night; and pregnancy status, which indicates whether the respondent is currently pregnant.

Definition of Terms: Access to bed nets refers to the ownership of bed nets within households, while use of bed nets refers to whether individuals, either the respondent or children, slept under a bed net the night before the survey.

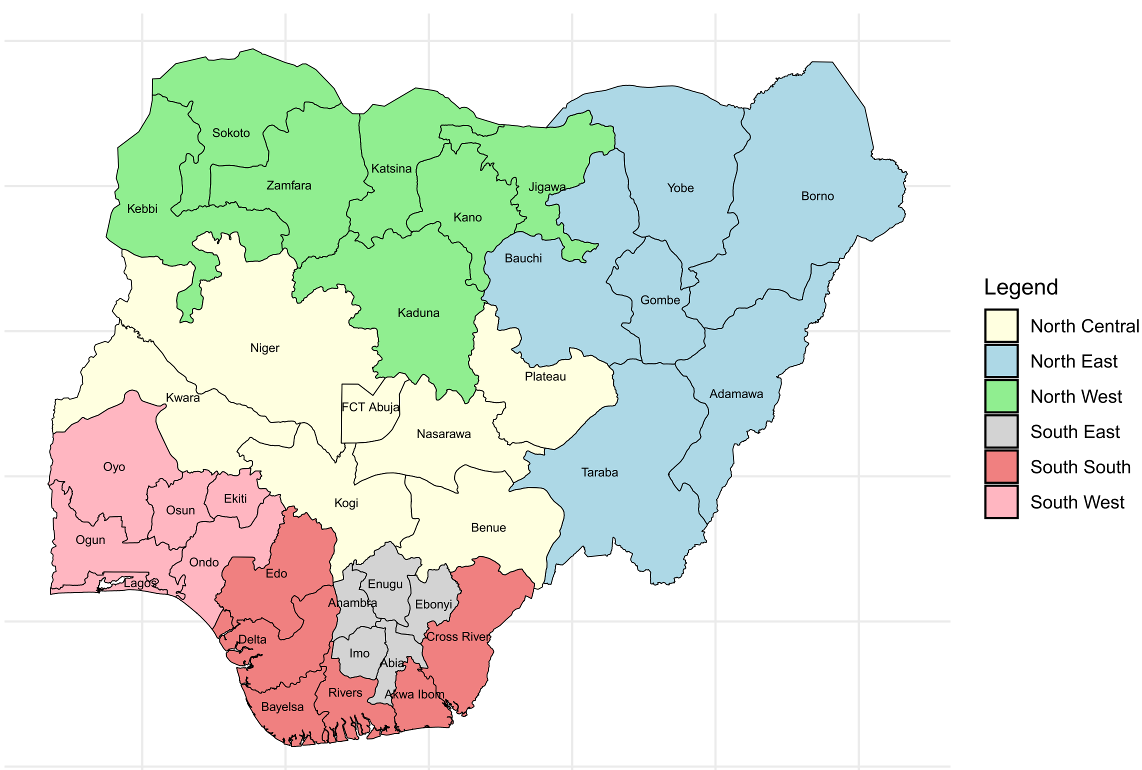

Fig. 1 Map of Nigeria showing the country's 36 States and the Federal Capital Territory, Abuja

Statistical method

A Bayesian spatiotemporal model was used for the analysis, which allows estimation of spatiotemporal random effects and structured temporal effects. This modelleing approach effectively captures variations in the access and usage of bed nets among pregnant women and children over time, providing a robust framework for inference. While the models for both bed net access/usage and ownership relative to household size rely on the same linear predictor with logit link function, the response variables differ. The access/usage variables were binary outcomes while access relative to household size variable was proportion.

The linear predictor was defined as:

$$\eta_{ijt} = \alpha + \tau_t + \phi(z_j, t), \tag{1}$$

where α is the intercept, τ_t represents the structured random time effects, and $\phi(z_j, t)$ captures the spatio-temporal random effects at cluster z_j and time t.

Both $\phi(z_j, t)$ and τ_t are assumed to evolve over time following first-order autoregressive dynamics:

$$\phi(z_j, t) = a\phi(z_j, t-1) + w(z_j, t), \tag{2}$$

$$\tau_t = b\tau_{t-1} + \nu_t. \tag{3}$$

In these equations, $w(z_j, t)$ and ν_t are white noise processes drawn from zero-mean Gaussian distributions with $w(z_j, t) \sim N\left(0, \frac{\sigma_w^2}{1-a^2}\right)$ for $|a| < 1$, capturing random fluctuations in the spatio-temporal effects and $\nu_t \sim N\left(0, \frac{\sigma_\nu^2}{1-b^2}\right)$ for $|b| < 1$, capturing random fluctuations in the temporal effects.

Model for bed net access and usage

The response variable y_{ijt} (whether respondent i in cluster j at time t owns/uses a bed net) is modeled using a Bernoulli distribution with success probability p_{ijt} and linked to the linear predictor through the logit link function given as

$$\text{logit}(p_{ijt}) = \log\left(\frac{p_{ijt}}{1-p_{ijt}}\right) = \eta_{ijt}. \tag{4}$$

p_{ijt} is interpreted as the probability that an individual uses a bed net. This leads to the following expression for the probability of use:

$$p_{ijt} = \frac{\exp(\eta_{ijt})}{1+\exp(\eta_{ijt})}. \tag{5}$$

Model for bed net access relative to household size

The number of bed nets per survey cluster was calculated by aggregating household-level data within each cluster. Specifically, we determined the total number of bed nets B and the total number of household members H within each cluster and used these to compute the number of nets per cluster (NPC) as:

$$\text{NPC} = \frac{B}{H}. \tag{6}$$

To address the presence of zero values in the NPC variable, we added a small constant (0.000001) to ensure that all response values fell strictly within the open interval (0, 1), thereby satisfying the distributional assumption of the beta regression model. A beta distribution was assumed for the response variable [31]. The logit link function was also used to model the mean proportion. Representing the shape parameters of standard beta distribution as $\alpha = \mu\phi$ and $\beta = (1-\mu)\phi$, where μ is the mean of NPC and ϕ is the precision, the re-parameterized beta probability distribution of NPC_{jt} for cluster j at time t is given as

$$f(\text{NPC}_{jt}|\mu_{jt}, \phi) = \frac{\Gamma(\phi)}{\Gamma(\mu_{jt}\phi)\Gamma((1-\mu_{jt})\phi)} \text{NPC}_{jt}^{\mu_{jt}\phi-1}(1-\text{NPC}_{jt})^{(1-\mu_{jt})\phi-1}, \tag{7}$$

$$\text{logit}(\mu_{jt}) = \log\left(\frac{\mu_{jt}}{1-\mu_{jt}}\right) = \eta_{jt}, \tag{8}$$

where NPC_{jt} represents the proportion of bed nets relative to household size for cluster j at time t. Consequently, the probability of any individual having bed net access in cluster j on year t is then given by:

$$\mu_{jt} = \frac{\exp(\eta_{jt})}{1+\exp(\eta_{jt})}. \tag{9}$$

In addition, the number of bed net usages per cluster (NUC) was fitted on NPC using similar beta probability distribution and logit link as in (8). The number of bed net usages per cluster in a given year (NUC_{jt}) was computed as the ratio of the total number of bed net usages (U_{jt}) to the total number of children (C_{jt}) under five in cluster j during year t. That is,

$$NUC_{jt} = \frac{U_{jt}}{C_{jt}}. \tag{10}$$

Beta regression, as defined earlier in this section, was then used to model to model NUC at the cluster level using NPC as a covariate.

Estimation procedure

Both models were estimated using the integrated nested Laplace approximation (INLA) [32], implemented in the

R-INLA package [33]. To model spatial effects, a spatial Gaussian process was employed, utilizing the stochastic partial differential equations (SPDE) framework described by [34] with a Matérn spatial covariance function. The SPDE approach was applied on top of a Gaussian Markov Random Field (GMRF) representation. To fit the model, a triangulated mesh was constructed based on the geographic boundary of Nigeria using the inla.mesh.2d() function. Key parameters for mesh construction included: max.edge = (0.5, 1.25), which controls the maximum edge length of mesh triangles; offset = (0.1, 1.5), which adjusts mesh density near the boundary; and cutoff = 0.1, which prevents overly small mesh elements. These choices were made to balance spatial resolution with computational efficiency. The inla.spde2.pcmatern() function was then used to build the SPDE model, specifying Penalised Complexity (PC) priors for the parameters of the Matérn field [35]. Specifically, priors for the range (prior.range = c(0.5, 0.01)) and variance (prior.sigma = c(1, 0.01)) were chosen based on prior knowledge on spatial smoothness and variance.

Model validation

To validate the estimates and projections, predicted prevalence values for each state were summed and compared with the observed values, as shown in Fig. 2. The root mean square and correlation values that indicate the relationship between the actual and predicted prevalence for each model are presented in Table 1. Except for the NPC model, the correlation values from the estimates of the other models are very high, indicating a strong agreement between the actual and computed prevalence.

Results

Figs. 3 and 4 present the estimates of bed net access and usage, highlighting the prevalence and uncertainties respectively, among women of reproductive age in Nigeria. Starting from 2003, bed net access was relatively low in places across the southwest, spreading through the southeast and northwest parts of the country. In contrast, higher prevalence of about 75% was noted in places around Kebbi, Sokoto, Jigawa, Borno, Taraba, Bayelsa, Cross River, Imo, Kogi, and Benue states. A shift occurred during 2008, as access began to rise in some southern states, although the northwest and northeast continued to exhibit higher ownership prevalence. Beginning 2010, there appears to be a north–south divide in access of bed nets among women of reproductive age, where access is higher in places along the northern fringe, although this pattern became more obvious from 2015 with about 100% coverage in Kebbi and Jigawa states in 2018. However, usage (Fig. 4) appears to be generally low throughout the country but particularly in the southern part, with most places having below 25% usage. The noted exceptions are Kebbi and Jigawa in 2018 but which was not sustained based on the estimate for 2021.

Figures 5 and 6 illustrate estimates of bed net access and use among pregnant women in Nigeria, highlighting the prevalence and associated uncertainties, respectively. In 2003, similar to patterns of bed net access among all women, access was relatively low in the southwest, extending to the southeast and northwest regions of the country. In contrast, the prevalence of access among pregnant women was notably high in states such as Kebbi, Sokoto, Jigawa, Borno, Adamawa, Bauchi, Taraba, Benue, Kogi, Cross River, Abia, Akwa Ibom, Rivers, Bayelsa, and Delta. In 2008, the trends shifted, with regions that had previously shown low access prevalence experiencing declines, while those with high access saw an increase in prevalence, highlighting growing disparities in access to bed nets. By 2010, the northeast and northwest continued to exhibit higher access prevalence, while the southwest showed persistently low prevalence, creating a clear north–south divide. This divide persisted into 2015 and became even more pronounced by 2018. Similar to Fig. 4, Fig. 6 also shows generally low usage among pregnant women throughout the country, particularly in the southern regions, where most areas reported usage rates below 25%. Notable exceptions included Kebbi and Jigawa in 2018; however, this higher usage was not sustained in Kebbi, as indicated by estimates for 2021.

Figure 7 presents estimates of bed net usage among children under five, along with the uncertainty plots. In 2003, usage was low, especially in the southwest, north-central, and northeast regions, though states like Kebbi, Jigawa, Kogi, Cross River, and Bayelsa had relatively higher prevalence. By 2008, usage increased in states like Sokoto, Borno, Jigawa, Bauchi, and Delta, but many areas, especially in the southwest, still had low prevalence. Estimates in 2010 reveals that states such as Kebbi, Sokoto, Borno, Gombe, Bauchi, Jigawa, Niger, and Rivers showed higher bed net usage, but it remained low in the southern part of the country at this period. In 2013, southern states like Oyo, Cross River, Ebonyi, Enugu, and Imo showed modest increases in prevalence. However, between 2015 and 2018, usage in the south remained low, while Kebbi and Jigawa saw significant increases in prevalence by 2018 but this increase was only sustained in Jigawa by 2021.

Figure 8 illustrates the availability of bed nets relative to household size over time in the various geographic clusters over time, accompanied by the uncertainty plots. Overall, bed net availability remains low across the country. In 2003, higher availability was observed in Kebbi, Sokoto, and Borno. This trend continued through 2008, with Sokoto and Borno showing significant availability.

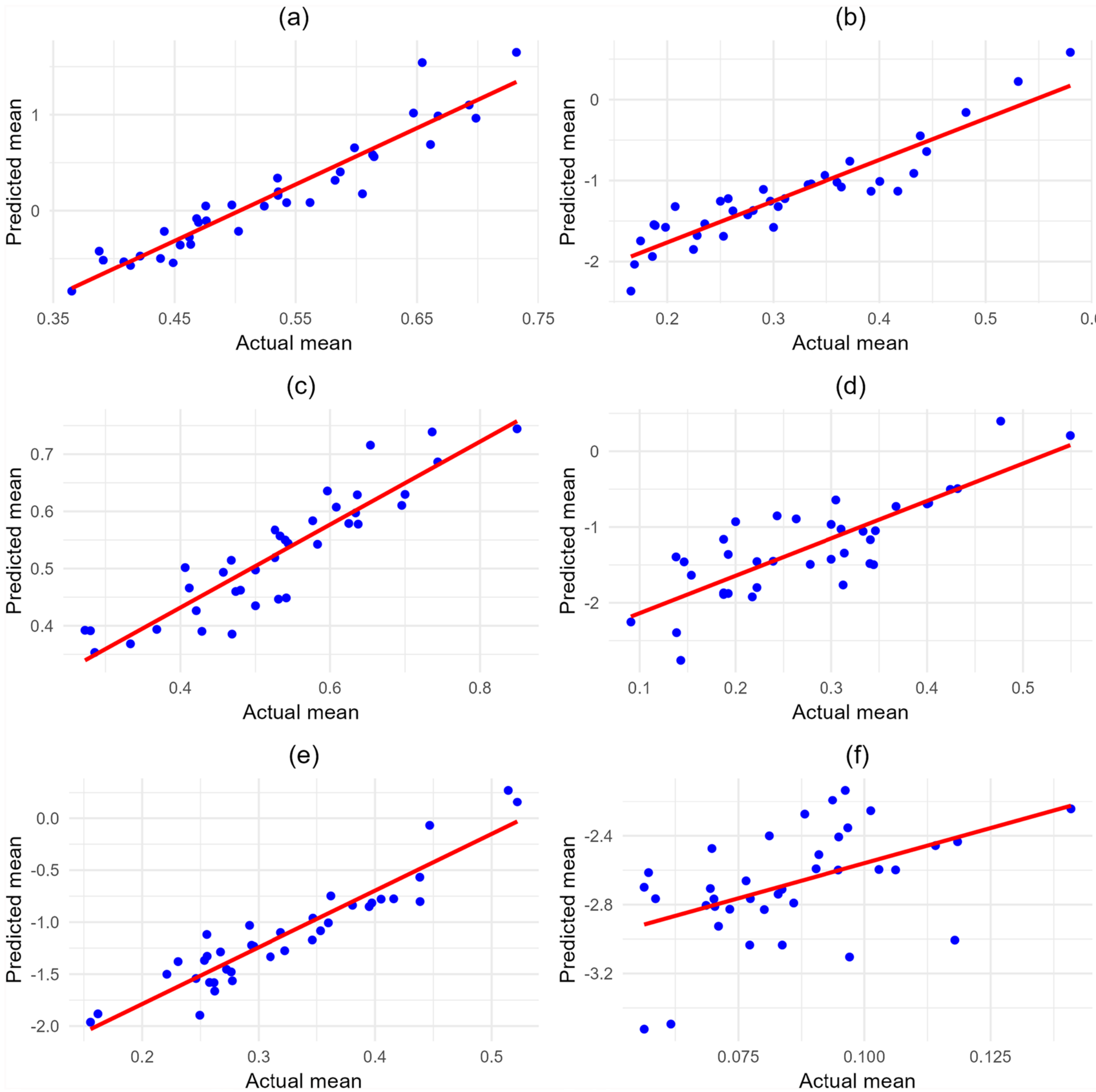

Fig. 2 Scatter plot of actual vs. predicted mean prevalence values with a regression line, illustrating model fit, showing mean bed net access and usage across Nigeria's 37 states for the following groups: (**a**, **b**) women, (**c**, **d**) pregnant women, (**e**) children under 5, and (**f**) nets per household member by cluster

Table 1 RMSE and Correlation values for the groups shown in Fig. 2

Description	RMSE	Correlation
a. Women access	0.1048	0.9501
b. Women usage	0.2609	0.9212
c. Pregnant women access	0.0094	0.9088
d. Pregnant women usage	0.2695	0.8069
e. Children usage	0.2485	0.9320
f. Nets per household member by cluster	0.4572	0.4950

By 2010, all states in the country exhibited very low bed net availability, a trend that persisted in 2021. This indicates that Nigerian households do not have enough bed nets to meet their family needs.

To further understand these dynamics, Figs. 3b and 4b present uncertainty plots for bed net access and usage among women, calculated based on the width of the confidence intervals (CIs). The colour scale ranges from blue to red, indicating the level of uncertainty: blue represents regions with narrower confidence intervals, while red indicates wider intervals. The years 2008, 2013, 2018, and 2021 reveal narrower CIs, likely due to the larger volumes

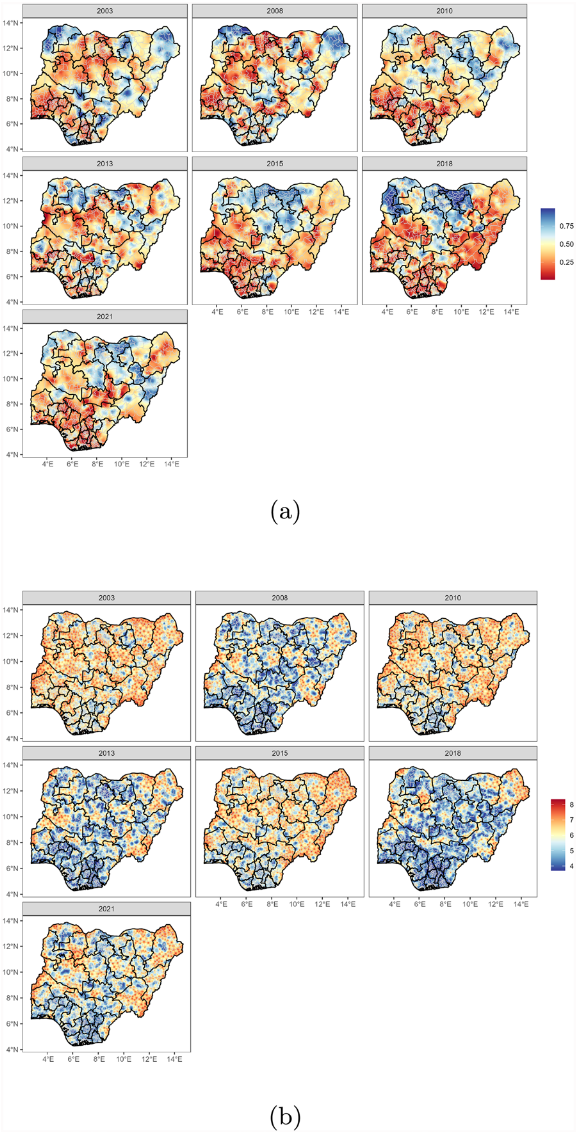

Fig. 3 Maps of Nigeria showing the (**a**) spatio-temporal dynamics of access to bed nets among women of reproductive age and (**b**) the width of the 95% credible intervals. (Estimates are derived from model in equation 1.)

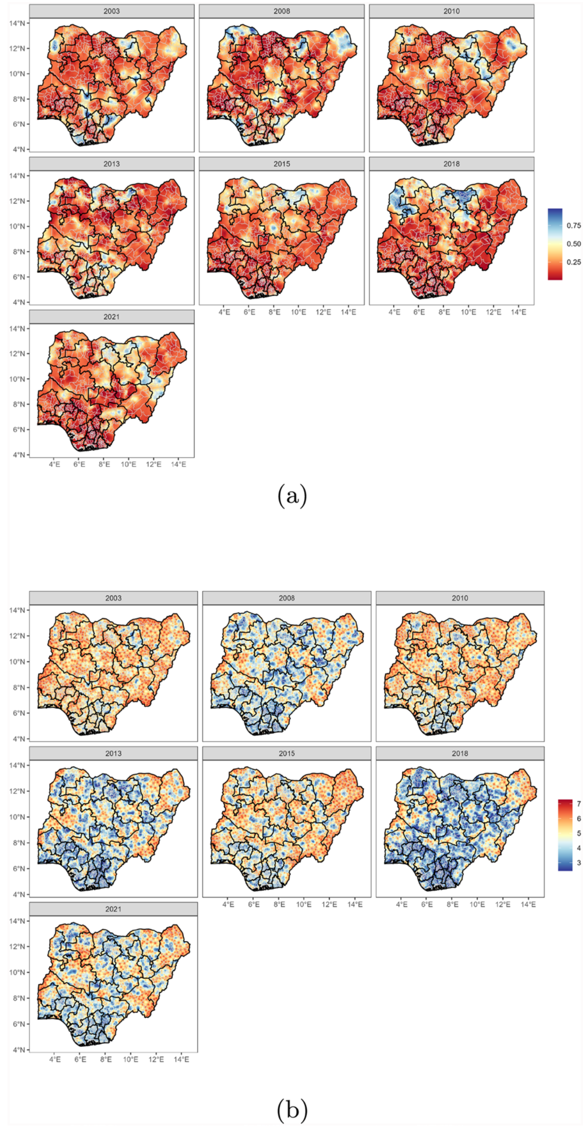

Fig. 4 Maps of Nigeria showing the (**a**) spatio-temporal dynamics of usage of bed nets among women of reproductive age and (**b**) the width of the 95% credible intervals. (Estimates are derived from model in equation 1.)

of data collected during these survey years compared to others, which had wider CIs. Similarly, for children under five and nets per household member by cluster, Figs. 7b and 8b show increased certainty for the years 2008, 2013, 2018, and 2021. For pregnant women, Figs. 5b and 6b reveal greater certainty in the years 2008, 2013, and 2021.

The plots in Fig. 9 illustrate trends in bed net ownership and usage among women, pregnant women, children, and nets per household member by cluster, over time. Bed net ownership among women increased from 2003 to 2015, followed by a decline (Fig. 9a). Usage patterns followed a similar trend, increasing between 2003 and 2010 but fluctuated thereafter until 2018, and a subsequent decrease (Fig. 9b). These trends in access and usage among all women are also reflected in the findings for pregnant women (Figs. 9c and 9d). Similarly, the usage patterns among these demographics align with those of children (Fig. 9e), highlighting a broader issue of disparities in bed net access and utilization across different groups. Finally, Fig. 9f shows that the number of nets per household member by cluster increased from

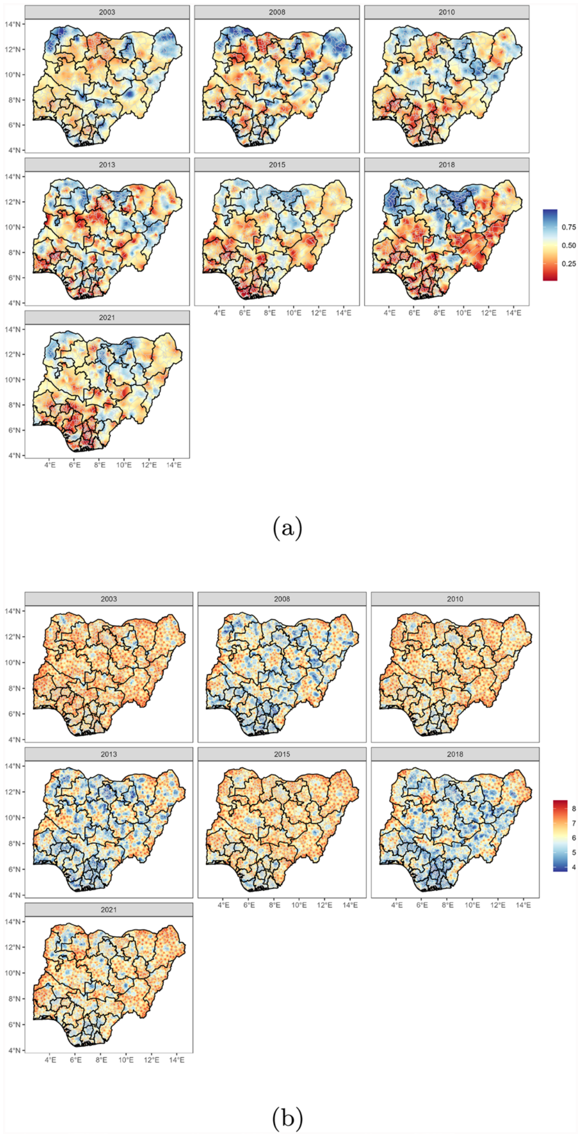

Fig. 5 Maps of Nigeria showing the (**a**) spatio-temporal dynamics of access to bed nets among pregnant women and (**b**) the width of the 95% credible intervals. (Estimates are derived from model in equation 1.)

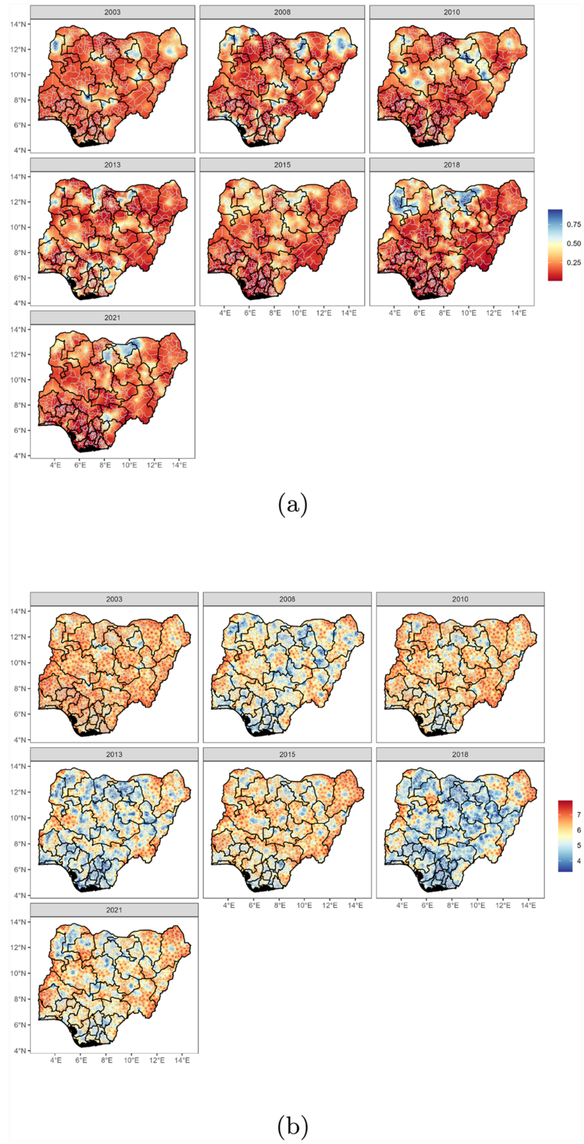

Fig. 6 Maps of Nigeria showing the (**a**) spatio-temporal dynamics of usage of bed nets among pregnant and (**b**) the width of the 95% credible intervals. (Estimates are derived from model in equation 1.)

2003 until 2010, after which it remained relatively stable through 2021.

Figure 10 examines the relationship between NPC and the proportion of bed nets used (NUC) among children under five across various clusters. A beta regression model was applied to predict the proportion of bed net usage based on NPC values, illustrating how changes in NPC influence usage rates. The scatter plot shows the observed data points for NPC and bed net usage, with the fitted curve representing the predicted probabilities of bed net usage.

Discussion

Malaria remains a pressing public health challenge in Nigeria, with a notable discrepancy between bed net access and actual usage among the vulnerable populations. This discrepancy raises concerns about whether households possess an adequate number of bed nets to protect their members effectively. The analysis reveals that ownership rates are alarmingly low and vary significantly across regions, with only a few states

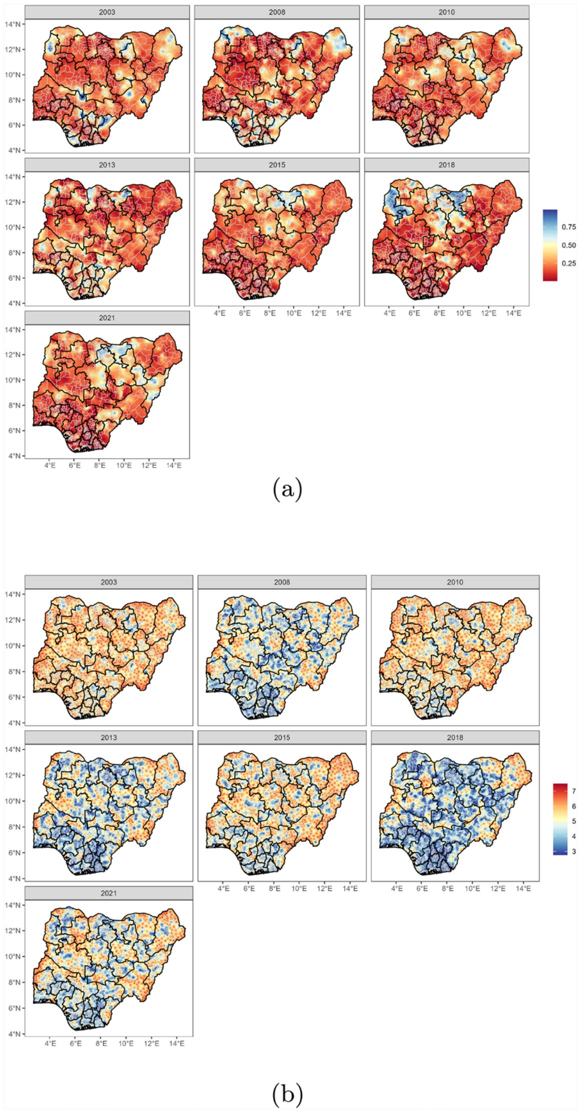

Fig. 7 Maps of Nigeria showing the (**a**) spatio-temporal dynamics of usage of bed nets among children under five years of age and (**b**) the width of the 95% credible intervals. (Estimates are derived from model in equation 1.)

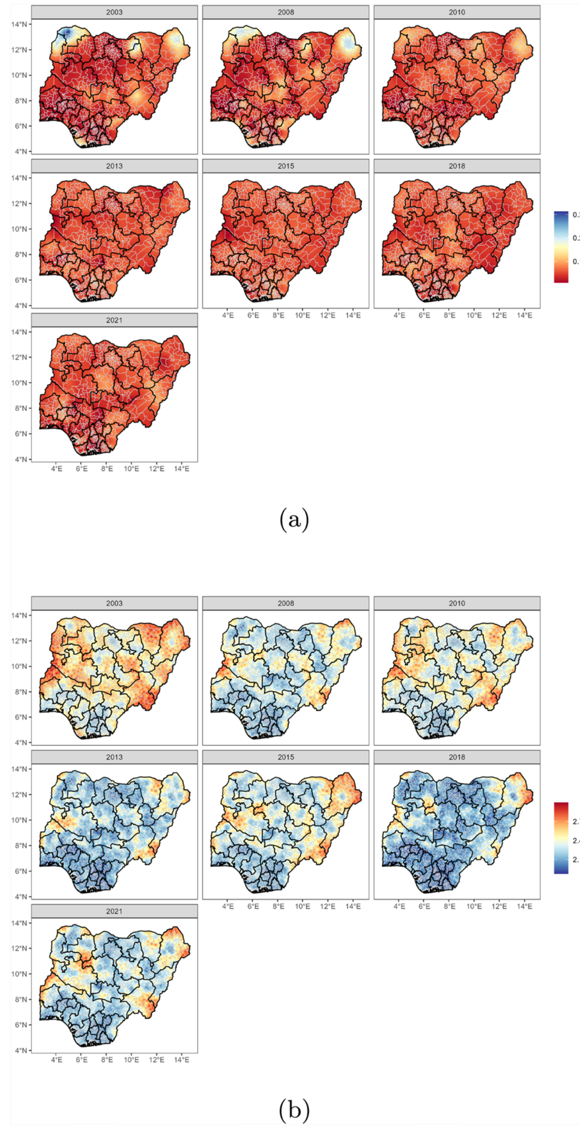

Fig. 8 Maps of Nigeria showing the (**a**) spatio-temporal dynamics of nets per household member by cluster and (**b**) the width of the 95% credible intervals. (Estimates are derived from model in equation 1.)

demonstrating improved access over time. This situation aligns with previous studies indicating inadequate ownership of insecticide-treated nets among Nigerian households [23, 36]. Furthermore, despite access, the overall utilization of bed nets remains disappointingly low, consistent with earlier findings [37–39]. The implications are particularly severe for children under five and pregnant women, who are at the highest risk for severe malaria complications. To ensure that each bed net meaningfully contributes to malaria prevention, it is critical to develop strategies that promote consistent usage and address the barriers that hinder effective application, particularly in relation to the number of bed nets available relative to household members.

The analysis reveals notable regional disparities in bed net usage, which have important implications for public health strategies. Northern states demonstrate higher utilization rates compared to southern states, likely due to the higher prevalence of malaria in these regions [40]. This heightened risk compels families to prioritize bed net usage, resulting in better protection for vulnerable groups. However, a study by [36] found that households in the North Central region had the lowest bed net

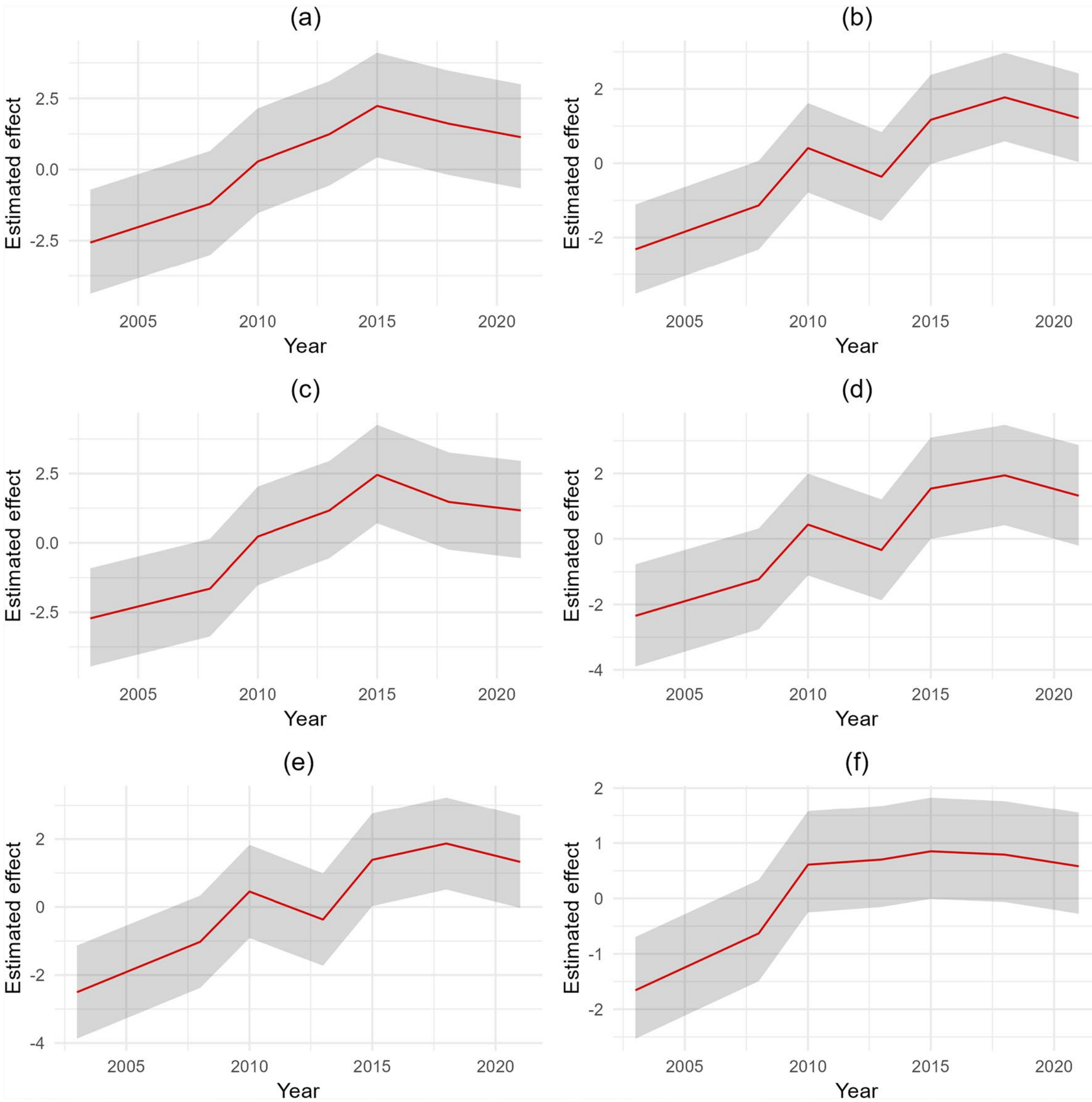

Fig. 9 Trends in bed net access and usage for women (**a**, **b**), pregnant women (**c**, **d**), children under 5 (**e**), and nets per household member by cluster (**f**) in Nigeria

ownership rate, and under five children in these households were the least likely to use bed nets, which aligns with the findings of this study. They attributed this to lower malaria parasitaemia rates in this region compared to other northern areas. Given the elevated malaria risk in the northern states, which already have higher bed net usage compared to the south, it remains crucial to scale up distribution and usage campaigns to address existing gaps. Expanding educational efforts and reinforcing consistent bed net use year-round could further reduce malaria transmission in these northern regions. In southern states, the low ownership and usage rates are particularly concerning, even though malaria prevalence is lower in these regions. The lack of consistent bed net use may foster complacency regarding malaria risk, potentially leaving populations unprepared if malaria incidence rises due to factors like climate change or increased mosquito populations.

Another issue highlighted by this study is the patterns of bed net usage among children under five and pregnant women. The patterns of bed net use among children under five years of age mirror those of pregnant women, indicating that both groups face similar challenges in access and utilization. Despite access, many mothers do not use bed nets consistently, often leaving their children unprotected. A study by [36] indicated that children

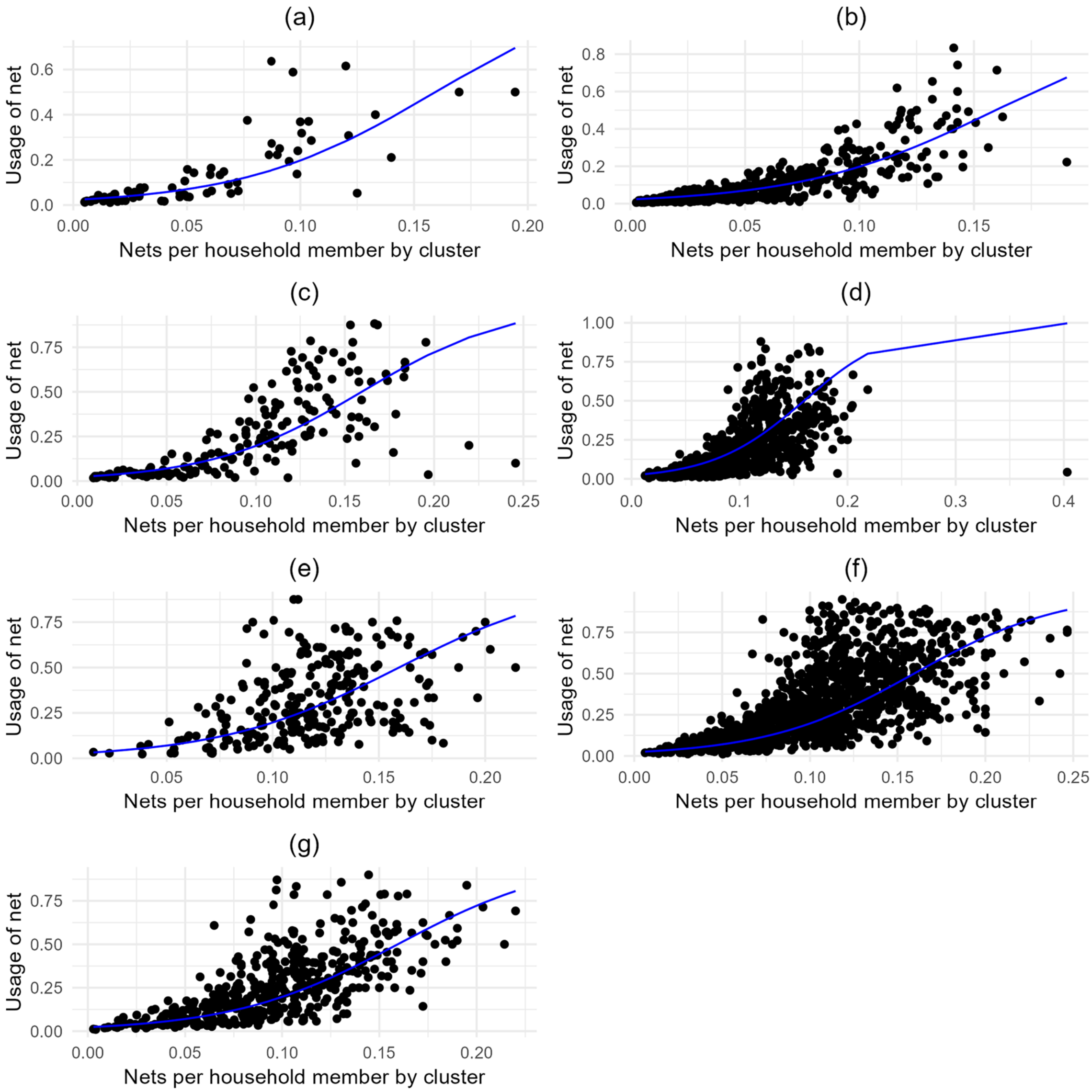

Fig. 10 Relationship between usage and nets per household member by cluster among children under five in Nigeria for the years 2003 (**a**), 2008 (**b**), 2010 (**c**), 2013 (**d**), 2015 (**e**), 2018 (**f**), and 2021 (**g**)

in households with two or more children under five, as well as those in households with multiple bed nets, were more likely to sleep under a bed net than those with only one child or one bed net. This underscores the necessity of tailoring bed net distribution to the specific needs and number of children in each household, rather than providing a fixed quantity. Simply providing access is insufficient; underlying barriers, such as lack of awareness and cultural beliefs, must also be addressed to ensure the effective use of these preventive tools.

Various factors hinder the full utilization of bed nets in Nigeria. Research by [41] emphasizes a strong interest in bed nets, yet misconceptions and insufficient awareness impede their effective use. While some individuals report using the nets, others reserve them for future grandchildren or repurpose them due to inadequate supply. In Anambra and Rivers states, fears of health issues like vomiting blood and skin irritation further contribute to low usage rates [25]. This attitude could be contagious, spreading to other neighbouring states in the south. Additionally, [25] identifies seven key themes influencing ITN usage: heat, low mosquito activity, phobia of chemicals, lack of space, difficulties in hanging nets, preference for alternative measures, and cultural beliefs. Educating households on the safety, proper usage, hanging techniques, and maintenance of bed nets is essential to enhance bed net utilization across all regions of Nigeria.

The limitations of the study include that the data on bed net ownership and usage are self-reported, which could be misrepresented. For example, respondents might provide a positive response on usage particularly for vulnerable populations for fear of reprimand. They could also report deny ownership with the hope that they would be identified and given priority in subsequent distributions. It is impossible to make causal inference from the study since the data came from cross-sectional survey.

Conclusion

The findings of this study highlight the urgent need for targeted public health interventions to address the disparities in the distribution and utilization of bed nets across various regions of Nigeria. To effectively combat malaria, it is crucial not only to increase access to bed nets but also to promote their consistent use. The disparities between northern and southern states emphasize the need for region-specific approaches that account for varying malaria risks. Expanding awareness and distribution campaigns in both high-risk northern states and lower-risk southern states will help ensure widespread and consistent use, ultimately reducing the malaria burden. Overcoming barriers to bed net use, such as misconceptions, cultural beliefs, and practical challenges, through focused educational outreach will be key to improving the effectiveness of these preventive measures.

Author contributions

Ezra Gayawan conceived the study. Ezra Gayawan and Faith Eshofonie implemented the methodology, performed the statistical analysis, and drafted the manuscript. Osafu Egbon contributed to model development and implementation. All authors reviewed and edited the manuscript, discussed the results, and approved the final version.

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Data availability

The datasets analyzed in the current study are publicly available from the Demographic and Health Surveys (DHS) and can be accessed online [42]. The code for reproducing the results are available at https://github.com/eosafu/InsecticideTreatNet.

Declarations

Ethics approval and consent to participate

This study was conducted under ethical guidelines. As this research relied on secondary data, consent from individual participants was not required. All data used were anonymized to protect participant privacy.

Consent for publication

Not applicable.

Competing interests

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