# Modelling Insecticide Treated Nets utilization among under-five children using Zero-Inflated Poisson Regression

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***Abstract* — Despite several evidence-based results on the relevance of Insecticide Treated Nets (ITNs) in the prevention of malaria, disparities between effective utilization and ownership among households is quite high. Among six geo-political zones in Nigeria, reports showed the lowest utilization of ITNs in the South-West region. This study assesses geo-spatial variations in utilization of ITNs among under-five children among six states of South-West Nigeria using the Zero Inflated Poisson model. Bayesian semi-parametric approach is used on data obtained from the 2018 Nigeria Demographic Health Survey. Fixed effect and non-linear effect are examined on the number of children that slept under ITN a night before the survey among under-five children in the region. Since the response variable is found to have many zeros (61.0%) of the total cases, the Zero-Inflated Poisson model is assumed. There is evidence of spatial variation in utilization among states in the region. Ondo state has the highest utilization while Lagos state has the least. The non-linear effect of an average age of children in each household on utilization showed a downward trend in utilization as the children approach 24 months. However, the trend started increasing till around 4 years when it began descending again. From the fixed effect model, wealth index, residence, and mother's level of education are found to affect utilization. To reduce cases of malaria among children under five, efforts should be geared towards educating caregivers on the importance of effective utilization especially in states with low usage.**

**Keywords -** *Zero-Inflated Poison Model, under-five children; spatial analysis; nonlinear effect; treated nets, South-West Nigeria.*

## I. INTRODUCTION

Efforts in combating the malaria scourge are yielding gradual results globally from around 251 million reported cases in 2010 and 231 million cases in 2017 to 228 million cases in 2018 [1]. India and 18 African countries recorded about 85% of 2018 cases with Nigeria alone having about 25% of the cases [1]. While other African countries like Uganda and Zimbabwe are reporting a continuous decline in reported cases, Nigeria had 3.2 million increase in 2018 when compared to 2017 [1]. The largest burden of malaria morbidity is recorded in Africa with 213 million cases in 2018 representing 93% of the world cases [1]. This is a minimal decrease from about 90% of the global burden reported in 2002 [2,3].

In Nigeria, malaria remains the number one cause of morbidity and mortality [4]. From about 85% of all global deaths due to malaria in 2018, Nigeria alone had 25% of the cases [1]. Among children under five, more than 60% of reported morbidity is due to malaria with about 300,000 reported mortality yearly [5]. From household surveys carried out in 21 malaria burden countries between 2015 and 2018, it was reported that overall anaemia was higher in children aged under five years who were positive for malaria than in those who were negative [1].

*Plasmodium falciparum* parasite accounts for 99.7% of reported cases of malaria in sub-Saharan African countries [1,6]. However, the resistance of the parasite to different malaria drugs is a major setback in combating the disease [7]. This is why WHO recommended a reduction in the chances of mosquito bites as the number one action in malaria prevention. This according to WHO can be achieved by sleeping under an Insecticide Treated Net (ITN) and Indoor Residual Spraying (IRS), [1]. Studies on the cost-effectiveness of both ITN and IRS revealed that ITN is easier to use [8] and more cost-efficient [9].

ITN has been reported to be one of the most important vector control interventions for mitigating against malaria (WHO, 2019) with results of its effectiveness in highly endemic areas [10,11]. With special

attention on the most vulnerable (pregnant women and children aged under five), WHO introduced the Roll Back Malaria (RBM) to encourage the utilization of ITN [12]. The RBM program has brought about an increase in awareness of different techniques (utilization of ITN, environmental sanitation, indoor residual spraying) in preventing malaria [13]. About 90% of 197 million globally manufactured ITNs in 2018 were delivered to countries in sub-Saharan Africa. 80% of these were distributed by mass distribution campaigns, 10% in antenatal care facilities, and 6% as part of immunization programs [1].

Results from household surveys carried out in sub-Saharan Africa revealed that over 70% of households had one or more ITN with about 57% of the population having access to an ITN, while only 40% of the studied population reside in households with sufficient ITNs for all occupants [1]. In spite of the relatively high reported percentage in ownership, [14,15,16] reported high disparities between ownership and utilization of ITN in different regions of Nigeria despite more than 40% prevalence of fever among children aged under-five in the country [1].

Reported cases of malaria have been reported to reduce by about 50% in places where ITNs are effectively utilized [10] but the lowest percentage of the population at risk sleeping under the net occurs in Nigeria [1]. The 2015 Nigeria Malaria Indicator Survey, a program implemented by the National Malaria Elimination Programme, the National Population Commission, and the National Bureau of Statistics reported the least ITNs ownership in South-West states [17]. With only 22% usage among children under the age of five and pregnant women, the region is also reported to have the least utilization in the country compared with North-West for example with 62% utilization [17].

Using data from the measure DHS 2018, this study focuses on the number of children under the age of five that slept under mosquito a night before the survey, this study assesses spatial variations, disparities, and other factors among states in the South-West region of Nigeria. With observed many non-utilization of ITN, the study uses the Zero Inflated Poisson (ZIP) model under a geo-additive model structure that allows joint modeling of spatial effects, non-linear effects, and fixed effects of covariates.

## II. METHODOLOGY

### A. Study Area

The research covers the South-Western part of Nigeria (*figures 1a and b*) consisting of six states of Osun, Oyo, Ogun, Lagos, Ondo, Ekiti. The zone is majorly agrarian except Lagos state which is the commercial nerve center in Nigeria.

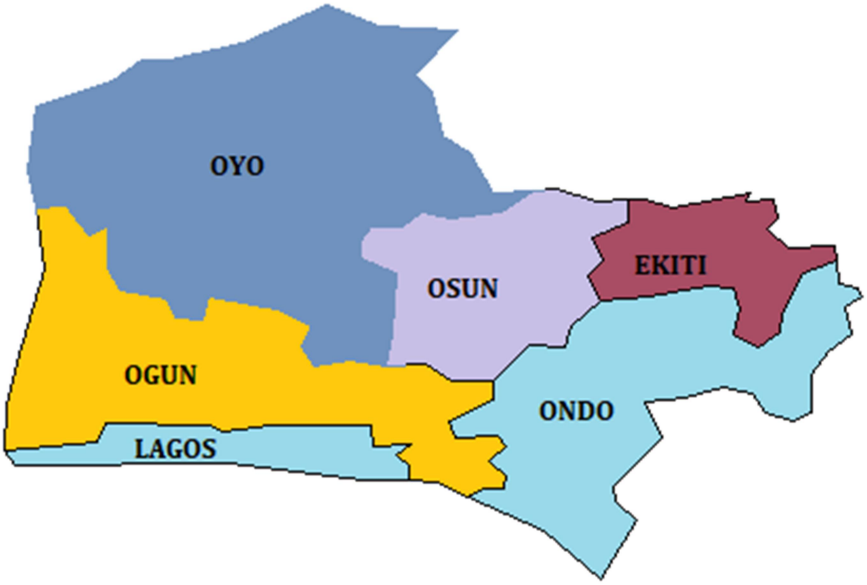


**Figure 1a:** South-Western states in Nigeria

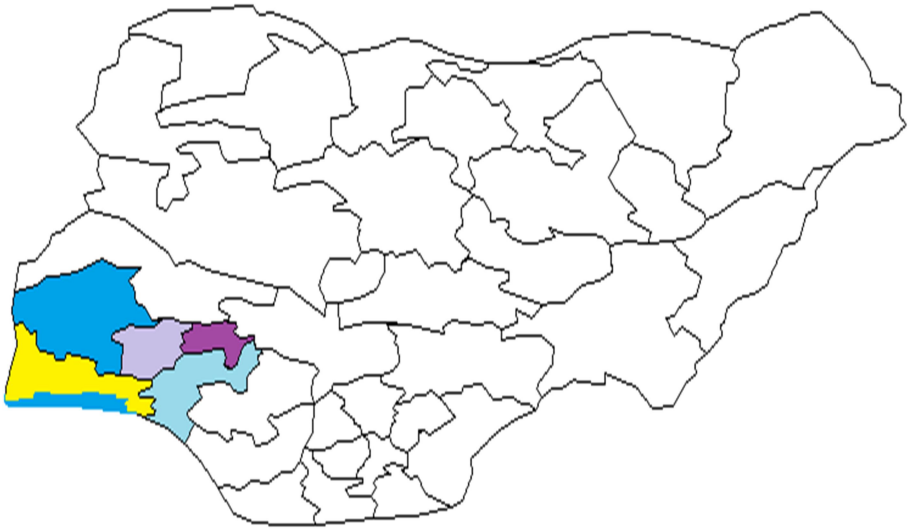

**Figure 1b:** Map of Nigeria showing States in South-West

**B. Data**

The study uses data from the Nigeria Demographic Health Surveys (NDHS) for 2018 obtained through the Measure DHS (https://dhsprogram.com). Data on different socio-economic and health indices are obtained once every five years from different countries by the DHS with the help of funding partners. From initial 188,010 households surveyed throughout the country in 2018, the study uses 1877 observations for states in the South-West of Nigeria after the piecewise deletion of missing values. Apart from the response variable (Number of children under mosquito bed net previous night), 9 other variables are examined (*Table 2*). The response variable is assumed to follow the Zero Inflated Poisson distribution. Table 1 and figure 2 present the distribution of the response variable, supporting the assumption of the ZIP model.

**Table 1:** Number of children under mosquito bed net previous night

| Observation | Frequency | Percent |
|---|---|---|
| 0 | 1145 | 61.0 |
| 1 | 417 | 22.2 |
| 2 | 285 | 15.2 |
| 3 | 26 | 1.4 |
| 4 | 4 | 0.2 |
| Total | 1877 | 100.0 |

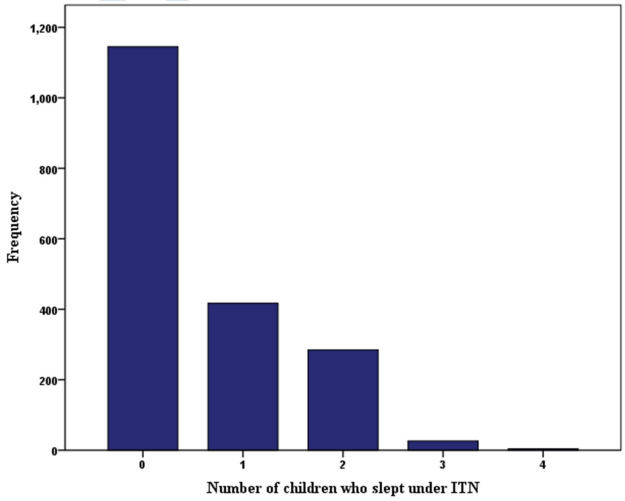


**Figure 2:** Bar chart showing the distribution of the response variable

**C. Zero-Inflated Poisson (ZIP) Model**

For modelling response variables with count data, the Poisson distribution has been used [18,19]. The Poisson distribution is known to have the same value for its mean and variance which is not usually applicable with real data. When the variance of a dataset is higher than the mean, there is an overdispersion, while it is underdispersion when the variance is lower. Assuming Poisson distribution for response variable with overdispersion causes biased estimations of the standard error [20-22]. Also, the effect of other important covariates may be lost if the wrong functional form is assumed for the data [23]. This was

observed in [24] using DMFT (Decayed, Missing and Filled Teeth) data. Since its proposition by [25] on defects in the factory process, the ZIP has been applied on several count data with excess zeros. [26] used the ZIP on domestic violence; [27] on insect-egg data; [28] on sea duck counting; and [29] on the prognosis of demographic factors associated with using crystal meth.

### D. Data Analysis

The study uses BayesX [30], a software for Bayesian Inference in Structured Additive Regression (STAR) models. Analysis is performed under the assumption that the response variable follows the Zero Inflated Poisson distribution. Second-order random walk prior with 3 spline degrees and 20 equidistant knots are used to examine the non-linear effect of the average age of children under-five in each household.

### E. Model

Different forms of covariates can be modelled in a semi-parametric regression using geo-additive predictors [31,32], hence,

$$\psi_{ij} = \mu + f(x_{ij}) + f_{nle} + f_{spat} \quad (1)$$

From equation (1), $f(x_{ij})$ represents various fixed effect variables, $f_{nle}$ represents the non-linear effect of the average age of the child in each household, and $f_{spatial}$ represents the spatial effect of states. The equation is expressed as:

$$\psi_{ij} = \mu + \delta_{residence} + \delta_{elect} + \delta_{fan} + \delta_{radio} + \delta_{tv} + \delta_{gender} + \delta_{wealth} + \delta_{education} + f_{age} + f_{state} \quad (2)$$

## III. Results

**Table 2:** Demographic details of respondents

| Variables | Freq. of children (%) | Mean no. of children (Variance) |
|---|---|---|
| Total | 1877 (100) | 0.580 (0.757) |
| State | | |
| *Lagos* | 368 (19.6) | 0.35 (0.501) |
| *Ogun* | 314 (16.7) | 0.71 (0.876) |
| *Ondo* | 233 (12.4) | 0.96 (0.645) |
| *Oyo* | 392 (20.9) | 0.61 (0.591) |
| *Osun* | 286 (15.2) | 0.52 (0.615) |
| *Ekiti* | 284 (15.1) | 0.41 (0.533) |
| Place of residence | | |
| *Urban* | 1299 (69.2) | 0.54 (0.643) |
| *Rural* | 578 (30.8) | 0.67 (0.676) |
| Gender | | |
| *Male* | 991 (52.8) | 0.58 (0.652) |
| *Female* | 886 (47.2) | 0.57 (0.663) |
| Has Electricity | | |
| *No* | 384 (20.5) | 0.66 (0.643) |
| *Yes* | 1493 (79.5) | 0.55 (0.659) |
| Has radio | | |
| *No* | 407 (21.7) | 0.60 (0.630) |
| *Yes* | 1470 (78.3) | 0.57 (0.665) |
| Has fan | | |
| *No* | 534 (28.4) | 0.62 (0.712) |
| *Yes* | 1343 (71.6) | 0.56 (0.634) |
| Has TV | | |
| *No* | 420 (22.4) | 0.61 (0.619) |
| *Yes* | 1457 (77.6) | 0.56 (0.668) |
| Wealth Index | | |
| *Poor* | 234 (12.5) | 0.63 (0.654) |
| *Middle* | 370 (19.7) | 0.61 (0.623) |
| *Rich* | 1273 (67.8) | 0.55 (0.667) |
| Mother's educational status | | |
| *No formal education* | 160 (9.4) | 0.53 (0.628) |
| *Primary* | 293 (17.2) | 0.62 (0.661) |
| *Secondary* | 937 (54.9) | 0.62 (0.695) |
| *Tertiary* | 317 (18.6) | 0.53 (0.611) |

**A. Descriptive Analysis**

It is observed from the demographic details of the surveyed households (table 2) that variances for the number of children who slept under the net are more than the means (an overdispersion). This also justifies the usage of the ZIP model which supports over-dispersed observations. On average, 58 children per 100 households slept undernet a night before the survey. The highest utilization is observed for Ondo state with an average of 96 children per 100 households while the Lagos state has the least with 35 children per 100 households.

The table also reveals that utilization is higher in the rural areas (67 per 100) than in urban areas (54 per 100). Utilization is also seen to be higher in households without electricity, radio, fan, and television. Households in the *Poor* Wealth category have the highest utilization while those in the *Rich* category have the least. Observations from the table are consistent since most being poor is characterized in the survey with lack of basic essentials like radio, television, and electricity.

The result of the fixed effects model is shown in table 3. Utilization is insignificantly lower in urban areas in comparison with rural areas. Also, ownership of electricity, fan, television, and radio among households are insignificant factors for the utilization of the net. Utilization is significantly higher among households where mothers has secondary education in comparison with those without no formal education.

**Table 3:** Results of the fixed effects model

| ***Variable*** | **Posterior Mean** | **Std. Dev.** | **97.5% Credible Intervals** |
|---|---|---|---|
| Constant | -0.3422 | 0.0667 | [-0.4750, -0.2161] |
| Place of Residence | | | |
| *Rural (ref. cat.)* | 0 | | |
| *Urban* | -0.0242 | 0.4203 | [-0.1074, 0.0585] |
| Has Electricity | | | |
| *No (ref. cat.)* | 0 | | |
| *Yes* | 0.0262 | 0.0557 | [-0.0840, 0.1356] |
| Has Fan | | | |
| *No (ref. cat.)* | 0 | | |
| *Yes* | 0.0159 | 0.0563 | [-0.0945, 0.1244] |
| Has Radio | | | |
| *No (ref. cat.)* | 0 | | |
| *Yes* | -0.0028 | 0.0439 | [-0.0876, 0.0844] |
| Has TV | | | |
| *No (ref. cat.)* | 0 | | |
| *Yes* | 0.0040 | 0.0580 | [-0.1095, 0.1186] |
| Gender | | | |
| *Female (ref. cat.)* | 0 | | |
| *Male* | 0.0205 | 0.0339 | [-0.0454, 0.0860] |
| Wealth Index | | | |
| *Poor (ref. cat.)* | 0 | | |
| *Middle* | 0.0322 | 0.0611 | [0.0865, 0.1490] |
| *Rich* | -0.0912 | 0.0937 | [-0.2744, 0.0950] |
| Mother's educational status | | | |
| *No education [ref. cat.]* | 0 | | |
| *Primary* | 0.0135 | 0.0727 | [-0.1293, 0.1549] |
| *Secondary* | 0.1084 | 0.0545 | [0.0024, 0.2144] |
| *Tertiary* | 0.0582 | 0.0807 | [-0.0994, 0.2186] |

The non-linear effect of age on nets utilization as shown in figure 3 reveals a sinusoidal shape. The average non-linear effect (blue line) reveals a persistent decrease in utilization till about 24 months (2 years) when it starts increasing till around 48 months (4 years). After 4 years of age, nets utilization starts reducing again among children. Both 80% (green line) and 95% (red line) credible intervals are also shown in the figure.

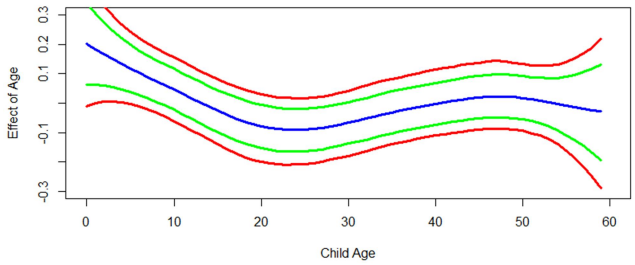


**Figure 3:** Non-linear effect of age of children

Figures 4 and 5 show the posterior mean and the 95% credible intervals of spatial effects for the model respectively. Ondo state has the highest net utilization while the least is observed in Lagos state. There is no significant difference in net utilization among the pairs of Ondo and Ogun states; Lagos and Ekiti states; and Oyo and Osun states (figure 5).

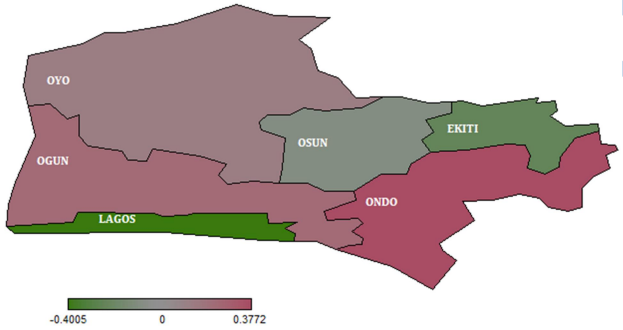


**Figure 4:** Posterior mean of spatial effects

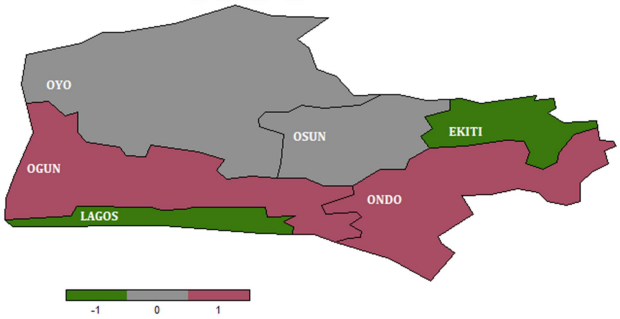


**Figure 5:** Spatial Effect for 95% Posterior Credible intervals

## IV. Discussion

***Residence***

For every 100 households surveyed in the rural areas, 67 children aged under five sleep under ITN while it is 54 for those from urban areas. This is also evident in the fixed effect model (table 3) where utilization in a rural area is found to be higher than what is obtainable in urban areas (although the disparities in utilization are not significant). Contrary to what was reported in research in some African countries [33,34], findings from this study support findings from [35,36]. This may be connected with the fact that most households in urban areas are equipped with facilities such as air-condition, window frames with nets, and serene environments that make the breeding of mosquitoes difficult, and hence the need to utilize ITN may not arise. Also, different programs on ITN utilization in Nigeria are focused on rural areas where most of these nets are mostly distributed freely.

***Gender***

As earlier reported by [35], there is no gender difference in ITN's utilization for children under five among the surveyed households although the fixed effect model shows higher but insignificant utilization for the male children. This is so expected as there is no basis for disparities in utilization between a male and female child.

***Socio-Economic Status Index***

Utilization is found to be lower in households without radio, fan, and television. All these are attributes of a typical rural set up in Nigeria and hence, this is expected since findings had shown low utilization among rural residents.

***Wealth Index***

The wealth index in the original data obtained from the measured DHS was categorized into five classes (Poorest, Poorer, Middle, Richer, and Richest), to ease the classification of results, the variable had been re-categorized in this study. Households that belongs to "*Poorest*" and "*Poorer*" categories are matched into "*Poor*" category while those that belong to "*Richest*" and "*Richer*" categories are matched into "*Rich*". Findings from the research show that utilization is highest in "*Poor*" households while it is least in "*Rich*" households. This result are corroborated by [35] unlike result obtained in a similar study in Tanzania [37] where poor households were reported to have lower utilization. Most residents in wealthy households can afford IRS, good environmental hygiene, among several other measures that can eradicate mosquitoes.

***Educational Status of Mother***

In this study, utilization is found to be lowest among mothers who have no formal education in comparison with those who are educated. The utilization of ITN for children has been reported to be affected by the educational status of mothers/caregivers [35,38]. With knowledge about the negative effects on the non-utilization of ITN, educated mothers are most likely to ensure their children sleep under ITN especially in mosquito-prone environments.

***Non-linear effect of age***

ITN's utilization is found to be decreasing as the children advance in age till they are about 2 years (24 months) when it picks up until they become 4 years (48 months) when it starts declining again. At a younger age, children usually sleep beside their mothers using their customized bed that comes with nets. Most mothers are also skeptical about using ITN with the notion that the chemical used in treating them may be harmful to children below 2 years. After two years of age, most children have developed some immunities and the need for customized baby beds may not arise, hence, the increase in utilization.

***Spatial Effect***

Among the six states of South-west Nigeria, utilization is highest in Ondo state while it is least in Lagos state. However, there is no significant difference in utilization between Ondo and Ogun states; Oyo and Osun states; and between Lagos and Ekiti states as shown in figure 5. Low utilization in Lagos state may not be unconnected with the fact that the state is the commercial nerve center in the country that has associated lifestyle with many residents ranked high in social status. Despite a high level of awareness of the benefits of ITN in the state, an earlier study [39] also reported low utilization. Affordability of other malaria control measures like IRS and hygiene environment may as well be the reason for low utilization in the state.

## V. CONCLUSION

With variously identified importance of effective utilization of the insecticide-treated nets and the accompanied disparities observed between ownership and utilization, efforts should be made to improve sensitization and education on proper usage of the net among mothers/caregivers for the children aged under-five. This will speed up global efforts towards malaria reduction. Government and supporting agencies should also scale up the provision and distribution of ITN especially among the vulnerable groups. Findings from the study revealed low utilization among the households in the "*Rich*" category of wealth index, therefore, innovative ideas in producing cheaper Indoor Residual Spraying (IRS) should also be among scientists. This will encourage more preventive actions against malaria especially among the rich who majorly reside in urban centers. Where practicable, donor agencies and various governmental and non-governmental organizations involved in the war against malaria should also venture into the mass distribution of the IRS as being done for ITN.

**Acknowledgments:** The authors acknowledge measure DHS for giving access to the data and TETFund (IBR) for financial assistance.

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