UPTAKE, UTILISATION AND SPATIAL DISTRIBUTION OF INSECTICIDE TREATED MOSQUITO NETS AMONGST PREGNANT WOMEN IN ZIMBABWE IN 2015

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Declaration

I hereby declare that except where specific reference is made to the work of others, the contents of this dissertation are original and have not been submitted in whole or in part for consideration for any other degree or qualification in this, or any other University. This research report is the result of my own work and includes nothing which is the outcome of work done in collaboration, except where specifically indicated in the text.

Chipo Mudzingwa

06 October 2021

Dedication

I dedicate this thesis to my loving and supporting husband, Blessing. You inspire me.

Abstract

Background

Despite proven efficacious interventions to prevent malaria, over 90% of malaria cases still occur in sub-Saharan Africa. In 2016, Zimbabwe reported more than 300 000 cases with a death toll of 3 200. Malaria in pregnancy is a significant cause of both maternal and child morbidity and mortality. The World Health Organization recommends full insecticide mosquito net coverage to decrease the incidence of malaria. The aim of this study is to determine the uptake, utilisation, spatial distribution of insecticide treated nets (ITNs) and determine the predictors associated with ITN uptake and utilisation amongst Zimbabwean women of childbearing age in 2015. Uptake is the ownership of an ITN or living in a household with at least one ITN. Utilisation was when the respondent slept under an ITN the night before the interview.

Methods

We carried out secondary data analysis on cross-sectional data from the 2015 Zimbabwe Demographic Health Survey. There were 611 pregnant women who were matched with 1 833 non-pregnant women using propensity score matching, to make a total of 2 444 study participants. There were two outcomes, uptake and utilisation. Survey adjusted proportions were used to determine ITN uptake and utilisation rates. Survey adjusted t-test and Pearson's Chi Squared test were carried out to determine baseline characteristics against the two outcomes. Exploratory spatial analysis which included mapping the ITN uptake and utilisation prevalences and hotspot analysis were carried out. Multi-level logistic models with non-random and spatial random effects were produced using variables significant in the bivariate analysis for both outcomes. Conditional autoregressive (CAR) models were fitted with

individual level data and simultaneous regressive (SAR) models were fitted with ecological data at district level and maps were produced to determine the predictors of ITN uptake and use after adjusting for spatial random effects. An intrinsic Bayesian multivariate CAR model for mapping multiple outcomes was fit to determine the correlation between uptake and utilisation of ITNs.

Results

Out of 2 444, 1 136 participants (45.66%) reported uptake and 245 participants (8.13%) reported to have slept under an ITN the night before. Results from the multi-level logistic models showed that for every year increase in age, the odds of ITN uptake increased by 0.02 (95% CI 1.01; 1.04 p-value 0.03). When compared to respondents who made decisions about their own health, those whose partners made decisions on their behalf had an adjusted odds ratio of 0.59 of ITN uptake (95% CI 0.40; 0.88 p-value 0.009). With Harare as the reference, living in Mashonaland West and in Matabeleland North increased the odds of ITN uptake and utilisation of ITNs. The adjusted odds ratios of ITN uptake for Mashonaland West and Matabeleland North were 10.04 and 12.27 respectively (95% CIs 5.60; 18.03 and 6.93; 21.72 respectively). Both outcomes displayed significant spatial autocorrelation. Using individual level data, after adjusting for spatial random effects, age and person has final say on respondent’s health remained significant predictors of ITN uptake, with age only being a predictor of ITN utilisation. The SAR model also showed that districts with higher employment levels had lower rates of ITN uptake. Spatial analysis using the intrinsic Bayesian CAR model showed that there was a positive correlation of 0.96 (95% BCI 0.80; 0.99) between uptake and utilisation of ITNs.

Conclusion

The ITN uptake and utilisation rates were suboptimal. Even though the spatial distribution of ITN uptake and use showed some relationship with the spatial heterogeneity of malaria transmission, there were still low levels of both ownership and use in malaria-endemic areas. We showed that women who have health autonomy and older women were more likely to own and use ITNs. There is a need to upscale ITN distribution and education campaigns in all parts of Zimbabwe to make sure that women from all age-groups and backgrounds are reached by these. Policies that empower women also have the potential to increase uptake of this efficacious intervention as well as increase uptake of other health interventions.

Key words: Malaria in pregnancy, ITN uptake/ownership, ITN utilisation/use

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List of Abbreviations

AIC- Akaike Information Criteria

ANC- Antenatal Care

BCI- Bayesian Credible Interval

CAR- Conditional Autoregressive

CI- Confidence Interval

EA- Enumeration Area

GIS- Geographical Information Systems

HIV- Human Immunodeficiency Virus

ITN- Insecticide Treated mosquito Net

LLIN- Long lasting insecticide net

NMCP- National Malaria Control Program

SAR- Simultaneous Autoregressive

WHO- World Health Organization

ZHDS- Zimbabwe Health and Demographic Survey

Nomenclature

Uptake- Ownership of an insecticide treated mosquito net or living in a household with at least one insecticide treated mosquito net.

Utilisation- Respondent slept under an insecticide treated mosquito net the night before the interview.

Chapter 1 Introduction

Chapter one considers the background of the study, the current literature, the statement of the problem, the rationale, the reason for the research and its associated objectives and justification. In the background we describe the epidemiology of malaria in pregnancy, as well as its effects on pregnancy. The literature explores contrasting views on the use of insecticide treated mosquito nets (ITNs) in malaria prevention across sub-Saharan Africa, further looking at studies that explored predictors of uptake and use of ITNs amongst women of childbearing age. The study aimed to explore ITN uptake, utilisation and spatial distribution amongst women of childbearing age in Zimbabwe. Understanding factors that can affect ITN use are important, given that malaria in pregnancy is a global health problem.

1.1 Background

The burden of malaria is experienced globally, in Africa and in Zimbabwe and directly affects maternal mortality. Tropical and sub-tropical regions of the world continue to be burdened by malaria, despite the scale-up of life-saving malaria control measures (1). Based on the 2019 World Health Organization (WHO) report, there was an estimate of over 200 million cases of malaria worldwide. Over 93% of these cases occurred in Africa (2). More than 400 000 people died from malaria in 2018 (2). In Zimbabwe, over 300 000 malaria cases were reported in 2016 with an estimated death toll of 3 200 people, accounting for about 40% of all hospital admissions (3,4). Importantly, malaria remains a significant cause of maternal mortality. In a study by Mbizvo et al., it was reported that malaria was a leading direct cause of maternal mortality in the rural setting of Zimbabwe(5).

Likelihood and susceptibility of acquiring malaria and the severity of malaria increase with pregnancy, especially in the first and second trimesters (6). When compared to non-pregnant women, pregnant women are 2.3 times more likely to acquire malaria (95% CI 2.01; 4.5) with a mortality rate of about 50% (7,8). Pregnant women are more susceptible to a more severe form of the disease due to the immunocompromised state of pregnancy and also due to the potential sequestration of malaria parasites into the placenta (7). Severity of disease differs with regional rates of malaria transmission. Adults usually develop some level of immunity in malaria-endemic regions, but disease with insidious onset can still occur, causing maternal anaemia and low birthweight (9). Women who live in low transmission areas are at a higher risk of more severe complications such as miscarriages, preterm birth and maternal mortality (9).

The burden of malaria in women and in infants cannot be over-stated. In sub-Saharan Africa, malaria attributes 15% of maternal anaemia, about 30% of preventable low birth weight in new-borns, 8% of infant mortality and approximately a third of preterm births are due to malaria (10). In addition to the high morbidity and mortality amongst women, malaria adds economic burden especially in impoverished countries in the sub-Saharan region. Adequate management of malaria costs the health care system significantly. (6).

WHO proposed a three-prong approach to combat malaria in pregnancy (11). The three-pronged approach comprises of intermittent preventive chemotherapy in pregnancy, universal coverage by ITNs and prompt and effective case management (11). Considering a large number of women from malaria-endemic areas become pregnant every year (11 million became pregnant in 2018), it is imperative we understand the extent of coverage of these interventions.

In this report, we are going to be looking at the second prong, specifically looking at the uptake and utilisation of ITNs amongst women of childbearing age.

1.2 Literature Review

1.2.1 Insecticide treated mosquito nets in malaria prevention

Mosquito nets have played a crucial role in malaria prevention for the past thirty years, with a history nearly as long as modern civilisation (12). The earliest records of net use are recorded in ancient Egypt (13). ITNs include both long-lasting insecticide nets (LLINs) and regular bed nets treated with chemicals that are lethal to mosquitoes. ITNs work through a series of mechanisms. Firstly, if an ITN is intact, large enough to cover the bed and used correctly, it can prevent almost 100% of mosquito bites (12). The second mechanism is through toxicity of the insecticide, where mosquitoes are killed when they make contact with the treated net or with vapours from the ITN (12). The chemical on ITNs additionally repels mosquitoes from entering the house and diverges the mosquitoes post-entry by inducing chemical irritation (12). There is a delayed effect as well, when mosquitoes are exposed to sub-lethal doses from the ITN but die after leaving the house(14). Lastly, if used at a large scale, ITNs may have community level effects that result from mass killing of mosquitoes, that may benefit non-users of ITNs (15). A review of several efficacy studies concluded strong evidence that ITNs reduce the incidence of malaria cases and reduce malaria related mortality and morbidity (16).

As part of a campaign to increase uptake of ITNs, the WHO recommends supplying ITNs free of charge or with subsidy, periodic mass campaigns and routine delivery channels such as antenatal and immunization services to deliver ITNs to vulnerable populations(11). Zimbabwe has adopted this as part of its national malaria control strategy with malaria prevention activities implemented as part of integrated maternal services (17).

1.2.2 Uptake and utilisation rates of ITNs amongst women of childbearing age

Studies done across Sub-Saharan Africa show that uptake of insecticide treated mosquito nets varies greatly, with uptake ranging from as low as 3% to as high as 96% (18,19). A systematic review published in 2013, showed that net ownership in households with pregnant women ranged between 3 and 44%, with Zimbabwe being amongst one of the countries with a low uptake and net use of 6% (20). Commonly noted, are the great discrepancies between uptake and utilisation. For example, an Ethiopian study by Oedraogo et al., done in Jimma zone, with moderate to high prevalence of malaria, revealed a pooled ITN uptake of about 48% amongst women of childbearing age, with only half of this proportion using the ITNs (21). Similarly, a rural community in South Nigeria was reported to have an ITN uptake of about 11.1% and only 78% of these women reporting use of ITNs (22).

1.2.3 Predictors of ITN uptake and utilisation amongst women of childbearing age

Uptake and utilisation of ITNs, like most medical interventions depend on both socio-demographic and institutional factors. Early antenatal booking has been seen to be an important predictor of ITN uptake and utilisation in several studies (23,24). Protas et al. concluded that institutional factors that affected timely uptake of ITNs included availability of ITNs at healthcare facilities and access to a discount voucher to purchase a mosquito net (24). They reported an uptake of 96%, and uptake failure was mainly associated with accessibility, with some of the women citing lack of top up money as a reason for not owning a net (24). Of course, this high uptake was most likely attributable to the fact that the study was done along the lake zone where malaria prevalence is high. Stock-outs at health facilities are also a commonly reported factor preventing optimal uptake of ITNs (19).

Socio-economic status appeared to be an important socio-demographic determinant of ITN uptake and utilisation. Most studies revealed that those who belonged to a higher wealth quantile were more likely to own and use an ITN. (23,25). This is most likely explained by better access to health care facilities and antenatal services amongst those from higher socio-economic classes.

In most studies, age was a predictor of ITN uptake and use, with higher ownership rates amongst older women.(23–25). The association between age and uptake of ITNs was also seen with increasing parity, where older women with more children had been exposed to more antenatal care (ANC) clinic visits and other mass campaign programmes and were more likely to own an ITN (26). Higher education levels have been associated with higher odds of net uptake and utilisation (25,27).

Some studies showed an association between both outcomes with religion. In a Kenyan study, Muslim pregnant women were more likely to use ITNs when compared to Christian women (25). Other sociodemographic characteristics associated with ownership and use of net were malaria knowledge, type of residence, health decision autonomy, media exposure and employment status (20,21).

1.2.4 GIS in malaria studies and spatial distribution of malaria and ITNs

Geographic information systems (GIS) is the science and technology that is used to study geographic relationships across space and integrate it with different types of information (28). Spatial studies have paved way for researchers to interlink population health with environmental data. GIS allows us to evaluate health-related factors and their link to surrounding risk factors at different geological scales in order to influence policy (29).

GIS assists us in organizing layers of information which is then visualized on maps and deals with the problem of spatial autocorrelation (30). Spatial autocorrelation is a recurring phenomenon in ecological data. Simply put, this means observed results from neighbouring places are usually similar than would be anticipated from random effects (31). Spatial autocorrelation may therefore affect coefficients of a regression model and influence a statistical model and this is solved by adopting spatial analysis (32).

Studies have shown that malaria transmission exhibits spatial heterogeneity, with malaria transmission clusters being influenced by temperature, rainfall and other environmental factors (33). Seven out ten of the provinces in Zimbabwe are considered to be malaria-endemic zones. Manicaland, Mashonaland East, and Mashonaland Central are the provinces with the highest malaria burden and the highest number of deaths (17). Figure 1.1 is a map illustrating the high-risk areas in Zimbabwe in different seasons.

Despite the fact that uptake and use of ITNs displays spatial autocorrelation, with uptake and utilisation of ITNs higher in malaria-endemic regions (23,25,34,35), spatial studies have also shown that there are still large populations living in high-risk areas but with low ITN use (36). Spatial studies on malaria in Zimbabwe include a study by Gwitira et al. where the authors reported spatial overlaps between HIV and malaria in five northern and eastern districts in Zimbabwe(37). However scanty work has been done to establish the spatial distribution of ITN uptake and utilisation amongst women of childbearing age in Zimbabwe.

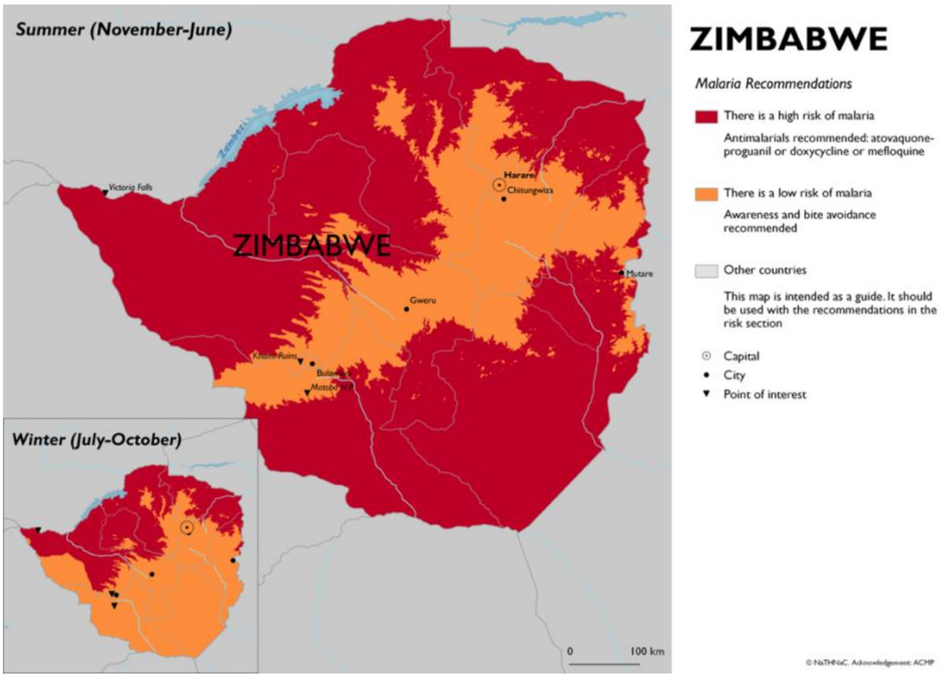

Figure 1.1: Map of Zimbabwe showing prevalence of malaria by region season.
(Map sourced at https://line.17qq.com/articles/kfmhnsky_p2.html)

1.3 Problem Statement

Half of the Zimbabwean population lives in malaria-endemic areas, and malaria in pregnancy continues to cause morbidity and mortality in mothers and neonates despite efficacious and cost-effective preventive interventions (38). Coverage of efficacious preventive interventions, including ITNs, remains low as it is currently estimated at 48% (39). The 2015 Zimbabwe Demographic and Health Survey(ZDHS) showed that only 6% of pregnant women slept under an ITN, falling from 25% in 2010 (39). Poor utilisation of ITNs amongst all women of childbearing age will eventually translate to an increased number of cases with a soaring of adverse pregnancy outcomes. However, there is limited information on the factors associated with uptake and utilisation of ITNs amongst women of childbearing age in Zimbabwe. Additionally, not much work has been done to understand the spatial distribution of ITN uptake and utilisation in this vulnerable population.

1.4 Justification

Insecticide-treated mosquito nets are a cheap intervention in the fight against malaria. When used consistently and properly, ITNs can reduce malaria cases by about 40% (16). The National Malaria Control Program(NMCP) in Zimbabwe aimed to reduce the incidence of malaria and reduce deaths from malaria by 90% by 2020 (17). Some of the strategies employed to achieve this goal include distribution of ITNs at ANC clinics, schools and mass distribution through campaigns (17). Given that perpetual use of ITNs is one of the effective interventions to reduce the risk of malaria, limited work has been done in Zimbabwe in this regard. There is a need to understand the spatial distribution and the uptake and, utilisation of ITNs; and determine how consistent women of childbearing are in using the ITNs. Also, to our knowledge, there is scanty literature on the relationship between the ownership and use of ITNs. The study findings will help to come up with possible interventions or policies which may improve and strengthen the use of ITNs to reduce malaria-related adverse outcomes among pregnant women subsequently.

1.5 Research Question

What are the uptake, utilisation, spatial distribution and the predictors of ITN uptake and utilisation amongst women of childbearing age aged 15-49 years in Zimbabwe based on the 2015 ZDHS?

1.6 Research Aim

The aim of this study is to determine the uptake, utilisation, spatial distribution of ITNs and determine the predictors of ITN uptake and utilisation amongst Zimbabwean women of childbearing age aged 15-49 years in 2015.

1.7 Research Objectives

1. To describe the uptake, utilisation and spatial distribution of ITNs amongst women of childbearing age aged 15-49 years in Zimbabwe in 2015.
2. To determine the predictors of uptake and utilisation of ITNs amongst women of childbearing age aged 15-49 years in Zimbabwe in 2015.
3. To determine the predictors of uptake and utilisation of ITNs amongst women of childbearing age aged 15-49 years in Zimbabwe in 2015, adjusting for spatial random effects.
4. To determine the combined effect of the relationship between ITN uptake and utilisation amongst women of childbearing age aged 15-49 years in Zimbabwe in 2015.

Chapter 2 Methodology

This chapter describes the approaches used to determine the uptake, utilisation and spatial distribution of ITNs amongst women of childbearing age in Zimbabwe. This study was a secondary data analysis. In this chapter, we first describe the primary study methodology then we describe secondary study methodology. Here we describe the study setting, data source, data management processes, statistical analysis carried out and all ethical considerations.

2.1 Primary Study methodology

2.1.1 Data source

The data were obtained from the 2015 Zimbabwe Demographic Health Survey (ZDHS). Data are available upon justified request on Measure DHS website. The ZDHS is a nationally representative survey, whose main aim is to provide up to date basic demographic and health indicators to aid in making policy, conducting research and program planning (40).

2.1.2 Primary study setting

The ZDHS was conducted in Zimbabwe, which is located in the Southern region of Africa. Zimbabwe has a temperate climate and is a landlocked country in sub-Saharan Africa bordered by South Africa, Botswana, Zambia and Mozambique. The study sites were all the sampled clusters from the sampled Enumeration Areas (EAs) from all 10 provinces in Zimbabwe. Malaria transmission varies with regions ranging from annual transmission in lowland areas to seasonal transmission in highland areas. Zimbabwe has 10 provinces which are further sub-divided into 60 districts. The map of Zimbabwe is shown in figure 2.1. Surveys were conducted in both rural and urban areas.

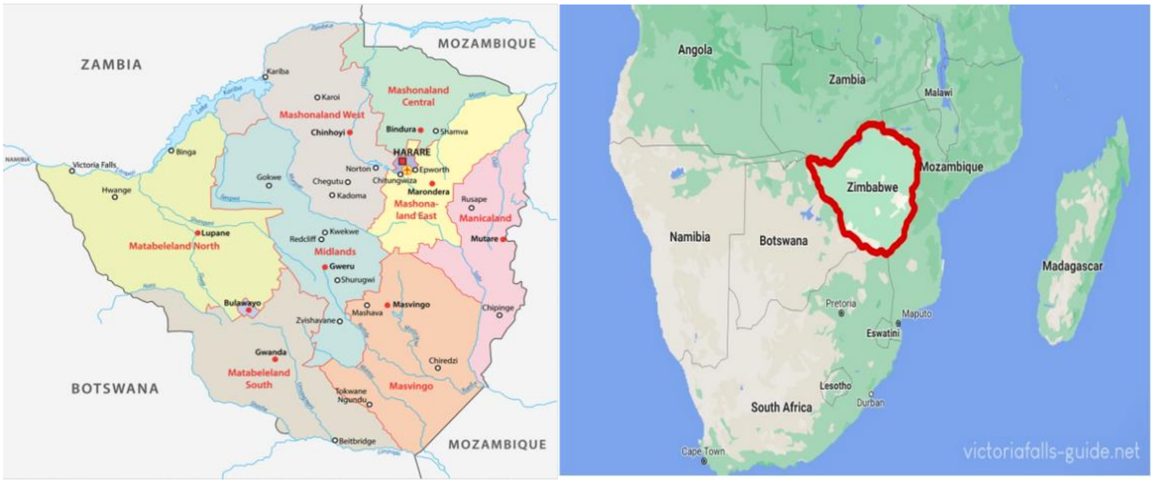

Figure 2.1: Map of Zimbabwe

2.1.3 Primary Study Design and Sampling Method

The ZDHS was a cross-sectional survey done in 2015 conducted between July and December 2015 (40). For the 2015 ZHDS, the 2012 Zimbabwe Population census was used as a sampling frame where wards from all ten provinces were divided into enumeration areas (40). A stratified two-stage cluster sampling procedure was used to choose households. Weighting was performed to adjust for variations in sampling clusters (40).

2.1.4 Primary Data Collection tool

Data were collected with the aid of pre-prescribed questionnaires loaded on electronic tablets. The questionnaires were in English and translated to both Shona and Ndebele. The household questionnaire included questions to determine ITN ownership, utilisation and information on socio-demographic characteristics of each household while the individual women's survey contained individual socio-demographic characteristics (40).

2.1.5 Data storage and archiving

Data that were collected onto interviewer's tablet were transferred to the supervisor's computer after which he/she sent it to the central data processing office. The data were checked for inconsistencies and outliers, which were reported back to the interviewing team who corrected and re-sent to the central office (40). The data are provided in a format compatible with Stata. The dataset is available at https://dhsprogram.com/data/dataset_admin on request.

2.2 Secondary Analysis Methods

2.2.1 Study design and target population

Secondary data analysis was carried out on cross-sectional survey data. The study included all women of child-bearing age who lived in Zimbabwe in 2015 aged 15-49 years. All pregnant women were included in the study together with non-pregnant women who matched certain characteristics of those pregnant women. Non-pregnant women whose propensity scores did not match those who were pregnant were excluded from the study.

2.2.2 Power Computation

To compute the statistical power of the study, the clustersampsi ado file in Stata was used to cater for the clustering sampling in the data (41). The formula is represented in equation 2.1

$$Z_{\beta} = \sqrt{\frac{k-1}{(p_a-p_0)(Bcv_{sizes}+1)\rho}} - Z_{\propto/2}$$ Where power = 1- $\boldsymbol{\beta}$. Equation 2.1: Power computation

A previous net uptake prevalence of 30% (p_o) was calculated from the 2010 demographic health survey, and the current uptake prevalence from the dataset was calculated to be 46% (p_a) in line with objective 1. The intra-cluster correlation was 0.0473 (ρ), from a total of 399 clusters (k), with an average cluster size of 6 (m) and a coefficient of variation of cluster size of 1.19 (Bcv_{sizes}). The power was calculated to be at least 90% at 0.05 significance.

2.2.3 Study Participants

In 2015, a total of 11 196 households were selected for the Demographic health survey (40). Out of this number, 10 657 were occupied and 10 534 households were successfully interviewed. In households that were successfully interviewed 9 995 women were interviewed and only 638 were pregnant at the time of the survey. Of these 638 pregnant women, 27 did not have one of the outcome variables and were excluded from the analysis, leaving 611 pregnant women. Using propensity score matching of ratio 1:3, these 611 pregnant women were matched with 1 833 non-pregnant women so that the total number of study participants was 2 444. This is illustrated in the flow diagram below in figure 2.2.

Figure 2.2: Flow diagram of study participant selection

2.2.4 Data Management & Analysis

2.2.4.1 Data Management

The dataset was obtained from measure DHS (available at https://dhsprogram.com/) in a version compatible with Stata version 16 (42), which is also compatible with R(43). Data from the household survey and the individual women's survey were downloaded from the DHS website. The two datasets were combined to obtain a final dataset with all the desired variables. Further management was done to drop unnecessary variables and observations. Observations with missing outcome variables were deleted. New variables were generated from existing variables to simplify analysis. To account for the complex multi-level weighted nature of the data, the data was survey set.

2.2.4.2 Potential sources of bias and efforts to address them

Potentially, the study was subject to information or recall bias because most of the variables were self-reported. This kind of bias can only be addressed at design stage and could not be addressed at analysis stage. In our study, the study population was made of women of childbearing age, both pregnant and non-pregnant. Pregnancy has been reported to influence the use of insecticide mosquito nets (44). Differences in characteristics would therefore exist between pregnant and non-pregnant women, potentially introducing selection bias in this study. We attempted to address this potential source of bias by using propensity score matching so that characteristics of both populations would be comparable.

2.2.5 Measurement of variables

The data source for all the variables was measure DHS and were derived from responses from questions asked in the questionnaire. The questionnaire can be viewed at https://dhsprogram.com/pubs/pdf/DHSQ7/DHS7_Household_QRE_EN_16Mar2017_DHSQ7.pdf. The 2 outcome variables were uptake and utilisation of ITNs. Explanatory variables included age of participant, age of household head, sex of household head, marital status, province of residence, person with final say on respondent's health, household size, parity, employment status, education level and wealth index. Further details of measurement of these variables are shown in table 4.1 and 4.2 in appendix B1 .

2.2.6 Statistical Analysis

Methods used in analysis include bivariate analysis with survey design adjusted Student's t-test and Pearson's Chi squared test, unadjusted univariate and adjusted multi-level logistic regression models which helped to adjust for potential confounders. Before bivariate analysis was conducted, assumptions for both the Student's t-test and Pearson's Chi squared test were checked. Continuous data was checked for normality as well as checking for homogeneity of variances before applying the t-test. For Pearson's chi squared test, tabulations were done to assess expected cell counts and if less than 5 in more than 20 % of the cells, the Fisher's Exact test was done instead. Data were first analysed at an individual level (non-random effects, random effects and CAR models) then analysed at ecological level using SAR and Bayesian models. All analyses were done after the data were survey set, to take into account sampling techniques. As part of sensitivity analysis, different models were fitted and compared. Models fitted in Stata were also fitted in R to check the robustness of all estimates made. If observations were missing one of the outcome variables, they were deleted and excluded from the analysis. There were 27 observations that were deleted as they did not have the utilisation variable. The command codebook was used to check for missing data in the explanatory variables, so as to later assess their influence on the outcome variables. There were no missing data from any of the observations. Figure 2.3 illustrates the analysis plan in relation to each objective. Further description of these methods is found in subsequent sections of this chapter.

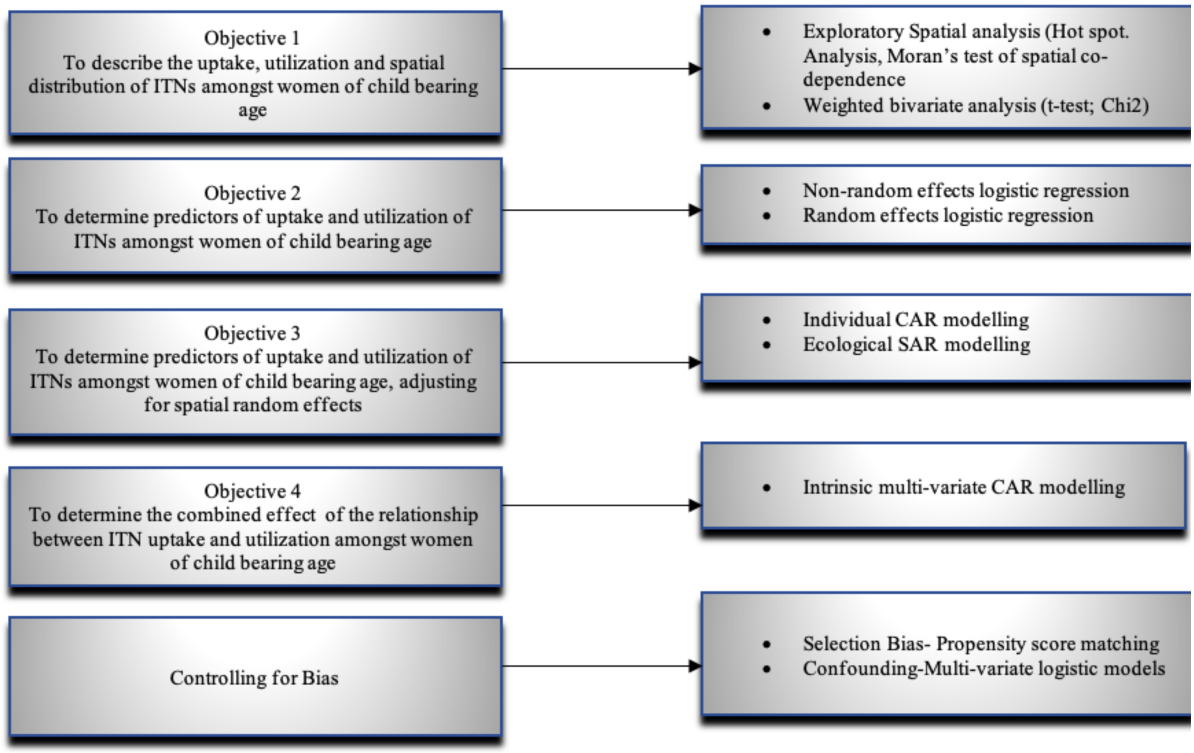

Figure 2.3: Statistical Analysis Plan

2.2.6.1 Propensity score matching

Preliminary analysis showed that there were imbalances with some of the explanatory variables between women who were pregnant and women who were not pregnant, potentially introducing selection bias. To address this, propensity score matching (PSM) was used. A variable which showed imbalance was used to run a logistic model with pregnancy as the outcome, after which propensity scores were generated and used to match the two groups of participants. The matching variable in the logistic regression model was number of children under five in the household. Bivariate analysis was conducted on a few variables before and after matching to evaluate if matching was successful. Propensity score graphs and kernel density graphs were also used to evaluate matching. Stata syntax used can be viewed in appendix B2.

2.2.6.2 Analysis for Objective 1: To describe the uptake, utilisation and spatial distribution of ITNs amongst women of childbearing age aged 15-49 years in Zimbabwe in 2015.

The uptake was calculated as number of women who owned an ITN divided by the total number of women in the study. The utilisation was also calculated as a proportion of women who slept under an ITN the previous night out of the entire study population. Additionally, we calculated the percentage of the women who slept under an ITN the previous night out of the total number of women in the study who owned an ITN. Both these proportions were survey weighted. Categorical variables were grouped into frequency and contingency tables after which Pearson's Chi Squared test was used to assess the presence of association with both uptake and utilisation of ITNs. For continuous variables, the t-test was used to assess differences in means after checking that all assumptions of the t-test were met. Both survey weighted and unweighted Pearson Chi Squared test and t-test were performed. District level shapefiles were downloaded from DIVA GIS, (available at https://www.diva-gis.org/). Exploratory spatial analysis was conducted in ArcMap. Moran's Index was computed to determine the presence of spatial autocorrelation. Unadjusted prevalence maps were generated for both outcomes using the symbology function in ArcMap. Lastly, Getis-Odi analysis was conducted to assess for hot and cold spots of ITN uptake and utilisation.

2.2.6.3 Analysis for Objective 2: To determine the predictors of uptake and utilisation of ITNs amongst women of childbearing age aged 15-49 years in Zimbabwe in 2015.

Survey adjusted univariate logistic models were fitted to get some idea of the effects of each socio-demographic factor on uptake and utilisation. For the final multi-level model, variables that were significant or marginally significant (using a significance level of 0.10) in the weighted bivariate analysis were fitted.

For the uptake outcome variable, age, age of household head, province of residence, household size, person with final say on respondent's health, marital status, employment status, highest education level, media exposure, parity and wealth index were included in the final model.

An ordinal logistic model was fitted for utilisation outcome with age, age of household head marital status, employment status, person with final say on respondent's health, highest education level, parity , province, media exposure and household size. Multi-level logistic regression models were fitted using the survey command to account for the clustering sampling frame of the data. Non-random effects and random effects models were fitted for both logistic models for ITN uptake and utilisation.

2.2.6.4 Analysis for objective 3: To determine the predictors of uptake and utilisation of ITNs amongst women of childbearing age aged 15-49 years in Zimbabwe in 2015, adjusting for spatial random effects.

To satisfy this objective, two approaches were used. The first approach used individual level data while the second analysis approach was done at ecological level. To analyse the data at individual level, Conditional autoregressive (CAR) models were fitted for both outcomes in R (see R codes used in appendix B3). These models were fitted using the same variables from the final logistic models in objective 2, however excluding the province variable as it would be accounted for in the spatial analysis. Simultaneous autoregressive (SAR) models were fitted in Stata to analyse the data at ecological level. The data was first collapsed by district and then merged with the district level shapefile. To avoid over-fitting, only variables that were statistically significant in the multi-level logistic models were used. Three SAR models were fitted for each outcome variable for comparison. The first was a spatial error model which assumes that spatial autoregressive effects are only found in the error term. See equation 2.2 below

$$Y = X\beta + \rho Wu + \varepsilon$$ Equation 2.2: Error lag SAR model form

The second model was a model with a spatial lag on the dependent variable which assumes that the autoregressive process occurs only in the response variable (equation 2.3).

$$Y = X\beta + \rho WY + \varepsilon$$ Equation 2.3: Dependent lag SAR model form

The last model was a model with a spatial lag on the independent variable (equation 2.4).

$$Y = X\beta + \rho WY + WX\gamma + \varepsilon$$ Equation 2.4: Independent lad SAR model Form

Where $\boldsymbol{W}$ *is the spatial weights matrix,* ρ *is the spatial autoregression estimate coefficient ,* $\boldsymbol{\beta}$ *represents the slopes of the explanatory variables in the original* $\boldsymbol{X}$*,* $\boldsymbol{u}$ *represents the spatially correlated residuals,* ε *are the spatially independent errors and* γ *is the autoregressive coefficient of the spatially lagged explanatory variables* (32)*.*

The model with the lowest Akaike Information Criteria (AIC) was selected and presented in the results. From the final models, predictions were generated and maps plotted.

2.2.6.5 Analysis for Objective 4: To determine the combined effect of the relationship between ITN uptake and utilisation amongst women of childbearing age aged 15-49 years in Zimbabwe in 2015

An intrinsic Bayesian multivariate CAR model for mapping multiple outcomes was fitted in WinBUGS using standardized uptake and utilisation rates to assess for a correlation between uptake and utilisation(46). Maps summarizing the random effects of both utilisation and uptake were plotted and correlation parameter was generated. The WinBUGS model syntax can be viewed in appendix B4 & B5.

2.2.7 Models' goodness of fit

Variables to be included in the final multi-level models were carefully chosen from variables that were significant or marginally significant in the bivariate analysis, to ensure all potential confounders were included. The final models were tested using the Hosmer-Lemeshow goodness of fit test. For the SAR models, the model with the lowest AIC was selected.

2.2.8 Ethical considerations

Informed consent was granted by respondents in the primary study. Permission to use the data was obtained from measure DHS. The University of Witwatersrand Research Ethics Committee (Medical) granted ethics clearance for this study. See ethics clearance certificate in appendix A1.

Chapter 3 Results

This chapter presents findings from the statistical analysis described in chapter 2. We start by reporting results from the propensity score matching followed by descriptive baseline characteristics of study population and regression model results. Included in this chapter are results from the spatial modelling, which include parameter estimates as well as maps.

3.1 Propensity Score Matching results

Propensity score matching was carried out using a number of children under 5 years in the household. The table 3.1 below shows differences between some variables before and after matching. The variables did not meet assumptions for t-test, therefore Mann-Whitney test was used to obtain p-values. After matching there were no statistically significant differences in household size and number of under-five children between pregnant women and non-pregnant women.

Table 3.1: Bivariate analysis of Matching variables before and after matching

	Before matching			**After matching**		
Variable	Not Pregnant Median(min, max)	Pregnant Median(min, max)	p-value	Not pregnant Median(min, max)	Pregnant Median(min, max)	p-value
Parity	2(0, 12)	1(0, 10)	<0.001	2(0, 11)	1(0, 10)	0.001
Household size	5(1, 27)	4 (1, 15)	<0.001	4(1, 25)	4(1, 25)	0.072
Under5s	1(0, 7)	1 (0, 7)	<0.001	1(0, 7)	1(0, 7	0.968

Table 3.2 shows the level of bias after matching. The non-significant p-values indicate non-significant bias in covariates between the two groups.

Table 3.2: Covariate imbalance testing results

Variable	**Pregnant (mean)**	**Non-pregnant (mean)**	**%bias**	**p-value**
Parity	1.90	1.99	-5.2	0.203
Household size	4.64	4.67	2.3	0.998
Under5s	0.84	0.81	4.6	0.260

To further illustrate reduction in bias are two plots in figure 3.1. The first one on the left hand side shows two superimposed kernel density plots on household size variable before and after matching. The second shows propensity score distribution of pregnant and non-pregnant groups.

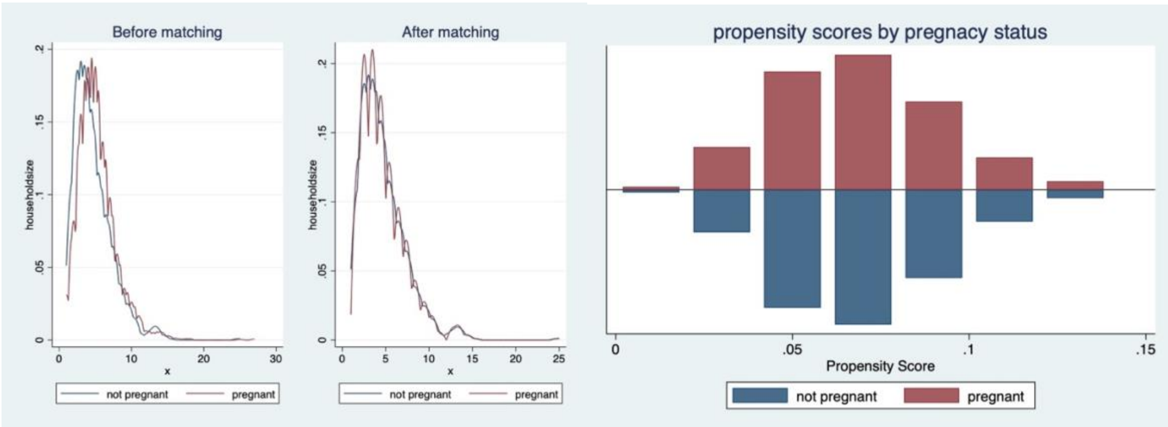

Figure 3.1: Kernel density plots on household size before and after matching & and propensity score graph

3.2 Baseline Characteristics of Study Population

The total number of participants was 2 444 (611 pregnant matched with 1 833 non-pregnant women). The mean age of participants was 28.21years. The majority of the household heads were male (55.11%). Most of the participants enrolled were married (62.40%). The richer and the richest wealth groups made up 54.75% of the study population while 30.86% were from the poorest and poorer wealth indices. The majority of respondents were part of the Apostolic Sect Faith religion group(38.38%).

Most of the participants had some form of education (66.94% reported to have a Secondary education) and only 0.86% had no education. The majority of women were involved in making decisions about their health, with 43.86% having no autonomy at all. More than half the study population (55.41%) had some form of media exposure, reporting reading the paper, listening to the radio or watching tv at least once a week. The majority of women had had at least 1 birth and resided in a household with at least 6 members. At baseline some differences were detected between the pregnant population and the non-pregnant population. Pregnant women were more likely to be married and have a male as the household head. Non-pregnant women were slightly older than the pregnant women. Table 3.3 shows these baseline characteristics.

Table 3.3: Baseline Characteristics of study participants

Variable	Category	N (%)	Not Pregnant N(%)	Pregnant N(%)	p-value[a]
Age in years Mean ± sd		28.21± 8.94[b]	27.49± 0.22[b]	26.34± 0.28[b]	0.006[b]
Age of household head Mean ± sd		40.10± 13.61[b]	41.09± 0.34[b]	37.53± 0.53[b]	<0.001[b]
Sex of household head	Male	1347(55.11)	944(51.50)	403(65.96)	<0.001
	Female	1097(44.89)	889(48.50)	208(34.04)	
Marital Status	Never in union	545(22.30)	497(27.11)	48(7.86)	<0.001
	Married	1525(62.40)	1020(55.65)	505(82.65)	
	Living with partner	95(3.89)	59(3.22)	36(5.89)	
	Widowed	101(4.13)	98(5.35)	3(0.49)	
	Divorced	98(4.01)	92(5.02)	6(0.98)	
	No longer living with partner	80(3.27)	67(3.66)	13(2.13)	
Province	Manicaland	259(10.60)	185(10.09)	74(12.11)	0.066
	Mashonaland Central	263(10.76)	178(9.71)	85(13.91)	
	Mashonaland East	210(8.59)	154(8.40)	56(9.17)	
	Mashonaland West	259(10.60)	190(10.37)	69(11.29)	
	Matabeleland North	223(9.12)	181(9.87)	42(6.87)	
	Matabeleland South	198(8.10)	145(7.91)	53(8.67)	
	Midlands	234(9.57)	175(9.55)	59(9.66)	
	Masvingo	266(10.88)	207((11.29)	59(9.66)	
	Harare	289(11.82)	217(11.84)	72(11.78)	
	Bulawayo	243(9.94)	201(10.97)	42(6.87)	
Wealth Index	Poorest	388(15.88)	267(14.57)	121(19.80)	0.012
	Poorer	368(15.06)	262(14.29)	106(17.35)	
	Middle	350(14.32)	263(14.35)	87(14.24)	
	Richer	685(28.03)	521(28.42)	164(26.84)	
	Richest	653(26.72)	520(28.37)	133(21.77)	
Employment Status	Employed	1187(48.57)	878(47.90)	309(50.57)	0.252
	Not Employed	1257(51.43)	955(52.10)	302(49.43)	
Religion	Traditional	21(0.86)	15(0.82)	6(0.98)	0.004
	Roman Catholic	157(6.42)	128(6.98)	29(4.75)	
	Protestant	373(15.26)	298(16.26)	75(12.27)	
	Pentecostal	676(27.66)	522(28.48)	154(25.20)	

	Apostolic Sect	938(38.38)	661(36.06	277(45.34)	
	None	123(5.03)	91(4.96)	32(5.24)	
	Other	156(6.38)	118(6.44)	38(6.22)	
Highest Level of Education	None	21(0.86)	14(0.76)	7(1.15)	0.045
	Primary	580(23.73)	410(22.37)	170(27.82)	
	Secondary	1636(66.94)	1239(67.59)	397(64.98)	
	Higher	207(8.47)	170(9.27)	37(6.06)	
Person with final say on respondent's health	Respondent	524(21.44)	363(19.80)	161(26.35)	
	Respondent & partner	848(34.70)	569(31.04)	279(45.66)	
	Partner only	230(9.41)	137(7.47)	93(15.22)	
	Someone else	842(34.45)	764(41.68)	78(12.77)	
Media Exposure	None	579(23.69)	428(23.35)	151(24.71)	0.034
	Does one less than once a week	511(20.91)	368(20.08)	143(23.40)	
	Newspaper at least once a week	78(3.19)	59(3.22)	19(3.11)	
	Radio at least once a week	444(18.17)	310(16.91)	134(21.93)	
	TV at least once a week	683(27.95)	539(29.41)	144(23.57)	
	All 3 at least once a week	149(6.10)	129(7.04)	20(3.27)	
Parity	0 births	674(27.58)	490(26.73)	184(30.11)	0.179
	1-3 births	1315(53.81)	997(53.30)	388(55.32)	
	More than 3 births	455(18.62)	366(19.97)	89(14.57)	
Household size	Less than 4 members	956(39.12)	717(39.10)	239(39.12)	0.998
	4-6 members	988(40.43)	741(40.45)	247(40.43	
	More than 6 members	500(20.46)	375(20.46)	125(20.46	

[a] p-values generated from survey adjusted Student's t-test for continuous variables and survey adjusted Pearson's Chi squared test for categorical variables.
[b] mean ± standard deviation

3.3 Description of uptake, Utilisation and spatial distribution amongst women of childbearing age in Zimbabwe

3.3.1 Description of ITN uptake against participant characteristics

The uptake of ITNs was 45.66%, where 1 103 women lived in a household with at least one ITN, whilst 1 313 women did not. The characteristics of women who possessed an ITN and those who did not are shown in the table 3.4. Survey weighted and non-weighted results are displayed. However, only the survey weighted results will be considered for discussion.

Older age was significantly associated with uptake of ITNs. The mean age of respondents who lived in households with at least one ITN was 28.81 years compared to 27.44 years amongst those who did not own an ITN. Older age of household head was also significantly associated with ITN uptake (p-value=0.032). The highest ITN uptake was seen in Matabeleland North, Mashonaland West, Masvingo and Mashonaland East with uptakes of 72.94%, 64.86%, 59.62% and 52.19% respectively. The lowest uptake rates were seen in Harare and Bulawayo (16.87% & 27.32% respectively). Person with final say on respondent’s health was significantly associated with ITN uptake (p-value=0.001). Respondents who had final say on their own health had the highest rate of ITN uptake (50.15%) followed by those who made health decisions together with their partners (49.31%). Those who had no say over their own health had the lowest uptake (39.31%). As shown in table 3.4, most of the variables were significantly associated with ITN uptake with the exception of sex of household head and religion.

Table 3.4: Baseline characteristics against uptake

Characteristic	**Category**	**Un-Weighted**			**Weighted**		
		No Uptake N=1308	**Yes Uptake N=1136**	**X^2(p-value)**	**No Uptake N=1313**	**Yes Uptake N=1103**	**F-statistic(p-value)**
Age of respondent Mean ± sd		27.57±8.79	28.95±9.06	**0.0001**	27.44±8.73	28.81±9.06	**0.001**
Age of household head Mean ± sd		39.36±13.93	40.96±13.21	**0.0039**	39.71±13.93	41.24±13.21	**0.032**
Sex of household head	Male	696(51.67)	651(48.33)	4.12**(0.042)**	711(52.64)	640(47.360)	1.90(0.169)
	Female	612(55.79)	485(44.21)		601(56.50)	463(43.50)	
Marital Status	Never in union	322(59.08)	223(40.92)	17.45**(0.004)**	311(59.62)	211(0.40)	2.87**(0.015)**
	Married	773(50.69)	752(49.31)		781(51.55)	734(48.45)	
	Living with partner	56(58.95)	39(41.05)		60(62.50)	3637.50)	
	Widowed	50(49.50)	51(50.50)		48(47.95)	52(52.05)	
	Divorced	62(63.27)	36(36.73)		60(62.00)	37(38.00)	
	No longer living with partner	45(56.75)	35(43.75		53(61.23)	34(38.77)	
Province	Manicaland	140(54.05)	119(45.95)	266.57**(<0.001)**	164(52.95)	145(47.05)	12.24**(<0.001)**
	Mashonaland Central	143(54.37)	120(45.63)		126(53.37)	110(46.63)	
	Mashonaland East	99(47.14)	111(52.86)		107(47.81)	117(52.19)	
	Mashonaland West	90(34.75)	169(65.25)		98(35.14)	180(64.86)	
	Matabeleland North	59(26.46)	164(73.54)		34(27.06)	91(72.94)	
	Matabeleland South	113(57.07)	85(42.93)		57(59.26)	39(40.74)	
	Midlands	139(59.40)	95(40.60)		160(55.46)	129(44.54)	
	Masvingo	108(40.60)	158(59.40)		124(40.38)	184(59.62)	
	Harare	241(83.39)	48(16.61)		338(83.13)	69(16.87)	
	Bulawayo	176(72.43)	67(27.57)		106(72.68)	40(27.32)	
Wealth Index	Poorest	187(48.20)	201(51.80)	28.18**(<0.001)**	215(49.34)	221(50.66)	7.46**(<0.001)**
	Poorer	169(45.92)	199(54.08)		197(45.07)	240(54.93)	
	Middle	172(49.14)	178(50.86)		180(45.72)	214(54.28)	
	Richer	404(58.98)	281(41.02)		387(62.46)	233(37.54)	
	Richest	376(57.58)	277(42.42)		333(63.06)	195(36.94)	

Employment Status	Not Employed	610(51.39)	577(48.61)	4.20**(0.040)**	598(50.87)	577(49.13)	7.01**(0.008)**
	Employed	698(55.53)	559(44.47)		715(57.63)	526 (42.37)	
Religion	Traditional	7(33.33)	14(66.67)	7.19(0.409)	8.8(38.37)	14(61.63)	1.3366(0.239)
	Catholic	86(54.78)	71(45.22)		81(52.03)	75(47.97)	
	Protestant	200(53.62)	173(46.38)		170(51.31)	161(48.69)	
	Pentecostal	368(54.44)	308(45.56)		370(59.25)	254(40.75)	
	Apostolic sect	492(52.45)	446(47.55)		544(52.77)	486(47.23)	
	Other Chris	79(54.11)	67(45.89)		56(49.93)	58(50.07)	
	None	68(55.28)	55(44.72)		74(57.94)	53(42.06)	
	Other	8(80.00)	2(20.00)		(89.56)	(10.44)	
Highest Level of Education	None	13(61.90)	8(38.10)	16.20**(0.001)**	18(64.93)	9.7(35.07)	4.46**(0.004)**
	Primary	270(46.55)	310(53.45)		293(47.12)	328 (52.88)	
	Secondary	903(55.22)	733(44.80)		893(56.00)	702(44.00)	
	Higher	122(58.94)	85(41.08)		109(63.34)	63(36.66)	
Person with final say on respondent's health	Respondent	264(50.38)	260(49.62)	17.71**(0.001)**	247(49.85)	249(50.15)	4.23**(0.006)**
	Respondent & partner	419(49.41)	429(50.59)		421(50.69)	410(49.31)	
	Partner only	135(58.70)	95(41.30)		159(60.69)	103(39.31)	
	Other	490(58.19)	352(41.81)		485(58.70)	342(41.30	
Media Exposure	None	279(48.19)	300(51.84)	19.66**(0.001)**	290(47.32)	323(52.68)	3.83**(0.003)**
	Does one less than once a week	283(55.38)	228(44.62)		304(56.93)	230(43.07)	
	Newspaper at least once a week	43(55.13)	35(44.87)		33(49.21)	34(50.79)	
	Radio at least once a week	222(50.00)	222(50.00)		253(52.04)	234(47.96)	
	TV at least once a week	384(56.22)	299(43.78)		333(58.7)	234(41.30)	
	All 3	97(65.10)	52(34.90		99(67.49)	48(32.51)	
Parity	0 births	392(58.16)	282(41.84)	10.55**(0.005)**	385(58.08)	278(41.92)	2.83**(0.059)**
	1-3births births	695(52.85)	620(47.15)		678(54.24)	572(45.75)	
	More than 3 births	221(48.57)	234(51.43)		249(49.65)	253(50.35)	
Household size	Less than 4 members	544(56.90)	412(43.10)	9.19 **(0.010)**	517 (58.56)	365(41.44)	5.01**(0.008)**
	4-6 members	520(52.63)	468(47.37)		546(54.26)	460(45.74)	
	More than 6 members	244(48.80)	256(51.20)		250(47.44)	277(52.56)	

Key: X^2(Pearson Chi Square statistic); sd(standard deviation)Description of utilisation of ITNs against participant characteristic

3.3.2 Description of ITN utilisation against participant characteristics

Out of the entire study population, 245 women reported to have slept under an ITN, giving a total utilisation of rate of 8.13%, which was 18.96% of those who owned an ITN. Amongst those who owned an ITN, 37% (n=891) did not sleep under one while 54.34% (n=1 308) did not have an ITN. The association between ITN use and age was only marginally significant. The mean age for women who used ITNs was 31.57 years while the mean age of those who did not use an available ITN was 28.15years. Utilisation rates were highest in Mashonaland Central and in Matabeleland North provinces. More women from poorer and poorest wealth quantiles slept under an ITN than women from richer and richest wealth quantiles (p-value<0.001). Almost all the variables were significantly associated with utilisation except for sex of household head and religion . Table 3.5 below shows these results.

Table 3.5: Baseline Characteristics against utilisation

Variable	Category	**No Uptake N=1308**	**Uptake only N=891**	**Utilized N=245**	**F-statistic (p-value)**
Age of respondent		27.44±8.79	28.15±8.96	31.58±9.13	0.089
Age of household head		39.70±13.93	41.15±13.43	41.65±12.35	0.060
Sex of household head	Male	711(52.64)	522(38.65)	118(8.71)	1.16 (0.313)
	Female	601(56.50)	372(34.91)	91(8.59)	
Marital Status	Never in union	311(59.62)	184(35.35)	26(5.03)	
	Married	781(51.55)	587(38.73)	147(9.72)	
	Living with partner	60(62.50)	33(34.03)	3.3(3.47)	**2.59 (0.005)**
	Widowed	48(47.95)	36(35.66)	16(16.38)	
	Divorced	60(62.00)	31(31.50)	6.3(6.5)	
	No longer living with partner	53(61.23)	24(27.63)	9.6(11.14)	
Province	Manicaland	164(52.95)	118(38.15)	27(8.9)	
	Mashonaland Central	126(53.37)	80(34.09)	30(12.54)	
	Mashonaland East	107(47.81)	93(41.58)	24(10.61)	
	Mashonaland West	98(35.14)	150(53.89)	30(10.98)	
	Matabeleland North	34(27.06)	72(57.68)	19(15.26)	**7.57(<0.001)**
	Matabeleland South	57(59.26)	29(30.01)	10(10.72)	
	Midlands	160(55.46)	107(37.21)	21(7.34)	
	Masvingo	124(40.38)	159(51.65)	25(7.98)	
	Harare	338(83.13)	58(14.20)	11(2.67)	
	Bulawayo	106(72.68)	28(19.110)	12(8.21)	
Wealth Index	Poorest	215(49.34)	179(40.93)	42(9.72)	
	Poorer	197(45.03)	183(41.93)	57(13.00)	**4.88(<0.001)**
	Middle	180(45.72)	181(45.95)	33(8.33)	
	Richer	387(62.46)	186(30.00)	47(7.54)	
	Richest	333(63.06)	165(31.20)	30(5.74)	
Employment Status	Not Employed	598(50.87)	483(41.09)	94(8.04)	**5.81 (0.003)**

	Employed	715(57.63)	411(33.12)	115(9.25)	
Religion	Traditional	8.8(38.37)	12(53.14)	1.9(8.49)	
	Catholic	81(52.03)	61(38.66)	15(9.31)	
	Protestant	170(51.31)	138(41.80)	23(6.89)	
	Pentecostal	370(59.25)	207(33.23)	47(7.52)	
	Apostolic sect	544(52.77)	388(37.63)	99(9.59)	1.19 (0.280)
	Other Chris	57(49.93)	46(40.42)	11(9.65)	
	None	74(57.94)	41(32.37)	12(9.70)	
	Other	8.7(57.94)	0.26(2.67)	0.75(7.76)	
Highest Level of Education	None	18(64.93)	4.4(15.94)	5.3(19.13)	
	Primary	293(47.12)	257(41.34)	72(11.54)	**4.21 (0.001)**
	Secondary	893(56.00)	588(36.85)	114(7.14)	
	Higher	109(63.34)	45(26.06)	18(10.6)	
Person with final say on respondent's health	Respondent	247(49.85)	205(41.35)	44(8.80)	
	Respondent & partner	421(50.69)	334(40.15)	76(9.16)	**3.19 (0.005)**
	Partner only	159(60.69)	73(27.85)	30(11.46)	
	Other	485(58.70)	282(34.13)	59(7.18)	
Media Exposure	None	290(47.32)	255(41.59)	68(11.09)	
	Does one less than once a week	304(56.93)	188(35.21)	42(7.86)	
	Newspaper at least once a week	33(49.21)	27(40.46)	7(10.32)	**2.23 (0.019)**
	Radio at least once a week	253(52.04)	189(38.88)	44(9.08)	
	TV at least once a week	333(58.70)	195(34.34)	40(6.97)	
	All 3	99(67.49)	39(26.76)	8.4(5.75)	
Parity	0 births	385(58.08)	243(36.71)	34(5.20)	
	1-3births births	678(54.24)	460(36.83)	112(8.93)	**4.40 (0.002)**
	More than 3 births	24949.65)	190(37.80)	63(12.55)	
Household size	Less than 4 members	517(58.56)	292(33.16)	73(8.28)	
	4-6 members	546(54.26)	370(36.71)	91(9.03)	**2.90(0.024)**
	More than 6 members	250(47.44)	232(43.98)	45(8.66)	

3.3.3 Descriptive spatial analysis

The Global Moran's Index was computed for both outcomes to establish whether there was spatial autocorrelation (see table 3.6). Both ITN uptake and utilisation showed spatial autocorrelation

Table 3.6: Moran's test of spatial dependence

Outcome	Moran's Index	p-value
Uptake	0.20	0.014
Utilisation	0.17	0.019

Figure 5 shows unadjusted prevalence rates of ITN uptake and ITN utilisation across Zimbabwean districts. Harare, Bulawayo, Gweru, Kwekwe, Shurugwi and other districts in the Midlands areas show low uptake and low utilisation of ITNs. High uptake is seen with some districts in the Matabeleland South and Matabeleland North regions such as Lupane, Hwange and Tsholotsho and also in most Mashonaland West districts such as Hurungwe, Makonde and Kariba. Figure 3.2 shows that where uptake was low, sometimes the utilisation was also low. However, in some districts like Makonde, Lupane and Mutasa ITN uptake was high but the utilisation was low.

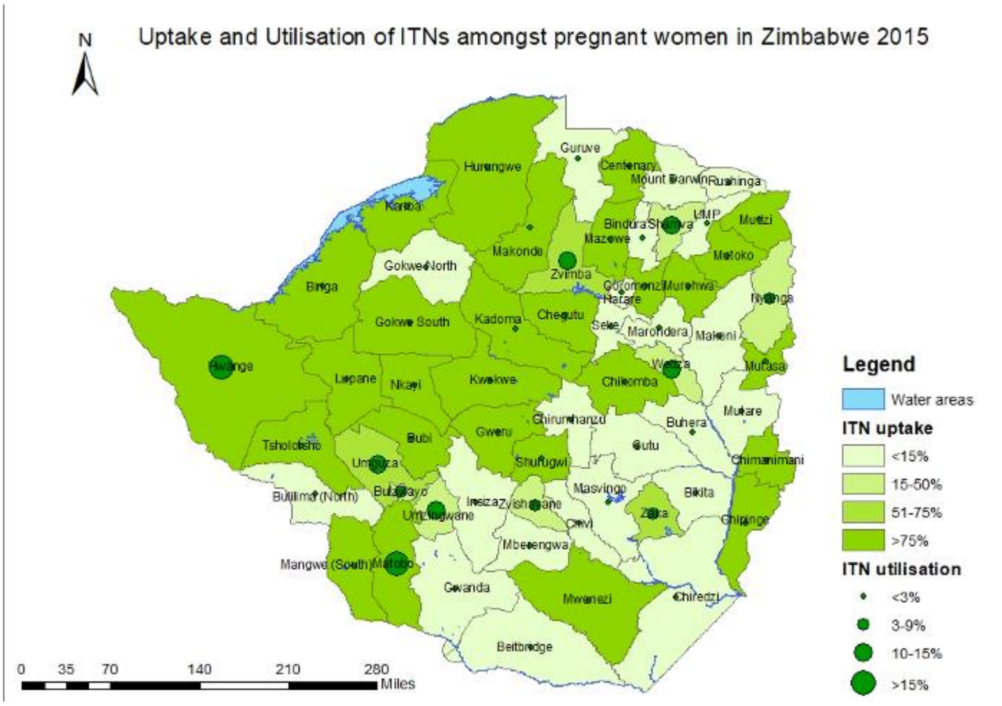

Figure 3.2: ITN uptake and Utilisation in the districts of Zimbabwe 2015

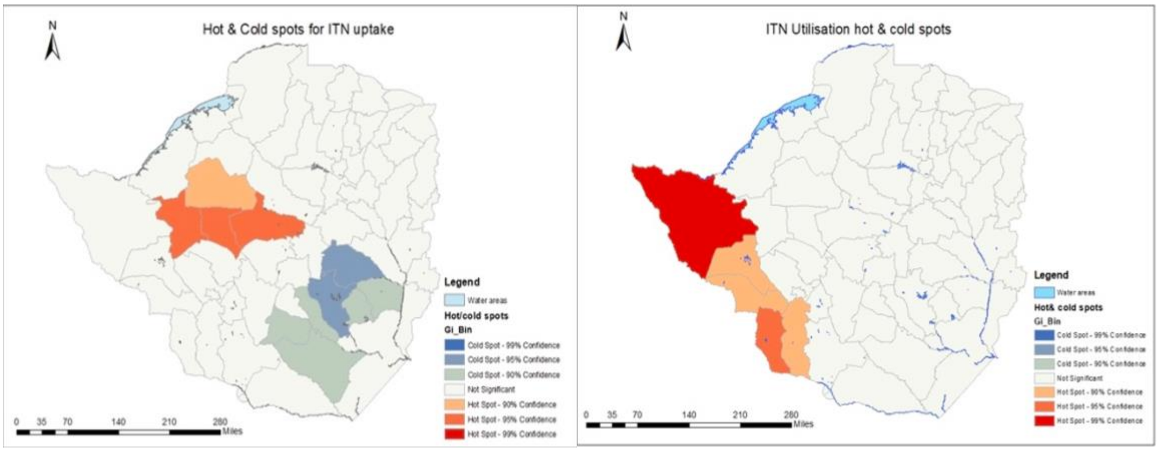

Figure 3.3: Hot & Cold spots for ITN uptake and Utilisation

Figure 3.3 shows hot and cold spot analysis at 90, 95 and 99% confidence intervals. Hot spots for ITN utilisation were Nkayi and Lupane districts while Gutu and Masvingo were cold spots.

Hwange was a hot spot for ITN utilisation and there were no significant cold spots for ITN utilisation.

3.4 Univariate Logistic Regression Results

3.4.1 Univariate logistic regression results for uptake of ITNs

Unadjusted logistic models were fitted for each explanatory variable. All of the variables except for sex of household head and religion had significant p-values of less than 0.05. The odds of residing in a household with at least one ITN increased by 2% for every year increase in age (95% CI 1.01; 1.03). In comparison to Harare, odds of ITN uptake were higher in all provinces, with Mashonaland West and Matabeleland North showing the highest odds, odds ratio (ORs) 9.10 and 13.28 respectively (95% CI 5.05; 16.37 and 7.65; 23.04 respectively), while likelihood of owning an ITN was lowest for Bulawayo, OR 1.85 (95% CIs 1.08; 3.16). Women from the richer and richest wealth quantiles had lower odds of ITN uptake when compared to women from the poorest wealth quantile. The OR for ITN uptake amongst women in the richest wealth quantile was 0.59 (95% CI 0.38; 0.86). Highest education level was associated with net ownership, with the odds of net ownership being higher for all the education levels when compared to no education. Person with final say on respondent's health was a significant factor. Women whose partners made decisions on their behalf were 46% less likely to own a net when compared to women who made their own decisions about their own health. When compared to women who lived in small households, women who lived in large house-holds with more than 6 members had an odds ratio of 1.57 of owning an ITN (95% CI 1.17; 2.09). When compared to nulliparous women (women with 0 births), women who had had more than 3 births were 57% more likely to live in a household with at least one ITN (95% CI 1.07;

1.89). Employed women had an OR of 0.86 of owning a net (95% CI 0.62; 0.93). Table 3.7 elaborates these results.

Table 3.7: Univariate logistic regression results for uptake

Variable	Level	Crude OR	95% CI	p-value
Age in years		1.02	1.01; 1.03	**0.001**
Age of Household head		1.01	1.01; 1.02	**0.034**
Sex of Household head	Male	1(ref)		
	Female	0.86	0.68; 1.07	0.1688
Marital Status	Never in union	1 (ref)		
	Married	1.38	1.08; 1.78	**0.009**
	Living with partner	0.89	0.52; 1.52	0.659
	Widowed	1.60	0.99; 2.58	0.052
	Divorced	0.91	0.54; 1.51	0.701
	No longer living with partner	0.93	0.57; 1.53	0.790
Province	Harare	1(ref)		
	Mashonaland Central	4.31	2.38; 7.79	**<0.001**
	Mashonaland East	5.38	2.91; 9.94	**<0.001**
	Mashonaland West	9.10	5.05; 16.37	**<0.001**
	Matabeleland North	13.28	7.65; 23.04	**<0.001**
	Matabeleland South	3.39	1.76; 6.52	**<0.001**
	Midlands	3.96	2.12; 7.37	**<0.001**
	Masvingo	7.27	3.85; 13.63	**<0.001**
	Manicaland	4.38	2.47; 7.57	**<0.001**
	Bulawayo	1.85	1.08; 3.16	**0.024**
Wealth Index	Poorest	1 (ref)		
	Poorer	1.19	0.89;1.59	0.251
	Middle	1.16	0.83; 1.62	0.397
	Richer	0.59	0.41; 0.83	**0.002**
	Richest	0.57	0.38; 0.86	**0.007**
Employment Status	Not Employed	1(ref)		**0.008**
	Employed	0.76	0.62; 0.93	
Religion	Traditional	1 (ref)		
	Roman Catholic	0.57	0.19; 1.76	0.331
	Protestant	0.59	0.21; 1.68	0.324
	Pentecostal	0.43	0.15; 1.22	0.112
	Apostolic sect	0.56	0.20; 1.57	0.268
	Other Christian	0.62	0.21; 1.87	0.399
	None	0.45	0.15; 1.32	0.145
	Other	0.07	0.01; 0.54	0.011
Highest Level of Education	None	1 (ref)		
	Primary	2.07	0.76; 5.62	0.149
	Secondary	1.45	0.54; 3.93	0.459
	Higher	1.07	0.36; 3.11	0.898
Person with final say on respondent's health	Respondent	1 (ref)		
	Respondent & partner	0.96	0.74; 1.25	0.800
	Partner only	0.64	0.44; 0.94	**0.022**
	Other	0.70	0.54; 0.91	**0.008**
Media Exposure	None	1(ref)		
	Did one less than once a week	0.67	0.50; 0.92	**0.012**
	Newspaper at least once a week	0.92	0.57; 1.50	0.756
	Radio at least once a week	0.82	0.61; 1.11	0.202

	TV at least once a week	0.63	0.45; 0.87	**0.007**
	All 3	0.43	0.26; 0.71	**0.001**
Parity	0 births	1 (ref)		
	1-3 births	1.16	0.92; 1.48	0.192
	More than 3 births	1.40	1.07; 1.84	**0.015**
Household size	Less than 4 members	1 (ref)		
	4-6 members	1.19	0.97; 1.46	0.093
	More than 6 members	1.57	1.17; 2.09	**0.003**

Key: OR(odds ratio); CI(Confidence interval); ref(reference)

3.4.2 Univariate logistic regression results for utilisation of ITNs

Univariate ordinal logistic regression on utilisation showed that age, age of household head, being married or being widowed, province, wealth index, employment status household size and parity were associated with utilisation. The odds of having slept under an ITN the previous night increased by 2% for each year increase in age (95% CI 1.01; 1.03). Women who had had more than 3 births were more likely to have slept under an ITN when compared to nulliparous women, OR 1.52 (95% CI 1.16; 2.00). Being employed decreased odds of ITN utilisation, crude OR 0.81 (95% CI 0.66; 0.98). When compared to those who had never been in a union, the odds of sleeping under an ITN were higher for those who were married or widowed. Participants from Matabeleland North and Mashonaland West had the highest odds of sleeping under an ITN. The results are shown in Table 3.8.

Table 3.8: Univariate Regression Results for Utilisation

Variable	Level	Crude OR	95% CI	p-value
Age in years		1.02	1.01; 1.03	**<0.001**
Age of household head		1.00	1.01; 1.02	**0.026**
Sex of Household head	Male	1(ref)		
	Female	0.87	0.70; 1.08	0.214
Marital Status	Never in union	1(ref)		
	Married	1.44	1.15; 1.80	**0.002**
	Living with partner	0.88	0.53; 1.46	0.611
	Widowed	1.85	1.10; 3.09	**0.019**
	Divorced	0.94	0.57; 1.53	0.791
	No longer living with partner	21.04	0.62; 1.74	0.883
Province	Harare	1 (ref)		
	Mashonaland Central	4.65	2.51; 8.61	**<0.001**
	Mashonaland East	5.43	2.96; 9.95	**<0.001**
	Mashonaland West	8.17	4.69; 14.21	**<0.001**
	Matabeleland North	11.40	6.72; 19.34	**<0.001**
	Matabeleland South	3.61	1.84; 7.09	**<0.001**
	Midlands	3.92	2.10; 7.34	**<0.001**

	Masvingo	6.54	3.68; 11.63	**<0.001**
	Manicaland	4.41	2.51; 7.75	**<0.001**
	Bulawayo	1.95	1.12; 3.44	**0.019**
Wealth Index	Poorest	1 (ref)		
	Poorer	1.23	0.91; 1.65	0.177
	Middle	1.10	0.80; 1.49	0.561
	Richer	0.60	0.42; 0.85	**0.004**
	Richest	0.57	0.39; 0.85	**0.005**
Employment Status	Not Employed	1 (ref)		
	Employed	0.81	0.66; 0.98	**0.032**
Religion	Traditional			
	Roman Catholic	0.66	0.26; 1.71	0.392
	Protestant	0.65	0.27; 1.54	0.326
	Pentecostal	0.50	0.20; 1.91	0.117
	Apostolic sect	0.65	0.27; 1.53	0.320
	Other Christian	0.71	0.28; 1.80	0.475
	None	0.54	0.22; 1.35	0.186
	Other	0.09	0.01; 0.72	**0.023**
Highest Level of Education	None	1 (ref)		
	Primary	1.67	0.50; 5.61	0.402
	Secondary	1.14	0.34; 3.82	0.825
	Higher	0.92	0.25; 3.30	0.899
Person with final say on respondent's health	Respondent	1 (ref)		
	Respondent & partner	0.98	0.77; 1.24	0.863
	Partner only	0.71	0.48; 1.04	**0.085**
	Other	0.72	0.56; 0.91	0.007
Media Exposure	None	1 (ref)		
	Did one less than once a week	0.68	0.51; 0.90	**0.009**
	Newspaper at least once a week	0.93	0.57; 1.50	0.751
	Radio at least once a week	0.82	0.62; 1.09	0.168
	TV at least once a week	0.63	0.46; 0.86	**0.003**
	All 3	0.44	0.26; 0.72	**0.001**
Parity	0 births	1 (ref)		
	1-3 births	1.21	0.98; 1.52	0.079
	More than 3 births	1.52	1.16; 2.00	**0.002**
Household size	Less than 4 members	1 (ref)		
	4-6 members	1.18	0.96; 1.45	0.109
	More than 6 members	1.47	1.11; 1.94	**0.007**

Key: OR(odds ratio); CI(Confidence interval); ref(reference)

3.5 Multi-level Logistic Regression Results

3.5.1 Multi-level logistic regression results for uptake of ITNs

Variables that showed significance in the bivariate analysis were used to fit the multi-variable logistic models. A non-random effects model and random effects model were fitted in Stata. The model with random effects will be the subject of discussion as it accounts for the cluster nature of the data. After accounting for spatial random effects, some of the predictors that were marginally significant were no longer statistically significant. Age, person with final say on respondent’s health and province were the only significant predictors of ITN uptake after adjusting for all potential confounders. For every year increase in age, the odds of ITN uptake increased by 0.02 (95% CI 1.01; 1.04). Respondents who had a say about their own health were more likely to live in a household with at least one ITN when compared with those whose partners had a final say over their health decisions. When compared to respondents who made decisions about their own health, those whose partners made decisions on their behalf had an adjusted odds ratio of 0.59 of ITN uptake (95% CI 0.40; 0.88). When compared to Harare province, odds of ITN uptake were higher in all provinces, with Mashonaland West and Matabeleland North showing the highest odds, AORs 10.04 and 12.27 respectively (95% CI 5.6; 18.03 and 6.93;21.22 respectively), while likelihood of owing an ITN was lowest for Bulawayo, OR 1.76 (95% CIs 1.08; 3.16). After adjusting for other factors and spatial random effects, wealth index, age of household head, parity, education level, employment status, media exposure, marital status and household size were not significant predictors of ITN uptake. These results can be seen in the table 3.9.

Multi-level Logistic Regression Results

Table 3.9: Multi-level logistic model for uptake of ITNs: Non-Random effects & Random effects models

		Non-Random Effects		**Random Effects**	
Characteristic	**Category**	**AOR(95% CI)**	**p-value**	**AOR(95% CI)**	**p-value**
Age		1.03 (1.01;1.05)	**0.001**	1.02 (1.01; 1.04)	**0.002**
Age of household head		1.00 (0.99; 1.01)	0.996	1.00 (0.99; 1.01)	0.287
Wealth Quantile	Poorest	1(ref)		1 (ref)	
	Poorer	1.35 (0.97; 1.86)	0.067	1.29 (0.91; 1.86)	0.152
	Middle	1.38 (0.96; 1.99)	0.080	1.37 (0.93; 2.01)	0.108
	Richer	1.12 (0.69; 1.79)	0.646	1.35 (0.90; 2.01)	0.149
	Richest	1.30 (0.73; 2.32)	0.368	1.42 (0.90; 2.24)	0.135
Household Size	Less than 3 members	1 (ref)		1 (ref)	
	4-6 members	1.2 (0.95; 1.51)	0.119	1.15 (0.91; 1.45)	0.243
	>6 members	1.42 (1.02; 1.98)	**0.037**	1.30 (0.96; 1.76)	0.088
Province	Harare	1 (ref)		1 (ref)	
	Mashonaland Central	4.04 (2.16; 7.54)	**<0.001**	5.25 (2.74; 10.03)	**<0.001**
	Mashonaland East	5.49 (2.95; 10.21)	**<0.001**	7.36 (3.81; 14.18)	**<0.001**
	Mashonaland West	10.04 (5.60; 18.03)	**<0.001**	15.91 (8.39; 30.57)	**<0.001**
	Matabeleland North	12.27 (6.93; 21.72)	**<0.001**	22.19 (11.06; 44.45)	**<0.001**
	Matabeleland South	3.92 (1.66; 6.53)	**0.001**	4.65 (2.38; 9.10)	**<0.001**
	Midlands	4.06 (2.12; 7.80)	**<0.001**	4.34 (2.26; 8.31)	**<0.001**
	Masvingo	6.89 (3.46; 13.73)	**<0.001**	10.66 (5.57; 20.38)	**<0.001**
	Manicaland	4.66 (2.62; 8.28)	**<0.001**	6.41 (3.38; 12.14)	**<0.001**
	Bulawayo	1.76 (1.02; 3.02)	**0.042**	2.18 (1.13; 4.21)	**0.020**
Person with final say on respondent's health	Respondent	1 (ref)		1 (ref)	
	Respondent & partner	0.96 (0.73; 1.28)	0.820	1.02 (0.78; 1.34)	0.878
	Partner only	0.61 (0.41; 0.90)	**0.012**	0.59 (0.40; 0.88)	**0.009**
	Other	0.77 (0.22; 2.69)	0.688	0.73 (0.22; 2.34)	0.598
Marital status	Never in union	1 (ref)		1 (ref)	
	Married	0.98 (0.26; 3.59)	0.981	0.86 (0.26; 2.80)	0.803
	Living with partner	0.58 (0.15; 2.20)	0.421	0.60 (0.17; 2.09)	0.426
	Widowed	1.14 (0.61; 2.11)	0.686	0.90 (0.49; 1.65)	0.739

	Divorced	0.80 (0.44; 1.48)	0.478	0.66 (0.36; 1.19)	0.170
	Separated	0.91 (0.53; 1.59)	0.759	0.76 (0.40; 1.44)	0.407
Employment status	Employed currently	1 (ref)		1 (ref)	
	Not employed	0.77 (0.61; 0.99)	**0.042**	0.83 (0.67; 1.03)	0.104
Media Exposure	None	1 (ref)		1 (ref)	
	Did one less than once a week	0.77 (0.56; 1.05)	0.101	0.84 (0.62; 1.14)	0.266
	Newspaper at least once a week	1.31 (0.77; 2.23)	0.313	1.22 (0.66; 2.27)	0.524
	Radio at least once a week	0.86 (0.63; 1.16)	0.325	1.11 (0.80; 1.53)	0.534
	TV at least once a week	1.04 (0.70; 1.57)	0.813	0.90 (0.64; 1.28)	0.556
	All 3	0.97 (0.59; 1.62)	0.915	0.81 (0.48; 1.35)	0.414
Parity	0 births	1 (ref)		1 (ref)	
	1-3 births	0.84 (0.59; 1.20)	0.337	0.95 (0.69; 1.32)	0.781
	>3 births	0.62 (0.38; 1.01)	0.059	0.75 (0.48; 1.18)	0.217
Highest Education Level	None	1 (ref)		1 (ref)	
	Primary	2.50 (0.91; 6.86)	0.074	2.28 (0.75; 6.82)	0.142
	Secondary	2.07 (0.76; 5.63)	0.153	1.88 (0.63; 5.64)	0.260
	Higher	1.73 (0.59; 5.08)	0.320	1.82 (0.57; 5.78)	0.312

Key: AOR(Adjusted Odds Ratio); CI(confidence interval); ref(reference)

3.5.2 Multi-level logistic regression results for utilisation of ITNs

The multi-level ordinal logistic model for utilisation included age, age of household head, wealth quantile, marital status, employment status, province, highest education level, parity, household size and person with final say on respondent's health. After accounting for spatial random effects, some of the predictors that were marginally significant in the non-random effects model were no longer statistically significant. Age and province were significant predictors of ITN utilisation, after adjusting for all factors. Utilisation rates were higher for older women. The odds of using an ITN increased by 2% for each year increase in age. The highest odds of ITN utilisation were seen in participants from Matabeleland North province, OR 10.17 (95%CI 5.86; 17.64). After adjusting for all factors, the rest of the explanatory variables were not significant predictors of ITN utilisation. Predictors of ITN utilisation are shown in Table 3.10.

Table 3.10: Multi-level logistic model for Utilisations of ITNs: Non-random effects & Random effects models

		Non-Random Effects		**Random Effects**	
Characteristic	**Category**	**AOR(95% CI)**	**p-value**	**AOR(95% CI)**	**p-value**
Age		1.03 (1.01;1.05)	**0.001**	1.02 (1.01; 1.04)	**0.001**
Age of household head		1.00 (0.99; 1.01)	0.908	1.00 (0.99; 1.01)	0.290
Wealth Quantile	Poorest	1(ref)		1 (ref)	
	Poorer	1.35 (0.98; 1.87)	0.069	1.30 (0.91; 1.86)	0.100
	Middle	1.26 (0.91; 1.77)	0.158	1.27 (0.90; 1.78)	0.176
	Richer	1.09 (0.69; 1.71)	0.720	1.41 (0.87; 2.03)	0.065
	Richest	1.20 (0.71; 2.02)	0.498	1.36 (0.90; 2.07)	0.143
Household Size	Less than 3 members	1 (ref)		1 (ref)	
	4-6 members	1.20(0.95; 1.50)	0.109	1.11 (0.91; 1.38)	0.243
	>6 members	1.42 (0.98; 1.85)	**0.066**	1.17 (0.89; 1.53)	0.088
Province	Harare	1 (ref)		1 (ref)	
	Mashonaland Central	4.38(2.31; 8.30)	**<0.001**	5.32 (2.91; 9.72)	**<0.001**
	Mashonaland East	5.53 (3.03; 10.08)	**<0.001**	7.05 (3.85; 12.92)	**<0.001**
	Mashonaland West	8.53 (4.93; 14.76)	**<0.001**	12.09 (6.70; 21.80)	**<0.001**
	Matabeleland North	10.17 (5.86; 17.64)	**<0.001**	18.52 (9.94; 34.50)	**<0.001**
	Matabeleland South	3.55 (1.76; 7.15)	**<0.001**	5.05 (2.70; 9.44)	**<0.001**
	Midlands	3.95 (1.76; 7.15)	**<0.001**	4.06 (2.21; 2.46)	**<0.001**
	Masvingo	6.13 (3.34; 11.24)	**<0.001**	8.61 (4.76; 15.56)	**<0.001**
	Manicaland	4.39 (2.55; 7.91)	**<0.001**	5.99 (3.31; 10.85)	**<0.001**
	Bulawayo	1.86 (1.05; 3.31)	**0.034**	2.27 (1.27; 4.42)	**0.06**
Person with final say on respondent's health	Respondent	1 (ref)		1 (ref)	
	Respondent & partner	0.98 (0.77; 1.26)	0.919	1.01 (0.80; 1.29)	0.920
	Partner only	0.69 (0.47; 1.03)	**0.070**	0.72 (0.51; 1.04)	**0.078**
	Other	0.77 (0.25; 2.35)	0.642	0.80 (0.27; 2.34)	0.678
Marital status	Never in union	1 (ref)		1 (ref)	
	Married	0.92 (0.29; 2.93)	0.887	0.91 (0.31; 2.72)	0.870
	Living with partner	0.53 (0.16; 1.75)	0.299	0.57 (0.18; 1.80)	0.342

	Widowed	1.21 (0.66; 2.25)	0.529	0.96 (0.56; 1.66)	0.888
	Divorced	0.80 (0.46; 1.39)	0.424	0.70 (0.40; 1.21)	0.201
	Separated	0.98 (0.55; 1.72)	0.937	0.80 (0.44; 1.45)	0.464
Employment status	Employed currently	1 (ref)		1 (ref)	
	Not employed	0.82 (0.66; 1.03)	**0.094**	0.89 (0.73; 1.08)	0.244
Media Exposure	None	1 (ref)		1 (ref)	
	Did one less than once a week	0.78 (0.58; 1.04)	0.091	0.86 (0.65; 1.13)	0.269
	Newspaper at least once a week	1.30 (0.77; 2.21)	0.319	1.19 (0.67; 2.07)	0.551
	Radio at least once a week	0.86 (0.64; 1.16)	0.329	1.11 (0.83; 1.47)	0.488
	TV at least once a week	1.04 (0.70; 1.53)	0.859	0.88 (0.64; 1.21)	0.433
	All 3	0.96 (0.59; 1.62)	0.859	0.74 (0.46; 1.20)	0.224
Parity	0 births	1 (ref)		1 (ref)	
	1-3 births	0.85 (0.61; 1.18)	0.339	0.96 (0.71; 1.29)	0.787
	>3 births	0.64 (0.40; 1.03)	0.067	0.81 (0.54; 1.24)	0.337
Highest Education Level	None	1 (ref)		1 (ref)	
	Primary	2.02 (0.57; 7.15)	0.274	1.75 (0.61;5.06)	0.142
	Secondary	1.66 (0.47; 5.88)	0.428	1.50 (0.52;4.32)	0.260
	Higher	1.51(0.40; 565)	0.543	1.50 (0.49; 4.55)	0.312

Key: AOR(Adjusted Odds Ratio); CI(Confidence Interval); ref(reference)

3.6 Predictors of ITN uptake and utilisation after adjusting for spatial random effects

3.6.1 Conditional Autoregressive (CAR) Model: Individual level analysis

A CAR model was fitted using the same variables from the logistic regression in objective 2 excluding the province variable as this would be accounted for in the spatial modelling. Table 3.11 is summary of the fixed effects on uptake of ITNs, which is similar to the random effects model, with differences in confidence intervals. After adjusting for spatial random effects, age (AOR 1.02, 95% BCI 1.01; 1.19) and person with final say on respondent's health (AOR 0.68 , 95% BCI (0.48; 0.95) were significant predictors of ITN uptake. The structural random effects of ITN uptake are summarized in the map in figure 3.4. This map shows that in comparison to Harare, probability of high ITN uptake is seen in several Mashonaland West districts such as Makonde, Zvimba and Murehwa as well as several districts in Matabeleland North region such as Hwange, Nkayi and Bubi (you may refer to map in figure 3.2 for names of districts).

Table 3.11 shows the fixed effects on ITN utilisation. After adjusting for spatial random effects, age was a significant predictor of ITN utilisation, AOR 1.03 (95% BCI 1.01; 1.05). Figure 3.4 shows the probability of ITN uptake in different districts as a summary of the random effects, with probability of highest utilisation in Matabeleland North and South regions as well as the Mashonaland West districts. Of note are areas where uptake was high which show low utilisation such as Chiredzi district.

Table 3.11: CAR model results

Characteristic	Category	Uptake AOR(95% BCI)	Utilisation AOR(95% BCI)
Age		1.02(**1.01; 1.19**)	1.03(**1.01; 1.05**)
Age of household head		1.00(0.99; 1.01)	1.00(0.99; 1.01)
Wealth Quantile	Poorest	1 (ref)	1 (ref)
	Poorer	1.30 (0.96; 1.77)	1.65 (1.03; 2.65)
	Middle	1.30 (0.95; 1.80	0.96 (0.55; 1.65)
	Richer	1.21(0.88; 1.66)	1.65(1.01; 2.75)
	Richest	1.38 (0.96; 1.97)	1.17 (0.65; 2.11)
Household Size	Less than 3 members	1 (ref)	1 (ref)
	4-6 members	1.14 (0.93; 1.40)	1.00 (0.73; 1.37)
	>6 members	1.25 (0.96; 1.62)	0.78 (0.50; 1.99)
Person with final say on respondent's health	Respondent	1 (ref)	1 (ref)
	Respondent & partner	1.04 (0.82; 1.31)	1.02 (0.71; 1.47)
	Partner only	0.68 (**0.48; 0.95**)	1.13 (0.81; 2.17)
	Other	0.82 (0.28; 2.25)	0.59 (0.05; 3.56)
Marital status	Never in union	1 (ref)	1 (ref)
	Married	0.98 (0.34; 2.72)	0.64 (0.06; 3.96)
	Living with partner	0.68 (0.22; 2.00)	1.22 (0.52; 2.61)
	Widowed	1.11(0.66; 1.89)	1.06(0.66; 1.55)
	Divorced	0.67 (0.39; 1.13)	0.87 (0.54; 1.40)
	Separated	0.95 (0.54; 1.65)	0.41 (0.15; 1.20)
Employment status	Not Employed	1 (ref)	1 (ref)
	Currently employed	0.86 (0.72; 1.04)	1.10 (0.81; 1.49)
Media Exposure	None	1 (ref)	1 (ref)
	Did one less than once a week	0.82 (0.63; 1.07)	0.91 (0.60; 1.39)
	Newspaper at least once a week	1.07 (0.63; 1.83)	1.07 (0.63; 1.83)
	Radio at least once a week	1.000 (0.67; 1.22)	1.000 (0.67; 1.22)
	TV at least once a week	0.90 (0.76; 1.32)	0.90 (0.76; 1.32)
	All 3	0.82 (0.73; 1.29)	0.82 (0.73; 1.29)
Parity	0 births	1 (ref)	1 (ref)
	1-3 births	0.97 (0.73; 1.29)	1.06 (0.66; 1.73)
	>3 births	0.79 (0.53; 1.18)	1.11 (0.59; 2.08)
Highest Education Level	None	1(ref)	1(ref)
	Primary	1.88 (0.75; 4.95)	0.58 (0.20; 2.01)
	Secondary	1.59 (0.64; 4.18)	0.51 (0.17; 1.79)
	Higher	1.46 (0.55; 4.03)	0.60 (0.18; 2.28)

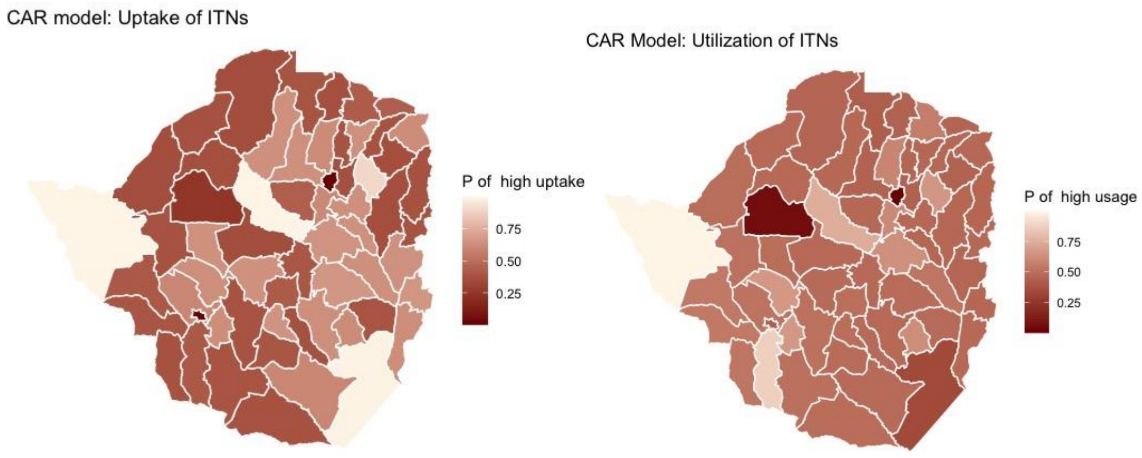

Figure 3.4: Predicted probabilities of ITN uptake and utilisation from CAR models

3.6.2 Simultaneous Autoregressive Modelling: Analysis at Ecological level

To obtain continuous variables to use in the SAR model, probability propensity scores were generated from the multi-level logistic models in objective 2. To prevent overfitting, levels of variables that were significant or marginally significant in the logistic model were chosen to fit the SAR models. Three models were fitted for both outcomes and the model with the spatial lag on the dependent variable was chosen for both outcomes. The models were selected based on having the lowest AIC and having a significant Wald test of spatial terms.

3.6.2.1 SAR modelling for Uptake of ITNs

Table 9 shows results of the simultaneous autoregressive model for uptake of ITNs. The prevalence of ITN uptake increased with increasing age in any district. That increase causes a further increase in uptake prevalence in neighbouring districts. These are known as spill over effects and are displayed in table 3.12 as indirect effects. The higher the employment rates, the lower the uptake rates for any district. Table 3.12 shows margins of uptake rates at different employment rates to further illustrate the negative effect of employment on ITN uptake in the districts. The model is summarized by equation .

$$Y = 34.84 + 0.33X_1 - 0.05X_2 - 0.10X_3 + 0.30WY + \varepsilon$$

Equation 3.1: Dependent lag SAR model for Uptake

Where Y is the dependent variable, uptake, 34.84 is the intercept, 0.30 is the spatial autocorrelation coefficient, W is the spatial weights matrix, X_1, X_2, and X_3 are the independent variables with their respective slopes and ε are the spatially independent errors.

Table 3.12: SAR model for ITN uptake

Variable	Direct Impact	p-value	Indirect Impact	p-value	Total Effect	p-value
Age	0.34	0.073	0.12	0.158	0.46	0.082
Employed	-0.10	0.003	-0.04	0.078	-0.14	0.008
Partner has final say	-0.05	0.441	-0.02	0.462	-0.07	0.443
Intercept	34.84	<0.0001				
Spatial term	0.30	0.0007				

Table 3.13: Predicted margins of ITN uptake

	Margins % Uptake
Baseline	54.40
+20%increase in employment rate	51.64
-20% increase in employment rate	57.16

Figure 3.5 below are two maps representing the full information mean and the spatially dependent residual errors. The full information mean is the mean that is predicted for the dependent variable conditional on the independent variables, and any spatial lags of the independent variables (42). The map shows high uptake in parts of Matabeleland North (Hwange, Lupane, Tsholotsho, Nkayi) and Mashonaland West regions (Binga, Gokwe, Kariba). The residual map shows the residuals errors including any autoregressive error terms (42).

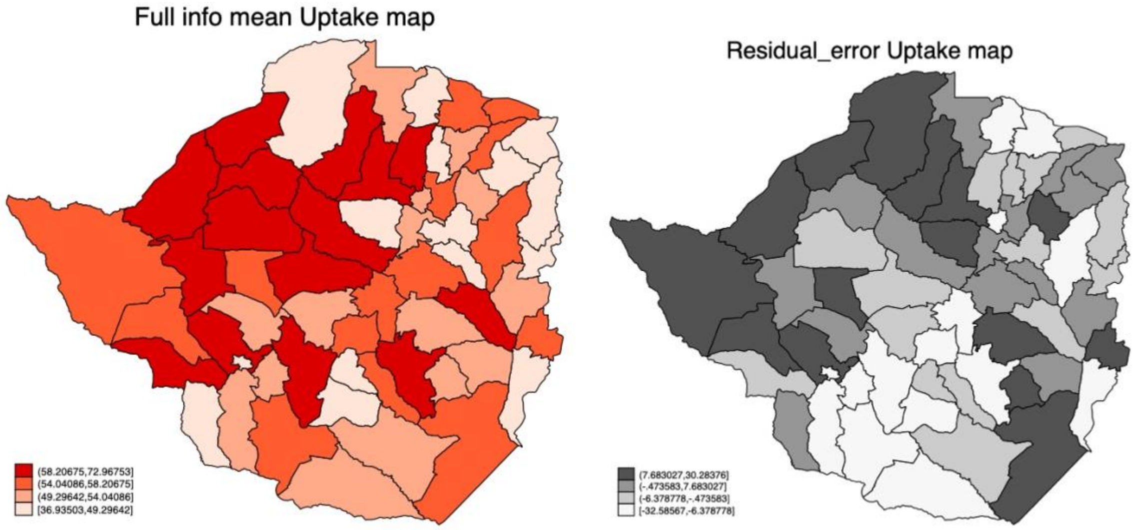

Figure 3.5: Prediction full mean and residuals of ITN uptake from SAR model

3.6.2.2 SAR modelling for Utilisation of ITNs

Table 3.14 shows results of SAR model for utilisation of ITNs. The prevalence of ITN utilisation increased with increasing age in that district. Table 3.14 shows margins of utilisation with a 5-year increase and decrease in age. The model is summarized by equation 3.2.

$$Y = 2.34 + 0.15X_1 - 0.16X_2 + 0.53X_3 + 0.22WY + \varepsilon$$

Equation 3.2: Dependent lag SAR model for Utilisation

Where Y is the dependent variable, uptake, 2.34 is the intercept, 0.22 is the spatial autocorrelation coefficient, W is the spatial weights matrix, X_1, X_2, and X_3 are the independent variables with their respective slopes and ε are the spatially independent errors.

Table 3.14: SAR model for ITN utilisation

Variable	Direct Impact	p-value	Indirect Impact	p-value	Total Effect	p-value
Age	0.24	0.003	0.08	0.215	0.32	0.010
Partner has final say	-0.02	0.533	-0.01	0.570	-0.03	0.536
Richer wealth quantile	-0.04	0.051	-0.01	0.226	-0.05	0.056
Intercept	2.16	0.451				
Spatial term	0.28	0.0614				

Table 3.15: Predicted margins for ITN utilisation

	Margins % Uptake
Baseline	11.05
5 year increase in age	12.67
5 year decrease in age	9.43

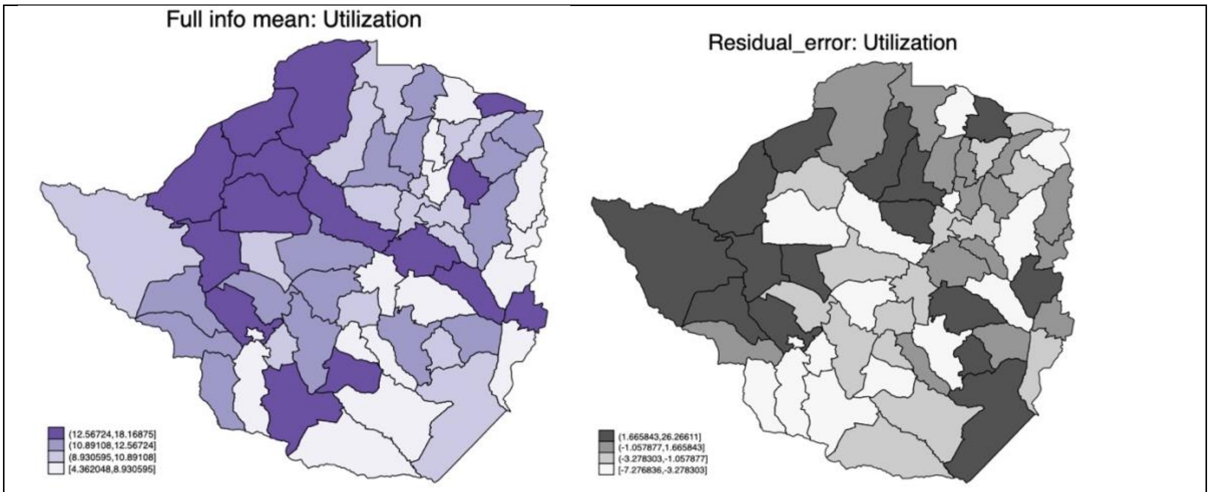

Figure 3.6: Prediction full mean and residuals of ITN utilisation from SAR model

Figure 3.6 above are two maps representing the full information mean and the spatially dependent residual errors on ITN utilisation. The map shows high utilisation in parts of Matabeleland North (Hwange, Lupane, Tsholotsho, Nkayi) and Mashonaland West regions (Binga, Gokwe, Kariba). The residual map shows the residuals errors including any autoregressive error terms.

3.6.3 Intrinsic Bayesian Multivariate Conditional Autoregressive model results for combined effect of ITN uptake and utilisation

To determine the correlation between ITN uptake and ITN utilisation, an intrinsic Bayesian multivariate CAR model was fitted. The results shown in table 3.16 display a significant positive correlation between the 2 outcomes, with a positive posterior correlation parameter of **0.96** (95% BCI 0.80; 0.99). The maps in Figure 3.7 show the different posterior means of the odds ratio from the models fitted for the 2 outcomes (uptake on the left and utilisation on the right). These two maps (figure 3.7) show that areas with high likelihood of uptake also have high utilisation of ITNs

Table 3.16: Correlation between ITN uptake and utilisation results

Parameter	Mean	95% Bayesian Credible Interval
Alpha 1	-0.037	-0.12; 0.05
Alpha 2	-0.106	-0.22; -0.001

Correlation	0.96	0.80; 0.99
Sigma 1	0.475	0.05; 0.10
Sigma 2	1.267	0.76;2.08

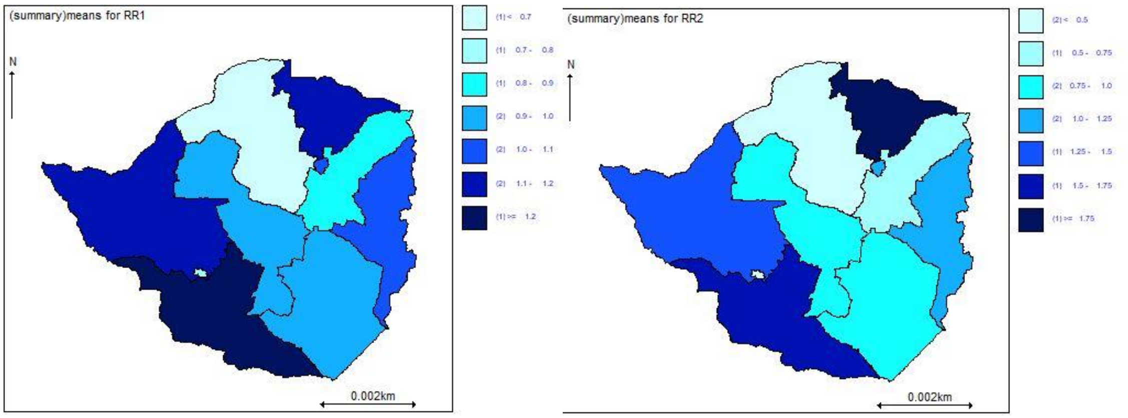

Figure 3.7: Summarized Random Effects from Intrinsic Bayesian CAR model

In this chapter we presented all the results from the analysis in detail. To summarize, we found that most of the explanatory variables had significant association with both outcome variables in bivariate analysis, before adjusting for all factors. After adjusting for all factors, including spatial random effects age and person with final say on respondent's health were significant predictors of ITN uptake amongst women of childbearing age. Age was a significant predictor of both ITN uptake and utilisation. In the following chapter we will discuss and interpret the major findings of this study.

Chapter 4 Discussion and conclusion

Malaria in pregnancy remains a major public health problem in the low-income countries. Consistent and correct use of ITNs can prevent a significant number of infections. It is therefore imperative to understand the uptake and use of ITNs amongst women of childbearing age to aid in making policies that improve use of this efficacious intervention. This study aimed to determine uptake, utilisation and spatial distribution of ITN uptake amongst women of childbearing age in Zimbabwe in 2015 using data collected in the 2015 Zimbabwe Demographic Health Survey. The findings of this study are discussed and interpreted in this chapter along with the strengths and limitations of the study and then the concluding remarks.

4.1 Discussion of main result findings

In this study we showed that uptake and utilisation of ITNs is influenced by a mixture of individual, household and spatial determinants. A key finding in this study was an ITN uptake of 45.66%, well below the 80% coverage recommended by WHO (11). This was associated with an even lower ITN utilisation of 8.13%. A utilisation this low meant only 18.96% of women who owned an ITN slept under one.

4.1.1 ITN uptake and utilisation

Several studies done in the sub-Saharan region report comparable results with suboptimal uptake and utilisation (20,21). Intriguingly, less than half of women who owned an ITN slept under one, insinuating causes beyond adequate access. The survey was however conducted between July and December 2015. Malaria transmission peaks between November and June meaning that some women were interviewed before the malaria transmission season and this may partly explain low utilisation. Other likely drivers of low utilisation are knowledge, attitudes and perceptions toward both malaria and ITNs. A study done in Chipinge district by Sande et al. found that difficulty in mounting ITNs and unavailability of related accessories to hang ITNs were major causes of poor ITN use amongst a population which was very perceptive of ITNs as an effective method to prevent malaria (47). Other studies have reported that failure to use an available ITN was caused by various reasons such as discomfort, inconvenience, lack of knowledge and preference to use other malaria prevention methods, and this may also explain the gap found in this study (48–50).

Of note, the low uptake and utilisation of ITNs reported in this study are inconsistent with an antenatal care coverage of 93% reported in 2015 (40). Between 2013 and 2014, the National Malaria Control Program (NMCP) in Zimbabwe has attempted to increase access to ITNs through mass distribution and provision through antenatal services (17). Provision of ITNs through antenatal care has been shown to improve ownership and use of ITNs amongst pregnant women (51). Possible explanations for this discord between ITN uptake and ANC coverage may include net stock-outs at local clinics and possibly health care worker delivery issues. For instance, in Nigeria, a study showed that a proportion of healthcare workers do not adhere fully to provision of malaria preventive services (52).

4.1.2 Age differentials on uptake and utilisation

In this study, age was a significant predictor of both ITN uptake and use. Older women were more likely to own and to sleep under an ITN. Our findings are relatable to other studies. Olapeju et al. observed that amongst women of childbearing age, those aged between 30 and 40 years were more likely to use ITNs when compared to younger women (53). Malaria prevention programmes usually focus on ensuring under-five children have access to nets through clinic visits and attendance at routine vaccination visits (54). Older women were more likely to have at least one child and would have been exposed to malaria prevention awareness information and access to ITNs during an antenatal clinic visit or routine immunization visit.

4.1.3 Health Autonomy as a predictor of ITN uptake

Our study showed that person with final say on respondent's health was a significant predictor of ITN uptake. The results showed that women whose partners made decisions on their behalf were less likely to own an ITN, and that women who had full autonomy over their own health were more likely to own an ITN. This is highly consistent with current existing knowledge. Nkoka et al. reported that ITN ownership and use were highest amongst women who lived in communities were women had high autonomy in health decisions (26). Women empowerment has been linked with increased uptake of maternal health services and better health outcomes (55–57). This is not a surprising fact, as women empowerment and autonomy is also usually associated with older age, being employed and a higher education level, which are all factors that have been associated with high utilisation of maternal health services (58,59).

4.1.4 Spatial Distribution of ITN uptake and utilisation

We observed extensive spatial heterogeneities with both uptake and utilisation of ITNs. Participants residing in Mashonaland West and Matabeleland North were the most likely to live in a household with at least one ITN and were more likely to have slept under the ITN, while those from Bulawayo and Harare were the least likely to own and use an ITN. Regional differences in ITN uptake and utilisation are to be expected.

Seven out of the ten Zimbabwean provinces are considered to have moderate to high malaria transmission. Highest prevalences of malaria are seen in Manicaland, Mashonaland East, Mashonaland Central, Mashonaland West, Matabeleland North and some parts of Matabeleland South. Before mass distribution of ITNs in 2013, there was targeted ITN distribution between 2008 and 2010, which focused on providing ITNs to people living in high transmission zones (44). Malaria endemic areas are more likely to be targeted by anti-malaria campaigns and other mass programs that focus on malaria prevention.

Large provincial cities such as Harare and Bulawayo showed the lowest ITN uptake and utilisation. This may be explained by several factors. Firstly, both provinces experience very low malaria transmission rates so women living in these provinces may not perceive the necessity of owning an ITN. Secondly, people who live in large cities may have access and higher preference towards other malaria prevention methods such as mosquito coils and mosquito repellents. These regional differences in ITN uptake have been noted by other authors in literature and have been attributed to heterogenous transmission of malaria (27,60).

The spatial heterogeneity of ITN uptake and utilisation is consistent with the heterogenous spatial distribution of malaria transmission in Zimbabwe. However, low uptake and utilisation of ITNs in districts with high malaria transmission such as Nyanga district remains unexplained. The maps also showed that some areas with high uptake had low utilisation. For example, Chiredzi district showed very high ITN uptake with very low ITN use, highlighting a major implementation gap.

4.1.5 Predictors of ITN uptake and Utilisation after adjusting for spatial random effects

After adjusting for spatial random effects in the CAR model, we saw that we still had the same predictors for both ITN uptake and utilisation, with more precise confidence intervals. This shows us that we obtained more precise estimates with spatial modelling. Both ITN uptake and utilisation amongst women of childbearing age cannot simply be attributed to socio-demographic predictors but spatial analysis helped explain these as the factors behind observed spatial patterns. Districts where women had higher health autonomy had higher ITN uptake rates. The ecological SAR model for uptake further showed that after adjusting for spatial random effects at district level, being employed was negatively associated with ITN uptake. Districts with higher employment rates had lower ITN uptake rates. A probable explanation is that employed women are less likely to attend public immunization programs and ANC clinics were anti-malaria campaigns are common. At ecological level, age was the single predictor of ITN use. Districts with older women had higher ITN utilisation rates.

ITN uptake and utilisation had high positive spatial correlation, further showing that geographical factors that influence ITN uptake also influence ITN utilisation and therefore policies can be made to collectively improve both ownership and use of ITNs.

4.2 Strengths and Limitations

The strengths and limitations of this study are grouped into four main classes: classification of variables, generalisability of results, confounding and robustness of methods used. These are described sequentially in the following paragraphs.

4.2.1 Classification of variables

One major strength of this research report was that there were several variable classifications at individual level depicting the person, place and time (socio demographic, household, geographical) and also ecological (mainly geographical level cluster, district and province). Another strength from this was being able to extract the wealth of data from the individual level variables to inform the ecological variable-based models. However, due to the cross-sectional study design, time varying covariates such as seasonal changes in use of ITNs could not be measured, given that malaria transmission is seasonal in some areas. Additionally the data was not originally collected to address our research question meaning several important covariates could not be investigated, such knowledge and perceptions of ITNs, as well as other institutional determinants

4.2.2 Generalisation of result findings

The data came from a nationally representative sample incorporating participants from all Zimbabwean districts making our results generalizable to Zimbabwean women of childbearing age. Additionally we had a large sample size, giving our study sufficient statistical power. Spatial heterogeneity that was observed in our study has also been observed with other studies done in sub-Saharan region(27,60). Our study findings can further inform future interventional studies aimed at understanding causes of low uptake and utilisation of ITNs.

4.2.3 Confounding adjustment and bias reduction

This study was subject to two forms of bias, recall bias and selection bias. The recall bias may have been present because most of the variables were self-reported, such as the question which asked whether respondent slept under an ITN the night before and wealth index variables. Selection bias may have occurred due to inherent differences between pregnant women and non-pregnant women of child-bearing age. For example we saw differences in age and other sociodemographic differences between the two populations. We attempted to address this bias using propensity score matching. There was some reduction in bias and this can be seen as a strength in our study. The multi-level logistic regression models which took into account spatial random effects improved the strength of our inferences by controlling for most possible confounders.

4.2.4 Robustness of analysis methods employed

Another major strength of this study was the use of several analysis approaches, beginning with simple logistic models that were compared with the random effects model. This approach led to more robust inferences because the clustering in the sample was accounted for. Furthermore, we incorporated a model with structural random effects using the CAR models with further narrowing of confidence intervals demonstrating an improvement in parameter estimation.

4.3 Conclusions and Recommendations

Besides the areas more prone to malaria than others, poverty in Zimbabwe is a major driver to uptake or none of interventions such what this study aimed to investigate. The spatial investigation demonstrates clearly worse uptake and utilisation in Harare, the economic hub of the nation. This then manifests itself in poor education and decision making latitude in these women.

The poor rates of ITN uptake and utilisation show us that there is a need to find strategies to increase these by our health systems. There is a need to upscale mass distribution campaigns to target women through promotion of utilisation of primary health care services. Also, the huge gap between uptake and utilisation is a sign that continuous education and reminders are important in making sure that women consistently use ITNs and are protected against malaria. Further research is needed to understand the reasons behind the low uptake and utilisation as well as understanding this gap. These further studies should also look at institutional and health provider factors that may be influencing the uptake of ITNs.

The finding that women whose partners made decisions on their behalf had lower rates of ITN uptake highlights the importance of women empowerment and promotion of gender equal rights. Even though uptake was spatially distributed, the results showed that there were areas with high malaria burden, such as Nyanga district, that still showed low uptake and low ITN use. Policy makers should consider community-led approaches in educating the masses on the importance and correct use of ITNs, especially in those areas that showed low uptake and utilisation of ITNs. There is evidence in literature that show that these approaches do improve use of ITNs (61).

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Appendix A Supporting Documents

A.1 Ethics Certificate

UNIVERSITY OF THE
WITWATERSRAND,
JOHANNESBURG

R 14/49 Dr Chipo Mudzingwa

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M201188

NAME: (Principal Investigator)	Dr Chipo Mudzingwa
DEPARTMENT:	School of Public Health
PROJECT TITLE:	Uptake, utilisation and spatial distribution of insecticide treated mosquito nets amongst pregnant women in Zimbabwe in 2015
DATE CONSIDERED:	27/11/2020
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Prof Eustasius Musenge
APPROVED BY:	Dr CB Penny, ~~Chairperson~~, HREC (Medical)
DATE OF APPROVAL:	25/01/2021

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and ONE COPY returned to the Research Office Secretary on the Third Floor, Faculty of Health Sciences, Phillip Tobias Building, 29 Princess of Wales Terrace, Parktown, 2193, University of the Witwatersrand. I/we fully understand the conditions under which I am/we are authorized to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to resubmit the application to the Committee. I agree to submit a yearly progress report. The date for annual re-certification will be one year after the date of convened meeting where the study was initially reviewed. In this case, the study was initially reviewed in November and will therefore be due in the month of November each year. Unreported changes to the application may invalidate the clearance given by the HREC (Medical).

Principal Investigator Signature   Date 14 April 2021

A.2 Turnitin Report

2374183: Chipo Mudzingwa

ORIGINALITY REPORT

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Student 's Signature ____________ 22 June 2021

Supervisor's Signature 23-June-2021

A.3 Plagiarism Declaration

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

FACULTY OF HEALTH SCIENCES

PLAGIARISM DECLARATION TO BE SIGNED BY ALL HIGHER DEGREE STUDENTS

SENATE PLAGIARISM POLICY: APPENDIX ONE

I CHIPO MUDZINGWA (Student number: 2374183) am a student registered for the degree of MSC EPIDEMIOLOGY IN THE FIELD OF IMPLEMENTATION SCIENCE in the academic year 2020.

I hereby declare the following:

- I am aware that plagiarism (the use of someone else's work without their permission and/or without acknowledging the original source) is wrong.
- I confirm that the work submitted for assessment for the above degree is my own unaided work except where I have explicitly indicated otherwise.
- I have followed the required conventions in referencing the thoughts and ideas of others.
- I understand that the University of the Witwatersrand may take disciplinary action against me if there is a belief that this is not my own unaided work or that I have failed to acknowledge the source of the ideas or words in my writing.
- I have included as an appendix a report from "Turnitin" (or other approved plagiarism detection) software indicating the level of plagiarism in my research document.

Signature: Date: 22 JUNE 2021

Appendix B Do files and Syntax Used in Analysis

B.1 Measurement of Variables

Table 4.1 Measurement of Outcome Variables

Variable	Method of measurement
Uptake	Binary variable categorized into Yes uptake and No uptake. This was derived from a question in the interview were the interviewer asked if the mosquito net in the household was a factory-treated net or a net that has been soaked with insecticide within the past 12 months.
Utilisation	Ordinal variable categorized into No uptake, Uptake only and utilized. This information was obtained by asking whether respondent slept under an ITN the previous night.

Table 4.2: Measurement of Explanatory variables

Variable	Method of Measurement
Age of respondent	Continuous variable calculated as a difference between the day the interview was conducted and the birthday of the respondent.
Age of household head	Continuous variable calculated as a difference between the day the interview was conducted and the birthday of the household head.
Sex of household head	Binary variable recorded as either male or female.
Province of residence	Recorded by interviewer based on where interview was conducted. Multi-nominal variable classified into 10 provinces- Harare, Bulawayo, Masvingo, Midlands, Matabeleland North, Matabeleland South, Mashonaland East, Mashonaland West and Mashonaland Central.
Wealth Index	Composite measure of a household's cumulative living standard. It was calculated based on self-reported ownership of certain items such as television, bicycle, household construction material and type of water access and then generated using principal components analysis. It was then categorized into five wealth quantiles; poorest, poorer, middle, rich and richer (45).
Media exposure	A multinominal variable constructed from 3 variables which were reads the newspaper, listens to the radio and watches tv. The final variable was then categorized into no media exposure, minimal exposure (which meant the respondent did one of the things less than once a week), reads newspaper at least once a week, listens to the radio at least once a week, watches TV at least once a week and lastly does all three at least once a week.
Person with final say on respondent's health	Multi-nominal variable divided into 4 categories- respondent only, respondent and partner, partner alone and someone else.
Religion	Categorized into Traditional, Roman Catholic, Pentecostal, Protestant, Apostolic Sect, Other Christian religion, None and Other.
Household size	This was initially a continuous variable which was categorized into three groups: less than 4 members, 4-6 members and more than 6 members.
Parity	Originally a continuous variable categorized into three groups: 0 previous births, 1-3 births and more than 3 births.

Employment Status	A binary variable: Employed and Not Employed. Employed category included all respondents that were currently employed and those that had been employed in the last 12 months.
Marital Status	A multinomial variable with never in union, married, lives with partner, divorced, no longer living with partner.
Highest level of Education	A multi-nominal variable with None (No education), Primary, Secondary and Higher levels as categories.

B.2 Propensity Score Matching

```
set seed 1712
gen x=uniform()
sort x, stable
***Kernel density plots before matching
tw (kdensity hhsize if pregnancy==1) (kdensity hhsize if pregnancy==0), title("Before matching") ytitle(householdsize)
legend(order(1 "not pregnant" 2 "pregnant")) saving(before)
logit pregnancy under5
predict double pscore
psmatch2 pregnancy ,outcome(uptake) pscore(pscore) odds noreplacement descending
rename _weight newtreat
replace newtreat=0 if newtreat==.
psmatch2 newtreat ,outcome(uptake) pscore(pscore) odds noreplacement descending
drop if _weight==.
psgraph, treated(pregnancy) pscore(pscore) bin(50)
pstest hhsize parity under5
tw (kdensity hhsize if prgnancy==1 & _weight>0) (kdensity hhsize if pregnancy==0 & _weight>0 ), title("After matching")
ytitle(householdsize) legend(order(1 "not pregnant" 2 "pregnant")) saving(after)
graph combine "before" "after"
```

B.3 R codes for CAR model

```
##Reading in the data
INLAdata <- haven::read_dta("Conditional.dta")

###Choosing vaariables to be included in the model
zim_itn_model <- INLAdata %>%
 select(id_2 , id_2, used, uptake, v012, v152, v501, v190, employed, v106, v743a, media_exposure, parity, hhsize)
zim_itn_model <- zim_itn_model[complete.cases(zim_itn_model),]
###Reading in the map
zim_OGR <- rgdal::readOGR("ZWE_adm/ZWE_adm2.shp")
plot(zim_OGR, border = "blue", axes = TRUE, las = 1)
zim_valid <- data.table(valid = gIsValid(zim_OGR, byid = TRUE))
sum(zim_valid$valid == F)

## Creating contiguity matrix
zim_nb <- spdep::poly2nb(zim_OGR)
num <- sapply(zim_nb, length)
adj <- unlist(zim_nb)
sumNumNeigh <- length(unlist(zim_nb))

# Spatial model in INLA
nb2INLA("ZWE_adm/zim_inla.graph", zim_nb)
zim_adj <- paste(getwd(), "/ZWE_adm/zim_inla.graph", sep = "")
```

```
#generate adjacency
H <- inla.read.graph(filename = "ZWE_adm/zim_inla.graph")
image(inla.graph2matrix(H), xlab = "", ylab = "")
##fitting CAR model for uptake
formula_inla1 <- uptake ~ 1 + v012 + v152 + as.factor(v501) + as.factor(v743a) + as.factor(v190) + as.factor(hhsize) +
as.factor(employed) + as.factor(v106) + as.factor(media_exposure) + as.factor(parity) +
 ##our CAR specification
 f(id_2, model="bym",graph=zim_adj, scale.model=TRUE, ## spefiying the priors for the unstri and str
  hyper=list(prec.unstruct=list(prior="loggamma",param=c(1,0.001)),
prec.spatial=list(prior="loggamma",param=c(1,0.001))))
model_inla1 <- inla(formula_inla1,family="binomial", data=INLAdata, control.compute=list(dic=TRUE))
summary(model_inla1)
####The  computation of the posterior mean for the random effects ξ is performed in two
# steps as we have more than one parameter:
# we extract the marginal posterior distribution for each element of the random effect
csi1 <- model_inla1$marginals.random$id_2[1:60]
# *** Code for posterior probablity
a <- 0
prob_csi1 <- lapply(csi1, function(x) {1 - inla.pmarginal(a, x)})## for each location estimate the probability in continous
cont_prob_csi1 <- data.frame(maps_cont_prob_csi1=unlist(prob_csi1)) %>%
 tibble::rownames_to_column("id_2") %>%
 mutate(id_2=gsub("index.","",id_2))
maps_cont_prob_csi1 <- cont_prob_csi1
## for each location estimate the probability in groups
prob_csi_cutoff <- c(0,0.2,0.3,0.4,0.6,1) ## can change accordingly
cat_prob_csi1 <- cut(unlist(prob_csi1),
          breaks=prob_csi_cutoff,
          include.lowest=TRUE)


maps_cat_prob_csi1 <- data.frame(id_2=unique(zim_itn_model$id_2), ## check whether it joins well
               cat_prob_csi1=cat_prob_csi1)
maps_cat_prob_csi1$id_2 <- as.character(maps_cat_prob_csi1$id_2)
zim_shp_df1 <- broom::tidy(zim_OGR, region = "ID_2")
zim_shp_df1 <- zim_shp_df1 %>%
 left_join(maps_cat_prob_csi1, by=c("id"="id_2")) %>%
 left_join(maps_cont_prob_csi1, by=c("id"="id_2"))
glimpse(zim_shp_df1)
p2 <- ggplot() +
 geom_polygon(data = zim_shp_df1, aes(x = long, y = lat,
                 group = group,
                 fill = maps_cont_prob_csi1),
        colour = "white") + theme_void() +
 ggtitle("CAR model: Uptake of ITNs") + labs(fill = "P of high uptake") +
 scale_fill_continuous(high = "#fff7ec", low = "#7F0000")
p2
```

B.4 Stata code for generating expected values for WinBUGS model

```
total ID
gen GT=2444
total owns_net
gen CT_uptake=1136
gen exp_uptake=(ID* CT_uptake)/ GT
total used_ITN
gen CT_usage=245
gen exp_usage=(ID* CT_usage)/ GT
```

B.5 WinBUGS Code for Intrinsic Bayesian CAR model

```
model {
        # Likelihood
                for (i in 1 : Nareas) {
                        for (k in 1 : Ndiseases) {
                                Y[i, k] ~ dpois(mu[i, k])
        # Note dimension of S is reversed:
                                log(mu[i, k]) <- log(E[i, k]) + alpha[k] + S[k, i]
        # rows=k, cols=i because mv.car assumes rows represent variables
        # (diseases) and columns represent observations (areas).
                        }
        # The GeoBUGS map tool can only map vectors, so need to create separate vector
        # of quantities to be mapped, rather than an array (i.e. RR[i,k] won't work!)
        # area specific relative risk for disease 1 (oral)
                        RR1[i] <- exp(alpha[1] + S[1, i])
        # area specific relative risk for disease 2 (lung)
                        RR2[i] <- exp(alpha[2] + S[2, i])
                }

        # MV CAR prior for the spatial random effects
        # MVCAR prior
                S[1:Ndiseases, 1 : Nareas] ~ mv.car(adj[], weights[], num[], omega[ , ])
                for (i in 1:sumNumNeigh) {
                        weights[i] <- 1
                }

        # Other priors
                for (k in 1 : Ndiseases) {
                        alpha[k] ~ dflat()
                }
        # Precision matrix of MVCAR
                omega[1 : Ndiseases, 1 : Ndiseases] ~ dwish(R[ , ], Ndiseases)
        # Covariance matrix of MVCAR
                sigma2[1 : Ndiseases, 1 : Ndiseases] <- inverse(omega[ , ])
        # conditional SD of S[1, ] (oral cancer)
                sigma[1] <- sqrt(sigma2[1, 1])
        # conditional SD of S[2,] (lung cancer)
        sigma[2] <- sqrt(sigma2[2, 2])
        # within-area conditional correlation
                corr <- sigma2[1, 2] / (sigma[1] * sigma[2])
        # between oral and lung cancers.
                mean1 <- mean(S[1,])
                mean2 <- mean(S[2,])
```