Epidemiology and control profile of malaria in

# Nigeria

# Contributing authors

| Name | Affiliation |
| --- | --- |
| Audu Bala<br>Perpetua Uhomoibhi<br>Ibrahim Maikore | National Malaria Elimination Programme (NMEP),<br>Ministry of Health |
| Geoffrey Namara<br>Linda Ozor | World Health Organization Regional Office for Africa |
| Victor Alegana<br>Damaris Kinyoki<br>Viola Kurui<br>David Kyalo<br>Peter Macharia<br>Joseph Maina<br>Betsy Makena<br>Emelda Okiro<br>Paul Ouma<br>Bob Snow | Spatial Health Metrics Group, KEMRI-Wellcome Trust<br>Research Programme, Nairobi, Kenya |
| Ngozi Erondu<br>Lauren Hashiguchi<br>Ruth Lorimer<br>Caroline Lynch<br>Nicholas Dellasanta | London School of Hygiene & Tropical Medicine, UK |

This report is supplemented by several resources that were provided to the Nigeria NMEP and Ministry of Health. This includes:

- A USB drive with the following contents:
  1. Profile
     a. Nigeria 2014 and 2018 profiles
     b. Nigeria health facility database
     c. Nigeria malaria PR by state databases
     d. Nigeria vectors
     e. State mapping summaries
     f. Nigeria local government area (LGA) shapefiles
     g. Images
  2. Library
  3. Policy and Strategies
  4. Implementation & Survey Reports

- A printed timeline of malaria events in Nigeria from 1900 to 2017
- A printed poster highlighting PR and malaria indicator trends

# Acknowledgements

**Suggested citation:** Nigeria National Malaria Elimination Programme, LSHTM and KEMRI-Wellcome Trust Research Programme (2018). Nigeria: A Profile of Malaria Control and Epidemiology, 2018 Overview. A report prepared for the Federal Ministry of Health, Nigeria and the Department for International Development, UK. 2018.

# 1    Contents

**Abbreviations**

| | |
|---|---|
| AA | Artesunate-amodiaquine |
| ACCESS | Achieving catalytic expansion of seasonal malaria chemoprevention in the Sahel |
| ACPR | Adequate Clinical and Parasitological Response |
| ACTs | Artemisinin-based combinations |
| AFRO | WHO Regional Office for Africa |
| AL | Artemether-lumefantrine |
| AMFm | Affordable Medicines for Malaria |
| ANC | Antenatal care |
| ASTER | Advanced Spaceborne Thermal Emission and Reflection Radiometer |
| BASICS | Basic Support for Institutionalizing Child Survival |
| BHCPF | Basic Health Care Provision Fund |
| BS | *Bacillus sphaericus* |
| BTI | *Bacillus thurigiensisvarisraelensis* |
| CHAI | Clinton Health Access Initiative |
| CORPS | Community-oriented resource persons |
| CQ | Chloroquine |
| DDT | Dichloro-diphenyl-trichloroethane |
| DEM | Digital Elevation Models |
| DETETs | Drug therapeutic efficacy tests |
| DFID | Department for International Development |
| DHIS 2 | District Health Information Systems 2 |
| DHS | Demographic and Health Survey |
| EPI | Expanded Programme on Immunisation |
| EVI | Enhanced Vegetation Index |
| FAO | Food and Agricultural Organization |
| FCT | Federal Capital Territory |
| FMoH | Federal Ministry of Health |
| GAUL | Global Administrative Unit Layers |
| GDP | Gross domestic product |
| GDEM V2 | Global Digital Elevation Model Version 2 |
| GIS | Geographic Information Systems |
| GIST | Geographic Information Support Team |
| GLWD | Global Lakes and Wetlands Database |
| GMEP | Global Malaria Eradication Programme |
| GPS | Global Positioning Systems |
| GRUMP | Global Rural-Urban Mapping Project |
| HIV/AIDS | Human immunodeficiency virus/acquired immunodeficiency syndrome |
| iCCM | Integrated community case management |
| ICJ | International Court of Justice |
| IHVN | Institute of Human Virology, Nigeria |
| IMF | International Monetary Fund |
| IMR | Infant mortality rate |
| INFORM | Information for Malaria Project |

| IPTp | Intermittent preventive treatment in pregnancy |
|------|------|
| IRM | Insecticide resistance monitoring |
| IRS | Indoor residual house-spraying |
| ITN | Insecticide treated nets |
| IVM | Integrated vector management |
| JICA | Japan International Cooperation Agency |
| KEMRI | Kenya Medical Research Institute |
| LGA | Local Government Areas |
| LLIN | Long-lasting insecticidal nets |
| LSHTM | London School of Hygiene & Tropical Medicine |
| M&E | Monitoring and evaluation |
| MABA | Malaria and Anthropometric Baseline Assessment |
| MAPE | Mean Absolute Prediction Error |
| MAP | Malaria Atlas Project |
| MARA/ARMA | Mapping Malaria Risk in Africa |
| MBG | Model-based geostatistics |
| MCMC | Markov Chain Monte Carlo |
| MDG-F | Millennium Development Goals Achievement Fund |
| MDG | Millennium Development Goals |
| MICS | Multiple Indicator Cluster Survey |
| MIS | Malaria Indicator Survey |
| MMR | Maternal mortality ratio |
| MODIS | MODerate-resolution Imaging Spectroradiometer |
| MPR | Malaria programme performance review |
| MPSS | Malaria Parasite Sentinel Surveillance |
| MTR | Mid-term performance review |
| NBS | Nigeria National Bureau of Statistics |
| NDHS | National Demographic and Health Survey |
| NFELTP | Nigeria Field Epidemiology and Laboratory Training Program |
| NGO | Non-governmental organisation |
| NHIS | National Health Insurance Scheme |
| NHMIS | National Health Management Information System |
| NMCP | National Malaria Control Programme |
| NMEP | National Malaria Elimination Programme |
| NMSP | National Malaria Strategic Plan |
| NMS | National Malaria Strategy |
| NSHDP | National Strategic Health Development Plan |
| NPC | National Population Commission |
| NPopC | National Population Commission |
| NPHCDA | National Primary Health Care Development Agency NWS |
| OCHA | Office for the Coordination of Humanitarian Affairs |
| ODA | Overseas development assistance |
| PA$Pf$PR$_{2-10}$ | Population adjusted $Pf$PR$_{2-10}$ |
| $Pf$PR$_{2-10}$ | Age-corrected *Plasmodium falciparum* parasite rate |
| PHC | Primary health care |
| PMI | US President's Malaria Initiative |

| | |
|---|---|
| PSCM | Private Sector Co-Payment Mechanism |
| QAACT | Quality-assured ACT |
| RBM | Roll Back Malaria |
| RDTs | Rapid diagnostic test |
| RIA | Rapid impact assessment |
| SAE | Small area estimations |
| SALB | Second Administrative Level Boundaries |
| SDG | Sustainable Development Goals |
| SMC | Seasonal malaria chemoprevention |
| SP | Sulphadoxine-Pyrimethamine |
| SUFI | Scale-Up for Impact |
| SuNMaP | Support to National Malaria Programme |
| TrAC | Tracking Resistance to Artemisinin |
| TSI | Temperature Suitability Index |
| TWG-Malaria | Ministerial Task Team on AIDS, Tuberculosis and Malaria Technical Working Group for Malaria |
| U5MR | Under-five mortality rate |
| UHC | Universal health coverage |
| UN | United Nations |
| UNDP | United Nations Development Programme |
| UNICEF | United Nations International Children's Emergency Fund |
| USAID | United States Agency for International Development |
| WHO | World Health Organization |
| WOCBA | Woman of child-bearing age |
| WTRP | Wellcome Trust Research Programme |

# Executive summary

This report is a product of collaboration between the National Malaria Elimination Programme (NMEP), national malaria control partners, WHO Regional Office for Africa (WHO AFRO) and the LINK programme (LSHTM and the Kenya Medical Research Institute-Wellcome Trust Research Programme [KWTRP]). The profile was developed to assist the NMEP and national level partners involved in malaria control to understand the impact of recently scaled intervention coverage, define what is required to achieve universal access and to prioritise future funding needs to meet intervention ambitions or to revise recommendations to accelerate impact.

In 2013, the NMEP, Support to National Malaria Programme (SuNMaP), WHO and Information for Malaria (INFORM) Project (KEMRI-WRTP) released a comprehensive malaria control profile. The profile was the second-ever attempt to map the intensity of malaria transmission across Nigeria, building on the Mapping Malaria Risk in Africa (MARA) project. This profile improved upon the limited survey data used in the MARA maps and presented the most precise malaria risk mapping in Nigeria. The 2013 profile also examined changes in risk since the launch of Roll Back Malaria (RBM) in 2000 to support the National Malaria Control Programme (NMCP) and state-level control agencies in planning and monitoring control, presenting this data alongside programmatic and historic descriptive information. Since the release of the 2013 epidemiological profile, Nigeria has distributed over 58 million long-lasting insecticidal nets (LLINs) and completed the 2013 Demographic Health survey (DHS) and 2010 and 2015 Malaria Indicator Surveys (MIS). In addition, the country released the National Malaria Strategic Plan (NMSP) 2014-2020, which established goals and objectives to guide the next half-decade of malaria control activities.

The 2017 Nigeria malaria epidemiological profile builds upon the former and uses newly available prevalence data from the 2015 MIS and the most recent routine health data, including LLIN distribution data and vector sentinel surveillance data from Nigeria's District Health Information System 2 (DHIS 2). Additionally, community-based surveys of malaria parasite prevalence have been assembled from a variety of sources including peer-reviewed journals, international and national Ministry of Health and academic archives, personal correspondence and more recent national household sample surveys. The current profile applies a new geospatial modelling strategy to present updated maps of malaria prevalence and LLIN distribution along with updated health facility mapping, vector, climate and historical information. Unlike previous risk mapping, the 2017 profile uses data most temporally proximal to prediction dates and only predicts to years when a national MIS was undertaken— as such 934 data points are presented between 2009 and 2015.

Malaria transmission in Nigeria is best described as mostly meso- with some hyper-holodemic (above 50% $Pf$PR$_{2-10}$) areas. Thirty-five of 36 states and the Federal Capital Territory (FCT) have a $Pf$PR$_{2-10}$ above 20%; Lagos, with an estimated 9% of the population is the only exception. There was a modest change in the national intensity of transmission over the last decade; modelled estimates of $Pf$PR$_{2-10}$ decreased from 20% to 25% in 26 states, mostly in the north central and southern regions. *Plasmodium falciparum* remains the dominant malaria infection in Nigeria, though *Plasmodium malariae* was found to account for 9% of infections. *Anopheles gambiae* complex and the *Anopheles funestus* group are sympatric across the entire county.

# i. Preview of updated and new maps

This profile will present a series of maps presenting geospatially-represented data. Here we overview the maps for quick reference.

**Panel 1** Maps of covariates for parasite prevalence model

Population distribution of Nigeria
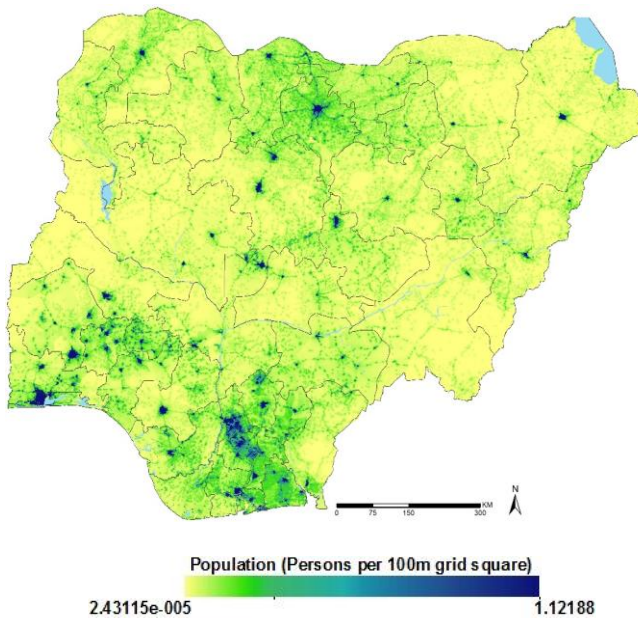
Elevation/topography of Nigeria
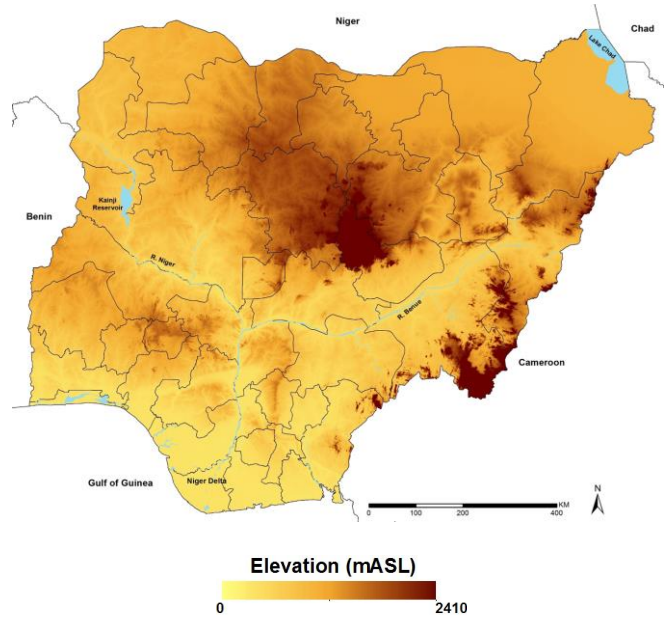


Annual precipitation in Nigeria
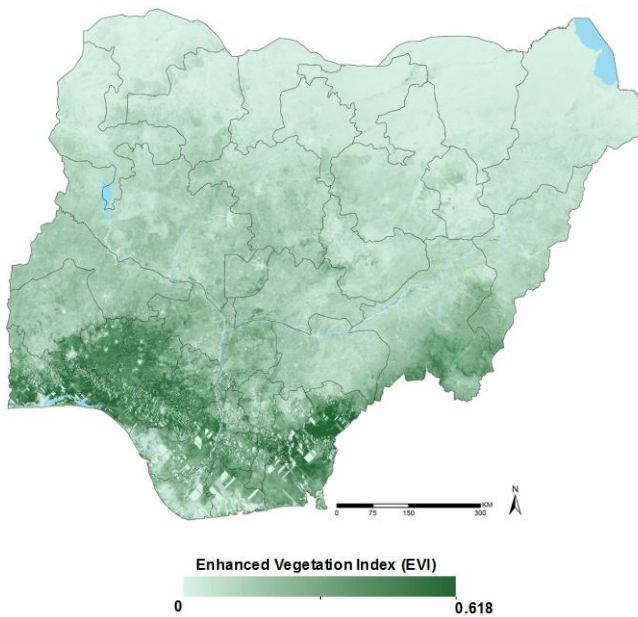
Enhanced vegetation index (EVI) of Nigeria
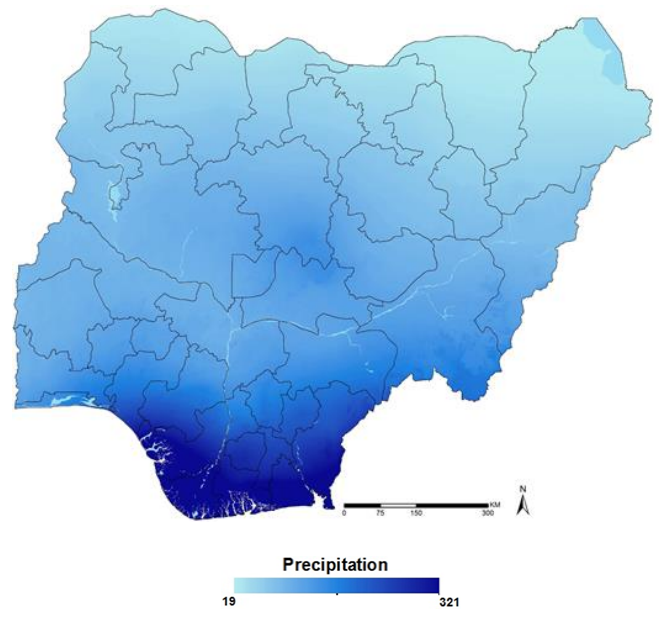


**Panel 2** Updated maps of age-corrected *Plasmodium falciparum* parasite rates ($Pf$PR$_{2-10}$) in Nigeria

Nigeria *Pf*PR$_{2-10}$ 2010

Nigeria *Pf*PR$_{2-10}$ 2015



- <5%
- 5% to <10%
- 10% to <20%
- 20% to <30%
- 30% to <50%
- 50% to 75%
- >75%
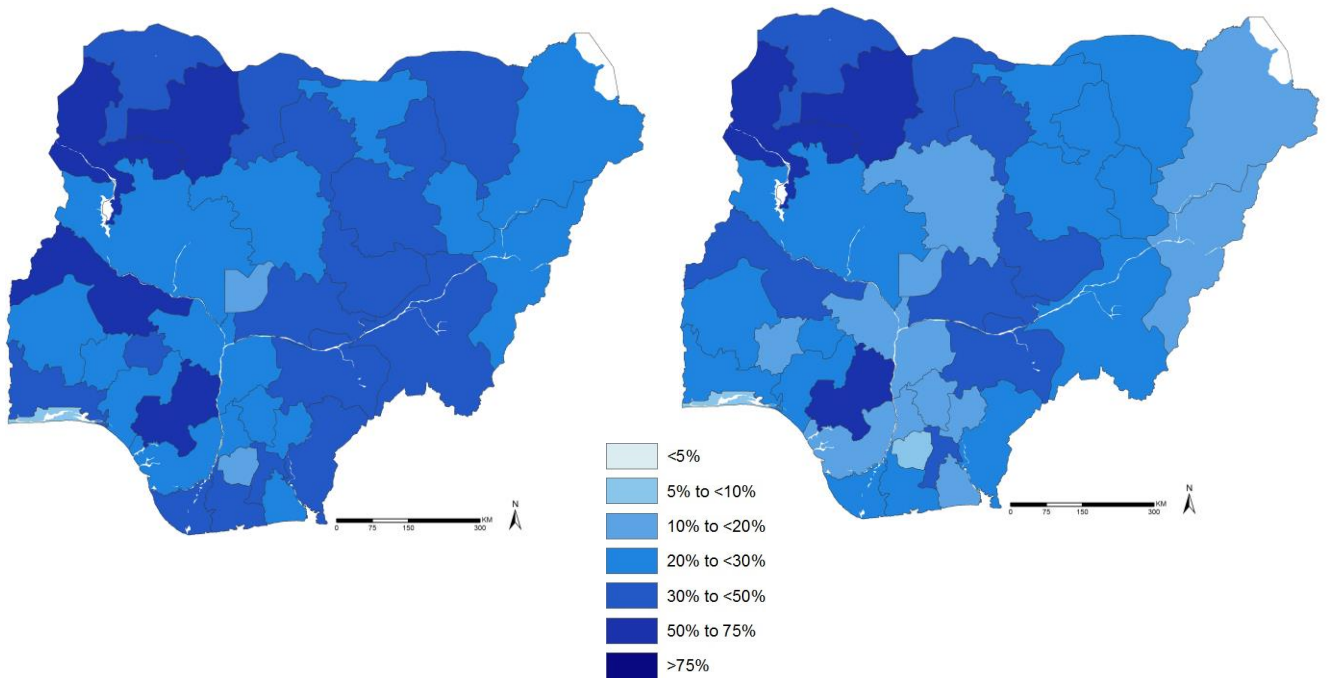
Percent decrease in *Pf*PR$_{2-10}$ between 2010 and 2015



- 10% to <15%
- 15% to <20%
- 20% to <25%
- >25%
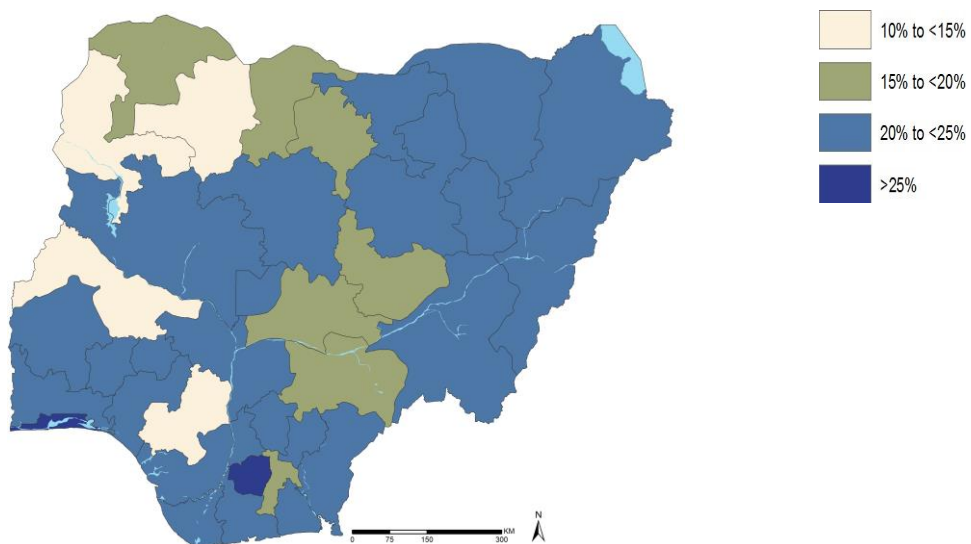
**Panel 3** ITN coverage and usage maps for 2013 and 2015

Percentage of households with at least one ITN for every two persons in Nigeria in 2013

Percentage of population sleeping under ITNs in Nigeria in 2013



| | |
|---|---|
| | <5% |
| | 5% to <20% |
| | 20% to <40% |
| | 40% to <60% |
| | 60% to <80% |
| | 80% to 100% |
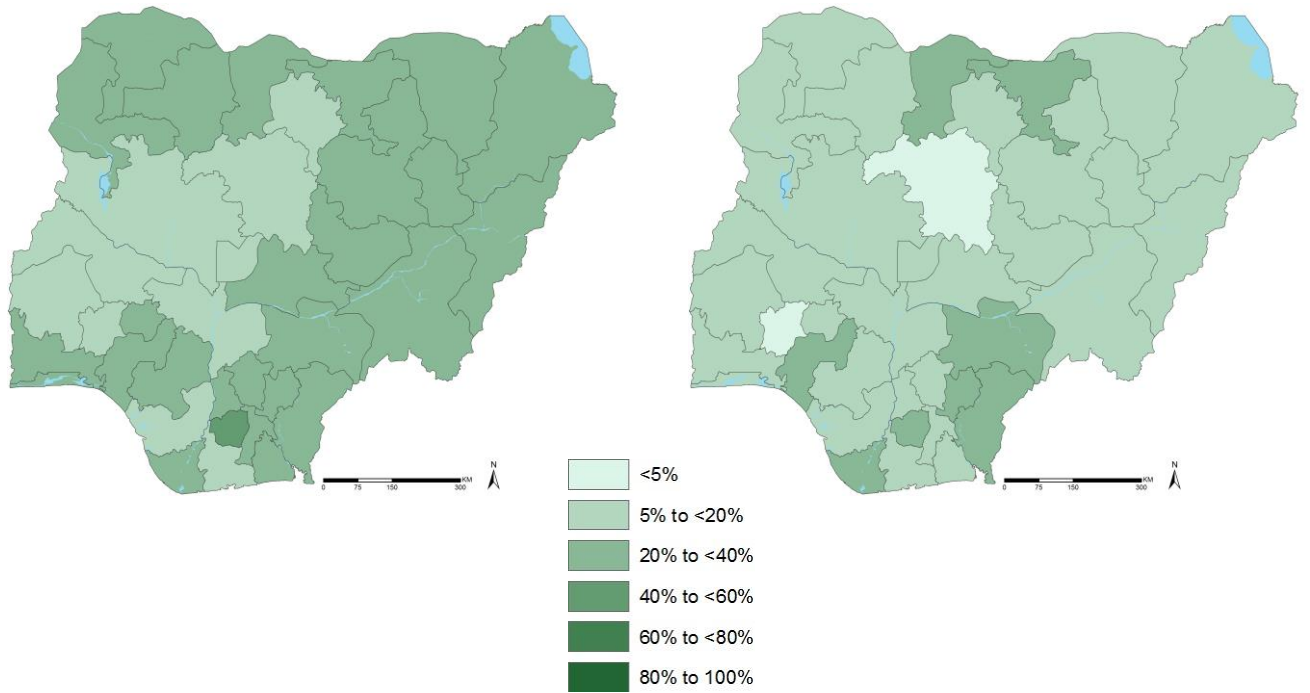
Percentage of households with at least one ITN for every two persons in Nigeria in 2015

Percentage of population sleeping under ITNs in Nigeria in 2015



| | |
|---|---|
| | <5% |
| | 5% to <20% |
| | 20% to <40% |
| | 40% to <60% |
| | 60% to <80% |
| | 80% to 100% |
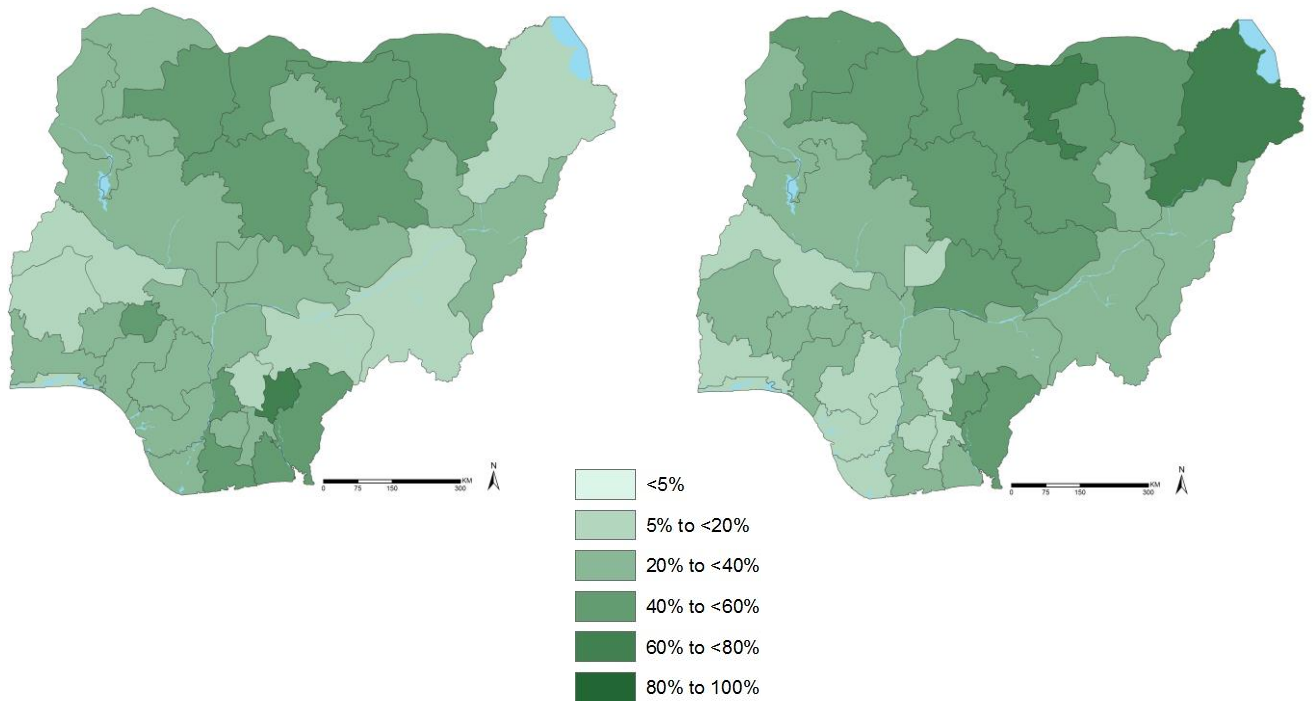
# 1 Introduction

The use of survey data, maps and epidemiological intelligence was routinely undertaken across many African countries during the Global Malaria Eradication Programme (GMEP) era from the mid-1950s. The art and skills necessary to design malaria control based on an understanding of the spatial epidemiology was lost during the 1970s when the agenda for malaria control fell under a less specialised, integrated primary care mandate focused on managing fevers. In 1996, there was a renewed plea for better malaria cartography to guide malaria control in Africa[1]. There has been growth in spatial data on malaria and populations over the last decade not available to malariologists or programme control managers 60 years ago. In addition, it is now possible to model and map risk and intervention access in space and in time using innovations in model-based geo-statistics (MBG)[2].

A national malaria epidemiological profile was developed in 2013 by the NMCP and SuNMaP, with funding support from DFID and technical support from INFORM project [3]. This effort was a result of a 2008 MARA meeting where Nigerian representatives conceived the idea to update maps on malaria risk in Nigeria. This effort also achieved the WHO AFRO 2011 recommendation for National Malaria Programme Performance Reviews (MPR) [4]—an initiative to support countries in updating and improving the National Malaria Strategy (NMS)—to include a detailed review of the malaria epidemiology and stratification including the geographical distribution of malaria burden, parasite prevalence and parasite species.

Using Bayesian predictive modelling, the 2013 Nigeria profile summarises parasite prevalence intensity across Nigeria and illustrates state-level transmission trends from 1960 to 2010. Notably, the findings indicated an apparent decline in mean population-adjusted $Pf$PR$_{2-10}$ (PA$Pf$PR$_{2-10}$) between 2000 and 2010 for all states. This profile generated considerable interest among malaria control stakeholders nationally, though there were divergent views on the externally-led process undertaken to secure data[5]. Nevertheless, a 2016 stakeholder and organisational review[5] found that the report underscored the need to deploy varied interventions across Nigeria's six ecological zones, including seasonal malaria chemoprevention (SMC). Additionally, the report was the primary source to rank Nigerian states according to burden in 2014; the highest burden 24 states were prioritised for funding from the Global Fund and USAID/PMI.

Before the 2013 malaria epidemiological profile, there had only been one previous attempt to map the intensity of malaria transmission across Nigeria, based on a climate model developed by MARA.[6] In line with the NMEP's commitment to continuous assembly and use of relevant evidence, it commissioned the LINK programme in March 2017 to start the process of developing an updated epidemiological profile in Nigeria with the aim of providing information on state level variations in both malaria risk and intervention coverage to support better control planning at the state level.

## 1.1 Nigeria aims for malaria control 2014-8

In 2014, the NMEP was renamed the NMCP and became the office responsible for reducing ill health and death caused by malaria with the eventual goal of complete elimination. Following this change, the revised NMS 2014-2020 was concurrently introduced with the determined long-term vision of a malaria-free Nigeria. The NMS 2014-2020 is built on two main principles: (1) ensuring scaled-up and improved coverage of effective malaria interventions including, indoor residual house-spraying (IRS), long-lasting insecticidal nets (LLIN) universal coverage, larviciding and environmental management, and intermittent preventive treatment in pregnancy (IPTp); and (2) providing universal prompt access to effective case management with an emphasis on parasitological confirmation of malaria diagnostics and treatment [7].

This strategy has set coverage targets to include 80% coverage of preventive measures by 2020, including 100% parasitological confirmation and treatment of confirmed cases with appropriate anti-malarial drugs. There are also targets set for education and communication of malaria preventive and treatment measures (80% of the population) and health facilities with timely reporting (80% of health facilities). This strategy also emphasises the timely availability of appropriate antimalarial medicines and commodities and a strengthened governance structure of NMEP and stakeholders by 2018.

This revised epidemiological profile draws on new data of infection prevalence collected during surveys since 2013 to illustrate the progress of malaria control in Nigeria. It also draws together evidence of parasite transmission risk and data on the distribution of dominant vector species. Risk is described using geospatial techniques to render district-level estimates from the data available in nationally representative surveys and small studies to better guide operational decisions of targeted sub-national control. This will ultimately contribute towards the achievement of the targets of the country's future national malaria strategic plans. Importantly, this work is intended to contribute to the NMEP's monitoring and evaluation (M&E) plans and data repositories.

# 2 Country context

## 2.1 Geography and climate

Nigeria covers an area of 923,768 km[2] and has borders with the Republic of Benin to the west, the Republic of Niger to the north, the Republic of Cameroon and Republic of Chad to the east, and the Gulf of Guinea to the south. Geographical features in Nigeria include the Adamawa plateau, Mambila plateau, Jos plateau, Obudu plateau, Niger river, River Benue and Niger Delta. Nigeria's most expansive topographical region is that of the valleys of the Niger and Benue River valleys, which merge into a 'Y' shaped confluence at Lokoja. The Niger Delta is located in the southern part of Nigeria [8].

The hydrology of Nigeria is dominated by two great river systems, the Niger-Benue and Chad systems. Thirteen lakes and reservoirs represent about 1% of the total area of Nigeria [9]. The water surfaces utilised in this profile and models are drawn from the Global Lakes and Wetlands Database (GLWD) shapefile developed by the World Wildlife Fund [10].

The Nigerian climate is equatorial and semi-equatorial in nature, characterised by high humidity and substantial rainfall. The climate is generally tropical in the south, with savannah in the north. The climate is further defined by a seasonal north-south movement of the dry northeasterly winds from the Sahara desert and the moist southwesterly winds from the Atlantic Ocean[11].

The wet season in Nigeria lasts from April to October, while the dry season lasts from November to March. Rainfall peaks between August and September in the Sahel and savannah regions. In the southern forest region the first peak is in July, trailed by a short and dry 'August break', which is then followed by a second peak in September[11]. Rainfall distribution also varies geographically, with the south receiving more rainfall annually than the north. The vegetation types of savannah (eg. woodland/tropical grassland) and forest (eg. significant tree coverage) follow this regional pattern[11].

The maps in Figure 1 illustrate the elevation and topography and annual precipitation in Nigeria as described above. The maps in Figure 2 illustrate the enhanced vegetation index (EVI) and the temperature suitability index (TSI) on transmission.

**Figure 1** Maps of Nigeria showing (a) Elevation/topography (mASL) [1] and (b) Annual precipitation (mm) [2]

a)
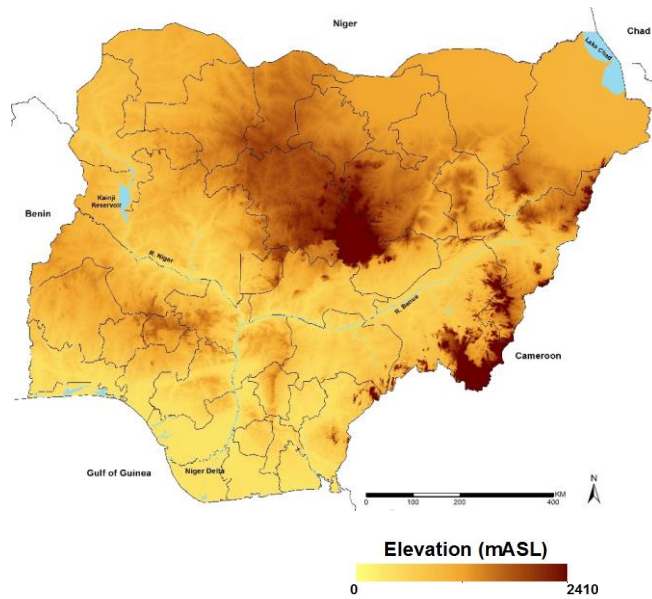


b)



---
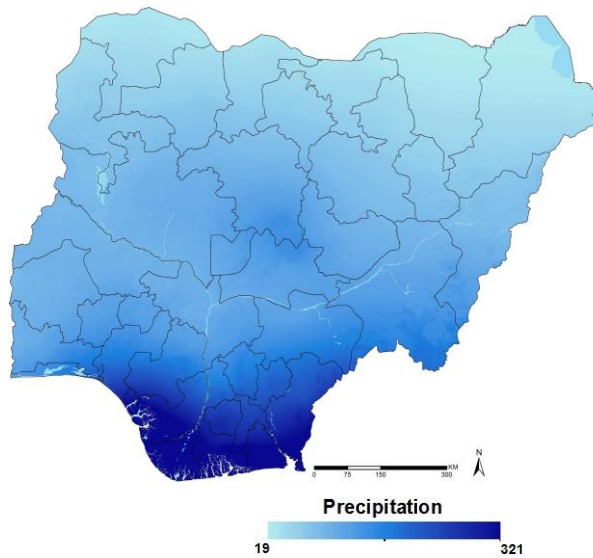
[1] **Figure 1a** The Digital Elevation Model (DEM) used is the 30 m resolution Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model Version 2 (GDEM V2) accessed at https://gdex.cr.usgs.gov/gdex/ on 31 January 2017. The regional surfaces were then merged using the mosaic tool function in ArcGIS to create a single grid surface, which was then clipped to the Global Administrative Unit Layers (GAUL) admin0 boundary of Nigeria.

[2] **Figure 1b** Rainfall is a major determinant of vector abundance. Monthly rainfall surfaces are produced from global weather station records gathered from a variety of sources for the period 1950-2000 and interpolated using a thin-plate smoothing spline algorithm to produce a continuous global surface[97]. Monthly average rainfall raster surfaces at 1×1 km resolution are available from the WorldClim website [98]. Data shown here are mean monthly rainfall in mm.

**Figure 2** (a) Enhanced Vegetation Index (EVI) [3] and (b) Temperature Suitability Index (TSI) [4] on transmission

a)



b)



---
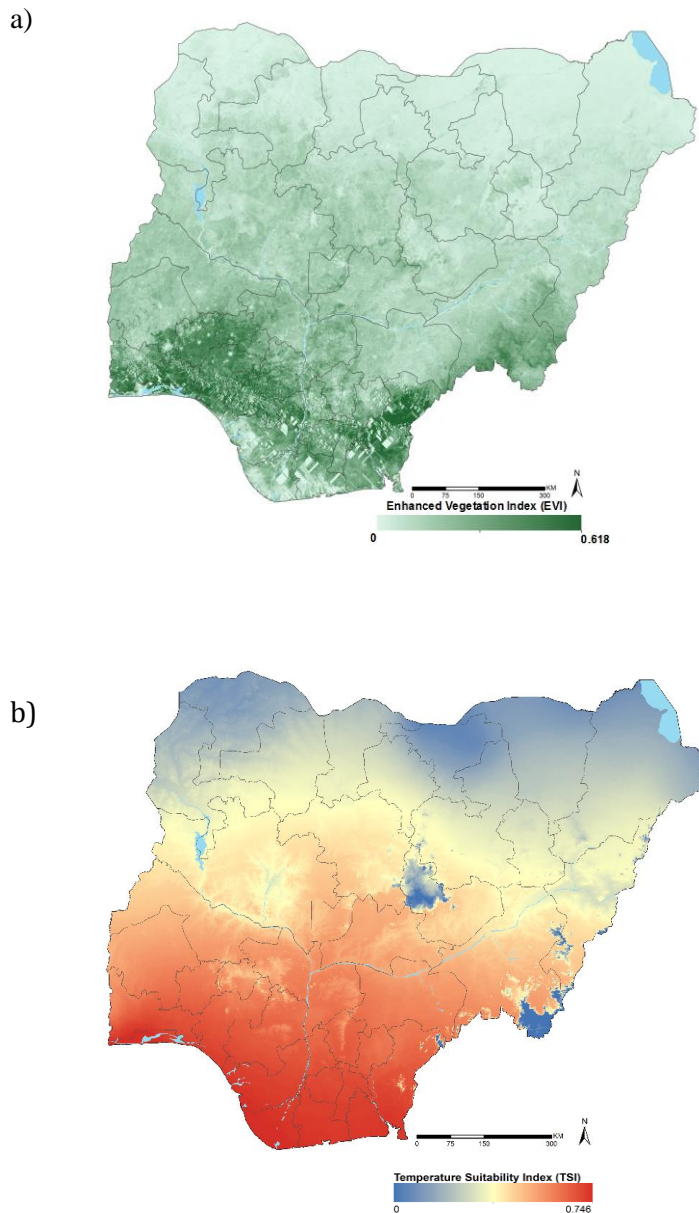
[3] **Figure 1c** For vegetation, Fourier–processed EVI, derived from the MODerate-resolution Imaging Spectroradiometer (MODIS) sensor imagery and available at approx. 1×1 km spatial resolution[99], was used to develop an annual mean EVI surface. EVI is an index of intensity of photosynthetic activity and ranges from 0 (no vegetation) to 1 (complete vegetation)

[4] **Figure 1d** As a metric for the effect of temperature on malaria transmission, a temperature suitability index (TSI) has been developed at a spatial resolution of 1×1 km[100]. The TSI model uses a biological framework based on survival of vectors and the fluctuating monthly ambient temperature effects on the duration of sporogony that must be completed within the lifetime of a single generation of anophelines and constructed using monthly temperature time series[97]. On a scale of increasing transmission suitability, TSI ranges from 0 (unsuitable) to 1 (most suitable). Unsuitable areas represented by a TSI value of 0 are classified as malaria-free. In Nigeria, there are no TSI Zero areas.

## 2.2 Population

Home to a sixth of all Africans and ranked as the seventh most populous country in the world, Nigeria is the most densely populated country in Africa. While exact figures remain in dispute [12], the December 2006 national household census estimated that there were over 140 million people with an estimated projected annual growth rates ranging from 2.7% and 3.5% [13]. Using the 3.5% growth rate and weighing additional factors, the National Population Commission estimated Nigeria's population at 182 million in 2017 [14]. The 2013 fertility rate was placed at 5.5 children per woman of reproductive age  contributing to the young population with a median age of 18.2 years of age [15]. Though delayed by two years, a new national census is planned for 2018.

Nigeria's population was 20 million during the first national census in 1931 [16]. According to United Nations (UN) projections, Nigeria is one of eight countries expected to account collectively for half of the world's total population increase from 2005–2050 [13]. By 2100, the UN estimates that the Nigerian population will be approximately 730 million [13]. Nigeria has eight cities with a population of over one million people (Lagos, Kano, Ibadan, Kaduna, Port Harcourt, Benin City, Maiduguri and Zaria). The largest and most populous city is Lagos, with estimates ranging from 18 to 21 million people, which would make it the biggest city in Africa [17, 18]. The exact population figure for Lagos differs between the state and federal government measures[8,17].

The proportion of the population living in urban areas was 48% in 2015 with an urbanisation rate of 2.7% [19]. Population densities are shown in Figure 3.The Nigerian federal government capital is located in Abuja. Additionally, there are 36 state government capitals. Nigeria has 45 urban centres [5]: Lagos, Kano, Ibadan, Kaduna, Port Harcourt, Benin City, Maiduguri, Zaria, Aba, Jos, Ilorin, Oyo, Enugu, Abeokuta, Abuja, Sokoto, Onitsha, Warri, Ebute Ikorodu, Okene, Calabar, Uyo, Katsina, Ado-Ekiti, Akure, Bauchi, Ikeja, Makurdi, Minna, Effon Alaiye, Ilesa, Owo, Umuahia, Ondo, Ikot Ekpene, Iwo, Gombe, Jimeta, Gusau, Mubi, Ikire, Owerri, Shagamu, Ijebu-Ode and Ugep.

There are unresolved disputes between Nigeria and Benin involving settlements in the Bagudo Local Government Area (LGA) of Kebbi State in Nigeria and Maladil in Benin. The location of the Benin-Niger-Nigeria tri-point is unresolved [20]. Twelve years after the International Court of Justice (ICJ) ruling that demarcated the Cameroon-Nigeria border, the UN and the governments of both countries are making headway in physically laying down the border and helping develop the long-marginalised and oil-rich Bakassi region [21]. Only Nigeria and Cameroon have heeded the Lake Chad Commission's admonition to ratify the delimitation treaty which also includes the Chad-Niger and Niger-Nigeria boundaries [22].

---

[5] To identify urban extents in Nigeria, we used the 2014 WorldPop population dataset projection (www.worldpop.org.uk). To identify urban extents, the population distribution dataset was reclassified to identify areas with population greater than 1000 per km². Only polygons with a total population greater than 200,000 people covering an area greater than 5 km² were selected. These were then matched to a place name gazetteer of Nigeria (www.geonames.nga.mil/gns/) to identify 45 major urban settlements. We could not find recent official population estimates or last census data for Nigerian cities.

**Figure 3** Estimated 2015 population distribution [6]



Population (Persons per 100m grid square)

2.43115e-005                                                                    1.12188

---
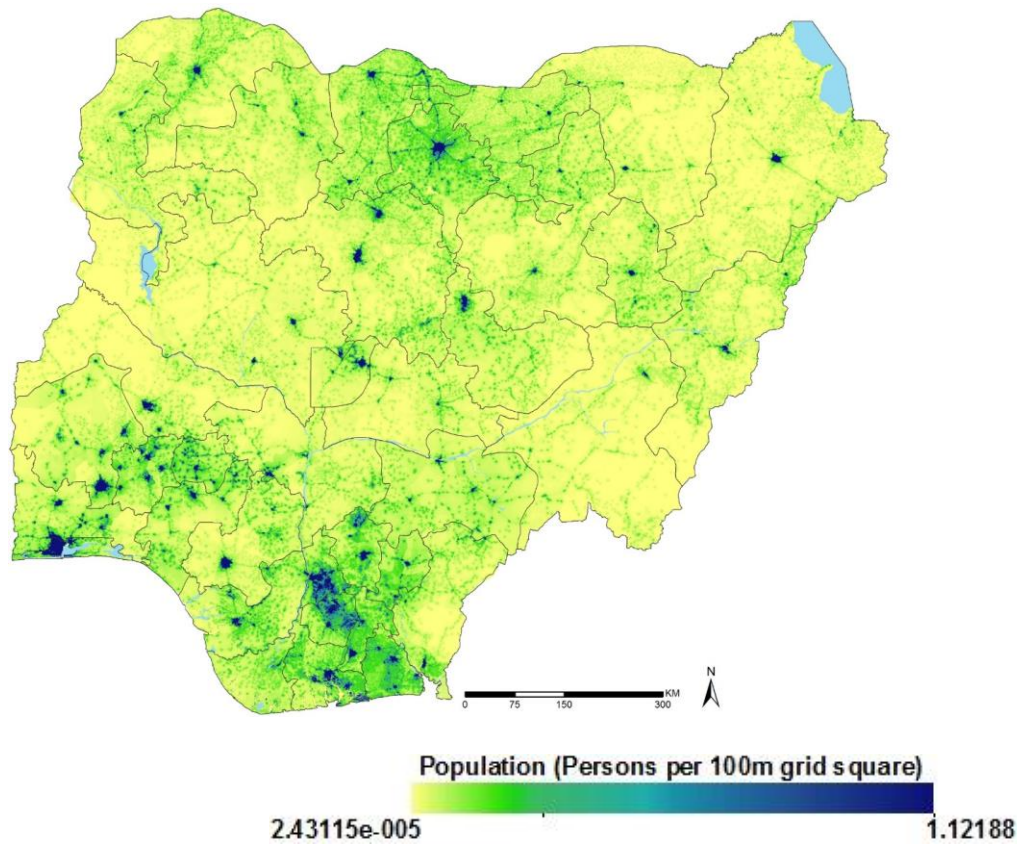
[6] To improve our understanding of human settlement patterns, spatial modelling techniques have been developed to reallocate populations within census units to finer gridded surfaces [101]. In brief, a dasymmetric modelling technique [102] was used to redistribute population counts within the 37 spatially defined states used during the 2006 national census and land cover data sets derived from satellite imagery. A different population weight was assigned to each land cover class in order to shift populations away from unlikely populated areas. For example, these areas include game reserves or arid deserts and concentrate populations in built-up areas. The net result was a gridded dataset of population distribution (counts) at 0.1 x 0.1 km resolution. The population distribution datasets were projected to years used to predict malaria risk and LLIN coverage (see later) using UN national rural and urban growth rates[103] and made to match the total national population estimates provided by the UN Population Division [56] for these years.

## 2.3 Socio-economic profile

Successive economic reforms to the agricultural, telecommunication and manufacturing sectors have resulted in an improved gross domestic product (GDP) growth; 8.4% in 2009 [23] and 8% in 2010 [24], where only China and India outperformed Nigeria in the same years. Oil and natural gas continue to account for 95% of foreign exchange and contribute to 80% of government expenditure. Nigeria is the 12th largest producer of petroleum, the 8th largest exporter, and has the 10th largest proven reserves worldwide. The equitable distribution of government revenues remains a constant challenge[25]. Twenty percent of Nigerians own 60% of national assets. In stark contrast, 60% of Nigerians receive an income of less than USD 1.25 per day (the World Bank's benchmark of extreme poverty). Poverty has increased since 1980 [8], with northern regions having lower household incomes compared to southern regions [8,26]. All regions have witnessed a general trend toward increasing depths of poverty despite a growing GDP. Although the entire population of Nigeria is at risk of malaria, children under five years of age, pregnant women and internally displaced persons (IDPs) in the northeastern part of the country are most susceptible with the highest morbidity and mortality.

### 2.3.1 Insecurity in Northern Nigeria

The presence of the Jihadist group Boko Haram since 2002 has further compounded issues associated with socio-economic development in Nigeria [27]. Boko Haram's primary aim is to make Northern Nigeria a separate Islamic state through, among other methods, resisting all Western influence and practices [28]. Activities of Boko Haram include the likes of mass kidnappings and suicide bombings, with the majority of attacks occurring in the northern states of Nigeria (Adamawa, Borno, Yobe) among civilian populations [27, 29]. While the number of deaths due to Boko Haram declined by 80% in 2016, the group has instigated the displacement of 2.6 million people as of 2017 and is responsible for the deaths of 12,000 people between 2013 and 2015 alone. This displacement has created observable practical difficulties reaching some populations and complicated malaria control efforts [30]

In 2017, WHO reported that millions of IDPs across Borno State were not able to access services and local health authorities estimated that 50% of all deaths were due to malaria[31]. In July of 2017, WHO and local health authorities launched several mass antimalarial drug administration campaigns (MDAs) aimed at protecting children under five years of age. This operation was expected to target 1.2 million children in five Local Government Areas (LGAs) of Borno State [32].

## 2.4 Health context and priorities

Health indicators for Nigeria have declined within the last decade and are among the worst globally [33]. Average life expectancy is estimated at 47 years of age, which is below the average for the least developed country average of 53 years of age. An under-5 mortality rate (U5MR) of 128 deaths per 1000 live births translates to one in every eight children in Nigeria dying before their fifth birthday[34]. Nine percent of neonatal deaths globally occur in Nigeria, and while the infant mortality rate (IMR) fell from 97 per 1000 live births recorded in 2011 to 70 per 1000 live births in 2016, it still remains very high [33]. Along with maternal mortality ratios (MMR), the IMR is the second highest in the world[35]. This is in part due to persistently low numbers of births occurring in health facilities and the low number of births being attended by trained healthcare service providers [34].

There is a trend of higher mortality across ages in rural compared to urban areas[36]. There is a regional disparity in childhood (12-59 months of age) mortality with the North East and North West regions having more than double the rates than North Central, South East, and South South regions, and nearly four times that of the South West region. A similar, though less drastic, regional trend is observed for U5MR [37].

Communicable diseases account for 66% of morbidity[15]. The primary contributors to this category of disease are pneumonia and diarrhoea, responsible for approximately 240,000 childhood deaths per year[28]. There is also high population morbidity attributed to human immunodeficiency virus/acquired immunodeficiency syndrome (HIV/AIDS), and other acute respiratory infections[37]. National immunisation rates are low with only 23% of children 12-23 months of age being fully immunised [33].

Malaria is still an important cause of morbidly and mortality in Nigeria. Though malaria cases decreased by over 750 million cases in 2016 compared to 2015, the 2017 World Malaria Report estimated that Nigeria contributed 27% of the 212 million malaria cases and 30% of the 445,000 malaria deaths reported globally[15]. In 2014 and 2015, malaria accounted for 21% of general outpatient attendance and 32% of paediatric outpatient attendance in secondary health facilities in Nigeria[38].

Additionally, emergences of outbreak-prone disease such as Ebola virus disease, Lassa fever and avian influenza have added to the burden of infectious disease in Nigeria and highlight the need for strong mechanisms to detect and control these outbreaks. Non-communicable diseases have also been on the rise in Nigeria, with increased morbidity and mortality attributed to diseases such as cardiovascular disease, cancers, and chronic obstructive lung disorder[15].

The National Strategic Health Development Plan (NSHDP) 2010-15 [37] was developed in 2010 and identified eight evidence-based priority areas to improve health sector performance (Figure 4).

**Figure 4** Priority health areas under the National Strategic Health Development Plan (NSHDP) 2010–2015



A 2013 mid-term performance review (MTR) of the NSHDP [39] found that most of the priority areas were either not yet initiated or had not made any substantial progress towards achieving indicators in the NSHDP.

The MTR also assessed the following nine overarching health indicators of the NSHDP:
1. MMR
2. U5MR
3. IMR
4. Life expectancy
5. Proportion of one-year olds immunised against measles
6. Prevalence of children under five years of age who are underweight (below two standard deviations)
7. Percentage of children under five years of age sleeping under an LLIN
8. HIV prevalence among populations aged 15-24 years of age
9. Adolescent birth rates

Out of the nine indicators, significant improvement was only seen in maternal mortality with a projection that it would meet the 2015 target. Minor progress was seen in wealth and urban/rural equity and in the U5MR and IMR.

The National Health Policy and Strategy to Achieve Health for all Nigerians came into force in 1988 and was revised in 2004. In 2016, the FMoH developed a new national health policy to direct Nigerian health towards unmet milestones in the Millennium Development Goals (MDGs) and to align with the new Sustainable Development Goals (SDGs) and other emerging issues [15]. This policy places universal health coverage (UHC) as its vision with a particular policy goal of strengthening primary health care (PHC) system delivery and service to all Nigerians[15]. This policy reignites government and stakeholder efforts to improve health status and wellbeing of Nigerians by outlining ten "policy thrusts" to refocus and guide action toward achieving UHC, the health-related SDGs, and towards contributing to the improvement of wellbeing and productivity under Nigeria Vision 20:2020.

# 3 Administration

## 3.1 Health service delivery

Nigeria is made up of six geo-political zones and 36 states and the FCT, Abuja. There are 774 LGAs and 9,565 wards in Nigeria. The six geo-political zones are the: South South, South East, South West, North East, North West and North Central zones [40–42]. The public health care system is divided into three tiers, each associated with one of the administrative levels of government: federal, state and LGA [15, 36]. Individual states and their respective LGAs are illustrated in Figure 5.

**The tertiary tier** represents 1% of health facilities and provides highly specialised health services through teaching hospitals, federal medical centres, specialist hospitals and medical research institutes from patients that are referred by the primary and secondary facilities. The federal government operates nearly 90% of these facilities.

**The secondary tier** provides specialised services through state general hospitals to patients referred from the primary health care facilities. The state government is responsible for the secondary tier, with oversight provided by the federal government.

**The primary tier** is the primary mechanism for health care delivery and it operates through primary health care (PHC) facilities. This tier represents 88% of health facilities, in which two-thirds are public. While the 774 LGAs are the constitutionally designated providers of primary health care, they are the weakest arm of the health care system[43]. The National Health Act (2014) stipulates that PHC services be funded through the Basic Health Care Provision Fund (BHCPF)[44]. The PHC system also includes community-oriented resource persons (CORPS), who deliver integrated community case management (iCCM) for childhood diseases, which include malaria, pneumonia and diarrhoea at the community level.

Private health facilities account for one-third of health facilities in Nigeria, and include hospitals, clinics, registered drug shops, and non-governmental organisations (NGOs). Malaria diagnostics and case management are available at every level of health care.

**Figure 5** Maps of Nigeria showing (a) States and (b) States with LGAs [7]

a)



b)



---

## 3.2 Health facility mapping

### 3.2.1 Previous health facility mapping in Nigeria

Mapping the locations of routine health service providers in Nigeria is not new. Health facility maps have been considered an important Ministry of Health and Sanitation tool since the late 1920s. Health facility maps for Nigeria were developed in 1927, 1928, 1934, and 1953 [45-48]. The 1926-27 map (Figure 6) showed the location of 69 facilities, including: dispensaries (18), leprosy centres owned by missionaries (6), hospitals run by native administration (9), government facilities (30) and six nursing homes. The 1934 health facility map (Figure 7) showed European and African hospitals (12), African hospitals (41) and dispensaries (239). The 1952-3 health facility map (Figure 8) showed hospitals maintained by the government (51), native administration (8), missions (38), and private/industry organisations (13); government nursing homes (13), leprosy centres maintained by the government (4) and missions (21); government rural health centres (5); dental care centres (3); Medical Field Unit Headquarters (10); and a mixture of 997 facilities designated as dispensaries, maternity centres, leprosy villages, health centres managed by the government, missions and private institutions. We obtained copies of these maps from the archives at WHO Geneva, the Wellcome Library UK and the Ministry of Health Archives in Nairobi, Kenya.

**Figure 6** Distribution of health facilities in Nigeria based on a 1926-7 map
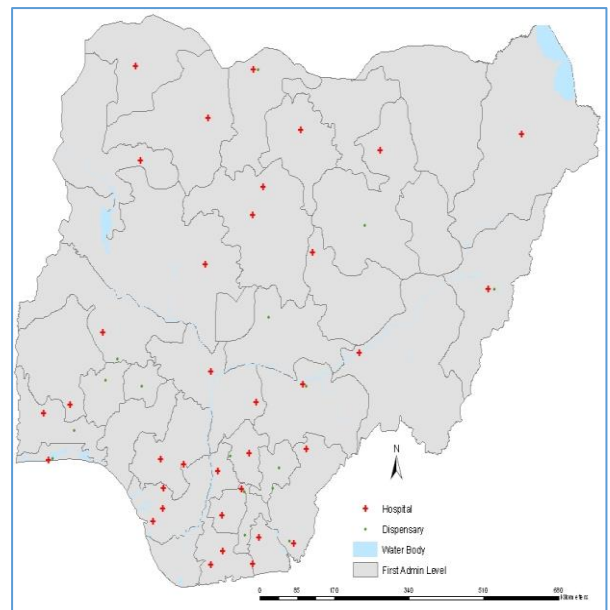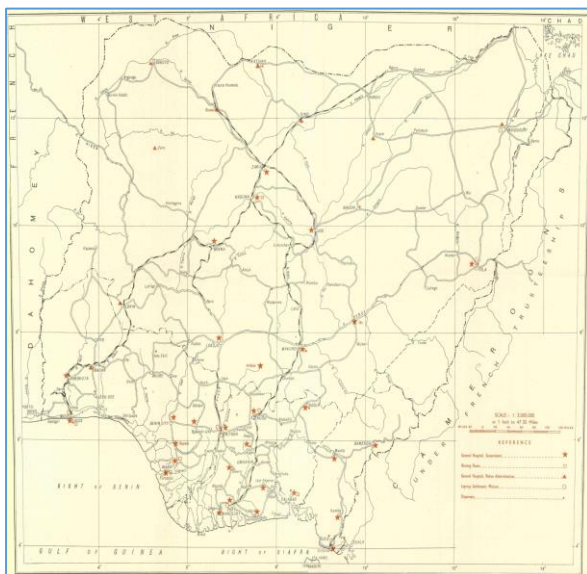
**Figure 7** Distribution of health facilities in Nigeria based on a 1934 map
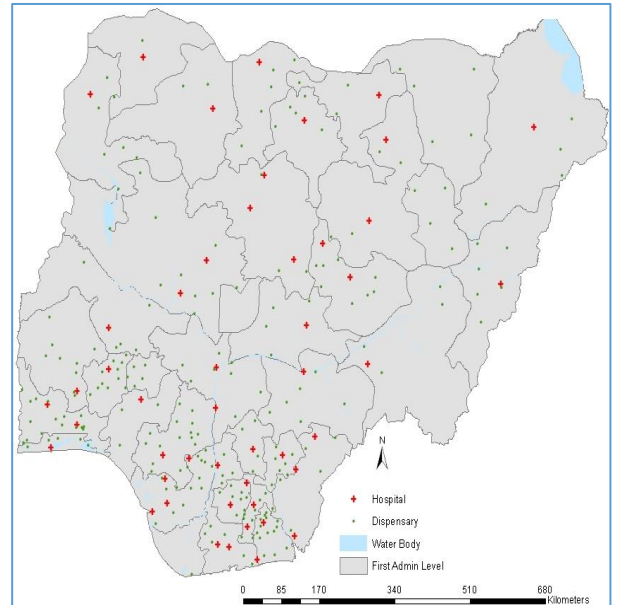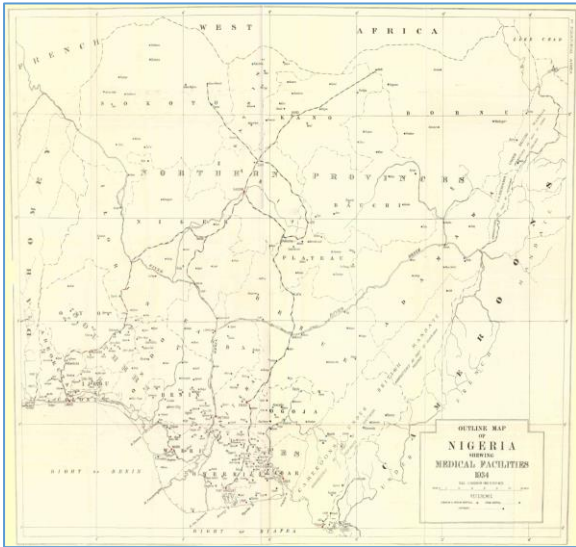


**Figure 8** Distribution of health facilities in Nigeria based on a 1952-3 map
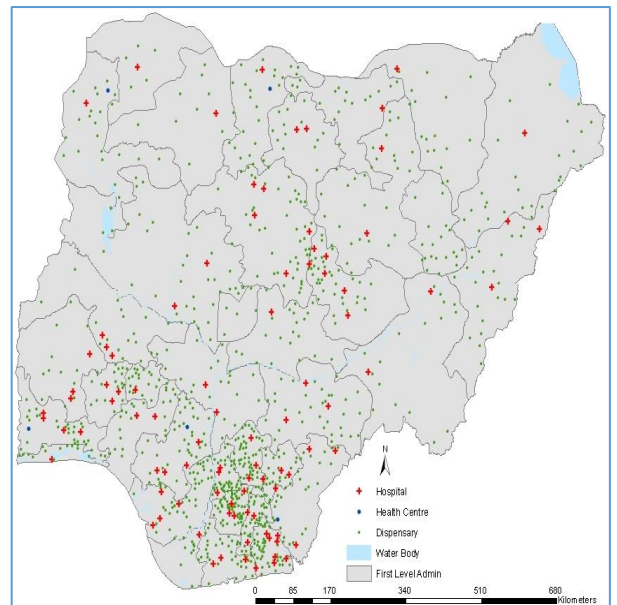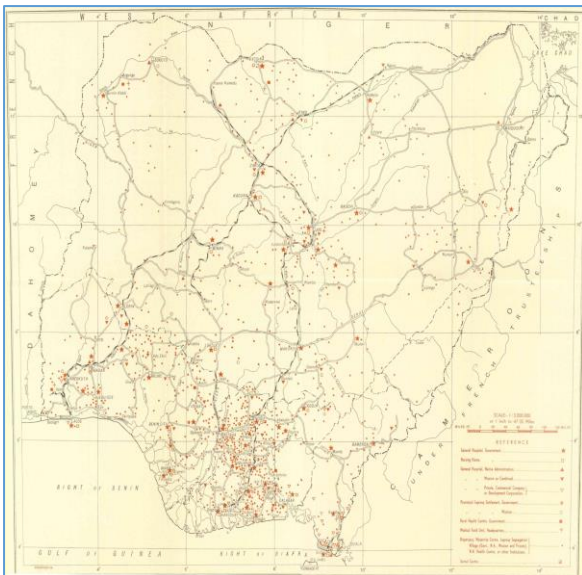
### 3.2.2 Contemporary health facility mapping efforts

In recent years, there have been several partial mapping activities within the health sector using Geographic Information Systems (GIS) dealing with specific areas of interests. First, a service availability mapping exercise was undertaken in 11 states in 2006-7 [49]. Second, a service utilisation mapping of health facilities accredited to the National Health Insurance Scheme (NHIS) in 2007-8 [50]. Third, the National Health Management Information System (NHMIS) unit of the FMoH mapped all service delivery points in selected LGAs in 2010 [51]. Fourth, an HIV/AIDS service provision mapping exercise was undertaken by the FMoH in 2010-1 [52,53]. Finally, a PHC facility mapping effort was undertaken by the National Primary Health Care Development Agency (NPHCDA) at ward levels in 2011 [54-55].

As of December 2011, the Directory of Health Facilities in Nigeria had listed 34,173 health facilities from the 36 states and the Federal Capital Territory. Of these, 22,850 are public facilities, which consist of 21,808 PHC facilities, 969 secondary and 73 tertiary health facilities. In June 2017, the Department of Health Planning Research and Statistics reported that a master list with private and public health facilities was being updated in coordination with states, LGAs and individual practitioners.

Figure 9 displays the distribution of hospitals and non-hospitals, which was updated in 2016, that could be mapped based on coordinate and data availability. A more thorough description of this process is available in Section 6.3 'Mapping health facility distribution'.

**Figure 9** Distribution of 19,698 public health facilities, hospitals (red) and non-hospitals (green)
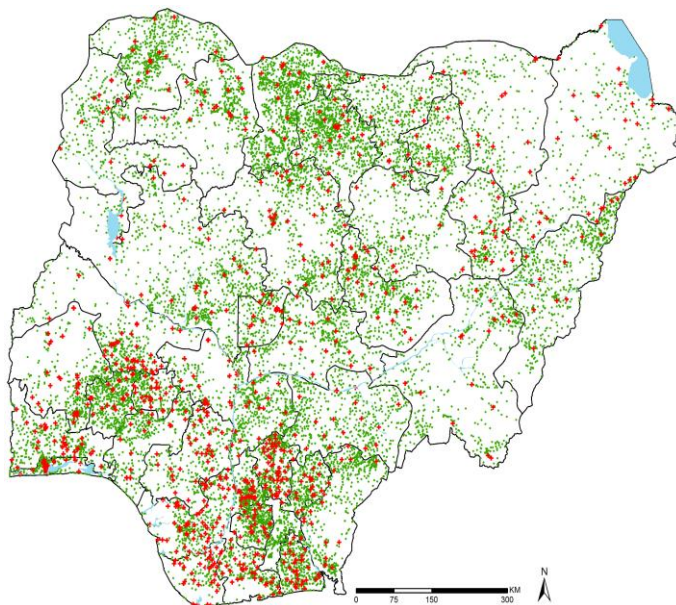
# 4  Malaria control in Nigeria

## 4.1  Overview

Malaria is endemic in Nigeria and 170 million Nigerians (97%) are at risk of infection. Consequently, malaria is a high priority for the FMoH.

The National Health Policy 2016 Priority objective 4.1.2 'Prevention and Control of Communicable Disease' [15] lists five policy orientations/initiatives for malaria:
1. Reduce malaria transmission through integrated vector management (IVM)
2. Ensure prompt parasitological diagnosis and appropriate treatment of clinical cases
3. Reduce burden of malaria prevention and treatment by ensuring universal availability of IPTp
4. Promote local production and affordability of artemisinin-based combination therapy (ACTs)
5. Improve access to antimalarial commodities and encourage innovation for malaria control and innovation.

## 4.2  NMEP structure

The NMEP is responsible for programming and implementing malaria control activities in Nigeria under the FMoH. This includes data management for all malaria-related data including routine reporting, surveillance, surveys and operations research. The NMEP is dependent on and interlinked to a core group of international donors and international and national implementing partners in the public and private sectors. The NMEP plays a traditional policy, coordination and regulatory role but also serves as a significant fundholder and implementing agency.

NMEP comprises six units (Figure 10) representing the programme's core tasks: (i) IVM; (ii) case management; (iii) Monitoring & Evaluation (M&E); (iv) advocacy, communication and social mobilisation; (v) procurement supply chain management; and (vi) financing. Currently, these branches work independently and relate directly with the National Coordinator. Branches also relate directly with relevant developmental partners and other stakeholders.

Partners involved with malaria control form the Ministerial Task Team on AIDS, Tuberculosis and Malaria Technical Working Group for malaria (TWG-Malaria). The overall objective of the TWG-Malaria is to prioritise within the FMoH to strengthen coordination, programme management, performance, information flow and alignment of the existing malaria control activities. The TWG-Malaria is responsible for reporting progress, actions and results of the programmes and progress towards strengthening FMoH leadership, systems and capacity on malaria control and in identifying and support development efforts of the RBM Partners and the government at all levels [57].

**Figure 10** NMEP organisational chart



Honourable Minister of Health & Honourable Minister of State for Health

AIDS, TB & Malaria Task Force

Permanent Secretary

Director of Public Health

National Coordinator

AIDS, TB & Malaria Technical Working Group - Malaria

Global Fund Project Management Unit

World Banroject Management Unit

Internal Audit

**Integrated Vector Management Branch**
- Long Lasting Insecticidal Net Unit
- Larval Source/ Environmental Management Unit
- Indoor Residual Spraying Unit

**Case Management Branch**
- Treatment & Research Unit
- Parasite-based Diagnosis Unit
- Seasonal Malaria Chemoprevention Unit
- Community Case Management Unit
- Malaria in Pregnancy Unit

**Monitoring & Evaluation Branch**
- Surveillance & Date Management Unit
- Operations Research
- Co-ordination & Reporting Unit
- Information Technology Unit

**Advocacy, Communication & Social Mobilization Branch**
- Civil Society Organisations Coordination Unit
- Advocacy Unit
- Media Regulation Unit
- Social Mobilisation Unit
- Communication Unit

**Procurement Supply Chain Management Branch**
- Procurement Unit
- Logistics Unit
- Distribution & Storage Unit
- Quality Assurance Unit

**Programme Management Branch**
- Strategic Planning Unit
- Partnership Unit
- Internal Coordination Unit
- Capacity Building & Sub-national Support Unit
- Reporting & Knowledge Management Unit

**Finance Unit**
- Financial Management
- Financial Reporting

**Source:** Nigeria NMEP, 2017

## 4.3 Financing malaria control

The Federal Government allots 6% of its budget toward health, which is significantly less than its commitment to 15% [15]. Consequently, Nigeria, like other malaria-endemic countries, relies on several partners to support programme activities. Figure 11 depicts each malaria control strategy and the shares funded by domestic versus external sources.

**Figure 11** Domestic and External Funding of Malaria Intervention Areas in Nigeria, 2018 - 2020
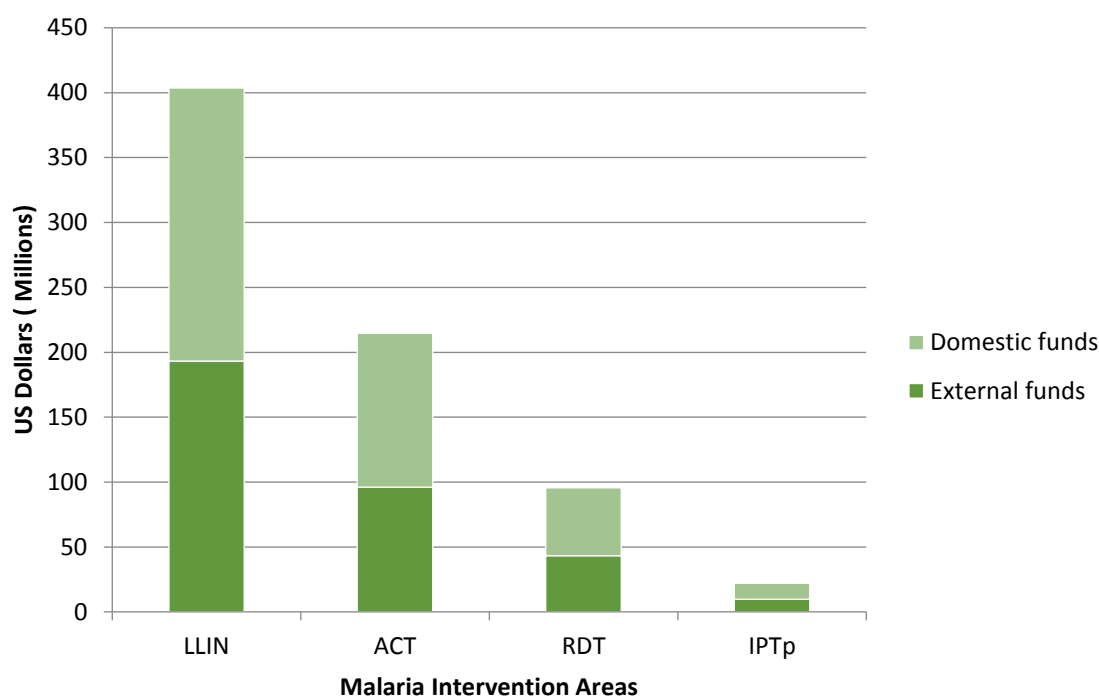


**Data source:** NMEP presentation, Malaria Implementation in Nigeria: Efforts Towards Elimination – successes and challenges, 20 April 2017

The majority of funding for malaria control activities is from the GFTAM and PMI.

GFTAM
Between 2006 and 2016, the Global Fund malaria investments dispersed in Nigeria was USD 950,531,723 of USD 1.3 million committed [58]. Between 1 February 2015 and 31 December 2016, Nigeria implemented a USD 400,253,346 malaria grant under the New Funding Model of the Global Fund [59]. The proposed FY 2017 GFTAM malaria funds request for Nigeria was USD 300 million.

PMI
In Financial Year 2011, Nigeria was selected as a PMI focus country. PMI's presence in Nigeria began with support in three states (Cross River, Zamfara and Nasarawa). In 2012, PMI expanded to six more states (Sokoto, Bauchi, Benue, Ebonyi, Oyo and Kogi), and in 2013, added two more states (Akwa Ibom and Kebbi), for a total of 11 states. A strategy review meeting held in April 2016 revisited the states for PMI support. States were selected based on malaria disease burden, LLIN coverage and use, presence of other donors, strength of state leadership and security. Based on these criteria, ten states were retained and Kogi, with a malaria prevalence of 5%, was replaced with Plateau State due to its malaria prevalence of 36%. Support to Kogi State was phased out in the calendar year 2016. The projected population of the 11 states to receive

PMI support in 2018 is USD 56.3 million. PMI provides support to all 230 LGAs. The Global Fund is also supporting eight of the 11 PMI-supported states. Currently, PMI and the Global Fund assist states by supporting 60% to 80% of their public health facilities. The proposed FY 2017 PMI budget for Nigeria was USD 75 million.

Partner support for key malaria control areas
Other partners support key areas of the NMEP malaria control strategy. Table 1 provides a summary of malaria intervention by malaria control partner or project.

**Table 1** Development partner support by key malaria control areas

| Partner/ Project | Key areas supported |
|---|---|
| Federal Government Nigeria – MDG | LLINs, rapid diagnostic tests (RDTs), ACTs, sulphadoxine-pyrimethamine (SP), human resources |
| Global Fund | LLINs, RDTs, ACTs, SP. diagnostics, M&E capacity building, human resources in 15 LGAs. Currently supporting 24 states. |
| World Bank | All intervention areas in 7 states - *Project ended March 2015* |
| USAID/PMI | LLINs, RDTs, ACTs, SP, MIP, ACSM, diagnostics, M&E, capacity building at national level and in 14 states |
| DFID | LLINs, RDTs, ACTs, SP, diagnostics, M&E, SMC, capacity building, demand creation at national level and ten states – *Project has ended* |
| WHO | Technical assistance |
| CHAI | Severe malaria and SMC in some LGAs in two states – *Project has ended* |
| UNICEF | iCCM in two states – *Project ended March 2017* |

## 4.4  Health information management for malaria data

In 2014, the 56th session of the National Council on Health approved the use of a single, integrated and decentralised national routine health database hosted at the FMoH and the Department of Health Planning, Research & Statistics (DHPRS) on a DHIS 2 platform. Harmonised NHMIS tools for data collection and reporting for routine data management were also instituted among all programmes and implementing partners [60].

Routine reporting of malaria-related data from health facilities comprises two levels of data capture:

> **Level 1** Data is generated and captured at health facilities using harmonised tools, ie. hard copy registers and summary forms. These are the primary data collection tools for recording and reporting services provided at the health facilities.

> **Level 2** DHIS 2 is utilised at the LGA, state and national levels, used to consolidate data from all the health facilities in the country (NMEP, 2017).

Malaria unit data from health facility registers are reported at the end of each month using the HNMIS monthly summary form. The monthly summary form from both private and public health facilities within each LGA are collated by the LGA M&E officers and entered into DHIS 2. Once entered in DHIS 2, the state and national levels can access the data. Community-based health data is not yet part of the National Health Management Information System (NHIMS) but is planned to be included in the near future. While dissemination reports are not distributed on a regular basis, malaria indicators are reviewed and shared with local and international partners at the monthly national Malaria Technical Working Group meeting. This process is illustrated in Figure 12.

**Figure 12** Flow of malaria reporting and feedback, NHMIS, Nigeria
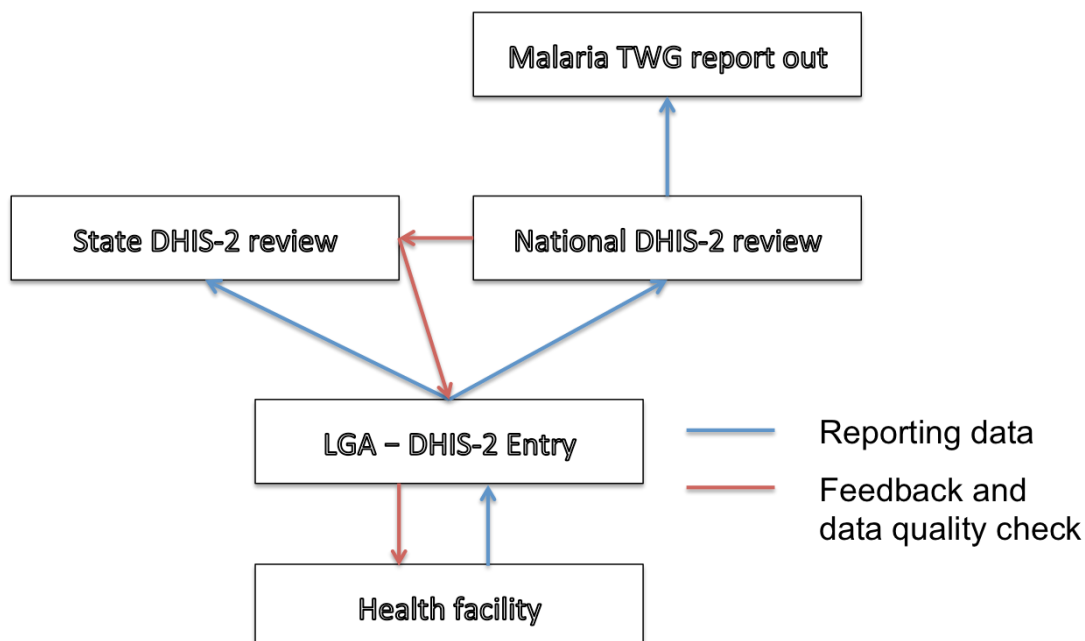
In 2016, 70% of health facilities reported through the DHIS 2, and of those 59% were reporting on time (NMEP HMIS, 2017). While this is progress for the NMEP relative to the previous years, it remains below the M&E targets of 90% and 80%, respectively. Further, the World Malaria Report states that malaria case reporting is at less than 50% in Nigeria, with only 8% of malaria cases captured by surveillance system [32]. There are several challenges that are contributing to this scenario, including the lack of a regularly updated master health facility list. To counter this issue the FMoH produced a directory of health facilities in Nigeria in 2011, which replaced the first (2000) version. The FMoH assigned a National Provider Identifier (NPI) to each health facility to enhance the information system [60]. (An updated master [public] health facility report is also provided with the current epidemiological profile.)

Other challenges include:
- Lack secondary and tertiary facilities reporting through NHIMS/DHIS 2
- Understaffing at health facilities and high turnover of staff leading to gaps in quality data management
- Low levels of supervision from some LGAs to the health facilities due to budget constraints
- Inadequate NHMIS tools at the health facility level – one contributor to this is still existing parallel reporting mechanisms by donors, government agencies and programs, which overburden the few available health facility staff [61]
- Irregular data quality audits and inadequate operational research to improve data quality

## 4.5   Drug and insecticide resistance monitoring

### 4.5.1   Drug resistance monitoring

Nigeria has conducted Drug Therapeutic Efficacy Tests/Trials (DTETs) on chloroquine (CQ) and SP in all six epidemiological zones since 2002. A 2009 DTET study showed a clinical cure rate of 100% and an Adequate Clinical and Parasitological Response (ACPR) of about 98% for first-line ACT treatments artemether-lumefantrine (AL) and artesunate-amodiaquine (AA).

The Malaria Parasite Sentinel Surveillance (MPSS) system was established in April 2014 to monitor daily confirmation of presumptive diagnoses and monitor parasite clearance in individuals. The aim of this system is to provide the NMEP and its partners with detailed information that can be used for measuring the effectiveness of the antimalarial programme. Reporting sites have been established in 24 states throughout the country. There are also 13 non-reporting states [62].

Several challenges were identified with the MPSS in its early phases, mostly surrounding the need for trained laboratory scientists to validate slide results. There were also issues in regular monthly reporting.

### 4.5.2   Insecticide resistance monitoring

The effectiveness of vector control interventions is affected by mosquito behaviour and insecticide susceptibility. Insecticide resistance in *An. gambiae s.s.* has been reported in several regions in Nigeria through independent research, including: Kaduna and Zaria in the North and Abeokuta, Ibadan and Lagos in the South South. Pyrethroid, carbamate and dichloro-diphenyl-trichloroethane (DDT) resistance have also been reported for *An. gambiae s.s.*. Other vectors have also demonstrated resistance, including *An. funestus* to dieldrin and DDT and *An. Arabiensis* to pyrethroids [7].

Conducting vector sentinel surveillance and resistance monitoring is strategy six in the NMSP 2014-2020, which establishes the target of at least three vector surveillance sentinel sites in each of the six ecological zones. In 2011, 14 sentinel sites for entomological surveillance were established, with six of these sites funded through the PMI Africa Indoor Residual Spaying (AIRS) project. Vector surveillance and monitoring surveys are scheduled for every two years within the NMSP, with the first one conducted in 2015.

# 5 A timeline of malaria control in Nigeria

In the 2013 epidemiological profile, Snow et al. presented a comprehensive history of malaria control in Nigeria [52]. This rich chronicle of history from the 1900s to 2013 reflects the laborious effort in retrieving and reviewing clandestine literature, colonial reports, and programme documentation and published articles. The current updated profile presents events from the year 2000 and after.

The first summit of African leaders on malaria was held in Abuja in April 2000. This provided much needed national and regional political support to the objectives outlined in the Abuja Declaration to essentially ensure that over the next five years at least 60% of at-risk populations would receive prompt and efficacious treatment, sleep under an LLIN, or receive at least two doses of IPTp with SP if pregnant.

In 2001, Nigeria launched a five-year strategic plan focusing on RBM targets[58] under the policy stewardship of the NMCP and with the aim of reducing the malaria burden by 25% by 2005. An LLIN strategy was developed to ensure 60% coverage among children by 2005, simultaneously promoting the creation of a private sector market combined with social marketing initiatives. Partners engaged with the FMoH at state levels for LLIN distribution included the UN International Children's Emergency Fund (UNICEF) (Ogun, Bauchi, Enugu and FCT-Abuja); the Futures Group/DFID (Ekiti, Jigawa, Benue and Enugu); USAID/Basic Support for Institutionalizing Child Survival (BASICS) (Lagos, Kano and Abia); and USAID/NetMark (Edo, Rivers, Lagos, Kano, FCT and Abia). Despite these initiatives, by 2005 LLIN use by children aged less than five years was only 1.7% [63,64]. During much of the 2001-2005 national policy, CQ and SP were the recommended first- and second-line antimalarial regimens, respectively. However, sensitivity tests undertaken across the country in 2002 revealed unacceptably high treatment failures with CQ (*circa* 39%) and SP (*circa* 43%) [65]. In 2004, the efficacy of two candidate ACTs were evaluated. AL was selected as first-line treatment in 2005 according to the evaluation results [66,67].

The second, post-Abuja strategic plan was launched in 2006. This plan revised targets to 80% coverage of key interventions, re-invigorating the role of selected IRS and environmental management [66] with a combined aim to reduce the malaria mortality and morbidity burden by 50% by 2010. In 2006, the optimistic vision of a "Malaria free Nigeria" was first declared. However, coverage of LLINs across the country by 2008 was extremely poor, with only 5.5% of children below five years of age sleeping under a treated net (NPC, 2009). Of all unprotected children in sub-Saharan Africa not sleeping under a net in 2007, a quarter were Nigerian [68].

Between 2004 and 2006, overseas development assistance (ODA) for malaria control was between USD 15 and USD 23 million per year. Between 2007 and 2010, USD 117 million was disbursed by the World Bank to support the delivery of interventions in seven states (Akwa Ibom, Anambra, Bauchi, Gombe, Jigawa, Kano and Rivers). Nigeria made successful applications to the Global Fund during Round 2 (USD 20 million), Round 4 (USD 64 million), and Round 8 (USD 220 million). Round 8 funding was largely used for mass LLIN campaigns in seven additional states, not covered by the World Bank Booster program (Adamawa, Ekiti, Kaduna, Kebbi, Niger, Ogun, and Sokoto).

Since 2007, other donors have included USAID, DFID, UNICEF, PMI and Japan International Cooperation Agency (JICA).

It is estimated that between 2008 and 2010, USD 3.5 million was spent on malaria control out of the Nigerian governmental budget and USD 78 million was disbursed through the Debt Relief Millennium Development Goals Achievement Fund (MDG-F) [69]. Nearly USD 600 million of external funds were provided for Nigeria's national malaria control efforts between 2004 and

2010. In 2009, donor disbursements reached a peak of around USD 325 million. While this is a staggering amount of ODA, it remains less than the estimated USD 4.46 needed per person at risk of malaria infection [70].

In 2009, the third strategic plan was launched. This plan provided a roadmap for malaria control in Nigeria, focusing on universal and equitable access and rapid scale up of a package of core interventions. Resultantly, from 2009 to 2013, ACTs, RDTs, and LLIN distribution were massively scaled across all states with support from donors such as the Global Fund, World Bank, DFID and PMI. During this period 57.8 million LLIN were distributed nationwide during an LLIN replacement campaign (NMEP HMIS, 2015). The percentage of health facilities with ACT in stock increased from 22% in 2006 to 52%, reflecting a slow but steady increase in compliance with the 2004 policy of ACTs as the first-line treatment [38].

A rapid impact assessment (RIA) of antimalarial interventions conducted in 2014 and 2015, showed a plausible impact of this scale-up on reducing malaria mortality in the general population by 18% from 2009 to 2012. However, the RIA also identified a sharp increase in malaria cases between 2012 and 2013 [38].

Indoor residual spraying (IRS) has not been implemented at the national level and has only occurred in specific states and LGAs where funding has been available. In 2008, IRS was implemented in three LGAs in seven states supported by the World Bank Malaria Booster Program (Bauchi, Jigawa, Gombe, Kano, Anambra, Akwa-Ibom and River State) and one state supported by PMI (Nassarawa) using alphacypermethrin, lambdacyhalothrin and deltamethrin. Between 2009 and 2011, Lagos State started a campaign of IRS covering 246,803 households [71].

## 5.1 Malaria control under National Malaria Strategic Plan 2014-20

The current National Malaria Strategic Plan covering 2014 to 2020 aims to achieve pre-elimination status (less than 5,000 cases per 100,000 persons) and reduce malaria-related deaths to zero by 2020. It also continues the scale-up of intervention strategies including LLIN universal coverage, and a new emphasis on IRS, and strategic use of larval source management, and calls for a "reinvigoration" or use of SP for IPTp and SMC. To achieve these aims, the plan lays out seven objectives[7]:

1. To ensure at least 80% of targeted population utilises appropriate preventive measures by 2020.
2. To test all care-seeking persons with suspected malaria using RDT or microscopy by 2020.
3. To treat all individual with confirmed malaria seen in private or public facilities with effective anti-malarial drugs by 2020.
4. To provide adequate information to all Nigerians such that at least 80% of the populace habitually takes appropriate malaria preventive and treatment measures as necessary by 2020.
5. To ensure the timely availability of appropriate antimalarial medicines and commodities required for prevention and treatment of malaria in Nigeria wherever they are needed by 2018.
6. At least 80% of health facilities in all LGAs report routinely on malaria by 2020.
7. To strengthen governance and coordination of all stakeholders for effective programme implementation towards an "A" rating by 2018 on a standardised scorecard.

## 5.2  LLIN coverage 2014-6

Seventy-eight million nets were distributed between 2014 and 2016 [32]. This leaves an operational gap as the country requires 34 million LLINs for routine distribution in 37 states [59]. Since 2011, LLINs have been continuously distributed free of charge through antenatal clinics (ANC), the routine immunisation services through the Expanded Programme of Immunisation services (EPI), and through mass campaigns. LLINs are also distributed through community programmes and the commercial private sector, which has a smaller role in net distribution. In 2016, 185,531 LLINs were distributed through school programmes in Jigawa, Katsina and Kogi states (NMEP HMIS, 2017).

Nigeria uses the "rolling mass campaigns" approach. These campaigns are conducted in different states each year; state selection is staggered for every three years and based on malaria risk, previous malaria control activities and routine LLIN distribution gaps. In 2014, mass campaigns occurred in the following states: Anambra, Akwa Ibom, Bauchi, Eketi, Gombe, Jigawa, Nawasara, Niger, Ogun and Rivers. In 2015, mass campaigns were completed in Abia, Cross Rivers, Ebonyi, Kaduna, Kano, Katsina, Kebbi, Plateau and Zamfara States. In 2016, only Oyo state had a mass LLIN campaign (NMEP HMIS, 2017). During this period mass campaigns were not conducted in the following states: Adamawa, Bayelsa, Benue, Borno, Delta, Edo, Enugu, Federal Capital Territory, Imo, Kogi, Kwara, Lagos, Ondo, Osun, Sokoto, Taraba and Yobe (NMEP HMIS, 2017).

We have developed a map to reflect programme activities using DHIS 2 routine and mass distribution data between 2013 and 2016. These data[8] reflect routine distribution through national ANC and the EPI as well as mass distributions (Figure 13).

---

[8] NMEP has noted that data used to develop map suffers from poor data quality

**Figure 13** LLIN coverage 2014-6
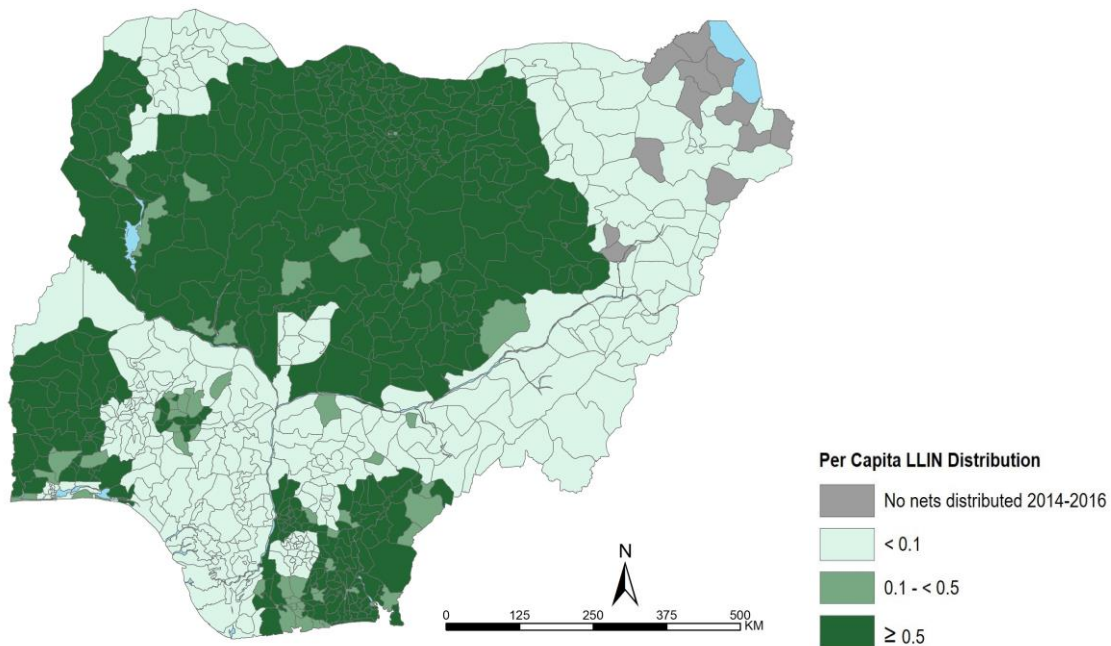


The percentage of households with at least one ITN for every two people increased from 22% in the 2013 DHS (Figure 17) to 35% in the 2015 MIS (Figure 18). The percentage of the total population that slept under an ITN increased from 23% in 2010 to 37% in the 2015 MIS. The percentage of the population that slept under an ITN in households owning at least in one ITN did not change between 2010 (49%) and 2015 (50%) (Figure 16 and Figure 17).

New maps on ITN ownership and use were produced using 2003, 2008 and 2013 DHS surveys as well as 2010 and 2015 MIS surveys. Figures 14 to 18 reflect improvement in access to and usage of ITNs.

**Figure 14** ITN usage (l) and universal coverage (r) in Nigeria, 2003



Proportion of households with at least 1 ITN for every 2 persons

<5%
5% to <20%
20% to <40%
40% to <60%
60% to <80%
80% to 100%

Proportion of population sleeping under ITN
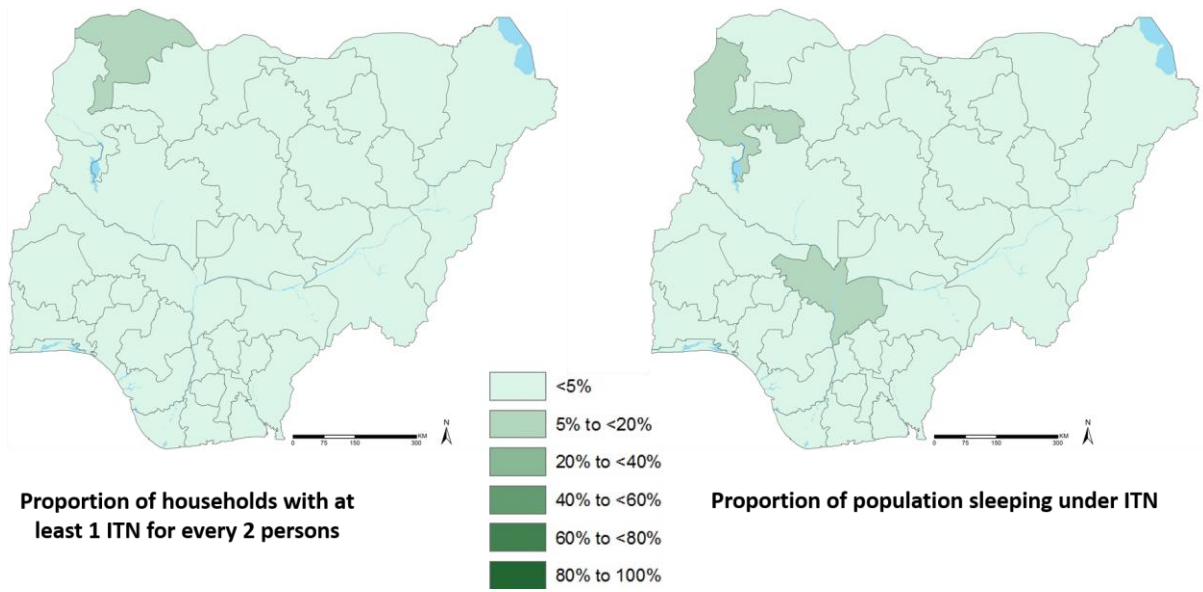
**Figure 15** ITN usage (l) and universal coverage (r) in Nigeria, 2008



Proportion of households with at least 1 ITN for every 2 persons

<5%
5% to <20%
20% to <40%
40% to <60%
60% to <80%
80% to 100%

Proportion of population sleeping under ITN
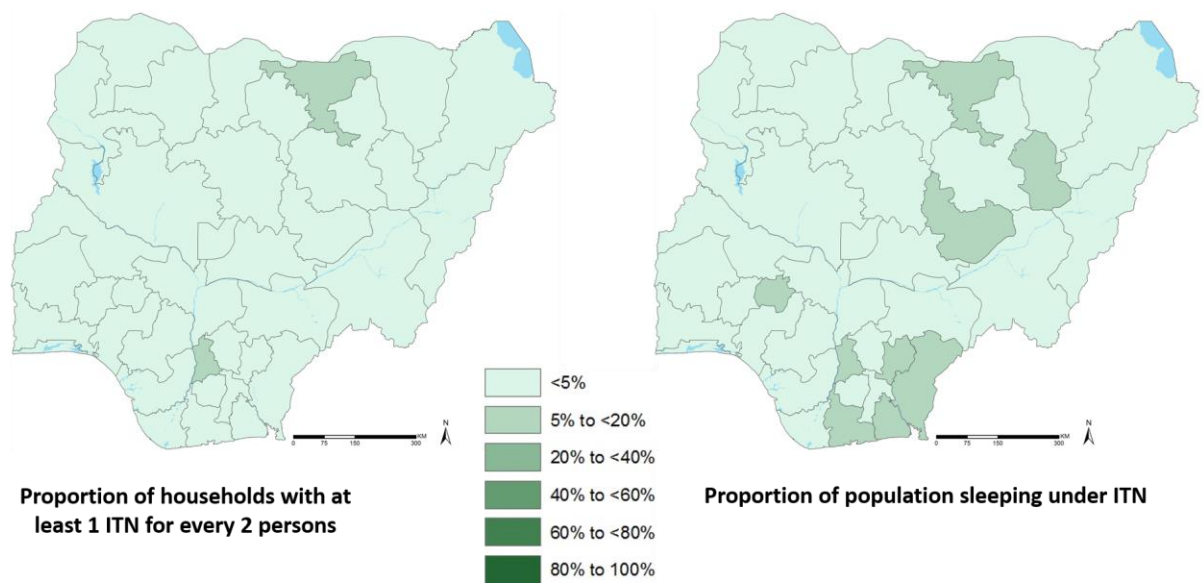
**Figure 16** ITN usage (l) and universal coverage (r) in Nigeria, 2010



| | |
|---|---|
| <5% | |
| 5% to <20% | |
| 20% to <40% | |
| 40% to <60% | |
| 60% to <80% | |
| 80% to 100% | |

**Proportion of households with at least 1 ITN for every 2 persons**

**Proportion of population sleeping under ITN**
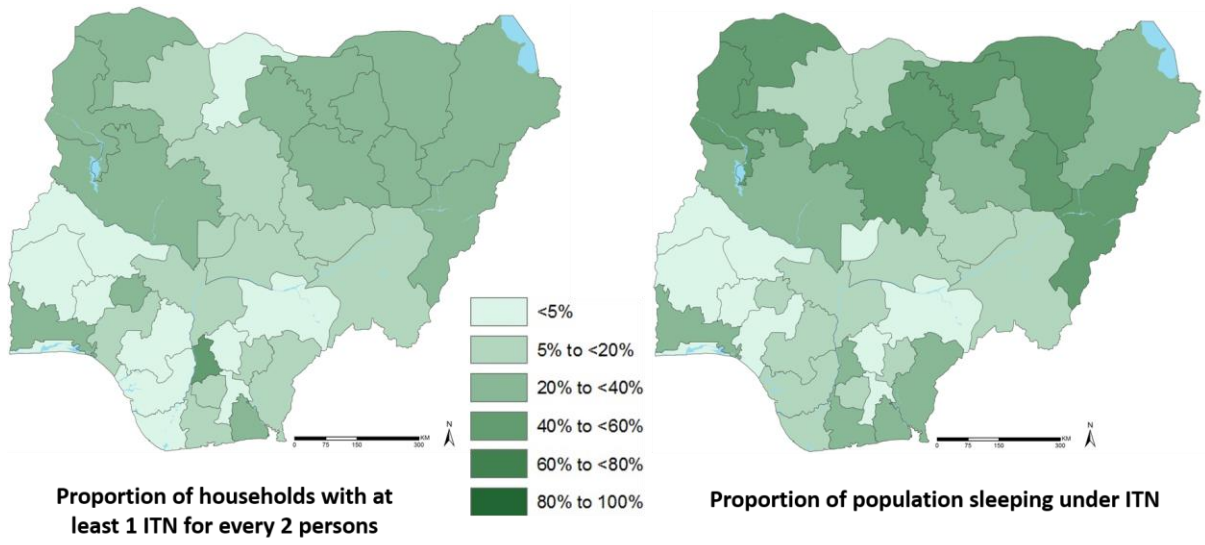
**Figure 17** ITN usage (l) and universal coverage (r) in Nigeria, 2013



| | |
|---|---|
| <5% | |
| 5% to <20% | |
| 20% to <40% | |
| 40% to <60% | |
| 60% to <80% | |
| 80% to 100% | |

**Proportion of households with at least 1 ITN for every 2 persons**

**Proportion of population sleeping under ITN**
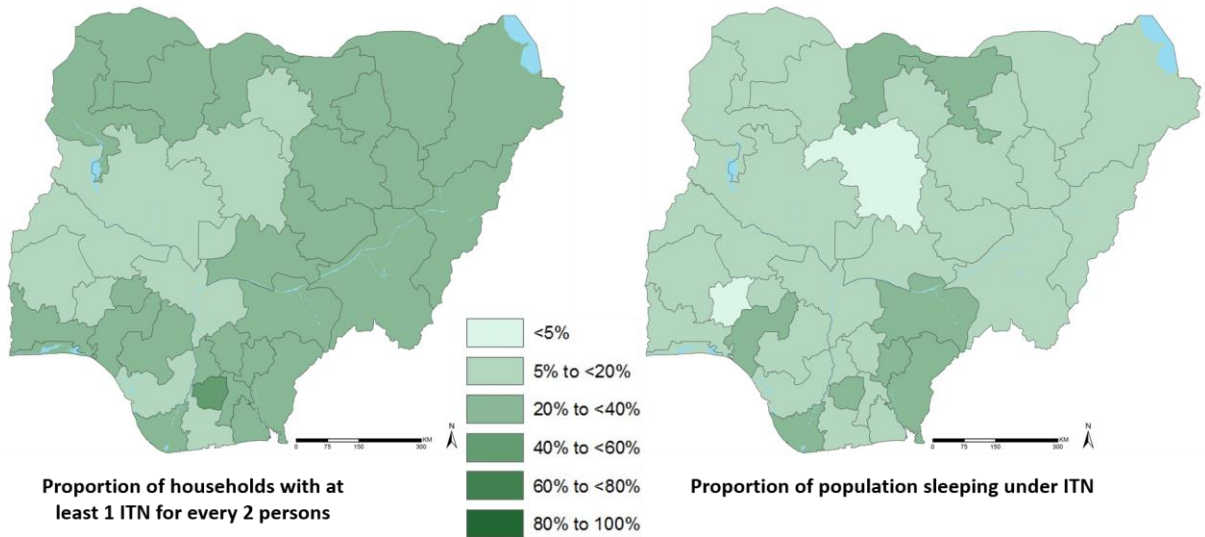
**Figure 18** ITN usage (l) and universal coverage (r) in Nigeria, 2015



Legend:
<5%
5% to <20%
20% to <40%
40% to <60%
60% to <80%
80% to 100%

**Proportion of households with at least 1 ITN for every 2 persons**

**Proportion of population sleeping under ITN**
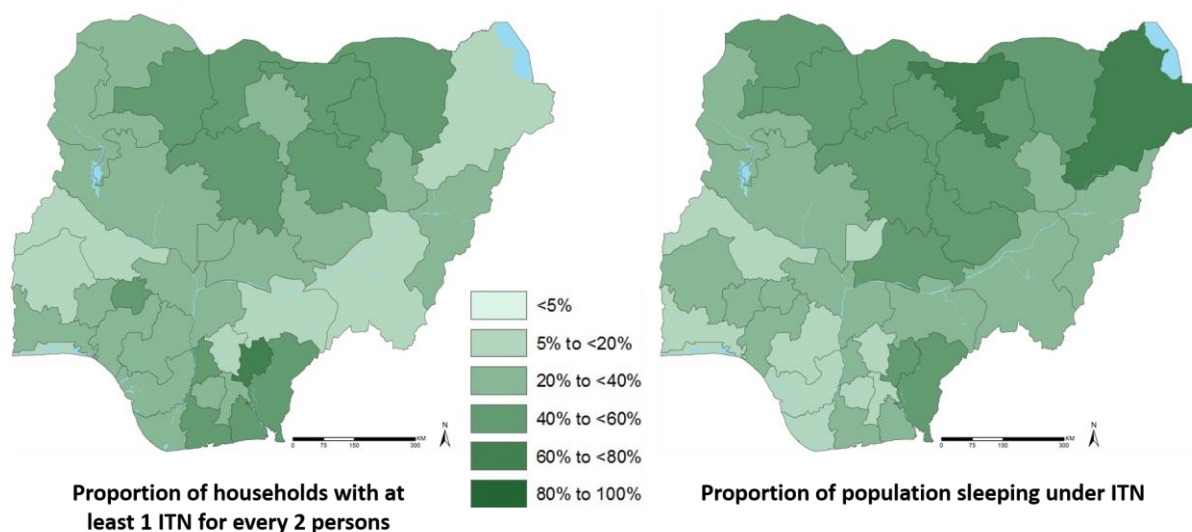
## 5.3 IRS 2014-6

The 2014-20 NSP calls to scale up IRS in targeted areas to interrupt malaria transmission. Specifically, the relevant IRS strategies and their associated targets in the NMSP prevention section are:

1. At least 40% of households in IRS targeted areas will be protected by 2020.

2. At least 85% of all structures in targeted LGAs will be covered using IRS during each spray cycle.

IRS is a supplementary intervention to LLINs in the current NSP. National coverage of IRS is estimated at 1% as reported in the 2015 MIS [72].

Most states did not have resources to continue IRS activities upon the conclusion of the World Bank Booster programme in March 2014. The exception was Lagos, which has consistently conducted IRS in two LGAs since 2009 [73]. In 2016, the Public Private Partnership (PPP) strategy was developed as part of the effort to scale up IRS and the Federal Government provided funds for a small IRS pilot to cover six selected states (ie. one per geo-political zone): Nasarawa (North Central), Bauchi (North East), Jigawa (North West), Lagos (South West), Rivers (South South) and Anambra (South East). IRS was implemented over a one and half month period in November and December 2015 using alphacypermethrin, lambdacyhalothrin and deltamethrin. A total of 19,837 households were sprayed, including 30,759 structures and 70,218 rooms. This provided a protective coverage for 130,061 persons [74].

## 5.4 Malaria diagnosis and treatment progress

In alignment to the NMSP priority action points, the NMEP seeks to strengthen diagnoses and treatment of malaria cases, in addition to strengthening IVM. The scale up of parasite-based diagnosis and access to ACTs in the private sector are two ways that Nigeria has improved its ability to reach vulnerable populations for malaria control, with procurement of RDTs and ACTs demonstrated in Figure 19 [7].

**Figure 19** Procurement of RDTs and ACTs in Nigeria, 2012-6
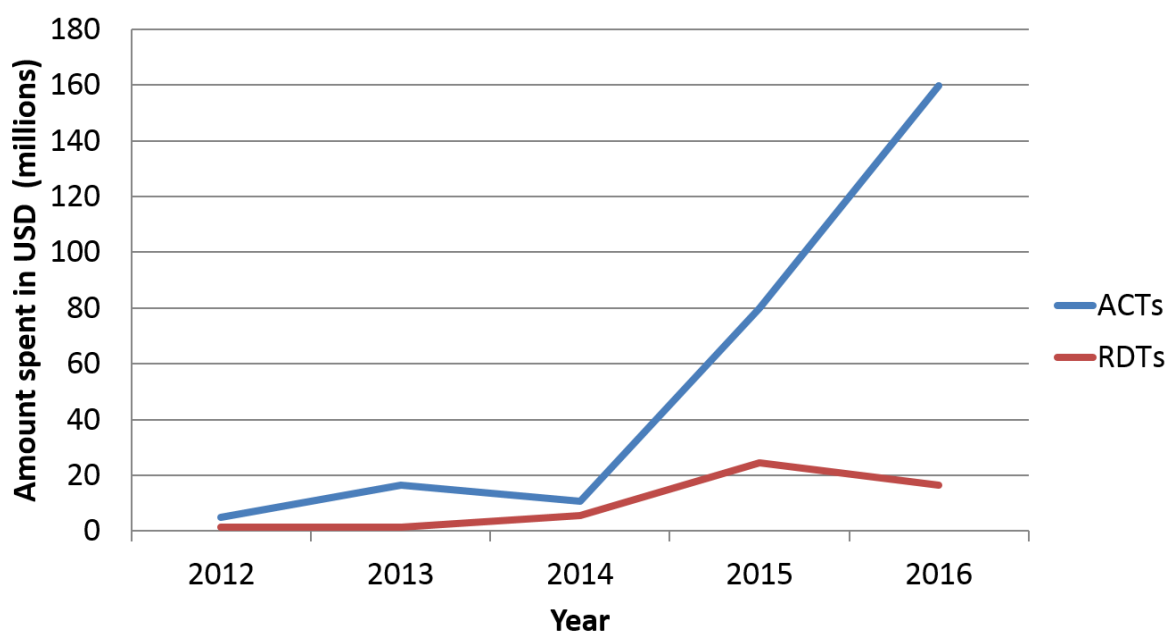


Nigeria implemented the Affordable Medicines for Malaria (AMFm) pilot initiative between 2010 and 2011 to strengthen the private sector (which constitutes about 60% of healthcare services) and to improve accessibility to ACTs [75]. In 2014-5, quality-assured ACT (QA ACT) market share was 35% in Nigeria and there was a significant decrease in median QA ACT price during the AMFm period [75]. However, in 2015 QA ACT remained over 3.4 times more expensive than the most popular non-ACT medicine [76]. Since 2016, over 200 million doses of ACTs have been distributed through public health facilities and the Private Sector Co-payment Mechanism (PSCM), which replaced AMFm [38].

According to the MIS 2015, 23% of women stated that malaria in children should be treated with aspirin, panadol or paracetamol only–a 21% decrease from the MIS 2010. Seventeen per cent reported that CQ should be the drug of choice, which was also an improvement on the 37% reporting in 2010. Nearly one quarter (24%) did not know which medicines could be used to treat children with malaria. Further, while in 2013 18% of children with fever received an ACT in 2013[9], that percentage more than doubled to 38% in 2015 [72,77]. The percentage of children under five years of age with fevers that took ACT appears in Figure 20.

---

[9] This is a difficult indicator to interpret as it could mean that either there were more malaria cases, there was more treatment of negative cases or that access to treatment increased. A better indicator would be the % of children <5 years old who were diagnosed with malaria in the past 2 weeks who received ACTs.

**Figure 20** Percentage of children under five years of age with fevers that took ACT, MIS 2015
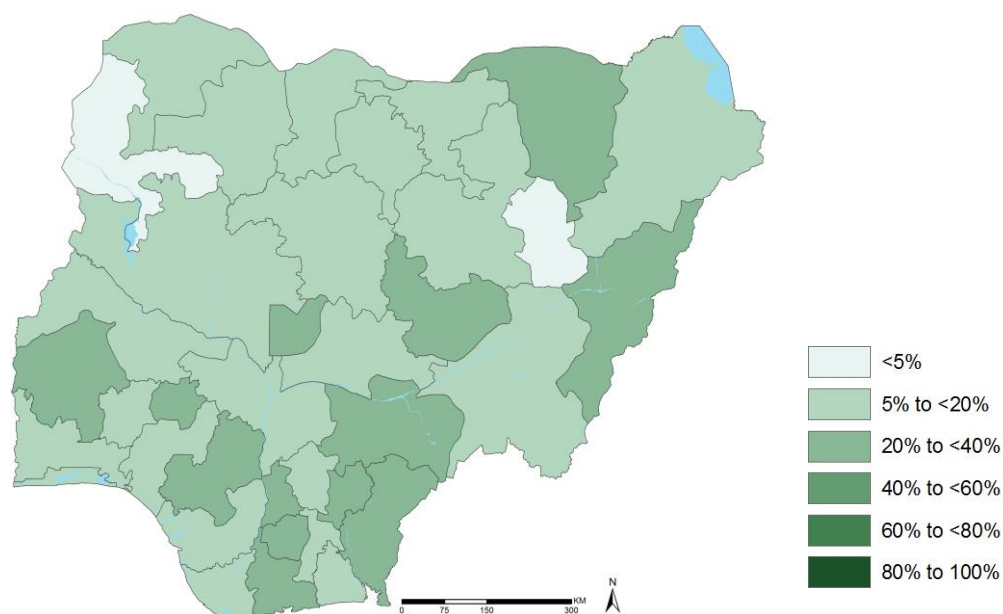


The WHO Rapid Access Expansion (RAcE), which piloted iCCM remote areas in Abia and Niger states between 2013 and 2017, has provided evidence indicating the benefits of reducing U5CM. As a result of their findings, the Nigeria Government is planning to extend iCCM to other states and will include the strategy in National Health Service delivery policies [78].

## 5.5 Seasonal malaria chemoprevention 2014-6

The NMSP 2014-2020 identifies SMC as a primary prevention strategy for the control of malaria in Nigeria. Noor et al [79] included nine Nigerian Sahelian states (Bauchi, Borno, Jigawa, Kano, Katsina, Kebi, Sokoto, Yobe and Zamfara) in a spatial decision framework to identify suitable health districts for targeting of SMC. From this analysis, 227 districts were identified for targeting with SMC between 2015 and 2020, with an estimated population coverage of 15.5 million by 2017. The NMSP lists the target population for this intervention as two million children under five years of age in the nine Sahel states. Both SP and AQ are the recommended drugs for SMC [7].

Implementation of SMC is contingent upon partner activities and donor funding. CHAI implemented SMC in four districts in Kano State as part of a cross-sectional study of nutrition between 2014 and 2015.

In 2015 and 2016, the NMEP in collaboration with the Malaria Consortium (through achieving catalytic expansion of seasonal malaria chemoprevention in the Sahel [ACCESS-SMC], funded by UNITAID) implemented SMC in Sokoto, and Zamfara, and one LGA in both Jigawa and Katsina states, covering 37 LGAs in total. This resulted in a total population vicarage of 967,000 and an increase of SMC coverage in 2016 at 14.1% of total eligible children for SMC in Nigeria compared to 8.3% in 2015 [32]. The remaining funding gap leaves out 190 SMC eligible LGAs. Figure 21 illustrates the shortfall of this implementation strategy by showing actual SMC coverage versus targeted SMC. SMC was included in the Global Fund grant request for 2018-20.

**Figure 21** Actual (green) versus targeted (orange) local government areas targeted for SMC, 2016
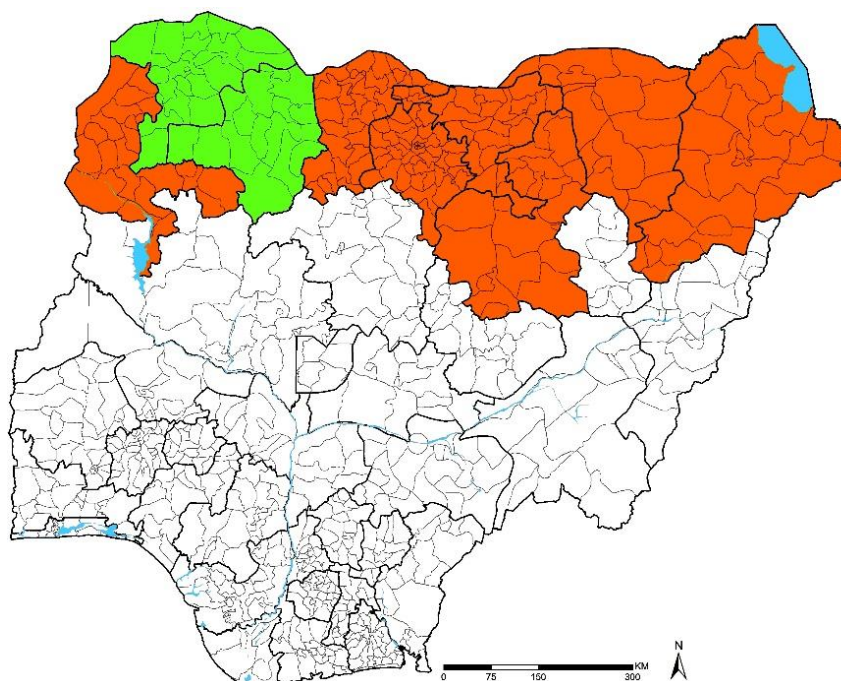


## 5.6  Malaria milestones

2000    12 million LLINs distributed, with half distributed through the private sector

2001    Nigeria hosts RBM summit where the Abuja Declaration was established and 44 African countries pledged to halve malaria mortality in Africa by 2010

2001    National Malaria Control Strategy 2001-2005 launched

2001    Nigeria institutes IPTp for women in the second and third trimesters of pregnancy

2002    Drug Therapeutic Efficacy Tests (DTETs) find high CQ treatment failure (39%) and low therapeutic efficiency for SP (57%), especially in the South South and South East

2002    First case of pyrethroid resistance in *An. gambiae* identified in south-west Nigeria

2003    Third DHS conducted

2005    ACTs adopted as first-line treatment following DTET findings of resistance to CQ and SP. CQ and SP banned as first-line drugs in the treatment of malaria in all age groups

2005    National Antimalarial Treatment Policy released, stating that women should receive at least two doses of SP during pregnancy

2005    SP included in the national essential list of medicines as an over-the-counter medicine

2006    *Ex vivo* tests show *An. gambiae* resistance to permethrin in Zaria

2007    Availability of ACTs increased, with nearly 270 million ACT doses administered nationwide

2007    Third MICS conducted

2008    Fourth DHS conducted

2008   Rapid Scale-Up for Impact (SUFI) launched as part of the NSP, 'A road map for malaria control' 2009-2013

2008   IRS implemented in three LGAs in each of the seven states, aiming to reach 6,765,146 households with alphacypermethrin, lambdacyhalothrin and deltamethrin

2009   NMCP, in collaboration with RBM partners, launches distribution of LLINs across 36 states and the FCT and improved distribution of ACTs in public and private health facilities; 64 million nets distributed in phase 1, to achieve universal coverage until 2012

2009   DTET study finds 98% parasitological cure rate for AL and ART-amodiaquine, authenticating their suitability for first-line therapy for uncomplicated malaria

2009   NMCP scales up IRS in Bauchi, Gombe, Kano, Jigawa, Ribers, Anambra, Akwa Ibon states to supplement LLIN and environmental management

2009   NMCP changes severe malaria treatment policy from quinine to artesunate

2009   New NSP (2009-13) developed, which aims for 80% LLIN ownership and use by 2010, and to reduce malaria-related morbidity and mortality by 50%

2009   National Malaria Control Strategy (2009-2013) launched

2010   NMCP incorporates larval source management as a component of IVM, pilot larviciding is carried out in five locations

2010   First MIS conducted

2010   High levels of DDT resistance observed in *An. arabiensis* and *An. gambiae* in Oyo, Lagos and Niger

2011   Tracking Resistance to Artemisinin (TrAC) study (2010-2) in Ilorin shows sensitivities to artemisinin compounds

2011   Four-year Advocacy, Community and Social Mobilisation plan is introduced to encourage reporting and dissemination on malaria

2011   National Antimalarial Treatment Policy developed

2011   Lagos State Government conducts a malariometric survey in four health zones of Lagos State

2011   IRS provided to 63,000 households in 13 states through Government of Nigeria (World Bank Booster Project and PMI)

2011   NMCP, with Global Fund, launch Phase 1 of the Affordable Medicines Facility-malaria (AMFm) programme, allowing for affordable purchase of first-line drugs (ACTs). 57,261,301 doses administered from July 2010 to December 2011

2011   Fourth MICS conducted

2012   Malaria Programme Review (MPR) conducted from November 2012 to April 2013, examining ten years of malaria control

2013   DTET monitoring efficacy of dihydroartemisinin-piperaquine and the two other deployed antimalarials at eight sentinel sites

2013   SMC targeting children aged three months to 5 years of age (referred to as the Nouakchott Initiative) started in 2013 with two LGAs in Katsina state then expanded to nine northern states

2013   iCCM launched by Malaria Consortium and Society for Family Health through the Rapid Access Expansion Programme (RaCE) in Niger and Abia

2013   NMCP changed to NMEP

2013   Fifth DHS conducted

2014   National Malaria Control Strategy 2014-2020 launched

2014   All intervention strategy polices harmonised into one national malaria policy

2015   Second MIS conducted

2016   Fifth MICS conducted

2017   Development and launch of national Insecticide Resistance Monitoring (IRM) Plan

# 6   Overview of technical methods

The analyses presented here draw on a series of datasets, which were assembled to house information on administrative boundaries, health facility locations, population, parasite prevalence and entomological data. The full digital Pdf library, database and bibliography accompany this report.

## 6.1   Space-time geostatistical modelling

Geostatistical methods were developed to interpolate data at sampled locations in space and time to provide predictions of quantities at locations and times where data do not exist. All MBG methods operate under Tobler's First Law of Geography, which states that things that are closer in space and time are more similar than those more spatially and temporally distal [80]. When applied within a Bayesian inference framework, these methods are referred to as MBG methods. Bayesian inference allows for better use of sparse data and through the application of prior knowledge of an outcome in an iterative process and also allows for robust estimation of uncertainties around the estimates of the outcome.

**Figure 22** Space time Kriging geostatistical model of *P falciparum* data in Bayesian framework
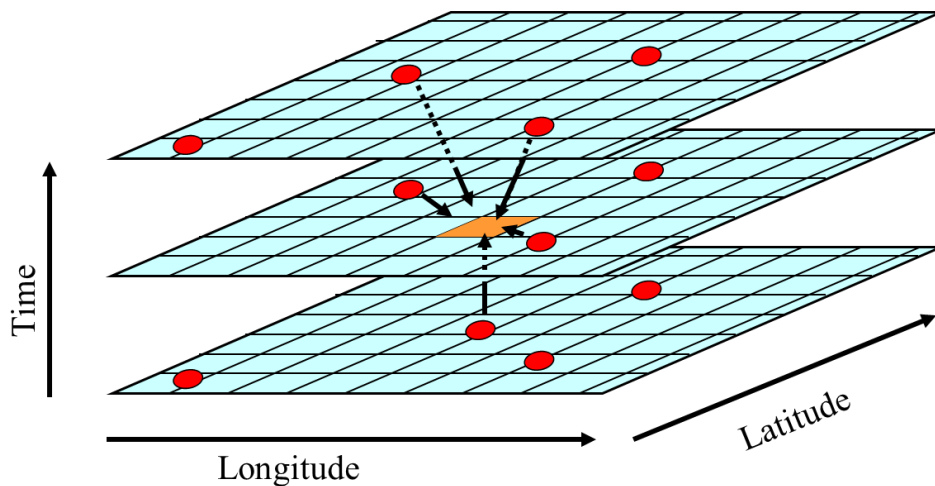


The geospatial modelling strategy used in the current profiles differs from the 2013 profile in that it uses small area estimation (SAE) and provides estimates by state rather than a continuous measure of risk in space, as was done in 2013. SAE is a statistical technique that provides reliable estimates of a target variable in a set of small geographical areas [81]. SAE is applied in survey data where it is impossible to have values of the target variable in all the small areas of interest. Unfortunately, sampling from all areas can be expensive in resources and time. The survey designs often aim to get representative samples from the population of interest and hence leaving out some areas in the population of interest.

Spatio-temporal modelling in SAE has an advantage of borrowing information from the neighboring areas when estimating spatially and temporally correlated random effects. These models have been shown to improve the estimate in the non-sampled areas[82]. In hierarchical spatial models, the area variation not explained by the available covariates is split in two components, structured and unstructured for each region. Structured effects reflect the likely

correlation between neighbouring regions while unstructured effects are termed to be independent in each area [83].

Bayesian approach for SAE has potential benefits in the way it consistently uses similar computation methods and software to provide a coherent framework that can handle different types of target variables (e.g. continuous, dichotomous, categorical), random effects structures (e.g. independent, spatially correlated), areas with no direct survey information, models to smooth the survey sample variance estimates and at the same time handle uncertainty about all model parameters.

Covariates included in the Nigerian model were TSI, EVI, precipitation and WorldPop's definition of 'urban.'

## 6.2 Malaria parasite prevalence surveys

Community-based surveys of malaria parasite prevalence have been assembled from a variety of sources including peer-reviewed journals, international and national ministry of health and academic archives, personal correspondence and more recent national household sample surveys. Methods used to identify, extract and geo-code survey reports are presented elsewhere [3,84].

A total of 1,193 survey locations were identified between February 1980 and November 2015 (Figure 24). Four survey locations undertaken during the MIS 2015 had no GPS coordinates. Of the remaining 1,189 surveys at 1,132 unique locations, 209 were undertaken as part of the first MIS in 2010 [77] and 116 were sampled prior to net distribution campaigns in Abia and Plateau States as a modified MIS conducted in September 2010 to determine baseline, state-level estimates of malaria prevalence, childhood anaemia, IRS coverage and bed net ownership and utilisation [85]. Data for 96 sites was provided confidentially by the Carter Center, 153 sites were included from a malaria and anthropometric baseline assessment (MABA) survey conducted by the FMoH in 2011 [86] and 306 survey locations were included from the MIS in 2015 [72].

**Figure 23** Malaria parasite prevalence surveys by year 1980-2015
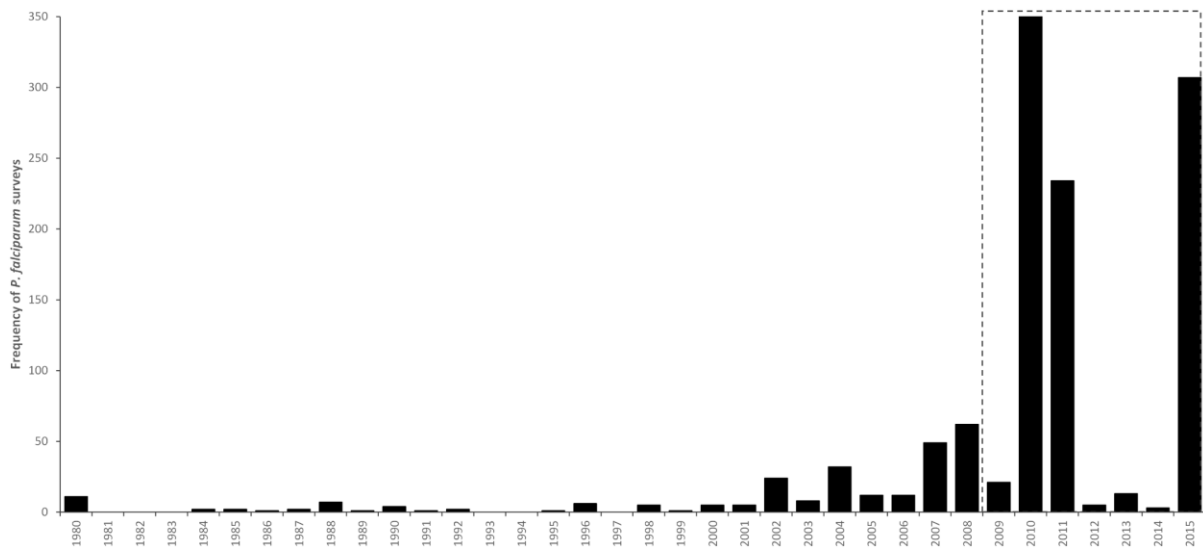


Among the 1,189 time-surveyed locations, 1,084 used microscopy for parasite detection, 100 used RDTs and five used RDTs but positives were confirmed by microscopy. All data assembled is provided to the NMCP accompanying this report for future use and updating.

**Figure 24** Locations of 1,189 P$f$PR$_{2-10}$ data between 1980-2015
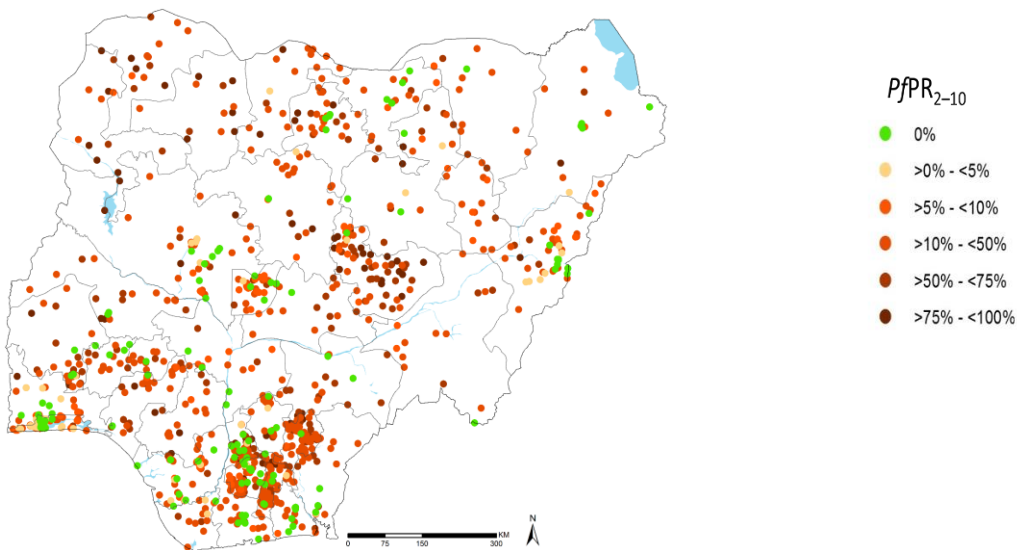


To make meaningful comparisons in time and space, a single standardised age range is required. Correction to a standard age for *P. falciparum* was done using adapted catalytic conversion Muench models. These static equations in R-script use the lower and upper range of the sample and the overall prevalence to transform into a predicted estimate in children aged two to ten years, *Pf*PR$_{2-10}$ [87] with data most temporarily proximal to prediction dates. Further, this is only to predict to years when a national MIS was undertaken – as such we have therefore selected 934 data points between 2009 and 2015 as shown below (Figure 25).

50

**Figure 25** Locations of 1,189 $PfPR_{2-10}$ data between 2009-2015
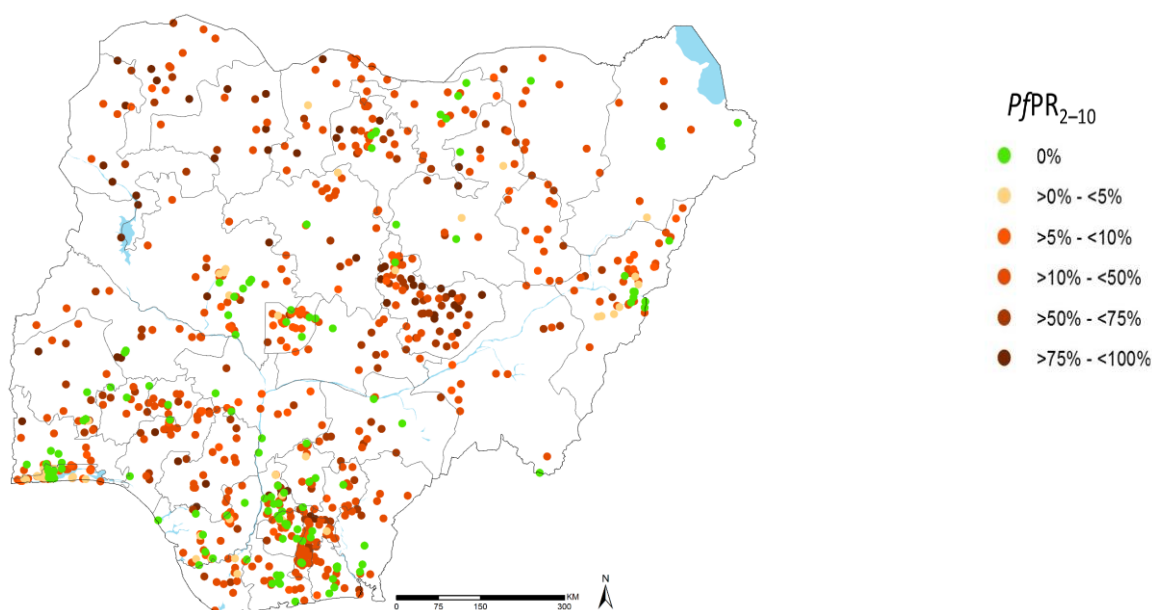


## 6.3 Mapping health facility distribution

### 6.3.1 First-level mapping in 2013-4

Health facility lists were provided through an agreement between the NMCP, SuNMaP and the FMoH in separate MS Excel files for each of the 36 states and FCT of Nigeria in 2013 [88]. Information on facility code, name, location (state, local government authority, ward), service level (primary, secondary, tertiary), management (public, private, others) was abstracted into a single excel sheet containing 33,142 records.

Data cleaning: The resultant file had several anomalies. To begin with, some wards were missing names in Kano, Ondo and Yobe States. The labelling of service providers was incorrect in several instances (five "primary", two "secondary" and one "closed"), these we relabelled as per the name provided of the facility. Several facilities originally coded as public state-managed services (Army, National Police Force etc) we relabelled to "other" public institution. Fifty-five mission and five community-care providers were incorrectly labelled and we relabelled them as "public" facilities. Several facilities only had facility type instead of a name, and we changed the latter by appending ward names to the facility type and removed the blank names and ward records (seven).

Duplicates: We identified 440 facilities that had duplicated codes despite having different names and locations. We were able to correct 346 facility code duplicates that occurred between states by changing state prefix codes. Gombe and Imo States shared a state code of 16, we changed the state code for Gombe to 15 which was missing in the entire database. The remaining 94 state code duplicates occurred within states and we are unable to correct for these until another file is availed to reconcile the duplicates. We noted these alongside the facilities. Facilities that were duplicated in names but had different facility codes were retained.

Public, private and other facilities: We excluded facilities that were labelled as dental clinics, laboratories, drug stores, X-ray clinics, eye clinics, maternity homes, mental clinics, youth centres or other specialist and teaching facilities that were unlikely to provide routine curative services or "closed" (1854); and facilities labelled as private (10,464). The final public sector facility list contained 20,812 facilities. We developed a new field with facility types extracted

from names and used this to recode facility types with 19,705 offering primary health care, 1,043 offering secondary health care and 68 offering tertiary health care. We have retained, where possible, two columns representing facility codes. The first facility code accompanied the original FMoH database (ten-digit number: first two digits were state code, the second two digits represented LGA code, followed by a one digit facility type code, one digit facility owner code, and finally four digits representing the facility) and the second coding column was used to record the seven-digit code used in the FMoH HIV/AIDS service provision database (not available for 83% of facilities). Hospitals were relatively easy to distinguish within the originator database. However, the nomenclature of all other facilities is confusing and not easy to reconcile against levels of care. For example, the database contains descriptions as follows: Comprehensive Health Centre/clinic, Health/medical Centre, Model Health Centre/clinic, Model Primary Health Centre/clinic, Primary/basic Health Centre/clinic, Clinic, Community Dispensary, Community Health Centre/clinic/Post, Dispensary, Government House Clinic, Health Post/Clinic/Facility, Mission Clinic, Out Post and Primary Health Clinic. This requires additional work to reconcile and improve to make the database of value.

Geocoding: Of the 20,812 public facilities, we were able to initially geo-locate 6,124 using FMoH database, 2,626 using Google Earth, 858 using Geonames, three using Encarta, 21 using Fallingrain, 4,844 using OSM database, 835 using GIST database, 356 using GIS-DIVA database, 81 using other sources and 2,517 using combinations of listed sources in cases where facilities were differentiated by type within same wards, these will however require further investigation and improvement using other datasets including the HIV/AIDS service mapping database.

### 6.3.2   Updated geocoding and mapping November 2016

Since the performance of the work described above, a database of Nigerian health sites was identified from the OCHA HDX portal [89] containing 34,139 health facilities which had only facility names, type and coordinates. It had no information on ownership and some facility names were absent. The original source of the health sites is stated as being the Nigeria MDG information system from the Office of the Senior Special Assistant to the President on MDGs. We used this database's GPS coordinates to improve the coordinates of the Nigeria main database. The final database of Nigeria's 20,812 health facilities has the following coordinate sources: 6,647 using Nigeria health sites database (GPS), 6,124 using FMoH database (GPS), 1,611 using Google Earth, 546 using Geonames, three using Encarta, 19 using Fallingrain, 2,659 using OSM database, 476 using GIST database, 232 using GIS-DIVA database, 60 using other sources and 1,321 using combinations of listed sources. In total, 19,698 (95%) facilities were successfully geo-located.

As of December 2011, the Directory of Health Facilities in Nigeria had listed 34,173 health facilities from the 36 states and the Federal Capital Territory. Of these, 22,850 are public facilities which consist of 21,808 PHC facilities, 969 secondary and 73 tertiary health facilities 40, 75 (Figure 26).

Due to a difference in definition and classification of facility types across Nigeria's 37 states—where some states like Taraba did not have any health centres while Kaduna and Plateau states had proportionally very few health posts after recoding facility types to three (hospitals, health centres and health posts)—we have recoded all facility types to hospitals and non-hospitals only for uniformity.

**Figure 26** Distribution of 19,698 public health facilities. Hospitals (red) and non-hospitals (green)
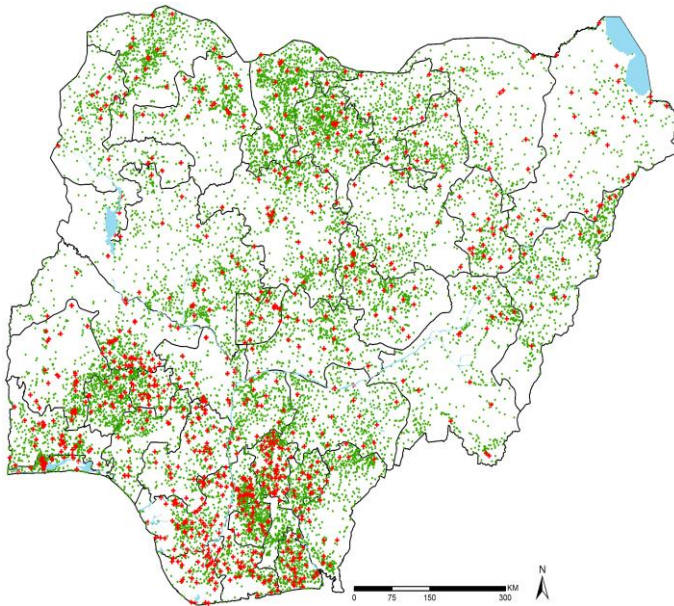


## 6.4  Malaria vector data

A systematic search of published reports on the presence of major malaria vectors in Nigeria over the period 1900 to 2010 has recently been completed [90]. This review is by far the most comprehensive undertaken but supplemented here from additional pan-African vector data assemblies by Sinka *et al.* (2010) and the MARA/ARMA collaboration[6] and updated with some materials from historical archives and recently published sources. We have attempted to include more information on potential secondary vectors. Full details of the data assembly, geo-coding methods and classifications of species according to their role in malaria transmission are provided elsewhere[84]. The database has been arranged as a site-specific, referenced inventory to capture details of species identification recorded since the earliest surveys in 1909 through to the latest records in 2015. The full digital Pdf library, database and bibliography accompany this report.

From each identified report, data extraction included whether a species was identified at a given site, methods used to capture adults or larvae and methods used to speciate each anopheline collection. "Y" was recorded if species was identified and "N" was only recorded when the true absence of the species was reported. The database is therefore one of species presence, not absence and nor is it proportional presence of various vectors. The latter is not possible given the wide variation in collection methods between surveys and an inability to standardise between sampling methods.

# 7 Malaria risk mapping 2010 and 2015

## 7.1 Previous efforts at mapping malaria risk in Nigeria

There are no early maps of malaria risk developed during the pre-independence period. Bruce-Chwatt, however, provides a narrative description of the epidemiology of malaria in the country in 1951, stating that the whole of Nigeria is malarious and that hyperendemic malaria extends from the coast to the 254-mm dry season (November-April) isohyet, with varying degrees of endemicity throughout the rest of the country [16]. To emphasise the uneven distribution, he highlights that in the traditionally hyperendemic southern region there are islands of low endemicity (Ijebu Ode), in the northern arid areas there are numerous hyperendemic foci (Katsina) and that even the Bauchi plateau is endemic for malaria [16]. Spleen rates among children aged one to ten years in the 1950s were between 65% and 80% with relatively little seasonal variation in the southern provinces, and between 50% and 60% in the northern provinces with extreme seasonal variation [16]. The global assembly of medical intelligence, parasite rates and climate data by Russian malariologists in the 1960s classified all of Nigeria as hyperendemic (parasite rates in children 50-74%) with small pockets of holoendemicity (parasite rates in infants above 75%) in the north west of the country and around Lagos [91]. Not until 2001 was an attempt made to formally quantify malaria endemicity in Nigeria.

**Figure 27** Nigerian survey data used in the regional malaria prevalence modelling/kriging exercise in 2001; and b) the results of the regional model shown as categories of $Pf$PR$_{0-10}$ [92]

a)

b)
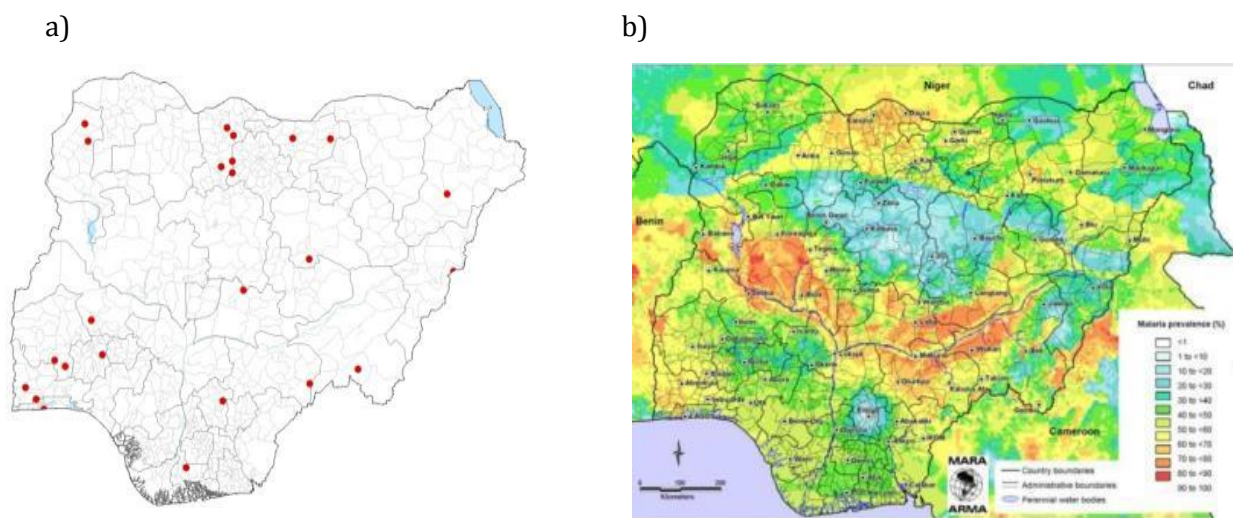


In 2001, the MARA collaboration used 450 parasite prevalence surveys from across West Africa among children aged below ten years from studies undertaken between 1960 and 1999 as the basis of a predictive model of *P. falciparum* prevalence across the region [6,92]. The input data to the model included only 22 survey locations in Nigeria (Figure 17, r). The model used a series of climatic and ecological covariates to train the predictions of prevalence from sparse data including long-term monthly average rainfall, minimum and maximum temperature, remotely-sensed satellite imagery of vegetation indices, soil drainage capacity and population density. The data were partitioned according to ecological zones used by the Food & Agricultural Organization (FAO) for crop potential: Equatorial Forest, (> 270 days of rainfall), Guinea Savannah zone (165-270 days of rainfall), and a combined Sudan and Sahel Savannah zone (less than 165 days of rainfall)[74]. The models were developed for each ecological zone using regression techniques (generalised linear models with logit functions) with the parasite prevalence as the dependent variable. The optimised model was then used to predict malaria

prevalence among children aged less than ten years at un-sampled 5 x 5 km grid squares and smoothed using a process of kriging. The resultant combination of modelling prevalence where data are sparse and kriging of available data is shown in the map 27b. This map has served as the only map of the intensity of malaria transmission used by the Nigerian NMCP since the launch of RBM and with MARA maps of seasonality appears in the Roll Back Malaria Focus series on Nigeria [93], National Malaria Strategy 2009-2013 [41], 2012 Operational Plan of Action for National Control [86] and applications to the Global Fund Rounds 4 and 8.

## 7.2 Malaria risk mapping as a partnership between NMCP, SuNMaP and KEMRI in 2013

In 2013, there was a need to repeat the risk mapping exercise undertaken during the MARA/ARMA years to provide a more empirically-based map of malaria risk for current malaria control planning in Nigeria. The work was a collaborative effort between the NMCP, WHO country office, SuNMaP programme of the Malaria Consortium and the Malaria Atlas Project-*Africa* initiative of the KEMRI-Wellcome Trust-University of Oxford's Malaria Public Health Department in Nairobi, Kenya[3]. Funding was provided by the Department for International Development, UK through the Roll Back Malaria programme, Geneva and the Wellcome Trust, UK.

The principle aim of the 2013 work was to improve the precision of malaria risk mapping in Nigeria and examine changes in risk since the launch of RBM in 2000 to support the NMCP and state-level control agencies in planning and monitoring control.

Nine hundred and twenty-one parasite prevalence survey location's data were identified, assembled and geo-coded from a variety of published, unpublished and personal contact sources. These data covered the examination of 155,343 individuals, of whom 64,768 were *P. falciparum*-positive between 1960 and 2010; 61% of the data was collected after 1990. Data inclusion rules included any community survey data since 1960 through to 2011 where a sample size of 15 or greater was surveyed.

Bayesian MBG methods were used to interpolate in space and time the $Pf$PR$_{2-10}$ data to provide a prediction of expected prevalence at un-sampled 1 x 1 km grids across Nigeria for the years 2000, 2005 and 2010 based on intrinsic priors of the effects of temperature, rainfall, distance to major rivers and urbanisation. Linear correlations of model predicted and observed hold-out data were over 0.79.

This work showed that in 2000, at the launch of RBM, 85% of Nigerians were exposed to hyper-holoendemic transmission (at least 50% of children aged two to ten years harbouring *P. falciparum* infection). By 2005, 45% of Nigerians were exposed to hyper-holoendemic transmission conditions and by 2010 this proportion reduced to only 15%. Figures 28-30 were in the 2013 Nigeria Epidemiological Profile and reflect the previous modelling techniques. These maps are included here for reference purposes.

**Figure 28a–c** Continuous mapped posterior predictions of mean P*f*PR$_{2\text{-}10}$ 2009, 2005 and 2010
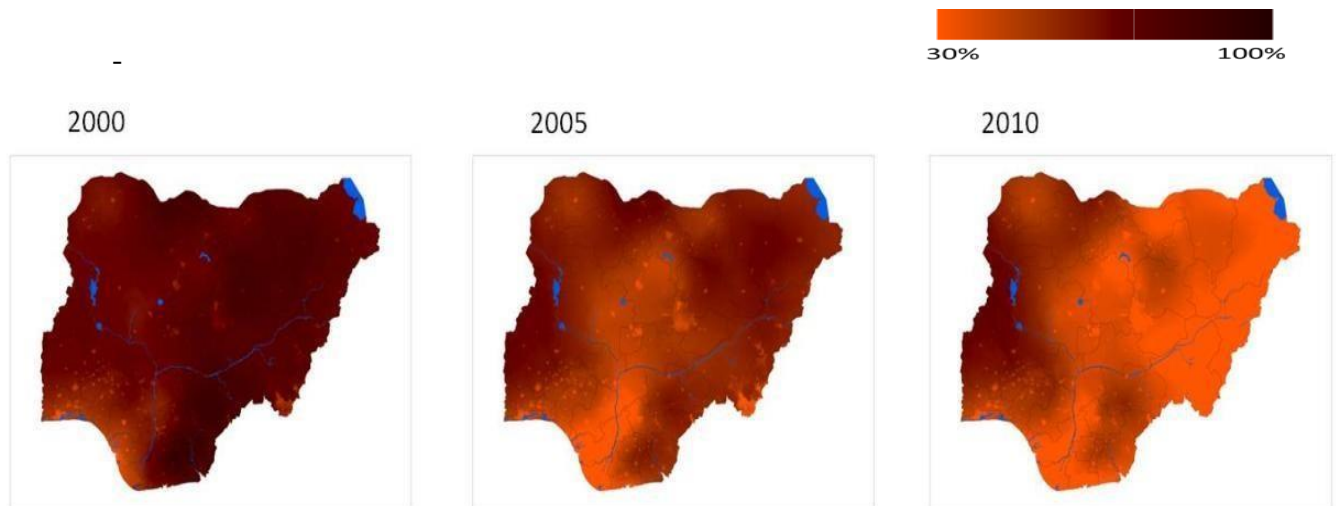


**Figure 29a–c** Binned forms of endemicity class 2000, 2005 and 2010 (light brown <10%, mid-brown 10-49% and dark brown ≥50%)
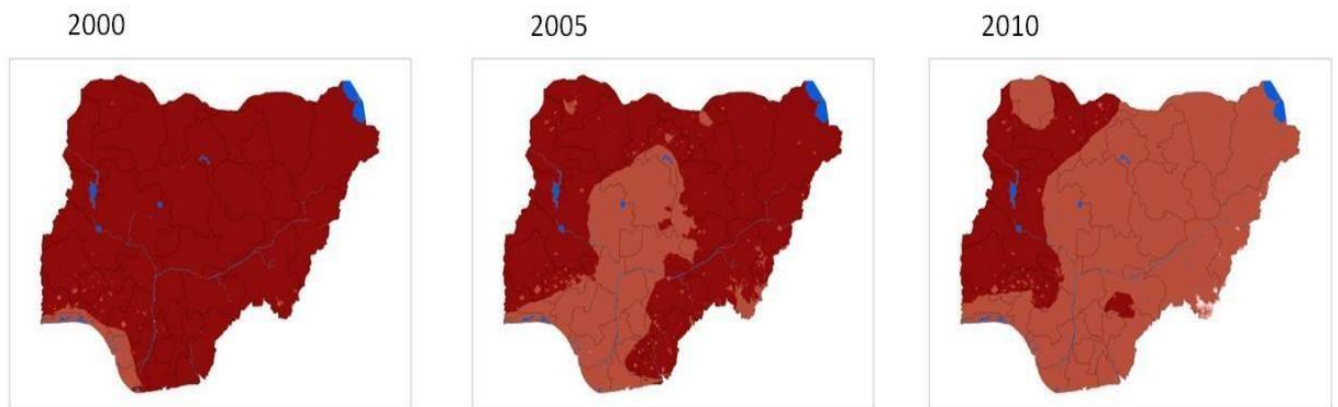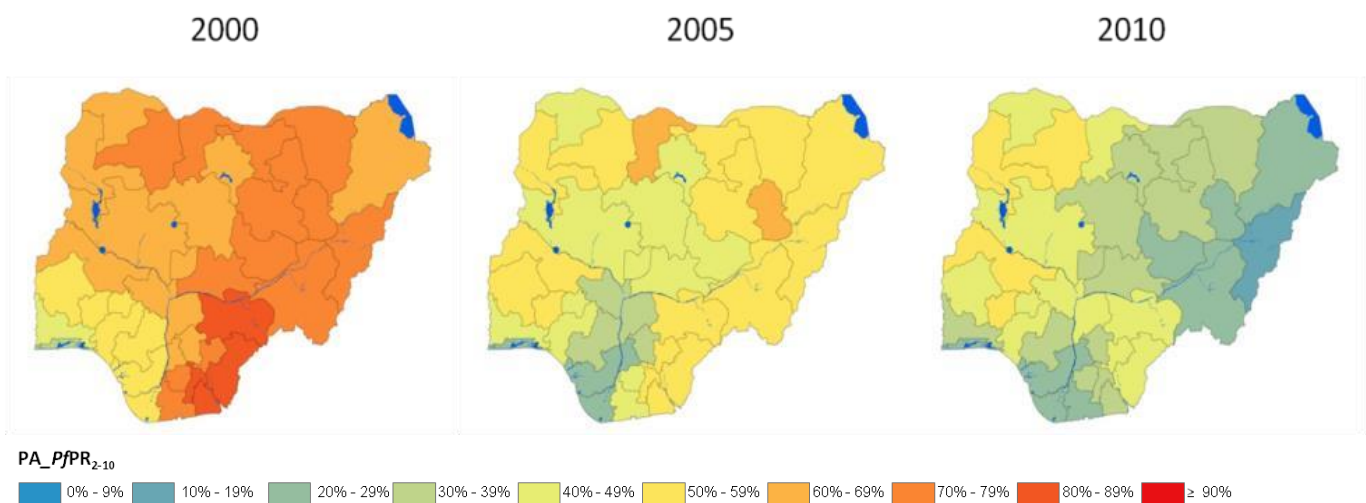


**Figure 30a–c** Population adjusted mean *Pf*PR$_{2\text{-}10}$



PA_*Pf*PR$_{2\text{-}10}$

0% - 9%   10% - 19%   20% - 29%   30% - 39%   40% - 49%   50% - 59%   60% - 69%   70% - 79%   80% - 89%   ≥ 90%

## 7.3 Updated prevalence estimates by state

The updated SAE models of malaria burden in Nigeria show a range between 5% and 61% in district averages of infection of the *P. falciparum* parasite in those two to ten years of age (Table 1). As seen in 2010, Lagos has a much lower prevalence than the rest of the country, with the highest burden in Kebbi State.

**Table 2** SAE state-level estimates of 2010 and 2015 *Pf*PR$_{2-10}$ and 2015 observed MIS *Pf*PR$_{6-10}$

| State | Predicted mean *Pf*PR$_{2-10}$ 2010 | Predicted mean *Pf*PR$_{2-10}$ 2015 | Observed MIS *Pf*PR$_{6-59}$ 2015 |
|---|---|---|---|
| Abia | 40.74 | 32.98 | 8.20 |
| Adamawa | 20.42 | 15.43 | 34.70 |
| Akwa Ibom | 24.53 | 18.81 | 22.80 |
| Anambra | 21.55 | 16.41 | 10.20 |
| Bauchi | 32.73 | 25.72 | 19.60 |
| Bayelsa | 33.81 | 26.66 | 31.40 |
| Benue | 46.78 | 38.59 | 44.50 |
| Borno | 20.32 | 15.40 | 0.00 |
| Cross River | 33.33 | 26.28 | 26.10 |
| Delta | 25.41 | 19.53 | 20.40 |
| Ebonyi | 23.26 | 17.78 | 30.00 |
| Edo | 60.01 | 51.81 | 18.60 |
| Ekiti | 35.63 | 28.37 | 28.80 |
| Enugu | 21.17 | 16.08 | 10.50 |
| FCT, Abuja | 17.96 | 13.52 | 20.20 |
| Gombe | 29.23 | 22.77 | 28.60 |
| Imo | 13.19 | 9.76 | 5.10 |
| Jigawa | 28.72 | 22.30 | 27.90 |
| Kaduna | 23.18 | 17.69 | 36.70 |
| Kano | 40.26 | 32.51 | 27.70 |
| Katsina | 42.21 | 34.26 | 27.80 |
| Kebbi | 69.09 | 61.51 | 63.60 |
| Kogi | 23.61 | 18.09 | 5.40 |
| Kwara | 56.35 | 47.95 | 26.40 |
| Lagos | 7.49 | 5.45 | 0.00 |
| Nassarawa | 40.66 | 32.81 | 35.90 |
| Niger | 26.34 | 20.29 | 33.50 |
| Ogun | 30.50 | 23.92 | 14.70 |
| Ondo | 28.37 | 22.08 | 21.30 |
| Osun | 23.99 | 18.39 | 33.40 |
| Oyo | 29.72 | 23.20 | 19.20 |
| Plateau | 44.08 | 36.13 | 35.80 |
| Rivers | 31.05 | 24.32 | 7.30 |
| Sokoto | 43.65 | 35.64 | 46.60 |
| Taraba | 35.09 | 27.99 | 42.90 |
| Yobe | 30.54 | 23.92 | 18.90 |
| Zamfara | 62.98 | 54.76 | 62.60 |

Applying these estimates to a geospatial model, results are shown in Figure 31 and Figure 32.

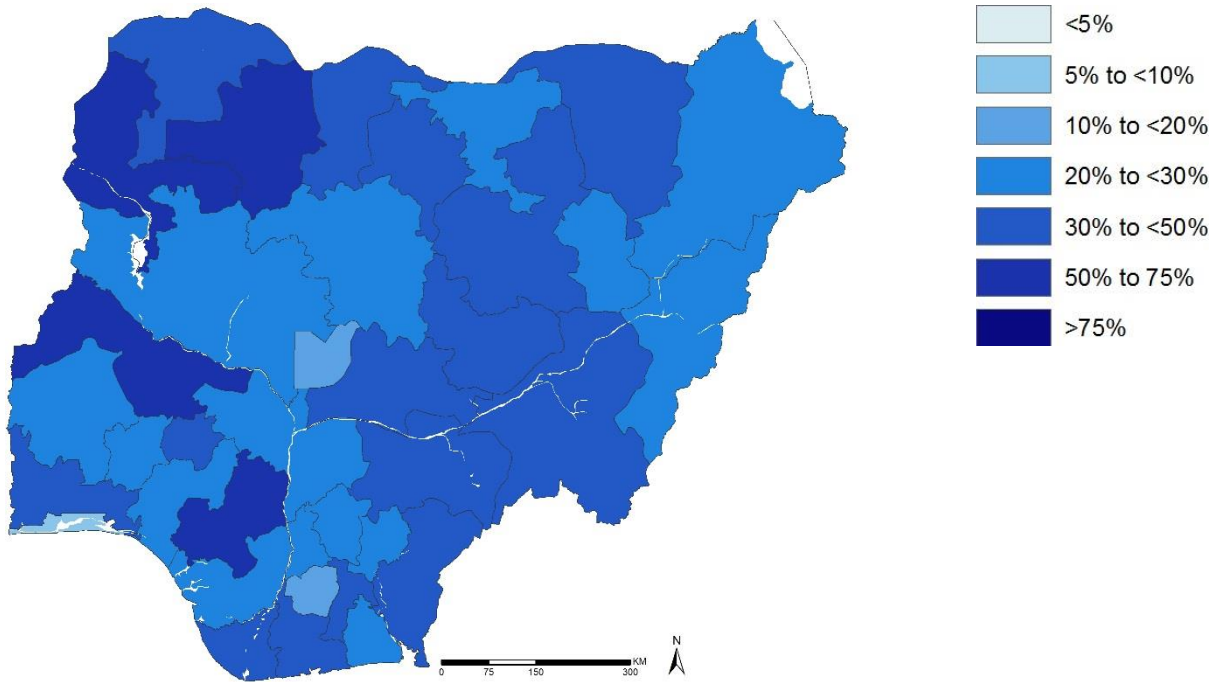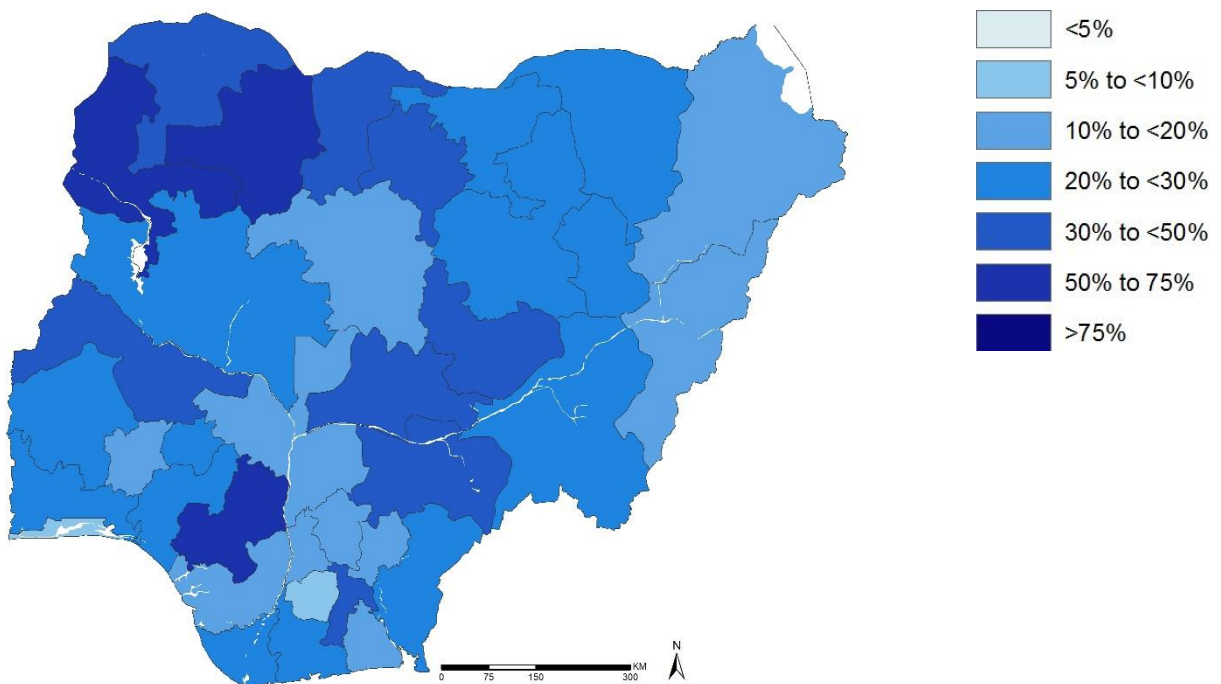**Figure 31** P*f*PR$_{2-10}$ prediction 2010 by health district in Nigeria using SAE



**Figure 32** P*f*PR$_{2-10}$ prediction 2015 by health district in Nigeria using SAE

The maps in Figure 31 and Figure 32 show that predicted malaria endemicity across Nigeria continues to be mostly mesoendemic (10-49% $Pf$PR$_{2-10}$) – with slightly less states in the hyper-holendemic class (above 50% $Pf$PR$_{2-10}$) in 2015 compared to 2010. The Northwest and Edo State are persistently above 75% $Pf$PR$_{2-10}$. Predicted prevalence appears to be decreasing in several central and southern states though these states remain in the mesoendemic class. The perceived decrease in predicted prevalence in the North East from 2010 to 2015 coincides with challenges to access the population, including during both MIS.

The standard deviation maps (Figures 33, 34) give an indication of the error around the mean distribution. If the standard deviations are close to 3, the uncertainty in the model predictions is very high. The range of the standard deviation is 0-0.04, indicating that the uncertainty in the model was very low.

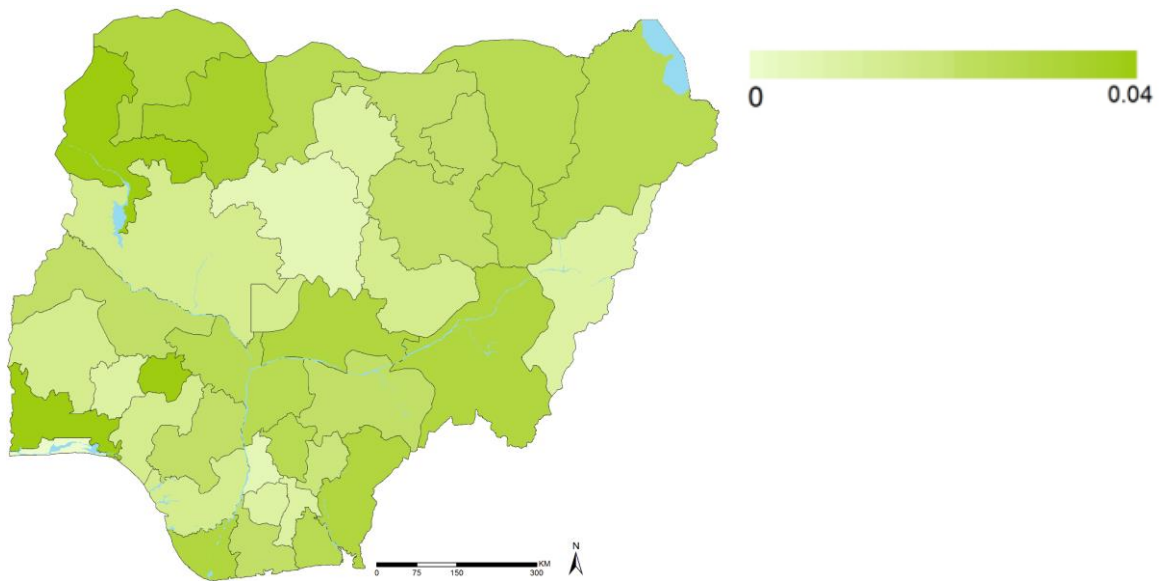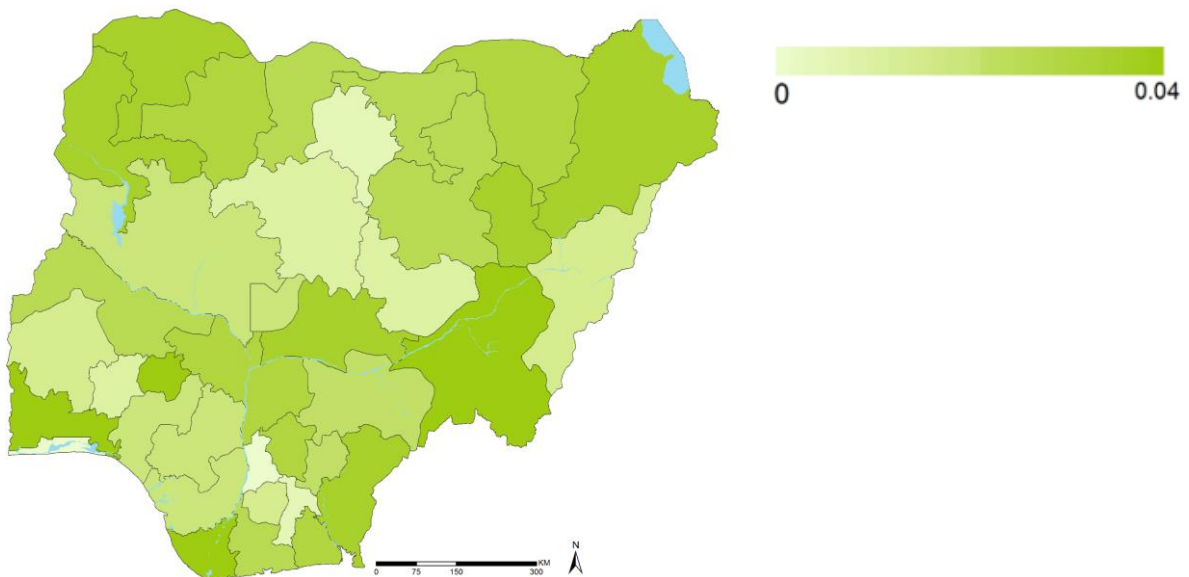**Figure 33** Standard deviation around predicted mean 2010



**Figure 34** Standard deviation around predicted mean 2015

Between 2010 and 2015, modelled estimates of *P. falciparum* parasite rate decreased between 20% to 25% in 26 of 36 states. The rate decreased by more than 25% in Lagos and Imo States (Figure 35).

**Figure 35** P*f*PR$_{2-10}$ prediction decrease 2010-5 by state in Nigeria using SAE
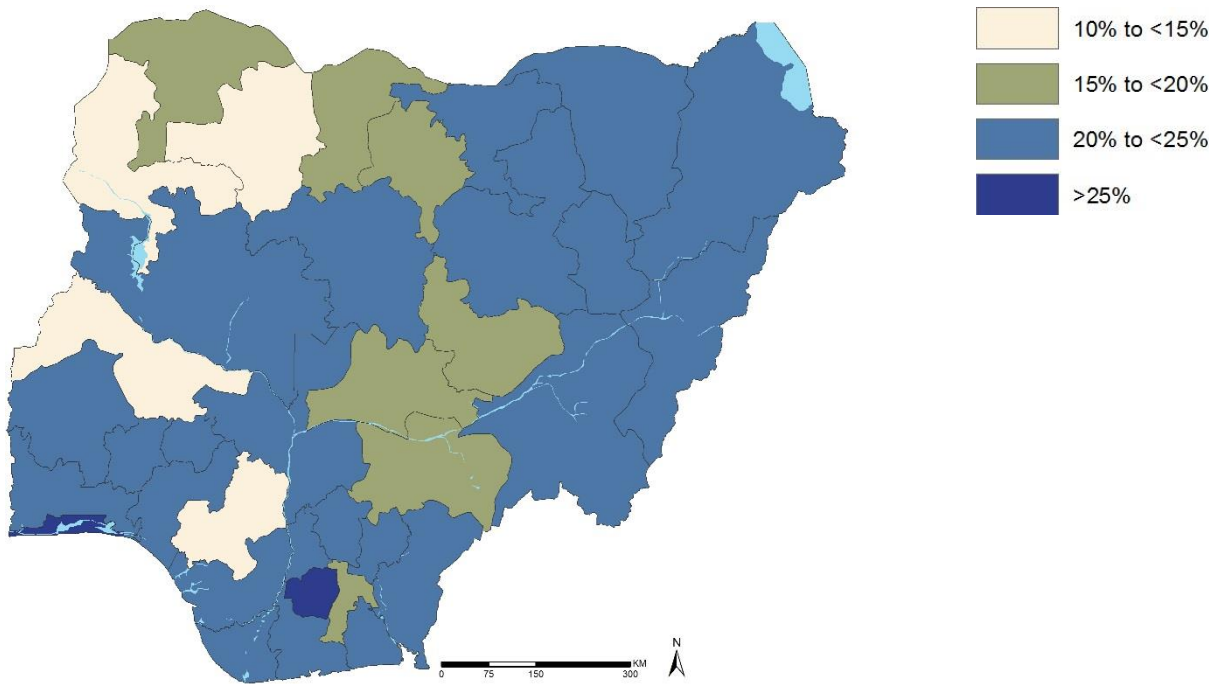
# 8   Vector profile and mapping

The final database contained 394 site/time specific reports of anopheline vectors in Nigeria between 1909 and 2015 for which we were able to geo-locate the survey site. The database has been arranged as a site-specific, referenced inventory to capture details of species identification recorded. We were unable to geo-locate only three (0.76%) of the survey sites. Vector sampling records have not been identified since 2005 for 14 states: Abia, Adamawa, Akwa lbom, Benue, Ebonyi, Edo, Federal Capital Territory, Gombe, Kaduna, Kebbi, Kogi, Sokoto, Taraba and Yobe.

The database includes some of the earliest inventories of anophelines in Nigeria undertaken by MW Service [94], detailing a checklist and the distribution of the Culicidae in Nigeria as well a place-names database showing longitudes/latitudes. We have not assembled geocoded information related to vector resistance, as these data have been carefully curated, validated and mapped by the IRBase initiative [95,96]. A full description of each vector is available in the previous malaria epidemiological profile for Nigeria[3].

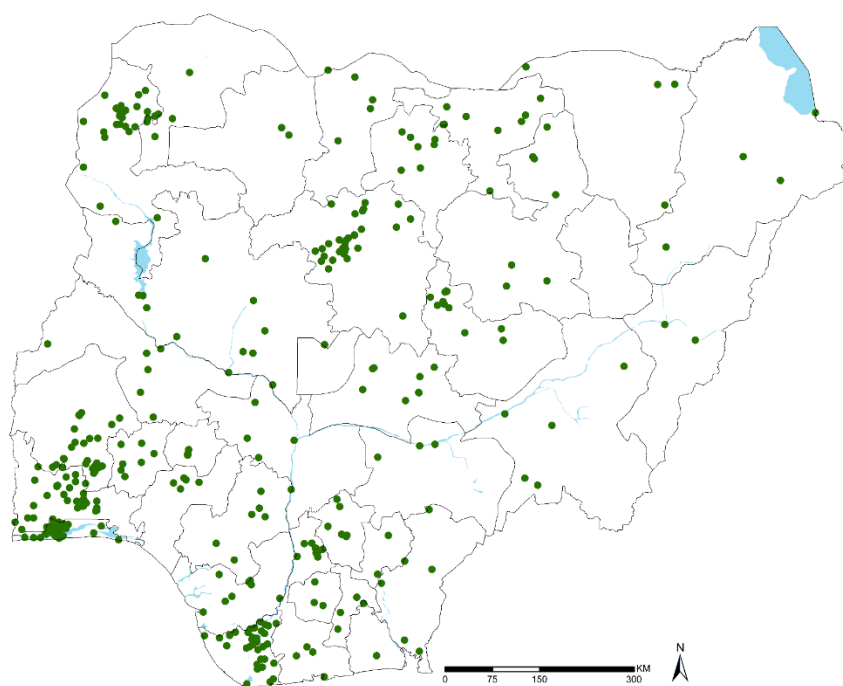**Figure 36** Location of mosquito sampling sites for 394 surveys undertaken between 1909 and 2015

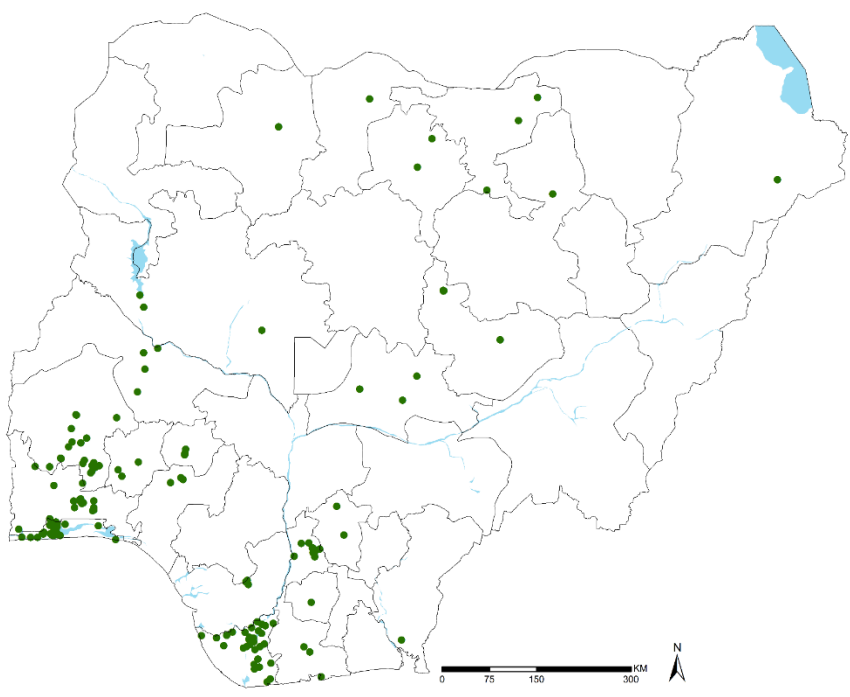**Figure 37** Location of mosquito sampling sites for 151 surveys undertaken since 2005



**Figure 38** Recorded species identifications across all surveys by region
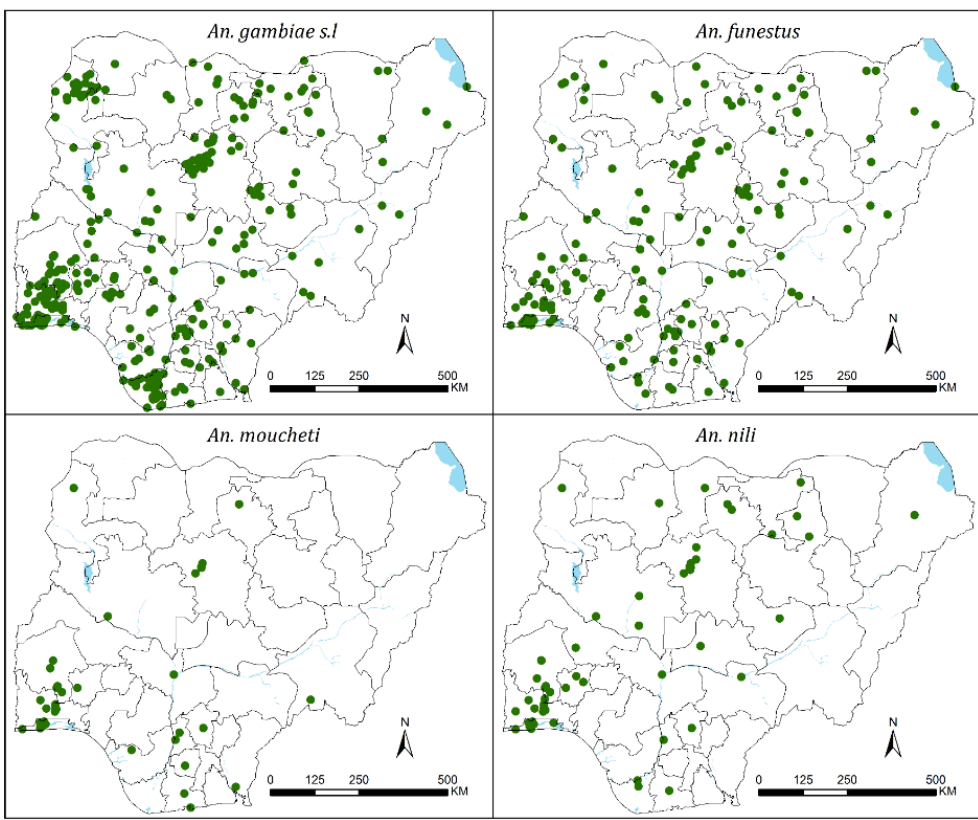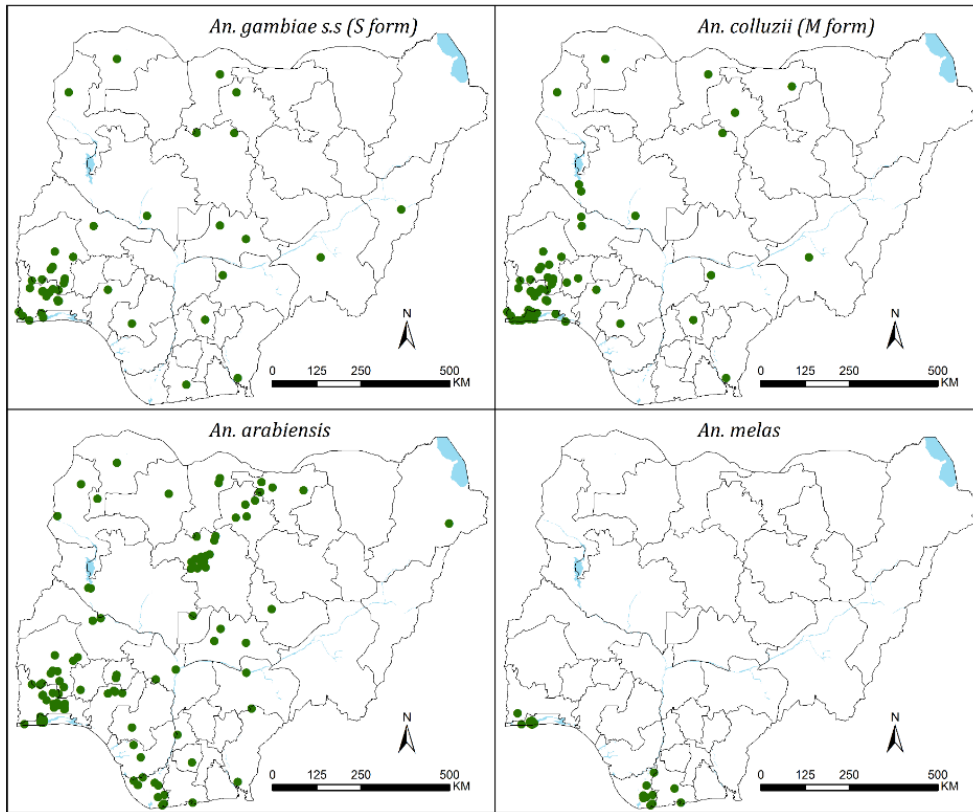
**Figure 39** Location of members of *An. gambiae* complex

# 9  Key findings

This report focuses on the basic epidemiological features of malaria transmission, assembling the data and interpolating information in space and time. We have assembled as much epidemiological data and control context as possible from a wide variety of sources to support the description of malaria in Nigeria. Central to the report has been the assembly of parasite prevalence data and modelling the spatial and temporal properties of this metric of transmission intensity.

## 9.1  Changing *P. falciparum* parasite prevalence 2010-5

From a 2010 baseline, the estimated *P. falciparum* malaria infection prevalence in children aged two to below 10 years of age (P$f$PR$_{2-10}$) has greatly shifted holoendmic to mesoendemic, reflecting a reduction of transmission throughout the country. In 2010, 8.2% of Nigeria's population lived in areas where P$f$PR$_{2-10}$ was >50% and by 2015, this decreased to 5.6%. In contrast, populations in areas of P$f$PR$_{2-10}$ between 10% and <50% or increased from 45% in 2010 to 90% in 2015. More of the population now live in areas within the middle risk bracket not only due to the decline of transmission in holoendemic areas, but also due to an increase in transmission in some areas that had lower endemicity (0% to <10% P$f$PR$_{2-10}$) in 2010, suggesting a reversal of progress in some areas.

**Table 3** Malaria prevalence by endemicity and population, 2010 and 2015

| P$f$PR$_{2-10}$ endemicity | 2010 | 2015 |
|---|---|---|
| 0% to <10% | 10,223,836 | 7,699,591 |
| 10% to <30% | 63,226,459 | 123,555,874 |
| 30% to <50% | 78,743,503 | 42,790,325 |
| ≥ 50% | 13,102,106 | 10,468,170 |
| Total population | 158,224,759 | 184,513,959 |

Despite reductions, 97% of Nigerians continue to live in areas where there is a risk of malaria infection. Recent challenges of insecurity in the Northeast and increased IDP movement have contributed pockets where transmission increased or was stagnant.

## 9.2  Progress in vector control interventions

Nigeria has seen a noteworthy decrease in IMR and U5MR mortality since 2003, which coincides with a massive scale up of vector control interventions from 2009 to 2015. Also, the recent MIS reflects an increase in coverage and use of LLINs in the population. However, IRS coverage has been a meagre 1% even though the current NSP call for at least 40% of all households to be protected by 2020.

## 9.3  Need for increased vector surveillance and mapping

Eighty-nine percent of all malaria infections in Nigeria are *P. falciparum*, 9% are *P. malariae* and 2% are *P. ovale.* A more extensive speciation of *An. gambiae* complex in Nigeria is needed. Additionally, only 730 survey locations had information on all parasite species undertaken during surveys between 1980 and 2015. Further vector sampling records have not been identified since 2005 for 14 states: Abia, Adamawa, Akwa lbom, Benue, Ebonyi, Edo, Federal Capital Territory, Gombe, Kaduna, Kebbi, Kogi, Sokoto, Taraba and Yobe.

An additional knowledge and capacity gap identified by stakeholders was entomological surveillance including capacity to characterise insecticide susceptibility, spatial and temporal composition, and distribution of anopheline species, to assist with vector mapping.

## 9.4  Need for improved malaria data

In 2017, the World Malaria Report estimated that Nigeria contributed 27% of malaria cases and 30% of malaria deaths reported globally [32]. The high burden of disease makes the NMEP goal to reduce malaria burden to pre-elimination levels and bring malaria-related mortality to zero by 2020 a challenge. To date, the M&E the current HMIS reporting rate continues to be too low for effective monitoring of impact (NMEP HMIS, 2017). Efforts such as data quality audits and supportive supervision are ongoing but must be expanded in order to harness better, more complete data from sentinel sites.

Funding, partners and intervention coverage have varied significantly between states since 2000. To understand and explain changes in transmission across Nigeria would require the assembly of additional data at state levels with higher temporal resolutions.

As mentioned in the 2013 profile, there were several missed opportunities to include data from community and state-wide surveys. The NMEP should lead in the coordination and storage of accurate parasite prevalence data for future mapping of malaria in Nigeria.

Another recommendation from the 2013 profile that merits repeating is the triangulation of routine malaria data with other sources, specifically hospital admissions. It would be valuable to try to retrospectively assemble monthly paediatric admission data (malaria versus non-malaria diagnosed) from several teaching hospitals across Nigeria likely to have maintained reasonable laboratory services for as complete a period as possible between 1999 - 2016. If enough data could be assembled from sufficient hospital sites these data would help interpret the rate, slope and magnitude of changing risks across the changing climate and intervention conditions in different regions of Nigeria since 2000.

# 10 References

1. Snow RW, Marsh K, Le Sueur D. The Need for Maps of Transmission Intensity to Guide Malaria Control in Africa. Parasitol Today. 1996;12(12):455-457. http://www.mara-database.org/docs/2.pdf. Accessed February 16, 2018.
2. Diggle P, Ribeiro PJ. Model-Based Geostatistics. Springer; New York (2007). ISBN 0387329072.
3. National Malaria Control Programme, SuNMAP, World Health Organization and the INFORM Project. A Description of the Epidemiology of Malaria to Guide the Planning of Control in Nigeria. A Report Prepared for the Federal Ministry of Health, Nigeria, the Roll Back Malaria Partnership and the Department for International Development, UK.; 2013.
4. World Health Organization Africa Regional Office. Manual for Developing a National Malaria Strategic Plan | WHO | Regional Office for Africa.; 2012. http://www.afro.who.int/publications/manual-developing-national-malaria-strategic-plan. Accessed February 16, 2018.
5. Maikore I. Decision Making in NMEP: An Analysis of the Driving Forces That Influence Use of Evidence in Policy Formulation. Abuja, Nigeria; 2016.
6. Mapping Malaria Risk in Africa (MARA). MARA/ARMA collaboration. https://www.mara.org.za.
7. Federal Ministry of Health of Nigeria. National Malaria Strategic Plan 2014-2020. Abuja, Nigeria; 2014.
8. Ploch Blanchard L,  Husted T. Nigeria: Current Issues and U.S. Policy. March 11, 2016, https://fas.org/sgp/crs/row/RL33964.pdf accessed July 25th 2018
9. Unpublished data, NIFFR. National Institute for Freshwater Fisheries Research.
10. Lehner B, Döll P. Development and validation of a global database of lakes, reservoirs and wetlands. J Hydrol. 2004;296(1-4):1-22. doi:10.1016/J.JHYDROL.2004.03.028.
11. Ogungbenro SB, Morakinyo TE. Rainfall distribution and change detection across climatic zones in Nigeria. Weather Clim Extrem. 2014;5-6:1-6. doi:10.1016/J.WACE.2014.10.002.
12. Onuah F. Nigeria gives census result, avoids risky details. Reuters. http://archive.li/n878d. Published December 29, 2006.
13. National Population Commission (NPC). Population Distribution By Age, Sex and Marital Status Tables: 2006 Census Priority Tables (Vol 5). http://www.population.gov.ng/. Published 2006.
14. NPC. Press release: Nigeria's population now 182 million.May 14, 2017.
15. Nigeria Federal Ministry of Health. National Health Policy 2016.; 2016.
16. Bruce-Chawatt LJ. Malaria in Nigeria. Bull World Health Organ. 1951;4(3):301-327. http://www.ncbi.nlm.nih.gov/pubmed/14886718. Accessed February 17, 2018.
17. Lagos Bureau of Statistics. Lagos Digest of Statistics. Alausa-Ikeja, Lagos, Nigeria; 2016.
18. Campbell J. This is Africa's New Biggest City: Lagos, Nigeria Populaton 21 Million. The Atlantic. https://www.theatlantic.com/international/archive/2012/07/this-is-africas-new-biggest-city-lagos-nigeria-population-21-million/259611/. Published July 10, 2012.
19. United Nations. World Population Prospects Data Booklet 2015 Revision. https://esa.un.org/unpd/wpp/Publications/Files/WPP2015_DataBooklet.pdf. Accessed July 25th 2018
20. Centeral Intelligence Agency. The CIA World Fact Book 2015.
21. IRIN. Cameroon-Nigeria border settlement faces tough development challenges. The Guardian. https://www.theguardian.com/global-development/2014/feb/16/cameroon-nigeria-border-settlement-development-challenges. Published February 16, 2014.
22. Global Security.org. International Disputes https://www.globalsecurity.org/military/world/war/disputes-n.htm. Accessed July 25th 2018
23. International Monetary Fund. Countries: Nigeria. http://www.imf.org/en/Countries/NGA#countrydata. Accessed July 25th 2018
24. International Monetary Fund. Countries: Nigeria.

http://www.imf.org/external/country/nga/index.htm. Published 2012.

25. Maier K. This House Has Fallen : Nigeria in Crisis. Westview Press; 2002. https://books.google.co.uk/books/about/This_House_Has_Fallen.html?id=3mcDtCd7-bQC&redir_esc=y. Accessed February 16, 2018.

26. Bello, Malam Ali, Roslan AH. Has poverty reduced in Nigeria 20 years after. Eur J Socal Sci. 2010;15(1):7-17.

27. Institue for Economics & Peace. Global Terrorism Index. Measuring and Understanding the Impact of Terrorism.; 2016. http://economicsandpeace.org/wp-content/uploads/2016/11/Global-Terrorism-Index-2016.2.pdf.

28. Schultz H. Nigeria's Boko Haram: Who Are They and What Do They Want? Natl Geogr News. May 2014. https://news.nationalgeographic.com/news/2014/05/140507-boko-haram-nigeria-borno-state-maiduguri-mohammed-yusuf-abubukar-shekau-goodluck-jonathan-world/.

29. Omole O, Welye H, Abimbola S. Boko Haram insurgency: implications for public health. Lancet (London, England). 2015;385(9972):941. doi:10.1016/S0140-6736(15)60207-0.

30. Nigeria Malaria Elimination Programme. Nigeria Global Fund Application Concept Note. Abuja, Nigeria; 2015.

31. World Health Organization. Malaria campaign saving young lives in Nigeria, Interview with Dr Pedro Alonso. Published October 31, 2017. http://www.who.int/malaria/news/2017/emergency-borno-state/en/. Accessed July 25th 2018

32. World Health Organization. World Malaria Report 2017. Geneva; 2017.

33. National Bureau of Statistics (NBS) and United Nations Children's Fund (UNICEF). Multiple Indicator Cluster Survey 2016-17, Survey Findings Report. Abuja, Nigeria; 2017.

34. National Population Commission (NPC), ICF International. Nigeria Demographic and Health Survey 2013. Abuja, Nigeria and Rockville, Maryland, USA; 2014.

35. The United Nations. Trends in Child Mortality Child Mortality Report 2017. New York; 2017. doi:10.1016/S0140-6736(10)60703-9.

36. Akinyemi JO, Bamgboye EA, Ayeni O. Trends in neonatal mortality in Nigeria and effects of bio-demographic and maternal characteristics. BMC Pediatr. 2015;15(1):36. doi:10.1186/s12887-015-0349-0.

37. Federal Ministry of Health. National Strategic Health Development Plan (NSHDP) 2010 - 2015. Abuja, Nigeria; 2010.

38. NMEP NFM of H. Rapid Impact Assessment of Antimalaria Interventions in Nigeria. Abuja, Nigeria; 2015.

39. Nigeria Federal Ministry of Health. National Strategic Health Development Plan Draft Mid Term Performance Review. Abuja, Nigeria; 2013.

40. Nigeria Federal Ministry of Health. Service Availability Mapping 2006 – 2007: Study Documentation. 2010. http://www.who.int/whr/2000/en/whr00_en.pdf?ua=1.

41. Federal Ministry of Health Abuja. National Malaria Control Programme, Strategic Plan 2009-2013 A Road Map for Malaria Control in Nigeria. Abuja, Nigeria; 2008. http://www.nationalplanningcycles.org/sites/default/files/country_docs/Nigeria/nigeria_draft_malaria_strategic_plan_2009-2013.pdf. Accessed July 25th 2018

42. World Health Organization. WHO Country Cooperation Strategy 2014–2019 – Nigeria.; 2014. doi:ISBN: 978 92 9 023207 0, NLM Classification: WA 540 HE8.

43. President's Malaria Initiative. Nigeria Malaria Operational Plan FY 2015.; 2015.

44. Nigeria Federal Ministry of Health. Naitonal Health Act.; 2014.

45. Survey Department. Nigeria Surveys. Medical Facilities in Nigeria 1952-53. Lagos, Nigeria; 1953.

46. Survey Department. Nigeria Surveys. Outline Map of Nigeria Showing Medical Facilities in 1934. Lagos, Nigeria; 1935.

47. Survey Department. Nigeria Surveys. Outline Map of Nigeria Showing Medical Facilities in 1928. Lagos, Nigeria; 1928.

48. Survey Department. Nigeria Surveys. Medical Facilities in Nigeria 1926-27. Lagos,

Nigeria; 1926.

49. Federal Ministry of Health, Federal Government of Nigeria. Service Availability Mapping 2006 – 2007: Study Documentation. 2009.

50. Indabawa S. Use of GIS Mapping to Determine the Distribution of Accredited Health Care Facilities in NHIS. 2011.

51. Adeleke B. Service Availability Mapping NHMIS Unit, FMOH Experience. Abuja, Nigeria; 2011. https://www.measureevaluation.org/our-work/gis/nigeria-health-and-mapping-summit-2011-resources/presentation-5/view.

52. Healthsystems2020.org. Health Systems Strengthening: Mapping Health Services of Nigeria to Improve Accessibility and Quality. http://www.healthsystems2020.org/content/news/detail/92775 (website no longer accesible). Published 2012.

53. Azeez A. Mapping HIV/AIDS Services in Nigeria.; 2011.

54. National Primary Health Care Development Agency (NPHCDA). Primary Health Care in Focus 2012: Activity and Progress Report of the National Primary Health Care Development Agency.; 2012.

55. Emmanuel O. GIS and Primary Health Care in Nigeria.; 2011. http://www.cpc.unc.edu/measure/our-work/gis/nigeria-health-and-mapping-summit-2011-resources/presentation-2.

56. United Nations Population Division. Total Population. http://www.un.org/en/development/desa/population/publications/database/index.shtml. Published 2010.

57. Global Roll Back Malaria Partnership, NMCP, Nigeria Federal Ministry of Health. Framework for the Coordination of Malaria Control Programme in Nigeria. Abuja, Nigeria; 2009.

58. The Global Fund. Nigeria Overview. https://www.theglobalfund.org/en/portfolio/country/?loc=NGA&k=430b8acd-ef36-4ef1-8231-0e730499d19a. Published 2017. Accessed February 17, 2018.

59. Nigeria Malaria Elimination Programme. Nigeria Global Fund Application Concept Note. Abuja, Nigeria; 2017.

60. Nigeria Federal Ministry of Health. National Health Information Stategic Plan 2014-2018. Abuja, Nigeria; 2014.

61. National Malaria Elimination Programme. Unpublished Report. Abuja, Nigeria; 2017.

62. Natonal Malaria Elimination Programme. Unpublished Report. Abuja, Nigeria; 2014.

63. NMCP NFM of H. National Malaria Control Programme. Annual Report. Abuja, Nigeria; 2005. http://www.who.int/countries/nga/areas/malaria/nmcp_annual_report_2005.pdf.

64. Oresanya OB, Hoshen M, Sofola OT. Utilization of insecticide-treated nets by under-five children in Nigeria: Assessing progress towards the Abuja targets. Malar J. 2008;7(1):145. doi:10.1186/1475-2875-7-145.

65. NMCP, Federal Ministry of Health. Strategic Plan for Rolling Back Malaria in Nigeria 2001-2005. Abuja, Nigeria; 2001.

66. NMCP, Nigeria Federal Ministry of Health. 2006–2010 National Strategic Plan for Malaria Control in Nigeria. Abuja, Nigeria; 2005.

67. Meremikwu M, Alaribe A, Ejemot R, et al. Artemether-lumefantrine versus artesunate plus amodiaquine for treating uncomplicated childhood malaria in Nigeria: randomized controlled trial. Malar J. 2006;5:43. doi:10.1186/1475-2875-5-43.

68. Noor AM, Mutheu JJ, Tatem AJ, Hay SI SR. Insecticide treated net coverage in Africa: mapping progress in 2000-2007. Lancet. 2009;373:58-67.

69. World Health Organization. Focus on Nigeria. Progress & Impact Series, Number 4. Progress and Impact Series. Geneva, Switzerland; 2012.

70. Snow RW, Marsh K. Malaria in Africa: progress and prospects in the decade since the Abuja Declaration. Lancet. 2010;376(9735):137-139. doi:10.1016/S0140-6736(10)60577-6.

71. World Health Organisation, Africa Regional Office. 2012 Malaria Programme Review. Abuja, Nigeria; 2012.

72. National Malaria Elimination Programme (NMEP), National Population Commission (NPopC), National Bureau of Statistics (NBS), and ICF International. Nigeria Malaria Indicator Survey 2015. Abuja, Nigeria and and Rockville, Maryland, USA; 2016.

73. President's Malaria Initiative. Nigeria Malaria Operational Plan FY 2017.; 2017.

74. Food and Agriculture Organization of the United Nations (FAO). Report on the agro-ecological zones project. Vol.1: Results for Africa. World Soil Resour Rep. 1978;1:32-41.

75. Tougher S, Hanson K, Goodman C. What happened to anti-malarial markets after the Affordable Medicines Facility-malaria pilot? Trends in ACT availability, price and market share from five African countries under continuation of the private sector co-payment mechanism. Malar J. 2017;16(1):173. doi:10.1186/s12936-017-1814-z.

76. Ujuju C, Anyanti J, Fajemisin W, Ntadom G. What happend to the malaria market in Nigeria afta AMFm. In: Atlanta, GA: Population Services International (PSI); 2016. http://www.psi.org/wp-content/uploads/2016/11/5-Nigeria-20161027-final.pptx.pdf.

77. National Population Commission (NPC) NMCP (NMCP). Nigeria Malaria Indicator Survey 2010. Abuja, Nigeria; 2012.

78. World Health Organisation. Remote Nigeria communities welcome child health programme. http://www.who.int/malaria/areas/rapid_access_expansion_2015/features/community-health-care-nigeria/en/. Published 2018. Accessed March 12, 2018.

79. Noor AM, Kibuchi E, Mitto B, Coulibaly D, Doumbo OK, Snow RW. Sub-national targeting of seasonal malaria chemoprevention in the Sahelian countries of the Nouakchott Initiative. PLoS One. 2015;10(8):1-14. doi:10.1371/journal.pone.0136919.

80. Tobler WR. A Computer Movie Simulating Urban Growth in the Detroit Region. Econ Geogr. 1970;46:234. doi:10.2307/143141.

81. Gomez-rubio, V, Best, N, Richardson, S, LI, G, and Clarke P. Bayesian Statistics for Small Area Estimation, Imperial College London Technical Report. http://www.bias-project.org.uk/papers/BayesianSAE.pdf. Published 2009. Accessed May 8, 2017.

82. Jiang J, Lahiri P. Mixed model prediction and small area estimation. TEST. 2006;15(1):1. doi:10.1007/BF02595419.

83. Besag J, York J, Mollié A. Bayesian image restoration, with two applications in spatial statistics. Ann Inst Stat Math. 1991;43(1):1-20. doi:10.1007/BF00116466.

84. Snow, RW, Kyalo, D, Amratia, P, Kabaria, CW, Noor A. Developing a Geo-Coded Repository of Malaria Vector Species Occurrence for Africa: Methods and Data Summaries 1900-2014. Working Paper 2: Report Prepared in Support of the INFORM Project Funded by the Department for International Development and the Wellc.; 2015. http://www.inform-malaria.org/wp-content/uploads/2015/07/Assembly-of-Vector-Data-Version-1.pdf.

85. Noland GS, Graves PM, Sallau A, et al. Malaria prevalence, anemia and baseline intervention coverage prior to mass net distributions in Abia and Plateau States, Nigeria. BMC Infect Dis. 2014;14(1):168. doi:10.1186/1471-2334-14-168.

86. NMCP Nigeria Federal Ministry of Health. 2012 Malaria Control Operational Plan. Draft Plan Produced for Federal Planning. Abuja, Nigeria; 2012.

87. Hanson K Oliveira-Cuz V, Mills A. RK. Expanding acces to priority health interventions: a framework for understanding the constraints to scaling-up. J Int Dev. 2003;15:1-4.

88. Federal Ministry of Health. Directory of Health Facilities in Nigeria. Abuja, Nigeria; 2011.

89. Humanitarian Data Exchange. HDX: Nigeria-healthsites. https://data.humdata.org/dataset/nigeria-healthsites. Published 2015.

90. Okorie PN, McKenzie FE, Ademowo OG, Bockarie M, Kelly-Hope L. Nigeria Anopheles Vector Database: An Overview of 100 Years' Research. Mores CN, ed. PLoS One. 2011;6(12):e28347. doi:10.1371/journal.pone.0028347.

91. Lysenko A, Semashko I. WHO | Medical Geography: A Medical-Geographical Study of an Ancient Disease. Moscow: World Health Organization; 1968.

http://www.who.int/malaria/publications/atoz/lysenko/en/. Accessed February 18, 2018.

92. Kleinschmidt I, Omumbo J, Briet O, et al. An empirical malaria distribution map for West Africa. Trop Med Int Heal. 2001;6(10):779-786. doi:10.1046/j.1365-3156.2001.00790.x.

93. Roll Back Malaria, World Health Organization. Focus on Nigeria. Progress & Impact Series, Number 4. Geneva, Switzerland; 2012.

94. Service M. Checklist and distribution of the Nigerian Culicidae (Diptera). J West African Sci Assoc. 1963;8:80-110.

95. IR Mapper. IRBase. http://www.irmapper.com/.

96. Knox TB, Juma EO, Ochomo EO, et al. An online tool for mapping insecticide resistance in major Anopheles vectors of human malaria parasites and review of resistance status for the Afrotropical region. Parasit Vectors. 2014;7(1):76. doi:10.1186/1756-3305-7-76.

97. Hijmans RJ, Cameron SE, Parra JL, Jones PG, Jarvis A. Very high resolution interpolated climate surfaces for global land areas. Int J Climatol. 2005;25(15):1965-1978. doi:10.1002/joc.1276.

98. Worldclim.org. WorldClim - Global Climate Data. http://www.worldclim.org/.

99. Scharlemann JPW, Benz D, Hay SI, et al. Global Data for Ecology and Epidemiology: A Novel Algorithm for Temporal Fourier Processing MODIS Data. Gething P, ed. PLoS One. 2008;3(1):e1408. doi:10.1371/journal.pone.0001408.

100. Gething PW, Van Boeckel TP, Smith DL, et al. Modelling the global constraints of temperature on transmission of Plasmodium falciparum and P. vivax. Parasit Vectors. 2011;4(1):92. doi:10.1186/1756-3305-4-92.

101. Linard C, Gilbert M, Snow RW, Noor AM, Tatem AJ. Population Distribution, Settlement Patterns and Accessibility across Africa in 2010. Schumann GJ-P, ed. PLoS One. 2012;7(2):e31743. doi:10.1371/journal.pone.0031743.

102. Mennis J. Dasymetric mapping for estimating population in small areas. Geogr Compass. 2009;3:727-745.

103. United Nations, UNDP. World Urbanization Prospects: The 2011 Revision. New York; 2011.

Epidemiology and control profile of malaria in

# Nigeria