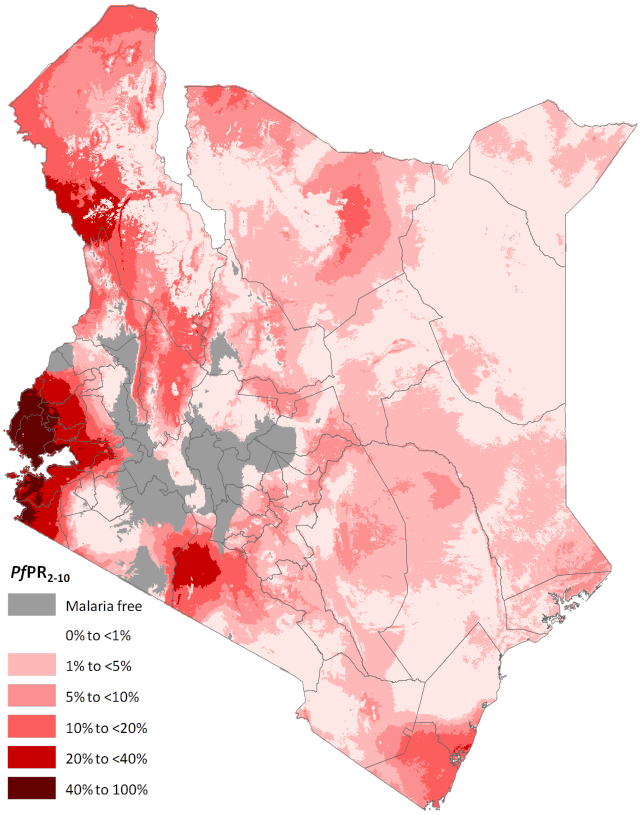
Republic of Kenya

The Malaria Epidemiology and Control Profile in Kenya:

Reviewing the Evidence to Guide Future Vector Control



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March 2013


MALARIA
CONTROL

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Please use the following citation when quoting any part of or the whole of this document:

Noor AM, Kinyoki DK, Ochieng JO, Kabaria CW, Alegana VA, Otieno VA, Kiptui R, Soti D, Yé Y, Amin AA, Snow RW. The epidemiology and control profile of malaria in Kenya: reviewing the evidence to guide the future vector control. Division of Malaria Control, Ministry of Public Health and Sanitation & Malaria Public Health Department, KEMRI-Welcome Trust-University of Oxford-Research programme, December 2012

Published by: *Division of Malaria Control*
Ministry of Public Health and Sanitation
P. O. Box 1992 KNH
Nairobi 00202, Kenya
Email: head.domc@domckenya.or.ke
http://www.nmcp.or.ke

The preparation of this report was made possible through financial assistance from the President's Malaria Initiative (PMI) through MEASURE Evaluation. MEASURE Evaluation (www.cpc.unc.edu/measure) is a project funded by the United States Agency for International Development (USAID) through Cooperative Agreement GHA–A–00–08–00003–00 and implemented by the Carolina Population Center at the University of North Carolina at Chapel Hill, in partnership with Futures Group International, John Snow, Inc., ICF International, Management Sciences for Health, and Tulane University. The opinions expressed in this publication do not necessarily reflect the views of the donor organizations supporting malaria control in Kenya and or their respective Governments.

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Preface

The Division of Malaria Control (DOMC) was established in 2001 with the ultimate goal of reaching populations at risk of malaria with the right preventive and curative interventions. In the last decade, there has been an unprecedented investment in malaria control in Kenya. Of prominence has been the tens of millions of insecticide treated nets (ITNs), especially the long lasting insecticidal nets (LLINs) distributed to communities across the country. Millions of households in selected Counties have also been covered with indoor residual spraying (IRS). This has been possible with guidance from the Roll Back Malaria Partnership and the generous funding support of the Global Fund to Fight Aids, Tuberculosis and Malaria (GFATM), the Department for International Development (DFID) and the President's Material Initiative (PMI) and other partners.

Recent reports from several parts of the country paint a picture of declining malaria risk and burden. However, a comprehensive sub-national analysis of the changing malaria risk and the progress made in scaling up interventions is required to support the National Malaria Strategy (NMS) 2009-2017, which has the fundamental vision of a malaria free Kenya. This is especially important as malaria control is decentralised under the new devolved system of County governance established by the new constitutional dispensation. It is for these reasons that the DOMC, with financial support from the PMI through MEASURE Evaluation have commissioned the Kenya Medical Research Institute/Wellcome Trust Research Programme to undertake a detailed review of the epidemiology and control of malaria in Kenya, with special focus on vector control.

The report describes the evolution of malaria control, the heterogeneity of malaria transmission in the country and audits the distribution of ITNs and IRS in Kenya. The report shows that malaria risk has declined in Kenya from the baseline epidemic year of 1990 to 2010 during which, for example, the proportion of population living in areas where parasite prevalence was >10% decreased from 62% to 31%. To a large extent, this was probably due to the more than 22 million LLINs distributed and the several million household sprayed with insecticides since 2000. The report also shows that with time, the efficiency of targeting vector interventions so that they match the epidemiological need has improved. However, in most counties coverage of LLINs remains below 60% and almost all have not yet reached the 80% target of the NMS 2009-2017. Therefore increased scale up of vector control interventions and more importantly value-for-money allocation of resources are critical.

We are confident that the County epidemiology and control profiles developed here will provide the basis for more efficient decision-making for malaria control as the provision of health care in the country is devolved.

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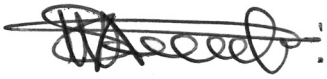
Acknowledgements

This report and County malaria epidemiology and control profiles have been developed with the support of various individuals and institutional stakeholders. We are grateful to James Sang, Beatrice Machini and Agnetta Mbithi of the Division of Malaria Control (DOMC) and Terry Muchoki of Population Services International (PSI) for the assembly of the vector control distribution data. We thank Viola Otieno, Clara Mundia, Punam Amratia, Viola Kirui and Betsy Makena presently or formerly of the Kenya Medical Research Institute/Wellcome Trust Research Programme (KEMRI/WTRP) for their help with the geo-coding of the parasite prevalence data.

The analysis presented in this report has been made possible by the generous contributions of survey and research data from a large number of people listed here: Timothy Abuya, Kubaje Adazu, Pauline Andang'o, Fred Baliraine, Nabie Bayoh, Philip Bejon, Simon Brooker, Maria Pia Chaparro, Jon Cox, Meghna Desai, Ulrike Fillinger, Florey Lia Smith, Andrew Githeko, Carol Gitonga, Joana Greenfield, Helen Guyatt, Katherine Halliday, Mary Hamel, Laura Hammitt, Allen Hightower, Susan Imbahale, Chandy John, Elizabeth Juma, Jimmy Kahara, Simon Kariuki, Charles King, Chris King, Rebecca Kiptui, Feiko ter Kuile, Kayla Laserson, Tjalling Leenstra, Hortance Manda, Kevin Marsh, Margaret MacKinnon, Noboru Minakawa, Sue Montgomery, Eric Muchiri, Richard Mukabana, Tabitha Mwangi, Miriam Mwjame, Charlotte Neumann, George Nyangweso, Christopher Nyundo, Christopher Odero, Edna Ogada, Bernard Okech, George Okello, Maurice Ombok, Simon Omollo, Judy Omumbo, Beth Rapuoda, Evan Secor, Larry Slutsker, Jennifer Stevenson, Willem Takken, Juliana Wambua, Vincent Were, Shona Wilson, Guofa Zhou and Dejan Zurovac.

We thank all the members of the two DOMC Technical Working Groups: Monitoring & Evaluation; and Operational Research for their valuable feedback which has contributed to the refinement of the reports. We are grateful for the financial assistance from the President's Malaria Initiative (PMI) through MEASURE Evaluation which made the preparation of this product possible and to the KEMRI/University of Oxford-WTRP for the overall responsibility for the analysis.



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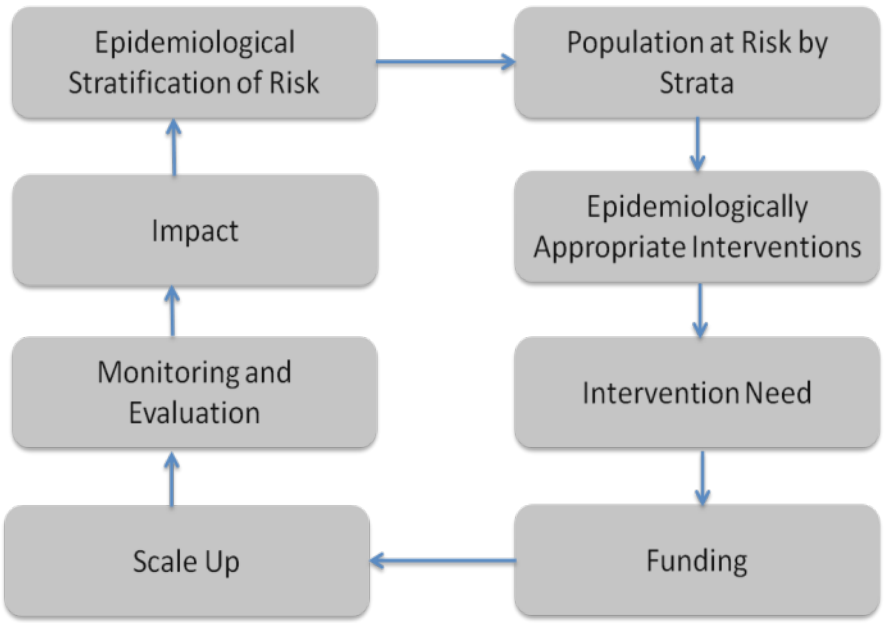
Chapter 1: Introduction

The recent global financial crisis has constrained the capacity of the international donor community and the national governments to provide funding for malaria control. This has led to a call for a much stronger evidence-based business case to effectively utilise limited resources. Such a business case is critically dependent on a reliable understanding of the epidemiology of the disease (Figure 1.1). This is because the clinical epidemiology [Snow & Marsh 2002], the effect-size and cost-effectiveness of malaria interventions [Smith et al 2009; Killeen et al 2010; Griffin et al 2010; Okell et al 2012] and timelines to elimination [Cohen et al 2010] depend on transmission intensity before intervention. As vector control interventions reach targeted levels of scale up, areas where to continue sustaining them must be informed by the pre-intervention transmission intensity [Cohen et al 2010; Noor et al 2012]. Understanding the current burden of malaria helps to inform decisions on where to continue some interventions such as intermittent preventive treatment of pregnant women. Information on the spatial and temporal changes in the epidemiology of malaria is also vital for evaluating the impact of the scale up of malaria control interventions.

Figure 1.1 A generic decision-making framework for evidence-based disease control intervention scale up



There are a variety of measures of the intensity of malaria transmission derived from field investigations of human populations or malaria vectors. The most ubiquitous measure, used for over 100 years, is the parasite rate, or the proportion of individuals on a single cross-sectional survey among an entire or sampled population who have evidence of a peripheral blood stage infection [Hay & Snow 2006]. These data are often expressed as infection prevalence among children aged 2-10 years ($PfPR_{2-10}$) and used since the 1950s to define categories of endemic risk designed to guide progress toward malaria elimination targets.

Recent modeling work has demonstrated the utility of the community *Plasmodium falciparum* parasite rate (*PfPR*), as it has a predictable relationship to other far less frequently measured parameters of transmission intensity [Smith et al 2007] and can be used to define control timelines to transmission reduction [Smith et al 2009] and the appropriate combinations of available interventions and a factor in the decision pathway to predict the likelihood of elimination.

In 2009, a revised national malaria strategy was launched in Kenya to ensure that 80% coverage of vector control interventions and clinical case-management strategies by 2013 and sustained through to 2017 to meet the targets of two-third reduction in the 2007/8 levels of the malaria burden. The strategy coincides with a changing political and administrative landscape prompted by Kenya's new constitution which promotes a devolved system and devolved planning for public services, including health, to the County administration.

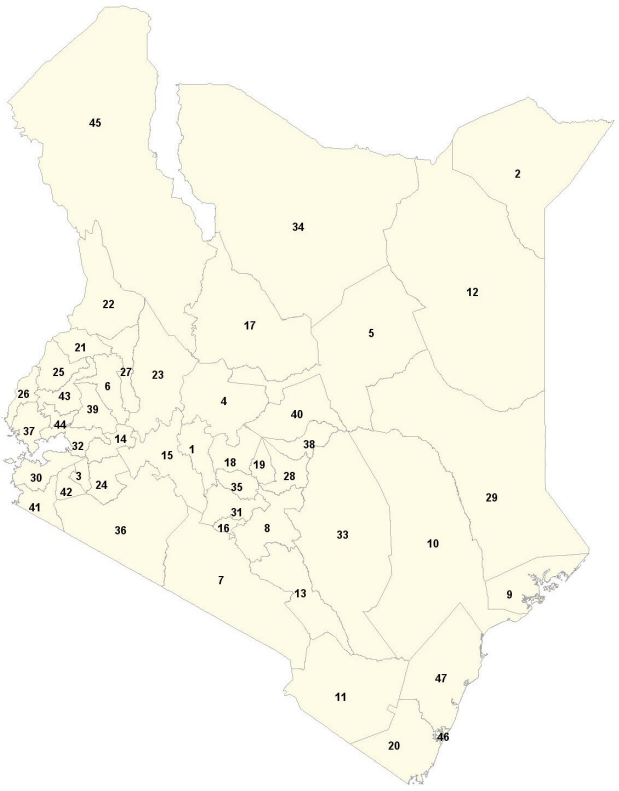
This report represents an analysis of a wealth of spatial data on malaria risk and intervention coverage available from multiple sources in Kenya. The aim is to provide an evidence-platform on the past and present levels of malaria risk, the progress made in the scale-up of malaria interventions and the efficiency of their targeting and the resources needed to meet the NMS objectives at the County level to prepare support to counties and design the future of malaria control in Kenya.

Chapter 2: Country context

2.1 Administration

Since independence local administration in Kenya has been through a provincial and district system headed by Commissioners managed under the Office of the President. In August 2010, however, a new constitution was promulgated which required a devolved system of government. Consequently 47 Counties (Figure 2.1) were created that will be led by an independently elected Governor. Although each County will receive support from the National Exchequer, they will have the responsibility to develop their own operational plans and generate internal revenues to supplement national support. The provision of health care is one of the several public services that Counties will be responsible for.

Figure 2.1 Kenya County boundary map. Table shows the name of County that corresponds to ID shown on the map



ID	County	ID	County
1	Nyandarua	25	Bungoma
2	Mandera	26	Busia
3	Nyamira	27	Elgeyo Marakwet
4	Laikipia	28	Embu
5	Isiolo	29	Garissa
6	Uasin Gishu	30	Homa Bay
7	Kajiado	31	Kiambu
8	Machakos	32	Kisumu
9	Lamu	33	Kitui
10	Tana River	34	Marsabit
11	Taita Taveta	35	Muranga
12	Wajir	36	Narok
13	Makueni	37	Siaya
14	Kericho	38	Tharaka
15	Nakuru	39	Nandi
16	Nairobi	40	Meru
17	Samburu	41	Migori
18	Nyeri	42	Kisii
19	Kirinyaga	43	Kakamega
20	Kwale	44	Vihiga
21	Trans Nzoia	45	Turkana
22	West Pokot	46	Mombasa
23	Baringo	47	Kilifi
24	Bomet		

2.2 Climate

Kenya covers an area of 582,550 km^2 and has an unusually diverse physical environment - savannah, tropical, equatorial volcanic and tectonic. Approximately 80% of Kenya's land is arid and semi-arid, only 20% is arable and only 1.9% of the total surface area is occupied by standing water. This diversity affects both the spatial epidemiology of malaria transmission and human settlement.

The arid and semi-arid areas, the savannah plateau and the coastal hinterland (Figure 2.2 A) have considerably lower rainfall which is acutely seasonal (Figure 2.2 B) with an annual average of about <250 in the arid areas to 500 mm and mean ambient temperatures of 22-27^{o}C. The Lake Victoria region and the Western highlands receive the highest rainfall in the country and exhibit less seasonality. The varied topography, altitude and rainfall contribute to potentially large variations in malaria seasonality (Figure 2.2 C).

Figure 2.2 Kenya maps of; A) Altitude; B) Annual total precipitation; C) Rainfall seasonality.

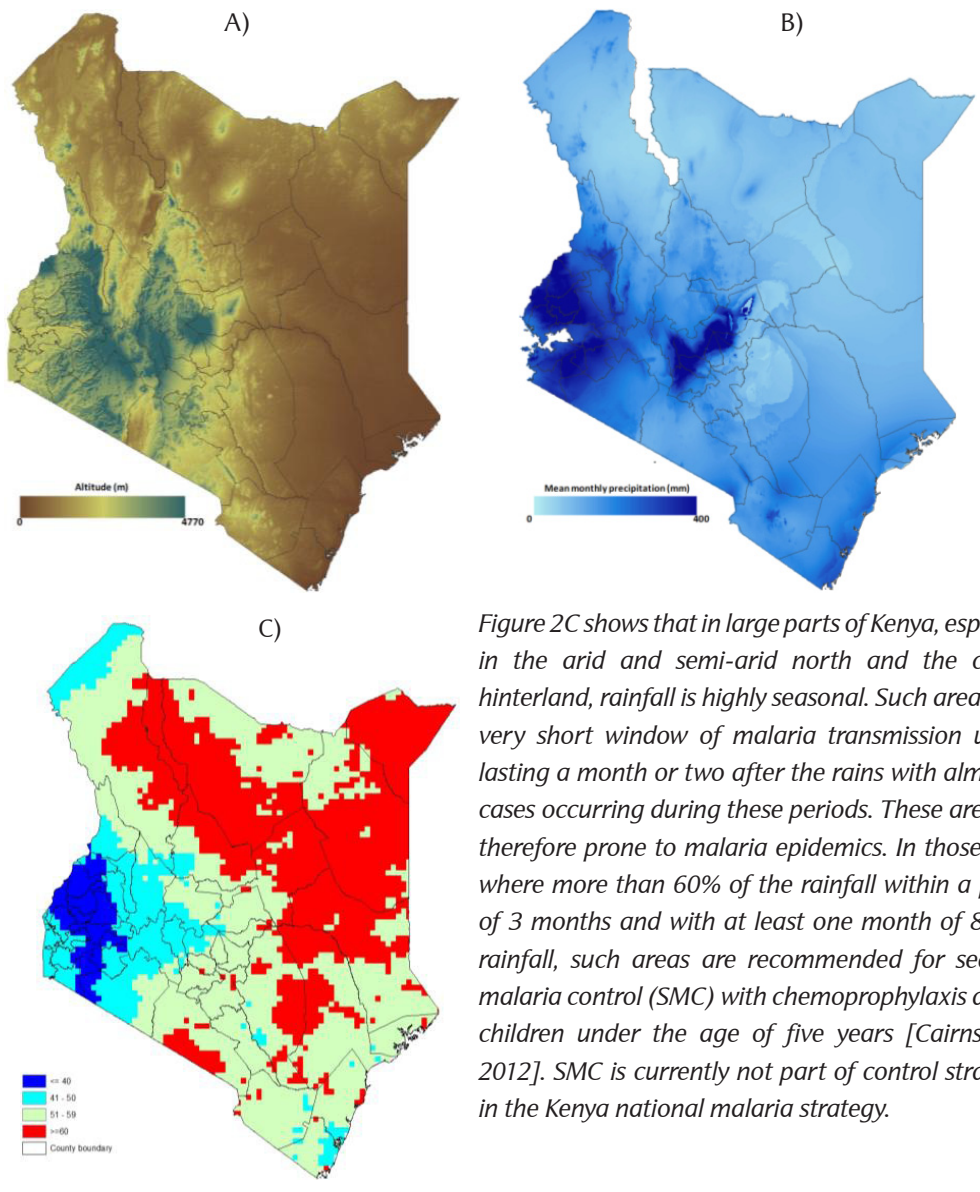
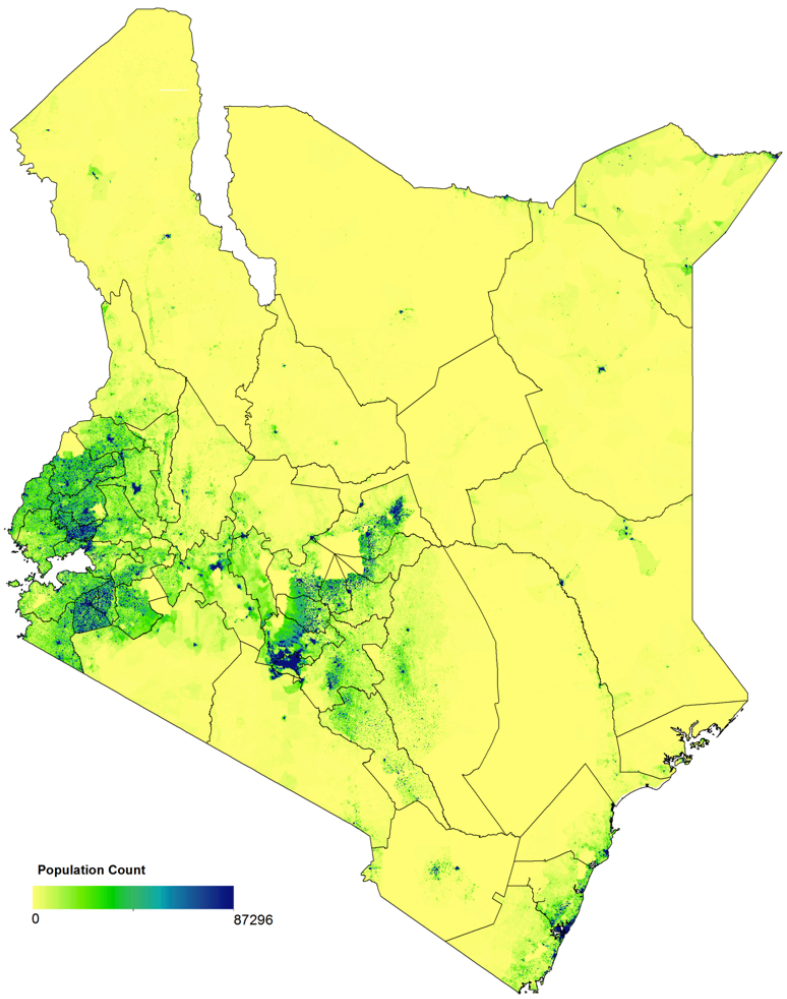


Figure 2C shows that in large parts of Kenya, especially in the arid and semi-arid north and the coastal hinterland, rainfall is highly seasonal. Such areas have very short window of malaria transmission usually lasting a month or two after the rains with almost all cases occurring during these periods. These areas are therefore prone to malaria epidemics. In those areas where more than 60% of the rainfall within a period of 3 months and with at least one month of 80 mm rainfall, such areas are recommended for seasonal malaria control (SMC) with chemoprophylaxis among children under the age of five years [Cairns et al 2012]. SMC is currently not part of control strategies in the Kenya national malaria strategy.

2.3 Population

At independence in 1964, Kenya's population was estimated to be slightly less than 10 million. The first complete national census was undertaken in 1969 and showed a total population of 11 million people [CBS 2001]. The 2009 national census estimated that there were 38.6 million residents including 3.1 million people living in Nairobi and 9 million people living in other urban areas [KNBS 2010]. By 2015 it is anticipated that Kenya's population will have grown to over 42 million. Almost 70% of the population is concentrated in only 20% of the country [Figure 2.3]

Figure 2.3 The gridded 100 x 100 m surface of the distribution of population showing the County boundaries in Kenya [www.afripop.org]



Notes: This map was constructed from a combination of satellite imagery and land cover maps which were used to develop models that identified the location of settlements. The modelled settlements map was then used to redistribute census population counts within the small enumeration area polygons. The resulting high-resolution map represented estimated population distribution in Kenya for the year 2010.

2.4 Health sector

In 2009 a new health sector strategic plan was launched [MoPHS and MoMS 2012] in line with the government's Vision 2030 and the new constitution promulgated in August 2010 [www.parliament.go.ke]. The Kenya Health Policy 2012 – 2030 has, as a goal, *'attaining the highest possible health standards in a manner responsive to the population needs'*. The policy aims to achieve this goal through supporting provision of equitable, affordable and quality health and related services at the highest attainable standards to all Kenyans. The constitution aims to devolve health care provision to County governments with plans to restructure the health systems governance drastically. Counties will be responsible for generation of local revenue and although they will receive budgetary support for health from the National Exchequer, the role of the central ministry of health will only be one of stewardship and policy direction. The highly decentralised health system has important implications for future malaria control in the areas of planning, resource allocation, accounting and monitoring and evaluation.

Chapter 3: History of Malaria Control in Kenya

3.1 The period 1912-1963

Early colonial malaria control was governed by the need to protect European settlers, followed by the realisation that the indigenous farm and government labour force also needed protection to safeguard the Colony's economic viability [Snow et al 1999]. By 1912 'mosquito brigades' had been established to conduct rudimentary environmental control activities such as clearing bottles and tins, cutting down bushes, and filling in of borrow pits. Vector-control legislation, applicable from 1911 in Nairobi and 1912 in Mombasa, appeared before the first national Public Health Ordinance of 1913 [Colony & Protectorate of Kenya 1910-1913]. Weekly dose of quinine prophylaxis was promoted while free mosquito nets were distributed mainly to European settlers, Indians, the police and railway workers.

By the 1920s sanitary inspectors were appointed in all the major towns, larvivorous fish were introduced in water tanks in Mombasa and quinine was the recommended first-line treatment [Gilks 1928]. Epidemics from 1926 began to shape a more concerted response to malaria and its links to economic development [Colony & Protectorate of Kenya 1926]. Interest however waned during inter-epidemic periods [Colony & Protectorate 1930].

The notion of treating all fevers as malaria in Kenya was formulated around this time following comments in the pamphlet published in 1936 - *'Malaria is common in Kenya that on every occasion when an African native complains of even a slight fever or 'Homa' in an area in which malaria occurs, he is suffering from malaria'* [Colony & Protectorate 1936].

As a result of the consequences of the 1940 epidemic, an anti-malarial organisation with an anti-mosquito military unit was set up to undertake vector control activities nationwide. The focus, however, was on urban areas and malaria remained a major problem among rural communities [Colony & Protectorate 1941].

In 1944, the Division of Insect-Borne Diseases (DIBD) was established to coordinate control efforts against all vector-borne diseases [Garnham & Harper 1944]. Control measures were intensified with dichloro-diphenyltrichloroethane (DDT) being used for the first time at Kericho. From 1948, prophylaxis (paludrine) was combined with DDT to protect labourers and their families in Kericho [Strangeways-Dixon 1950].

In 1952, trials of single dose Pyrimethamine (Daraprim) were started at Makueni and other trials by DIBD were undertaken using sulphadoxine, pyrimethamine and sulphadoxine-pyrimethamine as chemo-suppressants at Chemase in Nandi district between 1953 and 1954 and extended to include a DDT Indoor Residual Spraying (IRS) component for a further three years 1955-1957. In 1955, mass spraying using Dieldrin was undertaken in Nandi district with technical assistance from WHO and UNICEF [Roberts 1956; Roberts 1970].

3.2 The period 1964-1989

IRS using DDT or Gammaxene continued in several parts of the country during the early 1960s: notably at Shimba Hills and Malindi that included chloroquine or chloroquine plus sulphadoxine-pyrimethamine prophylaxis [Colony & Protectorate 1960; 1962; Roberts 1974]. The Malindi prophylaxis approach managed to maintain infection rates as low as 2.5% for several years. In Kisumu energetic larvicidal and peri-urban spraying using Dieldrin 50% helped in averting an epidemic following flooding caused by the high water levels in Lake Victoria in 1962.

All personnel on Irrigation and Settlement Schemes received fortnightly chloroquine prophylaxis from 1963 notably at Mwea Tebere, Kano, Hola, Bunyala, Ramisi, Mumias and Perkerra irrigation scheme. Daraprim intermittent treatment was provided to thousands of school children each year by the DIBD during the 1960s [DIBD 1960].

Despite some limited successes, the annual report of the DIBD in 1969 states *"The principle of malaria eradication which was propounded by World health authorities during the era 1950-60 has proved to be too distant an ideal for national malaria programmes in the immediate future. However, the objectives of the present malaria programmes are to control the degree of malaria transmission so that the disease ceases to be of Medical and Public Health importance in Kenya. It can be seen therefore that there is still a long way to go".*

During the 1970s, malaria control shifted toward integrated public health delivery including the adoption of a primary health care approach [WHO 1978]. One result was that vertical programmes were gradually dissolved into broader public health systems.

Small-scale anti-malarial activities did however continue during the 1970s especially in major towns. A WHO scheme to evaluate the impact of Fenitrothion was undertaken in an area west of Kisumu town from 1972 with impressive results [Fontaine et al 1975].

In 1981 the Kenya Anti-Malarial Strategy was launched by the Division of Vector Borne Diseases (DVBD, formerly DIBD), with the major objective of reducing mortality by the treatment of all fever cases using chloroquine (CQ) and reduction of prevalence using prophylaxis to vulnerable groups (children 0-14 and pregnant women) and other available control measures and ultimately leading to the eradication of malaria in Kenya [MoH, 1981]. Chloroquine was made readily available in most health institutions for therapeutic and presumptive therapy and widely available in the retail sector.

Confirmed cases of chloroquine-resistant falciparum infections were first reported in non-immune tourists to Kenya and Tanzania in 1978 [Fogh et al 1979; Faelmann et al 1981; Patterson et al 1981] and in semi-immune Kenyans in 1982 [Spencer et al 1982]. CQ resistance escalated during the 1980s. CQ remained the treatment of choice for uncomplicated malaria infections until revised guidelines were launched supporting the use of sulphadoxine-pyrimethamine (SP) in 1998 [Shretta et al 2000]

3.3 The period 1990-2000

Kenya launched a further National Plan for Malaria Control in 1992 and coincided with the formation of the National Malaria Control Unit (MCU) in 1994 under the auspices of DVBD. The plan was to reduce malaria morbidity and mortality by 30% by 2000 through the promotion of insecticide treated nets (ITNs), the routine surveillance of vectors and promotion of inter-sectoral collaboration in vector control activities through community participation.

Notable during this period was the expansion of the Bamako Initiative, first started in 1989 in Kisumu, and finally covering 25 districts and an estimated 237 communities with support from UNICEF. This came to an end in 1996 following the end of UNCEF's commitment.

From the mid-1990s there was an expansion of small-scale, community-based care programmes, largely managed by the Non-government Organization (NGO) sector across the country and led to the early expansion of ITN coverage to over 1000 communities.

In 1993 one of five pan-African definitive community randomized controlled trials of the impact of ITN on child survival was undertaken among a population at Kilifi [Nevill et al 1996]. A second trial was completed in 1996 at Asembo Bay near Lake Victoria [Philips-Howard et al 2003]. Both mortality trials demonstrated significant reductions in all-cause under-five mortality at the different endemic settings. Despite an overwhelming scientific evidence-base and small scale NGO led initiatives at the community level, by 2001 less than 5% of Kenyan children were sleeping under an ITN [MICS 2000; Waithaka et al 2001].

Coincidental with rapidly expanding CQ resistance, Kenya witnessed a series of malaria epidemics from the mid-1990s notably among communities in the Kenyan highlands; of equivalent political significance to those in the 1920s and 1940s [Snow et al 1999]. Flooding as a result of unseasonal rainfall led to severe epidemics across the arid and semi-arid areas of North Eastern Province in 1998. These epidemics did serve to galvanize a political support around malaria control in Kenya and coincided with a global recognition of malaria's significance to broader development goals and the formation of the Roll Back Malaria (RBM) partnership [WHO 2001].

3.4 The period 2001-2011

In Kenya, the first post-RBM ten year National Malaria Strategy was launched in April 2001 that aimed to ensure that by 2006, 60% of at risk children and pregnant women would be sleeping under an ITN, 60% of pregnant women would be protected with two presumptive doses of SP (IPTp) during their second and third trimesters, 60% of suspected malaria cases would be managed with an efficacious drug within 48 hours of the onset of symptoms and an important emphasis on being able to detect and contain epidemics. These programmatic ambitions were expected to translate into a reduction of malaria infection and consequent death in Kenya by 30% by 2006 and to sustain improved levels of control to 2010.

The launch of the NMS coincided with a restructuring of the Malaria Control Unit to form the Division

of Malaria Control (DOMC), a full division within the Ministry.

As part of ITN policy between 2001 and 2005 the focus was on the social marketing of ITN and net re-treatments to encourage the private sector to sell subsidized products [Noor et al 2007]. Nets were available in ANC clinics and rural shops at a cost of 100 KShs up to 2004. They then were reduced to 50 Kshs through ANC clinics from October 2004. Overall coverage of ITN among under-fives across Kenya in 2005 remained low, less than 25% [PSI-TRaC 2005; Noor et al 2007; Noor et al 2009]. IRS (lamdacyhalotrin) was used with ITN distributions for epidemic containment from 1999/2000 in Kisii and Gucha districts.

Epidemics continued to provide threats to the newly launched NMS and in 2002, a malaria epidemic occurred in the western highlands killing approximately 300 people and infecting over a 150,000 individuals [Snow et al 2009]. The greatest challenge for the newly formed DOMC was the rapid escalation of SP resistance, adopted as first-line treatment in 1998 [EANMAT 2003]. In April 2004 it was announced that Artemether-Lumefanthrine (AL) would replace SP as nationally recommended first-line treatment [Amin et al 2007]. This policy change was not effectively implemented until December 2006. SP was considered still effective for IPTp, however, a national household sample survey in 2007 showed that only 25% of women pregnant in the last year had received any IPTp and only 12.5% had received 2 or more doses [MIS 2007].

In 2006 the first free-mass distribution LLIN campaign was launched in Kenya and resulted in a rapid increase in ITN coverage and reduction in inequities between the most and least poor [Noor et al 2007; Hightower et al 2008]. Since the launch of the 2001 NMS national coverage of ITNs among children under the age of five years increased from <5% in 2003 [KDHS 2003], to 46% in 2008 [KDHS 2008-9], to slightly over 50% by 2010 [MIS 2010].

IRS has been used in 12 highland epidemic prone counties since 2007 using lambdacyhalothrin, deltamethrin or alphacypermethrin as a single yearly cycles just before the high transmission season. In 2010, IRS began in two lake-endemic counties, Migori and Homa Bay [James Sang, Personal Communication].

The funding landscape for malaria control in Kenya changed after 2005. Kenya was successful with Round 4 Global Fund support (52 million USD), increased support from DFID-UK from 2006 (45 million USD), the Presidents Malaria Initiative (PMI) from 2007 (20 million USD per annum, increasing to 40 million USD 2009/10) [Snow et al 2009]. In 2010 Kenya was one of a few countries in Africa successful in securing Global Fund Round 10 support (38 million USD) with about 7.7 million USD disbursed so far [www.aidspan.org/countr_grant/KEN-011-G13-M). Since 2002 approximately 250 million USD of Overseas Development Assistance has been invested in malaria control in Kenya.

Progress in malaria control and concordant reduction in its burden has motivated the DOMC to launch an ambitious national strategy covering the period 2009-2017 with an aim to reduce the burden of malaria by two-thirds of the 2007-2008 levels by 2017 and eventually achieve a malaria free status. As part of the new strategy, universal parasitological testing of all febrile patients has been recommended. The new strategy shifted the national ITN policy from targeting vulnerable populations to promoting universal coverage within prioritized regions of the country free of charge using empirical evidence of contemporary malaria risk [NMS 2010; Noor et al 2009].

Chapter 4: Mapping of Malaria Risk, Intervention Coverage and need in Kenya

4.1 Previous map development in Kenya

The earliest map of malaria risk in Kenya, developed in the early 1950s, was based on expert opinion of malaria seasons and climate [Butler 1959]. This map continued to serve as the basis upon which malaria risk was considered across Kenya until the late 1990s, when a more evidence-based approach was taken to mapping malaria risks in Kenya. This stratification was based on only 124 community estimates of infection prevalence and semi-qualitatively used to classify districts in Kenya according to the following classifications: stable endemic, highland unstable, arid low risk and very low risk as part of the National Malaria Strategy 2000-2010 [Snow et al 1998].

It was not until 2009 that a new empirical map was developed as a collaborative effort between the DOMC, WHO-country office and the KEMRI-Wellcome Trust Collaborative Programme based on 2682 *Plasmodium falciparum* parasite rate data points assembled from cross-sectional community based surveys undertaken from 1975 to 2009 [Noor et al 2009]. This was the first time that modern model-based geostatistical (MBG) methods had been used in Kenya to map malaria risk providing predictive maps of *P. falciparum* risk at a 1 by 1 km resolution for the year 2009. This map was used as the epidemiological basis for the NMS of 2009-2017 and subsequent monitoring & evaluation action plans.

Despite this being one of only a few recent attempts in Africa to use empirically defined risk stratification to guide the adaptation of control suites sub-nationally, the map developed was a prediction to a single recent year (2009) and represents risks under control, not risks pre-intervention and as such was unable to define areas that have transitioned to low levels of infection, what has happened over time or what might be expected if intervention coverage declines – i.e. a return to a more receptive natural state of endemicity. The following sections address this information void.

4.2 Mapping of receptive, maximal and current *P. falciparum* malaria risk

Details of the data search strategy and assembly, quality control and pre-processing are provided in Annex A. Analysis was restricted to age-standardized parasite prevalence survey estimates from 4063 unique space-time survey locations from 1970 to 2011. This represents a much larger assembly of data than previously used in Kenya and the largest for any country in Africa.

The 4063 data points included 1487 surveys in the same location but sampled at different times. The majority of community survey data (79%) came from archived unpublished sources including

historical monthly returns of the DVBD, national malaria indicator surveys in 2007 and 2010 and school surveys. Over 57% of the data were from the period 2001 to 2011 of which 74% were from unpublished sources. The location of the $PfPR_{2-10}$ survey data is shown in Figure 4.1.

A temporal scatter plot of the data with a lowess regression fit (Figure 4.2) shows that $PfPR_{2-10}$ in Kenya was around 18% overall in 1970, peaked in the 1990 and reduced sharply after 2005 to levels slightly lower than that observed in 1970. Although the temporal plot is subject to the spatial and temporal clustered distribution of the data, it nonetheless suggests that 1990 is probably the year of mean maximal risk in Kenya and serves as a valuable receptive, prediction year, i.e. the maximal likely risk over the last 40 years to which risks might return in the absence of control.

Figure 4.1 Map of 4,063 age-standardised P. falciparum parasite rate surveys ($PfPR_{2-10}$) undertaken between 1970 and 2011. Locations are displayed with higher values of $PfPR_{2-10}$ on top.

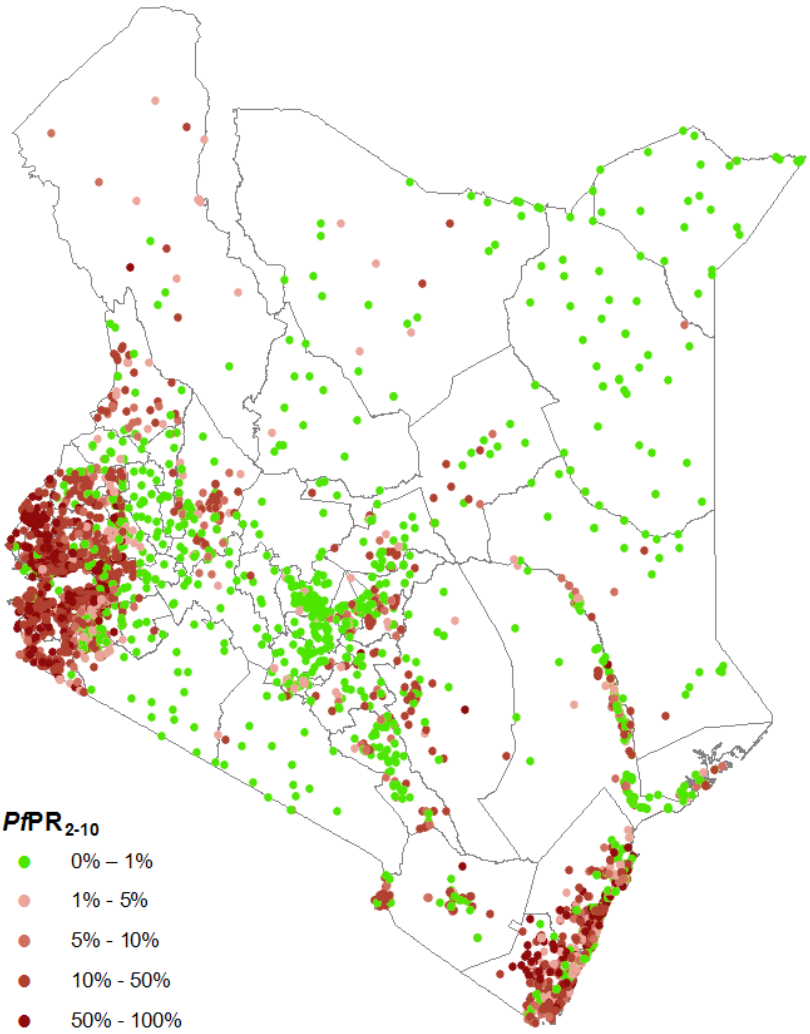
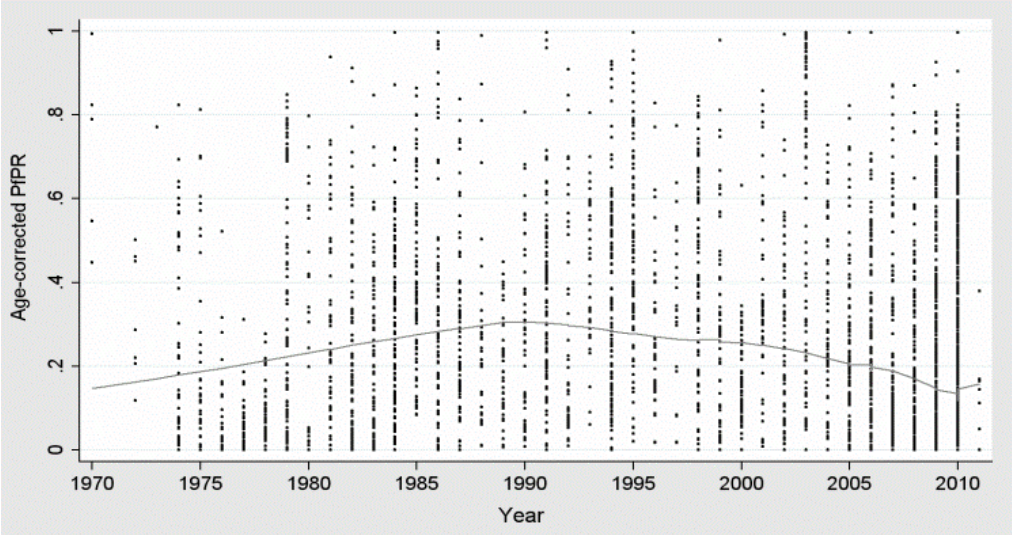


Figure 4.2 Scatter plot with a lowess fit of the $PfPR_{2-10}$ from 1970 to 2011 in Kenya. The uneven distribution of data in space and time may bias the observed temporal trends



Geostatistical techniques provide a robust means to interpolate from sparse data at known locations and over time to provide predictions of quantities at locations and times where data do not exist. These methods operate under the Tobler's first law of geography that things that are closer in space (and time) are more similar than those more distal spatially (and temporally). As these methods have evolved over the last 25 years, their formulation using Bayesian inference has become popular. These Bayesian interpolation methods often referred to as model-based geostatistics (MBG) are most suited to the analyses of noisy and sparse data and allow for the application of prior information on the data forms to improve the precision of model prediction. Importantly, such models also allow for the robust quantification of the uncertainty around the predicted values.

Ecological and climatic heterogeneity affect the development and survival of the *Plasmodium* parasite and the malaria-transmitting Anopheles vectors and these covariates are commonly used to improve the precision of modelled malaria map predictions. Here we have selected a set of four covariates most likely to improve model precision [Annex B]. These include long-term mean precipitation, urbanization, remotely sensed measures of aridity (EVI) and an index of temperature suitability (TSI) for parasite survival and transmission within vectors.

A Bayesian hierarchical spatial-temporal model was implemented through the Stochastic Partial Differential Equations (SPDE) approach using Integrated Nested Laplace Approximations to produce continuous maps of $PfPR_{2-10}$ at 1 x 1 km spatial resolution using data from 1970-2011. Technical details of model specifications are presented in Annex C.

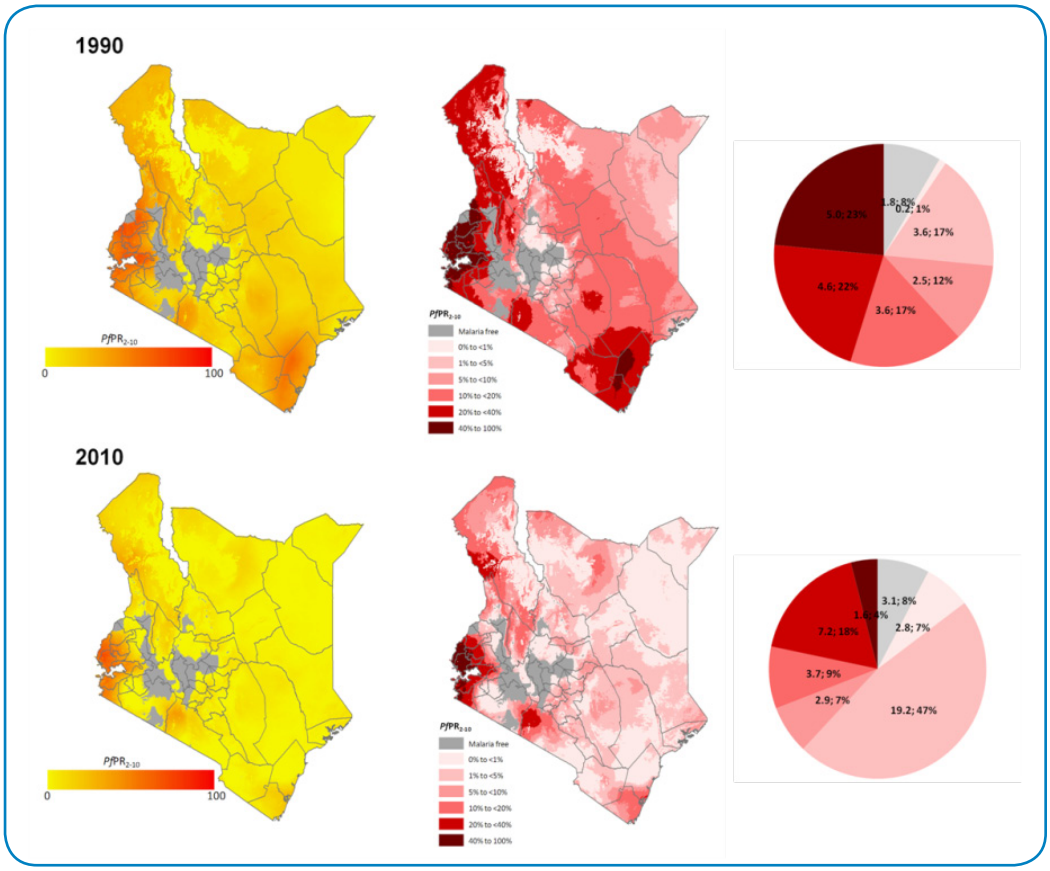
In the SPDE approach, the overall hierarchical space-time binomial model of the prevalence to malaria parasite was represented as the realization of a spatial-temporal process of the $PfPR_{2-10}$ at the community location and time, the covariates (EVI, TSI, urbanisation and precipitation) vector for the given location and time, the coefficient vector and the measurement error defined by the Gaussian

white noise process. The realization of state process or the unobserved level of $PfPR_{2-10}$ is defined by a spatial-temporal Gaussian field that changes temporally as a first-order autoregressive function.

For each grid location samples of the full posterior distribution of $PfPR_{2-10}$ were used to generate continuous maps of the annual mean $PfPR_{2-10}$ for the years 1990 (maximal receptive risk) and 2010 at 1 x 1 km grid locations. The annual posterior mean $PfPR_{2-10}$ maps were classified into the endemicity classes of $PfPR_{2-10}$ <0.1% (almost malaria free); <1% (low stable endemic control); $PfPR_{2-10}$ 1%-<5%; $PfPR_{2-10}$ 5%-<10%; $PfPR_{2-10}$ 10%-≤20%; $PfPR_{2-10}$ 20% - <40%; and ≥40%. Continuous and binned endemicity maps are shown in Figure 4.3A for 1990 and Figure 4.3B for 2010. Maps for all the prediction years of 1970, 1980, 1990, 2000 and 2010 are shown in Annex C.

Model accuracy was estimated by computing the linear correlation, the mean prediction error (MPE) which is a measure overall model bias and mean absolute prediction error (MAPE) as a measure of average error in prediction of the observations and predictions of a 10% hold-out dataset. The linear correlation of the observed and predicted $PfPR_{2-10}$ was 0.81 showing a high agreement between the two measures. The MPE and MAPE of the 1970-2010 full space-time $PfPR_{2-10}$ model were -0.09% and 9.3% percent respectively indicating a very low under-prediction and overall average prediction error of <10%.

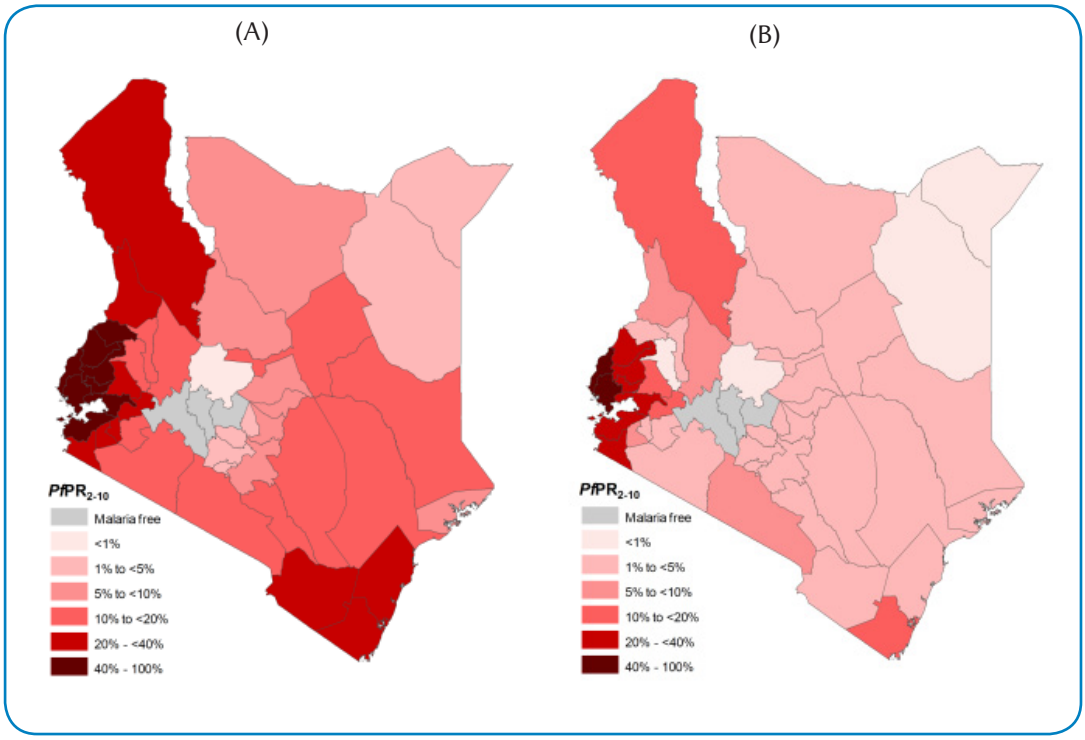
Figure 4.3 Annual continuous and binned mean predicted $PfPR_{2-10}$ at 1 x 1 km resolution and the population at risk by endemicity class from the years A) 1990 (maximal risk) and B) 2010



Comparison of the 1990 (maximal risk) and 2010 (current risk) population at risk estimates show that the proportion of population at highest risk (>20% $PfPR_{2-10}$) was 45% in 1990 and 22% in 2010 (Figure 4.3). The proportion of population in the risk class <5% $PfPR_{2-10}$ increased from 23% in 1990 to 62% in 2010.

Census data by County were assembled for the years 1989 and 2009 and using census-specific growth rates County level estimates of population for the years 1990, 2010 and for projected need to 2014 were computed. For each County, population-weighted aggregates of annual mean $PfPR_{2-10}$ were then computed. Population-weighting was achieved by extracting $PfPR_{2-10}$ prediction from the 1 x 1 km malaria risk maps only to populated areas within the County. Populated areas in a County were defined using a gridded surface of population distribution at 100 x 100 m spatial resolution for Kenya (Figure 2.1). $PfPR_{2-10}$ extractions were done using ArcGIS 10 (ESRI Inc. USA) to compute the overall mean $PfPR_{2-10}$ by County. The population count and percentage within each class were computed for the prediction years 1990 (Figure 4.4 A) and 2010 (Figure 4.4 B).

Figure 4.4 County population-weighted aggregates of annual mean $PfPR_{2-10}$: A) prediction to 1990 (maximal risk) B) prediction to 2010. Counties that are described as malaria free (grey shade) were those whose surface area was completely or predominantly within the temperature suitability index (TSI) of zero and considered ecologically unsuitable to sustain malaria transmission.



4.3 The distribution and coverage of LLIN in Kenya

We have combined two sources of information (volumes of ITN/LLIN distribution and household sample survey coverage data) within a Bayesian Small Area Estimation (SAE) approach to predict the coverage of ITN per county for the years 2003, 2005 and 2010/11. Data assemblies and technical details of SAE are provided in Annex D.

Distribution data were assembled from records held by Population Services International (PSI) and the DOMC and was attributed to the county where nets were issued (Annex D). Smaller scale distributions by non-governmental organisations, mainly targeted at focal areas for emergency relief (Figure 4.5) were harder to document and were excluded in the analysis. These distributions, however, contributed a very small percentage of overall ITN volumes [Snow et al 2009]. These data were used serially with time to estimate county level numbers and the per capita estimated volumes of distribution and to model all age ITN utilisation. Over 27 million ITNs, of which 22 million were LLIN, were distributed in Kenya since 2004 (Figure 4.6). Approximately 13 million of these nets were distributed through free mass campaigns.

Since 2003, there have been 10 national and sub-national household sample cross-sectional surveys that have reported information on household net ownership and utilisation of bed nets among either children under the age of five years or persons of all ages. The importance of estimating all-age groups is that this is the parameter necessary to understand universal coverage (proportion of persons of all ages sleeping under an ITN).

Figure 4.5 Map of counties showing the different strategys for the distribution of LLIN. 'Other' refers to small scale and less well documented distributions such as those by UNICEF, The Red Cross, World Vision, Mentor Initiative aimed at focal areas in response to emergencies in areas not systematically targeted by the DOMC for ITN scale up.

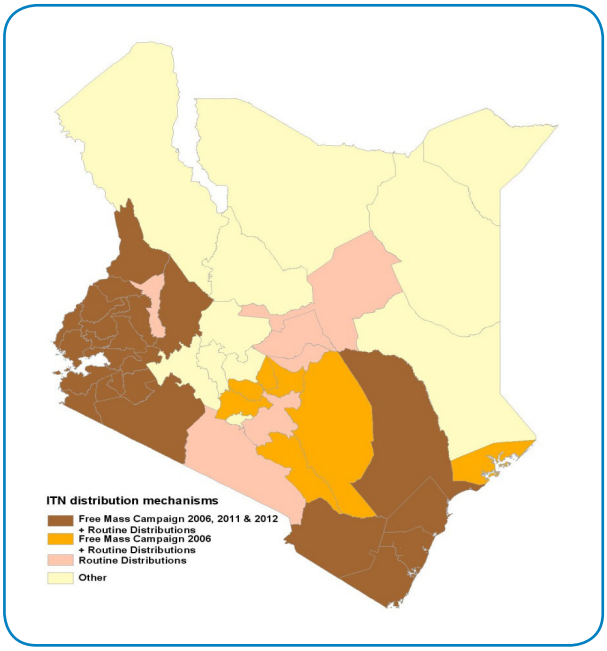
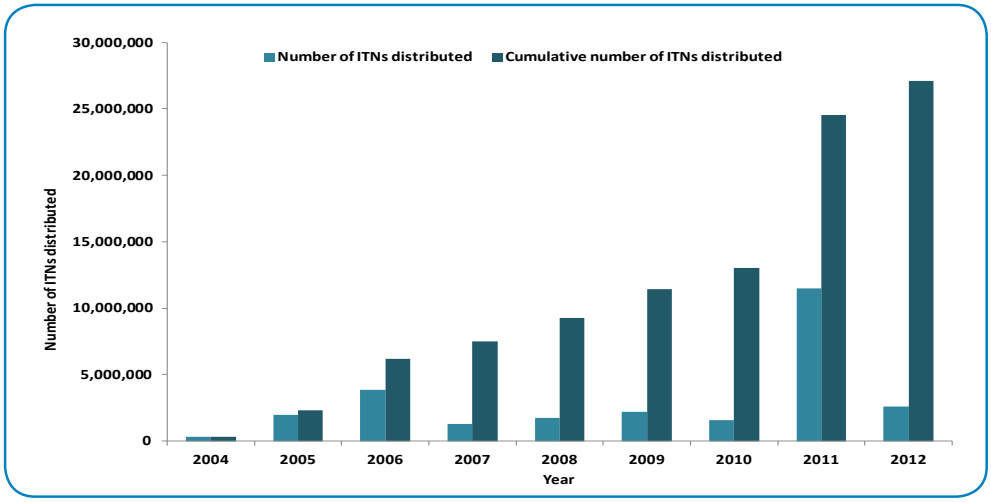


Figure 4.6 Annual and cummulative total distributions of ITNs in Kenya from 2004 to 2010. Over 85% of ITNs distribtuted in Kenya over this period were of the LLIN class. LLIN distribution started in May 2005.



The survey data are described and re-assembled as described in Annex D. Geo-coded cluster level data were used to develop small area space-time estimates of ITN coverage at the County for the years 2003 (400 clusters), 2005 (1721 clusters) and 2011 (1715 clusters).

SAE methods handle the problem of making reliable estimates of a variable of interest at areal units under conditions where the information available for the variable, on its own, is not sufficient to make valid estimates. We have used Bayesian SAE methods to interpolate the available household survey data with contextual process information on net volume distributions in a conditional autoregressive model to produce estimates of time-specific ITN coverage per county (Annex D).

Overall, the model performed well, the standard deviation of the predicted mean ITN coverage, a measure of uncertainty around model output and a function of the heterogeneity in the measure outcome, was overall less 2%, indicating a generally good model fit. Standard deviations of the predicted mean ITN coverage was higher in the latter years of 2010 and 2011.

Over the period 2003 to 2012, each County in Kenya experienced a rise in the proportion of the population who were covered with ITNs (Figures 4.7 A-D). Only Lamu and Kirinyaga, however, have achieved a coverage of >= 60% of all age-groups protected by an LLIN by 2012.

In 2003, coverage across the country was <5% except in Nyamira County where coverage was slightly above 5% of all-age groups. At this time, there were no major ITN distributions that had taken place in Kenya. By 2005, ITN coverage among all age groups was mostly below 20% except in a few counties and this was about a year after the large-scale highly subsidised ITN distribution had started in October 2004.

A dramatic rise in ITN coverage was recorded by 2010 in many counties of between 40% and 50% (Figures 4.7). This followed the free mass campaign of 2006, the introduction of free routine ITN distribution in health clinics and the national bed net retreatment campaign of 2008.

By 2011, several counties had ITN coverage of 50% and above but none had reached the 80% coverage targeted in 2013 (Figures 4.7D & 4.8). The coverage estimates for 2011 follow from the free mass campaign of 2011 in Nyanza and Western provinces and include the data from on-going mass

distribution in the coastal counties. Of the counties where baseline (1990) risk was ≥20% $PfPR_{2-10}$, ITN coverage was less than 50% in Kericho, Nandi, Migori, Turkana, Taita Taveta, Trans Nzoia and West Pokot.

Despite the large scale distribution of LLINs in the country within the last three years, by 2011 an estimated 15.8 million (53%) of the 29.8 million people living in counties where mean baseline $PfPR_{2-10}$ was greater than 5% were not protected with LLIN. When only those counties where mean baseline $PfPR_{2-10}$ was >10% (n=30) were considered, approximately 13.5 million people or 53% of the population were also not protected with an LLIN. Of these, 64% (8.6 million) of the unprotected population were from 15 counties (Bomet, Bungoma, Homa Bay, Kakamega, Kilifi, Kisii, Kisumu, Kitui, Makueni, Migori, Narok, Trans Nzoia, Turkana, Uasin Gishu and Vihiga). Except for Makueni and Turkana, the remaining 13 counties were those targeted during the 2011 free mass campaign and improvement in ITN coverage is expected.

Figure 4.7 Maps of predicted ITN coverage (percentage of population sleeping under an ITN the night before survey) in Kenya in: A) 2003; B) 2005; C) 2010; and D) 2011 modelled from household cross-sectional survey data.

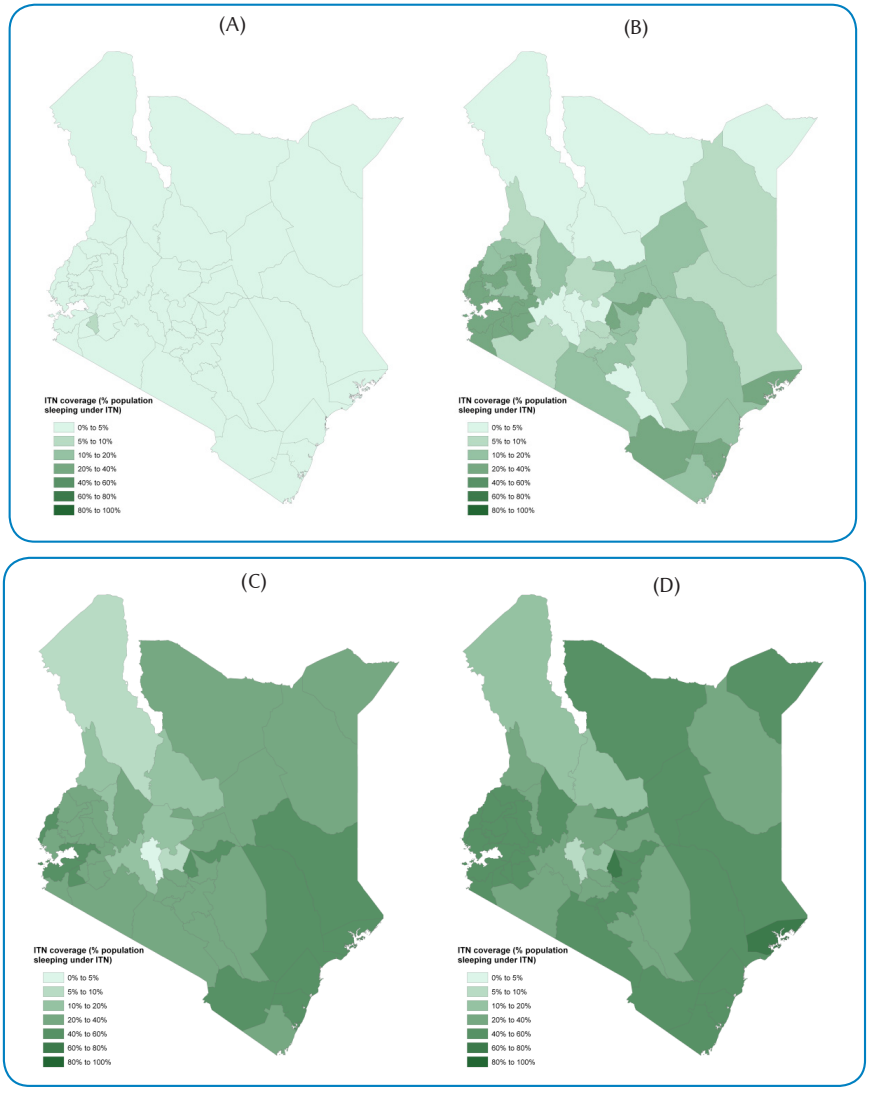
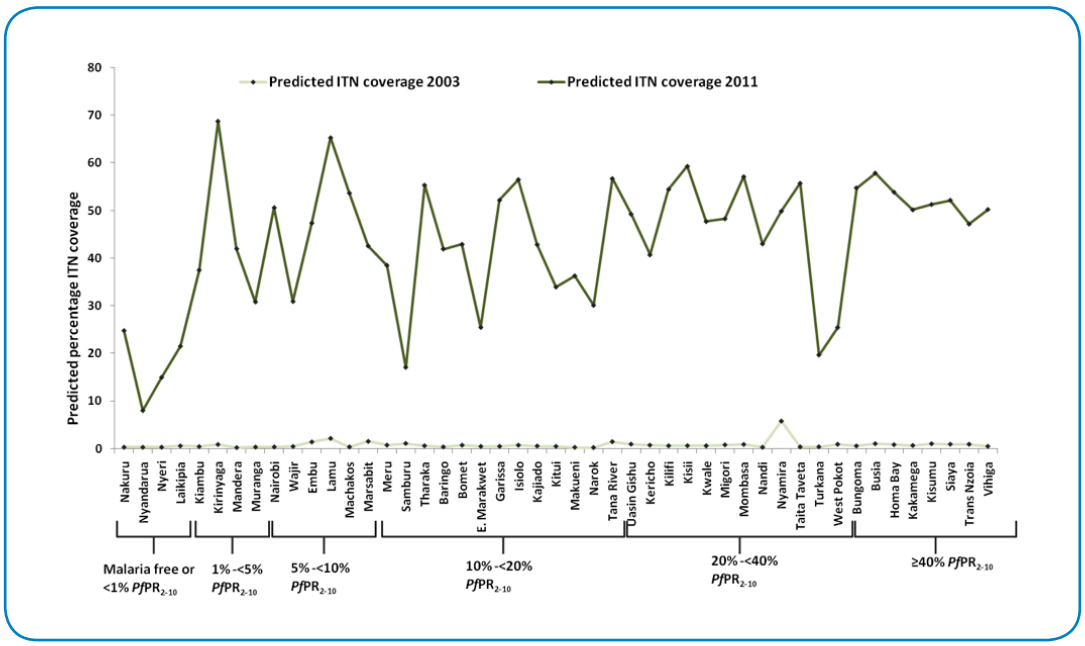


Figure 4.8 Graph of predicted ITN coverage (percentage of population sleeping under an ITN the night before survey) in Kenya in 2003 and 2011 modelled from household cross-sectional survey data.



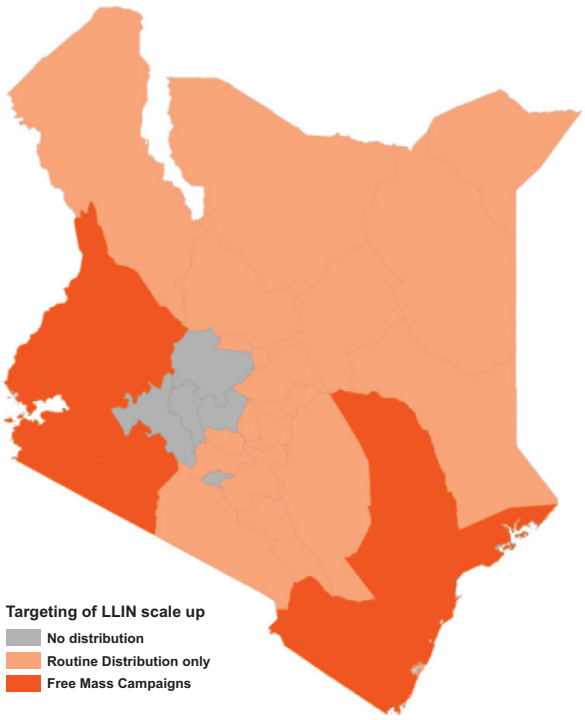
4.4 Estimating the LLIN gap in Kenya

The Roll Back Malaria Harmonization Working Group framework (Annex E) for estimating LLIN gap is used here as a means to estimate Kenya's target for universal (100%) coverage and the population at risk in targeted areas for the years 2013 and 2014. To define populations at risk, counties were first divided based on the 1990 endemicity into those where LLIN distribution was not necessary (receptive mean $PfPR_{2-10}$ or <1% or malaria free) as these are considered to be areas of naturally low stable endemic control and where universal coverage of vector control interventions may not be appropriate. In counties where baseline mean $PfPR_{2-10}$ of 1% to <10%, only free routine distribution targeting pregnant women and new born children would be recommended. Those with baseline $PfPR_{2-10}$ of ≥10% were targeted with both free routine distribution and mass campaigns (Annex E: Table E.1).

Figure 4.9 summarises the descriptions of counties and appropriate LLIN distribution mechanisms. Nyeri, Nyandarua, Nakuru and Laikipia districts were identified as countries where LLIN scale up was not appropriate due to the near absence of malaria transmission based on the 1990 baseline prediction year. Despite a mean prediction of almost 5% $PfPR_{2-10}$ in 1990, Nairobi was also classified as malaria free on the evidence of rapid urbanisation, which is likely to have permanently changed the receptive risk to conditions where most of the City cannot support transmission.

Estimates of the gap in routine and mass campaign LLIN distributions were computed from a baseline year of 2011, which corresponds to the last free mass campaign in Kenya and based on inter-censal growth rates, assumptions and WHO recommendations described in Annex E and projected population for 2011, 2012, 2013 and 2014.

Figure 4.9 Kenya County map showing the appropriate mechanism of scale-up of LLIN.



Footnote: Eighteen counties were selected as areas where only free routine distribution of LLINs to pregnant women and new born children was recommended, largely on the basis that they had mean baseline PfPR2-10 of 1% to <10%. The exceptions to this rule were Turkana, Garissa, Isiolo, Makueni and Kitui. Although their baseline mean PfPR2-10 was slightly above 10%, these counties are largely arid or semi-arid areas and their relatively high predicted infection rates could be as result of the scarce historical data in most low transmission counties and the associating high model uncertainty or that they have focal areas of moderate to high transmission which drive up the mean county PfPR2-10, such as the area around the Tana River in Garissa or along the Uganda and South Sudan borders in Turkana. For this reason, these counties were considered unlikely to support stable transmission in majority of their areas, despite model predictions, and free routine distribution was conservatively selected as an appropriate approach for LLIN scale up. The remaining 25 counties were selected for both free routine and mass campaign distributions (see Annex E Table E.1). For some counties, this classification is not consistent with the recommendation of the current national malaria policy.

To estimate the free mass campaign gap for the year 2014, the LLINs distributed in 2011, 2012 and 2013 in the targeted counties were assembled and adjusted by 50%, 20% and 8% loss rate respectively to compute the existing viable nets by 2014. These were then subtracted from the estimates of free mass campaign needs for 2014.

Overall, between 2012 and 2014, approximately 12 million nets will be required for universal scale in Kenya including the estimates for routine distribution in 2012 and 2013.

Table 4.1 LLIN gap in Kenya from in 2014 adjusted for expected existing nets by 2014

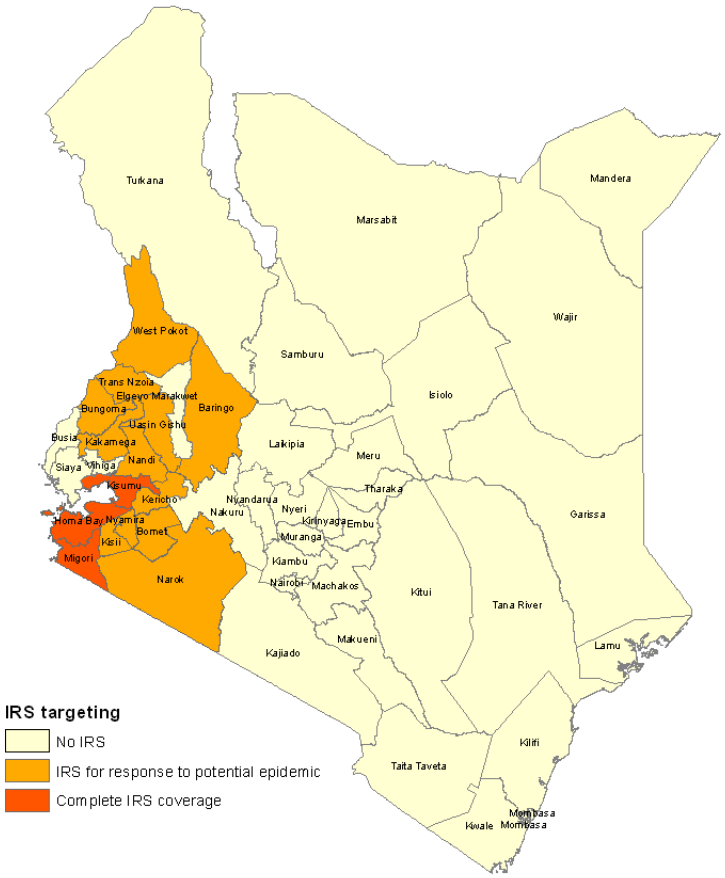
County	Type of recommended LLIN distribution	Routine LLINs distribution gap 2013*	Routine LLINs distribution gap 2014*	Free mass campaign gap 2014*	Total LLIN gap 2014*
Embu	Routine	41,199	42,031	0	42,031
Garissa	Routine	44,230	48,299	0	48,299
Isiolo	Routine	10,559	10,772	0	10,772
Kajiado	Routine	54,585	56,586	0	56,586
Kiambu	Routine	120,474	122,417	0	122,417
Kirinyaga	Routine	39,644	40,283	0	40,283
Kitui	Routine	73,202	74,681	0	74,681
Machakos	Routine	84,850	86,565	0	86,565
Makueni	Routine	69,594	71,000	0	71,000
Mandera	Routine	62,753	68,526	0	68,526
Marsabit	Routine	22,352	22,804	0	22,804
Meru	Routine	96,134	98,076	0	98,076
Mombasa	Routine	82,011	84,424	0	84,424
Muranga	Routine	66,061	67,126	0	67,126
Samburu	Routine	19,365	20,075	0	20,075
Tharaka	Routine	23,031	23,496	0	23,496
Turkana	Routine	66,314	68,745	0	68,745
Wajir	Routine	46,543	50,825	0	50,825
Baringo	FMC & Routine	45,647	47,320	221,279	268,600
Bomet	FMC & Routine	63,274	65,593	372,611	438,204
Bungoma	FMC & Routine	129,615	132,896	404,383	537,279
Busia	FMC & Routine	39,442	40,279	33,963	74,242
E. Marakwet	FMC & Routine	31,189	32,332	122,783	155,115
Homa Bay	FMC & Routine	65,429	66,817	185,115	251,932
Kakamega	FMC & Routine	132,885	136,249	342,453	478,702
Kericho	FMC & Routine	61,411	63,662	242,769	306,431
Kilifi	FMC & Routine	85,268	87,777	570,886	658,663
Kisii	FMC & Routine	112,914	115,310	37,697	153,008
Kisumu	FMC & Routine	72,471	74,009	222,691	296,700
Kwale	FMC & Routine	57,396	59,085	319,676	378,761
Lamu	FMC & Routine	8,429	8,677	49,458	58,135
Migori	FMC & Routine	38,748	39,571	9,124	48,695
Nandi	FMC & Routine	63,400	65,724	327,168	392,892
Narok	FMC & Routine	64,154	66,505	266,915	333,420
Nyamira	FMC & Routine	50,910	51,990	85,401	137,391
Siaya	FMC & Routine	62,926	64,261	177,355	241,616
Taita Taveta	FMC & Routine	23,144	23,825	147,635	171,460
Tana River	FMC & Routine	20,476	21,078	121,697	142,775
Trans Nzoia	FMC & Routine	72,739	75,405	48,811	124,216
Uasin Gishu	FMC & Routine	71,861	74,495	193,603	268,098
Vihiga	FMC & Routine	45,429	46,579	-92,045	-45,466
West Pokot	FMC & Routine	37,197	38,560	128,339	166,899
Total		2,479,253	2,554,730	4,539,768	7,094,498

**These estimates were adjusted for existing nets distribution in the three prior years using the net loss rate of 8%, 20% and 50% among nets distributed within the one, two or three years prior to the estimation year. See Annex E for details.*

4.5 Estimating the IRS coverage and gap in Kenya

IRS activities have been undertaken in 14 counties (Figure 4.10) in the Western and Rift Valley highlands of Kenya since 2005. In the three counties of Homa Bay, Migori and part of Kisumu where malaria transmission has been perennial, complete coverage with IRS began in 2010 (in Kisumu only Nyando district was targeted) as a pilot scheme to see if its combination with LLIN will bring down transmission rapidly. In the other counties 12 counties, IRS is targeted only at potential hotspots determined through weekly surveillance.

Figure 4.10 Counties targeted for the scale up of indoor residual spraying (IRS) (coloured pink)



IRS coverage estimates from household surveys, however, are difficult to interpret. Normally the question is asked on whether a household was sprayed with an insecticide in the last 12 months and rarely on the number of structures sprayed. In addition, respondents can confuse IRS with other forms of spraying which often results in households in non-IRS target areas providing a positive response to the question on IRS spraying. Process data is probably the only reliable data upon which to estimate needs for IRS using combinations of the number of people per household and the number of housing units eventually sprayed.

Because of the transient nature of potential hotspots in the epidemic prone counties, it is difficult to estimate IRS gap for them. A more complex forecasting approach supported by detailed longitudinal surveillance data is required to predict where hotspots are likely to occur to reliably estimate IRS need. For these reason, IRS gap was estimated for 2013 and 2014 only for Homa Bay, Kisumu and Migori where it is targeted universally. A single spraying cycle per year was assumed. Estimates of number of insecticide sachets and spraying operators required were estimated from the 2010 county level IRS filed data.

Table 4.2 Estimates for 2013 and 2014 of number of structures to be sprayed, the number of spraying operators and insecticide sachets required in Homa Bay, Migori and Kisumu counties

	Projected population		*Number of structures*		*Number of spraying operators*		*Number of insecticide sachets*	
County	*2013*	*2014*	*2013*	*2014*	*2013*	*2014*	*2013*	*2014*
Homa Bay	*1,042,809*	*1,064,939*	*312,843*	*319,482*	*669*	*683*	*1,076,566*	*1,099,413*
Migori	*612,371*	*625,367*	*183,711*	*187,610*	*393*	*401*	*632,194*	*645,611*
*Kisumu**	*1,130,813*	*1,150,178*	*342671*	*348,539*	*734*	*746*	*1,178,788*	*1,198,974*

**Assumes that the whole of Kisumu County is targeted*


FREE NET
FREE NET

Chapter 5: Discussion and conclusions

The space-time analysis of malaria transmission intensity would have been impossible but for the careful assembly of *PfPR* data which have been consistently assembled over time. The historical data are largely from project studies supplemented with DVBNTD school surveys. A good proportion of the more recent data come from national MIS. Malaria case data from health facility are sparse historically and currently albeit surveillance systems are improving. Therefore, until Kenya reaches very low national prevalence, e.g. <1% *PfPR*, continued monitoring of infection risk should provide the bench mark to define the impact of scaled intervention coverage and progress toward the ambitious targets of a "malaria free Kenya". This work should be adequately funded and optimize through school and community-based monitoring.

The evidence shows that a clear malaria epidemiological transition has occurred in Kenya and declines appear to have started before the large scale up of RBM-era interventions. The peak transmission year was in 1990 and was selected as the receptive year on which intervention planning was based. Between 1990 and 2010, population living in areas where predicted $PfPR_{2-10}$ was >10% reduced from 63% to 31%. To understand the magnitude of the changing disease burden due to this epidemiological transition in Kenya and to associate these changes to specific causal factors, a separate future analysis is required. This should examine changes in malaria risk against changing urbanisation, socio-economic well-being, population growth and migration, climate and malaria control interventions within the context of the historical review provided in this report.

The ITN distribution data when measured against baseline malaria transmission appeared generally congruent with the epidemiological need indicating reasonably efficient targeting. The predicted coverage estimates also show generally good match with the baseline endemicity with higher risk counties reporting, on average, higher coverage except for Lamu and Kirinyaga which have low baseline transmission but have been targeted with free mass campaigns to address focal transmission. However, although enough LLINs have been distributed across the country in the last three years to be able to achieve universal coverage today, there is no County where modeled estimates of coverage have reached 80% and only two are at approximately 60%. This mismatch between distribution and coverage may be due to behavioural issues around net use, but importantly could be due to skewed ownership of ITNs whereby only few of the households account for most of the nets and usage. Further studies are therefore needed to investigate reasons for any heterogeneity of ownership and usage of ITNs which are likely to be important obstacles to universal coverage.

The baseline endemicity criteria used to classify counties into those where LLINs scale up is not necessary, where only free routine distribution are recommended and where it should be combined with free mass campaigns largely matches the current decisions employed by the DOMC. However, Elgeyo Marakwet should be included in the counties targeted for free mass campaigns as its predicted baseline transmission is relatively high. Some counties where the main distribution mechanisms is free routine distribution because of aggregate estimates of mean PfPR 2-10, such as Garissa and Kirinyaga, may have moderate to high transmission hot spots which require targeting with free mass campaigns.

In estimating the need for LLINs, the RBM-HWG recommends adjustments for existing LLINs distributed within the last 3 years using rate of loss of 8%, 20% and 50% in the first, second and third years respectively, especially where net coverage is above 40% and where routine distributions exist. This adjustment has a big impact on the amount of LLIN needed for free mass campaigns, and in Kenya reduces overall LLIN need from 14 million to about 7 million for 2014. This assumption, while necessary, can perpetuate inequities where the coverage is highly variable and only a subset of the population own most of the nets. Care must be exercised in the application of such an adjustment.

Although there is need for more effort across all counties where baseline $PfPR_{2-10}$ is greater 5% to achieve universal coverage of target population with LLINs rapidly, special and immediate attention should be given to those counties where risk is >50% $PfPR_{2-10}$ but where ITN coverage is still less than 50%.

IRS is targeted at potential hotspots in 12 counties and universally in the three counties of Homa Bay, Migori and Kisumu (Nyando district). However, the data on numbers of households and residents protected through IRS remains difficult to assemble, by County, from existing records. In addition, all these counties have been targeted in free mass campaigns and routine distributions of LLINS and are among the highest in terms of ITN coverage. Although IRS is targeted at outbreaks and not universal coverage in most of these counties an analysis of location of reported outbreak signals against baseline transmission intensity may provide a mechanism for using the malaria maps to better target IRS.

The DOMC list of IRS counties reflect mainly those in the highland areas with Homa Bay, Migori and parts of Kisumu as the only perennial transmission ones selected as pilot case studies of the effect of combined IRS and LLIN. Little is known about the epidemicity of arid and semi-arid counties in northern Kenya where a good proportion of the population are nomadic pastroralists and what, if any, vector control interventions are most appropriate to mitigate epidemics. Research in this area is needed.

References

Amin AA, Zurovac D, Kangwana BB, Otieno DN, Akhwale WS, Greenfield J, Snow RW (2007). The challenges of changing national malaria drug policy to artemisinin-based combinations in Kenya. Malaria Journal, 6: 72

Atlas of Kenya (1959). 1st Edition. Surveys of Kenya, Nairobi, Kenya. Crown Printers. (page 20 of 44 pages). Compiled by by G Butler & GS Nelson.

Cairns M,Roca-feltrer A,Garske T,W Wilson AL,Diallo D,Milligan PG,Ghani AC,Greenwood BM (2012). Estimating the potential public health impact of malaria chemoprevention in African children.Nature communications, 6:381

Central Bureau of Statistics, (CBS) [Kenya], Ministry of Health [Kenya], and ORC Macro: Kenya Demographic and Health Survey 2003. Calverton, Maryland: CBS, MOH, and ORC Macro; 2004.

Cohen JM, Moonen B, Snow RW, Smith DL (2010). How absolute is zero? An evaluation of historical and current definitions of malaria elimination. Malaria Journal, 9: 213.

Colony & Protectorate of Kenya (1911-1961). Medical and Sanitation Department Annual Reports. Government of Kenya.

Chilés JP & Delfiner P. Geostatistics: Modelling Spatial Uncertainty. New York: Wiley; 1999.

Diggle P, Patrick H, Kung-Yee Liang , Scott Z(2002). Analysis of Longitudinal Data.Oxford: Oxford University Press.

Division of Insect Borne Diseases (1960). Annual Reports. Government of Kenya, Nairobi.

Division of Insect Borne Diseases (1967 & 1969). Annual Reports. Government of Kenya, Nairobi

Division of Malaria Control (2001). National Malaria Strategy 2001-2010. Ministry of Health, Republic of Kenya, April 2001

Division of Malaria Control (2009). Kenya Monitoring & Evaluation Plan 2009-2017. Ministry of Public Health & Sanitation, Nairobi, June 2009

Division of Malaria Control (2009). Kenya national malaria indicator survey 2007. Ministry of Public Health & Sanitation, Nairobi, Republic of Kenya, March 2009.

Division of Malaria Control (2011). Kenya national malaria indicator survey 2010. Ministry of Public Health & Sanitation, Nairobi, Republic of Kenya, July 2011.

Division of Malaria Control (2009a). National Malaria Strategy 2009-2017. Ministry of Public Health & Sanitation, Republic of Kenya, November 2009

DVBD (1979). Annual Report. Ministry of Health, Republic of Kenya.

EANMAT(2003).The efficacy of antimalarial monotherapies,sulphadoxine-pyrimethamine and amodiaquine in east Africa:Implications for sub-regional policy.Tropical Medicine & International health, 8:860-67.

Faelmann M, Rombo L & Hedman P (1981) Serum concentrations of chloroquine in a patient with late recrudescence of Kenyan *Plasmodium falciparum* malaria. Transactions of the Royal Society of Tropical Medicine and Hygiene, 75:362–364.

Fogh S, Jepson S & Effersoe P (1979). Chloroquine-resistant *Plasmodium falciparum* malaria in Kenya. Transactions of the Royal Society of Tropical Medicine & Hygiene, 73: 228–229

Fontaine RE, Joshi GP, Pradhan GD(1975): Entomological evaluation of fenitrothion (OMS-43) as a residual spray for the control of An. gambiae and An. funestus, Kisumu, Kenya.World Health Organization/Vector Biology and Control Unpublished Technical Report 1975, 75:547.

Garnham PCC & Harper JO (1944). The control of rural malaria by pyrethrum dusting. East African Medical Journal, 21: 310-320.

Government of Kenya (1962). Ministry of Health and Housing Annual Report for 1962. Republic of Kenya, Nairobi.

Griffin JT, Hollingsworth D, Okell LC, Churcher TS, White M, Hinsley W, Bousema T, Drakeley CJ, Ferguson NM, Basanez MG, Ghani AC (2010b). Reducing *Plasmodium falciparum* malaria transmission in Africa: a model based evaluation of intervention strategies. PLoS Medicine, 7: e1000324

Hay SI & Snow RW (2006). The Malaria Atlas Project (MAP): developing global maps of malaria risk. PLoS Medicine, 3: e473

Kenya 1989 Population Census (2001). Central Bureau of Statistics,Nairobi,Kenya.

Kenya Population Census (2009). Preliminary Report. Kenya National Bureau of Statistics, Nairobi, Republic of Kenya, 2010.

Kenya Demographic & Health Survey (2008-9). Preliminary Report. Kenya National Bureau of Statistics, Nairobi, Republic of Kenya, June 2009.

Kenya Demographic & Health Survey, 1998. A preliminary report prepared by the National Council for Population & Development, Ministry for Planning and National Development, GoK, September 1998.

Kenya Multiple Indicator Cluster survey (MICS) 2000. Preliminary Report. Central Bureau of Statistics, Nairobi, Republic of Kenya,2001.

Mentor (2007). Final programme report 2007: Emergency malaria control for the most vulnerable flood affected communities in Kenya. Report prepared for DFID and DOMC, 2007.

Ministry of Health, Kenya (1992) Kenya National Plan of Action for Malaria Control, Five Year Plan and Budget

Ministry of Health, Kenya (1995) Kenya National Five-Year Plan of Action for Malaria Control, 1996-2000

Nevill CG, Some ES, Mung'ala VO, Mutemi W, New L, Marsh K, Lenegler C, Snow RW (1996).

Insecticide treated bed nets reduce mortality and severe morbidity from malaria among children on the Kenyan Coast. Tropical Medicine & International Health, 1: 139-146

Noor AM, Amin AA, Akwhale WS, Snow RW (2007). Increasing coverage and decreasing inequity to insecticide-treated net use among rural Kenyan children. PLoS Medicine, 4: e255

Noor AM, Gething PW, Alegana VA, Patil AP, Hay SI, Muchiri E, Juma E, Snow RW, 2009. The risks of *Plasmodium falciparum* infection in Kenya in 2009. BMC Infectious Diseases, 9: e180.

Noor AM, Kangwana BB, Amin AA, Akwhale WS, Snow RW (2007). Increasing access and decreasing inequity to insecticide-treated net use among rural Kenyan children. PLoS Medicine, 4: e255

Noor AM, Moloney G, Borle M, Fegan GW, Shewshuk T, Snow RW (2008). The use of mosquito nets and the prevalence of *Plasmodium falciparum* infection in rural South Central Somalia. PLoS One 3: e2081.

Noor AM, Mutheu JJ, Tatem AJ, Hay SI, Snow RW (2009). Insecticide treated net coverage in Africa: mapping progress in 2000-2007. Lancet, 373: 58–67

Noor AM, Alegana VA, Patil AP, Moloney G, Borle M, Ahmed F, Yousef F, Amran J. and Snow RW (2012). Mapping the receptivity of malaria risk to plan the future of control in Somalia. British Medical Journal Open Access, 2: e001160.

Noor AM, Alegana VA, Patil AP and Snow RW (2010). Predicting the unmet need for biologically targeted coverage of insecticide-treated nets in Kenya. American Journal of Tropical Medicine and Hygiene, 83(4): 854

Okell LC, Ghani AC, Lyons E, Drakeley CJ (2009). Submicroscopic infection in *Plasmodium falciparum*-endemic populations: a systematic review and meta-analysis. Journal of Infectious Diseases, 200: 1509-1517.

Pettersson T, Kryonseppa H & Pitkanen T (1981) Chloroquine resistant malaria from East Africa. Transactions of the Royal Society of Tropical Medicine & Hygiene, 75: 112

Phillips-Howard PA, Nahlen BL, Alaii JA, ter Kuile FO, Gimnig JE, Terlouw DJ, Kachur SP, Hightower AW, Lal AA, Schoute E, Oloo AJ, Hawley WA (2003): Efficacy of permethrin-treated bed nets on child mortality and morbidity in western Kenya 1. Development of infrastructure and description of study site. Am J Trop Med and Hyg, 68:3-9

Roberts JMD (1956). Pyrimethamine(Daraprim) in the control of epidemic malaria. Journal of Tropical Medicine and Hygiene,59(9):201

Roberts JMD (1970). Sulphadoxine alone and suplhadoxine in combination with pyrimethamine as a malarial suppressant: a preliminary report of an extended trial in western Kenya. In: Offprints from Health and Dissease in Africa. Proceedings of the 1970 East African Medical Research Council Scientific Conference

Roberts JMD (1974). Malaria. In: Health and disease in Kenya by Vogel LC, Muller AS, Odingo RS, Onyango Z, De Geus A. Nairobi: East African Literature Bureau, 305–317

Shretta R, Omumbo J, Rapuoda BA, Snow RW (2000). Using evidence to change antimalarial drug policy in Kenya. Tropical Medicine & International Health, 5: 755-764

Smith DL & Hay SI (2009). Endemicity response timelines for *Plasmodium falciparum* elimination.

Malaria Journal, 8: e87

Smith DL, Hay SI, Noor AM, Snow RW (2009). Predicting changing malaria risk after expanded insecticide-treated net coverage in Africa. Trends in Parasitology, 25: 511-516.

Snow RW, Mwenesi B H, and B. Rapuoda(1998). Malaria: A situation analysis for Kenya. Nairobi, Kenya: Ministry of Health

Snow et al (1999).The epidemiology, politics and control of malaria epidemics in Kenya: 1900-1998.A report prepared for RBM,Resource Network on Epidemics, WHO.

Snow RW & Marsh K (2002). The consequences of reducing *Plasmodium falciparum* transmission in Africa. Advances in Parasitology, 52: 235-264

Snow RW, Okiro EA, Noor AM, Munguti K, Tetteh G. and Juma E. (2009). The coverage and impact of malaria intervention in Kenya 2007-2009. Division of Malaria Control, Ministry of Public Health and Sanitation, December 2009.

Snow RW, Okiro EA, Gething PW, Atun R. and Hay SI (2010). Equity and adequacy of international donor assistance for global malaria control: An analysis of populations at risk and external funding commitments. The Lancet, 376(9750): 1409-1416.

Spencer HC, Masaba SC & Kiaraho D (1982) Sensitivity of *Plasmodium falciparum* isolates to chloroquine in Kisumu and Malindi, Kenya. American Journal of Tropical Medicine & Hygiene, 31: 902–906.

Strangeways-Dixon D (1950). Paludrine (Proguanil) as a malarial prophylactic amongst African Labour in Kenya. East African Medical Journal, 27: 127-130.

Strangways Dixon D (1950). Paludrine (Proguanil) as a malarial prophylactic amongst African labour in Kenya. East African Medical Jounal, 27: 1-4

The AfriPop Project. http://www.clas.ufl.edu/users/atatem/index_files/Details.htm. Accessed 13 June 2010.

The Kenya National Assembly. http://www.parliament.go.ke/

Waithaka M, Cherop-Kaai S, Mwangi K (2001). Kenya knowledge, attitude and practice (KAP) survey 2000: malaria and malaria prevention. Report produced by Population Services International (Kenya), September 2001

WHO(1978) The Alma-Ata declaration on primary health care. Available at http://www.who.int/hrp/NPH/docs/declaration_almaata.pdf

WHO (2000) The African summit on Roll Back Malaria, Abuja, 25 April 2000. Geneva: WHO. Publication number WHO/CDS/RBM/2000.17. Available: http://www.rbm.who.int/docs/ abuja_declaration.pdf.

World Health Organization (1955). Information on the malaria control programme in Kenya. WHO-Lagos Conference, WHO/MAL/126.8.5, World Health Organization.

Annex A: Parasite prevalence data search strategies, abstraction and geo-coding methods

A revised search effort was mounted to complement previous data searches used to generate the mapped product of 2009 [Noor et al., 2010]. These are detailed below.

A.1 Data search and assembly

Electronic data searches: Online electronic databases were used as the main means for identifying peer reviewed published data on malaria infection prevalence. Due to its wide coverage of the biomedical literature, PubMed [http://www.ncbi.nlm.nih.gov/sites/entrez] was used as the basis for all the initial online searches of published sources as it covers all references compiled by the National Library of Medicine's MEDLINE database, approximately 13 million references to biomedical journals, plus references not indexed in MEDLINE. In addition we used the Armed Forces Pest Management Board – Literature Retrieval System [http://www.afpmb.org/publications.htm] that holds more than 100,000 articles on vector borne diseases available in full-text; the World Health Organization Library Database [http://www.who.int/library]. Regional journals not accessible routinely through the above sources but with titles and abstracts were searched on African Journals Online [http://www.ajol.info/], the world's largest online collection of African-published, peer-reviewed scholarly journals. In all digital electronic database searches for published work the free text keywords "malaria" and "Kenya" were used. We avoided using specialised MeSH terms in digital archive searches to ensure as wide as possible search inclusion. Major database searches were undertaken three times in the last 12 months and supplemented between searches with weekly notifications from Malaria World [http://www.malaria-world.com/], the Roll Back Malaria news alert service [http://www.rollbackmalaria.org] and the Environmental Health at USAID malaria bulletins [http://www.ehproject.org/].

Titles and abstracts from digital searches were used to identify possible cross-sectional survey data undertaken in a variety of forms: either as community surveys, school surveys, intervention trials (where pre-intervention, baseline and control groups could be identified), other studies investigating the prevalence of conditions associated with malaria directly or indirectly (e.g. anaemia, haemoglobinopathies and other erythrocytic polymorphisms, hepatitis B and human immunodeficiency viral infections) where concomitant malaria parasite prevalence were presented and early drug resistance surveys using older protocols based on screening community or school attendees. Reports showing possible data were either downloaded from journal archives where these have been made Open Access (OA) or sourced from HINARI [http://www.who.int/hinari/], a programme set up by WHO together with major publishers, to enable developing country scientists to access biomedical and health literature free of charge. If publications were not available OA for from HINARI we visited the library archives of the London School of Hygiene and Tropical Medicine, the

Liverpool School of Tropical Medicine and the Bodleian library at the University of Oxford. References not found following these searches were requested using world catalogue searches through the Oxford libraries at a per-page cost. All publications from which data were extracted were cross referenced using the bibliographies for additional sources that may have been missed or that may correspond to unpublished or 'grey' literature (i.e. not controlled by commercial publishers).

Historical archive data searches: A wealth of data, both published and unpublished, is available from a variety of archives in Kenya. We identified all the Colonial Medical Department Reports at the Wellcome Library located in the National Public Health Laboratories of the Kenyatta Hospital. In addition we undertook a manual search of all monthly returns from DIBD and DVBD stations since the 1940s which were stored in boxes and folders within the DVBD offices and are grateful to Dr Eric Muchiri for his assistance. We also visited at various times since 2000 the provincial DVBD offices in Mombasa, Kisumu and Embu. Other cited unpublished reports were followed up at the Wellcome Library in London [http://library.wellcome.ac.uk/]. Finally we performed a manual search of every volume of the East African Medical Journal between its first issue published in 1924 to 1966 when PubMed becomes more comprehensive of established regional journals.

Unpublished community survey data post-2005: We have been fortunate to have access to community-based survey data undertaken as part of national surveys supported by bi-lateral partners through national survey agencies or NGO partners. These data include parasitological data generated as part of the National Malaria Indicator Surveys (MIS) of 2007 and 2010, coastal and national school surveys supported by the DOMC and WHO undertaken between 2009-2010, unpublished survey data generously provided by research scientists in Kenya from Asembo Bay (CDC-KEMRI), Kilifi (KEMRI-Wellcome Trust), Suba (KEMRI-Nagasaki University), Rachuonyo and Bondo (DOMC-London School of Hygiene & Tropical Medicine) and many other smaller data sets; all those who have generously provided unpublished data are acknowledged below. This combined rich dataset would not have been accessible from traditional data search approaches and has significantly improved our ability to undertake the work described below and the precision of the malaria risks across Kenya in time and space. University lists of post-graduate theses were also searched for possible titles that could lead to unpublished survey data at the Kenyatta and Nairobi Universities.

Acknowledgments: The following Kenyan scientists, collaborators and control personnel have provided unpublished data, help in locating communities or disaggregated published data: Timothy Abuya, Kubaje Adazu, Willis Akhwale, Pauline Andang'o, Fred Baliraine, Nabie Bayoh, Philip Bejon, Simon Brooker, Maria Pia Chaparro, Jon Cox, Meghna Desai, Ulrike Fillinger, Florey Lia Smith, Andrew Githeko, Carol Gitonga, Joana Greenfield, Helen Guyatt, Katherine Halliday, Mary Hamel, Laura Hammitt, Allen Hightower, Susan Imbahale, Chandy John, Elizabeth Juma, Jimmy Kahara, Simon Kariuki, Charles King, Chris King, Rebecca Kiptui, Feiko ter Kuile, Kayla Laserson, Tjalling Leenstra, Hortance Manda, Kevin Marsh, Margaret McKinnon, Noboru Minakawa, Sue Montgomery, Eric Muchiri, Richard Mukabana, Tabitha Mwangi, Miriam Mwjame, Charlotte Neumann, George Nyangweso, Christopher Nyundo, Christopher Odero, Edna Ogada, Bernard Okech, George Okello, Maurice Ombok, Simon Omollo, Judy Omumbo, Beth Rapuoda, Evan Secor, Larry Slutsker, Jennifer Stevenson, Willem Takken, Juliana Wambua, Vincent Were, Shona Wilson, Guofa Zhou and Dejan Zurovac.

Search completeness: Our data searches have not adopted systematic, traditional evidence review strategies. These would have missed most unpublished sources of information. Rather our strategy

has been a cascaded, opportunistic approach. Authors of peer-reviewed papers were often asked about additional information within their paper and directions to other possible unpublished work in their geographic area or from their institution. Our search has missed one important source of data not made available from the 2010 nutritional survey undertaken by KEMRI-Public Health Centre and CDC. Despite this omission the Kenyan parasite survey database is the largest in Africa and possibly the largest archive of any parasitic infection survey data.

A.2 Data abstraction

The minimum required data fields for each record were: description of the study area (name, administrative divisions and geographical coordinates, if available), the dates of start and end of the survey (month and year) and information about blood examination (number of individuals tested, number positive for *Plasmodium* infections by species), the methods used to detect infection (microscopy, Rapid Diagnostic Tests (RDTs), Polymerase Chain Reaction or combinations) and the lowest and highest age in the surveyed population. Given its ubiquity as a means for malaria diagnosis, the preferred parasite detection method was microscopy. No differentiation was made between light and fluorescent microscopy nor is it possible to classify the kill and precision of individual studies microscopists. For data derived from randomized controlled intervention trials, data were only selected when described for baseline, pre-intervention and subsequent follow-up cross-sectional surveys among control populations. When communities were surveyed repeatedly in time we endeavoured to include only the first survey and subsequent surveys if these were separated by at least five months from the initial survey to avoid a dependence between observations based on treatment of preceding infected individuals. If it was not possible to disaggregate repeat surveys these were finally excluded from the analysis. Where age was not specified in the report for each survey but stated that the entire village or primary school children examined we assumed age ranges to be 0-99 years or 5-14 years respectively.

Occasionally reports presented the total numbers of people examined across a number of villages and only the percentage positive per village; here we assumed the denominator per village to be equivalent to the total examined divided by the total number of villages. In addition some reports presented no information on the denominator, here we have elected to presume a minimum sample size of 50 individuals examined per site unless other information from other sources indicated the sample size might have been smaller (where we presumed 15) or much larger (where we presumed 100) and included a record of this assumption. Where we were not confident on the necessary detail we excluded the record. It was possible to establish the year of every included survey; however the month of survey was occasionally not possible to define from the survey report. Here we used descriptions of "wet" and "dry" season, first or second school term or other information to make an approximation of the month of survey and included a record of this assumption. Some survey results were reported as an aggregate in space (e.g. a single *PfPR* for a group of villages) or time (e.g. a mean PfPR estimated from four different surveys conducted over time). In such cases we either sought additional reports of the same surveys with higher spatial or temporal resolution. Where this was not possible and where clusters of villages exceeded 50 km^2 we excluded the record from the analysis (see below). Where additional information to provide unique time, village, complete data was necessary and it was possible to contact authors by email we entered correspondence to provide any missing information. The many individuals who have assisted in the process of identifying survey data, providing additional information and cascading our enquiries are acknowledged at the end of this report.

A.3 Data geo-coding

Data geo-coding, defining the longitude and latitude for each survey location, was a particularly demanding task. According to their spatial representation, data were classified as individual villages, communities or schools or a collection of communities within a definable area, corresponding to an area ≤25 km^2 or within 5 x 5 km pixel grid squares. Where data were reported across communities that exceeded 25 km^2 we regarded these as too low a spatial resolution, with significant possible variation within the polygon of information to be excluded. To position each survey location in space we used a variety of digital resources, amongst which the most useful were Microsoft Encarta Encyclopedia [Microsoft, 2004] and Google Earth [http://www.google.com/earth/index.html]. Other sources of digital place name archives routinely used included GEOnet Names Server of the National Geospatial-Intelligence Agency, USA [http://www.earth-info.nga.mil/gns/html/cntry_files.html]; Falling Rain Genomics' Global Gazetteer [http://www.fallingrain.com]; and Alexandria Digital Library prepared by University of California, USA [http://www.alexandria.ucsb.edu]. We have also been fortunate to have access to a Ministry of Education and World Bank Global Positioning System (GPS) gazetteer of schools in Kenya and a village and landmark GPS dataset produced by the International Livestock Research Institute [http://192.156.137.110/gis/search.asp]. These high resolution data sets were defaulted to where places were identified. More latterly, with the unpublished data sets GPS have been used to record the longitude and latitude. While in theory GPS coordinates should represent an unambiguous spatial location, these required careful re-checking to ensure that the survey location and names matched the GPS coordinates. As routine we therefore rechecked all GPS noted data from all sources using place names and/or Google Earth to ensure coordinates were located on communities.

A.4 Database quality checks, exclusions and pre-processing

Data checks: The entire database was first checked using a series of simple range-check constraint queries to identify potential errors that could have occurred during data entry. These queries assessed all data fields relevant to modelling for missing or inconsistent information. The final objective was to check for any duplicates introduced during the iterative data assembly process. Pairs of survey sites found within 1 km or within five months at the same location were identified using bespoke R script. These may have entered erroneously into the data assembly where multiple reports reviewed describing similar data. These were listed, checked and duplicates removed.

Data exclusions: The data search identified a total of 4402 space and time specific survey reports of malaria infection prevalence between 1927 and 2011. Following rigorous and multiple attempts at geo-coding the assembled data we were unable to provide any coordinates with confidence for 21 survey locations; these survey points were excluded. No surveys reported information at a spatial resolution that exceeded 25 km^2. Data identified from surveys undertaken between 1927 and 1969 (n=283) were sparsely distributed, largely from descriptions of infection prevalence around Nandi, Taita, Makueni, Machakos, Mombasa and Kisumu. To simplify the modelling of temporal risks we have excluded survey data prior to 1970 leaving 4063 unique space-time survey data points from the period 1970 to 2011. Data were standardized to the age range 2-10 years ($PfPR_{2\text{-}10}$) using standard conversion models.

Age standardization: There was a large diversity in the age ranges of sampled populations between studies. To make any meaningful comparisons in time and space a single standardized age range is required. Correction to a standard age for *Plasmodium falciparum* is possible based on the observation and theory of infectious diseases where immunity is acquired following repeated exposure from birth. We have retained the classical age range of 2-10 years as this best describes the exposure to infection among semi-immune hosts and have adapted catalytic conversion to transform all parasite survey descriptions to this age group [Smith et al., 2008].

References

Noor AM, Gething PW, Alegana VA, Patil AP, Hay SI, Muchiri E, Juma E, Snow RW (2010). The risks of *Plasmodium falciparum* infection in Kenya in 2009. BMC Infectious Diseases, 9: e180

Smith DL, Guerra CA, Snow RW, Hay SI (2007). Standardizing estimates of malaria prevalence. Malaria Journal, 6: e131

Annex B: Selection of covariates for Kenyan malaria risk mapping

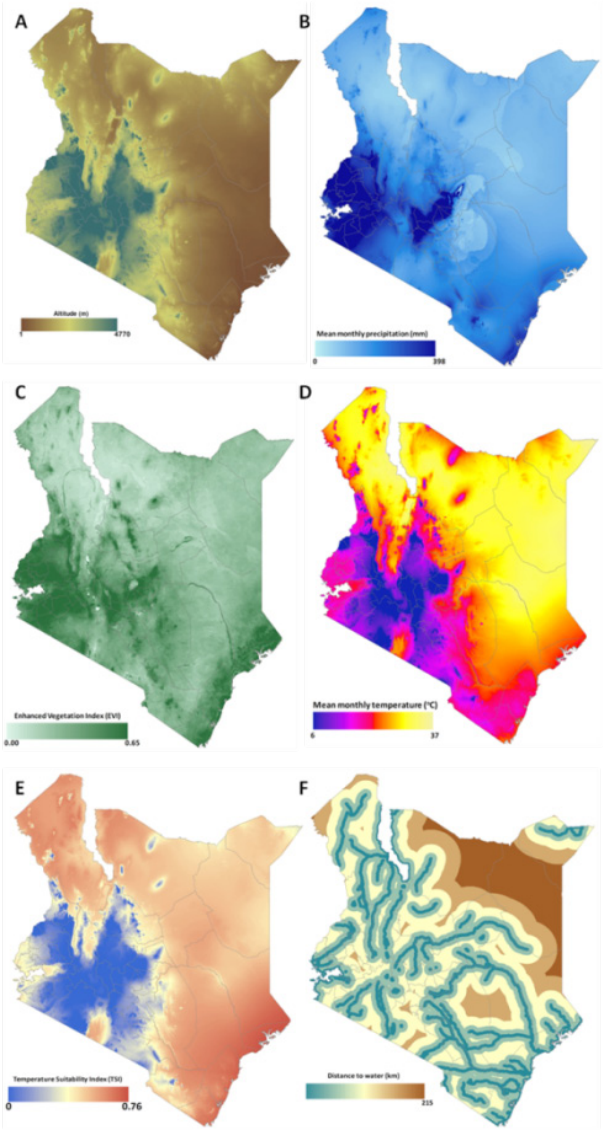
We tested a number of covariates including urbanisation, aridity and vegetation, rainfall, proximity to water features and temperature -see panels below. Urbanization has been shown to limit the availability of optimum environments for the development of the malaria transmitting anopheline populations resulting in reduced vector density, biting rates and transmission intensity. Ambient temperature affects sporogony and vector survivorship. For P. falciparum, sporogonic development takes approximately 9 days at 30°C, 10 days at 25°C, 11 days at 24°C and 23 days at 20°C. Below 16°C sporogony stops and above 35°C it slows down substantially or ceases. Rainfall, combined with suitable ambient temperatures, provides potential breeding environments for Anopheles vectors while humidity is associated with vector longevity. Vegetation indices act both as proxies for aridity, which constrains transmission through the reduced availability of oviposition sites and decreased vector survival. Distance to permanent and temporary water bodies has previously been used in malaria mapping as a proxy for availability of potential breeding sites for the Anopheles vector.

The covariates shown below (Table B.1 and Figure B.1) were extracted to each survey location in ArcGIS 10 (ESRI Inc., USA). A total-sets analysis based on a generalized linear regression model and implemented in bestglm package in R [Miller, 2002; Lumley, 2010] was then used to select those covariates that were most predictive of *P. falciparum* prevalence. The best combination of covariates, which was those with the lowest value of the Bayesian Information Criteria (BIC) statistic, [Schwarz, 1978] was selected for the prediction of malaria risk. The analysis of the regression showed that precipitation, EVI, TSI and urbanisation were all statistically significant predictors of $PfPR_{2-10}$ and were used in the prediction model (Table B.1). Proximity to water features, although a strong predictor at the univariate level, was not picked out as a statistically significant predictor of the space-time $PfPR_{2-10}$ in combination with the other environmental covariates.

Table B.1: The selected best-fit covariates for the prediction of $PfPR_{2-10}$ in Kenya

	Coefficient	*Std. Error*	*t value*	*P value*
Intercept	*-0.144*	*0.018*	*-7.891*	*<0.0001*
Precipitation	*0.032*	*0.002*	*20.001*	*<0.0001*
EVI	*0.214*	*0.006*	*-3.643*	*<0.0001*
TSI	*0.401*	*0.002*	*20.598*	*<0.0001*
Urbanization	*-0.097*	*0.001*	*-8.412*	*<0.0001*

Figure B.1: A) Digital elevation (m); B) Long-term mean monthly rainfall (mm); C) Enhanced Vegetation Index (EVI); D) Long-term monthly mean maximal temperature (oC); E) Temperature Suitability Index (0-1); F) Distance to water bodies.



Footnotes: A) Altitude in metres derived from digital elevations provided at http://asterweb.jpl.nasa.gov/gdem.asp; B) 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 [Hijmans et al., 2005] and monthly average rainfall raster surfaces at 1x1 km resolution available from the WorldClim website (http://www.worldclim.org/download.html). Data shown here are mean maximal rainfall in mm; C) EVI is an index of intensity of photosynthetic activity [Scharlemann et al., 2008]. Traditionally, this index has been used in malaria risk mapping as a proxy of rainfall and a measure of aridity that limits larval growth and vector survival. EVI ranges from 0 (no vegetation) to 1 (complete vegetation). Monthly EVI surfaces have been derived from the global Moderate Resolution Imaging Spectroradiometer (MODIS) satellite imagery for the period 2001-2005 and subjected to temporal Fourier analysis at 1x1 km spatial resolution [Scharlemann et al., 2008]. D) Temperature plays a key role in determining the transmission of human malaria based on its relationship with the duration of sporogony and is particularly relevant to P. falciparum. Temperature surfaces are produced from global weather station temperature records gathered from a variety of sources for the period 1950-2000 and interpolated using a thin-plate smoothing spline algorithm, with altitude as a covariate, to produce a continuous global surface [Hijmans et al., 2005] and monthly average temperature raster surfaces at 1x1 km resolution available from the WorldClim website. Data shown here are mean maximal temperatures; E) 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 x 1 km [Gething et al., 2011]. 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 [Hijmans et al., 2005]. On a scale of increasing transmission suitability, TSI ranges from 0 (unsuitable) to 1 (most suitable); F) A map of water bodies for Kenya was created from a combination of two sources: a rivers layer digitized from 1:50,000 topographic maps and provided by the International Livestock Research Institute, and a map of water bodies developed by the Africover project [www.africover.org]. Major perennial and seasonal water bodies were identified from the combined map by first excluding small and highly seasonal streams and tributaries and confirmed using Google Earth [www.google.com/earth].

References

Miller A (2002). Subset Selection in Regression. Boca Raton, FL: Chapman & Hall. 238 p.

Lumley T (2010). Leaps: regression subset selection (R package) Version 2.7.

Schwarz G (1978). Estimating dimensions of a model. Annals of Statistics, 6: 461-464.

Hijmans RJ, Cameron SE, Parra JL, Jones PG, Jarvis A (2005). Very high resolution interpolated climate surfaces for global land areas. International Journal of Climatology, 25: 1965-1978

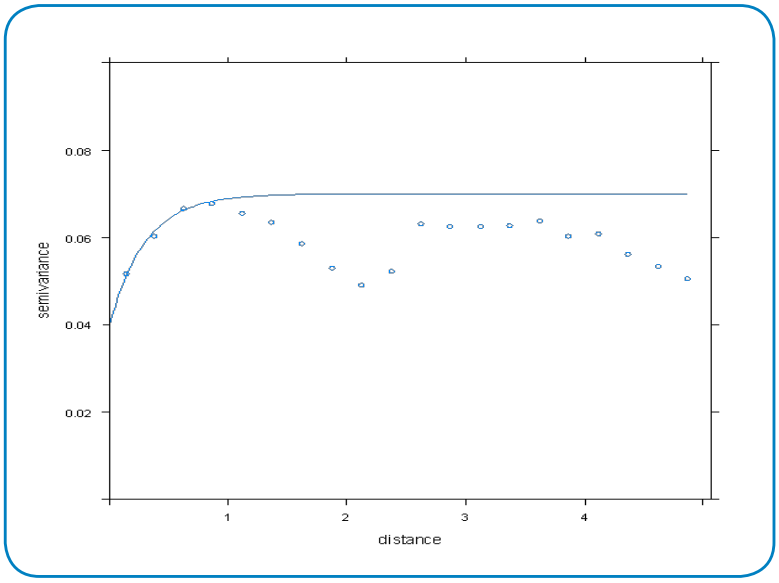
Scharlemann JPW, Benz D, Hay SI, Purse BV, Tatem AJ, Wint GR, Rogers DJ (2008). Global Data for Ecology and Epidemiology: A Novel Algorithm for Temporal Fourier Processing MODIS Data. PLoS One, 1: e1408

Gething PW, Van Boeckel, Smith DL, Guerra CA, Patil AP, Snow RW, Hay SI (2011). Modelling the global constraints of temperature on transmission of *Plasmodium falciparum* and P. vivax. Parasites & Vectors, 4: 92

Annex C: Model based geostatistical method used

A fundamental concept behind analyzing geographic data is determining the presence of spatial dependence [Tobler, 1970]. Spatial dependence simply means co-variation of properties within a geographic space driven by the principle that observations at proximal locations are more correlated (positively or negatively) than those at locations further away. There are a number of reasons for spatial dependence but all generally relate to factors that lead to spatial correlation, causality or interaction (e.g. people who live in same neighborhood are more likely to be similar than those who live in communities further away). Spatial dependence in data leads to the statistical problem of spatial autocorrelation which negates the conventional regression wisdom that observations at one location are independent of observations at a neighboring location often yielding unstable parameter estimates and unreliable significance results [Tobler, 1970; Isaacs & Srivastava, 1989]. Geo-statistical techniques overcome this challenge by incorporating the spatial effects in the data analysis. However, not all data from different locations exhibit spatial dependence and before geo-statistical techniques are used the data need to be explored for the presence of spatial structure or autocorrelation. To explore any data for spatial autocorrelation, the variogram, also commonly referred to as the semi-variogram, is used [Isaacs & Srivastava, 1989]. The variogram is a graphical summary (Figure C.1) of spatial autocorrelation structure and has three parameters: the nugget (n) which is the height of the jump of the variogram at the Y-axis and is considered to represent the measurement error; the sill (s) which is limit of the variogram tending to infinity lag distances; and the range (r) which is the distance in which the difference of the variogram from the sill becomes negligible. The semi-variance (half the variance of data pairs) is shown on the Y-axis and increases with increasing separation distances or lag between data pairs shown on the X-axis. For data to be used to construct the variogram, their location must be defined explicitly i.e. they are provided with latitude and longitude coordinates. The variogram of the Kenya $PfPR_{2\text{-}10}$ data (Figure C.1) shows a clear presence of spatial autocorrelation which appears to have a bimodal structure, indicating a bimodal distribution of the data. The range appears to be about 1 decimal degree or around 111 km at the equator.

Figure C.1: Variogram and model fit for distribution of $PfPR_{2-10}$ data (n=4063 clusters) from 1970 to 2011 in Kenya. The X-axis shows distance in degrees latitude and longitude while the Y-axis shows the semivariance.



After the presence of spatial structure has been established, a suitable MBG model is then developed to fit the data where the spatial (and temporal) covariance is used to generate samples of the predicted posterior distribution from which point estimates and the uncertainty around these estimates are computed simultaneously [Chilés & Delfiner, 1999; Diggle et al., 2002; Noor et al., 2010]. These models can include covariates of the outcome measure and account for non-stationarity, a condition where the statistical parameters (mean and standard deviation) of the data-generating process change over space and/or time [Isaacs & Srivastava, 1989; Atkinson & Tate, 2000]. Normally, Bayesian inference is done using Markov Chain Monte Carlo (MCMC) algorithms [Gilks et al, 1996]. MCMC approaches, although used widely, suffer from problems of convergence and dense covariance matrices which increase the computational time and cost significantly, especially where there are large data points spatially and temporally [Rue et al., 2009]. Recently, Integrated Nested Laplace Approximations (INLA) has been identified as an alternative algorithm for Bayesian inference [Rue et al., 2009]. The advantage of INLA-based approaches is mainly computational speed and can be undertaken in open source, easily adaptable R packages [R-INLA project]. Spatial and temporal analysis in INLA can be undertaken through the Stochastic Partial Differential Equations (SPDE) approach [Cameletti et al., 2012] and the covariance functions are represented as Gaussian Markov Random Field (GMRF) [Rue et al., 2009; Cameletti et al., 2012].

A Bayesian hierarchical spatial-temporal model was implemented through the SPDE approach using R-INLA library [R-INLA] to produce continuous maps of $PfPR_{2-10}$ at 1 x 1 km spatial resolution using data from 1970-2011. Technical equations can be provided on request. In brief, the $PfPR_{2-10}$ survey data were modelled as realizations of a continuously indexed spatial process (random field) changing in time. These realizations were used to make inference about the process and predict it at desired locations and at a specified time. In this report, the Gaussian Field (GF) with Matern covariance function was represented as a GMRF through the SPDE approach to carry out space-time predictions [Rue &

Held, 2005; Lindgren et al., 2011; Cameletti et al., 2012]. By using the GMRF approach the covariance function and the dense covariance matrix of a GF are replaced by a neighbourhood structure and sparse precision matrix respectively which allow for faster computation. The sparsity of the precision matrix offers the computational advantage when making inference with GMRF. This is because the linear algebra operation is performed using numerical methods for the sparse matrices which results in a considerable computational gain and this can be further enhanced by using the INLA algorithm for Bayesian inference [Rue & Held, 2005]. The GF Matern field with a Matern covariance function that is used in this report is a second-order stationary isotropic. A finite element representation is used to outline the Matern field as a linear combination of basic functions defined on a triangulation of the prediction surface, the domain. This is achieved by subdividing the domain into non-intersecting triangles meeting in at most common edge or corner, or a mesh.

Figure C.2. Annual mean predicted $PfPR_{2-10}$ at 1 x 1 km resolution and the population at risk by endemicity class from the years 1970 to 2010

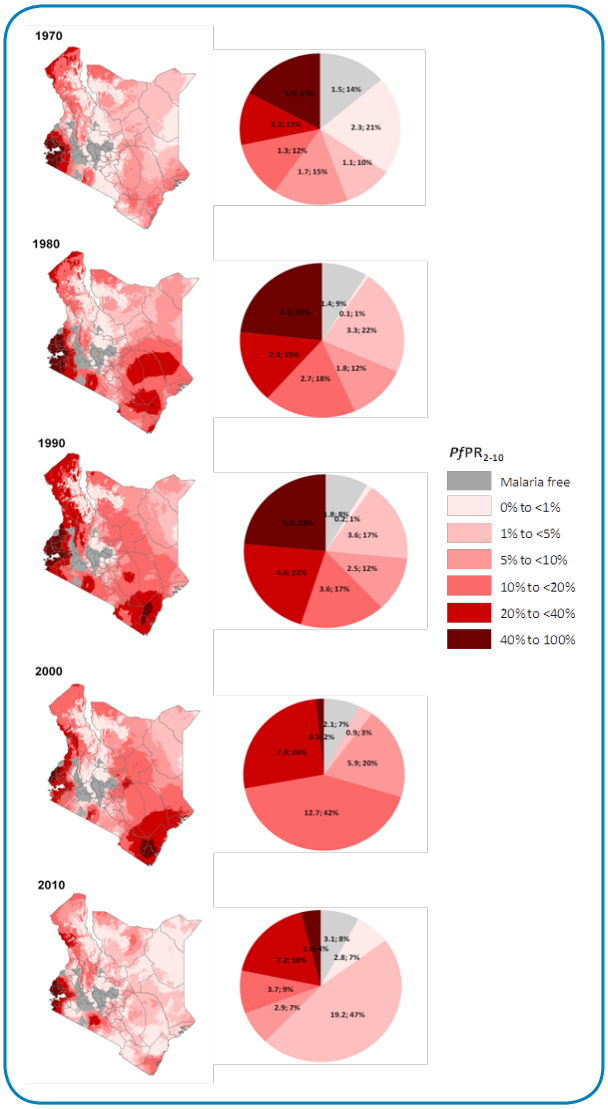
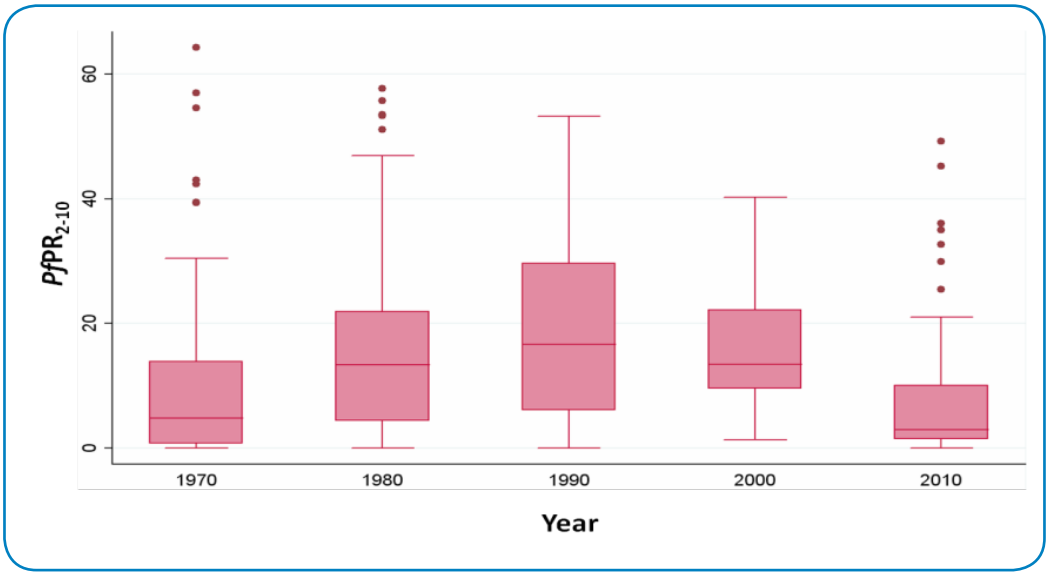


Figure C.3 A box plot of County aggregated annual mean predicted $PfPR_{2-10}$ by year.



References

Atkinson P, Tate N J (2000). Spatial scale problems and geostatistical solutions: A Review. Prof Geogr 52: 607–623.

Cameletti M, Lindgren F, Simpson D, Rue H (2012) Spatio-temporal modeling of particulate matter concentration through the SPDE approach. AStA Advances in Statistical Analysis, doi: 10.1007/s10182-012-0196-3.

Chilés J-P, Delfiner P (1999). Geostatistics: modeling spatial uncertainty. Wiley Series in Probability and Statistics. John Wiley & Sons Inc. New York

Gilks JL (1928). How to get value from the use of quinine in malaria. Medical Department, Colony & Protectorate of Kenya, Health Pamphlet number 647. Government Printers, Nairobi.

Gilks WR, Richardson S, Spiegelhalter DJ (1996). Markov Chain Monte Carlo Methods in Practice. Chapman & Hall/CRC Interdisciplinary Statistics.

Isaacs E, Srivastava R (1989). Applied geostatistics. Oxford University Press.

Lindgren F, Rue H, Lindstrom J (2011) An explicit link between Gaussian fields and Gaussian Markov random fields: The SPDE approach (with discussion). Journal of the Royal Statistical Society,Series B 73:423-498

Rue H & Held L (2005). Gaussian Markov random fields: theory and applications. Chapman & Hall.

Rue H, Martino S, Chopin N (2009). Approximate Bayesian inference for latent Gaussian models by using integrated nested Laplace approximations. Journal of the Royal Statistical Society,Series B 71: 319–392.

R-INLA project. http://www.r-inla.org/. Accessed 10 April 2012.

Tobler W (1970). A computer movie simulating urban growth in the Detroit region. Economic Geography, 46: 234-240.

Annex D: Modelling current ITN coverage from distribution and household survey data

This annex describes the assembly of the two sources of ITN/LLIN information (volumes of ITN/LLIN distribution and household sample survey coverage data) and the Bayesian Small Area Estimation approach taken using these data to predict the per-capita coverage of ITN per county for the years 2003, 2005 and 2010/11.

D.1 Assembling ITN/LLIN distribution data

Data on ITN distribution were assembled mainly from Population Services International inventories of their early social marketing campaigns and subsequent subsidised facility-based distributions from 2004 to 2012. Data were also assembled from the DOMC on the 2007 and the 2011 free mass campaigns and the net-retreatment campaigns of 2008 [Snow et al., 2010; Noor et al., 2010; DOMC unpublished data]. Smaller scale distributions, particularly in some of the northern arid counties such as Turkana, Garissa, Wajir and Mandera, were assembled from sources such as UNICEF, the Red Cross, Mentor Initiative, the World Vision and Against Malaria Foundation [Snow et al., 2010]. Distributions in the for-profit commercial sector were ignored as these represented a very small proportion of overall distributions. The PSI routine distribution data were linked to health facilities as monthly ITN volumes which were geo-coded using an updated version of the spatial health facility database described in Noor et al. (2009) and described by County. Process data of the free mass campaigns and the net re-treatment were available only at divisional administrative units and this information was used to define the data by County. These data were summarised by distribution mechanism and by year and were linked to a Kenya County shapefile in ArcGIS 10 (ESRI Inc., USA).

Over the period 2004 to 2012, approximately 25.3 million ITNs (Figure D.1 & D.2), of which almost 22 million were of the LLIN variety. About 19 million of these nets were distributed from 2007. Approximately 6 million ITNs were distributed through the PSI highly subsidised routine distribution from 2004 to the middle of 2008. Of the remaining 19 million nets, an almost equal amount was distributed through free mass campaigns and the PSI free routine distributions. The largest distribution through both of these free mechanisms was in 2011.

The County level summaries of the distribution of ITNs by year showed that, by 2004, none had received more than 50,000 nets and majority had received less than 10,000 (Figure D.2). In 2006, following the first free mass campaign, net distribution in the counties of Nyanza and Western provinces, Malindi and Kwale on the coast and the several Eastern province counties was between 75,000 to 250,000 ITNs. In 2011 following the free mass campaign many of the counties of Nyanza province and some in Western province had received ITNs exceeding 250,000 and in some cases more than 500,000. Overall,

in the period 2004 to 2012, all of the counties in Nyanza and Western provinces, Kitui and Kirinyaga in Eastern province and Kwale and Kilifi and Malindi in the coast had all received anywhere between 500,000 to 2 million ITNs.

Figure D.1 Annual total distributions of ITNs in Kenya from 2004 to 2010 by main mechanisms of distribution. SRD = subsidised routine distribution; FRD= free routine distribution; FMC= free mass campaigns; FNR=free net replacement

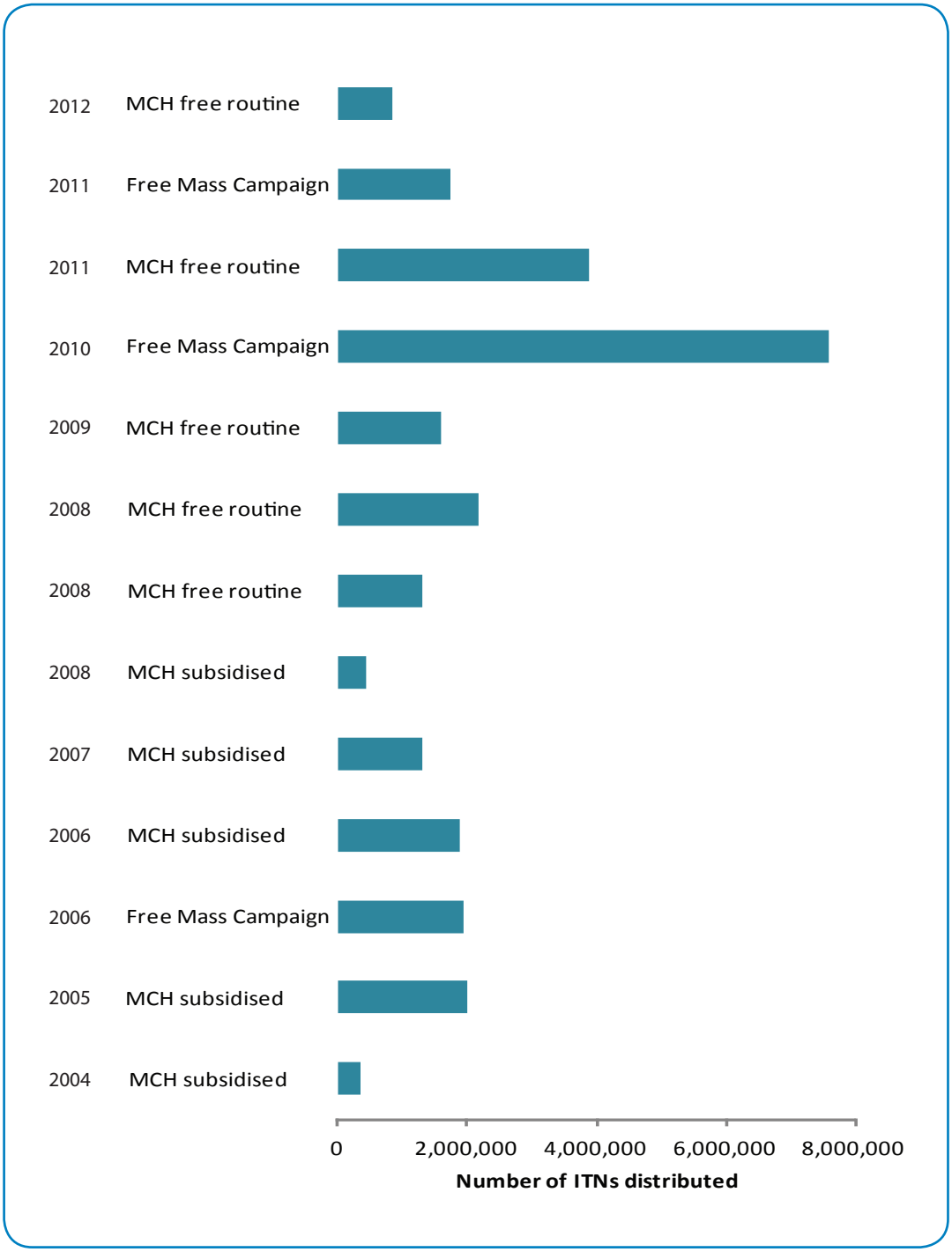
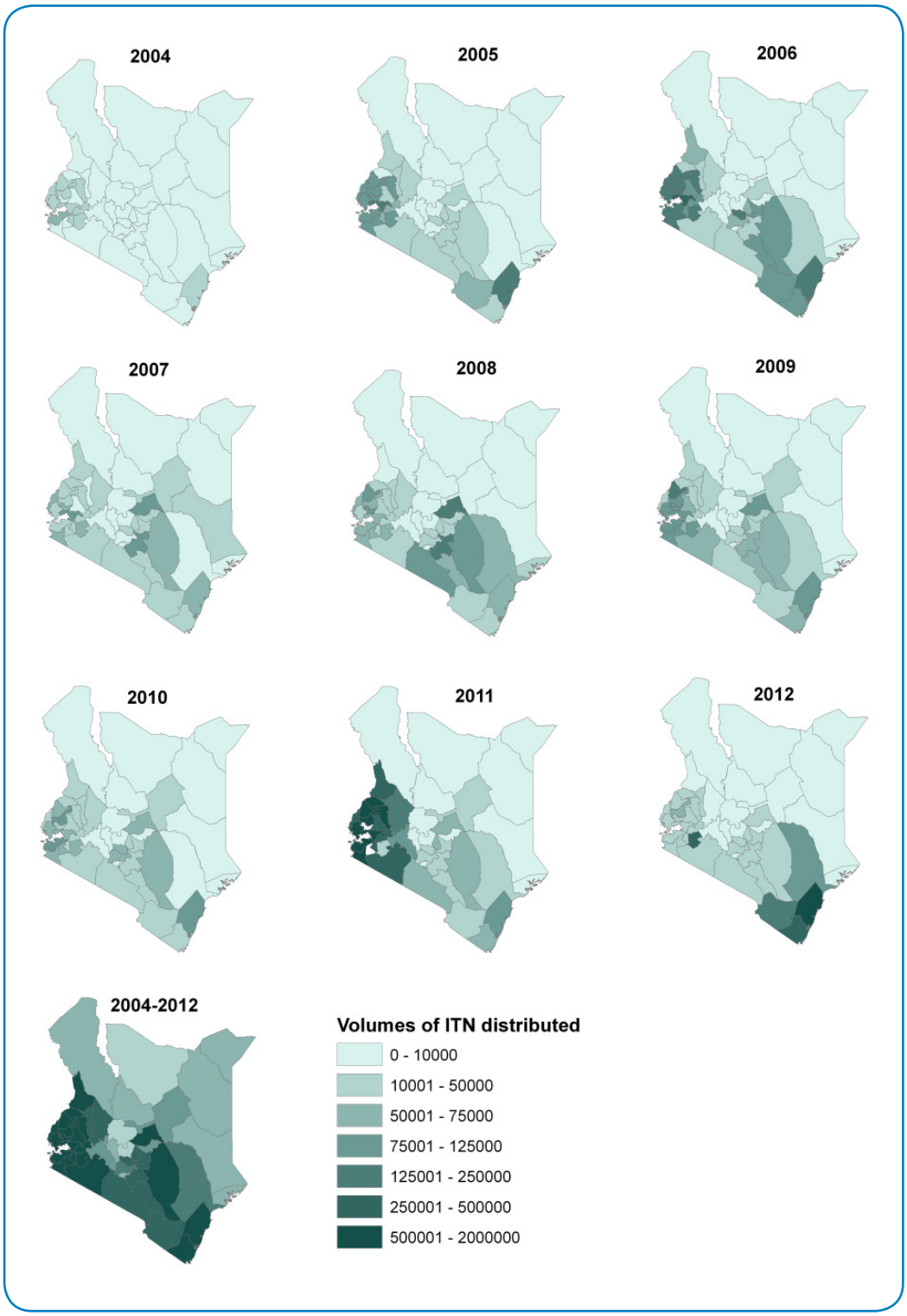


Figure D.2 Annual total distributions of ITNs in Kenya from 2004 to 2012 by County



D.2 Survey data on household ownership and individual use

Since 2003, there have been 10 national and sub-national household sample cross-sectional surveys that have reported information on household net ownership and utilisation of bed nets among either children under the age of five years or persons of all ages (Table D.1).

Table D.1: Summary of survey characteristics and that included questions on ITN ownership and use undertaken between 2003 and 2011

Survey type (Implementing agency)	*Survey dates*	*Number of clusters (urban clusters)*	*Households*	*Population surveyed*	*Age category for the ITN utilisation indicator*	*Sample domain included (out of 8 provinces)*
KDHS	*Apr-Aug 2003*	*400 (129)*	*8561*	*5,920*	*Under five*	*All*
PSI TRaC	*Sept-Oct 2005*	*280 (103)*	*3,192*	*15,714*	*All*	*6*
LLIN Campaign Evaluation	*Oct 2006*	*98 (14)*	*1,086*	*1,686*	*Under five*	*Excluded Nairobi and North Eastern*
KIHBS	*May-May 2005-6*	*1343 (482)*	*13,430*	*63,781*	*All*	
MIS	*Jul 2007*	*199 (36)*	*7,001*	*31,297*	*All*	*All*
PSI TRaC	*Sept-Oct 2007*	*265 (136)*	*4,057*	*18,183*	*All*	*6*
KDHS	*Nov-Feb 2008-9*	*400 (133)*	*9,057*	*30,049*	*All*	*All*
Financial Services Access (FSD) survey	*Jan-Mar 2009*	*646 (181)*	*6600*	*32,487*	*All*	*All*
MIS	*Jul-Sept 2010*				*All*	*7*
LLIN Campaign Evaluation	*Jul 2011*	*205 (44)*	*4,091*	*20521*	*All*	*Only Western & Nyanza and five Rift Valley counties*

All household surveys utilized a two-stage sample design which first involved selecting sample points (clusters) from a national master sample maintained by Kenya National Bureau of Statistics (KNBS) known as the fourth National Sample Survey and Evaluation Programme (NASSEP IV) and were designed to provide reliable estimates of the sampling domain and for urban and rural areas. The Kenya DHS surveys of 2003 and 2008-2009 both oversampled for urban areas to provide reliable estimates of HIV/AIDS related questions. The 2003 survey was the first to include questions on the household ownership nets and utilization focusing only on children under the age of five years. The PSI Tracking Results Continuously (TRaC) surveys are designed primarily to measure levels and trends of indicators such as behavior, behavioral determinants, and exposure to social marketing interventions [http://

www.psi.org/resources/research-metrics]. Both the 2005 and 2007 surveys were conducted in the same districts and clusters were geo-positioned using GPS. The malaria indicator surveys (MIS) were introduced by the Roll Back Malaria – Monitoring and Evaluation Resource Group (RBM-MERG) as a tool to monitor the outcome and impact indicators of key malaria interventions. The first one was done in Kenya in 2007 and was based on a representative probability sample designed to produce estimates for the country as a whole, rural and urban separately and by transmission strata (high, medium, low and no transmission). The MIS 2010 adopted a similar approach and covered all the provinces of the country. The Kenya Integrated Household Budget Survey (KIHBS) survey was undertaken to capture data to update national statistics on poverty and inequality. Indicators of income, expenditure, assets, employment, health and household size were assembled. Use of ITN by all household members was recorded under the health section. However, information on household ownership of nets was not recorded. Data collection for KIHBS continued for a period of one year from May 2005 to May 2006 and remains the largest household survey ever undertaken in Kenya. None of the clusters have been geo-positioned during survey and repeated attempts to obtain cluster names from the KNBS to enable their mapping using secondary sources of coordinates have failed. Following each of the free mass campaigns of 2006 and 2011 an evaluation survey was undertaken to evaluate the effectiveness of the campaign in terms of increasing coverage of LLINs and net retention. These surveys were undertaken only in 20/46 malarious districts in targeted during the LLIN distribution campaign in 2006. The 2011 survey was undertaken in the campaign counties of Nyanza and Western provinces. Finally, from January to March 2009, the Financial Sector Deepening (FSD) Kenya, a microfinance organization, undertook a national household survey of access to financial services in rural and urban communities. This survey was based on a national cluster sample of households covering all provinces. Although the FSD survey was not focused on health or malaria the MPH paid for the inclusion of additional questions on net/ITN use by household members of all ages. Questions on household ITN ownership were not included.

Before the assembled survey data were used for the space-time analysis of ITN coverage a series of preparatory work was undertaken. First the individual survey data were aggregated to the cluster and linked to the County. Each cluster file had a unique County ID, a cluster name and/or ID, the number of ITNs in the household, the number of individuals interviewed and those who slept under an ITN the night before survey. The 2003 DHS and 2006 LLIN evaluation survey data, which contained only information of ITN use among children under five years, were then standardised to provide estimates of use of ITNs among all ages. This was done using the ratio of under-five to all-age ITN use by province from the 2005 PSI TRaC and 2005-2006 KIHBS surveys respectively to adjust the numerator of the number of persons examined in the DHS 2003 and 2006 LLIN evaluation surveys. The number of ITNs for the FSD 2009 survey data, which had only information of ITN use among all ages, was computed by multiplying the per capita household ITN ownership from the DHS 2008-9 with number of individuals examined during the FSD survey. Finally, using the annual ITN distribution data and the population of the year of distribution, the annual per capita ITN distribution was computed for each County. The relationship between per capita household ITN ownership and the use of ITN the night before survey was statistically tested.

These cluster level data were used to develop small area space-time estimates of ITN coverage at the County for the years 2003-2011. The DHS 2003 was modelled separately to provide baseline ITN coverage for 2003 and was later combined with the PSI TraC 2005 and KIHBS 2005-6 to compute

County level estimates of ITN coverage for 2005. The rest of survey data were used to generate estimates of ITN coverage for 2010 (excluding the 2011 LLIN evaluation data) and 2011 (including the 2011 evaluation data). The reason for the separate 2010 and 2011 estimates was to use the former to compare the relationship between coverage and changing risk and latter to estimate unmet ITN coverage needs at the County.

D.3 Small area estimation (SAE) methods for space-time mapping of ITN coverage

SAE methods handle the problem of making reliable estimates of a variable of interest at areal units under conditions where the information available for the variable, on its own, is not sufficient to make valid estimates [Rao et al., 2003; BIAS URL]. This is normally the case where survey data from a small sample of locations is used to make estimates across a wider unsampled set of units. Bayesian SAE methods use the survey data along with contextual process information such as volumes of interventions distributed within conditional autoregressive specifications [Rao et al., 2003; BIAS URL] to produce precise estimates of the variable of interest. These methods account for the different random effect structures (spatial, temporal and unstructured) in the data, smooth the variance due to sampling, compute estimates for off-sample areas using data from sampled areas and auxiliary data that is available for all areas and quantify all sources of uncertainties in the model [Rao, 2003; Banerjee et al., 2004; Best et al., 2005; Jian & Lahiri, 2006; Jackson et al., 2006; BIAS URL; Singh et al., 2005].

ITN coverage data aggregated at cluster level was used within space-time area level model to predict to coverage to counties in Kenya. The target variable, the proportion of people who slept under ITN the night before survey, assumed a binomial distribution as follow: $y_{ij} \square Binom(p_i, N_i); j = 1, \ldots, n_i$ where $\log it(p_i) = \alpha + \beta X_i; i = 1, \ldots, K$. The percapita ITN distribution was used as covariate. The adjacency matrix of the areas was computed considering that two regions are neighbours if they have a common boundary. This information was used to define the correlation structure between the spatial random effects. The full model was specified as $\mu_i = \sum_j \frac{\mu_{ij}}{N_i} = \alpha + \overline{X_i}\beta + t_i + u_i + v_i$, where α is the intercept of the model, β is the vector of coefficients of the covariate used in the model, t_i denotes the time of the target variable at a specific area, u_i is a random effect which accounts for area level variation and is distributed independently as normally distributed with a mean of zero and standard deviation of σ_m^2 and v_i represents spatially correlated random effects which is assigned a conditional autoregressive (CAR) distribution. The implementation of the models was done using R-library INLA [www.r-inla.org].

References

Banerjee S, Carlin BP, Gelfand AE (2004). Hierarchical Modeling and Analysis for Spatial Data. Chapman & Hall, New York.

Best N, Richardson S, Thomson A (2005). A comparison of Bayesian spatial models for disease mapping. Statistical Methods in Medical Research 14(1): 35-59.

Jackson C, Best N, Richardson S (2006). Improving ecological inference using individual-level data. Statistics in Medicine 25 (12): 2136–2159

Rao JNK (2003). Small Area Estimation. John Wiley & Sons, Inc., Hoboken, New Jersey, 2003.

Jiang J & Lahiri P (2006). Mixed model prediction and small area estimation. Test, 15: 1–96

Singh BB, Shukla GK, KunduD (2005). Spatio-temporal models in small area estimation. Survey Methodology, 31: 183–196

Introduction to Bayesian Small Area Estimation, January 2007. http://www.bias-project.org.uk/software/SAE.pdf. Accessed 17 April 2012.

Annex E: Estimating the unmet need for LLIN to 2014 using coverage, biological risk and international recommendations

Box E.1 Guidelines for LLIN programmatic gap analysis adapted for the Kenyan situation (Source: http://www.rbm.who.int/toolbox/tool_CountryNeedsAssessment.html]

- Define national target – (recommended a 100% sustained coverage of the targeted malaria endemic population)
- Define areas targeted for LLIN intervention and the population living in them.
- Decide on the forecast years. WHOPES recommendation is that campaigns are carried out every three years.
- Estimate LLIN requirements for universal coverage (1 net for 2 persons) in malaria endemic areas. WHO and RBM recommend use a calculation of the target population divided by 1.8 to account for people living in households with an odd number of family members.
- Calculate the number of nets required through ANC by multiplying the population living in target areas by the % of pregnant women in the population. If ANC coverage is relatively low, factor in current and projected ANC coverage.
- Calculate the number of nets required through EPI by multiplying the target population by the % of children under 1. If EPI coverage is relatively low, factor in current and projected EPI coverage.
- Compute the total number of nets distributed through routine systems by adding the target population for EPI and ANC.
- The total number of LLINs required is calculated by adding the campaign nets (usually once every three years, unless the country has adopted a programme of rolling campaigns) and the routine nets in all years.
- In campaigns, existing nets should be accounted for especially where there is a strong routine system, and population coverage is over 40%. Existing nets should then be subtracted from the number of nets needed in a campaign to demonstrate good value for money. HWG/AMP estimates that nets are lost at the rate of 8% during the first year, 20% during the second year, and 50% during the third year. These nets will also require replacement, and these loss rates should be factored into the calculation for net need.
- Calculate the cumulative number of existing nets for mass campaign planning by adding the nets distributed in the current year, and previous two years. Any nets distributed more than three years ago should not be included in this calculation, as they will be coming to the end of their useful life (unless there is local data indicating durability beyond three years).
- Subtracting the number of existing nets from the total number of nets needed gives the total net need for mass LLIN distribution campaigns every three years.
- LLINs planned to be met under other programs are summed to show what is currently funded or expected to be funded.
- The expected annual gap in achieving targets is calculated from the number of nets required minus number of nets funded.

The expected annual gap in achieving targets is calculated from the number of nets required minus number of nets funded.

Here we have estimated the gap in routine and mass campaign LLIN distributions from a baseline year of 2011, which corresponds to the last free mass campaign in Kenya. Following the WHOPES recommendation of free mass distributions every three years, only estimates of free routine distributions were computed for both 2012 and 2013. The year 2014 was selected as the time of the next campaign in Kenya and the gap for both routine and campaign nets was estimated for this year. This was done by applying the parameters in Tables E.1 and F.2 assemble for Kenya to the RBM-HWG gap analysis approach (above). The 2009 population census and inter-censal growth rates (Table E.1) were used to compute projected population for 2011, 2012, 2013 and 2014. The percentage population who were <1 year was also obtained from the 2009 census and was available by province which was applied to all counties in the same province. The percentage of population who were pregnant in a given year and the provincial estimates of coverage of ANC and EPI were both obtained from the Kenya DHS of 2008-2009 (Table E.1). Estimates of LLIN gap by county were then generated (Table E.2).

The RBM-HWG approach recommends that when estimating the gap in LLIN distribution for free mass campaigns, the existing nets should be accounted for especially where there is a strong routine system, and population coverage is over 40%. These should then be subtracted from the number of nets needed in a campaign to come up with an adjusted final estimate of LLIN gap. To compute the existing nets, only LLINs distributed in the last three years are considered and adjusted for attrition using the rate of 8% during the first year, 20% during the second year, and 50% during the third year. Therefore, to estimate the free mass campaign gap for the year 2014, the LLINs distributed in 2011, 2012 and 2013 in the targeted counties were assembled and adjusted by 50%, 20% and 8% loss rate respectively to compute the existing viable nets by 2014 (Table E.3). These were then subtracted from the estimates of free mass campaign needs for 2014.

If the LLIN gap was not adjusted for the estimated existing nets by the time of the next free mass campaign in 2014, approximately 11.8 million nets would be required in addition to routine distributions (Table E.3). However, using the RBM-HWG recommendation of the rate of net loss, about 7 million of the 14.8 million distributed between 2011 and 2013 would be viable LLINs by 2014 (Table E.3). When subtracted from the free mass campaign unadjusted estimates for 2014, approximately 4.5 million LLINs would be needed to for the 2014 free mass campaign. When added to the 2.5 million nets that would be distributed in 2014 through the routine sector, a total of 7.1 million LLINs will be required for scale up in 2014. Overall, between 2012 and 2014, approximately 12 million nets will be required for universal scale in Kenya including the estimates for routine distribution in 2012 and 2013.

Table E.1 A classification of counties by the type of LLIN distribution mechanism, population growth rate, proportion of population pregnant and <1 year of age, ANC and EPI coverage. FMC=free mass campaign.

County	Type of LLIN distribution	Population growth rate	Proportion Population pregnant	Proportion ANC coverage	Proportion population <1 year	Proportion EPI coverage
Laikipia	No LLIN distribution	3.6	0.045	0.884	0.041	0.71
Nairobi	No LLIN distribution	3.8	0.045	0.964	0.036	0.91
Nakuru	No LLIN distribution	3.6	0.045	0.884	0.041	0.71
Nyandarua	No LLIN distribution	1.6	0.045	0.927	0.031	0.90
Nyeri	No LLIN distribution	1.6	0.045	0.927	0.031	0.90
Embu	Routine Only	2	0.045	0.934	0.036	0.88
Garissa	Routine Only	8.8	0.045	0.695	0.025	0.75
Isiolo	Routine Only	2	0.045	0.934	0.036	0.72
Kajiado	Routine Only	3.6	0.045	0.884	0.041	0.71
Kiambu	Routine Only	1.6	0.045	0.927	0.031	0.90
Kirinyaga	Routine Only	1.6	0.045	0.927	0.031	0.93
Kitui	Routine Only	2	0.045	0.934	0.036	0.69
Machakos	Routine Only	2	0.045	0.934	0.036	0.81
Makueni	Routine Only	2	0.045	0.934	0.036	0.85
Mandera	Routine Only	8.8	0.045	0.695	0.025	0.47
Marsabit	Routine Only	2	0.045	0.934	0.036	0.80
Meru	Routine Only	2	0.045	0.934	0.036	0.65
Mombasa	Routine Only	2.9	0.045	0.945	0.039	0.90
Muranga	Routine Only	1.6	0.045	0.927	0.031	0.78
Samburu	Routine Only	3.6	0.045	0.884	0.041	0.86
Tharaka	Routine Only	2	0.045	0.934	0.036	0.45
Turkana	Routine Only	3.6	0.045	0.884	0.041	0.67
Wajir	Routine Only	8.8	0.045	0.695	0.025	0.73
Baringo	FMC & Routine	3.6	0.045	0.884	0.041	0.77
Bomet	FMC & Routine	3.6	0.045	0.884	0.041	0.88
Bungoma	FMC & Routine	2.5	0.045	0.915	0.045	0.68
Busia	FMC & Routine	2.1	0.045	0.936	0.041	0.79
Elgeyo Marakwet	FMC & Routine	3.6	0.045	0.884	0.041	0.81
Homa Bay	FMC & Routine	2.1	0.045	0.936	0.041	0.50
Kakamega	FMC & Routine	2.5	0.045	0.915	0.045	0.69
Kericho	FMC & Routine	3.6	0.045	0.884	0.041	0.74
Kilifi	FMC & Routine	2.9	0.045	0.945	0.039	0.66
Kisii	FMC & Routine	2.1	0.045	0.936	0.041	0.65
Kisumu	FMC & Routine	2.1	0.045	0.936	0.041	0.65
Kwale	FMC & Routine	2.9	0.045	0.945	0.039	0.93
Lamu	FMC & Routine	2.9	0.045	0.945	0.039	0.81
Migori	FMC & Routine	2.1	0.045	0.936	0.041	0.52

County	Type of LLIN distribution	Population growth rate	Proportion Population pregnant	Proportion ANC coverage	Proportion population <1 year	Proportion EPI coverage
Nandi	FMC & Routine	3.6	0.045	0.884	0.041	0.81
Narok	FMC & Routine	3.6	0.045	0.884	0.041	0.62
Nyamira	FMC & Routine	2.1	0.045	0.936	0.041	0.88
Siaya	FMC & Routine	2.1	0.045	0.936	0.041	0.65
Taita Taveta	FMC & Routine	2.9	0.045	0.945	0.039	0.77
Tana River	FMC & Routine	2.9	0.045	0.945	0.039	0.86
Trans Nzoia	FMC & Routine	3.6	0.045	0.884	0.041	0.91
Uasin Gishu	FMC & Routine	3.6	0.045	0.884	0.041	0.73
Vihiga	FMC & Routine	2.5	0.045	0.915	0.045	0.73
West Pokot	FMC & Routine	3.6	0.045	0.884	0.041	0.56

Table E.2 Unadjusted estimated LLIN gap in Kenya from 2011 to 2014. The 2011 estimates do not exclude the LLIN distributed in 2011 and capture the gap in both routine and mass campaign prior to the last free mass campaigns in Nyanza and Western counties. For 2012 and 2013 only estimates for routine distribution were computed. For 2014 estimates include the gap in both routine and free mass campaigns. None of the estimates exclude LLINs in circulation at the time of estimation.

Projected LLIN need by year of distribution				
County	2011	2012	2013	2014
Embu	39,583	40,383	41,199	42,031
Garissa	37,092	40,504	44,230	48,299
Isiolo	10,145	10,350	10,559	10,772
Kajiado	50,793	52,655	54,585	56,586
Kiambu	116,679	118,561	120,474	122,417
Kirinyaga	38,395	39,015	39,644	40,283
Kitui	70,332	71,753	73,202	74,681
Machakos	81,523	83,170	84,850	86,565
Makueni	66,865	68,216	69,594	71,000
Mandera	52,626	57,467	62,753	68,526
Marsabit	21,476	21,910	22,352	22,804
Meru	92,364	94,230	96,134	98,076
Mombasa	77,389	79,667	82,011	84,424
Muranga	63,980	65,012	66,061	67,126
Samburu	18,020	18,681	19,365	20,075
Tharaka	22,128	22,575	23,031	23,496
Turkana	61,707	63,969	66,314	68,745
Wajir	39,032	42,623	46,543	50,825
Baringo	374,163	44,033	45,647	416,836
Bomet	491,240	61,037	63,274	547,265
Bungoma	1,075,823	126,415	129,615	1,159,613

Projected LLIN need by year of distribution				
County	2011	2012	2013	2014
Busia	320,586	38,622	39,442	341,433
Elgeyo Marakwet	249,922	30,086	31,189	278,426
Homa Bay	618,248	64,069	65,429	658,450
Kakamega	1,096,290	129,604	132,885	1,181,674
Kericho	509,896	59,239	61,411	568,049
Kilifi	733,798	82,831	85,268	800,498
Kisii	983,966	110,567	112,914	1,047,950
Kisumu	630,862	70,965	72,471	671,885
Kwale	436,796	55,756	57,396	476,500
Lamu	67,733	8,188	8,429	73,890
Migori	363,368	37,943	38,748	386,997
Nandi	508,539	61,158	63,400	566,536
Narok	567,722	61,885	64,154	632,470
Nyamira	395,434	49,852	50,910	421,148
Siaya	548,357	61,618	62,926	584,015
Taita Taveta	189,426	22,482	23,144	206,644
Tana River	160,662	19,891	20,476	175,265
Trans Nzoia	556,509	70,167	72,739	619,977
Uasin Gishu	600,721	69,320	71,861	669,232
Vihiga	367,135	44,307	45,429	395,728
West Pokot	340,704	35,881	37,197	379,561
Total	13,148,032	2,406,656	2,479,253	14,316,770

Table E.3 LLIN gap in Kenya from in 2014 adjusted for expected existing nets by 2014.

County	Type of recommended LLIN distribution	LLINs distributed in 2011	LLINs distributed in 2012	aLLINs distributed in 2013	Existing LLINs for 2014 free mass campaign	Routine distribution gap	Unadjusted free mass campaign gap	adjusted free mass campaign gap	Total LLIN gap 2014
Embu	Routine	13,600	10,280	41,199	0	42,031	0	0	42,031
Garissa	Routine	10,000	10,000	44,230	0	48,299	0	0	48,299
Isiolo	Routine	16,240	4,440	10,559	0	10,772	0	0	10,772
Kajiado	Routine	50,930	24,680	54,585	0	56,586	0	0	56,586
Kiambu	Routine	37,260	25,680	120,474	0	122,417	0	0	122,417
Kirinyaga	Routine	67,980	47,393	39,644	0	40,283	0	0	40,283
Kitui	Routine	74,720	26,640	73,202	0	74,681	0	0	74,681
Machakos	Routine	33,840	30,600	84,850	0	86,565	0	0	86,565
Makueni	Routine	34,880	18,160	69,594	0	71,000	0	0	71,000
Mandera	Routine	10,000	10,000	62,753	0	68,526	0	0	68,526
Marsabit	Routine	10,000	10,000	22,352	0	22,804	0	0	22,804
Meru	Routine	51,000	26,300	96,134	0	98,076	0	0	98,076
Mombasa	Routine	56,810	16,760	82,011	0	84,424	0	0	84,424
Muranga	Routine	37,620	20,480	66,061	0	67,126	0	0	67,126
Samburu	Routine	10,000	10,000	19,365	0	20,075	0	0	20,075
Tharaka	Routine	8,120	7,560	23,031	0	23,496	0	0	23,496
Turkana	Routine	10,000	10,000	66,314	0	68,745	0	0	68,745
Wajir	Routine	10,000	10,000	46,543	0	50,825	0	0	50,825
Baringo	FMC & Routine	209,680	7,000	45,647	148,236	47,320	369,515	221,279	268,600
Bomet	FMC & Routine	49,920	32,360	63,274	109,060	65,593	481,671	372,611	438,204
Bungoma	FMC & Routine	943,520	39,160	129,615	622,334	132,896	1,026,717	404,383	537,279
Busia	FMC & Routine	395,953	41,160	39,442	267,191	40,279	301,154	33,963	74,242

County	Type of recommended LLIN distribution	LLINs distributed in 2011	LLINs distributed in 2012	aLLINs distributed in 2013	Existing LLINs for 2014 free mass campaign	Routine distribution gap	Unadjusted free mass campaign gap	adjusted free mass campaign gap	Total LLIN gap 2014
E. Marakwet	*FMC & Routine*	*152,945*	*22,680*	*31,189*	*123,310*	*32,332*	*246,093*	*122,783*	*155,115*
Homa Bay	*FMC & Routine*	*632,295*	*37,720*	*65,429*	*406,518*	*66,817*	*591,633*	*185,115*	*251,932*
Kakamega	*FMC & Routine*	*1,046,682*	*71,720*	*132,885*	*702,971*	*136,249*	*1,045,425*	*342,453*	*478,702*
Kericho	*FMC & Routine*	*387,008*	*14,520*	*61,411*	*261,618*	*63,662*	*504,387*	*242,769*	*306,431*
Kilifi	*FMC & Routine*	*85,240*	*25,960*	*85,268*	*141,835*	*87,777*	*712,721*	*570,886*	*658,663*
Kisii	*FMC & Routine*	*1,531,180*	*31,840*	*112,914*	*894,943*	*115,310*	*932,640*	*37,697*	*153,008*
Kisumu	*FMC & Routine*	*569,856*	*29,480*	*72,471*	*375,185*	*74,009*	*597,876*	*222,691*	*296,700*
Kwale	*FMC & Routine*	*55,180*	*21,680*	*57,396*	*97,739*	*59,085*	*417,414*	*319,676*	*378,761*
Lamu	*FMC & Routine*	*6,400*	*6,000*	*8,429*	*15,755*	*8,677*	*65,213*	*49,458*	*58,135*
Migori	*FMC & Routine*	*557,499*	*29,880*	*38,748*	*338,302*	*39,571*	*347,426*	*9,124*	*48,695*
Nandi	*FMC & Routine*	*190,953*	*24,800*	*63,400*	*173,644*	*65,724*	*500,813*	*327,168*	*392,892*
Narok	*FMC & Routine*	*462,713*	*10,840*	*64,154*	*299,050*	*66,505*	*565,965*	*266,915*	*333,420*
Nyamira	*FMC & Routine*	*453,680*	*12,600*	*50,910*	*283,757*	*51,990*	*369,158*	*85,401*	*137,391*
Siaya	*FMC & Routine*	*528,565*	*25,280*	*62,926*	*342,398*	*64,261*	*519,753*	*177,355*	*241,616*
Taita Taveta	FMC & Routine	10,760	10,640	23,144	35,184	23,825	182,819	147,635	171,460
Tana River	FMC & Routine	13,160	8,840	20,476	32,490	21,078	154,187	121,697	142,775
Trans Nzoia	FMC & Routine	802,836	34,280	72,739	495,762	75,405	544,572	48,811	124,216
Uasin Gishu	FMC & Routine	644,316	16,080	71,861	401,134	74,495	594,737	193,603	268,098
Vihiga	FMC & Routine	750,224	30,360	45,429	441,195	46,579	349,149	-92,045	-45,466
West Pokot	FMC & Routine	352,530	2,720	37,197	212,662	38,560	341,001	128,339	166,899
Total		**11,376,095**	**906,573**	**2,479,253**	**7,074,036**	**2,554,730**	**11,762,040**	**4,539,768**	**7,094,498**

References

Roll Back Malaria Partnership Need Assessment Package. http://www.rbm.who.int/toolbox/tool_CountryNeedsAssessment.html. Accessed on 20 September 2012.

Acronyms

ACT	Artemisinin based Combination Therapy
AL	Artemether-Lumefanthrine
ANC	Ante-Natal Care
CBS	Central Bureau of Statistics
CDC	Centers for Disease Control, USA
CHW	Community Health Worker
CQ	Chloroquine
DEM	Digital Elevation Map
DFID	Department for International Development
DHMT	District Health Management Teams
DOMC	Division of Malaria Control
DSS	Demographic Surveillance System
DVBD	Division of Vector Borne Diseases
DVBND	Division of Vector Borne and Neglected Diseases
EA	Enumeration Area
EPI	Expanded Programme of Immunization
EVI	Enhanced Vegetation Index
FSD	Financial Services Deepening
GIS	Geographic Information System
GFATM	Global Fund to Fight AIDS, Tuberculosis and Malaria
GMP	Global Malaria Programme, WHO
GOK	Government of Kenya
HIMAL	Highland Malaria Project
HMIS	Health Management Information System
IEC	Information, Education & Communications
IMCI	Integrated Management of Childhood Illness
IPTp	Intermittent Presumptive Treatment in pregnancy
IRS	Indoor Residual House-Spraying
ITN	Insecticide-treated nets
KAIS	Kenya Aids Indicator Survey
KDHS	Kenya Demographic & Health Survey
KEMRI	Kenya Medical Research Institute
KEMRI-WTRP	Kenya Medical Research Institute-Wellcome Trust Research Programme
KEMSA	Kenya Medical Supplies Agency
KEPI	Kenya Expanded Programme of Immunization
KNBS	Kenya National Bureau of Statistics
KNMS	Kenya National Malaria Strategy
KSPA	Kenya Service Provision Assessment
LLIN	Long-Lasting Insecticidal Net
M&E	Monitoring & Evaluation
MDG	Millennium Development Goal

MCH	Maternal & Child Health
MIP	Malaria in Pregnancy
MIS	Malaria Indicator Survey
MOE	Ministry of Education
MOH	Ministry of Health
MOMS	Ministry of Medical Services
MOPHS	Ministry of Public Health & Sanitation
MPHD	Malaria Public Health Department
NGO	Non-Governmental Organization
NHFD	National Health Facility Database
NHSSP	National Health Sector Strategic Plan
PfPR	*Plasmodium falciparum* parasite rate
$PfPR_{2\text{-}10}$	*Plasmodium falciparum* parasite rate standardized to ages 2 to 9 years
PMI	Presidents Malaria Initiative
PSI	Population Servwices International
QN	Quinine
RBM	Roll Back Malaria
RBM-HWG	Roll Back Malaria Harmonization Working group
RDT	Rapid Diagnostic Test
SP	Sulphadoxine-Pyrimethamine
TSI	Temperature Suitability Index
UN	United Nations
UNICEF	United Nations Children's Fund
USAID	United States Development Agency
WHO	World Health Organization

County Profiles

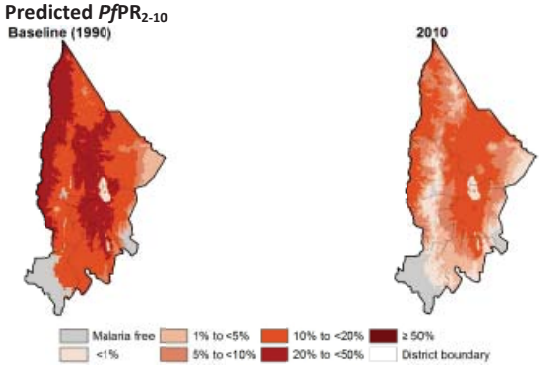
BARINGO COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	281,279	415,888	575,926	597,037	618,921	641,609	665,127
Percentage rural[2]			89.0				
Percentage poor[3]			57.4				
ANC coverage[4]			88.4				
EPI coverage[5]			76.5				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

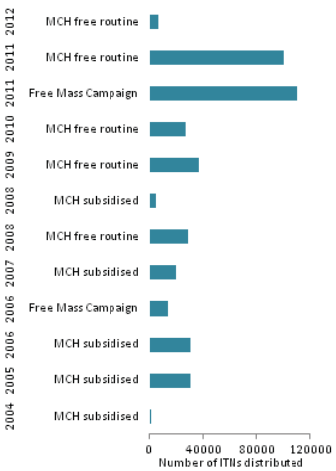


Population at risk in 1990 and 2010 by malaria endemicity

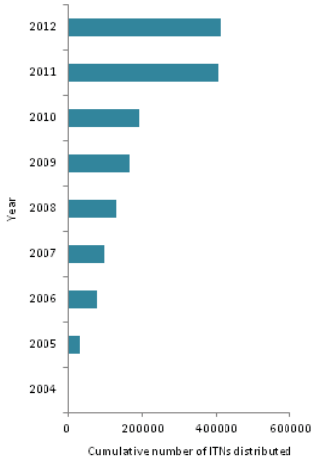
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	50,721 (18.0%)	104,632 (18.2%)
0 to <1%	498 (0.2%)	154,252 (26.8%)
1% to <5%	18,301 (6.5%)	92,497 (16.1%)
5% to <10%	12,576 (4.5%)	70,958 (12.3%)
10% to <20%	129,753 (46.1%)	153,296 (26.6%)
20% to <50%	69,431 (24.7%)	292 (0.1%)
≥50%	0 (0.0%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

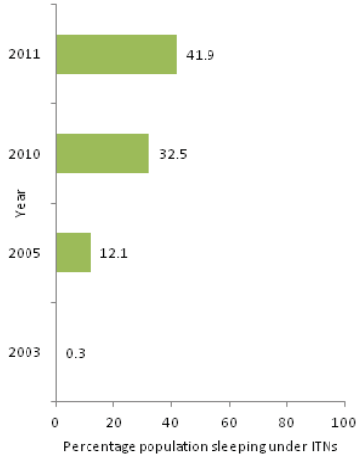
ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage



VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	45,647	0	45,647
	2014	47,320	221,279	268,599
	Total	92,967	221279	314,246

	Year	Insecticide sachets	Spraying operators
IRS	2013	TBD	TBD
	2014	TBD	TBD

[1] Population Projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06
TBD: To be determined based on hotspots identified through surveillance sites

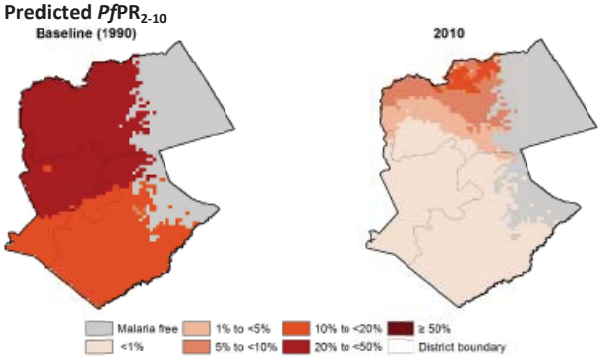
BOMET COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	369,780	718,825	750,732	778,250	806,778	836,351	867,008
Percentage rural[2]			81.7				
Percentage poor[3]			46.5				
ANC coverage[4]			88.4				
EPI coverage[5]			87.5				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

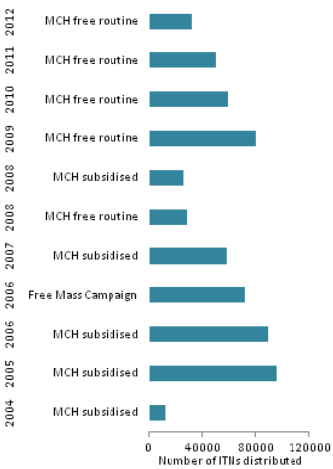


Population at risk in 1990 and 2010 by malaria endemicity

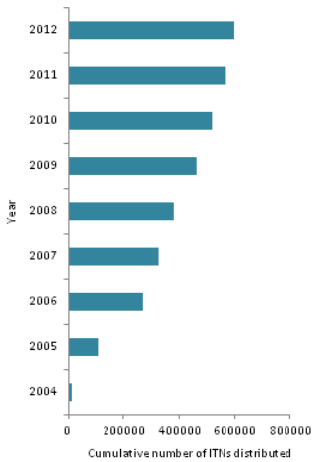
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	50,243 (13.6%)	101,858 (13.6%)
<1%	0 (0.0%)	486,860 (64.9%)
1% to <5%	0 (0.0%)	86,771 (11.6%)
5% to <10%	1,864 (0.5%)	67,404 (9.0%)
10% to <20%	129,621 (35.1%)	7,839 (1.0%)
20% to <50%	188,053 (50.9%)	0 (0.0%)
≥50%	0 (0.0%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

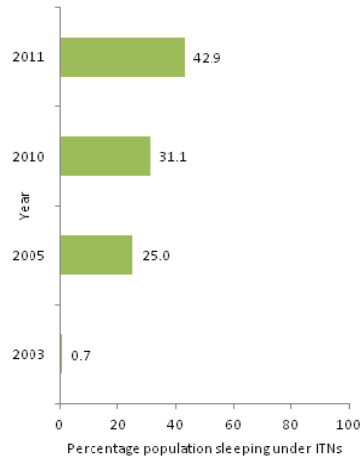
ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage



VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	63,274	0	63,274
	2014	65,593	372,611	438,204
	Total	128,867	372,611	501,478

	Year	Insecticide sachets	Spraying operators
IRS	2013	TBD	TBD
	2014	TBD	TBD

[1] Population Projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06
TBD: To be determined based on hotspots identified through surveillance sites

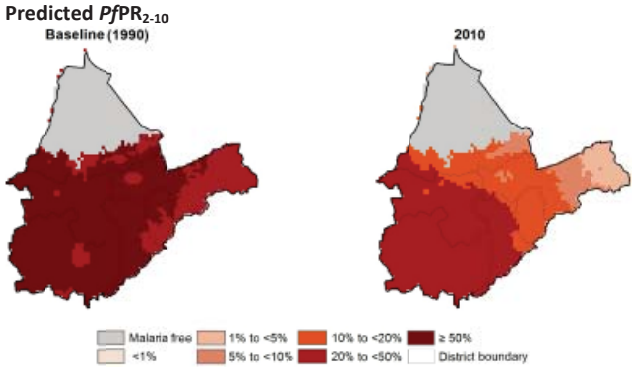
BUNGOMA COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	739,605	1,053,177	1,409,873	1,445,564	1,482,159	1,519,680	1,558,151
Percentage rural[2]			78.3				
Percentage poor[3]			52.9				
ANC coverage[4]			91.5				
EPI coverage[5]			68.3				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

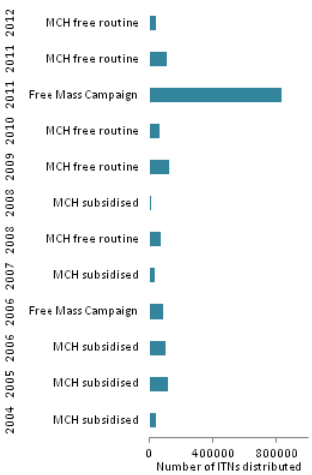


Population at risk in 1990 and 2010 by malaria endemicity

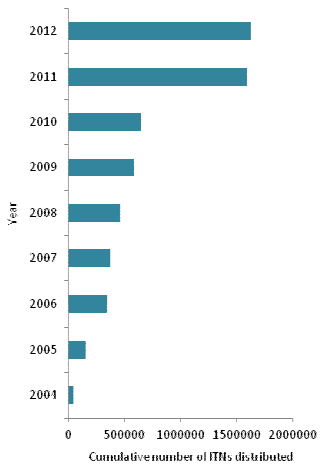
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	16,988 (2.3%)	30,805 (2.2%)
<1%	0 (0.0%)	0 (0.0%)
1% to <5%	0 (0.0%)	69,992 (5.0%)
5% to <10%	0 (0.0%)	121,171 (8.6%)
10% to <20%	0 (0.0%)	409,032 (29.0%)
20% to <50%	187,212 (25.3%)	778,873 (55.2%)
≥50%	535,404 (72.4%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

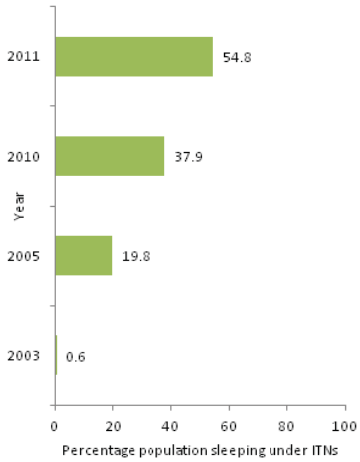
ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage



VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	129,615	0	129,615
	2014	132,896	404,383	537,279
	Total	262,511	404,383	666,894

	Year	Insecticide sachets	Spraying operators
IRS	2013	TBD	TBD
	2014	TBD	TBD

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06
TBD: To be determined based on hotspots identified through surveillance sites

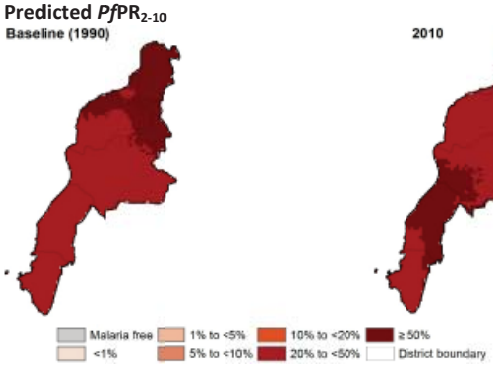
BUSIA COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	422,878	570,070	759,734	775,857	792,322	809,137	826,309
Percentage rural[2]			83.6				
Percentage poor[3]			66.7				
ANC coverage[4]			93.6				
EPI coverage[5]			78.5				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

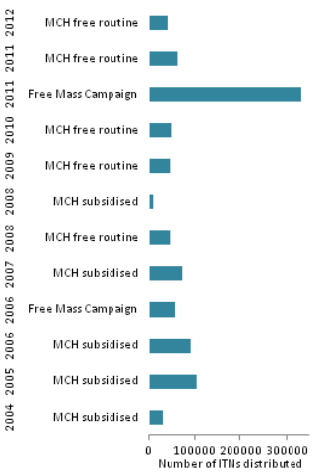


Population at risk in 1990 and 2010 by malaria endemicity

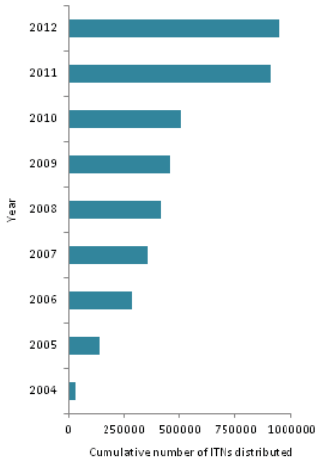
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	0 (0.0%)	0 (0.0%)
<1%	0 (0.0%)	0 (0.0%)
1% to <5%	0 (0.0%)	0 (0.0%)
5% to <10%	0 (0.0%)	0 (0.0%)
10% to <20%	0 (0.0%)	0 (0.0%)
20% to <50%	313,223 (74.1%)	614,054 (80.8%)
≥50%	109,655 (25.9%)	145,680 (19.2%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

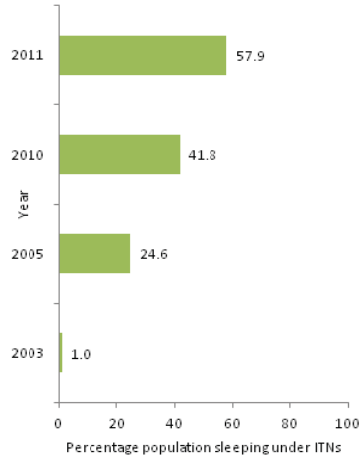
ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage



VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	39,442	0	39,442
	2014	40,279	33,963	74,242
	Total	79,721	33,963	113,684

	Year	Insecticide sachets	Spraying operators
IRS	2013	NA	NA
	2014	NA	NA

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2008-09
[4] Source: DHS 2008-09
[5] Source: KIHBS 2008-09

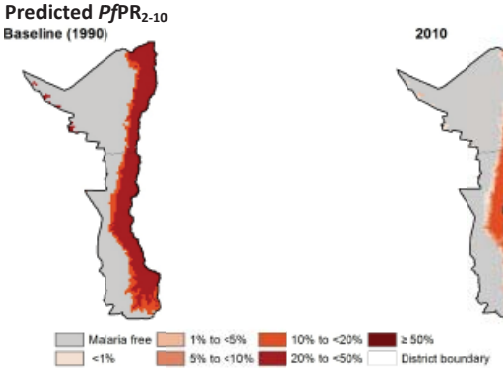
ELGEYO MARAKWET COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	237,019	292,283	383,561	397,620	412,195	427,305	442,968
Percentage rural[2]			85.6				
Percentage poor[3]			55.5				
ANC coverage[4]			88.4				
EPI coverage[5]			81.0				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

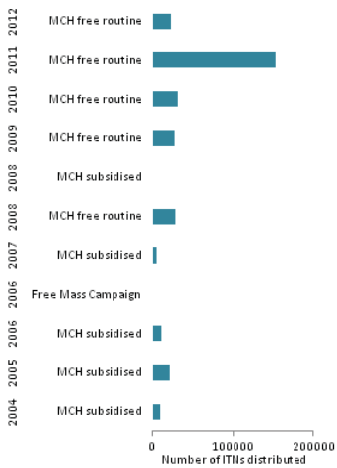


Population at risk in 1990 and 2010 by malaria endemicity

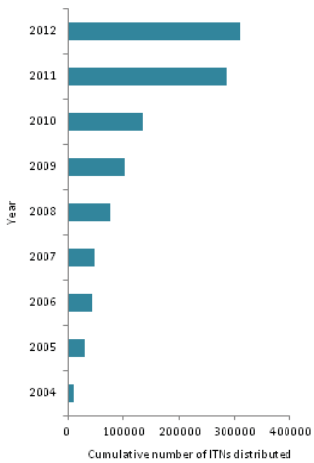
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	163,263 (68.9%)	266,210 (69.4%)
<1%	0 (0.0%)	26,467 (6.9%)
1% to <5%	0 (0.0%)	22,440 (5.9%)
5% to <10%	0 (0.0%)	21,201 (5.5%)
10% to <20%	26,134 (11.0%)	47,243 (12.3%)
20% to <50%	47,622 (20.1%)	0 (0.0%)
≥50%	0 (0.0%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

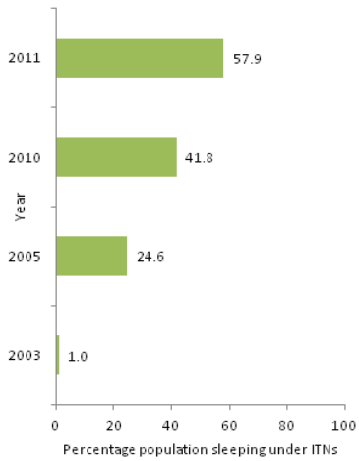
ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage



VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	31,189	0	31,189
	2014	32,332	122,783	155,115
	Total	63,521	122,783	186,304

	Year	Insecticide sachets	Spraying operators
IRS	2013	NA	NA
	2014	NA	NA

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2008-09
[4] Source: DHS 2008-09
[5] Source: KIHBS 2008-09

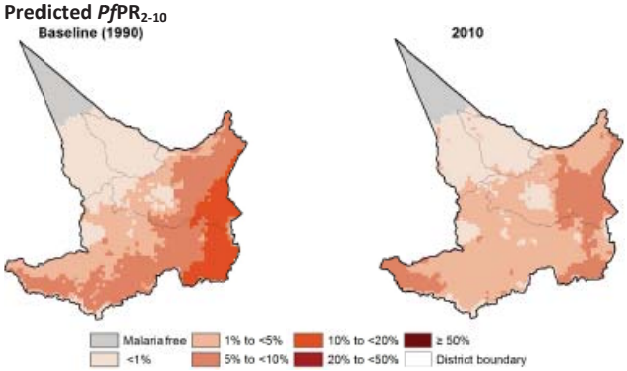
EMBU COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	368,194	457,896	526,640	537,279	548,133	559,206	570,502
Percentage rural[2]			83.9				
Percentage poor[3]			42.0				
ANC coverage[4]			93.4				
EPI coverage[5]			87.9				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

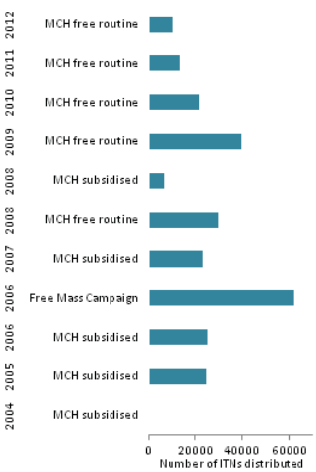


Population at risk in 1990 and 2010 by malaria endemicity

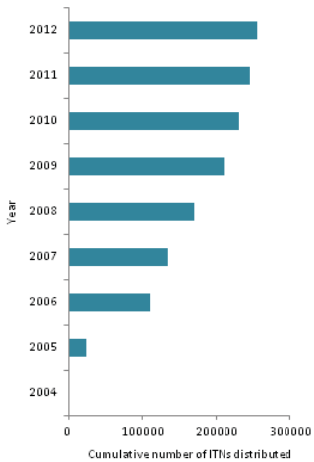
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	2,077 (0.6%)	2,902 (0.6%)
<1%	222,829 (60.5%)	302,979 (57.5%)
1% to <5%	72,321 (19.6%)	167,772 (31.9%)
5% to <10%	58,465 (15.9%)	52,986 (10.1%)
10% to <20%	12,502 (3.4%)	0 (0.0%)
20% to <50%	0 (0.0%)	0 (0.0%)
≥50%	0 (0.0%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage

VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	41,199	0	41,199
	2014	42,031	0	42,031
	Total	83,230	0	83,230

	Year	Insecticide sachets	Spraying operators
IRS	2013	NA	NA
	2014	NA	NA

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06

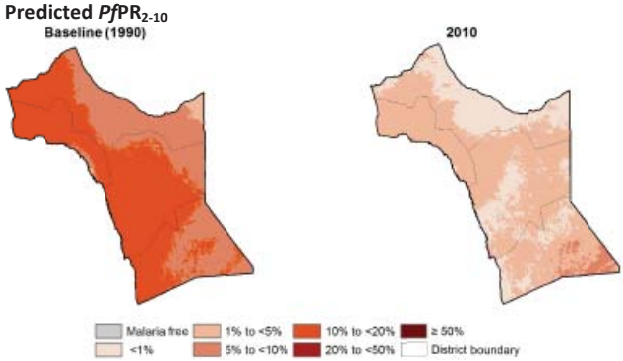
GARISSA COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	134,597	420,970	680,374	742,960	811,304	885,934	967,430
Percentage rural[2]			75.5				
Percentage poor[3]			49.2				
ANC coverage[4]			69.5				
EPI coverage[5]			74.6				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

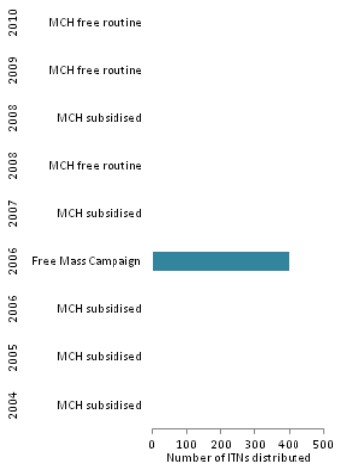


Population at risk in 1990 and 2010 by malaria endemicity

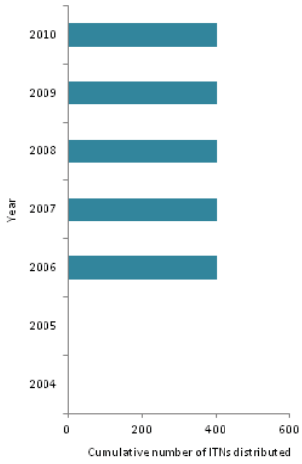
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	0 (0.0%)	0 (0.0%)
<1%	51 (0.0%)	360,778 (53.0%)
1% to <5%	16,245 (12.1%)	314,966 (46.3%)
5% to <10%	60,173 (44.7%)	4,630 (0.7%)
10% to <20%	58,128 (43.2%)	0 (0.0%)
20% to <50%	0 (0.0%)	0 (0.0%)
≥50%	0 (0.0%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage

VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	44,230	0	44,230
	2014	48,299	0	48,299
	Total	92,529	0	92,529

	Year	Insecticide sachets	Spraying operators
IRS	2013	NA	NA
	2014	NA	NA

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06

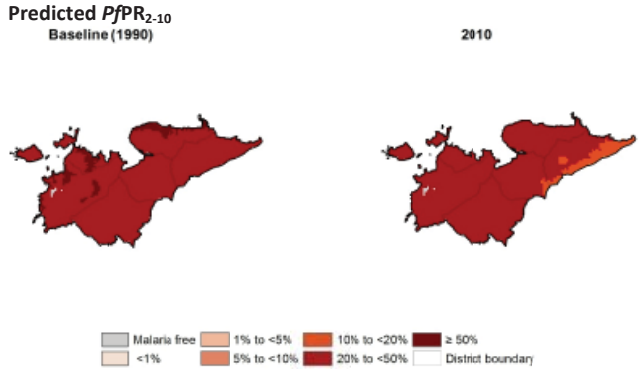
HOMA BAY COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	677,224	770,487	984,248	1,005,135	1,026,466	1,048,250	1,070,496
Percentage rural[2]			85.6				
Percentage poor[3]			44.1				
ANC coverage[4]			93.6				
EPI coverage[5]			50.3				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

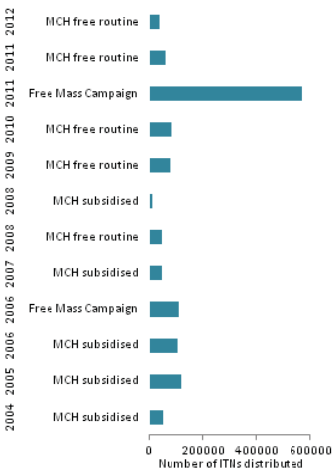


Population at risk in 1990 and 2010 by malaria endemicity

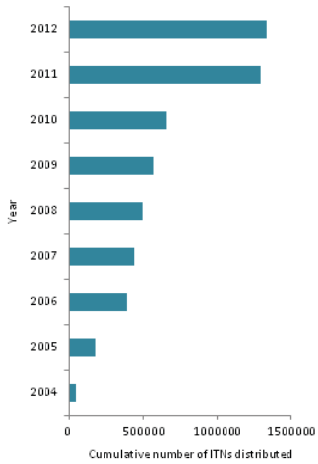
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	970 (0.1%)	1,371 (0.1%)
<1%	194 (0.0%)	624 (0.1%)
1% to <5%	0 (0.0%)	0 (0.0%)
5% to <10%	0 (0.0%)	0 (0.0%)
10% to <20%	0 (0.0%)	109,552 (11.1%)
20% to <50%	622,892 (92%)	872,701 (88.7%)
≥50%	53,168 (7.9%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage

VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	65,429	0	65,429
	2014	66,817	185,115	251,932
	Total	132,246	185,115	317,361

	Year	Insecticide sachets	Spraying operators
IRS	2013	1,076,566	669
	2014	1,099,413	683

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06

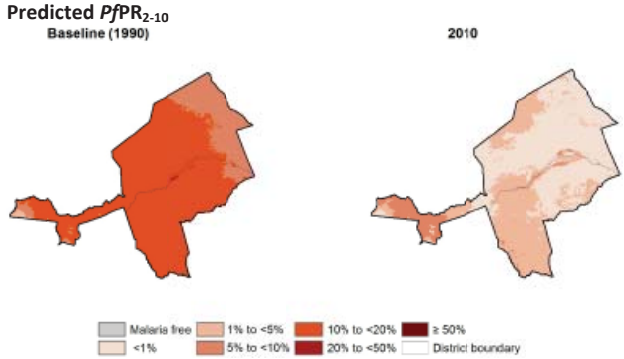
ISIOLO COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	68,325	104,558	146,189	149,142	152,155	155,229	158,364
Percentage rural[2]			56.5				
Percentage poor[3]			72.6				
ANC coverage[4]			93.4				
EPI coverage[5]			72.2				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

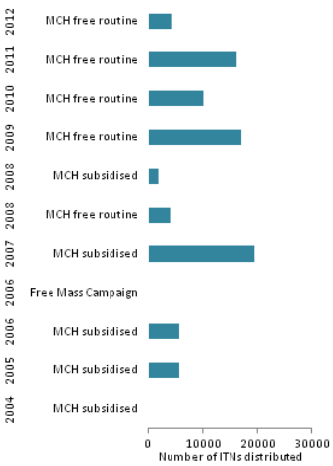


Population at risk in 1990 and 2010 by malaria endemicity

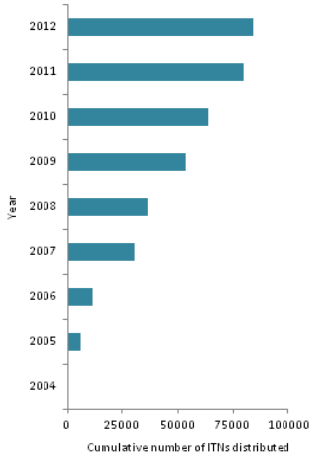
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	14 (0.0%)	0 (0.0%)
<1%	66 (0.1%)	31,083 (21.3%)
1% to <5%	2,118 (3.1%)	80,471 (55.0%)
5% to <10%	18,861 (27.6%)	31,212 (21.4%)
10% to <20%	46,995 (68.8%)	3,422 (2.3%)
20% to <50%	271 (0.4%)	0 (0.0%)
≥50%	0 (0.0%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

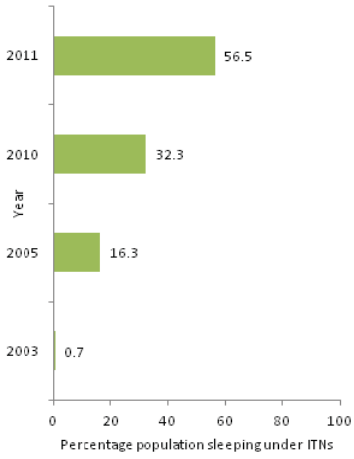
ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage



VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	10,559	0	10,559
	2014	10,772	0	10,772
	Total	21,331	0	21,331

	Year	Insecticide sachets	Spraying operators
IRS	2013	NA	NA
	2014	NA	NA

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06

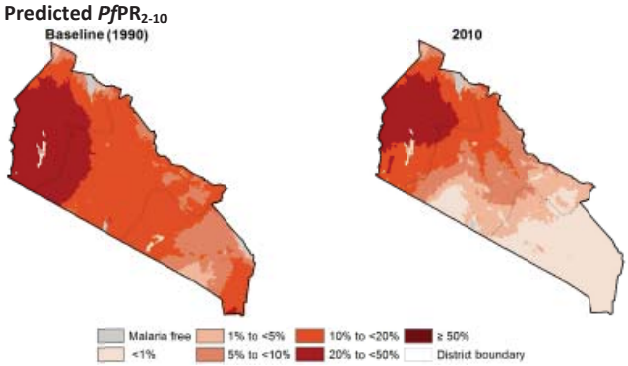
KAJIADO COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	256,454	424,744	712,506	738,624	765,698	793,766	822,862
Percentage rural[2]			58.6				
Percentage poor[3]			11.6				
ANC coverage[4]			88.4				
EPI coverage[5]			70.7				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

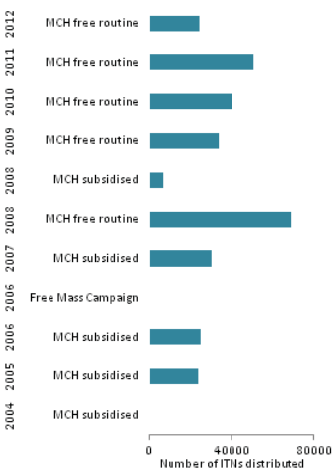


Population at risk in 1990 and 2010 by malaria endemicity

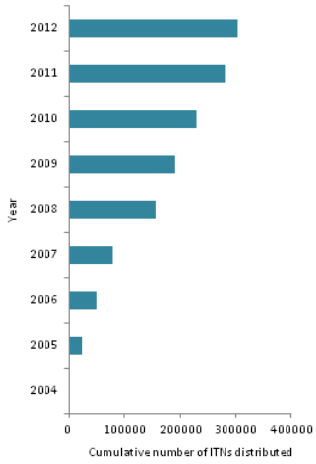
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	24,909 (9.7%)	77,061 (10.8%)
<1%	3,540 (1.4%)	145,919 (20.5%)
1% to <5%	61,434 (24.0%)	232,250 (32.6%)
5% to <10%	38,369 (15.0%)	72,569 (10.2%)
10% to <20%	106,345 (41.5%)	153,698 (21.6%)
20% to <50%	21,857 (8.5%)	31,008 (4.4%)
≥50%	0 (0.0%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage

VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	54,585	0	54,585
	2014	56,586	0	56,586
	Total	111,171	0	111,171

	Year	Insecticide sachets	Spraying operators
IRS	2013	NA	NA
	2014	NA	NA

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06

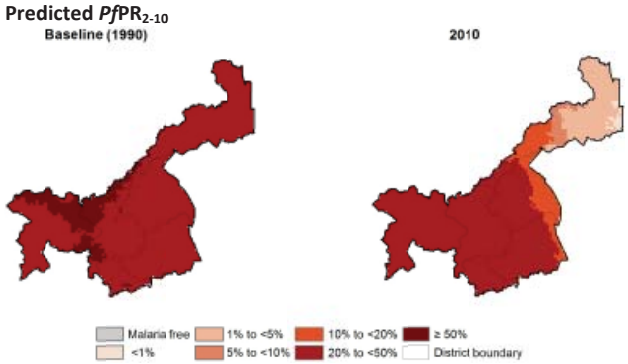
KAKAMEGA COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	994,790	853,633	1,702,691	1,745,794	1,789,989	1,835,303	1,881,764
Percentage rural[2]			84.8				
Percentage poor[3]			53.0				
ANC coverage[4]			91.5				
EPI coverage[5]			69.4				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

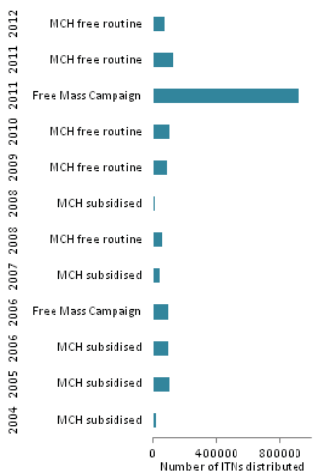


Population at risk in 1990 and 2010 by malaria endemicity

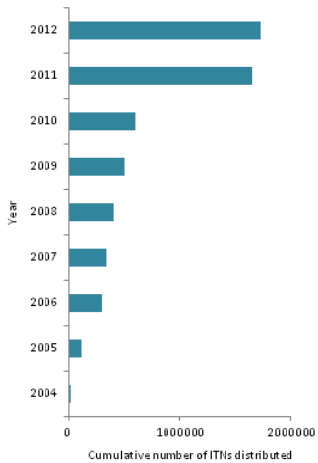
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	0 (0.0%)	0 (0.0%)
<1%	0 (0.0%)	21,405 (1.3%)
1% to <5%	0 (0.0%)	184,560 (10.8%)
5% to <10%	0 (0.0%)	47,309 (2.8%)
10% to <20%	0 (0.0%)	171,231 (10.1%)
20% to <50%	867,795 (87.2%)	1,276,193 (75.0%)
≥50%	126,995 (12.8%)	1,992 (0.1%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage

VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	132,885	0	132,885
	2014	136,249	342,453	478,702
	Total	269,134	342,453	611,587

	Year	Insecticide sachets	Spraying operators
IRS	2013	TBD	TBD
	2014	TBD	TBD

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06
TBD: To be determined based on hotspots identified through surveillance sites

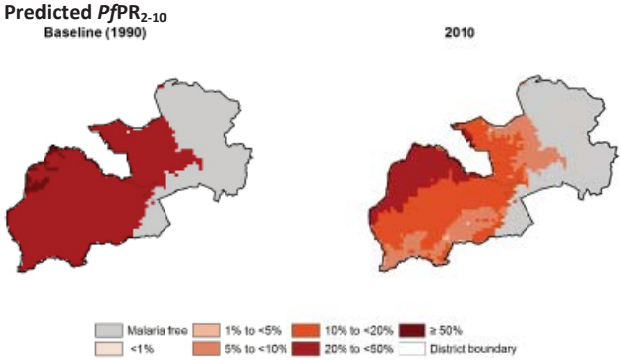
KERICHO COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	497,552	479,873	786,137	814,953	844,826	875,794	907,897
Percentage rural[2]			71.1				
Percentage poor[3]			44.2				
ANC coverage[4]			88.4				
EPI coverage[5]			74.0				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

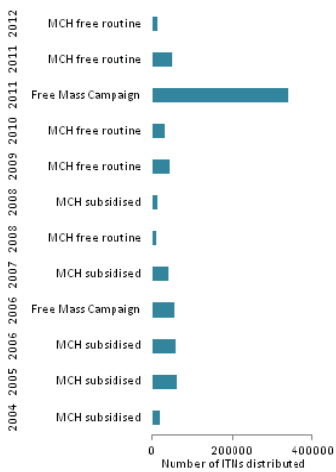


Population at risk in 1990 and 2010 by malaria endemicity

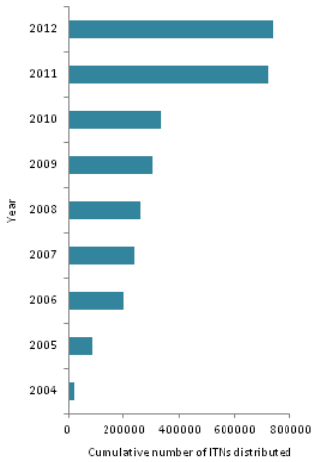
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	95,506 (19.2%)	145,296 (18.5%)
<1%	0 (0.0%)	0 (0.0%)
1% to <5%	0 (0.0%)	9,954 (1.3%)
5% to <10%	0 (0.0%)	215,857 (27.5%)
10% to <20%	0 (0.0%)	361,903 (46.0%)
20% to <50%	398,817 (80.2%)	53,127 (6.8%)
≥50%	3,229 (0.6%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

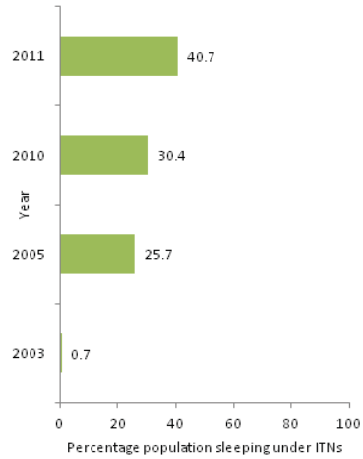
ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage



VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	61,411	0	61,411
	2014	63,662	242,769	306,431
	Total	125,073	242,769	367,842

	Year	Insecticide sachets	Spraying operators
IRS	2013	TBD	TBD
	2014	TBD	TBD

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06
TBD: To be determined based on hotspots identified through surveillance sites

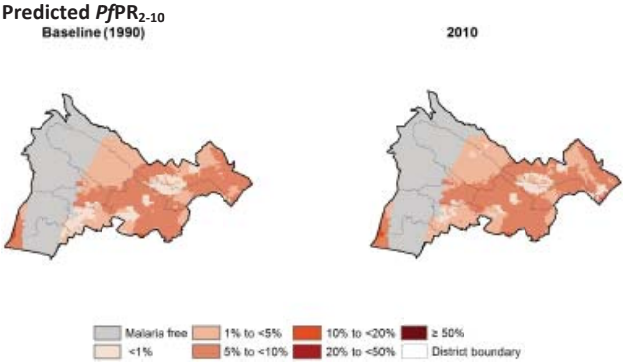
KIAMBU COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	886,090	1,408,423	1,649,463	1,676,067	1,703,100	1,730,569	1,758,480
Percentage rural[2]			39.2				
Percentage poor[3]			27.2				
ANC coverage[4]			92.7				
EPI coverage[5]			90.0				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

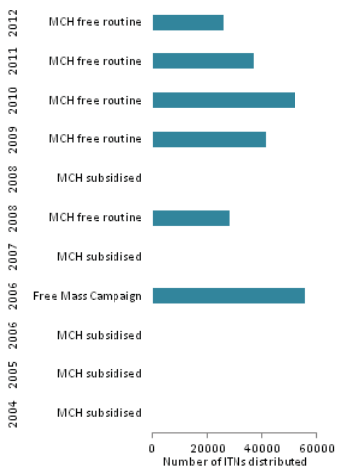


Population at risk in 1990 and 2010 by malaria endemicity

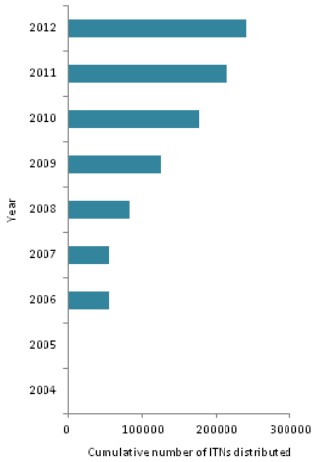
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	280,553 (31.7%)	512,742 (31.1%)
<1%	193,671 (21.9%)	231,304 (14.0%)
1% to <5%	252,487 (28.5%)	607,983 (36.9%)
5% to <10%	158,623 (17.9%)	295,585 (17.9%)
10% to <20%	756 (0.1%)	1,849 (0.1%)
20% to <50%	0 (0.0%)	0 (0.0%)
≥50%	0 (0.0%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

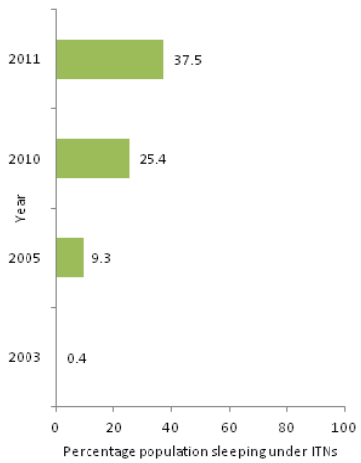
ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage



VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	120,474	0	120,474
	2014	122,417	0	122,417
	Total	242,891	0	242,891

	Year	Insecticide sachets	Spraying operators
IRS	2013	NA	NA
	2014	NA	NA

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06

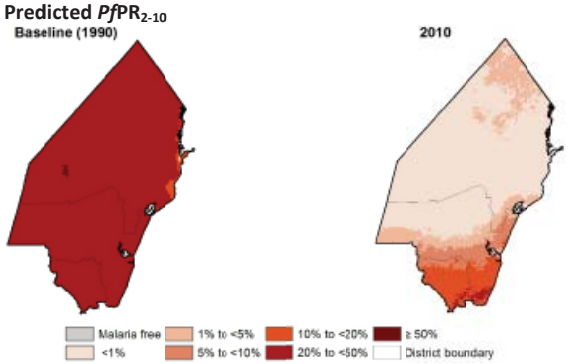
KILIFI COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	639,169	852,730	1,142,389	1,176,003	1,210,606	1,246,228	1,282,898
Percentage rural[2]			74.3				
Percentage poor[3]			71.4				
ANC coverage[4]			94.5				
EPI coverage[5]			66.4				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

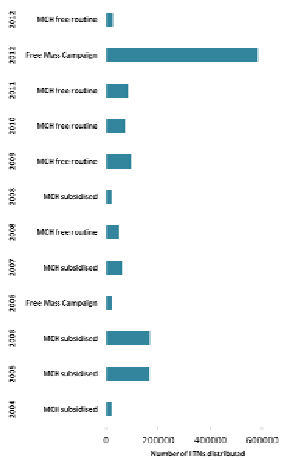


Population at risk in 1990 and 2010 by malaria endemicity

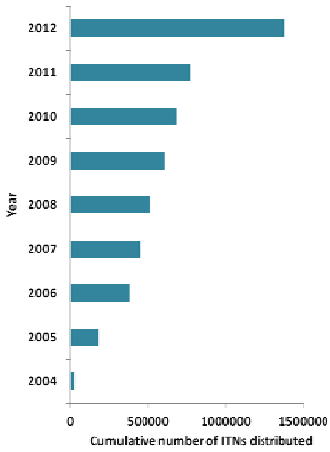
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	0 (0.0%)	0 (0.0%)
<1%	469 (0.1%)	454,537 (39.8%)
1% to <5%	0 (0.0%)	121,925 (10.7%)
5% to <10%	489 (0.1%)	128,238 (11.2%)
10% to <20%	89,879 (14.1%)	407,578 (35.7%)
20% to <50%	548,239 (85.8%)	30,112 (2.6%)
≥50%	94 (0.0%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

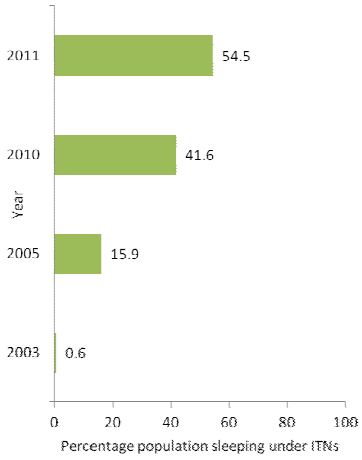
ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage



VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	85,268	0	85,268
	2014	87,777	570,886	658,663
	Total	173,045	570,886	743,931

	Year	Insecticide sachets	Spraying operators
IRS	2013	NA	NA
	2014	NA	NA

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06

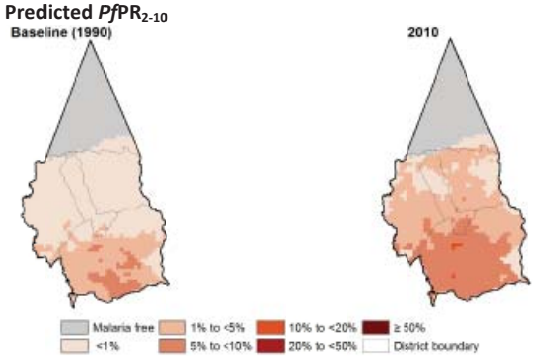
KIRINYAGA COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	397,492	464,013	536,571	545,225	554,019	562,954	572,034
Percentage rural[2]			84.2				
Percentage poor[3]			25.2				
ANC coverage[4]			92.7				
EPI coverage[5]			92.6				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

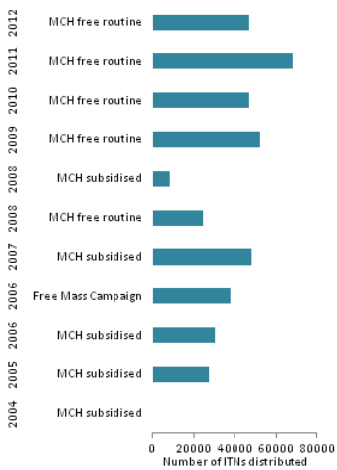


Population at risk in 1990 and 2010 by malaria endemicity

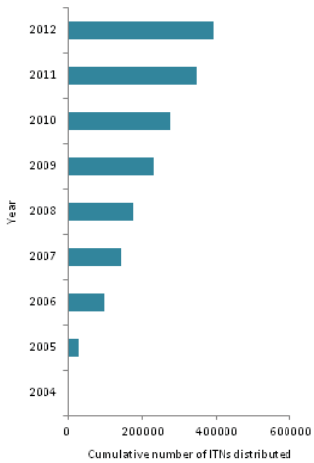
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	3,683 (0.9%)	4,888 (0.9%)
<1%	287,772 (72.4%)	131,433 (24.5%)
1% to <5%	82,453 (20.7%)	251,845 (46.9%)
5% to <10%	23,585 (5.9%)	146,541 (27.3%)
10% to <20%	0 (0.0%)	1,864 (0.3%)
20% to <50%	0 (0.0%)	0 (0.0%)
≥50%	0 (0.0%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage

VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	39,644	0	39,644
	2014	40,283	0	40,283
	Total	79,927	0	79,927

	Year	Insecticide sachets	Spraying operators
IRS	2013	NA	NA
	2014	NA	NA

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06

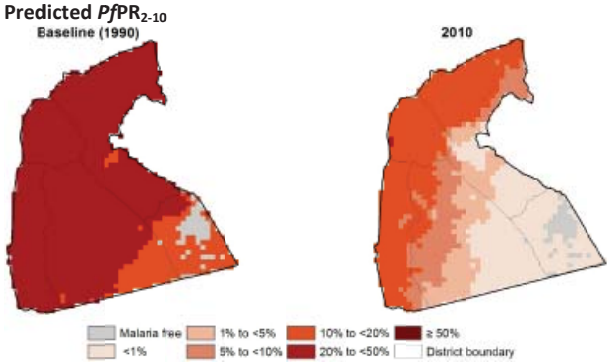
KISII COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	727,990	975,275	1,176,736	1,201,709	1,227,211	1,253,255	1,279,852
Percentage rural[2]			78.5				
Percentage poor[3]			60.7				
ANC coverage[4]			93.6				
EPI coverage[5]			64.8				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

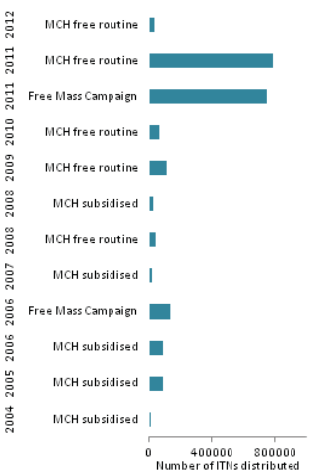


Population at risk in 1990 and 2010 by malaria endemicity

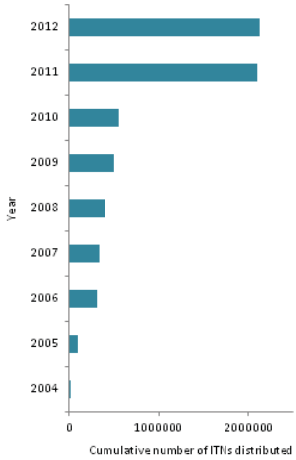
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	21,211 (2.9%)	34,247 (2.9%)
<1%	0 (0.0%)	350,543 (29.8%)
1% to <5%	0 (0.0%)	190,827 (16.2%)
5% to <10%	0 (0.0%)	188,052 (16.0%)
10% to <20%	95,647 (13.1%)	412,350 (35.0%)
20% to <50%	611,132 (83.9%)	717 (0.1%)
≥50%	0 (0.0%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage

VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	112,914	0	112,914
	2014	115,310	37,697	153,007
	Total	228,224	37,697	265,921

	Year	Insecticide sachets	Spraying operators
IRS	2013	TBD	TBD
	2014	TBD	TBD

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06
TBD: To be determined based on hotspots identified through surveillance sites

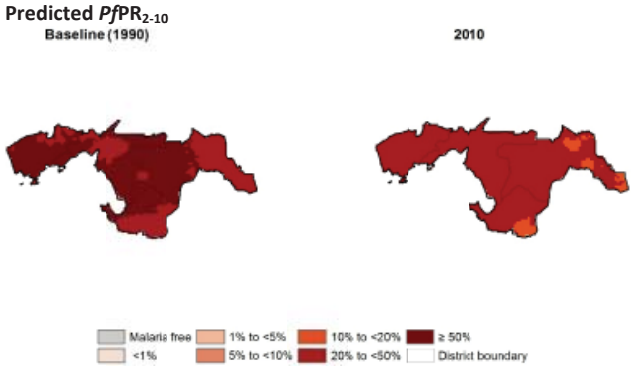
KISUMU COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	741,220	824,851	989,471	1,010,470	1,031,914	1,053,813	1,076,178
Percentage rural[2]			47.6				
Percentage poor[3]			47.8				
ANC coverage[4]			93.6				
EPI coverage[5]			65.0				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

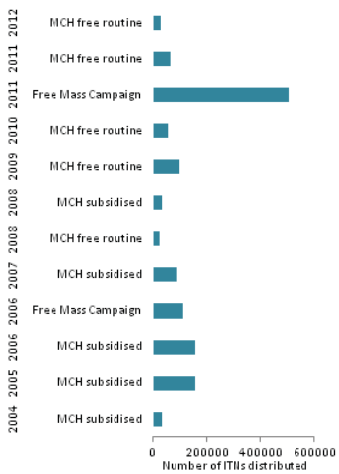


Population at risk in 1990 and 2010 by malaria endemicity

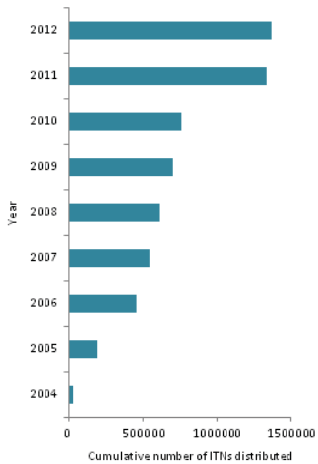
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	0 (0.0%)	0 (0.0%)
<1%	0 (0.0%)	0 (0.0%)
1% to <5%	0 (0.0%)	0 (0.0%)
5% to <10%	0 (0.0%)	0 (0.0%)
10% to <20%	0 (0.0%)	51,048 (5.2%)
20% to <50%	377,770 (51.0%)	938,423 (94.8%)
≥50%	363,450 (49.0%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage

VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	72,471	0	72,471
	2014	74,009	222,691	296,700
	Total	146,480	222,691	369,171

	Year	Insecticide sachets	Spraying operators
IRS	2013	1,178,788	734
	2014	1,198,974	746

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06

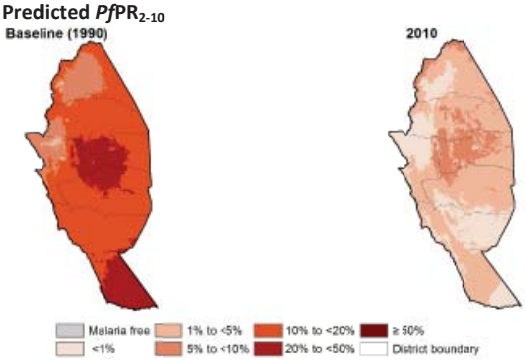
KITUI COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	622,216	838,095	1,033,167	1,054,038	1,075,331	1,097,055	1,119,217
Percentage rural[2]			86.2				
Percentage poor[3]			63.5				
ANC coverage[4]			93.4				
EPI coverage[5]			68.6				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

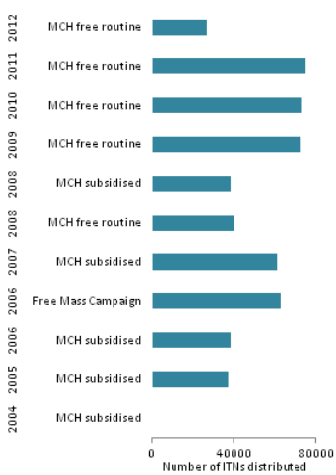


Population at risk in 1990 and 2010 by malaria endemicity

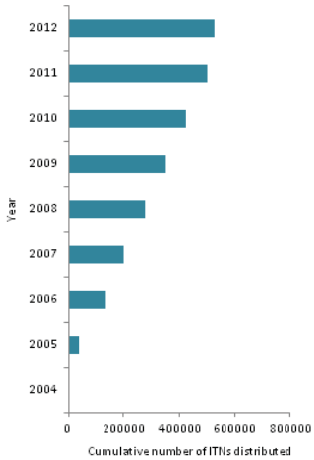
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	8 (0.0%)	0 (0.0%)
<1%	95 (0.0%)	461,302 (44.6%)
1% to <5%	46,877 (7.5%)	445,186 (43.1%)
5% to <10%	186,285 (29.9%)	126,679 (12.3%)
10% to <20%	338,286 (54.4%)	0 (0.0%)
20% to <50%	50,666 (8.1%)	0 (0.0%)
≥50%	0 (0.0%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

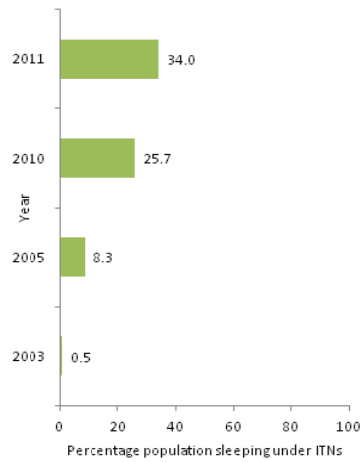
ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage



VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	73,202	0	73,202
	2014	74,681	0	74,681
	Total	147,883	0	147,883

	Year	Insecticide sachets	Spraying operators
IRS	2013	NA	NA
	2014	NA	NA

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06

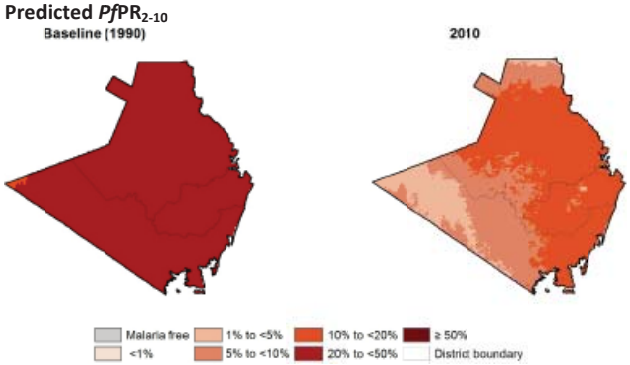
KWALE COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	381,806	509,202	669,055	688,742	709,008	729,870	751,346
Percentage rural[2]			81.9				
Percentage poor[3]			74.9				
ANC coverage[4]			94.5				
EPI coverage[5]			92.6				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

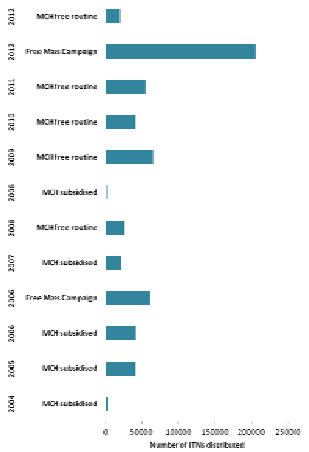


Population at risk in 1990 and 2010 by malaria endemicity

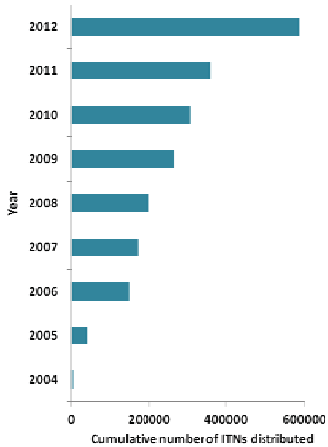
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	0 (0.0%)	0 (0.0%)
<1%	1,578 (0.4%)	2,855 (0.4%)
1% to <5%	0 (0.0%)	21,136 (3.2%)
5% to <10%	0 (0.0%)	137,081 (20.5%)
10% to <20%	104 (0.0%)	507,638 (75.9%)
20% to <50%	380,124 (99.6%)	345 (0.1%)
≥50%	0 (0.0%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

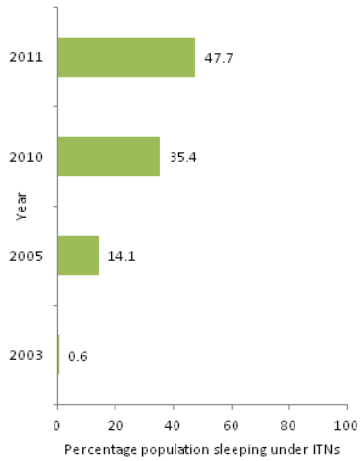
ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage



VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	57,396	0	57,396
	2014	59,085	319,676	378,761
	Total	116,481	319,676	436,157

	Year	Insecticide sachets	Spraying operators
IRS	2013	NA	NA
	2014	NA	NA

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06

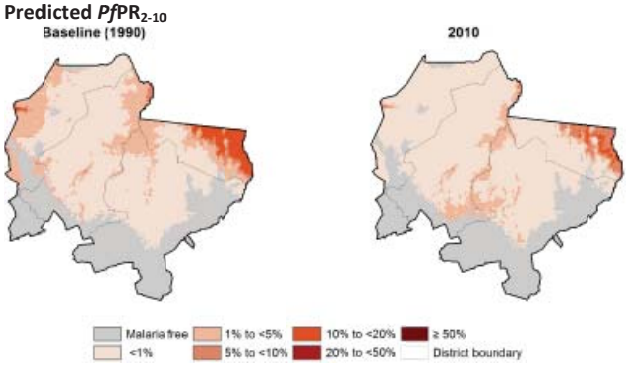
LAIKIPIA COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	228,683	335,001	413,861	429,031	444,758	461,061	477,961
Percentage rural[2]			75.2				
Percentage poor[3]			50.5				
ANC coverage[4]			88.4				
EPI coverage[5]			86.9				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

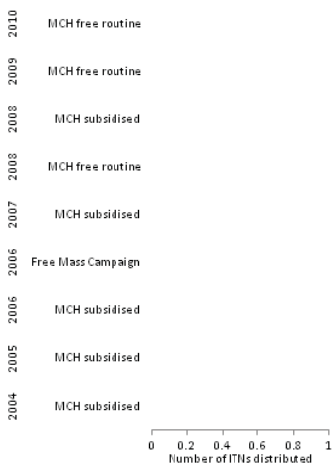


Population at risk in 1990 and 2010 by malaria endemicity

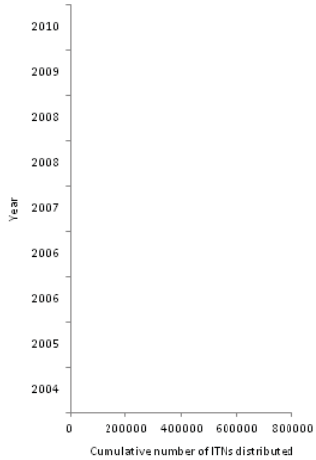
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	138,159 (60.4%)	255,728 (61.8%)
<1%	61,020 (26.7%)	141,912 (34.3%)
1% to <5%	25,286 (11.1%)	11,243 (2.7%)
5% to <10%	1,297 (0.6%)	3,847 (0.9%)
10% to <20%	2,920 (1.3%)	1,131 (0.3%)
20% to <50%	0 (0.0%)	0 (0.0%)
≥50%	0 (0.0%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

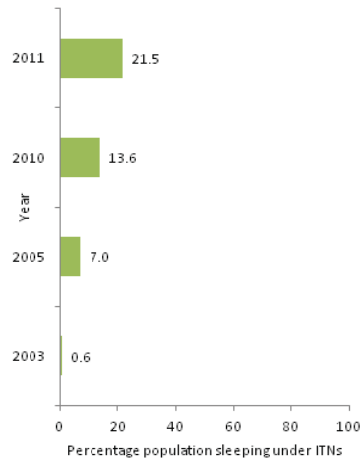
ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage



VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	NA	NA	NA
	2014	NA	NA	NA
	Total	NA	NA	NA

	Year	Insecticide sachets	Spraying operators
IRS	2013	NA	NA
	2014	NA	NA

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06

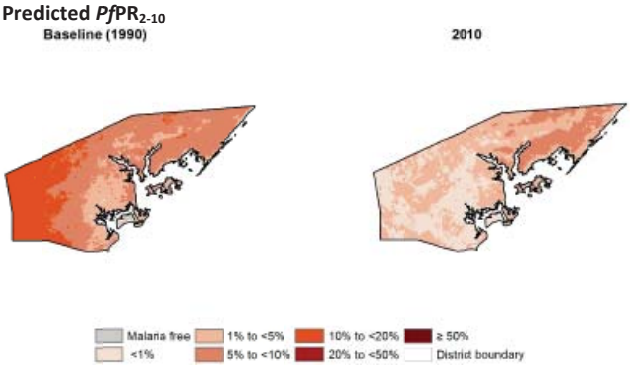
LAMU COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	81,809	74,526	104,527	107,602	110,769	114,028	117,383
Percentage rural[2]			80.1				
Percentage poor[3]			32.7				
ANC coverage[4]			94.5				
EPI coverage[5]			80.5				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

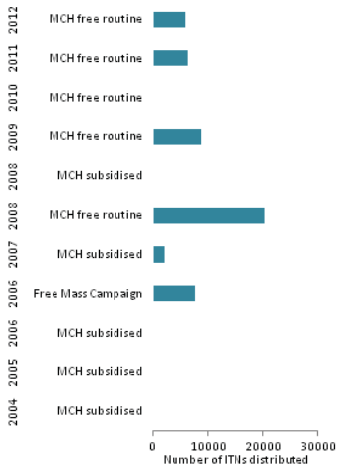


Population at risk in 1990 and 2010 by malaria endemicity

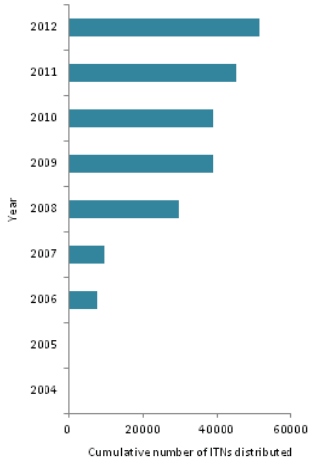
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	0 (0.0%)	0 (0.0%)
<1%	17,820 (21.8%)	61,633 (59.0%)
1% to <5%	26,104 (31.9%)	40,042 (38.3%)
5% to <10%	24,914 (30.5%)	2,852 (2.7%)
10% to <20%	12,971 (15.9%)	0 (0.0%)
20% to <50%	0 (0.0%)	0 (0.0%)
≥50%	0 (0.0%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

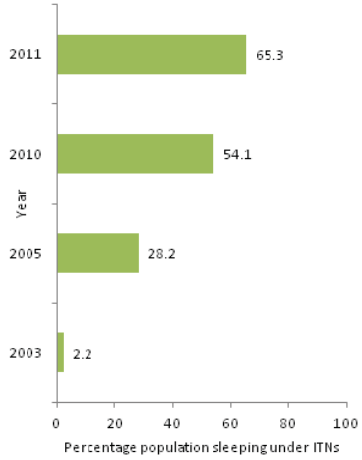
ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage



VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	8,429	0	8,429
	2014	8,677	49,458	58,135
	Total	17,106	49,458	66,564

	Year	Insecticide sachets	Spraying operators
IRS	2013	NA	NA
	2014	NA	NA

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06

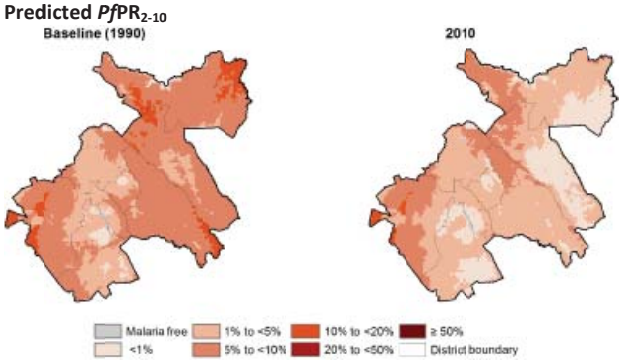
MACHAKOS COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	704,440	932,389	1,120,777	1,143,418	1,166,517	1,190,082	1,214,123
Percentage rural[2]			48.0				
Percentage poor[3]			59.6				
ANC coverage[4]			93.4				
EPI coverage[5]			81.3				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

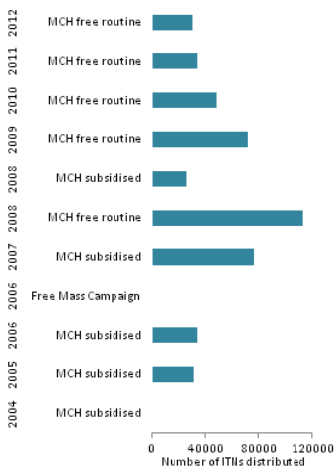


Population at risk in 1990 and 2010 by malaria endemicity

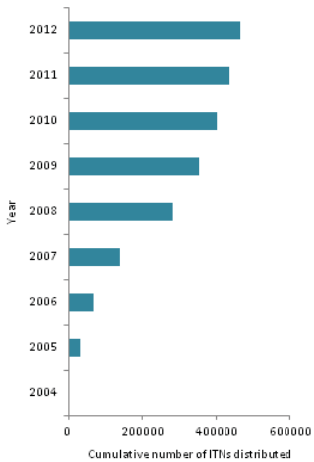
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	4,121 (0.6%)	6,577 (0.6%)
<1%	63,695 (9.0%)	287,330 (25.6%)
1% to <5%	241,602 (34.3%)	631,154 (56.3%)
5% to <10%	369,836 (52.5%)	188,321 (16.8%)
10% to <20%	25,185 (3.6%)	7,396 (0.7%)
20% to <50%	0 (0.0%)	0 (0.0%)
≥50%	0 (0.0%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage

VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	84,850	0	84,850
	2014	86,565	0	86,565
	Total	171,415	0	171,415

	Year	Insecticide sachets	Spraying operators
IRS	2013	NA	NA
	2014	NA	NA

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06

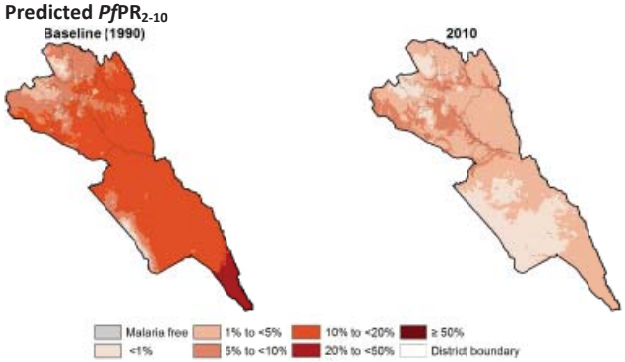
MAKUENI COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	653,804	793,454	902,396	920,625	939,223	958,197	977,554
Percentage rural[2]			88.2				
Percentage poor[3]			64.1				
ANC coverage[4]			93.4				
EPI coverage[5]			85.0				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

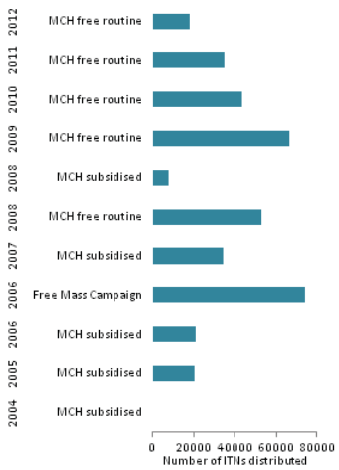


Population at risk in 1990 and 2010 by malaria endemicity

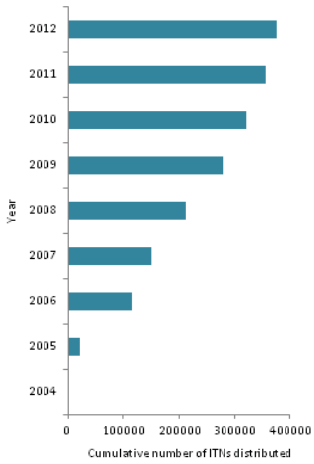
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	600 (0.1%)	825 (0.1%)
<1%	17,476 (2.7%)	299,767 (33.2%)
1% to <5%	93,413 (14.3%)	481,543 (53.4%)
5% to <10%	184,935 (28.3%)	120,261 (13.3%)
10% to <20%	356,896 (54.6%)	0 (0.0%)
20% to <50%	483 (0.1%)	0 (0.0%)
≥50%	0 (0.0%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

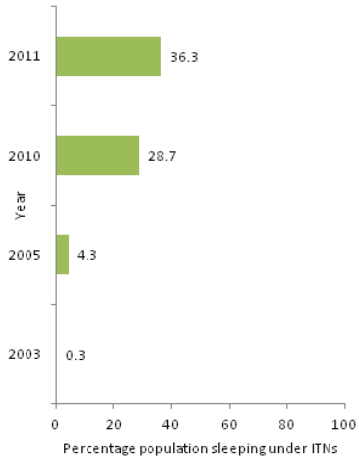
ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage



VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	69,594	0	69,594
	2014	71,000	0	71,000
	Total	140,594	0	140,594

	Year	Insecticide sachets	Spraying operators
IRS	2013	NA	NA
	2014	NA	NA

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06

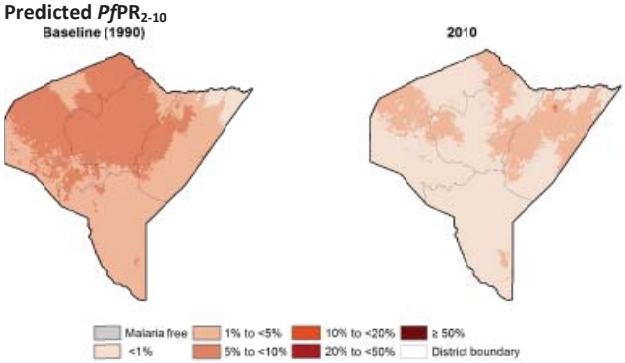
MANDERA COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	120,572	268,526	1,120,113	1,223,150	1,335,666	1,458,531	1,592,699
Percentage rural[2]			81.9				
Percentage poor[3]			87.8				
ANC coverage[4]			69.5				
EPI coverage[5]			47.0				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

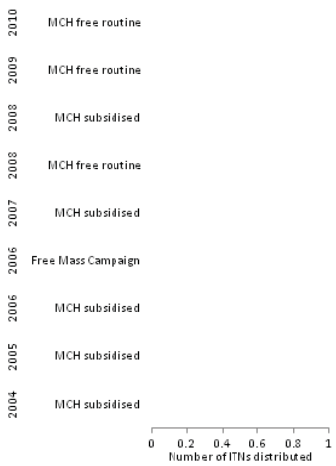


Population at risk in 1990 and 2010 by malaria endemicity

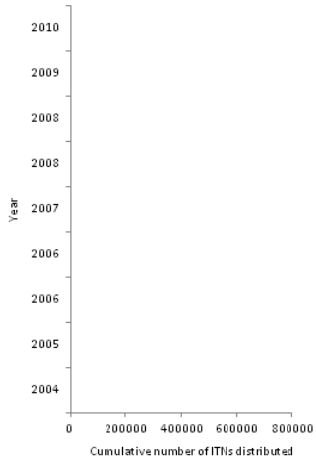
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	0 (0.0%)	0 (0.0%)
<1%	11,976 (9.9%)	883,474 (78.9%)
1% to <5%	71,476 (59.3%)	235,768 (21.0%)
5% to <10%	37,120 (30.8%)	870 (0.1%)
10% to <20%	0 (0.0%)	0 (0.0%)
20% to <50%	0 (0.0%)	0 (0.0%)
≥50%	0 (0.0%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

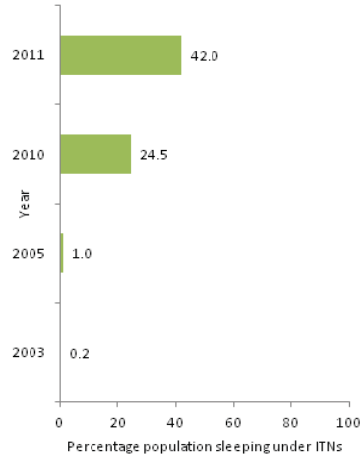
ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage



VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	62,753	0	62,753
	2014	68,526	0	68,526
	Total	131,279	0	131,279

	Year	Insecticide sachets	Spraying operators
IRS	2013	NA	NA
	2014	NA	NA

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06

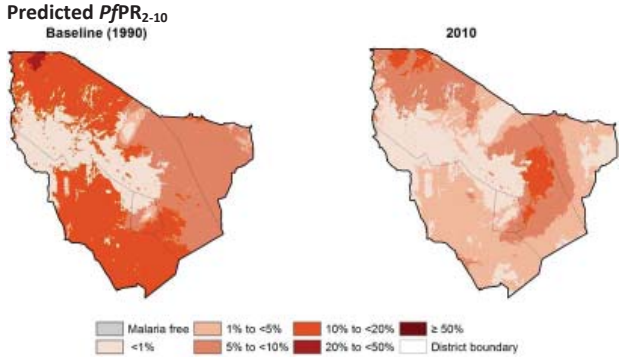
MARSABIT COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	109,069	179,651	297,048	303,049	309,171	315,416	321,788
Percentage rural[2]			78.0				
Percentage poor[3]			83.2				
ANC coverage[4]			93.4				
EPI coverage[5]			80.1				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

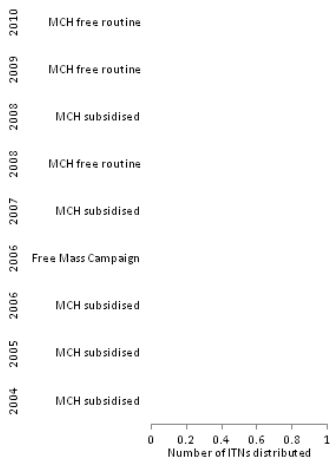


Population at risk in 1990 and 2010 by malaria endemicity

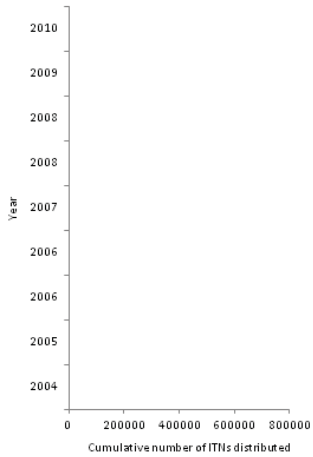
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	5 (0.0%)	15 (0.0%)
<1%	32,506 (29.8%)	125,383 (42.2%)
1% to <5%	9,103 (8.3%)	106,020 (35.7%)
5% to <10%	30,566 (28.0%)	59,395 (20.0%)
10% to <20%	36,462 (33.4%)	6,236 (2.1%)
20% to <50%	426 (0.4%)	0 (0.0%)
≥50%	0 (0.0%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

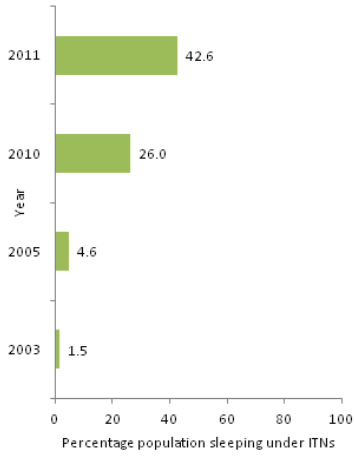
ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage



VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	22,352	0	22,352
	2014	22,804	0	22,804
	Total	45,156	0	45,156

	Year	Insecticide sachets	Spraying operators
IRS	2013	NA	NA
	2014	NA	NA

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06

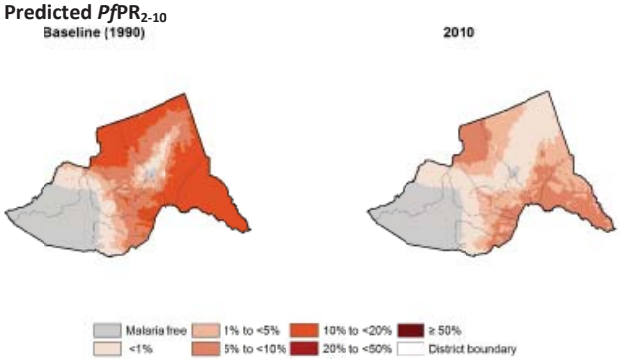
MERU COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	854,505	1,132,933	1,383,700	1,411,653	1,440,170	1,469,263	1,498,944
Percentage rural[2]			88.0				
Percentage poor[3]			28.3				
ANC coverage[4]			93.4				
EPI coverage[5]			65.0				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

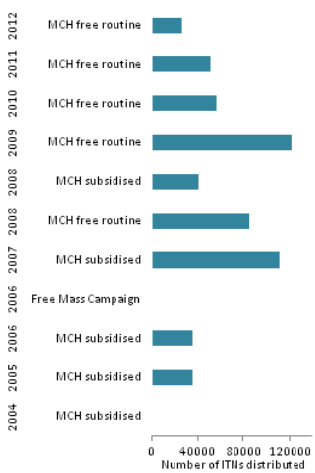


Population at risk in 1990 and 2010 by malaria endemicity

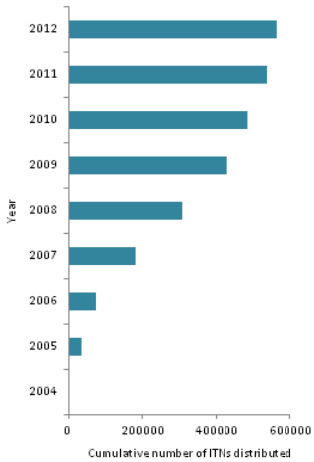
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	95,705 (11.2%)	154,974 (11.2%)
<1%	243,534 (28.5%)	819,150 (59.2%)
1% to <5%	184,573(21.6%)	282,275 (20.4%)
5% to <10%	216,190 (25.3%)	127,300 (9.2%)
10% to <20%	114,504 (13.4%)	0 (0.0%)
20% to <50%	0 (0.0%)	0 (0.0%)
≥50%	0 (0.0%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

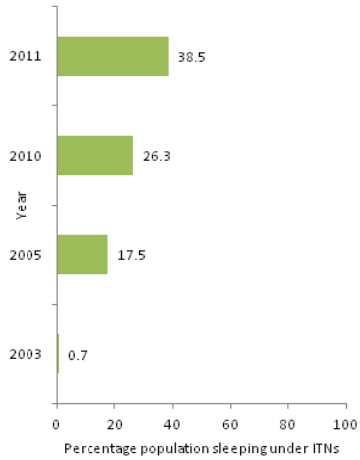
ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage



VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	96,134	0	96,134
	2014	98,076	0	98,076
	Total	194,210	0	194,210

	Year	Insecticide sachets	Spraying operators
IRS	2013	NA	NA
	2014	NA	NA

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06

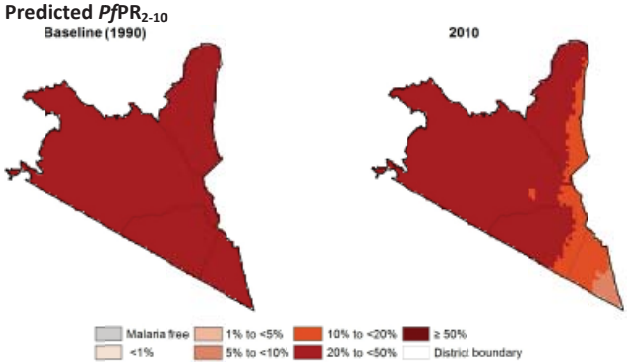
MIGORI COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	455,978	689,036	936,634	956,512	976,811	997,541	1,018,710
Percentage rural[2]			66.0				
Percentage poor[3]			46.7				
ANC coverage[4]			93.6				
EPI coverage[5]			51.6				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

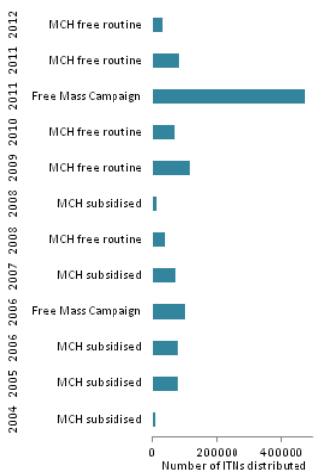


Population at risk in 1990 and 2010 by malaria endemicity

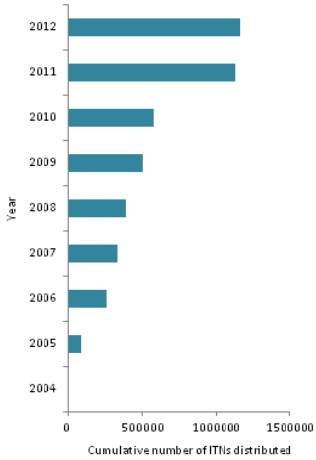
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	0 (0.0%)	0 (0.0%)
<1%	1,287 (0.3%)	2,580 (0.3%)
1% to <5%	0 (0.0%)	213 (0.0%)
5% to <10%	0 (0.0%)	33,003 (3.5%)
10% to <20%	0 (0.0%)	169,804 (18.1%)
20% to <50%	454,574 (99.7%)	731,034 (78.0%)
≥50%	117 (0.0%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage

VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	38,748	0	38,748
	2014	39,571	9,124	48,695
	Total	78,319	9124	87,443

	Year	Insecticide sachets	Spraying operators
IRS	2013	632,194	393
	2014	645,611	401

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06

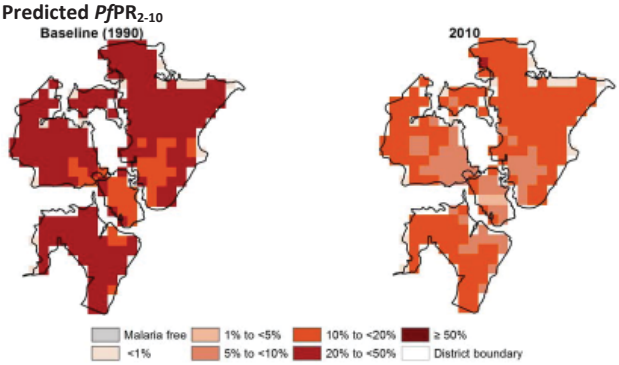
MOMBASA COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	452,264	689,395	967,011	995,464	1,024,756	1,054,909	1,085,949
Percentage rural[2]			0.0				
Percentage poor[3]			37.6				
ANC coverage[4]			94.5				
EPI coverage[5]			90.3				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

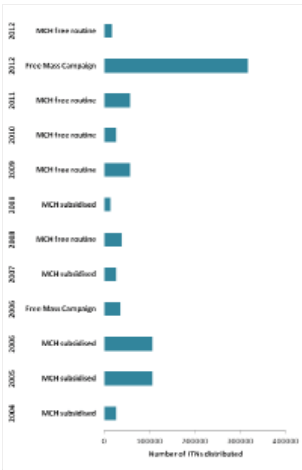


Population at risk in 1990 and 2010 by malaria endemicity

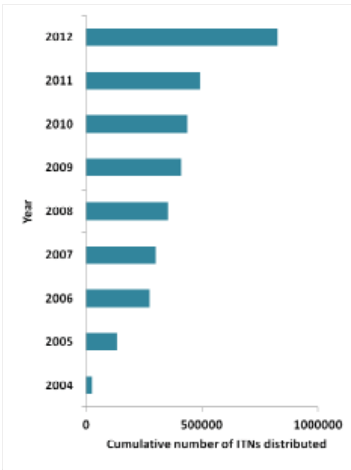
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	0 (0.0%)	0 (0.0%)
<1%	3,437 (0.8%)	7,299 (0.8%)
1% to <5%	0 (0.0%)	35,821 (3.7%)
5% to <10%	0 (0.0%)	492,564 (50.9%)
10% to <20%	184,230 (40.7%)	430,531 (44.5%)
20% to <50%	264,597 (58.5%)	796 (0.1%)
≥50%	0 (0.0%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

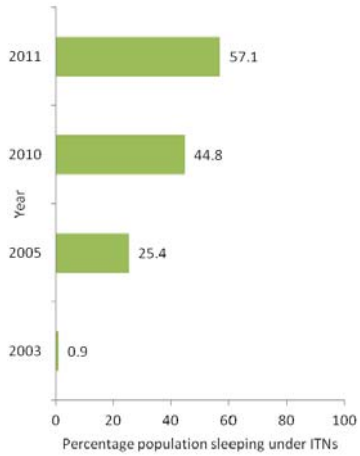
ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage



VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	82,011	0	82,011
	2014	84,424	0	84,424
	Total	166,435	0	166,435

	Year	Insecticide sachets	Spraying operators
IRS	2013	NA	NA
	2014	NA	NA

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06

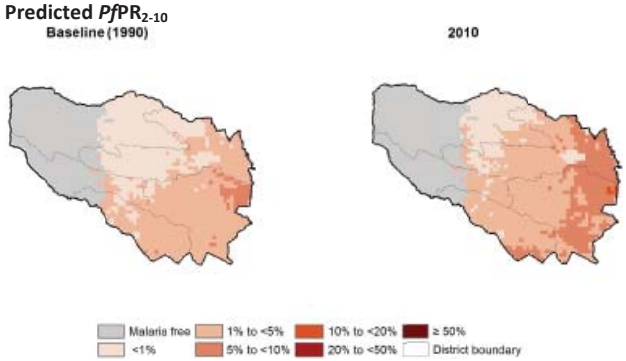
MURANGA COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	858,634	740,087	957,784	973,231	988,928	1,004,878	1,021,086
Percentage rural[2]			83.7				
Percentage poor[3]			29.9				
ANC coverage[4]			92.7				
EPI coverage[5]			77.5				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

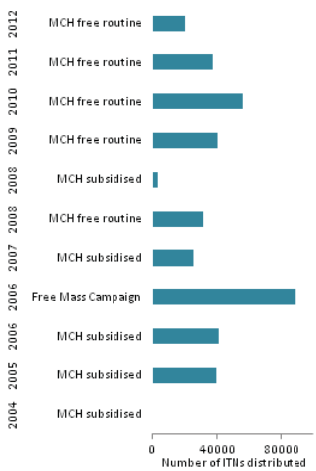


Population at risk in 1990 and 2010 by malaria endemicity

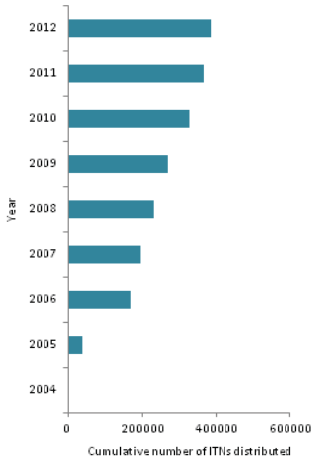
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	125,836 (14.7%)	255,425 (26.7%)
<1%	341,180 (39.7%)	90,480 (9.4%)
1% to <5%	375,554 (43.7%)	485,474 (50.7%)
5% to <10%	16,064 (1.9%)	125,668 (13.1%)
10% to <20%	0 (0.0%)	737 (0.1%)
20% to <50%	0 (0.0%)	0 (0.0%)
≥50%	0 (0.0%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

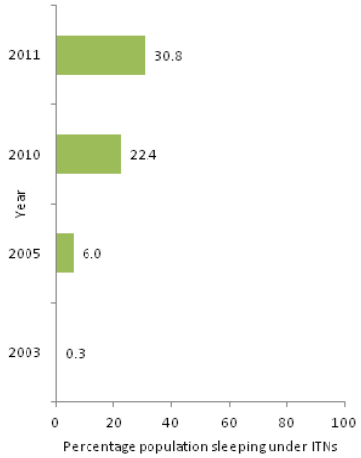
ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage



VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	66,061	0	66,061
	2014	67,126	0	67,126
	Total	133,187	0	133,187

	Year	Insecticide sachets	Spraying operators
IRS	2013	NA	NA
	2014	NA	NA

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06

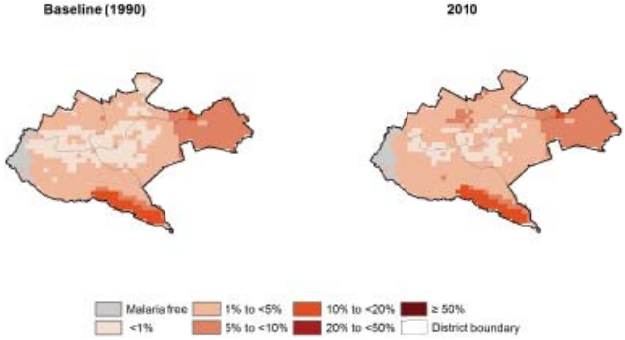
NAIROBI COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	1,254,725	2,248,639	3,259,922	3,386,183	3,517,334	3,653,564	3,795,071
Percentage rural[2]			0.0				
Percentage poor[3]			22.5				
ANC coverage[4]			96.4				
EPI coverage[5]			91.0				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

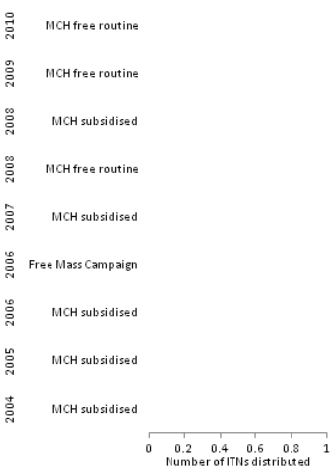


Population at risk in 1990 and 2010 by malaria endemicity

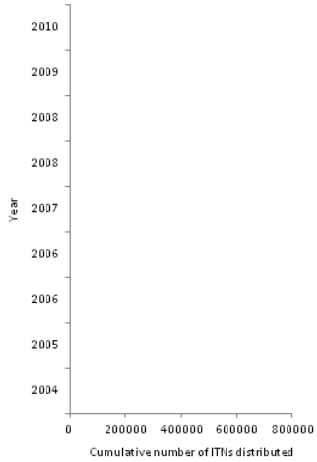
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	19,125 (1.5%)	49,852 (1.5%)
<1%	886,774 (70.7%)	1,546,568 (47.4%)
1% to <5%	330,134 (26.3%)	1,611,461 (49.4%)
5% to <10%	16,560 (1.3%)	47,286 (1.5%)
10% to <20%	2,132 (0.2%)	4,755 (0.1%)
20% to <50%	0 (0.0%)	0 (0.0%)
≥50%	0 (0.0%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage

VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	NA	NA	NA
	2014	NA	NA	NA
	Total	NA	NA	NA

	Year	Insecticide sachets	Spraying operators
IRS	2013	NA	NA
	2014	NA	NA

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06

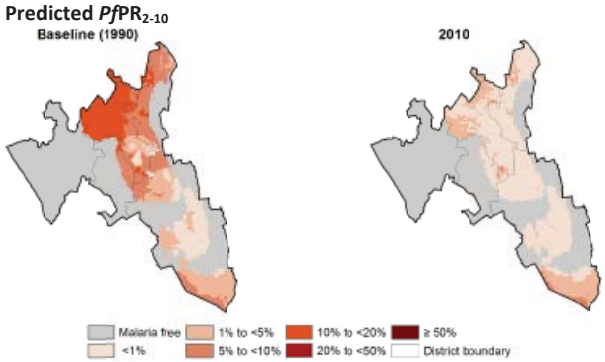
NAKURU COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	850,132	1,228,092	1,662,096	1,732,022	1,786,181	1,851,655	1,919,529
Percentage rural[2]			54.2				
Percentage poor[3]			40.1				
ANC coverage[4]			88.4				
EPI coverage[5]			64.3				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

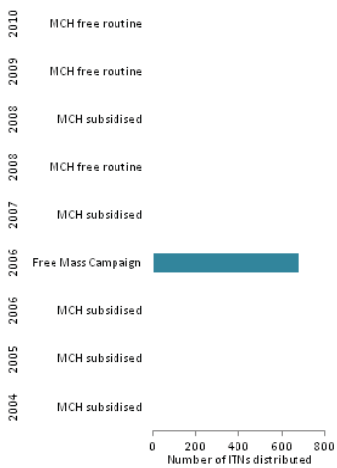


Population at risk in 1990 and 2010 by malaria endemicity

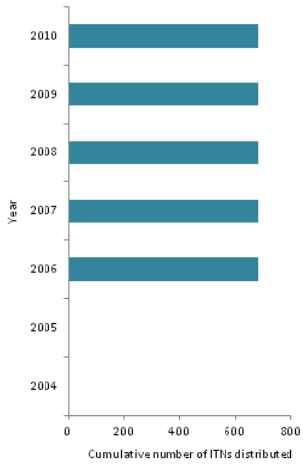
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	445,515 (52.4%)	841,322 (50.6%)
<1%	110,827 (13.0%)	731,294 (44.0%)
1% to <5%	136,909 (16.1%)	87,283 (5.3%)
5% to <10%	97,429 (11.5%)	2,196 (0.1%)
10% to <20%	59,452 (7.0%)	0 (0.0%)
20% to <50%	0 (0.0%)	0 (0.0%)
≥50%	0 (0.0%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

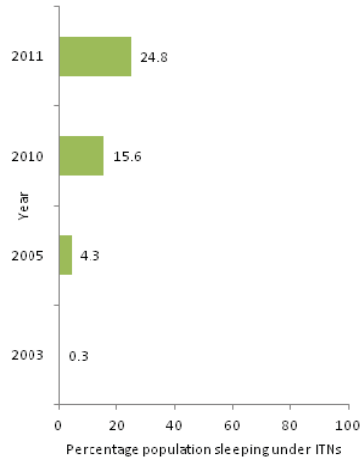
ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage



VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	NA	NA	NA
	2014	NA	NA	NA
	Total	NA	NA	NA

	Year	Insecticide sachets	Spraying operators
IRS	2013	NA	NA
	2014	NA	NA

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06

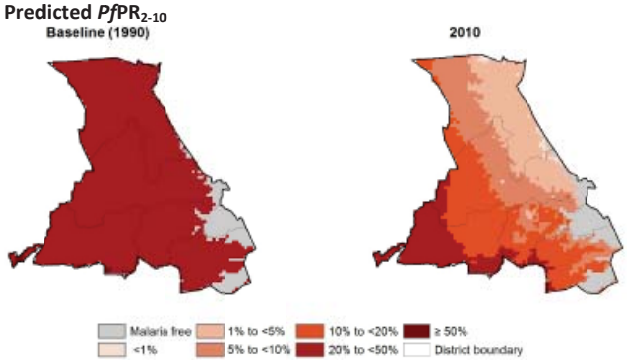
NANDI COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	452,017	595,781	780,566	809,178	838,839	869,587	901,463
Percentage rural[2]			86.4				
Percentage poor[3]			47.4				
ANC coverage[4]			88.4				
EPI coverage[5]			80.8				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

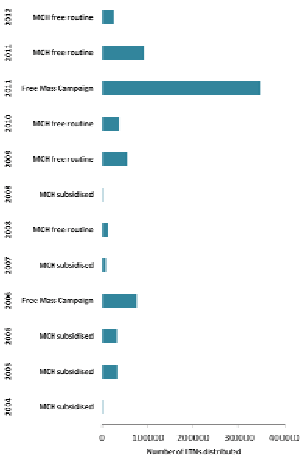


Population at risk in 1990 and 2010 by malaria endemicity

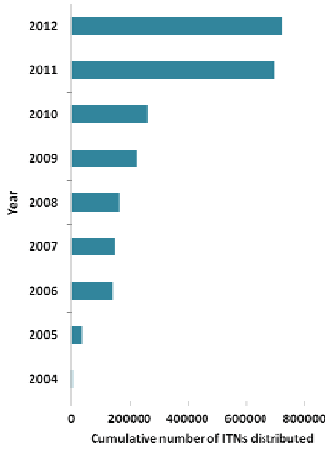
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	19,769 (4.4%)	33,838 (4.3%)
<1%	0 (0.0%)	10,916 (1.4%)
1% to <5%	0 (0.0%)	159,250 (20.4%)
5% to <10%	0 (0.0%)	229,987 (29.5%)
10% to <20%	0 (0.0%)	208,598 (26.7%)
20% to <50%	429,610 (95.0%)	137,977 (17.7%)
≥50%	2,638 (0.6%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

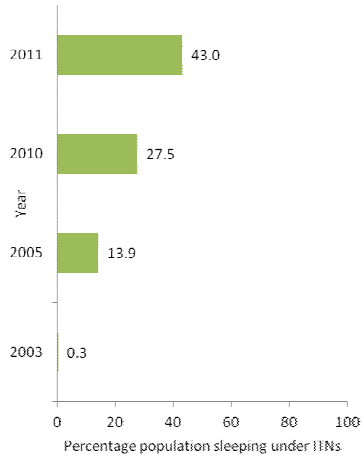
ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage



VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	63,400	0	63,400
	2014	65,724	327,168	392,892
	Total	129,124	327,168	456,292

	Year	Insecticide sachets	Spraying operators
IRS	2013	TBD	TBD
	2014	TBD	TBD

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06
TBD: To be determined based on hotspots identified through surveillance sites

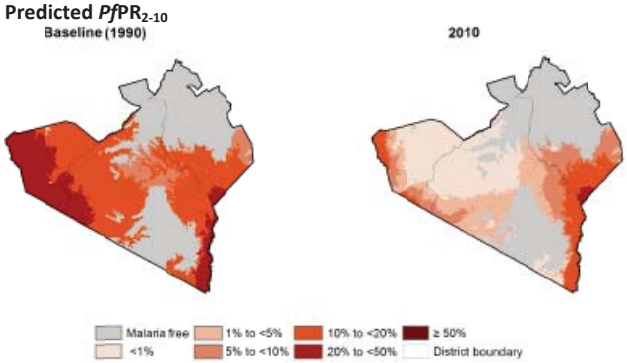
NAROK COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	411,169	552,581	882,111	914,446	947,966	982,714	1,018,736
Percentage rural[2]			93.1				
Percentage poor[3]			33.8				
ANC coverage[4]			88.4				
EPI coverage[5]			62.2				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

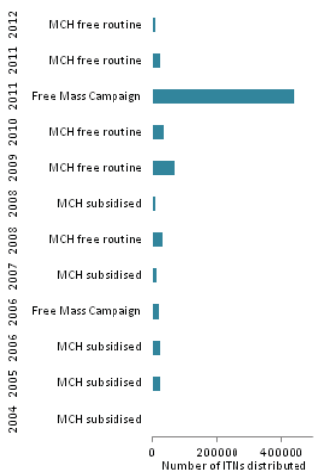


Population at risk in 1990 and 2010 by malaria endemicity

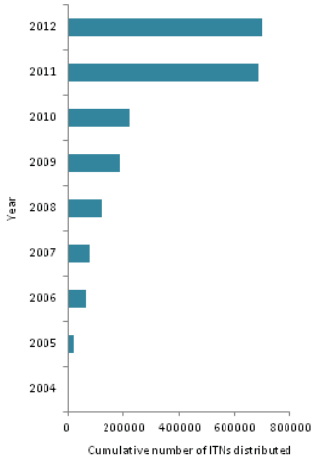
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	176,977 (43%)	378,461 (42.9%)
<1%	0 (0.0%)	306,799 (34.8%)
1% to <5%	4,430 (1.1%)	77,486 (8.8%)
5% to <10%	15,141 (3.7%)	76,705 (8.7%)
10% to <20%	161,327 (39.2%)	40,493 (4.6%)
20% to <50%	53,295 (13.0%)	2,166 (0.2%)
≥50%	0 (0.0%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

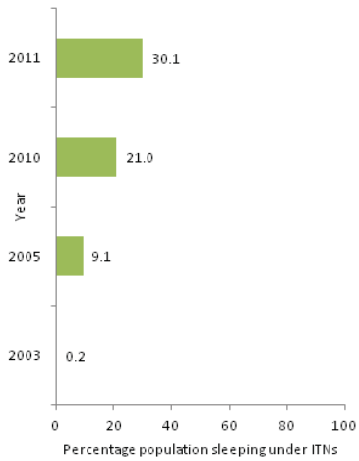
ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage



VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	64,154	0	64,154
	2014	66,505	266,915	333,420
	Total	130,659	266,915	397,574

	Year	Insecticide sachets	Spraying operators
IRS	2013	TBD	TBD
	2014	TBD	TBD

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06
TBD: To be determined based on hotspots identified through surveillance sites

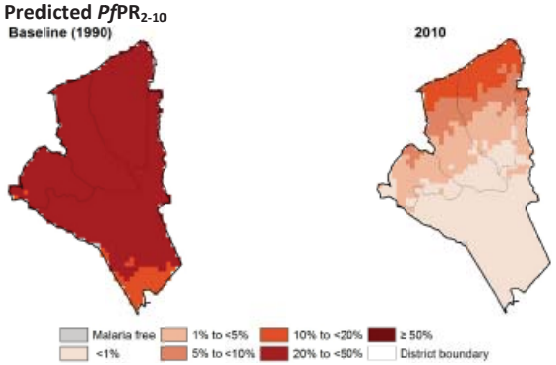
NYAMIRA COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	420,848	508,673	610,948	623,914	637,154	650,676	664,485
Percentage rural[2]			86.0				
Percentage poor[3]			48.1				
ANC coverage[4]			93.6				
EPI coverage[5]			88.1				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

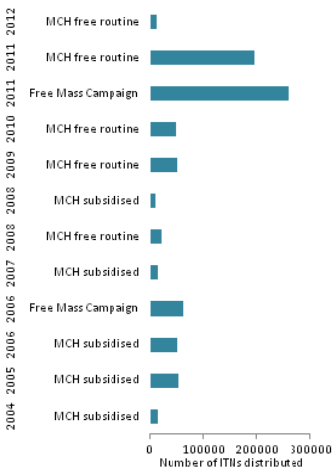


Population at risk in 1990 and 2010 by malaria endemicity

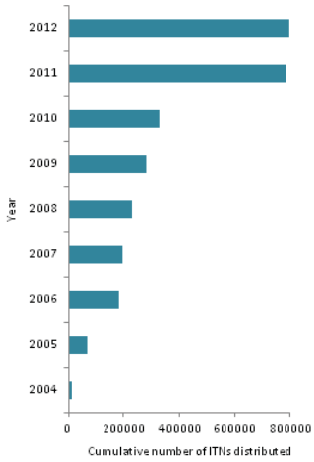
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	1,576 (0.4%)	2,278 (0.4%)
<1%	0 (0.0%)	280,608 (45.9%)
1% to <5%	0 (0.0%)	169,680 (27.8%)
5% to <10%	0 (0.0%)	84,451 (13.8%)
10% to <20%	13,191 (3.1%)	73,931 (12.1%)
20% to <50%	406,081 (96.5%)	0 (0.0%)
≥50%	0 (0.0%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

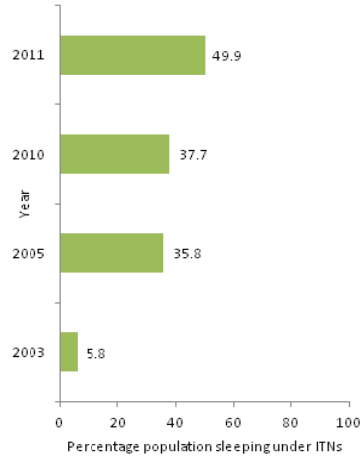
ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage



VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	50,910	0	50,910
	2014	51,990	85,401	137,391
	Total	102,900	85,401	188,301

	Year	Insecticide sachets	Spraying operators
IRS	2013	NA	NA
	2014	NA	NA

[1] Population Projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06

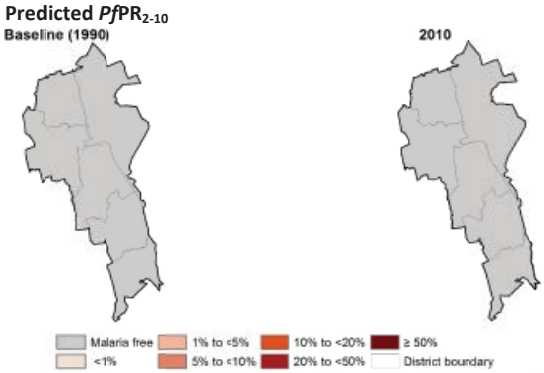
NYANDARUA COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	352,474	496,003	605,885	615,657	625,587	635,677	645,929
Percentage rural[2]			81.5				
Percentage poor[3]			46.3				
ANC coverage[4]			92.7				
EPI coverage[5]			88.3				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

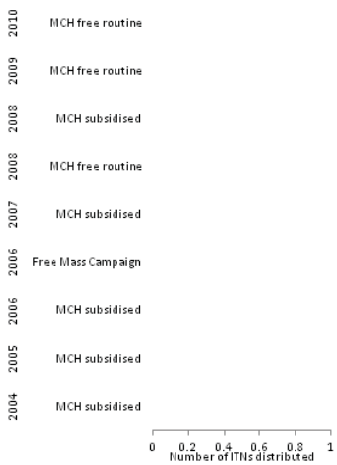


Population at risk in 1990 and 2010 by malaria endemicity

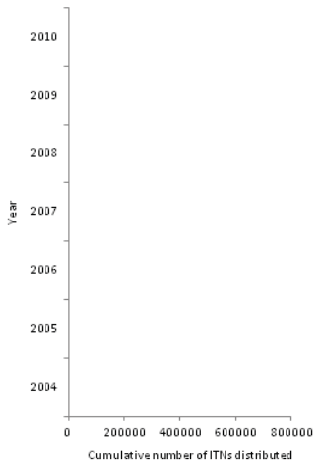
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	352,474 (100%)	605885 (100%)
<1%	0 (0.0%)	0 (0.0%)
1% to <5%	0 (0.0%)	0 (0.0%)
5% to <10%	0 (0.0%)	0 (0.0%)
10% to <20%	0 (0.0%)	0 (0.0%)
20% to <50%	0 (0.0%)	0 (0.0%)
≥50%	0 (0.0%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

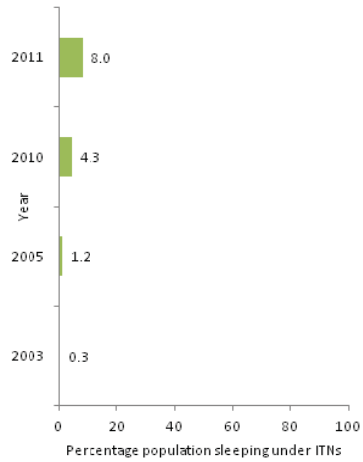
ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage



VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	NA	NA	NA
	2014	NA	NA	NA
	Total	NA	NA	NA

	Year	Insecticide sachets	Spraying operators
IRS	2013	NA	NA
	2014	NA	NA

[1] Population Projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06

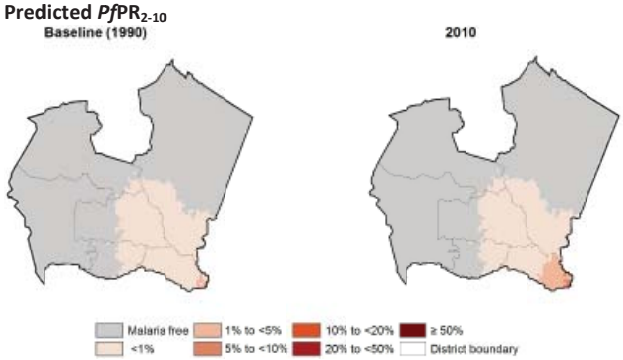
NYERI COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	619,217	666,466	704,744	716,111	727,661	739,397	751,322
Percentage rural[2]			75.5				
Percentage poor[3]			32.7				
ANC coverage[4]			92.7				
EPI coverage[5]			85.1				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

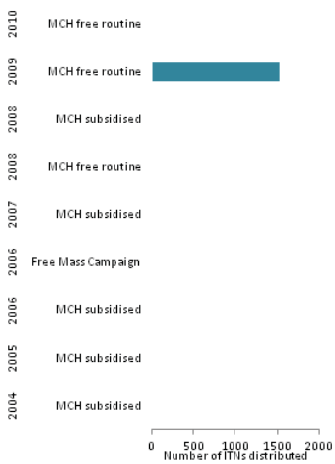


Population at risk in 1990 and 2010 by malaria endemicity

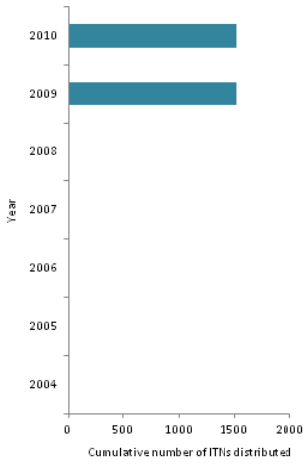
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	256,496 (41.4%)	285,272 (40.5%)
<1%	361,196 (58.3%)	394,173 (55.9%)
1% to <5%	1,525 (0.2%)	24,374 (3.5%)
5% to <10%	0 (0.0%)	925 (0.1%)
10% to <20%	0 (0.0%)	0 (0.0%)
20% to <50%	0 (0.0%)	0 (0.0%)
≥50%	0 (0.0%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

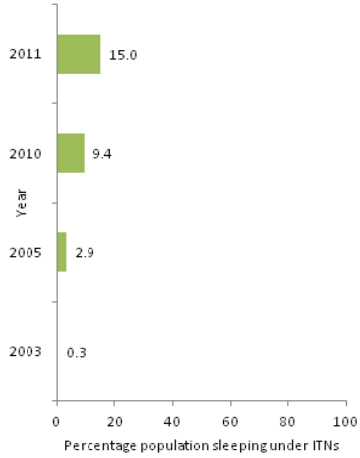
ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage



VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	NA	NA	NA
	2014	NA	NA	NA
	Total	NA	NA	NA

	Year	Insecticide sachets	Spraying operators
IRS	2013	NA	NA
	2014	NA	NA

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06

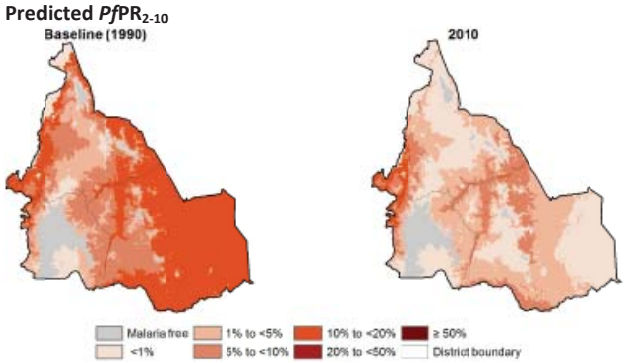
SAMBURU COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	107,371	147,623	232,156	240,666	249,488	258,633	268,113
Percentage rural[2]			81.7				
Percentage poor[3]			73.0				
ANC coverage[4]			88.4				
EPI coverage[5]			85.6				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

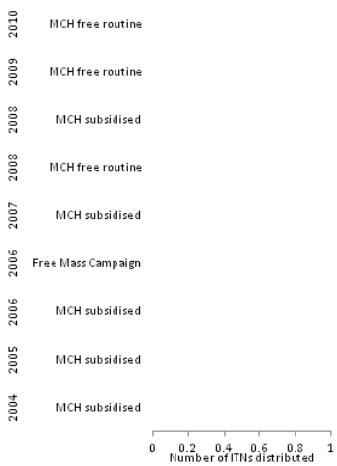


Population at risk in 1990 and 2010 by malaria endemicity

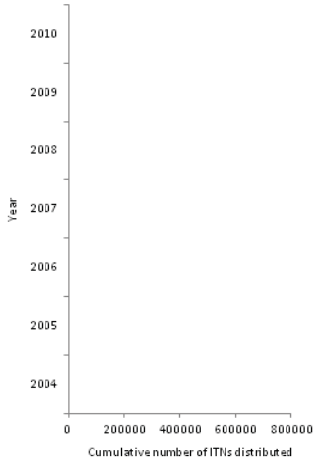
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	31,068 (28.9%)	69,061 (29.7%)
<1%	11,251 (10.5%)	68,511 (29.5%)
1% to <5%	12,146 (11.3%)	70,038 (30.2%)
5% to <10%	28,536 (26.6%)	22,893 (9.9%)
10% to <20%	24,370 (22.7%)	1,653 (0.7%)
20% to <50%	0 (0.0%)	0 (0.0%)
≥50%	0 (0.0%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

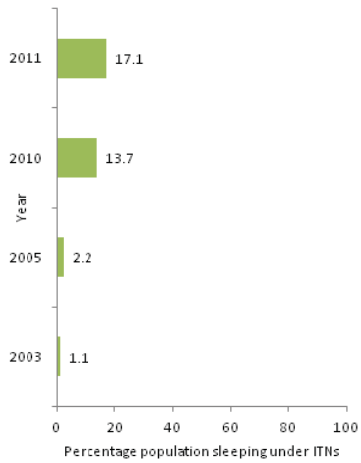
ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage



VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	19,365	0	19,365
	2014	20,075	0	20,075
	Total	39,440	0	39,440

	Year	Insecticide sachets	Spraying operators
IRS	2013	NA	NA
	2014	NA	NA

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06

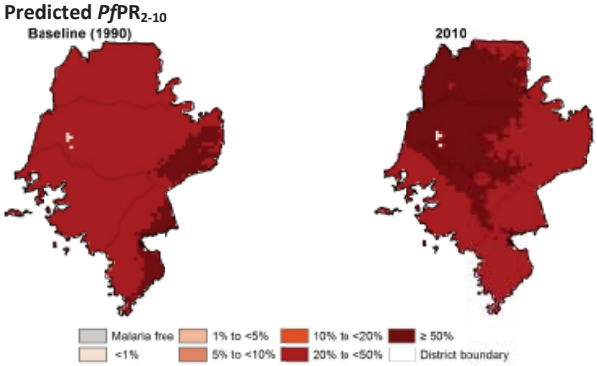
SIAYA COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	687,935	727,642	860,179	878,434	897,076	916,114	935,556
Percentage rural[2]			89.2				
Percentage poor[3]			35.3				
ANC coverage[4]			93.6				
EPI coverage[5]			64.8				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

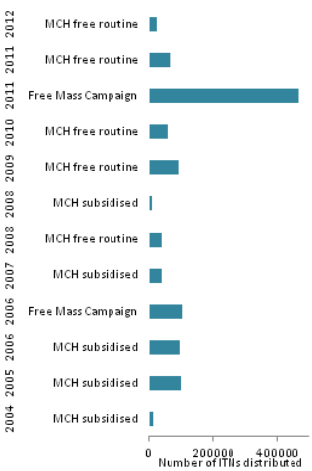


Population at risk in 1990 and 2010 by malaria endemicity

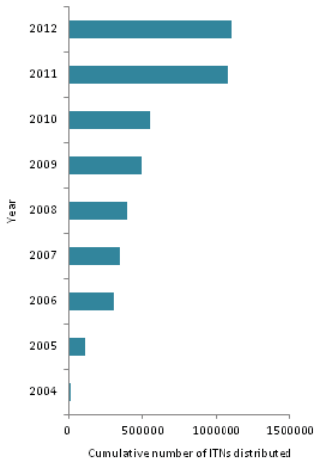
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	0 (0.0%)	0 (0.0%)
<1%	688 (0.1%)	803 (0.1%)
1% to <5%	0 (0.0%)	0 (0.0%)
5% to <10%	0 (0.0%)	0 (0.0%)
10% to <20%	0 (0.0%)	0 (0.0%)
20% to <50%	602,265 (87.5%)	502,906 (58.5%)
≥50%	84,982 (12.4%)	356,471 (41.4%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage

VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	62,926	0	62,926
	2014	64,261	177,355	241,616
	Total	127,187	177,355	304,542

	Year	Insecticide sachets	Spraying operators
IRS	2013	NA	NA
	2014	NA	NA

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06

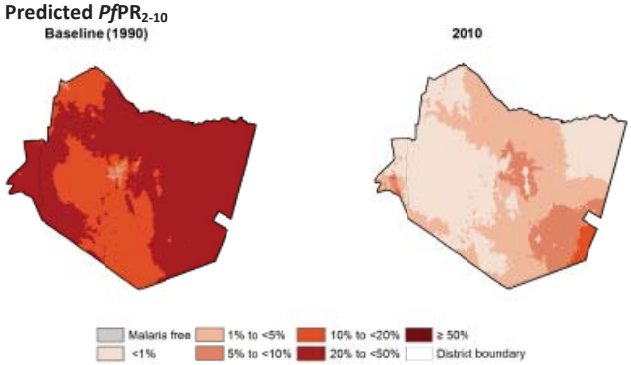
TAITA TAVETA COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	199,386	250,900	293,033	301,655	310,531	319,669	329,075
Percentage rural[2]			77.4				
Percentage poor[3]			54.8				
ANC coverage[4]			94.5				
EPI coverage[5]			76.6				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

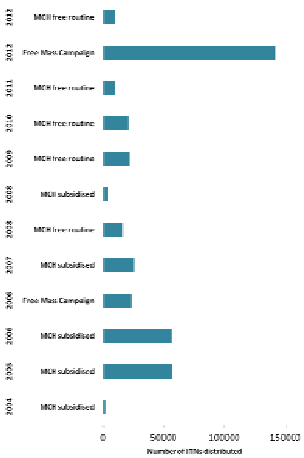


Population at risk in 1990 and 2010 by malaria endemicity

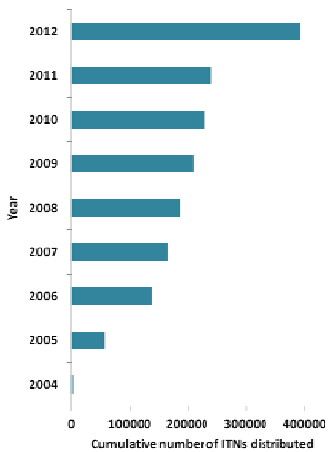
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	786 (0.4%)	1,110 (0.4%)
<1%	0 (0.0%)	191,027 (65.2%)
1% to <5%	1,067 (0.5%)	63,168 (21.6%)
5% to <10%	26,789 (13.4%)	36,246 (12.4%)
10% to <20%	79,053 (39.6%)	1,482 (0.5%)
20% to <50%	91,691 (46.0%)	0 (0.0%)
≥50%	0 (0.0%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage

VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	23,144	0	23,144
	2014	23,825	147,635	171,460
	Total	46,969	147,635	194,604

	Year	Insecticide sachets	Spraying operators
IRS	2013	NA	NA
	2014	NA	NA

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06

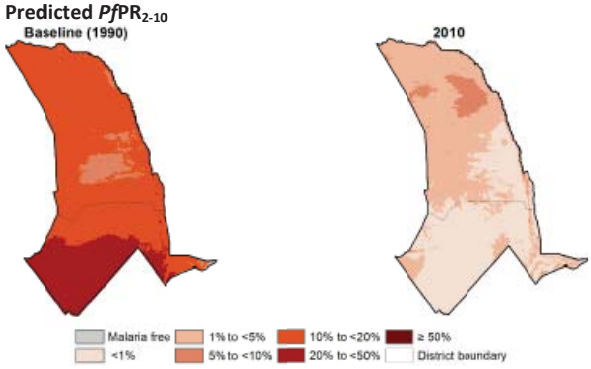
TANA RIVER COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	137,987	187,157	247,139	254,411	261,897	269,603	277,536
Percentage rural[2]			85.0				
Percentage poor[3]			76.9				
ANC coverage[4]			94.5				
EPI coverage[5]			85.7				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

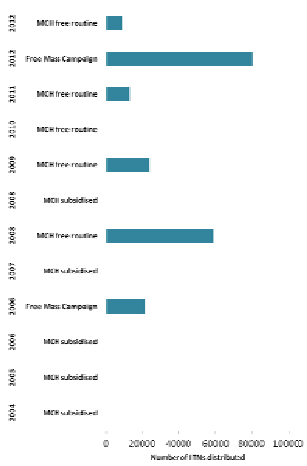


Population at risk in 1990 and 2010 by malaria endemicity

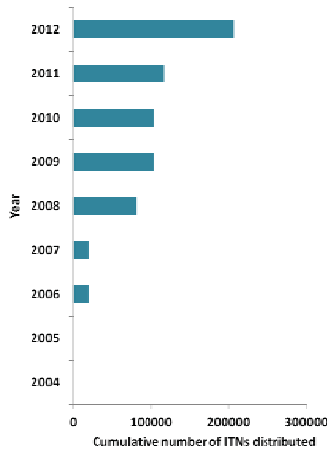
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	0 (0.0%)	0 (0.0%)
<1%	55 (0.0%)	110,244 (44.6%)
1% to <5%	8,083 (5.9%)	117,666 (47.6%)
5% to <10%	8,629 (6.3%)	19,230 (7.8%)
10% to <20%	110,917 (80.4%)	0 (0.0%)
20% to <50%	10,302 (7.5%)	0 (0.0%)
≥50%	0 (0.0%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage

VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	20,476	0	20,476
	2014	21,078	121,697	142,775
	Total	41,554	121,697	163,251

	Year	Insecticide sachets	Spraying operators
IRS	2013	NA	NA
	2014	NA	NA

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06

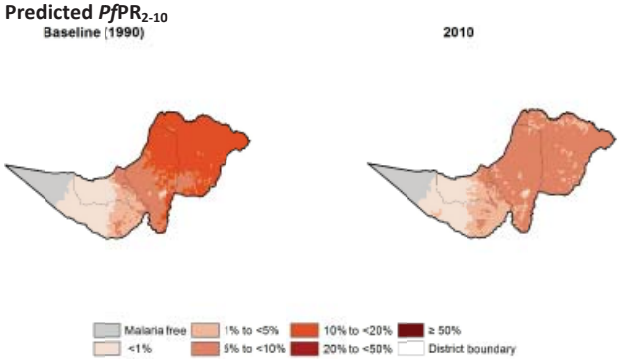
THARAKA COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	250,510	315,776	372,710	380,239	387,921	395,757	403,752
Percentage rural[2]			93.4				
Percentage poor[3]			48.7				
ANC coverage[4]			93.4				
EPI coverage[5]			44.9				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

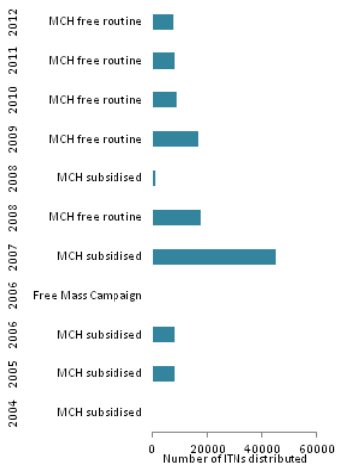


Population at risk in 1990 and 2010 by malaria endemicity

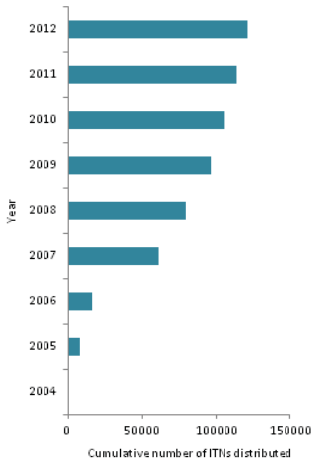
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	0 (0.0%)	0 (0.0%)
<1%	129,007 (51.5%)	178,340 (47.8%)
1% to <5%	22,032 (8.8%)	58,074 (15.6%)
5% to <10%	39,534 (15.8%)	136,296 (36.6%)
10% to <20%	59,937 (23.9%)	0 (0.0%)
20% to <50%	0 (0.0%)	0 (0.0%)
≥50%	0 (0.0%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage

VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	23,031	0	23,031
	2014	23,496	0	23,496
	Total	46,527	0	46,527

	Year	Insecticide sachets	Spraying operators
IRS	2013	NA	NA
	2014	NA	NA

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06

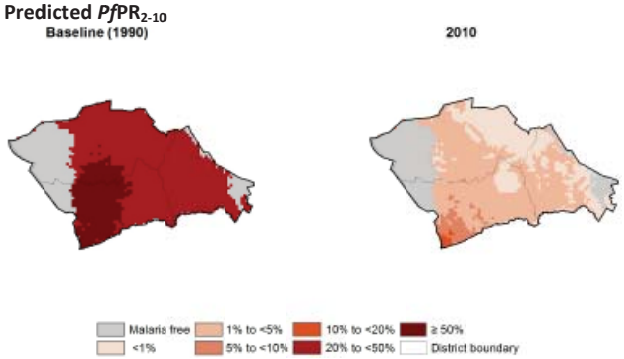
TRANS NZOIA COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	338,712	597,958	848,769	879,882	912,134	945,569	980,230
Percentage rural[2]			79.6				
Percentage poor[3]			50.2				
ANC coverage[4]			88.4				
EPI coverage[5]			90.6				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

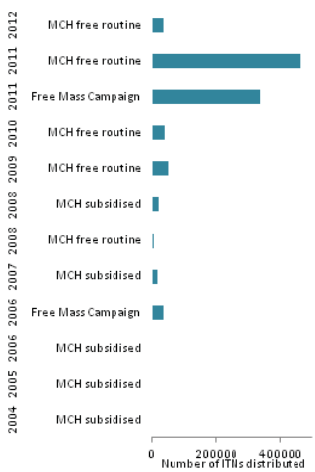


Population at risk in 1990 and 2010 by malaria endemicity

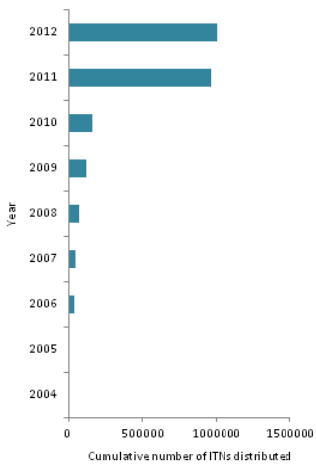
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	27,959 (8.3%)	67,473 (7.9%)
<1%	0 (0.0%)	303,479 (35.8%)
1% to <5%	0 (0.0%)	415,373 (48.9%)
5% to <10%	0 (0.0%)	52,210 (6.2%)
10% to <20%	0 (0.0%)	10,234 (1.2%)
20% to <50%	241,403 (71.3%)	0 (0.0%)
≥50%	69,349 (20.5%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage

VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	72,739	0	72,739
	2014	75,405	48,811	124,216
	Total	148,144	48,811	196,955

	Year	Insecticide sachets	Spraying operators
IRS	2013	TBD	TBD
	2014	TBD	TBD

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06
TBD: To be determined based on hotspots identified through surveillance sites

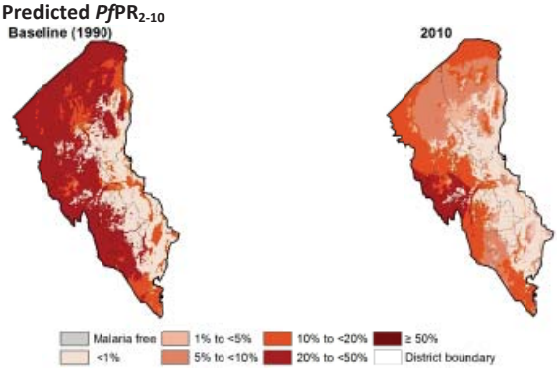
TURKANA COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	183,472	465,987	886,754	919,259	952,955	987,887	1,024,099
Percentage rural[2]			85.8				
Percentage poor[3]			94.3				
ANC coverage[4]			88.4				
EPI coverage[5]			66.7				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

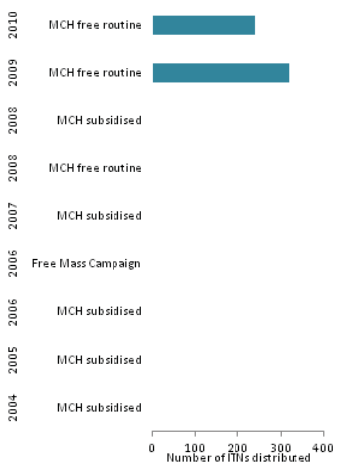


Population at risk in 1990 and 2010 by malaria endemicity

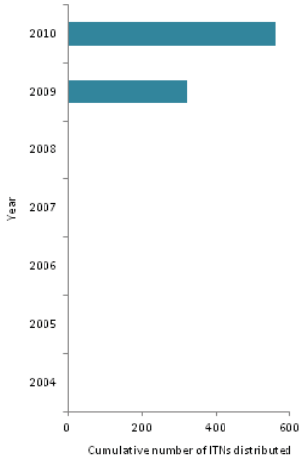
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	0 (0.0%)	0 (0.0%)
<1%	57,264 (31.2%)	277,170 (31.3%)
1% to <5%	27 (0.0%)	44,228 (5.0%)
5% to <10%	486 (0.3%)	206,979 (23.3%)
10% to <20%	26,351 (14.4%)	281,817 (31.8%)
20% to <50%	99,344 (54.1%)	76,560 (8.6%)
≥50%	0 (0.0%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage

VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	66,314	0	66,314
	2014	68,745	0	68,745
	Total	135,059	0	135,059

	Year	Insecticide sachets	Spraying operators
IRS	2013	NA	NA
	2014	NA	NA

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06

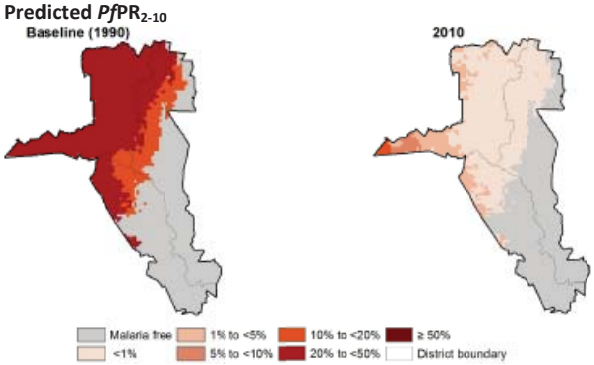
UASIN GICHU COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	453,025	643,597	926,956	960,934	996,158	1,032,673	1,070,527
Percentage rural[2]			61.4				
Percentage poor[3]			51.3				
ANC coverage[4]			88.4				
EPI coverage[5]			72.7				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

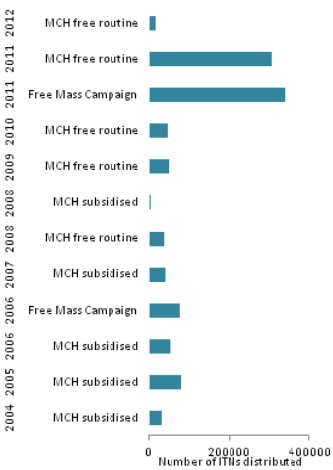


Population at risk in 1990 and 2010 by malaria endemicity

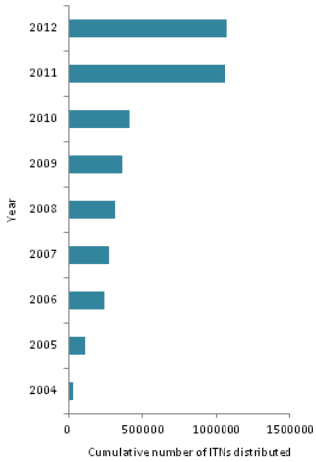
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	125,480 (27.7%)	240,207 (25.9%)
<1%	0 (0.0%)	577,979 (62.4%)
1% to <5%	0 (0.0%)	83,875 (9.0%)
5% to <10%	0 (0.0%)	18,188 (2.0%)
10% to <20%	143,966 (31.8%)	6,708 (0.7%)
20% to <50%	183,579 (40.5%)	0 (0.0%)
≥50%	0 (0.0%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage

VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	71,861	0	71,861
	2014	74,495	193,603	268,098
	Total	146,356	193,603	339,959

	Year	Insecticide sachets	Spraying operators
IRS	2013	TBD	TBD
	2014	TBD	TBD

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06
TBD: To be determined based on hotspots identified through surveillance sites

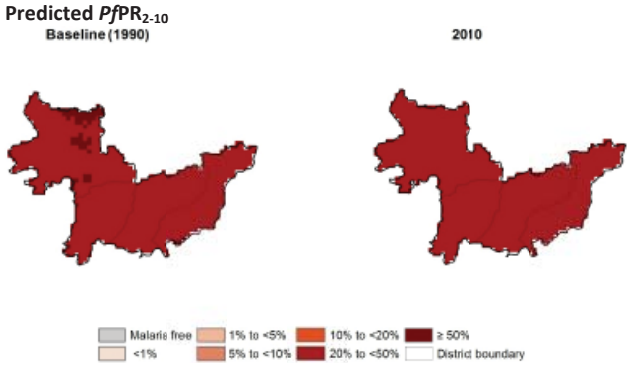
VIHIGA COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	446,227	1,003,645	568,662	583,058	597,818	612,952	628,469
Percentage rural[2]			68.6				
Percentage poor[3]			41.8				
ANC coverage[4]			91.5				
EPI coverage[5]			73.2				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

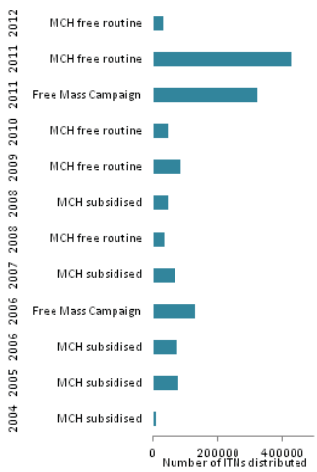


Population at risk in 1990 and 2010 by malaria endemicity

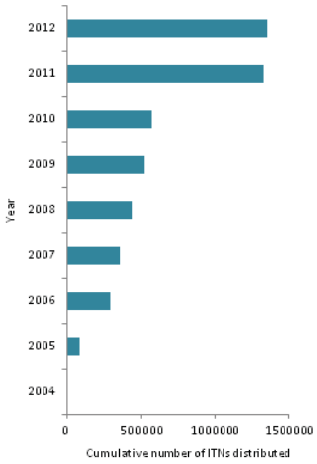
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	0 (0.0%)	0 (0.0%)
<1%	0 (0.0%)	0 (0.0%)
1% to <5%	0 (0.0%)	0 (0.0%)
5% to <10%	0 (0.0%)	0 (0.0%)
10% to <20%	0 (0.0%)	0 (0.0%)
20% to <50%	432,175 (96.9%)	568,662 (100%)
≥50%	14,052 (3.1%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage

VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	45,429	0	45,429
	2014	46,579	92,045	138,624
	Total	92,008	92,045	184,053

	Year	Insecticide sachets	Spraying operators
IRS	2013	NA	NA
	2014	NA	NA

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06

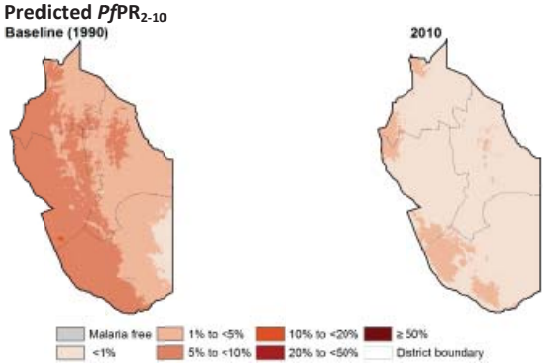
WAJIR COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	122,769	351,429	722,832	789,324	861,932	941,220	1,027,801
Percentage rural[2]			85.4				
Percentage poor[3]			84.0				
ANC coverage[4]			69.5				
EPI coverage[5]			72.7				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

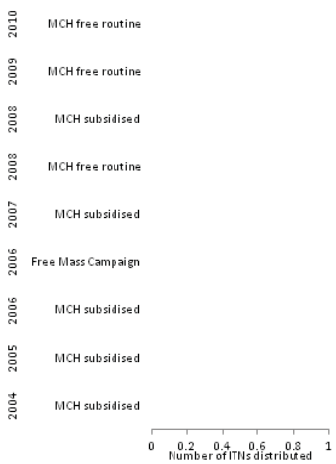


Population at risk in 1990 and 2010 by malaria endemicity

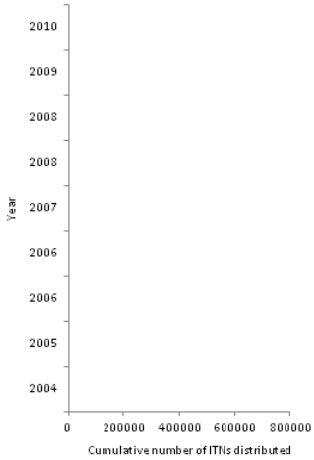
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	0 (0.0%)	0 (0.0%)
<1%	10,568 (8.6%)	630,185 (87.2%)
1% to <5%	56,729 (46.2%)	92,647 (12.8%)
5% to <10%	55,264 (45.0%)	0 (0.0%)
10% to <20%	208 (0.2%)	0 (0.0%)
20% to <50%	0 (0.0%)	0 (0.0%)
≥50%	0 (0.0%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

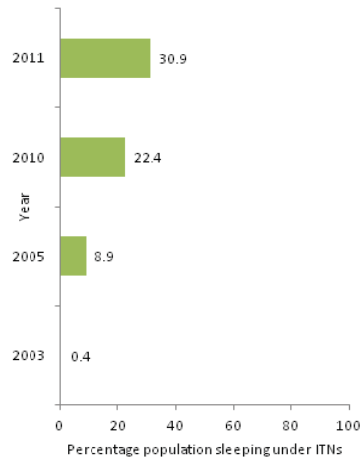
ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage



VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	46,543	0	46,543
	2014	50,825	0	50,825
	Total	97,368	0	97,368

	Year	Insecticide sachets	Spraying operators
IRS	2013	NA	NA
	2014	NA	NA

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06

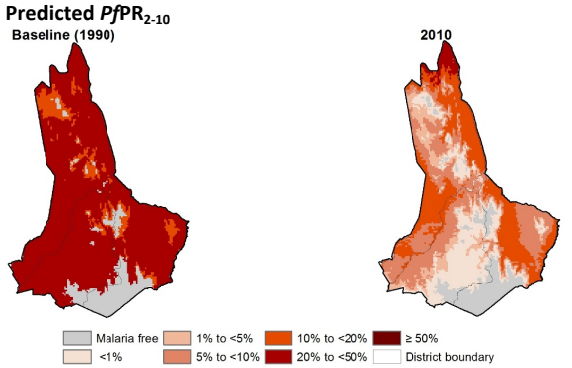
WEST POKOT COUNTY

GENERAL PROFILE

Year	1990	2000	2010	2011	2012	2013	2014
Population[1]	225,182	317,786	531,483	550,965	571,161	592,098	613,801
Percentage rural[2]			91.7				
Percentage poor[3]			69.8				
ANC coverage[4]			88.4				
EPI coverage[5]			56.2				

EPIDEMIOLOGICAL PROFILE

Predicted *Pf*PR$_{2-10}$

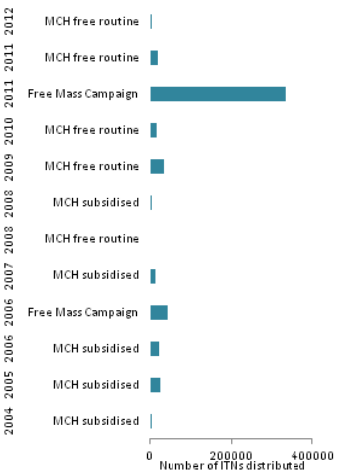


Population at risk in 1990 and 2010 by malaria endemicity

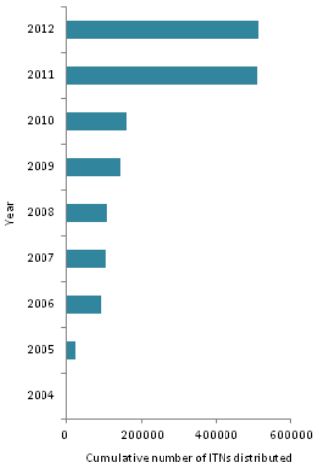
*Pf*PR$_{2-10}$ endemicity	1990	2010
Malaria free	56,732 (25.2%)	134,233 (25.3%)
<1%	17 (0.0%)	150,668 (28.3%)
1% to <5%	0 (0.0%)	59,800 (11.3%)
5% to <10%	0 (0.0%)	101,876 (19.2%)
10% to <20%	21,714 (9.6%)	82,640 (15.5%)
20% to <50%	146,719 (65.2%)	2,265 (0.4%)
≥50%	0 (0.0%)	0 (0.0%)

VECTOR CONTROL INTERVENTIONS: DISTRIBUTION AND COVERAGE

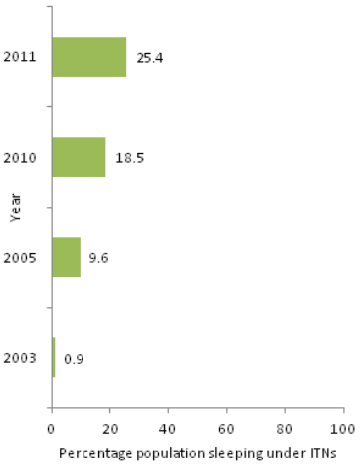
ITN distribution by delivery mechanism



Cumulative ITN distribution



ITN coverage



VECTOR CONTROL INTERVENTIONS: LLIN and IRS GAP ESTIMATION

	Year	Free routine distribution	Free mass campaign	Total
LLINs	2013	37,197	0	37,197
	2014	38,560	128,339	166,899
	Total	75,757	128,339	204,096

	Year	Insecticide sachets	Spraying operators
IRS	2013	TBD	TBD
	2014	TBD	TBD

[1] Population projections from intercensal growth rate
[2] Source: KNBS 2009
[3] Source: KIHBS 2005-06
[4] Source: DHS 2008-09
[5] Source: KIHBS 2005-06
TBD: To be determined based on hotspots identified through surveillance sites


$PfPR_{2-10}$
Malaria free
0% to <1%
1% to <5%
5% to <10%
10% to <20%
20% to <40%
40% to 100%