Human Ecology of Malaria in a Rural Highland Region of South-West Kenya

Dissertation

zur

Erlangung des Doktorgrades (Dr. rer. nat.)

der

Mathematisch-Naturwissenschaftlichen Fakultät

der

Rheinischen Friedrich-Wilhelms-Universität Bonn

vorgelegt von

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aus

Nairobi

Bonn 2009

Angefertigt mit Genehmigung der Mathematisch-Naturwissenschaftlichen Fakultät der Rheinischen Friedrich-Wilhelms-Universität Bonn

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Tag der Promotion: 30.11.2009

„…und je weiser einer ist, um so mehr wird er um seine Unwissenheit wissen. Um dieses Zieles willen habe ich die Mühe auf mich genommen, einiges wenige über die wissende Unwissenheit zu schreiben…“

Auszug aus *„De docta ignorantia“* (1440) Hl. Nikolaus von Kues (1401~1464)

ABSTRACT

Malaria kills nearly a million people a year, uses almost half of the clinical services in Africa, and reduces economic growth by up to 1%. These numbers illustrate the immense and persistent burden of malaria, making its control one of the most important challenges in global public health. Interventions such as the use of insecticide treated nets (ITNs) for people at risk; appropriate anti-malaria drugs for people with probable or confirmed malaria and indoor residual spraying (IRS) of insecticides have been at the forefront of global efforts to control the disease. While these measures are important, proven environmental measures that succeeded in eradicating malaria vectors in vast parts of Europe and the Americas in the early 20th century and even in some parts of Africa are largely lacking.

Malaria is considered to result from special interactions between vectors, parasites, human beings and various environmental and anthropogenic determinants. The present study set out to investigate the extent to which actual malaria incidences could be related to these interactions. Specifically, the study examined the associations of malaria incidences with micro-ecological, socio-demographic and behavioural aspects in a rural epidemic zone in south western Kenya.

A case-control epidemiological study design was applied. Malaria patients seeking treatment at a rural health care facility were randomly sampled during a peak transmission period between May and July 2007. Each case was individually matched with a control of the same sex and approximately the same age. Controls were drawn from patients suffering from diseases of the respiratory system diagnosed at the facility during the same time period. In total, 342 cases and 328 controls were sampled. Home visits for both cases and controls were done within a period of two weeks from the day of treatment at the health facility. A standardised questionnaire investigating the social, demographic and behavioural aspects related to malaria at the household level was administered to each case, control or their carer.

The houses and homesteads of the study subjects were spot checked for the presence of factors which could favour mosquito breeding and their contact with human beings. These included housing characteristics such as openings through which mosquitoes could enter the houses, presence of stagnant water and proximity to known breeding sites such as swamps and valley bottoms. In addition, the survey homesteads were geo-positioned with a hand held global positioning system and straight line distances from the study homesteads to possible risk areas measured. Statistical analysis was done with conditional logistic regression using STATA. Spatial analysis was done with SaTscan^{TM} and ArcGIS.

Location of houses on flat swampy areas (mOR 1.81, *p*-value 0.03), staying outdoors at night (mOR 1.94, *p*-value 0.03); presence of oxen in the compound (mOR1.53, *p*-value 0.03); sleeping in a house with open eaves (mOR 1.45, *p*-value 0.03) and family size greater than four people (odds ratio 1.44, *p*-value 0.04) were significantly associated with increased risk of malaria. On the other hand, having sufficient food supplies throughout the year (mOR 0.60, *p*-value 0.003) and keeping medicine at home (mOR 0.58, *p*-value 0.006) were significantly associated with reduced risk of malaria. Analysis of perceptions showed that apart from mosquitoes, malaria was commonly associated with environmental factors (24.7%) and nutritional deficiencies (24.5%) among other factors. 48.2% of the respondents perceived malaria to be transmitted through direct or indirect contacts with sick persons. Spatial analysis identified two clusters of malaria both located on the lower parts of the study area close to a big river.

These findings point to the need for holistic approaches that draw connections between behavioural, socio-economic and micro-ecological factors in malaria control.

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LIST OF ABBREVIATIONS

ACT	Artemisinin Based Combination Therapies
DFID	Department for International Development
DOMC	Division of Malaria Control
HIMAL	Highland Malaria Project
ITNs	Insect Treated Nets
IRS	Indoor Residual Spraying
SP	Sulphadoxine Pyrimethamine
UNDP	United Nations Development Programme
ICIPE	International Centre for Insect Physiology and Ecology
DALYs	Disability Adjusted Life Years
DSS	Demographic Surveillance System
IVM	Integrated Vector Management
D. V. B. D.	Division of Vector Borne Diseases
WHO	World Health Organisation
mOR	Matched Odds Ratio
GFATM	Global Fund to fight Aids, Tuberculosis and Malaria
MMV	Medicines for Malaria Venture
RBM	Roll Back Malaria
UNICEF	United Nations Children's Fund
GDP	Gross Domestic Product
SOK	Survey of Kenya
NGO	Non Governmental Organisation

1 GENERAL INTRODUCTION

Malaria is a vector-borne infectious disease caused by protozoan parasites of the genus *Plasmodium* which are transmitted from person to person by the bite of an infected female *Anopheles* mosquito (Barry, 2005). Four *Plasmodium* species are responsible for human malaria: *Plasmodium falciparum, Plasmodium vivax*, *Plasmodium ovale* and *Plasmodium malariae. Plasmodium falciparum* is the most virulent parasite and is responsible for the majority of malaria related mortality. It is found in all malaria endemic regions of the world and is the most common human malaria parasite in Africa (WHO, 2005). A fifth species, *Plasmodium knowlesi,* causes malaria in macaques but has been increasingly reported to infect humans in south east Asia (Vythilingam et al., 2008).

The malaria parasite has a complex life cycle involving both asexual and sexual stages with obligatory phases in both humans and female *Anopheles* mosquito. Figure 1.1 shows the life cycle of the parasite *Plasmodium falciparum*. When a parasite infected mosquito feeds on a human, it injects a small number of sporozoites from its salivary glands into the blood. Sporozoites travel to the host liver and invade hepatocytes. After about two weeks of maturation to exo-erythrocytic schizonts, the parasites, now in the merozoite stage, burst out of the hepatocytes and invade red blood cells. Here, they go through several stages from rings to trophozoites to erythrocyte schizonts, a process that takes around two days. The mature schizonts again rupture the cells to release merozoites which re-invade new red blood cells. Clinical features of malaria, including fever and chills, anaemia and cerebral malaria are all associated with infected red blood cells, and most current drugs target this stage of the life cycle. Parasites can continue to replicate asexually using this mechanism, but some can also form transmission stages known as gametocytes.

When a mosquito bites the infected human, it takes up blood containing gametocytes, which develop into male and female reproductive cells. These fuse in the insect's gut to form a zygote. The zygote in turn develops into the ookinete, which crosses the wall of the gut and forms a sporozoite-filled oocyst. When the oocyst bursts, the sporozoites move to the mosquito's salivary glands, and the process begins again during the subsequent mosquito bites. The mosquito stage takes two weeks and begins with gametocytes ingested with mosquito blood meal (Wirth, 2002).

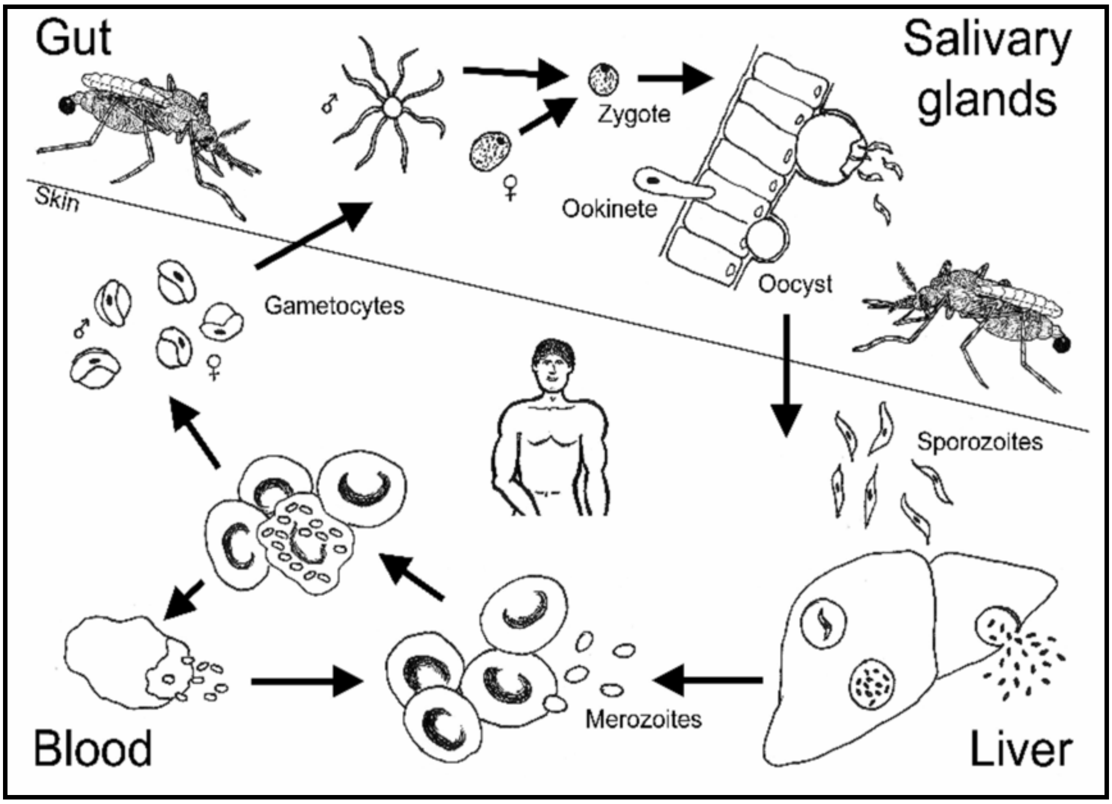


Figure 1.1 Life cycle of the parasite *Plasmodium falciparum*

Malaria continues to be an important vector borne disease and a leading cause of morbidity and mortality in Africa south of the Sahara (WHO, 2005). Globally, it has been estimated that the burden of malaria exceeds 40 million disability adjusted life years (DALYs) (Lopez et al., 2006). In sub- Saharan Africa, 15% of all disability adjusted life-years are lost to malaria (Chima et al., 2003). According to 2006 estimates, globally 3.3 billion people were at risk of malaria. 41% of malaria endemic countries were found in the WHO African region. 247 million cases were reported world wide; 86% of them in Africa. 881,000 malaria deaths were estimated; 91% occurring in Africa (WHO, 2008b).

The extent of human suffering caused by malaria and its devastating cost has been recognised by international bodies and many initiatives taken over the years. Since the 1990s renewed global efforts to combat malaria have emerged with activities from organisations such as: Global Fund to fight Aids, Tuberculosis and Malaria (GFATM), Medicines for Malaria Venture (MMV) and the Roll Back Malaria (RBM) among others. With more than 100 years of malaria research, there is still no effective vaccine, and the disease uses almost half of the clinical services in tropical Africa. Controlling malaria may therefore be the most important challenge in global public health.

Over the past decade, there has been a substantial increase in resources for malaria control from less than US $ 100 million to about $ 1 billion in 2008. Sleeping under insecticide treated bed nets, indoor residual spraying, intermittent preventive treatment for pregnant women and timely treatment of the sick with effective drugs are the main interventions applied to control malaria (Grabowsky, 2008). The Roll Back Malaria target to reach 80% coverage of each of these interventions by 2010 is a huge challenge. Even in countries like Kenya where a high proportion of people have access to anti-malaria drugs or insecticide treated nets, routine surveillance does not show, unequivocally, the expected reductions in mortality and morbidity (WHO, 2008a).

1.1 Country background

Kenya is situated on the eastern part of the African continent. It lies between 5 degrees north and 5 degrees south of latitude and between 24 and 31 degrees east longitude. It is almost bisected by the equator. The country has diverse physical features which include the Great Rift Valley; which runs from north to south, Mount Kenya, the second highest mountain in Africa; Lake Victoria, the largest fresh water lake on the continent and a number of inland lakes found within the rift valley. The country falls into two regions: lowlands, including the coastal and the lake basin and highlands, which extend on both sides of the Great Rift Valley (Figure 1.2).

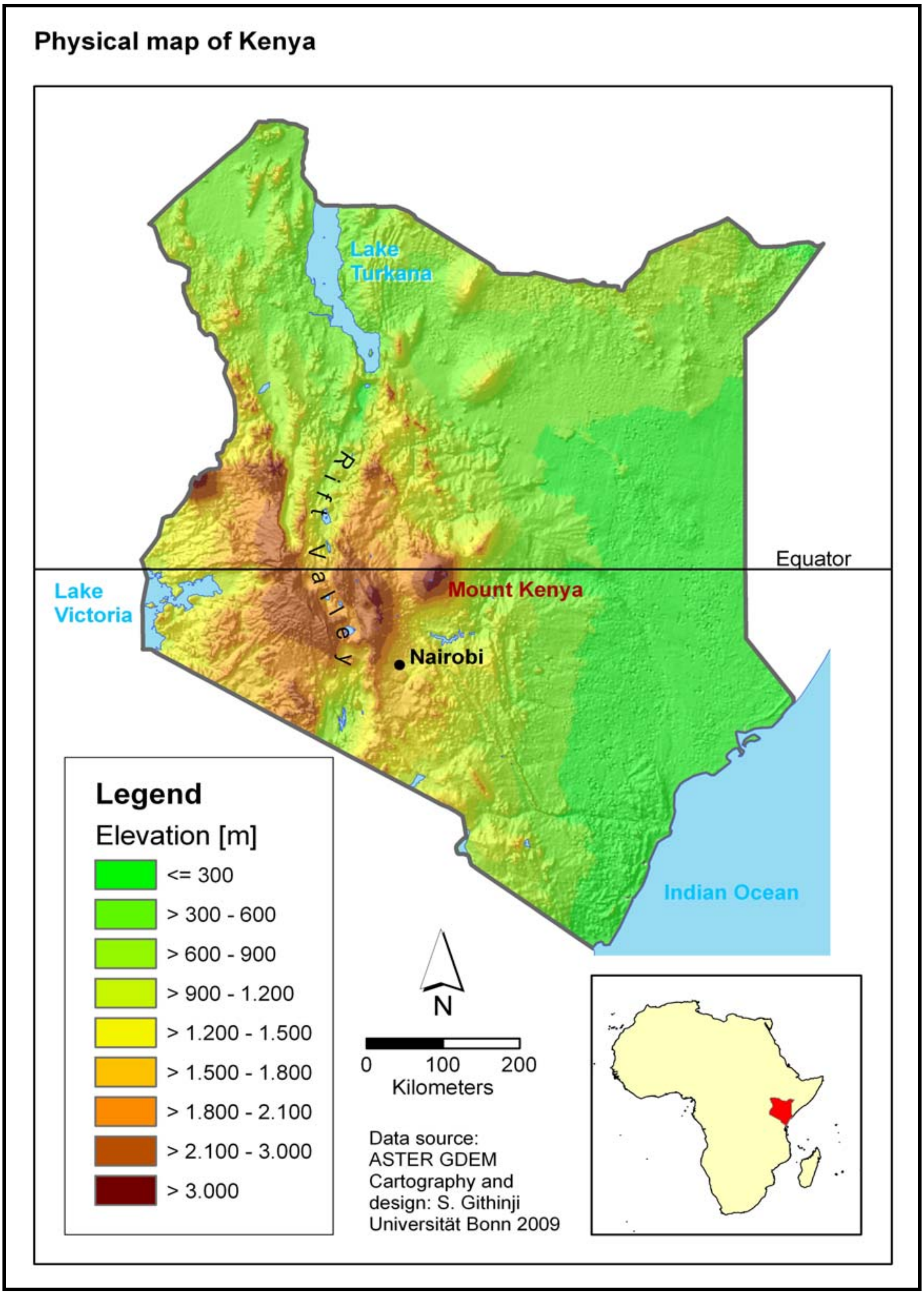


Figure 1.2 Physical map of Kenya

Rainfall and temperature are influenced by altitude and proximity to lakes and the Indian Ocean which borders the country on the southeast. There are four seasons in a year: a dry period from January to March, the long rainy season from March to May, a long dry spell from May to October, and finally the short rains between October and December.

The country has a total land area of 582,646 km^2. It is divided into eight provinces and 72 districts. Approximately 80% of the country's land area is arid or semiarid (Kenya, 2004). Kenya has a population of approximately 34 million with an annual growth rate of 2.3%. The country's economy is predominantly agricultural with a strong industrial base. The agricultural sector contributes 25% of the gross domestic product (GDP). Coffee, tea and horticulture are the main agricultural export commodities. The manufacturing sector contributes about 13% of the total GDP (Kenya, 2004, Kenya, 2009).

1.2 Malaria situation in Kenya

More than 70% of the population of Kenya lives in areas where malaria is transmitted. The disease is responsible for approximately 30% of all out- patient visits, and 19% of all hospital admissions. Children under the age of five are particularly vulnerable. About 3.5 million children are at risk of infection and developing severe malaria. At least 14,000 children are hospitalised annually for malaria. There are an estimated 34,000 deaths annually among children under-five years of age. It is estimated that 170 million working days are lost annually due to malaria (Kenya, 2004, Kenya, 2001, Kenya, 2009). In 2006, an estimated 11.3 million malaria cases occurred in Kenya, making it one of the five countries contributing over half of malaria cases reported in the WHO African region. Between 2001 and 2006, the number of reported cases in Kenya increased in four out of five years (WHO, 2008b). Four malaria epidemiological zones can be identified in Kenya (Figure 1.3). These include the perennial high transmission areas near Lake Victoria and the south coast; the western highlands prone to malaria epidemics; the seasonal transmission zone in most of the arid and semi arid areas and finally, the low transmission risk area around Nairobi and parts of central province (Kenya, 2009, Kenya, 2004).

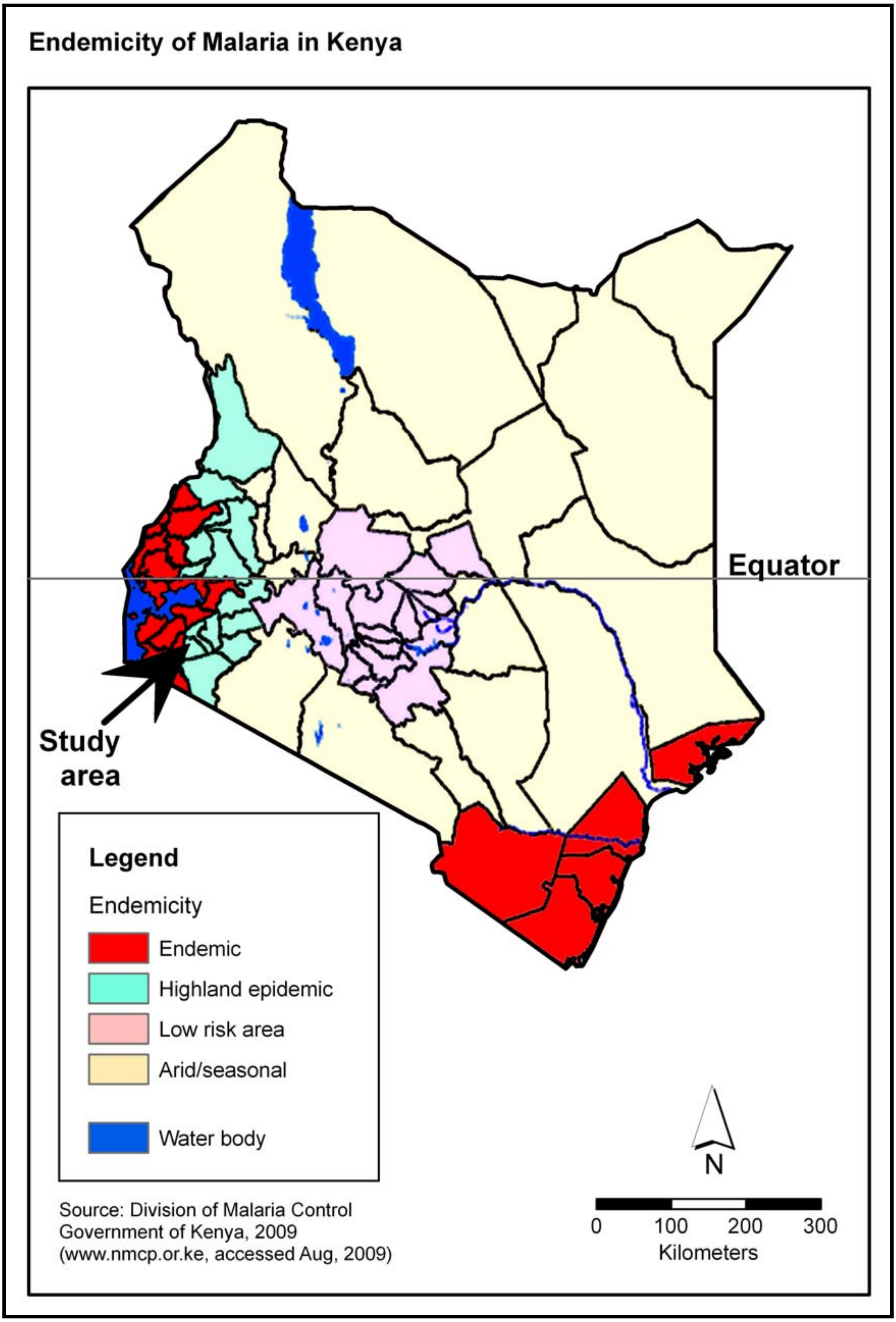


Figure 1.3 Endemicity of malaria in Kenya

In the endemic areas along Lake Victoria and the south coast, malaria transmission is perennial but peaks co-incidental with the rains occur from June to August and again in late November. However, the burden of malaria varies little between the years. In the epidemic zone of the western highlands, there is always a potential for limited transmission lending itself to an overall low disease risk on an average year. However, variations in rainfall and ambient temperatures between years can lead to epidemics affecting all members of the community. These epidemics are relatively frequent events occurring every 3-5 years.

The seasonal transmission zone in the arid and semi-arid areas is traditionally unable to support the breeding of malaria vectors except around either man-made water bodies or perennial rivers. Consequently, malaria infection risks are extremely low and locally acquired clinical disease is rare. However, unusual rainfall and flooding in these areas can lead to severe epidemic crises. Although these conditions are rare, they can lead to devastating levels of disease and deaths among the entire population. In the low risk areas, the potential for transmission can always occur with favourable climate conditions for the vector and parasite. People living in these areas acquire infections elsewhere and require clinical management but promotion of personal protection is not accorded a high priority.

Since the late 1980s, malaria has re-emerged in the highland regions west of the rift valley spreading to fifteen districts defined as highland malaria epidemic zones. Remotely sensed data suggest that the epidemics are triggered by rainfall abnormality during key pre-epidemic periods; relative drought in the two or three pre-epidemic years and above average rainfall 1 - 2 months before epidemic onset (Checchi et al., 2006). The impact of climate on malaria has been widely researched and models to predict malaria based on meteorological data developed (Shanks et al., 2005b, Hay et al., 2002, Malakooti et al., 1998). However, it has been proved difficult to link the increase in epidemics in East African highlands to global climatic changes (Mueller et al., 2005).

Several other factors have been put forward as contributing to the observed trends of malaria in African highlands. These include: increased drug resistance (Malakooti et al., 1998, Shanks et al., 2005b), increased transmission rate due to environmental change (Pascual et al., 2006), change in mosquito life history mediated by land use and agricultural practices (Mutero et al., 2004, Kebede et al., 2005) and increased human mobility between highland and lowland endemic regions (Shanks et al., 2005a).

Malaria transmission in most agricultural ecosystems like the Kenya highlands is complex and involves the interactions of the host-vector-parasite triad, together with environment and socio-economic factors in the community. Environmental factors related to breeding sites and vector densities have been widely documented in the western Kenya highlands (Minakawa et al., 2005a, Zhou et al., 2007, Afrane et al., 2008). However, little has been done to relate these environmental factors to behavioural and socio-economic factors associated with actual malaria incidences. In modelling malaria, there is a need to take into account the ecological as well as socio-economic factors. This has the potential to provide a more direct link with real world data as well as providing a complete overall picture (Ruiz et al., 2006, Vries, 2001).

Kenya has been ranked the third leading nation in malaria research in the world (Thomson Scientifics' Essential Science Indicators (ESI) November 2005). Scientists in Kenya produce some of the world's top research on malaria, yet the disease continues to be a major cause of morbidity in the country. Why this lack of connection between research and control? Environmental control measures and involvement of the communities have been indicated as necessary steps which need to be integrated in the fight against the disease. There is a growing need to develop holistic malaria control interventions with adequate consideration of socio-economic and behavioural factors. The present study aims to address this gap by investigating how human behaviour manifested in its social and cultural aspects, interact with environmental factors leading to malaria incidences.

1.3 Objectives of the study

The main objective of this observational study is to analyse the human and micro-scale ecological inter-linkages that impact on transmission of malaria in the household. Specifically, the study aims to:

1. Examine the links between human beings and their micro-scale environment in relation to malaria transmission

2. Investigate the socio-economic and demographic factors associated with the risk of malaria

3. Explore the health seeking behaviour and perceptions relating to malaria causation, diagnosis, treatment and prevention

1.4 Research questions

In view of these objectives, the following research questions are posed:

- Do the day to day interactions between human beings and their micro-scale environment pose a risk of contracting malaria?

- Is there a relationship between socio-economic conditions and malaria incidences in a household?

- Are malaria cases related to demographic factors such as age, sex, migration and seasonal movements?

- Do perceptions of malaria causation, diagnosis and prevention impact on the occurrence, treatment and health seeking behaviour?

1.5 The study area

The study was conducted in Nyamarambe division of south Kisii district. The area is located in the malaria epidemic zone of the western highlands of Kenya (Figure 1.3). The district was curved out of two neighbouring districts (Gucha and Kisii central) in early 2007. The newly gazetted south Kisii district comprises Nyamarambe, Etago and Suneka divisions. Nyamarambe and Etago divisions were formally part of Gucha district while Suneka was part of Kisii Central. Nyamarambe division has a land area of 94.5 km^2 and a population of 81,360 (according to 2006 projections). It is made up of three locations and nine sub locations with the river Kuja forming its southern border (Figure 1.4). The annual population growth rate is 2.8%, with a population density of 861 inhabitants per km^2. The population is mainly rural with 80% of the people working in the small scale agricultural sector. As a result, the area is heavily cultivated with no natural forests and vegetation (Kenya, 2002). Figure 1.5 shows an overview of the study area with densely cultivated hills.

The area experiences a highland equatorial climate. It receives an annual average of 1,500 mm of rainfall which occur in two wet seasons. The long rains occur between March and June while the short rains are from September to November. The average temperature is 21°C with a maximum of 27°C and a minimum of 14°C. The area is mainly hilly with elevation ranging between 1,400 m at the valley bottoms and over 1,800 m at the hill tops. The soils are mainly red volcanic (nitsols), which are deep and rich in organic matter. However, some parts have clay soils which are poorly drained. These are usually found in the valleys and swampy areas.

Malaria in Kisii area is best described as hypo-mesoendemic (DOMC, 2001), characterised by year round transmission with seasonal peaks following the heavy rains. According to unpublished routine health information data at the time of the study, malaria recorded a prevalence rate of 33% and an incidence rate of 23%. The disease accounted for 60% of deaths in children below the age of five years and 33% of all deaths in Kisii and Gucha districts (Nyamongo, 2004).

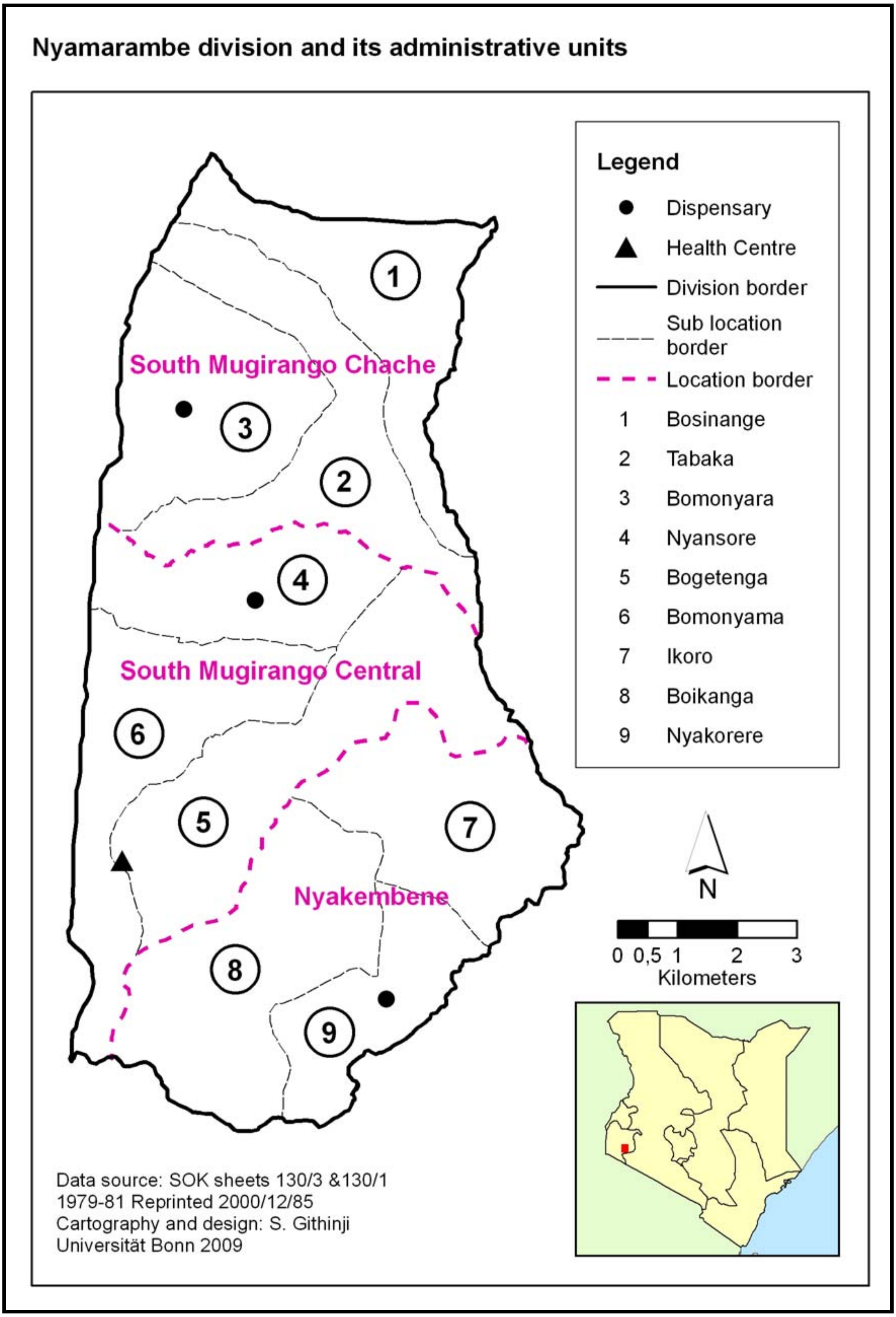


Figure 1.4 Administrative units of Nyamarambe division

Figure 1.5 Intensively cultivated hilly landscape

Kisii highlands have experienced some devastating malaria epidemics since 1998. The epidemics followed a pattern of short dramatic peaks in May and June. As a result of these epidemics, Gucha district was one of four districts in Kenya and Uganda involved in a Highland Malaria Project (HIMAL) that carried out district level surveillance and predictive modelling of malaria epidemics in the highlands of East Africa. Nyamarambe division recorded one of the highest malaria figures in the former Gucha district. At the time of the field study, Nyamarambe division had four government health care facilities which included one health centre and three dispensaries (Table 1.1).

Table 1.1 Health facilities in Nyamarambe division

Name of facility	Catchment Population	Annual Attendance	Utilization rate (%)
Nduru health centre	17,957	12,924	84
Boige dispensary	8,029	8,089	101
Gotichaki dispensary	7,774	3,106	40
Nyatike dispensary	8,862	7,475	72

Data source: Ministry of Health, Gucha district 2007

Data were collected from the population served by Nduru health centre. This population was spread over four sub-locations: Bogetenga, Bomonyama and Nyansore in south Mugirango Central location and Boikanga in Nyakembene location (Figure 1.4). Nduru health centre was one of five sentinel health facilities which monitored the stability of malaria on a routine basis in Kisii highlands. It was gazetted as a sub-district hospital during the data collection exercise. It had an inpatient capacity of 30 beds and was served by 11 nurses, a clinical officer and a number of community health workers. It also served as a referral facility for the three other dispensaries in the area.

Boige dispensary was located in the most remote part of the division with very steep hills, hence its high utilization rate. It was served by two nurses and two community health workers. Gotichaki dispensary was opened in 2006 and was operating temporarily from a classroom of a local polytechnic. It was served by one nurse and a community health worker.

Nyatike dispensary was the most well equipped of the three dispensaries. Construction of a maternity wing and staff houses were nearly completed at the time of data collection. Measures were under way to install electricity at the facility. The dispensary was located near a tarmac road within the Tabaka soap stone carvings area, a major tourist attraction site in Kisii highlands.

In summary, Nyamarambe division may be described as a remote area with poor infrastructures. There is only one dry weather road cutting across the area. During the rainy season, the road is impassable as vehicles get stuck in the mud. Public transport is inadequate, partly because of the poor road network and the hilly topography (Figure 1.6).

Figure 1.6 Poor roads and over crowded vehicles

1.6 Conceptual framework

The resurgence of malaria in the highland regions of Kenya can be seen as a unique blend of ecological circumstances and social responses that have developed within highly specific political, economic and cultural contexts. Current approaches to malaria control call for integration of environmental and social approaches involving communities, governments other social institutions. These approaches represent a socio-ecological perspective of health (Curtis, 1996) reflected in the definition of health as a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity. This concept of health implies complex interactions between humans and their environment, more particularly between social and economic factors, physical environment and biological environment (WHO, 1986). Based on this concept, the variables assessed in the study were derived from the following models:

- The socio-ecological model
- Salutogenic model by Aaron Antonovsky (1992)
- Modern public health model by Noack (2005)
- Livelihood model - adapted by UNDP and DFID
- The human ecology of disease

The socio-ecological model describes the relationships between health behaviour and interpersonal, organisational, community and social subsystems (Kothari A. et al., 2007). The model recognises that while individuals are responsible for instituting and maintaining the lifestyle changes necessary to reduce risk and improve health, individual behaviour is determined to a large extent by social environment, e.g. community norms and values, regulations, and policies. The model stresses that the most effective approach leading to healthy behaviours is a combination of the efforts at all levels i.e. individual, interpersonal, organizational, community, and public policy (Socio-ecological model - Looking beyond the individual. Available from: http://www.balancedweightmanagement.com/TheSocio-EcologicalModel.htm (Accessed 22 June 2009). Although this model is useful for explaining health behaviour, it puts more emphasis on the social environment and does not explicitly address the natural environment.

Antonovsky proposed the salutogenic model as a guide to research and practice in health promotion. The model sees health and disease as two poles of a continuum, along which every person (whether healthy, sick or even dying) can be fitted. The model focuses on all aspects that can help a person to move towards the health pole of the continuum (Antonovsky, 1992). Antonovsky critically opposed the concern with risk factors. He saw the task of reducing risk factors and engaging in wise low risk behaviour as very narrow. The Antonovsky approach presents health (not sickness) as the starting point. While this may be true in the developed world, in the less developed countries, it is difficult to talk of helping people move to the health pole of the continuum (to use Antonovsky's words) without first treating the sick ones and protecting those susceptible. To do this requires addressing risk factors and helping people to apply wise, low risk behaviour.

In spite of its criticism of risk factors, Antonovsky's model presented a useful foundation for the third objective of this study, which assessed perceptions regarding health and disease in general and malaria in particular. The sense of coherence (SOC) interpreted as a generalised orientation through which a person sees the world as comprehensive, manageable and meaningful (Antonovsky, 1992) was useful in assessing how perceptions may influence health seeking behaviour.

Noack (2005) proposed a modern model of public health which combines the risk factors (pathogenic perspective) and the salutogenic perspective. The model distinguished four perspectives of public health namely:

- Individual disease prevention and disease care
- Collective disease prevention and disease care (collective care)
- Collective health promotion and health care (community health)
- Individual health promotion and care

Noack's ideas were useful in exploring the preventive measures applied at the individual and collective level. However, the model does not offer a specific place for consideration of environmental factors.

The livelihood model was developed by UNDP and DFID as a means of understanding the factors that influence the lives of people and their well being (Soussan J. et al., 2001). Livelihood is defined to be comprised of capabilities, assets (including both material and social resources) and activities required for a means of living (Carnel, 1998). The livelihood model distinguishes different types of assets and strategies that people use to cope with different vulnerabilities. Although this model is useful in analysing the socio-economic conditions, it is not specifically designed to deal with health issues. The model presents environmental factors as sources of vulnerabilities. It does not bring out the interaction of these environmental factors with human beings.

The human ecology of disease is concerned with the ways human behaviour, in its cultural and socio-economic context, interacts with environmental conditions to produce or prevent diseases among susceptible people. The model defines health in terms of adaptability that is related to complex systems of interactions among the habitat (environment), population and cultural behaviour. Habitat is that part of the environment within which people live, and which directly affects them. Population is concerned with humans as the potential hosts of disease. Behaviour on the other hand, springs from cultural precepts, economic constraints, social norms and individual psychology (Meade and Earickson, 2000). The model (Figure 1.7) was considered suitable for the present study because it incorporates an environmental component to aspects already reviewed in the other models. To explicitly define the study variables, an adapted version of the model (Figure 1.8) was adopted.

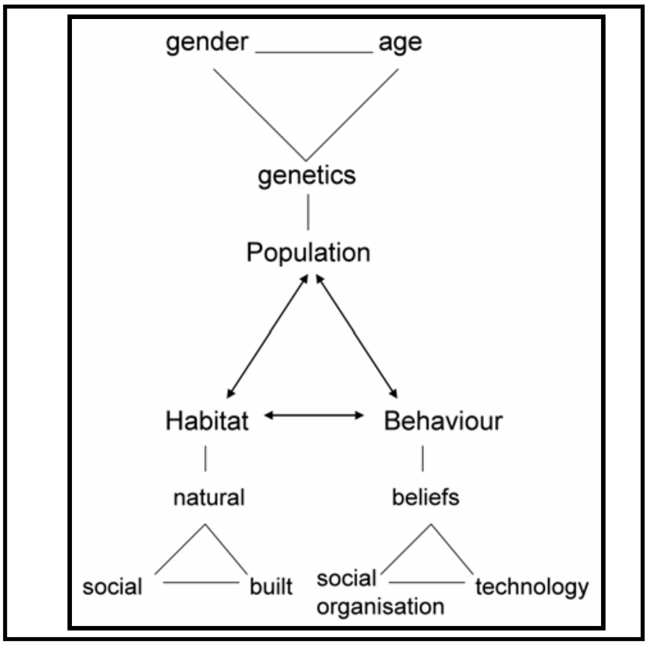


Figure 1.7 Triangle of human ecology of disease

Source: Meade and Earickson (2000)

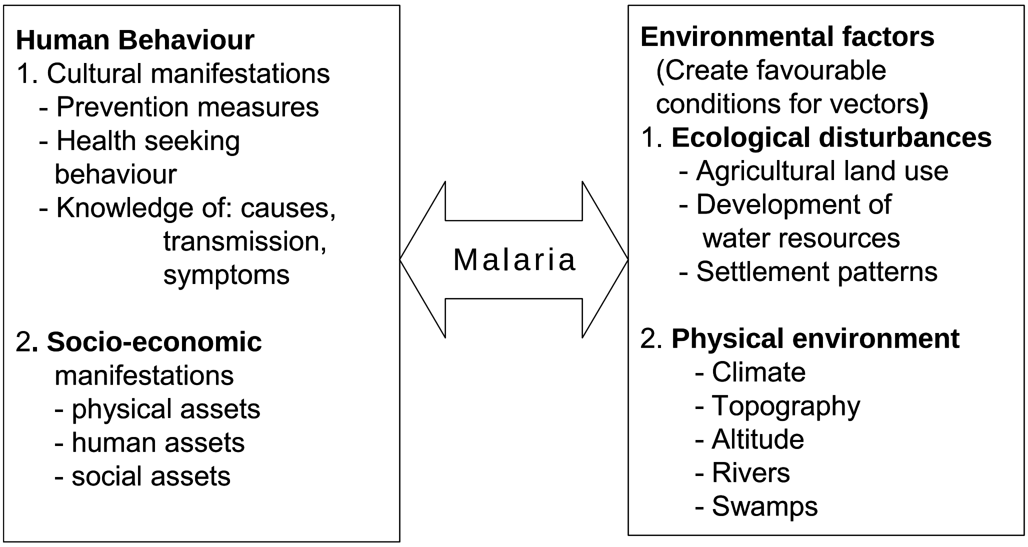


Figure 1.8 Adapted model of human ecology of disease

The left hand side of the model presents behavioural and socio-economic aspects. The behavioural factors were drawn from the socio-ecological, the public health and the salutogenic models. The socio-economic variables were derived from the livelihood model. Moving to the right hand side, environmental factors associated with location such as topography, vegetation, water resources and agricultural land use systems are added to the model.

The arrow in the middle represents human beings interacting with their environment on the one hand and the environmental aspects dictating those interactions on the other. Topography, for example, may influence human decisions on where to build a house while drainage systems such as rivers may determine the source of drinking water. Socio-economic factors on the other hand determine what materials will be used to construct a house. Cultural beliefs about causation of disease may influence health seeking behaviour. All these factors interacting in different ways may lead to increased or reduced risk of malaria among individuals exposed to the same risk factors.

The expected outcome of this model is a better identification and ranking of important human and micro-ecological factors associated with the persistent high incidences of malaria in spite of elaborate efforts made to control the disease.

2 METHODS

A case-control epidemiological study design was employed. A case was defined as any individual from the study area who was diagnosed with malaria at Nduru health centre during the monitoring period (May to July 2007). Malaria was diagnosed according to the national procedures which recommended clinical diagnosis for children under the age of five while parasitological testing, done through a blood smear examined under a microscope, was required for patients aged five years and above. Treating children aged less than six years on the basis of clinical diagnosis was considered cost effective in semi-immune populations where young children carried the highest risk of severe malaria (Zurovac et al., 2008). At the time of data collection, Nduru health centre had one microscope. Lack of reliable microscopy in the peripheral health units (Abeku et al., 2008) has been cited as a major reason for the clinical diagnosis of malaria in most African countries.

Controls were selected from patients suffering from diseases of the respiratory system (with the exception of pneumonia). This decision was reached after considering the monthly classification of the most common diseases at Nduru health centre. Table 2.1 shows the ranking of most common diseases recorded at the health centre from October 2006 to August 2007. Given the high number of malaria cases, no other disease could have provided adequate number of controls. Secondly, selecting controls from different diseases would have jeopardized the comparability of the two groups.

Table 2.1 Most common diseases at Nduru health centre

Disease	Female	Male	Total
Malaria	4,588	3,528	8,116
Other Dis. of Resp. System	1,918	1,833	3,751
Pneumonia	479	351	830
Diarrhoeal diseases	257	241	498
Intestinal Worms	158	165	323
Dysentry	30	27	57
Anaemia	3	6	9

Data source: Ministry of Health, Gucha district 2007

2.1 Sampling of cases and controls

A detailed record of all the cases and controls visiting Nduru health centre was taken from 30th April to 31st July 2007. Objectives of the study were explained to eligible cases, controls or their carers. The subjects or their respective carers were asked for their consent to participate if sampled for the study (appendix 8). Subject to consent, they were asked to provide details about where they lived, the name of their household head, clan elder, and nearest primary school and other land marks. This information was used to trace the subjects in their villages during the home visits. The follow-up visits were carried out from 2nd May to 5th August 2007. Acceptance rate was high with only three subjects (0.4%) refusing to consent.

On Friday evenings, random numbers were assigned to all the cases recorded during the week. Using a table of random numbers, 50 cases were drawn each week. Each sampled case was matched with one control of the same sex and age, recorded during the same week. Where a suitable control was not identified among those recorded in the same week, selection was extended to the previous week. Thus sampled, the cases and controls were visited in their homes during the week following their attendance at Nduru health centre. To minimise recall biases, follow up duration was restricted to two weeks after the subjects visit to the health facility. If a case or control was not located within this duration, they were removed from the sample. To avoid information bias, enumerators were blinded on whether their interviewees were cases or controls.

Sample size

The sample size was calculated using a formula applied in a previous study in western Kenya (Munyekenye et al., 2005). Given that the study was done during the high malaria transmission season, a prevalence of 50% was assumed to get the best sample size. The sample size was calculated with a 95% confidence interval and a precision level of 5% using the formula:

$$n = \frac{z^2 (p * q)}{d^2}$$

where: n = required sample size

z = critical value of the standard normal distribution at the 5% level (1.96)

p = proportion of people with malaria (prevalence)

q = proportion of people without malaria

d = acceptance range of error in estimating the risks of malaria

(set at 5% or 0.05).

Applying the formula: $n = \frac{1.96^2 (0.5 * 0.5)}{0.05^2}$

n = 384

By the end of the study, 342 cases and 328 controls had been followed up. Cases and controls were sampled only once. Once interviewed, no other member of the household was eligible for recruitment into the sample. There was a short fall of 42 cases from the targeted 384 because the subjects' households had already been interviewed. At the analysis stage, fourteen cases were dropped because there were no suitable controls identified for them during the data collection phase. Additional eight cases and consequently, eight controls were dropped at the analysis stage because the pairs had been erroneously matched on sex. Only those pairs (320) that were adequately matched were included in both univariate and multivariate analysis.

2.2 Development and testing of research tools

A standardised questionnaire (appendix 1) containing open ended and closed questions was designed to collect data on demographic factors, malaria morbidity and mortality in the households, health seeking behaviour, preventive measures and socio-economic factors. The questionnaire was translated into Kisii language by an independent native speaker. To check the authenticity of the translation, another independent native speaker of Kisii language translated the questionnaire back into English.

Spot check forms were designed to collect data on the micro-ecological risk factors of malaria at the household level. Three different spot check forms were developed to investigate risk factors associated with housing characteristics, homestead surroundings and use of bed nets (appendix 2-4). The forms were designed in such a way that it was easy to record the observations by ticking yes or no against the features and characteristics outlined.

The questionnaire and spot check forms were pre-tested during the training period of enumerators. Seventeen pre-tests were conducted with malaria patients attending the health care facility prior to the survey period. Returned pre-test questionnaires and spot check forms were checked and discussions held with the respective enumerators. Unclear questions were reformulated and tested in the successive pre-tests until the final clear versions of the research tools were arrived.

2.2.1 Training of enumerators

Six enumerators (two men and four women) were recruited to conduct the surveys and spot checks. Five of the enumerators were recent college graduates in different fields which included two laboratory assistants, two nurses and one information technologist. The other enumerator had been involved in various surveys in the area. The enumerators underwent a two weeks intensive training on scientific data collection methods which included interviewing, spot checking and sketching techniques.

Enumerators were involved in simulated face to face interviews among themselves. The researcher evaluated the sessions and gave feedback to enable the trainees improve on the skills. Practical sessions on spot checking and homestead mapping were conducted in the homesteads of some of the enumerators. The enumerators were trained on how to look out for the features and characteristics outlined in the spot check forms and to record their presence or absence immediately. Special training was given on how to check and identify mosquito larvae in containers and stagnant water.

The enumerators then did spot checks and sketches of their own homesteads. The completed spot check forms were evaluated and discussed with the respective enumerators for improvement. Assimilation of all the skills and techniques taught was evaluated during the pre-tests surveys conducted as part of the training.

Training was enhanced throughout the study period by conducting brief interactive sessions every morning before departing to the field. Difficulties experienced in the field were discussed and solutions suggested by the group. Enumerators were instructed to telephone the researcher directly where there were doubts or situations which required her immediate attention. Motivation was maintained through holding weekly lectures on topics of general interest. Additionally, an excursion, a seminar on job interviews and how to write curriculum vitae were organised for the enumerators.

Figure 2.1 Enumerators in a training session

Quality of data collection was ensured through strict supervision by the researcher who accompanied the enumerators to the field and individually checked each completed questionnaire, spot check and homestead sketch for clarity and completeness. Incomplete questionnaires and spot check forms or those containing mistakes were returned to the respective enumerator for completion or clarification. Enumerators were given written instructions for reference during the data collection exercise (appendix 7).

2.2.2 Administration of the questionnaire

The questionnaire was administered in the local language through face to face standardised interviews with the wife or household head. In situations where none of them was available, information about their availability was sought from other members of the household and a revisit appointment made. Where a revisit was not feasible (for example deceased members or prolonged absence) then another adult member of the household was interviewed. When there was no other adult member available, a son or daughter (≥ 15 years) was interviewed. The duration of the interview was fixed to 30-40 minutes.

Demographic factors were investigated by recording the names of all the resident members of the household, their age, place of birth, and duration of residence in the study area. History of travel for the two weeks preceding the survey was investigated for all the members of the household. Frequency of travel outside the study area was sought and members involved recorded. These data were used as proxy measures to investigate whether the cases recorded may have been imported from outside the study area. The data were also useful in determining whether the cases recorded affected non-immune migrants originating from other districts. In addition to these demographic factors, data on educational level and occupation of all resident members of the households were recorded.

Health seeking behaviour was investigated by carrying out a detailed event analysis of the sickness episode for which the subject was sampled as a case or control. All forms and sources of treatment applied prior and after visiting the health care centre were recorded. Any other member(s) of the household who got sick with malaria in the two weeks preceding the survey plus the treatments they took were recorded. Respondents were asked if their households reserved any medicine at home for emergency purposes. If so, they were asked to show the medicines to the enumerator. The names of the medicines and their expiry dates (if available) were recorded.

Data on preventive measures was collected by asking the respondents if members of their household protected themselves from mosquito bites. If the answer was in the affirmative, they were asked to say how they protected themselves. The questionnaire incorporated a bed net survey which gathered data on ownership of these devices. The number of bed nets, whether or not they had been treated with insecticide, their cost and where they were obtained from were recorded. Bed net use was investigated by asking and recording the names of all members of the household who slept under a net during the previous night. Indoor residual spraying was investigated by asking the respondents if their houses had been sprayed with insecticide to kill mosquitoes.

Perceptions were investigated by asking the respondents what they thought caused malaria. Respondents were further asked how they thought the disease was transmitted and how it could be prevented. All responses given were recorded in the order in which they were mentioned. Concluding the perceptions section, respondents were asked to rate the seriousness of malaria based on a three level scale: serious, not very serious or very serious.

Details of the households' socio-economic characteristics were recorded based on ownership of selected household goods and assets. Given that the study population comprised of rural people, many of them without a regular income, this was considered a more feasible way of assessing the socio-economic status. A detailed inventory of cash crops grown, domestic animals kept and durable goods owned by the household was filled in at the end of the face to face interview. The inventory was developed after discussions with key informants on what goods and assets best indicated the measure of socio-economic status of a household in the area. In addition to the inventory, nutritional status was assessed by asking and recording the number of usual meals consumed by the household per day and whether they had enough food supplies throughout the year. If a household did not have enough supplies, respondents were asked to state the months in which they encountered food shortages.

2.3 Spot checks

After administering the questionnaire, the enumerators filled in the spot check forms by looking out for the features outlined and recording (by ticking yes or no) their presence or absence as appropriate. The duration of spot checks ranged between 30 and 60 minutes depending on the size of the household, closeness to water collection points and proximity to other risk factors like swamps, fishponds and local sugar cane processing units popularly referred to as “jagerries”.

2.3.1 Housing characteristics

A standardised spot check form (appendix 2) was designed to record data on housing conditions of the survey households. Data collection involved direct observation and recording the number of housing units owned by household. The names of household members sleeping in each unit were recorded. The type of walls, roofs, floors, windows and doors were recorded for each unit. The condition of the houses was checked and recorded for presence or absence of eaves, cracks on the walls, openings on the roof, ceilings and curtains. Other factors checked inside the houses included presence of potted plants and water storage containers. Some water was drawn from the inner walls of the containers and checked for mosquito larvae. Figure 2.2 to 2.6 show some housing characteristics observed during the spot checks.

Figure 2.2 Uncovered ventilation holes

Figure 2.3 A broken grass-thatched roof

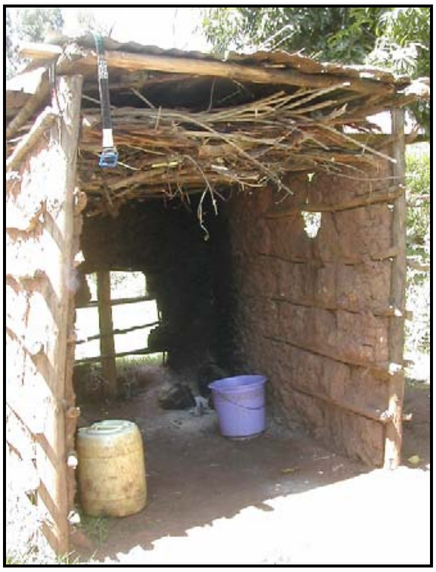
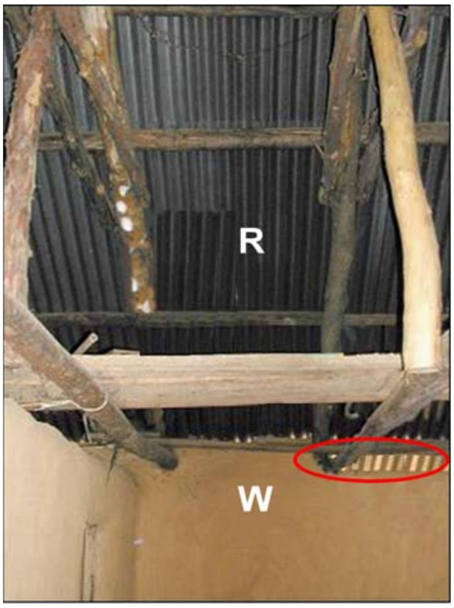


Figure 2.4 Open-walled house

Figure 2.5 Window fixed with old pieces of metal



Overhanging roof (R); Wall (W) ; Eaves (circled in red)

Figure 2.6 Eaves between roof and walls

2.3.2 Homestead surroundings

A standardised spot check form (appendix 3) was used to record the topographical features, crops and vegetation around the survey homesteads. Garbage/waste water disposal places, utensils racks and animal stalls were checked and recorded for presence of stagnant water, puddles, ditches, mosquito larvae and containers that could hold water. Figure 2.7 to Figure 2.12 show some of the observations made. The nearest source of domestic water was visited and checked for stagnant water, mosquito larvae and vegetation surrounding it. Distance to the water source was measured and recorded in paces. Respondents were asked about the presence of swamps, brick-making sites, fish ponds or local sugarcane processing units (jaggery) near the homesteads. If any of these features was present, the place was visited and its distance from the home measured in paces. During the data entry, all distances recorded in paces were converted to meters (one pace was equivalent to 0.7m).

Figure 2.7 Crops grown very close to the house

Figure 2.8 Stagnant water around a house

Figure 2.9 A homestead built on a valley bottom

Figure 2.10 Stagnant water formed by animal hoof prints

Figure 2.11 Homesteads close to a swamp

Figure 2.12 Fish ponds near a homestead

2.3.3 Bed net spot check

Following up on the bed nets survey (section 2.2.2); a detailed spot check (appendix 4) was done on all bed nets in the households. This involved an examination of the bed net condition considering cleanliness, holes/ tears and whether it was hung up around the sleeping area (Figure 2.13 and Figure 2.14). Bed nets that had not been opened and those used for other purposes e.g. curtains and decorations were also recorded and spot checked.

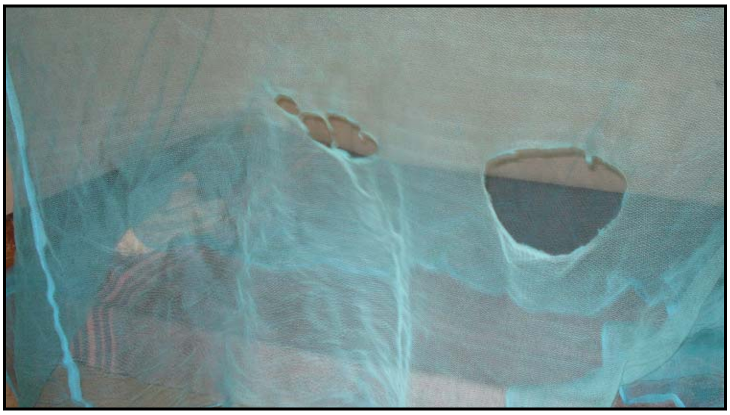


Figure 2.13 A torn bed net

Figure 2.14 A bed net used for decoration

2.3.4 Homestead sketching

A sketch showing the layout of the homestead was drawn. Standardised symbols (Figure 2.15) were used to show the location of different structures and facilities within the homestead. These included housing units (main house, separate kitchen, houses for dependant children), granaries, animal stalls, compost pit, vegetable garden and latrine. Water sources like bore holes or taps located within the vicinity of the homestead were also shown.

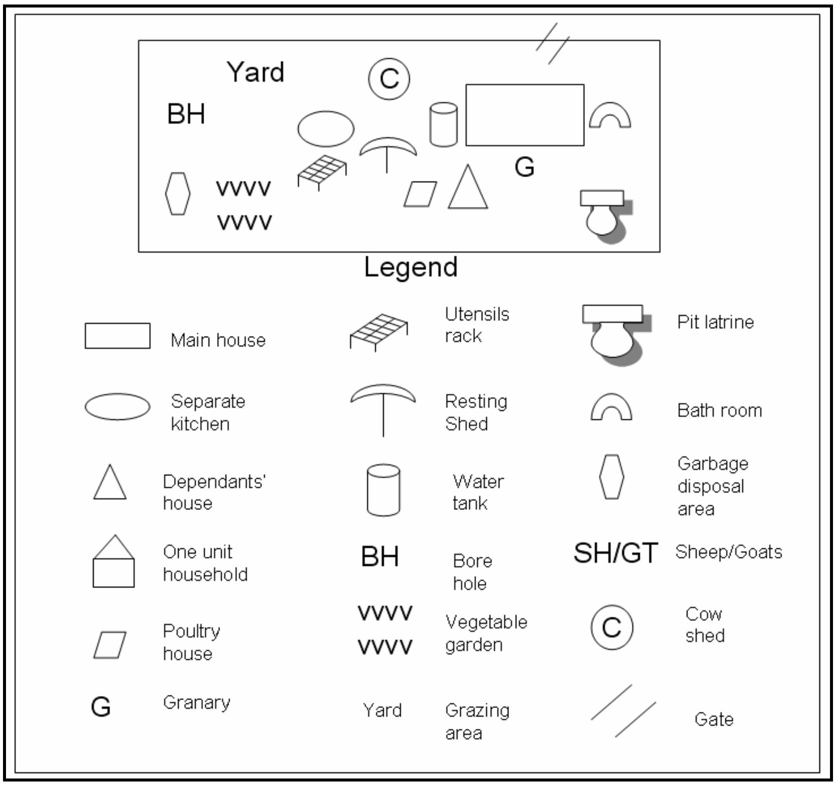


Figure 2.15 Homestead sketch map

2.3.5 GPS mapping

Location and elevation of the survey homesteads was determined using a hand-held global positioning system GPSMAP® 60 which gives the positional accuracy within <15 m. The location of Nduru health centre and three other dispensaries in the study area were also determined. Coordinates were taken for the boundaries of major swamps in the area. A swamp was defined as a low lying area with frequent standing water during the rainy season (Staedke et al., 2003).

ArcGIS 9.1 was used to visually display the distribution of the cases and controls. Proximity to swamps, rivers, steams, roads and tracks were determined by measuring the nearest distance of the survey homesteads to these features. All distances were measured from a digitized map of the study area.

2.4 Community interviews

Four community interviews were held to gather the general perceptions about health, disease and malaria in particular. One of the research assistants was trained to facilitate the community interviews. One interview involved community leaders drawn from different groups which included a women's group, a widows/widowers association and different church groups. A retired teacher and chair person of a women's group was contacted and requested to call a meeting of the leaders of the other groups. These leaders were considered to represent the views of their group members. The participants were asked to assemble at the grounds of the local health centre for a discussion on health matters affecting the community.

The other three community interviews were conducted with patients and/or their accompanying carers awaiting treatment at each of the small dispensaries situated in the study area. This was done to capture perceptions and views of communities lying beyond the catchments area of Nduru health centre, the health facility selected for the study. Arrangement was made with the health care personnel working in those dispensaries to schedule the interviews during days set aside for routine child immunization. These days were characterized by an increased number of patients making use of the routine visit to seek treatment for minor illnesses.

The interviews took the form of general questions directed to lead to an open discussion related to the research objectives. The sessions were organised into five major themes (appendix 5). Starting with questions seeking general perceptions on health and disease, participants were directed to name the common diseases in their area. Volunteers from the group listed the names of the diseases on large sheets of paper fixed on the wall. After listing, the sheets were removed and participants asked to identify the five most common diseases. A vote was taken to rank the five diseases in order of importance.

A general discussion on the causes, symptoms, prevention and treatment of malaria was initiated after the disease ranking exercise. The interviews ended with a social mapping exercise where the participants marked the location of their homes relative to the health facility, major roads, rivers, schools and other important social amenities.

Figure 2.16 Participants in a community interview

Figure 2.17 A social mapping exercise

2.4.1 Interviews with key informants

Before the onset of the field research, semi-structured interviews were conducted with key informants in the area. The district health information systems officer and the district public health officer of Gucha district were interviewed. A projects manager and a field officer of Merlin (an NGO which had conducted malaria control programmes in Gucha and Kisii central districts) were also interviewed. These interviews provided variable information on the situation of malaria in the district and facilitated decisions on selection of Nyamarambe division as the specific study site.

At Nduru health centre, semi-structured interviews were conducted with the clinical officer in charge of the facility, the chief nursing officer, a nurse and a public health officer. All the experts were asked what they thought were the factors underlying the observed situation of malaria in the area. In addition, questions on malaria control, diagnosis and treatment were asked (appendix 5).

2.4.2 Data mining

Malaria data from 1998 to 2007 were obtained from Kisii district health information system (HIS) department. Climate data (monthly rainfall and monthly maximum and minimum temperature) for the same period were obtained from the Kisii meteorological station.

Data on malaria control activities in the study area were obtained from the Ministry of Health in Gucha district. Reports from the International Centre for Insect Physiology and Ecology (ICIPE) Kisii office provided useful background data on malaria situation in the area. Additional data were obtained from the Merlin. The Merlin malaria project was started in 1999 following severe malaria epidemics in Kisii and Gucha districts. Initially, the project focused on indoor residual spraying, distribution of insecticide treated nets and community awareness programmes. In 2001, the focus of the project shifted to capacity building where traditional birth attendants (TBA), shopkeepers, schools and medical personnel were trained on malaria prevention. Advocacy groups, malaria free days and theatre groups were initiated to create more awareness about the disease.

2.5 Summary of data collected

The main objective of this study was to examine the micro-ecological risk factors of malaria at the household hold level. Data for this objective were obtained from three spot check forms designed to record observations on conditions of the houses in which the subjects lived, immediate surroundings of the homestead, garbage/waste water disposal points and domestic water collection points. In addition, a sketch map was drawn to illustrate the micro-ecological aspects of each homestead. The second objective of the study was to analyse selected aspects of demographic and socio-economic factors that could pose a risk for malaria transmission. Data were collected through the administration of a standardised questionnaire. The third objective was to investigate the households' perceptions of malaria and how they respond to the disease in terms of health seeking behaviour and preventive measures. Data were obtained partly from the standardised questionnaires administered during the household survey and partly from semi-structured interviews with the area health care personnel and community members.

2.5.1 Data entry and processing

All data collected were entered into a relational data base using ACCESS 2000®. Data entries were manually checked for completeness and cross-checked through queries. Data collected from key informants and community interviews were transcribed and ordered according to themes. Data were exported to SPSS 16® where they were cleaned and categorical variables transformed into dummy variables. Indicator variables were created for questions with multiple answers. For the open ended questions, a detailed content analysis involving grouping of responses into categories of related answers was done. Dummy variables were then assigned to the categories formed. These data transformations were necessary for all the data collected to be analysed with logistic regression.

2.5.2 Variable classification

The outcome variable was defined as a case which was coded as 1 for malaria cases and 0 for the controls. Independent variables consisted of micro-ecological risk factors, behavioural and socio-economic factors investigated in the study. These were categorised into five major categories based on the study objectives (Table 2.2). Each variable was coded as 1 if the exposure was present and 0 when it was absent. Quantitative variables were categorised into classes and analysed as categorical variables.

Table 2.2 Classification of variables

Variable Category	Description
Housing factors	Type of house -brick or mud walled, corrugated iron sheet or thatched roof Condition of house e.g. eaves, broken roofs, cracked walls
Homestead surroundings	Vegetation around the homestead Animal stalls Utensils rack Garbage/ waste water disposal facilities Altitude Topography Water collection points Closeness to: swamps, fishponds, brick making sites and sugarcane jaggeries
Demographic factors	Age and sex Migration and seasonal movements Duration of residence in study area Staying outside at night Malaria mortality and morbidity
Socio-economic factors	Ownership of land and size Cash crops Domestic animals Health resources Education level Occupation Ownership of selected household goods
Behavioural aspects	Event analysis of last sickness episode Preventive measures Health seeking behaviour Knowledge and perceptions about malaria

2.6 Data analysis

Data were analysed using logistic regression. This is the standard method for analysis of data concerned with describing the relationship between a response variable and one or more explanatory variables. Logistic regression makes use of several variables that may be either numerical or categorical to predict the occurrence of an event by fitting data to a logistic curve. The logistic regression model differs from the linear regression model in that the outcome variable is binary or dichotomous. The following paragraphs highlight the general principles of logistic regression as explained by Hosmer and Lemeshow (2000).

In any regression problem the key quantity is the mean value of the outcome variable, given the value of the independent variable. This quantity is called the conditional mean that is the expected value of Y, given the value x. This is expressed mathematically as $E(Y \mid x)$ where Y denotes the outcome variable and x denotes a value of the independent variable. In linear regression this mean is expressed as an equation linear in x and it is possible for $E(Y \mid x)$ to take any value as x ranges between $-\infty$ and $+\infty$. With dichotomous data, the conditional mean must be greater than or equal to zero and less than or equal to 1 [i.e. 0 ≤ $E(Y \mid x)$ ≤ 1]. The change in $E(Y \mid x)$ per unit change in x becomes progressively smaller as the conditional mean gets closer to zero or 1. This is graphically displayed as an *S – shaped* curve.

A second important difference between linear and logistic regression models concerns the conditional distribution of the outcome variable. In linear regression, an observation of the outcome variable may be expressed as: $y = E(Y \mid x) + \varepsilon$. The most common assumption is that the errors, ε i.e. deviations from the mean follow a normal distribution with a mean 0 and some variance that is constant across levels of the independent variable. In the case of a dichotomous outcome variable, the value of the outcome variable given x may be expressed as: $y = \pi(x) + \varepsilon$. The errors ε, may assume one of two possible values. If y =1, then ε =1- $\pi(x)$ with probability $\pi(x)$, and if y = 0 then ε = -$\pi(x)$ with probability 1-$\pi(x)$. Thus, ε has a distribution with mean zero and variance equal to $\pi(x)$ [1-$\pi(x)$]. The conditional distribution of the outcome variable follows a binomial distribution with probability given by the conditional mean, $\pi(x)$. The logistic distribution is applied in the analysis of dichotomous outcome because of its mathematically flexible and easy to use function. Secondly, it lends itself to clinically meaningful interpretation. The specific logistic regression model used is expressed as:

$$\pi(x) = \frac{e^{\beta_0 + \beta_1 x}}{1 + e^{\beta_0 + \beta_{1x}}}$$ Equation 2.1

Central to this logistic regression model is the logit transformation of $\pi(x)$ which is defined as:

$$g(x) = In\left[\frac{\pi(x)}{1 - \pi(x)}\right]$$

$$= \beta_0 + \beta_1 x$$ Equation 2.2

The importance of this transformation is that the logit, $g(x)$, has many desirable properties of the linear regression. These include linear parameters which may be continuous ranging from $-\infty$ to $+\infty$. Hence, the general principles used in linear regression analysis are applied in logistic regression.

Fitting the logistic regression model to a set of data where the outcome variable is coded 0 or 1 requires estimating the unknown parameters i.e. β_0 and β_1. In linear regression, the method mostly used for estimating unknown parameters is least squares. The method uses those values of β_0 and β_1 which minimise the sum of squared deviations of the observed values of *Y* from the predicted values based on the model. The general method of estimation that leads to the least squares function under the linear regression model is called maximum likelihood.

In a very general sense, the method of maximum likelihood yields values for the unknown parameters which maximise the probability of obtaining the observed set of data. To apply the method of maximum likelihood, a function called the likelihood function is constructed. This function expresses the probability of the observed data as a function of the unknown parameters. The maximum likelihood estimators of these parameters are chosen to be those values that maximise this function. Thus, the resulting estimators are those which coincide most closely with the observed data.

In a logistic regression model where y is coded as 0 or 1, the expression for $\pi(x)$ given in the general logistic regression model (Equation 2.1) provides for an arbitrary value of $\beta = (\beta_0, \beta_1)$, the conditional probability that Y is equal to 1 given x. This is denoted as $P(Y=1 \mid x)$. It follows that the quantity 1-$\pi(x)$ gives the conditional probability that Y is equal to zero given x, $P(Y=0 \mid x)$. Thus for those pairs (x_i, y_i), where $y_i = 1$, the contribution to the likelihood function is $\pi(x_i)$, and for those pairs where $y_i = 0$, the contribution to the likelihood function is 1-$\pi(x_i)$, where the quantity $\pi(x_i)$ denotes the value of $\pi(x)$ computed as x_i. The contribution to the likelihood function for the pair (x_i, y_i) is expressed as:

$$\pi(x)^{y_i}\left[1-\pi(x_i)\right]^{1-y_i} \qquad \text{Equation 2.3}$$

Since the observations are assumed to be independent, the likelihood function is obtained as the product of the terms in the expression in Equation 2.3 and it is given as:

$$l(\beta) = \prod_{i=1}^{n} \pi(x_i)^{y_i}\left[1-\pi(x_i)\right]^{1-y_i} \qquad \text{Equation 2.4}$$

The principle of maximum likelihood requires using, as the estimate of β, the value that maximises the expression in Equation 2.4. To find the value of β that maximises $l(\beta)$, the value of $l(\beta)$ is differentiated with respect to β_0 and β_1 and the resulting expressions, known as likelihood equations, are set to zero as follows:

$$\sum\left[y_i - \pi(x_i)\right] = 0 \qquad \text{Equation 2.5}$$

$$\sum x_i\left[y_i - \pi(x_i) = 0\right] \qquad \text{Equation 2.6}$$

The value of *β* given by the solution to equations 2.5 and 2.6 is called the maximum likelihood estimate and is denoted as $\hat{\beta}$. This quantity provides an estimate of the conditional probability that Y is equal to 1, given that x is equal to $x_{i.}$ It represents the fitted or predicted value for the logistic regression model. The consequence of equation 2.5 is that the sum of the observed values of y is equal to the sum of the predicted (expected) values.

It is important to stress that the goal of any logistic analysis is to find the best fitting, most parsimonius, yet reasonable model to describe the relationship between the outcome variable and a set of independent variables. Considering the design applied in the present study, conditional logistic regression, which is useful in investigating the relationship between an outcome and a set of prognostic factors in matched case - control studies, was applied. The outcome variable is whether a subject is a case or a control. When there is one case and one control in a matched set, the matching is 1:1 while 1:n matching refers to the situation where there is one case and a varying number of controls in a matched set (Breslow, 1980, Hosmer and Lemeshow, 2000). The following section focuses on the specific characteristics of conditional logistic regression.

2.6.1 Conditional logistic regression

Conditional logistic regression obtains the slopes (betas) which represent the effect of the exposure of interest conditioning on the matching factors. It is called *conditional* since the effect of beta is defined conditional on the subject. By contrast, the effects of unconditional models are population averaged since they refer to averaging the entire population rather than individual subjects (Agresti, 2002). Conditional logistic regression differs from ordinary logistic regression in that the data are divided into groups. Within each group, the observed probability of positive outcome is predetermined due to the data construction such as matched case - control. Thus, the likelihood of the data depends on the conditional probabilities i.e. the probability of the observed pattern of positive and negative responses within a group, conditional to that number of positive outcomes being observed (Gould, 2000).

The most frequently used matched design is one in which each case is matched to a single control, thus there are two subjects in each stratum. In a single matched control per case, the sampling unit is the pair and the regression variables are the differences in exposure for the case versus control. In using conditional logistic regression, the matching variables are guaranteed to be uncorrelated with disease in the sample as a whole.

The stratum specific parameters are regarded as nuisance parameters and their estimation is not done. This changes the likelihood from one modelling the probability of the outcome to one modelling the probability of the covariate values (Hosmer and Lemeshow, 2000). Supposing that there are *K* strata with n_{1k} cases and n_{0k} controls in the stratum k, k = 1, 2,…*K*, the stratum – specific logistic regression model is given by

$$\pi_k(x) = \frac{e^{\alpha_k + \beta' x}}{1 + e^{\alpha_k + \beta' x}} \qquad \text{Equation 2.7}$$

where α_k denotes the contribution to the logit of all terms constant within the *k*th stratum i.e. the matching or stratification variables. If the vector of coefficients, β contains only the *p* slope coefficients, $\beta' = (\beta_1, \beta_2, \ldots \beta_p)$. Each slope then gives the change in the log odds for a one unit increase in the covariate holding all other covariates constant in every stratum.

The conditional likelihood for *k*th stratum is obtained as the probability of the observed data conditional on the stratum total and the total number of cases observed. In this setting, it is the probability of the observed data relative to the probability of the data for all possible assignments of n_{1k} cases and n_{0k} controls to $n_k = n_{1k}+n_{0k}$ subjects. The number of possible assignments of case status to

n_{1k} subjects among the n_k subjects, denoted as c_k, is given by the mathematical expression

$$c_k \binom{n_k}{n_{1k}} = \frac{n_k!}{n_{1k}!(n_k - n_{1k})!} \qquad \text{Equation 2.8}$$

Letting the subscript *j* denote any one of the c_k assignments, and letting subjects 1 to n_{1k} correspond to the cases and subjects n_{1k}+1 to n_k to controls indexed as *i* for the observed data and by i_j for the *j* th possible assignment, the conditional likelihood is given by:

$$l_k(\beta) = \frac{\prod_{i=1}^{n_{1k}} e^{\beta' x_i}}{\sum_{j=1}^{c_k} \prod_{i_j=1}^{n_{1k}} e^{\beta' x_{jij}}} \qquad \text{Equation 2.9}$$

where *β* is the only unknown parameter. The conditional maximum likelihood estimator for *β* is that value that maximizes the value of $l_k(\beta)$ (Hosmer and Lemeshow, 2000). The most frequently matched design is one in which each case is matched to a single control, thus there are two subjects in each stratum. To simplify the notation, let x_{1k} to denote the data vector for the case and x_{0k} the data vector for the control in the *k*th stratum of pair, the conditional likelihood for the *k*th stratum is given by:

$$l_k(\beta) \frac{e^{\beta' x_{1k}}}{e^{\beta' x_{1k}} + e^{\beta' x_{0k}}} \qquad \text{Equation 2.10}$$

Given the specific values for *β*, x_{1k} and x_{0k} this equation is the probability that the subject identified as the case is in fact the case under the assumption that there are two subjects one of whom is the case and the stratum specific logistic model is the correct one. If the data for the case and control are identical, then $x_{1k} = x_{0k}$, then (*β*) = 0.5 for any value of *β* (i.e. the data for the case and control are equally likely under the model). Thus, case-control pairs with the same value for any covariate do not help to distinguish which subject is more likely to be the case. This tends to occur frequently with dichotomous covariates where common values (concordant pairs) are most likely. When this is the case, the estimator is based on a small fraction of the total number of possible pairs.

To conclude, it has been noted that failure to account for matching in the analysis of data collected using matched case control design can and often results in conservatively biased estimates. Breslow and Day (1980) showed that even in a situation where both the matched and unmatched analysis tend to estimate correctly the true odds ratio, the conditional analysis has a higher log likelihood which suggests a better fit.

2.6.2 Model development

Univariate logistic regression is recommended as an essential first step in any model building process. It is a useful way to determine the strength of association between the outcome variable and any one of the covariates investigated in a study (Hosmer and Lemeshow 2000). Univariate analysis was done by forming 2 x 2 tables cross-classifying cases versus controls for all dichotomous covariates investigated. The general layout of a matched case-control 2 x 2 table takes the form shown in table 2.3, where *A* is the number of pairs (+ +) where both the case and control are exposed, *B* is the number of pairs (+ -) where only the case is exposed, *C* is the number of pairs (- +) where only the control is exposed and *D* is (- -) where both case and control are unexposed. The marginal totals *A* + *B* and *C* + *D* represent respectively the number of exposed and unexposed cases whereas the marginal totals *A* + *C* and *B* + *D* represent the corresponding numbers of exposed and unexposed controls. *N* denotes the total number of pairs, so that the total number of cases and controls is 2*N* (Schlesselman, 1982).

Table 2.3 General layout of matched case-control 2 x 2 tables

		Controls		
		+	-	Total
Cases	+	A	B	A + B
	-	C	D	C + D
	Total	A + C	B + D	N

Exposed (+), non-exposed (-)
Source: Schlesselman (1982)

As noted by Hosmer and Lemeshow (2000), the case control pairs with same value for any covariate are uninformative as they do not help to distinguish which subject is more likely to be a case. These pairs are essentially dropped from the analysis and the odds ratios are calculated from the discordant pairs only. Breslow and Day (1980) observed that the maximum likelihood estimator of the coefficient for a dichotomous covariate in a univariate conditional logistic regression model fit to 1-1 matched data is the log of the ratio of discordant pairs.

Variables for inclusion in the multivariate analysis were selected based on the odds ratios calculated from the 2 x 2 tables (outlined in Table 2.3). Any variable whose univariate test had a *p*-value ≤ 0.25 was considered a candidate for multivariate analysis. It has been shown that use of the traditional *p*-value of 0.05 often fails to identify variables known to be important (Mickey J.; Greenland, 1989, Hosmer and Lemeshow, 2000, Bendel, 1977). Furthermore, selection of variables based solely on statistical significance has been discouraged by various authors (Rothman, 1998, Vandenbroucke et al., 2007, Hosmer and Lemeshow, 2000). The authors recommend that decisions about excluding or including variables should be guided by knowledge or explicit assumptions on casual relations. For these reasons, each variable was carefully considered before making a decision on whether or not to include it in the multivariate analysis. These considerations were guided by observations made during the data collection together with knowledge gathered from published literature.

Multivariate analysis of variables significant at the univariate analysis was performed using conditional logistic regression to construct a parsimonious model that included only those factors which remained statistically significant in the presence of other significant factors. The importance of each variable was examined by comparing its odds ratio in the multivariate model with that contributed by a model containing only that variable. Variables which did not contribute to the model based on this criterion were excluded and a new model fit. The new model was compared to the previous one using the likelihood ratio test. The process of excluding, refitting and verifying was continued until a main effects model containing those variables that were statistically important was obtained.

The interactions among the variables in the main effects model were then assessed. Interaction exists when the association of an exposure with the risk of disease differs in the presence of another exposure (Vandenbroucke et al., 2007). The main objective of assessing interactions is to see how the joint effect of two exposures differs from their separate effects. A list of possible pairs of variables that had some scientific basis to interact with each other was made and their interaction variables created.

The interaction variables were then created as the arithmetic products of the pairs of main effect variables. The interaction variables were then added, one at a time, to the model containing the main effects and their significance assessed using the likelihood ratio test. Only those interactions that contributed to the model at the 0.05% level of significance were added to the model. Inclusion of a non-significant interaction term typically increases the estimated standard errors without changing the point estimates. The interaction term must therefore be statistically significant for it to alter both the point and interval estimates (Hosmer and Lemeshow, 2000). The interaction term that best improved the estimates of the variables in the main effects model was added into the final effects model.

2.6.3 Spatial point pattern analysis

As mentioned in section 2.3.5, the GPS coordinates of the survey homesteads were taken. The aim of the spatial analysis was to describe the point pattern distribution of the cases and controls. This was examined using the kernel density estimation. The kernel may be described as a moving three dimensional window which counts events per unit area. The window is defined to be of a fixed size and is centred on a number of locations in turn. This analysis is a partitioning technique where the incidents are partitioned into a number of different clusters. Mathematically, if ***s*** represents a vector location anywhere in a region *R* and $s_i \ldots s_n$ are the vector locations of the *n* observed events, then the intensity, λ(*s*) at *s* is estimated as:

$$\hat{\lambda}_\tau(s) = \sum_{i=1}^{n} \frac{1}{\tau^2} k\left(\frac{s - s_i}{\tau}\right) \qquad \text{Equation 2.11}$$

where $k(\ )$ represents the kernel weighting function which is expressed in standard form that is centred at the origin and having a total volume of 1 under the curve. This is then centred on *s* and stretched according to the parameter $\tau > 0$, which is referred to as the band width (Gatrell et al., 1996).

Figure 2.18 shows a graphic representation of the kernel density estimation. Distances to each observed event s_i that lies within the region of influence (as controlled by the band width (τ), are measured and contribute to the intensity estimate at ***s*** according to how close they are to *s*. Some form of raster display may then be used to represent the resulting intensity as a continuous surface showing how the intensity varies over a region *R* (Gatrell et al., 1996). The choice of the kernel band width strongly affects the density surface. A larger band width results in more points falling inside the larger neighbourhood. The main effect of a larger radius is that density is calculated considering a larger number of points, which can be situated further from the raster cell. This results in a more generalized output raster. On the other hand, reducing the band width results in an increasingly spiky estimate.

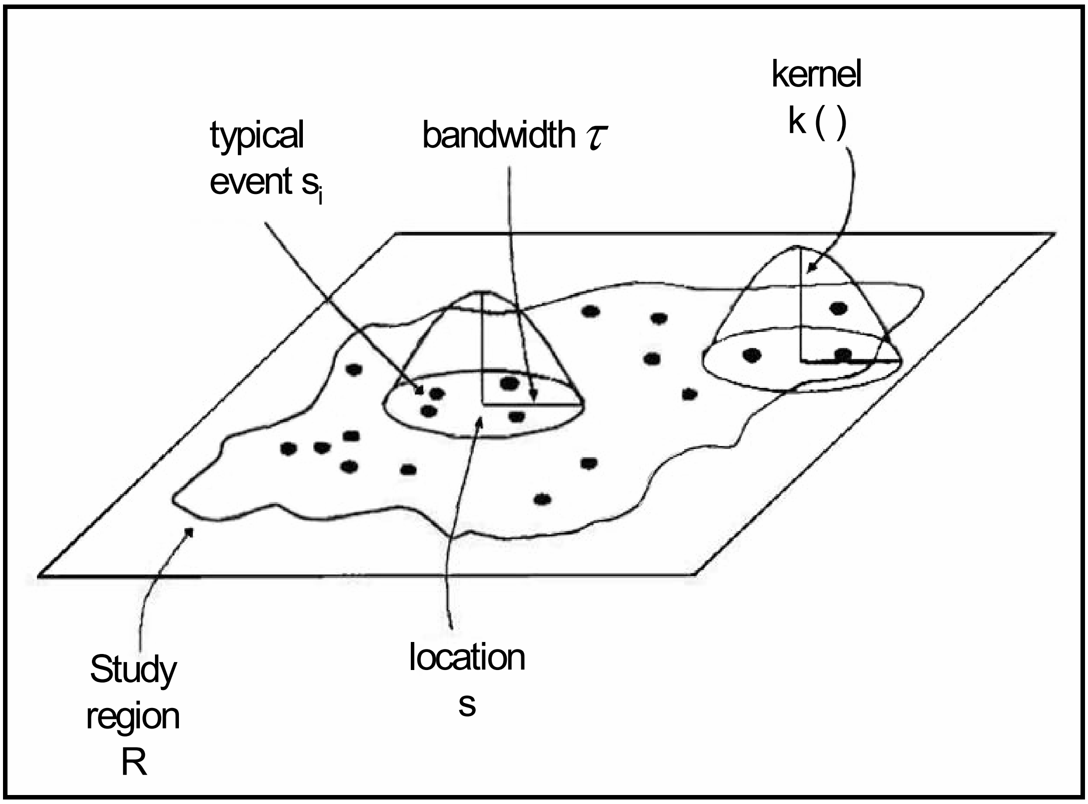


Figure 2.18 Kernel estimation of a point pattern
Source: Gatrell et al., (1996)

Kernel density calculates the density of point features around each output raster cell. Conceptually, a smoothly curved surface is fitted over each point. The surface value is highest at the location of the point and diminishes with increasing distance from the point, reaching zero at the search radius distance from the point. Only a circular neighbourhood is possible. The volume under the surface equals the population field value for the point, or one if none is specified. The density at each output raster cell is calculated by adding the values of all the kernel surfaces where they overlay the raster cell centre.

For epidemiological studies, the kernel density estimation is of most value in estimating the intensity of one type of event relative to another. In the present study, the separate kernel estimates relating to cases and controls were performed using a band width (r = 300 m) based on documented flight range of the anopheles mosquitoes.

2.6.4 Spatial clustering

The SaTscan^{TM} software (http://satscan.org/) was used to identify spatial clusters of malaria in the study area. The scan statistics are used to detect and evaluate clusters of cases in either purely temporal, purely spatial or space time settings. This is done by gradually scanning a window across time and/or space, noting the number of observed and expected observations inside the window at each location. The scanning window may be an interval (in time), a circle or an eclipse (in space) or a cylinder with a circular or ecliptic base (in space and time) (Kulldorff, 2009).

The standard purely spatial scan statistic imposes a circular window on the map. The window is in turn centred on each of several possible grid points positioned throughout the study region. For each grid point, the radius of the window varies continuously in size from zero to some upper limit specified by the user. In total the method creates an infinite number of distinct geographical circles with different sets of neighbouring locations within them. Each circle is a possible candidate cluster. For each location and size of the scanning window the alternative hypothesis is that there is an elevated risk within the window as compared to outside. The maximum spatial cluster size can be specified either as a percentage of the population used in the analysis or in terms of geographic size using the circle radius. The recommended choice is to specify the upper limit as a percent of the population at risk and to use 50% as the value (Kulldorff, 2009).

The scan statistics use different probability models depending on the nature of the data. For count data, discrete Poisson, Bernoullli and space time permutation models may be used. A discrete Poisson-model is used where the number of events in a geographical location is Poisson-distributed according to known underlying population at risk. A space time permutation model is used for case only data with information about the spatial location and time for each case. The model does not require information about controls or a background population at risk.

A Bernoulli model is used where there are cases and controls represented by a 0/1 variable. These variables may represent people with or without a disease, or people with different types of disease. They may reflect cases and controls from a larger population or they may together constitute the population as a whole.

The Bernoulli model requires information about the location of cases (case file) and controls (control file) provided in separate files. The model also requires a coordinates file providing the geographic coordinates for each location. The coordinates may be specified either using the standard Cartesian coordinate system or in latitude and longitude. Latitude and longitude coordinates must be given in decimal number of degrees. Coordinates specified in standard Cartesian coordinate system must be in the same units.

The likelihood function for the Bernoulli model is given by:

$$\left(\frac{c}{n}\right)^{c}\left(\frac{n-c}{n}\right)^{n-c}\left(\frac{C-c}{N-n}\right)^{C-c}\left(\frac{(N-n)-(C-c)}{N-n}\right)^{(N-n)-(C-c)} I() \quad \text{Equation 2.12}$$

where: ***C*** is the total number of cases,

c is the observed number of cases within the window,

n is the total number of cases and controls within the window,

N is the combined number of cases and controls in the data set.

The likelihood function is maximised over the window locations and sizes. The location with the maximum likelihood constitutes the most likely cluster. This is the cluster that is least likely to have occurred by chance. The likelihood ratio for this window constitutes the maximum likelihood ratio test statistic. Its distribution under the null hypothesis is obtained by repeating the same analytic exercise on a large number of random replications of the data set.

A *p*-value is assigned to the most likely cluster. The value is obtained through Monte Carlo hypothesis testing, by comparing the rank of the maximum likelihood from the real data set with the maximum likelihood from the random data sets. The number of Monte Carlo simulations is restricted to 999 or some other number ending in 999 so that it is always clear whether or not to reject the null hypothesis.

The *p*-values are adjusted for the multiple testing stemming from the multitude of circles corresponding to different spatial locations and sizes of potential clusters evaluated. This means that under the null hypothesis of complete spatial randomness there is a 5% chance that the *p*-value for the most likely cluster will be smaller than 0.05% and a 95% chance that it will be bigger. Under the null hypothesis there will always be some areas with rates higher than expected just by chance alone. Hence even though the most likely cluster always has an excess rate when scanning for areas with high rates, the *p*-value may actually be very close or equal to one (Kulldorff and Nagarwalla, 1995, Kulldorff, 1997, Kulldorff, 2009).

Although the scan statistic can scan for areas with high rates (clusters), areas with low rate or both, the common practice is to scan for high rate only. For purely spatial and space-time analyses, secondary clusters in the data set are identified in addition to the most likely cluster. These are ordered according to their likelihood ratio test statistic. There will almost always be a secondary cluster that is almost identical with the most likely cluster and that will have almost as high likelihood value (Kulldorff, 2009).

Applying the scan statistic to the present study, the Bernoulli model was the most suitable for the data. The model was run with 339 cases and 301 controls. (The GPS points of 30 homesteads were missing due to errors in the recording process). The coordinates were specified in the standard Cartesian coordinate system. A purely spatial analysis using the circular scanning window for areas with high rates only was done. The number of Monte of Carlo replications was set at 999. The maximum spatial cluster size was set at 50% of the population at risk.

Clusters identified were incorporated and displayed on a GIS map showing the distribution of malaria cases in the study area. Expected numbers and relative risks were calculated for the identified clusters. The relative risk is defined as the estimated risk within the cluster divided by the estimated risk outside the cluster. The observed/expected is the observed number of cases within the cluster divided by the expected number of cases within the cluster when the null hypothesis is true, that is when the risk is the same inside and outside the cluster.

In brief, the main method of analysis in this study was conditional logistic regression. However, some basic spatial methods were applied to display and analyse the distribution patterns of the cases and controls. Results of both types of analyses are presented in the following two chapters.

3 DESCRIPTIVE RESULTS

This chapter presents some background characteristics of the survey households focusing on the age, sex, educational attainment and occupation of the study subjects and the survey respondents. The socio-economic status of the households is assessed based on ownership of selected consumer goods and housing characteristics. Finally, some general trends of malaria and climatic factors in the study area are highlighted.

3.1 Demographic and socio-economic characteristics

The mean household size was slightly lower for the controls (5.43) as compared to the cases (5.51). Females comprised 56.6% of the survey subjects with males making up the remaining 43.4%. Children under the age of five comprised over half (52.6%) of the randomly sampled cases, implying their higher vulnerability to the disease. Infants (below one year) comprised 25.8% of the sample (Table 3.1).

Table 3.1 Demographic characteristics of the study subjects

	Cases n = 342		Controls n = 328		Total n = 670	
	n	%	n	%	n	%
Sex						
Male	153	44.7	138	42.1	291	43.4
Female	189	55.3	190	57.9	379	56.6
Age						
<1 year	85	24.9	88	26.8	173	25.8
1 to 5	95	27.8	93	28.4	188	28.1
>5	162	47.4	147	44.8	309	46.1

A slightly higher proportion of cases compared to controls had no formal education (Table 3.2). A higher percentage of controls as compared to cases had completed primary education. A higher proportion of controls compared to cases were involved in agriculture. There were slightly higher proportions of cases in formal employment compared to controls.

Table 3.2 Characteristics of study subjects by educational attainment and occupation

	Cases n = 342		Controls n = 328		Total n = 670	
	n	%	n	%	n	%
** Education*						
No formal education	33	9.6	24	7.3	57	8.5
Incomplete primary	83	24.3	87	26.5	170	25.4
Complete primary	75	21.9	82	25.0	157	23.4
Secondary education	75	21.9	78	23.8	153	22.8
College	11	3.2	7	2.1	18	2.7
In school pupil/student	65	19.0	50	15.2	115	17.2
** Occupation*						
Farming	240	70.2	253	77.1	493	73.6
Business	19	5.6	14	4.3	33	4.9
Casual labourer	6	1.8	2	.6	8	1.2
Formal employment	12	3.5	9	2.7	21	3.1
Pupil/student	65	19.0	50	15.2	115	17.2

*For children under 5 education and occupation of mother was considered

Table 3.3 presents the background characteristics of the survey respondents. These were mainly women (85.3%), most of them (68.8%) wives of the household heads. Male respondents comprised only 14.7%. The proportion of respondents with secondary education was slightly higher among the controls as compared to the cases but more respondents among the cases had acquired post secondary education. More respondents among the controls compared to the cases were involved in agriculture.

Table 3.3 Characteristics of survey respondents

	Cases n = 342		Controls n = 328		Total n = 670	
	n	%	n	%	n	%
Female	285	83.3	287	87.5	572	85.3
Male	57	16.7	41	12.5	98	14.7
Relationship to household head						
Household head	41	12.0	26	7.9	67	10.0
Wife	227	66.4	234	71.3	461	68.8
Son	15	4.4	15	4.6	30	4.5
Daughter	42	12.3	28	8.5	70	10.4
Other	17	5.0	25	7.6	42	6.3
Education						
No formal education	32	9.4	25	7.6	57	8.5
Primary incomplete	91	26.6	95	29.0	186	27.8
Primary complete	91	26.6	91	27.7	182	27.2
Secondary	83	24.3	87	26.5	170	25.4
Post secondary	14	4.1	6	1.8	20	3.0
Pupil/student	31	9.1	24	7.3	55	8.2
Occupation						
Farming	268	78.4	280	85.4	548	81.8
Pupil/Student	31	9.1	22	6.7	53	7.9
Business	23	6.7	12	3.7	35	5.2
Formal employment	13	3.8	10	3.0	23	3.4
Casual labourer	7	2.0	4	1.2	11	1.6

Table 3.4 shows the percentage of households of the cases and controls possessing selected durable goods. These goods were listed as indicators of socio-economic status together with other assets presented elsewhere in the regression analysis (section 4.2.2). The table shows that slightly higher

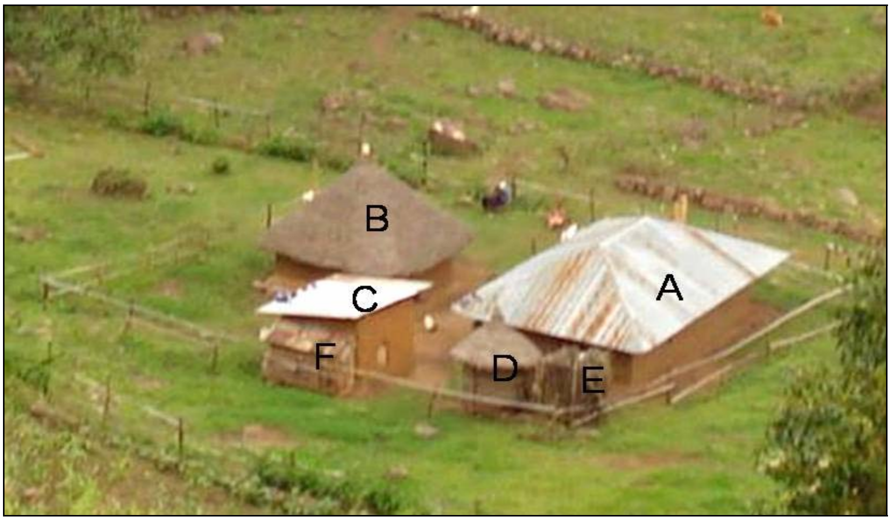
proportions of controls compared to cases owned valuable goods such as television, mobile phone, bicycle and car.

Table 3.4 Household characteristics by ownership of durable goods

	Cases n = 342		Controls n = 328		Total n = 670	
Good	n	%	n	%	n	%
Radio	270	78.9	254	77.4	524	78.2
Television	21	6.1	26	7.9	47	7.0
Mobile phone	108	31.6	110	33.5	218	32.5
Bicycle	20	5.8	26	7.9	46	6.9
Car	6	1.8	9	2.7	15	2.2
Sewing machine	17	5.0	10	3.0	27	4.0
Lantern lamp	237	69.3	229	69.8	466	69.6
Pressure lamp	49	14.3	31	9.5	80	11.9
Electricity	11	3.2	8	2.4	19	2.8
Clock	136	39.8	133	40.5	269	40.1
Sofa set	104	30.4	98	29.9	202	30.1
Kerosene stove	80	23.4	67	20.4	147	21.9
Gas cooker	12	3.5	10	3.0	22	3.3
Water storage tank	5	1.5	8	2.4	13	1.9

3.2 Housing characteristics

The survey households live in homesteads referred to as *bomas.* A typical *boma* consists of several housing units belonging to one family (Figure 3.1). These include a main house with a living room, a kitchen as a separate unit and one or more houses for dependant children. Poultry houses, cowsheds, granaries, pit latrines and other structures (highlighted in section 2.3.4) are usually located within the homesteads. Table 3.5 shows the housing units owned by the survey households. 52.4% of the households had two housing units made up of a main house and a separate kitchen. In addition to the main house and separate kitchen, 23.3% of the households had one or more houses for dependant children. 24.3% of the survey households lived in *bomas* with only one house. These were usually young families or very poor households. Nineteen one unit households cooked outside in the open air (Figure 3.2).



Main house (A); Separate Kitchen (B); Dependants' house (C);
Granary (D); Pit latrine (E); Poultry house (F)

Figure 3.1 A typical *boma* with several housing units

Figure 3.2 An open air kitchen

Before concluding this descriptive section of the survey characteristics, Table 3.6 gives an overview of the four community interviews (section 2.4) that were held in addition to the individual household surveys.

Table 3.5 Housing units owned by the survey households

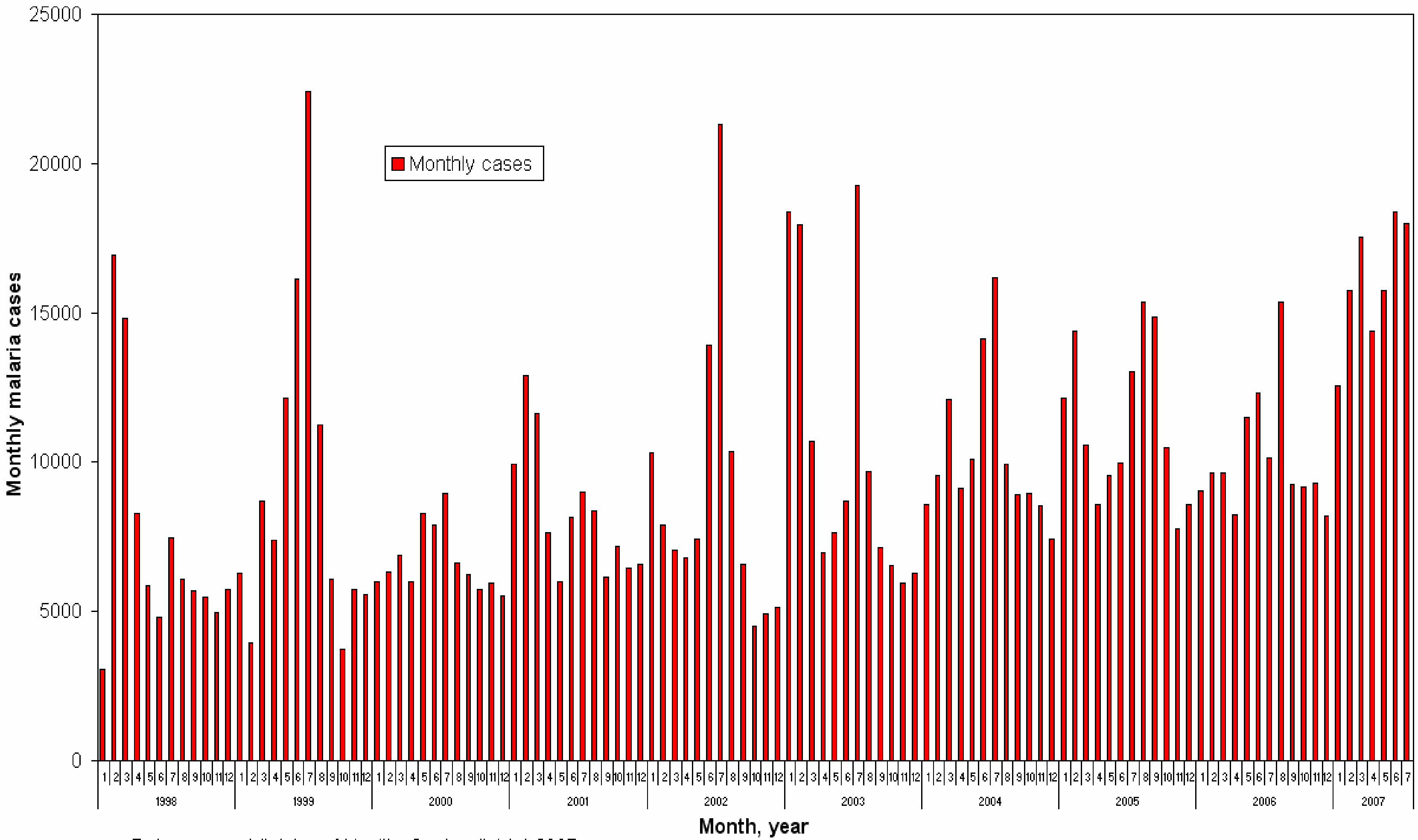
	Cases n = 342		Controls n = 328		Total n = 670	
	n	%	n	%	n	%
Housing units						
One unit	80	23.4	83	25.3	163	24.3
Main house, separate kitchen & dependants' house	83	24.3	73	22.3	156	23.3
Main house & separate kitchen	179	52.3	172	52.4	351	52.4

Table 3.6 Community interviews

Group	Place	Date	Duration	Number of participants Males	Females	Total
1	Nduru Health centre	17.07.2007	120 min	10	28	38
2	Boige dispensary	23.07.2007	90 min	6	14	20
3	Gotichaki dispensary	30.07.2007	90 min	3	12	15
4	Nyatike dispensary	07.08.2007	60 min	9	21	30

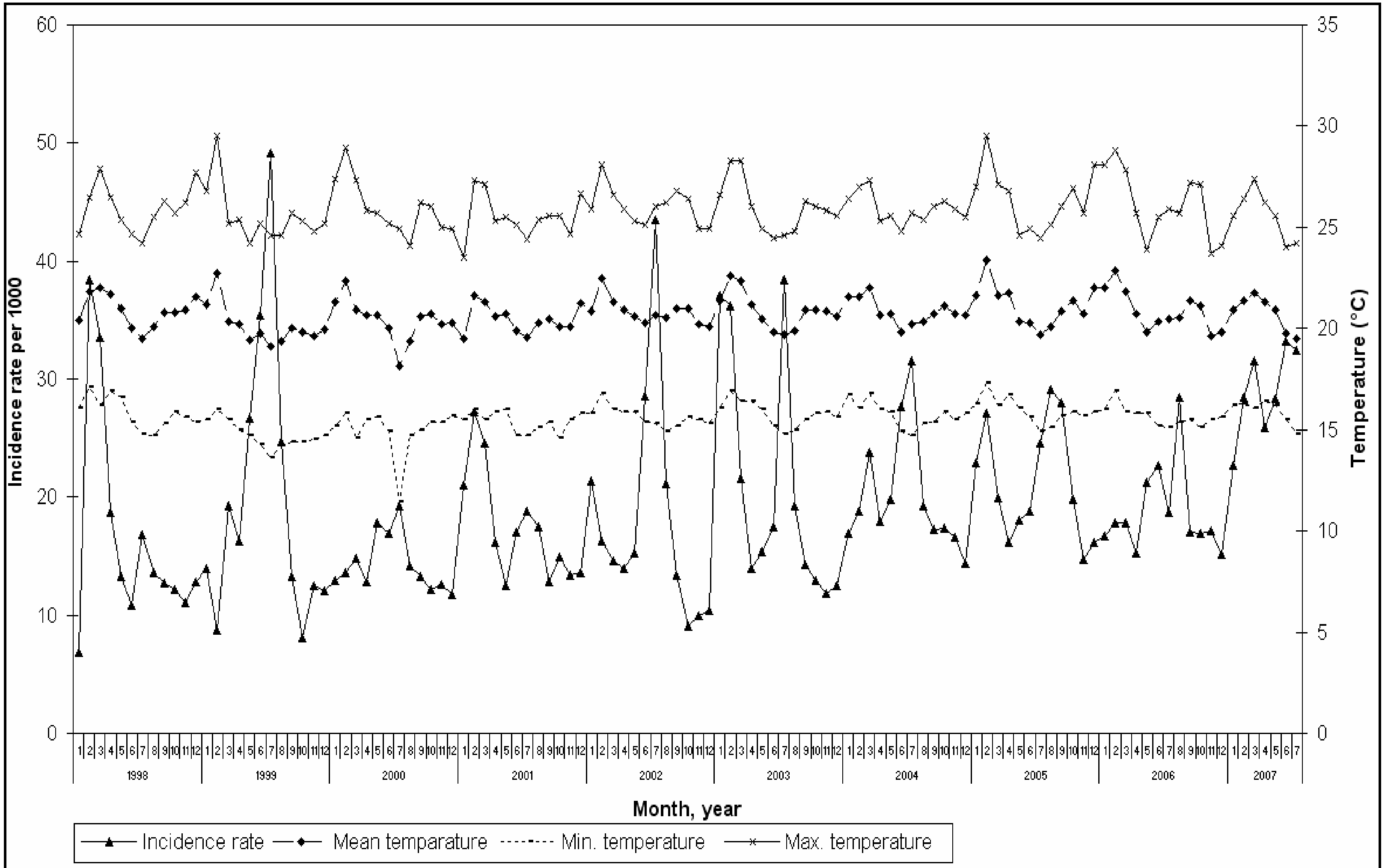
3.3 Malaria trends and climatic characteristics of the study area

In depth analysis of the links between climate and malaria is beyond the scope of this study. Nevertheless, some basic statistics were carried out so as not to overlook any obvious trends, if present. Figure 3.3 shows the number of malaria cases recorded in Gucha district from January 1998 to July 2007. Over the years, the number of malaria cases increased between May and July. Smaller peaks were recorded between February and March. The highest peaks were recorded in July 1999, 2002 and 2003. Monthly malaria incidence rates were calculated and plotted against the maximum and minimum temperatures (Figure 3.4). The three highest malaria peaks (July 1999, 2002 and 2003) coincided with maximum temperature of 24.6°C, 26.0°C and 24.6°C respectively. Figure 3.5 relates monthly malaria incidence rates with rainfall. The peaks in malaria cases appear to occur following a month of exceptionally high rainfall. Malaria peaks in July 1999, 2002 and 2003 were preceded respectively by 164 mm, 140 mm and 230 mm of rainfall.



Data source: Ministry of Health, Gucha district 2007

Figure 3.3 Malaria cases in Gucha district



Data source: Kisii meteorological station

Figure 3.4 Monthly malaria incidence rate and temperature

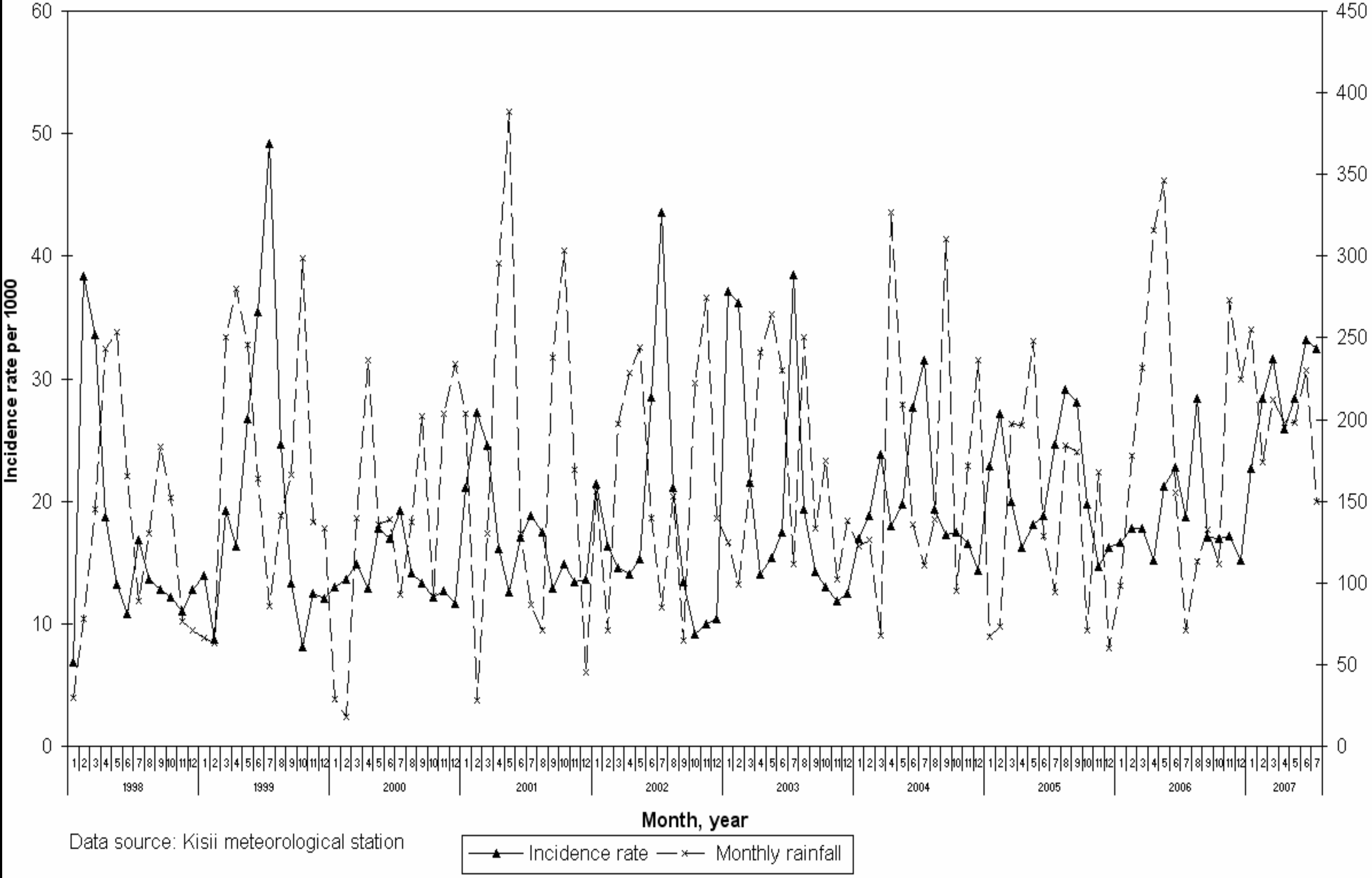


Figure 3.5 Monthly malaria incidence rate and rainfall

Bivariate correlations (Spearman's rho) between the climate variables and malaria incidences were performed. No significant correlations were found between climatic variables and malaria incidences. However, some significant correlations were found between pairs of different climatic factors: maximum temperature and mean monthly temperature r = 0.933; minimum temperature and mean monthly temperature r = 0.769; minimum and maximum temperature r = 0.512; maximum temperature and monthly rainfall r = -0.372; previous month rainfall and maximum temperature r = -0.4 (Table 3.7).

Table 3.7 Correlation matrix of climatic variables and malaria incidences

	Monthly malaria cases	Incidence rate per 1000	Monthly mean temperature	Minimum temperature	Maximum temperature	Monthly rainfall	Rainfall previous month
Monthly malaria cases	1.000						
Incidence rate per 1000	0.986**	1.000					
Mean temperature	0.038	0.003	1.000				
Minimum temperature	0.114	0.076	0.769**	1.000			
Maximum temperature	0.025	-0.002	0.933**	0.512**	1.000		
Monthly rainfall	-0.082	-0.088	-0.256**	0.060	-0.372**	1.000	
Rainfall previous month	0.019	0.005	-0.305**	-0.039	-0.400**	0.241**	1.000

** Correlation is significant at the 0.01 level

This chapter has described the characteristics of the survey households and some general trends of malaria and climatic factors in the study area. The following chapter focuses on statistical analysis of specific variables investigated in the study.

4 ANALYTICAL RESULTS

This chapter presents univariate and multivariate logistic regression analysis of the variables investigated in the study. Univariate analysis follows the variable subgroups outlined in Table 2.2. Variables selected in each subgroup are highlighted and the rationale for their inclusion (section 2.6.2) pointed out. The subsequent process of model development is then presented. A descriptive analysis of perceptions held by the survey respondents regarding malaria is given after the model results. Throughout the chapter, matched odds ratios (mOR) calculated on the basis of 320 matched pairs of cases and controls (explained in section 2.1) are presented.

4.1 Micro-ecological risk factors

Following the first objective of the study, this section presents univariate analysis of risk factors associated with housing conditions, homestead surroundings, home hygiene and domestic water collection points.

4.1.1 Housing factors

Table 4.1 shows the univariate logistic regression analysis of the risk of malaria based on the type and condition of house. Subjects who slept in the kitchen and the dependants' house had respectively 13% and 14% higher risk of getting malaria. In comparison, those who slept in the main house and one unit households had respectively 8% and 11% lower risk of getting malaria. Subjects living in houses with eaves showed a 25% higher risk of malaria, while those whose houses had cracks on the walls showed a 28% lower risk of getting the disease. The variables, eaves and wall cracks were selected for model development based on the magnitude of their odds ratios and experiences gathered during the data collection exercise.

Table 4.1 Malaria risk by condition of house

Variable	Cases n = 339[1] [n (%)]	Controls n = 325[1] [n (%)]	mOR	*p*-value	95% CI	
(i) Housing unit where subject slept						
Main house	156 (46.0)	155 (47.7)	0.92	0.57	0.66	1.26
Kitchen	94 (27.7)	79 (24.3)	1.13	0.51	0.77	1.67
Depend.Hse	45 (13.3)	52 (16.0)	1.14	0.56	0.71	1.83
One unit	44 (13.0)	39 (12.0)	0.89	0.60	0.58	1.38
(ii) Condition of house						
Roof						
Iron sheet	267 (78.1)	258 (78.7)	0.9	0.61	0.59	1.37
Grass	72 (21.1)	67 (20.4)	1	1		
Roof cracks	67 (19.6)	71 (21.6)	0.94	0.77	0.64	1.40
Walls						
Mud and sticks	307 (90.6)	296 (91.1)	0.9	0.69	0.51	1.56
Bricks	35 (10.4)	29 (8.9)	1.1	0.7	0.64	1.89
Wall cracks	**167 (49.2)**	**187 (57.5)**	**0.72**	**0.06**	**0.51**	**1.02**
Eaves	**315 (92.9)**	**297 (91.3)**	**1.25**	**0.45**	**0.67**	**2.37**
Floor						
Cemented	42 (12.4)	32 (9.8)	1.21	0.45	0.71	2.04
Earth	297 (87.6)	293 (90.1)	1	1		
Window material						
wood	297 (87.6)	284 (87.4)	1.03	0.9	0.64	1.62
glass	22 (6.5)	20 (6.2)	1	1		
other	20 (5.9))	21 (6.4)	0.58	0.26	0.22	1.48
Door material						
wood	321(94.7)	308 (94.8)	1	1		
metal	14 (4.1)	12 (3.7)	1.09	0.83	0.48	2.47
other	4 (1.2)	5 (1.5)	1	1		
Furnishings						
Ceiling	7 (2.1)	10 (3.1)	1	1		
Curtains	43 (12.7)	32 (9.8)	1	1		
Other conditions						
Water stored	294 (86.7)	295 (90.8)	0.66	0.1	0.38	1.12
Wet	45 (13.2)	38 (11.7)	1.19	0.47	0.72	1.96

[1] 6 subjects (3 cases and 3 controls) slept in houses not belonging to their households

4.1.2 Elevation and slope

The elevation of the survey homesteads ranged from 1,406 m to 1,876 m. This variable was grouped into 50 m intervals as shown in Table 4.2. The risk of malaria was high in the lower elevations (1,400 to 1,500 m). High risk was also observed between 1,601 m and 1,650 m. The table shows that subjects whose homesteads were built on sloping ground had a 17% lower risk of malaria compared to those living in homesteads located on flat ground.

Table 4.2 Malaria risk by elevation and slope

Variable	Cases n = 339 [n (%)]	Controls n = 301 [n (%)]	mOR	*p*-value	95% CI
[1]*Elevation*					
1400-1450	**23 (6.8)**	**11 (3.7)**	**1.7**	**0.18**	**0.78 3.71**
1451-1500	46 (13.6)	34 (11.3)	1.31	0.30	0.78 2.18
1501-1550	156 (46.0)	150 (49.8)	0.93	0.63	0.68 1.28
1551-1600	50 (14.7)	57 (18.9)	0.72	0.15	0.46 1.12
1601-1650	**29 (8.6)**	**15 (5.0)**	**2**	**0.06**	**0.97 4.12**
1651-1700	18 (5.3)	19 (6.3)	0.69	0.34	0.32 1.48
1700+	17 (5.0)	15 (5.0)	0.86	0.69	039 1.85
Slope					
Sloping ground	**160 (46.8)**	**171 (52.1)**	**0.83**	**0.25**	**0.60 1.16**

[1] GPS points of 30 households missing

Elevation 1,400 to 1,450 m and 1,601 to 1,650 m together with location of homestead on sloping ground were selected for multivariate analysis based on the magnitude of their odds ratio and *p*-value ≤ 0.25 as explained in section 2.6.2.

4.1.3 Proximity to breeding habitats

Where a homestead was located in proximity to swamps, brick-making sites, fishponds or jaggeries, the distance to the feature was measured as described in section 2.3.2. The distances were categorised broadly as ≤ 100 and > 100 meters based on documented flight range and breeding habits of *Anopheles* mosquitoes. Table 4.3 shows that the risk of malaria incidence decreased when the observed feature was over 100 m away from the homestead. Proximity to swamps was selected for multivariate model development based on the magnitude of its matched odds ratios and *p*-value set at ≤ 0.25 (section 2.6.2).

Table 4.3 Malaria risk by closeness to breeding habitats

Variable	Cases n = 342 [n (%)]	Controls n = 328 [n (%)]	mOR	*p*-value	95% CI	
Swamps	**65 (19.0)**	**52 (15.9)**	**1.29**	**0.23**	**0.83**	**2.05**
Jaggeries	143 (41.8)	133 (40.5)	1.01	0.93	0.73	1.40
Bricks making sites	53 (15.5)	50 (15.2)	1.04	0.82	0.67	1.64
Fishponds	27 (7.9)	24 (7.3)	1.13	0.66	0.62	2.07
Distance from risk features						
Swamps						
<100m	25	21	1	1	1	
>100m	40	31	0.86	0.7	0.41	1.83
Jaggeries						
<100m	55	59	1	1	1	
>100m	87	74	0.79	0.34	0.49	1.28
Brick-making sites						
<100m	21	20	1	1	1	
>100m	32	28	0.92	0.84	0.41	2.03
Fishponds						
<100m	5	8	1	1	1	
>100m	21	15	0.45	0.22	0.12	1.63

4.1.4 Home hygiene and vegetation

Twenty three variables were investigated in this category. These included garbage and waste water disposal facilities, presence of stagnant water, mosquito larvae, containers, crops and vegetation around the homesteads (Table 4.4). Presence of stagnant water at the waste disposal areas and utensils rack, empty containers, flowers and short grass around the homestead were selected for the multivariate analysis based on the magnitude of their odds ratios and *p*-value set at ≤ 0.25 (section 2.6.2).

Table 4.4 Malaria risk by home hygiene and vegetation

Variable	Cases n = 342 [n (%)]	Controls n = 328 [n (%)]	mOR	*p*-value	95% CI	
Garbage area						
Containers	188 (55.5)	178 (54.5)	1.02	0.87	0.74	1.43
Flies	142 (41.4)	132 (40.2)	1.09	0.6	0.77	1.60
Stagnant water	26 (7.6)	21 (6.4)	1.26	0.44	0.66	2.44
Larvae	3 (0.9)	5 (1.5)	0.6	0.47	0.09	3.08
Utensils rack						
Stagnant water	**44 (12.9)**	**31(9.5)**	**1.42**	**0.16**	**0.84**	**2.45**
Flies	63 (18.4)	53 (16.2)	1.18	0.4	0.77	1.82
Waste water area						
Stagnant water	**37 (10.8)**	**27 (8.2)**	**1.55**	**0.1**	**0.89**	**2.77**
Drainage	48 (14.0)	53 (16.2)	0.9	0.64	0.56	1.45
Containers	**137 (40.0)**	**110 (33.5)**	**1.33**	**0.08**	**0.95**	**1.87**
Flies	137 (40.1)	114 (34.8)	1.3	0.12	0.92	1.85
Larvae	6 (1.8)	4 (1.2)	1.5	0.52	0.36	7.23
Animal stalls						
Hoof prints	157 (45.9)	147 (44.8)	1.25	0.28	0.84	1.87
Stagnant water	63 (18.4)	63 (19.2)	1.03	0.88	0.68	1.56
Containers	45 (13.2)	47 (14.3)	0.98	0.96	0.62	1.56
Larvae	4 (1.2)	5 (1.5)	0.79	0.73	0.21	2.98
Vegetation around the homestead						
Flowers	**197 (57.3)**	**175 (53.4)**	**1.25**	**0.17**	**0.90**	**1.76**
Live fence	295 (86.3)	289 (88.1)	0.85	0.48	0.52	1.38
Crops	218 (63.7)	213 (64.9)	1	1		
Tall grass	112 (32.7)	103 (31.4)	1.03	0.85	0.71	1.49
Short grass	**288 (84.2)**	**263 (80.2)**	**1.3**	**0.21**	**0.84**	**2.02**
Trees	193 (56.4)	177 (54.0)	1.14	0.41	0.82	1.59
Bushes	81 (23.7)	70 (21.3)	1.14	0.49	0.77	1.70
Bare ground	265 (77.5)	245 (74.7)	1.14	0.46	0.80	1.65

4.1.5 Water collection points

Domestic water collection points were recorded and spot checked for stagnant water, mosquito larvae, containers and animal hoof prints. Although springs, streams and boreholes were the most common sources of water, households which fetched their water from rivers and taps had respectively 73% and 64% higher risk of malaria (Table 4.5). These two variables were selected for multivariate analysis because of their association with high risk of malaria.

Presence of stagnant water and mosquito larvae around domestic water collection points showed no positive association with increased risk of malaria.

Table 4.5 Malaria risk by sources of water

Variable	Cases n = 342 [n (%)]	Controls n = 328 [n (%)]	mOR	*p*-value	95% CI	
Water source						
Tap	**21 (6.1)**	**11 (3.4)**	**1.64**	**0.2**	**0.77**	**3.46**
River	**31 (9.1)**	**20 (6.1)**	**1.73**	**0.09**	**0.91**	**3.27**
Boreholes	118 (34.5)	103 (31.4)	1.1	0.56	0.79	1.51
Spring	188 (55.0)	189 (57.6)	0.88	0.49	0.63	1.24
Roof tops	95 (28.4)	82 (25.0)	1.14	0.45	0.79	1.65
Stream	114 (33.3)	109 (33.2)	1			
Condition of water collection point						
Stagnant water	239 (69.9)	245 (74.7)	0.77	0.13	0.53	1.10
Drainage	256 (74.9)	253 (77.1)	0.92	0.64	0.63	1.34
Larvae	76 (22.2)	86 (26.2)	0.85	0.36	0.58	1.23
Animals hoof prints	145 (42.4)	131 (39.9)	1.1	0.55	0.78	1.56

Closeness to rivers and streams was further assessed using GIS techniques. On a digitized map of the area, buffer zones of different sizes were created around the rivers and streams. Univariate analysis based on the number of case and control households in each buffer zone was done. Results show a decrease in malaria risk in the buffer zones 400 m and 500 m. None of the buffer zones was included in the multivariate analysis because the expected high risk associated with closeness to rivers and streams was rather low.

Table 4.6 Distance of homestead to river or stream

[1] *Distance*	Cases n = 339 [n (%)]	Controls n = 301 [n (%)]	mOR	*p*-value	95% CI	
Buffer zone in meters						
0 -100	44	34	1.05	0.85	0.65	1.68
101-200	57	44	1.2	0.39	0.78	1.84
201-300	56	42	1.18	0.44	0.76	1.82
301-400	51	52	0.75	0.18	0.49	1.15
401-500	44	56	0.69	0.1	0.45	1.07
> 500	87	73	1.2	0.31	0.83	1.72

[1] GPS points of 30 households missing

In brief, ten micro-ecological risks factors associated with house construction, altitude, topography, home hygiene and sources of domestic water showed strong associations with the risk of malaria. These variables were included in multivariate analysis along with demographic and socio-economic factors selected in the following section.

4.2 Demographic and socio-economic factors

In line with the second objective of the study, this section assesses the strength of association between malaria and demographic as well as socio-economic factors. Demographic variables include migration and seasonal movements, number of people in the household, sleeping patterns, malaria morbidity and mortality. Socio-economic status is analysed based on ownership of selected assets and households' food supplies. Other durable goods owned by the households were presented in Table 3.4.

4.2.1 Demographic factors

Table 4.7 shows that households in which some members had stayed outside at night had a 62% higher risk of malaria compared to those households where everyone remained indoors. Households with one to three persons had a 23% lower risk of malaria while those with four to six persons had a 31% higher risk of the disease. Households which went to bed after 9 p.m. had a 43% higher risk of malaria compared to those who slept earlier.

On mortality, nineteen households (2.8%) reported a malaria death in the previous one year preceding the survey. Respondents were probed on the age of the deceased and place of death. Five deaths were reported in children under the age of five. Three of the children died in hospital, one at home and one on the way to a hospital. Two of the deceased were adults aged 26 and 30 and the remaining 12 were aged between 40 and 66.

Table 4.7 Malaria risk by demographic factors and sleep patterns

Variable	Cases n = 342 [n (%)]	Controls n = 328 [n (%)]	mOR	*p*-value	95% CI	
Migration and seasonal movements						
Travel previous 2 weeks	69 (20.2)	69 (21.0)	0.89	0.57	0.60	1.33
Regular travel	84 (24.6)	101 (30.8)	0.68	0.03	0.46	0.99
Born in study area	314 (91.8)	307 (93.6)	0.82	0.52	0.41	1.60
Out at night	**40 (11.7)**	**24 (7.3)**	**1.62**	**0.08**	**0.94**	**2.79**
No. of people in household						
1 to 3	47 (13.7)	59 (18.0)	0.77	0.23	0.50	1.18
4 to 6	**211(61.7)**	**181(55.2)**	**1.31**	**0.1**	**0.94**	**1.81**
7+	84 (24.6)	88 (26.8)	0.86	0.4	0.59	1.23
Sleep patterns - bed time						
Bed time						
Before 9 pm	143 (41.8)	134 (40.9)	1.01	0.93	0.72	1.42
9 pm	150(43.9)	160 (48.8)	0.83	0.28	0.60	1.15
After 9 pm	**49 (14.3)**	**34 (10.4)**	**1.43**	**0.15**	**0.88**	**2.31**
Sleep patterns - get up time						
Before 6 am	44 (12.9)	46 (14.0)	0.94	0.81	0.58	1.51
6 am	229 (67.0)	212 (64.6)	1.07	0.68	0.77	1.47
After 6 am	69 (20.2)	70 (21.3)	0.95	0.78	0.65	1.37
Malaria morbidity and mortality						
Malaria deaths	6 (1.8)	13(4.0)	0.44	0.1	0.17	1.17
Other malaria cases in HH	95(27.8)	93(28.4)	0.96	0.85	0.68	1.37

Three variables: out at night, sleeping after 9 p.m. and 4 to 6 persons in the household were selected for multivariate analysis. Regular travel, household size category 1 to 3 and malaria deaths in the previous one year, though meeting the inclusion criteria of *p*-value ≤ 0.25, were not selected because of their negative association with malaria.

Other malaria cases in the households (apart from the ones sampled at the health centre) were investigated for the two weeks preceding the survey. Table 4.7 shows that case and control households reported similar numbers of malaria in the two weeks preceding the survey, implying no difference in the prevalence of the disease. To further investigate this, data were reconstructed to analyse the control households which reported any malaria in the two weeks preceding the survey as cases. Controls were defined as those households which did not have any malaria case in the previous two weeks. As a result, 435 households were defined as cases and 235 households as controls. Another reconstruction involved breaking the matched pairs and analysing the data using the unmatched logistic regression. Univariate logistic regressions were performed using the three different data constructions i.e. model with matching (mcc), model without matching (cc) and redefined cases (c435). Results, (Table 4.8) show similarities in odds ratios obtained from the three models except for the first two variables where the estimates for c435 model are much higher compared to the other two models. This could be attributed to the low number of controls compared to the cases. As no major differences were found in the three models, it was considered appropriate to continue analysis with the matched case-control design.

Similarly, subgroup analyses based on age and sex were done. Age was broadly categorised as under five and over five, as is commonly done in malaria studies. Univariate analyses were again performed using the study variables. Results, (appendix 6) showed similar associations to those of non-stratified analysis. However, there were some differences in the magnitude of odds ratios for some of the variables. Having found similar trends upon considering different classifications of the data set, analysis of the complete data was continued.

Table 4.8 Comparisons of different models

Variable	Model	odds ratio	*p*-value	95% C I	
Demographic variables					
	mcc	0.89	0.57	0.60	1.33
Travel last 2 weeks	cc	0.94	0.78	0.64	1.40
	cc435	1.24	0.27	0.82	1.91
	mcc	1.62	0.08	0.94	2.79
Out at night	cc	1.67	0.05	0.95	2.98
	cc435	2.82	0.001	1.41	6.11
Slope					
	mcc	0.83	0.25	0.60	1.16
Sloping ground	cc	0.8	0.16	0.58	1.10
	cc435	1.02	0.85	0.73	1.43
House characteristics					
	mcc	0.72	0.06	0.51	1.02
Wall cracks	cc	0.71	0.03	0.52	0.98
	cc435	0.75	0.08	0.53	1.04
	mcc	1.25	0.45	0.67	2.37
Eaves	cc	1.23	0.46	0.67	2.28
	cc435	1.17	0.59	0.61	2.17
Proximity to other risk factors					
	mcc	1.29	0.23	0.83	2.05
Swamps	cc	1.24	0.28	0.81	1.90
	cc435	1.26	0.28	0.80	2.00
	mcc	1.01	0.93	0.73	1.40
Jaggeries	cc	1.05	0.73	0.76	1.45
	cc435	1.02	0.89	0.73	1.43
	mcc	1.04	0.82	0.67	1.64
Bricks-making sites	cc	1.01	0.92	0.65	1.58
	cc435	0.95	0.84	0.60	1.52
Vegetation around the houses					
Short grass	mcc	1.3	0.21	0.84	2.02
	cc	1.19	0.58	0.72	1.72
	cc435	0.98	0.93	0.61	1.53
	mcc	1.25	0.17	0.90	1.76
Flowers	cc	1.1	0.53	0.80	1.51
	cc435	1.13	0.43	0.81	1.58

mcc: matched case-control model
cc: case -control model without matching
c435: case control model with 435 cases and 235 controls

4.2.2 Socio-economic factors

Table 4.9 shows that households which grew sugarcane had a 26% lower risk of malaria, while those who owned oxen had a 43% higher risk of the disease. Year round sufficient food supplies was associated with 33% lower risk of malaria.

Table 4.9 Malaria risk by socio-economic factors

Variable	Cases n = 342 [n (%)]	Controls n = 328 [n (%)]	mOR	*p*-value	95% CI	
Land						
Own land	331 (96.8)	320(97.6)	0.7	0.46	0.96	2.02
Cash crops						
Sugar cane	**192 (56.1)**	**202 (61.6)**	**0.74**	**0.05**	**0.54**	**1.01**
Horticulture	197 (60.1)	197 (43.9)	0.91	0.56	0.66	1.25
Coffee	42 (12.3)	36 (11.0)	1.06	0.80	0.65	1.73
Tea	22 (6.4)	18 (5.5)	1.18	0.61	0.61	2.30
Household items						
Ox plough	103 (30.1)	72 (22.0)	1.39	0.08	0.96	2.02
Latern lamp	105 (32.0)	78 (22.8)	0.94	0.73	0.67	1.32
Livestock						
Oxen	**94 (27.5)**	**64 (19.5)**	**1.43**	**0.05**	**1.00**	**2.04**
Dairy cows	222 (64.9)	208 (63.4)	0.98	0.93	0.71	1.36
Sheep	15 (4.4)	17 (5.2)	0.86	0.71	0.41	1.82
Goats	45 (13.2)	49 (14.9)	0.78	0.27	0.51	1.21
Poultry	291 (85.1)	268 (81.7)	1.21	0.35	0.80	1.82
Dogs	111 (32.5)	106 (32.3)	0.95	0.79	0.68	1.34
Food supply						
Sufficient food supply	**159(46.5)**	**181 (55.2)**	**0.67**	**0.01**	**0.49**	**0.92**

Growing sugarcane, keeping oxen and having sufficient food supplies were selected for the multivariate analysis based on the magnitude of odds ratios in addition to *p*-value set at ≤ 0.25. Possession of ox plough, though meeting the inclusion criteria, was not selected because it was closely related with ownership of oxen.

In brief, from the socio-economic and demographic factors, six variables (three demographic and three socio-economic) were selected for multivariate analysis. In line with the third objective of the study, the following section proceeds to consider behavioural factors.

4.3 Behavioural factors

Health seeking behaviour, proximity to health care and use of preventive measures were considered in this analysis.

4.3.1 Health seeking behaviour

A number of factors presumed to influence health seeking behaviour were analysed. These included: self treatment prior to visiting the health care facility, days of sickness before seeking treatment, cost of treatment, medicine kept at home and accessibility to health care centre.

Prior/self treatment

Table 4.10 shows that 30% of the subjects applied self treatment prior to visiting the health care facility. Self treatment involved buying medicine from local shops, taking medicine left over from previous prescriptions and use of traditional herbs. A small proportion of those who reported prior treatment had been to other health care facilities. There were no significant differences between the cases and controls on measures of self treatment.

Subjects or their carers were asked to name the medicines or herbs they took for self treatment. Content analysis of answers given showed that 48% of the subjects took Panadol®, an analgesic drug. Nine out of 102 cases had taken anti-malaria drugs. Six of them had taken Amodiaquine® (a form of combination therapy recommended for malaria) and the remaining three had taken Fansidar®, (a form of *Sulphadoxine Pyrimethamine* recommended for malaria prevention).

Medicine at home

22.8% of the cases, compared to 31.7% of controls kept medicine at home for emergency use (Table 4.10). The table shows that the risk of malaria was 38% lower in households which kept medicine compared to those which did not. Analysis of the type of medicines kept showed that storage of anti-malaria drugs was considerably low in both case and control households. Analgesics were the most commonly stored drugs. A significantly higher proportion of controls (28.4%) compared to cases (19.3%) stored analgesic drugs. The risk of malaria was 40% lower for the households which kept these drugs.

Table 4.10 Event analysis of last sickness episode

Variable	Cases n = 342 [n (%)]	Controls n = 328 [n (%)]	mOR	*p*-value	95% CI	
Prior treatment	102 (29.8)	99 (30.2)	1.01	0.92	1.71	1.44
Measure applied						
Bought medicine	50 (14.6)	47 (14.3)	1.10	0.65	0.71	1.71
Left over medicine	24 (7.0)	24 (7.3)	0.95	0.87	0.51	1.75
Traditional herbs	16 (4.7)	16 (4.9)	0.85	0.67	0.39	1.85
Visited other health facility	18 (5.3)	13 (4.0)	1.36	0.45	0.62	2.96
Medicine kept at home						
Any medicine stored	**78 (22.8)**	**104 (31.7)**	**0.62**	**0.01**	**0.43**	**0.89**
Anti - malaria	13 (3.8)	13 (4.0)	0.91	0.83	0.40	2.07
Analgesics	**66 (19.3)**	**93 (28.4)**	**0.60**	**0.01**	**0.42**	**0.88**
Antibiotics	21 (6.1)	19 (5.8)	1.10	0.73	0.58	2.15
Others	17 (5.0)	8 (2.4)	2.00	0.11	0.85	4.67
Days of sickness before visit to health centre						
1	60 (17.5)	50 (15.2)	1.12	0.58	0.73	1.72
2	112 (32.7)	118 (36.0)	0.88	0.49	0.63	1.24
3+	170 (49.7)	160 (48.8)	1.03	0.81	0.76	1.70
Cost of treatment (in Kenya shillings)						
0-50	290 (84.8)	285(86.9)	0.89	0.64	0.57	1.42
51 - 100	23 (6.7)	26 (7.9)	0.76	0.41	0.39	1.46
100+	29 (8.5)	17 (5.2)	1.52	0.17	0.82	2.82

17.5% of malaria cases received treatment within 24 hours of onset of symptoms (Table 4.10). On average, malaria cases went to Nduru health centre after three days of sickness. Comparing the costs of treatment, the table shows that slightly higher proportions of controls paid between 0 -100 Kenya shillings. However, the proportion of cases that paid more than 100 shillings was higher than that of controls.

Two variables; any medicine at home and treatment cost over 100 Kenya shillings were selected for the subsequent model development based on the magnitude of their odds ratios and *p*-value ≤ 0.25. The category of analgesics drugs, though meeting the inclusion criteria, was not selected because it was already included in the larger category of medicine kept at home.

4.3.2 Accessibility to health care centre

Distances from the survey homesteads to the health centre together with proximity to roads and motorable tracks were considered useful determinants of accessibility. Straight line distances from the survey homesteads to Nduru health centre (Figure 4.1) were measured from a digitized map of the area.

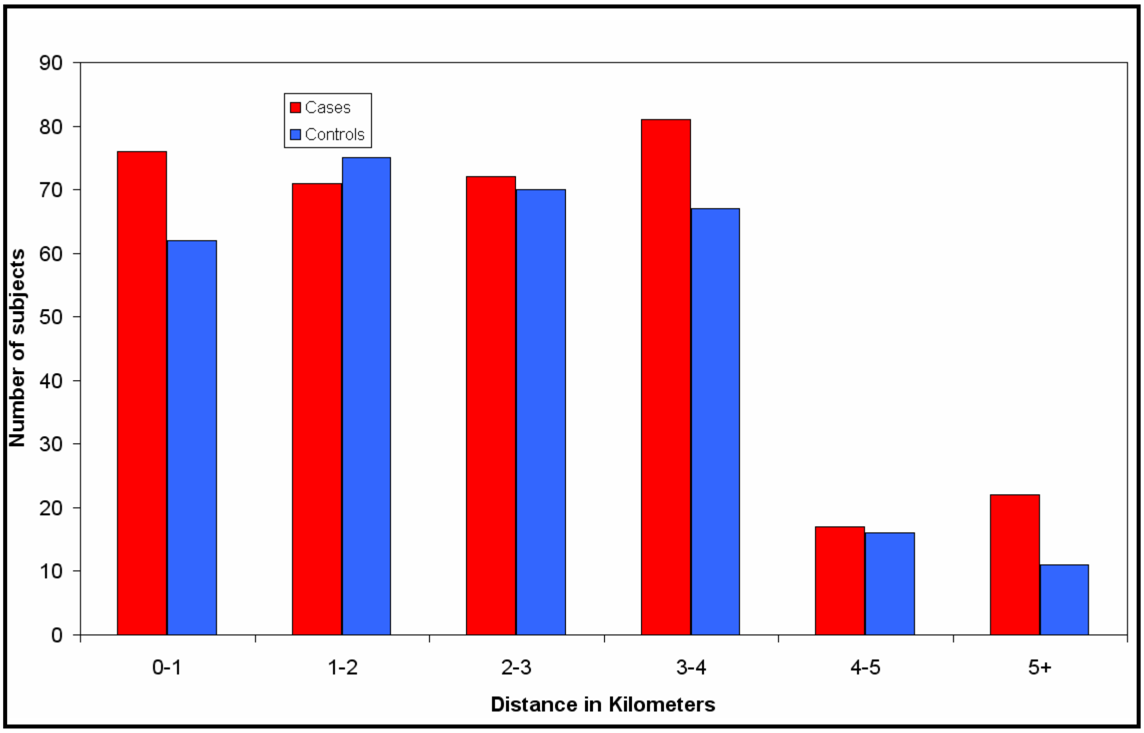


Figure 4.1 Distance to Nduru health centre

Univariate analysis showed a higher risk of malaria for those households located in categories 0-1 and >5 km from the health centre (Table 4.11). The mean distances show that compared to controls, the cases lived slightly further away from the health centre. The category of those who lived more than 5 km to the health centre was chosen for multivariate analysis.

Table 4.11 Distance to health care centre

	Cases n = 339 [n (%)]	Controls n = 301 [n (%)]	mOR	*p*-value	95% CI
[1] *Distance to health centre*					
<1km	76 (22.4)	62 (20.6)	1.19	0.37	0.81 1.76
1.1 - 2km	71 (20.9)	75 (24.9)	0.88	0.51	0.61 1.27
2.1 - 3km	72 (21.2)	70 (23.3)	0.87	0.49	0.59 1.29
3.1 - 4km	81 (23.9)	67 (22.3)	1.00	1.00	1.00
4.1 - 5km	17 (5.0)	16 (5.3)	0.93	0.85	0.45 1.93
5+	**22 (6.5)**	**11 (3.7)**	**1.70**	**0.18**	**0.77 3.71**
Mean distance (km)	2.41	2.34			

[1]GPS points for 30 homesteads missing

Proximity to roads and tracks

Table 4.12 shows that the risk of malaria was higher for the households living within a radius of 500 m from motorable track and road. Beyond the 500 m radius to tracks and roads, the number of cases and controls visiting the health centre decreased considerably. However, none of the categories fulfilled the selection criteria for multivariate analysis.

Table 4.12 Proximity to road and tracks

Proximity	Cases n = 339 [n (%)]	Controls n = 301 [n (%)]	mOR	*p*-value	95% CI
Distance to track (m)					
0-500	214 (63.1)	187 (62.1)	1.09	0.56	0.79 1.51
501 -1000	113 (33.3)	106 (35.2)	0.91	0.56	0.65 1.25
1000+	12 (3.5%)	8 (2.7)	1	1	1
Distance to road (m)					
0 - 500	147 (43.4)	119 (39.5)	1.16	0.36	0.83 1.61
501-1000	85 (25.1)	84 (27.9)	0.93	0.71	0.64 1.34
1001-1500	42 (12.4)	40 (13.3)	0.91	0.71	0.56 1.47
1501-2000	26 (7.7)	17 (5.6)	1.31	0.41	0.68 2.51
2001-2500	13 (3.8)	10 (3.3)	1.11	0.81	0.45 2.73
2501-3000	15 (4.4)	18 (6.0)	0.66	0.32	0.29 1.08
3001+	11 (3.2)	13 (4.3)	0.54	0.23	0.20 1.47

4.4 Preventive measures

Protection from malaria was reported in 635 (94.8%) of the survey households. Nearly all the households reporting protection used mosquito nets. Table 4.13

shows actual protective methods reported in the survey households. The term actual is used to distinguish from perceived methods (Table 4.26).

Table 4.13 Actual methods of protection against malaria

	Cases n = 326 [n (%)]	Controls n = 309 [n (%)]	Total 635 [n (%)]
**Protective methods*			
Mosquito nets	314 (96.3)	306 (99.0)	620 (97.6)
Spray	11 (3.4)	13 (4.2)	24 (3.8)
Mosquito repellants	4 (1.2)	9 (2.9)	13 (2.0)
Others	5 (1.5)	4 (1.3)	9 (1.4)

*Multiple answers were allowed

4.4.1 Bed net survey and indoor residual spraying

Table 4.14 presents univariate logistic regression analysis of bed net ownership, source, treatment and use in the survey households. Bed net ownership and treatment did not show the expected association with reduced risk of malaria. Similar unexpected results were obtained for bed nets treated ≤ six months prior to the survey date, compared to those treated more than six months before. These unexpected findings suggest that actual use of nets may be more important in achieving the expected outcome of lowering the risk of malaria.

Bed net use in the previous night showed a 7% reduced risk of malaria. The risk of malaria was 12% lower for households which bought their bed nets while those which obtained nets distributed free of charge at health care facilities appeared not to have any effect. Households which owned five or more nets showed a 32% lower risk of malaria compared to the categories owning fewer nets. There was no difference between the cases and controls based on the whether or not their houses had been sprayed during an indoor residual spraying campaign conducted in the study area. Ownership of more than five bed nets was selected for multivariate analysis because of its association with reduced risk of malaria.

Table 4.14 Bed net survey and indoor residual spraying

Variable	Cases n = 342 [n (%)]	Controls n = 328 [n (%)]	mOR	*p*-value	95% CI	
Own bednets	328 (95.9)	310 (94.5)	1.36	0.39	0.67	2.78
Bednet use previous night	287 (83.9)	278 (84.8)	0.93	0.77	0.62	1.42
Bed net treated	124 (36.3)	110 (33.5)	1.13	0.46	0.82	1.54
**'Last insecticide treatment of bed net*						
0 - 6 months	90(27.4)	73 (23.5)	1.24	0.22	0.88	1.78
> 6months	24 (7.3)	28 (9.0)	0.81	0.46	0.46	1.43
No. of bed nets per in household						
1	62 (18.9)	58 (18.7)	1.06	0.75	0.71	1.59
2	121 (36.9)	123 (39.7)	0.97	0.86	0.69	1.35
3 - 4	128 (39.0)	107 (34.5)	1.16	0.35	0.83	1.62
5+	**17 (5.2)**	**22 (7.1)**	**0.68**	**0.25**	**0.35**	**1.31**
Source of bed nets						
Bought all nets	102 (31.1)	103 (33.2)	0.88	0.49	0.63	1.24
All nets from malaria campaigns	152 (46.3)	146 (47.1)	1.03	0.81	0.75	1.42
Bought & Malaria campaigns	63 (19.2)	49 (15.8)	1.25	0.28	0.62	1.91
Other sources (gifts, NGOs)	11 (3.4)	12 (3.9)	1.00	1		
Cost of bed net (in Kenya shillings)						
< 50	89 (27.1)	81 (26.1)	1.03	0.86	0.73	1.44
51 - 100	41 (12.5)	32 (10.3)	1.21	0.44	0.73	2.00
>100	35 (10.6)	39 (12.5)	0.83	0.46	0.51	1.35
Indoor residual spraying						
Homestead sprayed	104 (30.4)	101 (30.8)	1.03	0.86	0.73	1.47

*'19 households could not remember when their nets were treated

4.4.2 Bed net spot check

Table 4.15 presents the characteristics of the bed nets spot checked in the survey households. White nets were associated with a statistically significant 26% higher risk of malaria compared to blue and green nets. The PermaNet® brand of nets was associated with 18% higher risk of malaria, while Supanet® and Olyset® were associated respectively with 19% and 39% lower risk of the disease. Contrary to expected results, torn nets were associated with lower risk of malaria compared to those that were intact. This may suggest that those with torn nets were more regular users compared to those whose nets were intact.

Unexpectedly, those with nets hung up around sleeping areas had a higher risk of malaria compared to those whose nets were not hung up. This may suggest an increased net use following a malaria incidence in the household.

Table 4.15 Characteristics of bed nets in the survey households

Variable	Cases *n = 835 [n (%)]	Controls *n = 792 [n (%)]	mOR	*p*-value	95% CI
Colour					
White	**469 (56.2)**	**392 (49.5)**	**1.26**	**0.04**	**1.01 1.58**
Blue	203 (24.3)	222 (28.0)	0.90	0.44	0.69 1.17
Green	163 (19.5)	178 (22.5)	0.79	0.09	0.60 1.04
Brand					
PermaNet®	322 (38.6)	277 (35.0)	1.18	0.17	0.93 1.48
Supanet®	434 (52.2)	453 (57.2)	0.81	0.08	0.65 1.02
Olyset®	24 (2.9)	33 (4.2)	0.61	0.15	0.31 1.20
No label	55 (6.6)	29 (3.7)			1
Shape					
Rectangular	620 (74.3)	592 (74.7)	0.91	0.46	0.70 1.17
Conical	215 (25.7)	200 (25.3)			1
Bed net condition					
Torn	317 (38.0)	331 (41.8)	0.85	0.16	0.67 1.07
Clean	508(60.8)	488 (61.6)	0.96	0.73	0.75 1.23
Hung up	**607 (72.7)**	**536 (67.6)**	**1.43**	**0.01**	**1.09 1.86**

* n is the total number of bed nets in the case and control households

Data on characteristics of the specific bed nets used by the cases and controls were available for 301 subjects (141 cases and 160 controls). Spot checks done in the first half of the study recorded bed net users in the households without accounting for the specific user(s) of each bed net. Modification to include specific users of each bed net was made later following the large number of bed nets constantly observed in the households. Table 4.16 presents the analysis of bed nets used by the cases and controls. Unlike results presented in table 4.15, the colour and brand of the nets were not significantly associated with malaria but rectangular bed nets were associated with a 38% reduced risk of malaria.

Table 4.16 Characteristics of specific bed nets used by cases and controls

Variable	Case n = 141 [n (%)]	Control n = 160 [n (%)]	mOR	*p*-value	95% CI
Colour					
White nets	91 (64.5)	91 (56.8)	1.3	0.37	0.72 2.32
Blue net	34 (24.1)	39 (24.4)	1.13	0.72	0.56 2.26
Green net	16 (11.3)	30 (18.8)	0.53	0.11	0.23 1.18
Shape					
Rectangular	94 (66.7)	118 (73.8)	0.62	0.17	0.31 1.23
Conical	47 (33.3)	42 (26.3)			
Brand					
PermaNet®	53 (37.6)	55 (34.4)	1.05	0.87	0.56 1.93
Supanet®	78 (55.3)	99 (61.9)	0.77	0.38	0.43 1.37
No label	6 (4.3)	3 (1.9)	n /c		
Olyset®	4 (2.8)	3 (1.9)	n/c		
Bed net condition					
Torn	49 (34.8)	73 (54.4)	0.47	0.01	0.25 0.85
Clean	76 (53.9)	89 (55.6)	0.91	0.76	0.49 1.70

n/c could not be calculated

Results presented in table 4.15 and 4.16 show no plausible associations between malaria and use of bed nets. In brief, under this category of preventive measures, only one variable i.e. ownership of five or more bed nets, was selected for multivariate analysis. The next section gives an overview of all variables selected.

4.4.3 Summary of variables selected

The purpose of univariate analysis was to assess the association of malaria incidence with each of the covariates investigated and secondly, to select variables for subsequent model development. A total of 23 variables (Table 4.17) were selected. The next section highlights the process of model building based on these variables.

Table 4.17 Summary of selected variables

Variable	mOR	*p*-value	95% CI	
High risk variables				
Elevation 1,601 -1,650 m	2.00	0.06	0.97	4.12
Elevation 1,400 -1,450 m	1.73	0.14	0.82	3.62
River	1.73	0.09	0.91	3.27
>5km to health centre	1.70	0.18	0.77	3.71
Tap	1.64	0.20	0.77	3.46
Out at night	1.62	0.08	0.94	2.79
Stagnant water at waste disposal	1.55	0.10	0.89	2.77
Treatment cost Ksh >100	1.52	0.17	0.82	2.82
Bed time after 9 pm	1.43	0.15	0.88	2.31
Oxen	1.43	0.05	1.00	2.04
Stagnant water at rack	1.42	0.16	0.84	2.45
Containers	1.33	0.08	0.95	1.87
Family size >4	1.31	0.10	0.94	1.81
Short grass	1.30	0.21	0.84	2.02
Swamps	1.29	0.23	0.83	2.05
Planted flowers	1.25	0.17	0.90	1.76
Eaves	1.25	0.45	0.67	2.37
Low risk variables				
Sloping ground	0.83	0.25	0.60	1.16
Sugar cane	0.74	0.05	0.54	1.01
Wall cracks	0.73	0.06	0.51	1.03
Bed nets 5+	0.68	0.25	0.35	1.31
Sufficient food supply	0.67	0.01	0.49	0.92
Medicine at home	0.62	0.01	0.43	0.89

4.5 Multivariate analysis

All the variables in Table 4.17 were subjected to multivariate analysis using the conditional logistic regression routine in STATA. Table 4.18 presents the results of fitting this model. The importance of each variable in this initial multivariate model was verified by comparing its odds ratios, *p*-values and confidence intervals with those obtained at the univariate analysis. Variables that did not contribute to the model based on these criteria were omitted and a new model fit. The new model was compared to the larger older model using the likelihood ratio test and odds ratios for the remaining variables compared to those obtained from the full model.

Table 4.18 Multivariate model with all selected variables (n=320 pairs)

Variable	mOR	*p*-value	95% CI	
High risk variables				
River	2.51	0.03	1.11	5.70
Out at night	2.11	0.03	1.07	4.16
Elevation 1,400 -1,450 m	1.96	0.15	0.79	4.90
>5 km to health centre	1.91	0.19	0.73	4.96
Stagnant water at waste disposal	1.76	0.10	0.90	3.42
Eaves	1.59	0.02	1.07	2.35
Family size >4	1.55	0.03	1.05	2.29
Elevation 1,601 -1,650 m	1.52	0.34	0.64	3.60
Bed time after 9 pm	1.47	0.21	0.81	2.67
Oxen	1.45	0.09	0.95	2.24
Short grass	1.38	0.21	0.84	2.26
Containers	1.37	0.13	0.92	2.04
Planted Flowers	1.35	0.13	0.91	2.01
Swamps	1.35	0.25	0.81	2.27
Stagnant water at rack	1.08	0.81	0.58	2.00
Low risk variables				
Tap	0.88	0.79	0.35	2.20
Bed nets 5+	0.75	0.49	0.33	1.69
Sloping ground	0.74	0.13	0.50	1.10
Sugar cane	0.73	0.10	0.50	1.06
Medicine at home	0.72	0.15	0.46	1.13
Sufficient food supply	0.64	0.02	0.43	0.94
Wall cracks	0.64	0.02	0.43	0.94
Treatment cost Ksh>100	0.63	0.14	0.34	1.16

The process of fitting, refitting and verifying resulted in a preliminary model presented in Table 4.19. Based on observations made during the actual field study, elevation 1,400-1,450 m, swamps, flowers planted around the houses, and sloping ground were included in the preliminary model even though they did not meet the conventional 0.05 level of statistical significance.

Table 4.19 Preliminary main effects model

Variable	mOR	*p*-value	95% CI	
High risk variables				
Out at night	2.11	0.02	1.16	3.85
River	1.99	0.05	0.99	4.02
Elevation 1,400 -1,450 m	1.65	0.23	0.73	3.74
Oxen	1.53	0.03	1.04	2.24
Family size >4	1.50	0.03	1.05	2.13
Swamps	1.49	0.09	0.93	2.38
Eaves	1.41	0.05	1.00	1.99
Planted flowers	1.37	0.09	0.96	1.95
Low risk variables				
Sloping ground	0.79	0.19	0.55	1.12
Wall cracks	0.71	0.05	0.50	1.00
Medicine at home	0.63	0.02	0.42	0.94
Sufficient food	0.59	0.003	0.41	0.83

4.5.1 Model refinement

Following the traditional approach to statistical model building which involves seeking the most parsimonious model, the model in Table 4.19 was reduced further to include only those variables that were statistically significant at 0.05 level. This model (Table 4.20) was considered the main effects model. Model refinement measures that require checking the linearity of the logit for continuous variables could not be applied as all the variables in the model were dichotomous, coded as 1 and 0 depending on whether the exposure was present or not. The next step was therefore to check interactions in the model.

Table 4.20 Main effects model

Variable	mOR	*p*-value	95% CI	
High risk variables				
Out at night	1.90	0.03	1.07	3.28
Oxen	1.48	0.04	1.01	2.16
Family size >4	1.42	0.05	1.01	2.00
Eaves	1.41	0.04	1.01	1.96
Low risk variables				
Wall cracks	0.71	0.04	0.51	0.99
Medicine at home	0.61	0.01	0.42	0.89
Sufficient food	0.62	0.005	0.44	0.86

4.5.2 Assessing interactions

Because of their direct importance to malaria, variables in Table 4.19 were considered in generating a list of variables that had a scientific basis of interacting with each other. Table 4.21 presents the likelihood ratio test statistic (G) and *p*-values for the interactions of interest when added to the main effects model in Table 4.20. Table 4.21 indicates that only one interaction term; slope x swamp was significant at 0.05 level.

Table 4.21 Likelihood ratio test (G) of interactions assessed

Interaction	G	*p*-value
Elevation x river	0.17	0.68
Elevation x swamps	0.42	0.51
Slope x river	0.22	0.64
Slope x swamp	**4.14**	**0.04**
Swamp x river	1.62	0.20

A likelihood ratio test of 4.14 (*p*-value 0.04) was obtained after comparing the model with the interaction (Table 4.22) to the one without the interaction (Table 4.20). This indicates that inclusion of the interaction term improves the model. The odds ratios of the model with interaction improved slightly (between 1.6% 6.4%) compared to those of the model without interaction.

Table 4.22 Final main effects model with one interaction

Variable	mOR	*p*-value	95% CI	
High risk variables				
Out at night	1.94	0.03	1.08	3.48
Slope x swamps	1.81	0.04	1.02	3.23
Oxen	1.53	0.03	1.04	2.24
Eaves	1.45	0.03	1.04	2.03
Family size >4	1.44	0.04	1.02	2.03
Low risk variables				
Wall cracks	0.69	0.03	0.49	0.96
Sufficient food	0.60	0.003	0.43	0.85
Medicine at home	0.58	0.006	0.40	0.86

In addition, the inclusion of the interaction term brings into the model the effects of two important variables that would have been missed out due to lack of statistical significance. The separate effects of the two variables (mOR 1.41 for swamps; and mOR 0.79 for sloping) yielded a statistically significant joint matched odds ratio of 1.81.

4.5.3 Description of the model

The best fitting conditional multiple regression model included seven covariates and one interaction. The odds ratio for the variable 'out at night' estimates that subjects who were out at night were 94% more likely to get malaria compared to those who remained indoors. The confidence interval suggests that the risk could be as low as 1.08 or as much as 3.48 times with 95% confidence.

The odds ratio for variable oxen suggests that subjects who kept oxen in their compounds were 53% more likely to get malaria compared to those who did not keep these animals. The confidence interval suggests that the risk could be as low as 1.04 or as high as 2.24 times with 95% confidence. Sleeping in a house with eaves increased the risk of getting malaria by 45% and the risk could be as low as 1.04 or as high as 2 times more. Subjects coming from households with four or more people were 44% more likely to get malaria compared to those from smaller households. The risk could be as little as 1.02 or as much as 2.03.

The odds ratio for wall cracks suggests that subjects who lived in houses with cracks in the walls were 31% less likely to get malaria compared to those living in houses without cracks. Reduction in risk could be as high as 0.49 or as little as 0.96 with 95% confidence. Subjects whose households had sufficient food supply throughout the year were 40% less likely to get malaria compared to those who did not have enough supplies. The decrease in risk could be as much as 0.43 or as little as 0.85 times smaller with 95% confidence. Similarly, subjects who kept medicine at home were 42% less likely to get malaria compared to those who kept no medicine at all. The decrease in risk could be as high as 0.4 or as little as 0.86.

Before describing the interaction between slope and swamp, the coding of the two variables is explained. Slope was coded as 1 if the homestead was built on sloping ground and 0 if it was on flat ground. Similarly, swamp was coded 1 if the homestead was near a swamp and 0 if not. Logically, swamps form in flat areas that allow accumulation of flow due to poor drainage. The interaction term is therefore interpreted as a combination of homesteads located on flat and swampy area. The odds ratio for the interaction between swamp and slope suggest that subjects whose households were built on flat swampy areas were 81% more likely to get malaria compared to those who lived in homesteads located on well drained sloping areas. The risk could be as low as 1.02 or as high as 3.23 times with 95% confidence. So far this chapter has focused on statistical modelling involving univariate and multivariate analysis. The result of this process is the development of the model just described. The next section presents some results of spatial analysis.

4.5.4 Spatial analysis and detection of clusters

Figure 4.2 to Figure Figure 4.4 display the point distribution of cases and controls sampled during the study. The point density of the cases and controls was examined using the kernel density estimation described in section 2.6.3. Higher densities of malaria cases (>50 cases/km^2) were found near the health centre and in the lower part (Figure 4.5). For the controls, higher density areas (>50 controls/km^2) were found in the middle and upper parts (Figure 4.6).

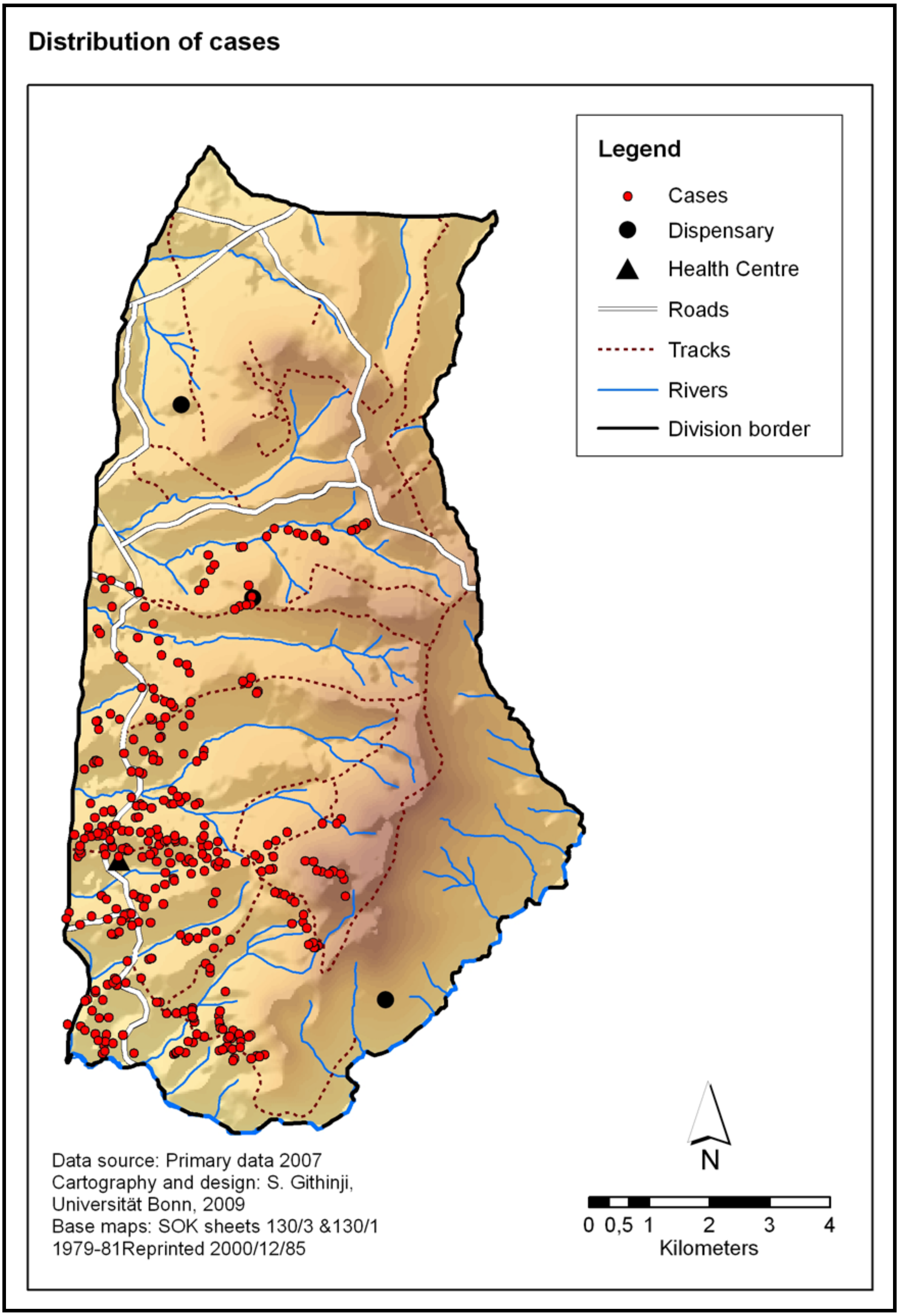


Figure 4.2 Distribution of cases

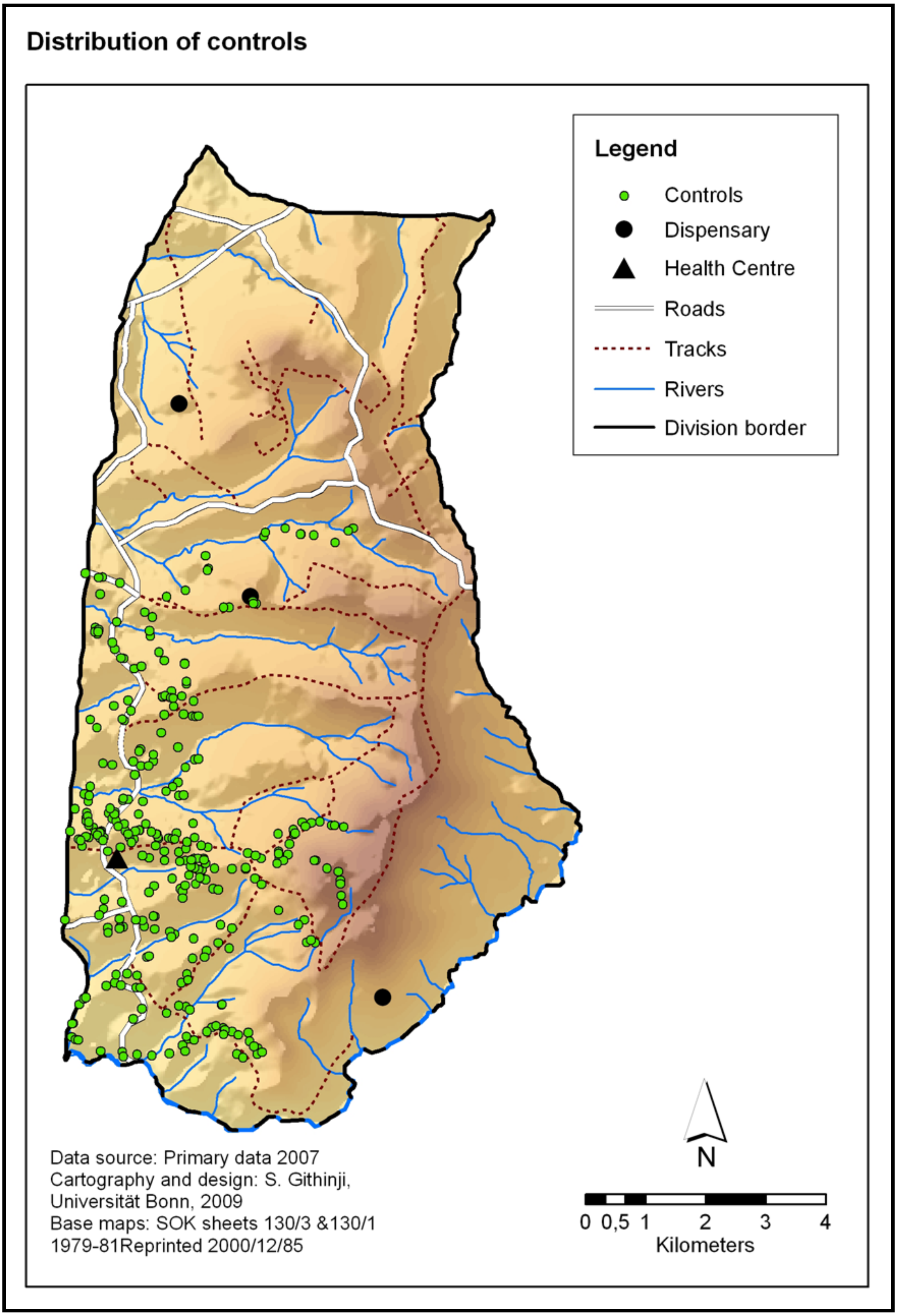


Figure 4.3 Distribution of controls

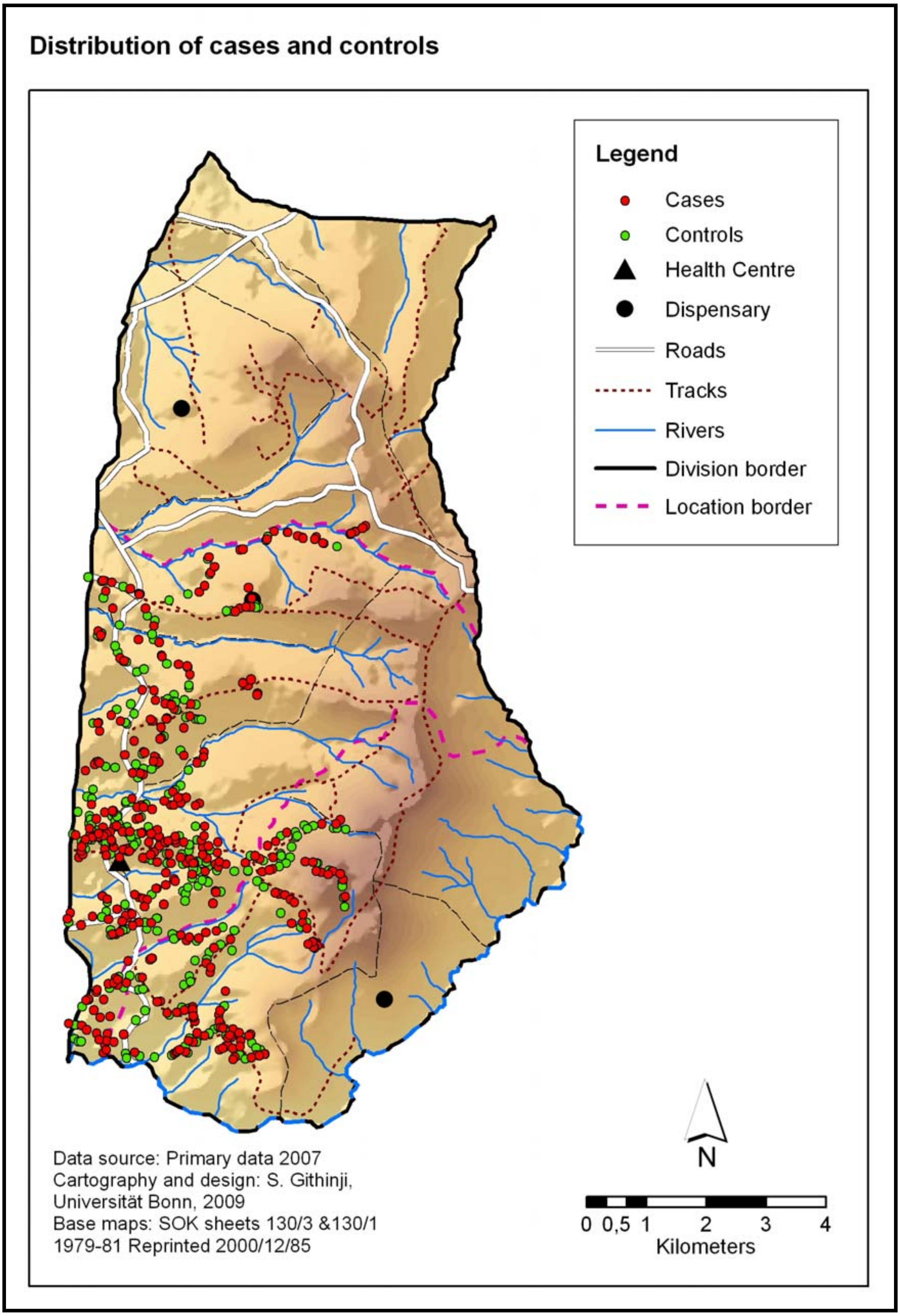


Figure 4.4 Distribution of cases and controls

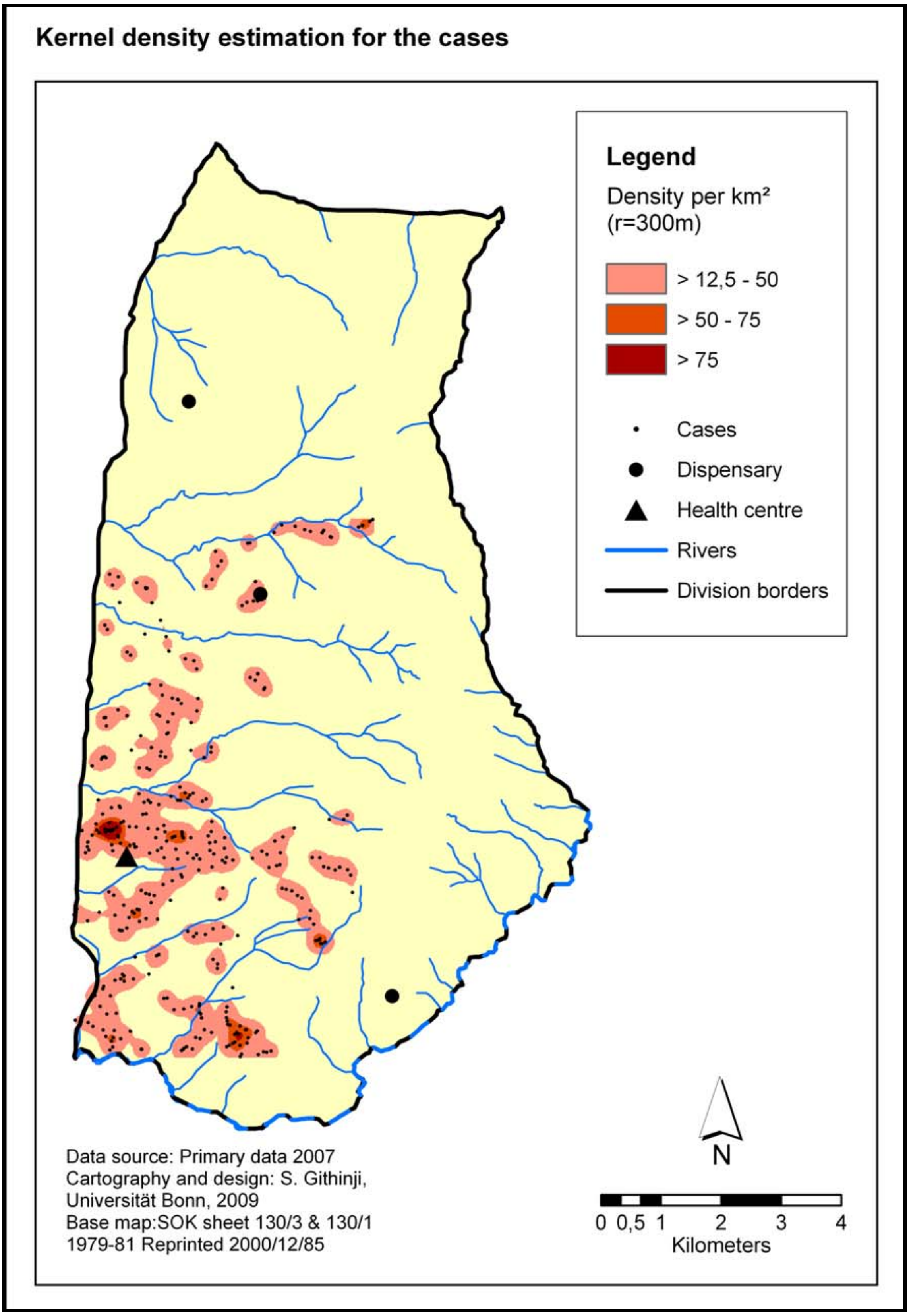


Figure 4.5 Kernel density estimation for the cases

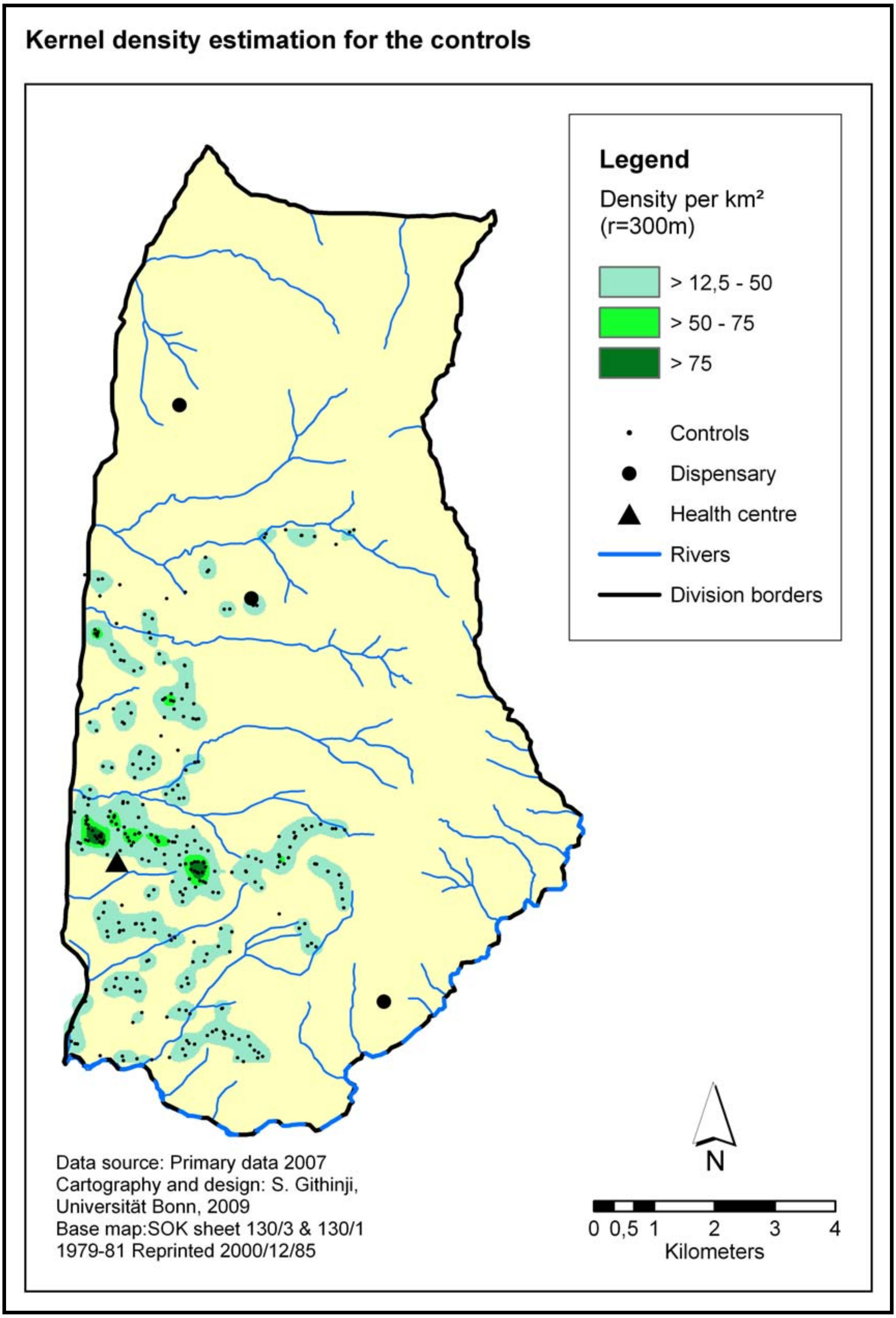


Figure 4.6 Kernel density estimation for the controls

To identify distinct spatial clusters of malaria cases, further analysis was done with spatial scan statistic (described in section 2.6.4). Two clusters; a single most likely cluster (A) and one non-overlapping secondary cluster (B) were detected on the southern part of the study area (Figure 4.7). The most likely cluster had ten cases (5.26 expected) and a relative risk of 1.93. The non-overlapping secondary cluster had 12 cases (6.85 expected) and a relative risk of 1.78 (Table 4.23). Neither of the two clusters detected was statistically significant.

Table 4.23 Clusters of malaria identified with spatial scan statistics

Cluster	Number of cases	Population	Expected cases	Observed/ expected	Relative risk	Log likelihood	Montecarlo rank	*p*- value
Most likely cluster (A)	10	10	5.26	1.90	1.93	6.487209	476/1000	0.476
Secondary cluster (B)	12	12	6.84	1.75	1.78	5.005791	909/1000	0.909

This brief section has visualised how the cases and controls were distributed in the study area. The next section highlights the non-visual aspects of malaria related to how the survey households and the community at large perceived the disease.

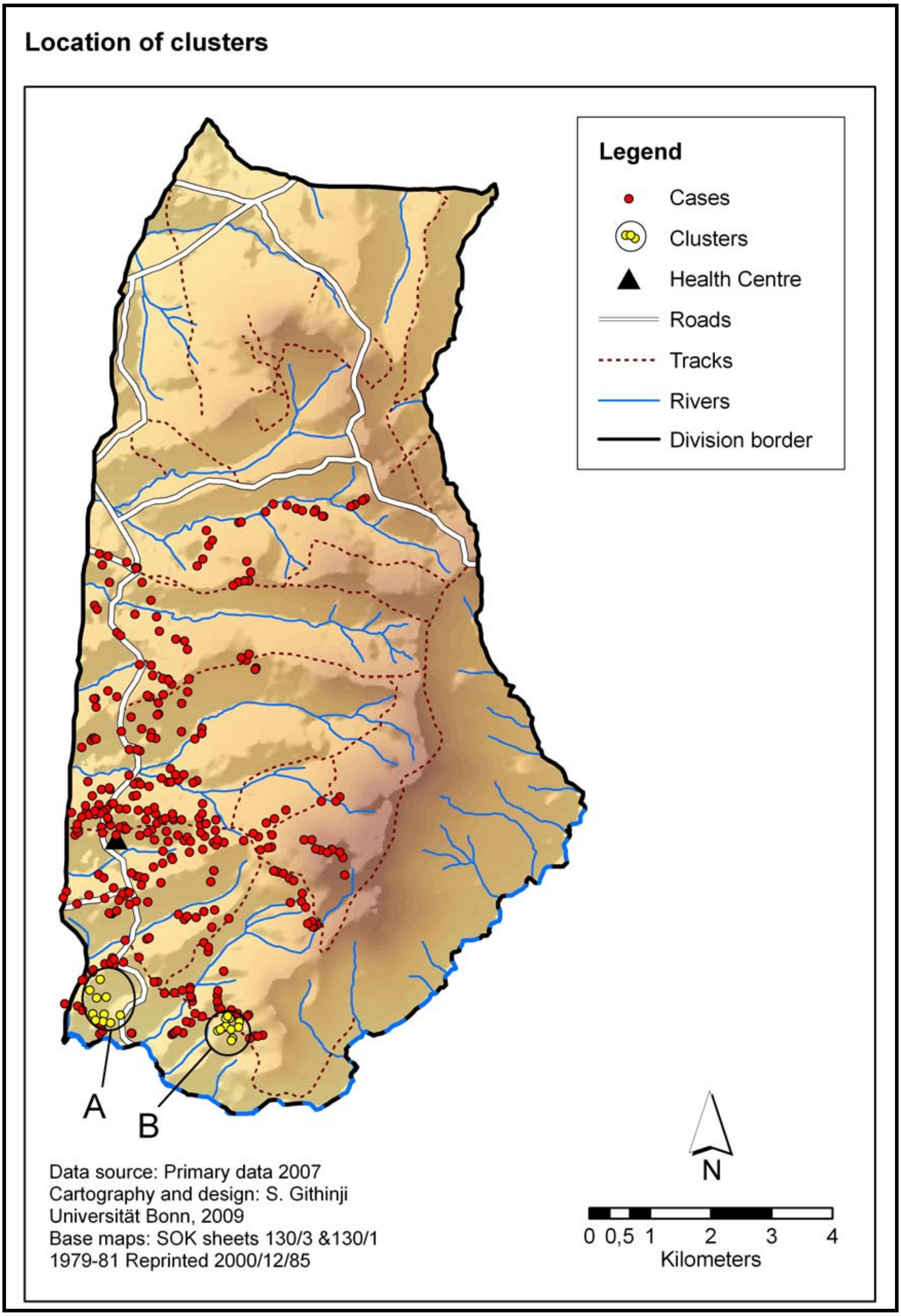


Figure 4.7 Location of clusters

4.6 Perceptions of malaria

In addition to investigating the health seeking behaviour and preventive measures, the third objective of this study aimed at exploring perceptions relating to malaria causation, diagnosis, treatment and prevention. Given the subjectivity of these aspects, they were not included in the multivariate analysis. However, their univariate analysis is presented.

4.6.1 Perceptions of factors leading to occurrence of malaria

Respondents were asked what they thought caused malaria. A detailed content analysis of the responses given was done. The responses were grouped into 12 categories as shown in Table 4.24. Those who associated malaria with mosquitoes, environmental factors, sugarcane and maize, dietary deficiencies and stress showed a lower risk of malaria while those who related it with dirty beddings, poverty, migration and funerals showed a higher risk. Respondents were asked to rate the seriousness of malaria on three level scale. Those who rated malaria as very serious showed a higher risk compared to those who rated it on the other two scales.

Table 4.24 Perceptions of causes of malaria and its seriousness

Variable	Cases n = 342 [n (%)]	Controls n = 328 [n (%)]	mOR	*p*-value	95% CI
Factor associated with cause					
Mosquitoes	322 (94.2)	314 (95.7)	0.68	0.29	0.33 1.38
Environmental factors	80 (23.4)	86 (26.2)	0.84	0.38	0.57 1.23
Dirty beddings	12 (3.5)	8 (2.4)	1.67	0.32	0.60 4.48
Climatic factors: rainfall, cold, wind	59 (17.3)	58 (17.7)	1.00		
Sugarcane and maize	**23 (6.7)**	**29 (8.8)**	**0.71**	**0.25**	**0.40 1.26**
Dirty food/unbalanced diet	**31 (9.1)**	**40 (12.2)**	**0.69**	**0.16**	**0.42 1.16**
Dirty water	21 (6.1)	20 (6.1)	1.00		
Stress/ a lot of work	8 (2.3)	12 (3.7)	0.67	0.37	0.27 1.63
Poverty	20 (5.8)	17 (5.2)	1.21	0.59	0.59 2.46
Contact with sick persons	5 (1.5)	5 (1.5)	1.00	1.00	
Migration/ seasonal movements	5 (1.5)	4 (1.2)	1.25	0.73	0.33 4.65
Attending funerals	8 (2.3)	8 (2.4)	1.14	0.79	0.41 3.15
[1] *Malaria seriousness*					
Very serious	25 (7.3)	16 (4.9)	1.57	0.18	0.80 3.07
Serious	**150 (43.9)**	**158 (48.2)**	**0.80**	**0.18**	**0.57 1.11**
Not serious	159 (46.5)	148 (45.1)	1.08	0.63	0.79 1.48

4.6.2 Perceptions of malaria transmission and prevention

Table 4.25 shows that mosquito bites, poor hygiene, direct and indirect social contacts were perceived as transmission channels. The table shows a significant association of malaria with poor hygiene. Table 4.26 shows that those who perceived bed nets and indoor spraying as preventive measures had a lower risk of malaria. Mention of preventive drugs was associated with a higher risk of malaria. Twelve respondents (1.8%) who perceived malaria as unpreventable showed a higher risk of the disease. Respondents were also asked what they thought were the symptoms of malaria. Table 4.27 shows that malaria was mainly associated with nausea, headaches and fever.

Table 4.25 Perceptions of malaria transmission

Perceived transmission	Cases n = 342 [n (%)]	Controls n = 328 [n (%)]	mOR	*p*-value	95% CI
Mosquito bites	265 (77.5)	259 (79.0)	0.93	0.69	0.63 1.35
Sharing things	50 (14.6)	53 (16.2)	0.95	0.82	0.61 1.47
Sleeping together	76 (22.2)	78 (23.8)	0.92	0.69	0.62 1.36
Poor Hygiene	**41 (21.0)**	**20 (6.1)**	**2.05**	**0.01**	**1.20 3.49**
Breathing	31 (9.1)	29 (8.8)	1.09	0.77	0.61 1.95
Body contact	33 (9.6)	33 (10.1)	0.94	0.80	0.57 1.54

Table 4.26 Perceptions of preventive measures

Perceived prevention	Cases n = 342 [n (%)]	Controls n = 328 [n (%)]	mOR	*p*-value	95% CI
Bed nets	**295 (86.3)**	**296 (90.2)**	**0.66**	**0.10**	**0.41 1.07**
Clean environment	132 (38.6)	124 (37.8)	1.04	0.81	0.75 1.43
Clean beddings	39 (11.4)	36 (11.0)	1.03	0.90	0.63 1.67
Indoor spraying	**28 (8.2)**	**33 (10.1)**	**0.73**	**0.26**	**0.42 1.27**
Mosquito coils/ repellants	17 (5.0)	18 (5.5)	1.00	1.00	
Preventive drugs	**29 (8.5)**	**16 (4.9)**	**1.68**	**0.10**	**0.91 3.13**
Boiling water	14 (4.1)	18 (5.5)	0.80	0.57	0.37 1.71
Clean/balanced diet	19 (5.6)	26 (7.9)	0.75	0.35	0.41 1.38
Clothing	8 (2.3)	7 (2.1)	1.16	0.78	0.39 3.47
Isolate patient	2 (0.6)	4 (1.2)	0.50	0.42	0.09 2.72
No prevention	**8 (2.3)**	**4 (1.2)**	**1.99**	**0.32**	**0.5 7.99**
Others (cow dung, sanitation)	23 (6.7)	24 (7.3)	0.95	0.88	0.52 1.71

Table 4.27 Perceptions of symptoms

Symptom	Cases n = 342 [n (%)]	Controls n = 328 [n (%)]	mOR	*p*-value	95% CI	
Nausea	**157 (45.7)**	**142 (43.3)**	**1.13**	**0.49**	**0.83**	**1.58**
Headache	**156 (45.6)**	**167 (50.9)**	**0.83**	**0.27**	**0.59**	**1.15**
Fever	**131 (38.3)**	**140 (42.7)**	**0.85**	**0.33**	**0.62**	**1.17**
Joint pains	90 (26.3)	89 (27.1)	0.96	0.84	0.64	1.42
Weakness	73 (21.3)	70 (21.3)	0.93	0.76	0.63	1.39
Loss of appetite	78 (22.8	99 (30.2)	0.67	0.03	0.47	0.95
Cough	42 (12.3)	51 (15.5)	0.78	0.3	0.49	1.24
Stomach pains	36 (10.5)	31 (9.5)	1.22	0.48	0.70	2.11
Red eyes	5 (1.5)	9 (2.7)	0.55	0.29	0.18	1.65
Skin rashes	5 (1.5)	6 (1.8)	0.83	0.76	0.25	2.73
Diarrhoea	16 (4.7)	14 (4.3)	1.17	0.69	0.53	2.52
Fatigue	4 (1.2)	6 (1.8)	0.66	0.53	0.18	2.36

4.6.3 Perceptions gathered from community interviews

As explained in section 2.4, disease ranking was done during the community interviews. Table 4.28 shows that malaria was ranked as the most common disease in three out of four community interviews.

Table 4.28 Ranking of malaria in the community

	Rank			
Disease	**Group 1**	**Group 2**	**Group 3**	**Group 4**
Malaria	1	1	2	1
Pneumonia	2	4	3	4
Homa (common cold)	3	2	-	2
HIV/AIDS	-	3	1	-
Typhoid	-	-	4	-
TB	5	5	-	-
Diarrhoea	-	-	5	-
Wounds	-	-	-	3
Asthma	4	-	-	-
Gastro-intestinal	-	-	-	5

The community interviews revealed that among other factors, malaria was mainly associated with nutritional deficiencies and poor hygiene. Measures leading to general improvement in home and environmental hygiene were commonly perceived to prevent malaria (Table 4.29). Although vectors and nutritional aspects were commonly perceived as factors leading to occurrence of malaria, measures targeting them were less frequently mentioned in prevention.

Table 4.29 Community perceptions of causes and prevention of malaria

A Factors associated with occurence of malaria	
(i) Insects	**(ii) Nutritional factors**
Mosquitoes	Lack of enough food
Bed bugs	Contaminated/dirty food
Flies	Lack of vitamin A
(iii) Hygiene	**(iv) Others**
Dirty beddings	Just comes by itself
Stagnant water	Carelessness/ignorance
Dark places	
Bushes around the houses	
B Perceived preventive measures	
(i) Housing factors	**(ii) Home hygiene**
Avoid dark places	Clear bushes
Plaster walls to cover cracks	Wash beddings
Good ventilation	Drain stagnant water
Enough light in the house	Cover pit latrines & boreholes
Plant bananas away from houses	Burn/bury empty containers
	Cover water storage containers
(iii) Vector control	**(iv)Nutritional factors**
Use treated bed nets	Avoid uncooked food
Spray houses	Eat balanced diet

Summary

In brief, analysis of perceptions shows that malaria was frequently perceived to occur as a result of poor hygiene, environmental factors and nutritional deficiencies. Keeping the environment clean was perceived as the most important preventive measure against the disease. To conclude, this chapter has assessed the association of malaria with three major groups of factors (micro-ecological, socio-demographic, and behavioural/ perceptual) as specified in the objectives of the study. The next chapter discusses the major findings of the study.

5 DISCUSSION

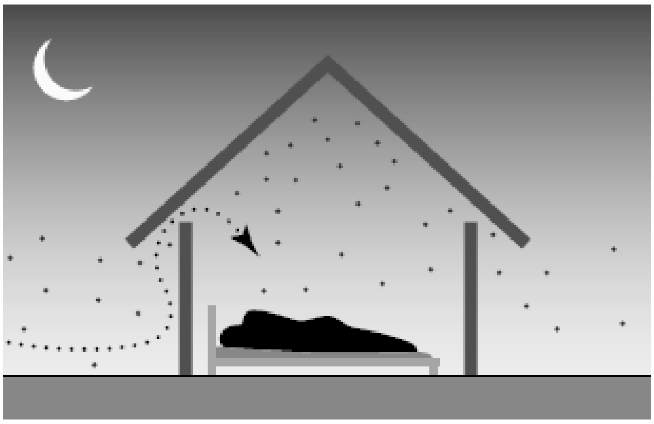
Malaria is considered to result from special interactions between vectors, parasites, humans and various environmental and anthropogenic determinants (Kiszewski and Teklehaimanot, 2004). Human behaviour in its socio-economic and cultural manifestations interacts with environmental factors thus leading to or preventing malaria. The present study set out to investigate the extent to which actual observed malaria incidences could be related to these interactions.

Staying outside at night, keeping oxen within the homestead, living in houses with open eaves, household size greater than four members and the interaction of proximity to swamps and location of the homesteads in flat areas were associated with increased risk of malaria. On the other hand, sufficient food supply throughout the year, keeping medicine at home and cracks on walls were associated with lower risk of malaria. All these variables point to the importance of the home environment in transmission of malaria.

It has been pointed out that the development of the larval forms of the mosquitoes and their contact with human beings relate to the immediate surroundings of the home. The home environment is also the starting point of diagnosis and treatment of malaria. Strategies for controlling diseases such as improvement of houses to control entry of mosquitoes, application of residually acting insecticides on house walls, use of insecticide treated nets, installation of screening on windows and promotion of early diagnosis and treatment must be frequently implemented at the household level involving active participation of the household members (Winch et al., 1994). The following section highlights the interactions between housing characteristics and malaria.

5.1 Housing characteristics

The quality of housing affects the ease with which mosquitoes can enter a home (Brooker et al., 2004). In most tropical rural areas, housing is characterised by flimsy, open walled structures, overcrowding, poor ventilation, open eaves and unscreened windows which provide easy access for mosquitoes to get into the houses and bite people (Ng'ang'a et al., 2008). Figure 2.2 to Figure 2.5 show some observations of these flimsy housing as observed in the present study. The *Anopheles gambiae* are exquisitely adapted to entering houses and feeding on people because of a simple behavioural trait. They detect human odours drifting out of the houses through the eaves and other openings in the houses (Figure 5.1). Unlike most mosquitoes which fly off sideways upon coming into contact with a wall, the *Anopheles gambiae* fly upwards and are funnelled by the over hanging roof inside the house (Snow, 1987).



Dots represent host odours and broken line the path of *Anopheles gambiae*

Figure 5.1 How *Anopheles gambiae* enter houses through open eaves

Source: Lindsay et al., (2002)

The model estimates of the present study showed that subjects who slept in houses with open eaves (mOR 1.45; *p*-value 0.03) had a higher risk of malaria. On the other hand, cracks in the walls (mOR 0.69; *p*-value 0.03) were associated with a reduced risk of the disease. The low risk of malaria associated with cracks in the walls could be attributed to the practice of plastering the walls with clay and cow dung, which was a common cultural trait in the study area. Houses with cracked walls were not plastered in accordance with the common practice. Compared to plastered houses, these houses may have had lower indoor temperatures hence providing unfavourable resting conditions for mosquitoes.

The association of malaria with housing characteristics has been documented in several other studies. In western Kenya, adult mosquito abundance was found to be higher in houses with mud and grass-thatched roofs compared to those with other types of walls and metal roofs (Zhou et al., 2007, Ernst et al., 2006). The authors explained that mud walled and grass-thatched houses provided benign resting places for blood fed mosquitoes. A study done in Cameroon found that crevices on wooden walls allowed easy passage of mosquitoes and also provided refuge for them (Nkuo-Akenji et al., 2006). In Ethiopia, earth roofed houses were found to be associated with a higher risk of malaria compared to corrugated and thatched ones. Other housing traits significantly associated with malaria included type of windows, open eaves and no separate kitchen (Ghebreyesus et al., 2000).

A randomized controlled study testing different improvements of housing design (i.e. adding plywood ceiling, covering eaves with synthetic insecticide treated netting, plastic net screen or simply covering the eaves with mud) demonstrated that addition of simple ceilings to houses of traditional design significantly reduced exposure to malaria vectors (Lindsay et al., 2003). Mosquito entry in the treatment houses decreased by over 70% for all treatments except mud covered eaves where a reduction of 37% was recorded. The authors concluded that simple improvement of housing structure could reduce the intensity of malaria transmission for the occupants and provide long term protection against malaria. However, air temperature taken at 10.00 p.m. showed that houses with closed eaves were 0.9°C warmer than those with netting or screen and those with a wooden ceiling were 0.8°C warmer than those with screen or netting. Closing the eaves with mud may therefore create favourable indoor resting conditions for mosquitoes leading to a shorter gonotrophic cycle, higher biting rates and consequently, increased malaria transmission.

In Sri Lanka, an association between poorly constructed houses and a higher risk for malaria was observed. When houses were structurally improved, malaria was reduced by 36% in the whole population and by 75% in the communities whose houses were improved (Gunawardena et al., 1998).

Similarly, the risk of infection was halved among residents of houses with complete walls and ceiling compared to that among residents of poor houses (Gamage-Mendis et al., 1991). In Yemen, Al-Taiar et al. (2008) found association of malaria with traditional earth roof which probably provided favourable hiding and resting places for mosquitoes.

In the early 20th century, improved housing and screening were regarded as some of the main methods to control malaria. Modifying house structure was used to protect people from malaria in Italy, Greece, Panama and USA (Lindsay et al., 2002). The first trials showing that people could be protected from malaria by mosquito proofing houses were done between 1899 and 1904 along two railway lines in Italy. Houses of the intervention group had their windows covered with frames of tulle or muslin and doors were screened with wire gauze, while the control group was left unprotected. 17% of the treatment group compared to 96% of the control group contacted malaria. These findings were translated in to broader public health action and by 1904, 12,378 people were living in mosquito proofed houses. Protection from malaria was observed even if only parts of the houses were screened. 25 to 96% of the people in unscreened houses got malaria compared to only 1.9% in completely screened houses and 10.9% in partly screened houses (Keiser et al., 2005).

Improvement in housing structure, however, does not always lead to reduced incidence of malaria. In Indonesia, for example, malaria outbreaks increased in 44 of 71 districts that carried out house improvements. The improved houses had better ventilation and were often smoke free which probably presented more suitable resting places for adult mosquitoes (Keiser et al., 2005). Likewise, a study done on the Kenyan coast was unable to demonstrate any statistically significant effect upon disease outcome based on house construction (Snow et al., 1998). The authors argued that improvements in house design may significantly reduce malaria risk at low vector densities but may be less effective in higher transmission areas. They concluded that it is likely that the impact of household features on disease outcome is dependent upon both the density of infecting mosquitoes and acquired immunity within a given locality.

All in all, studies cited in this section support the association of malaria with aspects of housing found to be statistically significant in the present study. These findings point to the potential of controlling malaria using simple modifications that are possible even in poor human dwellings in rural Africa. Such modifications need to be monitored carefully so that the improvements do not create favourable indoor resting conditions for mosquitoes. Improved housing used with already widely implemented ITNs and IRS may be a step further in the battle against malaria. The next section discusses characteristics related to sites where the houses were built.

5.2 Elevation and slope

The complex topography of the highlands of East Africa consisting of hills and valleys contribute to restricted and spatially heterogeneous distribution of vectors, their breeding habitats and consequently, intensity of malaria transmission. Unlike the lowlands where mosquito breeding sites are extensive, mosquito habitats in the highlands are confined to the valley bottoms because the hillside gradients provide efficient drainage (Minakawa et al., 2004, Minakawa et al., 2005a).

It has been demonstrated that slope and elevation may interact with other factors such as wind to facilitate dispersion of adult mosquitoes (Li et al., 2008, Miller, 2003). Host and larval habitat availability as well as wind direction are proven determinants of mosquito flight direction and distance (Killeen et al., 2001, Service, 1997). Studies have shown that malaria transmission in holo-endemic settings was via mosquitoes that were 2-3 weeks old which may have travelled several kilometres since emergence (Killeen et al., 2000a). Referring to the present study, it is possible that the hilly topography and windy conditions of the area, facilitated migration of mosquitoes from the valley bottoms to the upper hill sides. Cold winds from the surrounding hills were among the climatic and weather conditions perceived to cause malaria in the area (Table 4.24).

Going back to the model estimates in this study, univariate analysis (Table 4.2), showed a lower risk of malaria (mOR 0.83; *p*-value 0.25) for those subjects whose houses were located on sloping areas as compared to those built on flat areas. In the final model (Table 4.22), the interaction of location of houses on flat and swampy areas was significantly associated with increased risk of malaria (mOR 1.81; *p*-value 0.04). These findings correspond to a study done in the Usambara Mountains in Tanzania where the risk of malaria increased in houses situated on or near swampy ground, compared to those situated further away on steeper and drier ground. Presence of flat areas (50 to 500 m) from the houses was also associated with an increased risk of malaria (Balls et al., 2004). Similar inferences can be made from the clusters of malaria detected in the present study (Figure 4.7). Both clusters were located in the flatter lower elevations on the southern part of the area. All the cases in the most likely cluster were located between 1,406 to 1,448 m above sea level while those in the secondary cluster were found between 1,488 to 1,530 m. The cluster areas were adjacent to very steep hill sides where house construction was difficult. As a result, houses were built on the valley bottoms close to the river. Figure 2.9 is an example of one of the homesteads in the most likely cluster which was built only a few metres from the river. This example demonstrates how slope and elevation interact to influence occurrence of malaria in specific areas.

The valley bottoms are ideal breeding sites for mosquitoes throughout the year. Studies in western Kenya showed that during the rainy season, 75.1% of anopheline positive habitats were located in the valley bottoms between 1,400 and 1,420 m. In the dry season the proportion of anopheline positive habitats in the mentioned valley bottoms reached 100% (Minakawa et al., 2002, Minakawa et al., 2005b, Minakawa et al., 2004). Similarly, Zhou et al. (2007) found that houses located at elevations less than or equal to 1,470 m above sea level had more than three fold greater abundance of *Anopheles gambiae* compared to those located at higher elevations. A study in the highlands of Burundi also showed that the proportion of individuals who declared a history of malaria-like illness was significantly higher in the valleys than in the hilltops (Protopopoff et al., 2008). It has been reported that the risk of P*lasmodium falciparum* malaria decreases with every 50 m increase in altitude. A study done along a hill transect in western Kenya found that there was a linear relationship between

Plasmodium falciparum prevalence and altitude (R^2 = 0.98) and a 15.9% reduction in prevalence for every 50 m increase in altitude. The study found a 68% prevalence of malaria at the valley bottom, 40.2% at mid hill and 26.7% at the hill top (Githeko et al., 2006).

In high altitudes, however, the existence of pockets of high transmission areas located in the flatter parts which favour accumulation of flow have been demonstrated. Investigating the influence of altitude on splenomegaly and parasitaemia at different altitudes in the Usambara region of Tanzania, Ball et al. (2004) concluded that splenomegaly was positively correlated with decreasing altitude. It is argued that the distance to the foci of transmission is likely to influence the immunity profile of malaria in the highlands because of delay in the ability to suppress parasite density. Githeko et al. (2006), for example, found that although children living at the hilltops had lower transmission, their parasite density was higher because they had not developed mechanisms to control the parasites and therefore were characterised by a more severe disease. The study concluded that while the population living in and near the valley maintained a large reservoir of infectious gametocytes, those living further up hill comprised a high proportion of individuals susceptible to infections that could lead to severe disease. This argument may explain why in the present study significantly high malaria incidences were observed between 1601-1650 m above sea level (Table 4.2).

The effect of altitude is probably because of its influence on temperature. Low temperatures at higher altitudes reduce the development and survival of aquatic stages of anopheline mosquitoes and slow down the development of parasites in the vector, reducing the chance of malaria transmission (Lindsay and Birley, 1996). Bodker et al. (2003) note that malaria transmission may still continue at higher altitudes because the endophillic *Anopheles gambiae* and *Anopheles funestus* rest indoors where, on average, the temperature is up to 2.6°C higher than the surrounding outdoors. Higher temperature shortens the gonotrophic cycle of *Anopheles* implying more frequent blood meals and consequently, higher malaria transmission. Further to this, the authors note that in the east

African highlands, malaria transmission is supported by a relatively low vector density and epidemics may be driven by increased localised vector breeding where topographical features and even rainfall intensity may vary greatly.

Slope and elevation are also related to location of rivers. In the present study (Table 4.5), univariate analysis showed a higher risk of malaria for households that fetched water from the river (mOR 1.73; *p*-value 0.09). Rivers are often found in valley floors which collect run off water in various depressions hence forming more breeding habitats (Li et al., 2008).Though not statistically significant, further investigations (Table 4.6) showed decreasing risk of malaria for households located further away from the rivers and streams. These findings correspond with a study by Zhou et al. (2007) which found that houses within 500 m range of the river had five or six fold higher mosquito abundance than houses up hill and more than 1,000 m from the river. Similarly, a study done in Sri Lanka found that the probability of getting malaria was higher for the people living less than 250 m from the stream compared to those living more than 500 m away (van der Hoek et al., 1998). A study done in Yemen also found an association between malaria and nearby presence of a stream and marshy land (Al-Taiar et al., 2008).

Summing up this section, consideration of local topography in addition to the dominant altitudinal trend can be useful in detecting and mapping local pockets at high risk of malaria. Although the clusters identified in the present study were not statistically significant, their location was closely related with elevation and slope. Environmental control measures may be applied at these focal points of transmission to ease the burden of malaria. After discussing the characteristics of the houses and their location, the next section focuses on other environmental aspects surrounding the homesteads.

5.3 Risk factors within the homestead surroundings

Starting with the most immediate environment, the present study found significant association between malaria and presence of oxen in the homesteads (mOR 1.53; *p*-value 0.03). Studies have shown that cattle ownership and housing practices can profoundly influence human exposure to malaria in African settings (Seyoum et al., 2002, Saul, 2003, Killeen et al., 2004). Livestock, particularly cattle, kept very close to the homesteads may increase the risk of individuals being bitten by attracting mosquitoes to the general proximity of human dwellings (Schultz, 1989, Bouma and Rowland, 1995, Killeen et al., 2001). This may also lead to increased vector population and consequently, the absolute numbers of mosquitoes biting people (Sota and Mogi, 1989). Additionally, animal hoof prints may create an abundance of small amounts of stagnant water thus increasing mosquito breeding sites close to the homesteads. Figure 2.10 is an example of such small pools of water formed by animals hoof prints as observed in one of the survey homesteads.

An experimental study done in Ethiopia found that presence of cattle in homesteads tended to increase the man biting rate of *Anopheles arabiensis* while keeping the animals in separate cattle sheds outside of the human dwellings tended to reduce the species biting rate and malaria transmission (Seyoum et al., 2002). Similarly, it has been documented that sleeping close to cattle or goats significantly increased the human biting rate (HBR) by zoophilic anophelines in Pakistan (Bouma and Rowland, 1995).

In his simulation models, Saul (2003) demonstrated that although increasing the number of animals in the proximity of human dwelling places may divert mosquitoes from biting humans, more animals would also lead to the vectors spending less time foraging. Consequently, mosquito mortality in search for food would reduce, resulting in more vectors surviving the intrinsic incubation and increasing the number of blood meals by the infectious vectors. The author recommended that the most effective strategy would be to minimise the number of breeding habitats in the vicinity of animals and humans.

Looking at other factors around the homesteads, proximity to swamps has been associated with increased vector density in western Kenya (Ndenga et al., 2006, Minakawa et al., 2004). Similarly, a study on urban malaria in Uganda, demonstrated that distance of residence from swamps was an independent predictor of incidence of clinical episodes of malaria (Staedke et al., 2003). In the present study, as already mentioned in the discussion on elevation, proximity to swamps was associated with increased risk of malaria. The study area is endowed with numerous ground water resources which develop into large, permanent and seasonal swamps due to the excessive amount of flow during the heavy rains. Ground water has been observed to be generally clean enough to support breeding of large numbers of *Anopheles gambiae* and *Anopheles funestus* (Maxwell et al., 2006). Figure 2.11 shows some homesteads built very close to one of the swamps observed in the area.

Closely connected to swamps were brick-making sites and fishponds. Recurring malaria upsurges and epidemics in the Kisii-Gucha region has been frequently associated with brick-making sites which are mainly concentrated at the swampy areas in the valley bottoms. Functional brick-making sites have been found to have 4-6 fold higher larval population densities of *Anopheles gambiae* than natural habitats. In addition to encroachment and degradation of wet lands, brick making activity has led to creation of malaria vector breeding habitats in close proximity to homesteads (ICIPE, 2007, Carlson et al., 2004). Brick-making is a good example of an anthropogenic activity linked to an environmental interface i.e. swamps, leading to increased the risk of malaria transmission. The present study however, did not find a significant association between malaria and proximity to brick-making sites. This could be attributed to the timing of the study which was done during the heavy rainy season. Brick-making is mainly practised during the dry season because the heavy rains are bound to destroy the bricks.

Fish farming was introduced in the early 1980s as an initiative of the fisheries department to make use of the numerous water resources in Kisii area. With time, lack of maintenance and over-fishing led to abandonment of many of the ponds. Studies in Kisii area have shown that compared to functional fish ponds, abandoned fish ponds contained significantly more *Anopheles gambiae* and *Anopheles funestus* larvae (Howard and Omlin, 2007). Upon introducing larvivorous fish; *Oreochromis niloticus* in abandoned fish ponds, more than 94% reduction in both *Anopheles gambiae* and *Anopheles funestus* was observed after 15 weeks (Howard et al., 2007). Additionally, clearing vegetation from fish ponds containing tilapiine fish reduced the risk of the ponds having mosquitoes by half. In the present study, fish farming was practised in two villages, Bomonyama and Ichuni. The two villages had been part of an ICIPE project (between 2002 and 2006) that rehabilitated abandoned fishponds and trained owners about the connection between malaria and environment (ICIPE, 2007). This may explain why no significant associations were found between malaria incidences and proximity to fishponds. Figure 2.12 shows rehabilitated fish ponds observed at Ichuni village.

Other micro-ecological factors which had strong associations with malaria at the univariate level (Table 4.4) included stagnant water at waste water disposal areas (mOR 1.55; *p*-value 0.1) and utensils rack (mOR 1.42; *p*-value 0.16), together with containers around the compound (mOR 1.33; *p*-value 0.08). Although these variables did not reach the 0.05% statistical significance in the subsequent multivariate models, the magnitude of the odds ratios highlight the importance of these small ecosystems in malaria transmission.

Studies have shown that malaria vectors of the *Anopheles gambiae* complex of sub-saharan Africa characteristically breed in quite small, transient and unpredictably scattered bodies of water where larvae predation is less prevalent compared to large permanent habitats (Killeen et al., 2002a). The species has been classified as an opportunistic *typical r* strategist species reproducing rapidly in niches where there is no competition and exploiting the increased resources of warmer, open habitats that tend to produce more algae than shaded habitats (Gimnig et al., 2002). The highly specific adaptation of the *Anopheles gambiae* to feeding on humans and their breeding characteristics lead them to aggregate around human habitations, often in small artificial water bodies (Killeen et al., 2002a, Bodker et al., 2003).

Malaria vectors seldom fly further than one kilometre radius from the breeding sites (Carter et al., 2000). In rural African settings, simulated models estimated the mean distance moved by an individual mosquito to be in the range of 350 - 650 m per day (Costantini et al., 1996). Similarly, Zhou et al. (2007)

demonstrated that in the highlands where breeding sites are clustered in the valley bottoms, vectors did not spread beyond 500 m. These characteristics of the *Anopheles* render environmental management especially suitable in the highlands of western Kenya (Mutuku et al., 2006), where breeding sites are man-made and close to human habitats (Carlson et al., 2004).

A study investigating mosquito breeding in tree holes in western Kenya found anopheline larvae in habitats containing as little as one litre of water, hence demonstrating that *Anopheles* breeding did not discriminate between sizes of habitats. The study found a correlation between the depth of the habitats and anopheline density suggesting a link between use of traditional ground pool habitats and the large tree holes.

From these few examples, it is clear that the importance of small breeding places close to the human dwellings cannot be underestimated. Application of environmental measures can contribute significantly to making these potential habitats unsuitable for mosquito breeding. Simple environmental measures like draining stagnant water around the homesteads and better disposal of garbage may be important malaria control measures at the household level.

Implications of micro-ecological risk factors on malaria control

Since 2001, the WHO has been promoting Integrated Vector Management (IVM). This has been defined as the targeted use of different vector control methods alone or in combination with other sustainable and cost effective measures that reduce human vector contact. Although there is a rising interest in environmental management as a component of integrated vector management (Keiser et al., 2005, Yohannes et al., 2005, Le Menach et al., 2005, Gu et al., 2008), it has been argued that regular vector control measures may be a waste of resources in epidemic areas (Abeku, 2007). In these zones, emphasis has been put in malaria early warning systems and early detection systems (Nájera JA, 1998, WHO, 2003). Measures targeting reduction of the survival rate of adult mosquitoes are preferred to those focussing on lowering the vector density. As a result, ITNs and IRS measures are recommended by

WHO and RBM and supported by various donor partners, while larval control interventions are largely neglected in tropical Africa (Gu and Novak, 2005).

While interventions using only ITNs and/or IRS successfully reduce transmission intensity and the burden of malaria in many situations, it is not clear if these interventions alone will achieve those critical low levels that result in malaria elimination (Beier et al., 2008). In the present study, for example, bed net coverage reached over 95% (Table 4.14) but the number of malaria cases remained considerably high (Table 2.1). Entomological surveys in Gucha district at the time of the study showed that vector larvae density was on the increase in spite of the ITNs coverage reaching 75.9% (D.V.B.D, 2007). This may point to the need to focus on measures geared towards reducing mosquito larvae habitats.

Targeting the larval stages has the advantage of killing mosquitoes before they disperse to human habitations. Secondly, mosquito larvae, unlike adults (Charlwood and Graves, 1987, Yohannes et al., 2005), cannot change their behaviour to avoid control activities targeted at the larval habitat (Killeen et al., 2002b). It has been demonstrated that the larvae control approach requires no substantial change in human behaviour or the management of key resources, such as water and land (Mukabana et al., 2006). It is argued that the patterns of larvae control may work best in sites where larval habitats occur seasonally, are well defined, accessible, and where human population density is high enough to justify repeated treatment of all breeding sites (Fillinger and Lindsay, 2006). These specifications fit well in the present study where numerous, easily identifiable and accessible temporary breeding sites developed during the rainy season and the population density was high (861 inhabitants per km^2).

Population models based on mosquito physiological mechanisms and behavioural change reveal that aquatic habitat reduction through environmental management or other larvae control interventions exert an unexpected impact on malaria transmission (Le Menach et al., 2005, Gu and Novak, 2005, Gu et al., 2006, Gu and Novak, 2006). The models show that application of domestic protection, involving nets and screening of houses together with water management approaches, may substantially increase dispersal by forcing the mosquitoes to spend longer in search of human hosts or aquatic habitats. This may have the effect of reduced biting rate and sporozoite prevalence. The predictions showed that even in an exceedingly challenging setting, modified agricultural practices, reduction of breeding habitats and simple housing modifications could reduce transmission intensity from more than 300 to less than one infectious bite per person per year (Killeen et al., 2004).

Keiser et al. (2005) observed that the most successful environmental and habitat modifications which reduced the risk of malaria in different micro-ecological settings were implemented before the global malaria eradication programmes (1955 – 1969). These programmes involved small populations and were highly site specific. They were implemented over a period of several years and tuned to adapt to changes over time. By contrast, most clinical trials today are standardized, fixed in advance but only lasting for relatively short periods of time. The organisational framework of these early programmes incorporated community participation, health education and multiple interventions guided by specifically trained multi-sectoral staff with expertise in malaria epidemiology, entomology, vector ecology, land and water engineering. These features are largely lacking in most of today's malaria control measures, many of which are subject to donor funding whose interests and objectives change after short term projects.

The present study has demonstrated the association of malaria with micro-ecological risk factors that are not adequately addressed by the existing control measures. Studies quoted in this section give evidence to the potential role of environmental measures in malaria control. Such measures call for environmental awareness and behaviour change at the household level. This will require health education and measures to ensure sustainability. For this, an understanding of socio-demographic aspects is required.

5.4 Demographic and socio-economic factors

The present study found a significant association of malaria with households having more than four resident members (mOR 1.44; *p*-value 0.04). Studies have demonstrated the association between the risks of malaria and overcrowding. Ghebreyesus et al. (2000) found that families with a single sleeping room had a higher risk of malaria compared to those who had more rooms. Similar results were reported in Sudan (El Samani et al., 1987), Colombia (Banguero, 1984), Gambia (Koram et al., 1995) and Cameroon (Kuate Defo, 1995).

The abundance of vector species, the length of feeding cycle and blood meal host choice are key predictors for transmission intensity of malaria. These parameters depend on the effort expended by the vector in the pursuit of blood meals and the relative availability of different species for blood meal acquisition (Killeen et al., 2000b, Killeen et al., 2001). Demographic aspects that make it easier for mosquitoes to acquire blood meals may therefore enhance malaria transmission. More people result in a higher production of carbon dioxide and other host related odours attractive to mosquitoes (Gillies, 1988). Secondly, infective mosquitoes entering the house may infect more than one person on the same night (Lindsay et al., 1990). Infected mosquitoes have reduced levels of salivary apyrase which affect their ability to locate blood vessels, resulting to longer vector-host contact (Rossignol et al., 1986). In nature, duration of contact is reduced due to host behavioural defences eliciting irritation. Infected mosquitoes will therefore attempt to feed unsuccessfully on different persons in quick succession with subsequent enhancement in parasite transmission. Therefore, the more people there are in a house, the easier it is for such probing mosquitoes (Ghebreyesus et al., 2000).

Working or sleeping outdoors may influence the occurrence of malaria (van der Hoek et al., 1998). The present study found a significant association of malaria with staying outside at night (mOR 1.94; *p*-value 0.03). Closely related to this variable, univariate analysis (Table 4.7) showed a higher risk of malaria (mOR 1.43; *p*-value 0.15) for subjects who went to bed after 9 p.m. compared to those who slept earlier. Experiences gathered during the data collection period showed that community ceremonies such as funeral rites were commonly carried out at night. This resulted to long or overnight stays outdoors, leading to an increased exposure to the risk of mosquito bites. Conventionally used protective measures such as insecticide treated nets and indoor residual spraying could not protect individuals participating in such ceremonies (Githinji et al., 2009).

Malaria transmission occurs between dusk and dawn, corresponding to the habits of the *Anopheles gambiae* and *Anopheles funestus* which primarily bite indoors during the late hours of the night (Hawley et al., 2003). A study in western Kenya (Githeko et al., 1996) showed that the A*nopheles gambiae* exhibited strong anthropophagic behaviour with increasing biting rates in the later hours of the night. In the early hours of the night, however, the outdoor biting population of the *Anopheles* was more active than the indoor population. Similarly, a study done in Cameroon showed that the biting cycles of all *Anopheles* species peaked between 1 and 3 a.m. The biting rates were higher for the *Anopheles gambiae* than other species (Nkuo-Akenji et al., 2006). Any measure that reduces exposure to the evening and night time biting female *Anopheles* will therefore reduce the risk of acquiring malaria (Mahidol, 2004).

Other demographic factors investigated included travel in the two weeks preceding the survey, regular or cyclic travels, and duration of residence in the study area (Table 4.7). Results showed that 92.7% of the households had all their members born in the study area. This implies that the observed malaria cases could not be associated with immigrants coming form other regions. Similarly, the risk of malaria was not positively associated with travelling outside the study area. It can therefore be concluded that observed malaria cases were mainly due to factors inherent in the study area.

Looking at socio-economic factors, sufficient food supply was significantly associated with a lower risk of malaria (mOR 0.60; *p*-value 0.003). Improved nutritional status lessens severity of malaria episodes and results in a decrease in malaria deaths (Breman et al., 2004). It has been observed that deficiencies in vitamin A, zinc, iron folate and other micronutrients are responsible for a substantial proportion of malaria morbidity and mortality (Caulfield et al., 2004).

The lack of significant association of malaria with the other selected socio-economic factors could be attributed to the homogenous characteristics of the study population, making the factors less discriminatory. Al-Taiar et al. (2008) and Koram et al. (1995) also found no significant associations between malaria and socio-economic factors. However, studies done in Asia and Latin America in the 1980s showed that socio-economic factors led to a predisposition to malaria (Banguero, 1984, Butraporn et al., 1986, Fungladda et al., 1987, Adiamah et al., 1993). These studies used different measures of socio-economic status such as knowledge about malaria prevention and level of education. Today, with increased publicity about malaria, these factors may not be ideal measures of socio-economic status.

In conclusion, the highly significant low risk of malaria associated with sufficient food supplies in a population that is so homogenous in many aspects underscores the importance of this single aspect as a factor determining who gets infected with the disease. This finding supports a recommendation made by Caulfield et al. (2004) on the need to integrate improved agricultural practices and nutritional programmes in existing malaria intervention programmes. The following section discusses some socio-cultural factors which may be necessary for such integration.

5.5 Socio-cultural factors

Diseases occur under social conditions beyond the control of the biomedical scientist. By implication, health interventions must also operate beyond the biomedical level, spreading to the domestic domain in which public health policies are implemented (Winch et al., 1994). The success of malaria intervention programmes depends on health care delivery systems in place and how the affected communities perceive the disease and measures applied to control it. This section discusses the health seeking behaviour and preventive measures employed to control malaria at the household level.

5.5.1 Health seeking behaviour

The WHO recommends that anyone suspected of having malaria should receive diagnosis and treatment with an effective drug within 24 hours of the onset of symptoms (http://www.cdc.gov/malaria/control_prevention/control.html accessed on: 04/09/ 2008). Where access to formal health care is limited, effective home treatment with anti-malaria drugs is recommended. The present study found a significantly low risk of malaria for those households that kept medicine at home (mOR 0.58; *p*-value 0.006). Although the proportion of those who stored anti-malaria drugs (Table 4.10) was much lower, the significant low association of malaria with keeping medicine at home may be an indicator of prompt treatment of related symptoms hence preventing development of severe disease.

Besides modern anti-malaria drugs, 16 (4.7%) of the malaria cases reported having taken traditional herbs for self treatment. A study investigating anti-plasmodial activity of some medicinal plant extracts used as traditional anti-malaria treatment in Kisii district, found that 63.6% of the plants were active (IC_{50} ≤ 100µg/mL) against K 39, a chloroquine sensitive *Plasmodium falciparum* isolate. The study noted that even though some of the plant extracts may not have direct effect on the parasite in vitro, they may deal with malaria symptoms such as fever in vivo (Muregi et al., 2004). Two of the herbs tested (*Senna didymobotrya* and *Melia azedarach)* were among those used by respondents in the present study. *Melia azedarach* has been found to be an anti-plasmodial compound and is used as an anti-malaria drug in many communities around the world (Khalid et al., 1989). Given the delayed treatment of malaria in the study area, it may be viable to further explore the traditional methods used to treat the disease.

Turning to the health care delivery system, treatment for malaria was free in government health care facilities. Personal communication with health care personnel at the study health centre revealed that anti-malaria drug supplies, delivered on a quarterly basis, were largely insufficient. It was reported that the drugs ran out within the first month, leaving the health facility without the much needed medicines until the next consignment. This communication concurs with a WHO (2008) report which documented that despite increased procurement of artemisinin-based combination therapy (ACT) as the first line treatment for *Plasmodium falciparum* malaria, provisions were not in constant supply. Even where malaria drugs are free, the associated costs and logistics of delivery need to be explored (Breman et al., 2004).

The present study showed that on average patients went to the health facility three days after the onset of symptoms. Only 17.5% of malaria subjects sought treatment within the recommended 24 hours of onset of symptoms. In a previous study in Kisii area, a median delay of two days was reported with only 19.6% seeking treatment within 24 hours of onset of symptoms (Amin et al., 2003). It is clear that a commitment made by African leaders to ensure 80% of malaria episodes are adequately treated within 24 hours of onset of symptoms by 2010 (WHO/RBM, 2005), is still far from being realised.

Delayed treatment could be explained by other factors such as distance to the health facilities. Table 4.11 shows that 64.5% of the malaria cases sampled in the study lived within a distance of 3 km from the health facility. This concurs with a previous study in Kisii area which demonstrated that the number of patients using health facilities was highest at two or three kilometres radius around the health centres (Noor et al., 2003). Another study in western Kenya found that the rate of clinic visits decreased linearly at 0.5 km intervals up to 4 km. The study found that for every 1 km increase in distance of residence from a demographic surveillance system (DSS) clinic, the rate of clinic visits decreased by 34% from the previous kilometre (Feikin et al., 2009). Elsewhere, the risk of *Plasmodium falciparum* infections was associated with distances to health care facilities in Cote d'Ivoire (Silue et al., 2008) and in Yemen, distance to healthcare (>2 km) and delay to treatment were significantly associated with development of severe malaria among children aged six months to ten years (Al-Taiar et al., 2008).

In brief, it can be said that the health seeking behaviour in the study area is characterised by delayed treatment influenced by distance to the health care facility. Distances, limited resources in health facilities, inadequate staffing and lack of essential drugs (Hopkins et al., 2007) are well known shortcomings in the health care delivery system in resource poor countries.

5.5.2 Preventive measures

Looking at preventive measures, the present study showed an almost universal coverage with bed nets. 95% of the survey households owned mosquito nets and 84% of the subjects slept under a net during the previous night (Table 4.14). This high coverage could be attributed to free mass distribution of bed nets, integrated with a measles campaign, conducted in Kisii district in July 2006 (Fegan et al., 2007). It is argued that when coverage with ITNs is high, almost every net encounter by an *Anopheles* mosquito has a high probability of killing it (Magesa et al., 2005, Erlanger et al., 2004). At full coverage, it is assumed that bed nets halve both the probability of mosquito vectors surviving each feeding cycle and the probability that they will obtain a blood meal from people rather than other vertebrates (Killeen et al., 2002b).

One effect of ITNs is therefore to reduce the personal risk of clinical malaria, severe malaria, and malaria mortality for the individuals who use them (Killeen and Smith, 2007). Contrary to expected results, a large proportion of malaria cases in the present study reported regular bed net use. Previous night bed net use showed a non significant 7% reduction in the risk of malaria. Why then the large number of malaria cases despite the nearly universal coverage with ITNs? One reason could be the proportion of out door biting. A significant association of malaria with the factor of staying outside at night has already been explained. It is therefore possible that outdoor biting mosquitoes may have been responsible for the transmission of malaria among the cases sampled in this study. Secondly, ITNs do not provide perfect protection and full coverage may not be sufficient to achieve sustained endemic control in areas with very high baseline *Plasmodium falciparum* parasite ratio. Even in the best case in which ITNs coverage is rapidly scaled up to the maximum, reduction in *Plasmodium falciparum* parasite ratio does not occur instantly, a time lag of up to 4 years is expected before a reduction of 1% is achieved (Smith et al., 2009).

Spot checks revealed that 40% of the bed nets in the survey households were torn. Similar observations were made in Burundi where despite the high number of ITNs retained after distribution, the lifespan and fabric integrity of the nets drastically reduced because of holes (Protopopoff et al., 2007). Even though experimental studies have reported that ITNs purposely holed can still kill mosquitoes and prevent mosquito bites (Smith et al., 2007, Prasittisuk et al., 1996), presence of holes is commensurate with loss of insecticide hence reduced efficacy. The large proportion of torn nets suggest that besides their insecticidal properties, ITNs should be resistant enough to withstand hard field conditions like those of rural Africa (Protopopoff et al., 2007).

The present study found 236 (14.5%) bed nets, mainly those distributed free of charge, were not used. Of these, 88 (5.4%) had not been opened. In another study, ITNs distributed free of charge for malaria control, were used for drying fish along Lake Victoria (Minakawa et al., 2008). As efforts to control malaria through distribution of ITNs continue to be implemented, there is need to review their impact not only in terms of coverage but also on how people perceive and use them. This fact, together with the poor condition of the bed nets may explain the observed large numbers of malaria incidences (Table 2.1) despite wide coverage and high use of bed nets in the study area.

Another preventive measure, indoor residual spraying (IRS), was targeted at valley bottoms and homesteads within a radius of 2 km from the swamps. 206 (30.6%) of the survey homesteads had been sprayed. IRS is based on the observation that after feeding on human blood, many endophilic mosquitoes species rest on walls until the eggs are fully developed, when the females fly outdoors in search of oviposition sites. However, it has been reported that Anopheles *gambiae* tend to leave the houses after freshly feeding on blood, hence not absorbing the insecticide sprayed on the walls. This exophilic behaviour of the *Anopheles gambiae* was increased by the permethrin insecticide (Githeko et al., 1996, Vulule et al., 1994). This could explain the observed lack of association of malaria with IRS (mOR 1.03; *p*-value 0.86) in the present study. The effect of IRS may also have been destroyed by a common practice of re-plastering the mud walled houses with a new coating of earth, clay and cow dung (Monica 2007, personal communication). Effective implementation of IRS relies on highly professional vector control services, good planning and timing of the activities, strict management and logistics support (WHO, 2006). IRS was introduced in the area in 2007 and the laid down criteria for success may have been difficult to achieve in the first year of implementation.

Taking a brief look at traditional methods of protection, herbs, for example nema leaves, have been shown and scientifically advocated for larviciding in the study area (ICIPE, 2007). Given that the present study found a significant association between malaria and staying out at night, traditional methods such as burning cow dung and local herbs to keep mosquitoes away may be useful control measures. Use of traditional methods even under indoor conditions have been advocated when people cannot be protected by other methods like bed nets, for example in the early evenings before retiring to bed or early morning (Ng'ang'a et al., 2008).

In brief, the study area, like in many other malaria endemic regions, was subject to high-impact malaria control programs emphasizing use of ITNs and IRS. The data analysed did not show evidence of reduced malaria as a result of these measures. There may be a need to explore additional vector control measures necessary to achieve significant reductions in malaria morbidity.

5.5.3 Perceptions: do they matter?

Understanding the lay views on causation of health and ill health is important for the design of health education and health promotion programmes aimed at making people change their behaviour in a way likely to improve health. It also contributes to understanding some of the basis for individuals’ use or non-use of health services and compliance with treatment (Curtis, 1996). Analysis of perceptions (Table 4.24 to Table 4.29) showed a lower risk of malaria for those who had adequate knowledge of the disease, judged by perception about the causes, symptoms and prevention. The odds ratios from these analyses, though not statistically significant, imply that perceptions may have an important role in influencing behaviour leading to better prevention and control of malaria. This concurs with a study (Safeukui-Noubissi et al., 2004) which found that mothers' adequate knowledge about malaria was associated with a decreased risk of severe malaria in children.

Although most respondents (95%) rightly associated malaria with mosquitoes, detailed content analysis (Table 4.24 and Table 4.25) revealed a number of misconceptions about what causes the disease and the nature of its transmission. Fifty two (7.8%) respondents perceived malaria to be caused by chewing sugarcane and/or eating boiled maize. Seventy one (10.6%) respondents associated the disease with eating dirty foods or unbalanced diet. Other perceived causes included stress associated with working in the fields (3.0%), dirty beddings (3.0%) and attending funerals (2.4%). A survey conducted in an irrigated rice scheme in eastern Kenya revealed similar perceptions where 95% of the respondents related malaria with mosquitoes together with other non biological causes such as long rains/ being rained on (12.5%) stagnant water (16%), dirty home surroundings (4.6%), wet and cold conditions (10.6%), eating raw food/mangoes (5.2%) and taking dirty and polluted water (4.1%) (Ng'ang'a et al., 2008). Similar misconceptions were reported in Yemen where malaria was said to be caused by playing in bad weather, missing breakfast, flies, eating uncovered food and sleeping with a child in the same bed (Al-Taiar et al., 2008). In Uganda, malaria was believed to be caused by what is eaten or drunk, poor diet, environmental conditions, mosquitoes and also part of other illnesses (Kengeya-Kayondo et al., 1994). Going back to the present study, 88.2% of the respondents mentioned bed nets as a method of prevention (Table 4.26). However, 3.5% of those mentioning bed nets expressed mistrust of this method as an effective measure of malaria control. Twelve respondents (1.8%) categorically stated that malaria could not be prevented. Although these proportions are low, they may be an indicator of hidden mistrust in a much larger proportion of the community who may not have been bold enough to express contrary views, given the widely promoted control campaigns. Ng'ang'a et al. (2008) observed that local people mostly judge or determine the effectiveness of an intervention by its immediate or noticeable potential in reducing adult mosquito population, stopping the nuisance biting or reducing breeding habitats. Failure to satisfy these conditions, the intervention may be deemed ineffective consequently reducing community support or even developing negative perception.

Studies reviewed in this section show that although the causes, transmission and prevention of malaria are fairly well known, still the disease is yet to be fully understood as a vector borne parasitic disease transmitted by female *Anopheles* mosquitoes. In the present study for example, only 34% of respondents mentioned mosquitoes as the single factor leading to malaria. Health interventions have been described as fundamentally social interventions (Mosley, 1989). Perceptions reviewed in this section show that there is still a great deal to be done to improve the community understanding of malaria. Only then can interventions, usually targeted at vector control, be understood and applied meaningfully at personal and community level.

Limitations of the study

A methodological limitation of this study was that the cases and controls were drawn from a very homogenous population; hence some potential environmental, socio-economic and behavioural risk factors may have been omitted due to lack of discrimination. The cases and controls were recruited from a health facility where malaria was diagnosed presumptively among children under five. This may have added to the homogeneity factor given that children under five made up more than half of the subjects sampled. Nevertheless, the study was able to identify some important risk factors in this relatively homogenous population.

6 CONCLUSIONS

The expected outcome of this study was to identify important human and micro-ecological risk factors associated with malaria incidences. The background theory (section 1.6) defined key categories of human and environmental factors interacting in different ways to increase or reduce the risk of malaria. Applying the conceptual model (Figure 1.8) to the key findings of the study, staying outside at night was identified as an important behavioural aspect associated with a high risk of malaria. This may suggest a need to promote other methods of personal protection to cater for situations where individuals cannot be protected by commonly used approaches (ITNs and IRS) designed for indoor protection.

Sufficient food supplies were identified as a key socio-economic factor associated with reduced risk of malaria. There is documented evidence that improved nutrition influences immunity status resulting in ability to suppress parasite density thus reducing the risk of developing malaria. It is no wonder then that the study of perceptions revealed that malaria was frequently associated with nutritional deficiencies. Given the subsistence nature of the rural economy of the study area, it may be necessary to incorporate improved agricultural practices in malaria control programmes.

Keeping medicine at home was another factor associated with reduced risk of malaria. This may imply that those families who kept medicine at home were likely to respond promptly to malaria hence reducing the severity of the disease. This factor suggests a need to promote effective home management of malaria using appropriate anti-malaria drugs, particularly in places where access to formal health care services is limited.

Household size was identified as a socio-demographic factor associated with an increased risk of malaria. Larger households are likely to have more people sleeping in the available rooms. This may make it easier for probing mosquitoes to infect more people. Some members of such households may also sleep in poor make shift houses that make it easier for mosquitoes to enter and bite people at night.

Under the variables related to the physical environment, the interaction of low slopes and proximity to swamps was identified as a main factor associated with an increased risk of malaria. Even on steep hills, houses were constructed in the relatively lower flat areas which also happened to be ideal places for mosquito breeding. In the home environment, keeping oxen was associated with a higher risk of malaria. These animals, mainly reared for ploughing, were kept in zero grazing units adjacent to human dwellings. The small puddles formed by the hoof prints of these animals may create ideal breeding places for mosquitoes in the vicinity of the homesteads. Additionally, presence of cattle close to human dwellings has been known to attract mosquitoes to the general proximity. It can therefore be argued that the physical environment dictating the choice of house construction sites interacts with the anthropogenic factors like keeping animals to create favourable mosquito breeding sites in the vicinity of human dwellings. This may imply the need for environmental measures aimed at destroying mosquito breeding places resulting from these interactions.

Housing characteristics, specifically open eaves, were identified as another factor associated with an increased risk of malaria. Open eaves in houses could be a factor allowing easy entry of mosquitoes into the houses. After feeding on human blood, the open eaves may have also contributed to the mosquitoes leaving the houses hence not absorbing insecticides sprayed on the walls. This suggests a need to extend improvement in housing design as a malaria control measure.

Looking at preventive measures, the large number of malaria incidences reported among bed net users and the high proportion of torn bed nets lead to questions about effective use and quality. There may be a need for manufacturers to improve the physical strength of the bed nets to withstand the rough walls and sticks used to support them around the sleeping areas. In agreement with findings from other studies, there are genuine concerns that while ITNs are widely distributed free of charge in high risk communities, this intervention is not always properly used and in some situations, it has even been abused. There is therefore a great need for ITNs providers to educate communities on effective use, care and maintenance of these devices.

In addition to conventional knowledge about the causes, transmission and prevention of malaria, analysis of perceptions revealed that malaria was associated with the general socio-cultural notions about health and disease. Nutritional deficiencies and factors related to environmental hygiene were commonly perceived to cause malaria. Contact with sick persons was frequently mentioned as a channel through which the disease is transmitted, while keeping the home environment clean was perceived as a preventive measure. Given the association of malaria with environmental factors, larvae control measures may be readily acceptable and effective interventions. While making use of these notions to improve hygiene may be a useful resource in controlling malaria, the findings reveal that malaria is not yet fully understood as a vector borne parasitic disease spread by female anopheles mosquitoes.

Referring to the research questions (section 1.4), the study has demonstrated that the day to day interactions between human beings and their micro-scale environment may lead to increased risk of malaria. Secondly, the study has shown that socio-economic and demographic factors may influence malaria incidences. Finally, perceptions about the factors leading to malaria occurrence were found to play an important role in shaping health seeking behaviour and preventive measures. It can therefore be concluded that although climatic factors may influence general trends of malaria occurrences (section 3.3), it is the individuals' interaction with his/her environment together with their socio-economic and behavioural factors that determine whether or not the person gets the disease.

The main contribution of this study was to relate socio-economic, behavioural aspects and micro-ecological conditions with actual observed malaria cases. While a large number of studies have succeeded in identifying mosquito species, their breeding characteristics and testing intervention measures, few studies have shown interest in behavioural and perceptual aspects. Malaria transmitting mosquitoes bite human beings and breed in places close to human dwelling places. Interventions geared towards adult mosquitoes or larvae stages must therefore consider behaviour and perceptions which enhance contact between human beings and the malaria vectors.

The findings of this study demonstrate the need to emphasize holistic approaches that draw connections between human behaviour and the environment. The simple measures of keeping the home environment free of puddles and objects in which water could collect to form breeding grounds for mosquitoes hold today just as they did when they were first applied in the early 20th century.

As much effort is put on mosquito control, it is important to remember that the vector transmits the parasites which it collects from infected hosts. A strong health care delivery system is indispensable to ensure that infected persons are effectively treated. Improved infrastructure and partnership with the broader development community to ensure that the most vulnerable regions are vigorously and equitably developed; may be the way forward to roll back malaria in sub-Saharan Africa.

7 GLOSSARY

Analgesic drugs	Any member of diverse group of drugs used to relieve pain.
Anthropogenic factors	Factors derived from human activities as opposed to those occurring in natural environments without human influences.
Bed net	Any mosquito net regardless of its treatment status.
Eaves	An open gap between the wall and roof of a house.
Environmental management	The planning, organisation, carrying out and monitoring of activities for modification and or manipulation of environmental factors or their interaction with human beings with a view to preventing or minimising vector propagation and reducing human-vector pathogen contact.
Environmental modification	Measures aimed at creating a permanent or long-lasting effect on land, water or vegetation to reduce vector habitats.
Environmental manipulation	Methods of creating temporary unfavourable conditions for the vector.
Epidemiological study	A study design that investigates distribution and determinants of health conditions and health incidents in a defined population group and the resulting application for controlling health problems.

Highland malaria	Incidence of highly unstable malaria at the local attitudinal limits of transmission typified by acutely seasonal transmission with large inter-annual variations in intensity.
Homestead	A cluster of several houses belonging to one household. It includes other structures (animal sheds, granaries, utensils rack) adjacent to the houses.
Homestead sketching	Small courtyard mapping aimed at showing the micro-scale ecological factors surrounding the homestead.
Household	Individuals living together as a family unit and sharing a common budget. These may include domestic help and other members of the extended family.
Indoor residual spraying	A process of spraying the inside of dwellings with an insecticide to kill mosquitoes that spread malaria. A dilute solution of insecticide is sprayed on the inside walls of certain types of dwellings i.e. those with walls made from porous materials such as mud or wood. Mosquitoes are killed or repelled by the spray, preventing the transmission of the disease.
Global malaria campaign	A campaign carried out between 1955 and 1979 aimed at eradicating malaria with emphasis on indoor residual spraying and DDT.
Insecticide treated bed nets	Conventional nets requiring re-treatment after six months.

Integrated vector management	Rational decision-making process for the optimal use of resources for vector control. It involves collaboration within the health and other sectors, advocacy, social mobilisation, legislation and capacity building.
Long-lasting insecticide treated nets	Bed nets treated with pyrethroid insecticides which retain the insecticidal properties for over five years.
Malaria early warning system	A series of approaches comprising of forecasting, early warning and early detection aimed at improving the understanding of the geographical variation of malaria in a changing environment. Forecasting refers to seasonal climate forecasts, early warning refers to the monitoring of meteorological conditions and early detection is case surveillance.
Merozoites	A daughter cell of a protozoan parasite. In malaria, these spores infect red blood cells and then rapidly reproduce asexually. They break and destroy the host red blood cells and infect other red blood cells.
Micro-ecological risk factors	Small scale interactions between human beings and their immediate environment which pose a risk to contracting malaria. They include housing characteristics and the immediate environment of a household.

Odds ratio	A measure of effect size, describing the strength of association or non-independence between two binary data values. It is used as a descriptive statistic, and plays an important role in logistic regression. In this study matched odds ratio (mOR) were calculated for the case-control pairs.
Upper respiratory tract infections	Illnesses caused by an acute infection which involves the upper respiratory tract: nose, sinuses, pharynx or larynx.
Trophozoites	Activate feeding stage in the cycle of protozoan parasites such as malaria causing *Plasmodium falciparum*.
Sentinel site	A health care facility used to monitor and assess the level of stability or changes in malaria on a routine basis selected as the best representation of a larger population than that actually sampled.
Sporozoites	In malaria, the sporozoites are cells that develop in the mosquito salivary glands. They leave the mosquitoes during a blood meal and enter the liver cells of the human host where they multiply. Cells infected with sporozoites burst releasing merozoites into the blood stream.

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9 APPENDICES

APPENDIX 1: HOUSEHOLD SURVEY (HHS)

Administrative unit	Name										ID. Code		
Location													
Sub-location													
Village													

Category	Case	1	Control	0

Name of HH head															
Household ID															

Name of Patient										
Name of Respondent										
Relation to HH Head										
Ethnic group										
Religion										

Date of interview dd/mm/yr			/			/	0	7
Start time of interview					A.M.	P.M.		
End time of interview					A.M.	P.M.		
Interview complete?	YES	NO						
Scheduled date of return interview			/			/	0	7
Scheduled time of return interview					A.M.	P.M.		
Enumerator's name								
Editor's name								
Name of data operator								
Date of data entry			/			/	0	7

CODES TO SURVEY SECTIONS

RH: Residence history
EA: Event analysis
MB: Malaria morbidity
KM: Knowledge about malaria
MM: Malaria mortality
PM: Preventive measures
MC: Migration and seasonal movement
EF: Exposure factors
SE: Socio-economic factors

LIST OF MEMBERS OF HOUSEHOLD

	Name	Sex		Year birth	Relationship to HH head *1	Occupation *2	Educational level *3
		M	F				
01		1	2				
02		1	2				
03		1	2				
04		1	2				
05		1	2				
06		1	2				
07		1	2				
08		1	2				
09		1	2				
10		1	2				
11		1	2				
12		1	2				
13		1	2				
14		1	2				
15		1	2				

*1 **Relationship codes:** (HH 1) (Wife **2**) (Son 3) (Daughter 4) (Parent **5**) (Domestic help **6**) (Other **7** - specify)

*2 **Occupation codes:** (Farming**1**); (Business **2**); (Informal sector /Jua Kali **3**); (Casual labourer **4**); (Formal employment **5**); (Pupil/Student **6**); (Other **7** specify)

*3 **Education codes:** (No formal education **1**) (Primary school incomplete **2**) (Completed primary education **3**) (Secondary education **4**) (College **5**) (University **6**)

RESIDENCE HISTORY

RH 01 Have all the members of your household always lived in this area (i.e. Nyamarambe division)?

Yes 1 (IF ***YES*** GO TO QUESTION ***EA 5***)

No 0 (IF ***NO*** FILL IN THE TABLE BELOW)

RH 02 **Line number of migrants (from the list of HH members)**	**RH 03** **District/division of origin**	**RH 04** **Duration of residence in study area in months**

EVENT ANALYSIS OF THE LAST SICKNESS EPISODE

(TO BE ANSWERED BY THE CASE/ CONTROL OR CARE GIVER)

EA 05 A few days ago you went to Nduru health centre. Are you able to tell us how many days you had been sick before you went to the health centre? (WRITE THE EXACT NUMBER OF DAYS)

_____ Days

EA 06 Had you applied any treatment before going to the health centre?

Yes 1

No 0 (IF ***NO*** GO TO QUESTION ***EA 12***)

EA 07 What treatment did you apply? (WRITE THE NAMES OF ALL FORMS OF TREATMENT MENTIONED BY THE RESPONDENT)

____

____

EA 08 Where did you get the treatment? <<MULTIPLE ANSWERS POSSIBLE>>

Shops	1
Local chemists	2
Drug vendors	3
Left over medicines	4
From friends/relatives	5
Community health worker	6
Traditional herbalists	7
Other	8
(Specify)	

____

EA 09 From the time you experienced the first symptoms, after how long did you take the first treatment? (WRITE EXACT NUMBER OF HOURS OR DAYS)

_________Hours **or**

_________Days

EA 10 How many times did you apply the treatment? (WRITE EXACT NUMBERS IN THIS ORDER)

Number of tablets/spoons (or any other measurement) _________

How many times a day ___________

For how many days ____________

EA 11 How much did the treatment cost? (STATE WHETHER THE COST IS PER DOSE OR FOR THE WHOLE TREATMENT)

___________ cost per dose **or** (in Kenya shillings)

___________ cost for the whole (in Kenya shillings)

(IF TREATMENT WAS FREE, ASCERTAIN THE SOURCE FROM QUESTION EA 8)

EA 12 Why did you choose to go to Nduru health centre?

<<MULTIPLE ANSWERS POSSIBLE>>

Cost	1
Distance (nearest)	2
Good services	3
Good relations/rapport	4
Other (Specify)	5

____

EA 13 Which means of transport did you use to go to the health centre?

Walking	1
Matatu/ bus	2
Bicycle	3
Hired vehicle	4
Wheelbarrow	5

EA 14 How long did it take you to get to the health centre?

(WRITE ANSWER IN HOURS)

_______hrs

EA 15 Did anyone accompany you to the health centre?

Yes	1	
No	0	(IF ***NO*** GO TO QUESTION ***EA17***)

EA 16 Who accompanied you? (WRITE THE NAME OF THE ACCOMPANYING PERSON AND HIS/HER RELATIONSHIP TO THE RESPONDENT)

Name of accompanying person: ___________________

Relationship to the respondent: ___________________

EA 17 How long did you wait at the health centre before you got treated? (WRITE ANSWER IN HOURS)

______hours

EA 18 How much did you pay for the treatment at the health centre?

________ (cost in Kenya shillings)

EA 19 Were you satisfied with the services offered at the health centre? (Briefly explain your answer)

Yes 1

No 0

____

____

EA 20 Are you still on medication?

Yes 1

No 0

EA 21 Since you went to Nduru health centre, have you taken any other form of treatment for the same sickness?

Yes 1

No 0 (IF ***NO*** GO TO QUESTION ***MB 23***)

EA 22 What other treatments have you taken?

<<MULTIPLE ANSWERS POSSIBLE>>

Visited another hospital 1

Name of hospital visited________________________________

Used other traditional methods of treatment 2

Name: ____

Source: ____

Obtained other medicines 3

Name: _______________________________________

Source: ____

Other 4 (specify) ____

MALARIA MORBIDITY IN THE HOUSEHOLD

(TO BE ANSWERED BY HEAD OF HOUSEHOLD OR HIS/HER REPRESENTATIVE) NOW WE WOULD LIKE TO ASK YOU SOME QUESTIONS ABOUT MALARIA

MB 23 Has any member(s) of your household suffered from malaria in the last two weeks?

Yes 1

No 0 (IF ***NO*** GO TO QUESTION ***KM 30***)

MB 24 Who in your household was infected with malaria in the last two weeks?

(WRITE THE NAME(S) OF ALL THE PERSON(S) IN THE HH WHO HAVE SUFFERED FROM MALARIA IN THE LAST TWO WEEKS AND INDICATE THEIR LINE NUMBER(S) IN THE HH MEMBERS LIST)

Name: ____________________________ line number: ______________

____________________________ ______________

____________________________ ______________

MB 25 Did the person(s) seek any treatment?

Yes 1 (IF ***YES*** GO TO QUESTION ***MB 27***)

No 0

MB 26 Why did the person(s) not seek any treatment?

<<MULTIPLE ANSWERS POSSIBLE>>

The sickness was not serious 1

Lack of money 2

Others (please specify) 3

____

MB 27 What did they do for treatment? <<MULTIPLE ANSWERS POSSIBLE>>

Bought medicines 1

Used left over medicines 2

Obtained medicine from relatives or friends 3

Went to hospital 4 (name: _______)

Went to a traditional herbalist 5

Used traditional herbs 6 (name: _______)

Other 7 (specify: ______)

MB 28 What medicine(s) did the person(s) take? (WRITE DOWN THE NAMES OF ALL THE MEDICINES MENTIONED)

____

____

MB 29 How much did the medicines cost? (STATE WHETHER THE COST IS PER DOSE OR FOR THE WHOLE TREATMENT)

_____ cost per dose **or**

_____cost for the whole

KNOWLEDGE ABOUT MALARIA

KM 30 What do you think causes malaria? (PLEASE RECORD ALL THE RESPONSES IN THE ORDER MENTIONED BY THE RESPONDENT).

1____

2____

3____

KM 31 How do you think malaria is transmitted?

1____

2____

3____

KM 32 What do you think are the signs/symptoms of malaria? (PLEASE RECORD ALL THE RESPONSES IN THE ORDER MENTIONED BY THE RESPONDENT).

1____

2____

3____

KM 33 How can one protect himself/ herself from malaria? (PLEASE RECORD <u>ALL</u> THE RESPONSES IN THE ORDER MENTIONED BY THE RESPONDENT).

1______________________________

2______________________________

3______________________________

KM 34 How would you classify the seriousness of malaria in this area? **Give reasons for your answer**

Very serious	1
Serious	2
Not very serious	3
Not serious at all	4

Reasons:

____

____

MALARIA MORTALITY IN THE HOUSEHOLD

(PLEASE ASK THESE QUESTIONS VERY POLITELY. THE QUESTIONS COULD BE ASKED TO ANOTHER MEMBER OF THE HOUSEHOLD IF THE RESPONDENT DOES NOT WANT TO ANSWER THEM OR IS TOO EMOTIONAL)

MM 35 Has any member of your family died of malaria in the last one year?

Yes	1	(MAY I ASK YOU SOME DETAILS ABOUT THAT?)
No	0	(IF ***NO*** GO TO QUESTION ***PM 43***)

MM 36 Name of the deceased	
MM 37 Age at the time of death	
MM 38 Month and year of death	Month: Year:
MM 39 Place of death	Hospital 1 Name of health care facility ___________ Home 2

(IF THE PERSON DIED AT HOME)

MM 40 Had the deceased sought any treatment before the event of death?

Yes 1

No 0 (IF ***NO*** GO TO QUESTION ***PM 43***)

MM 41 Where had the deceased sought treatment?

Hospital 1 Give name______________________________

Home treatment 2

MM 42 What medicines had the deceased taken?

____

____

USE OF PREVENTIVE MEASURES

PM 43 Do you think mosquitoes have an effect on your body?

Yes 1

No 0

PM 44 Where do you think mosquitoes are most likely to be found? (WRITE ALL RESPONSES IN THE ORDER MENTONED BY THE RESPONDENT)

1____

2____

3____

PM 45 Do you and other members of your household protect themselves from mosquito bites?

Yes 1

No 0 (IF ***NO*** GO TO QUESTION ***PM 47***)

PM 46 How do you and other members of your household protect themselves from mosquito bites?

Mosquito nets	1
Mosquito coils	2
Sprays	3
Mosquito repellents	4
Burning cow dung	5
Smoke	6
Lighting the lamp	7
Others	8 (Please specify)

____

PM 47 Does your household own any mosquito nets?

Yes	1	
No	0	(IF ***NO*** GO TO QUESTION ***PM 56***)

PM 48 How many nets do you have in your household? (INDICATE ACTUAL NUMBER OF NETS IN THE HOUSEHOLD)

___________________nets

PM 49 How did you get the net(s)?

Bought	1	(IF BOUGHT GO TO QUESTION ***PM 50***)
Donated/gift	2	(IF DONATED GO TO QUESTION ***PM 51***)

PM 50 How much did the net(s) cost?______cost in Kenya shillings

PM 51 Who provided the net(s).

NGO (Please write name) Name:______________________	1
Clinic/Hospital Name:______________________	2
Friends/ relatives	3
Other (please specify) ___________________________	4

PM 52 Did you and any other members of your family sleep under a mosquito net last night?

Yes	1	
No	0	(IF ***NO*** GO TO QUESTION ***PM 54***)

PM 53 Who slept under a mosquito net last night? (WRITE THE NAMES OF PERSONS AND THEIR LINE NUMBERS IN THE HOUSEHOLD LIST)

Names ________________________ Line number: ____________________

________________________ Line number: ____________________

PM 54 Are the nets in your household treated?

Yes 1

No 0 (IF ***NO/ DON'T KNOW*** GO TO QUESTION ***PM 56***)

Don't know 2

PM 55 When was the last treatment of the nets done? (WRITE THE EXACT DURATION OF TIME THAT HAS ELAPSED SINCE THE LAST TREATMENT OF THE NET(S)

____ Days **or**

____ Weeks **or**

____ Months **or**

____ Years

What chemical was used to treat the net(s)?

____

Who treated the net(s)?

____

REQUEST TO SEE THE NET(S) AND FILL IN SPOT CHECK FORM (SCF3-MN)

PM 56 Has your homestead been sprayed with any chemical to kill mosquitoes?

Yes 1

No 0 (IF ***NO*** GO TO QUESTION ***MC 60***)

PM 57 When is the last time your homestead was sprayed to kill mosquitoes? (WRITE THE EXACT DURATION OF TIME THAT HAS ELAPSED SINCE THE LAST SPRAYING OF THE HOMESTEAD)

____ Days **or**

____ Weeks **or**

____ Months **or**

____ Years

PM 58 Who paid for the spraying? (WRITE THE NAME OF THE PERSON OR ORGANISATION SUPPORTING THE SPRAYING)

____

PM 59 What chemical was used to spray the homestead?

____

MIGRATION AND CIRCULATION DATA

MC 60 Did you or any other member of your household travel to another district or division in the last two weeks?

Yes	1	(IF ***YES*** GO TO QUESTION ***MC 61***)
No	0	(IF ***NO*** GO TO QUESTION ***MC 64***)

MC 61 Name and line numbers of person(s) who travelled	MC 62 District/division of travel	MC 63 Duration of stay in days

MC 64 Do you or any other member of your household travel regularly to other places outside Nyamarambe division?

Yes	1	
No	0	(IF ***NO*** GO TO QUESTION ***EF 67***)

MC 65 State the name and line number(s) of the person(s) in the household list

Name ______________________ Line number ______________________

______________________ ______________________

MC 66 How regularly does the person(s) travel?

Daily	1
Weekly	2
Monthly	3
Seasonally	4
Yearly	5

EXPOSURE FACTORS

EF 67 Has any member of your household been to a funeral, *kesha* or any other ceremony at night in the last two weeks?

Yes 1

No 0 (IF ***NO*** GO TO QUESTION ***EF 69***)

EF 68 State the name(s) and line number(s) of the person(s) in the household list.

Name ___________________________ Line number ______________________

___________________________ ______________________

EF69 At what time do the members of your household normally wake up?

____

EF70 At what time do the members of your household normally go to sleep? ____

SOCIO-ECONOMIC INDICATORS

SE 71 Do you own any land?

Yes 1

No 0 (IF ***NO*** GO TO QUESTION ***SE 76***)

SE 72 How many acres of land do you own?

(WRITE EXACT NUMBER OF ACRES) _______acres

SE 73 Do you grow any of the following crops for sale?

	Yes	No
Tea	1	0
Coffee	1	0
Sugarcane	1	0
Horticultural produce	1	0
Others(specify) _________________	1	0

SE 74 Do you own any of the following farm tools/implements?

	Yes	No
Wheel barrow	1	0
Ox plough	1	0
Knapsack sprayer	1	0
Water pump	1	0

SE 75 Do you keep any of the following domestic animals in your household?

	Yes	No	Number
Cattle	1	0	
Sheep	1	0	
Goats	1	0	
Donkey	1	0	
Poultry	1	0	
Pigs	1	0	
Oxen	1	0	
Dogs	1	0	

SE 76 Do you own any of the following items in your household?

	Yes	No
Radio	1	0
Television	1	0
Mobile phone	1	0
Bicycle	1	0
Motorcycle	1	0
Motorcar	1	0
Sewing machine	1	0
Lantern lamp	1	0
Pressure lamp	1	0
Clock	1	0
Electricity	1	0
Sofa set	1	0
Kerosene stove	1	0
Gas cooker	1	0
Water tank	1	0

SE 77 If someone in your household gets sick, how do you get money for treatment? <<MULTIPLE ANSWERS ARE POSSIBLE>>

Health insurance	1
Emergency Loans	2
Sell household assets	3
Adjust other expenses	4
Borrow from friends	5
Help from the extended family	6
Harambee (fund raising)	7
Support from Religious groups	8
Other (Please specify)	9

____

SE 78 Do you normally keep medicines in your house?

Yes	1	
No	0	IF ***NO*** GO TO QUESTION ***SE 80***)

SE 79 Which medicines do you have in the house at the moment?

(ASK THE RESPONDENT TO SHOW YOU THE MEDICINES AND CONFIRM THE NAMES FROM THE LABELS. CHECK EXPIRELY DATES AND NOTE IF ANY IS EXPIRED)

1____________________________ 4____________________________

2____________________________ 5____________________________

3____________________________ 6____________________________

SE 80 Do you normally take the following meals in your household?

	Yes	No
Break fast	1	0
Lunch	1	0
Supper	1	0
In –between snack	1	0

SE 81 Do you have enough food supplies to sustain your family throughout the year?

Yes	1	
No	0	(IF ***NO*** GO TO QUESTION ***SE 84***)

SE 82 How much of your household's food do you grow yourself?

Surplus	1
Sufficient	2
Fairly sufficient	3
Insufficient	4
None at all	5

SE 83 In which month(s) of the year do you normally face food shortage? <<MULTIPLE ANSWERS ARE POSSIBLE>>

January – March	1
April – June	2
July – September	3
October – December	4

SE 84 What does your household use for fuel? <<MULTIPLE ANSWERS ARE POSSIBLE>>

Fire wood	1
Charcoal	2
Kerosene	3
Gas	4
Maize cobs	5
Saw dust	6
Cow dung	7
Electricity	8
Others	9

(Please specify)____

(IF FIREWOOD IS NOT MENTIONED AS ONE OF THE SOURCES OF FUEL SKIP TO QUESTION ***SE 88***)

SE 85 Where does your household fetch firewood? <<MULTIPLE ANSWERS ARE POSSIBLE>>

From the farm	1
Forest/bush	2
Buying	3

SE 86 Who normally collects firewood for your household?

Name ____________________ Line number __________________

____________________ __________________

SE 87 At what time of the day does the person(s) normally gather firewood? <<MULTIPLE ANSWERS POSSIBLE>>

5 to 9am (Early morning) 1

10 am to 4 p.m. (Day time) 2

5 to 7 pm (Evening) 3

8 p.m. to 4 am (Night) 4

SE 88 How would you rate your socio-economic standards in relation to other people in this area?

Above average 1

Average 2

Below average 3

APPENDIX 2: SPOT CHECK FORM - HOUSING CONDITIONS (SCF1 -HC)

Administrative unit	Name										ID. Code		
Location													
Sub-location													
Village													

Category	Case	1	Control	0

Name of HH head															
Household ID															

Name of Patient										
Name of Respondent										
Relation to HH Head										

Date of spot check			/			/	0	7
Start time of spot check					A.M.	P.M.		
End time of spot check					A.M.	P.M.		

Enumerator's name															
Editor's name															
Name of data operator															

Date of data entry			/			/	0	7

CODES TO SPOT CHECK ITEMS

SCF1 – HC Spot check form for housing conditions
HC – Housing conditions
SCF2 – HS Spot check form for homestead surroundings
HS – Homestead surroundings
SCF3 – MN Spot check form for Mosquito nets
MN – Mosquito net

HC 01 How many housing units are there in the household (HOUSING UNIT HERE REFERS TO ANY SEPARATE HOUSE OWNED BY THE HOUSEHOLD) <<MULTIPLE ANSWERS POSSIBLE>>

Unit		**No. of rooms**	**Line number(s) of person(s) sleeping in each unit**
One unit household	1		
Separate kitchen	2		
Main house	3		
Dependants' house	4		
Others (specify) ______________________	5		

PLEASE RECORD THE OBSERVATIONS OF EACH HOUSING UNIT ON A SEPARATE FORM.

CLEARLY INDICATE THE HOUSING UNIT YOU ARE OBSERVING ACCORDING TO CLASSIFICATIONS GIVEN IN HC 01

HOUSING UNIT: ________________________________

HC 02 What type of material is used to make the walls?

Mud and sticks	1	
Iron sheets	2	
Tin	3	
Bricks	4	
Stone	5	
Wood	6	
Other (Specify)	7	________________________________

HC 03 Are there any cracks or holes in the walls?

Yes	1
No	0

HC 04 What type of material is used to make the roof?

Iron sheets	1	
Tin	2	
Tiles	3	
Grass	4	
Other (specify)	5	________________________________

HC 05 Are there any cracks or holes in the roof?

Yes	1
No	0

HC 06 Are there eaves (openings) between the roof and walls?

Yes	1
No	0

HC 07 Does the house have a ceiling?

Yes	1
No	0

HC 08 What type of floor does the housing unit have?

Cemented	1
Earth	2
Wooden	3
Tiles	4

HC 09 Does the house have windows?

Yes	1
No	0

HC 10 What material is used to make the windows?

Wood	1
Metal	2
Glass	3
Other (specify)	4

____

HC 11 Are there curtains on the windows?

Yes	1
No	0

HC 12 What material is used to make the doors?

Wood	1
Metal	2
Glass	3
Other (specify)	4

____

HC 13 Is there water stored in the housing unit?

Yes	1	
No	0	(IF ***NO*** GO TO QUESTION ***HC 15***)

(OBSERVE THE WATER STORED IN THE HOUSING UNIT AND FILL IN THE FOLLOWING DETAILS)

HC 14 Quality of water stored in the household

Type of storage container	Container covered		Visible plants		Visible insects		Mosquito larvae visible	
	Yes	No	Yes	No	Yes	No	Yes	No
	1	0	1	0	1	0	1	0
	1	0	1	0	1	0	1	0
	1	0	1	0	1	0	1	0

HC 15 Are there other containers that could hold water in the housing unit (e.g. empty tins etc?)

Yes 1 (IF YES SPECIFY THE TYPE AND NUMBER)

No 0

___

HC 16 Are there potted plants in the housing unit?

Yes 1

No 0

HC 17 Is the floor wet or damp?

Yes 1

No 0

Please take note of any other important characteristics of the housing unit.

___

___

___

APPENDIX 3: SPOT CHECK FORM - HOMESTEAD SURROUNDING (SCF2 -HS)

HS 01 What is the nature of the topography around the homestead?

Sloping ground	1
Valley	2
Flat ground	3
Stony ground	4

HS 02 What type of vegetation cover is found around the homestead? (OBSERVE AND RECORD) <<MULTIPLE ANSWERS POSSIBLE>>

Planted flowers	1	
Living fence	2	
Tall grass	3	
Short grass	4	
Bushes	5	
Trees	6	
Forests	7	
Bare ground	8	
Crops	9	(Please specify the type)

____

HS 03 Are there swamps near the homestead?

Yes	1
No	0

HS 04 What is the straight line distance between the swamp and the homestead?

<<MEASURE AND RECORD THE DISTANCE IN PACES>>

_____________paces

HS 05 Are there brick-making sites near the homestead?

Yes	1
No	0

HS 06 What is the straight line distance between the brick-making site and the homestead?

<<MEASURE AND RECORD THE DISTANCE IN PACES>>

_____________paces

HS 07 Is there a jaggery near the homestead?

Yes	1
No	0

HS 08 What is the straight line distance between the jaggery and the homestead?

<<MEASURE AND RECORD THE DISTANCE IN PACES>>

_____________paces

HS 09 Is there a fish pond near the homestead?

Yes 1

No 0

HS 10 What is the straight line distance between the fish pond and the homestead?

<<MEASURE AND RECORD THE DISTANCE IN PACES>>

_____________paces

HS 11 Is there an utensils rack within the homestead?

Yes 1

No 0

HS12 Where is the utensils rack?

Inside the kitchen 1

Outside on the compound 2

(OBSERVE THE CONDITIONS AROUND THE UTENSILS RACK AND FILL IN THE FOLLOWING TABLE)

HS 13 Conditions surrounding utensils rack

	Yes	No
Is there stagnant water around the rack?	1	0
Are there any observable mosquito larvae?	1	0
Are there flies around the rack?	1	0

HS 14 Where does the household get water for its domestic use? (ASK THE RESPONDENT) <<MULTIPLE ANSWERS POSSIBLE>>

Tap 1

River 2

Stream 3

Bore-hole 4

Well 5

Spring 6

Roof tops 7

Swamp 8

Others 9 (specify) ___________________________

HS 15 What is the straight line distance between the water collection point and the kitchen door?

_______________paces

HS 16 What time does the household fetch water for its domestic uses? (ASK THE RESPONDENT) <<MULTIPLE ANSWERS POSSIBLE>>

5 to 9 a.m. (Early morning) 1
10 a.m. to 4 pm (Day time) 2
5 to 7 p.m. (Evening) 3
8 p.m. to 4 a.m. (Night) 4

HS 17 Who normally fetches water for domestic use? (ASK THE RESPONDENT AND WRITE THE NAME AND LINE NUMBER(S) OF PERSONS(S) WHO FETCH WATER FOR THE HH)

Name ____________________ Line number ________________________

____________________ ________________________

ASK TO SEE WHERE THE HOUSEHOLD FETCHES ITS WATER FOR DOMESTIC USES AND RECORD THE FOLLOWING OBSERVATIONS:

HS 18 Conditions around domestic water collection points

	Yes	No
Is there stagnant water around the point?	1	0
Is there a channel to drain excess water?	1	0
Are there any observable mosquito larvae?	1	0
Is there grass around the place?	1	0
Are there bushes around the place?	1	0
Are there crops growing around?	1	0
Are domestic animals brought there to drink	1	0

HS 19 Where does the household dispose its waste water? (ASK THE RESPONDENT) <<MULTIPLE ANSWERS POSSIBLE>>

Pour in the garden 1
Pouring on the floor in the house 2
Drainage channel 3
Pour anywhere in the yard or road 4
Other (please specify) 5

____

REQUEST TO SEE WHERE THE HOUSEHOLD DISPOSES ITS WASTE WATER AND RECORD THE FOLLOWING OBSERVATIONS:

HS 20 Condition surrounding waste water disposal places

	Yes	No
Is there facility to drain the waste water?	1	0
Is there stagnant water around the place?	1	0
Are there containers that could collect water?	1	0
Are there flies around the place?	1	0
Is there odour coming from the place?	1	0
Are there observable mosquito larvae?	1	0

HS 21 What is the straight line distance between the kitchen door and the waste water disposal place? (MEASURE THE STRAIGHT LINE DISTANCE AND RECORD THE RESULT IN PACES)

_______________paces

HS 22 Where does the household dispose garbage? (ASK THE RESPONDENT) <<MULTIPLE ANSWERS POSSIBLE>>

In the garden	1
Compost pit	2
Community dumping site	3
Organised garbage collection facility	4
Littering	5
Other (Please specify)	6

REQUEST TO SEE THE PLACE WHERE THE HOUSEHOLD DISPOSES GARBAGE AND RECORD THE FOLLOWING OBSERVATIONS:

HS 23 Condition surrounding garbage disposal places

	Yes	No
Is the place covered?	1	0
Is the place wet or damp?	1	0
Is there stagnant water around the place?	1	0
Are there containers that could hold water?	1	0
Are there flies around the place?	1	0
Is there odour coming from the place?	1	0
Are there any observable mosquito larvae?	1	0

HS 24 What is the straight line distance between the garbage disposal place and the kitchen door? (MEASURE THE STRAIGHT DISTANCE AND RECORD THE RESULT IN PACES)

________paces

HS 25 What type of sanitation facilities does the household use?

Pit latrine 1

Flush toilet 2

Other (specify) 3 ____

REQUEST TO SEE THE TOILET/PIT LATRINE AND RECORD THE FACILITIES PROVIDED

HS 26 Toilet/pit latrine

	Yes	No
Wash basin	1	0
Bucket/basin with water	1	0
Soap	1	0
Toilet paper/substitutes	1	0
Toilet cover	1	0
Ventilation	1	0
Hand drying towel /substitute	1	0

HS 27 How would you rate the cleanliness of the toilet? (EVALUATE BASED ON PRESENCE OR ABSENCE OF FLIES, ODUOR, WETNESS AND HUMAN WASTE ON THE FLOOR)

Very clean 1

Clean 2

Dirty 3

Very dirty 4

HS 28 Observe the conditions around the cow shed and milking place and record the following.

	Yes	No
Are there footmarks left by the animals	1	0
Is there stagnant water around the place?	1	0
Are there containers that could harbour water?	1	0
Are there flies around the place?	1	0
Are there observable mosquito larvae?	1	0

Take notes of any other important characteristics surrounding the homestead.

____

APPENDIX 4: SPOTCHECK 3 - MOSQUITO NET (SCF-MN)

ASK THE RESPONDENT TO SHOW YOU THE NET(S) IN THE HOUSEHOLD AND RECORD THE FOLLOWING OBSERVATIONS. IF THE HOUSEHOLD HAS MORE THAN ONE MOSQUITO NET, USE A SEPARATE FORM FOR EACH NET.

MN 1 What is the colour of the mosquito net?

White	1	
Blue	2	
Green	3	
Other	4	(specify)

MN 2 What is the shape of the net?

Rectangular	1
Circular	2

MN 3 What is the brand name of the mosquito net?

____

MN 4 Is the mosquito net torn?

Yes	1
No	0

MN 5 Is the mosquito net clean?

Yes	1
No	0

MN 6 Is the mosquito net hung up around the sleeping area?

Yes	1
No	0

PLEASE NOTE IF THE MOSQUITO NET IS NOT IN USE E.G. NETS THAT HAVE NOT BEEN OPENED (IF ANY STATE NUMBER) ______________________

APPENDIX 5: THEMES FOR COMMUNITY INTERVIEWS AND KEY INFORMANTS (TCKI)

Theme 1: Perceptions on health and disease

What is health?

What is disease?

Theme 2: Disease ranking

What are the main diseases affecting people in this area?

Ask the participants to list and then rank them in order of importance

Theme 3: Malaria

Direct the participants to focus on malaria under the following:

Symptoms

Causes

Prevention

Theme 4: Health seeking behaviour

Where do people seek treatment when they are sick?

What factors determine the choice of where and what to seek for treatment?

Theme 5: socio-mapping

Involve the participants into a socio-mapping exercise showing the location of their homesteads in relation to major socio-amenities such as: shopping centres, schools, dispensary/ health centre, chief's camp, church, roads and physical features like swamps and rivers.

THEMES FOR KEY INFORMANT INTERVIEWS

Theme 1: Situation of malaria in the study area

Leading question

- How would you describe the situation of malaria in this area?

Theme 2: Factors underlying the situation in theme 1

Leading question

- What do you think are the factors underlying the situation you have just explained?

Theme 3: Possible remedies

Leading question

- What do you think could be done to improve the situations that contribute to malaria in this area?

Theme 4 Malaria diagnosis and treatment (For health care personnel)

Guiding questions

- How is malaria diagnosed at the health facility where you work?
- How is it treated?

Theme 5 Community response to malaria

Guiding questions

- Is the community you serve able to recognise malaria?
- What kind of treatment do the people normally use for malaria?
- Do people in this area protect themselves from malaria?
  If so how do they protect themselves?

Appendix 6 Sub group analyses based on age and sex

A univariate comparison of malaria risk factors by age

	Univariate under 5				Univariate over 5			
Variable	mOR	p- value	95% CI		mOR	p- value	95% CI	
Demographic factors								
Regular travel	0.54	0.02	0.32	0.91	0.96	0.89	0.56	1.65
Out at night	**2.00**	**0.11**	**0.85**	**4.67**	**1.23**	**0.57**	**0.59**	**2.53**
Wake up time	0.78	0.24	0.52	1.18	1.05	0.80	0.69	1.60
Protection measures								
Slept under a net	0.80	0.51	0.42	1.53	1.04	0.88	0.57	1.90
Homestead sprayed	0.91	0.71	0.56	1.47	1.34	0.27	0.78	2.31
Housing factors								
Separate kitchen	0.78	0.35	0.46	1.31	1.61	0.08	0.93	2.78
Main house	1.10	0.65	0.71	1.70	0.73	0.20	0.46	1.17
Eaves	1.55	0.30	0.67	3.50	0.98	0.34	0.96	1.01
Iron sheet	1.28	0.35	0.75	2.15	0.56	0.08	0.29	1.07
Homestead surroundings								
Short grass	**1.20**	**0.54**	**0.66**	**2.17**	**1.42**	**0.24**	**0.79**	**2.55**
Flowers	**1.02**	**0.90**	**0.65**	**1.64**	**1.62**	**0.04**	**0.76**	**1.92**
Animal Footmarks	0.78	0.27	0.51	1.21	1.38	0.13	0.90	2.13
Sloping	**1.02**	**0.91**	**0.68**	**1.53**	**0.62**	**0.07**	**0.36**	**1.04**
Jaggeries	0.65	0.06	0.41	1.01	1.51	0.07	0.96	2.38
Garbage disposal area								
Stagnant water	**0.75**	**0.51**	**0.31**	**1.77**	**1.85**	**0.18**	**0.74**	**4.65**
Flies	0.72	0.21	0.44	1.19	1.51	0.09	0.93	2.46
Odour	1.15	0.59	0.68	1.95	1.76	0.06	0.97	3.19
Waste water disposal area								
Drainage	1.05	0.86	0.55	2.01	0.72	0.33	0.38	1.38
Stagnant water	**1.00**	**1.00**	**0.48**	**2.04**	**2.42**	**0.04**	**1.00**	**5.85**
Containers	1.05	0.82	0.67	1.64	1.72	0.03	1.05	2.81
Flies	0.92	0.72	0.58	1.45	1.81	0.02	1.08	5.05
Utensils rack								
Stagnant water	**2.30**	**0.02**	**1.09**	**4.80**	**0.81**	**0.57**	**0.39**	**1.68**

A univariate comparison of malaria risk factors by sex

	Male				Female			
Variable	mOR	p- value	95% CI		mOR	p- value	95% CI	
Demographic factors								
Out at night	**2.57**	**0.03**	**1.07**	**6.15**	**1.14**	**0.71**	**0.55**	**2.34**
Protective aspects								
Net use	1.10	0.75	0.59	2.05	0.79	0.44	0.43	1.45
Net treat	1.27	0.32	0.78	2.07	1.06	0.75	0.7	1.62
Sprayed	0.71	0.22	0.42	1.22	1.37	0.18	0.85	2.22
Housing factors								
Separate Kitchen	0.84	0.56	0.47	1.49	1.34	0.22	0.83	2.17
Dependants house	0.92	0.84	0.43	1.97	1.38	0.28	0.75	2.54
Homestead surroundings								
Swamps	**1.10**	**0.75**	**0.59**	**2.05**	**1.50**	**0.18**	**0.82**	**2.72**
Fish ponds	0.87	0.71	0.42	1.79	1.71	0.25	0.65	4.35
Short grass	**1.04**	**0.87**	**0.57**	**1.90**	**1.57**	**0.11**	**0.88**	**2.80**

APPENDIX 7: GENERAL INSTRUCTIONS FOR ENUMERATORS

1. Personal introduction

Greet the respondent with respect and introduce yourself. It is recommended that you refer to your family e.g. I am so and so. I am the son/daughter of so and so from such and such village. This will help the respondent to build a sense of confidence and trust in you.

ALWAYS HAVE IN YOUR FILE ALL THE DOCUMENTS AND LETTERS AUTHORISING THE RESEARCH BUT ONLY PRODUCE THEM IF A RESPONDENT OR OTHER PERSON IN AUTHORITY ASKS FOR THEM.

2. Introducing the study

Drawing reference to the patients visit to Nduru health centre, explain very clearly the purpose of the study taking ideas from the consent form and request the respondent to participate. Upon acceptance, thank the respondent, fill in the consent form and then proceed with the interview.

3. Interview process

(a) The household survey

Clearly read out each question to the respondent and allow him/her time to answer before proceeding to the next. If the respondent does not understand the question, briefly explain what the question intends to find out.

NB NEVER READ THE ANSWER OPTIONS TO THE RESPONDENT AS THIS MAY INFLUENCE THEM TO GIVE THE ANSWERS THEY THINK YOU WANT

All the questions and spot check forms should be filled in by the enumerator. Respondents are not allowed to self administer the questionnaire or fill in the spot check forms themselves. If they demand to do so, explain the reasons as to why this is not allowed. (The order of the questions may influence their answers). The respondent may **(only if they ask to)** read through the questionnaire and spot check forms once the enumerator has finished administering them.

Where multiple answers are possible, do some probing by asking questions like: What else? Any thing else etc

Show keen interest in the respondent by maintaining eye contact and listening attentively. For open ended questions, write the answers in brief. Details can be filled in later when you are editing the survey before handing it in.

(b) Spot check forms

After the interview, alert the respondent about the spot checks and proceed with the exercise asking questions where necessary. Be discreet when noting down certain aspects that my not be appealing e.g. dirty/torn nets, pit latrines etc.

(c) Homestead mapping

Stand at a point where you can secure a good view of the homestead. Involve the respondent in the exercise by asking him/her to point at the different structures as you sketch them. Show the completed sketch to them explaining the different symbols. This will help you to make corrections on the sketch.

4. Collection and handing in of research instruments

Before setting out to the field, ensure that you have all the materials you need i.e.:

1. Household survey questionnaires
2. Spot check forms
3. Consent forms
4. Enough housing condition forms
5. Enough mosquito net spot check forms
6. Code sheets for locations, sub locations and villages
7. List of households to be visited for the day with all the details of how to locate them.
8. Print out of mosquito larvae
9. General instructions for enumerators
10. Stationery: Biros, Pencils, rubber, ruler etc
11. Field note book

At the end of each interview and spot check, ensure that all the items are answered before leaving the homestead. Incomplete questionnaires and spot checks shall not be accepted. The enumerator who administered them will be sent back to fill in any missing information.

Before handing in the questionnaires and spot check forms, ensure that all the meta-data is clearly filled in and then clip the spot check and the survey together using the paper clips provided. Make use of your field note book to record any observations, suggestions, problems or any thing else you think should be brought to the notice of the researcher or other enumerators. These should be reported to the researcher at the end of the day so that they can be discussed before setting out the following day.

GENERAL CODE OF CONDUCT DURING THE STUDY

1. Confidentiality

All the data collection tools and materials: household survey, spot check forms, homestead mapping scheme, files, field notebooks etc are **HIGHLY CONFIDENTIAL** and **MUST NOT** be shown to any unauthorised person. The respondent may (**only if they ask to**) be allowed to see the completed questionnaire and spot check form.

Strive to build confidence and establish rapport with the respondent to avoid situations that my lead to terminating the interview prematurely.

If any body else asks to see the data collection tools, they should be referred to the main researcher. Enumerators must avoid discussing about the homesteads they have visited with their families or friends. **FAILURE TO OBSERVE THIS RULE MAY LEAD TO THE ENUMERATOR BEING DISCONTINUED FROM THE EXERCISE.**

2. Courtesy

Observe courtesy and self discipline in dealing with the respondents. Always refer to the respondent by name and remember to thank them at the beginning, during and after the interview. Present yourself in a manner that will command respect. Be ready to apologise should you make a mistake or realise that a question or remark has disappointed the respondent.

3. Work schedules

Strictly adhere to the work schedules and **DO NOT** get involved in any personal issues during the interviews and spot checks.

When in doubt

The main researcher will be on call throughout the study period. Feel free to consult in case of any doubts or any unusual happenings in the field.

Emergencies

Please inform the main researcher of any emergencies pertaining to your personal life or the study.

Sophia Githinji
30/04/07

APPENDIX 8: CONSENT STATEMENT FOR THE RESPONDENTS

Hello, my name is ______________________________. We are carrying out a survey on environmental factors influencing health in this area. The survey is part of a PhD dissertation conducted by Sophia Githinji, a Kenyan student, studying at the University of Bonn in Germany. The study is fully permitted by the government of Kenya: Research permit number: **MOST 13/001/28C 66 issued on 8.3.2007.**

Your household has been selected to participate in this survey. We request that you participate in this survey by answering some questions and allowing us to take some observations on some environmental conditions in and around your homestead.

All the information you give to us shall be treated with optimum confidentiality and will be used solely for the purpose of analysis of data collected.

Do you have any questions?

We hope that you will accept to take part in the survey but if you decide not to, it is your right and we shall respect your decision.

ACCEPTANCE

I accept/do not accept to take part in the survey.

Name: ____

Date: ____

INFORMATION FOR TRACING THE SUBJECTS IN THE VILLAGES

Name of patient: ______________________________

Age______ Male ______ Female_______

Name of household head: ______________________________

Mother's name: ______________________________

Name of clan elder: ______________________________

Name of sub location: ______________________________

Village name: ______________________________

Nearest primary school: ______________________________

Other land marks: ______________________________

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to every one who contributed to making this work possible. I feel especially indebted to the following people:

Prof. Dr. Thomas Kistemann, my first supervisor, for his dedicated support, encouragement, constructive criticism and the valuable opportunities he gave me to present the preliminary findings of this work in different forums;

Dr. Susanne Herbst, my tutor, for her moral support, valuable advice and very specially for visiting me during the field study in Kenya;

Prof. Dr. Martin Exner, director of the Institute for Hygiene and Public Health at the University of Bonn, for hosting me at his institute during the entire PhD work; Prof. Dr. Paul Vlek, my second supervisor, for giving me the opportunity to take part in an international doctoral course at the centre for development research (ZEF); Guido Lüchters for his valuable support with statistical analysis and literature;

Katholischer Akademischer Ausländer Dienst (KAAD), for awarding me a full PhD scholarship and for the enriching educational seminars and workshops;

My colleagues at the institute for Hygiene and Public Health, Christoph Höser for his valuable assistance with GIS and cartographic work, Maria Leppin for her promptness in obtaining literature, Christiane Schreiber for her assistance and pleasant company in the office, Andrea Rechenburg for her advice, encouragement and humour, Yvonne Walz, Oxana Krämling, Silvia Schäffer, Tobias Frechen, Sebastian Völker, Phi Vo and Corinna Berger for their support and encouragement;

Mr Abuya Daudi Tamaro and Mrs Celina Bonareri Abuya, for all the support they gave me during the field study, Mr Julius Eric Muga, head master of Kuja primary school for the deaf, for hosting me at the school premises during the data collection period; Margaret Aoko Opany for her motherly care during the field exercise; The research assistants: Bernard Omoke, Edgar Onchieku, Hellen Araka, Janet Mogoi and Lydia Nyatei for their dedicated work of data collection; Felistas Muma and Caroline Motaroki - staff of Nduru health centre, for their cooperation and allowing me to use the health centre and its facilities for my research; Wilfred Obwacha, the Health Information Officer of Gucha district and staff of Merlin NGO Kisii branch, for providing me with the necessary background information and data of the study area;

My companions at the Deutsch Internationaler Kultur Verein (D. I. K); Elisabeth Püllen, Marianne Büsse, Barbara Dohr, Hildegard Carvelius, Anna Mauro, Radeguld Doetsth, Paloma Mena, Gertrud Geißelbrecht, Monika Löser and Irene Flachskampf for creating a very warm family environment for me in Germany, Agatha Follmann and Alexandra Muthny for their friendship, Carmel Fennesy and Rufina King'ori for keeping in touch throughout my absence and to my family for their loving support and patience throughout my stay in Germany.