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CLACC

CAPACITY STRENGTHENING IN THE LEAST DEVELOPED COUNTRIES (LDCS) FOR ADAPTATION TO CLIMATE CHANGE (CLACC)

Climate Change and Health in Tanzania

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FOREWORD

As advocates for capacity strengthening for Least Developed countries on issues of climate change, the International Institute for Environment and Development (IIED) UK, introduced the CLACC programme. This was initiated with fellowships in different centres for CLACC fellows to study issues of climate change and share the knowledge. With support from DFID, the programme has been able to increase awareness to climate change in health sectors of 12 LDCs, including Tanzania. These projects in Tanzania have been involved with local NGOs, included awareness workshops, and an expert case study on a specific climate-sensitive disease in Tanzania.

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Acronyms

CEEMI	Centre for Enhancement of Effective Malaria Interventions
DSS	Demographic Surveillance System
ENSO	El Nino Southern Oscillation
EPMS	Environmental Protection and Management Services
GHGs	Greenhouse gases
IIED	International Institute of Environment and Development
INC	Initial National Communication
IPCC	Intergovernmental Panel on Climate change
IPT	Intermittent Presumptive Treatment
ITNs	Insecticide Treated Nets
MOH	Ministry of Health
NAPA	National Adaptation Programme of Action
NMCP	National Malaria Control Programme
OPD	Outpatient Department
TMA	Tanzania Meteorological Agency
UNEP	United Nations Environment Programme
WHO	World Health Organization
WMO	World Meteorological Organization

Section I

1 Introduction

Africa is a minor contributor of global GHG emissions, a fact clearly indicated by its share of global carbon dioxide emissions. Variability and extremes in climate is part of life in Africa and Tanzania particularly. Over 70% of Tanzanians survive on subsistence agriculture; their livelihoods depend fully on rain, and fail when the rains fail. These extremes of droughts and floods threaten the lives and livelihoods of the poor more than other social groups.

The fact that the climate is changing is no longer a subject of controversy. The Intergovernmental Panel on Climate Change (IPCC) has been mostly responsible for this through their assessment of the available scientific information. Climate change impacts are projected to be severe on a number of key sectors such as agriculture, health, and water. The impacts of climate change will be experienced globally, but will most negatively affect poor countries which have limited adaptation and coping capabilities. As one of the least developed countries (LDCs), Tanzania is highly vulnerable to the impacts of climate change. As a country it is committed to the objectives of the UNFCCC, which is to achieve the stabilization of greenhouse gas (GHGs) concentration at a level that would prevent continued dangerous anthropogenic interference with the climate system. To show this commitment, the country has submitted a National Communication to the UNFCCC in 2003, and is now in a process of preparing a second report. Tanzania has also prepared a NAPA document, which reports on immediate and urgent needs for adaptation to climate change (United Republic of Tanzania, 2007). Since the impacts of climate change are also severe at the community-level, non governmental institutions (NGOs) in Tanzania also have an obligation to respond to the impacts of climate change.

Climate thus presents a risk, to livelihoods and sometimes lives at the individual level, and to economy and infrastructure at the national at the national and regional levels. The report presented here gives an overall situation of Tanzania in terms of climate change impacts on health. In this way it lays a foundation for continued progress with climate change adaptation activities in Tanzania.

2 Climate Change

Climate describes average day-to-day weather, including seasonal extremes and variations, for a specific location or region. More personally, climate is what people expect, and weather is what they actually experience. *Climate change* is a long-term shift or alteration in the climate of a specific location, region, or the entire planet. The shift is measured by changes in some or all of the features associated with average weather, such as temperature, wind patterns, and precipitation. A change in the variability of climate is also considered climate change, even if average weather conditions remain unchanged.

Climatologists have determined that the 20th century was very likely the warmest in the past 1000 years, and that the 1980s and 1990s were likely the warmest decades since the mid-1800s. The Earth's average surface temperature has risen 0.6 ± 0.2ºC since the 1860s. Ten of the warmest years since the 1860s have all occurred in the past 15 years (IPCC, 2001). Climate model projections summarized in the Fourth IPCC report (2007) indicate that the global surface temperature will probably rise a further 1.1 to 6.4 °C (2.0 to 11.5 °F) during the twenty-first century. Scientists have noted many other signs of global climate change as well. For example (IPCC, 2001; Hassol, 2004):

- Global sea levels have risen 10-20 cm in the past 100 years
- Snow cover extent in the Arctic has declined about 10% over the past 30 years
- In the Arctic, the average extent of sea-ice cover in summer has declined by 15-20% over the last 30 years
- Many mountain glaciers the world over are melting
- Key seasonal stages in plant development, such as budding, leafing, and flowering are occurring earlier
- Species of plants and animals are being found in parts of the world where they had not previously been seen.

Scientists use elaborate computer models to try to hypothesize how the Earth's climate will be affected under differing future GHG emissions and socio-economic scenarios. These models are more reliable when projecting worldwide changes than local or regional ones. However, work is under way to improve regional projective modelling capacity.

Despite these difficulties, all projections agree that future changes in climate will not be uniform. Consequently, Tanzania's insignificant relative GHG emission in the world does not spare it from negative climate change impacts. Tanzania is already experiencing a number of impacts as predicted by the Third and Fourth IPCC Assessment Reports (2001, 2007) for sub Saharan countries. The impacts vary throughout the country. For example, the highest mountain in Africa, Kilimanjaro, has been observed to have lost almost 82% of its ice cap since it was observed in 1912, and further studies in 2000-2001 shows that glaciers are not only retreating but also rapidly thinning (Thompson, 2001).

In other areas of Tanzania, the impacts of climate change have also been felt. The submerged Maziwe island in Tanga region, the salt water intrusion into shallow fresh water wells of Bagamoyo district, the recent recurrence of droughts in a large part of the country, and frequent outbreak of diseases such as cholera, diarrhoea, and malaria (United Republic of Tanzania, 2007). These impacts are severe for the country because it has little capacity to address or adapt to these tragedies. There is therefore a need to prepare communities to cope with the potential adverse impacts of climate change, by improving levels of awareness and understandings of the impacts and their potential solutions.

2.1 Climate trends in Tanzania

A brief overview of projected climate change and its impacts in Tanzania is necessary. According to the INC (2003), the mean temperatures will increase throughout the country, particularly during the cool months. Annual temperatures will increase between 2.1^{o}C in the North Eastern parts to 4 ^{o}C in the Central and Western parts of the country by 2100. In terms of precipitation, annually it is projected to increase by 10% by 2100, although seasonal declines of 6% are projected for June, July and August and increases of 16.7% for December, January and February.

Climate projections indicate that northern and southeastern of the country would experience an increase in rainfall ranging from between 5% and 45% under doubling of CO_2 scenarios. The central, western, southwestern, southern, and eastern parts of the country might experience a decrease in rainfall of 10% to 15%. The southern highlands might similarly experience a decrease of 10%, which could alter the suitability of this area for maize cultivation (Mwandosya, Nyenzi and Luhanga, 1998).

Analysis of total annual rainfall for 21 meteorological stations in selected regions of Tanzania indicated that there is a decreasing trend for over 13 stations (61.9%) whereas an increasing rainfall trend was observed over 7 stations (33.33%). The most affected stations were Pemba, Zanzibar, Moshi and Arusha. However, one common feature of the rainfall pattern was a greater variability in rainfall (United Republic of Tanzania, 2007).

The IPCC (2007) report emphasizes climate change is equivocal. It is probable that the observed changes are indications of climate change. Although rainfall does not show significant changes for the past 30 years, there is little doubt that increases in temperature increase evaporation rates of soil and water bodies, as well as transpiration rate of plants (United Republic of Tanzania, 2007). Furthermore, increase in temperature would cause ecosystem shifting (INC, 2003). This means that areas previously used to grow perennial crops would now be suitable for annual crops. In addition, global warming would tend to accelerate plant growth thus shortening growing periods of crops (Yanda et al, 2008). The impacts of this will be measured in terms of decreased crop production (yield). Plants require a specific time to reach its maximum yield. Other impacts will be the erosion of a natural resource base, and environmental degradation.

2.2 Vulnerability of Tanzania

Vulnerability to climate change is a function both of the exposure to changes in climate and the ability to adapt to the impacts associated with that exposure (IPCC, 2005). Tanzania is one of the countries that regularly suffer from various climate-related hazards such as floods and droughts which have substantial effects on economic performance and poverty reduction.

The climate disasters include periods of drought and floods which results into hunger and outbreaks of diseases. Studies undertaken during INC indicate that increases in temperature of 2^{o}C- 4^{o}C would cause ecosystem shifting. This means that areas previously used to grow perennial crops would now be suitable for annual crops. In addition, global warming would tend to accelerate plant growth thus shortening growing periods of crops (Yanda et al, 2008). The impacts of this will be measured in terms of decreased crop production (yield). Plants require a specific time to reach their maximum yield. Other impacts will be the erosion of a natural resource base, and environmental degradation.

Pastoral communities are extremely vulnerable as climate change is shrinking the rangelands which are necessary for livestock keeping communities in Tanzania. Currently, it is estimated that about 60% of the total rangeland is infested by tsetse fly, making it unsuitable for livestock pastures and human settlements (United Republic of Tanzania, 2007). Further, shrinkage of rangelands is likely to exacerbate conflicts between farmers and agriculturalists and contribute to the death of livestock, thereby increasing poverty. Conflicts between pastoralists and farmers have already been reported in Morogoro region, Kilosa District, Mamba ward, Mara region, and Kilimanjaro district (DILAPS, 2007). Climate change also has an impact on child development in these livestock keeping communities, as children are forced to migrate endlessly in search of grazing areas and can not attend school. Their future also appears bleak as upon reaching adulthood, they may find themselves with no economic foundation to run their own life.

Projected decrease in rainfall will have an impact on the sources of water that provide hydropower production. The Mtera and Nyumba ya Mungu dam has been experiencing a constant trend of depth decreases which has an implication on electricity production (United Republic of Tanzania, 2007). Blackouts and power rationing as a result of low water levels in the hydro power dams have impacts for both domestic and industrial use. Such blackouts leave Tanzania’s economy even more vulnerable to climate change related disasters and result in inefficient service provision to the public.

3 Human health in Tanzania

3.1 Burden of disease

Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity (WHO, 1946). Climate change will affect health in countries in ways consistent with existing burdens of disease. Because of this, it is important to understand general demographic, health system, and mortality specifics of a country. Below in Table 1, are some selected indicators for Tanzania, which may be relevant to current and future magnitudes of the health impacts of climate change in the country.

Tanzania's health sector struggles with these many challenges, with the most important possibly being child and maternal death. The Tanzanian Ministry of Health (MOH) has been working to reduce these and so far it has accomplished a reduction in child mortality from 99/ 1000 live births in 1996 to 68/ 1000 live births in 2005. In controlling epidemic diseases, the ministry has successfully reduced death from cholera from 12,266 patients in 1999 to 6,254 patients in 2004. Despite of this success, Tanzania has one of the highest maternal mortality ratios (MMR) in Sub-Saharan Africa, with national estimates as high as 1100 in 1995 (WHO, 2001) increasing to 1500 per 100 000 live births in 2006 (WHO, 2007).

Table 1: **Selected demographic, health system, and mortality indicators for Tanzania** (WHOSIS, 2008)

Indicator	Metric
Population total	39 459 000
Population annual growth rate (%)	2.5
Population living below poverty line (% living on < US$1 per day)	57.8[C]
Population proportion under 15 years (%)	44
Children <5 years of age stunted for age (%)	44.4[A]
Children <5 years of age underweight for age (%)	16.7[A]
Environment and public health workers density (per 10 000 population)	<1.0[B]
General government expenditure on health as percentage of total government expenditure	12.6[A]
Adult mortality rate (probability of dying between 15 to 60 years per 1000 population) both sexes	504
Under-5 mortality rate (probability of dying by age 5 per 1000 live births) both sexes	118
Infant mortality rate (per 1 000 live births) both sexes	74
Deaths among children under five years of age due to diarrhoeal diseases (%)	16.8[C]
Deaths among children under five years of age due to malaria (%)	22.7[C]
Population with sustainable access to improved drinking water sources (%) Total	55
" " (%) Urban	81
" " (%) Rural	46
Population with sustainable access to improved sanitation (%) Total	33
" " (%) Urban	31
" " (%) Rural	34

All metrics from 2006 unless superscript: A= 2005, B=2002, C=2000

Unfortunately, undermining accurate descriptions and understandings of the burden of disease, birth and death registration can be virtually non-existent in parts of sub-Saharan Africa. In such cases a sentinel demographic surveillance system (DSS), which collects data through regular monitoring at the household level, can track the burden and causes of mortality and thus permit estimation of the burden of disease.

The burden of disease in Tanzania addressable by interventions aimed at acute febrile illness is disproportionately borne by children under 5 (48%). The other important risk group is women of reproductive age who suffer about 10% of the malaria burden. Older children, youth, men, and older women bear nearly half the burden. This illustrates the importance of prompt and effective malaria case management, employing antimalarial drug regimes according to the new National Guidelines, using interventions such as Insecticide Treated Nets (ITNs) (especially for mothers and young children), and implementing Intermittent Presumptive Treatment (IPT) during pregnancy.

3.2 Climate change and health in Tanzania

Climate change can affect human health and well-being through a variety of mechanisms. For instance, climate change can adversely impact the availability of fresh water supplies, the efficiency of local sewerage systems, and food security (Menne et al, 2002). Changes in food production and security would significantly affect health in Tanzania. The distribution and seasonal transmission of several vector borne infectious diseases (such as malaria, dengue and schistosomiasis) may also be affected by climate change. Other climate sensitive diseases include water related diseases (cholera, typhoid, amoebiasis, giardiasis, cryptosporidiasis and leptospirosis) and additional vector borne diseases (filariasis, trypanosomiasis, onchocerciasis, Lyme disease, Rift Valley fever, yellow fever, encephalitis, leishmaniasis and plague). Tanzania has at one time or another suffered the burden of many of these diseases.

Sensitivity of vector-borne disease transmission to weather and climate depends upon (Kovats, 2006):

- **rainfall**, which affects the availability and suitability of disease vector habitats; and,
- **temperature**, which affects the rate of vector and pathogen development and also the vector blood-feeding rates, and, affects the suitability of habitats for disease reservoirs.

Climate change can also result in direct injury and loss of life: violent weather can destroy shelter, contaminate water supplies, cripple food production, foster myriad infectious diseases, and tear apart existing health service infrastructures. This will increase the existing burden of disease, whose successful treatment is already hampered by the poor infrastructure of the health system. Considering these health outcomes and their relationship with climate, it is easy to understand how long-term climate change will have an effect on global population health.

3.3 Malaria in Tanzania

Malaria is one of the worlds most serious and complex public health problems and it has now been identified as the disease most likely to be affected by climate change (WHO/WMO/UNEP, 1996). For tropical African countries, environmental conditions are already favourable for malaria transmission. The vulnerable areas are those where transmission is currently constrained by temperature, such as the East African highlands (Lindsay and Martens, 1996).

Malaria remains one of the major threats to public health and economic development in Africa. It is estimated that three million deaths result from malaria throughout the world, with Africa having more than 90% of this burden (Breman et al 2004). Over recent years, malaria has 're-emerged' as a major burden of disease in developing countries. For the countries of Sub-Saharan Africa, deaths due to malaria declined dramatically over most of the 20th century falling from 223 per 100 000 in 1900 to 107 per 100 000 in 1970. Since 1970, however, mortality rates have risen to 165 per 100 000, roughly reversing in 30 years half of the gains achieved over the century (Jowet et al, 2005).

Malaria is the cause of more mortality and morbidity in Tanzania than any other disease. The burden of malaria in Tanzania, in particular, remains high. Every year 14– 18 million new malaria cases are reported in Tanzania, resulting in 120,000 deaths it also accounts for about 40 per cent of all outpatient attendances. Of these deaths, 70,000 are in children less than five years of age. The annual incidence rate is 400–500/1,000 people and this number doubles for children less than five years of age (MOH, 2003). Malaria is the leading cause of outpatients, inpatients, and admissions of children less than five years of age at health facilities. Malaria is considered to be the major cause of the loss of economic productivity in persons 15–56 years of age and an impediment to learning capacity of people 5–25 years of age (WHO, 2002).

Study by Jowett et al, (2005), estimates that over 1% of GDP is devoted to the disease, representing US$2.2 per capita, and 39% of total health expenditure nationally. Government facilities devote almost one-third of their resources to the disease. Private expenditure, primarily on drugs, coils, sprays and bed-nets, represents 71% of total expenditures. The disease is one of the most important obstacles to economic development and foreign investment in Tanzania (Makundi et al, 2007).

A study conducted by Kangalawe and Yanda (2004) indicates that malaria is endemic in the lowlands but unstable in the highlands of the Lake Victoria region, with a creeping increase of the disease towards the highlands. In recent years malaria disease pattern has dramatically changed, spreading to areas previously known as being malaria-free [www.tz.undp.org/mdgs_goal6.html]. The study further indicates that women and children are more vulnerable to malaria than men due the roles they play in the society, and that poverty influences impinges on successful adaptation to malaria/cholera in the area.

Climate change may affect malaria in fringe areas by; increasing its distribution where it is currently limited by temperature, decreasing its distribution where it becomes too dry for mosquitoes to be sufficiently abundant for transmission, and increasing or decreasing the suitable months of transmission depending on the area. Thus areas projected to experience suitable rises in temperature will be more favourable to the development of vectors including those which contribute to malaria.

So far, the Ministry of Health through a 5-year strategic plan advocates four main approaches in the fight against the disease (Mboera et al, 2007). These include:

i) improved case management,
ii) vector control using insecticide treated mosquito nets,
iii) prevention and control of malaria in pregnancy and;
iv) epidemic preparedness, prevention and control.

However, these strategies face various challenges including inadequate human, financial, and material resources; inefficiency in the healthcare system that is incapable of providing quality health services and access to prompt diagnosis and treatment; lack of an effective disease surveillance system; and an inefficient health education communication mechanism.

The MOH, in collaboration with different stakeholders, continues to advocate community sensitization to the use of impregnated bed nets. On the 22^{nd} of October 2004, the Ministry launched a National programme which enables pregnant women and children under five to obtain impregnated bed nets at a low price.

As a serious threat to the health sector of Tanzania and a climate-sensitive disease, malaria deserves research attention form the climate change and health community. EPMS in collaboration with IIED, UK has undertaken a study covering coastal areas of Tanzania including Dar es Salaam, Tanga, Coast and Morogoro region. Most parts of this study area experience stable perennial malaria transmission with the exception of Lushoto district in Tanga region. The study tries to assess the impact of climate variability for the past ten years on the health sector through a case study of Malaria. Lushoto area has been chosen since Lushoto district is located in the highlands and therefore prone to malaria epidemics.

Section II

4 Case study: Climate and Malaria in Lushoto District

4.1 Background

In Tanzania malaria is the leading health problem, where it accounts for the most hospital attendances, hospital admissions, and is among the leading causes of hospital deaths. Malaria is a disease locally transmitted mainly by two anopheline mosquito species, namely *Anopheles gambiae* complex and *An. funestus*. *Anopheles gambiae*, which has several species and is the most efficient vector for malaria. Three Plasmodium species are responsible for malaria in Tanzania, but *Plasmodium falciparum* is responsible for 95% of all infections and *P. vivax* is extremely rare. The whole country is malaria endemic with about 60% hyperholoendemic.

The effects of temperature on both the vectors and parasites of malaria are most pronounced at the borders of endemic malaria areas and at higher altitudes within malaria areas. This could have been established by many highland areas experiencing malaria epidemics in the past few years (Hay *et al*., 2002, Zhou *et al* 2005). In Tanzania for example malaria epidemics have been experienced in the highlands of Lushoto, Babati, and Muleba districts. However there are many variables that affect malaria transmission in addition to climatic changes, so that changes in malaria risk must also be interpreted on the basis of environmental conditions (e.g. deforestation, increases in irrigation, swamp drainage), socioeconomic development (population growth, limited access to health care systems), and lack of or unsuccessful malaria control measures (Zhou *et al*., 2005). Despite these other contributing factors, there is clear evidence to suggest strong meteorological influence on *P. falciparum* malaria (Shanks *et al*., 2002).

Assessing the impact of climate in malaria resurgence is difficult because of high spatial climate variability and the lack of a long-term data series on malaria cases from different localities. Yet it is known that temperature affects the development rates and survivorship of malaria parasites and mosquito vectors, that rainfall influences the availability of mosquito larval habitats and thus mosquito density, and that temperature and rainfall together may have synergistic effects on malaria transmission. Thus, simultaneous analysis on the long-term time series of meteorological and malaria cases data are needed to accurately demonstrate the effects of climate on malaria resurgence.
Here we study the association between climatic variability and the number of monthly malaria outpatients over the past 10 years (1995-2004) in Lushoto district Tanzania. Lushoto district was selected based on the fact that it is among the highlands in East Africa prone to malaria-relevant climatic variability. It is envisaged that information emanating from this study could be used to influence guidelines on climate change and malaria control practices and stimulate action towards limiting the continued anthropogenic GHG driven health impacts for the highlands of Tanzania.

4.2 Objectives

- Review monthly malaria data in Lushoto District for past 10 years
- Explain variation of trends with respect to weather variability using temperature and rainfall climate data for spatio-temporal period
- Identify statistics within malaria cases, particularly morbidity rates, and also relate to weather variability effects on the district

4.3 Methods

Study Area

The study was conducted in Lushoto district, which is one of 7 districts of Tanga region situated in north-eastern Tanzania. Lushoto district is located in the western Usambara Mountains at 4.48°S and 38.2°E. Altitude in the district varies from 200m in the lowland to above 2000m in the highland, the average annual rainfall ranges from 400 to 1800 mm, and the mean annual temperature and humidity are 16°C and 70% respectively. As mentioned, the district is prone to malaria epidemics. It has a total of 29 health facilities including one district hospital at Lushoto Township, 3 health centres and 25 dispensaries as illustrated in Figure 1 below. According to a 2002 national census, the estimated total population of the area is about 418,652 inhabitants of which 69,166 are children below five years. Ninety six percent of the population lives in rural areas and their main economic activity is subsistence farming of vegetables, fruits, and maize.

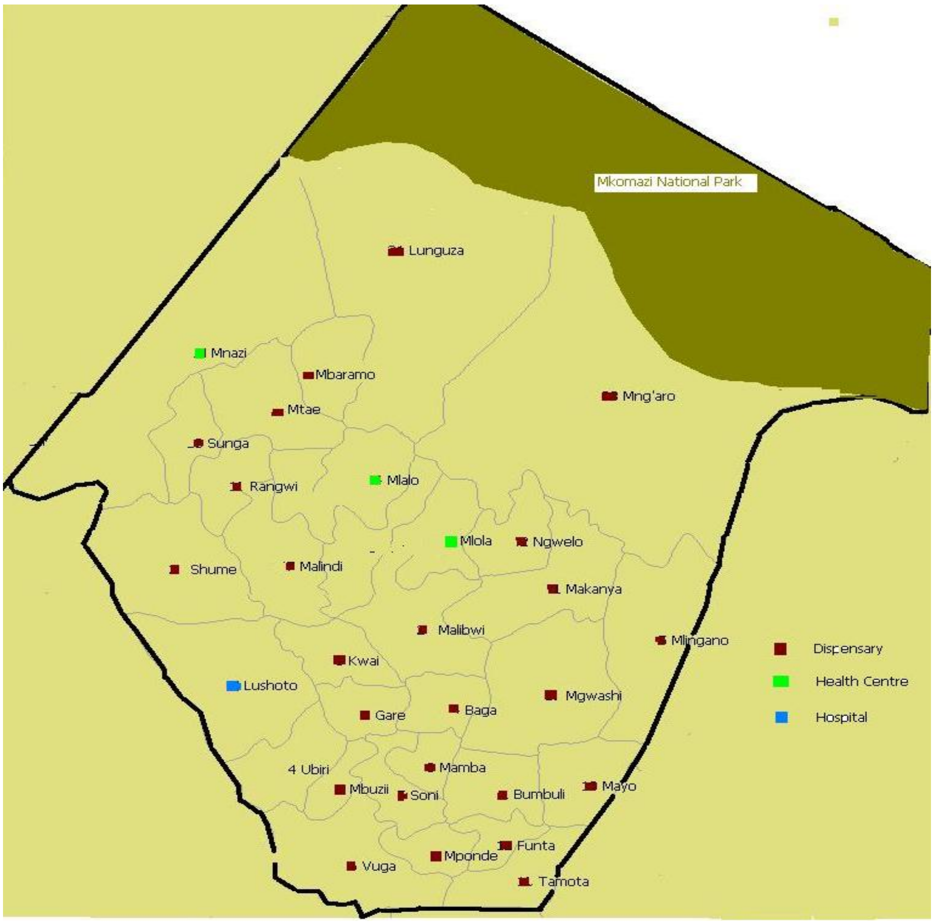

Figure 1: **A map of Lushoto district showing health facilities**

Study Design

The study was a cross-sectional documentary review of Lushoto District on malaria and climate data over the previous decade (1995 to 2004). Malaria case data presented in this report was obtained from the National Malaria Control Programme (NMCP) database. The NMCP has a surveillance system for districts prone to malaria epidemic. The meteorological data were received from Tanzania Meteorological Agency (TMA) through Environmental Protection and Management Services (EPMS).

Data analysis

The dataset used in the present analysis were from outpatient departments (OPD) which included clinical malaria cases, with most from dispensaries and health centres as laboratory services are inadequate. Few malaria clinical cases were confirmed with laboratory examination (parasitological diagnosis) from the district hospital and health centres. Descriptive analysis was made to relate the pattern of malaria cases with monthly and annual rainfall and mean, minimum, and maximum annual temperatures.

4.4 Results

Data presented in this report covers a period of 10 years. However, a malaria cases dataset for different age groups and parasitological diagnosis was not available for year 1995. Hence, no analysis was made on these parameters for the said year.

Patterns of malaria cases and rainfall
In each year, malaria cases were recorded through out the year indicating perennial transmission in the area. Two peaks of high malaria cases were observed, each peak coinciding with a peak rainfall pattern of the bimodal annual rain seasons. In all years malaria cases were high between January-May as well as October-December. The highest number of cases was during March 1998, with 11,419 malaria cases. Considering rainfall, heavy rainfall was recorded between March-May and October-January. The highest rainfall (814 mm) was recorded in October 1997.

When analyzing monthly mean malaria cases and mean monthly rainfall over the ten year period (Figure 2), it was clear that mean rainfall was high in April (249.1 mm, 95%CI: 149.18-349.06) which was associated with increase of mean malaria cases in April (5325.70 cases, 95%CI: 3587.04-7064.36) to May (5889.25 cases, 95%CI 4677.31-7101.19). Similarly the high rainfall of September–October was associated with a steady increase of mean malaria cases from October–March.

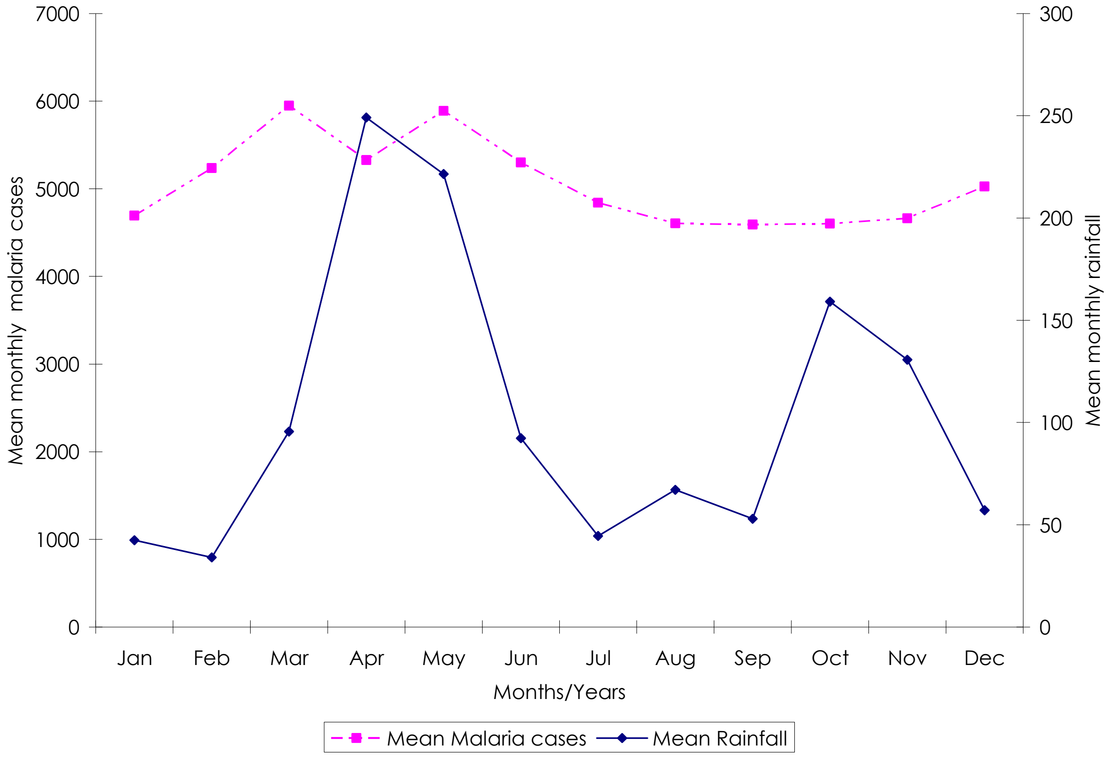

Figure 2: **Mean monthly malaria cases and rainfall from Lushoto district, 1995-2004**

Based on annual analysis, there is a general increase of malaria cases from 1995 (35,937 cases/114418 pop., 31.4%, 95%CI: 31.1-31.7) to 2004 (75,866 cases/205481 pop., 36.9%, 95%CI:36.7-37.1). As presented in Figure 9 below, there was a steady increase between 1996 and 1998 which was followed by a sharp drop in 1999 and 2002.

Figure 3: **Pattern of OPD annual malaria cases and annual rainfall in Lushoto district, 1995-2004**

The most malaria cases (89,440 cases) were recorded in 1998 with annual rainfall of 1595.4 mm. Assuming that rainfall *is* associated with increase of malaria cases, there was a low number of malaria cases (35,937 cases) in 1995, the year which had the highest rainfall (32114.2 mm). During the year, there was a sharp increase of rainfall from February to April (reaching 320 mm) which was followed by sharp drop to June (8.6 mm). After this sharp drop, there was again a steady increase from July to November with a slight drop in September (data not shown).

The average annual malaria cases and rainfall are given in Figure 4. There was a general trend of increasing mean number of malaria cases in following years if the preceding year had recorded high mean rainfall. For example, the high rainfall of 1997 was associated with an increase in mean number of malaria cases in 1998; from 4436.8 cases in 1997 to 7453.3 cases in 1998.

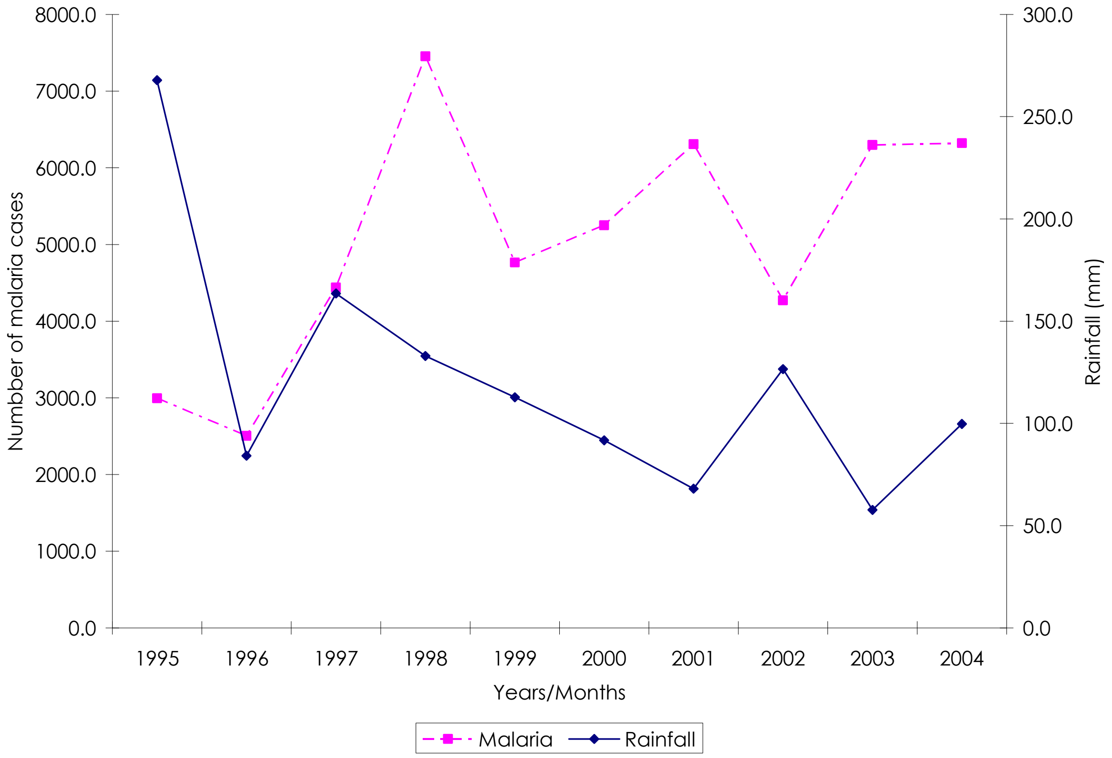

Figure 4: **Mean annual OPD malaria cases and rainfall from Lushoto district, 1995-2004**

Assessing by age group, there were more malaria cases which were reported to the clinic (attended) in individuals aged 5 years and above than in children below five years. Proportionally among attended there were significantly more malaria cases (247721 cases/745157 pop., 33.2%, 95%CI: 33.1-33.4) in children below five years as compared to individuals aged 5 years and above (323612 cases/994007 pop., 32.5%, 95%CI: 32.5-32.6). Examining years which had high (1998) and low (2001) malaria cases, there were more malaria cases in individuals aged five years and above (63,600 cases/204466 pop., 31.1%, 95%:CI, 30.1-31.3) as compared to children below five years (25,840 cases/90688 pop., 28.7%, 95%CI: 28.2-28.8) in 1998. While the situation was the opposite in 2001, where cases in children below five years (38,985 cases/113585 pop., 34.3%, 95%CI:34.1-34.6) were more than for individuals aged five years and above (36,717 cases/ 107355 pop., 34.2%, 95%CI:33.9-34.5), but the difference was not statistically significant.

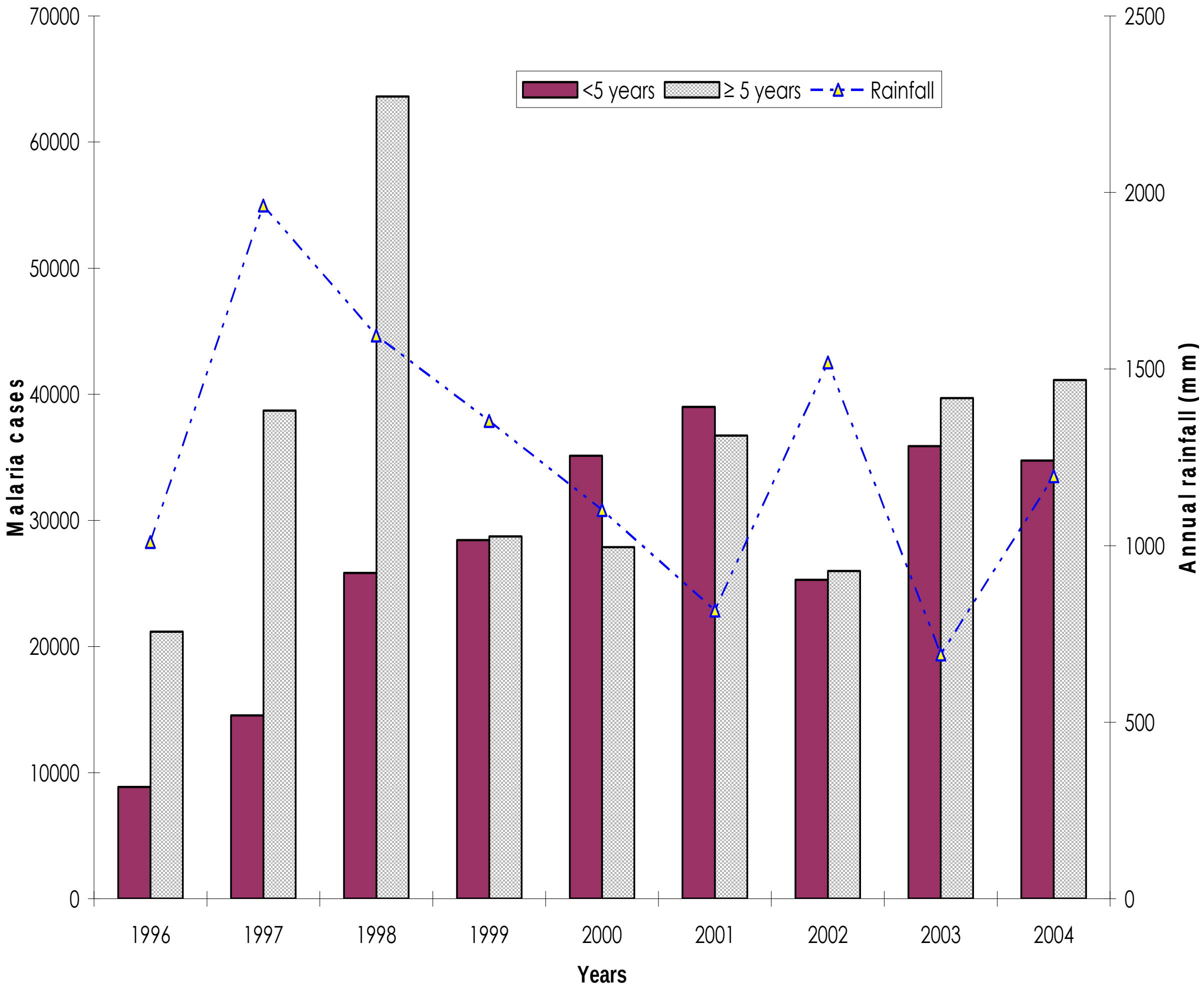

Figure 5: **Pattern of OPD annual malaria cases by age group and annual rainfall for Lushoto district, 1996-2004**

As shown in Figure 5, there was no clear correlation of high rainfall and malaria cases. The highest rainfall (1963 mm) was recorded in 1997 and lowest in 2003 (693.1 mm), and 2003 had high OPD malaria cases in both children below five years and 5 years and above.

Comparing parasitological diagnosis and rainfall pattern, there was a general increase of malaria cases confirmed by microscopy from 1996 (1860 cases/ 30037 pop., 6.2%, 95%CI:5.9-6.5) to 2004 (13,634 cases/ 75866 pop., 18.2%, 95%CI:17.7-18.2) with the highest parasitological confirmed cases in 2000 (18,924 cases/ 63008 pop., 30.0%, 95%:CI 29.7-30.4). Interestingly, parasitological confirmed malaria cases were recorded most in years proceeding years with large amounts of rainfall.

Patterns of malaria cases and temperature

In general, the annual increase in temperature was associated with increase of malaria cases seen and recorded at OPD, from 30037 cases/ 102997 pop. (29.2%) in 1996 to 75866 cases/ 205481 pop. (36.9%) in 2004. The sharp raise of mean annual temperature from 26.6 ºC in 1997 to 26.9 ºC in 1998 was associated with increase of malaria cases from 53 241 cases to 89 440 cases over the same period. Although proportionally, based on all diagnosis, there was an insignificant drop from 30.8%

(95%CI:30.5-31.0) to 30.5% (95%CI:30.3-30.7) over the time period. A significant increase of malaria cases was observed from 2000 (63008 cases, 33.0%, 95%CI:32.8-33.2) to 2001 (75702 cases, 34.0%, 95%CI:33.8-34.1) as well as from 2002 (51275 cases, 31.4%, 95%CI:31.2-31.7) to 2003 (75584 cases, 35.9%, 95%CI:35.8-36.1). in where mean annual temperature shoot from 26.6°C in 1999 to 26.8°C in 2000 and 26.7°C in 2002 to 27.1°C in 2003 respectively.

When analyzing the number of malaria cases with annual minimum temperature, the pattern was similar to that for mean annual temperature (Figure 6). Here it is seen that the increase in minimum temperature in 1997 and steady increase from 2000 to 2004 was associated with increases of malaria cases. The pattern of monthly malaria and minimum temperatures therefore showed a general correspondence; the increase in minimum temperature was associated with increase of malaria cases.

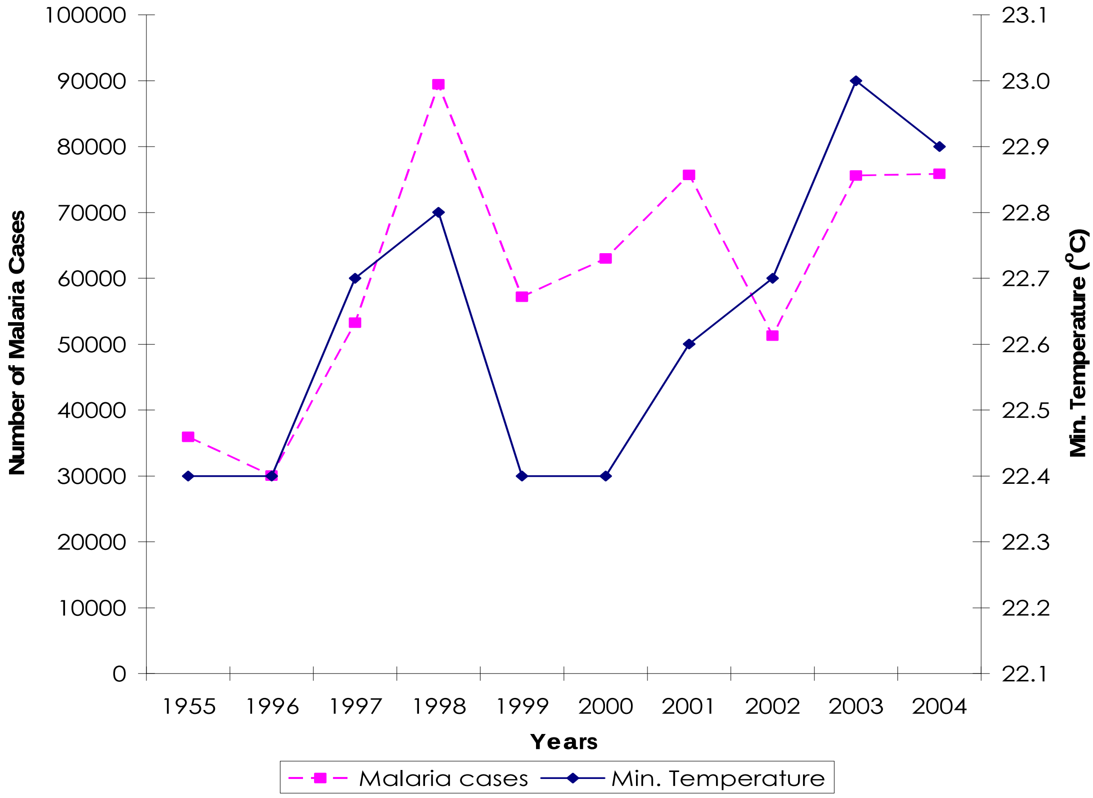

Figure 6: **Pattern of OPD annual malaria cases and minimum annual temperature in Lushoto district, 1995-2004**

In both under five years and over five years age groups, mean annual temperature was associated with increases of malaria cases (Figure 7). The difference between the age groups was not remarkable except for years 1996, 1997 and 1998 where there were more cases in the age group of 5 years and above than children below five years with a difference of 12301 cases (58.1%) in 1996, 24169 cases (62.4%) in 1997, and 37760 cases (59.4%) in 1998.

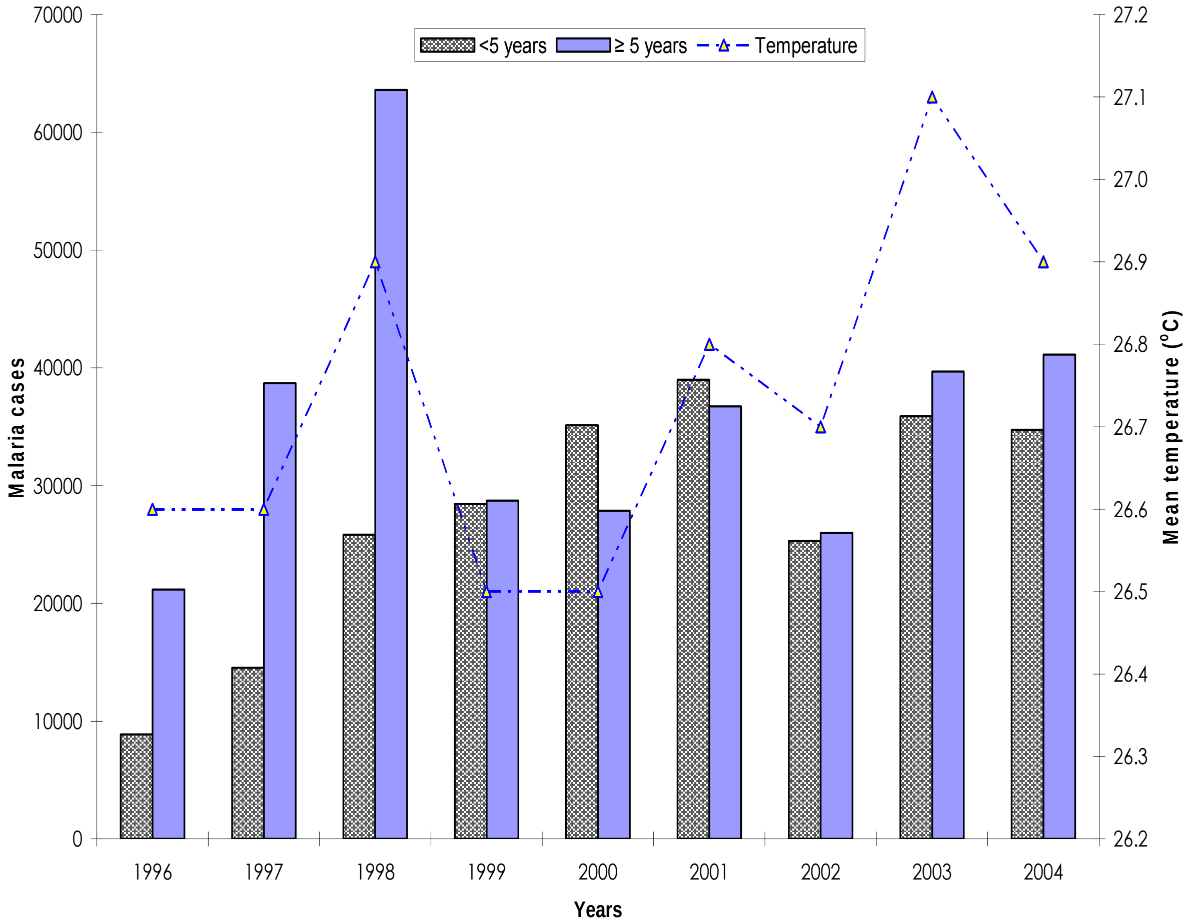

Figure 7: **Pattern of OPD annual malaria cases by age group and mean annual temperature in Lushoto district, 1996-2004**

Considering parasitological diagnosis, there was similarly an increase of malaria cases. The increase corresponded with increases in mean annual temperature except in the year 2000. In year 2000, the 18 924 malaria cases had increased from 14 685 in the previous year (1999) despite the mean temperature remaining 26.5 °C.

4.5 Conclusions

The results from this study suggest that climate change may affect health in the highlands of Tanzania. The climate change projected increase in the magnitude and frequency of extreme rainfall events (as examined in ENSO and during rainy seasons) in the highlands, and the correlation with increased malaria prevalence, implies that climate change may affect malaria transmission by increasing relative humidity and modifying temperature. However, the lack of significant associations between climate factors and malaria during the study period when temperature was observed to rise could be due to the fact that the period of ten years is too short to detect significant trends. It may be more informative to extended study period coverage to 30 years or more.

Recent increases of malaria in the highlands of East Africa have been attributed to climate changes. To determine whether the increase of malaria in the highlands of Western Usambara Mountains could be associated with meteorological parameters, trends of incidence of malaria cases from Lushoto district for a period of ten years, 1995-2004, were examined. Malaria case datasets were obtained from the National Malaria Control Programme (NMCP) database while meteorological datasets were provided by the Tanzania Metrological Agency through Environmental Protection and Management Services (EPMS).

It was found that despite increases of malaria cases from 1995 (31.4%, 95% CI 31.1-31.7) to 2004 (36.9%, 95% CI 36.7-37.1) there was no clear trend throughout the period. Similarly the meteorological parameters, especially annual rainfall, showed no trend for the past ten years. Month-wise time series analysis of data on rainfall and temperature showed seasonality of malaria cases during the rainy seasons of March–June and October–December. Based on annual malaria cases, malaria started increasing from 1997 and reaching a peak in 1998. The increase of malaria cases in 1998 corresponded with increases in rainfall and temperature, probably associated with the El Nino Southern Oscillation (ENSO) event of 1997-1998. Proportionally, based on all annual diagnosis (clinical malaria and parasitological confirmed) there were significantly more malaria cases (33.2%, 95%CI: 33.1-33.4) in children below five years as compared to individuals aged 5 years and above (32.5%, 95%CI: 32.5-32.6). Also no clear trend was observed between parasitological confirmed malaria cases with rainfall as opposed to trends associated with minimum, maximum, or mean temperature

In conclusion, the descriptive analysis based on malaria cases in Lushoto district indicated a mismatch of malaria case trends with rainfall but matching with temperature. Further analysis using a time series climate driven model of malaria patterns and taking into consideration non-climatic malaria risk factors could provide clearer evidence on the links between climate and malaria.

4.6 Discussion

Climate change has been associated with the growth of malaria in the highlands areas of East Africa (Zhou et al 2005), but our health facility based data for the past ten years from Lushoto district indicates a mismatch of malaria cases trend with rainfall and slightly match with mean temperature. The data showed an increase of malaria cases from 1995 to 2004 with no clear correspondence with pattern of rainfall suggesting that other contributor factors might have played a role. According to Zhou and co-workers (2005) apart from climate changes, there is empirical evidence to suggest that re-surges of malaria in highlands of East Africa to be contributed with non-climatic factors including drug resistance, failure of the health care system and population growth including migration and lifestyle. Therefore, it is important that information on these confounding variables are collected and considered in the analysis. Otherwise, further analysis to the present data using time series climate driven model are needed which might be able to show clear malaria pattern.

Month-wise assessment over the years revealed limited trend in rainfall with malaria cases but there was an indication of seasonality such that there are months when conditions were suitable for malaria transmission. The peaks were observed during and after long and short rainy season of March – June and October – December respectively. This pattern could be explained by the fact that the natural distribution of malaria among other things depends on abundance of effective mosquito vectors which are favoured by conducive environmental or climatic factors namely temperature, rainfall, and relative humidity (Pampana, 1969, Bouma and van der Kaay, 1996). Anopheline mosquitoes which are the main effective vectors in Tanzania breed in water habitats, thus requiring just the right amount of precipitation in order for mosquito breeding to occur. Therefore, during rainy seasons, there numerous breeding sites leading to increased mosquito density. Also there is evidence to suggest that rainfall affects malaria transmission because it increases relative humidity and modifies temperature (Pampana, 1969). On the other hand, rainfall not only increase amount and intensity of precipitation for breeding sites but also affects malaria survival (Russell *et al.*, 1963). In Tanzania the daily survivorship of *An. gambiae* is estimated to range from 0.77 to 0.84 meaning that at the end of one day between 77% and 84% will have survived (Charlwood *et al*., 1997).

The findings are in agreement with other researchers (Sutherst, 2004) speculating that temperature and rainfall may alter the distribution of mosquito vectors as an indication of essential events of climatic variability.

Throughout 1998, malaria cases were high this could be associated with El Nino Southern Oscillation (ENSO) and aftermath effect. This observation contravene with findings form a study which was conducted in Lushoto district among children below five years on infection rate between 1997-1998 where less malaria cases than preceding year were recorded (Lindsay et al., 2000), suggesting that rainfall can't be responsible for changes in malaria. Although it is well established that if there is too much rainfall, or rainfall accompanied by storm conditions can flush away breeding larvae leading to low adult mosquito density which might occurred but our data set showed an increase of malaria cases which was recorded as an epidemic. On the other hand, our results corroborates with findings from the Madagascar highlands observed by Bouma (2003) where there was correlation of temperature rise with increase of malaria incidences leading to epidemic.

The district did not show much warming trend, the mean annual temperature recorded varied from 26.6 °C in 1995 to 27.1 °C in 2003. Despite the minimal raise in mean annual temperature, there was a fluctuation increase of microscopically confirmed malaria cases with raise of temperature. The observed correlation of temperature and increase of malaria cases it could be associated with effect of temperature on many parts of the malaria life cycle. For example, the duration of the extrinsic development phase of Plasmodium (development in the mosquito) depends on temperature and on the species of the parasite the mosquito is carrying. The extrinsic cycle normally lasts 9 or 10 days, but sometimes can be as short as five days (Bradley *et al.*, 1987); i.e.; it takes the least amount of days when the temperature is 27°C. This correlation could be confirmed by the existing intersections of the ranges of minimum and maximum temperature for parasite and vector development which determine the impact of changes in temperature on malaria transmission. That is why there is malaria transmission throughout the year as the temperature is optimal for both mosquito and parasite. According to McMichael and co-workers (1996), the minimum temperature for mosquito and parasite development is between 8-10°C, and 14-19°C respectively; while the optimum temperature for mosquitoes is 25-27° C and the maximum temperature for both vectors and parasites is 40°C. It is a clear indication, the recorded mean temperatures from this study were favourable for both parasite and mosquito development hence the observed correlation.

The findings from this study contribute to the existing controversy on the pattern of malaria cases using time-series model analysis in highlands of East African as some researchers observed correlation (Pascual *et al.,* 2006, Bouma, 2003) while others did not (Hay et al., 2002). Bouma (2003) found correlation between temperature and malaria cases in Madagascar attributed the controversy to methodological issues.

Acquired clinical and parasitological immunity develop progressively over several years after repeated exposure to infection which contributes in protection against clinical malaria attack incidence of malaria. Therefore, in areas of perennial transmission, children below five years are more affected than adults (WHO, 2006), proportion-wise this quite agree with our findings as the proportion of children below five years were statistically significant affected than individuals aged 5 years and above. Assuming that the entire population is residing in area where is less exposed to malaria attack, hence little immunity to malaria then the infection rate would have been the similar.

Section III

5 Key Vulnerabilities of Tanzania

Concern for human health is one of the most compelling reasons to study the effects of global climate change. Health is a focus that will reflect the combined impacts of climate change on the physical environment, ecosystems, the economic environment and society. Long-term changes in world climate may affect many of the requisites of good health: sufficient food, safe and adequate drinking water, and secure dwellings.

Tanzania has some unique vulnerability to the health impacts of climate change. Other current large-scale social and environmental changes mean that an even higher priority must be assigned to population health in the policy debate on climate change.

6 Policy Recommendations

- Weather and climate forecasts and early warnings systems need to be developed and implemented. Such systems can be used to provide information that enables and persuades people and organizations to protect themselves and their property, and thereby reduces the deaths, injury and damage caused by the hazard.
- Through the contribution of modern meteorological and hydrological sciences and technology (such as meteorological satellites, weather radar, and numerical weather prediction models) it is possible to provide communities threatened by potential climate disasters with information to instigate timely preventive action. Such sciences and technology therefore need the appropriate funding and resources.
- Other governmental organizations, local and national officials, emergency managers, local decision makers, the media, voluntary organizations, and weather-sensitive businesses (known collectively as the hazards community) need to create effective preparedness plans, warning systems, mitigation strategies and public education programmes.
- Global malaria control strategies include early diagnosis and prompt treatment and selective and sustainable preventive measures, including vector control, early detection, and containment or prevention of epidemics. Local capacity building for basic and applied malaria research is essential to allow the regular assessment of malaria, particularly the ecological, social and economic determinants of the disease.

7 Research Recommendations

Although mean temperature does help explain the variability in malaria prevalence in Tanzania; far from all of the variability is explained. There are many other factors such as minimum and maximum temperature, relative humidity, wind, distribution of malaria control efforts, drug resistance, failure of the health care system and population growth including migration and lifestyle that must be further investigated. If these factors are taken into consideration during analysis and time-series climate driven model are used for analysis, the variability of malaria rates in Lushoto district could be better understood.

This study should be seen as a preliminary assessment of malaria and climate in Lushoto district. It should be used to stimulate further research into the relationship between climate and malaria, with more robust data sets that include non-climatic factors and malaria vector/parasite ecological systems, so that the results can be used for more accurate malaria predictions.

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