Government of Malawi

Ministry of Health

VULNERABILITY AND ADAPTATION ASSESSMENT OF THE HEALTH SECTOR IN MALAWI TO IMPACTS OF CLIMATE CHANGE

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EXECUTIVE SUMMARY

Malawi is one of the seven countries that is implementing a multi-agency Global Framework for Climate Services (GFCS) project funded by the Norwegian Ministry of Foreign Affairs. The health component of the project aims at building climate resilience of the health sectors in Malawi and Tanzania by improved use of climate information to inform health planning, research, and public health responses to climate-related health risks such as cholera, malaria, malnutrition, and disasters. Discussed in this report is the vulnerability and adaptation assessment of the health sector in Malawi.

Recent climate trends in Malawi show a temperature increase of 0.9^{o}C between 1960 and 2006, an average rate of 0.21^{o}C per decade. The increase in temperature has been most rapid in December-January-February (DJF) and slowest in September-October-November (SON). Daily temperature observations show an increase in the frequency of hot days and nights in all seasons. The frequency of cold days and nights has significantly decreased in all seasons except in SON. Observed rainfall over the country does not show statistically significant trends. Also, there are no statistically significant trends in the extremes indices calculated using daily precipitation observations.

Under climate change scenario, mean annual temperatures in Malawi are expected to rise by 0.9 to 1.1 degree in 2030, and a further 1.6 to 2.0 degrees in 2050. Mean annual precipitation is projected to change by -1.4% to 3.3% in 2030 while in 2050 this will change by -2.2% to 6.2%. The effects of these temperature and precipitation changes will have adverse impacts on human health in Malawi. In the light of the above, an assessment was conducted with a view to determine the vulnerability of the health sector in Malawi to impacts of climate change and to propose adaptation strategies.

The methodology adopted for conducting the study entailed two main approaches, namely: desk studies and stakeholder consultations. General Circulation Models (GCMs) were used to project the future changes of climate while statistical models were applied in the vulnerability assessment. Two semi-structured questionnaires, one for District Health Officers (DHOs) and another for local communities were administered as part of the data collection process. The document titled "Protecting Health from Climate Change: Vulnerability and Adaptation Assessment" by the World Health Organization (WHO) was used as one of the key reference materials for the study.

Results of vulnerability assessment show that malaria, diarrhoeal diseases, and malnutrition are among the main causes of death in Malawi, a situation which will be exacerbated by climate change. Specifically, the findings show that the incidence of diarrhoea may increase in Lilongwe, Salima and Chikwawa Districts. In Lilongwe District, malaria is projected to increase while malnutrition will decrease by about 5% by 2030. In Chikwawa, both malaria and malnutrition are set to decrease by 2030 by 4.8% and 1.5%, respectively.

Proposed adaptation measures for malaria include use of insecticide-treated nets (ITNs) and mosquito repellents; whereas adaptive strategies for diarrhoea include household water treatment and safe storage (HWTS), such as water filtration and chlorination (using Water Guard), and improved sanitation and personal hygiene. For malnutrition, proposed adaptation measures include income generation through casual labour in order to enhance income, crop diversification, growing of drought resistant varieties, winter cropping and irrigated agriculture to improve climate change resilience and food security at household level. Health sector adaptation strategies for the three key diseases are further outlined in the National Adaptation Programmes of Action (NAPA), and Intended Nationally Determined Contributions (INDC) and will be included in the National Adaptation Plans (NAP) that is being developed.

The study has also shown that there is inadequate capacity in the Ministry of Health (MoH) to manage key climate change related diseases highlighted above. Additionally, the Ministry does not have adequate capacity to apply early warning systems for the prediction of the diseases; it does not have adequate financial and human resources to manage the impacts of climate change on health; and furthermore, the ministry has not explored the potential of using local indigenous knowledge systems and practices (LIKSP) in the assessment of vulnerability and adaptation of the health sector to impacts of climate change.

Although the report has covered a number of issues that need addressing, four stand out as key if the health sector is to perform efficiently and effectively, namely: the need to address information gaps; the need for improved coordination among various stakeholders and organizations that deal with climate change issues in Malawi; the need to address capacity building (human, financial and institutional) in the Ministry of Health; and the need to identify critical areas of research.

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ABBREVIATIONS AND ACRONYMS

ADMARC	Agriculture Development and Marketing Corporation
AIDS	Acquired Immune Deficiency Syndrome
BRACE	Building Resilience Against Climate Effects
CDC	Centre for Disease Control
CHAM	Christian Health Association of Malawi
COP	Conference of the Parties
DCCMS	Department of Climate Change and Meteorological Services
DHO	District Health Officer
DHS	Demographic and Health Survey
EHP	Essential Health Package
ENSO	El Nino Southern Oscillation
GCMs	General Circulation Models
GDP	Gross Domestic Product
GFCS	Global Framework on Climate Services
GHG	Greenhouse Gases
GIS	Geographical Information Systems
GIZ	German Cooperation Agency
GoM	Government of Malawi
HCCCT	Health and Climate Change Core Team
HDP	Health Development Partners
HH	Household
HIV	Human Immuno-deficiency Virus
HMIS	Health Management Information System
HSSP	Health Sector Strategic Plan
ICPAC	IGAD Climate Prediction and Application Centre
IGAD	Intergovernmental Authority in Development
INC	Initial National Communication
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Inter Tropical Convergence Zone
MDG	Millennium Development Goals
MGDS	Malawi Growth and Development Strategy
MoAIWD	Ministry of Agriculture Irrigation and Water Development
MoFEP&D	Ministry of Finance, Economic Planning and Development
MoH	Ministry of Health
NAMA	Nationally Appropriate Mitigation Actions
NAP	National Adaptation Plan
NAPA	National Adaptation Programmes of Action
NCD	Non-communicable Diseases
NGO	Non-Governmental Organization
NMCP	National Malaria Control Program
NSO	National Statistical Office
NTD	Neglected Tropical Diseases
STDs	Sexually Transmitted Diseases

SNC	Second National Communication
STD	Sexually Transmitted Diseases
SWAp	Sector Wide Approach
TB	Tuberculosis
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Framework Convention on Climate Change
VCT	Voluntary Counselling and Testing
WHO	World Health Organisation

GLOSSARY OF TERM

(Source: IPCC 4th Assessment Report, 2007)

Adaptation

Initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected *climate change* effects. Various types of adaptation exist, e.g. *anticipatory* and *reactive*, *private* and *public*, and *autonomous* and *planned*. Examples are raising river or coastal dikes, the substitution of more temperature-shock resistant plants for sensitive ones, etc.

Anthropogenic emissions
Emissions of *greenhouse gases*, greenhouse gas precursors, and *aerosols* associated with human activities, including the burning of *fossil fuels*, *deforestation*, *land-use changes*, livestock, fertilisation, etc.

Carbon dioxide (CO2)
A naturally occurring gas, also a by-product of burning fossil fuels from fossil carbon deposits, such as oil, gas and coal, of burning *biomass* and of *land use changes* and other industrial processes. It is the principal *anthropogenic greenhouse gas* that affects the Earth's radiactive balance. It is the reference gas against which other greenhouse gases are measured and therefore has a *Global Warming Potential* of 1.

Carbon sequestration
The uptake of carbon containing substances by a reservoir, in particular *carbon dioxide.*

Climate model
A numerical representation of the *climate system* based on the physical, chemical and biological properties of its components, their interactions and *feedback* processes, and accounting for all or some of its known properties. The climate system can be represented by models of varying complexity, that is, for any one component or combination of components a spectrum or hierarchy of models can be identified, differing in such aspects as the number of spatial dimensions, the extent to which physical, chemical or biological processes are explicitly represented, or the level at which empirical parameterisations are involved. *Coupled Atmosphere-Ocean General Circulation Models (AOGCMs)* provide a representation of the climate system that is near the most comprehensive end of the spectrum currently available.

Climate scenario
A plausible and often simplified representation of the future *climate*, based on an internally consistent set of climatological relationships that has been constructed for explicit use in investigating the potential consequences of *anthropogenic climate change*, often serving as input to impact models.

Extreme weather event

An event that is rare at a particular place and time of year. Definitions of “rare” vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile of the observed probability density function.

Fossil fuels

Carbon-based fuels from fossil hydrocarbon deposits, including coal, peat, oil, and natural gas.

Greenhouse gas (GHG)

Greenhouse gases are those gaseous constituents of the *atmosphere*, both natural and *anthropogenic*, that absorb and emit radiation at specific wavelengths within the spectrum of *thermal infrared radiation* emitted by the Earth’s surface, the atmosphere itself, and by clouds. This property causes the *greenhouse effect*. Water vapour (H2O), *carbon dioxide* (CO2), *nitrous oxide* (N2O), *methane* (CH4) and *ozone* (O3) are the primary greenhouse gases in the Earth’s atmosphere.

El Nińo-Southern Oscillation (ENSO)

The term *El Niño* was initially used to describe a warm-water current that periodically flows along the coast of Ecuador and Perú, disrupting the local fishery. It has since become identified with a basinwide warming of the tropical Pacific east of the dateline. This oceanic event is associated with a fluctuation of a global-scale tropical and subtropical surface pressure pattern called the *Southern Oscillation*. This coupled *atmosphere*ocean phenomenon, with preferred time scales of two to about seven years, is collectively known as *El Niño-Southern Oscillation*, or *ENSO*. It is often measured by the surface pressure anomaly difference between Darwin and Tahiti and the sea surface temperatures in the central and eastern equatorial Pacific. This event has a great impact on the wind, sea surface temperature and precipitation patterns in the tropical Pacific. It has climatic effects throughout the Pacific *region* and in many other parts of the world, through global teleconnections. The cold phase of ENSO is called *La Niña*.

Kyoto Protocol

The Kyoto Protocol to the *United Nations Framework Convention on Climate Change (UNFCCC)* was adopted in 1997 in Kyoto, Japan, at the Third Session of the Conference of the Parties (COP) to the UNFCCC. It contains legally binding commitments, in addition to those included in the UNFCCC. Countries included in *Annex B* of the Protocol (most Organization for Economic Cooperation and Development countries and countries with *economies in transition*) agreed to reduce their *anthropogenic greenhouse gas* emissions (*carbon dioxide*, *methane*, *nitrous oxide*, *hydrofluorocarbons*, *perfluorocarbons*, and *sulphur hexafluoride*) by at least 5% below 1990 levels in the commitment period 2008 to 2012. The Kyoto Protocol entered into force on 16 February 2005.

Mitigation

Technological change and substitution that reduce resource inputs and emissions per unit of output. Although several social, economic and technological policies would produce an emission reduction, with respect to *Climate Change*, mitigation means implementing policies to reduce *greenhouse gas* emissions and enhance *sinks.*

Resilience

The capacity of a system, community or society potentially exposed to hazards to adapt, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure. This is determined by the degree to which the social system is capable of organizing itself to increase its capacity for learning from past disasters for better future protection and to improve risk reduction measures. (UN/ISDR, 2004)

Scenario
A plausible and often simplified description of how the future may develop, based on a coherent and internally consistent set of assumptions about driving forces and key relationships. Scenarios may be derived from *projections*, but are often based on additional information from other sources, sometimes combined with a *narrative storyline*.

Sink
Any process, activity or mechanism which removes a *greenhouse gas*, an *aerosol* or a precursor of a greenhouse gas or aerosol from the *atmosphere*.

Source
Source mostly refers to any process, activity or mechanism that releases a *greenhouse gas*, an *aerosol*, or a precursor of a greenhouse gas or aerosol into the *atmosphere*. Source can also refer to e.g. an *energy* source.

United Nations Framework Convention on Climate Change (UNFCCC)
The Convention was adopted on 9 May 1992 in New York and signed at the 1992 Earth Summit in Rio de Janeiro by more than 150 countries and the European Community. Its ultimate objective is the "stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system". It contains commitments for all Parties. Under the Convention, Parties included in *Annex I* (all OECD member countries in the year 1990 and countries with *economies in transition*) aim to return *greenhouse gas* emissions not controlled by the Montreal Protocol to 1990 levels by the year 2000. The Convention entered in force in March 1994.

Vulnerability
Vulnerability is the degree to which a *system* is susceptible to, and unable to cope with, adverse effects of *climate change*, including *climate variability* and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its *sensitivity*, and its *adaptive capacity*.

1 BACKGROUND

There is ample scientific evidence that climate change is real and that anthropogenic activities, in particular emissions of greenhouse gases (GHGs), are its principal cause (Boko, et al., 2007; Epstein, 2002; Smith, 2001; IPCC, 2007a). The world's poorest countries, mainly in sub-Saharan Africa, are most vulnerable to impacts of climate change because of their weak economies and adaptive capacities. Thus, failure to respond to this phenomenon will stall and reverse efforts to reduce poverty (Tadross, et al., 2009)

Ways in which climatic factors affect the prevalence of diseases or human health are complex (Figure 1). Climate change is linked to increases in a wide range of non-communicable as well as infectious diseases such as vector and water borne diseases, and malnutrition. Furthermore, climate change has the potential to cause heat waves, floods, droughts, and storms, resulting in increased deaths, injury, and changing disease scenarios. Identification of communities and places vulnerable to these changes can help health authorities assess and prevent associated adverse impacts on human health. These adverse impacts can be averted by putting in place a combination of strategies such as strengthening key health system functions and improving the use of early warning systems for climate and weather information for planning and climate risk management.

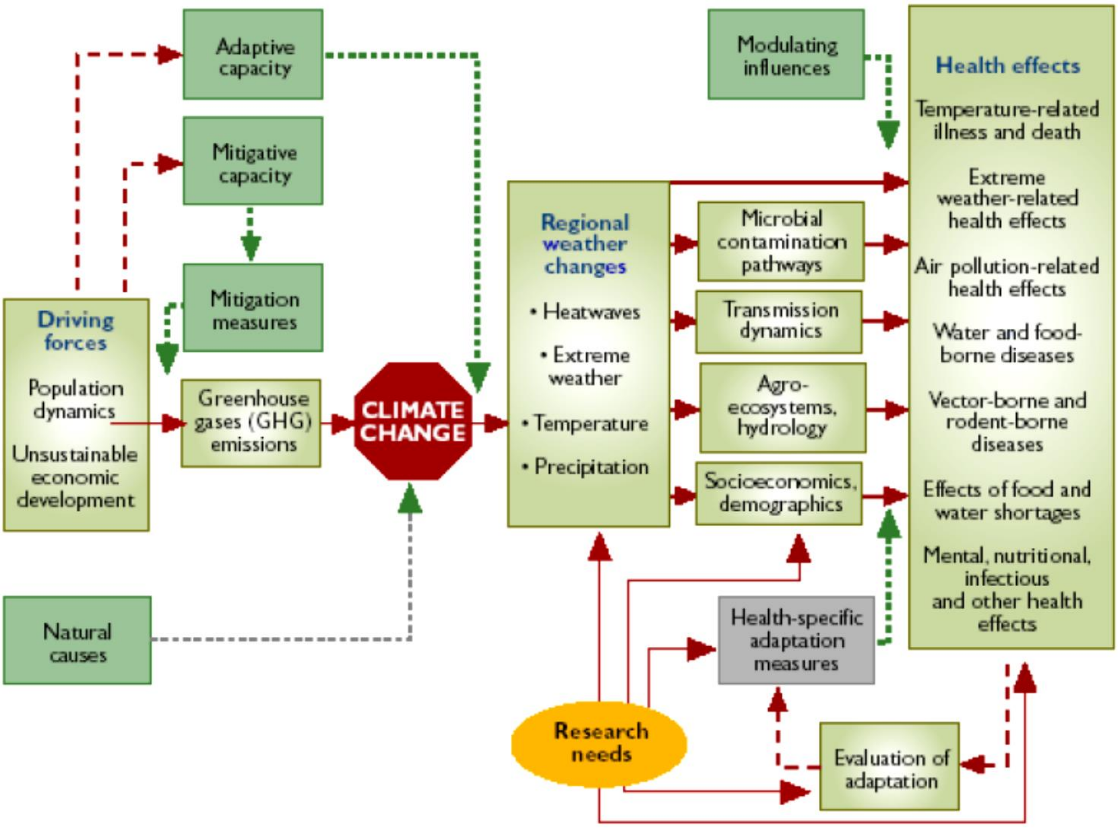


Figure 1: Potential Health Effects of Climate Change (Source: IPCC (AR3), 2001)

Climate change poses a serious threat to Malawi's development agenda (UNDP, 2010). In the short to medium term, climate change will significantly affect the functioning of natural ecosystems, with serious repercussions on weather-sensitive sectors, such as agriculture, forestry, water resources, energy, fisheries, and wildlife; as well as human health, human settlements, and gender (GoM, 2010; GoM, 2011; Oxfam International, 2009) In the long-term, climate change will undermine the attainment of Sustainable Development Goals (SDGs), Vision 2020, and the Malawi Growth and Development Strategy (MGDS II), thereby exacerbating poverty in the country.

In view of the above and in line with global efforts, the Government of Malawi signed and ratified the United Nations Framework Convention on Climate Change (UNFCCC) in June 1992 and April 1994, respectively. In addition to ratifying the UNFCCC, the Government ratified the Kyoto Protocol in October 2001, and submitted the Initial National Communication (INC) and Second National Communication (SNC) reports to the Conference of the Parties (COP) of the UNFCCC in 2002 and 2011, respectively (GoM, 2002; GoM, 2011). In 2006, the Malawi Government developed the National Adaptation Programmes of Action (NAPA) to address short to medium-term impacts of climate change on the country's social and economic sectors (GoM, 2006). The Government of Malawi recognized Climate Change, Environment and Natural Resources Management as one of the Key Priority Areas (KPA) in the Malawi Growth and Development Strategy (GoM, 2011 b). At the moment, the Government is developing the Climate Change Policy and the Nationally Appropriate Mitigation Actions (NAMAs) and National Adaptation Plans (NAPs), and has also conducted a review of the National Adaptation Programme of Action (NAPA) and developed the Intended Nationally Determined Contributions (INDC). It is worth noting that the health sector has lagged behind in the implementation of adaptation measures for averting the adverse impacts of climate change in Malawi.

The Ministry of Health (MoH) in Malawi is taking bold steps to address climate change risks to human health and develop adaptation mechanisms. These efforts are attested by the MoH's participation in the Africa Adaptation Program of the Global Framework for Climate Services (GFCS). The ministry plans to work with multiple sectors to improve understanding and readiness for the health risks of climate change and variability. An initial activity of this project involved conducting a nationwide assessment of the potential vulnerabilities and adaptation mechanisms to impacts of climate change. To this end, the MoH commissioned a study on Health and Climate Vulnerability and Adaptation Assessment with financial support from the German Development Cooperation (GIZ) through the World Health Organization (WHO).

1.1 Vulnerability and Adaptation Assessment of the Health Sector to Climate Change

The main benefit derived from a vulnerability and adaptation assessment is that it allows health authorities to understand the people and places in their jurisdiction that are more susceptible to adverse health impacts associated with the climate-related exposures modified by climate change. An assessment of vulnerability and adaptive capacity is a means of prioritising and directing action where it is needed most urgently by determining which regional areas and populations are most at risk. It can thus be used to implement more targeted public health actions to reduce harm to vulnerable communities.

Vulnerability may be defined as the degree to which a system is susceptible to, and unable to cope with adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, the sensitivity and adaptive capacity of that system, see Figure 2 (IPCC, 2007b).

Adaptation to climate change has the potential to reduce adverse impacts of climate, and enhance the beneficial impacts, and hence enable people to continue to live their lives and participate in developmental issues.

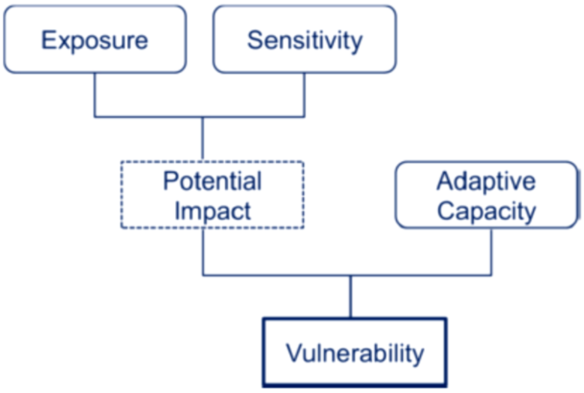


Figure 2: Factors that determine vulnerability (Source: CDC, Undated)

Generally, vulnerability assessments of impacts of climate change on various sectors of the economy begin with the generation of climate change scenarios for temperature and precipitation using General Circulation Models (GCMs), Regional Circulation Models, or Down Scaled GCMs. These data are then used as inputs into sector specific models, e.g. water balance models for water resources, crop models for agriculture, etc. Outputs from sector specific models are then fed into economic models in order to assess potential impacts of climate change on the GDP. The WHO has developed guidelines for assessing the vulnerability of the health sector to climate change as depicted in Figure 3. Statistical models find wide application in the assessment of the vulnerability of the health sector to adverse impacts of climate change. These models are used to indicate the likelihood of future climate events.

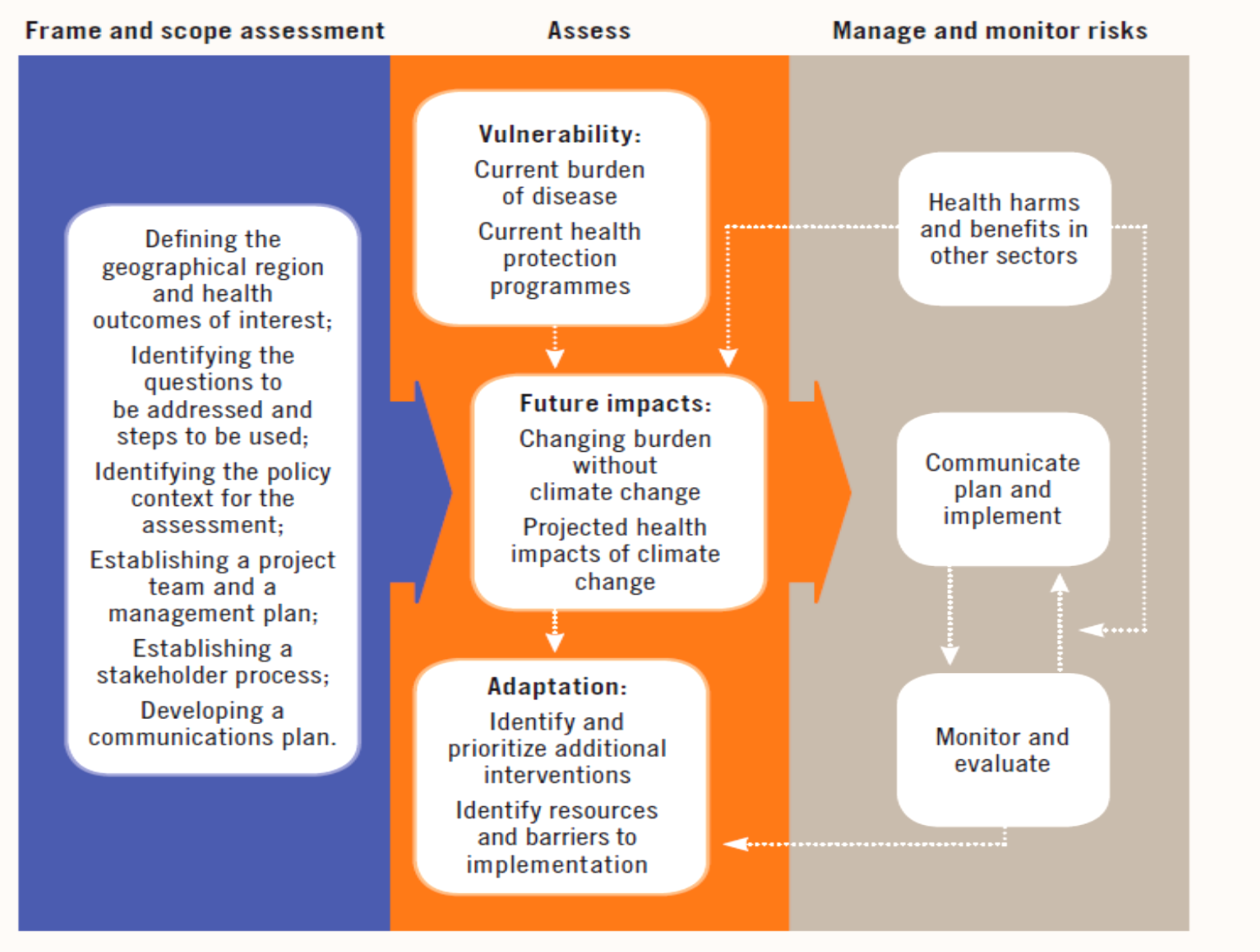


Figure 3: Steps for Assessing Vulnerability and Adaptation of the Health Sector (WHO, 2013)

1.2 Justification

There is strong evidence that climate change is having serious repercussions on human health worldwide. In many countries or regions, climate-sensitive diseases have increased over the years, causing untold misery to huge human populations. The WHO Global Burden of Disease Project (2000) estimated that climate change caused over 150,000 deaths globally and the loss of 5.5 million disability-adjusted life years from climate sensitive health outcomes (i.e. diarrheal disease, malnutrition, malaria and floods) in the year 2000 alone. The Health Management Information Systems (HMIS) data shows an increase of incidence of malaria, diarrhoea and malnutrition, and variation in both space and temporal distribution. The Malawi NAPA has shown that key climate related diseases in the country are: malaria, diarrhoea, and malnutrition (GoM, 2006). In the light of the above, there is need to conduct vulnerability and adaptation assessments of the health sector if deleterious effects of climate change are going to be avoided.

2 OBJECTIVES OF THE STUDY

The main objective of the study was to assess the vulnerability of the health sector in Malawi to impacts of climate change and to propose adaptation strategies. And the following were specific objectives of the study:

1) To establish a baseline by determining the magnitude and distribution of the vulnerability of the health sector to climate change and variability, with special focus on the four priority health issues, namely: nutrition, vector-borne diseases, water-borne diseases, and disasters (floods, drought, storms, etc.);
2) To establish a capacity-baseline of the health sector (including the community) to address current and future risks of climate change, including the policy landscape;
3) To explore how the projected future impacts of climate change may impact the four health priorities in Malawi;
4) To identify key indicators and risk factors to be monitored overtime to observe additional future impacts of climate on health;
5) To identify key opportunities to bridge the identified gaps in information and capacity;
6) To identify research needs and information gaps; and

3 SCOPE OF WORK

The consultancy involved the implementation of the following tasks:

1) Developing the vulnerability and adaptation assessment protocol, and administering the same in the selected study areas;
2) Drawing a list of key stakeholders;
3) Conducting the analysis and writing the assessment report;
4) Disseminating the findings of the assessment to key stakeholders;
5) Holding a stakeholder validation workshop to review the findings; and
6) Incorporating comments from stakeholders, and submitting the final report to the Ministry of Health.

7) To develop recommendations of key national strategies and sectoral programming that can be considered for inclusion under a climate strategy for health

4 METHODOLOGY

Approaches described in Sections 4.1 to 4.7 were employed in addressing the seven specific objectives highlighted in Section 2.0

4.1 Baseline Assessment of the Vulnerability of the Health Sector

In order to establish a baseline of the magnitude and distribution of the vulnerability of the health sector to climate change and variability, with regards to nutrition, vector-borne diseases, water-borne diseases, and disasters (floods, drought, storms, etc.), literature review of existing documents on climate change and human health in Malawi, particularly the NAPA, and stakeholder consultations with District Health Officers (DHOs) for Karonga, Chikwawa, Zomba, Mangochi, Mchinji, Ntcheu, and Kasungu Districts through a questionnaire survey were employed for data collection. These were complemented by information obtained from the HSSP 2011-2016, the MDG Endline Survey 2014 report, and the Service Provision Survey of 2014. Baseline data on flood and drought disasters were collected from the Departments of Disaster Management Affairs, Climate Change and Meteorological Services, and Water Resources.

Baseline data on the use of Local Indigenous Knowledge Systems and Practices (LIKSP) for diagnosing and treating climate related diseases was conducted in Chikwawa and Nsanje Districts covering more than ten villages. Additionally, the application of LIKSP in predicting the occurrence of floods and droughts was assessed.

4.2 Baseline Assessment of the Capacity to Address Climate Change

In order to establish a capacity-baseline of the health sector (including the community) to address current and future risks of climate change, including the policy landscape, a semi-structured questionnaire was administered to DHOs with a view to establishing the existence of capacity to manage the key climate sensitive diseases identified in the NAPA. Additionally, their capacity to understand climate change science and related issues, financial and institutional capacity to cope with the adverse impacts of climate change, and the existence as well as application of early warning systems for diseases and extreme climatic weather events, namely floods and droughts was assessed. The information obtained from the questionnaire survey was complemented with literature review involving the NAPA, NAP and INDC.

4.3 Vulnerability Assessment

This task was done in two stages. Firstly, climate change projections of temperature and precipitation were generated using General Circulation Models. Secondly, data on climate change projections for temperature and precipitation were applied in the statistical modelling of future impacts of the selected diseases, namely: malnutrition, malaria, and diarrhoeal diseases.

The task of generating climate change scenarios of temperature and precipitation involved the application of an ensemble of General Circulation Models (GCMs) for the entire country (GoM, 2011; GoM, 2002). This was complemented by results presented by the IPCC in its Fourth Assessment Report (IPCC, 2007a), the UNDP Report (McSweeney, New, & Lizcano, 2008), Intergovernmental Authority in Development (IGAD) and ICPAC (IGAD Climate Prediction and Application Centre) report of 2007.

After the generation of climate change scenarios of temperature and precipitation, univariate analysis was conducted for each of the selected disease and climatic variables with cross-correlation analysis in order to assess associations between malaria, malnutrition, dysentery, cholera and climatic variables, together with other covariates over a range of time lags. The time lags chosen for the final model simulation were outcomes of cross-correlational analysis using seasonally differenced data.

A dynamic linear model (DYLM) model, which is equivalent to the seasonal autoregressive integrated moving average (SARIMA), was then applied to examine independent contributions of malaria, dysentery, or cholera transmission covariates. The number of terms for SARIMA were determined using the autocorrelation function (ACF) and partial autocorrelation function (PACF). When fitting the SARIMA model, the outcome variables were transformed using Johnson and Wichern (1998) approach. For the cholera outcome, a square root transformation to account for zero-inflation was used while logarithmic transformation was employed for malaria, malnutrition and dysentery.

To create an appropriate stationary time series for the analysis, all dependent and independent variables were differenced at an appropriate lag periodicity. For malaria and dysentery, lags at month 1 and 2 were created while for cholera constructed seasonally adjusted lags of 12 months were applied. For malnutrition, lags at 6 and 12 months were created, guided with the prior belief that most of malnutrition cases in Malawi might be due to chronic under-nutrition (stunting) and seasonal under-nutrition (wasting).

Data on climatic variables (temperature and rainfall) and number of cases of key diseases were collected from the Department of Climate Change and Meteorological Services (from meteorological stations at Chikwawa, Makoka, Chitedze and Salima) and Ministry of Health - Health Management Information System (HMIS), respectively. These data were then correlated with a view to exploring exiting relationships.

Furthermore, future projections of climate change scenarios obtained from the IPCC Fourth Assessment Report of 2007 were used to determine the future impacts on the key diseases using statistical modelling for the periods 2030 and 2050. (McSweeney, New, & Lizcano, 2008)

Annual excess incidence of disease attributable to future climate-related changes in temperature and precipitation was estimated by

$$\Delta inc = inc_0(e^{\beta\Delta X} - 1)$$

where Δinc is the expected incidence change due future climatic change ΔX (as provided in Table 2 and 3), while inc_0 is the baseline incidence at the present time. Here, the relative risk captures the expected change in disease risk following a 1^{o}

Celsius change in temperature or 1% change in rainfall. The average incidence in 2007 was used as a baseline incidence to calculate future incidence.

4.4 Indicators and Risk Factors for Tracking Climate Change Impacts on the Health Sector

This involved the identification of key indicators for use in tracking the disease burden (e.g. proportion of disease cases) and their spatial distribution, as well as noting the frequency and magnitude of flood and drought disasters. The vulnerability assessment above assisted in the identification of some indicators that can be used in tracking climate change impacts.

Risk factors for tracking climate change were identified using literature review and questionnaires that were administered to stakeholders.

4.5 Identification of Opportunities for Bridging Gaps in Information and Capacity

This involved synthesising data collected through desk/literature review and stakeholder consultations. Opportunities were then identified for bridging gaps in information and capacity.

4.6 Identification of Research Needs and Information Gaps

Research needs were identified through results obtained for Sections 4.1-4.5. This involved comprehensive review of literature, consultation with key stakeholders, data collection and analysis and statistical modelling.

4.7 Identification of Potential Adaptation Strategies

After the assessment of the health sector to impacts of climate change, potential anticipatory adaptation strategies were proposed for implementation.

4.8 Development of Recommendations of Key National Strategies and Sectoral Programming

The compilation of recommendations made by this study was based on the findings for Sections 4.1 to 4.8

4.9 Study Limitations

This had several limitations. The study largely relied on desk review method for data collection. This resulted in missed information due to unavailability of the required data and inadequate consultations with key stakeholders. Further, the study design failed to generate new information on adaptation and mitigation of the effects of climate change on health. There was also high non-response rate (28%) to the mailed questionnaire to the District Health Officers.

Usually, for appropriate climate projection one requires data collected for a minimum period of 30 years. However, in this study projections of disease occurrences were made based on eight years data due to unavailability of health data.

5 STUDY FINDINGS

5.1 Baseline on the vulnerability of the health sector

The baseline assessment focused mainly on information on three key climate sensitive diseases and the relationship between the occurrences of these diseases and climatic variables.

5.1.1 Information on Key Diseases in relation to climatic variables

The study findings show that malaria, diarrhoeal diseases and malnutrition are among the main causes of illnesses and deaths. Findings from the study areas revealed that the average number of diarrheal cases in Chikwawa was 1242 while malaria was 7098 and malnutrition was 272.73.

The results show that diarrhoea, malaria and malnutrition are weakly correlated with climatic variables (correlation r<0.2), except for rainfall and diarrhoea (r=0.54). In Zomba, the mean number of diarrheal cases of 1096.4 was slightly lower than in Chikwawa district. The mean number of malaria and malnutrition cases were 9825 and 213.7 respectively. The correlation of malaria with rainfall and minimum temperature was moderate (r=0.5), but weak for malnutrition and diarrhoea. During the period of study, Lilongwe posted slightly higher number of cases of all disease types. The mean cases of diarrhoea was 3516 while malaria and malnutrition were 22194 and 783.4 respectively. For all diseases, the highest correlation with climatic variables was observed between malaria and rainfall and minimum temperature, otherwise for other diseases this was estimated at r<0.3.

In Salima, the mean cases were 585, 5259, and 162.7 for diarrhoea, malaria and malnutrition respectively. Table 4 below shows the summary statistics for the observed disease cases and climate variables.

Table 1: Summary statistics of disease incidence and climatic variables in Chikwawa, Zomba, Lilongwe and Salima districts.

District	Variable	Number (months)	Mean	Median	Standard deviation	Minimum	Maximum
Chikwawa	Diarrhoea	84	1242.0	1135	400.67	706	2701
	Malaria	84	7098.0	7618	2952.86	1799	14764
	Malnutrition	84	272.7	217	221.33	39	1261
	Rain	84	59.6	22.20	86.87	0	391.60
	Minimum Temperature	84	20.3	21.20	3.50	12.00	25.90
	Maximum Temperature	84	32.9	32.90	3.11	25.20	38.60
Zomba	Diarrhoea	96	1096.4	1078.0	406.01	479.0	2986.0
	Malaria	180	9825.0	9286	4075.68	3260	25893
	Malnutrition	132	213.7	173.0	125.75	100.0	1127.0
	Rain	180	82.3	18.65	110.64	0	439.10
	Minimum Temperature	180	15.9	16.75	2.86	10.40	20.80
	Maximum Temperature	180	26.6	26.80	2.39	21.60	31.60
Lilongwe	Diarrhoea	84	3516.0	3178	1640.02	40	7919
	Malaria	84	22194	20013	12229.1	306	51999
	Malnutrition	84	783.4	781.5	423.68	0	1943.0
	Rain	84	69.77	15.95	98.41	0	407.80
	Minimum Temperature	84	15.14	15.60	3.25	9.00	19.60

	Maximum Temperature	84	27.21	27.00	2.18	22.70	32.00
Salima	Diarrhoea	132	585.8	643.0	491.14	11.0	2760.0
	Malaria	132	5259	5798	3271.64	393	14643
	Malnutrition	132	162.7	127.0	159.14	5.0	945.0
	Rain	132	96.24	8.50	153.95	0	760.70
	Minimum Temperature	132	20.51	20.86	2.34	15.70	24.60
	Maximum Temperature	132	29.56	29.40	2.17	24.60	34.50

5.1.2 5.1.2 Trends and Seasonality of Disease Incidence

The box plots (Figures 5 to 12) present the observed incidences of diarrhoea, malaria and malnutrition in the four districts under study. These plots display the long-term trend (years) in disease incidence, and seasonality of disease using month. Figure 5illutrates monthly average variations in disease incidence in Chikwawa district, and provides evidence of strong seasonality of diarrhoea while for malaria, highest average incidence are generally in the first months of the year, which coincides with the hot and rainy season. The trend shows the average incidence of diarrhoea has been increasing while that of malaria and malnutrition has been decreasing.

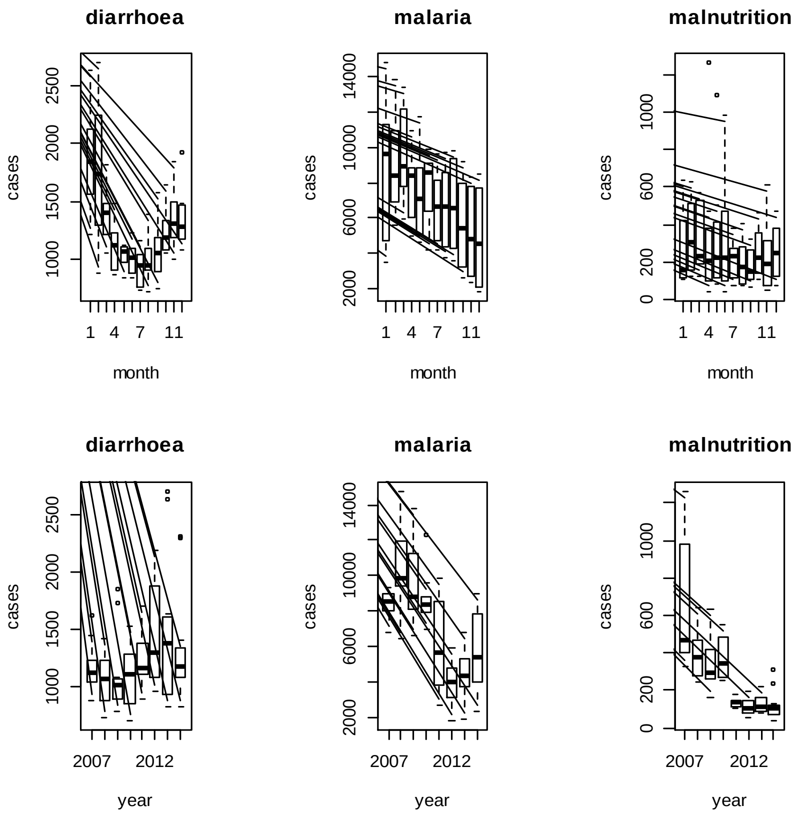


Figure 4: Box plots for Chikwawa at various years and months

In Zomba, all diseases show a strong seasonality variation (Figure 6). High average numbers of cases coincide with the hot and rainy season (November-March) while average low incidences were recorded in the cold season. The trend presented displays an increasing average number of diarrhoea and malaria, but a nearly constant pattern with regards to malnutrition. The variability of malaria within each year is relatively higher than for the other two diseases.

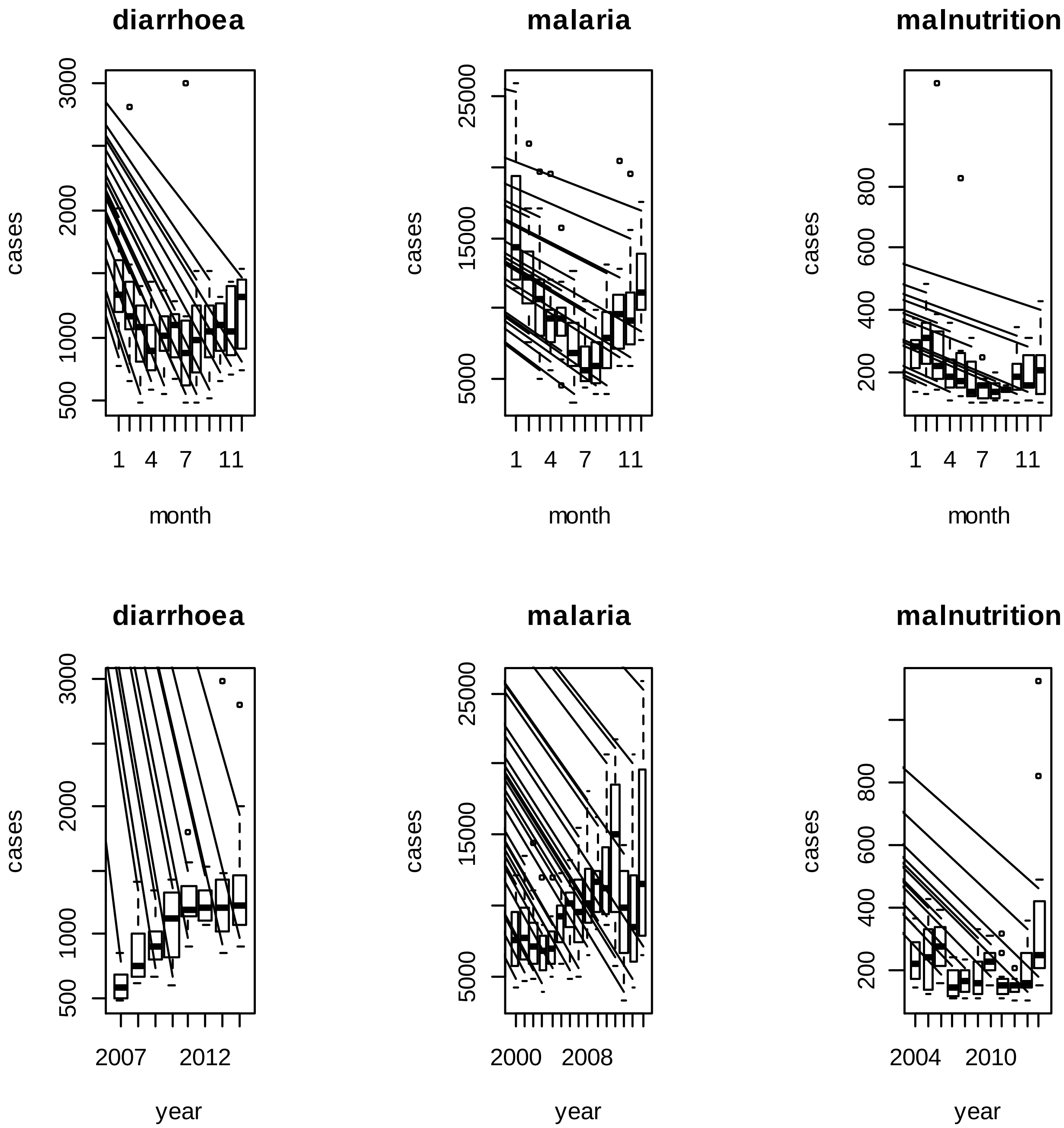


Figure 5: Box plots showing monthly and yearly pattern in Zomba district

The trends in average incidence of diarrhoea, malaria and malnutrition in Lilongwe are presented in Figure 7 below. The three selected diseases show seasonality variations. High average numbers of reported cases were recorded in January and February, and also in November-December, which is a rainy season, while low average incidences were recorded in the second or third quarters of the year. The clear increase in trend was visible in diarrhoea incidence while for malaria this increased for four consecutive years (2007-2010). and decreased in subsequent years only to increase again in the year 2012.

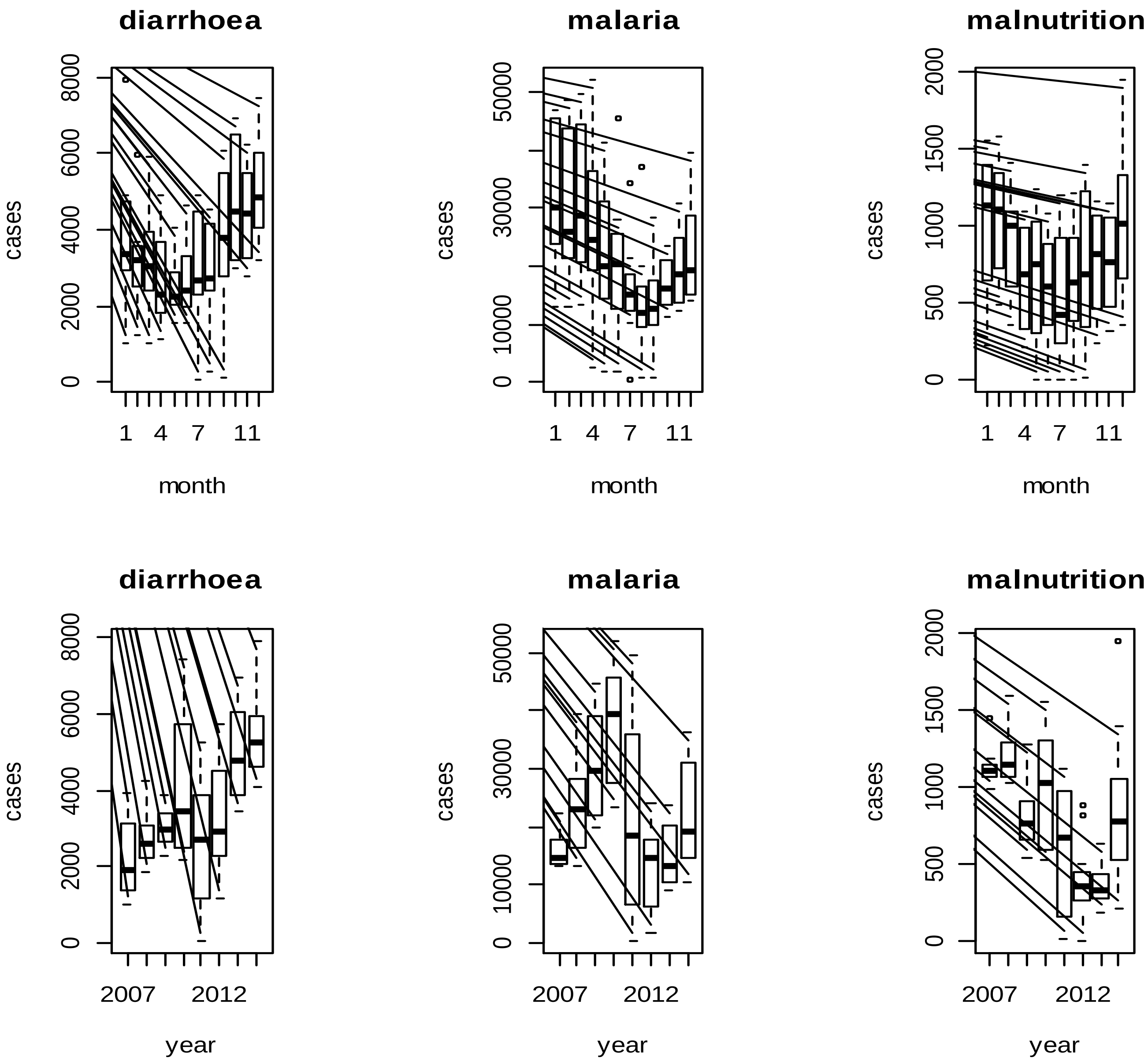


Figure 6: Box plots of disease data for Lilongwe at different months and years

Figure 8 shows the distribution average incidence of diarrhoea, malaria and malnutrition in Salima. All box plots show that in general no disease displays seasonal variation, although diarrhoea and malnutrition depict some peaks towards the beginning and end of the year. As in other districts, the average incidence of diarrhoea and malnutrition has increased since the year 2007. For malnutrition, the trend of incidence is somewhat constant

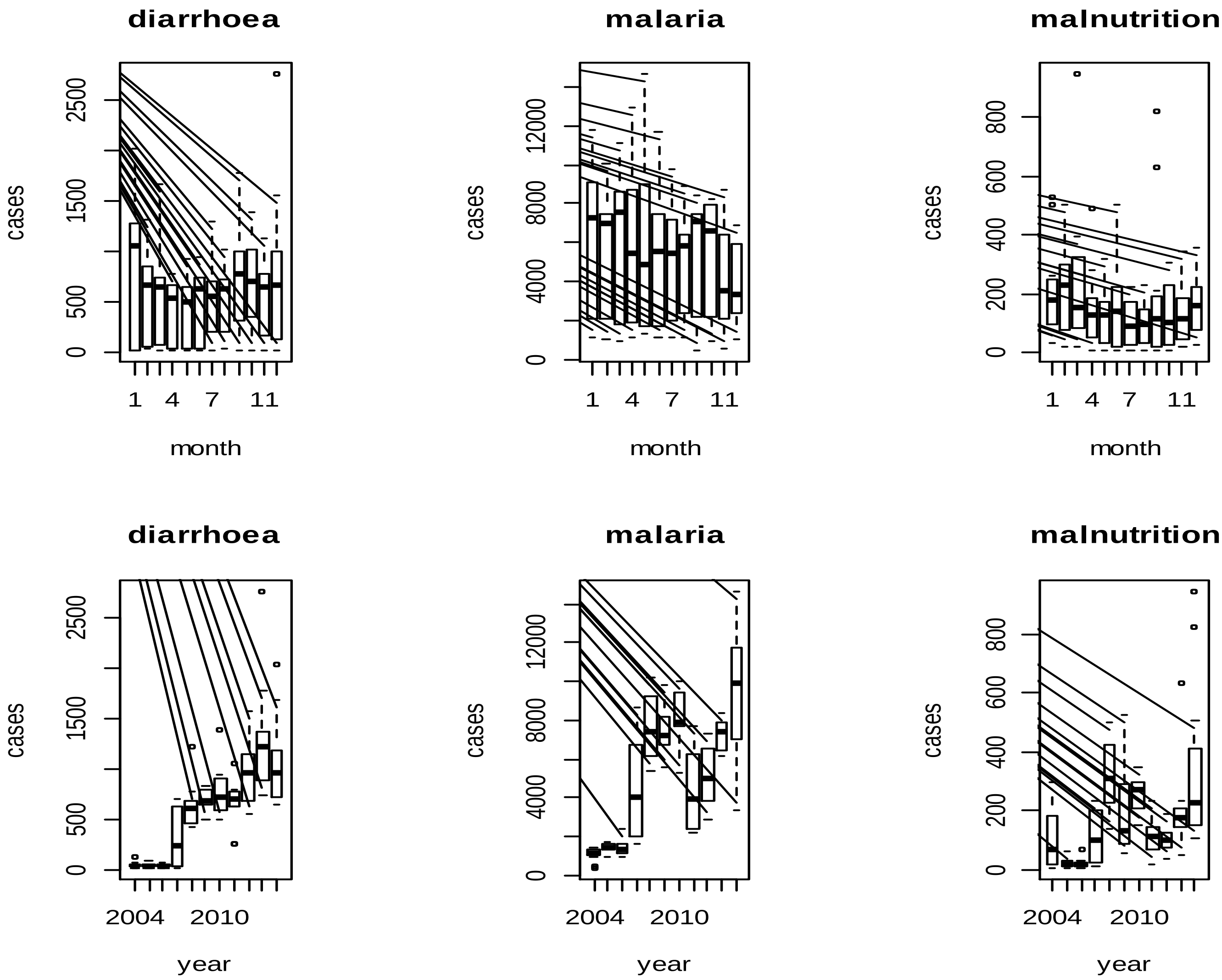


Figure 7: Box plots of disease data for Salima at different months and years

5.1.3 Relationship between disease incidences and climatic variables

The findings on the relationship between diseases and climatic variables are presented in Figure 9 to 12. The top panel shows a plot of diarrhoea against each climatic variable while presented in the middle panel is the relationship between malaria and climatic variables and bottom graphs are showing the relationship between malnutrition and climatic varables.

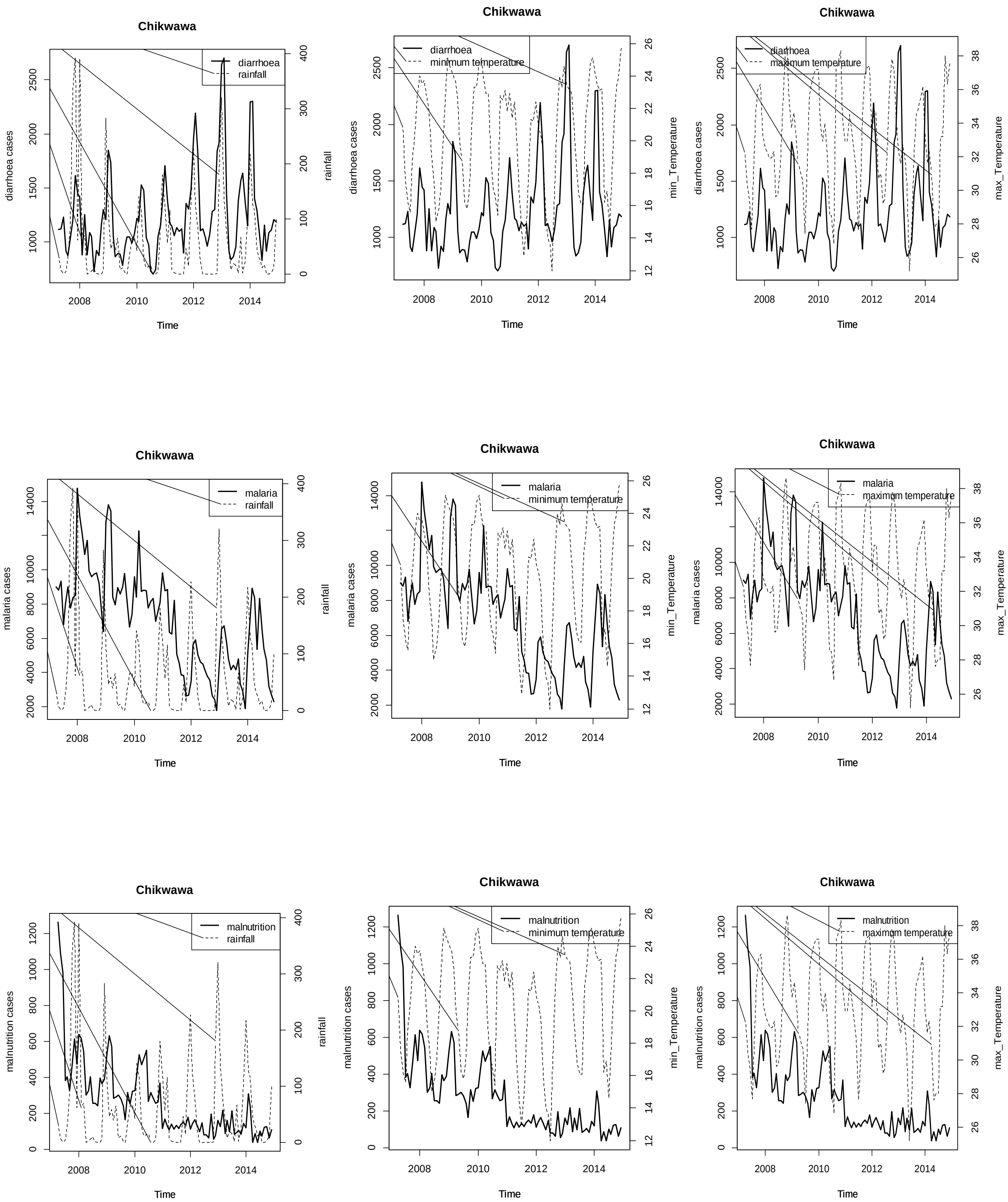


Figure 8: Time series plots of diarrhoea (top panel), malaria (middle panel) and malnutrition (bottom panel) and climatic variables in Chikwawa district.

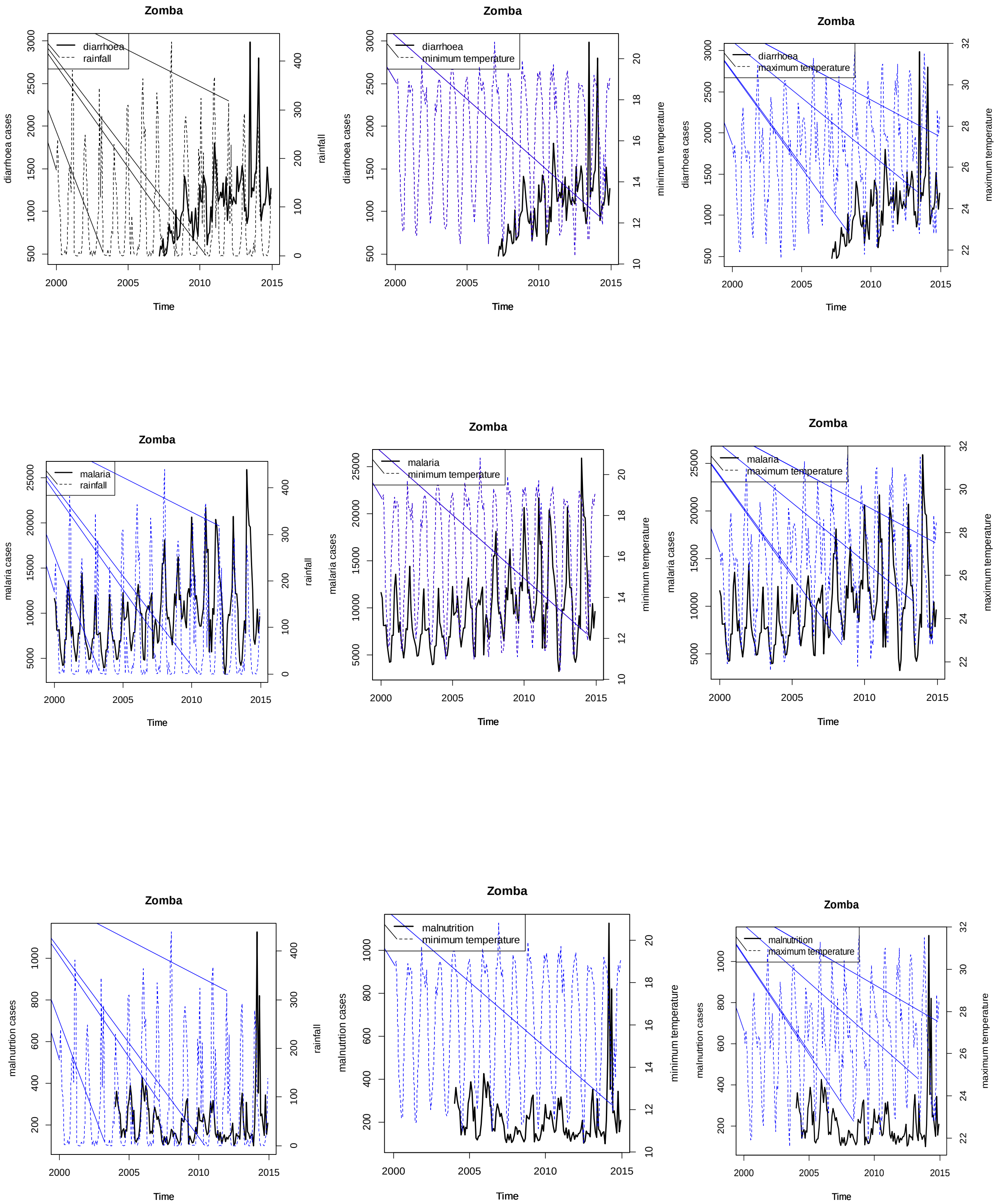


Figure 9: Time series plots of diarrhoea (top panel), malaria (middle panel) and malnutrition (bottom panel) and climatic variables in Zomba district.

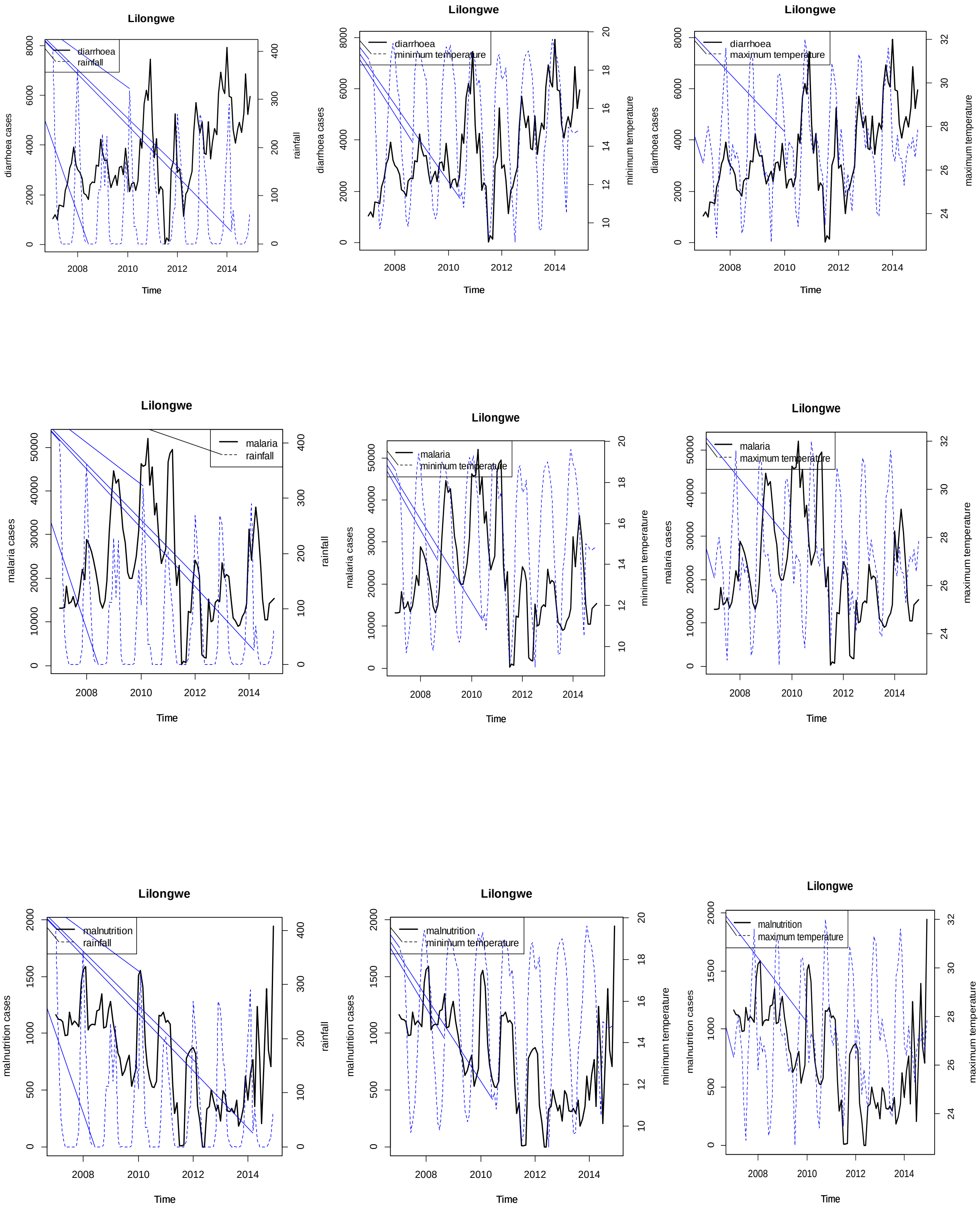


Figure 10: Time series plots of diarrhoea (top panel), malaria (middle panel) and malnutrition (bottom panel) and climatic variables in Lilongwe district.

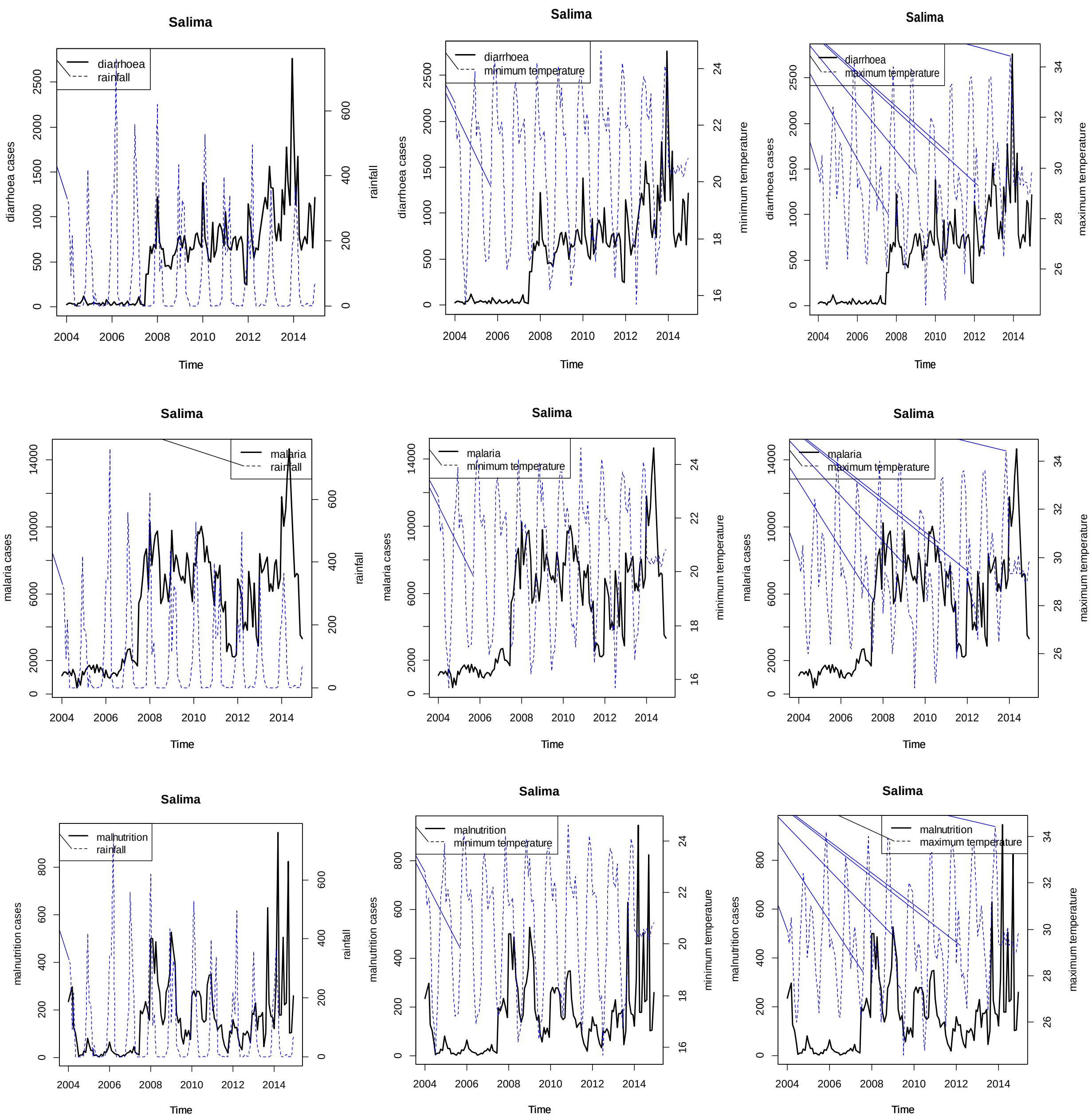


Figure 11: Time series plots of diarrhoea (top panel), malaria (middle panel) and malnutrition (bottom panel) and climatic variables in Salima district.

5.1.4 Vulnerability Situation

Regression analysis was used to determine the relationship between climate variables and disease incidences.

The root mean square error was used to validate the model. The best fitting model was identified and used. Summary of results are presented in Tables 5 and 6 below.

Table 2: Regression coefficients for Chikwawa and Zomba districts

		Chikwawa			Zomba		
Variable		Diarrhoea (95% CI)	Malaria (95% CI)	Malnutrition (95% CI)	Diarrhoea (95% CI)	Malaria (95% CI)	Malnutrition (95% CI)
Climatic	Rainfall (Lag0)	1.001 (1.000-0.002)	1.001 (1.000-1.001)	1.000 (1.0001-1.0004)	1.0006 (1.0005-1.008)	1.0003 (1.00031-1.00037)	1.001 (1.0004-1.002)
	Rainfall (Lag1)	1.005 (1.004-1.006)	1.001 (1.001-1.002)	1.000 (1.0000-1.0003)	1.0005 (1.0004-1.0006)	1.000 (1.0002-1.0003)	1.000 (1.0003-1.0009)
	TMin (Lag1)	1.004 (1.002-1.005)	0.967 (0.994-0.999)	1.037 (1.01-1.04)	0.988 0.97-0.99)	0.953 (0.94-0.97)	1.016 (1.01-1.02)
	TMin Lag2)	1.031 (1.001-1.004)	1.027 (1.011-1.068)	0.984 (0.98-1.01)	1.004 (0.99-1.007)	0.935 (0.92-0.94)	0.873 (0.84-0.89)
	TMax (Lag1)	1.031 (1.000-1.004)	1.04 (1.02-1.005)	0.953 (0.94-0.99)	1.042 (1.03-1.047)	1.013 (1.01-1.03)	0.983 (0.93-1.01)
	TMax (Lag2)	1.019 (1.000-1.002)	0.987 (0.971-0.999)	1.046 (1.03-1.06)	1.076 (1.07-1.088)	1.071 (1.035-1.11)	1.09 (1.02-1.13)
Year	2007	1.000	1.000	1.000	1.000	1.000	1.000
	2008	0.856 (0.822-0.878)	1.150 (1.12-1.18)	0.668 (0.64-0.72)	1.474 (1.44-1.49)	1.047 (1.03-1.045)	0.980 0.96-0.99)
	2009	0.873 (0.814-0.929)	1.052 (1.03-1.08)	0.586 (0.55-0.64)	1.586 (1.55-1.61)	1.157 (1.13-1.19)	1.176 (1.15-1.195)
	2010	0.864 (0.855-0.877)	0.970 (0.96-0.99)	0.643 (0.62-0.69)	1.837 (1.62- 2.01)	1.248 (1.21-1.26)	1.457 (1.13-1.61)
	2011	1.005 (1.002-1.008)	0.647 (0.62-0.66)	0.236 (0.22-0.25)	2.135 (2.08-2.21)	1.380 (1.33-1.42)	1.037 (1.01-1.05)
	2012	1.163 (1.141-1.190)	0.434 (0.42-0.44)	0.197 (0.18-0.22)	2.028 (1.93-2.11)	0.923 (0.91-0.95)	0.951 (0.89-0.98)
	2013	1.184 (1.178-1.197)	0.488 (0.47-0.50)	0.214 (0.201-0.23)	2.343 (2.16-2.55)	0.936 (0.91-0.96)	1.186 (0.16-1.21)
	2014	1.075 (1.057-1.091)	0.624 (0.61-0.64)	0.197 (0.188-0.22)	2.620 (2.51-2.74)	1.488 (1.42-1.57)	2.459 (2.22-2.64)

For Chikwawa district, it was noted that the effect of rainfall was positively related to all diseases at both lag of 0 and 1 month. There was approximately 0.1% increase in diarrhoea, malaria and malnutrition per unit percentage increase in rainfall in the current month, and 0.5% increase in diarrhoea per percentage increase in rainfall in the previous month. Both minimum and maximum temperatures were associated with diarrhoea, malaria and malnutrition. For malaria and minimum temperature, results show a 4% reduction in malaria when temperature increases by 1 degree in the previous month, while malnutrition decreases by 2% in 1 degree increase in temperature in the past 2 months (Table 5). Across all years in Chikwawa, compared to the year 2007, the incidence of diarrhoea has increased, however, a reduced risk of malaria and malnutrition was estimated.

In Zomba district, rainfall was the main driver of all diseases, but the effect was relatively small (0.06%, 0.03% and 0.1% increases for diarrhoea, malaria and malnutrition respectively, for every 1% increase in rainfall). Minimum temperature at a lag of 1 month was negatively associated with the incidence of diarrhoea, and malaria, but positively related to the incidence of malnutrition. However, at lag of 2 months, a positive relationship was noted with the incidence of diarrhoea, at the same time negatively associated with the incidence of malaria and malnutrition. Maximum temperature also positively affected diarrhoea and malaria incidence, but negatively with malnutrition. Overall, the incidence of all diseases has increased since 2007.

Table 3:Regression Coefficients for Lilongwe and Salima Districts

		Lilongwe			Salima		
Variable		Diarrhoea (95% CI)	Malaria (95% CI)	Malnutrition (95% CI)	Diarrhoea (95% CI)	Malaria (95% CI)	Malnutrition (95% CI)
Climatic	Rainfall (Lag0)	0.998 (0.9983-0.9988)	0.99 (0.992-0.994)	0.998 (0.982-0.990)	1.000 (1.0003-1.0005)	0.999 (0.9987-0.9998)	1.001 (1.0008-1.0011)
	Rainfall (Lag1)	0.999 (0.9990-0.9994)	0.98 (0.981-0.986)	0.998 (0.980-0.999)	1.000 (0.999-1.0001)	0.999 (0.9986-0.9998)	0.999 (0.9985-0.9998)
	TMin (Lag1)	1.000 (0.991-1.002)	1.051 (1.02-1.07)	1.105 (1.05-1.12)	0.875 (0.87-0.89)	0.972 (0.962-0.986)	1.059 (1.02-1.071)
	TMin (Lag2)	0.995 (0.991-0.999)	1.136 (1.11-1.15)	0.961 (0.94-0.98)	1.042 (1.03-1.06)	0.948 (0.942-0.952)	0.995 (0.96-1.01)
	TMax (Lag1)	1.021 (1.015-1.022)	0.99 (0.995-0.996)	0.884 (0.85-0.91)	1.120 (1.09-1.15)	1.048 (1.02-1.06)	1.084 (1.04-1.10)
	TMax (Lag2)	1.036 (1.025-1.042)	0.904 (0.89-0.91)	0.959 (0.94-0.96)	0.987 (0.96-1.001)	1.043 (1.02-1.05)	1.033 (1.02-1.07)
Year	2007	1.000	1.000	1.000	1.000	1.000	1.000
	2008	1.138 (1.12-1.15)	1.350 (1.32-1.37)	1.007 (1.004-1.10)	2.045 (2.02-2.06)	1.62 (1.30-1.89)	2.984 (2.84-3.14)
	2009	1.268 (1.22-1.28)	1.639 (1.59-1.67)	0.614 (0.59-0.63)	2.409 (2.20-2.71)	1.57 (1.39-1.78)	1.963 (1.81-2.12)
	2010	1.641 (1.57-1.72)	1.979 (1.97-1.99)	0.817 (0.80-0.82)	2.72 (2.41-2.92)	1.874 (1.84-1.95)	2.343 (2.23-2.44)
	2011	1.060 (1.03-1.08)	1.234 (1.20-1.26)	0.479 (0.43-0.51)	2.21 (2.20—2.23)	0.968 (0.94-0.98)	1.01 (1.004-1.012)
	2012	1.324 (1.28-1.36)	0.713 (0.66-0.75)	0.314 (0.28-0.33)	2.98 (2.87-3.12)	1.058 (1.02-1.07)	0.892 (0.74-0.96)
	2013	2.025 (2.02-2.03)	0.825 (0.80-0.84)	0.301 (0.28-0.32)	4.083 (4.03-4.11)	1.487 (1.34-1.56)	1.742 (1.66-1.89)
	2014	2.271 (2.24-2.29)	1.056 (1.03-1.07)	0.628 (0.60-0.64)	3.538 (3.31-3.76)	1.947 (1.82-2.01)	2.904 (2.80-2.98)

Table 6 shows regression estimates for Lilongwe and Salima districts. Results show that the incidence of diarrhoea has been increasing in both Lilongwe and Salima. Diarrhoea was negatively associated with rainfall in Lilongwe, but was positively related to rainfall in Salima. A one degree change in maximum temperature at lag of 1 was associated with a 2% increase in diarrhoea in Lilongwe and 12% increase in Salima. Similarly rainfall was negatively associated with malaria and malnutrition in Lilongwe. A unit increased change in rainfall was associated with about 1% reduction in malaria or malnutrition in Lilongwe. Current rainfall levels were associated with increased malnutrition in Salima, with a 0.1% increase for a 1 unit increase in rainfall. Minimum temperature at lag of 1 month was likely to increase malaria and malnutrition risk by 5% in Lilongwe, and 13% at lag 2 for malaria only in Lilongwe. The same margin of association of 5% was observed between minimum temperature and malnutrition in Salima. Maximum temperature at lag 1 was also associated with a 4.8% and 8.4% increase in malaria and malnutrition respectively.

5.1.5 Information on Flood and Drought Disasters

The findings from this study show that notable flood events that Malawi has experienced so far include the Zomba and Phalombe flash floods of 1946 and 1991, respectively. The Zomba flash floods were caused by high intensity rainfall resulting from the joint effect of the ITCZ and the Zomba Cyclone when 711 mm of rainfall fell in 36 hours (Water Department/UNDP, 1986), leaving in its wake severe loss of life and serious damage to property. During the Phalombe flash floods of 1991, 417 mm rainfall fell within a period of three days resulting in the failure of Michesi Hill, causing severe loss of life and extensive damage to property. Severe floods affected 15 out of 28 districts in 2015, casing 176 fatalities and displacing 230,000 people. Of the four selected districts, Chikwawa, Zomba and Salima Districts are most vulnerable to floods.

The study also revealed that Malawi has experienced severe droughts in the past and notable among these occurred in 1948/49 and 1991/92 seasons. Nearly all the droughts that have taken place in the country have been associated with the El Nino and Southern Oscillation (ENSO) phenomena. Recent studies about the ENSO warm phase episode in southern Africa show the existence of two drought cells both of which affect Malawi, mainly the southern part of the country (Eastman *et al*., 1996). The first drought cell shows a path originating from Namibia but covering Botswana, Zimbabwe, southern Zambia, northwest Mozambique and the southern part of Malawi. The second drought cell has its center located near southern Mozambique and southern Zambia and appears to expand outwards. This drought cell too affects Malawi, particularly the southern part of the country. There are no signs at the moment to suggest the abetment of these drought cells and a lull from impacting negatively on the socio-economic development of the country as evidenced by climate change studies done in Malawi (Chavula & Chirwa, 1996). Chikwawa is the most vulnerable districts to drought hazards out of the four study areas.

5.2 5.2 Baseline on the Capacity to Address Climate Change and Health issues

Findings obtained from literature review and s consultations with five DHOs showed that malaria, diarrhoea and malnutrition are the common diseases that are related to climate change and weather variability. Other diseases which were also mentioned included respiratory diseases like asthma, skin infections, sleeping sickness, eye infection, and cholera.

In terms of capacity to manage the above diseases and conditions, the findings indicate that there are existing strategies that at being implemented. These included Case Management, Community sensitization in hygiene practices (CLTS) and health issues, management of malnutrition, LLINs and indoor residual spraying for malaria prevention, infrastructure, and surveillance system.

The study also identified some gaps in health sector capacity which include: inadequate knowledge on the impact of climate change on health due to lack of formal training; very few professionals are conversant with climate change science, vulnerability assessments, and adaptation to climate change, link between health events and climate data. weak coordination among programmes within the health and other related sectors, weak governance structures such as epidemic management committees, village health committees and facility committees, and lack of integration of climate change issues in existing health policies, guidelines, strategies and plans. The results also showed that the community does not have adequate knowledge on climate change and health. Very few professionals are conversant with climate change science, vulnerability assessments, and adaptation to climate change, link between health events and climate data.

5.3 Future impacts of Climate change on Health

This section presents findings on projected impacts of climate change on health. The findings cover the following aspects: climate change projections, trends and seasonality of disease incidence, relationship between disease and climatic variable, and vulnerability assessment. In order to predict future impacts of climate change on health, GCMs were used based on McSweeney *et al*., 2008

5.3.1 Climate Change Projections

Recent climate trends in Malawi show a temperature increase of $0.9^{o}C$ between 1960 and 2006, an average rate of $0.21^{o}C$ per decade. The increase in temperature has been most rapid in December-January-February (DJF) and slowest in September-October-November (SON). Daily temperature observations show an increase in the frequency of hot days and nights in all seasons. The frequency of cold days and nights has significantly decreased in all seasons except in SON. Observed rainfall over the country does not show statistically significant trends. Also, there are no statistically significant trends in the extremes indices calculated using daily precipitation observations (McSweeney *et al*., 2008).

Based on energy situation in Malawi, the A1B scenario was selected for the generation of climate change predictions (IPCC AR4, 2007). The future climatic changes in temperature and rainfall are presented in Figures 7 and 8 respectively, for the year 2030 and 2050.

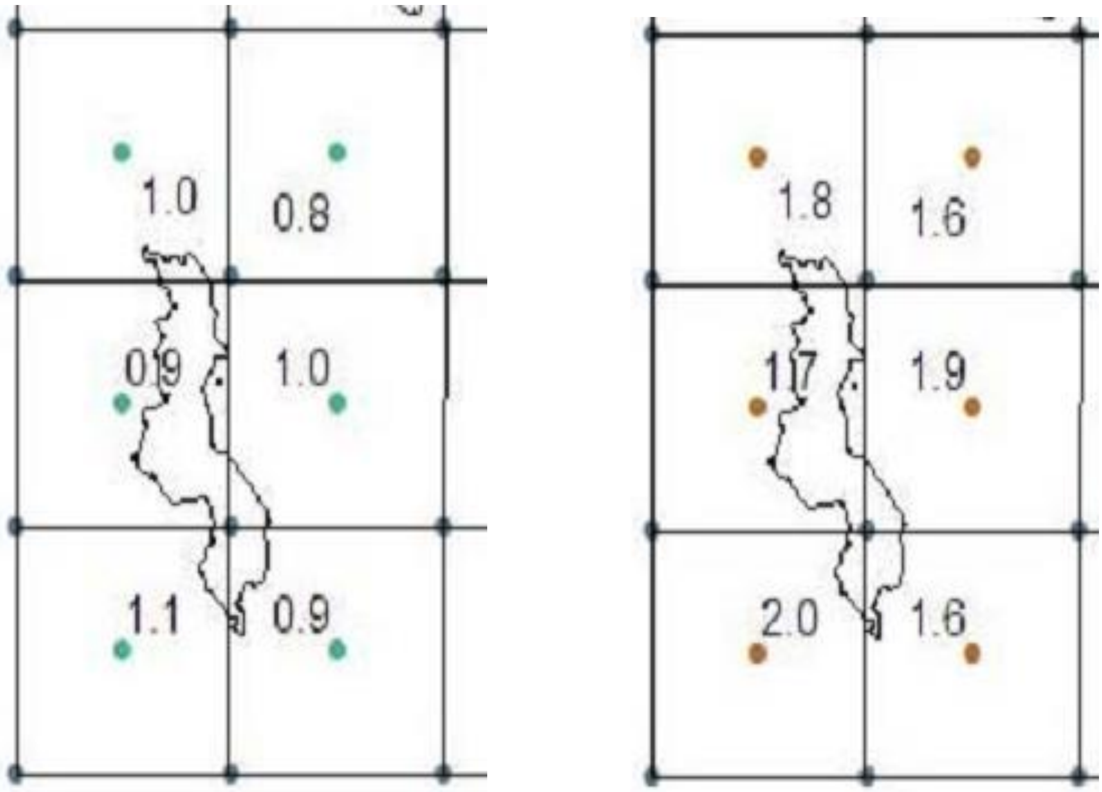
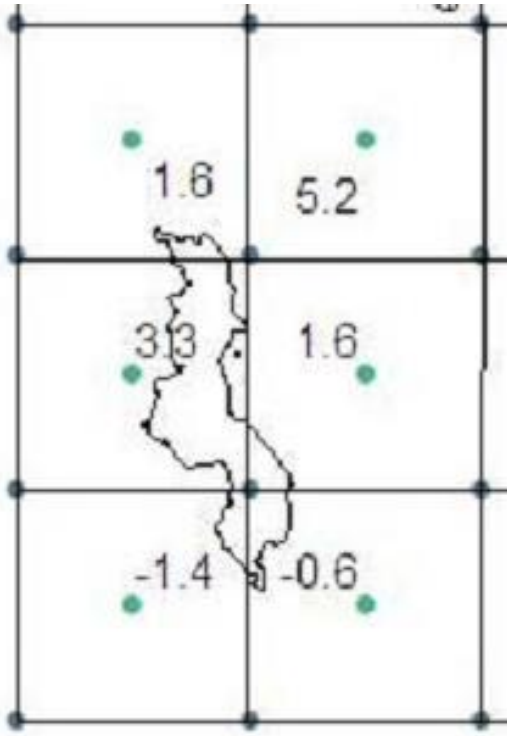


Figure 12: Composite change in mean annual temperature by 2030 (left panel) and 2050 (right panel) in Malawi, using six GCMs (CSM_98, ECH395, ECH498, GFDL90, HAD295, and HAD300). Source: IGAD and ICPAC, 2007.



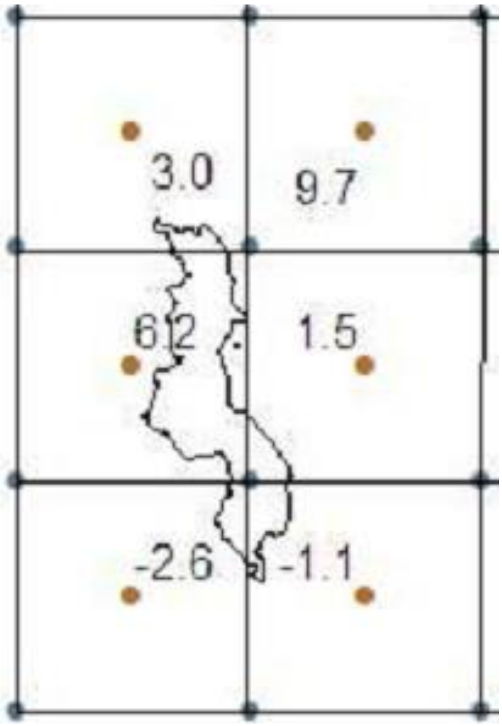


Figure 13: Composite change in mean Annual precipitation by 2030 (left panel) and 2050 (right panel) in Malawi using six GCMs (CSM_98, ECH395, ECH498, GFDL90, HAD295, and HAD300). Source: IGAD and ICPAC, 2007.

Table 4: Composite projected change in mean annual temperature and rainfall by 2030 and 2050 in four study district.

Climatic variable	District	Expected Change in Year 2030	Expected Change in Year 2050
Temperature	Chikwawa	1.1	2.0
	Zomba	0.9	1.6
	Lilongwe	0.9	1.7
	Salima	0.9	1.7
Rain	Chikwawa	-1.4	-2.6
	Zomba	-0.4	-1.1
	Lilongwe	3.3	6.2
	Salima	3.3	6.2

Source: IGAD and ICPAC, 2007.

In summary, mean annual temperatures are expected to rise by 0.9 to 1.1 degree in 2030, and a further 1.6 to 2.0 degrees in 2050 (Table 4). Mean annual precipitation is projected to change by -1.4% to 3.3% in 2030, while in 2050 this will change by -2.2% to 6.2%. The respective expected changes in Lilongwe, Salima, Zomba and Chikwawa are presented in Table 7.

Table 4: Disease incidence change in 2030 and 2050 based on projected climatic change

District		Diarrhoea		Malaria		Malnutrition	
		Year 2030	Year 2050	Year 2030	Year 2050	Year 2030	Year 2050
Salima	Rain	0.12	0.22	0.01	0.02	0.41	0.76
	Tmin	-9.71	-17.54	-4.20	-7.79	6.65	12.92
	Tmax	9.66	19.21	6.68	12.98	8.95	17.58
	Overall	-0.88	-1.67	2.14	4.02	14.34	25.45
Lilongwe	Rain	-0. 09	-0.17	-0.31	-0.58	-0.49	-0.92
	Tmin	1.29	2.46	6.69	13.02	4.85	9.36
	Tmax	2.21	4.20	-2.46	-4.53	-9.14	-16.57
	Overall	3.32	6.16	3.63	6.73	-5.47	-10.53
Zomba	Rain	-0.02	-0.04	0.01	0.003	-0.04	-0.12
	Tmin	-0.65	-1.14	-6.19	-10.74	-2.33	-4.09
	Tmax	4.04	7.29	2.91	5.24	0.97	1.74
	Overall	3.24	5.68	-3.58	-6.45	-1.44	-2.61
Chikwawa	Rain	-0.08	-0.16	-0.11	-0.18	0.03	0.06
	Tmin	0.41	0.75	-3.34	-5.96	3.50	6.46
	Tmax	0.03	6.24	-1.18	-2.14	-4.85	-8.65
	Overall	3.59	6.41	-4.76	-8.81	-1.51	-2.76

A summary of changes in disease incidence induced by each climatic variable and the overall change for all climatic variables are presented in Table 6.

Figures 13 to 16 show the percentage change in disease incidence for each district under climate change scenario.

Figure 13 shows the projected change in incidence of diarrhoea, malaria and malnutrition for Salima district. The highest increase is estimated in malnutrition, projected at 14.3% in the year 2030 and 25.4% in 2050. Diarrhoea was estimated to decrease by 0.9% and 1.7% in 2030 and 2050 respectively.

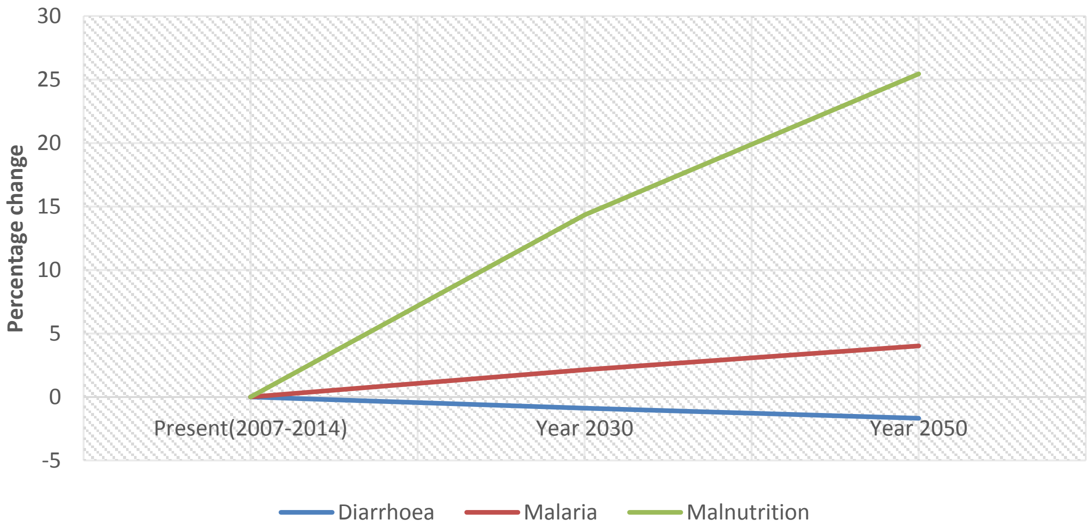


Figure 14:Projected change in incidence of diarrhoea, malaria and malnutrition in Salima district.

In Lilongwe, both diarrhoea and malaria incidences are expected to increase (Figure 14). In 2030 and 2050, diarrhoea incidence are expected to increase by 3.32% and 6.16% respectively while malaria in the same periods will increase by 3.36% and 6.73% respectively. On the other hand, malnutrition will decrease by about 5% in 2030 and by 6% in 2050.

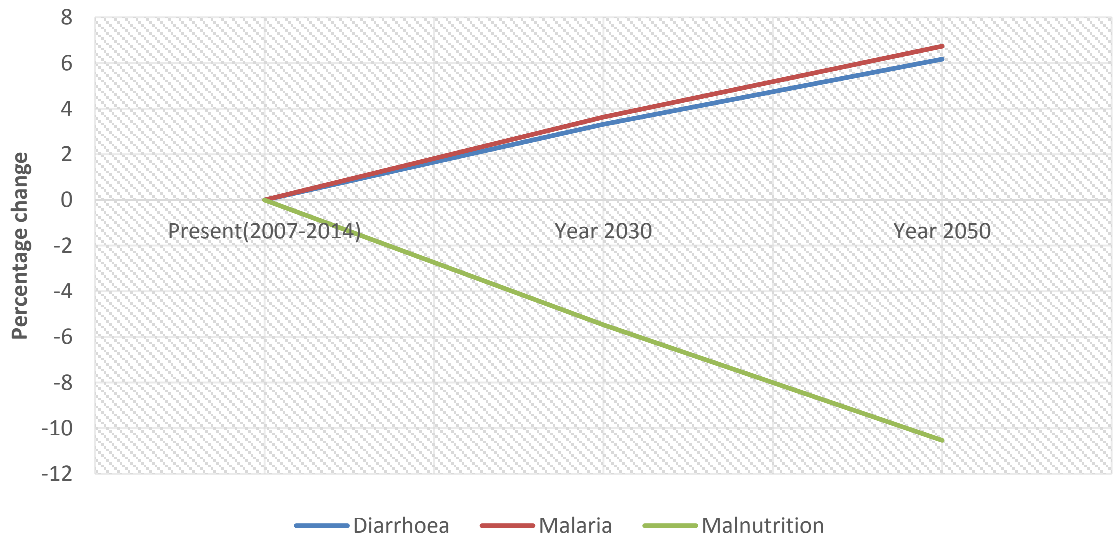


Figure 15: Projected changes in incidence of diarrhoea, malaria and malnutrition in Lilongwe district

Figure 15 shows the anticipated changes in incidence of malaria, diarrhoea and malnutrition in Zomba. By 2030 and 2050 diarrhoea incidence is estimated to increase 3.2 % and 5.7%respectively compared to the present period (2007-2014). Future malaria incidence will decrease by about 4%, in 2030, and 6.5% in 2050, whereas malnutrition will decline by 1.4% and 2.6% in the two future projected periods.

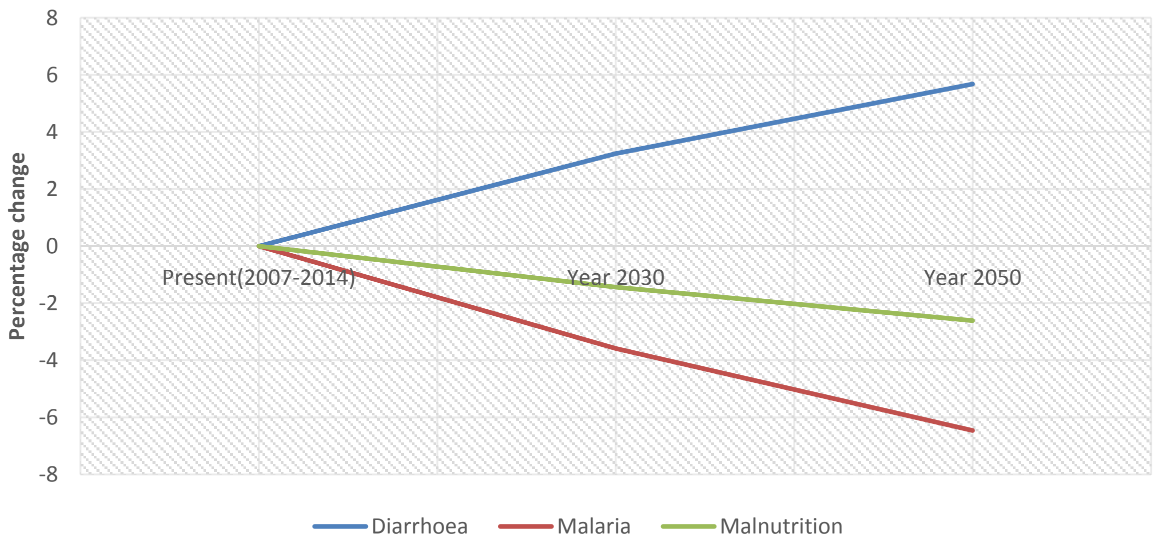


Figure 16: Projected change in incidence of diarrhoea, malaria and malnutrition in Zomba districts

A similar pattern of projected change in disease incidence for Chikwawa is depicted in Figure 16. Diarrhoea incidence will increase by 3.6% in 2030 and 6.4% in 2050. At the same time, malaria incidence will decrease by 4.8% and 8.8% in 2030 and 2050 respectively, while malnutrition will decrease by 1.5% and 2.8% for both 2030 and 2050 respectively.

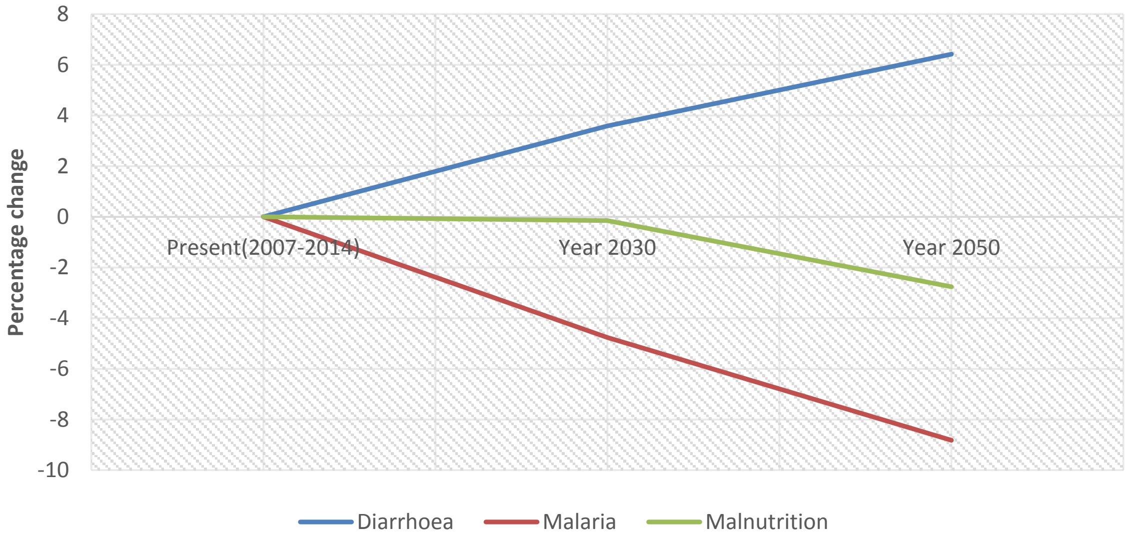


Figure 17: Projected change in incidence of diarrhoea, malaria and malnutrition in Chikwawa district

5.4 Indicators for Tracking Climate Change Impacts on Human Health

Based on the results of the baseline assessment, the following indicators are proposed for monitoring and tracking climate change impacts on health:

- Proportion of malaria cases
- Proportion of diarrhoeal cases
- Proportion of malnutrition cases
- Rainfall (mm)
- Maximum and minimum temperatures
- Humidity

These indicators will be captured by Ministry of Health and Department of Climate Change and Meteorological Services through HMIS and CLIMSOFT respectively.

5.5 Opportunities for Bridging Gaps in Information and Capacity

Based on the identified gaps in the baseline assessment, the study revealed the following opportunities:

The existence of Health Management information System (HMIS) in the Ministry of Health which captures climate sensitive diseases, CLIMSOFT information system in the Department of Climate Change and Meteorological Services which captures weather data, disease surveillance system and availability of weather stations in various districts including the pilot districts that can be used to improve data management and use in motoring impact of climate change on health. There is also the availability of governance structures such as the health committees and civil protection committee at various levels that can be utilized to advance issues of climate change and health.

There are other Institutions and Non-Governmental Organizations (NGOs) working on climate change issues such as Department of Climate Change and Meteorological Services, Department of Environmental Affairs, training institutions, Malawi Red cross Society and World Food Programme. Frontline staff such as HSAs, weathermen and CDAs are also existing that could be trained and used to advance issues of climate change and health, in addition, policies on climate change in other sectors such as environment, disaster risk reduction and agricultures are available and there is also the existence of indigenous knowledge and funding mechanisms for climate change that can be used to fill in the gaps in information and capacity.

5.6 Research Needs

A number of research areas were identified through and these include:

a) Utilization of weather and climate information in predicting health events and strategic planning in Malawi
b) Use of indigenous knowledge and practices in health adaptation to the impact of weather variability and climate change on health.
c) Underlying factors influencing the temporal and spatial occurrence of malaria, diarrhoea and malnutrition.
d) Comprehensive Health sector baseline on Health and Climate Change.

6 DISCUSSION

Overall, there is a positive correlation between the climatic variables (temperature and rainfall) and the incidences of malaria, diarrhoea and malnutrition although the association is weak between climatic variables and malnutrition.

Amongst the three diseases, malaria and diarrhoea show seasonal variations especially in the months of November to March. These are the months when temperatures and rainfall are high. The seasonal variation in disease incidence was more pronounced in Chikwawa, Lilongwe and Zomba.

In general, there was a strong correlation between disease and climatic variables at lags of 1 and 2. For maximum temperature, the lag went as far as 4 months. However, there was lack of plausible epidemiological relationship to extend the models to include lags at month 4.

Since 2007, Chikwawa district has been vulnerable to malaria, diarrhoea and malnutrition due the effect of rainfall and temperature variability. Similarly, in Zomba the same situation occurred but the effects of rainfall and temperatures on disease incidences was small. In Lilongwe the incidence of diarrhoea has been increasing though not associated with rainfall variations. Similarly, rainfall was negatively associated with malaria and malnutrition in the same district. Salima district has been experiencing diarrhoea, malaria and malnutrition which have been positively related to rainfall and temperature variations.

Among the four study districts, Chikwawa, Zomba and Salima are more vulnerable to floods. However, Chikwawa district is also more prone to drought.

The analysis has shown that there are existing adaptation strategies within the health sector for the three climate sensitive diseases (malaria, diarrhoea and malnutrition) which are being implemented as part of the routine health care delivery system. However, there are some capacity gaps that have been noted namely inadequate knowledge on the impact of climate change on health; very few professionals are conversant with climate change science, weak coordination among programmes within the health and other related sectors, weak governance structures and lack of integration of climate change issues in existing health policies, guidelines, strategies and plans and inadequate knowledge among community members on the relationship between health and climate change.

Projected climate change scenarios generated by general circulation models, the mean annual temperatures are expected to rise from 0.9 to 1.1 degrees by2030 and further 1.6 to 2.0 degrees by 2050. Mean annual precipitation is projected to change from -1.4% to 3.3% by 2030 while by 2050 this will change from -2.2% to 6.2%. The respective expected changes are based on the data from the four study districts (Chikwawa, Lilongwe, Salima and Zomba). These rising temperatures and precipitation are likely to exacerbate the effects of climate change on these diseases.

The indicators above will be used for monitoring the relationship between climate change and health and these will be captured by the health management information system in the Ministry of Health and CLIMSOFT system in the Department of Climate Change and Meteorological Services.

The opportunities identified above will be the platform for fostering collaboration and coordination during the implementation of the health adaptation to climate change programme.

The research areas identified in this study will be used to generate more evidence to strengthen the implementation of the climate and health programme. Additionally, during the implementation of the programme more research areas will be identified that will further improve the health sector understanding of the relationship between climate change and health.

7 CONCLUSION AND RECOMMENDATIONS

7.1 Conclusion

In summary, there is a positive correlation between the climatic variables (temperature and rainfall) and the incidences of malaria, diarrhoea and malnutrition although the association is weak between climatic variables and malnutrition.

Additionally, the mean annual temperatures are expected to rise by 0.2 degrees by2030 and further 0.4 degrees by 2050. Mean annual precipitation is projected to rise to 4.7% by 2030 and further rise by 8.4% by 2050. Hence these changes in climatic variables are likely to exacerbate disease trends by 2030 and 2050.

Generally there is inadequate capacity in dealing with issues on climate change and health. Notable deficiencies include inadequate knowledge among health workers and community, infrastructure and equipment, weak coordination and lack of integration of climate change issues in health policies.

7.2 Recommendations

The following are the recommendations that have been developed in respect of key national strategies and sectoral programming for the Ministry of Health:

1. Establish a surveillance system that will integrate health and climate change information for early warning and emergency preparedness and planning.
2. The health sector should strengthen adaptation and mitigation measures for malaria, diarrhoea and malnutrition based on seasonal variations of climatic variables and disease incidences.
3. The health sector in collaboration with relevant sectors should develop resilient health programmes, mitigation and adaptation measures to deal with the effects of floods and drought.
4. Introduce formal pre-service training in climate change in health training institutions
5. Introduce formal in-service training programme in climate change for health workers.
6. Strengthen and promote multi-sectoral collaboration on health and climate change.
7. Mainstream climate change issues in health policies, guidelines, strategies and plans.
8. Create public awareness on the relationship between climate change and health.
9. Strengthen governance structures for the management of climate change risks and effects on health.
10. Develop a platform for monitoring Health and Climate trends.
11. Promote research on health and climate change in order to generate new knowledge and innovative approaches.

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