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CLIMATE RISK MANAGEMENT FOR MALARIA CONTROL IN KENYA: THE CASE OF THE WESTERN HIGHLANDS

Prepared by the International Institute for Sustainable Development (IISD)

January 2013

United Nations Development Programme

CRISIS PREVENTION AND RECOVERY

This report was commissioned by the United Nations Development Programme's Bureau for Crisis Prevention and Recovery (BCPR), under the Climate Risk Management Technical Assistance Support Project (CRM TASP). The International Institute for Sustainable Development (IISD) implemented the CRM TASP in seven countries (Dominican Republic, Honduras, Kenya, Nicaragua, Niger, Peru and Uganda).

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Cite as: United Nations Development Programme (UNDP), Bureau for Crisis Prevention and Recovery (BCPR). 2012. *Climate Risk Management for Malaria Control in Kenya: The Case of the Western Highlands.* New York, NY: UNDP BCPR.

Published by

United Nations Development Programme (UNDP), Bureau for Crisis Prevention and Recovery (BCPR), One UN Plaza, New York–10017

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FOREWORD

Climate change has the potential to exacerbate conflict, cause humanitarian crises, displace people, destroy livelihoods and set-back development and the fight against poverty for millions of people across the globe.

For example it is estimated that over 20 million people in the Mekong Delta and 20 million in Bangladesh could be forced to move as their homes are affected by salt water incursion from rising sea levels. Entire populations of some low lying island states, such as Nauru or the Maldives may have to be relocated. In countries like Honduras, where more than half the population relies on agriculture, climate induced risks, such as Hurricane Mitch in 1998, which caused over US$ 2 billion in agricultural losses, will continue to pose a staggering potential for damage. Similarly, climate risk assessments in Nicaragua show that changes in rainfall patterns, floods and drought could put human health at risk by increasing the prevalence of respiratory and water borne diseases and malnutrition.

Long-term incremental changes will mean that people everywhere must learn to adapt to weather or rainfall patterns changing or shifts in ecosystems that humans depend upon for food. Perhaps more worrying however, is that climate variability and change will also bring unpredictable weather patterns that will in-turn result in more extreme weather events. Heat waves, droughts, floods, and violent storms could be much more common in the decades to come. Climate change is "loading the dice" and making extreme weather events more likely. These disasters will undermine the sustainability of development and render some practices, such as certain types of agriculture, unsustainable; some places uninhabitable; and some lives unliveable.

As climate change creates new risks, better analysis is needed to understand a new level of uncertainty. In order to plan for disasters, we need to understand how climate change will impact on economies, livelihoods and development. We need to understand how likely changes in temperature, precipitation, as well as the frequency and magnitude of future extreme weather will affect any sector, including agriculture, water-use, human and animal health and the biodiversity of wetlands.

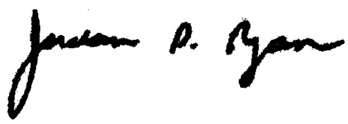
This report is a product of the Climate Risk Management – Technical Assistance Support Project, which is supported by UNDP's Bureau for Crisis Prevention and Recovery and Bureau for Development Policy. This is one in a series of reports that examines high-risk countries and focusses on a specific socio-economic sector in each country. The series illustrates how people in different communities and across a range of socio-economic sectors may have to make adaptations to the way they generate income and cultivate livelihoods in the face of a changing climate. These reports present an evidence base for understanding how climatic risks are likely to unfold. They will help governments, development agencies and even the communities themselves to identify underlying risks, including inappropriately designed policies and plans and crucial capacity gaps.

This series is part of a growing body of climate change adaptation resources being developed by UNDP. The Climate Risk Management – Technical Assistance Support Project has formulated a range of climate risk management assessments and strategies that bring together disaster risk reduction and climate change adaptation practices. The project is designing a common framework to assist countries in developing the necessary capacity to manage climate-induced risks to respond to this emerging threat. The climate risk assessments discussed in this report and others in the series will feed into a set of country-level projects and regional initiatives that will inform the practice of climate risk management for decades to come.

Addressing climate change is one of UNDP's strategic priorities. There is a strong demand for more information. People at all levels, including small communities want to understand the potential impact of climate change and learn how they can develop strategies to reduce their own vulnerability. UNDP is addressing this demand and enabling communities and nations to devise informed risk management solutions. UNDP recognises that climate change is a crucial challenge to sustainable development and the goal of building resilient nations.

As the full effect of climate change becomes apparent, it is assessments such as these that will become the lynchpin of national responses and adaptation strategies for many years to come. Like the threat from many disasters, there is still time to prepare for the worst impacts of climate change in developing countries if we expand our understanding now.

This knowledge must be combined with real preparedness and action at all levels. Only then will we be able to stave off the worst impacts of climate change in the most vulnerable and high risk countries of our world.



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ACKNOWLEDGEMENTS

This report, 'Climate Risk Management for Malaria Control in Kenya: The Case of the Western Highlands' was commissioned under the Climate Risk Management Technical Assistance Support Project (CRM TASP), a joint initiative by the Bureau for Crisis Prevention and Recovery (BCPR) and the Bureau for Development Policy (BDP), UNDP, implemented by the International Institute for Sustainable Development (IISD).

The general methodology and analytical framework of the CRM TASP was conceptualized by Maxx Dilley, disaster partnerships advisor, and Alain Lambert, senior policy advisor, with key inputs from Kamal Kishore, programme advisor, Disaster Risk Reduction and Recovery Team, BCPR, in consultation with Bo Lim, senior climate change advisor, Environment and Energy Group, BDP. Within BCPR, the project implementation process has been supervised by Alain Lambert, Rajeev Issar and Ioana Creitaru, who provided regular inputs to ensure in-depth climate risk assessments and identification of tangible risk reduction and adaptation options. From BDP, Mihoko Kumamoto and Jennifer Baumwoll provided their input, comments and oversight to refine the assessment and recommendations. The overall project implementation has benefitted immensely from the strategic guidance provided by Jo Scheuer, coordinator, Disaster Risk Reduction and Recovery Team, BCPR, and Veerle Vandeweerd, director, Environment and Energy Group, BDP.

The climate risk assessments under the CRM TASP have been undertaken with the funding support of the Government of Sweden.

Building upon the CRM TASP general framework to tailor the process to country-level analysis, IISD developed a more detailed methodological framework for assessing climate risks and identifying climate risk management options in seven countries, including Kenya. Within IISD, Anne Hammill supervised the overall project implementation. Julie Dekens supervised all in-country activities in Kenya and is the lead author of the present report, with support from Jo-Ellen Parry, Alicia Natalia Zamudio-Trigo and Daniella Echeverria of IISD.

For their valuable contributions to the project implementation and climate risk assessment process, the project team and lead authors would like to gratefully acknowledge the unstinted support provided by the Kenya Red Cross Society, especially Kioko Kiilu, David Otieno, Sylvia Khamati, Muli Elijah, Emmanuel Wamalwa and James Kisia; David Gikungu from the Kenya Meteorological Department; colleagues from the UNDP Country Office, especially Chris Gakahu and David N. Githaiga; the Ministry of Public Health and Sanitation, especially Ibrahim P. Longolomoi and Gamaliel Omondi; the Ministry of Environment and Mineral Resources; Harun Maina Warui and Martha Lahai from the Africa Adaptation Programme – Kenya; Solomon M. Nzioka and Wilfred Ndegwa of the World Health Organization (WHO) – Kenya; the national and regional stakeholders who participated in the interactions; the communities and district officials of Kericho, Kisii, Nandi and Trans-Nzoia, and all participants of the local and national workshops. Special thanks are also due to Andrew K. Githeko from the Kenya Medical Research Institute and to Augustine Ngindu, for useful comments and feedback on drafts of this report.

LIST OF ABBREVIATIONS AND ACRONYMS

ASALs	arid and semi-arid lands
BCPR	Bureau for Crisis Prevention and Recovery
CIA	Central Intelligence Agency
CRED	Centre for Research on the Epidemiology of Disasters
CRiSTAL	Community-Based Risk Screening Tool – Adaptation and Livelihoods
CRM	climate risk management
CRM TASP	Climate Risk Management Technical Support Assistance Project
CVCA	Climate Vulnerability and Capacity Analysis
DOMC	Department of Malaria Control
GDP	Gross Domestic Product
GOK	Government of Kenya
ICPAC	IGAD Climate Protection and Analysis Centre
IISD	International Institute for Sustainable Development
IPCC	Intergovernmental Panel on Climate Change
KMD	Kenya Meteorological Department
KNPDRR	Kenya National Platform on Disaster Risk Reduction
KNBS	Kenya National Bureau of Statistics
MDGs	Millennium Development Goals
MEMR	Ministry of Environment and Mineral Resources
MENR	Ministry of Environment and Natural Resources
MMS	Ministry of Medical Services
MOPHS	Ministry of Public Health and Sanitation
MOSSP	Ministry of State for Special Programmes
MOTW	Ministry of Tourism and Wildlife
MSPNDV	Ministry of State for Planning, National Development and Vision
NCCRS	National Climate Change Response Strategy
NDOC	National Disaster Operation Centre
NEMA	National Environment Management Authority
NGO	non-governmental organization
NHSSP	National Health Sector Strategic Plan
RoK	Republic of Kenya
SEI	Stockholm Environment Institute
UNDP	United Nations Development Programme
USDS	United States Department of State
WHO	World Health Organization
WRI	World Resources Institute
WWAP	World Water Assessment Programme

EXECUTIVE SUMMARY

Kenya experiences a number of development challenges, such as environmental degradation, high poverty (particularly in rural areas), economic inequality, and limited access to critical services like water and health care. Malaria continues to be the number-one cause of disease and mortality. Although prevalence is low in most parts of the country, the disease is re-emerging in the western highlands due to a combination of climate and non-climate factors. The combination of unusually high temperatures, rainfall and humidity encourages malaria epidemics. Kenya is highly prone to climate hazards, in particular droughts and localized floods, which have considerable effects on the economy (up to 2 percent of GDP per year), but uncertainty remains regarding changes in frequency and severity of extreme climate events. Higher temperatures are expected in the future, with some regional differences. But greater uncertainties are associated with future rainfall projections. This study was conducted to assess climate risks on malaria control in the western Kenyan highlands and to identify climate risk management options.

Data collection and analysis were based on detailed literature reviews; field surveys in four counties (Kericho, Kisii, Nandi and Trans-Nzoia), including 12 focus groups with community members and district health management teams; 14 key informant interviews at the district level; a climate analysis of the four counties based on historical rainfall and temperature data; and national stakeholder consultations.

Our results highlight that the vulnerability of the population of the Western Kenyan highlands to malaria epidemics in the context of climate risks is very high due to increasing but differentiated exposure to malaria risk, high sensitivity to malaria risk, and relatively low adaptive capacity, especially at district and community levels. Without any intervention, rising temperatures and changes in rainfall patterns may intensify existing health risks and create new ones. These risks may be exacerbated by other socio-economic trends such as population growth, poverty and environmental degradation. However, temperature increases may not automatically result in increased malaria transmission and diffusion, because temperature interacts with many other factors (such as environmental, socio-economic, cultural and political factors). In addition, Kenya has made recent positive strides towards establishing an enabling institutional and policy environment for reducing risks from disasters and for addressing climate change, as well as for malaria control.

Based on these results, key stakeholders at national and local levels identified five priority actions to ensure malaria control in the context of climate variability and change:

- Strengthening the health system, especially ensuring equitable access to health care services and providing adequate funding.
- Improving malaria epidemic prediction through intensive monitoring and routine surveillance of climate and non-climate risk indicators, development of malaria early-warning systems that combine local knowledge of weather change with scientific knowledge, and improving data flow across all levels.
- Developing targeted, innovative interventions adapted to local needs and contexts to account for the heterogeneous nature of malaria transmission. A specific focus should be on improving understanding of the socio-cultural barriers to malaria control.
- Improving communication and increasing awareness on climate and health risks, especially in communities.
- Strengthening cross-sectoral collaboration among actors engaged in malaria control, disaster risk reduction and adaptation to climate change. Continuous progress, especially in terms of coordinating actions and securing resources (human and financial), is required to ensure effective implementation of key strategic documents.

Further research is also needed regarding the factors (climatic or non-climatic) responsible for malaria transmission in the selected sites, the livelihood activities in the western Kenyan highlands most likely to enhance malaria transmission, analysis of the complex drivers behind deforestation in the study area, local perceptions and responses to malaria burden in a context of climate risk, with a focus on socio-cultural factors (including gender relations), use of local knowledge of weather forecasting for developing early-warning systems for malaria epidemics, and the impacts of climate risk on malaria in urban slums.

INTRODUCTION

Climate risk management (CRM) is the systematic approach and practice of incorporating climate-related events, trends and projections into development decision-making to maximize benefits and minimize potential harm or losses. Climate change is altering the nature of climate risk, increasing uncertainty and forcing us to re-evaluate conventional CRM practices. Historical experience with climate hazards may no longer be a sound basis for evaluating risk; observable trends and longer-term, model-generated projections must also be taken into account if development is to be truly sustainable.

Recognizing this shifting reality, the United Nations Development Programme (UNDP), through its Bureau for Crisis Prevention and Recovery (BCPR) as well as the Environment and Energy Group of its Bureau for Development Policy, designed the Climate Risk Management Technical Assistance Support Project (CRM TASP) to assist countries in identifying climate-related risks and risk management priorities and capacity needs as a basis for programme development, policy and planning. The International Institute for Sustainable Development (IISD) was commissioned to implement the project in seven countries in Africa and the Latin America and Caribbean region, including Kenya, in close collaboration with UNDP Country Offices, governments and other partners.

In each country, the main outputs of the project are the prioritization of climate-related risks, a focused risk assessment for a priority sector or area, and the identification of risk management options for that sector or area. This information provides an evidence base for examining the adequacy of the institutional and policy environment for implementing risk management solutions. The present report summarizes the main results of the research conducted in Kenya, where the project stakeholders chose health as the focus sector.

APPROACH AND METHODS

Three key principles guide the implementation of the CRM TASP in each country. First, the project builds on existing climate risk information and aims to fill critical knowledge gaps. Second, the main research phase focuses on one key sector, in order to produce useful and concrete recommendations. Third, with a view to building capacity to identify, prioritize and manage climate risk, IISD works closely with in-country partners who execute important parts of the research. These principles are put into practice in each country through a generic six-step implementation process (see table 1).

TABLE 1. PROJECT STEPS AND METHODS

PROJECT STEP	PURPOSE	METHODS USED IN KENYA
1. Engagement	• Raise awareness about CRM TASP. • Secure country-level ownership and support for process.	• Inception meetings and discussions with key stakeholders.
2. Broad climate risk assessment	• Understand and synthesize existing data and information on climate risk, vulnerability and risk management options.	• Detailed literature reviews.
3. Risk prioritization I	• Identify gaps and priorities for climate risk assessment and management, which can be addressed in a focused risk assessment.	• National inception meeting with key stakeholders; human health identified as one of the focus sectors.
4. Focused climate risk assessment	• Understand the nature of climate risk for malaria in the western Kenyan highlands.	• Community consultations based on the CVCA and CRiSTAL tool, conducted by the Kenya Red Cross Society. • Climate analysis in the selected sites.
5. Risk prioritization II	• Identify and prioritize climate risk management options based on the more focused assessment.	• Stakeholder meetings. • Policy and capacity analysis.
6. Reporting and dissemination	• Elaborate and validate results. • Secure country-level ownership of results.	• National revision workshop. • Publication of final report.

In Kenya, IISD worked with the UNDP Country Office in Nairobi to integrate the CRM TASP into the Africa Adaptation Program, a climate change adaptation project with a strong climate risk management component. In a national workshop in Nairobi in October 2010, representatives of different ministries, research institutes, non-governmental organizations (NGOs) and international NGOs, and donor agencies identified agriculture, water, energy and human health as the priority sectors. IISD and UNDP, in collaboration with other partners, decided to focus the climate risk assessment on malaria in the western Kenyan highlands in order to reflect priorities identified by the Ministry of Public Health and Sanitation (MOPHS) and WHO and to build upon synergies with the Global Environment Facility project Piloting Climate Change Adaptation to Protect Human Health.

The assessment of climate risk for malaria control mainly relied on a qualitative approach combining literature review; consultations at the community, district and national levels; and climate analysis. Focused **literature reviews** were conducted on climate risks, vulnerability, malaria and climate change, and on malaria-related policies and strategies, with a specific focus on the western Kenyan highlands.

Prior to field work, IISD, with the support of the International Union for the Conservation of Nature, organized a two-day training session in Nairobi to build the team's capacity for local data collection and use of information analysis tools (CVCA and CRiSTAL). The Kenya Red Cross Society carried out **consultations** at community and district levels from August to September 2011, over eight days, in four malaria-epidemic zones in the western highlands: Kericho, Kisii, Nandi and Trans-Nzoia.[1] In each county (previously called 'districts'), the Kenya Red Cross selected two study sites.[2] The consultations in the four counties were undertaken using the Climate Vulnerability and Capacity Analysis (CVCA) framework developed by CARE (Dazé et al., 2009). Eight community focus group discussions occurred, with approximately 15 participants each. The team used tools such as hazard mapping, seasonal calendars, historical profiles and Venn diagrams to identify climate risks and health hazards and to understand how they interrelate, their impacts on the lives and livelihoods of people, and existing responses. Data analysis was carried out using the CRISTAL tool (Community-Based Risk Screening Tool—Adaptation and Livelihoods). At the district level, the Kenya Red Cross Society conducted a total of four focus group discussions with the district health management teams and 14 key informant interviews with medical superintendents, malaria coordinators, district environment officers, researchers and district meteorological officers.

Figure 1. Hazard map developed by communities during the local consultations. Photo: Kenya Red Cross Society

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[1] The new Constitution of Kenya (in 2010) divided the country into 47 semi-autonomous counties, which form the primary administrative subdivisions. The four old districts of Kisii, Trans Nzoia, Nandi and Kisii are now called counties, and they re-group smaller districts. No updated map was available at the time of this study, and most references refer to the pre-2010 administrative divisions, so we still refer in this report to the old districts unless otherwise mentioned.

[2] Selected administrative locations were Mabonde and Waitaluk in Trans-Nzoia; Kilimbwoni and Chepterit in Nandi, Ainamoi and Tendwet in Kericho, and Nyakoe and Bugusero North in Kisii.

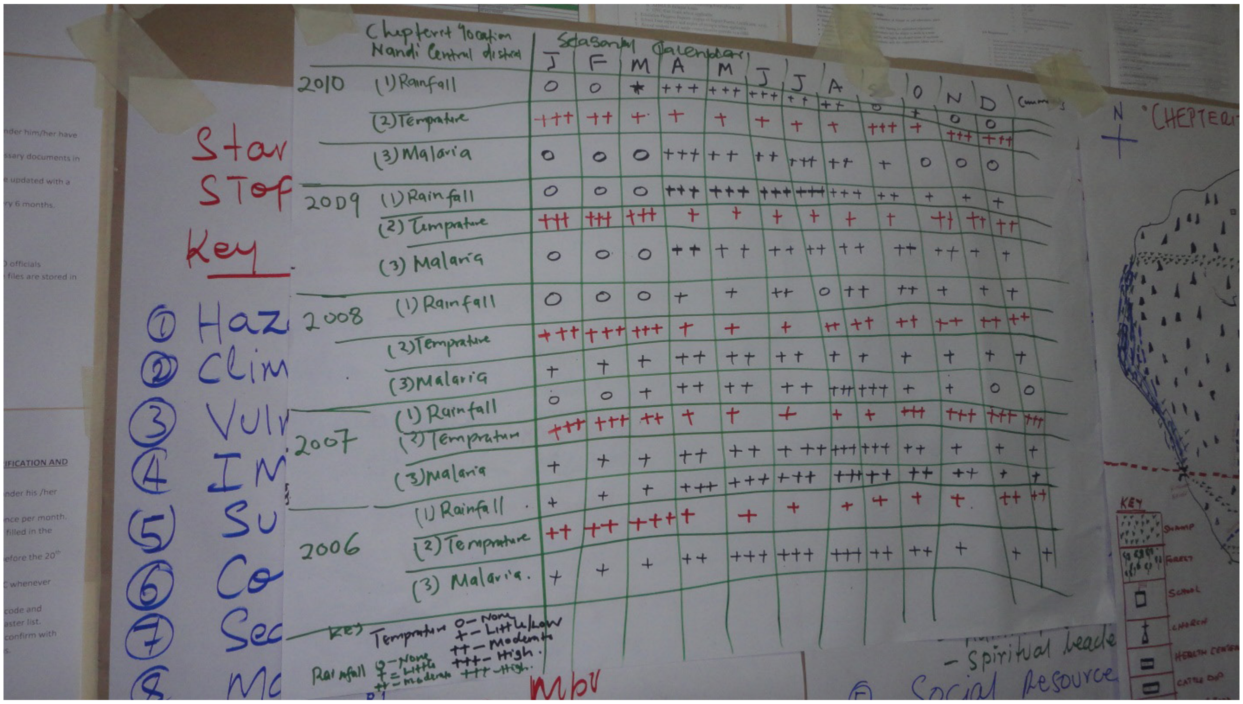

Figure 2. Seasonal calendar showing trends in rainfall, temperature and malaria prevalence between 2006 and 2010 in Chepterit, Nandi. Photo: Kenya Red Cross Society

A **climate analysis** of the selected study sites was also conducted in collaboration with the Kenya Meteorological Department (Gikungu, 2012). The analysis was based on historical rainfall and temperature data collected at the respective meteorological stations (except for Nandi, which is represented by a rainfall station within a tea estate) in each county. Microsoft Excel and Instat statistical software were used to determine rainfall patterns. Trends of projected rainfall and temperature for the next 57 years (2013 to 2069) were determined by using the Precis Regional Climate Model, which was chosen because of its regional coverage. Data generated by the model were based on real-time observations.

KEY CONCEPTS

In this report, 'climate risk' refers to the probability of harmful consequences or expected losses resulting from the interaction of climate hazards with vulnerable conditions (UNISDR, 2004). 'Climate hazard' refers to a potentially damaging hydrometeorological event or phenomenon that can be characterized by its location, intensity, frequency, duration and probability of occurrence. This report considers both events with an identifiable onset and termination, such as a storm, flood or drought, and more permanent changes, such as a trend or transition from one climatic state to another, as hazards (Lim et al., 2005).

'Exposure' is a second element of climate risk. It refers to the presence of people and assets in areas where hazards may occur (Cardona et al., 2012). Finally, 'vulnerability' refers to the potential for a system to be harmed by something, and in the CRM TASP this 'something' is a climate hazard. When assessing vulnerability, we need to recognize the hazard specificity of people's vulnerability; indeed, the factors that make people vulnerable to earthquake are not necessarily the same as those that make people vulnerable to floods (UNDP 2004). We understand vulnerability to be a function of a system's sensitivity and its adaptive capacity, as depicted in figure 3.

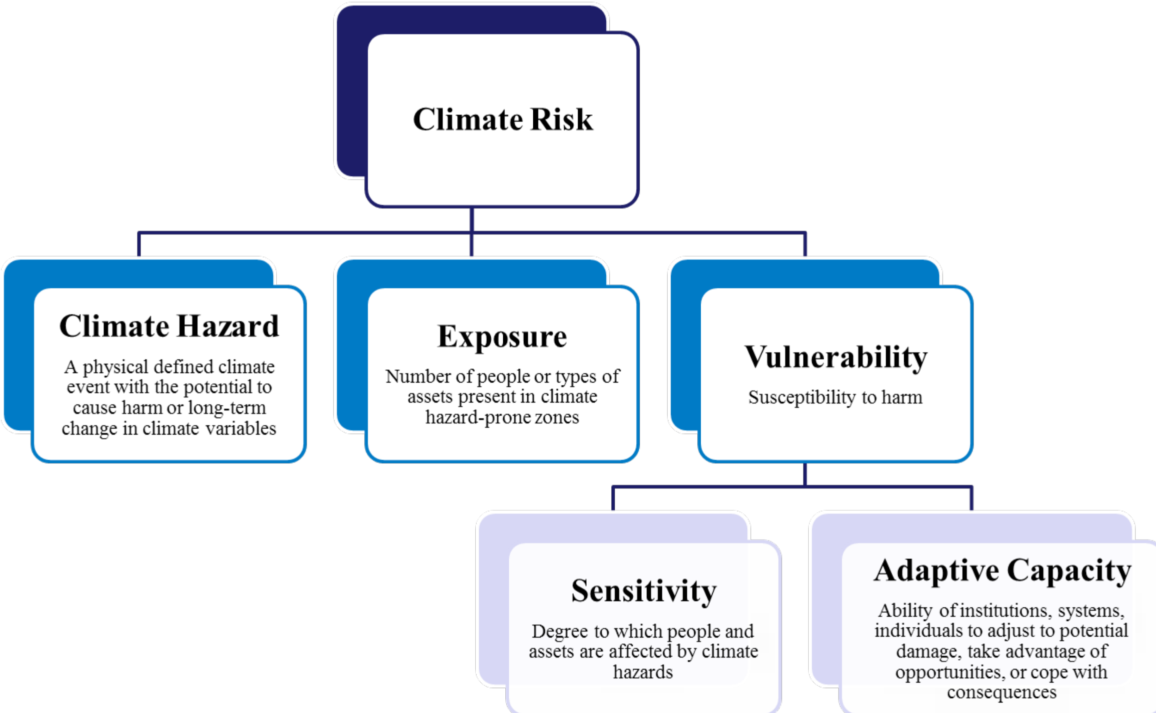

Figure 3. Components of climate risk

REPORT STRUCTURE

This report has six chapters. After this introduction, 'Development Profile' (pp. 14–20) describes current development conditions, trends and objectives, with a subsection on health, which will set the baseline against which climate risks can be assessed. 'Climate Profile' (pp. 21–25), on climate conditions, variability and change, describes mainly the hazard side of the risk equation. Next, 'Climate Impacts and Risks' (pp. 26–39) provides a detailed analysis for malaria control in the western Kenyan highlands, building on the primary research tasks described above. 'Institutions and Policies for Climate Risk Management' (pp. 40–44) looks at what currently exists at the national level to deal with climate impacts and risks. Finally, 'Recommendations for Climate Risk Management' (pp. 45–48) concludes with recommendations on actions to reduce the risk of negative impacts concerning malaria, as well as the changes to institutions and policies necessary to facilitate the implementation of such actions, and ends with directions for further research.

DEVELOPMENT PROFILE

The general development conditions of a country play an important role in determining climate risk, particularly the vulnerability of its sectors. This chapter lays the basis for the subsequent risk analysis on malaria by summarizing development conditions, trends and challenges, as well as the vision, objectives and priorities for future development. Conditions, trends and priorities of the health sector, including malaria, are given particular attention.

NATIONAL DEVELOPMENT CONDITIONS, TRENDS AND CHALLENGES

Kenya is bordered by Ethiopia to the north, Somalia to the east, Uganda to the west, northern Sudan to the northwest and Tanzania to the south. The country has access to the Indian Ocean on part of its southeast side (see figure 4).

Figure 4 .Administrative map of Kenya (reprinted from UN, 2011)[3]

[3] The boundaries and names shown on this map do not imply official endorsement or acceptance by the United Nations.

Since the country achieved independence, the number of Kenyans has grown from just over 8 million in 1963 to more than 40 million today (World Bank, 2011). This growth is projected to continue at a rate of more than one million people per year; by 2040, the population of Kenya is expected to reach 75 million (World Bank, 2011). Driven originally by an increase in the birth rate, growth is today increasingly due to a combination of greater life expectancy and greater survival rates, leading to more women in their twenties and thirties (World Bank, 2011). Although 70 percent of the population resides in rural areas today, Kenya is expected to become a predominately urban country by 2033 (World Bank, 2011). At present, many urban dwellers live in poverty: 60 percent of the population of Nairobi lives in slums (ROK, 2009).

Poverty and human development

Nearly half of all Kenyans (46.9 percent, or 17 million people) lived below the national poverty line in 2006 (GOK, 2008: 4; World Bank, 2009). Table 2 shows that the proportion of the population living in poverty has remained relatively unchanged over the past couple of decades. Average annual income per person was US$650 in 2006 (GOK, 2008: 4). National statistics disguise significant differences between regions (World Bank, 2009). The vast majority of poor Kenyans live in rural areas (World Bank, 2009). The proportion of people in poverty is highest in North Eastern Province, and lowest in Nairobi and Central Province (World Bank, 2009)—the only regions in Kenya where poverty is below 50 percent (ROK, 2009: 1). High economic and social inequality persists in Kenya (World Bank, 2009). Economic gains made since 1997, for example, have been concentrated among the wealthiest quintile of Kenyans and urban residents (World Bank, 2009), and women constitute more than half of the total number of poor people in Kenya (Wong et al., 2005: 3). Kenya ranks 117 of 138 countries in gender equality (UNDP, 2010).

TABLE 2. INDICATORS OF HUMAN DEVELOPMENT IN KENYA

		1990[A]	2000[C]	2010[D]
POPULATION	Total population (in millions)	24.0	30.7	40.9
	Annual population growth rate	3.6% (1960–1990)	3.3% (1975–2000)	2.6% (2010–2015)
	Population in urban centres	18.2%[e]	19.7%[e]	22.2%
ECONOMY	Gross National Income per capitab (in GDP per capita PPP US$)	1,058b	1,022	1,628
	Population below (Kenya's) national poverty line		42.0% (1987–2000)	46.6% (2000–2008)[1]
ACCESS	Gender inequality index		0.511	0.738 (in 2008)
	Adult literacy rate (15 years of age and above)[b]	69%[b]	82.4	86.5% (2005–2008)[1]
	Population with access to improved/safe water sources	30% (in 1988–1990)	49%	59% (in 2008)[1]
HEALTH	Life expectancy at birthb (in years)	59.7[b]	50.8	55.6
	Mortality of infants (per 1,000 live births)	68	77	81 (in 2008)[1]
	Mortality of children under 5 years (per 1,000 live births)	108	120	128 (in 2008)[1]

Sources: (a) UNDP (1992) unless otherwise indicated; (b) UNDP (1993); (c) UNDP (2002); (d) UNDP (2010) and (e) World Bank (2012). Calculations are based on population estimates from the World Bank and urban ratios from the United Nations World Urbanization Prospects (World Bank, 2012).
[1]Data refer to the most recent year available during the period specified.

Although Kenya has made progress since 2000 towards its sustainable development objectives, as reflected in the positive trend of its Human Development Index, its human development remains low (UNDP, 2010). Following the economic decline of the 1980s and 1990s, the annual growth rate of Kenya's Gross Domestic Product (GDP) rose from 0.6 percent in 2002 to 6.1 percent in 2006

(GOK, 2007a), fell to less than 2 percent in 2008 (USDS, 2011) and rebounded to 5.6 percent in 2010 (World Bank, 2011). While these rates are less than what is envisioned in the 'First Medium Term Plan' (GOK, 2008), they are higher than in all previous decades, and they put Kenya on track for achieving middle-income country status (i.e., US$1,000 GDP per capita) by 2019 (World Bank, 2011).

Kenya has made greater progress recently in education. Primary education has increased in all provinces since 2003 (World Bank, 2009), when Kenya introduced free primary education for all. This policy immediately enabled an additional 1.2 million people to enrol (Omwami and Omwami, 2009), including members of the country's poorest households (World Bank, 2009). In 2008 Kenya introduced free secondary education (Anonymous, 2008) as well as bursaries to make access more affordable (World Bank, 2009). By 2009 Kenya had attained net primary enrolment of 83 percent and net secondary enrolment of 50 percent (World Bank, 2012). The country's target is to increase the number of students transitioning from primary to secondary school to 75 percent by 2012 (GOK, 2008: ix). Despite this progress, access to education remains unequal: less than 20 percent of children, particularly girls, are enrolled in school in the northeastern districts (ROK, 2009).

Health indicators for Kenya suggest that while life expectancy at birth has increased in the past decade, no progress has been made with respect to reducing infant and child mortality; in fact, both have increased since 2000 (see table 2). The challenges Kenya faces in improving health are linked to overall poverty and limited access to clean water and preventive services (World Bank, 2009). Access to safe water has increased since 1990 across all provinces (see table 2) (World Bank, 2009). Still, most Kenyans obtain their water from open water sources, with associated health risks. During flood periods, drinking water becomes polluted, which increases the chances of outbreaks such as cholera and malaria (WRI et al., 2007). It is estimated that only half the population has access to safe water in rural areas (compared with 75 percent of the urban population) (GOK, 2008). Access is also significantly lower among the poor (World Bank, 2009).

Economy and politics

Governance in Kenya has improved since the early 1990s, beginning with the establishment of democratic, multiparty elections. Some progress has been made towards reducing the endemic corruption that has sullied Kenya's reputation. Still, further effort is needed to build a political system that responds to the needs of the people and is results-oriented and accountable (GOK, 2007a). The results of the 2007 presidential election were disputed and spurred ethnic violence in early 2008, leading to a new government structure and a new constitution in August 2010. The new constitution includes provisions for the devolution of responsibility to new county governments (World Bank, 2011). This process creates both risks and opportunities, including the potential to bring decision-making closer to the people and make governments more accountable for delivery of services (World Bank, 2011).

The national economy remains driven primarily by agriculture, tourism and the services industry, along with pastoralism, horticulture, fisheries and forest products. Agricultural production has strongly influenced Kenya's economic performance historically, and continues to do so today. For instance, Kenya's unexpectedly strong economic performance in 2010 was in part due to good rains, which enabled the agriculture sector to grow by 6.3 percent (World Bank, 2011), also demonstrating the direct influence of climate on the national economy. Many of Kenya's critical economic sectors, including agriculture, tourism and pastoralism, are climate-dependent.

Agriculture is the backbone of Kenya's economy: critical to employment, food security, livelihoods and economic development (De Wit, 2006; ROK, 2010; Wong et al., 2005). The sector directly generates about 26 percent of annual GDP, and indirectly creates another 25 percent through links to agro-based manufacturing, transport, and wholesale and retail trade (GOK, 2008; ROK, 2010; Harding and Devisscher, 2009). Further, it constitutes 65 percent of total exports and employs 18 percent of the formal sector (ROK, 2010: 1). In rural Kenya, 70 percent of the population derives its economic activities from agriculture, namely subsistence farming, livestock and fishing (International Fund for Agriculture Development, 2007). Despite aggregate growth over the past decade, growth within Kenya's agriculture sector remains low, and its potential to promote rural development and alleviate poverty has not been fully explored (Deutsche Gesellschaft fur Internationale Zusamenarbeit, 2011). The agriculture sector also faces several challenges, including a skewed landholding system, poor infrastructure, inefficient land policies and legislation, government corruption, and vulnerability to climatic variability and shocks (ETC, 2006; FAO, 2011; ROK, 2010; Ikiara et al., 2009).

Kenya's industrial sector is one of the largest in sub-Saharan Africa (MENR, 2005; World Bank, 2011) and includes the production of refined petroleum products, cement, soft drinks and textiles; the milling of grains and sugar; and light manufacturing (USDS, 2011).

Generating about 16 percent of GDP in 2010 (CIA, 2011), the sector was expected to grow by 3.4 to 5.3 percent in 2010—down from a rate of 7.1 percent in 2007 (World Bank, 2011). Most industrial activities take place in Nairobi and Mombasa.

The services sector constituted 62 percent of the Kenyan economy in 2010 (CIA, 2011). Tourism forms a large part of this sector, as Kenya's coastal rainforests, marine ecosystems and wildlife, as well as Mount Kenya, make the country one of the world's top tourist destinations (WRI et al., 2007). A significant proportion of wildlife conservation activity occurs in Kenya's arid and semi-arid lands (ASALs), where tourism is the major economic activity (WRI et al., 2007).

Energy production and consumption is instrumental to Kenya's development. At present, energy from all sources is primarily used by the residential sector (77.6 percent), followed by transportation (14.7 percent), industry (5.9 percent), agriculture and forestry (0.8 percent), commercial and public services (0.5 percent), and others (0.6 percent) (Karekezi et al., 2008: 17). The dominance of the residential sector in part reflects the fact that over 85 percent of Kenyans continue to rely on traditional energy sources such as wood, charcoal, dung and agricultural residues.

Environment

Due to a combination of rapid population growth, shifting climate patterns and overgrazing (USDS, 2011), all critical ecosystem services are under stress in nearly every province (Wong et al., 2005). Nearly one-third of Kenyans live on degraded lands (UNDP, 2010). These changes have led to a decline in living standards, especially in rural areas, and have encouraged migration to urban centres.

Water resources cover 1.9 percent of Kenya (Mango et al., 2010: 5852), mostly supplied by a network of perennial rivers that originate from five sources: Mount Elgon, the Aberdare Range, the Mau Escarpment, Cherangani Hills and Mount Kenya. These resources are unevenly distributed, being more densely located in the central and western regions of the country; for example, the Lake Victoria drainage basin contains 65 percent of Kenya's renewable surface water supply (WRI et al., 2007: 28). The rivers used most for human consumption are primarily recharged by rainfall (Kandji, 2006). Despite these water resources, Kenya is one of the most water-scarce countries in Africa (Kandji, 2006; Mango et al., 2010; WRI et al., 2007). In 2004, Kenya's water availability was estimated at 936 m^3 per capita[4] (WRI et al., 2007: 28). Based on current population growth rates, this is projected to fall to 350 m^3 per person by 2020 (WRI et al., 2007). Degradation of existing water supplies is an additional challenge and is estimated to cost the country at least US$38.5 million per year, or 0.5 percent of GDP (Magoka et al., 2006: xv). With demand for water projected to exceed supply, achieving Kenya's economic goals and the MDGs could become increasingly difficult (WWAP, 2006). All sectors of the Kenyan economy depend on water, but the greatest demand (70 percent) comes from agriculture (WWAP, 2006), and the second-greatest from domestic consumption.

Regional comparison

Poverty, high inequality, social exclusion and vulnerability to shocks are pervasive in East African countries. All have agriculture-based economies, and except for Djibouti, a high proportion of their populace lives in rural areas. Several are rebuilding following periods of civil unrest or war, and security remains a concern in some locations, particularly Somalia. Kenya has the third-highest population in the region, after Tanzania and Ethiopia (CIA, 2011) and projected population growth of 2.6 percent between 2010 and 2015, ranking fifth in the region (UNDP, 2010).[5] Although life expectancy of Kenyans improved from 50.8 years in 2000 to 55.6 in 2010 (4.8 years), six countries in the region experienced an average increase of ten years. Kenya has the highest adult literacy rate in East Africa (see table 3), as well as one of the top primary and secondary net enrolments, and its employment rate is one of the strongest in East Africa. However, its economy has recently grown more slowly than that of Tanzania or Ethiopia. Moreover, Kenya has greater income inequality than Tanzania, Rwanda or Burundi, and its health indicators lag behind those of countries of similar size and economy. The rising economies of several of Kenya's East African neighbours indicate a positive trend, which creates opportunities for improved trade relations and cooperation in areas such as disaster response.

[4] A country is characterized as being 'water scarce' when its water availability is less than 1,000 m^3 per capita (WRI et al., 2007: 28)
[5] This ranking excludes consideration of Somalia, for which no information is available.

TABLE 3. COMPARISON OF DEVELOPMENT INDICATORS OF EAST AFRICAN COUNTRIES IN 2000 AND 2010

	HUMAN DEVELOPMENT INDEX RANKING		LIFE EXPECTANCY		ADULT LITERACY RATE (%)		ACCESS TO CLEAN WATER (%)	
	2000[c]	2010[c]	2000[a]	2010[b]	2000[a]	2010[b]	2000[a]	2010[b] (in 2008)[1]
Burundi	0.223	0.282	40.6	51.4	48.0	65.9	n/a	72
Djibouti	n/a	0.402	43.1	56.1	65.6	n/a	100	92
Eritrea	n/a	n/a	52.0	60.4	55.7	65.3	46	61
Ethiopia	0.250	0.328	43.9	56.1	39.1	35.92	24	38
Kenya	**0.424**	**0.470**	**50.8**	**55.6**	**82.4**	**86.5**	**49**	**59**
Rwanda	0.277	0.385	40.2	51.1	66.8	70.3	41	65
Somalia	n/a	n/a	46.9	50.4	n/a	n/a	n/a	n/a
Tanzania	0.332	0.398	51.1	56.9	75.1	72.6	54	54
Uganda	0.350	0.350	44.0	54.1	67.1	74.6	50	67

Source: (a) UNDP, 2002; (b) UNDP, 2010 ; (c) UNDP, 2011

[1] Data refer to the most recent year available during the period specified.

NATIONAL DEVELOPMENT VISION, OBJECTIVES AND PRIORITIES

Since gaining independence in 1963, the thrust of Kenya's development agenda has been to alleviate poverty, improve human capital, reduce disease and foster economic prosperity (GOK, 2003; GOK, 2007a). The country's capacity to achieve these objectives has varied. Under the flagship of 'Kenya Vision 2030,' the government's development blueprint for 2008 to 2030 aims to transform Kenya into a "middle-income country providing a high quality of life to all of its citizens by the year 2030" (GOK, 2007a: 1). Specific objectives are set forward in relation to three pillars: economic, social and political.

The **economic pillar** identifies six sectors as priorities for investment: tourism, agriculture, wholesale and retail trade, manufacturing for markets in eastern and central Africa, business-process offshoring;[6] and financial services. Key components of the **social pillar** are education and training; health care; water and sanitation; environment; housing and urbanization; gender, youth and vulnerable groups, which include sports and culture; and equity and the elimination of poverty. And activities in the **political pillar** concern the rule of law, electoral and political processes, democracy and public service delivery, transparency and accountability, and security, peace-building and conflict management (GOK, 2007a).

'Kenya Vision 2030' is being implemented through successive five-year medium-term plans, beginning with the period from 2008 to 2012. Key targets of this medium-term plan include (GOK, 2008):

- Increasing real growth of the country's GDP to between 7.9 and 8.7 percent by 2009/2010, and to 10 percent by 2012.
- Reducing the number of Kenyans living in poverty from 46 percent to 28 percent.
- Improving rural and urban access to clean water, in part through rehabilitation and protection of forests in five critical watersheds.
- Expanding the agriculture sector's contribution to GDP by between 6 and 8 percent through measures such as irrigating an additional 1.2 million ha.
- Restructuring the health system to focus more on disease prevention.

[6] Business-process offshoring refers to the provision of business services to companies and organizations in developed countries using Internet-based technologies (GOK, 2007a).

- Connecting one million households to electricity and linking Kenya to the southern Africa power pool.
- Trebling national earnings from the tourism sector.

Reflecting the commitment in 'Kenya Vision 2030' to "enhance disaster preparedness in all disaster-prone areas and improve the capacity for adaptation to global climatic change" (GOK, 2007a: 19), the medium-term plan also includes commitments that specifically address climate risk. To improve disaster preparedness, the government intends to implement a meteorological systems modernization programme that will establish a tidal gauge station and marine automatic weather systems and introduce dynamic modelling capabilities for prediction of weather and climate (GOK, 2008). It is also committed to securing funding from international sources to support adaptation in Kenya's ASALs and high-risk zones, improving Kenya's disaster preparedness strategy (GOK, 2008: 111), and establishing conflict and disaster early-warning and response mechanisms based on monitoring of trends such as food and water shortages (GOK, 2008). The government is also committed to strengthening its National Climate Change Secretariat by 2012 (GOK, 2008).

THE HEALTH SECTOR

Kenya faces a heavy disease burden. About 30 percent of this disease burden is due to malaria, which is ranked as the number-one cause of disease and mortality in both adults and children (MOPHS, 2009; Yanda et al., 2006). According to the Ministry of Medical Services and the Ministry of Public Health and Sanitation (2011), 31 percent of outpatient morbidity is due to malaria. About 1.4 million people, or 7.4 percent of the population, have HIV/AIDS (ROK, 2009: 3), and approximately 85,000 people die annually of the disease (GOK, 2008). In addition, tuberculosis is on the rise, despite past improvements (Ochieng & Makoloo, 2009; GOK, 2008). Non-communicable diseases are also a burden, causing the death of 729 people per 100,000 in 2004 (UNDP, 2010). Malnutrition affects 54 percent of children under the age of five, and three out of five children demonstrate underdeveloped growth due to long-term nutritional deficiency (GOK, 2008). A national review of the progress made to 2011 concluded that "the country is not on track to attain the commitments towards the health related Millennium Development Goals, with no progress noted towards MDG 5 (improve maternal health), and limited progress towards MDGs 1 (eradicate extreme poverty and hunger), 4 (reduce child mortality rates) and 6 (combat HIV, malaria, and other diseases)"(MMS and MOPHS, 2012a).

Kenya's capacity to provide an equitable and effective health care system is limited by poverty and inequality (World Bank, 2009), and most Kenyans lack access to quality health care. Kenya's expenditure on health is low: US$10.90 per person in 2007 (GOK, 2008). This funding is not distributed evenly within the country, with significant disparities between and within provinces (MOH, 2006). As one indicator, only 30 percent of Kenya's health care budget was allocated to rural areas in 2007 (GOK, 2008), although 70 percent of Kenyans reside in these areas (World Bank, 2011). Moreover, spending in health services is lopsided towards the highest quartiles, with the poor receiving less-than-proportional benefits from total public spending (World Bank, 2009). Lack of access to quality health care, combined with poor water and sanitary services, affects preventive measures (World Bank, 2009).

Parallel to a lack of funds and inefficient administration, Kenya has few qualified medical personnel. Between 2000 and 2009, there was an average of one physician for every 10,000 Kenyans. The number of hospital beds per 10,000 people has remained at 14 over the last decade. Infant mortality in 2008 was 81 per 1,000 live births, and mortality of children under age five was 128 per 1,000 live births (UNDP, 2010). Disparities exist within provinces regarding infant mortality. For example, in 2008 in Central Province, infant mortality was 54 per 1,000 live births, while in North Eastern Province and Nyanza it was 163 and 206, respectively (GOK, 2008: 98). Maternal mortality was approximately 560 out of 100,000 live births (UNDP, 2010), with about 60 percent of births occurring outside hospitals and only 40 percent attended by skilled medical personnel (GOK, 2008). Moreover, an estimated 14,700 women die each year from pregnancy-related complications (GOK, 2008).

Various strategic policy documents position the country to improve inefficiencies and inequalities in the health sector. In line with 'Vision 2030,' a final draft **Kenya health policy** for 2012 to 2030 (MMS and MOPHS, 2012a) provides long-term policy direction. A draft **health law** (MMS and MOPHS, 2012b), the 'Comprehensive **National Health Policy Framework** 2011–2030' (MOPHS, 2011), which will follow the 'Second **National Health Sector Strategic Plan** of Kenya NHSSP II 2005–2010' (MOH, 2005), and a revised **community health strategy** (MOH, 2006) are also being prepared. The overall orientation set since the NHSSPII is to reduce inequalities in health care and reverse the downward trend in health-related impact and outcome indicators (MOH, 2005). The focus is on decentralization to enhance communities' access to health care and their role in health care delivery (MOH, 2006). The Ministry of Public Health and Sanitation's '**Strategic Plan**, 2008–2012' (MOPHS, 2008) further articulates plans for strengthening Kenya's health care system, with a focus on improving equitable access and the quality, responsiveness and efficiency of public health and sanitation services; fostering partnerships; and improving financing (MOPHS, 2008). The plan also aims to reduce malaria incidence to 15 percent "by utilizing cost effective control measures such as long-lasting insecticide treated nets and indoor household spraying." In line with the NHSSP II and the international targets (such as the Abuja Declaration and the MDGs), the goal of the 2009–2017 **National Malaria Strategy** is to reduce morbidity and mortality from malaria by 66 percent by 2017 (MOPHS, 2009).

Key messages: Development profile

- Overall, Kenya continues to experience a number of development challenges, such as high poverty (particularly in rural areas), inequality, limited access to critical services like water and health care, and environmental degradation.
- Kenya is not expected to meet all of its Millennium Development Goals (UNDP, n.d.a), including in health. Nor is the government's objective of "raising the level of Kenya's Human Development Index from approximately 0.5 in 2007 to 0.7 by 2012" (GOK, 2008: 4) likely to be achieved. However, Kenya has made recent positive strides with respect to developing and diversifying its economy and providing education.
- Malaria is the number-one cause of disease and mortality in both adults and children. Various strategic health documents position the country to improve inefficiencies and inequalities in health. The country aims to reduce morbidity and mortality from malaria by 66 percent by 2017.

CLIMATE PROFILE

This section discusses Kenya's climate today and in the past, and how it is projected to change in the future. It begins by providing an overview of general climatic conditions in Kenya and historic climate hazards, then examines how general climatic conditions and the characteristics of climate hazards might be altered by the ongoing process of climate change. It concludes with an overview of the status of climate information, and projections at the national and regional levels.

Kenya's complex tropical climate varies significantly among regions due to variable topography and the influence of regional and global climatic processes (MENR, 2002). Although Kenya's coastal areas are warm and humid, most of its interior is arid and semi-arid; nearly 80 percent of the country receives less than 700 mm of rain per year (MENR, 2002: 36). In contrast, more temperate conditions occur in the western and central highlands. Areas near Lake Victoria and the central highland east of the Rift Valley can receive between 1,200 mm and 2,000 mm of rain annually (MENR, 2002: 36), while the valleys and basins can be dry (AEA Group, 2008a).

Seasonal rainfall patterns in Kenya are driven mainly by the migration of the Intertropical Convergence Zone (McSweeney et al., 2009). The movement of the zone is sensitive to changes in the surface temperature of the Indian Ocean, but generally travels southward from October to December—the 'short' rainy season—and then northward between March and May, the 'long' rainy season (MENR, 2002; McSweeney et al., 2009; Seitz and Nyangena, 2009; Thornton et al., 2008). Historically, more than 70 percent of annual rainfall occurs during the long rains, and less than 20 percent during the short rains (SEI, 2009). However, regional disparities exist, as some parts of the country (e.g. Meru in central Kenya) receive more rainfall during the short rainy season than the long. A strong El Niño/La Niña results in very wet/dry conditions over most of the country (personal communication, David Gikungu, KMD, 29 March 2012).

In recent decades changes have occurred in Kenya's climate. Mean annual temperatures have increased by 1.0° C since 1960, an average of 0.21° C per decade (McSweeney et al., 2009). The Lewis Glacier on Mount Kenya has lost 40 percent of its mass since 1963 (MENR, 2002).

Changes in rainfall patterns have also been noticed since the 1960s, but do not show any statistically significant national trends (AEA Group, 2008b; McSweeney et al., 2009). Greater rainfall has occurred during the 'short' rains of October to December, which have begun to extend into the hot and dry months of January and February (GOK, 2010). In contrast, local observations suggest that the 'long' rains of March to April have become increasingly unreliable in locations such as Eastern Province (Awuor, 2009). Rainfall intensity has also altered, especially along the coast (MENR, 2002). However, while indications are that more heavy rainfall events are occurring, no statistically significant trend has been found (McSweeney et al., 2009).

PAST AND CURRENT CLIMATE HAZARDS

Kenya is one of the most disaster-prone countries in the world (MOSSP, n.d.). Between 2000 and 2009, out of every one million Kenyans, an average of 94,526 people per year, were affected by natural disasters (see table 4; UNDP, 2010). More than 70 percent of the natural disasters in Kenya are due to extreme climatic events (MOSSP, 2009), with the most common being floods and droughts. Major droughts occur about every 10 years, while moderate droughts or floods occur every three to four years (AEA Group, 2008b). The number of people affected by these climate disasters increased substantially in the 1990s and 2000s (CRED, 2012), in part due to Kenya's population growth. Collectively, the economic cost of floods and droughts is estimated to create a long-term fiscal liability equivalent to about 2.0 percent (SEI, 2009: ii) to 2.4 percent (AEA Group, 2008a: 1) of GDP each year.

Drought occurs cyclically, and historically has affected the greatest number of people and posed a substantially greater risk of adversely affecting GDP than floods (Earth Institute at Columbia University, n.d.). Between 1900 and 2011, nearly 43 million people were affected by 12 recorded droughts, while nearly 2.5 million were affected by 38 recorded floods. During this same period, 196 were killed by drought, while 1,595 died due to flooding (See table 6; CRED 2012). Major droughts occurred in 1991/1992, 1995/1996, 1998/2000, 2004/2005 and 2009 (GOK, 2006; SEI, 2009). Droughts cost about 8.0 percent of GDP every five years (AEA Group, 2008a: 1). The social consequences of drought are also significant. In pastoralist communities, for instance, observed consequences include undermining the social position of households, breaking up families, damaging social safety nets and increasing vulnerability to food insecurity (Aklilu and Wekesa, 2002).

TABLE 4. POPULATION AFFECTED BY NATURAL DISASTERS, 2000–2009* (AVERAGE PER YEAR, PER MILLION PEOPLE)

GLOBAL COMPARISON			REGIONAL COMPARISON		
1	Swaziland	156,115	**1**	**Kenya**	**94,526**
2	Mongolia	120,113	2	Djibouti	94,144
3	Tajikistan	100,709	3	Eritrea	87,758
4	Cuba	97,163	4	Zimbabwe	75,240
5	China	96,359	5	Malawi	70,315
6	**Kenya**	**94,526**	6	Somalia	67,697
			7	Ethiopia	37,289
			8	Sudan	20,408
			9	Uganda	10,899

**Natural disasters include droughts, earthquakes, epidemics, extreme temperatures, floods, insect infestations, storms, volcanoes and wildfires (UNDP, 2010: 171). Data source: UNDP (2010)*

While droughts are widespread throughout the country, **floods** are usually more localized and frequent. They have also caused the highest mortality (see table 6) (CRED, 2012). Floods seasonally affect parts of Nyanza and Western provinces, especially around the Lake Victoria basin, as well as the Tana River drainage basin and coastal settlements (AEA Group, 2008b). The ASALs periodically experience flash floods (World Bank, n.d.). Nyando, Kisumu, Rachuonyo and Busia districts are most affected by floods (World Bank, n.d). Since 1950, six serious floods have occurred (MENR, 2002), including in 1961, 1997/1998 (AEA Group, 2008a) and 2006 (SEI, 2009). The cost of floods is estimated at 5.5 percent of GDP every seven years (AEA Group, 2008a: 1). The floods of 1997/1998 (during an El Niño event), for example, affected approximately one million people (SEI, 2009) and resulted in an economic loss of US$0.8 to US$1.2 billion in infrastructure damage, public health impacts and crop losses (SEI, 2009: ii). Only about one-eighth (or US$0.1 million) of the infrastructure damaged by this event was replaced, suggesting a long-term negative impact on development (Magoka et al., 2006: xvi).

TABLE 5. CLIMATE HAZARDS IN KENYA, 1900–2011

	NUMBER OF EVENTS	TOTAL KILLED	TOTAL AFFECTED	DAMAGE (000 US$)
Drought	12	196	42,904,585	1,500
Flood	38	762	2,474,461	22,388
Landslide	4	56	26	-
Local storm	1	50	-	-
Total	55	1,064	45,379,072	23,888

Data source: CRED, 2012

Other climate-related hazards in Kenya include landslides, storms and forest fires. Landslides occur mostly during the rainy season and are associated with floods. They are particularly a concern in regions with steep slopes and annual rainfall over 1,200 mm (UNDP, n.d.b). Provinces such as Western, Nyanza and Rift Valley are most affected (UNDP, n.d.b), and the most affected regions are Murang'a (in Central Province), Kirinyaga, Nyeri and parts of Meru—all of which are areas around Mount Kenya—plus Kisii and Mombasa Island (UNDP, n.d.a: 38). The number of landslides is increasing as forested lands are converted to agriculture, resulting in looser soils and fewer trees to slow the flow of water down slopes (UNDP, n.d.b). However, statistical data on landslide destruction has not yet been quantified (World Bank, n.d). Forest fires are an additional hazard influenced by climatic conditions. Since about 1990, Kenya has lost an average of more than 5,700 ha of forested land per year due to forest fires (Mutimba et al., 2010: 25). The economic cost of this loss has not yet been calculated (Mutimba et al., 2010).

Whether the frequency and/or severity of extreme climate events in Kenya have changed in recent decades, and the causes of any such change, is uncertain. Some researchers claim the severity of droughts in Kenya has increased over the past 40 years due to environmental degradation caused by factors such as deforestation (UNDP, n.d.b). On the other hand, Michigan State University reviewed temperature and precipitation in northwestern Kenya and found no indication of greater frequency or intensity of drought, although local farmers perceived an increase (Ziervogel et al., 2008). Ziervogel et al. (2008) suggest that the observed rise in average temperatures has put additional stress on vegetation such that "it takes less extreme hot and dry spells to inflict drought like conditions" (p. 19).

PROJECTED CLIMATE TRENDS

The higher temperatures and changes in rainfall and drought patterns observed over the past couple of decades are broadly consistent with the changes in climate projected to occur in the country due to global climate change. Kenya is expected to experience higher temperatures year-round (AEA Group, 2008b), although uncertainty remains regarding how much warming will occur. In the medium term, projections suggest that mean annual temperature will rise by 1.0° C to 3.5° C by 2046 to 2065 (SEI, 2009: iii).[7] McSweeney et al. (2009) project a less dramatic rise in temperatures in the medium term: an increase of 1.0° C to 2.8° C by the 2060s, and by 1.3° C to 4.5° C by the 2090s, which will manifest through increased frequency of hot days and nights, with cold days and nights becoming rare (McSweeney et al., 2009).

While temperatures are projected to rise country-wide, regional differences are expected. Plateaus and mountain ranges, for instance, could remain much cooler than the lowlands (Funk et al., 2010). As well, by 2025, western Kenya is projected to experience temperature increases ranging from 0.9° C to 1.1° C, while temperatures in the southern coastal area could increase by an average of 0.5° C; in the northern tip of eastern Kenya, temperatures could rise by 1.1° C (see figure 5) (Funk et al., 2010).[8] In comparison, analysis based on a regional climate model suggests that temperatures in northwestern Kenya will rise by 1o C above the rest of Kenya by 2100, while temperatures in northeastern Kenya (e.g. around Wajir) will see 1° C to 2° C less warming compared with the national average (AEA Group, 2008b: 16).

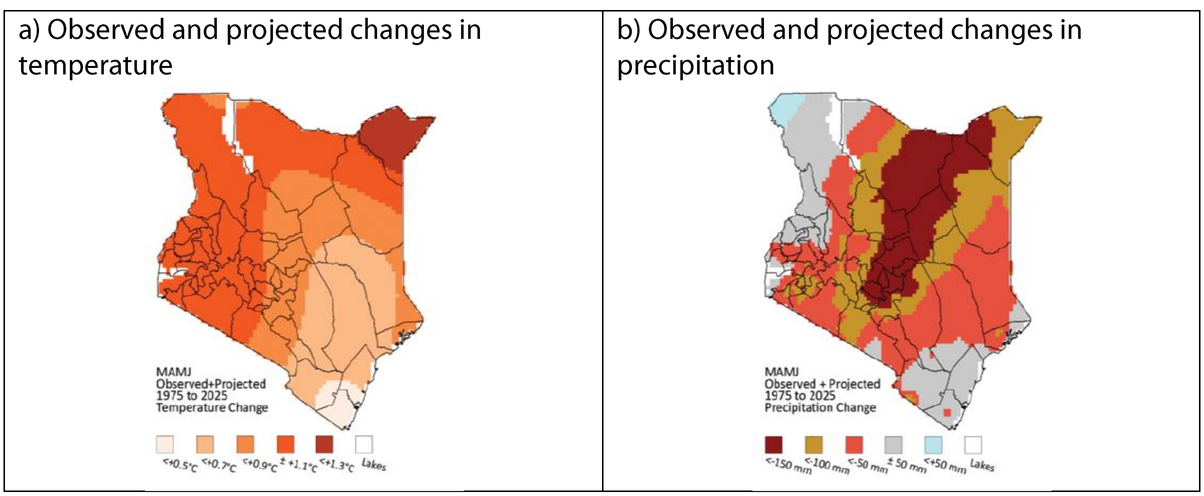

Figure 5. Regional distribution of observed and projected changes in rainfall and temperature for the period from 1975 to 2025 (reprinted with permission from Funk et al., 2010: 2)

Uncertainty persists regarding the impact of climate change on future rainfall patterns. In part this uncertainty is due to the absence of a clear understanding of the processes (such as the El Niño Southern Oscillation) that affect Africa's current climatic drivers, and how these processes may change in the future (Conway, 2009). Regionally, analysis by the Intergovernmental Panel on Climate

[7] Projection based on a comparison of monthly average minimum temperatures across nine global circulation models for the period from 2045 to 2065, statistically downscaled using the Climate Change Explorer tool by the Climate Systems Analysis Group and SEI.

[8] Projected temperature increase to 2025 based on extension of observed changes in temperature between 1960 and 2009 (Funk et al., 2010).

Change (IPCC) using global circulation models projects that eastern Africa will likely become wetter, particularly during rainy seasons (Boko et al., 2007). These models also anticipate rainfall patterns becoming less uniform over time, with possible increases in sporadic and intense precipitation. By the end of the century the number of extreme wet seasons may increase by 5 to 20 percent (Christensen et al., 2007; Seitz and Nyangena, 2009). The timing of the rainfall seasons is not expected to change in coming decades (Boko et al., 2007). However, the Kenya Meteorological Department (KMD) predicts a decrease in the average of the projected rainfall in Kenya, with the March-April-May season depicting a general decrease, and only the October-November-December season in the northern parts of Kenya expected to experience increases (personal communication, David Gikungu, KMD, 29 March 2012).

Climate change will also lead to a rise in global sea levels and ocean temperatures, with implications for the probability of coastal flooding and the intensity of storms. Projections suggest that by 2030, sea level rise will result in 10,000 to 86,000 Kenyans being affected each year by coastal flooding and lead to the loss of coastal wetlands and coastal erosion (SEI, 2009). The economic cost of sea-level rise is projected to be between US$7 million and US$58 million per year by 2030, and US$31 million to US$313 million per year by 2050 (SEI, 2009: iii).[9] Considerable uncertainty remains regarding the probable implications of climate change for extreme climate events such as floods and droughts (SEI, 2009). The projected 1 to 13 percent increase in the proportion of rain that falls in heavy rainfall events (McSweeney et al., 2009) in the wet season suggests flood risk will increase (SEI, 2009). Droughts are likely to continue (Boko et al., 2007). One study suggests that droughts will remain at least as extreme as at present, and will possibly increase in intensity over this century (AEA Group, 2008b).

STATUS OF NATIONAL AND REGIONAL CLIMATE INFORMATION

In Kenya, climate information is provided through the Intergovernmental Authority on Development Climate Prediction and Analysis Centre (ICPAC) and the Kenya Meteorological Department (KMD). ICPAC supports the national and regional climate risk reduction strategies of seven countries in the greater Horn of Africa.[10] The regional centre collects, processes, stores and offers access to climate and remote sensing data, provides early warning of climate-related hazards, identifies climate change adaptation options, and supports capacity building for climate tools and information. A key activity of ICPAC is hosting the annual Greater Horn of Africa Climate Outlook Forum, where major climate centres from around the world agree upon seasonal climate forecasts for the region. Information collected by ICPAC is disseminated to national meteorological and hydrological services, including KMD (ICPAC, n.d.).

Housed within the Ministry of Environment and Mineral Resources (MEMR), KMD is Kenya's primary source of national and subnational climate information. Along with maintenance of historical records since 1896 (NEMA, 2005), the department provides access to daily, multi-day and monthly weather forecasts and seasonal, three- to six-month climate forecasts (KMD, n.d.). Developments in weather and seasonal rainfall prediction have increased the accuracy and reliability of KMD's seasonal forecasts (Ndegwa et al., 2010). KMD also provides forecasts for extreme events (floods and droughts) and monitors, assesses, models and communicates the extent to which climate change is occurring in the country (KMD, n.d.). KMD disseminates climate information through print and electronic media.

Development of climate projections for Kenya depends on understanding the processes that drive climatic patterns in Africa today—namely the movement of the Intertropical Convergence Zone, the formation of monsoons in the Indian Ocean and the **El Niño Southern Oscillation** (Conway, 2009). While understanding of these processes is growing, many questions remain regarding how they interact and will change as average global temperatures rise. Africa also lacks trained climatologists (Conway, 2009). These conditions make it difficult to develop climate projections for Kenya and the East African region (Conway, 2009).

A further complication is a "severe" lack of local weather data in Kenya and for Africa as a whole. The limited number of stations restricts capacity to validate climate models and therefore reduces confidence in the scenarios they generate (Conway, 2009). Kenya has only 25 official meteorological stations (Ziervogel et al., 2008: 43), and where they exist, weather recording may be too short, full of gaps, or only collect information regarding a few parameters. Kenya has recognized this challenge and has committed to rehabilitating its hydrometeorological data–gathering network by 2030 (GOK, 2007a). Notably, Kenya has an estimated 600 staffed and volunteer weather stations, some with data series for the past 40 to 50 years. Collecting this data and converting it into digital form could help Kenya overcome some of its data and modelling limitations (Ziervogel et al., 2008: 43).

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[9] Based on prices as of 2009, with no discounting (SEI, 2009).

[10] These countries are Djibouti, Eritrea, Ethiopia, Kenya, Somalia, Sudan and Uganda. ICPAC also facilitates access to climate information by Burundi, Rwanda and Tanzania (ICPAC, n.d.).

Climate models also require topographic, land-use and socio-economic information. However, baseline data regarding Kenya's land forms, land uses and topography is insufficient, making it difficult to account for spatial variability of microclimates. As well, limited data regarding current and projected socio-economic conditions restricts capacity to project future climatic circumstances. Land-use changes significantly affect climate and are significantly influenced by factors such as policy interventions, population dynamics and world markets. For these reasons, given that simulation models require substantial temporal and spatial data, considerable uncertainty remains regarding projections of future climatic change—and of climate risk more broadly—in Kenya.

Key messages: Climate profile

- Kenya's climate varies significantly among regions due to variable topography and the influence of regional and global climatic processes. Most of the interior is arid and semi-arid, while temperate conditions occur in the western and central highlands.
- The country is highly prone to climate hazards, in particular droughts and localized floods, which have considerable effects on the economy (up to 2 percent of GDP per year).
- Nationally, mean temperatures have increased by 1.0° C since 1960, but changes in rainfall patterns do not show any statistically significant trends. Uncertainty remains in relation to any observed change in frequency and severity of extreme climate events.
- Higher temperatures are expected in the future, with some regional differences. Greater uncertainty is associated with future rainfall projections, and differing opinions prevail. KMD predicts a decrease in the average of the projected rainfall, with only the October-November-December season in the northern parts of Kenya expected to experience an increase.

CLIMATE IMPACTS AND RISKS

Debate continues over which factors, climatic or non-climatic, are most responsible for influencing malaria's transmission rate and distribution in the past, present and future. The IPCC (2001) and WHO (2003, 2009a), among others, argue that climate change, by leading to rising temperatures, changes in precipitation, and climate variability, could increase malaria infection. For example, such changes could favour proliferation of malaria-carrying mosquitoes at higher altitudes (USAID, 2008).

Others (e.g. Gething, et.al., 2010; Hay et al., 2002) argue that socio-economic factors such as economic development, population changes, immunity and drug resistance, urbanization, and land-use changes "have exerted a substantially greater influence on the geographic extent and intensity of malaria worldwide during the twentieth century than have climatic factors" (Gething et al. 2010: 343). According to these authors, any impact that climate change could have on disease distribution can be more than offset by expanding disease control techniques, such as bednets and drugs (Gething et al., 2010; Tatalović, 2010). To support their case, they point to the "global decrease [since 1900] in the range and intensity of malaria transmission" during a century marked by a rise in global temperature (Gething, et al., 2010).

The picture is complex. Climate change may increase the risk of malaria becoming more prevalent, but whether this greater risk is translated into reality (i.e. more prevalence) and whether it becomes more of a danger to human health (e.g. more prevalence, but greater treatment improves outcomes) will depend on many other factors and will be context-specific. Overall, the potential impact of climate change on malaria remains uncertain (Confalonieri et al., 2007; Paaijmans et al., 2009). The difficulty lies in determining which factors are most responsible for influencing the distribution and intensity of the disease (WHO, 2003). The purpose of this report was not to solve the controversy but to review the state of knowledge and provide additional information from a local perspective.

A recent study (Adbisalan et al., 2009), using geostatistical modelling, developed a national map of malaria's risk distribution in Kenya for 2009 (see figure 6). It shows that malaria infection prevalence is low over 94 percent of Kenya's territory. The risk of transmission is moderate to high in only well-defined areas: the western Kenyan highlands and the northwestern part of Kenya close to Lake Turkana in the Great Rift Valley. The Government of Kenya has classified the country into four malarial eco-epidemiological zones (DOMC/MOPHS, 2011):

- **Stable endemic area** around Lake Victoria and in the coastal region. High transmission throughout the year due to a climate favourable for rapid development of parasites in the mosquito.
- **Malaria epidemic–prone areas** of the western highlands. Seasonal transmission with considerable year-to-year variation (i.e., 'unstable' transmission because the inoculation rate is erratic). Level of transmission generally low, but can be very high during epidemics, which occur when climatic conditions are favourable.
- **Seasonal low malaria transmission** in the arid and semi-arid areas of the northern and south-eastern parts of the country. Short periods of intense malaria transmission during rainfall seasons.
- **Low-malaria-risk zones** in the central highlands, including Nairobi, where temperatures are generally too low for malaria transmission to take place.

Malaria burden is decreasing in Kenya's endemic areas, malaria is expanding in the low-transmission zones, and the size of outbreaks is increasing (DOMC/MOPHS, 2011). It is worth reiterating that malaria remains the number-one cause of disease and mortality in Kenya. The Kenyan highlands (1,500 m and above) were malaria-free before the 1910s, and have generally been so compared with the western lowlands, where malaria has been endemic for generations (Baliraine et al., 2010). Malaria epidemics in the East African highlands in general occurred in the mid-1920s up to the 1940s, and were successfully controlled in the Kenyan highlands in the 1950s and 1960s. But the 1980s and 1990s saw the resurgence of malaria in the East African highlands (Paaijmans et al, 2010; Omumbo et al, 2011). In western Kenya, malaria epidemics have spread to 15 districts, from three in 1988 (Githeko et al., 2000). Therefore, while global and national malaria trends have been decreasing since 2004 (WHO, 2009b), malaria incidence in the East African highlands, including in the western Kenyan highlands, has increased since the end of the 1970s (Pascual et al., 2006), and this re-emergence has not yet been controlled.

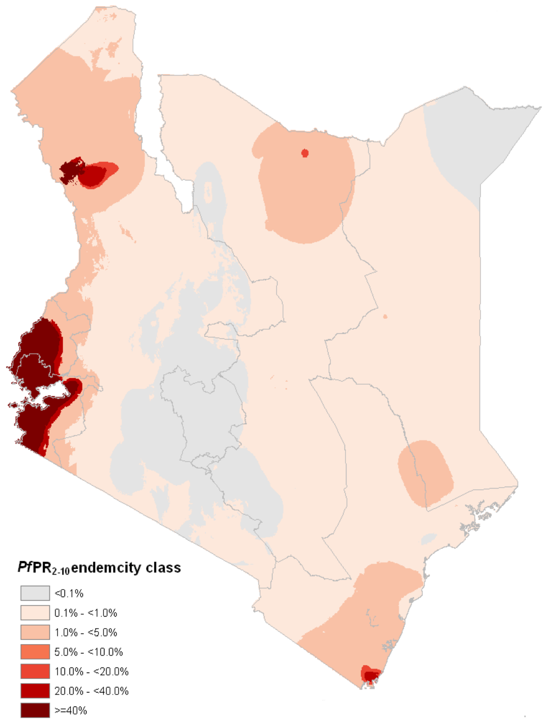

Figure 6. Spatial distribution of P. falciparum malaria in Kenya in 2009 based on geospatial modelling and showing different endemicity classes. Source: Abdisalan et al., 2009

The cause of the re-emergence of malaria in East Africa, and particularly in the western Kenyan highlands, is also the subject of heated debate. Antimalarial drug resistance and migration of vectors from lowland regions to the highlands due to increased human mobility have been suggested as causes. Until the year 2000, the role of climate in malaria epidemics and as a driver of transmission was disregarded (Githeko, 2010). Today, the debate over climate and malaria linkages in East African highlands has focused on four main questions: whether malaria is increasing and re-emerging in the region; whether temperatures are increasing in the region; if yes to the latter, what might be the exact causes (e.g., land-use change, climate change); and finally, whether there is a causal relationship between trends in temperature and malaria incidence (Omumbo et al., 2011).

Figure 7 presents a framework of linkages between climate and malaria in the western Kenyan highlands. It is based on a detailed review of the literature and was validated by key national stakeholders. It shows how different drivers influence malaria parameters, which in turn impact the key characteristics of malaria epidemics. The framework especially highlights how climate drivers are only one type of driver among others. In addition to other biophysical and environmental drivers, consideration needs to be given to socio-economic, policy, and cultural and behavioural drivers, some of which have been largely ignored in previous studies. These drivers include social relations, inequalities and gender, which influence how natural resources are managed and determine differing levels of risks and health behaviours (Plaen et al., 2004). The figure also points out the importance of understanding how climate drivers may interact with, and therefore influence, other drivers (and vice versa). For example, climatic events may change food and water quantity and quality and indirectly affect sensitivity to malaria risk due to reduced ability to fight infections and disease. Most drivers influence the transmission and diffusion of malaria epidemics indirectly by modifying parasite and/or vector development and human vulnerability to malaria epidemics. Policies (e.g., control efforts such as distribution of bed nets) can directly influence the transmission and diffusion of malaria.

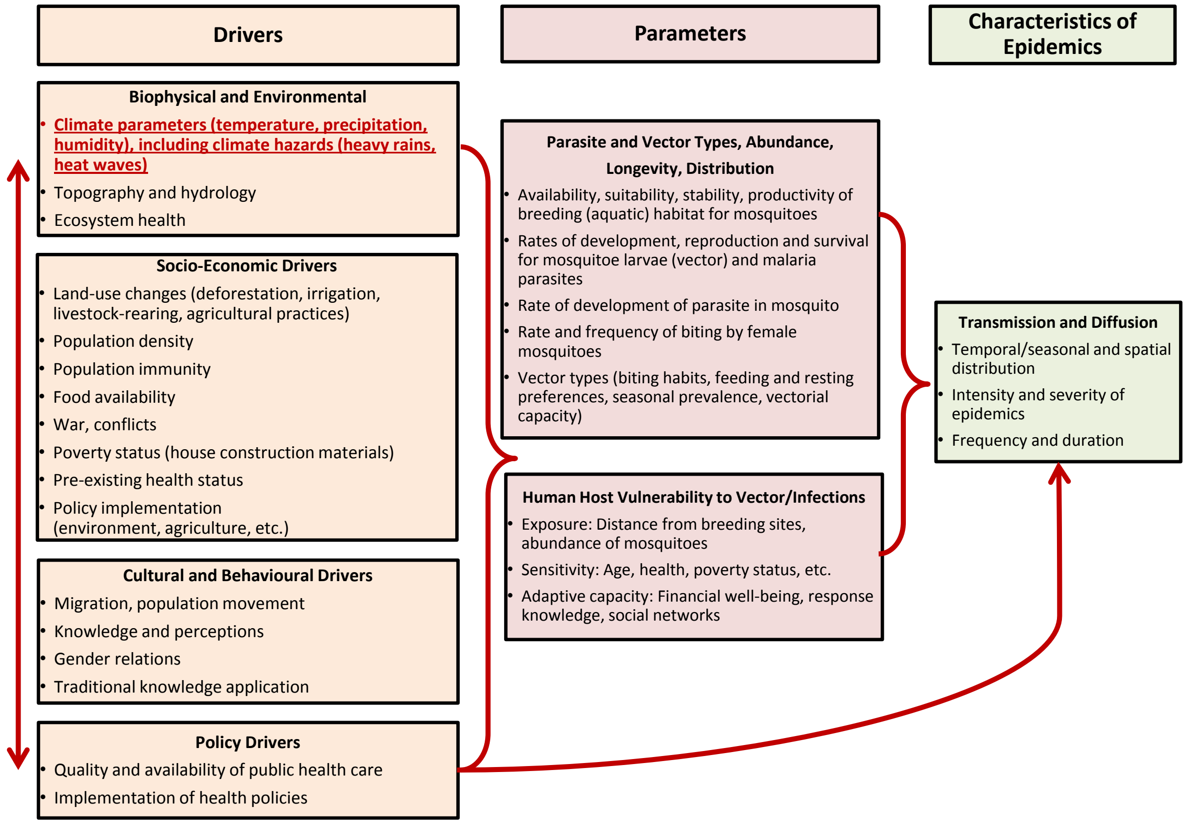

Figure 7. General framework showing the links between climate parameters and malaria epidemics in the western Kenyan highlands

CURRENT IMPACTS OF CLIMATE ON LIVELIHOODS AND MALARIA EPIDEMICS

Abnormal temperatures followed by rainfall exceeding certain thresholds can create conditions favourable to malaria epidemics, depending on topography (Githeko, 2010). In the western highlands, the outbreaks of malaria are seasonal. Peak transmission generally occurs in June-July-August—after the long rainfall season of March-April-May—and when climatic conditions favour mean temperatures around 18o C (DOMC/MOPHS, 2011). Overall, the link between unusual climate variables (temperature, precipitation and humidity) and malaria in the area has already been documented. For example, 6 shows that the combination of unusually high temperature, rainfall and humidity has led to major epidemics in Nandi District.

TABLE 6. ASSOCIATION OF ANOMALOUS WEATHER CONDITIONS WITH MALARIA IN NANDI DISTRICT OVER 14 YEARS (1986–1999)

YEAR		EPIDEMIC	UNUSUALLY HIGH TEMPERATURE		UNUSUAL RAINFALL	UNUSUAL HUMIDITY	
			MAXIMUM	MINIMUM		9 A.M.	3 P.M.
1	1986				**		
2	1987	Minor	**	**			
3	1988	Minor	**	**			*
4	1989				**	*	*
5	**1990**	**Major**	**	**	**	**	**
6	**1991**	**Major**		*	**	**	**
7	1992		*	*	*		*
8	1993		*			*	*
9	**1994**	**Major**	**	**	**	**	**
10	1995				**		
11	1996				**		
12	**1997**	**Major**	**	**	**		**
13	1998	Minor	*	**	**	**	
14	1999	Minor					

Source: Reprinted from DOMC/MOPHS (2011)

Impacts of temperature. Malaria is caused by a parasite transmitted to humans via mosquitoes (the vector). Development of the mosquito and, even more, of the malaria parasite is temperature-sensitive. Temperature can influence the timing and intensity of malaria transmission by modifying the development speed of the parasite, the frequency of blood feeding by adult female mosquitoes, and the time it takes malaria parasites to mature inside them (Githeko and Ndegwa, 2001). The lower temperature threshold for the *Anopheles gambiae* mosquito vector (the main mosquito species found in the East African highlands) for biological activity is 8º C to 10º C (Patz and Olson, 2006). The minimum temperature threshold for transmission of the *Plasmodium falciparum* parasite (the main parasite species found in the East African highlands) is 16º C to 19º C, and the maximum temperature threshold is 33º C to 39º C (Patz and Olson, 2006). Outside these thresholds, the parasite's development may slow or stop (Githeko, 2009). Temperature has a strong effect on the time it takes for the parasite to develop, mature and become infectious in the mosquito (i.e., the incubation period). For example, it takes malaria parasites 56 days to mature in the mosquito at 18° C (which is longer than the 23-day average life span of Anopheles gambiae mosquitoes), 19 days at 22° C and only 8 days at 30° C (Githeko, 2010).

At between 18° C and 22° C, the average temperature in the East African highlands is already conducive to malaria transmission. The mean maximum monthly temperatures in the study area range from 23.5° C (Kericho) to 25.7° C (Trans Nzoia), and the minima from 10.5° C (Kericho) to 15.4° C (Kisii). So far, based on research conducted in the western Kenyan highlands (e.g. Githeko and Ndegwa, 2001), it is generally accepted that "if the mean annual temperature is superior, or equal, to 18º C; anomalies superior or equal to 3o C would be expected to precipitate malaria outbreaks as long as the mean monthly rainfall is greater than 150 mm."

However, given the high complexity associated with emergence of malaria epidemics, drawing a direct correlation between temperature and malaria risk is unwise. Uncertainties remain regarding parasite-mosquito-temperature interactions. Moreover, general epidemiological models use mean monthly temperatures as their variable, rather than diurnal temperature fluctuations, which appear to be much more important than monthly averages in influencing the parasite's life cycle (Paaijmans et al., 2009). Many studies also use air temperature alone (versus water temperature) when assessing the influence of temperature on the development rate of mosquito vectors, while mosquito larvae live in aquatic habitats (Paaijmas et al., 2010; Githeko et al, 2000).

Impacts of precipitation and humidity. Rapuro (n.d.: 3) points out that "warm conditions allow both the *Anopheles [gambiae]* mosquito and the malarial parasite it carries to develop more quickly" and "wet conditions increase mosquito life expectancy and provide breeding habitats." Rainfall generally increases vector populations by creating new breeding sites for mosquitoes in stagnant water (CCD Commission, 2009: 7). But heavy rains and floods can also wash away breeding sites, killing mosquito larvae and potentially decreasing malaria transmission (CCD Commission, 2009; Imbahale et al., 2011). Githeko (2010:12) finds that in the western Kenyan highlands "rainfall will normally increase the vector population 2–3 fold" and unusual heavy rains extend mosquito breeding season, and both of these can lead to bigger epidemics.

In Kenya's arid and semi-arid lowlands, the temperature threshold of over 18° C is constant, so it could be argued that, in terms of climate variables only, rainfall variability, more than temperature, influences malaria epidemics in these areas. Comparatively, the Kenyan highlands benefit from a cooler and wetter climate with plenty of water resources. While most of Kenya experiences a bimodal rainfall pattern (two rainfall peaks in March-April-May—the long rains—and in October-November-December—the short rains), the western parts of the country experience a tri-modal rainfall pattern (March-April-May, October-November-December and June-July-August-September). The study area has rich water resources. In the Kenyan highlands, since water has been relatively constant, it can be argued that temperature variations contribute, among other factors, to influencing seasonal malaria outbreaks.

Impacts of climate variables on malaria burden from a community perspective. Communities' estimates of monthly malaria prevalence and temperature trends over a 5- to 10-year period were documented in the study sites as part of the CRM TASP. This was done by using the stockpiling technique: community members were asked in focus groups to assess the intensity of temperature and malaria burden using stones (for example, five stones = high temperature, one stone = low temperature). The results were used to draw malaria and temperature trends in each site (see figure 8). The results show that the communities in the area of study have a good understanding of the seasonality of malaria epidemics. They understand that the peak of malaria epidemics traditionally occurs during the June-July-August period, approximately three months following a temperature increase. Interestingly, in most sites, the stockpiling exercise shows that community perceptions of malaria epidemics correlate with clinical data (see, for example, figure 9).

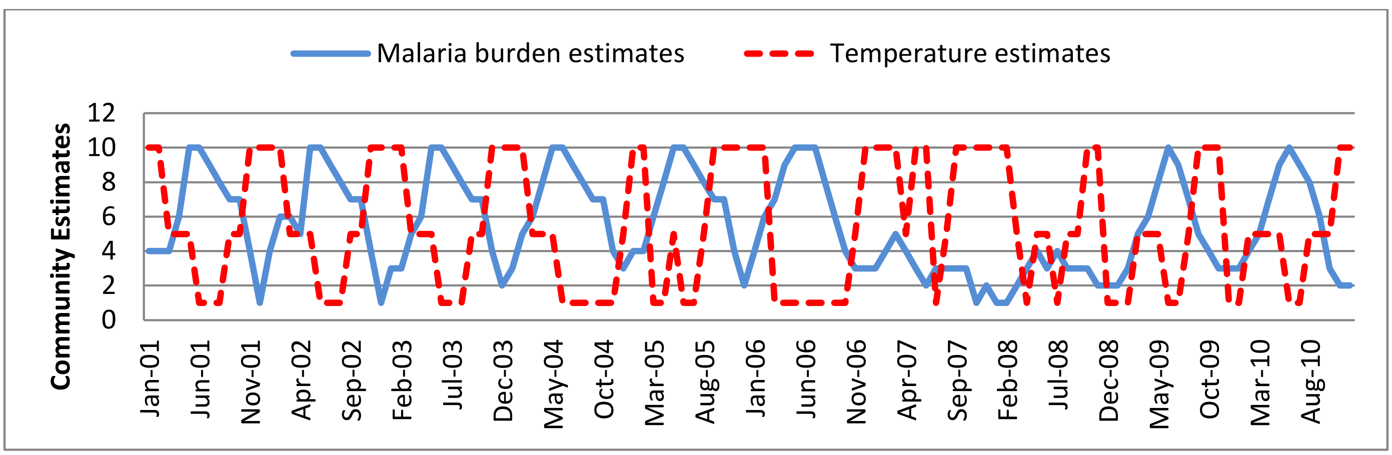

Figure 8. Correlation between community estimates of malaria burden and temperature trend over 10 years (2001–2010) in Ainamoi, Kericho District. Data collected by the Kenya Red Cross Society for the CRM TASP

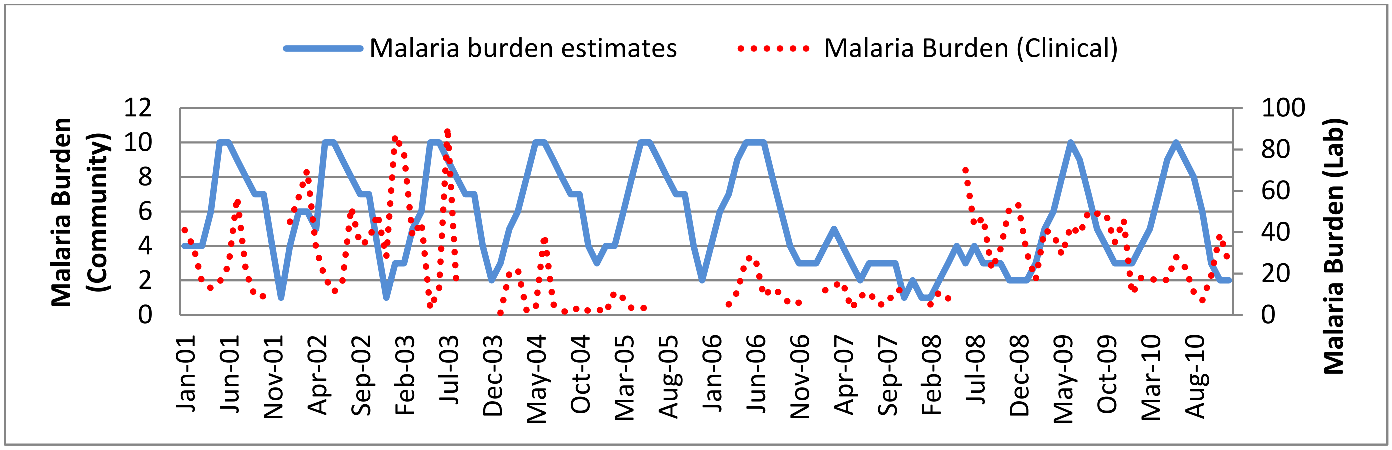

*Figure 9. Correlation between community estimates of malaria burden and confirmed malaria cases by laboratory diagnosis * over 10 years (2001–2010) in Ainamoi, Kericho District. Data collected by the Kenya Red Cross Society for the CRM TASP*

**Data sources: MOPHS (Global Environment Facility project on Piloting Climate Change Adaptation to Protect Human Health) for malaria burden (clinical); Kenya Red Cross Society for malaria burden estimates*

Impacts of climate hazards. Compared with other parts of Kenya, the Western highlands are not highly prone to climate hazards. The main climate hazards in the study area are heavy rainfall, floods and hailstorms (MSPNDV, 2009a–d). Despite high precipitation in some districts, other districts have also experienced prolonged droughts in the past (i.e., Trans-Nzoia West) (MSPNDV, 2009c). Kericho also experiences frost, while Kisii and Nandi are impacted by landslides. Floods (in the lower areas) and landslides are associated with environmental degradation (deforestation) in the upper highlands. According to the local consultations, the communities also experience greater seasonal unpredictability. Table 7 summarizes the main impacts of those identified climate hazards on livelihoods and on malaria epidemics. It shows that climate hazards can contribute to the deterioration of livelihoods, which are heavily dependent on farming activities, and this can constrain access to health care services. Depending on the local context (e.g., topography), climate hazards such as floods and droughts can either increase malaria risk by increasing mosquito breeding sites, or decrease risk by destroying the mosquitoes' habitats or slowing development of the vector.

TABLE 7. MAIN IMPACTS OF CLIMATE HAZARDS AND VARIABILITY ON LIVELIHOODS AND MALARIA EPIDEMICS IN THE STUDY AREA

MAIN CLIMATE HAZARDS IN THE STUDY AREA	DIRECT IMPACTS ON LIVELIHOODS	IMPACTS ON MALARIA EPIDEMICS
Heavy rainfall events	• Destruction of maize plantations and young tea bushes (waterlogging). • Increased size of swamps. • Deterioration of feeder roads.	• Creation and/or destruction of breeding habitats for mosquitoes. • Economic losses leading to less economic power to buy/access health care.
Greater seasonal unpredictability	• Lower crop yields.	• Shift in the occurrence and timing of malaria epidemics. • Economic losses leading to less economic power to buy/access health care.
Increasing temperature	• Some areas becoming unfavourable for tea-growing (Kericho, Nandi).	• Increase in areas prone to malaria epidemics.More chances to reach the 18° C threshold.
Landslides (Kisii, Nandi)	• Destruction of property and infrastructure.	• Limited/decreased access to health care facilities.
Frost (Kericho)	• Destruction of tea leaves (frost damage).	• Very low temperatures not conducive for vector breeding.
Prolonged droughts (Trans-Nzoia)	• Lower crop yields.	• Creation of breeding sites (running streams turning into stagnant pools of water suitable for vector breeding). • Fewer vectors due to high temperatures beyond their development threshold.

Impacts of extreme weather events. The El Niño Southern Oscillation has been linked to malaria epidemics in Africa, Asia and South America (Githeko et al., 2000) because it can seasonally increase the local temperature and rainfall (Githeko, 2009). According to the GOK, "since 1997/98, when all countries in the East and Great Lake region experienced malaria epidemics due to El Niño Southern Oscillation events, malaria epidemics now occur at least yearly either as localized or wide spread in several eastern Africa and Great Lakes countries during the malaria transmission season" (DOMC/MOPHS, 2011). The 1998/1999 malaria epidemics that ravaged the Kenyan highlands have been associated with short-term increases in temperature and rainfall related to the 1998/1999 El Niño (DOMC/MOPHS, 2011; Githeko et al., 2000). The El Niño phenomenon can also contribute to changing the timing of the 'normal' malaria peak season (Githeko and Ndegwa, 2001) and has been associated with increased frequency and severity of epidemics (Githeko, 2009; Githeko, 2010).

VULNERABILITY TO MALARIA EPIDEMICS IN THE CONTEXT OF CLIMATE RISKS

The vulnerability of the population of the western Kenyan highlands to malaria in the context of climate risks is very high due to a combination of increasing but differentiated exposure to malaria risk, high sensitivity to that risk, and relatively low adaptive capacity, especially at district and local levels.

Increasing but differentiated population exposure to malaria risks in the western highlands

The current pattern of malaria in the highlands is characterized by increased frequency, expanded geographic distribution and increased case-fatality rates compared with the period from the 1920s to the 1950s (Zhou et al., 2004). A review of case studies in the Western Kenyan highlands and consultations at local, district and national levels shows that a number of factors can explain the recent increasing exposure to malaria risk. These include changing climatic conditions that may be more favourable to malaria, combined with rapid changes in socio-economic and non-climate environmental conditions. Exposure to malaria risk is not homogenous, due to the topography of the highlands and population dynamics between the highlands and the lowlands.

Climatic conditions may be more favourable to malaria epidemics. As part of the CRM TASP, Gikungu (2012) conducted a climate analysis of the Kenyan highlands. The results show that temperature has increased in all sites over the last 30 years (contact the lead author at geneva@iisd.org for detailed results). Even if the temperature had not increased drastically, the impact on malaria risk may be important because the development of the vector is very sensitive to small temperature increases. The results indicate disparities among the four districts in relation to changing annual and seasonal rainfall patterns.[11] These trends are important because previous studies indicated that from an epidemiological view, temperature and rainfall interannual variability may be more important than mean annual variability (Zhou et al., 2004; Paaijmans et al., 2009; Bomblies and Eltahir, 2009). While some studies in East Africa, particularly in the western Kenyan highlands, have also found increasing temperatures (e.g., Omumbo et al., 2011, Wandiga et al., 2010; Githeko, 2009; Pascual et al., 2006), others (i.e., Hay et al, 2002; Zhou et al., 2004) have concluded that mean temperature and rainfall have not significantly changed in the East African highlands, or that regional disparities exist. These diverging results have been linked to the origins and type of data used to analyse temperature trends (Omumbo et al., 2011).

Socio-economic conditions becoming more favourable to malaria epidemics. The climate and soil of the western Kenyan highlands provides a rich agricultural potential, attracting very high population density. "Nearly seven million people (23 percent of the population) live in the 15 highland districts at risk of malaria epidemics including Nandi, Kisii, and Kericho" (Githeko, 2010: 89). The four study districts are among the 20 most densely populated districts of the country, with an average of 261 (Nandi) to 595 people per km^2 (Kisii), compared with a national average of more than 66 people per km2 (KNBS, 2009). In addition, the population growth rate is high. For example, Nandi North District reports a rate of 2.9 percent per year (MSPNDV, 2009c), higher than the national average of 2.4 percent (MMS & MOPHS, 2012a).

[11] Annual rainfall measurements in Kericho and Kisii indicate a decreasing trend, while the results for Kisii and Nandi indicate an increase. All districts except for Kisii have a tri-modal rainfall pattern (March-April-May, October-November-December and June-July-August-September). The amount of rainfall received during the long rainfall season (March-April-May) is decreasing in Kericho and Kitale, but is increasing in Kisii and Nandi. Rainfall received during the short rainfall season (October-November-December) is decreasing in Kisii, but it is increasing in Kericho, Kitale and Nandi. The rainfall received during the June-July-August-September season has been decreasing in Kericho but increasing in Nandi. The season does not show any clear trend in Kitale.

Agriculture is the main source of livelihoods in all four districts, and most of the land in the study area is under cultivation and homestead. Farmers often grow a combination of food and cash crops. Tea and coffee are generally produced in the area receiving a minimum of 1,500 mm rainfall per annum, while maize and livestock are found in the drier area (MSPNDV, 2009c). The main cash crops grown in the study area are maize, tea, coffee, sunflowers, pyrethrum (a perennial plant cultivated for flower heads) and beans (SoftKenya.com, 2012). The Trans-Nzoia West District acts as "the country's bread basket," with some of the country's highest maize production (MSPNDV, 2009d). Kericho is the main tea-growing region (Malakooti et al., 1998). This high proportion of land under cultivation increases the population's exposure to malaria, because agriculture tends to provide moist, disturbed environments that are likely to act as mosquito breeding habitats (Imbahale et al., 2011).

Over recent decades, **rapid land-use changes** have occurred in the region, resulting in more people living close to a growing number of potential breeding sites for mosquitoes. High density and high population growth have led to increasing settlements around water sources and increased farming around settlements. Development activities have led to an increase in infrastructure such as roads, dams, and quarries/excavation of sand and building stones, which can increase mosquito-breeding grounds. Large-scale plantations (tea, coffee, maize) have also attracted immigrants for work. High population growth and density combine with high poverty (see more information on this in the next section) to lead to encroachment on wetlands and riparian areas, increased cultivation and destruction of wetlands, and deforestation. The shrinking size of farms is contributing to reduced productivity and the development of new livelihood activities outside of farming that can be destructive to the land (e.g., brick-making).

Most of these changes are leading to serious **environmental degradation** and **microclimatic changes**, which are increasing exposure to malaria (e.g., Zhou et al. 2004; Afrane et al., 2008). In general, man-made habitats are more favourable to malaria parasites and mosquito vectors. For example, clearing vegetation can create clear, sunlit pools of water; increase local temperatures and change humidity levels; and change the area's biodiversity and decrease predation (Carlson et al., 2004). Community consultations and direct observations in the study areas done as part of the CRM TASP confirmed the proliferation of livelihood activities that create many sources of stagnant water, such as cultivation in swamps, brick-making, maize plantations, cultivation and animal grazing along riverine areas and riverbeds, quarrying, excavation of shallow wells, development of fish ponds, and excavation of animal watering points. Of these, the most significant activities increasing exposure to malaria were:

- **Deforestation.** Studies on the consequences of deforestation for malaria in Kenya have found that deforested sites have higher temperatures and decreased humidity levels, which affect biting, survival and reproductive rates of vectors, leading to higher vector capacities in deforested sites (Afrane et al., 2008). For example, it has been reported that "deforestation may partly explain why temperatures in Kakamega (western highlands) have risen 1.2 to 1.8 degrees in recent years" (Rapuro, n.d.: 3).
- **Cultivated swamps.** Cultivated swamps lack tall vegetation, such as papyrus, found in natural swamps, which increases shading (Minakawa et al., 2004). Communities are aware that cultivated swamps can represent a health risk, and they tend to locate themselves away from such sites whenever possible.
- **Brick-making.** One of the most abundant habitat types containing *A. gambiae* larvae are brick-making pits (Carlson et al., 2004). Brick-making has become an important economic activity in western Kenya. Proper back-filling as required by law is rarely carried out, so water ponds form. A study of brick-making pits in Kisii (Carlson et al., 2004) showed they provided man-made aquatic habitats during the dry season for malaria vectors. Coupled with the bushes around them, these sites increase mosquito breeding grounds and therefore malaria risk.
- **Large maize plantations.** These plantations are associated with a bushy environment that retains water and therefore may be conducive for mosquito development. In local consultations, it was noted that there has been a shift from tea to maize plantations in lower altitudes of the study area. This shift may be attributed to increasing temperatures, but further research would need to be conducted to validate this hypothesis.

While research has shown that the habitats most suitable for the development of A. gambiae cannot be generalized (Fillinger et al., 2004), studies done in the western Kenyan highlands tend to show that, in general, changes in land-use practices, such as swamp cultivation and deforestation, have improved the conditions for malaria vectors in the region (Minakawa et al., 2004).

Figure 10. Maize plantation (right), swamp (left) and houses on the background in Trans-Nzoia. Photo: Kenya Red Cross Society

Differentiated exposure due to heterogeneous topography and highland-lowland linkages. Topography influences the drainage system and therefore the development of breeding sites. The topography of the Kenyan highlands is heterogeneous, and so some areas in the highlands are more prone to epidemics than others (Wanjala et al. 2011). The topography of the Kenyan highlands can be classified as flat-bottomed valleys (U-shaped), narrow-bottomed valleys (V-shaped) and plateaus (Wanjala et al., 2011). U-shaped valleys only need 150 mm/month of rainfall to provide favourable conditions for breeding sites, because they have large flat surfaces where water can accumulate (Wanjala et al., 2011; Githeko, 2010). V-shaped valleys are much better drained, as they have a relatively small flat surface that provides smaller stable breeding sites. They need at least 250 mm to 300 mm/month of rainfall combined with high temperatures to provide stable breeding sites and initiate an epidemic (Githeko, 2010). People living in U-shaped valley systems are therefore more often exposed to malaria infections than those living in V-shaped ones. To sum up, populations living at lower altitudes within the highlands are more at risk from malaria epidemics, and populations closer to U-shaped valleys/valley bottoms are more exposed to malaria risks.

Population mobility also influences exposure to malaria risk. Human movements, such as the seasonal movement of workers between lowlands and highlands (that is, between endemic areas and non-endemic areas) can facilitate the spread of malaria to the highlands, where people have a much lower degree of immunity (Bloland and Williams, 2003; Malakooti et al., 1998; Carlson et al., 2004).The spread of malaria in the highlands in the early 1900s has been associated with the improvement of road transport and increased population movement (and especially the tea plantation workers) from malaria hyperendemic areas into the highlands (Malakooti et al., 1998). Today, the western highlands continue to attract labour from surrounding endemic regions of Western and Nyanza provinces to work in the maize plantations of Trans-Nzoia and the tea estates of Kericho and Kisii.

High population sensitivity to malaria risks

Sensitivity to malaria risk in the context of climate variability and change is considered to be high in the four districts in the study area due to at least three key factors: low immunity to malaria epidemics, relatively high poverty levels and poor health status. These factors tend to reinforce one another and form a vicious circle. Indeed, and as Dhiman (2009: 184) put it, "am I sick because I am poor, or am I poor because I am sick?"

Low immunity to malaria epidemics affecting all age groups. A population's immunity to malaria is a function of the intensity and duration of exposure to infections (Githeko, 2010: 34). Immunity is inversely related to malaria endemicity: people who are regularly exposed to malaria have greater immunity to the more severe outcomes of infection. According to MOPHS (DOMC/MOPHS, 2011), "case fatality rates during an epidemic can be up to 10 times greater [in non-epidemic areas] than what is experienced in regions where malaria occurs regularly." The characteristics of malaria epidemics in the Kenyan highlands thus mean that "people in the area have generally been less exposed to malaria risk and are therefore less immune and more sensitive to severe forms of malaria during malaria epidemics" (Wanjala et al. 2011: 4). In the highlands, malaria epidemics affect all age groups, as compared with endemic areas, where children under five and pregnant women are most affected.

High poverty. Limited access to resources (health services, food, information, etc.) can intensify communities' sensitivity to malaria (Wandiga et al., 2010). Despite their rich natural endowments and agricultural potential, poverty is still the main barrier to the development of the districts (see MSPNDV, 2009a–d). The four districts have poverty levels ranging from more than 44 percent (Kericho) to more than 60 percent (Kisii) in 2005/2006, compared with a national average of nearly 46 percent in 2005 (KNBS, 2009; World Bank, 2012). The poorest are the landless, small-scale farmers, casual workers and female-headed households (see MSPNDV, 2009a–d). High poverty contributes to environmental degradation but also negatively influences the rate of immunization. It is generally acknowledged that "the poor are disproportionately at risk" of malaria (Dhiman, 2009): they have less access to the most appropriate and timely treatment, and they are more prone to severe forms of malaria because malnutrition compromises their immune system and they have a higher probability of being affected by other diseases (e.g., HIV/AIDS).

Very young population with poor health status. Kenya has a very young population: in 2009, 43 percent of the population was under 15 years old (DOMC/MOPHS et al., 2011), and the western highlands are no exception. A young population is more sensitive to health risks, including malaria, because their immune systems have not fully developed. For example, in west Trans-Nzoia and central Kisii, about 15 percent of the population is under five years old (MSPNDV, 2009d,b).

High incidences of disease, in particular malaria and HIV/AIDS, are identified as a main barrier to development in all four districts. Trans-Nzoia and Kisii experience higher malaria rates than the average of the four districts (27.7 percent), while Nandi and Kericho are lower than the average. In north Nandi, the HIV/AIDS rate has increased from 2.3 percent in 1988 to 5.1 percent in 2007 (MSPNDV, 2009c). Causes of high disease incidence (MSPNDV, 2009a–d) include inadequate community mobilization, few trained community resource personnel, drug-resistant strains, high poverty levels, high costs of drugs, low doctor-patient ratios, few functional health facilities, poor geographical distribution of health facilities, poor feeding habits, malnutrition and few partners in the health sector. Environmental degradation (e.g., pollution of drinking water) further increases incidences of disease such as malaria, typhoid and cholera. In general, poor health negatively influences the rate of immunization and tends to increase the population's sensitivity to malaria risk because the people are immune-compromised.

Limited adaptive capacity

Despite political commitment and the progress made in fighting malaria, the adaptive capacity of the population to decrease the negative impacts of malaria epidemics in the western Kenyan highlands is limited due to at least three factors: the limited implementation of national strategies and plans, the inadequate and inequitable healthcare system, and the mixed effectiveness of national malaria control efforts.

Political commitment to fighting malaria, but implementation remains a challenge. Moving towards a malaria-free Kenya is a priority investment that represented 25 percent of the total health expenditure in 2009/2010—equivalent to expenditures on HIV/AIDS (MMS and MOPHS 2011). An institutional framework for malaria control is in place from the national to the community level and includes:

- The **Division of Malaria Control (DOMC) within MOPHS**, which has overall responsibility for planning and coordination of inputs and activities for malaria control at all levels.
- The **Malaria Inter-Agency Coordinating Committee,** established in 1999, which includes members from the Ministry of Health, civil society and the private sector. It also coordinates the implementation of all malaria programmes in Kenya.
- The **Kenya Medical Supplies Agency**, which is in charge of purchasing and supplying all drugs (including malaria drugs) to the districts.
- The **district health management teams**, the main coordinating mechanism at the district level for all health activities. All four districts have a malaria coordinator who reports on a regular basis to a functional and active district health management team.

Antimalaria efforts operating within this framework are guided by a collection of national policies and plans. A 'National Malaria Strategy' and 'Monitoring and Evaluation Plan for 2009–2017' have been developed, together with various guidelines, such as the 'National Malaria Treatment Guidelines' (GOK, 2010) and 'Integrated Vector Management Policy Guidelines'). The 2009–2017 'National Malaria Strategy' (MOPHS, 2009) provides a framework for the prevention, control and treatment of malaria in Kenya. The strategy is based on two priorities in line with the national health sector strategic plan for 2005 to 2010 (MOH, 2005) and the community health strategy (MOH, 2006): the shift from curative to preventive health care and decentralization of malaria control operations (i.e., focus on community participation in the health care system). The National Malaria Strategy is being rolled out at all levels through provincial and district malaria control coordinators and provincial and district malaria coordinating committees. Health surveillance teams are in place in each district, and information collected at the district level (including health surveillance reports) is shared electronically nationally on a weekly and monthly basis. The information is centralized in a national health database.

Guided by these policies, systems for the procurement and mass distribution of mosquito nets, malaria drugs, equipment and chemicals, which constitute the main national responses to malaria risk, are in place. But implementation of these strategies remains weak (e.g., Glenngard and Maina, 2007). Policy development remains top-down and ill-suited to local contexts. Other major barriers to implementation include inadequate funding, lack of coordination among stakeholders (e.g., donor agencies) and government institutions, and high dependency on malaria control programmes from central government and on external funding.

Inadequate and inequitable healthcare and related services. All the district development plans have identified inadequate health services as one of the main challenges to development (MSPNDV, 2009a–d). The high population density and increasing population growth create a substantial pressure on health care services, including high competition for hospital beds between general patients and those with HIV/AIDS. Other causes, as reported in the district development plans (MSPNDV, 2009a–d), include overstretched health facilities, lack of access to health centres due to bad roads, shortage of personnel and drugs, and low funding. This was validated during the local consultations conducted as part of the CRM TASP.

Improved access to clean drinking water and good roads were common cross-cutting issues in the district development plans and can have a major influence on human health. Limited access to clean drinking water increases the risk of water-borne diseases, while poor road networks limit access to health-care services. Finally, good roads can improve people's access to health centres and other services, especially in rural areas. The percentage of roads that are paved in the country is not very high, and the four counties considered are all close to the national average (9.4 percent) (Commission on Revenue Allocation, 2011).

Mixed effectiveness of national malaria control efforts. The decline in malaria rates from 1999 to 2009 has mainly been attributed to vector-control efforts, especially mass distribution of nets (insecticide-treated nets and long-lasting insecticidal nets) and indoor residual spraying against mosquitoes. A mass net-distribution campaign aimed at universal coverage for all children under five years old was organized in 2006. But due to funding constraints, only one follow-up campaign has happened since, in 2011, aiming at providing one net for every three inhabitants. Indoor spraying has been used in the highland epidemic region since 2005. Besides vector control, interventions have centred on improving access to malaria treatment and improving malaria diagnosis (DOMC/MOPHS et al., 2011).

Results from the '2010 Kenya Malaria Indicator Survey' (DOMC/MOPHS et al., 2011) show that the percentage of households that own one bednet has decreased from 63 percent in 2007 to 57 percent in 2010, presumably due to the lack of continued intervention, with the poorest owning fewer nets compared with the richest segment of the population. However, households in epidemic-prone areas tend to own more nets than in other zones. In the highland epidemic zone, 60 percent of households own at least one net, and 51 percent own at least one insecticide-treated net; the average number of treated nets per household is 0.9. In response to this decreasing trend in bed-net ownership, a campaign is planned to provide one net per two people, which is the universal coverage target, in endemic and highland epidemic-prone zones.

Overall, the results of the survey and the local consultations carried out as part of the CRM TASP show that communities are very dependent on government interventions for malaria control and that any reduction or cessation of malaria-control programmes can have a major impact on malaria burden. For example, in Nyakoe, Kisii, communities were asked to estimate malaria prevalence using the stockpiling method (see figure 11) and to comment on the results. They attributed the significant drop in malaria prevalence in 2007 to bednets and indoor residual spraying interventions carried out by MOPHS. The government also supports other integrated vector-management measures, such as larvicide and environmental management, in targeted areas (DOMC/MOPHS et al., 2011). However, according to the local consultations, bednet use is often considered to be the most effective strategy, because some responses may simply displace the risk to other areas (e.g., the destruction of hiding places in bushes can result in the vector seeking refuge in houses).

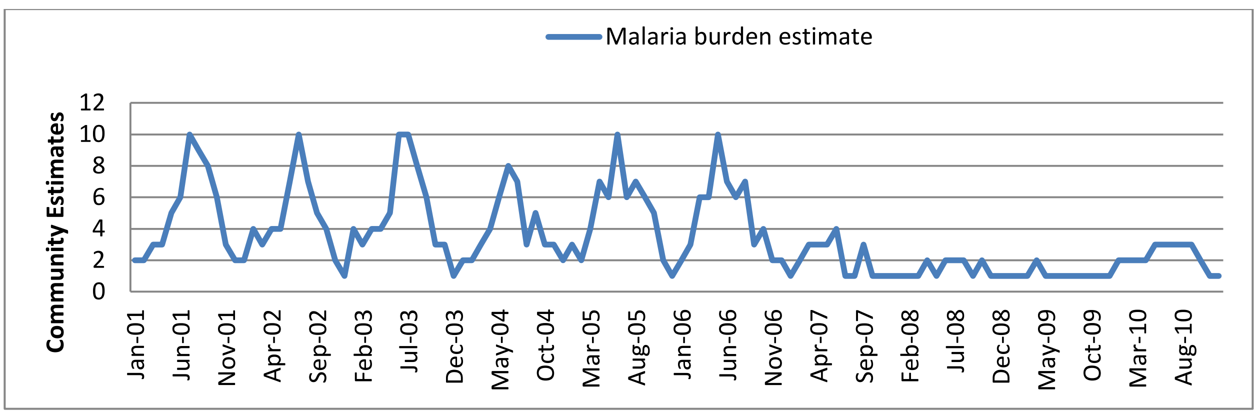

Figure 11. Population estimates of malaria burden in Nyakoe, Kisii, for a 10-year period (2001–2010)

Table 8 summarizes the main responses to malaria risk at national, district and local levels, demonstrating community dependence on national malaria programmes. Some local strategies appear unsustainable (e.g., drainage of swamps, larviciding using old engine oil, and in some cases self-medication). Interestingly, local consultations revealed that despite relatively high bednet ownership, the (constant) use of mosquito nets for protection against malaria is still low among households in the study area. This disconnect between community knowledge and action has also been documented in other studies in Kenya and elsewhere. As a result, awareness is growing of the importance of understanding the socio-cultural barriers (instead of solely financial ones) to the use of nets nationally. For example, the 2010 national malaria survey (DOMC/MOPHS et al., 2011) integrated data on attitudes towards bednets, which is a good step forward.

Other challenges to effective malaria control exist, such as limited effectiveness of antimalarial drugs, insecticide resistance, lack of coordination among different sectors and institutions, uncertainties due to lack of adequate data and the complexity of the issues, the short lead time of malaria epidemics, and the lack of prediction methods. But progress is also underway. For example, research on malaria forecasting in the western Kenyan highlands has been ongoing, with the aim to develop a predictive model (Githeko and Ndegwa, 2001). A model for early warning of malaria epidemics has already been developed and tested by Kenya Medial Research Institute (personal communication, Dr. Githeko, 08 February 2011), and MOPHS is also researching the development of a malaria early-warning and response system.

TABLE 8. EXISTING RESPONSES TO MALARIA RISK AT NATIONAL, DISTRICT AND LOCAL LEVELS

LEVEL	RESPONSE
National	1. Formulation of policies, strategies and guidelines.
	2. Procurement and mass distribution of mosquito nets.
	3. Procurement and distribution of malaria drugs, equipment and chemicals.
	4. Fund mobilization for district activities.
District	5. Distribution of medical supplies and nets to households.
	6. Surveillance by district malaria-control coordinator.
	7. Afforestation and agroforestry.
Local	8. Screening of windows (wire mesh and nets/cloths, sporadic use).
	9. Larviciding using old engine oil and *Bacillus thuringiensis israelensis* (a larvicide).
	10. Draining of swamps (sporadically undertaken in study area).
	11. Use of mosquito nets (over 50 percent).
	12. Crop-clearing around human habitations (people know about it, but they are not doing it because income from crops is rated higher than the risk of getting malaria).
	13. Self-medication.

FUTURE CLIMATE IMPACTS AND RISKS

The Government of Kenya has projected that current efforts should significantly reduce malaria burden by 2030 (MMS and MOPHS, 2012a). However, climate change has the potential to undermine achievement of this target. According to Gikungu (2012), rainfall projections for the next 57 years (to 2069) suggest varying rainfall patterns in all four stations. The 10-year projection (2013 to 2023) does not always match longer-term projections (up to 2069) in each site, and accuracy of projections beyond 10 years is relatively low. Temperature analyses for all four stations indicate that the area is warming, and this trend is expected to persist for the period from 2013 to 2069, albeit at different rates.

Assuming that all other characteristics of the districts remain constant (e.g. socio-economic, environmental, health care services etc.), the projected rising temperature and changes in rainfall may intensify existing health risks and create new ones. The influences of climate on malaria may occur directly or indirectly and may include:

Potential direct risks:

- **Changes in parasite and vector species, abundance and behaviour.** Pages 33–37 discuss the impact of climate variables on malaria transmission. In addition, species may adapt to environmental/climatic changes, and new malaria parasite and vector species may be found in the area.
- **Changes in the occurrence, distribution and intensity of malaria epidemics.** Because of the above, malaria transmission may increase, and so may the frequency and severity of epidemics. As a result, more people in the highlands may be affected by severe forms of malaria epidemics. In the lowlands, current malaria-control interventions may effectively render the area unstable; as the population becomes less exposed to malaria, they may also be at greater risk of explosive epidemics whenever climatic conditions are favourable.

- **Risk of higher mortality rate**. All the changes mentioned above and related uncertainties may further complicate prediction of malaria epidemics.

Potential indirect risks:

Changing climatic conditions could indirectly affect the level of malaria risk in the Kenyan highlands in a variety of ways, including:

- **Deterioration of water quantity and quality,** with direct implications for the overall health of people, and indirect implications for food production.
- **Deterioration of health care**, as the effect of climate risk on other diseases and (in the case of extreme events) on morbidity and mortality overstretch the health system.
- **Declining food production systems**, potentially leading to malnutrition, which would further increase people's vulnerability to malaria epidemics.
- **Migration**, as people from other districts and countries move to the more fertile and productive highlands. The associated population pressures could constrain access to health services and increase the spread of disease and people' exposure to malaria risks. Risk of conflicts over resources (land, water) also may increase.
- **Increased socio-economic costs** due to loss of work and high expenditures on malaria and other health treatments. At the same time, should Kenya's economic performance decline due to the negative impacts of climate change on all the sectors of the country, the total government expenditure on health may decrease.
- **Intensified socio-economic inequalities due to increased poverty.** The poorest are already the most vulnerable to malaria and pay the highest costs. Climate change will exacerbate these inequalities.

These future risks may be amplified by socio-economic trends such as population growth, poverty and environmental degradation. Additionally, drug and insecticide resistance could render disease-control measures less effective. Thus, though climate change could only have a limited impact on disease spread, this impact could be more important within this changing context (Thomas, 2010, in Tatalović, 2010).

Key messages: Climate risk profile

- Malaria continues to be the number-one cause of disease and mortality in Kenya. The disease is now re-emerging in the western Kenyan highlands, which were previously malaria-free, due to a combination of climate and non-climate factors. Of the former, the combination of unusually high temperatures, rainfall and humidity are conducive to malaria epidemics.
- The current vulnerability of the population of the western Kenyan highlands to malaria epidemics is very high due to increasing but differentiated exposure to malaria risk, high sensitivity, and relatively low adaptive capacity, especially at district and community levels.
- Without any intervention, the projected rising temperatures and changes in rainfall patterns may intensify existing malaria risks and create new ones. These risks may be exacerbated by other socio-economic trends such as population growth, poverty and environmental degradation.
- Temperature increases may not result in an increase of malaria transmission and diffusion, due to their interaction with other factors (environmental, socioeconomic, cultural, political). As a result, there is uncertainty about the future risk associated with malaria.

INSTITUTIONS AND POLICIES FOR CLIMATE RISK MANAGEMENT

This chapter looks at current institutional and policy arrangements for climate risk management as well as key actions, followed by an analysis of current national risk management capacity. Climate risk management involves the systematic use of climate information in development decision-making to minimize the potential harm or losses associated with climate variability and change. For climate risk management efforts to be successful, an effective policy framework needs to be in place; institutions must enable effective communication among different stakeholders, and high-quality climate data and information must be available, with sufficient resources (human, technical and financial) to use information effectively (Hellmuth et al., 2007). This section examines the extent to which these requirements for successful climate risk management are present in Kenya today—and therefore the country's capacity to cope with the greater complexity and uncertainty of climate risks in the future due to climate change.

Climate risk management is most prominently undertaken as part of efforts to facilitate disaster risk management and climate change adaptation. Despite their interconnectedness, in Kenya, as in many developing countries (UNDP, 2002), different institutions and policies support disaster risk management efforts and adaptation to climate change.

DISASTER RISK MANAGEMENT

Disaster risk management, including management of climate risks, is the responsibility of the **Ministry of State for Special Programmes (MOSSP)** in collaboration with the National Disaster Operation Centre in the Office of the President. The MOSSP was established within the Office of the President in 1994 (GOK, 2009). Its overall objective is to promote the establishment of comprehensive disaster management in Kenya, including disaster prevention, mitigation, preparedness, response and recovery (MOSSP, n.d.). Its functions include the development and implementation of comprehensive disaster management policies and programmes, as well as coordination of resources mobilized to manage disasters (MOSSP, n.d.).

The **National Disaster Operations Centre (NDOC)**, established in 1998, focuses primarily on emergency response. Composed of officers from different ministries and departments (Ngethe, 2010), it is responsible for executing decisions of the **National Disaster Coordination Committee**, an inter-ministerial committee composed of permanent secretaries and formed when major disasters occur (Mutimba et al., 2010; Sana 2007). NDOC coordinates rapid-onset disaster-response efforts by liaising with, coordinating and mobilizing responsible ministries/departments and donors. Further responsibilities of NDOC are monitoring, collecting and disseminating relevant information before, during and after a disaster year-round, collaborating with other stakeholders, sensitizing the public, and preparing an inventory of resources (Ngethe, 2010).

Other institutional arrangements established to address disaster risk reduction include:

- A **National Disaster Management Executive Committee** that falls under the Cabinet office and is responsible for developing disaster intervention programmes, and **district disaster management committees** responsible for managing disasters within their jurisdictions (Sana, 2007).
- A **National Platform on Disaster Risk Reduction**, established in 2004 to support implementation of the 'Hyogo Framework of Action 2005–2015.' The platform provides a forum for stakeholder engagement (ministries, governmental bodies, NGOs, multilateral organizations and the private sector) and coordinates the integration of disaster risk reduction into development (MOSSP, n.d.; ROK, 2009).
- A **national drought-management system** established almost 20 years ago (Zwaagstra et al., 2010). This coordination and response system includes the Kenya Food Security Structure composed of the Kenya Food Security Meeting (an advisory group composed of national stakeholders and donor agencies) and the Kenya Food Security Steering Group, which coordinates the monitoring of food emergencies and manages response mechanisms to food insecurity and droughts (MOSSP, n.d.; Mutimba et al., 2010; ROK, 2009; Zwaagstra et al., 2010).
- A **Drought Management Authority**, housed within the Ministry for Development of Northern Kenya and other Arid Lands and established in November 2011 (National Council for Law Reporting, 2011). Its mandate is to "establish mechanisms to ensure that drought does not become famine and the impacts of climate change are sufficiently mitigated" (MDNKAL, n.d.; National Council for Law Reporting, 2011).

Current disaster risk management efforts in Kenya are mostly focused on reactive, short-term emergency or relief responses as opposed to comprehensive disaster management (IRIN, 2010; MOSSP, n.d.). They are also impeded by the absence of a coordinated institutional framework that enables systematic preparation for and response to disasters (MOSSP, n.d.; Zwaagstra et al., 2010). This situation has resulted in slower and less coordinated responses to disasters, and additional costs (IRIN, 2010; Ngethe, 2010). For example, an assessment of the costs associated with responding to the 1999 to 2001 drought estimated that an effective disaster management system would have saved US$172 million (IRIN, 2010).

To address this situation, a **'National Disaster Management Policy'** has been drafted (GOK, 2009). The creation of this policy was initiated in early 1999 (GOK, 2009), and its content has evolved over the years in response to the emergence of new issues like climate change (IRIN, 2010) and the need to align it with Kenya's new constitution (KNPDRR, 2011). A final draft of the policy was presented to Cabinet in 2010 (KNPDRR, 2011), but has not yet been approved. The draft 'National Disaster Management Policy' establishes a framework for institutionalizing and coordinating disaster risk management across sectors and actors, placing equal emphasis on prevention, preparedness and recovery (GOK, 2009).

The draft policy specifically recognizes the inter-linkages between disaster risk management and climate change adaptation. Acknowledging that climate change is likely to increase the frequency and unpredictability of climate-related hazards, climate change adaptation is presented as a "foundational concept" of the draft policy (GOK, 2009: 10). It is expected that the MOSSP will have greater responsibilities related to climate change adaptation, including undertaking research, advising the National Environment Management Authority (NEMA) and the Ministry of Environment on measures "to safeguard the environment based on hazard risk analysis and climate change research," advising line ministries on how to reduce natural hazard risks, including those linked to climate variability and change, and providing information to communities about the potential impacts of climate change and ways to increase their resilience (GOK, 2009: 29).

A **'Disaster Risk Reduction Strategy for Kenya 2006–2016'** has also been prepared. It aims to "lay a firm foundation to sustain community resilience to disaster events," support an integrated approach to disaster management, and provide guidance on the mainstreaming of disaster risk reduction into development programming, planning and implementation (GOK, 2006: 49). The strategy sets out seven goals, including enhancing the legal and policy framework for disaster management in Kenya, establishing a focal point for disaster management activities, and reducing the impacts of climate change. With respect to the latter, the strategy seeks to support local adaptation, build capacity to use climate forecasts and risk assessments to develop plans, mainstream adaptation into development planning, and integrate climate change projections into disaster management efforts (GOK, 2006).

CLIMATE RISK MANAGEMENT

The **Ministry of the Environment and Mineral Resources (MEMR)** is the focal point for climate change and has lead responsibility for coordinating and supervising climate change efforts (adaptation and mitigation) across all sectors (Mutimba et al., 2010). The Ministry of Forests and Wildlife is primarily involved in efforts to reduce greenhouse gas emissions through forestry activities, and the Kenya Forestry Service has been designated as the focal point for REDD (reducing emissions from deforestation and forest degradation) activities. A number of other ministries and government agencies are also engaged in climate change–related projects and programming. These include NEMA and the Kenya Meteorological Department, but also the ministries of Land, Water and Irrigation; Northern Kenya and other Arid Lands; Fisheries, Tourism, Public Health and Sanitation; Agriculture; and Energy (Mutimba et al., 2010). As well, the Kenya Agriculture Research Institute has established a climate change unit with the principle objective of providing leadership, information and technologies that will support climate change adaptation.

Main institutional arrangements established to address climate change adaptation include:

- The **National Climate Change Activities Coordinating Committee,** established in 1992, is composed of 25 representatives from several ministries as well as municipalities, public universities, the private sector and NGOs (Mutimba et al., 2010; Ogola, n.d.). Aside from coordinating the activities of the Government of Kenya on climate change, it also aims to facilitate research on climate change impacts and possible adaptation measures, establish a database on climate change impacts and response strategies, and provide policy advice on climate change (Ogola, n.d.).

- An **Environment and Climate Change Coordination Unit,** formerly called Climate Change Coordination Unit, was established in the Office of the Prime Minister in 2008 to support coordination of activities and the mainstreaming of climate change into the work of different ministries (Matiru, 2009; Mutimba et al., 2010). However, the Office of the Prime Minister has been removed under Kenya's new constitution. This office will not exist after national elections, expected in March 2013. The status of the unit after this date has not yet been determined.
- A **Climate Change Secretariat,** established in 2011 within MEMR, is responsible for overseeing all climate change issues and programs (GOK, 2010).

At the policy level, Kenya released the **'National Climate Change Response Strategy' (NCCRS)** in 2010. The strategy was developed in part to address a perceived shortcoming in 'Vision 2030,' which does not fully recognize the potential for climate change to hamper achievement of Kenya's ambitious development goals (GOK, 2010). Within the context of achieving 'climate-smart' development, the main focus of the strategy is to ensure the integration of climate change adaptation and mitigation into "all government planning, budgeting and development objectives" (GOK, 2010: 12). It proposes key adaptation measures for the sectors of health, agriculture, water, fisheries, tourism/wildlife, livestock/pastoralism, physical infrastructure and social amenities (which include human settlements). It also recommends modernization and enhancement of Kenya's national meteorological services and strengthening of the country's capacity to plan for, cope with and recover from climate disasters (GOK, 2010).

The Climate Change Secretariat is currently spearheading the development of a **climate change action plan**. The action plan process, to be completed in 2012, will include sections on adaptation, mitigation, financing, policies and laws, monitoring and review, technology and capacity development. The adaptation work includes examination of options for adaptation and the creation of a national adaptation plan. The MEMR is also encouraging the establishment of climate change focal points in all ministries to better enable effective facilitation of climate change adaptation activities at the ministry level. To further strengthen Kenya's institutional system for managing climate change, the NCCRS suggests that the National Climate Change Activities Coordinating Committee continue to perform an advisory role, while a new National Climate Change Steering Committee be established to support coordination of Kenya's climate change activities (GOK, 2010).

The Government of Kenya has acted to improve its climate change institutions, yet action remains somewhat uncoordinated, leading to duplication of efforts in certain cases (Mutimba et al., 2010). Other concerns include the absence of sufficient human and physical resources and capacity within MEMR and the Climate Change Coordination Unit for them to effectively fulfill their responsibilities (Mutimba et al., 2010).

MAINSTREAMING OF CLIMATE RISKS INTO KEY HEALTH STRATEGIC DOCUMENTS

The government has made a substantial effort to integrate climate risk considerations (related to climate variability and change) into its policy planning. However, so far limited effort has been made to mainstream climate risk into key health strategic documents. But interest is growing in the links between climate change and health (for example, a national working group on climate and health exists), which could help move in this direction. The key planning documents that consider health are provided below and assessed in terms of how well they integrate climate change considerations:

Somewhat integrated

- '2009–2017 National Malaria Strategy.'
- Ministry of Public Health and Sanitation's strategic plan for 2008 to 2012.
- 'Kenya National Plans of Joint Action for the Implementation of the Libreville Declaration on Health and Environment in Africa' (MOPHS and MEMR, 2010).

Not integrated

- Final draft 'National Health Policy,' 2012 to 2030 (MMS and MOPHS, 2012a).
- 'Second National Health Sector Strategic Plan of Kenya (NHSSPII) 2005–2010' (MOH, 2005).
- Community health strategy (MOH, 2006).

CLIMATE RISK MANAGEMENT ACTIVITIES

Projects related to human health tend to focus on improving health-delivery systems at the national and local level as part of broader development activities, including actions such as rehabilitating health clinics and dispensaries, strengthening disease outbreak monitoring, and distributing insect repellents and mosquito nets. Few health initiatives explicitly focus on climate change and more specifically on the development of a malaria epidemic prediction model. In this regard, research capacities exist, for example within the Kenya Medical Research Institute and its Climate and Human Health Research Unit. Most current adaptation projects in Kenya address needs related to agriculture and, to a lesser extent, freshwater resources, disaster risk management, pastoralism and coastal zone management (Hove et al., 2011), which are also closely related to human health. Many of these ongoing adaptation projects focus on the ASALs and other rural areas (Hove et al., 2011).

Early lessons from the implementation of dedicated climate change adaptation projects highlight the need for greater capacity and coordination. While awareness has been raised regarding the need to respond to the threat posed by climate change, the capacity of people and organizations to act upon this knowledge and integrate these concerns into their mandates remains limited. As well, the sharing of experiences and knowledge gained through the implementation of current adaptation projects between different NGOs and organizations is not taking place due to various factors, such as the absence of time for overworked personnel to write up and share lessons learned with others, the format in which reports are made available, and competition among organizations for limited financial resources (Matiru, 2009). Moreover, few projects and programs involve collaboration among diverse stakeholders (Matiru, 2009), further limiting the opportunity for knowledge-sharing and capacity development. In particular, greater collaboration is required among agencies focused on research that supports climate risk management and those implementing measures at the community level (Matiru, 2009).

Limited coordination among current initiatives is also a concern. The presence of multiple actors within and outside of government actively engaged in climate risk management activities provides a considerable base upon which to take action. However, in the absence of effective coordination, there is a risk of duplication of efforts and inefficient use of financial and human resources (Matiru, 2009). The establishment of the Climate Change Coordination Group by donors and the Kenya Climate Change Working Group by civil society aims in part to address this challenge, but the success of each depends on the degree to which participants have the capacity and willingness to share information and coordinate their efforts (Matiru, 2009). A further concern is the lack of clarity regarding the mandate of different agencies within the GOK with respect to climate change, which has led to confusion and conflict (Matiru, 2009; Mutimba et al., 2010).

To effectively engage in climate risk management in Kenya, there is a need for enhanced capacity by actors in different sectors and at different levels of jurisdiction, greater sharing of lessons learned, and more coordinated implementation.

ASSESSMENT OF CLIMATE RISK MANAGEMENT CAPACITY

An assessment of Kenya's capacity to manage climate risks may be informed by application of the 'National Adaptive Capacity Framework' developed by the World Resources Institute (WRI, 2009). The framework evaluates capacities based on availability, systematization and mainstreaming of and capacity to conduct risk assessments; existence of explicit risk management priorities and a process to revise these priorities; existence of coordination processes and bodies; sound management of information; the identification of risks for priority areas; and evaluation of adaptation options as well as their implementation. The 'National Adaptive Capacity Framework' was used in the context of this study based on a desk-based review of the literature.

Assessment. In Kenya, a range of assessments have been undertaken that focus primarily on the country's vulnerability to climate change and are used to inform policy responses. These assessments have looked at a number of sectors (particularly agriculture), in different regions of the country (particularly the ASALs). While providing a strong basis for going forward, understanding of the potential impacts of climate change on certain sectors such as freshwater fisheries, infrastructure and tourism, and vulnerable groups remains limited. As well, a comprehensive assessment of Kenya's disaster risk has not yet been completed. Nor has a consolidated national vulnerability assessment been prepared, although ongoing efforts related to the development of the National Adaptation Plan should address this. The NCCRS also recommends periodic assessments of how climate change might affect Kenya's people, economy and environment (GOK, 2010).

Prioritization. The NCCRS (GOK, 2009) has already identified priority interventions for adaptation in the most vulnerable sectors (agriculture, tourism, infrastructure, health and natural resources—forestry, wildlife, fisheries and marine), including sectoral research needs. The completion of the National Adaptation Plan will further support these positive steps.

Coordination. The institutions described on pages 50–53 represent efforts to coordinate climate risk management vertically and horizontally. The Ministry of Planning has also developed the Threshold 21 Model (T21), which integrates the analysis of the risks and impacts of climate change across the major sectors in the economy. Despite this clear progress, some important deficiencies remain. For both climate change adaptation and disaster risk management, vertical coordination continues to be limited, with most efforts taking place at the national level. The establishment of structures like the National Climate Change Activities Coordinating Committee has not necessarily led to greater interministerial coordination or the integration of climate concerns into national planning processes, in part because of lack of understanding by participants (NEMA, 2005) and weak capacity of existing institutions (Matiru, 2009). As well, some overlap in mandates exists, authority in the area of disaster risk management is hampered by the absence of an enacted policy framework, and implementation is impeded by financial, human resource and capacity limitations. Finally, coordination between risk management and adaptation institutions remains limited and may lead to duplication of efforts. The Government of Kenya is addressing these deficiencies through recommended policy and institutional changes, such as the establishment of the Climate Change Secretariat, a review of policies and laws, and the development of an action plan, which itself involves interministerial coordination.

Information management. One of Kenya's strengths is the country's capacity to collect, assess and disseminate information on climate and associated risks. Climate observation and monitoring systems of KMD and ICPAC are established, maintained and updated well. Data is also being gathered through government bodies like the Central Bureau of Statistics, Department of Resource Surveys and Remote Sensing, and National Disaster Operations Centre. To facilitate information-sharing related to climate risks, MOSSP has formatted a 'one-stop-shop data centre' that provides access to a national inventory of resources and capabilities available in all national, private, NGO, community-based and individual institutions (MOSPP, n.d.: 22). Gaps remain, however. KMD, for instance, is understaffed and has limited resources to collect and disseminate data, and its products are not as widely used by institutions, sectors and the public as is desirable (Matiru, 2009). The number of professionals with expertise in the area of meteorology in Kenya is also limited (Matiru, 2009). Furthermore, climate forecasts prepared by the KMD, particularly for some high-impact weather events like floods, could be improved by providing greater access to real-time data (Mwangi, n.d.). Notably, information is limited about key natural ecosystems, progress towards health goals and sex-disaggregated data. Better coordination of the collection and sharing of socio-economic data between public and private sector institutions is also required (GOK, 2008: 41). In response to these concerns, Kenya's 'Vision 2030' includes a Meteorological Systems Modernization Programme, which includes a component for enhancing capacity for dynamic modelling for weather forecasting and climate projections (GOK, 2007b). As well, as part of its 'Medium-Term Plan 2008–2012,' Kenya has stated its intention to improve climate data and information management (GOK, 2008).

Climate risk reduction. Overall, Kenya has a number of vibrant institutions in place that provide the basis for creating a more coherent and stronger climate risk management system. It also has demonstrated a clear policy commitment to addressing climate risks, through development of the 'National Climate Change Response Strategy' and draft 'National Disaster Management Policy.' However, a recent assessment concluded that "Kenya is not adequately adapted to deal with existing climate risks" (SEI, 2009: ii). Kenya will need to build upon its existing assets to address gaps in policy, institutional coordination, vulnerability assessments and information access that presently impede its capacity to actively engage in climate risk management.

Key messages: Institutions and policies

- Recently, Kenya has made very positive strides towards the establishment of an enabling institutional and policy environment for reducing risks from disasters and for addressing climate change.
- Continuous progress, especially in terms of coordination of actions and securing resources (human and financial), is required to ensure effective implementation of key strategic documents.

RECOMMENDATIONS FOR CLIMATE RISK MANAGEMENT

Climate variability and change can pose significant threats to human health, yet many impacts are avoidable if vulnerability is reduced, particularly through strengthening adaptive capacity at national and subnational levels. Based on the risk and capacity analysis previously presented, this chapter outlines key recommendations for specific local actions, avenues for further research, and adjustments in policies and institutions to facilitate action and research.

PRIORITY ACTIONS

Most of the following climate risk management options for malaria control were identified during a national workshop (January 2012) with key stakeholders from health, climate change and disaster risk reduction sectors based on the results of the climate risk assessment.

Strengthen the health system

A strong (effective and equitable) health-care system is a prerequisite for minimizing the negative impacts of climate risks on human health, including a potential rise in the malaria burden. People's ability to fight malaria infection partly depends on their immunosuppression, or the extent to which their immune system may be already compromised as a result of certain diseases such as AIDS or malnutrition. Patients who are immunocompromised are at greater risk of suffering malaria attacks that could be fatal. A healthy nation can contribute to reducing the socio-economic costs related to health care and provides a dynamic workforce that can support economic development. Two critical barriers to improving the health system remain, however: equitable access and adequate funding.

Funding to strengthen the health system should especially be allocated to:

- Responding to the current shortage in staff and medical supplies and improving emergency preparedness in case of epidemic alerts (i.e., increased 'surge' capacity to respond to emergencies), which may increase in the context of climate change.
- Training the health workforce and health officials, especially at the county level, to increase and update the understanding of climatic influences on health
- Monitoring and surveillance to provide timely information for malaria epidemic prediction
- Providing insurance mechanisms for the poorest and most vulnerable segments of the society.

An additional concern going forward is the management of Kenya's ongoing decentralization process. In the future, county health departments will be formed with the responsibility of planning and raising resources for defined services (MMS and MOPHS, 2012b). This structure could facilitate access to financial resources at the district level.

Improve malaria epidemic prediction

Climate change brings greater uncertainties in malaria transmission. Improving malaria epidemic prediction is therefore important, and it requires at least the following actions:

- Intensive monitoring and routine surveillance of climate and non-climate risk indicators.
- Development of a malaria early-warning system to determine the timing of epidemics so timely responses can be deployed
- Combining local knowledge of weather changes with scientific knowledge, and improving data flow.

Monitoring and surveillance. Due to climate risk, the spatiotemporal distribution of malaria is highly variable: it can change constantly. Climate variability and change therefore call for increasing monitoring and surveillance of the dynamics of malaria transmission and diffusion by locality. This includes monitoring of climate, health and socio-economic risk indicators (e.g., climate anomalies, mosquito numbers, allergen concentration, migration patterns) and health outcomes (e.g., infectious disease outbreaks, etc.) in sentinel sites across the different malaria risk zones, and especially in the unstable malaria areas where people have low immunity. Specific efforts also need to be made to collect baseline data pertaining to topography, land-use cover and socio-economic indicators as well as data regarding Kenya's diverse land forms to account for spatial variability of microclimates, and analysis of such data. In addition, initiatives should be developed to build the capacity of weather-monitoring agencies and their staff to enable them to collect, analyze and interpret the weather/climate data and information for accurate prediction of likely climatic risks and impacts.

A malaria early-warning system. Currently, a three-month advance malaria prediction is necessary for sound epidemic alerts and increasing preventive actions, and a one-month advance malaria prediction is necessary for sound confirmatory epidemic alerts for increasing treatment capacity of health facilities (Longolomoi and Nzioka, 2012). Early alert systems should be developed to detect signals related to impending weather extremes and infectious disease outbreaks. This requires the application of epidemiological, geographical and climatic information (historical and forecast data) to predict epidemics. In addition to and in spite of sound institutional systems for collection and analysis of climate data, a gap is felt in in-depth climate and weather analysis due to a severe lack of local weather data in Kenya. This necessitates establishing appropriate institutional and technical systems for addressing the entire cycle of early-warning systems, including setting up hydrometeorological stations, monitoring and tracking, analysis and assessment, dissemination, and feedback from stakeholders. The private sector could play a larger role.

Community participation and improving flow of data and information. Combining local knowledge of weather change with scientific knowledge may help predict malaria upsurges. A lot of data already exist, but there is a need to improve the flow of data- and information-sharing across all levels: vertically, especially from community to district and national levels and vice versa, and horizontally, across government (the different ministries) and between government and civil society (research institutions, NGOs and the private sector).

Develop targeted, innovative interventions adapted to local needs and contexts

In the introductory subsection of 'Climate Impacts and Risks' (pp. 33–35), we highlighted the heterogeneous nature of exposure, sensitivity and adaptive capacity to malaria epidemics. Studies have demonstrated that the effects of different variables on malaria transmission cannot be generalized, and transmission patterns are often very specific by species and site (Patz and Olson 2006). Githeko (2009) argues that increases in malaria cases in the central Kenyan highlands can solely be explained by an increase in mean annual temperature after the 1990s because this is the only change that occurred at the time in the area; while in the western Kenyan highlands, other factors need to be taken into account, such as drug resistance, human mobility, land-use changes and lack of vector control. Habitats most suitable for the development of *A. gambiae* cannot be generalized (Fillinger et al., 2004). Changing climatic factors may further accentuate the dynamic conditions of malaria transmission. This calls for the development of more targeted and innovative interventions adapted to local conditions. So far, however, malaria control measures have mainly been top-down, with limited community involvement.

Control measures have mainly focused on technical responses (bednets, spraying) and on removing financial barriers (i.e., mass distribution of nets), while understanding of social-cultural barriers remains limited. Accounting for socio-cultural barriers should become systematic in the design and application of antimalaria activities and programs. For example, during the consultations it was mentioned that white nets may be associated with death (i.e., covering of coffins with white cloths), which may prevent their use in some cases. Women also tend to give the nets to their children or husbands and may therefore be more at risk. Working closely with landowners and homeowners in the design and development of health programs can lead to more effective and efficient interventions. Mapping aquatic vector breeding sites may be useful to support targeted interventions such as targeted indoor residual spraying, as recommended by Githeko (2009) and Zhou et al. (2011.

Improve communication and increase awareness

There is a need to improve communication and information flow on climate and health risks, especially to the communities. The mass distribution of mosquito nets in itself is not sufficient. It needs to be supported by information and awareness campaigns on behaviour, actions and practices that limit exposure to mosquito bites. The information (e.g., use of bednets) should be repackaged in such a way that it can be understood by the users (e.g., translated in their own languages) and better received (i.e., appropriate timing). Cross-sectoral collaboration is also important to support an integrated approach to risk communication. For example, malaria control information can be integrated in existing activities and communication channels such as agricultural extension and

HIV/AIDS campaigns, to ensure continuous and consistent behavioural change messages. The repackaging of information should build on best practices in other sectors and on other issues (such as MOPHS's successful campaign to promote hand-washing).

GOVERNANCE

Climate change and its (uncertain) impacts on malaria transmission further heighten the need for cross-sectoral collaboration. Climate risk management measures can also increase health risks (e.g., irrigation schemes to mitigate drought can create more breeding grounds for mosquitoes) or create new ones. Inherent competing priorities and trade-offs between different sectors and actors at different scales should be made explicit and addressed. This calls for strong cross-sectoral collaboration among ministries and across all levels and actors (researchers, policy-makers and decision-makers, and the public and private sector) to improve policy coherence and implementation and to increase effectiveness of climate risk management and malaria control measures. The need to strengthen collaboration with health-related sectors is already reflected in key health strategic documents (see 'Conditions, Trends and Priorities of the Health Sector,' pp. 24–25, for a list). To achieve this, the Government of Kenya plans to adopt "a 'Health in all Policies' approach, which ensures the health sector interacts with and influences design implementation and monitoring processes in all health related sector actions" (MMS and MOPHS, 2012a).

To strengthen cross-sectoral collaboration, we have identified the following recommendations:

- **Implement the Libreville Declaration,** signed in 2008 by various African governments, including Kenya, to address the links between environment and health issues. Ensure that **natural resource management** is an integral part of disaster risk reduction and adaptation interventions by adopting and promoting the **ecosystem-based adaptation approach.**
- **Legislate on potentially conflicting acts of Parliament** that protect wetlands and that promote the destruction of mosquito breeding grounds.
- **Strengthen the links between malaria control and disaster risk reduction activities** at all levels, and especially improve links between the standard operating procedures developed to respond to malaria epidemics and the national disaster platform, and between the disaster management committees and the district malaria coordinating committees.
- **Institutionalize the collaboration** between the Meteorological Department and the Ministry of Health on climate and meteorological information-sharing.
- **Strengthen coordination between actors engaged in disaster risk management and climate change adaptation,** through clear institutional guidance.
- **Ensure that climate risk management interventions focus on both climatic and non-climatic drivers** that accentuate risks and impacts of processes related to climate risks.

FURTHER RESEARCH

Globally, progress to combat malaria is underway, including the development of a vaccine (Kelland, 2011). Nationally too, progress is underway, with, for example, the development and testing of a malaria prediction model. A lot of research has already been done in Kenya on the links among climate variability, climate change and malaria, especially in rural areas and in the highlands. However, uncertainties remain as to the relationship between climate change and malaria transmission. Further research needs on the links between climate and malaria in Kenya include:

- **Longitudinal case studies.** Our study could not determine the extent to which climate factors exacerbate or mitigate malaria burden in the study area now or in the future. Indeed, temperature increase may not automatically result in increased malaria transmission and diffusion, because many factors and feedback loops are involved. This calls for much more detailed analysis of the factors responsible for malaria transmission in selected sites over time.
- **Malaria-prone livelihoods.** Some livelihood activities may be more conducive to malaria transmission, but the degree to which they are risk factors will depend on the local context. Further detailed entomological research studies are required to assess which livelihood activities in particular locations in the western Kenyan highlands (e.g., brickmaking, maize plantations) are most conducive to enhancing malaria transmission. This is important in the context of climate risk, because climate variability and change and associated changes in temperature and hydrological conditions may induce livelihood changes (such as the observed transition from tea to maize plantations in the lower altitudes due to warmer temperatures).

- **Forests and malaria transmission.** In general, research in the western Kenyan highlands seems to show that deforestation plays an important role in increasing malaria transmission. There is a need to deepen the understanding of the complex drivers behind deforestation in the study area and identify opportunities for reversing this process. The prevention of deforestation and the process of afforestation could provide a number of co-benefits related to biodiversity conservation, access to wild foods used in times of stress, and mitigation of climate change (and therefore potential access to carbon financing).
- **Use of local knowledge and malaria monitoring.** Research should be carried out on the potential use of local knowledge of weather forecasts to track indicators for malaria outbreaks and to identify how to combine this local knowledge with 'outside' knowledge for the development of local early-warning systems for malaria epidemics.
- **Community responses to malaria.** Additional field work would be required at the local level to document and understand in more detail local perceptions and responses to malaria risk in a context of climate risk. The use of the CVCA and CRiSTAL tools proved to be useful, but further adjustments would be required to increase the applicability of their use in the health sector.
- **Gender and malaria prevalence.** More research emphasis should be given to gender analysis and socio-cultural factors in general. For example, previous research in northern Côte d'Ivoire (Plaen et al., 2004) indicated that changes in gender roles associated with changes in agricultural practices can influence household capacities to access malaria treatment.
- **Urban malaria risks.** Given its growing urban population, research on the impact of climate risks in urban slums in Kenya should be explored (including assessing whether a threshold for malaria transmission has already been reached in Nairobi). Undertaking such research will require overcoming some particular challenges. These include the high level of migration between urban and rural areas, which makes it extremely difficult to identify the key factors influencing malaria transmission in these areas. As well, health data quality is more problematic in urban areas compared with rural areas (personal communication, Dr. Githeko, Kenya Medical Research Institute, 08 February 2011).

Key messages: Climate risk management options

- Key stakeholders have identified four priority climate risk management actions for malaria control: (1) strengthening the health system, (2) improving prediction of malaria epidemics, (3) developing targeted, innovative interventions adapted to local needs and contexts, and (4) improving communication and increasing awareness.
- Climate risks call for strengthening cross-sectoral collaboration among actors engaged in malaria control, disaster risk reduction and adaptation to climate change.
- Future research needs include (1) longitudinal case studies on the factors responsible for malaria transmission, (2) detailed entomological studies to assess which livelihood activities in the western Kenyan highlands are most likely to enhance malaria transmission, (3) analysis of the links between forest, malaria and climate change adaptation and mitigation, (4) research on the potential use of local knowledge of weather forecasts for the development of early-warning systems for malaria epidemics and malaria monitoring, (5) more detailed analysis of local perceptions and responses to malaria burden in a context of climate risk, (6) analysis of malaria prevalence through a gender lens, and (7) analysis of the impacts of climate risk on malaria in urban slums.

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