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AfricaInteract: Enabling research-to-policy dialogue for adaptation to climate change in Africa

Review of Research and Policy for Climate Change Adaptation in the Health Sector in Central Africa

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Abbreviations and Acronyms

AAP	Africa Adaptation Programme
ARV	Antiretroviral
CAR	Central African Republic
COMIFAC	Commission des Forêts d'Afrique Centrale
DHS	Demographic and Health Survey
DRC	Democratic Republic of Congo
GDP	Gross domestic product
HIV/AIDS	Human immunodeficiency virus / acquired immunodeficiency syndrome
IPCC	Intergovernmental Panel on Climate Change
LDC	Least Developed Country
NAPA	National Adaptation Programme of Action
NGO	Non-governmental organisation
STP	São Tomé and Príncipe
TB	Tuberculosis
UNFCCC	United Nations Framework Convention on Climate Change
WHO	World Health Organization

Executive summary

There is a growing research interest in and support for adaptation to climate change in Africa. It is thus imperative that the findings emerging from relevant research are actually applied and used to inform policymaking concerning climate change adaptation. The objective of this review is to enhance the knowledge base and to support research-based policy formulation for climate change adaptation in the health sector in Central Africa. This work is an initiative of a project funded by the International Development Research Centre (IDRC) and coordinated by the West and Central African Council for Agricultural Research and Development (CORAF/WECARD) to review research related to adaptation to climate change in the health sector in the Central African region. The review encompassed peer-reviewed journal articles, theses, grey literature and reports over the past 15-20 years to capture as much as possible of scientific and indigenous knowledge as well as policies related to climate change adaptation. The possible gaps that form the basis for further research and policy formulation were also identified.

Climate change analysis indicates that Central Africa is less affected than other parts of the continent of Africa. Projected climate change impacts in Central Africa include: two to three percent losses in agricultural production by the end of the century; increases in precipitation leading to a gradual shift from grasslands to forests, reducing available pasture; increased rate of evapo-transpiration; changes in the length, timing and predictability of the planting seasons; increases in heavy rainfall events; increased risk of drought and flooding; and potential increase in the distribution of harmful livestock disease vectors.

The major climate change vulnerability issues of the health sector in Central Africa are related to vector borne diseases, food and water borne diseases and human immunodeficiency virus / acquired immunodeficiency syndrome (HIV/AIDS). From Angola in the south to Chad in the north, depending on the situation, climate change in Central Africa may have positive or negative effects on vector borne diseases. For instance, in cold highland areas, higher temperatures may increase mosquito activity and malaria transmission, while in already hot areas it may have the opposite effect. Deforestation can lead to the replacement of malaria vector species by others more competent in disease transmission. Sea level rise in coastal areas may lead to floods, which favour the expansion of water borne diseases. For instance, Vibrio cholera ecology is intimately linked to that of plankton. Floods, subsequent to sea level rise, will expand the distribution of the pathogen of cholera with potential epidemic outbreaks. There is also association between extreme and frequent weather events (drought and/or flood) and cholera outbreaks. A direct effect of climate change on HIV/AIDS is heat wave stress on the immune system. Indirect effects are through malnutrition and food insecurity, which debilitate the immune system, making HIV infected people more susceptible to malaria, tuberculosis (TB) and other opportunistic diseases. Lack of access to clean water makes antiretroviral (ARV) treatment ineffective, and increases the risk of its side effects.

Gender inequity is an important factor in the relationship between climate change and disease. Hence, policies should be empowering for women and gender sensitive. Women are very vulnerable to climate change because they account for a large proportion of the agricultural workforce and have fewer alternative income opportunities, which are crucial factors at times when climate variability affects agricultural yields and food security. Climate change mitigation and adaptation strategies should integrate gender sensitive policies at all levels. Traditional healers play an important role in population health in Central Africa. Efforts should be made to also formalise and integrate traditional healers into the health system.

Health systems in Central Africa are experiencing a shortage in quantity and quality of human resources as well as appropriate infrastructure. More investment in both human resources and infrastructure to strengthen health systems are needed. It is fundamental for health adaptation to climate change to improve the monitoring and surveillance of disease and mortality in sensitive regions. The challenge is to incorporate a strong public health infrastructure and empower communities to achieve effective disease surveillance and to increase cooperation between countries in the identification of public health responses to outbreaks and epidemics.

Policymakers, planners and development activists need to understand the potential health impacts of climate change, the effectiveness of current adaptation and mitigation policies and the options available for addressing them. Better understanding of the relationships between climate and climate sensitive diseases under different environmental conditions through interdisciplinary, multi-sectoral and multi-centre research is a prerequisite in this region in order to elaborate and integrate climate change adaptation strategies in the health system. The region is suffering from a lack of public health specialists and financing to undertake evidence-based operational research to feed the health system's needs. Therefore, more investment in human resource capacity building through multidisciplinary training and advocacy for more funding is required to strengthen local researchers' ability to respond effectively to the health system needs for addressing the direct and indirect health effects of climate change. It is also recommended to strengthen community based organisations to develop locally owned sustainable strategies for adaptation to climate change in their communities, taking into account local knowledge. A gender sensitive approach to interventions at all levels is also recommended. Advocacy for mobilisation of funding, both internally and externally, is required.

1 Introduction

Climate is hardly a new source of threat in the history of Africa. However, with climate change the continent's vulnerability is deepening, making it the most exposed region in the world to the impacts of climate change (World Bank 2009). Climate projections for Africa in this century include a likely average temperature increase of 1.5 to 4°C, which is higher than the reported global average (World Bank 2009; IPCC 2007). Food and water security, livelihoods, shelter and health are all at risk. Widespread poverty, fragile ecosystems, weak institutions, the continent's unique geography and other issues compound those challenges. In this context, climate change has emerged as a key development issue for Africa. We argue that Africans themselves have an important role to play in finding efficient solutions for adequate adaptation to climate change.

While there is undisputed evidence that the climate is changing, there is a lot of uncertainty regarding the pace and extent of the change, and the different impacts on sub-regions, sectors, nations and communities. This uncertainty renders policymaking more complex and magnifies the need for Africa to build its knowledge and analytical base and to strengthen the capacity of country and regional institutions in developing the evidence base needed to address climate change adaptation issues. At present, virtually all countries on the continent have performed some stock-taking of the variability and change in the climate and of the impact of those changes on livelihoods. The Least Developed Countries (LDCs) in Africa have been supported by the United Nations Framework Convention on Climate Change (UNFCCC) to undertake National Adaptation Programmes of Action (NAPAs), while all remaining countries have, in varying degrees, pursued climate change adaptation measures on their own. Besides the fact that most NAPAs are generally agreed to have been inadequately designed and implemented, a regional perspective on climate change adaptation is yet to be fully realised.

There is growing research interest in and support for adaptation to climate change in Africa. It is thus imperative that the findings emerging from relevant research are actually applied and used to inform policymaking concerning climate change adaptation. A stock-taking, synthesis and review of research results from relevant sources (peer-reviewed articles, theses, grey literature, etc.) and the way they feed into and influence policies for climate change adaptation in the agricultural, health, water and urban sectors is needed. It is critical that the sector policies are appropriately informed by the existing body of knowledge on climate change and climate variability generated from the scientific research. These policies should enable the respective sectors to build resilience against climate change and climate variability through adequate adaptation strategies and contribute to mitigation of climate change through use of improved and innovative technologies and management practices. This review can help to identify gaps in current climate change adaptation research and policies and measures needed to move from current practice to best practice.

AfricaInteract, a project funded by the International Development Research Centre (IDRC) and coordinated by the West and Central African Council for Agricultural Research and Development (CORAF/WECARD), aims at providing an appropriate forum for interaction among a broad range of African stakeholders including civil society, researchers, policymakers, donors and the private sector working on adaptation to climate change in the agricultural, health, water and urban sectors. The objective of this review is to enhance the knowledge base and to support research-based policy formulation for climate change adaptation for the health sector in sub-Saharan Africa.

2 Background and motivation

Climate projections for Africa in this century include a likely average increase in temperature of 1.5 to 4°C (IPCC 2007). This will affect in profoundly adverse ways some of the most fundamental determinants of life. These include food and water security, livelihoods, shelter and health. Widespread poverty, fragile ecosystems, weak institutions and other issues compound those challenges. In this context, climate change has emerged as a key development issue for Africa. Therefore, Africans themselves have an important role to play in finding efficient solutions for adequate adaptation to climate change.

In the Intergovernmental Panel on Climate Change (IPCC) assessment reports, the continent is divided into four principal regions: Sahara, West, East and Southern Africa, with North African countries captured in the Mediterranean region. Central African countries are included on the margins of these regions, but are not treated as a geographically distinct entity. Nevertheless, Central Africa is projected to warm by approximately 3°C this century. This warming will be at a slightly lower rate than the continental average, according to the General Circulation Models (Christensen et al. 2007). Therefore, the region is generally seen as being of relatively lower climate risk than other parts of the continent. However, Central Africa will experience a number of different impacts from climate change due to the region's considerable size and the variety of ecosystems, topographies and climates that lie between Angola in south and Chad in the north (Boko et al. 2007). These include agricultural losses, sea level rise and variability in precipitation.

Adverse health impacts resulting from climate change are expected for Central Africa, although they are poorly understood as a whole. Vulnerability assessments provided in Central African countries' National Communications to the UNFCCC and NAPAs commonly state that countries should expect an increase in water and vector borne diseases such as cholera and malaria due to increases in annual precipitation and the intensity of heavy rainfall events.

Despite a low climate risk relative to the rest of the continent, vulnerabilities to climate change in Central Africa will increase without adaptation actions. Adaptation in the context of climate change is 'adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities' (IPCC 2007). Thus, adaptation refers to a process of action in a system (household, community, group, sector, region and country) in order for this system to better cope with, manage or adjust to some changing conditions such as stress, hazard, risk or opportunity. Resilience, when referring to natural systems, is the amount of change a system can undergo without changing state. If referring to human systems, IPCC defines resilience as the 'ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner' (Béné et al. 2012). Coping is the use of available skills, resources and opportunities to address, manage and overcome adverse conditions, with the aim of achieving basic functioning in the short to medium term. The strengthening of coping capacities, together with preventive measures, is an important aspect of adaptation and usually builds resilience to withstand the effects of natural and other hazards. Ultimately, adaptation, resilience and coping are different manifestations of more general processes of response to changes in the relationship between open dynamical systems and their external environment.

The health sector is made up of people, institutions and resources, arranged together in accordance with established policies, whose primary purpose is to promote, restore and maintain health (WHO, u.d). In other words, the health sector refers to all organisations and resources in place to cope with human well-being in its environment. Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity (WHO 1948). The health of a population requires clean air, safe water, adequate food, tolerable temperatures, protection from the elements and high levels of biodiversity. Climate change is expected to alter these conditions in various ways and to varying degrees throughout the world. By altering the balance of most determinants of health, climate change will affect human health directly by heat effects (including on physiology-related diseases like HIV/AIDS) or flood injury, or indirectly through changes in the transmission of vector borne diseases, secondary effects following flood events, and shifts in water quality and food security.

2.1 Methodology

We searched for original articles published in journals, grey literature and reports through PubMed and Google. Original research articles from 1990 to date were retrieved from PubMed using Reference Manager software. The search strategy consisted of keyword searches using 'climate change' and 'health' along with the names of each of the nine countries in Central Africa. The process was then repeated after removing the term 'health'. When we could not find relevant original research articles on the Central African region, we extended the search to other parts of the continent for scientific evidence on climate change and health. In this case we used the terms 'climate change', 'health' and 'Africa'. For each identified article, the abstract was read for its relevance to the topic, and if relevant further investigation was undertaken.

The grey literature search was performed using the following keywords: 'climate change' and 'health'; 'climate change', 'health' and 'Central Africa'; 'climate change', 'health' and 'Cameroon'; 'climate change', 'health' and 'Congo'; 'climate change', 'health' and 'Gabon'; 'Climate change' and 'vector borne diseases'; 'Climate change' and 'water borne diseases'; 'climate change' and 'HIV/AIDS'; and 'climate change' and 'gender'. All relevant documents or websites were further investigated with regard to the topic.

Using Reference Manager software we were able to retrieve 95 research articles published in journals from PubMed, among which 29 of relevance were reviewed. From the grey literature search more than 100 documents were found, among which 15 were research articles published in journals not indexed in PubMed and 81 were other documents such as reports and working documents. After review, 66 documents proved relevant to our topic.

3 Overview of the health situation in the region

3.1 Key facts for the health sector in the region

Central Africa is a region of contrasts. It spans a number of different ecosystems and climates: Saharan desert in the far north, savannahs in the north and south, glaciers in the east, and the world's second-largest expanse of tropical rainforest in the Congo River Basin. Central Africa as a geographic entity is a landscape of plateaus of different geological structures. It is one of the most resource-rich regions on the African continent. It consists of Angola (20,821,000 inhabitants), Cameroon (21,700,000 inhabitants), Central African Republic (CAR; 4,401,000 inhabitants), Chad (11,227,000 inhabitants), Republic of the Congo (4,337,000 inhabitants), Democratic Republic of the Congo (DRC; 65,705,000 inhabitants), Equatorial

Guinea (736,000 inhabitants), Gabon (1,633,000 inhabitants) and São Tomé and Príncipe (STP; 188,000 inhabitants) (WHO, u.d). The two biggest economies are Cameroon and DRC.

The climate of Central Africa is characterised by hot and wet weather on both sides of the equator. The equatorial strip is influenced by the intertropical convergence zone (ITCZ), which causes heavy and intense precipitation. The mean annual temperature in the area varies between 25° and 27°C. The annual rainfall can exceed 2,000mm, particularly in the coastal area of Gabon, the centre of the Congo Basin and the mountain border of the Western Rift Valley.

Economically, Central Africa has performed relatively well over the last ten years, with an average growth rate of about 6.2 percent during the 1999-2009 period – 7.3 percent on average in the six oil-producing countries (Angola, Cameroon, Congo Republic, Gabon, Equatorial Guinea and Chad) and 4.7 percent in the other countries. Economic growth in the region, which is above the African average of 4.8 percent, was generally marked by higher exports of crude oil and mining products making it possible to finance non-oil activities. Accordingly, the region's economy remains vulnerable to external shocks, mainly on account of its heavy dependence on oil production. The good economic performance and potential of the region has not translated into human resource development because of political instability and weak governance. Indeed, with regard to the human development index (HDI), the region recorded a score of 0.417 (the 1999-2008 average), which is fairly similar to that of sub-Saharan Africa as a whole (0.48) (ADB 2011).

The biggest causes of morbidity in Central Africa are malaria, respiratory tract infections, diarrhoea and human immunodeficiency virus/acquired immunodeficiency syndrome (HIV/AIDS). Mortality related to HIV/AIDS and tuberculosis (TB) has significantly affected the region's life expectancy. According to the statistics of the World Health Organization (WHO 2012), the mean life expectancy in Central Africa in 2007 was 51.4 years compared to 65.4 years in developed countries and 54.2 years in Africa. In Cameroon the life expectancy decreased from 55 to 51 between 1990 and 2009. In Congo and Gabon it remained unchanged for the same period at 55 and 62 years, respectively. The region's infant mortality rate was 93.70 per 1,000, compared to 85.30 per 1,000 in Africa in 2007.

The major causes of death in children under five years were malaria (16 percent in Cameroon, 26 percent in Congo and 15 percent in Gabon), pneumonia (15 percent in Cameroon, 14 percent in Congo and 11 percent in Gabon) and diarrhoea (13 percent in Cameroon, 11 percent in Congo and seven percent in Gabon). Mortality due to prematurity was also relatively high, with 11 percent, 13 percent and 16 percent observed respectively in Cameroon, Congo and Gabon. Malaria incidence in children under five years was 26.8 percent in Cameroon and 32 percent in Congo. From 2005 to 2011, only 30 percent of children under five years of age received care at health facilities and 13 percent of them slept under insecticide treated nets in Cameroon, and only six percent in Congo slept under insecticide treated nets.

According to the 2011 Cameroon Demographic and Health Survey (DHS), overall HIV prevalence in Cameroon has decreased since 2004, from 5.5 percent to 4.3 percent. HIV prevalence is almost twice as high among women (5.6 percent) as men (2.9 percent). Among women, HIV prevalence is higher among those living in urban areas (6.4 percent) than those living in rural areas (4.6 percent). There is little difference among men, as three percent of men living in urban areas are HIV positive compared to 2.7 percent of men living in rural areas(DHS-MICS, 2011). The 2009 Congo Republic DHS reported that overall HIV prevalence is higher in urban than rural areas and is approximately two times higher in women than men: 4.1 percent of women are HIV, against 2.1 percent of men(DHS, 2009) . The 2012 DHS results of Gabon showed that 4.1 percent of people aged 15-49 years are infected with HIV. HIV prevalence is more than twice as high among women (5.8 percent) than men (2.2 percent). HIV prevalence is higher among women living in urban areas (5.9 percent) than among those in rural areas (5.3 percent). In contrast, HIV prevalence is higher among men in rural areas (2.7 percent) than those in urban areas (2.1 percent) (EDSG-II, 2012).

The percentage of the population using improved drinking water sources in 2008 was 87 percent for Gabon, 74 percent for Cameroon, and 71 percent for Congo. In urban areas of Gabon and Congo, 95 percent of the population have access to improved drinking water sources, along with 92 percent in urban Cameroon. In rural areas only 51, 41 and 34 percent of the population have access to improved drinking water sources in Cameroon, Gabon and Congo, respectively.

The table below shows the total numbers and densities of the health workforce in Congo Republic, Gabon and Cameroon and under the African Regional Office of the World Health Organization (WHO/AFRO). The overall workforce density per 1,000 population is below that of AFRO as a whole (2.626) for Congo (1.878) and Cameroon (2.317). For Gabon (5.973), it is twice as high as that of AFRO.

	Congo Republic		Gabon		Cameroon		AFRO
	Total number	*Density per 1,000*	*Total number*	*Density per 1,000*	*Total number*	*Density per 1,000*	*Density per 1,000*
Physicians	756	0.198	395	0.292	3124	0.192	0.217
Nurses & Midwives	3672	0.962	6974	5.162	26042	1.598	1.172
Dentists & Technicians	12	0.003	66	0.049	147	0.009	0.035
Pharmacists & Technicians	99	0.026	63	0.047	700	0.043	0.063
Environmental & Public Health Workers	9	0.002	150	0.111	28	0.002	0.049
Laboratory Technicians	554	0.145	276	0.204	1793	0.110	0.057
Other Health Workers	957	0.251	1	0.001	16	0.001	0.173
Community Health Workers	124	0.032	NA	NA	NA	NA	0.449
Administrative & Support Staff	987	0.259	144	0.107	5902	0.362	0.411
Sum Total	**7170**	**1.878**	**8069**	**5.973**	**37752**	**2.317**	**2.626**

In Central Africa expenditure on health per capita and on health as percentage of the gross domestic product (GDP) varies from country to country. The annual per capita expenditure ranges from US$32 in DRC to US$514 in Gabon. The GDP percentage for health ranges from 2.5 percent in Congo Republic to 7.7 percent in STP. The table below summarises the health expenditure per capita in Cameroon, Gabon and Congo from 2009 to 2011.

Countries	Year 2009 (US$)	Year 2010 (US$)	Year 2011 (US$)
Cameroon	60	61	68
Congo Republic	55	68	87
Gabon	273	309	358

The overall health system performance of 191 countries as measured by Tandon et al. (undated) ranked Central African countries between 133 (STP) and 189 (CAR). The low workforce densities and the weak health systems with insufficient sustainable financial resources undermine efforts to reduce the burden of diseases in Central Africa. Climate change is going to exacerbate this situation for climate sensitive diseases if nothing is done.

4 The role of climate change challenges

Central Africa will experience climate change, even though it is expected to be less than in other parts of the continent. Projections according to General Circulation Models indicate that equatorial and coastal areas of Central Africa could warm by approximately 3°C this century at a slightly lower rate than the continental average (Boko et al. 2007; Christensen et al. 2007). The western region of Central Africa, including Cameroon, Congo and Gabon, faces a projected increase in the mean annual temperature of 0.9°C to 2.9°C by 2060, and 1.3°C to 4.7°C by 2090 (McSweeney et al. 2010). The range of projection under any one emissions scenario is 1-2°C. The warming will be faster in continental interior regions and lower in the coastal areas. The frequency of days and nights considered 'hot' in the current climate will increase, although considerable variations between different climate prediction models are observed. Days and nights considered 'cold' in the current climate will be very rare by 2090. Projections of mean annual rainfall averaged over the region indicate a wide range of changes in precipitation. For instance, projected changes range from -8 percent to +17 percent in Cameroon (ensemble median = 0 to + 2 percent), and from -22 percent to + 25 percent in Gabon (ensemble median = -1 to + 1 percent) by 2090. All models' projections tend toward an increase in September-October-November (SON) rainfall.

The proportion of total rainfall that falls in heavy events will increase, even in seasons when mean rainfall does not increase. Sea level in this region is projected to rise by a minimum of 0.13m to a maximum of 0.18m by 2090 relative to 1980 -1999 sea level. In the context of Central Africa, forests are at the forefront of any debate regarding climate change issues. Indeed, forests are carbon sinks as they absorb CO2 and sequester it. Therefore, in addition to warming of the climate due to greenhouse gas emission, environmental changes such as deforestation, land use and land cover changes could increase local temperatures and relative humidity. For instance, deforestation accounts for nearly 20 percent of global annual carbon emissions (Afrane et al. 2011).

Central Africa will experience a number of different impacts from climate change due to the region's considerable size and the variety of ecosystems, topographies and climates that lie between Angola in the south and Chad in the north (Crawford et al. 2011). The projected climate change impacts include two to three percent losses in agricultural production by the end of the century; increases in precipitation leading to a gradual shift from grasslands to forests, reducing

available pasture; increased rate of evapo-transpiration; changes in the length, timing and predictability of the planting seasons; increases in heavy rainfall events; increased risk of drought and flooding; and potential increase in the distribution of harmful livestock disease vectors. For coastal areas, the projected impacts include coastal flooding from sea level rise; intrusion of salt water into lagoons, coastal lakes and coastal aquifers; threatened coastal infrastructure and industry; and short-term migration from coastal settlements. For human health, climate change expected impacts are: increase in vector borne diseases and water borne diseases such as cholera; and increase in the incidence of meningitis. Because of the high dependency of the population on ecosystem goods and services in Central Africa, deforestation may exacerbate climate change vulnerability. Climate vulnerability profiles specific to Cameroon, Congo Republic and Gabon as examples are detailed below:

Cameroon: Current projections suggest that Cameroon will experience a moderate increase in temperature this century: 1ºC to 2.9oC by the 2060s and 1.5 ºC to 4.7ºC by the 2090s. Warming is expected to be faster in the interior and slower in the coastal areas, and to reflect an increase in the number of 'hot' days and nights and a decrease in 'cold' days and nights (McSweeney et al. 2008). Although temperatures will rise, there is no consensus among climate models on projected mean annual rainfall. Models are, however, consistent in projecting increases in the proportion of total annual rainfall that falls in heavy events (-2 to +15 percent) (McSweeney et al. 2008). This could have an impact on flooding, and sea level rise is also a concern for Cameroon. The specificity of Cameroon is that it consists of several climates which will likely be affected differently. In the tropical forest zone of Cameroon, changes in temperature will affect natural regeneration of forests and the water balance. If managed well, overall food security may be affected positively in this area, with probable higher production rates, both in terms of agriculture and inland fisheries. However, the deforestation to which the country is overtly exposed will affect forest goods and services on which the population rely for basic resources and income generation, thereby significantly affecting the economic, social and environmental and health dimensions (Bele et al. 2013).

The coastal and maritime zone is predicted to be particularly affected by sea level rise due to climate change. Depending upon future emissions scenarios, it is projected that the coastal areas of Cameroon could experience a rise in sea level of between 0.13m and 0.56m by 2090 (McSweeney et al. 2008). By 2100, sea level rise could lead to the displacement of 580,300 people and the destruction of 39,000 homes (McSweeney et al. 2008). Sea level rise may also threaten the natural forests through inundation and more intense wave activity. In the savannah zone, climate change impacts are predicted to lead to more extreme inter-annual climatic variability and increasing aridity and more frequent droughts. Such changes would potentially impact negatively on agricultural and pastoral productivity; vector borne disease transmission patterns through effects on vector species composition and distribution; and the country's hydroelectric developments. Food security, water availability and health are the poorest in the Sudano-Sahelian zone of Cameroon, and climate change impacts will likely further exacerbate this situation (UNDP-AAP, 2011).

Congo Republic: According to the Second National Communication of the Republic of Congo's Ministry of Sustainable Development, Forestry and the Environment, the country has experienced an increase in its mean annual temperature between 1951 and 1999 of between 0.69ºC and 0.76ºC. Looking forward, the country is projected to continue to experience rising mean average annual temperatures by between 1ºC and 2.5ºC by 2050. Summer temperature increases could reach 4ºC during the dry season by 2100, which could lead to further water scarcity during this season (Crawford et al. 2011) Altered precipitation patterns have also been observed and are projected to occur in the future. A general decrease in rainfall was observed between 1950 and 1980, with isohyets moving south-southwest (RCMSDFE 2009). Although no significant change in mean annual rainfall by 2050 is projected to occur in the Congo Republic, rainfall could increase in the country's northern and central regions by 2100 (RCMSDFE 2009). No significant change in consecutive dry days or in extreme rainfall events (measured by the maximum five-day precipitation) is expected.

Superimposed on these climate-induced problems are already existing environmental and developmental pressures such as coastal erosion, siltation of rivers, inadequate use of water supplies and deforestation. For example, in the Congo Basin, climate change effects on forest ecosystems are predicted to amplify the existing pressure on food security, urging expansion of current agricultural lands at the expense of forest, biodiversity and socioeconomic stability (Bele et al. 2013). Thus, as a result of both changes in climatic conditions and anthropogenic activities, there has been increasing environmental degradation such as a reduction in river flow since the 1970s, an increase in erosion and a decrease in agricultural potential. These changes are directly impacting on important economic sectors such as the energy sector – there has already been a substantial decrease in the productivity of hydroelectric power stations – and are likely to continue to impact on them(UNDP-AAP, 2011).

Gabon: The coastal area is about 950km long. The entire coastline hosts almost 75 percent of the population and a significant share of national economic activities: tourism development, oil, mining, fisheries and urbanisation. For several years, erosion along the coastline has been accelerating, which is threatening coastal infrastructure and may disrupt traffic flow along the coastline and the country's economic activities. As a result of sea level rise and coastal erosion there is also the threat of water depletion due to increasing salinity

of the water in the lowlands. Population growth, the deterioration of wetlands and more frequent storms are also increasing the number of floods and threat of flooding in the future (UNDP-AAP, 2011).

The implications of climate change for other key challenges (and opportunities) in Central Africa's health sector include population growth and urbanisation; water resources supply and demand; gender and health; and traditional health versus formal health systems. Population increase in developing countries like those of Central Africa significantly impacts on the capacity for climate change adaptation. The Central African population is currently about 128.9m and is expected, by 2050, to reach 273m. It is growing faster than any other region in Africa (UNFPA 2010). The average level of urbanisation in Central Africa in 2000 was 48 percent, ranging from 81 percent in Gabon to 24 percent in Chad (UNEP 2012). In 2012, it ranges from 86.5 percent in Gabon to 21.9 percent in Chad. The urbanisation rate was over three percent for all countries, surpassing five percent in Equatorial Guinea and Gabon. One of the most important environmental impacts of uncontrolled urbanisation in Central Africa is its spread into coastal areas which are fragile ecosystems. These areas are delicate, highly erodible slopes, natural drainage waterways or valleys, and are subject to flooding. Because of the intense competition for space in urban areas, unsuitable areas for housing are the only places available for the urban poor, who are then vulnerable to flooding, landslides and outbreaks of pests and diseases. Dense, unstable and poorly located settlements are also vulnerable to the impacts of floods.

With the exception of the deserts of northern Chad and the Sahelian parts of northern Cameroon and central Chad, the Central African region is well supplied with water resources (UNEP 2002). However, over the past 30 years some inter-annual variation in rainfall has been observed with more common flooding in the humid zone, and an increased in drought frequency in Chad and northern Cameroon (IPCC 2007). This uneven distribution of water resources, with respect to time and population distribution, has created challenges for water supply. The demand of water for domestic use is predicted to increase fivefold over the next 25 years, due to population growth and increases in per capita consumption (WHO/UNICEF 2000). Increasing demand from other sectors is also expected as agricultural and industrial developments expand to meet economic growth imperatives. Rise in sea level and reductions in rainfall related to climate change are expected to lead to localised problems of water quality in coastal areas and in rural northern Cameroon and Chad where water supply systems are already inadequate (IPCC 2007). Poor access to potable water due to floods or drought and inadequate water supply and sanitation pose a threat to human health via exposure to pathogens such as cholera and intestinal parasites. Unless significant improvements to the existing infrastructure and supply networks are made, the population will be at a high risk of water borne diseases in the next 20-30 years.

The social and human consequences of climate change include migration and displacement, shifting in farming and land use and urbanisation, all of which have a gender related health component. Women are generally more involved in child health care than men. Pregnant women are also vulnerable to malaria. They are twice as 'attractive' as non-pregnant women to malaria-carrying mosquitoes (Lindsay et al. 2000). On average disasters kill more women than men, or kill women at a younger age than men (WHO 2010a). Women, young people and people with low socioeconomic status are thought to be at comparatively high risk of anxiety and mood disorders after disasters like windstorms and tropical cyclones.

Contamination of drinking water by sea water increases pre-eclampsia, eclampsia and hypertension risk in pregnant women (Nicholls et al. 2007) and the general population. Hazards associated with flooding include stress-related illness and risk of malnutrition related to loss of income and subsistence, which are known to have a strong gender dimension (Cannon 2002). The health impacts of drought have a gender dimension because in most developing countries women are responsible for collecting, storing, protecting and distributing water. During water scarcity periods, they have to carry water home from unsafe sources that are likely to be contaminated. This exposes them to water-related diseases such as diarrhoeal disease, which is a leading cause of death among children less than five years of age in developing countries (WHO/UNICEF 2005).

There is an uncertainty in the direct impact of climate change on HIV/AIDS. One of the main reasons why climate change can have an impact on HIV/AIDS seems to be related to food shortage (Aminatu et al. 2010). Over 70 percent of the population in Central Africa are farmers. The HIV/AIDS burden not only greatly reduces human capital, but leaves many children and women to fend for themselves. Malnutrition, brought by food security, will exacerbate the effects of HIV/AIDS (Bruce-Lockhart 2012). Reduction in rainfall and associated drought reduces the household food supply capacity of men, shifting the greater burden onto the women who have to ensure the feeding of the household and thereby placing a significant weight of the effects of climate change on women (Aminatu et al. 2010). Another important factor about food insecurity is that it could increase the spread of HIV/AIDS from the use of transactional sex. Women who are desperate and suffer malnutrition are more likely to sell their bodies in order to support themselves. Food insecurity and poverty may also prevent people from seeking a diagnosis or prevent them from having the ability to afford treatment. The spread of Malaria due to climate change will also add to the burden of disease of HIV/AIDS (UNEP 2012). As people become infected by HIV/AIDS and are then exposed to Malaria, it will create an even more substantial loss of life because AIDS victims will be less able to fight the malaria infection.

Climate change may also increase the spread of HIV/AIDS. Central Africa is home to many civilian wars, leading to the displacement of people who are forced

to live in crowded areas. There is evidence to suggest that this could 'aggravate gender inequalities' (UNEP 2012) that have the potential to raise the possibility of transmission of the disease. Migrants often have poor living conditions, are separated from their spouses and families, perform demanding and dangerous jobs and have limited access to health care (UNEP 2012). This can all lead to an increased risk of contracting HIV/AIDS. Also, climate change will reduce the funds available to mitigate HIV/AIDS. As more money is spent on repairing infrastructure due to the increasing nature of extreme weather, less money will be available for programmes to prevent HIV/AIDS and to look after those who are already infected. (Ziervogel and Drimie, 2008). This is especially true in developing countries where they are least able to cope. The governments in these countries are less able to provide for their populations, and will be under more strain from climate change related costs. The twin effects of HIV/AIDS and climate change will therefore adversely affect human health more than either individually.

Traditional healers are integral to African culture. Traditional practitioners' availability generally outstrips by far that of doctors in most parts of Africa. The majority of the population first seek care from traditional healers. Therefore, expanding the utility and integration into the health system of traditional healers would relieve health care providers to put more effort into adaptation measures in the health sector, while improving and regulating traditional practices for the benefit of the clients (Kaseje 2006). The formalisation of traditional health systems is ongoing in Cameroon and many other countries of Central Africa.

5 The current state of knowledge on adaptation to climate change in the health sector in Central Africa

In order to reduce negative health impacts of climate change, various programmes or measures, known in the climate literature as adaptation measures, are being put in place or planned in Central African countries. Some of these ongoing or planned adaptation measures have been reported in the countries' National Communications to the UNFCCC and NAPAs. The key priority sectors are agriculture, human health, freshwater resources, coastal zone management, forestry and fisheries (Crawford et al. 2011). The adaptation needs for the health sector include strengthening current management strategies; undertaking preventive initiatives including education programmes, improved water systems, early warning systems for natural disasters and improved access to health services; improving basic sanitation infrastructure; launching anti-malaria campaigns; and enhancing measures in place to reduce malaria.

Adaptations to extreme weather events include good urban planning; building of flood protection structures like dams, dykes, walls and pump stations; and reforestation. Reactive adaptations to vector borne diseases include scaling up vector control intervention; vaccination; insecticide treated net distribution; surveillance, prevention and control programmes; and epidemic forecasting. For water borne disease they include promoting water treatment and distribution; monitoring water sources; installing regulated water pipelines in houses; improved sanitation (latrines); household drain connections; and surveillance, prevention and control programmes. Reactive adaptations to food borne disease include food refrigeration; chlorination of drinking water; pasteurisation of milk; and sanitary slaughter and processing of meat, poultry and seafood. Health preventive measures include health education and early warning systems. Examples of ongoing and proposed adaptation action in Cameroon, Congo and Gabon are summarised below.

Cameroon: Cameroon has more adaptation activities underway than any other country in Central Africa. As a signatory to the UNFCCC, Cameroon established a dedicated climate change unit, the Cellule Nationale des Changements Climatiques, within the Ministry for Environment and Conservation in 1999. A diverse set of scattered climate change adaptation related interventions are being implemented in Cameroon by different organisations and development partners. The Africa Adaptation Programme (AAP) is building on already existing structures and experiences and integrating them into a national approach to adaptation. Prior to AAP, there were severe shortcomings in addressing adaptation through a coherent and strategic country approach. AAP is addressing the climate change risks in Cameroon and identifying/overcoming existing barriers to the proposed responses. Recent activities of AAP in Cameroon include: 1) the development of a climate change risk map and three studies on climate extremes, multi-sector vulnerability and on coastal integrated management, respectively; 2) establishment of a National Observatory on Climate Change (ONACC) as a centre of excellence for climate change adaptation; 3) establishment of an inter-ministerial working group on climate change adaptation and parliamentary taskforces on climate change adaptation issues; and 4) establishment of information sharing and experience exchange platforms at the local level on climate change and adaptation. Other projects focusing on forests, water, coastal zones, agriculture, energy and natural resource management have been or are being implemented in Cameroon. They are designed as research, capacity building, knowledge sharing, awareness raising, vulnerability assessment, policy formation and community based adaptation projects. For example, at the national level there is a project entitled 'The Pygmies of Eastern Cameroon face Climate Change'. This project (2009-2010) aimed to increase awareness and improve Pygmies' capacity to adapt to climate change. More specifically, it will survey Pygmy perceptions on climate change and provide them with a forum for identifying the major climatic changes affecting their lives and identifying adaptation options. Through these processes they will be able to articulate their expectations around the actions needed to strengthen their resilience.

Cameroon has also proposed the following adaptation actions: 1) in the coastal zones, improved zoning and resettlement programmes, resilient housing and improved protection through the construction of dykes; 2) in the health sector, preventive initiatives such as education and communication programmes, improved water systems, early warning systems for natural disasters, improved access to health services, improved capacity for health workers, better distribution of medication, improved sanitation information, improvements in the basic sanitation infrastructure and anti-malaria and anti-schistosomiasis campaigns; and 3) at the administrative and organisational level, improved coordination between institutions involved in the management of epidemics and natural disasters, the establishment of the national disaster management programme and the creation of a fund for emergency responses to natural disasters (Crawford et al. 2011).

At the regional level, Cameroon is participating in many climate adaptation programmes as listed in the table below.

Molua and Lambi (2007) report that indigenous climate change adaptation activities undertaken in Cameroon in the Benoué Valley are the following:

Programmes	Goal in Cameroon
1. Supporting Integrated and Comprehensive Approaches to Climate Change Adaptation in Africa (2008)	To ensure that the country has the institutional, individual and systemic capacity to address climate change risks and opportunities through a national approach to adaptation
2. Altering the Climate of Poverty under Climate Change: The Forests of the Congo Basin	To underscore the importance of the Congo Basin forests in climate change adaptation efforts
3. Advancing Capacity to Support Climate Change Adaptation	To emphasise the generation, organisation and communication of information on the risks resulting from climate change, climate variability and extreme climatic events, as well as preparation for their effects on food security
4. Building Mangrove Resilience to Climate Change	To build resilience to climate change in tropical mangroves and associated coral reefs
5. Climate Proofing Energy Systems: Vulnerability-Adaptation-Resilience (2007-2009)	To conduct an assessment of the vulnerability and resilience of energy systems to climate change in Cameroon
6. Lake Chad Sustainable Development Support Program	The program aims at the rehabilitation and the conservation of the productive capacities of Lake Chad's ecosystems and its basin; and the adaptation of the production systems to climate change

- Shifting crop mix to more drought tolerant and short season varieties
- Reducing the area planted initially, then increasing it gradually, depending on the nature of the season
- Staggering planting dates (early or late planting)
- Increasing plant spacing
- Maximising the use of clay soils where these are available, since clay soils have a high water holding capacity
- Implementing soil water conservation techniques (pot-holing, weeding)
- Adjusting level and timing of fertiliser
- Undertaking traditional and religious ceremonies

Congo Republic: A relatively low level of adaptation programming is being done in the Republic of Congo at present relative to other Central African countries. Recent adaptation activities being undertaken by AAP include 1) training of 50 people from academia, government and civil society organisations on climate analysis; 2) development of hydro-climatic index to evaluate the vulnerability and adaptation of key sectors; 3) alignment of AAP with the national scheme on territorial organisation; 4) contribution to the integration of climate change into national legislation; and 5) sharing of climate change adaptation knowledge on television and establishment of knowledge-sharing processes with AAP Senegal.

The country is part of two regional programmes. 'Supporting Integrated and Comprehensive Approaches to Climate Change Adaptation in Africa', with a focus in Congo Republic on the health, economy, agriculture, water and energy sectors, is designed around capacity building, knowledge sharing and policy formation. The integration project 'Climate Change Scenarios for the Congo Basin' is aimed at enabling decision-makers in the country and throughout the region of the Commission

des Forêts d'Afrique Centrale (COMIFAC) to adapt and prepare their natural resource management strategies to meet the regional challenges of climate change. Proposed adaptation action in the National Communication are: in agriculture and food security, to continue the implementation of the *Programme National de Securité Alimentaire* (PNAS); reforestation, conservation and sustainable management with reference to the potential for significant Reducing Emissions from Deforestation and Forest Degradation (REDD) benefits in the forestry sector; increased coherence to urbanisation policies, public transportation development and improved rainwater harvesting, among other things. In the human health sector, primary adaptation strategies identified include information and early warning systems, improved water basin management for potable water, urban planning and environmental management. Secondary adaptation strategies noted are improved training for health workers, better sanitation planning, expanded public education and greater disease and epidemic monitoring.

Gabon: It was only in May 2010 that the government established a Climate Council to develop national policies relating to climate change as well as prepare a National Climate Plan. Once complete, the National Climate Plan will be integrated into the country's broader development plan. The Climate Council reports directly to the Head of State. The government has also established a National Carbon Agency and a National Observatory to monitor climate risks. The number of climate change adaptation projects underway in Gabon is very low compared to other Central African countries. At the national level, AAP is helping to institutionalise the national strategy for coastal adaptation and the prevention and mitigation of natural disasters. AAP is also strengthening partnership and cooperation with all actors involved in coastal zone management. Like Congo Republic, the country is part of the regional programmes 'Supporting Integrated and Comprehensive Approaches to Climate Change Adaptation in Africa', which aims to strengthen coastal zone resilience and directly address the priority vulnerability assessment of the First National Communication, and COMIFAC's 'Climate Change Scenarios for the Congo Basin'.

6 Research related to climate change in the health sector

Globally, an estimated 350,000 people die each year due to major diseases and health disorders related to climate change (DARA 2010). Unless measures are taken, by 2030 climate change will increase its toll to more than 800,000 deaths per year. Vulnerabilities to diseases related to climate change are very unevenly distributed around the world but implicate mostly the poor and the children of vulnerable communities. Infectious diseases take a heavy toll on populations around the world. Some of the most virulent infections are also highly sensitive to climate conditions. Climate vulnerability assessments provided in Central African countries' National Communications and NAPAs commonly state that countries should expect an increase in water and vector borne diseases (such as cholera and malaria) due to increases in annual precipitation and in the intensity of heavy rainfall events (Crawford et al. 2011).

6.1 Food and water borne diseases

The term water borne disease is reserved largely for infections that predominantly are transmitted through contact with or consumption of infected water. Food borne disease is caused by consuming contaminated foods or beverages. The IPCC (2007) predicts that climate change will, for example, increase the burden of diarrheal diseases like cholera. *Vibrio cholerae*, a bacterium autochthonous to the aquatic environment, is the causative agent of cholera. *V. Cholera* is found in association with crustacean zooplankton, mainly copepods, and notably in ponds, rivers, coastal water and estuarine systems globally. Temperature, salinity, rainfall and plankton have proven to be important factors in the ecology of *V. Cholerae*, influencing the transmission of the disease. Water scarcity forces people to rely on unsafe sources of drinking water, increasing the likelihood of contamination. Central Africa is known to be endemic for cholera and is regularly affected by small outbreaks. Projected climate change impacts in the region, which include increase in extreme weather events, increased risk of drought and flooding and coastal flooding from sea level rise will exacerbate the situation. For example in 2010, an unusually high incidence of cholera was reported in Cameroon and Chad (WHO, 2010b) . Seasonal factors, such as flooding in the rainy season, as well as poor hygiene conditions and population movements in the area contributed to this outbreak. Many research efforts across the world are attempting to build an early warning system for cholera outbreaks based on *V. Cholerae* ecology (Constantin de Magny et al. 2008) and using demographic, economic, environmental and climatic predictors with a one month lag time (Buczak et al. undated). These results suggest that accurate forecasting of cholera outbreaks in Africa may be achievable, which could support decision-making in epidemic outbreaks. Other risk factors for cholera outbreaks include a rapid urbanisation rate (over three percent), which enhances the development of informal settlements characterised by overcrowded, unstable and unhealthy housing with inadequate water supply and sanitation systems.

The current coping strategies for water borne diseases in the region include routine surveillance in health facilities for early detection and case management; education for public awareness on preventive measures; improved access to and treatment of drinking water; and clean toilets. The different stakeholders generally involved are the Ministry of Health, the health facilities, non-governmental organisations (NGOs) and the WHO. Careful research is needed to document not only the seasonal nature of these illnesses in the region, but also their susceptibility to climate variability as well as the extent to which social, demographic and political conditions will exacerbate or improve current coping strategies.

6.2 Vector borne diseases

Vector borne diseases are infections transmitted by the bite of infected arthropod species, such as mosquitoes, ticks, sandflies and blackflies (IPCC 2007). Their pathogens can be viruses, bacteria, protozoa or helminths. It has long been recognised that vector borne diseases are climate sensitive because of the biology of their vectors. One area of particular concern is how climate change will affect the spread of insect-borne diseases. These include dengue fever, malaria, Lyme disease, West Nile virus, Rift Valley fever, chikungunya and yellow fever, which are spread through the bite of vectors such as mosquitoes, ticks and flies. Central African countries should expect an increase in annual precipitation and in the intensity of heavy rainfall events. This should lead to an increase in water and vector borne diseases such as cholera and malaria.

The most studied climate-related disease is malaria, the major cause of death in Africa, particularly among young children (Snow et al. 1999). Malaria is a vector borne disease involving the female *Anopheles* mosquito, the *Plasmodium* protozoon and humans. Transmission is affected by factors influencing the reproductive life cycle of the vector and the agent, as well as the opportunities for contact with people (Molineaux 1988). Climate affects all of these through temperature, humidity and rainfall variations, as well as by affecting land use, human and livestock distribution patterns and migration (Craig et al. 1999; Bouma and Van der Kaay 1994; Molineaux 1988).

Studies in the laboratory were able to quantify the direct effects of climate variables on the biology of malaria vectors (Lyons et al. 2012). Based upon these biological constraints of climate on parasite development in mosquitoes and mosquito's development cycle, modelling was used to define the distribution of malaria transmission risk (Craig et al. 1999; Snow et al. 1999) and to show long term changes in the spatial distribution of malaria vector species (Sogoba et al. 2007a; Minakawa et al. 2002; Bayoh et al. 2001) and subspecies (Sogoba et al. 2008). In Cameroon, the natural distribution patterns of *Anopheles* species were largely determined by altitude, with some species having unique environmental tolerance limits (Tanga et al. 2010; Tchuinkam et al. 2010). However, the links between climate and insect borne disease are far from simple.

For example, changes in temperature can have opposing effects depending on where they occur. In low temperature regions, the expected effects of increasing temperature is faster vector and pathogen development with more generations per year and more transmission (IPCC 2007). In the highland areas of East Africa, there is evidence that malaria transmission is more sensitive to increases in the minimum temperature rather than the maximum (Githeko et al. 2000). Increased temperatures in already hot regions could reduce the spread of malaria mosquitoes by pushing temperatures higher than the mosquitoes can survive to transmit the disease. Most mosquitoes cannot survive above about 40°C. This scenario has been observed in Senegal, a Sahelian country, where malaria prevalence has dropped by more than 60 percent in the past 30 years (Mouchet et al. 1996; Faye et al. 1995). It should also be noted that warming trends during cold periods may make the transmission of malaria less seasonal, which would increase overall incidence. The effect of rainfall on malaria transmission is too uncertain and regionally variable to estimate. For example, increased rainfall in normally dry areas can create stagnant pools of water where mosquitoes can breed and transmit the disease. Alternatively, increased rainfall in wet regions could reduce malaria by washing immature mosquitoes away.

Changes in land use or land cover, especially deforestation, have been linked to changes in the microclimate of the area in question. These changes in microclimate due to changes in land uses and cover have been linked to changes in malaria transmission. Indeed, the changes in land use affect temperature, humidity and rainfall or precipitation patterns of the area. These also affect the microhabitat of malaria transmitting mosquitoes and the parasite they transmit, thus affecting malaria transmission in the area (Afrane et al. 2011).

Cameroon consists of several climate zones which will likely be differently affected by climate change. In the tropical forest zone of Cameroon, changes in temperature will affect natural regeneration of forests and the water balance. This can enhance vector development and extend its life span to transmit the disease. On the other hand, ongoing deforestation in Cameroon has the potential to also change the microclimate of an area to become suitable to malaria vector species that previously could not survive in the area. For example Manga et al. (1995), working in an area that has been deforested to build a new airport, observed that deforestation caused the introduction of *An. gambiae* into a habitat that was previously predominated by *An. moucheti*. *An. gambiae* is the most ferocious of all the malaria vectors in Africa. It has been found to be the most efficient vector of *P. falciparum* in Africa. If the effects of deforestation made it possible for *An. gambiae* to inhabit this new place, the implications are that malaria transmissions in this area will most likely increase. However, if climate change is well-managed in this climatic zone, overall food security may be positively affected, with higher production rates probable, both in terms of agriculture and inland fisheries. These economic outcomes could alleviate the malaria burden.

The coastal and maritime zone is predicted to be particularly affected by sea level rise due to climate change. This will enhance erosion and expand the breeding areas of saltwater mosquito species. However, the relation between flooding and vector borne disease is complex. Many important infections are transmitted by mosquitoes, which breed in, or close to, stagnant or slow-moving water (puddles, ponds). Floodwaters can wash away breeding sites and hence lower disease transmission by mosquitos. On the other hand, the collection of stagnant water due to the blocking of drains,

especially in urban settings, can also be associated with increases in transmission, and there have been numerous such reports from Africa (Ahern et al. 2005).

In the savannah zone, climate change impacts are predicted to lead to more extreme inter-annual climatic variability and increasing aridity and more frequent droughts. Such changes would potentially impact negatively on both agricultural and pastoral productivity, as well as hydroelectric developments and vector borne diseases. Food security, water availability and health are the poorest in the Sudano-Sahelian zone of Cameroon, and climate change impacts will likely further exacerbate this situation (AAP 2011a).

In the Sudano-Sahelian zone of Cameroon, for both malaria and schistosomiasis, higher temperatures, when they are below 35°C, shorten the extrinsic incubation period such that several broods of infective parasites are produced (CICERO 2000). Under a warming projection of 6°C by the year 2100 (assuming a high climate sensitivity area), the incidence of malaria will increase as a result of accelerated metabolic processes and nutritional requirements of the vector. It is likely that the vector's biting rate will increase, which in turn will lead to increased egg production, vector population and malaria transmission potential. Assuming a low climate sensitivity area, a temperature increase of 1.5°C accompanied by a precipitation decrease of 10 percent would lead to a 28 percent reduction in the incidence of schistosomiasis. In contrast, under a projected 6°C change it is expected that schistosomiasis will spread southward from its current hyper-endemicity zone, following the migration of isotherms. Temperature has an effect on snail reproduction and growth, schistosome cercariae mortality, infectivity and human water contact. Changing precipitation patterns can also have short- and long-term effects on vector habitats. Increased precipitation has the potential to increase the number and quality of breeding sites for vectors such as mosquitoes, ticks and snails, as well as the density of vegetation, affecting the availability of resting sites (Githeko et al. 2000). Malaria transmission is perennial but rainfall dependent in coastal areas (Bigoga et al. 2007). Other diseases will also be influenced by climate change. For example, increased frequency of droughts (under a scenario of 10 percent reduced precipitation) would lead to longer transmission periods for meningococcal meningitis, including increased epidemic potential and a southward spread beyond the current distribution belt (CICERO 2000).

In Congo, as a result of both changes in climatic conditions and anthropogenic activities, there has been increasing environmental degradation such as a reduction in river flow since the 1970s, an increase in erosion and a decrease in agricultural potential. These changes are directly impacting on important economic sectors such as the energy sector and are likely to continue to impact on them (AAP 2011b). River flood recession can enhance creation of suitable breeding sites for malaria vectors and sustain malaria transmission after the rainy season (Sogoba et al. 2007b; Toure et al. 1996).

In Gabon, erosion along the coastline has been accelerating for several years, which is threatening coastal infrastructure and may disrupt traffic flow along the coastline and the country's economic activities. As a result of sea level rise and coastal erosion there is also the threat of water depletion due to increasing salinity of the water in the lowlands. Saltwater breeding malaria vector species will colonise new areas and expand malaria transmission. Population growth, the deterioration of wetlands and more frequent storms are also increasing the number of floods and the threat of flooding in the future (AAP 2011c).

6.3 HIV/AIDS

The human immunodeficiency virus (HIV) is a retrovirus that infects cells of the immune system, destroying or impairing their function. As the infection progresses, the immune system becomes weaker, and the person becomes more susceptible to infections. The most advanced stage of HIV infection is acquired immunodeficiency syndrome (AIDS). It can take 10-15 years for an HIV-infected person to develop AIDS. Antiretroviral (ARV) drugs can slow down the process even further (WHO, u.d).

Central Africa is experiencing a rapid spread of HIV/AIDS. In 2007, the prevalence among the sexually-active population of the region was 4.6 percent, compared to 1.3 percent in developing countries. This rate varies from country to country, from 5.5 percent in Angola to 14.8 percent in CAR (AfDB 2011). The dynamics of the disease seems to be related to population density, nutrition, health status and seasonal or exceptional movements of people. The links between climate change and HIV/AIDS are still conjectural but they are becoming a subject of increasing concern and study. Food insecurity, patterns of infectious disease, effects of pollution and heat stress debilitate the immune system (Bolton and Talman 2010), which makes HIV infected people more susceptible to malaria, TB, and other opportunistic diseases. When changes in temperature and precipitation lead to droughts or floods, agricultural yields and production will likely be affected. Agricultural loss and declining household incomes (WWF 2007) may compromise food security, which will lead to further progression of HIV and AIDS. On the other hand, HIV/AIDS can lead to lowered productivity as more and more farmers are infected and affected. Survivors have to spend time attending funerals (which in Central Africa can last days) and look after orphans.

Heavy rainfall events cause storm water runoff that may contaminate drinking water. Lack of access to clean water makes ARV treatment ineffective and increases its side effects (Thornton et al. 2006). Chronically poor environmental conditions due to degradation and environmental stresses including extreme climate events create favourable conditions for the development and spread of infectious diseases, through migration, food shortages and forcing people to resort to new activities for survival. Spread of HIV/AIDS is likely to be accelerated in a situation of large-scale migration (Thornton et

al. 2006). A high positive correlation was repeatedly observed between rainfall in a given month and the risk of mother-to-child transmission of HIV-1 in children born three months later in Yaoundé, Cameroon (Ayouba et al. 2003).

Vector borne diseases interrelated with AIDS (malaria, dengue, yellow fever and sleeping sickness) are all sensitive to changes in temperature and humidity, rainfall and rising sea level, and therefore highly responsive to climate change.

The complex relationship between HIV/AIDS and the food security impacts of droughts and floods can evolve in two ways. On the one hand, the nutritional requirements of people living with HIV/AIDS are higher: up to 15 percent greater for protein and 50 percent greater for energy (Piwoz and Preble 2000). Consequently, HIV/AIDS amplifies the effect of drought on nutrition (Mason et al. 2005). This creates a vicious cycle: inability to provide adequate nutrition in times of drought weakens the immune system and increases susceptibility to opportunistic infections, which in turn undermine the overall nutritional status. De Waal and Whiteside (2003) argue that HIV/AIDS has created a new variant famine because the pandemic has reduced the viability of farming livelihoods. The pandemic has substantially increased the susceptibility of rural communities to droughts and other climate-related shocks (Foster 1993). The joint effects of climate change and HIV/AIDS can be greater than the sum of their separate effects.

Currently, preventive measures and treatment are the only ways to stop HIV/AIDS transmission and should be integrated into any health programme. For example, integrating sexual and reproductive health care with HIV/AIDS programmes increases people's access to information and services that reduce sexually transmitted infections (including HIV), unintended pregnancies, maternal and newborn deaths and mother-to-child transmission of HIV. Because clients seeking HIV/AIDS services and those seeking family planning services share many needs and concerns, integrating services enables providers to address them efficiently and comprehensively. Integration also assures that the reproductive health and rights of people living with HIV/AIDS are addressed and respected. Improving access to reproductive health services, including contraception, is one of the most important interventions for effective HIV prevention, treatment and care. The main barrier is that the process of adaptation to chronic illness and particularly to HIV/AIDS is highly individual. Research is still ongoing to better understand physical, psychological, social and religious adaptation to HIV/AIDS.

7 Major gaps in research on adaptation to climate change in the health sector

The health systems of African countries, including Cameroon, Gabon and Congo Republic, are generally pyramidal with three levels: central (strategic), intermediary (technical) and peripheral (operational). They consist of various public and private entities, but the principal provider of health care is the public sector even thought there is also a private sector (faith-based and for-profit) and a traditional medicine sector, which in many cases is not institutionalised.

One of the major constraints in African countries for addressing health challenges in general and climate change challenges in particular is the limited number of trained health workers to ensure the health system's full functionality from the central to the peripheral levels. Cameroon is presently facing a growing crisis in the medical field due to an acute shortage of qualified personnel, especially medical doctors (Amani 2010). This is supported by the fact that an early warning system put in place for early detection of cholera and meningitis epidemics in the North and Far North provinces failed because of lack of trained workers in some health districts (CICERO 2000). The region also lacks specialists in public health and climate science to undertake interdisciplinary research that feeds into evidence-based decision-making. This kind of weakness in disease control and climate surveillance and reporting systems is making it difficult to obtain the long-term linked data sets on climate and disease that are necessary for the development of early warning systems in African countries (WHO 2005).

Due to scarce resources, the governments of the region allocate little funding to health research. For the most part, research is supported by bilateral and multilateral organisations with limited participation of scientists from the home country. This results in donor-driven– as opposed to priority-driven – research agendas. Generally research is taking place in separate ministries, sectors and institutions and there are no overarching inter-sectoral or inter-institutional mechanisms for information, knowledge, collaboration and addressing of priorities. These ministries are unaware of each other's research projects, a situation that contributes to the lack of clearly defined national health research priorities. In addition, priorities for individual research institutions are set internally, rather than in collaboration with other institutions.

At the policy implementation level there is a limited awareness of climate change across governments. Therefore, there is no national strategy or policy for climate change in the region, including in Cameroon, Gabon or Congo. In addition health practitioners and communities have limited understanding of the effects of climate change on health to undertake appropriate climate change adaptation actions. Research findings need to be taken up and integrated into policies in order i) to strengthen the health systems by promoting the capacity building in interdisciplinary and multi-sectoral domains; ii) to improve the understanding of the health practitioners and communities on the effects of climate change on health; and iii) to strengthen the community-based organisations to develop locally owned sustainable strategies for adaptations to climate change in their communities, taking account of local knowledge.

8 Health policies related to climate change

The governments of African countries through their respective Ministers of Health and Ministers of Environment made firm commitments to address climate change while emphasising health adaptation. The WHO, the United Nations agencies in collaboration with Member States and other partners developed a framework for health adaptation to climate change. The framework provides guidance to enable African governments to translate the commitments into action (WHO 2011; WHO/AFRO 2011). Each country was requested to submit a National Communication or a NAPA to UNFCCC. The main objective of the NAPA is to minimise the adverse public health effects of climate change in Africa. These plans will be based on an essential public health package of interventions that would include baseline risk and capacity assessments, capacity building, integrated environment and health surveillance, awareness raising and social mobilisation, public health-oriented environmental management, scaling-up of existing public health interventions, strengthening of partnerships and promotion of research. Policy responses to meet these adaptation needs have been initiated throughout the region, primarily at the national level. Seven of the nine countries in Central Africa have submitted National Communications to the UNFCCC. Four of the six countries in the region classified as LDCs (CAR, Chad, DRC and STP) have prepared NAPAs; a fifth country, Angola, is currently preparing its report. All vulnerability assessments produced by governments of all countries in the region identified human health as a source of significant vulnerability to climate change.

The degree to which governments in the region have integrated climate change into national development plans varies. At one extreme, Angola and Equatorial Guinea have yet to submit National Communications or NAPAs; on the other, Cameroon and Gabon have made significant progress toward integrating climate change considerations into their national development policies (Crawford et al. 2011). Cameroon has integrated climate change adaptation and mitigation strategies into its National Plan for Environmental Management, while the government of Gabon has established a national Climate Council to develop national climate change policies and prepare a National Climate Plan. Intra-regional climate change action at the policy level, such as through the Economic Community of Central African States (ECCAS) and COMIFAC, is limited. Policy initiatives in general lag behind project- and programme-based initiatives.

Cameroon: The Cameroon health system is a pluralistic system because it is characterised by multiple sources of funding and health care providers. The main funding sources are the government, public enterprises, foreign aid donors, private enterprises, households, religious missions and NGOs, and the providers are government health facilities, public enterprise health clinics, health facilities of religious missions and NGOs, private clinics, pharmacies, drug retailers and traditional doctors. It is also a vertical system in the sense that funding sources deal directly with the providers without going through intermediaries or financing agents.

To address climate change issues, the government of Cameroon has established a body called the Cellule Nationale des Changements Climatiques, which is mandated to: 1) create an inventory of national greenhouse gas emissions and adaptation measures; 2) put into place an information system and database on climate change, and establish an online home for this information to ensure its accessibility and dissemination; 3) design sectoral projects addressing priority actions for climate change prevention, mitigation and adaptation; and 4) evaluate the impacts and policies associated with adaptation and mitigation.

Cameroon is in a process of scaling up its national malaria control strategy to meet the challenge of the millennium development goals (Wonghi et al. undated). The proposed strategies include a governance arrangement and delivery arrangements. The governance arrangements consist of clearing the drug market of all antimalarials that are not in the national policy; putting into effect the national health regulation through reinforced inspection and supervision activities; shifting from the current unified approach to specific strategies according to the epidemiological picture and the emerging trends such as co-morbidity with HIV/AIDS; and transferring greater responsibilities to and empowering municipalities and communities for comprehensive and integrated malaria control interventions. The delivery arrangements consist of shifting from the current unified approach to specific strategies according to epidemiological profiles and the emerging trends in the epidemiology of diseases; promoting distribution of Long Lasting Impregnated Nets (LLINs) and Intermittent Preventive Treatment for Pregnant women (IPTp) to the communities supported by NGOs, civil society organisations, community health workers and community based associations;

and fostering public-private partnerships through Service Level Agreements (SLAs) or Performance Based Contracting (PBF) as appropriate.

Gabon: Following commitments made in December 2009 at the United Nations Conference on Climate Change in Copenhagen, the Gabon government decided to establish a National Climate Council. This structure aims to develop and strategically direct national policy on climate change, with the ultimate goal of drafting a National Climate Plan. A carbon reporting tool is already available from Agence Française de Développement (AFD). The Gabonese Agency for Space Study and Observation (AGEOS) is monitoring the forests, the coasts and the land by satellite.

9 An analysis of stakeholders and opportunities for collaboration

The health systems in Central African countries, as in most the continent, are pyramidal with three levels: central (strategic), intermediate (technical) and peripheral (operational). The stakeholders are local government health institutions, the private sector, NGOs, bilateral and multilateral partners and the communities themselves. The health systems of most of the countries are suffering from shortage of quantitative and qualitative human resources for proper implementation of their health strategies. In many cases the communities are not involved in the implementation strategies of health policies. Generally there is not good coordination between the different stakeholders, and climate change adaptation strategies are not precisely defined and integrated into the health policies. For example the health systems of Cameroon, Congo Republic and Gabon are described below with the difficulties, the opportunities and the challenges they are facing.

Cameroon: The health system is suffering from a quantitative and qualitative shortage of human resources despite recruitment efforts in recent years; technical and managerial shortcomings and unethical behaviour of staff; gaps in information to control the epidemiological phenomena and to improve the management of health services; a weak legal framework for the effective implementation of drug regulation to dispose of medical products (including vaccines); and insufficient and inadequate funding, as well as difficulty in absorbing funding made (WHO, 2009a).

The health sector is primarily funded by the national budget, households (cost recovery and other direct payments), external funding and to a lesser extent local government authorities and private health insurance. North-South cooperation is predominant and is carried out through the main specialised agencies of the UN system, the European Union, the World Bank, the African Development Bank and the Islamic Development Bank. Bilateral cooperation is dominated by France's AFD and Germany's KfW Entwicklungsbank and Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ).

Cameroon has many opportunities, as it:

- is politically stable;
- has a vision and a Strategy Paper for Growth and Employment with a horizon to 2035;
- has ongoing reforms in the health system and the fight against disease since the adoption of the Health Sector Strategy (2001-2011); and
- has developed a conceptual framework for health districts, minimum packages of primary care and additional packages of health activities at all levels of the health pyramid.

The updating of the Health Sector Strategy to meet the deadline for achieving the MDGs (2015) includes:

- the implementation of a development emergency human resources plan;
- improving access to medicines, especially in the priority programmes;
- decentralised planning at the district level;
- a health development plan to be implemented under a common programme (Health SWAp);
- the existence of a framework for cooperation partners in health development.

The challenges include the development of human resources quality and quantity necessary for the proper functioning of health facilities; ensuring access to essential medical products to the most vulnerable; making health districts viable in the context of primary health care; developing a reliable health information system for proper monitoring of progress; reducing the levels of maternal, infant and child mortality by implementing integrated and efficient interventions; scaling up interventions in child survival and health promotion for adolescents; controlling the major communicable and non-communicable diseases, including HIV/AIDS, TB, malaria and neglected tropical diseases; making the health system effectively responsive to the health consequences of humanitarian emergencies; and addressing the health determinants and creating favourable conditions for healthy environments.

Gabon: The health system comprises three sectors cohabiting without any formal relationship or complementarity: the civil public health sector (peripheral, intermediate and central levels), the semi-private sector (National Health Insurance Fund and the

National Social Security Fund) and the private sector (including for-profit, non-profit and traditional). The traditional sector legal framework is being developed.

Although the health sector has been considered as a national priority, very few bilateral and multilateral partners are willing to invest financially in this sector, which is essential for sustainable development. The few partners who contribute to the financing of health and social interventions include United Nations agencies– the WHO, United Nations Children's Fund (UNICEF), United Nations Population Fund (UNFPA) and United Nations Development Programme (UNDP) – and bilateral partners including France, Italy, the USA and Canada. The private sector is also involved in the health sector but the extent of its contribution is not officially available.

The health system of Gabon is dysfunctional, mainly due to the inadequate quality and quantity of human resources, the low availability of essential drugs and medical equipment and non-involvement of communities in the management of health problems. Opportunities include Gabon joining the initiative of Harmonization for Health in Africa, the Ouagadougou Declaration on Primary Health Care and Health Systems in Africa and the Libreville Declaration on Health and Environment in Africa (WHO, 2009b). The health challenges that WHO has identified with the Health Ministry of Gabon are:

- the reduction of maternal mortality by strengthening emergency obstetric and neonatal care in health facilities as well as the prevention and early treatment of sexual transmitted diseases;
- the reduction of infant and child mortality by improving coverage for all vaccination and scaling of maternal childhood disease management;
- controlling disease by strengthening the surveillance of communicable and non-communicable diseases and better management of the cases; and
- improving the health system through the operability of the health departments, strengthening of hospital medicine and revitalisation strategy of primary health care.

Congo Republic: The health system is inefficient due to multiple factors. These include poor distribution of health facilities in the territory; under-equipping of facilities; insufficient human resources in quantity and quality; mismanagement and inefficiency of the supply system; the irrational use of medicines; and a lack of financial resources associated with modes of inadequate funding and an inefficient use of available (WHO, 2009c).

Opportunities in Congo Republic are the consolidation of peace and stability of political institutions; the improvement of the macroeconomic situation of the country; the political commitment reflected in particular by increasing the resources allocated to the health sector and taking initiatives such as those related to the introduction of free access to ARV and antimalarial treatments; the existence of the PRSP as a framework of reference for the overall implementation of health policy; and the eligibility of the country for health financing initiatives at the global level, as well as the initiative of debt relief for heavily indebted poor countries (HIPCs). The challenges include creating conditions for the reduction of morbidity and mortality related to communicable and non-communicable diseases and those related to reproductive health; scaling up priority health interventions, particularly those related to malaria, HIV/AIDS and TB and ensuring universal access to populations; strengthening disease surveillance and response systems for emergencies; preventing disability and creating conditions for better integration of people with disabilities; ensuring humanitarian assistance to populations affected by crises; promoting positive health behaviours; and improving access to safe drinking water and waste disposal systems including for biomedical waste in both urban and rural areas.

10 Conclusion and recommendations

This analysis of climate change and health revealed that the biggest causes of morbidity in Central Africa are malaria, respiratory tract infections, diarrhoea and HIV/AIDS. Low health workforce densities, weak health systems and insufficient sustainable financial resources are undermining efforts to reduce the burden of these diseases.

Central Africa is less affected by climate change than other parts of the continent of Africa. However, the region is already experiencing climate change impacts. There are different climate change impacts in the region due to its considerable size and the variety of ecosystems, topographies and climates. The major climate change vulnerability issues of the health sector in Central Africa are related to vector borne diseases, food and water borne diseases and HIV/AIDS. Depending on the situation (from Angola in the south to Chad in the north), climate change in Central Africa may have positive or negative effects on vector borne diseases. For instance, in cold highland areas higher temperatures may increase mosquito activity and malaria transmission, while in already hot areas it may suppress mosquito activities. Deforestation can lead to the replacement of malaria vector species by others more competent in disease transmission. Sea level rise in coastal areas may lead to floods which favour the expansion of water borne diseases. For instance, *Vibrio cholera* ecology is intimately linked to that of plankton. Floods, subsequent to sea level rise, will expand the distribution of the pathogen of cholera with enhanced potential for epidemic outbreaks. There is also an association between extreme and frequent weather events (drought and/or flood) and cholera outbreaks. Food shortage due to either flood or drought leads to malnutrition, which will in turn

exacerbate the health situation of people already living with HIV/AIDS. Heat stress also debilitates HIV/AIDS patients' immune systems.

It is important to note here that there is limited knowledge on the relationship between diseases and current and future climate change to support decision-makers and the communities most vulnerable in Central Africa. There is a need for key stakeholders to join forces to clearly define health risks of climate change and to bring to the attention of decision-makers the serious threat of climate change to population health. For this purpose, multi-disciplinary and cross-sector operational research in each ecosystem is required to determine appropriate and effective responses. This can only be done by putting in place improved disease mortality monitoring and surveillance systems run by sufficiently numerous and qualified human resources and infrastructure to generate accurate and reliable data. In addition, accurate and reliable meteorological data are also required.

There is an inadequate regional, and in countries institutional, coordination of climate change adaptation mechanisms in Central Africa. Projects that address climate change in the region and even in the same country are fragmented. They generally tend to be short-term, donor-driven and sometimes alien to community needs and interests.

Sectors reported by Central African countries in their NAPAs or National Communications to the UNFCCC as key priority sectors for climate change adaption are agriculture, human health, freshwater resources, coastal zone management, forestry and fisheries. There are very few focused climate change adaption strategies implemented or integrated in countries' health policies. Current adaptations for the health sector consist of strengthened management strategies, preventive initiatives, good urban planning, building of flood protection structures, vaccination, insecticide treated net distribution, promoting water treatment and distribution, food refrigeration, chlorination of drinking water, pasteurisation of milk, sanitary slaughter and processing of meat.

Women are very vulnerable to climate change because they account for a large proportion of the agricultural workforce and have fewer alternative income opportunities, which are crucial factors at times when climate variability affects agricultural yields and food security. Efforts to minimise the adverse impacts of climate change should recognise women as powerful agents of change and ensure they are fully integrated into climate change mitigation and adaptation strategies at all levels.

The prominent challenges for Central Africa to address the direct and indirect effects of climate change in the health sector are:

- To build up a strong public health system with sufficient number of qualified human resources and infrastructure.
- To generate reliable health and meteorological data in order to establish a clear understanding of the links between climate change and health and disease mortality.
- To promote communication strategies for better awareness and understanding of climate change health risks at the levels of decision-makers, health practitioners and communities.
- To undertake multidisciplinary and cross sector operational research for a better risk assessment of climate change impacts in the health sector.
- To mainstream potential public health impacts of climate change in national policies and plans.
- To strengthen community based organisations to develop locally owned sustainable strategies for adaptations to climate change in their communities, taking account of local knowledge.
- To promote a gender sensitive approach to interventions on climate and health in cross sectoral disaster risk reduction and preventive health strategies.
- To mobilise national and international funding for vulnerability assessment, risk monitoring and risk reduction activities as well as disaster management institutions.

References

AAP (2011a) *Cameroon Climate Vulnerability Profile,* Dakar, Senegal: Africa Adaptation Programme of the United Nations Development Programme / https://www.undp-aap.org/countries/cameroon [accessed 17 May 2013]

AAP (2011b) *Congo Climate Vulnerability Profile,* Dakar, Senegal: Africa Adaptation Programme of the United Nations Development Programme / https://www.undp-aap.org/countries/congo [accessed 17 May 2013]

AAP (2011c) *Gabon Climate Vulnerability Profile,* Dakar, Senegal: Africa Adaptation Programme of the United Nations Development Programme/https://www.undp-aap.org/countries/gabon [accessed 17 May 2013]

AfDB (2011) *Central Africa Regional Integration Strategy Paper (RISP)*, Abidjan, Côte d'Ivoire: African Development Bank/www.afdb.org/fileadmin/uploads/afdb/Documents/Policy-Documents/RISP%20CENTRAL%20AFRICA-ECCAS%20English%20FINAL.pdf. [accessed 20 May 2013]

Afrane, Y.A., Githeko, A.K. and Guiyun, G. (2011) 'Malaria Transmission in the African Highlands in a Changing Climate Situation: Perspective from Kenyan Highlands', in Casalegno, S. (ed), *Global Warming Impacts: Case Studies on the Economy, Human Health, and on Urban and Natural Environments,* Rijeka, Croatia: InTech

Ahern, M., Kovats, R.S., Wilkinson, P., Few, R. and Matthies, F. (2005) 'Global Health Impacts of Floods: Epidemiologic Evidence', *Epidemiologic Reviews*, 27:36-46

Amani, A. (2010) *The Health Workers Crises in Cameroon*. Public Health Theses paper 139, Atlanta, GA: Georgia State University. Available at digitalarchive.gsu.edu/cgi/viewcontent.cgi?article=1141&context=iph_theses&sei-redir=1&referer=http%3A%2F%2Fwww.google.ml%2Furl%3Fsa%3Dt%26rct%3Dj%26q%3Damani%25202010%2520cameroon%26source%3Dw [accessed 5 June 2013]

Aminatu, G., Yasmine, R. and Bamboye, G. (2010).) Indigenous Women and Climate Change in South and North West Cameroon. Philippines, Tebtebba Foundation.

Ayouba, A., Nerrienet, E., Menu, E., Lobe, M.M., Barre-Sinoussi, F., Martin, P. and Cunin, P. (2003) 'Mother-to-Child Transmission of Human Immunodeficiency Virus Type 1 in Relation to the Season in Yaounde, Cameroon', *American Journal of Tropical Medicine and Hygiene,* 49(4):447-449

Bayoh, M.N., Thomas, C.J. and Lindsay, S.W. (2001) 'Mapping Distributions of Chromosomal Forms of *Anopheles gambiae* in West Africa using Climate Data', *Medical and Veterinary Entomology,* 15(3):267-274

Bele M Y, Tiani A M, Somorin OA, Sonwa DJ (2013) Exploring vulnerability and adaptation to climate change of communities in the forest zone of Cameroon. Climatic Change, DOI 10.1007/s10584-013-0738-z.

Béné, C., Wood, R.G., Newsham, A. and Davies, M. (2012) *Resilience: New Utopia or New Tyranny? Reflection about the Potentials and Limits of the Concept of Resilience in Relation to Vulnerability Reduction Programmes.* IDS Working Paper 405, Brighton, UK: Institute of Development Studies

Bigoga, J.D., Coetzee, M, Leke, R.G., Manga, L. and Titanji, V.P.K. (2007) 'Malaria Vectors and Transmission Dynamics in Coastal South-Western Cameroon', *Malaria Journal,* 6(1):5

Boko, M., Niang, I., Nyong, A. ,Vogel, C., Githeko, A., Medany, M., ... Yanda, P. (2007) 'Africa', in *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* Cambridge, UK: Cambridge University Press

Bolton, S. and Talman, A. (2010) 'Interactions between HIV/AIDS and the Environment: A Review of the Evidence and Recommendations for Next Steps', Nairobi, Kenya: International Union for Conservation of Nature Eastern and Southern Africa / cmsdata.iucn.org/downloads/hiv_aids_and_environment.pdf [accessed 26 December 2013]

Bouma, M.J. and Van der Kaay, H.J. (1994) 'Epidemic Malaria in India and the El Niño Southern Oscillation', Lancet, 344(8937):1638-1639

Bruce-Lockhart, K. (2012) 'Alleviating the Double Burden: Women, Food Security and HIV/AIDS in Sub-Saharan Africa', *Women & Environments International Magazine,* Fall 2011/Winter 2012 (88/89):14-15

Buczak, A.L., Chretien, J.P., Lewis, S.H., Philip, T.L. and George, D. (undated) 'Prediction of Cholera Epidemics in Africa', unpublished manuscript / www.jhuapl.edu/sages/resources/modeling/modeling_prediction_cholera_paper%20.pdf [accessed 31 December 2013]

Cannon, T. (2002). Gender and climate hazards in Bangladesh. Gender & Development 10(2): 45-50.

Center for International Climate and Environmental Research (CICERO) (2000) Developing Strategies for Climate Change: The UNEP Country Studies on Climate Change Impacts and Adaptations Assessment. Report 2000:2 http://www.cicero.uio.no/media/314.pdf [Accessed 26 May 2014].

Christensen, J.H., Hewitson, B., Busuioc, A., Chen, A., Gao, X., Held, I., ... Whetton, P. (2007) 'Regional Climate Projections', in *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* Cambridge, UK: Cambridge University Press

Constantin de Magny, G., Murtugudde, R., Sapiano, M.R., Nizam, A., Brown, C.W., Busalacchi, A.J., ... Colwell, R.R. (2008) 'Environmental Signatures Associated with Cholera Epidemics', PNAS, 105(46):17676-17681

Craig, M.H., Snow, R.W. and Le, S.D. (1999) 'A Climate-Based Distribution Model of Malaria Transmission in Sub-Saharan Africa', *Parasitology Today,* 15(3):105-111

Crawford, A., Hove, H. and Parry, J.E. (2011) *Review of Current and Planned Adaptation Action: Middle Africa,* Adaptation Partnership / www.adaptationpartnership.org/sites/default/files/Middle%20Africa%20Regional%20Profile.pdf [accessed 20 May 2013]

DARA (2010) *Climate Vulnerability Monitor: The State of the Climate Crisis,* Madrid, Spain: DARA / daraint.org/

wp-content/uploads/2011/07CVM-exec-sum-01072011.pdf [accessed 26 December 2013]

De Waal, A. and Whiteside, J. (2003) *HIV/AIDS and Food Security in Africa: A Report for the Department for International Development* / tacilim.com/emergencies/deWaalFood.pdf [accessed 22 May 2013]

DHS (2009) VIH/sida dans l'Enquête de Séroprévalence et sur les Indicateurs du Sida au Congo. http://dhsprogram.com/pubs/pdf/HF31/HF31.pdf [Accessed 17 May 2014]

DHS-MICS (2011) HIV Prevalence in Cameroon: Findings from the 2011 DHS-MICS http://dhsprogram.com/pubs/pdf/HF42/HF42.pdf [Accessed 17 May 2014].

EDSG-II (2012) Prévalence du VIH/sida au Gabon : résultats de l'EDSG-II 2012. http://dhsprogram.com/pubs/pdf/HF44/HF44.pdf [Accessed 17 May 2014]

Faye, O., Gaye, O., Fontenille, D., Hebrard, G., Konate, L., Sy, N., ... Molez, J. F. (1995) La sécheresse et la baisse du paludisme dans les Niayes du Sénégal [Drought and malaria decrease in the Niayes area of Senegal], *Sante*, 5(5):299-305

Foster, S. (1993) 'Maize Production, Drought and AIDS in Monze District, Zambia', *Health Policy Planning,* 8(3):247-254

Githeko, A.K., Lindsay, S.W., Confalonieri, U.E. and Patz, J.A. (2000) 'Climate Change and Vector-Borne Diseases: A Regional Analysis', *Bulletin of the World Health Organization,* 78(9):1136-1147

IPCC (2007) *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* Cambridge, UK: Cambridge University Press

Kaseje, D. (2006) *Health Care in Africa: Challenges, Opportunities and an Emerging Model for Improvement,* presented at the Woodrow Wilson International Center for Scholars, 2 November, Washington DC / wilsoncenter.org/sites/default/files/Kaseje2.pdf [accessed 5 June 2013]

Lindsay, S., Ansell, J., Selman, C., Cox, V., Hamilton, K. and Walraven, G. (2000) Effect of Pregnancy on Exposure to Malaria Mosquitoes', *Lancet,* 355(9219):1972

Lyons, C.L., Coetzee, M., Terblanche, J.S. and Chown, S.L. (2012) 'Thermal Limits of Wild and Laboratory Strains of Two African Malaria Vector Species, *Anopheles arabiensis and Anopheles funestus', Malaria Journal,* 11:226

Manga L, Toto JC, Carnevale P. (1995) Malaria vectors and transmission in an area deforested for a new international airport in southern Cameroon. Ann Soc Belg Med Trop. 1995 Mar;75(1):43-9.

Manga, L., Bagayoko, M., Meredith, T. and Neira, M. (2010) *Overview of Health Considerations within National Adaptation Programmes of Action for Climate Change in Least Developed Countries and Small Island States.* Available at: http://www.who.int/phe/Health_in_NAPAs_final.pdf. [Accessed 26 May 2014]

Mason, J.B., Bailes, A., Mason, K.E., Yambi, O., Jonsson, U., Hudspeth, C., ... Martel, P. (2005) 'AIDS, Drought, and Child Malnutrition in Southern Africa', *Public Health Nutrition,* 8(6):551-563

McSweeney, C., New, M., Lizcano, G. and Lu, X. (2010) *The UNDP Climate Change Country Profiles: Improving the Accessibility of Observed and Projected Climate Information for Studies of Climate Change in Developing Countries,* American Meteorological Society, pp.157-166

Minakawa, N., Sonye, G., Mogi, M., Githeko, A. and Yan, G. (2002) 'The Effects of Climatic Factors on the Distribution and Abundance of Malaria Vectors in Kenya', *Journal of Medical Entomology,* 39(6):833-841

Molineaux, L. (1988) 'The Epidemiology of Human Malaria as an Explanation of its Distribution, Including Some Implications for its Control', in Wernsdorfer, W.H. and McGregor, I. (eds), *Malaria: Principles and Practice of Malariology,* 2nd Edition, London, England: Churchill Livingstone, pp.913-998

Molua, E.L. and Lambi, C.M. (2007) *The Economic Impact of Climate Change on Agriculture in Cameroon.* Policy Research Working Paper Series 01/2007, Washington DC: The World Bank

Mouchet, J., Faye, O., Juivez, J. and Manguin, S. (1996) 'Drought and Malaria Retreat in the Sahel, West Africa', *Lancet*, 348(9043)1735-1736

Nicholls R.J, Wong P.P, and Burkett V.R (2007). Coastal systems and low-lying areas. In: Climate change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press, 2007.

Nicholls, R.J., Hanson, S.E., Lowe, J.A., Warrick, R.A., Lu, X., Long, A.J. and Carter, T.R. (2011) *Constructing Sea-Level Scenarios for Impact and Adaptation Assessment of Coastal Areas: A Guidance Document,* Intergovernmental Panel on Climate Change Task Group on Data and Scenario Support for Impacts and Climate Analysis / www.ipcc-data.org/docs/Sea_Level_Scenario_Guidance_Oct2011.pdf [accessed 5 June 2013]

Piwoz, E G. and Preble E A. (2000) HIV/AIDS and Nutrition: A Review of the Literature and Recommendations for Nutritional Care and Support in Sub-Saharan Africa, Washington, DC: SARA Project, FHI 360.

Republic of the Congo Ministry of Sustainable Development, Forestry and the Environment (RCMSDFE) (2009) Second National Communication. Brazzaville: Ministry of Sustainable Development, Forestry and the Environment of the Republic of Congo and the United Nation Development Programme. http://www.adaptationlearning.net/democratic-republic-congo/profile [Accessed 26 May 2014].

Snow, R.W., Craig, M.H., Deichmann, U. and Le, S.D. (1999) 'A Preliminary Continental Risk Map for Malaria Mortality among African Children', *Parasitology Today,* 15(3):99-104

Sogoba, N., Vounatsou, P., Bagayoko, M.M., Doumbia, S., Dolo, G., Gosoniu, L., ... Smith, T. (2007a) 'The Spatial Distribution of *Anopheles gambiae sensu stricto* and *An. arabiensis* (Diptera: Culicidae) in Mali', *Geospatial Health,* 1:213-22

Sogoba, N., Doumbia, S., Vounatsou, P., Baber, I., Keita, M., Maiga, M., ... Ribeiro, J.M. (2007b) 'Monitoring of Larval Habitats and Mosquito Densities in the Sudan Savanna of Mali: Implications for Malaria Vector Control', *American Journal of Tropical Medicine and Hygiene,* 77(1):82-88

Sogoba, N., Vounatsou, P., Bagayoko, M.M., Doumbia, S., Dolo, G., Gosoniu, L., ... Toure, Y.T. (2008) 'Spatial Distribution of the Chromosomal Forms of *Anopheles gambiae* in Mali', *Malaria Journal,* 7:205

Stern, N. (2006) *Stern Review: The Economics of Climate Change,* Cambridge, UK: Cambridge University Press

Tandon, A., Murray, C.J.L., Lauer, J.A. and Evans, D.B. (undated) *Measuring Overall Health System Performance for 191 Countries*. GPE Discussion Paper Series No. 30 EIP/GPE/EQC, Geneva, Switzerland: World Health Organization

Tanga, M.C., Ngundu, W.I., Judith, N., Mbuh, J., Tendongfor, N., Simard, F., Wanji, S. (2010) 'Climate Change and Altitudinal Structuring of Malaria Vectors in South-Western Cameroon: Their Relation to Malaria Transmission', *Transactions of the Royal Society of Tropical Medicine and Hygiene,* 104(7):453-60

Tchuinkam, T., Simard, F., Lélé-Defo, E., Téné-Fossog, B., Tateng-Ngouateu, A., Antonio-Nkondjio, C., ... Awono-Ambéné, H.P. (2010) 'Bionomics of *Anopheline* Species and Malaria Transmission Dynamics along an Altitudinal Transect in Western Cameroon', *Infectious Disease,* 19(10):119

Thornton, P.K., Jones, P.G., Owiyo, T., Kruska, R.L., Herrero, M., Kristjanson, P., ... Omolo, A. (2006) *Mapping Climate Vulnerability and Poverty in Africa.* Report to the Department for International Development, Nairobi, Kenya: International Livestock Research Institute

Toure, Y.T., Traore, S.F., Sangare, O., Sow, M.Y., Coulibaly, A., Esposito, F. and Petrarca, V. (1996) 'Perennial Transmission of Malaria by the *Anopheles gambiae* Complex in a North Sudan Savanna Area of Mali', *Medical and Veterinary Entomology,* 10:197-199

UNDP-AAP (2011) Supporting Integrated and Comprehensive Approaches to Climate Change Adaptation: The Republic of the Congo. http://www.undp-aap.org/sites/undp-aap.org/files/Congo.pdf [Accessed 17 May 2014]

UNEP (2002) *Africa Environment Outlook: Past, Present and Future Perspectives,* Nairobi, Kenya: United Nations Environment Programme

UNEP (2012) *Africa Environment Outlook: Past, Present and Future Perspectives,* Nairobi, Kenya: United Nations Environment Programme / www.unep.org/dewa/Africa/publications/aeo-1/index.htm [accessed 23 May 2013]

UNFPA (2010) *State of World Population 2010: From Conflict and Crisis to Renewal: Generations of Change,* New York, NY: United Nations Population Fund

Wonghi, J.N., Ongolo-Zogo, P., Tallah, E., Leke, R. and Mbacham, W. (undated) *Policy Brief on Scaling Up Malaria Control Interventions in Cameroon,* Geneva, Switzerland: World Health Organization / www.who.int/alliance-hpsr/projects/alliancehpsr_policybriefscalingupmalariacameroon.pdf [accessed 5 June 2013]

WHO (1948) *Preamble to the Constitution of the World Health Organization,* as adopted by the International Health Conference, 19-22 June, New York, NY: World Health Organization

WHO (2005) *Using Climate to Predict Diseases Outbreaks: A Review.* WHO/SDE/OEH/04.01, Geneva, Switzerland: World Health Organization

WHO (2009a). Stratégie de Coopération de l'OMS avec les pays 2010-2015: Cameroun. Bureau régional de l'OMS pour l'Afrique. Geneva, Switzerland: World Health Organization

WHO (2009b). Stratégie de Coopération de l'OMS avec les pays 2008-2013: Gabon. Bureau régional de l'OMS pour l'Afrique. Available at : http://www.who.int/countryfocus/cooperation_strategy/ccs_gab_fr.pdf

WHO (2009c). Stratégie de Coopération de l'OMS avec les pays 2009-2013: Congo. Bureau régional de l'OMS pour l'Afrique.WHO. Available at : http://www.who.int/countryfocus/cooperation_strategy/ccs_cog_fr.pdf

WHO (2010a) Gender, Climate Change and Health, Geneva, Switzerland: World Health Organization. Available at: www.who.int/globalchange/GenderClimateChangeHealthfinal.pdf. 1-44.

WHO (2010b).Cholera in Central Africa. Global Alert and Response- Disease outbreak news. Available at : http://www.who.int/csr/don/2010_10_08/en/).

WHO (2011) Gender, Climate Change and Health, Geneva, Switzerland: World Health Organization. Available at: www.who.int/globalchange/GenderClimateChange Healthfinal.pdf. Last accessed May 23 2013.

WHO (2012) World Health Statistics 2012: Part III Global health indicators, Geneva, Switzerland: World Health Organization. Available at: www.who.int/healthinfo/EN_WHS2012_Part3.pdf [accessed 23 May 2013]

WHO (2013) Piloting climate change adaptation to protect human health. Available at: www.who.int/globalchange/climate/gefproject/en/index.html [accessed 17 May 2013]

WHO/AFRO (2011) *Framework for Public Health Adaptation to Climate Change in the Africa Region,* Sixty-First Session, 29 August-2 September, Yamoussoukro, Côte d'Ivoire: World Health Organization Regional Committee for Africa

WHO (undated). Countries statistics. Available at: http://www.who.int/countries/en/, Accessed 17 May 2014

WHO (undated) Health Topics: HIV/AIDS available at: http://www.who.int/topics/hiv_aids/en/ [Accessed 26 May 2014].

WHO (undated). The health sector. Available at http://www.who.int/trade/glossary/story048/en/, Accessed 26 May 2014

WHO/UNICEF (2000) *Global Water Supply and Sanitation Assessment 2000 Report,* Geneva, Switzerland and New York, NY: World Health Organization and United Nations Children's Fund

WHO/UNICEF (2005) *Water for Life: Making it Happen,* Geneva, Switzerland and New York, NY: World Health Organization and United Nations Children's Fund. Available at: www.who.int/water_sanitation_health/waterforlife.pdf [accessed 23 May 2013]

World Bank (2009). Africa's Development in a Changing Climate. Published by the International Bank for Reconstruction and Development . The World Bank: Washington DC.

WWF (2007) *HIV/AIDS and the Environment: Impacts of AIDS and Ways to Reduce Them. Fact Sheet for the Conservation Community,* Gland, Switzerland: World Wide Fund for Nature: Available at: assets.worldwildlife.org/publications/371/files/original/HIV_AIDS_and_the_Environment_Impacts_of_AIDS_and_Ways_to_Reduce_Them.pdf [accessed 22 May 2013]

Ziervogel G, Drimie S (2008) The integration of support for HIV and AIDS and livelihood security: district level institutional analysis in southern Africa. *Population and Environment Volume 29, Issue 3-5, pp 204-218.*

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