Climate change as an amplifier of health risks: highland malaria in Africa.

Chapter 4

Climate change as an amplifier of health risks: highland malaria in Africa[1]

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Abstract

The interactions between climate and non-climate factors are of vital importance in shaping human vulnerability to global warming. In this chapter, this is illustrated for an important health risk induced by climate change, namely highland malaria in Africa. Despite the known causal links between climate and malaria transmission dynamics, the anticipated future impacts on disease risk are still surrounded by uncertainty, partly due to the fact that the relationship between vector-borne disease incidence and climate variables is complicated by many non-climate factors. We discuss some important non-climate factors that are crucial in determining the vulnerability context in the face of global warming. Although we focus on the example of highland malaria in Africa, the need for a systems approach is equally valid for other health impacts (e.g. food security, heat waves, flooding, and health impacts related to water scarcity).

4.1 Introduction

Climate change is perceived as one of the most important future health risks (Costello, Abbas et al. 2009) and as a threat to the achievement of sustainable development (World Bank 2009). This arises from the fact that climate change can act as an important amplifier of existing health risks, particularly in developing regions.

According to the IPCC's fifth assessment report (IPCC 2013), the increase in global mean surface temperatures for 2081–2100 (relative to 1986–2005) is likely be in the range of 0.3°C to 4.8°C. The prospect of global warming is accompanied by increasing concern about its health impacts, including impacts on heat stress, flooding, infectious diseases, sanitation and water security, air quality (including aeroallergens such as pollen), and food security (McMichael, Woodruff et al. 2006; Comrie 2007; IPCC 2007; IPCC 2014). A joint report by The Lancet and University College London (UCL) (Costello, Abbas et al. 2009) stressed that "climate change is the biggest global health threat of the 21st century," as its impacts "will affect most populations in the next decades and put the lives and wellbeing of billions of people at increased risk."

The World Health Organisation's (WHO) Global Burden of Disease Project has estimated that climate change has been responsible for 5.5 million disability-adjusted life years (DALYs) lost in 2000 (WHO 2002), with developing countries bearing a disproportionately high share of this disease burden (McMichael, Campbell-Lendrum et al. 2004). Climate change impacts on health are of particular concern for the developing world, as global warming is believed to further exacerbate the already existing vulnerabilities to disease. Furthermore, it has been argued by the World Bank (2009) that unmanaged climate change will reverse important development progress in developing countries.

An ever growing number of health researchers (Albrecht, Freeman et al. 1998; Colwell 2004; McMichael 2005; Wilcox and Colwell 2005; Pearce and Merletti 2006; Lang 2012) argue that our health can or must be viewed within the broader system of health determinants. Populations are not simply collections of individuals, but are shaped by, and shape, the systemic context in which they operate (Pearce and Merletti 2006). Hence, the multitude of health determinants does not operate in isolation, but occur in a particular population context. In line with the increasing call for systems approaches to health, this chapter argues that vulnerability to climate change impacts should be seen within the broader "system/context" of health determination, including many non-climate factors. Taking such a systems perspective on health demonstrates that the interactions between climate and non-climate factors are of vital importance in shaping the high vulnerability to the adverse impacts of global warming in developed countries and especially developing countries.

This is illustrated below for an important climate change induced health risk, namely highland malaria in Africa. We examine in more detail some important linkages between climate and non-climate factors that are crucial in determining the vulnerability context

in the face of global warming (Huynen, Martens et al. 2013). Finally, we conclude that understanding and addressing the interdependencies between factors that create a higher vulnerability to adverse health impacts is central to formulating effective climate change adaptation policies.

4.2 Climate change as an amplifier of malaria risk

Malaria is a life-threatening disease caused by Plasmodium parasites that are transmitted to people through the bites of infected mosquitoes. Malaria contributes greatly to the disease burden in the developing world (WHO 2002; FAO 2010; WHO 2011), negatively affecting development progress. Not surprisingly, lowering the number of malaria cases is an important Millennium Development Goal (UN 2012). While there has been some promising progress in tackling malaria (UN 2012), the observed declines in incidence and mortality are falling short of the ambitious Global Malaria Action Plan goals of reducing global malaria cases by 75% and preventable global malaria deaths to near-zero by 2015 (RBM Partnership 2008; UN 2012). According to the World Malaria Report 2011 (WHO 2011), there were about 216 million cases of malaria and an estimated 655,000 deaths in 2010. Others (Murray, Rosenfeld et al. 2012) suggest that mortality rates are even substantially higher. It is the people living in the poorest countries who are the most vulnerable to malaria; the WHO (2011) estimates that 90% of all malaria deaths in 2010 occurred in Africa.

Climate and climate change is believed to be an important factor in the dynamics of malaria transmission (Chaves and Koenraadt 2010; Caminade, Kovats et al. 2014; IPCC 2014). For example, temperature affects mosquito survival as well as parasite development (Martens, Kovats et al. 1999; IPCC 2007; Chaves and Koenraadt 2010). The influence of temperature on malaria development, however, appears to be nonlinear and vector-specific. Increased variations in temperature, when the maximum is close to the upper limit for vector and pathogen, tend to reduce transmission, while increased variations in mean daily temperature near the minimum boundary increase transmission (IPCC 2014). Additionally, mosquito survival is also affected by changes in humidity, while developments in rainfall patterns can affect the number of suitable breeding sites.

Most simulation studies have focussed on the impacts of changes in the general climate on potential shifts in the distribution and magnitude of endemic malaria in at-risk regions and on changes in regions at the margins of current endemic distributions (IPCC 2007). The health-impact models are typically based on climatic constraints on the development of the vector and/or parasite (IPCC 2007). Several approaches are being used to model malaria (e.g. multivariate statistical techniques, process-based biological models), and all have their specific advantages and disadvantages (Huynen, Martens et al. 2013). Some model studies (e.g. Martens et al.(1999), Ermert et al.(2012)) indicate a significant change in areas suitable for malaria mosquitoes or in malaria transmission;

others (Rogers and Randolph 2000) conclude that climate change will not result in any significant net change in malaria risk. In projections by Gething et al. (2010) the risk was even found to decline by 2050, due to control measures. The recent multimalaria model intercomparison exercise by Caminade et al. (2014) concluded that future climate might become more suitable for malaria transmission in the tropical highland regions.

Based on the outcomes of several modelling studies, climate change is believed to have mixed effects on malaria; some places will experience a reduction in the geographical range of the disease, while other locations will see an expanding geographic range and a changing transmission season (IPCC 2007). Despite the known causal links between climate and malaria transmission dynamics, the anticipated future impacts on disease risk are still surrounded by uncertainty, partly due to the fact that the relationship between vector-borne disease incidence and climate variables is complicated by many non-climate factors (IPCC 2007; IPCC 2014). The models used so far have included limited non-climate assumptions (IPCC 2007; IPCC 2014) and forecasts cannot be very precise, due to the sensitivity of nonlinear multidimensional systems to all of their underlying dynamics and interactions, especially those that are not accounted for by the models studied (Chaves and Koenraadt 2010).

Consequently, the search for important non-climate malaria drivers has become one of the major fields of inquiry (Chaves and Koenraadt 2010). In an elaborate literature review, Cohen et al. (2012) identified the following suggested causes of past malaria resurgence events: weakening of control activities (e.g. due to funding constraints, poor execution, purposeful cessation), technical problems (e.g. vector resistance, drug resistance), human or mosquito movement, development/industry changes (including land-use change), socio-economic weakening, climate/weather, and war. Malaria is also closely linked to poverty; poorer communities have a higher disease risk due to factors like less access to health services due to financial barriers, poorer nutritional status, lower education levels, poor sanitation, and inadequate housing (Ricci 2012). Although the above list is probably far from exhaustive, it clearly illustrates that climate change is just one of many processes that affect infectious disease risk. Hence, the assessment of the impacts of climate change on malaria is challenged by the complex interactions between climate and non-climate factors. Let us explore this in more detail by looking at the various drivers of malaria emergence in the East African highlands. The IPCC (2007), for example, explicitly expressed its concern about future climate change impacts on malaria risk in the highlands of East Africa. A recent study by Ermert et al. (2012) concluded that climate changes will significantly affect the spread of malaria in tropical Africa well before 2050, with a changing geographic distribution of the areas where malaria is epidemic (e.g., highlands) in the coming decades.

The numerous reports of increased malaria in the East African highlands have shown that malaria is becoming established in regions that belong to the territorial margins of its previous distribution (Lindsay and Martens 1998; Chaves and Koenraadt 2010; Tesi 2011; Himeidan and Kweka 2012). In the past two decades, there has been some

debate about the importance of climate change in driving these observed changes in malaria distribution and transmission in highland regions (IPCC 2007; Chaves and Koenraadt 2010). A recent review by Chaves and Koenraadt (2010) concludes that, even though the existing studies all applied different modelling approaches and techniques, they all show an association between malaria and climate variables, making the linkage between climate change and malaria in the highlands of Africa rather robust. In the same publication they argue, however, that overemphasising the role of climate as the autonomous main driver of highland malaria does not account for the clear multi-factorial causality of disease transmission.

The East African highlands are among the most populated regions in Africa, and their population growth rates are among the highest in the world. The regions are also faced with high rates of poverty. Poverty and demographic pressures have spurred massive land-use and land-cover changes (including massive deforestation) for agricultural purposes (Himeidan and Kweka 2012). The upland communities are often remote from regional health centres, and health services are patchy, hampering the surveillance and control of malaria. It is increasingly acknowledged that the risk of highland malaria moving to higher altitudes depends on the interplay between climate change and factors like land-use change, population growth, population movement, agricultural practice (e.g., pesticide use, irrigation systems), cessation of malaria control activities, drug resistance, limited immunity of people living at higher altitudes, and socio-economic status. Additionally, malaria invasion of the East African highlands has been associated with the migration of people from the lower areas to the higher altitudes (Lindsay and Martens 1998), introducing the malaria parasite into highland regions. Furthermore, the massive deforestation in East Africa has proved to be associated with changes in the local climate. As such, land-use changes and global warming may act together in causing the observed regional change in the local climate of the East African highlands (Himeidan and Kweka 2012). Changes in crop choice can also play a role, as demonstrated by the invasion of malaria in the Bure highlands of Ethiopia due to the fact that the mosquito vector thrived on maize pollen, just shortly after this crop was introduced (Ye-Ebiyo, Pollcak et al. 2000; Kebede, McCann et al. 2005). Irrigation activities and forest clearing have been associated with increases in vector densities, as they increase the number of mosquito breeding sites (Himeidan and Kweka 2012). Susceptibility to the increasing mosquito densities and the associated malaria risk are further complicated by the high poverty rates in the East African highlands. Fortunately, malaria prevalence in the highlands has decreased since the early 2000s, due to ongoing malaria interventions (Chaves and Koenraadt 2010; Stern, Gething et al. 2011; Himeidan and Kweka 2012). However, the sustainability of these interventions is questionable (Himeidan and Kweka 2012). African countries mostly rely on external donors, and global funding levels for malaria are in an increasingly precarious state (Pigott, Atun et al. 2012); weakening of malaria control programmes has been an important driver of malaria resurgence observed in the past (Cohen, Smith et al. 2012).

As Berrang-Ford et al. (2009) state, "climate change is one of several determinants of infectious disease occurrence, whose impact is superimposed upon, and moderated by, parallel changes in non-climate determinants." A recent report by the Africa Initiative (Tesi 2011) also stressed the multi-causality of malaria; although climate change has been associated with the emergence of malaria in African highlands, other factors are also involved in accelerating this process. The report argues that climate factors (increases in temperature, rainfall, and humidity) act as primary factors, because as long as the disease transmission is constrained by climate factors, the disease will automatically be limited as well. The secondary factors, such as drug resistance, agricultural development, population growth, migration, conflicts, and land-use change, can accelerate the process set in motion by climatic factors. Similarly, Chaves and Koenraadt (2010) emphasise that "a multidimensional array of underlying factors is likely to be at play here, most of which may be sensitive to climatic change." Hence, although climate change is believed to primarily affect the intrinsic malaria transmission potential (Tesi 2011; Cohen, Smith et al. 2012), it interacts with other factors and developments that also affect disease dynamics. Most of them, such as agriculture, food security, migration, and poverty, are expected to be affected by climate change (IPCC 2007; McMichael, Barnett et al. 2012).

Using the framework by Huynen et al. (Huynen, Martens et al. 2005; Huynen 2008), Table 4.1 illustrates the wide array of interacting factors that determine a population's vulnerability context within the wider climate-malaria system.

Table 4.1 Emergence of highland Malaria in Africa: examples of important system variables

Causal level of health determination	Institutional	Economic	Socio-cultural	Environmental
Contextual determinants (upstream macro-level conditions shaping the distal and proximate health determinants*	Public health infrastructure, including number of healthcare centres in highland areas	Economic infrastructure	High population growth and density resulting in demographic pressures	Climate change, ecosystem change
Distal determinants (are set further back in the causal chain and act via intermediate causes)	Health policy including efforts to reduce malaria, agricultural policies	Slow economic development, agricultural sector developments	Population movement, high poverty rates	Substantial land use/cover change, agricultural irrigation, altered local climate regulation
Proximate determinants (act directly to cause disease or health gains)	Pre-2000: lack of health care (or access to it) and control/ surveillance activities Post-2000: increasing malaria interventions and control	-	Lack of immunity to malaria in highlands, incorrect use of antibiotics or bed nets, drug resistance	Changes in local climate including temperature rise, increase in mosquito breeding sites

* i.e. they form the context within which the distal and proximate factors operate and develop

4.3 Systems approach toward vulnerability and adaptation

We argue that vulnerability to climate change impacts should be seen within the broader system of health determination, including many non-climate factors. The interactions between climate and non-climate factors are of vital importance in shaping human vulnerability to global warming. Although this chapter focuses on the example of highland malaria risk in Africa, the need for a systems approach is equally valid for other health impacts (e.g. food security, heat waves, flooding, health impacts related to water scarcity) (Huynen, Martens et al. 2013). In line with the above, the recent IPCC fifth assessment report (IPCC 2014) argues that future trends in social and economic development are critically important to vulnerability.

In view of their particular vulnerability context, the health effects of climate change are expected to be especially harsh in the developing countries. This is not only due to differential exposure to the hazard, but also to the interactions between climate and non-climate factors that fundamentally shape the high vulnerability of developing countries' populations to the anticipated health impacts. Developing countries are, for example, more reliant on agriculture, more vulnerable to droughts, and have a lower adaptive capacity (USGCRP 2008). The IPCC (IPCC 2014) concludes, however, that that there have been comparatively few studies of vulnerability among low- and-middle income populations, or of more complex disease pathways. Additionally, efforts to mainstream climate change adaptation into development planning in order to reduce local vulnerabilities are still at a relatively early stage in many countries (UNDP and UNEP 2011).

In order to avoid a multiplication of health risks in the developing world, there is a need to better understand the multi-faceted and complex linkages involved. We need to move away from the discussion about the relative importance of climate change to other stressors, towards approaches that take possible synergies between different developments into account. This chapter demonstrates that an effective response to climate change related health risks should take a systems approach towards adaptation, acknowledging the importance of the local context of the most vulnerable. Hence, adaptation measures have to be specific for the local context, seeking to address the causes of higher vulnerability and lower adaptive capacity by focussing on measures to reduce poverty and other non-climatic factors that make people vulnerable. Without efforts to improve our understanding of this system and subsequent action to protect the most vulnerable, the amplification of existing and emerging health risks might become the greatest tragedy resulting from climate change (Huynen, Martens et al. 2013).

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