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Global Warming and Health: The Issue of Malaria in Eastern Africa's Highlands

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ABSTRACT

Discussion on various aspects of global warming has been intense but disjointed. This paper synthesizes the discussion that deals with the nature of and relationship between global warming and malaria. It draws on empirical materials in the East Africa Highlands, broadly defined, to clarify the nexus between global warming and malaria epidemics in East Africa, highlight the main points of contention in that discussion, examine the financial limitations that constrain the ability of African governments to effectively deal with global warming-malaria issues, and outline the policy tools available to governments in the East Africa Highlands to address the impact of global warming on malaria.

INTRODUCTION

The subject of global warming has generated much discussion worldwide over the past three decades. As of 2010, the debate has not subsided. Those following the discussion in Western media and among the interested public may have the impression that the concerns are too abstract, or driven by ideology or by corporate greed. They may believe that responsibility for dealing with the issue should lie with the countries of the industrialized world, which have emitted most of the greenhouse gases, and with countries such as China, India and Brazil, which are undergoing mass industrial transformation and have now joined the ranks of heavy emitters. Industrialized countries and the so-called emerging economies have been at the forefront of the issue of global warming, both because they are the largest emitters of greenhouse gases and also because they have much more to gain economically if there are no restrictions on their behaviour. Yet the reality is that the burden of doing nothing will be heaviest on many countries in Africa, for the simple reason that they have the least capacity to adapt to or deal with the consequences. While it is important to study exactly which particular consequences of global warming will most affect Africa, it is equally important to understand the decisions that African governments will have to make in addressing those consequences, and to recognize the pressures and constraints that they will face in making such decisions. In short, the impact of the problem, the pressure for adaptive and mitigating action, and the constraints limiting government decisions and actions characterize the context for discussing global warming in Africa.

The discussion on global warming has been cast in four principal categories, namely, whether global warming is actually taking place, the causes of such changes, the likely consequences of the changes and how best to stop or mitigate its impact. With the exception of a few dissenters, there is a convergence of views among scientists on the first two and last questions, although some of the lingering disagreements are more methodological than substantive. The third question is perhaps the most challenging among the issues that scientists face because of the uncertainty associated with predicting the responses of different ecological universes when a universe cannot be subjected to controlled observation. This notwithstanding, the composition of different ecological systems, their climatic conditions, their range and the interactive dynamics associated with life within various ecological universes can be known. Under such circumstances, and with all things being constant, it follows that the introduction of an external or foreign element or actor in the existing ecological mix would be identifiable, and so the impact of such an element or actor could be identified. It is from this viewpoint that this analysis is being carried out. That is, we know the characteristics of the different ecological universes in Africa, and their dynamics, and so we can therefore detect abnormalities within them.

The focus of this paper is global warming and health security in Africa, specifically, the impact of global warming on public health through increased disease transmission. Global warming has led, either directly or indirectly, to an increase in the incidence of certain diseases such as malaria in Africa. This is happening not only when Africa emits very little, comparatively, of the greenhouse gases that generate global warming, but also when it is the region of the world that has the least capacity to deal with the health problems associated with greenhouse gases. African countries are under enormous pressure to address the impacts of global warming, yet they are constrained by the limited courses of action at their disposal in a policy arena in which other equally critical issues have to compete with the increased health challenges. (See, for example, the Eighth Meeting of the Africa Partnership Forum held in Berlin, Germany, May 22–24, 2007.) Their success or failure will depend on how much help they are able to get for their efforts.

IS GLOBAL WARMING TAKING PLACE IN AFRICA?

Given the overwhelming evidence, the question as to whether global warming is taking place should be a resolved debate. Climate records for Africa suggest that the issue of climate change resulting from global warming is not an issue of the future; it is an issue of the present. Scientists have attributed the volatile climatic conditions that have been occurring in Africa, especially the alternation of drought and floods, to changes associated with global warming. Periodic occurrences of drought in the Sahel region of Africa from the late 1960s through the early 1980s are recognized as signs of a trend of decreasing rainfall in that region beginning in the 1950s (Xie et al., Held, 2005). Multi-year data from the United Nations Development Programme's (UNDP) *Human Development Report* indicates that over a quarter of a billion people suffered from climate-related disasters between 2000 and 2004 (Human Development Report 2007/2008:8). The Intergovernmental Panel on Climate Change's (IPCC) Fourth Assessment Report, "Climate Change 2007," compared the impact of climate-related disasters and showed that more than 90 percent of those affected by these disasters were from developing countries (Parry et al., 2007; Human Development Report 2007/2008). The ratio of one to 19 people in developing countries against one to 1,500 people in developed countries affected by climate-related disaster, highlights yet another aspect of the debate; that is, the limited adaptive capacity of poor countries to deal with the problem (Human Development Report 2007/2008: 8). Let us examine the predicament of climate change in Africa. Is Africa's climate warming and becoming more extreme?

"GLOBAL WARMING HAS LED, EITHER DIRECTLY OR INDIRECTLY, TO AN INCREASE IN THE INCIDENCE OF CERTAIN DISEASES SUCH AS MALARIA IN AFRICA"

Over the past decade, various studies have confirmed what has been conventional wisdom in many parts of Africa — that temperatures are getting extraordinarily hot. Predicting warmer climates with increases of between 3 to 6 degrees Celsius on average by 2100, the IPCC's Third Assessment Report, "Climate Change 2001," revealed that average temperatures in Africa were already 0.7 degrees Celsius warmer (McCarthy et al., 2001). This mean increase in warming does not tell the entire story, however. In some areas of the continent, the warming was greater, but for others, it was below the mean. In parts of Kenya, for example, temperatures on average were warmer by 3.6 degrees Celsius from the mid-1980s to 2006 (Oxfam et al., quoted in BBC News, 2006). In comparison, Africa's tropical forests registered a 0.29 degree Celsius increase (Malhi and Wright, 2004; Boko et al., 2007), while the increase in South Africa averaged between 0.1 and 0.3 degrees Celsius (Kruger and Shongwe, 2004; Boko et al., 2007). Minimum and maximum temperature increases have also been registered in various parts of the African continent. IPPC's "Climate Change 2007" also documents increases in the number of warm-weather spells between 1960 and 2000 in the western and southern parts of the continent.

> "CHANGES IN TEMPERATURE AFFECT PRECIPITATION AND RAIN FORMATION IN THE ATMOSPHERE BY REDUCING OR LENGTHENING THE PERIOD OF DRY WEATHER"

Rainfall is a key component of climate and affects how cold or warm weather conditions will be. Likewise, changes in temperature affect precipitation and rain formation in the atmosphere by reducing or lengthening the period of dry weather. Concerns about global warming have consequently generated much interest in precipitation. It is assumed that if Africa is already experiencing warming, such warming will also be manifested in rainfall variability on the continent. A problem arises, however, when it comes to measuring rainfall variability. Which should be used? Inter-annual, decadal or multi-decadal variability? Irrespective of which measures are used, the rainfall data in the years after 1960 show a trend of decreasing mean rainfall of between two to four percent in the tropical rain-forests regions, and a drastic annual decrease of 20 to 40 percent in Western Africa (Boko et al., 2007: 433–467). On the other hand, the Southern Africa region shows an increase in and more erratic patterns of rainfall and drought (Richard et al., 2001: 873–885). Meanwhile, a 2008 analysis of data from satellites and ground stations showed a 15 percent decline in rainfall during the rainy season between March and May in Eastern and Southern Africa dating back to the 1980s (Funk et al., 2008: 11081–11086).

WARMER CONTINENTAL AFRICA TEMPERATURE AND GLOBAL WARMING

The issue of climate change and global warming revolves around the argument that global warming and climate change are induced by human activities, through the emission of greenhouse gases in the atmosphere and also by the destruction of vegetation covers and rainforests, which act as protective sinks to absorb such gases from the atmosphere. Naturally induced climatic variability has been known to delay the arrival of the rainy season in Africa, thereby delaying planting seasons for farmers and resulting in a much longer dry season (Ajibade and Shokemi, 2003: 37–44; Leautier, 2004; Boko et al., 2007: 433–467). Early rains have also tended to shorten the dry season and disrupt crops that require long sunny seasons.

Natural variability in climatic conditions, however, occurs without a pattern and without great frequency. Beginning in about the late 1960s and early 1970s, significant changes in climatic conditions in Africa have been more frequent, so much so that the changed conditions are becoming the new normal, leading to more erratic weather with unpredictable outcomes that are often very destructive.

A principal point of contention in the thesis that Africa's climate is getting warmer and changing because of global warming is the issue of finding a connection between the warming trend and any human causation. The model of global warming posits that greenhouse gases emitted in the atmosphere trap the sun's rays in the atmosphere, causing higher rates of evaporation of ocean waters, which moist air then mixes with cold currents and falls back as rain, flooding coastal areas, generating hurricanes and so on, and melting ice caps on mountains and in the polar regions (Parry et al., 2007). If, however, the rainfall over the oceans and seas is very intense, it can disrupt the flow of moist air over land. For dryer regions, the trapped heat can increase the temperatures, making them even dryer and leading to drought (Parry et al., 2007). The model of climate change therefore requires that links be found between the warming taking place in Africa and sources associated with human activities in any of the ecosystems that influence climatic conditions in Africa.

Studies of patterns of drought and rainfall during the past decade and a half have shed some light on the relationship between ocean-atmospheric climatic patterns and drought. Chris Funk at the University of California Santa Barbara and his colleagues studied rainfall over the Indian Ocean and Eastern Africa using three different data sets and found a relationship between a decline in rainfall on the eastern shore of Eastern Africa and increased precipitation in the Indian Ocean (Funk et al., 2008: 11081–11086). Funk and his colleagues also tested the relationship using computer models. They explained that human-caused warming of the Indian Ocean increased rainfall over the ocean. The increased rainfall added powerful energy to the atmosphere, which in turn created a weather pattern that decreased the flow of moist air from the ocean onto the shore (Funk et al., 2008). Another study by Yves Richard and his colleagues (Richard et al., 2001: 873–885) found a similar link between ocean-atmosphere connections, with drought in three different periods in Southern Africa: from 1950 to 1969, associated with ocean-atmosphere erratic occurrences over the southwest Indian Ocean region; from 1970 to 1988, associated with the El Niño-Southern Oscillation (ENSO); and from 1970 to 1998, associated with the Southern Oscillation Index and the Southern African Rainfall Index. Other studies, including the IPCC's "Climate Change 2007," have also linked ocean-atmospheric temperatures, including Indian Ocean sea-surface temperature (SST), ENSO, the African Easterly Jet and the Tropical Easterly Jet in the Sahel region of Africa (Boko et al., 2007: 433–467).

"THE CHANGED CONDITIONS ARE BECOMING THE NEW NORMAL"

FRAMING THE QUESTION: GLOBAL WARMING AND DISEASE IN AFRICA

The debate on climate change and global warming is of interest to Africa for a variety of reasons, not least of which is public health. Africa, unlike most regions of the world, has its major health threats. The existence, spread and intensification of infectious diseases are related to the presence of suitable environmental conditions for their carriers. To the extent, therefore, that climatic conditions are able to alter conditions of a particular ecosystem, through persistent warming or flood, for instance, it is only normal that such changes will also affect diseases endemic to that ecosystem. Diseases often depend on conditions in the ecosystem and are sustained by ecosystem dynamics. While it is true that a disease not endemic to an area could also be transmitted to other areas as long as there are carriers and available hosts, such transmission would be difficult without an existing source and conditions favourable for the disease to thrive in.

> "THE EXISTENCE, SPREAD AND INTENSIFICATION OF INFECTIOUS DISEASES ARE RELATED TO THE PRESENCE OF SUITABLE ENVIRONMENTAL CONDITIONS FOR THEIR CARRIERS"

Studies linking malaria to climate change have not been fully accepted, based on the argument that they fail to account for non-climate related variables such as drug resistance, inadequate treatment, migration, economic activities and poor health-care infrastructures (Hay et al., 2002: 905–909; Lomborg, 2007). Although such considerations may be valid, they are not strong enough to negate the link between climate change and an environmentally related disease such as malaria. The issue of increased incidence of disease refers to more than normal rise in the number of cases. Whether or not such new levels are due to resistance to drugs, and whether or not there are adequate health facilities, environmental conditions hospitable to the disease and its vector (the carrier of the disease — in malaria, the female anopheles mosquito) still have to exist in order for the disease to emerge, thrive and be transmitted. In the case of malaria, not everyone is resistant to some of the drugs. This may mean that a patient is being counted twice: first as the person who has the disease, and second as the person who has the disease and is resistant to drugs. Statistical data for measuring disease increases and linking such increases to ecosystem conditions conducive to transmission, sustenance and intensification of the disease are critical to understanding the impact of climate change on disease. We also see an important role for the observation of biological data and climatic conditions as well.

CLIMATIC FACTORS AND DISEASE IN AFRICA

Among the critical health concerns in Africa are infectious diseases, most of which are also considered diseases of the environment. These are diseases that are deemed to be most affected by the warming taking place on the continent. The World Health Organization (WHO), the African Union, the IPCC and various environmental and development groups have identified such diseases as targets for observation in order to consider how best to deal with the potential risk that climate change poses for them. Despite much disagreement among scientists as to the precise nature of the impact of climate changes on diseases in Africa, some diseases such as malaria, Rift Valley fever, sleeping sickness, yellow fever, meningococcal meningitis and cholera are directly linked to climate (Wildlife Conservation Society, 2008). Of these diseases, malaria has been the most discussed in the literature and has also been the most referenced by policy makers. Much of that discussion, moreover, has focused on Africa, and Eastern Africa in particular. This should not be surprising given that Africa accounts for 90 percent of the malaria in the world (WHO, 1999). At issue has been whether climate change is linked to increases in malaria epidemics in Eastern Africa's highlands or whether other factors such as inadequate health infrastructure or drug resistance might be responsible for the upsurge of malaria. Regarding the increased incidence of malaria in Eastern Africa's highlands, research shows that most of the epidemics have occurred mainly after major climatic incidents such as a period of protracted drought followed by severe rainfall (Report on Climate Change: Economic Commission for Africa; Thomson et al., 2005: 214–221; Brown et al., 1998: 1356–7). Yet policy is usually devised only when there is a problem, or in anticipation of a problem. The Kenyan government took mitigating policy steps to deal with problems related to the adequacy of health facilities. The government worked to increase the country's health infrastructure in proportion to growth in population. As far back as 1998, it also put out a directive replacing the drug of first order in the line of treatment against malaria so as to deal with the issue of drug resistance.

IS THE WARMING ASSOCIATED WITH INCREASED INCIDENCE OF MALARIA?

The response to this question depends on whether the warming creates conditions conducive to the development, survival and transmission of malaria vectors (mosquitoes) and the malaria parasite. Physical and climatic conditions favourable to transmission include temperature, humidity, rainfall and topography. The breeding of mosquito carriers, their parasite and its transmission to human hosts is very temperature-sensitive. The mosquito ceases to develop at temperatures below 16 degrees Celsius. Temperatures of around 20 degrees Celsius can trigger an epidemic (Lindsay and Martens, 1998: 34, 35). But temperatures near 40 degrees Celsius will kill the mosquitoes (Aisling, 2009). Most transmission of the parasite through mosquito bites takes place during the night, when temperatures drop. Although temperatures below 16 degrees Celsius are not suitable for the vectors' development, they can simply wait in occupied houses under more favourable temperatures and then develop later when conditions are more hospitable (Lindsay and Martens, 1998: 34). The larvae of the anopheles mosquito responsible for most of the transmission of the malaria parasite in Africa is mainly laid in water. Excessive rainfall creates ideal conditions for the multiplication of the mosquito population because the number of pools of standing water that mosquitoes use as breeding grounds increases. Breeding sites do not necessarily have to be extensive. Landforms shaped in ways that enable rain water to collect in them, and cans, containers and discarded objects such as automobile tires that can trap and hold water during periods of heavy and persistent rains, become breeding sites (Stuckenberg, 1969: 145–197; Tansa et al., 2003: 1795; Gubler, 1988: 7). Moist and humid ecosystems such as forests and wetlands also provide

> "PHYSICAL AND CLIMATIC CONDITIONS FAVOURABLE TO TRANSMISSION INCLUDE TEMPERATURE, HUMIDITY, RAINFALL AND TOPOGRAPHY"

fertile grounds for sustaining malaria vectors. Here also, persistent rainfall plays a significant role in generating moisture and the suitable conditions for vector and parasite survival and development (Stuckenberg, 1969: 145–197; Tansa et al., 2003: 1795; Gubler, 1998). Rainfall without the availability of appropriate sites for breeding may reduce the vector population, making it difficult for the disease to develop. Another factor is whether people have immunity to the malaria parasite, in which case they may have the parasite but it will not develop to the diseased stage. Where such immunity exists in the population, the disease dynamic takes a different form (Lindsay and Martens, 1998: 33).

MALARIA AND CLIMATE CHANGE IN EAST AFRICA'S HIGHLAND AREAS

Malaria in East Africa's highlands presents a case study for understanding the challenges that climate change poses to Africa. The topic has been widely discussed in the literature with contradictory findings (Hay et al., 2002: 905–909; Pascual et al., 2006: 5829–5834; Pascual et al., 2008: 123–132; Mouchet et al., 1998: 522–523; Lomberg, 2007). At issue is the position that climate change has contributed to a malaria epidemic and has led to an expansion of malaria to highland areas beyond the lowland limit where the mosquito vectors are usually found (Lindsay and Martens, 1998). Among the other projected consequences of global warming, the malaria issue stands out because of the general ecological dynamics associated with its spread. It is an endemic disease that develops, survives and spreads triggered by climatic factors. It can survive only under certain climatic conditions, specifically temperatures of not below 16 degrees Celsius, and it requires a moist environment for its larvae to develop. High-altitude areas have been unsuitable for the survival of the parasite and its mosquito carrier due to the colder temperatures of the highlands (Curtin, 1989; Lindsay and Martens, 1998: 33). With few exceptions, highland areas have fewer marshes or wetlands to provide natural breeding sites for the mosquito vectors. The highland areas also do not have significant numbers of pan-shaped landforms to collect and retain rain water over time to serve as breeding grounds for the insect transmitters (Curtin, 1989; Lindsay and Martens, 1998: 33). Yet the highlands areas of Ethiopia, Western Kenya, Uganda, Burundi, Tanzania and Zimbabwe have exhibited an upsurge in malaria cases over the past two decades. The increased incidence is considered alarming because it is occurring in unstable malaria zones, meaning that the people there do not have the same immunity to the disease as do people in stable malaria regions (Mouchet et al., 1998, 2008).

> "THE HISTORY OF MALARIA IN AFRICA IS A HISTORY OF PAIN, TORTURE AND DEATH"

The history of malaria in Africa is a history of pain, torture and death. Various parts of the continent have experienced epidemics at one time or another. Kenya experienced an epidemic in 1940, and Ethiopia went through two epidemics within a period of three years in 1953 and 1958 (Lindsay and Martens, 1998: 33, 35). Significant progress was made in reducing infections and the incidence of epidemics during the 1960s and 1970s (Roberts, 1964: 230–237). Such progress was set back beginning in the mid-1980s (WHO, Roll Back Malaria) with reports of new epidemics occurring beyond the traditional malaria belts of Western and Central Africa. The East African

Highlands (from Ethiopia through Kenya and Tanzania to as far south as South Africa) became a hotbed of malaria resurgence in ways that had rarely been heard of. Malaria had tended to be more prevalent in Eastern Africa's lowlands and valleys than uplands. What has also been challenging about this resurgence is that the bacterium is resistant to drugs such as chloroquine, which was previously crucial in the fight against the disease (WHO, Roll Back Malaria).

The changing map of malaria in Africa and a growing incidence of the disease in the highland areas are of major concern to health workers and policy makers (Kiszewski and Teklehaimanot, 2004: 128–135; Lindsay and Martens, 1998: 3; Hay et al, 2002). While no precisely defined limit exists beyond which malaria will not be found, Lindsay and Martens contended that 2,000 meters was the elevation beyond which malaria was believed unlikely to exist (Lindsay and Martens, 1998: 33; Bodker et al., 2003: 706–717). That limit, however, has been identified at a much lower level for some countries and at much higher levels for others (Lindsay and Martens, 1998; Bodker et al., 2003: 706–717; Negash et al., 2005: 186–192; Kiszewski and Teklehaimanot, 2004: 3, 5). Such limitations are based on how far up mountains and highlands mosquitoes are able to go in particular localities and not on any other reasons (Lindsay and Martens, 1998: 35; Bodker et al., 2003). In general, an elevation of 1,500 meters above sea level is used to define the limit above which the likelihood of finding malaria will be rare. This places Eastern Africa's various highlands above that limit; but again, the disease has been found in some areas of Ethiopia above 2,000 meters (Negash et al., 2005).

Eastern Africa has some of the most varied physical features in Africa. It has the continent's largest lake (Lake Victoria), the highest mountain peaks (Mount Kilimanjaro and Kenya) and the Great Rift Valley and lowlands. The lowlands and valleys are in the stable malaria zones (where malaria is common and the people have developed immunity to it) while the highlands are in the unstable malaria zone, where people do not have immunity (Mouchet et al., 1998 and 2008). Epidemic malaria incidents in the highland areas have generated great interest. As Table 1 shows, the malaria situation at four sites in four countries in Eastern Africa is alarming ,yet quite instructive as to the severity and growth of the disease. In some regions such as Rwanda and Kenya, the incidence of the disease was overwhelming. The morbidity and mortality associated with malaria in Burundi suggests that significant achievements have not yet been realized in the fight against the disease.

“EPIDEMIC MALARIA INCIDENTS IN THE HIGHLAND AREAS HAVE GENERATED GREAT INTEREST”

Table 1: Growth of Malaria Incidents in the East African Highlands

Highland Area	Country	Year	Malaria Cases/ Deaths	Year	Malaria Rate/Deaths
Kericho	Western Kenya	1986	16/1,000 cases	1998	120/1000 cases
Kabale	Southwest Uganda	1992–96	17/1,000 cases	1997–98	24/1000 cases
Gikonko	Southern Rwanda	1976	160/1,000 cases	1990	260/1000 cases
Muhanga	Northern Burundi	1980s	18/1,000 deaths	1991	25–35/1000 cases

Source: Derived from Simon I. Hay et al., "Climate Change and the Resurgence of Malaria in the East African Highlands," *Nature* 415.

COUNTRY CASES

"THIS MAKES MALARIA THE NUMBER ONE DISEASE IN ETHIOPIA, CAUSING ABOUT 70,000 DEATHS A YEAR"

Research in other highland areas also shows a large increase in the prevalence of malaria over the past two and a half decades. Although Ethiopia falls in the stable malaria zone, the impact of the disease on the country has been catastrophic. Since 1958, when a malaria epidemic in Ethiopia affected 3.5 million people and led to 150,000 deaths, that country has endured frequent malaria epidemics (Kiszewski and Teklehaimanot, 2004: 4). Efforts to eradicate the disease were first undertaken in an experimental form in the 1950s, and then made national in the 1960s (Adugna). During the 1970s, the strategy shifted from eradication to control. These strategies, however, were not very successful and malaria continues to be a major threat in the country. According to some reports, malaria is present in three-fourths of the territory below elevations of 2,000 meters (Negash, 2004). This places two-thirds of the country's 85 million people at risk (Negash, 2004). Epidemics occurred in the country in 1987–1988, 1991, 1992 and 1998–1999 (Kiszewski and Teklehaimanot, 2004: 3–4). The number of documented cases rose dramatically from the average annual figure of around 5 million to almost double that, at 9.5 million, from 2001 to 2005 (President's Malaria Initiative, 2008). This makes malaria the number one disease in Ethiopia, causing about 70,000 deaths a year (President's Malaria Initiative, 2008). The country suffered another severe occurrence in 2003 with 50 epidemics at elevations of from 1,500 to 2,500 meters in three regions and 25 districts (Negash et al., 2005).[1] The 1998 and 2003 epidemics were unusual in that they appeared at a higher elevation than previously (Negash et al., 2005; Kiszewski and Teklehaimanot, 2004: 4). The role that climatic factors have played in generating malaria epidemics has been observed over the years (Fontaine, 1961: 795–803). One analyst summarizes the distribution of malaria and the role of climatic factors in that distribution this way: "The Dega zone of Ethiopia (altitude above 2,500 meters) with a mean annual temperature of 10–15 degrees Celsius is malaria-free. Much of the Woina Dega zone (elevation 1,500–2,500 meters) is also malaria free, especially the zone in the 2,000–2,500 meters above sea level." Malaria in Ethiopia "… often occurs below 2,000 meters, with short-lived transmission following the rains. However, malaria epidemics have been recorded up to 2,400 meters during periods when increased temperature and adequate precipitation are conducive for both vector survival and parasite development within the vector" (Adhanom et al., 2006, quoted in Adugna).The underlying argument is that high rainfall, elevated temperatures and humidity have been key factors in the appearance of malaria epidemics in the country. But research and the Ethiopian government also have found non-climatic factors in the upsurge of malaria cases. Factors associated with human habitation, migration, waste disposal, dams, irrigation and more have all been linked to increased incidence of malaria (Adhanom et al., 2006, in Adugna).

Tanzania, another Eastern African country, has shown a high occurrence of epidemic malaria in the highlands and edges of the Rift Valley, even though malaria is endemic to the area. The Rift Valley also happens to have high population density, which makes malaria occurrences particularly threatening (Matola et al., 1987: 127–134). Some 16 million people a year contract the disease in Tanzania, and between 100,000 and 125,000 die every year from it (Jones et al., 2007). Malaria incidence in Tanzania has increased by 146 percent over the baseline for 1995–2002. Like its neighbours, Tanzania has highland areas that rise from about 1,500 to 2,500 meters and which are associated with cooler temperatures. This should mean that the area would be free of malaria. Temperatures have been rising ever since the 1970s, however, creating conditions under which the area has been infested with malaria vectors. The country's other major landform, Mount Kilimanjaro, is also being negatively affected by climatic change; its snow cap is melting. Tanzania, like the other countries in the Rift Valley, suffers the effects of El Niño, including adverse temperature changes and their role as triggers for malaria. Tanzania also encounters drug resistance as well as problems associated with human-induced causes of the epidemics.

"MALARIA INCIDENCE IN TANZANIA HAS INCREASED BY 146 PERCENT OVER THE BASELINE FOR 1995–2002"

Kenya's highlands' history with malaria goes a long way back, to colonial days. The country experienced a major outbreak in its highlands in 1940. In the 1950s and 1960s the government embarked on a major campaign to eradicate the disease (Roberts, 1964, Part I: 161–168, Part II: 230–237). As a result, malaria was under control in the 1970s through to the 1980s. Beginning in 1989, epidemic malaria outbreaks erupted and became a lot more frequent in the 1990s and 2000s (Brown et al., 1998: 1356–1357). Studies have found that the occurrences of these epidemics are related to a number of factors, some not related to climate variability, but including land use, drug resistance, poor and inadequate health infrastructure, and migration (Shanks et al., 2002: 1404–1408; Hay, 2002: 905–909). Later, more focused and refined research by Zhou et al. showed in a study of the Kenyan highland sites of Kericho, Kilgoris and Eldoret that climatic factors account for more than 40 percent of the "temporary variance in malaria outpatient figures" there, while acknowledging the role of other factors (Zhou et al., 2004: 2375–2380). Pascual et al., in studies they conducted in the highlands of Kenya, also contradict earlier studies that disputed a definitive role for climatic factors in malaria resurgence in the highlands of Kenya (Pascual et al., 2006: 5829–5834). The link between El Niño events and malaria epidemics has also been made. In Kenya it was found that the

1997–1998 El Niño events associated with heavy rains were followed by a serious malaria epidemic in the Kenyan and surrounding highlands (Bouma et al., 1994: 1440; Rapuro, 2007). Temperatures also rose during the same period by about four degrees while malaria incidence increased by 300 percent over the average for 1995–2002 (Rapuro, 2007). As in Ethiopia and Tanzania, various non-climatic factors, including drug resistance, land use, migration and population growth, have also been seen as having an impact on malaria.

Malaria epidemics in Uganda have been frequent and quite intense. Incidents are concentrated in the southwest at the borders with Tanzania and Rwanda. The region is swampy and contains areas reclaimed for agriculture. Transmission varies with elevation; it takes place at a stable rate below 1,500 meters and unstably between 1,500 to 2,300 meters (Kiszewski and Teklehaimanot, 2004: 5). Years of civil conflicts in Uganda during the past three decades have led to mass movements of people, exposing them to higher risks of contracting malaria. Rwanda and Burundi have had similar experiences with malaria epidemics (Loevinsohn, 1994: 714–718). Large parts of these countries are in unstable malaria zones. They have gone through several years of civil conflicts and massive displacement of population. They are also very densely populated, consequently raising their vulnerability to epidemics. In 2000 and 2001, a major epidemic occurred in Burundi resulting in some 1,287 deaths. Rwanda's experience has been similar, as Table 1 shows (Kiszewski and Teklehaimanot, 2004: 5; Loevinsohn, 1994).

"AS IN ETHIOPIA AND TANZANIA, VARIOUS NON-CLIMATIC FACTORS, INCLUDING DRUG RESISTANCE, LAND USE, MIGRATION AND POPULATION GROWTH, HAVE ALSO BEEN SEEN AS HAVING AN IMPACT ON MALARIA"

The South Eastern Africa countries of Mozambique, Malawi, Zimbabwe, Madagascar, and Zimbabwe, are in some ways similar to the Eastern African countries (Kiszewski and Teklehaimanot, 2004: 3, 5). Malaria incidents are clustered for the most part in the highlands, although it is a different anopheles mosquito that carries the malaria parasite. They are in a stable malaria zone. Madagascar presents an interesting case because it did not have malaria before 1878. After rice cultivation using irrigation was introduced in the country, malaria also emerged. Massive indoor residual spraying was employed to eradicate it. But when the campaign was terminated in the mid-1980s, the epidemic returned. Eradication efforts that had been abandoned were restarted with some success (Mouchet, 1998: 64–66; de Zulueta, 1998, in Kiszewski and Teklehaimanot, 2004: 5). Sahelan Africa, the arid and semi-arid countries of Senegal, Chad, Niger, Mauritania, Burkina Faso and Sudan, falls in the unstable malaria zone. For these countries, rainfall is a more important factor than temperature in malaria epidemics (Morbidity Mortality Weekly Report, 1989: 785–788).

WHAT HAVE WE LEARNED

The issue of climate change and its effects on health and security in Africa is a complex issue that cannot be ignored. This analysis has examined that relationship to see if the there is a logical and measurable connection between global warming and the incidence of malaria. The premise — that infectious diseases are intricately tied to their environment and therefore changes to that environment will affect the diseases' development, survival, multiplication and intensity — seems to be quite logical. This does not imply that some other factors can not be involved in accelerating any of the processes. To the extent that the basic ecological actors necessary for the disease to function are not there, or are present only in limited quantities, the disease will also be limited. In that regard, the basic ecological actors in the disease and its vector's life cycle are the primary factors while others that also affect the disease's process are secondary factors.

Climatic factors associated with increases in temperature, rainfall and humidity, as the discussion of our various cases show, are primary factors. They induce the emergence of mosquito vectors in abundance. The secondary factors, such as drug resistance, agricultural development, population growth, migration, conflicts, land reclamation and so on, only accelerate a process put in motion by climatic factors. This is a crucial point, because policy makers and strategists need to make a distinction between the two in order to allocate resources and prioritize accordingly. Within the context of policy, it is more feasible to control the secondary factors. They are short-term factors, and relief from them would yield more immediate and much-needed benefits to victims of malaria. The primary factors are more complex to deal with because they require the involvement of the international community, and far greater resource commitment of all types. They require long-term solutions. Such forward-thinking solutions will necessitate complex negotiations and diplomacy in order to reduce carbon emissions, devise new technologies, switch to renewable energy sources, and deal with various development challenges of developing countries, including the need to devise innovative agricultural technologies and energy-efficient industrialization.

Because of the deep and complex nature of malaria in Africa, dealing with it has been a major challenge, both financially and in terms of health infrastructure. Given the large numbers of the population infected, any countries that ignore the challenge will be faced with economic disaster. There have been efforts made by individual countries. Additionally, various governments in malaria-prone areas and especially those in Africa with perennial epidemics have been involved in the World Health Organization's Roll Back Malaria (RBM) program to fight malaria. This program, launched in 1998, has brought international political commitment and resources from donor countries, international organizations and foundations to support Africa's fight against malaria. It set targets for halving malaria by 2010 at its Head of States Summit in Abuja, Nigeria, in 2000. In attendance at the 2000 Summit were delegations from 44 African governments of which 19 were led by heads of states and the rests led by Vice Presidents Prime Ministers, or Ministers of Health (The Abuja Declaration and Plan of Action of Roll Back Malaria: April 2000). Heads of states present included the host, Olusegun Obasanjo of Nigeria, and Abdulaziz Bouteflika, Chairman of the Organization of African Unity (OAU). Other major participants were heads of major International Organizations that deal with development and health issues, including the Director General of the World Health Organization (WHO), Ibrahim M. Samba, UNESCO Director General, Koichira Matsuura, Executive Director of UNICEF, Carol Bellamy and many others, including Omar Kabbaj, President of the African Development Bank and leaders of

"ANY COUNTRIES THAT IGNORE THE CHALLENGE WILL BE FACED WITH ECONOMIC DISASTER"

the Foreign Aid Agencies of the main donor states. (The heads of states and governments present agreed in a Declaration to a concerted strategy to deal with malaria in Africa. They set various targets for dealing with the issue by addressing both preventive and treatment measures, and also required countries to develop Country Strategic Plans on malaria (The Abuja Declaration and Plan of Action of Roll Back Malaria: April 2000). It is as yet unclear how much has been achieved in meeting the RBM goals. What is clear, though, is that malaria continues to be a menace to African countries. It is an obstacle to economic as well as human health that must constantly be monitored and remedied in order to allow the region to progress and prosper.

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