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Malaria and Climate Change: Discussion on Economic Impacts

[1]Md. Shahin Mia, [1]Rawshan Ara Begum, [2]Ah-Choy Er,
[1]Raja Datuk Zaharaton Raja Zainal Abidin and [1]Joy Jacqueline Pereira
[1]Institute for Environment and Development,
[2]School of Development and Environmental Studies, Faculty of Social Sciences and Humanities,
University Kebangsaan Malaysia, 43600, UKM, Bangi, Selangor DE, Malaysia

Abstract: Problem statement: Climate change is a global environmental change that is adversely affecting human health by causing various health impacts in countries throughout the world. Climate is the most influential driving force of vector-borne diseases such as malaria. Changes in climate factors substantially affect reproduction, development, distribution and seasonal transmissions of malaria. Climate change increases the outbreak of malaria which causes adverse economic impacts in endemic regions. This study reviews literature related to economic impacts of malaria at different levels such as household and national level. The study also focuses on the impacts of malaria on the economic growth of various nations. **Approach:** Literatures were identified for review through a comprehensive search by using electronic and non-electronic databases. Several electronic databases were searched for published literature in a systematic way using a range of key words relating to economic impacts of malaria illness. Related literature and documents were also found through communicating with colleagues working in this research area. Related literature and documents were also found through communicating with colleagues working in this research area. **Results:** The literature review indicates that malaria causes great economic losses at household level through human morbidity and mortality and consequently lower labor productivity, disability and poverty. At the national level, malaria affects negatively the trade, investments, savings and tourism sector. Macroeconomic studies estimated that the annual growth rate of per capita GDP of malaria endemic countries was 0.25-1.3% points lower per year than that of non-malarious countries. **Conclusion:** Reducing the burden of malaria could help to break the vicious cycle between illness and poverty that contributes to economic growth of the endemic countries. Therefore, further research is urgently needed to ensure interventions for controlling the malaria disease more effectively in the advent of climate change.

Key words: Malaria disease, climate change, economic impacts, Disability-Adjusted Life Years (DALYs), Gross Domestic Product (GDP), United Arab Emirates (UAE), Sub-Saharan Africa (SSA), treatment of malaria, endemic countries, transmissions of malaria, capital accumulation

INTRODUCTION

Climate change is one of several unprecedented, large-scale, environmental changes that are affecting our planet (Kovats *et al*., 2003b) though different regions may be affected in different ways and to different degrees. Particularly, the developing countries are experiencing adverse effects of climate change on key economic sectors such as energy, industries, transport, forestry, agriculture, water and coastal resources, public health and waste sector ((Begum *et al*., 2011a). Climate change is becoming a serious threat to human health by causing various health impacts such as heat-related illness and death in countries throughout the world. It also affects human health indirectly, through changes in the volume of food production, water supply, natural resources, population migration and poverty (McCarthy, 2001; Hamdi *et al*. 2009). World-wide natural disasters kill over 140,000 people per year and affect the lives of more than 100 million (Kovats, 2000). The World Health Organization estimated that climate change, on aggregate, contributed (by the year of 2000) to 150,000 deaths (0.3% deaths globally per year) and 5.5 million Disability-Adjusted Life Years (DALYs) lost per year (0.4% global DALYs lost per year) (WHO, 2002). Costello *et al*. (2009) reported that cardiovascular disease, malaria, injuries from flooding or landslides,

Corresponding Author: Md. Shahin Mia, Institute for Environment and Development (LESTARI), University Kebangsaan Malaysia, 43600, UKM, Bangi, Selangor DE, Malaysia Tel: +60143626214 Fax: +603-89255104

diarrheal diseases and malnutrition contributed to the above mentioned number of DALYs lost. Overall, the effects are predicted to be heavily concentrated in poorer countries at low latitudes, where the most important climate-sensitive health outcomes (such as malnutrition, diarrhoea and malaria) are already common and where vulnerability to climate effects is greatest (Haines *et al*., 2006). The most vulnerable peoples due to climate change are the poor and hardcore poor (Begum *et al*., 2011b).

Malaria is one of the most important public health problems in the world. It has been ranked as one of the top three killers among communicable diseases (Sachs and Malaney, 2002). The estimated annual mortality attributed to malaria ranges from 700,000-2.7 million worldwide and more than 75% of them are African children and expectant mothers who have less immunity (Kumar *et al*., 2007). This disease is mainly confined to the poorer countries in the tropical and sub-tropical regions of the world. Sub-Saharan Africa (SSA) and South and Southeast Asia are the most malaria-affected regions. Climate is the most influential driving force of malaria transmission. The geographical distribution and incidence of malaria are hugely influenced by the climate and ecology. Changes in climate factors such as temperature, precipitation, humidity and sea level rise affect the reproduction, development, behavior and population dynamics of malaria (Gage *et al*., 2008). Temperature plays a fundamental role in the rate of multiplication of the parasite in the mosquito (National Research Council, 2001). Both vector (i.e., female anopheles mosquito) and parasite of this disease are sensitive to changes in temperature, as temperatures rise the malaria parasites develop and multiple more quickly in the mosquito vectors, thereby increasing the proportion of infective vectors (Ambu *et al*., 2003). Increased rainfall leads to increase the number and quality of breeding sites (such as mud-pools, marshes and natural ponds) for malaria vectors e.g., mosquitoes and increases the humidity, which enhances survival and vectorial capacity of the vectors and henceforth the transmission of the parasites (Ambu *et al*., 2003; Snow *et al*., 1999). For example, a short-term increase in temperature and rainfall associated with 1997-98 El-Nino caused plasmodium falciparum malaria epidemics in Kenya (Weekly Epidemiological Record, 1998). Similarly, in north-east Panjub, the former province of India, malaria epidemics increased fivefold in the year following an El-Nino event while in Sri Lanka the risk of malaria epidemics increased fourfold during an El-Nino year (Githeko *et al*., 2000). El-SafiHimeidan *et al*. (2005) also found that malaria transmission depends on seasonal variation and reaches its peak during rainy season (August-October) in Eastern Sudan. In fact, global malaria outbreaks have been regularly linked to temperature and/or rainfall variations brought about by El-Nino events (Bouma and Van Der Kaay, 1994; Bouma *et al*., 1994; Kovats *et al*., 2003a; Berrang-Ford *et al*., 2009). Sea level rise can also play an important role in malaria transmission. Global worming leads to melt polar ice caps and consequently a rise in sea level which would cause coastal flooding in many areas. Salt-water intrusion into fresh water of coastal areas can extend breeding sites for malaria vectors and enhance transmission of the disease. For example, Anopheles Sundaicus is a malaria vector which breeds in brackish water in the coastal areas of Peninsular Malaysia (Ambu *et al*., 2003).

In humans, the malaria parasites infect red blood cells, causing periodic chills and fever and in some species of Plasmodium the parasite can ultimately cause death (National Research Council, 2001). People of all ages and all income levels (e.g., rich and poor) within malaria-endemic regions suffer from morbidity and mortality of the disease. Tropical Africa carries more than 90% of the global malaria burden (UN Millennium Project, 2005). The Indian subcontinent and Southeast Asia bear most of the remaining burden (WHO, 2004). Climate change increases the outbreak of malaria which causes great economic losses at the household level through human morbidity and mortality and consequently lower labor productivity, disability and poverty. The disease affects severely the poor households in endemic regions through direct output and income losses. At the national level, malaria has negative impacts on demographics, trade, investments, savings and human capital accumulation which can, in the long-term, impede economic growth of a country. The aim of this study is to review studies related to economic impacts of malaria at different levels such as household and national level. The study also highlights the impacts of malaria on the economic growth of various nations.

MATERIALS AND METHODS

This study reviews literature from various sources such as journals, reports, proceedings and related documents on assessment of economic impacts of malaria due to climate change. Studies were identified through a comprehensive search by using electronic and non-electronic databases. Several electronic databases (Science Direct, Springer Link, Blackwell, Social Science Citation Index, Medline, Pubmed Central and so on) were searched for published literature in a systematic way using a range of key words relating to economic impacts of malaria illness. Internet search engines were also used to find the related documents and reports published by the organizations undertaking research in this area. References cited in the literature were searched and important studies were collected in full text. Related literature and documents were also

found through communicating with colleagues working in this research area. The review was limited to studies in English and there was no country restriction. But the studies were mostly from Sub-Saharan Africa (SSA) and Asian countries. This review included the studies that contained data, findings and evidences on climate change and malaria illness and its impacts at the family level and health systems as well as national and regional economy. However, the fact is that there is very rare literature that included discussion and demonstrated findings and evidences on economic impacts of malaria due to climate change.

RESULTS AND DISCUSSION

This study is based on the evidences and findings from published literatures and documents that highlight and discuss the economic impacts of malaria either or nor from the view of climate change, depending on the availability of literatures and documents.

Impacts of malaria at household level: Evidence shows that malaria causes morbidity and mortality among the people of all ages and all income levels in the endemic regions. The disease burden of malaria carries with it a corresponding and significant economic burden on households, especially the poor who are more vulnerable to the disease. Households face a substantial amount of direct cash expenses to purchase preventive measures and seek treatment for malaria. In addition to direct expenditures on prevention and treatment of malaria, households experience the indirect costs of productive time lost due to malaria illness. Most of the malaria burden is borne by economically active workforce (Kumar *et al*., 2007) as the adults loss income, other earnings or valuable time due to becoming ill themselves or caring for and accompanying sick person for treatment. Several studies estimated the direct costs of malaria per episode in terms of the proportion of households' income, monthly or annually, as shown in Table 1. When substantial direct expenses for treatment are combined with a loss of household income due to ill-health or attending the sick person for treatment, there can be catastrophic consequences for families, which may push them into poverty or force into deeper poverty (McIntyre *et al*., 2006). One of the reasons for the consequences is that households have to pay in full the expenses for treatment at the time of illness when income may be lower than usual due to inability of carrying out normal activities. In addition, households incur other expenses as a direct result of having malaria which can be termed as 'complementary cost of treatment' that includes cost of vitamins, nutritional food, special foods and drinks (Attanayake *et al*., 2000). For example, in Sri Lanka, cost for non-medical items such as special and nutritional foods constituted 46% of the total treatment costs (Attanayake *et al*., 2000). Apart from these, informal payments (e.g., illegal payments) by households in public health care facilities contribute to the high cost of malaria treatment (Onwujekwe *et al*., 2010). These are hidden costs of illness but critical to household ability to pay for treatment (Russell, 2004). Moreover, households' treatment costs for malaria are inflated by people's widespread preference to use private doctors and pharmacies for outpatient treatment, particularly in urban areas and even by the poorest (Russell, 2004). The high costs of treatment for malaria represent significant outlays of scarce cash income of poor households.

Studies suggest that economic burdens of malaria are highly regressive; i.e. the poor households spend a significantly higher proportion of their income on malaria than the high-income families do (Ettling *et al*., 1994; Attanayake *et al*., 2000; Chuma *et al*., 2006). For example, in Malawi, the average total cost of malaria among the very low income households was 32% of annual income compared to 4.7% of annual income among the low to high income households (Onwujekwe *et al*., 2000). Leighton and Foster (1993) figured out that the typical rural households in Kenya and lower income urban households in Nigeria were the hardest hit by the economic impacts of malaria. In rural tropical areas, especially in Africa, the subsistence farmers bear the greatest burden of malaria as they are mainly dependent on agriculture and the malaria transmission season generally coincides with that of planting or harvesting. A brief period of illness that delays planting or coincides with harvesting may cause catastrophic economic effects in the world's poorest regions, deepening the impoverishment of rural agricultural households through direct output and income losses (UN Millennium Project, 2005; Rithidet *et al*., 2005). Moreover, the farming households have to meet the treatment costs and purchase preventive measures for malaria out of their scarce cash reserves, which push them into the worst economic situation. Studies show that the poor households use a range of strategies to adapt with the economic consequences of malaria disease burden. The most commonly used strategy is intra-household labor substitution (i.e., tasks are re-allocated among the household members) in response to lost work time of household members (Chima *et al*., 2003) and in some cases external labor may be hired to take on the responsibilities of the ill household member (Attanayake *et al*., 2000). While the most frequently used strategy to cope with prevention and treatment costs of the disease is to mobilize available cash reserves and savings, the poor households, in many instances, borrow from friends, neighbors or money lenders (Sauerborn *et al*., 1996). The very poor households, who have limited opportunities to borrow money due to low creditworthiness, sell arable land,

Table 1: Direct costs of malaria to households

Country/ Province	Direct costs as % of household income
Malawi (Ettling *et al*., 1994)	28% of annual income among very low income households and 2% of annual income among low to high income households.
Nigeria, Enugu State (Onwujekwe *et al*., 2000)	2.9% of monthly income
Sri Lanka (Attanayake *et al*., 2000)	2% of monthly income
Kenya (Leighton and Foster, 1993)	18% of annual income
Nigeria (Leighton and Foster, 1993)	13% of annual income
Northern Ghana (Akazili *et al*., 2007)	34% of annual income of poor households and 1% of annual income of rich households
Kenya, Ganze State (Chuma *et al*., 2006)	7.1% of monthly income in wet season and 5.9% in dry season
Mozambique, Maputo Province (Castillo-Riquelme *et al*., 2008)	18% of monthly income
South Africa, KZN Province (Castillo-Riquelme *et al*., 2008)	2.1% of monthly income
South Africa, Mpumalanga Province (Castillo-Riquelme *et al*., 2008)	1% of monthly income
Tanzania (Jowett and Miller, 2005)	0.7% of annual income
Guyana (Booth and MacLean, 2001)	10-20% of average monthly income
Sudan, Khartoum State (Mustafa and Babiker, 2007)	5.3% of average monthly income

Table 2: Cost burden of malaria in the public health system

Country	Cost burden in the public health system
Rwanda (Ettling and Shepard, 1991)	19% of the total health budget of the country
Coastal Kenya (Kirigia *et al*., 1998)	15% of the annual recurrent expenditures for inpatient care and 9% by paediatric Malaria admissions
Ghana (Asante and Asenso-okyere, 2003)	9.74% of the per capita government expenditure on health
Sri Lanka (Attanayake *et al*., 2000)	25% of the total costs of malaria illness
Tanzania (Jowett and Miller, 2005)	39% of total national health expenditures

economic trees and livestock which force them into a vicious cycle of poverty (Sauerborn *et al*., 1996). Other strategies for dealing with the financial costs of illness include reducing consumption, most often of food and households selling their labor (Foster, 1994). In some cases, the highly vulnerable households, who have many young children, borrow drugs from neighbors and share between siblings who fall ill within the same period (Chuma *et al*., 2006). The poor may find it hard to deal with persistent malaria problem, as coping with the disease is economically disastrous for the communities whose margin of survival is so fragile (Kumar *et al*., 2007).

Burden of malaria on public health system: Evidences show that malaria has been an important subject of attention of the public health authorities of most of the endemic countries since the disease imposes a heavy cost burden on public health system of a country. However, literature on government expenditure for malaria prevention and treatment is scanty. Table 2 presents the findings, in brief, of some studies that have given effort to estimate public health sector expenditures for malaria prevention and treatment. The evidences suggested that malaria is responsible for a high proportion of public health expenditure on curative treatment in endemic countries. In Tanzania, it was estimated that government facilities devoted almost one-third of their resources to the disease (Jowett and Miller, 2005). Apart from the direct resource costs, the increased number of malaria patients at the public health facilities could adversely affect the efficiency of service delivery (Asante and Asenso-okyere, 2003). Though the government of a country is the mostly responsible for malaria prevention and treatment, many governments, particularly in poor African countries, lack the resources for effective prevention and treatment. In this circumstance, several governments in regions hard-hit by malaria promote home treatment, arrange trainings for mothers to identify and respond to symptoms and provide them with pre-packaged treatment tools (Bloom, 2006).

Public health expenditures on malaria prevention and treatment constitute the direct costs for malaria surveillance, vector control, health facilities, health education and research related to malaria. But the fact is that most expenditure is incurred by health facilities providing treatment. The costs incurred by the health facilities include expenditures on personnel, supplies, administration, maintenance, accommodation, allowances and general services such as sanitation and utility among others (Asante and Asenso-okyere, 2003). Public health system provides general treatment and certain costs are shared by several activities. Due to this nature of the public health system, the direct costs of particular disease are often not separated from other health service costs in budgeting and accounting system of public health services. This is why, it is difficult to quantify precisely the amount of public health resources spent on malaria prevention and treatment. In this regard, 'shared cost' approach can be applied to estimate the institutional cost of a particular disease in the public health facilities. This approach measures the shared costs prorated among various services in the

public health care facilities by observing the total costs and apportioning them for various diseases using morbidity data. For example, Asante and Asenso-Okyere (2003) used 'shared cost' approach to estimate the total annual recurrent expenditures for malaria treatment in the public health sector of Ghana.

Impacts of malaria on demography, savings and human capital accumulation: Studies demonstrated that malaria can play an important role in changing household behavior, which results in broad social costs such as demography, school absenteeism and savings. Malaria has a significant impact on the demographic structure of a society where the disease is endemic. In general, mortality burden of malaria falls heavily on infant and children. It is on record that, Sub-Saharan Africa accounts for 1.5-2.7 million deaths caused by malaria annually of which about 90% occur in young children (Asante and Asenso-okyere, 2003). This has serious demographic consequences for the continent. High mortality rates among the infant and children are linked closely to high fertility rates, though other factors, such as household income, female education and the availability of birth control affect importantly the fertility decisions of households (Sachs and Malaney, 2002). Murthy (2007) emphasized that infant mortality is also affected adversely by the degree of income inequality prevailed among population of a country). In a high mortality environment, parents generally tend to have additional children to replace the ones that they lose. In this process, women have to spend a major part of their productive life to take care children. Consequently women not only exclude themselves from workforce, but also loss work opportunity and job experience. Another impact of high fertility is that parents may be discouraged to invest in the education of women since they are less likely to produce economic returns. These effects, in the long run, can be detrimental to the productivity and economic growth of a country.

Malaria places significant financial hardship on both households and the economy. The direct costs of prevention and treatment of the disease deplete a substantial portion of poor household's meager cash reserves. In addition to direct costs of prevention and treatment, households forfeit wages, salaries and other earnings as indirect costs of malaria morbidity and mortality. At very low levels of income, households shoulder the heaviest burden of the disease because their margin of survival is so fragile. In some cases, households are forced to borrow from neighbors and friends or sell assets such as livestock. Direct and indirect costs of malaria diminish household savings as well as investment in physical and financial assets. Apart from these, premature death of an economically active workforce due to malaria infection destroys permanently the potential output to household. At the same time, his/her contribution to the Gross Domestic Product (GDP) is lost to the country. In this way, the disease can slow the pace of formation of physical capital within a country.

Human capital development is a key factor of economic development. Human capital accumulation is affected even more directly by malaria through its effects on school attendance and performance (Malaney *et al*., 2004). School-age children in malaria-endemic countries fall ill from the disease repeatedly, which causes school absenteeism. Malaria is responsible for 15% of health-related absenteeism from school in endemic areas (Holding and Kitsao-Wekulo, 2004). For example, in Kenya, primary school children missed an estimated 20 school days, on the average, per year due to malaria which amounts to over 10% of the total school days (Leighton and Foster, 1993). The study also found that secondary school students missed 8 school days per year. In Ghana, school children lost, on the average, 4 school days due to malaria illness (Asante and Asenso-okyere, 2003). High rates of absenteeism result in children's poor educational performance, which increases failure rates, repetition of school years and drop-out from school. Moreover, frequent episodes of severe malaria in childhood reduce physical ability of children to engage in schoolwork as well as affect negatively the learning abilities and cognitive development of children. They may also suffer from behavioral problems and language difficulties which can reduce educational outcomes. Consequently, children experience inability to carry out intellectual and executive functions in later life. This would ultimately result in diminished productivity of adults, absenteeism and unemployment (Economic Commission for Africa, 2005). Malaria endemicity, therefore is a threat to human capital development of a nation. However, there is currently no direct and quantitative evidence of overall impact of the disease on human capital development.

Impacts of malaria on foreign investment, trade and tourism: A number of studies found that malaria has adverse impact on foreign direct investment and trade in endemic countries. In today's globalized economy, international trade and foreign investment are very important for economic development, especially for the poor countries. Moreover, the poor countries have to rely on technical assistance; project and non-project aid from foreign countries to fill the savings-investment deficit as well as the deficit in balance of payment (Al-Khaldi, 2008). The prevalence of malaria strongly discourages foreign direct investment and trade in the world's poorest regions. Investors from non-malarious regions generally do not tend to economic invest in

malarious regions for the fear of their employee's morbidity and mortality from malaria infection (UN Millennium Project, 2005). Businesses have been known to be negatively affected by malaria, from the construction of the Panama Canal to more recent large construction projects in Africa (Bloom, 2006). For example, BHP Billiton, a London-based mining and metals company, built a Mozal aluminum smelter in Mozambique with a joint venture investment of US$1.4 billion (the largest foreign investment so far in that country) and the company was faced with 7,000 cases of malaria in two years and the death of 13 expatriate employees (Sachs and Malaney, 2002). The total cost of the company due to malaria related illness, absenteeism and treatment was estimated at almost US$2.7 million. Similarly, Exxon Mobil, an oil firm, constructed an oil pipeline from Chad to Cameroon and found that without an effective malaria control effort, the project would delay over 4 days and cost an extra US$4 million. Indeed, malaria endemicity can impede foreign investment in many kinds of production such as mining, agriculture and manufacturing due to heavy disease burden or higher cost of attracting the needed labor to a malarious region (UN Millennium Project, 2005). For example, effective malaria control was a driving force in attracting expatriate labors to extract minerals in Zambia during the colonial period between 1900 and 1950 (Utzinger *et al*., 2002). Similarly, after the eradication of malaria, previously unfarmed areas of Corsica, Italy, Greece and Nepal became the most agriculturally productive parts of those countries (Gallup and Sachs, 2001; Bloom, 2006).

Foreign traders are also less likely to choose malaria-endemic sites for trading and investment due to considerable risk of illness or death. Moreover, local traders and skilled workers may be reluctant to move within and between malarious regions for fear of infection. By limiting movement of foreign and local traders and skilled workers, malaria would inhibit maximization of worker productivity, expansion of existing markets and development of new markets in endemic regions. Like many production sectors of an economy, tourism industry may be affected negatively by malaria prevalence. From the perception of malaria risk, well-to-do foreign tourists and visitors may avoid visiting the malarious countries and consequently the growth of tourism industry of those countries may be halted. For example, Mozambique and South Africa are trying to encourage investment in tourism sector with limited success because of being malaria-endemic countries (Sachs and Malaney, 2002). On the other hand, the increased foreign investment and heavy growth of tourism industry in the subtropical regions of southern Europe were linked with malaria control (Sachs and Malaney, 2002). The adverse effects of malaria on foreign investment, trade and tourism can cause tremendous macroeconomic consequences in endemic countries and suppress economic linkages of those countries with the rest of the world. It should be noted that there is lack of evidence based on monetary valuation of macroeconomic impact of the disease on foreign investment, trade and tourism sector of a country or region.

Impacts of malaria on economic growth: Malaria is commonly referred to as a disease of poverty (Sachs and Malaney, 2002; Chuma *et al*., 2006; Sachs, 2001). There is an intimate correlation between malaria and poverty. Malaria's link to poverty is ultimately a link to economic growth (Economic Commission for Africa, 2005). However, it is said that the relationship between economic growth and malaria is two-way (Lieshout *et al*., 2004). Malaria may be a cause of poor economic growth as well as an effect. In other words, poverty may promote malaria transmission; malaria may cause poverty by impeding economic growth; or causality may run in both directions (Sachs and Malaney, 2002). It is true that poverty can contribute to high transmissions of malaria in the poor countries. For example, malaria is widely prevalent in the poor countries of Africa and Asia. But malaria is not a direct consequence of poverty. The incidence and severity of the disease are largely determined by geography, climate and ecology. For example, certain relatively wealthy countries, such as Oman and United Arab Emirates (UAE) still face serious malaria problems due to their geographical location and high year-round temperatures (Gallup and Sachs, 2001). McCarthy, *et al*. (2000) also confirmed that climate played a dominant role in accounting for cross-country differences in malaria morbidity. Even individuals from high income families in malaria-endemic countries often suffer from illness of the disease. On the other hand, studies suggest that malaria exacerbates poverty and contributes to lower economic growth. The fact is that a country's economic development is very much influenced by a number of social and economic factors such as tax revenues, gross domestic savings, population growth and so on (Rahman and Manprasert, 2006; Anastassiou and Dritsaki, 2005). However, a few studies have attempted to assess the impact of malaria on economic growth (e.g., growth of GDP per capita) as shown in Table 3. The findings of the studies indicate that countries with intensive malaria in the Africa region experienced dramatically lower growth in per capita GDP in the long run, even after controlling for other determinants of economic growth such as initial income levels, life expectancy, initial human capital stock, economic policy variables, initial health and education levels and tropical location.

Table 3: Impact of malaria on economic growth

Country	Impact on economic growth
150 countries (Gallup and Sachs, 2001) (Cross-country regression analysis)	Growth in per capita GDP of malaria-endemic countries was 1.3% lower per year than that of non-malarious countries between 1965 and 1990
78 countries (McCarthy *et al*., 2000) (Cross-country regression analysis)	Average growth in per capita GDP for the countries with intensive malaria (most of them were the SSA countries) was 0.55% lower per year than that of non-malarious countries between 1983 and 1997.
Ghana (Asante and Asenso-okyere, 2003)	Growth in per capita GDP decreased by 0.41% per year from 1984-2000
Tanzania (Jowett and Miller, 2005)	Total cost of malaria was almost 1.1% of GDP of the country
Kenya (Leighton and Foster, 1993)	The value of malaria-related lost production was equivalent to 2-6% of GDP of the country.
Nigeria (Leighton and Foster, 1993)	The value of malaria-related lost production was equivalent to 1-5% of GDP of the country.
4 countries of SSA (Shepard *et al*., 1991) (Burkina Faso, Chad, Rwanda and the Republic of Congo)	Total cost of malaria was 0.6% of GDP of those 4 countries

The cumulative effect of this lower growth in per capita income is sever and impedes the economic growth of the entire region (Sachs, 2001). On the other hand, countries including Greece, Spain, Italy and Portugal experienced rapid economic growth in the last century compared to the rest of Western Europe after eradicating malaria (Bloom, 2006). Similarly, Taiwan and Jamaica became able to achieve increased economic growth quickly relative to their regions after controlling the disease in the late 1950s and early 1960s (Gallup and Sachs, 2001). Malaria endemicity has recently been recognized as a development problem due to the adverse impacts of the disease on economic growth of a country (UN Millennium Project, 2005). However, there is still lack of research or study that clearly addresses the methods and mechanisms how malaria impacts a country's economic growth.

CONCLUSION

Studies demonstrate that malaria incidence is hugely influenced by the conditions of climate and ecology. Among the climatic features, seasonal temperature variation is a predominant factor in explaining the geographical distribution of the disease (Sachs and Malaney, 2002). The high level of malaria transmissions is confined to the tropical and subtropical countries which are the poorest regions of the world. The disease has a significant negative impact on household as well national economy of the endemic countries. Microeconomic studies demonstrate that the direct and indirect costs of a single case of malaria deplete a significant portion of a household's income. The direct cost of malaria in terms of the proportion of households' income varies to different degrees in different areas (Table 1). However, poor families are the most vulnerable to the disease because they are not financially sound enough to purchase preventive measures and to seek prompt effective treatment. The disease imposes a heavy cost burden on the public health system of endemic countries. It is beyond the capabilities of many poor countries to provide treatment to all the malaria cases. The disease contributes towards national poverty and consequently, impedes economic growth of a country through its long-term negative impact on trade, foreign direct investment, savings, human capital development and tourism. Macroeconomic studies estimated that the per capita GDP in highly malarious countries is, on average, one-fifth that of non-endemic countries and that the annual growth rate of per capita GDP in endemic countries is 0.25-1.3% points lower per year than that of non-malarious countries, even after controlling for other determinants of economic growth (Gallup and Sachs, 2001). Indeed, malaria affects almost every segment of the society, including fertility, schooling, intellectual development, population mobility and living standards (Sachs and Malaney, 2002).

There is very limited study on economic impacts of malaria in the advent of climate change. This is partly attributable to inadequate data and information of malaria morbidity and mortality due to climate change. Moreover, studies on malaria have employed a wide variety of methods and approaches to estimate the economic impacts. As a result, comparison of the findings from different studies cannot be done directly due to lack of common methodology. It is also difficult to select the best approach that meets the needs of the research and study due to limitation of existing data, assumptions and estimates. There is great need for research to conduct both at the micro and macro level for understanding and monetary valuation of the economic impacts of malaria due to climate change in order to set target and control efforts to minimize the disease burdens for effective policy and planning strategies.

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REFERENCES

Akazili, J.M.A., M. Aikins and F.N. Binka, 2007. Malaria treatment in Northern Ghana: What is the treatment cost per case to households? Afr. J. Health Sci., 14: 70-79.

Al-Khaldi, M.D., 2008. Impact of foreign aid on economic development in Jordan (1990-2005). J. Soc. Sci., 4: 16-20. DOI: 10.3844/jssp.2008.16.20

Ambu, S., L.H. Lim, M. Sahani and M.A. Bakar, 2003. Climate change- impact on public health in Malaysia. Environ. Health Focus, 1: 13-21.

Anastassiou, T. and C. Dritsaki, 2005. Tax revenues and economic growth: An empirical investigation for Greece using causality analysis. J. Soc. Sci., 1: 99-104. DOI: 10.3844/jssp.2005.99.104

Asante, F.A. and W.K. Asenso-okyere, 2003. Economic burden of malaria in Ghana. Institute of Statistical, University of Ghana. http://www.who.int/countries/gha/publications/Economic_Burden_of_Malaria_in_Ghana_Final_Report_Nov03.pdf

Attanayake, N., J. Fox-Rushby and A. Mills, 2000. Household costs of 'malaria' morbidity: A study in Matale district, Sri Lanka. Tropical Med. Int. Health, 5: 595-606. PMID: 11044273

Begum, R.A., R.D.Z.R.Z. Abidin and J.J. Pereira. 2011a. Initiatives and Market Mechanisms for Climate Change Actions in Malaysia. J. Environ. Sci. Tech., 4: 31- 40. DOI: 10.3923/jest.2011.31.40

Begum, R.A., C. Siwar, R.D.Z.R.Z. Abidin and J.J. Pereira. 2011b. Vulnerability of Climate Change and Hardcore Poverty in Malaysia. J. Environ. Sci. Tech., 4: 112- 117. DOI: 10.3923/jest.2011.112.117

Berrang-Ford, L., J.D. MacLean, T.W. Gyorkos, J.D. Ford and N.H. Ogden, 2009. Climate change and malaria in Canada: A systems approach. Interdis. Perspectives Infect. Dis., 2009: 1-13. DOI: 10.1155/2009/385487

Bloom, DE, 2006. Business and Malaria: A Neglected Threat? 1st Edn., World Economic Forum, USA., pp: 54

Booth, C.M. and J.D. MacLean, 2001. Knowledge, treatment-seeking and socioeconomic impact of malaria on the Essequibo Coast of Guyana. McGill J. Med., 6: 17-25.

Bouma, M.J. and H.J. Van Der Kaay, 1994. Epidemic malaria in India and the El Nino southern oscillation. Lancet, 344: 1638-1639. PMID: 7984012

Bouma, M.J., H.E. Sondorp and H.J. Van Der Kaay, 1994. Climate change and periodic epidemic malaria. Lancet, 343: 1440-1440. PMID: 7910922

Castillo-Riquelme, M., D. McIntyre and K. Barnes, 2008. Household burden of malaria in South Africa and Mozambique: is there a catastrophic impact? Tropical Medicine Int. Health, 13: 108- 122. DOI: 10.1111/j.1365-3156.2007.01979.x

Chima, R.I., C.A. Goodman and A. Mills, 2003. The economic impact of malaria in Africa: A critical review of the evidence. Health Policy, 63: 17-36. PMID: 12468115

Chuma, J.M., M. Thiede and C.S. Molyneux, 2006. Rethinking the economic costs of malaria at the household level: Evidence from applying a new analytical framework in rural Kenya. Malaria J., 5: 76-76. DOI: 10.1186/1475-2875-5-76

Costello, A., M. Abbas, A. Allen, S. Ball and S. Bell *et al*., 2009. Managing the health effects of climate change: Lancet and university college London institute for global health commission. Lancet, 373: 1693-1733. PMID: 19447250

Economic Commission for Africa, 2005. Enhancing health systems: Malaria's negative impact in Africa. Economic Commission for Africa.

Ettling, M., D.A. McFarland, L.J. Schultz and L. Chitsulo, 1994. Economic impact of malaria in Malawian Households. Trop. Med. Parasitol., 45: 74-79. PMID: 8066390

Ettling, M.B. and D.S. Shepard, 1991. Economic cost of malaria in Rwanda. Trop. Med. Parasitol., 42: 214-218. PMID: 1801149

Foster, A.D., 1994. Poverty and illness in low-income rural areas. Am. Econ. Rev., 84: 216-220.

Gage, K.L., T.R. Burkot, R.J. Eisen and E.B. Hayes, 2008. Climate and vectorborne diseases. Am. J. Prev. Med., 35: 436- 450. DOI: 10.1016/j.amepre.2008.08.030

Gallup, J.L. and J.D. Sachs, 2001. The economic burden of malaria. Am. J. Trop. Med. Hyg., 64: 85-96.

Githeko, A.K., S.W. Lindsay, U.E. Confalonieri and J.A. Patz, 2000. Climate change and vector-borne diseases: A regional analysis. Bull. World Health Organ., 78: 1136-1147. PMID: 11019462

Haines, A., R.S. Kovats, D. Campbell-Lendrum and C. Corvalan, 2006. Climate change and human health: impacts, vulnerability and public health. Public Health, 120: 585-596. DOI: 10.1016/j.puhe.2006.01.002

Hamdi, M.R., M. Abu-allaban, A. Al-Shayeb, M. Jaber, N.M. Momani, 2009. Climate change in Jordan: A comprehensive examination approach. Am. J. Environ. Sci., 5: 58-68. DOI: 10.3844/ajessp.2009.58.68

El-SafiHimeidan, Y., E.M. Malik and I. Adam, 2005. Epidemiology and seasonal pattern of malaria in an irrigated area of Eastern Sudan. Am. J. Infec. Dis., 1: 75-78. DOI: 10.3844/ajidsp.2005.75.78

Holding, P.A. and P.K. Kitsao-Wekulo, 2004. Describing the burden of malaria on child development: What should we be measuring and how should we be measuring it? Am. J. Trop. Med. Hyg., 71: 71-79. PMID: 15331821

Jowett, M. and N.J. Miller, 2005. The financial burden of malaria in Tanzania: implications for future government policy. Int. J. Health Plann. Mgmt., 20: 67-84. DOI: 10.1002/hpm.796

Kirigia, J.M., R.W. Snow, R.W. Snow, J. Fox-Rushby and A. Mills, 1998. The cost of treating paediatric malaria admissions and the potential impact of insecticide- treated mosquito nets on hospital expenditure. Tropical Med. Int. Health, 3: 145-150. DOI: 10.1046/j.1365-3156.1998.00204.x

Kovats, R.S., M.J. Bouma, S. Hajat, E. Worrall and A. Haines, 2003a. El Nino and health. Lancet, 362: 1481-1489.

Kovats, S., K.L. Ebi and B. Menne, 2003b. Methods of assessing human health vulnerability and public health adaptation to climate change. WHO Regional Office for Europe, USA., ISBN-10: 9289010908, pp: 111.

Kovats, R.S., 2000. Climate Change and Human Health: Impact and Adaptation. 1st Edn., World Health Organization, Geneva, pp: 48.

Kumar, A., N. Valecha, T. Jain and A.P. Dash, 2007. Burden of Malaria in India: Retrospective and Prospective View. Am. J. Trop. Med. Hyg., 77: 69-78.

Leighton, C. and R. Foster, 1993. Economic impacts of malaria in Kenya and Nigeria. Abt Associates Inc. USA.

Lieshout, M.V., R.S. Kovats, M.T.J. Livermore and P. Martens, 2004. Climate change and malaria: analysis of the SRES climate and socio-economic scenarios. Global Environ. Change, 14: 87-99. DOI: 10.1016/j.gloenvcha.2003.10.009

Malaney, P., A. Spielman and J. Sachs, 2004. The Malaria Gap. Am. J. Trop. Med. Hyg., 71: 141-146. PMID: 15331830

McCarthy, F.D., H. Wolf and Y. Wu, 2000. The growth costs of malaria. National Bureau of Economic Research Cambridge, MA.

McCarthy, J.J., 2001. Climate Change 2001: Impacts, Adaptation and Vulnerability: Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. 1st Edn., Cambridge University Press, Cambridge, UK., ISBN-10: 0521015006, pp: 1032.

McIntyre, D., M. Thiede, G. Dahlgren and M. Whitehead, 2006. What are the economic consequences for households of illness and of paying for health care in low- and middle-income country contexts? Soc. Sci. Med., 62: 858-865. DOI: 10.1016/j.socscimed.2005.07.001

Murthy, V.N.R., 2007. Income distribution and health status: Econometric evidence from OECD countries. Am. J. Applied Sci., 4: 192-196. DOI: 10.3844/ajassp.2007.192.196

Mustafa, M.H. and M.A. Babiker, 2007. Economic cost of malaria on households during a transmission season in Khartoum State, Sudan. Eastern Mediterr. Health J., 13: 1298-1307. PMID: 18341180

National Research Council, 2001. Under the Weather: Climate, Ecosystems and Infectious Disease. 1st Edn., National Academies Press, Washington, D.C., ISBN-10: 0309072786, pp: 146.

Onwujekwe, O., N. Dike, B. Uzochukwu and O. Ezeoke, 2010. Informal payments for healthcare: Differences in expenditures from consumers and providers perspectives for treatment of malaria in Nigeria. Health Policy, 96: 72-79. DOI: 10.1016/j.healthpol.2009.12.014

Onwujekwe, O., R. Chima and P. Okonkwo, 2000. Economic burden of malaria illness on households versus that of all other illness episodes: a study in five malaria holo-endemic Nigerian communities. Health Policy, 54: 143-159. PMID: 11094267

Rahman, M.H. and S. Manprasert, 2006. Landlessness and its impact on economic development: A case study on Bangladesh. J. Soc. Sci., 2: 54-60. DOI: 10.3844/jssp.2006.54.60

Rithidet, P., P. Piampongsan, P. Prathepa and B. Yodmalee, 2005. The development of community economic system of thung kula ronghai farmers at Ban Ta Yuak, Northeastern Thailand. J. Soc. Sci., 1: 240-242. DOI: 10.3844/jssp.2005.240.242

Russell, S., 2004. The economic burden of illness for households in developing countries: A review of studies focusing on Malaria, Tuberculosis and Human Immunodeficiency Virus/Acquired Immunodeficiency Syndrome. Am. J. Trop. Med. Hyg., 71: 147-155. PMID: 15331831

Sachs, J. and P. Malaney, 2002. Review article the economic and social burden of malaria. Nature, 415: 680-685. DOI: 10.1038/415680a

Sachs, J., 2001. Macroeconomics and Health: Investing in Health For Economic Development: Report of The Commission on Macroeconomics and Health. 1st Edn., World Health Organization, Geneva, ISBN-10: 924154550X, pp: 202.

Sauerborn, R., A. Adams and M. Hien, 1996. Household strategies to cope with the economic costs of illness. Soc. Sci. Med., 43: 291-301. DOI: 10.1016/0277-9536(95)00375-4

Shepard, D.S., M.B. Ettling, U. Brinkman and R. Sauerborn, 1991. The economic cost of malaria in Africa. Trop. Med. Parasitol., 42: 199-203. PMID: 1801147

Snow, R.W., M. Craig, U. Diechmann and K. Marsh, 1999. Estimating mortality, morbidity and disability due to malaria among Africa's non-pregnant population. Bulletin World Health Organ., 77: 624-640. PMID: 10516785

Millennium Project, 2005. HIV/AIDS, Malaria, TB and Access to Essential Medicines: Coming to Grips with Malaria in the New Millennium., Working Group on Malaria. Millennium Project.

Utzinger, J., Y. Tozan, F. Doumani and B.H. Singer, 2002. The economic payoffs of integrated malaria control in the Zambian copperbelt between 1930 and 1950. Tropical Med. Int. Health, 7: 657-677. PMID: 12167093

Weekly Epidemiological Record, 1998. El Nino and its health impacts. Weekly Epidemiological Record, 73:148-152.

WHO, 2002. The World Health Report, 2002, Overview: Reducing Risks, Promoting Healthy Life. 1st Edn., World Health Organization, Geneva, pp: 14.

WHO, 2004. The world health report 2004: Changing history. World Health Organization, Geneva, Switzerland.