Research Journal of Environmental and Earth Sciences 2(4): 194-198, 2010
ISSN: 2041-0492

Submitted Date: June 07, 2010 Accepted Date: July 23, 2010 Published Date: October 05, 2010

Environmental and Socio-economic Determinants of Malaria Prevalence in Uganda

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Abstract: The main objective of this study was to establish the relationship between malaria prevalence and environmental and socio-economic variables. An understanding of the factors that are associated with malaria prevalence is critical for the design of policies aimed at reducing malaria prevalence. Regression results using OLS indicate no relationship between malaria prevalence and environmental and socio-economic variables. There is need for further study using disaggregated data, panel data, and adding more control variables to the health production model to identify the factors that are associated with malaria prevalence in Uganda.

Key words: Literacy, malaria prevalence, poverty, rainfall, temperature

INTRODUCTION

Global climate change and its interactive components, such as water availability, related Vulnerability of natural and socio-economic systems and health, affects human wellbeing. The effects of climate change on human health continue to be a matter of scientific debate. Some review in the literature suggests that climate change can lead to an expansion of the areas suitable for malaria transmission, and thus increase risk of the disease. Others argue, however, that malaria risk should be interpreted on the basis of local environmental and socioeconomic development, where land use decisions and the ineffectiveness (or absence) of malaria control programs may in fact be driving force of the disease. As a consequence, health authorities have had a problem in deciding which factors are the most important and therefore which policy interventions to institute. It is critical to know what to expect in the future in terms of disease trends, so that adaptive measures can be put in place. Equally, it is important to establish the population's adaptive capacity in terms of the ability to prevent and treat climate-related illnesses.

If environmental conditions change in ways that would increase the survival time of mosquitoes, then they would be able to transmit other species of malaria that were not present in that area before (Pampana, 1969). Higher temperatures increase the number of blood meals taken and the number of times mosquitoes lay eggs (Martens *et al.*, 1995). The minimum temperature for mosquitoes development is between 8-10ºC, the minimum temperatures for parasite development are between 14-19ºC. The optimum temperature for mosquitoes development is 25-27ºC, and the maximum temperature for both vectors and parasites development is 40ºC (McMichael *et al.*, 1998).

Malaria is one of the world's most serious and complex public health problems and it has now been identified as the disease most likely to be affected by climate change (WHO/WMO/UNEP, 1996). With climate change it is expected that the disease may spread to newer areas. Malaria occurrence may not only be a function of climate determinants, but is also controlled by the prevailing socio-economic conditions. According to the World Health Organisation (WHO), malaria results in approximately 1.5 to 2.7 million deaths annually, out of which, more than 90% occur in Africa (Omortor and Atubi, 2007). It is the number-one killer of children, pregnant women, and the elderly on the continent (Greenwood and Mutabingwa, 2002). It constitutes 10% of the continent's malaria overall disease burden (WHO/UNICEF, 2003). Moreover, malaria causes at least 300 million cases of acute illness each year costing Africa more than US$12 million annually and slows economic growth in African countries by 1.3% a year thus trapping malaria vulnerable countries into poverty (Sachs and Malaney, 2002). The vulnerable areas are mainly those where transmission is currently limited mainly by low temperatures in highland areas (Lindsay and Martens, 1998).

In Uganda, the number of epidemics of malaria has been on the increase. In 2002 and 2003, there were 5,694,342 and 7,147,152 reported cases of malaria, which resulted in 6,735 and 8,500 deaths, respectively (Yanda *et al.*, 2006).Malaria is the leading cause of death and illness in Uganda, taking hundreds of lives every day. The most vulnerable are pregnant women and young children. The disease now accounts for almost a quarter

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of all deaths in children under age 5 in Uganda. Environmental factors have so far been alluded to the increased prevalence of malaria in Uganda, particularly in Southwestern region where it has reached epidemic proportions. In the highland areas, malaria incidence malaria incidence has increased by 256% over the baseline average for 1995-2002.

Temperatures in the East African highlands have risen by half a degree Celsius in the last 50 years, mostly since the late 1970s. According to the Climate Change Unit of Uganda's Ministry of Water and Environment, one of the highest peaks in Uganda's Rwenzori Mountains, Mount Speke, went from being covered with 536 acres of ice in 1906, to a mere 45.7 acres in 2006 over the baseline average for 1995-2002. Southwestern Uganda, where temperatures have risen by 0.3º in a decade, is cited as one of the hardest hit areas in terms of malaria outbreaks. The highlands, which were malaria free, are now invaded by the disease. People living in highlands have not developed resistance and are therefore more susceptible to it. The resurgence of highland malaria epidemics has been closely associated with climate change and climate variability. The impacts of malaria have been devastating and are increasingly exposing vulnerable groups to the adverse effects of climate change and climate variability, as well as challenging their ability to cope. The population of disease-carrying mosquitoes is expected to increase as a result of changes in temperature and precipitation, leading to increased malaria epidemics (Lindsay and Martens, 1998). In some locations, reduced rainfall or incremental temperature may cause decrease in transmission of some vector borne diseases. Such changes in the climate may affect the vector-borne disease in several ways, namely, their survival and reproduction rates; the intensity and temporal pattern of vector activity and the rates of development, survival and reproduction of pathogens within vectors.

Controlling malaria is crucial if Uganda is to achieve the UN Millennium Development Goal of halving the incidence of infectious diseases such as malaria, tuberculosis and HIV/AIDS by 2015. Given the prevalence of this scourge, its devastating toll, and the likelihood that climate change is altering its patterns, a tool that better predicts its occurrence may have impacts far beyond Uganda. Given the ability to predict climate changes, it may be possible to predict increases in malaria prevalence. In addition to predictions of the effects of climate change on malaria, identifying the factors that are most responsible for any changes in malaria in order to understand the complexities of malaria in the actual world is crucial.

It is thus critical to know what to expect in the future in terms of disease trends, so that adaptive measures can be put in place. Equally, it is important to establish the population's adaptive capacity in terms of the ability to prevent and treat climate-sensitive illnesses, such as malaria. Most responses to malaria have been reactive, slow, and often late. There is an urgent need to develop early warning systems that will address future climate change challenges. Efforts that improve early warning systems, knowledge of determinants of malaria prevalence would reduce the existing malaria situation in Uganda and beyond.

Despite the huge burden malaria imposes on Uganda, little was known about the relationship between malaria prevalence and environmental variables. Some few previous studies that have been carried out in Uganda were mainly qualitative and covering few locations. Considering the present endemic nature of malaria in Uganda, this study focused on an assessment of the climate determinants governing malaria prevalence in Uganda using quantitative techniques. In addition, we controlled for other factors that influence malaria prevalence that have been found in previous studies. Mean temperature, humidity and precipitation variables were hypothesized to be positively associated the variability in malaria prevalence in Uganda.

Literature review: The role of climatic factors has been studied extensively in the epidemiology of malaria due to its global public health importance. Mean temperature, night-time temperature, temperature in combination with rainfall, and mean November and December temperature, were found to be related to malaria in Zimbabwe, the Debre Zeit sector of Ethiopia, Rwanda, and the Northwest Frontier Province in Pakistan, respectively (Tulu, 1996; Loevinsohn, 1994). Van Lieshout *et al.* (2004) reported that malaria has already increased in the highlands of Rwanda and Tanzania associated with recent changes in temperature. It has been hypothesized that increasing temperatures could be part of the reason why malaria can now survive at higher altitudes (Patz and Lindsay, 1999). Many other confounding factors, however, could be causing the increase in malaria in these areas (Patz and Lindsay, 1999).

Kigotho (1997) has established that increasing temperature and relative humidity were also associated with malaria epidemic in Kenya. One study of the malaria epidemic in the highlands of Madagascar claimed that the epidemic was caused by anthropogenic climate change, but no statistics were shown to defend this assertion (de Zulueta, 1994).

Three studies of epidemics of malaria in different areas of the highlands of Kenya show that increased rainfall was related to the epidemic, although one of the studies also claimed that increasing drug resistance had an effect, and another study showed that increasing temperature and relative humidity were also involved (Kigotho, 1997). The epidemic in Ethiopia was attributed to higher temperatures, rainfall and relative humidity than in previous years (Woube, 1997).

A large group of studies relate the El Nino Southern Oscillation (ENSO) to malaria epidemics. Many areas have experienced periodic malaria epidemics every five to eight years, which may have been related to the ENSO cycle. Malaria epidemics in the former British Punjab, Pakistan, Sri Lanka, the highlands of Uganda, Columbia, Argentina, Ecuador, Peru, and Bolivia were proposed to be associated with ENSO cycles (Kilian *et al.*, 1999; Bouma and van der Kaay, 1995; Bouma *et al.*, 1995). The apparent correlation between outbreaks of malaria with El Nino years (e.g., 1982-1983 and 1997-1998) supports a causal link between climate variability and health (McCarthy *et al.*, 2001).

There are many variables that affect malaria transmission in addition to climatic changes, such as environmental modification (e.g., deforestation, increases in irrigation, blocked swamp drainage), population growth, limited access to health care systems, and lack of or unsuccessful malaria control measures (Patz and Lindsay, 1999). Most of the studies, however, do not take into account all of the factors that are related to malaria transmission. Although malaria is one of the most climate-sensitive vector-borne diseases (Morse, 1995), several other factors have been identified as contributing to its emergence and spread. These include environmental and socio-economic change, deterioration of health care and food production systems, and the modification of microbial/vector adaptation (McMichael *et al.*, 1998; Morse, 1995; Epstein, 1992).Increases in population density in the highlands led to an increase in human exposure and stressed limited productive land (Lindsay and Martens, 1998). Stresses on productive land, force farmers to clear forests and reclaim swamps. Puddles and elevated temperatures result from lost tree and ground cover, providing ideal breeding sites for mosquitoes (Walsh *et al.*, 1993). Papyrus, found in many of the swamps in valley bottoms of the East African highlands, excrete oil and provide shade, which inhibit *Anophelesgambiae* reproduction (Lindblade *et al.*, 2000).

In a more qualitative study, climate and forest clearing were alleged to be related to malaria rates in the Usambara Mountains of Tanzania (Matola *et al.*, 1987). One study in the highlands of Kenya claimed that climate was not a factor in malaria transmission because average temperature and rainfall did not change during the time that malaria rates changed. According to the study, deforestation might have been a reason behind changes in malaria transmission in the highlands of Kenya (Malakooti *et al.*, 1998). In Tanzania, malaria epidemics were attributed to drug resistance, home treatment of malaria, deforestation, traditional beliefs, and changes in vector biting behavior (Mbooera and Kitua, 2001).

Deforestation of jungle areas in Uttar Pradesh has also changed malaria in that region by changing relative parasite survival. Clearing of the forest caused a reduction in humidity which shortened the longevity of the Anopheles vectors until they did not live long enough to successfully transmit *P. malariae*, which needs a longer time within the mosquito before it can be transmitted to the human host. *P. vivax* and *P. falciparum* have increased and *P. malariae* has not returned to the area since (Sharma, 1996). Deforestation of the area allows new vectors to invade the forest fringes (Sharma, 1996), producing epidemics, especially in the non-tribal non-immune people who have moved to these areas because of the development projects that have caused the deforestation.

According to Warsame *et al.* (1995), increased flooding could facilitate the breeding of malaria carriers in formerly arid areas. Small geographical changes in the distribution of malaria may expose large numbers of people to infection e.g. densely populated East African highlands (Lindsay and Martens, 1998). Malaria has been creeping upward from the lowlands to the highlands in the Lake Victoria region in East Africa, and indications are that it has been aggravated by climate variability and change, as well as poverty.

Evidence reveals that the interplay of poverty and other variables do intensify the vulnerability of a population to the impact of highland malaria in East Africa. This is because of a lack of economic resources to invest in health-coping mechanisms that can offset the costs of adaptation. The poverty of the communities undermines the coping mechanisms that could help these communities reduce their vulnerability to malaria (Yanda *et al.*, 2006). For example, in Bugarama village in Tanzania, the richer people, locally known as Washongole can afford to meet health-related costs as compared to the poor group, locally known as Abworu (Yanda *et al.*, 2005). It should be noted that vulnerability to climate-related health risks is also compounded by other stress factors, such as high poverty levels and incidences of HIV/AIDS.

Although many of the studies reviewed show a link between climatic variables and malaria, it is hard to extrapolate each of those findings to an assertion that anthropogenic climate change is the cause of the changes in meteorological variables that were found to be related to changes in malaria rates. The results of all of these studies reveal that more research needs to be done on the causes of increases in malaria prevalence, taking into account all of the factors that could be associated with malaria prevalence. This study combines climatic and environmental factors associated with malaria prevalence as most studies discussed did not do this.

MATERIALS AND METHODS

This study was carried out in 2010 at Makerere University, Uganda. To establish the correlation between

socio-economic and environmental variables and malaria prevalence in Uganda we adopted modified health production model to establish this relationship. In addition, we controlled for other factors that have been hypothesized in the literature to be among the factors that may explain variation in malaria prevalence. However due to availability of data on the controls only for some few years we used cross section data for the year 2003 and Ordinary Least Squares to regress the following model;

$$Yi = \beta 0 + \beta 1 Xi + \beta 2 Zi + \beta 3 Wi + \beta 4 Di + \beta 5 Hi + \lambda CONTi + \varepsilon i \quad (1)$$

Where Y is the malaria prevalence rate, X is monthly average temperature, Z is monthly average rainfall, W is the wetlands area coverage, D is the deforestation rate, and H is presence of a water body and CONT are control variables that include; literacy rates, poverty rates, population density and i is district subscript.

Malaria rate was defined as the number of reported cases in a district per year as a percentage of the district population size. Rainfall was estimated using the average monthly rainfall received in a year. Temperature was estimated using the average monthly temperature defined as the average monthly minimum temperature plus the average monthly maximum temperature divided by two. Poverty was defined as the proportion of poor individuals below the poverty line (head count) in a given district. Deforestation is the clearance of naturally occurring forests by the process of logging or burning trees in a forested area as a proportion of the district area and was estimated using the difference between the forest cover in 2002 and 2005.Population density was defined as the total population of the district divided by the total district area in square kilometers. Literacy was measured as the number of individuals that can both read and write as a percentage of the total district population. Complete data was obtained for only 43 districts in Uganda.

RESULTS AND DISCUSSION

Table 1 shows regression results of the modified health production model. Deforestation was shown not to be a significant determinant of malaria prevalence. This finding contradicts earlier findings which show that deforestation is positively associated with malaria prevalence in Tanzania (Mbooera and Kitua, 2001; Sharma, 1996). However, Guerra *et al.* (2008) observed that the effects of deforestation on malaria transmission were spatially variable and highly dependent on vector distribution. This is because the vector species could adapt to different types of land cover and therefore could make the effect on malaria transmission regionally distinctive and even locally specific.

Contrary to our expectation, temperature was shown not to be associated with malaria prevalence (Table 1).

Table 1: Determinants of Malaria prevalence: OLS estimates, Dependent variable: Malaria Prevalence

Variable	Coefficient	t-statistics
Constant	305.8276	0.87
Deforestation	-0.2547612	-0.56
Poverty	-0.175934	-0.44
Literacy	-0.1726644	-0.56
Population density	0.0492312	1.17
Wetlands	-0.3486087	-0.75
Rainfall	0.0897011	0.66
Temperature	-14.79302	-0.67
Water Dummy	4.164928	0.63

According to Walsh *et al.* (1993), higher temperatures can increase the pace at which mosquitoes develop into adults, the frequency of their blood feeding, the rate at which parasites are acquired, and incubation of parasites within mosquitoes (Walsh *et al.*, 1993), however, this is not supported by data from Uganda. Similarly, rainfall, wetlands conversion and the presence of water bodies such as lakes and rivers were shown not to be significantly associated with malaria prevalence in Uganda.

Results in Table 1 also show that there is no significant association between malaria prevalence and poverty levels. This finding contradicts the assertion that poverty undermines the coping mechanisms that could help poor people reduce their vulnerability to malaria (Yanda *et al.*, 2006).Similarly, population density and literacy rates were shown not to be associated with malaria prevalence at district levels in Uganda. There is need for further study using disaggregated data, panel data, and adding more control variables to the health production model to identify the factors that could be associated with malaria prevalence in Uganda.

CONCLUSION

This study set out to establish the relationship between malaria prevalence and environmental and socio-economic variables. An understanding of the factors that are associated with malaria prevalence is critical for the design of policies aimed at reducing malaria prevalence. To establish the correlation between socio-economic and environmental variables and malaria prevalence in Uganda we adopted modified health production model to establish this relationship using cross sectional data. Regression results using OLS indicate no relationship between malaria prevalence and environmental and socio-economic variables. There is need for further study using disaggregated data, panel data, and adding more control variables to the health production model to identify the factors that are associated with malaria prevalence in Uganda.

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