World Journal of Zoology 11 (4): 160-165, 2016
ISSN 1817-3098

DOI: 10.5829/idosi.wjz.2016.160.165

# Effect of Climate Change on the Prevalence of Malaria in Ethiopia: Distribution of Mosquito and Preventive Techniques

[1]*Aschalew Alelign* and [2]*Tadesse Dejene*

[1]Department of Animal,
Rangeland and Wildlife Science in Mekelle University, Mekelle, Ethiopia
[2]Department of Biology in Mekelle University, Mekelle, Ethiopia

**Abstract:** When the temperature increases and the changes in levels of precipitation indicate, there are some aspects of climate change that may affect the rate of vector-borne diseases such as malaria. The warm and wet environments are excellent places for mosquitoes to breed. An increase in global temperatures will result in an expansion of warm temperature regimes into higher altitudes and latitudes. Mosquito can breed in different water habitats from shaded ponds and pools to hoof prints and tyre tracks. The life cycle of mosquito can take 7-16 days but is influenced by humidity and temperature. In Ethiopia the cold zone, covers areas higher than 2,500m asl with a mean annual temperature of 10-15°C, is considered free of local malaria transmission. The altitude ranging from 1,500-2,500m with a mean annual temperature between 15-20°C has diverse malaria transmission patterns. Areas below 1,500m asl (in hot lowlands), where the mean annual temperature varies from 20-25°C , malaria transmission is endemic and its intensity and duration are mainly dictated by the amount and duration of rainfall in Ethiopia. Malaria can be prevented and controlled by cleaning environments, indoor residual spraying and mosquito nets.

**Key words:** Anopheles Mosquito · Climate Change · Control · Malaria

## INTRODUCTION

Reports of glacial melting, higher altitude melting points and changing species distribution provide evidence of climate change [1]. Climate plays an important role in the seasonal pattern or temporal distribution of diseases that are carried and transmitted through vectors because the vector animals often thrive in particular climate conditions. For example, warm and wet environments are excellent places for mosquitoes to breed. If those breeding mosquitoes happen to be a species that can transmit disease and if there is an infected population in the region, then the disease is more likely to spread in that area [2].

Climate change has the potential to alter the average exposure of human populations to vector-borne diseases by changing the geographical distribution of conditions that are suitable for the vectors and disease pathogens. An increase in global temperatures will result in an expansion of warm temperature regimens into higher altitudes and latitudes. Any associated changes in rainfall in tropical and subtropical zones will alsorender habitats more or less suitable for vectors. In addition, the implications of the asymmetrical increases of temperature with global warming for the epidemiology of vector-borne diseases need to be clarified [3].

The mosquito is both an elegant, gracefully adapted organism and a curse of humanity. The principal mosquito-borne human illnesses of malaria, filariasis, dengue and yellow fever are almost exclusively restricted to the tropics. Malaria, the most important parasitic disease in the world, is thought to be responsible for 500 million cases of illness and up to 2.7 million deaths annually, more than 90% of which occur in sub-Saharan Africa [4]. There are approximately 2, 700 species of mosquito in the world; the three most significant genera are the Aedes, Anopheles and Culex, as these types of mosquitoes are responsible for transmitting various diseases that are hazardous to mankind. The anopheles is different from other types of mosquitoes as it is the genus

**Corresponding Author:** Aschalew Alelign, Department of Animal, Rangeland and Wildlife Science in Mekelle University, Mekelle, Ethiopia. P.O. Box 231.

most accountable for spreading malaria to humans. Malaria can be fatal; its typical symptoms include fever, headaches, chills and general flu symptoms [5]. The species of anopheles known as gambiae is infamous for transmitting plasmodium falciparum, the most threatening form of malaria in the world [6].

**Climate Change and Distribution of Anopheles Mosquito:** Increased ranges of temperature and possible changes in levels of precipitation are some aspects of climate change that may affect the rate of vector-borne diseases such as malaria. Lengthened seasons of transmission will make contraction of vector-borne diseases possible for longer periods of time, leading to higher rates of infection [3].

Specific areas will be likely to experience diverse effects in the rate of vector-borne disease growth. Areas with inadequate rainfall and higher temperatures may become too dry for transmission and thereby lower the rate of distribution. Whereas, areas that currently have temperatures too low for malarial transmission may experience increased rates of distribution with increases in temperature [6]. There may be changes in the length of the season of transmission due to ranging temperatures. The risk of outbreaks may be increased in locations where vectors are still present and the disease has been controlled [7].

Climate change affects the spread of vector borne diseases such as global warming and increased rainfall that contribute to the abundance and distribution of vectors such as mosquitoes and ticks although mosquitoes are the most common. Increased rainfall leads to stagnant water pools in which mosquitoes breed and global warming leads to increased global temperatures allowing mosquitoes to survive winters where they would otherwise have perished [6]. Subsequently, more mosquitoes are alive to breed and transmit disease during the summer season. In addition, mosquito larvae develop much faster at higher temperatures and after ingestion of the virus become more infectious at higher temperatures [8].. This will also increase the incidence of infection by vector borne diseases and their transmission to first world countries which harbor mostly immune populations [9].

**Effect of Global Warming on the Spread of Malaria:** The impact of greenhouse gas emissions on temperature and rainfall and fine-scale land use and land cover changes were linked to malaria transmission and infection rates. The effects of local terrain on temperature and rainfall caused by land use and land cover changes. The shift towards higher temperatures and significantly decreased rainfall will reduce the spread of malaria in most areas of tropical Africa. Changes in the distribution, range and spread of the disease are likely to be most notable in parts of the Sahel (a narrow strip of land, south of the Sahara desert, spanning North Africa coast to coast), the horn of Africa (north east Africa) and various highland territories. Across the greater horn of Africa, significantly increased temperatures and a small increase in rainfall is projected to cause a marked increase of malaria infection across large parts of east Africa [10]. Malaria is likely to spread to higher altitudes in the highland areas, including areas above 2000 m that were previously free of the disease and will turn into epidemic malaria regions. The researchers suggested the infection rate in the 2020s and 2040s is likely to be greatest in the Ethiopian highlands, eastern arc mountains and parts of the western rift valley. By including the impact of land use changes on local climate, an accelerated rainfall decline is projected for West Africa [11].

**Impact of Climate on Epidemiology of Vector-borne Disease:** The geographical distribution of vector-borne diseases is influenced by the geographical distribution of the vector [12]. For example, temperature can affect both the distribution of the vector and the effectiveness of pathogen transmission through the vector. The possible mechanisms whereby changes in temperature impact on the risk of transmission of vector borne disease includes; increase or decrease in survival of vector according to the geographical position, changes in rate of vector population growth, changes in feeding behavior, changes in susceptibility of vector to pathogens, changes in incubation period of pathogen, changes in seasonality of vector activity, changes in seasonality of pathogen transmission [13]. This relationship between el-nin˜o and increased malaria risk is partly due to increased temperature and partly due to increased rainfall leading to increased mosquito breeding sites because of surface water collections in hot areas. The rainfall also has impact on the risk of transmission of vector-borne disease by increased surface water can provide breeding sites for vectors, low rainfall can also increase breeding sites by slowing river flow [2].

**Mosquito Entomology:** There are different species of mosquitoes found beyond the tropical and subtropical regions of the world with which they are classically associated [14]. Most female mosquitoes take blood meals from vertebrates to obtain the necessary nutrition to produce their eggs, injecting saliva (which may contain pathogens) into the host animal. While many mosquitoes are distinctly selective feeders, restricted to one or a few closely related species, some feed in a less restrictive manner, varying between mammals, birds and reptiles. Those which regularly feed on humans and in which pathogens can complete an obligatory life cycle phase and multiply in the mosquito's salivary glands, can be important vectors of human diseases [11].

Anopheles mosquitoes can breed in numerous different water habitats from shaded ponds and pools to hoof prints and tyre tracks. They lay their eggs on surface water. It takes approximately 48 hours for most eggs to hatch into the larvae stage. Development time for larvae depends on specific environmental conditions (temperature, nutrient supply, degree of available light), with most tropical mosquito larvae developing in approximately week, while the larvae of many species endemic to temperate zones may [11]. Female mosquitoes lay their eggs in stagnant water for several reasons. Stagnant water contains bacteria and algae that mosquito larvae feed on. When mosquitoes become adults, they hatch out of their pupal cases and need to rest on the surface of the water until their wings and bodies have dried out and they are able to fly away. They prefer water that is not too polluted but some *anopheles gambiae* species have been shown to breed in stagnant drains. Artificial containers such as pots or tanks are usually only suitable breeding sites for *aedes* vectors [15].

**There Are Four Distinct Life Stages to a Mosquito's Life Cycle:** egg, larva, pupa and adult, which are aquatic until reaching the adult stage. This process can take between 7-16 days but is influenced by humidity and temperature; the higher the temperature and humidity, the more rapid the life cycle. Digestion of the blood meal and simultaneous development of the eggs takes about two to three days during which time the mosquito does not usually bite [11]. Anopheles' larvae get their oxygen supply through spiracles (an opening used for oxygen) and must lie parallel to the water surface.

**Climatic Factors That Influence the Transmission of Malaria:** Climate affects both parasites and mosquitoes. Mosquitoes cannot survive in low humidity. Rainfall expands breeding grounds and in many tropical areas, malaria cases increase during the rainy season. Mosquitoes must live long enough for the parasite to complete its development within them. Therefore, environmental factors that affect mosquito survival can influence malaria incidence [9]. Plasmodium parasites are affected by temperature; their development slows as the temperature drops. *P. vivax* stops developing when the temperature falls below 60 degree Fahrenheit. P. falciparum stops at somewhat higher temperatures [16]. Rainfall in tropical areas creates an opportunity for anopheles mosquitoes to lay eggs, which can reach adulthood. The anopheles mosquito transmits the causative agent, plasmodium species, when the environmental parameters (such as water availability, temperature and humidity) permit. In many parts of the world where temperature is not a limiting factor, seasonal malaria transmission takes place during peak rainfall periods [17]. The Vector abundance, distribution and pattern of vector behavior are changing because of climate change [18, 19].

The occurrence of vector-borne disease such as malaria is determined by the abundance of vectors and intermediate and reservoir hosts, the prevalence of disease causing parasites and pathogens suitably adapted to the vectors and human and animal hosts and their resilience in the face of the disease [20]. Local climatic conditions, especially temperature and moisture are also determinant factors for the establishment and reproduction of the anopheles mosquito [9]. The possible development of the disease in mountain regions thus has relevance, because populations in uplands where the disease is currently not endemic may face a new threat to their health and well-being as malaria progressively invades new regions under climatic conditions favorable to its development. The occurrence of vector-borne diseases is widespread ranging from the tropics and subtropics to the temperate climate zones. With few exceptions, they do not occur in the cold climates of the world and are absent above certain altitudes even in mountain regions of the tropical and equatorial belt [21].

The infection rate for malaria is an exponential function of temperature [15]; small increases in temperature can lead to a sharp reduction in the number of days of incubation. Regions at higher altitudes or latitudes may thus become hospitable to the vectors; disease-free highlands that are today found in parts of Ethiopia and Kenya, for example, may be invaded by vectors as a result of an increase in the annual temperature [8]. If this were to occur, then the number of persons infected by malaria would increase sharply investigated the possible changes in the distribution of malaria. Increases in temperature and rainfall would most probably allow malaria vectors to survive in areas immediately surrounding their current distribution limits. How far these areas will extend both in terms of altitude and latitude depends upon the extent of warming.

**Factors of Malaria Transmition in Ethiopia:** Malaria transmission intensity, along with its temporal and spatial distribution in Ethiopia, is mainly determined by the diverse eco-climatic conditions. Climatic factors such as temperature, rainfall and humidity show high variability mainly as a function of altitude and are the most important variables that influence malaria transmission. Based on this altitudinal variation and associated climatic characteristics, areas of the country are categorized into climatic zones, namely, the cold zone locally known as "Dega"; the hot zone, "Kolla"; and areas of average climatic conditions, known as "Weyna Dega." [5, 22].

The cold zone, which covers areas higher than 2,500 meters asl with a mean annual temperature of 10-15°C, is considered free of local malaria transmission. The midland area, ranging in altitude from 1,500-2,500m with a mean annual temperature between 15-20°C, has diverse malaria transmission patterns. In the hot lowland zone, located in areas below 1,500m above sea level, where the mean annual temperature varies from 20-25°C, malaria transmission is endemic and its intensity and duration are mainly dictated by the amount and duration of rainfall. Malaria transmission varies among communities largely due to environmental factors, such as proximity to breeding sites [16]. Many water resources development and management projects result in local outbreaks of malaria and other vector-borne diseases such as schistosomiasis, lymphatic filariasis and Japanese encephalitis. These outbreaks can be attributed to an increase in the number of breeding sites for mosquitoes, an extended breeding season and longevity of mosquitoes, relocation of local populations to high-risk reservoir shorelines and the arrival of migrant populations seeking a livelihood around the newly created reservoirs [17].

In the midland zone of Ethiopia, where temperature is a determining factor, malaria transmission often occurs in areas below 2,000m, while areas between 2,000 and 2,500m may become affected during epidemics. Rainfall decreases northwards and eastwards from the high rainfall pocket area in the southwest and seasonality is not uniform. The western half of the country has two distinct seasons (wet from June-September and dry from November-February), with the rainfall peak occurring in July and august. The central and most of the eastern part of the country have two rainy periods and one dry period. The south and southeastern parts of Ethiopia have two distinct dry periods (December-February and July-August) and two rain seasons (March-June and September-November). The major malaria transmission season is from September to December, following the main rainy season from June to September and a shorter transmission season from April to May following the short rainy season from December to February [5]. Due to the unstable and seasonal pattern of malaria transmission, the protective immunity of the population is generally low and all age groups are at risk of infection and disease [22].

**Distribution of Malaria in Ethiopia:** The distribution of malaria in Ethiopia varies from place to place due to the above factors directly or indirectly affecting the pattern of malaria transmission. For example, the distribution of malaria in Ethiopia is largely determined by altitude. Altitude affects the pattern of malaria distribution in Ethiopia through its effect on temperature [11]. Risk of malaria is highest in the western lowlands of Oromia, Amhara, Tigray and almost the entire regions of Gambella and Benishangul Gumuz [17]. The midlands of Ethiopia between 1,000 and 2,200 meters altitude experience seasonal transmission of malaria with sporadic epidemics every few years. In the eastern lowlands of Ethiopia (primarily afar and Somali), malaria is endemic only along the rivers, as this part of the country is largely dry away from rivers. Transmission is limited by the lack of water collections for mosquito breeding and low humidity due to low rainfall and sparse vegetation. The central highlands of Ethiopia are free of malaria mainly due to the low temperatures, which slows the development of the vector and the parasite [22].

The exact number of people getting sick and dying of malaria every year in Ethiopia is not known. However, it is known that millions of people get sick and tens of thousands of people die due to malaria every year and that rates of mortality (death) and morbidity (illness) dramatically increase during epidemics. The distribution of malaria in Ethiopia is not uniform. There are areas where the risk of malaria is high and there are areas where the risk is low. There are even areas, 25% of the country, that are malaria free [18].

**Malaria Prevention and Control:** Before DDT, malaria was successfully eradicated or controlled also in several tropical areas by removing or poisoning the breeding grounds of the mosquitoes or the aquatic habitats of the larva stages, for example by filling or applying oil to places with standing water. These methods have seen little application in Africa for more than half a century [16].

**Indoor Residual Spraying:** Indoor residual spraying (IRS) is the practice of spraying insecticides on the interior walls of homes in malaria affected areas. After feeding, many mosquito species rest on a nearby surface while digesting the blood meal, so if the walls of dwellings have been coated with insecticides, the resting mosquitoes will be killed before they can bite another victim, transferring the malaria parasite [23]. Though DDT has never been banned for use in malaria control and there are several other insecticides suitable for IRS, some advocates have claimed that bans are responsible for tens of millions of deaths in tropical countries where DDT had once been effective in controlling malaria. Furthermore, most of the problems associated with DDT use stem specifically from its industrial-scale application in agriculture, rather than its use in public health [16].

The World Health Organization currently advises the use of 12 different insecticides in IRS operations. These include DDT and a series of alternative insecticides (such as the *pyrethroids permethrin* and *deltamethrin*) to both, combat malaria in areas where mosquitoes are DDT-resistant and to slow the evolution of resistance. This public health use of small amounts of DDT is permitted under the Stockholm Convention on Persistent Organic Pollutants, which prohibits the agricultural use of DDT. However, because of its legacy, many developed countries discourage DDT use even in small quantities [1].

**Mosquito Nets and Bedclothes:** Mosquito nets help keep mosquitoes away from people and thus greatly reduce the infection and transmission of malaria. The nets are not a perfect barrier, so they are often treated with an insecticide designed to kill the mosquito before it has time to search for a way past the net [21]. Insecticide-treated nets (ITN) are estimated to be twice as effective as untreated nets and offer greater than 70% protection compared with no net [5]. Although ITN are proven to be very effective against malaria, less than 2% of children in urban areas in Sub-Saharan Africa are protected by ITNs. Since the *Anopheles* mosquitoes feed at night, the preferred method is to hang a large "bed net" above the center of a bed such that it drapes down and covers the bed completely [21].

The extensive distribution of mosquito nets impregnated with insecticide often (permethrin or deltamethrin) has shown to be an extremely effective method of malaria prevention and also one of the most cost-effective methods of prevention [23]. For maximum effectiveness, the nets should be re-impregnated with insecticide every six months. This process poses a significant logistical problem in rural area [2]. New technologies like Olyset or DawaPlus allow for production of long-lasting insecticidal mosquito nets, which release insecticide for approximately 5 years. ITNs have the advantage of protecting people sleeping under the net and simultaneously killing mosquitoes that contact the net. This has the effect of killing the most dangerous mosquitoes. Some protection is also provided to others, including people sleeping in the same room but not under the net [5].

## REFERENCES


1. Sutherst, R.V., 2004. Global Change and Human Vulnerability to Vector-Borne Diseases. Clin. Microbiol. Rev., 17: 136-173.
2. Jaggernath, J., D. Haslam and K. Naidoo, 2013. Climate change: Impact of increased ultraviolet radiation and water changes on eye health. Health, 5: 921-930.
3. Lieshout, V.M., R.S. Kovats, T.J. Livermore and P. Martens, 2004. Climate Change and malaria: analysis of the SRES Climate and socio-economic scenarios. Global Environ. Chang., 14: 87-99.
4. Holt, R.A., G.M. Subramanian, A. Halpern, G.G. Sutton, R. Charlab, D.R. Nusskern, P. Wincker, A.G. Clark and J.M. Ribeiro, 2002. The genome sequence of the malaria mosquito Anopheles gambiae. Science, 298: 129-149.
5. Aschalew, A. and D. Tadesse, 2016. Current Status of Malaria in Ethiopia: Evaluation of the Burden, Factors for Transmission and Prevention Methods. APG, (1): 01-06.
6. Olijira K., B. Meshesha and G. Teshome, 2011. Environmental factors associated with larval habitats of anopheline mosquitoes (Diptera: Culicidae) in irrigation and major drainage areas in the middle course of the rift valley. J. Vector Borne Dis., 48: 85-92.
7. Tanser, F.C., B. Sharp and D.L. Sueur, 2003. “Potential effect of climate change on malaria transmission in Africa. Lancet, 362(9398): 1792-1798.
8. Alsop, Z., 2007. Malaria returns to Kenya’s highlands as temperatures rise. Lancet, 370(9591): 925-926.
9. Epstein, P.R., 2001. Climate change and emerging infectious diseases. Microbes Infect., 3: 747-754.

10. Ermert, V., A.H. Fink, A.P. Morse and H. Paeth, 2012. The impact of regional climate change on malaria risk due to greenhouse forcing and land-use changes in tropical Africa. Environ. Health Persp., 120(1): 77-84.
11. Tadesse, D., Y. Mekonnen and A. Tsehaye, 2011. Characterization of mosquito breeding sites in and in the vicinity of Tigray micro dams. Ethiop. J. Health. Sci., 21: 1.
12. Gubler, D.J., R. Epstein, L.E. Kristie, Y. Wendy, N. Roger and J.A. Patz, 2001. Climate Variability and Change in the United States: Potential Impacts on Vector- and Rodent-Borne Diseases, Environ. Health Persp., 109(2): 223-233.
13. Bouma, M.J. and C. Dye, 1997. Cycles of malaria associated with El Niño in Venezuela., J. Amer. Med. Assoc., 278: 1772-4.
14. Reiter, P., 2001. Climate change and mosquito borne disease. Environ. Health Persp., 109: 141-161.
15. WHO (World Health Organization), 1990. Potential health effects of climatic change. WHO report WHO/PEP/90/10. World Health Organization, Geneva, Switzerland.
16. Daddi, J., G. Asefaw, B. Hana, R.W. Steketee, P.M. Emerson, P.M. Graves, G. Teshome, R. Reithinger and J. Hwang, 2010. Malaria indicator survey 2007, Ethiopia: coverage and use of major malaria prevention and control interventions. Malaria J., 9: 58.
17. Delenasaw, Y., L. Worku, V.B. Wim, G. Solomon, H. Kloos, L. Duchateau and N. Speybroeck, 2009. Malaria and water resource development: the case of Gilgel-Gibe hydroelectric dam in Ethiopia. Malaria J., 8: 21.
18. Kassahun, N., 2004. "Ethiopia Roll Back Malaria Consultative Mission: Essential Actions to Support the attainment of the Abuja Targets, Ethiopia RBM Country Consultative Mission Final Report, 2004.
19. Arega, D.G. ,2009. Vulnerability analysis and malaria risk mapping in Hawassa and Wondo Genet Woreda. MSc thesis, Addis Ababa University, Ethiopia.
20. McMichael, A.J., 1993. Planetary Overload: Global environmental change and the health of the human species. Cambridge University Press., 16: 352.
21. WHO (World Health Organization), 2001. Global water supply and sanitation assessment 2000 report. 1. Water supply statistics. 2. Water resources development. 3. Sanitation statistics. I. WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation. World Health Organization and UNICEF, Geneva, Switzerland.
22. Adhanom, T., W. Deressa, K.H. Witten, A. Getachew and T. Seboxa, 2006. In Epidemiology and ecology of health and disease in Ethiopia. Edited by: Berhane Y, Haile-Mariam D, Kloos H. Ethiopia, Addis Ababa: Shama Books; pp: 556-576.
23. Baird, J.K., 2005. Effectiveness of Antimalarial Drugs. New Engl. J. Med., 35: 2-15.