



## Thwack of Worldwide Weather Transformation on Vector and Vector-Borne Parasitic Infections

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**Abstract:** Debatably one of the most important effects of environment transformation is the potential impact on human and animal health. The substantiation that environment warming is changing the distribution of arthropods vectors and the pathogens they transmit is reviewed and assessed. The principal looms are either phenomenological, which typically presume that environment alone limits existing and future distributions, or mechanistic, asking which arthropod-demographic restriction is affected by specific abiotic situation. By 2100 it is estimated that average worldwide warmth will have risen by 1.0-3.5 °C, increasing the likelihood of many vector-borne diseases in new areas. Vector-borne animal diseases sham a continuous and substantial danger to livestock economies around the world. Escalating intercontinental voyage, the globalization of deal, and environment transformation are likely to play an increasingly more significant role in the opening, establishment and transmission of arthropod-borne disease worldwide. Higher temperature may be connected with increased insect abundance-thereby amplifying the risk of disease transmission. Most important disease at par are malaria, leishmania, trypanosomiasis, chagas, babesiosis, filariasis, onchocerciasis, loaiais and heart worm infection, so attempts to be made to reduce the chance of global warming and save our future.

**Keywords:** Global-warming, vector-borne diseases, parasites, livestock, human-beings

### 1. INTRODUCTION

One of the environmental threats our globe faces today is the potential for long term change in the earth's climate patterns known as 'global climate change (GCC)'. According to United Nations Framework Convention on Climate Change (UNFCCC) "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods" [1]. Examples of GCC are global warming, changes in rainfall patterns, and changes in the frequency of extreme weather events. The global warming is different from global climate change which mean's an increase in Earth's average surface temperature [2]. Environment transformation may occur due to in-house natural procedure or outside forcing, or to constant anthropogenic alteration in the composition of the atmosphere or in ground use so the usual basic factors, such as alteration in the solar power strength or sluggish alteration in

the Earth's path in the solar system; natural procedure within the environment structure (e.g. alteration in sea motion); person actions that cause alteration the air composition (e.g. via using of fossil fuels) and the ground surface (e.g. cutting of plants, making of more cities etc.) [3]. In order to understand why global climate change occurring, it helps to understand what is occurs in the earth's atmosphere [1]. The earth's atmosphere consists mainly of mainly nitrogen and oxygen, with small amount of hydrogen, helium, argon, neon and other gases. The greenhouse gases play an important role in determining the climate and climate change. A greenhouse gases is a gas that traps infrared energy (heat) in the atmosphere [4]. Carbon dioxide i.e. CO<sub>2</sub> (sources: fossil fuel combustion and land use changes), Methane i.e. CH<sub>4</sub> (sources: arable farming and livestock production), Nitrous oxide i.e. N<sub>2</sub>O (sources: arable farming and water incineration) and chlorofluorocarbon i.e. CFC-12 and CFC-11 are major greenhouse gases. The relative heat

trapping ability of CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O and CFC are 1, 23, 296, and 12,000 respectively [2]. Sources of global atmospheric concentrations of CO<sub>2</sub> percentage from burning of fossil fuels is about 49%, industrial process is 24%, deforestation is 14% and agriculture is 13%. Global atmospheric concentrations of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of year concentrations of CO<sub>2</sub> have increased from 280 ppm (pre-industrial value) to 390.5 ppm Jan 2012, CH<sub>4</sub> from 700ppb to 1871ppb, N<sub>2</sub>O from 270 to 323ppb, CFC-11 from 0 to 241ppt in 2012 [5]. So the Carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), CFC-12 and CFC-11 are considered to be the major greenhouse gases as they are continuously increasing in concentration since 1978 [6].

In order to make Earth as a livable planet the occurrence of greenhouse gases in the environment is a natural part of the atmospheric system. But generally these gases are more transparent to incoming solar emission, which in turn causes the sun's power to pass through the climate and reach to the earth surface [6]. As a result of this process the solar energy is absorbed on ground surface, and used in reaction like photosynthesis by plants, or returned back to space as infrared rays. So, at last some of these rays passes the environment and goes back to space, whereas some is engrossed by greenhouse gas molecules and then re-emitted in all directions [3]. As a result the Earth's surface temperature goes up and it became a threat to melting of polar ice bergs also. Major greenhouse gases are Methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), chlorofluorocarbons (CFCs) which have a strong warming effect due to its heat-trapping abilities [7]. Earth's normal average temperature would be -0.4°F (-18°C), rather than the present 59°F (15°C) in the absence of this greenhouse effect. So the warming of the climate system is unequivocal, as it is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level [8]. Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic GHG concentrations. The IPCC predicted that climate change will become apparent in the following main ways: by around 2100 global temperatures will have risen by

between 1.1-6.4°C, in the course of the present century sea levels will rise by between 18-59 centimeters [2].

The maximum effect of environment change on transmission is likely to be observed at the extremes of the range of temperatures at which the transmission may occur [4]. Malaria and dengue fever are among the most important vector-borne diseases in the tropics and subtropics; Lyme disease is the most common vector-borne disease in the USA and Europe [3]. Encephalitis is also becoming a public health concern. By 2050 it is approximated that the Sahara and the semi-arid parts of southern Africa may get warm by 1.6 °C, while equatorial countries such as Cameroon, Kenya and Uganda could experience rises of 1.4 °C [8]. Climate oscillations can affect the dynamics of dengue fever [5], which is transmitted by the predominantly urban mosquito *Aedes aegypti*. In Latin America, about 78% of the inhabitants around 81 million public live in urban settlements and the disease has been on the increase in the past decade [9].

Many reason can explain the climate changes, among which all most all are some ware related to human, such as the rise in commercial transportation, but also owners traveling with their pet during the holidays, the expansion of "outdoor" activities [3], the increase of individual housings with gardens; the ignorance of the risks, linked to animals in general and to wildlife in particular; ecological transformation like forest breakup, establishment of parks; the increase of wild mammal populations [10]. Environment transformation is a reality which may explain the increase of density of arthropod vectors, but also of their hosts, changes in periods of activity and variations in geographical distribution. Universal warming has speeded up over the last hundred years with an average gain of 0.74°C in 100 years [11]. *Dermacentor reticulatus*, the tick vector of canine babesiosis caused by *Babesia canis*, is present in 2/3 of the French territory [12]. It is undoubtedly scattering to the East, favoring milder winters. It has now been documented in Belgium [13], the Netherlands, where cases of canine babesiosis have become more and more frequent, it has also been observed in other country like Germany, Czech Republic and Slovakia [14, 15]. In Slovakia, field studies showed that its limited area of presence had gained 200 km north since 1970s, as well as 300

m in altitude [16]. These studies conducted have exposed that shorter winters have a straight blow on the ecosystem of ticks. Concerning *Ixodes ricinus*, its occurrence and density are obviously related to the plant cover, but also to the density of its hosts: micro mammals for larvae and nymphs and large mammals for adult ticks [10]. *Ixodes scapularis* is highly vulnerable to desiccation when relative humidity drops below approximately 90% [17]. Even a few hours at stumpy humidity can be deadly, but ticks returned to humid air may bear petite mortality [18]. Low relative humidity (50%) allows survival when temperatures are below 58 °C, but relative humidity above 70% is required when temperatures exceed 150 °C. Even short term exposure to extreme cold (e.g. below -15 °C) can be lethal to *I. scapularis* [19, 20] and *I. ricinus* [21] so cold winter weather could be responsible for a significant amount of mortality, and might constrain *Ixodes* populations.

The overall effects of global climate change are likely to be harmful. Humans and animals could suffer from increased spread of infectious diseases, heat related deaths, and air pollution [10]. Global climate change and increased climatic variability are particularly likely to affect vector and vector borne parasitic diseases. Temperature, precipitation, humidity, and other climatic factors are known to affect the reproduction, development, behavior, and population dynamics of the arthropod vectors of these diseases [22].

## 2. IMPACT OF GLOBAL CLIMATE CHANGE ON VECTOR-BORNE PARASITIC DISEASES

The diseases that are transmitted by arthropod (flies, ticks, bugs etc) are known as Vector-borne diseases (VBDs). Almost half of the world's inhabitants, which subsist in the tropical and subtropical areas of the globe i.e. mainly in the developing country, are affected by these diseases, it may lead to high cause of morbidity and mortality between them [9]. It has been documented that CBDS infection lead to 1.5 million (approximate) human deaths/year [7]. But many infection of parasitic disease like Onchocerciasis and Lymphatic filariasis remain unreported, it may be due communication gap or religious blockage. The ecological allocation of both vectors and their reservoir hosts effect the geological allocation of VBDs. Mainly all

vectors want to have hot and humid environment because they are cold-blooded organism so they can't regulate their own internal temperature and therefore rely on outer environment [13]. In order to complete life cycle parasite need vectors, they can also act as the main mode of transmission of infection [17]. Mainly in VBDs transmission is of two types: Anthroponotic infections or human-vector-human transmissions, in this type human beings act as reservoir of the disease. While in other type i.e. Zoonotic infections or animal-vector-human transmission, animals are the reservoir and human being are considered secondary hosts and do not normally add to the disease diffusion cycle as their levels of circulating pathogen are often too low to help maintain transmission [5, 7]. Anthroponotic infectivity can hypothetically be eliminated if all human cases of the disease are cured; while on other hand control of zoonotic diseases is difficult because all animal reservoirs of the infection would need to be treated [13].

### Vector-borne Disease Dynamics

For the spreading of VBD there should be 3 things: first is the susceptible population in which the disease can spread, second is the vector which can spread the infection and third is the parasitic organism which can cause the disease. In hot and humid countries environmental condition are favorable, which are required for survival and reproduction of both vector and parasite [3]. In a parasitic prone area even if all conditions are good for the propagation of disease then also it can be controlled if we have better health programs [20]. All these parameters are more or less related to increase in the environmental temperature [23]. Improved temperature level can reduce the development time of some arthropod species [20].

### Direct Effects of Climate Change on Vector-borne Disease

Climate change has the potential to: Increase range or abundance of animal reservoirs and/or arthropod vectors (e.g., Malaria, Schistosomiasis). Enhance transmission (e.g., West Nile virus and other Arbo viruses). Increase importation of vectors or pathogens (e.g., Dengue, Chikungunya). Increased animal disease risk lead to potential human disease risk (e.g., African trypanosomiasis) [24].

### **Temperature Effects on Vectors and Pathogens**

**Vector-** Temperature can enhance or reduce any vector population like *Hyalomma* tick prefer hot temperature while *Bhoophilus* tick prefer less hot temperatures [8]. It can also alter the vulnerability of vectors for some parasitic agents [7]. Alterations in temperature can transform in the rate of vector growth, feeding rate and host contact can be altered moreover it can also transform the seasonality of inhabitants. Temperature and moisture modulate key events in the life cycle of *Culicoides* vectors, and climate change-related alterations of these environmental variables have the potential to (1) increase the range, abundance and seasonal activity of the vector, (2) increase the proportion of competent vector individuals, and (3) increase the development rates of the virus within the vector. Outbreaks of West Nile and St. Louis encephalitis viruses are associated with above average summer temperatures

**Pathogen-** In hot temperatures there is reduced extrinsic incubation era of the parasite which is present inside the vector [13].

### **Effects of changes in rainfall on vector and vector-borne pathogens**

**Vector-** Change in the humidity as a result of rainfall may enhance larval territory and also effect vector population like *Hyalomma* tick prefer less humid area while *Bhoophilus* tick prefer more humid area. But sometime excessive rainfall can also lead to flood like situation which in turn cause decrease in vector population [7]. It is also seen that sometime low rainfall can generate favorable condition for the vector habitat, so pools can be formed due to excessive drying of small river which can act as conductive place for malaria parasite. It can also lead to water storage in small container by human which in turn became a good place for the propagation of the mosquitoes. Generally it is seen that enhanced humidity increases vector survival and reduced humidity level decreases vector survival rate [11].

**Pathogen-** Development of *Plasmodium* inside anopheline mosquito can be effected by humidity [19].

**Increased sea level effects on selected vector-borne pathogens-** Changed flow and salt marshes are associated with mosquito species

elimination because there is reduction in mosquito breeding-sites (e.g. reduced habitat for *Culiseta melanura*) [23].

**Vector Activity-** Humidity and precipitation can also have a significant role in vector activity. A higher relative humidity can increase vector activity, but heavy rainfall can actually decrease activity. Increased activity increases transmission rates [24].

### **Vector Survival**

Relationship between temperature and vector mortality is quadratic: mortality rates increase at high and low temperatures. Temperature effects on development may affect mortality rates: particularly high rates of development of mosquitoes can result in small adults with poorer survival [9]. This is one example where the terms in epidemiological models of VBDs interact with one another. Another important interaction is the dependence of transmission coefficients for tick-borne pathogens on the numbers of vectors feeding on the host [23]. The understanding of such interactions is, however, largely rudimentary. When relative humidity is low, ticks have to make more frequent, energy-expensive trips to the litter layer to rehydrate. High “monsoon” rainfall knocks ticks off the herbage and prevents them from finding a host. Lower humidity increase the energy requirement for host seeking by ticks shortening their lives. Lower rainfall decrease breeding areas for mosquitoes, compounded by density-dependent intra-specific competition among the larvae [25].

### **Vector and Host Seasonality**

In parasitic infection seasons play a very crucial role in the interaction between vectors and hosts mainly in case of zoonotic infection having life cycle sustained in wildlife. In this case both host and vector are affected by seasonal alteration in environment and weather independent effects like day length [7]. The lifecycle and activity level of the host along with vector can be affected as well. It depends upon how fast immune animals die and how fast uninfected animals are borne [26]. There are many VBDs of concern, especially in developing countries, a number of which are on the WHO list of neglected tropical diseases (including Leishmaniasis , Trypanosomiasis, Chagas, Lymphatic filariasis, and Onchocerciasis) Table no.1 [7] because they occur in areas where

poverty is the most significant risk factor for their occurrence.

**Table1.** Information of major parasitic diseases

Disease	Pathogen	Vector
Malaria	<i>Plasmodium falciparum</i> , <i>P. vivax</i> , <i>P. ovale</i> , <i>P. malariae</i>	<i>Anopheles</i> spp. Mosquitoes
Leishmaniasis *	<i>Leishmania</i> spp.	<i>Lutzomyia</i> & <i>Phlebotomus</i> spp. Sandflies
African Trypanosomiasis *	<i>Trypanosoma brucei</i> , <i>T. gambiense</i> , <i>T. b. rhodesiense</i>	<i>Glossina</i> spp. (tsetse fly)
Chagas disease *	<i>Trypanosoma cruzi</i>	Triatomine spp.
Babesiosis	<i>Babesia microti</i> , <i>B. divergens</i> ,	Ixodid tick
Lymphatic filariasis*	<i>Wucheria bancrofti</i> , <i>Brugia malayi</i>	Mosquito
Onchocerciasis*	<i>Onchocerca volvulus</i>	Black flies
Loiasis	<i>Loa loa</i>	Tabanid flies
Heart worm	<i>Dirofilaria immitis</i> , <i>D. repens</i>	Mosquitoes

\* WHO neglected tropical disease

### Malaria

There are approximate, more than 3,500 species of mosquitoes (Diptera: Culicidae) [4, 27]. By means of new thermal sensitivities, malaria transmission has recently been predicted to peak at 25 °C (dramatically lower than previous predictions) and decline significantly above 28 °C [28]. Approximately 40% of the world’s population lives in areas which are at risk for malaria. Every year about 500 million people become severely ill from malaria. Between 700,000 and 2.7 million mostly children in sub-Saharan Africa die each year due to malaria [7]. While most of the increase is predicted to occur in Africa, some increased risk is projected in Britain, Australia, India and Portugal. IPCC predicts that the global population at risk for malaria will increase by 220-400 in the next century. Malaria is an extremely climate sensitive disease [9]. Clearly transmission does not occur in climates where mosquitoes cannot survive.

Malaria is a mosquito-borne infectious disease caused by parasitic protozoans of the genus

*Plasmodium* (*vivax*, *malariae*, *ovale*, *knowlesi* and *falciparum*) and is transmitted by female mosquito vectors of the *Anopheles* species [13]. Following the worldwide Malaria eradication program launched by the WHO in the 1950s, 79 countries have eradicated malaria. Between 2000-2010 the incidence of malaria has fallen by 17% globally and by 33% in the African regions. There were 655,000 reported malaria deaths in 2010, out of which 86% were of children under 5 year of age [29]. Optimal larval development occurs at 28°C and optimal adult development between 28 and 32°C. Transmission cannot occur below 16°C or above 33°C as sporogony (the production of sporozoites which comprises dissemination and development of the parasite in the vector) cannot take place. Vectorial capacity of mosquitoes increases as temperature increases (optimal temperature between 22-30°C) [6]. Generally mosquito lifespan increases with higher temperatures. Females increase blood meal frequency at higher temperatures. Aquatic life cycle of mosquitoes reduced from 20 to 7 days. Transmission cannot occur below 16°C or above 33°C as sporogony (the production of sporozoites which comprises dissemination and development of the parasite in the vector) cannot take place. *Plasmodium* species grow faster at higher temperatures (optimal between 27-30°C) [13]. The minimum temperature required for development of *Plasmodium vivax* parasite in anopheline mosquitoes ranges from 14.5-16.5 °C, while for *Plasmodium falciparum* it ranges from 16.5-19 °C. However, the best conditions for development of the malaria parasite are 20-30 °C temperature and 60% relative humidity (RH) [30].

Dengue is a another important mosquito-borne disease in humans, caused by a virus of the *Flavi virus* genus, *Flaviviridae* family affecting about 390 million people each year, through the years 2008-2012, dengue fever cases were reported in several Mediterranean (and Adriatic) countries: Greece, Croatia, Italy, Malta, France, Spain and Portugal [31]. Although most cases were probably imported, in 2010 local transmission of dengue was reported in both Croatia and France [31]. Today, there is an apparent threat of dengue outbreaks in the Mediterranean European countries [9, 31].

### Leishmaniasis

It is endemic in warmer part of the world covering almost 88 countries (16 developed and 72 developing countries) around the globe. It is

estimated that 2 million new cases occur yearly (1.5 million for cutaneous leishmaniasis and 500,000 for visceral leishmaniasis) and that 12 million people are infected worldwide [32]. It was noticed that *P. papatasi* were less active in temperature of 11-20 °C and 37-40 °C, moreover preferred range to temperature for this sand fly is 32-36 °C [33]. This sand fly prefer hot temperature so it was active in dry season (May to November), so in turn its activity peaks were recorded in between May and November [31].

Out of 5 lakhs cases of VL, more than 90 percent are reported from India, Bangladesh, southern Sudan, Nepal and northeast Brazil [23]. Climate directly affect the growth of sand fly and distribution of VL disease, in addition to it climate also has indirect impacts on disease transmission or sand fly by influencing-

1. The distribution of hosts,
2. The local vegetation (important as resting sites and sugar sources),
3. Possible impact of future climate risks

The rises in temperature in day time and humidity level during night time have greatly influenced the growth of flies and the distribution of leishmaniasis but in the cold climatic countries the prevalence is limited because the growth of fly is limited and they are not able to suck the blood in night [14]. High level of precipitation (rain) has also played very important role in the spreading of disease, flooding may spread the vector of disease and the larvae of fly to distant and non infected areas also. In some parts of Latin America, deforestation has led to an increase in leishmaniasis [13]. The former forest has been replaced by areas of farmland, interspersed with patches of forest. With growth of the fox population, an excellent reservoir host of visceral leishmaniasis, Kala-Azar has increased and the sylvatic leishmaniasis vector sand flies have become peri-domestic [25]. In the Amazon region, human populations, accompanied by their infected dogs, have immigrated, serving to increase the prevalence of leishmaniasis. Recent studies have highlighted the spreading of the leishmaniasis, as they accompany the movement of the phlebotomine vectors into previously free areas as suggested for the spread of canine leishmaniasis from southern to northern Italy [26] and from northern to southern Brazil [34]. Indeed, canine leishmaniasis is now well established in South America as far south as northern Argentina [35]. Global warming could

prompt the establishment of canine leishmaniasis in areas such as the United Kingdom, where the vectors are currently absent, but where *Leishmania infantum* infected dogs that had travelled to endemic areas are present [36].

### Dirofilariasis

Dirofilariasis is a mosquito borne filarial nematodal diseases caused by Genus *Dirofilaria*. The transmission of *Dirofilaria* occurs by mosquito of the genera *Anopheles*, *Aedes* and *culex*. *Dirofilaria* is a common parasite of domestic and wild carnivores mainly the canines. It is considered to be a great hazard for the dogs of tropical, subtropical and in some temperate countries [3]. They may cause zoonotic filarial infection in man producing various pathological lesions in the lung, heart, subcutaneous tissue and conjunctiva. *Diofilaria immitis* is a common parasite of dog in many tropical, subtropical and warm temperate areas of the world mainly distributed in the United States, Mediterranean countries of Europe and Africa, Pacific islands, South-East Asia including India, and Japan, and Australia. While *Dirofilaria repens* is commonly distributed in United States, Europe, Africa, India and Sri Lanka [14]. However human dirofilariasis have been reported from France, Italy, Greece, and other countries of Europe and less commonly from Israel, Africa, and Sri Lanka [9]. Dirofilariasis is a mosquito borne parasitic diseases therefore climate suitable for breeding of mosquito is the time of occurrence of this type of parasitic diseases [13]. The mosquito are abundant in the warmer climate therefore new cases become available during this period at the same time dog population of a particular area is an important factors for maintenance of this parasite in that area [37]. Temperature, precipitation, and relative humidity are the three main factors that determine the abundance of mosquitoes and the prevalence of mosquito-borne *Dirofilaria* infection. The optimum temperature for mosquito development of tropical/temperate species is 25-27.8°C. For *Dirofilaria* infection climate based models that determine the effect of temperature on the extrinsic incubation of larval stage in *Aeopheles albopictus* the development from microfilaria stage to infective larvae takes 14-18 days at 26.8°C for *D. immitis* and 16-18 days for *D. repens* [38]. The global warming projected by the IPCC suggested that warm summer is suitable for *Dirofilaria* transmission and that will be the rule in the further decades and if the

actual trend of temperature increase continue filarial infection should spread into previous infection free area. These factors not only favor incubation of *Dirofilaria* but also impact on mosquito species [21].

It is implicit by the models that 130 DUs (heartworm Development Unit) are necessary per year for the parasite to maintain itself in one same area [11]. Therefore, it seems that heartworm disease can now be maintained beyond the Mediterranean region, based only on the biology of vectors and parasites and the evolution of temperatures [39]. Typical weather transformation may be reflected by an increase in the number of days of activity per year. This is actually happening now with the expansion across Europe of the tiger mosquito, *Aedes albopictus*, which was imported from Asia to Italy in 1990 through a trade of old, tires for the remolding industry [40]. Today, it has been reported as far as in the Netherlands. Arriving from Italy to France via Nice, it is now present in approximately 1/3 of the southern French territory, up to Lyon [10]. This mosquito is a competent host for *D. immitis*, with a rapid development to infective L<sub>3</sub>. It is also a more violent and diurnal vector than our autochthonous mosquitoes (*Culex* spp.). It is worth noting that this mosquito plays a significant role in human medicine since it is the main vector of dengue and chikungunya viruses in subtropical areas.

### **Chagas disease or American Trypanosomiasis**

It is estimated that over 7 million people are infected and 109 million individuals are at risk of infection in Latin America [41]. Changes in land use, deforestation and movement of human populations can also bring people into contact with potential wild triatomine vectors [42] that might incidentally assume to play a primary role in *T. cruzi* transmission. For *Triatoma* infection animals such as dogs, cats, armadillos, opossums and rodents serve as host reservoirs in region of Central and South America [27]. In Amazon forest region of Brazil risk for Chagas disease is increasing due deforestation and urban colonization, thus changing the equilibrium between reservoir hosts and wild vectors [13].

### **African Trypanosomiasis**

Trypanosomiasis, spread by tsetse flies, imposes a huge burden on African people and livestock

[9]. Many aspects of the vectors' life cycles are sensitive to climate, and spatial distributions can be predicted using satellite-derived proxies for climate variables. Sleeping sickness is found in remote sub-Saharan areas where health systems are often weak. *T. b. gambiense* is endemic in 24 countries of west and central Africa and causes more than 90% of reported cases of sleeping sickness. *T. b. rhodesiense* is endemic in 13 countries of eastern and southern Africa, representing less than 10% of reported cases [32]. The transmission of African trypanosomiasis follows an animal-vector-animal transmission cycle with occasional spillover into humans. *T. b. gambiense* sleeping sickness is transmitted from human to human by the tsetse fly and is the most common form of transmission of this disease [13]. As some animals can host the human pathogenic parasite, transmission can occasionally take place directly from animals to humans, which is believed to be one of the potential mechanisms of the long-term maintenance of the disease in endemic areas [21]. The length of the *Glossina* pupal development period decreases with increasing temperature, whereas larval production decreases above a certain threshold, and both pupal and adult mortality increase with temperature [33]. The minimum temperature required for development of *T. b. rhodesiense* is predicted to be 20.7-26.18°C with *G. pallidipes* and for *T. b. gambiense* 20.9-25.68 °C in *G. morsitans*. After deforestation the land is used for 2 purpose one is either colonization and other is making fields for crop/plant cultivation, if fields for crop/plant cultivation are made then tall crops such as cocoa, coffee, oil palms and mangoes are grown these tall corps/plant provide comfortable habitats for tsetse fly population [29]. So for crop cultivation when ever human come for ploughing of field they became more vulnerable to infection. It was noticed that in some region of African like Sahel zone these mainly like the river banks mainly in rainy season, but during dry season they migrate to the forests [5].

### **3. ADAPTATION STRATEGIES**

Adaptation Strategies to be adopted for reducing the climate related vector and vector-borne parasitic diseases- Decision Support Tools- Enhance early warning systems based on climate and environmental data for selected diseases [13]. Surveillance and Monitoring- Enhance vector surveillance and control

programs and monitor disease occurrence. Technology Development- Develop vaccines for vector and other vector-borne diseases, Develop more rapid diagnostic tests, Deploying low-cost, low-tech solutions like mosquito nets and water filters ,Using satellite data and geographical information systems to feed into surveillance systems. Infrastructure development- Consider possible impacts of infrastructure development such as water storage tanks [40]. Anticipating the potential for new and emergent VBD pathogens and their potential to change the current VBD burden. All countries should make polices for serious attempts to mitigate global warming [13]. The following adaptation measures are recommended: 1) to go beyond empirical observations of the association between climate change and infectious diseases and develop more scientific explanations, 2) to improve the prediction of spatial-temporal process of climate change and the associated shifts in infectious diseases at various spatial and temporal scales, and 3) to establish locally effective early warning systems for the health effects of predicated climate change [43, 44]. Outlining improvement and adaptation measures can be used specifically in the livestock sector to minimize the impacts of climate change-associated livestock diseases [45].

#### 4. CONCLUSION

Warming of the climate system is unequivocal. Continued GHG emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21<sup>st</sup> century that would very likely be larger than those observed during the 20<sup>th</sup> century. Climate change will affect the distribution and incidence of VBD globally.

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