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REVIEW ARTICLE

CLIMATE CHANGE AND HUMAN SECURITY - THE PROLIFERATION OF VECTOR-BORNE DISEASES DUE TO CLIMATE CHANGE

Martina Benito Olmos [1], Vanda Bostik [2] ✉

[1] Masters in International Security Studies(MISS), Charles University, Prague, Czech Republic
[2] Department of Epidemiology, Faculty of Military Health Sciences, University of Defence, Hradec Kralove, Czech Republic

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Summary

Human activity has had severe effects on the changes in climate over the last decades affecting, as a consequence, human security overall. The importance of changes in climate and their consequent effects have been long overlooked to the point that nowadays human health is being threatened by sea rise, extreme weather events, lack of adequate basic resources, and the spread of numerous diseases, to name some. This article aims to demonstrate how these variations have promoted the spread of vector-borne diseases (VBD). More specifically, it follows the developments of Dengue fever (DENV) as a result of higher temperatures and abundant precipitations, with a particular focus on the effects of humidity and a warm environment on the proliferation of VBD. To provide evidence of these climate consequences, two empirical cases are analysed and explained, one in Bangladesh and another in Ecuador. Overall, the analysis shows a positive correlation between the increase in temperatures and the changes in the weather and the proliferation of DENV in the above-mentioned territories. This article concludes that the increased temperatures, together with the evolution of extreme weather events have facilitated the reproduction of mosquitoes carrying DENV, and have enlarged the geographic and temporal distribution in which they inhabit. On this basis, the importance of climate change and its effects on human health should be tagged as a primary concern when facing challenges over human security.

Key words: Bangladesh; Climate Change; Dengue Virus; Ecuador; Human Security; Vector-borne Diseases

Introduction

The United Nations (UN) defines Climate Change as 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).

✉ University of Defence, Faculty of Military Health Sciences, Department of Epidemiology, Trebesska 1575, 500 01 Hradec Kralove, Czech Republic
vanda.bostikova@unob.cz

Over the past decades, human activity has had huge impacts on the environment producing a climate change that is now backfiring and threatening human health. The emission of large quantities of carbon dioxide (CO_2) and other greenhouse gases have rosen the temperatures of the globe and have negatively affected the global climate and all that goes with it (2). It is not a simple issue of extreme temperatures or increased gases in the atmosphere but the negative post-effects these have on rising sea levels, melting glaciers and extreme weather events, or on clean air, drinking water, and safe food and shelter (3). Alongside these, numerous diseases have proliferated as a result of the newly variants in climate, such as the case of the dengue fever, a virus that has become of primary concern for human health (2). While everyone is affected by climate change and its consequences, there are certain populations more vulnerable than others. The severity of these health risks depends on factors such as behavior, age, gender, and economic status, as well as the access to public health institutions and the resources of these. Developing countries, isolated and coastal or mountainous regions are particularly susceptible to these changes. Moreover, older people, people with pre-existing medical conditions and children, especially those living in poorer territories, are also more vulnerable than other age groups (2).

In what follows the consequences of climate change will be discussed, especially the effects it has on vector-borne diseases and how this affects human health. Due to the impossibility to analyse and explain every single case of vector-borne disease, this paper will focus on the virus known as Dengue (DENV). Two explained empirical studies will follow to present further evidence of the climate change consequences (4-5). The decision to limit the paper to two case studies is due to the desire to provide a short article about such a relevant topic. These articles were found to be both important and relevant for the subject presented.

Consequences of Climate Change

As many have come to know, climate change has become a growing challenge during the past decade. The increase in temperatures has been raising the levels of CO_2 and other pollutants trapped in the atmosphere worsen the air quality. Aeroallergens, such as pollen, have also increased with higher temperatures multiplying the number of asthmatics over the population (2). Besides this, there is a long list of negative effects as a consequence of climate change, most of them triggering numerous diseases that affect animals, plants and humans. These impacts have been categorised according to their degree of danger to the world population by *Butler and Harley, 2010* (6). The primary effects are those causing a physical impact on the wellbeing of the affected public. In here it is placed, for example, migrations caused by extreme droughts, hurricanes or any other extreme weather events (6). These devastating disasters have increased over the past years as a result of the change in climate resulting in 60 thousand deaths every year (2). They have destroyed homes, communication channels, medical facilities and other essential services. Not only this, these events have also damaged the availability of food and drinkable water causing malnutrition or gastrointestinal diseases in affected territories with insufficient resources to manage these catastrophic events (2). The secondary effects are those including alterations generated in the ecology of the vectors, parasites and other hosts animals (6). In other words, the climatic conditions have a strong effect on water-borne diseases or other diseases transmitted through insects, snails or other cold-blooded animals. Any changes in climate can have a consequent effect on the seasons and life-length of important vector-borne diseases and the geographic range they occur (7). An example of this would be Dengue Virus. This disease is transmitted by mosquitoes and it is strongly influenced by climate, killing about 22 thousand people per year, growing in relevance every day (7). Finally, the tertiary effects would operate at a level where climate, politics, and ecology, both human and non-human, are interconnected (6). These would be the governmental and ethical conflicts taking place as a root of climate change and extreme weather conditions which can result in unequal food distribution or relevant loss of important flora and fauna.

While all of these groups are of high importance and relevant to understanding the effects of climate change in human health, the subsequent section will focus on the second group: the effects that climate change has to human health with regards to the proliferation of vector-borne diseases born out of this negative effect.

Vector-Borne Diseases (VBD)

Vector-Borne diseases (VBD) are illnesses that are mostly transmitted by infected arthropod species, also called disease vectors, such as mosquitoes, ticks, fleas, and other blood-feeding insects (8). An infected vector will carry

infectious pathogens, such as viruses, bacteria or other germs from their host – animals like birds, bats, rats, etc. – and spread it to humans.

As seen in the previous section, climate change can have a significant effect on transmission cycles and the occurrence of VBD in humans. Alterations in temperature, humidity and other extreme weather factors can affect the development or reproduction of certain pathogens in vectors and dynamics of those animals carrying these vector-borne diseases (8). To elaborate further, the geographic location and the season distribution of infected animals, and the illnesses they carry, depend largely on the climate of a region (7). If the climate of a specific region varies, this can result in a shift or enlargement of the geographic area in which a vector or pathogen occurs, or even an adaptation or mitigation of the same (7).

To the time of writing, the CDC claims that, among these creatures, mosquitoes are known to be the most infectious species and "*one of the world's most deadly animals*" (9) as they can transmit a large variety of the most critical and overlooked infectious diseases affecting human health, including malaria, dengue, chikungunya and West Nile disease (7-10), many of which can end up in death. Malaria, for example, is the deadliest VBD killing over 1.2 million people every year; or in a similar line, according to the World Health Organization (WHO), dengue is the world's fastest growing vector-borne disease (11).

Climate change is relevant for these insects as specific climatic conditions can help them digest blood faster, increasing their feeding frequency, resulting in more bites and leading to greater viral transmission. Moreover, with higher temperatures mosquitoes take a relative shorter time to mature and reproduce (12). Thus, the higher the temperatures and humidity are, the higher the proliferation of mosquitoes becomes, including the infection rates as a consequence. This is significant nowadays because climate change and its consequences have broken the past understanding and assumption that cooler temperatures and economic development prevented mosquito-borne diseases from moving towards the Northern Hemisphere and other less affected and wealthier regions (13). The shifts inciding in the pathogen mutation and in vector-host interaction can deeply affect human health while, at the same time, producing an extensive damage on the same or different region completely or partially unprepared to face these diseases (13). The WHO asserts that, although it has a global range, Africa, South and Central America and Central and Southeast Asia are of the regions with the highest risk for numerous VBDs.

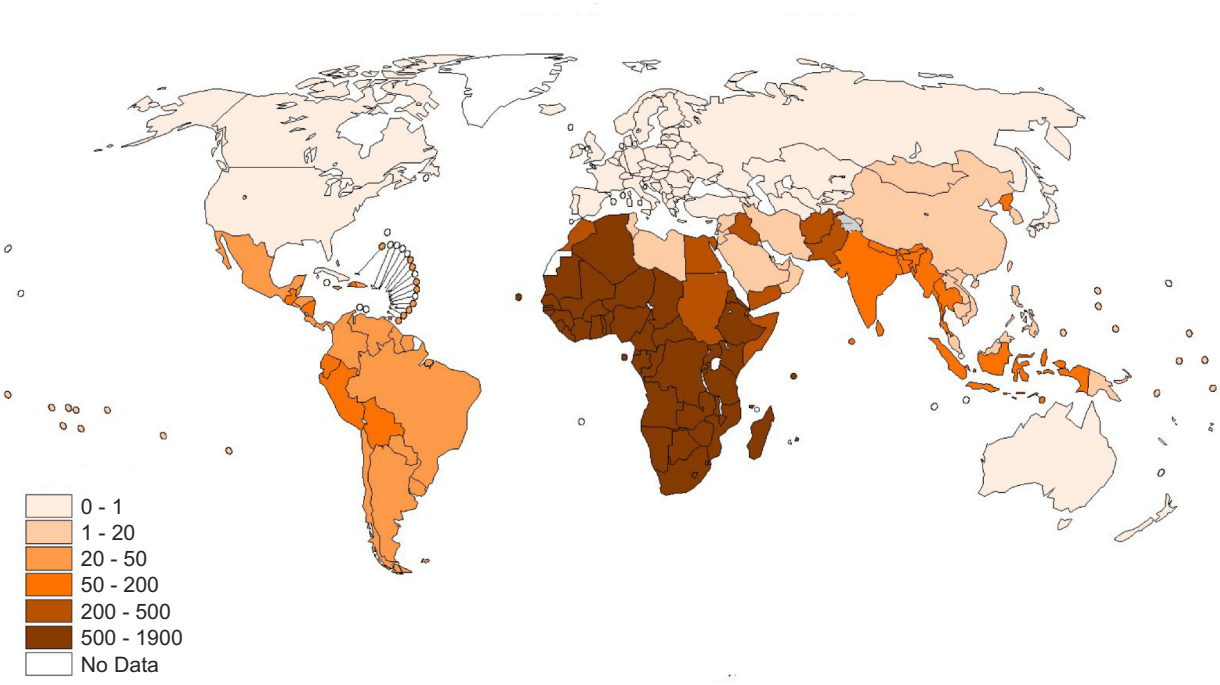

Figure 1. Deaths caused by Vector-Borne Disease in million (11)

Dengue Virus (DENV)

Dengue is a mosquito-borne viral disease. It is caused by one of four distinct, but closely related, dengue viral serotypes (DENV-1, DENV-2, DENV-3, and DENV-4) belonging to the family *Flaviviridae*. It is transmitted to people through the bite of infected female mosquitoes from the *Aedes* (*Ae.*) family (*Ae. aegypti* or *Ae. albopictus*) (14). DENV can spread from one place to another, not only by infected vectors, but by infected travellers that either have mild symptoms or no symptoms at all. DENV is now widespread around more than a 100 countries mostly placed throughout the tropics, regions of high temperature, high precipitation seasons, humid and with a large concentration of human population (14).

In mid 2020, the WHO claimed that around 400 million people get infected with dengue every year with deaths going up to 22 thousand (15). From the WHO reports, the largest number of dengue cases ever reported at a global level was in 2019 with 4.2 million infections at a global scale (15). Some of the symptoms include fever, nausea, aches, rashes or pain. These mild symptoms can easily be confused with other illnesses which makes it rather difficult to diagnose. To a lesser extent, some people can develop severe DENV. In this case, the symptoms are a lot more critical resulting, in some cases, in severe bleeding, organ damage and plasma leakage (15). There is no specific treatment for dengue, although the symptoms can be regulated by medical resources. This being said, there are many territories affected by this illness that lack the capabilities to manage it appropriately. These regions lack the tools as well as the knowledge or communication strategies needed to treat patients and prevent further spread. In recent decades the occurrence of dengue has significantly grown and expanded around the globe. Nowadays, severe dengue affects three main regions: Americas, South-East Asia, and Western Pacific Asia, becoming a major cause of hospitalisation and deaths among children and adults in countries from these territories (15).

According to an article written by *Ebi and Nealon, 2016* (16) "*dengue is the most important vector-borne viral disease that is transmitted to humans by mosquitoes*". They concluded that among factors such as globalisation, increase in trade, rapid urbanisation and large populated migrations, increased temperatures (around 25ºC to 29ºC), and high levels of precipitation are variables that elevate the risk of DENV due to their adequacy for the survival of infected mosquitoes (16). In this line then, climate change has been one of the most important factors leading to the determinants of dengue transmission. To have a clear image of these impacts, the following subsections will present studies done about recent outbreaks of dengue fever in the capital of Bangladesh, Dhaka, and in the tropical parts of Ecuador.

Empirical cases

As it has been established, the geographic range of mosquitoes that carry DENV thrive in certain climate conditions. As the temperature rises or the precipitations become more prominent outside the rainy season, mosquitoes become active earlier in the season and their range of occurrence can shift or expand to neighbouring territories. Bangladesh and Ecuador can serve as empirical examples of the influence that climate has over vector-borne diseases with outbreaks of DENV becoming more critical in the last decade. For the purpose of this paper, two articles will be used as a main source of data. First the research article published by the Canadian Journal of Infectious Diseases and Medical Microbiology (2019), "*Dengue Situation in Bangladesh: An Epidemiological Shift in terms of Morbidity and Mortality*", in the first example (4). Secondly, "*Influence of climate change on the biology of Ae. aegypti (Diptera: Culicidae) mosquito that transmits human arboviruses*" (2016), a study published by the Center for Health Research in Latin America (CISeAL) will be used for the second example (5).

<u>*Bangladesh*</u>

Bangladesh is a country located in a tropical and subtropical region in Southeast Asia. Due to the climate conditions of the territory, it is an optimal habitat for many VBD, in this case, for vectors carrying DENV like *Ae. aegypti* and *Ae. albopictus* mosquitoes. According to the article, prior to the year 2000 cases of dengue reported in Dhaka and around were rather sporadic. It wasn't until after 2000 that an unexpected outbreak caused alarm with more than 5.500 cases and almost 100 deaths in the state (4). Although this was not the first time, the re-emergence of this disease created a serious public health concern as a result of a lack of sufficient medical and food resources to tackle the new burst (4). Results from this research article show that the trends of dengue

cases reported abruptly changed after 2014. While before that time most of the cases presented themselves during the monsoon or post-monsoon period (July to October), after 2014 there was a noticeable increase in reported cases of DENV earlier in the year (4). More concretely, the authors claim that between 2015 and 2017, dengue cases were seven times higher in the pre-monsoon season than in the previous 14 years, as well as an increase in the numbers of reported cases in the post-monsoon period (4). At the same time, their study and analysis of the climate data during the same period presented a higher precipitation, humidity and temperature index than in prior years (4).

These findings are significant because they indicate a strong correlation between the changes in climate, especially in temperature and humidity in the air, and the prolongation of the monsoons season throughout the year. This ecological imbalance in the environment, as the research indicates, could have pushed the mutation process of the virus in the area resulting in an unexpected increase of disease incidence rates in the region, not only during the monsoon season, but more significantly during the pre-monsoon period which was unusual in the past (4)[1]. In other words, from an epidemiological perspective, with this correlation, we can assume that the climate changes occurring after 2014 facilitated the growth cycle and survival capabilities of infected mosquitoes, key for the propagation of the dengue virus in Bangladesh. In a similar line, we can also safely predict that, unless crucial measures are taken to prevent the spread of the virus and enough resources are put to face it, climate change can create a future unexpected imbalance in the epidemiological characteristics of DENV resulting in a possible upsurge in cases and deaths in the future.

Ecuador

Similar to the case presented above, Ecuador is geographically placed in a region of mostly tropical climate in South America. Likewise, the climate conditions of most parts of the territory are highly suitable for the proliferation of Dengue-infected mosquitoes. The study indicates that while in the period between 2011 and 2014 the number of cases would not overpass the 13.235 cases in average, after that period the registered cases more than tripled reaching up to 42.500 cases in 2015 (5).

The study suggests an important correlation between climate and DENV transmission in Ecuador with specific seasons or with extreme weather events, such as El Niño (17)[2], being more adequate for mosquitoes than others. In Ecuador, DENV transmission has its greatest incidence of reported cases in the hot and rainy season (between February and May)[3]. Nonetheless, the noticeable sharp increase in DENV cases in 2015 is related, as the article states, to climate alterations which would have elongated the warm seasons and made the environment more suited for mosquito expansion (5). According to the authors, these changes would have affected the latitudinal range of dispersal of this species allowing these disease-transmitting insects to spread to previously vector-free regions in the rest of the nation and neighbouring countries (5). At the same time, as in the case of Bangladesh, the increase in temperatures and precipitations throughout the entirety of the year have not only expanded the range of occurrence, but elongated the seasons of extreme warm weather and precipitations. This, in compliance with the authors, is correlated to the increase of disease incidence rates in Ecuador (5).

López-Latorre and Neira present some interesting predictions regarding the consequences of climate change for the future of Ecuador relevant to this paper and the consequences to human health. According to their findings, within the upcoming decades the yearly precipitations index could increase up to 30% until 2100, as well as an increase in the frequency and intensity of extreme weather events, such as the above mentioned, El Niño. Moreover, the study also foresees an alarming increase in temperatures that could go up to 5.5ºC more for the year 2100 (5). As it has been established that temperature and precipitations (humidity) play a key factor in the DENV transmission cycle, the predictions of the study are of great concern. Following that logic, DENV transmission could become a great danger for local health care institutions creating an overwhelming burden for health workers, government and population overall. We cannot predict with exactitude what will be the actual consequences of these alterations, there are other factors involved in this vicious cycle, however, it is safe to assume that the results could be disastrous.

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[1] See studies providing similar findings correlating dengue incidence and climate change by Karim et al., 2012; and, Gould and Higgs (2009).

[2] According to the National Oceanic Atmospheric Administration (NOAA), El Niño is a weather condition that occurs when the water surface in the equatorial Pacific becomes warmer than normal and east winds blow weaker than average. They usually take place every 3-5 years.

[3] See further information in the article by Sippy, R., Herrera, D., Gaus, D., Gangnon, R. E., Patz, J. A., & Osorio, J. E. (2019). "S*easonal patterns of dengue fever in rural Ecuador: 2009-2016. PLoS neglected tropical diseases*", 13(5), e0007360. https://doi.org/10.1371/journal.pntd.0007360

Conclusion

Climate change is a global issue that should be labeled as a primary threat to human health. This paper has indicated that the consequences of climate change are strong enough to alter the geographic and temporal distribution of VBD, more concretely DENV. The variation in temperatures and precipitations, are among the most important drivers of dengue in the world. Humidity and a warm environment affect mosquito density and their capacity to reproduce and transmit viruses if infected. The higher the temperatures and humidity in the air, the higher is the opportunity for further geographical and temporal expansion of VBD, in this case DENV. The outbreak of DENV in both Ecuador (2015) and Bangladesh (2016) have been correlated to an increase of temperatures and precipitations due to climate change. These weather conditions have been reported as major factors that influence not only the population dynamics of this species but also its ability to transmit viruses. Although these are not the only factors affecting the dengue vector-carriers, these should be constantly monitored to better predict future outbreaks and protect the global population.

In order to face potential future outbreaks, effective strategies and policies are crucial to prepare and manage any future occurrence as well as any change in the virus distribution. Measures need to be taken to improve surveillance systems as well as constant vector control to foresee and refrain VBD transmissions. Moreover, awareness raising of the disease and its impacts should be employed to provide and disseminate relevant information to prevent transmission and promote healthy habits. Finally, regional collaboration could help decrease the vulnerability of populations by uniting resources and creating a fast-response strategy when these outbreaks occur.

Dengue and other VDB are a growing concern, and will remain a serious public health problem worldwide for decades to come. However, the above-mentioned strategies as well as many other climate change campaigns can help regulate and decrease the threat they entail at a global level.

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Conflict of Interest

The authors state that there are no conflicts of interest regarding the publication of this article.

Adherence to Ethical Standards

This article does not contain any studies involving animals performed by any of the authors. This article does not contain any studies involving human participants performed by any of the authors.

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