Climate change and health: An analysis of causal relations on the spread of vector-borne diseases in Brazil

Article *in* Journal of Cleaner Production · December 2017

DOI: 10.1016/j.jclepro.2017.12.144

7 authors, including:

Walter Leal Filho
Hochschule für Angewandte Wissenschaften Hamburg

Juliane Bönecke
Hochschule für Angewandte Wissenschaften Hamburg

Ulisses Miranda Azeiteiro
University of Aveiro

Fátima Alves
Universidade Aberta; Centre for Functional Ecology University of Coimbra

Journal of Cleaner Production 177 (2018) 589–596

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Climate change and health: An analysis of causal relations on the spread of vector-borne diseases in Brazil

Walter Leal Filho [a, b, *], Juliane Bönecke [a], Hannah Spielmann [a], Ulisses M. Azeiteiro [c], Fatima Alves [d], Mauren Lopes de Carvalho [e], Gustavo J. Nagy [f]

[a] Research and Transfer Centre "Sustaiinable Development and Climate Change Management", Hamburg University of Applied Sciences, Germany
[b] School of Science and the Environment, Manchester Metropolitan University, UK
[c] Department of Biology & CESAM Centre for Environmental and Marine Studies, University of Aveiro, 3810-193, Aveiro, Portugal
[d] UnversidadeAberta, Portugal & Centre for Functional Ecology, University of Coimbra, Portugal
[e] Instituto Federal de Educação, Brazil
[f] Facultad de Ciencias, UdelaR, Uruguay

ARTICLE INFO

Article history:
Received 14 August 2017
Received in revised form
27 November 2017
Accepted 16 December 2017
Available online 18 December 2017

Handling Editor: Cecilia Maria Villas Bôas de Almeida

Keywords:
Health
Extreme events
Arbovirus infections
Brazil
Zika
Policy-making

ABSTRACT

The increases in greenhouse gas concentrations caused by anthropogenic activities such as industrial emissions, transport and burning of forests and other resources, recorded over the past decades, are known to have an impact on the global environment. In particular, this paper reviews the evidence that climate change has an impact on human health as a whole and on the spread of vector-borne diseases in particular. It offers an analysis of previous research on the connections between climate change and health, with a case study from Brazil, and lists some areas which may guide future policy-making.

1. Introduction

According to the Intergovernmental Panel on Climate Change (IPCC), rises in global temperatures due to anthropogenic influence are a fact, and human influence in this system is clear. Moreover, it is highly probable that one of the main causes of global warming since the Industrial Revolution is the release of greenhouse gases as a result of human activity (IPCC, 2014). (see Fig. 1)

The IPCC classifies the effects of the climatic changes in three categories (IPCC, 2012):

- Impacts on the physical systems: floods and droughts;
- Impacts on the biological systems: forest fires; and
- Impacts on human and management systems: food production; means of subsistence; health.

In the context of health, Butler and Harley (2010) have described the primary, secondary and tertiary effects of the climatic change, and have called for the medical community to expand their involvement with this problem, which has been affecting global health. The primary effects of climate change on human health come from the direct impacts of the physical systems on human well-being, such as heat waves, floods and droughts. Managing the risk of extreme events under climate change is therefore crucial (Yuan et al., 2017) considering its interlinkages with health and well-being. The secondary effects may occur from changes in the distribution and ecology of vectors, parasites and animal reservoirs. For the most part, these vectors rely on water reservoirs to complete their biological cycle. The improvement of water management systems, namely residential rainwater harvesting systems, assumes vital importance (Haque et al., 2016) by assuring the

* Corresponding author. Research and Transfer Centre "Sustaiinable Development and Climate Change Management", Hamburg University of Applied Sciences, Germany.
E-mail address: walter.leal2@haw-hamburg.de (W. Leal Filho).

https://doi.org/10.1016/j.jclepro.2017.12.144

	Climate conditions: Temperature (↑ / ↓)	Climate conditions: Prolonged precipitation* (↑ / ↓)	Extreme events: Drought	Extreme events: Flooding
Vector	***Development*** [1,2,3] ↑ accelerated egg and larvae development/breeding ↑ increased longevity and fertility of adults ↓ larvae rigidity (survival over months) ***Abundance*** [4] ↑ vector population growth ↑ favored geographical distribution ↑/↓ changes in seasonality ***Behavior*** [1,5] ↑ increased biting rate ↑ increased host contact ↓ refusal in feeding ***Survival*** [6] ↑/↓ depends on species, life cycle increased or decreased	***Breeding sites*** [1,8,9] ↑ increased larvae habitat (accumulation of water) ***Abundance*** [5,9,10] ↑ increase in vector population ↑ favored geographical distribution/new habitat ↓ alternative habitat/breeding sites in urbanized areas ***Behavior*** [9] ↓ increased vector-host contact (seeking for artificial breeding sites like pools, water tanks, plant pots, garbage items, ...)	***Abundance*** [5,8] ↑ expanded vector range due to alternative breeding habitats (water storage in containers, pools, stagnant water bodies) ***Survival/Behavior*** [4,5] ↑ reduction of vector life span ↑ reduced mosquito activity	***Abundance*** [1,9] ↑ inhibited development (harm of eggs, larvae, adults) ↑ decrease in vector population ↑ reduced habitat ***Breeding sites*** [5] ↑ destruction of larvae habitat
Pathogen	***Development*** [3,7,8] ↑ increased replication rate ***Infectiousness*** [1,3] ↑ increased extrinsic incubation period, vector is infectious sooner ***Seasonality*** [5] ↑ expected peak during warm season	***Prevalence*** [5,9,10] ↑ increased spread due to accelerated development and distribution of vectors (breeding sites/surface water) ** pattern and form of rainfall may have diverse impacts*	***Infectiousness*** [4] ↓ susceptible host population increases after dry period due to a decreased virus pre-valence and thus decrease in immune defence during drought	***Prevalence*** [1,9] ↑ inhibited circulation (decrease in vector population)

Fig. 1. Climate conditions and their impact on the vector (*Aedes spp.*) and pathogen (arboviruses) present in Brazil. Source: Information drawn from the reviewed literature. 1: Parham et al. (2015); 2: Wu et al. (2016); 3: Honório et al. (2009); 4: Confalonieri et al. (2007); 5: Hales et al. (1999); 6: Reeves et al. (1994); 7: Nazareth et al. (2016); 8: Paz and Semenza (2016); 9: Gubler et al. (2001); and 10: Mills et al. (2010).

conditions to prevent health hazards on environmental and public health. Finally, the tertiary effects are related to the political-ecological conflicts that have been occurring, such as the displacement of populations and the expansion of inequality in the production and allocation of food.

However, the primary, secondary and tertiary effects of climate change on health are closely related. Heat waves, for instance, have influenced the increase in morbidity and mortality, not only among the elderly (Benmarhnia et al., 2015) but also among adults and children with newborns being the most concerned represented by a high infant mortality rate (Basagaña et al., 2011). A low socioeconomic status and thus often lowered resilience may aggravate the level of vulnerability to heat waves (Benmarhnia et al., 2015; Gronlund, 2014). Torrential rainfall, flooding and the scarcity of rain also exacerbate diseases and health problems in terms of water contamination, emerging infectious diseases or habitat destruction. Extreme floods and flooding compromise livelihoods and health services, strongly hitting those with fewer compensatory resources. According to the international disasters database, EM-DAT, the recorded incidence of floods has been increasing drastically in the world. In 1975, 17 events were registered while in 2015, 160 situations of floods were recorded. Although part of this growth is related to the improvement of information systems, the real growth in the number of events is undeniable (http://www.emdat.be/disaster_trends/index.html - accessed in 12/27/2016). Droughts, a phenomenon that has been intensified due to climatic changes (Dai, 2011), clearly emphasizes this relation. In order to face droughts, people need to store water for long periods of time (Meason and Paterson, 2014).

Speaking of the diverse health impacts, a shortage of water may cause malnutrition and nutritional deficiencies, health complaints related to inadequate water supply, sanitation, and water storage, changes in the quality of air, as well as acute and chronic respiratory diseases. Populations subjected to situations of floods usually show symptoms of post-traumatic stress (Alderman et al., 2012; Stanke et al., 2012). Furthermore, there are water-borne and vector-borne agents that affect the eyes, skin and gastrointestinal tract (Huang et al., 2016), many of them being transmitted by vectors such as Leptospirosis, Schistosomiasis and arboviruses like Dengue, Zika, or Malaria (Freitas and de Ximenes, 2012).

With the rapid spread of the Zikavirus in the Americas (Ferguson et al., 2016), and the global expansion of vectors that are able to transmit Dengue, Zika, and Chikungunya virus (Kraemer et al., 2015), neglected tropical diseases that are associated with climate dynamics reiteirate the need for intensified political attention and global health action (Watts et al., 2017). Climate-sensitive vector-borne diseases on the one hand, and mosquito-transmitted diseases in particular, seem multi factorially conditioned and have evolved, since the rise in global temperature leads to an increase in rainy and barren periods (Meason and Paterson, 2014). These, in turn, but may also directly influence vector and virus development and the vectorial capacity of mosquitoes (Caminade et al., 2017; Naidoo and Olaniran, 2013). Changes in temperature, humidity and rain patterns are known to have also contributed to the transmission of Malaria (Chirebvu et al., 2016). However, other factors linked to environmental changes need to be considered, such as changes in the use of the soil, increase in population, migratory movements, global trade and travel, increasing urbanization and economic growth (Becker et al., 2012,; Caminade et al., 2014).

As a consequence of climate-related natural hazards and health issues, economic and financial impacts compromise mental health by causing stress, anxiety, alcoholism and suicide. They may also unleash migratory processes that contribute to the dissemination of diseases and epidemics (Alpino et al., 2016). Weakened and more susceptible to health risks, the populations also become more vulnerable to physical and mental diseases, which undermine their capacity for work and subsistence. Consequently, climatic changes affect health through different mechanisms. Extreme events have increased worldwide since 1950, especially concerning more hot days and heavy rainfall episodes (Herring et al., 2014), and there are more frequent weather extremes (Hulme, 2014).

2. Climate change and health: reviewing the impacts

There is widespread consensus among the scientific community that the global climate is changing (Alves et al., 2014; Leal Filho et al., 2014, 2016), threatening all forms of life on Earth as we know it. Despite some contradictory information that mostly circulates in the mass media and political spheres, science has integrated climate change into the public agenda and has emphasized not only its natural course and causes but also its anthropogenic nature (Watts et al., 2017). These anthropogenic actions, mainly cumulated since the Industrial Revolution, are the main cause of the environmental crisis that we face nowadays. The consequences of climate change on health are inevitable and are likely to become more intensive in the future, especially in poor countries, where the ability to adapt is limited by restricted access to resources and technology (Leal Filho et al., 2016). Climate change may interfere with population health levels by either aggravating existing conditions or even causing disability and death. We can, however, consider the positive effects on the health of populations if we consider mitigation and adaptation measures to cope with climate change and its direct and indirect impacts on health, which may create better social and environmental conditions to increase the health levels and well-being of populations. Therefore, addressing climate change could be the greatest global health opportunity of the 21st century (Watts et al., 2015, 2017), since the impacts of climate change on health are very sensitive to both climate change policy and climate and environment-related health measures.

2.1. Climate change and health relationships: types of impacts

The impacts of climate change on health can be of direct, as for example extreme events, or indirect influence through the effects on ecosystems, biodiversity and societies' organization (e.g., economic production systems, climate migrations, poverty, inequalities). Following the findings of Watts et al. (2015), the interactions between greenhouse gas emissions, climate change and human health are complex associated with various health challenges like undernutrition, harmful algal bloom, mental health issues, cardiovascular and respiratory diseases, and vector-borne and water-borne infections. Although climate change does not directly create new diseases, scientific research proves the links between climate change and health and highlights the increased burden from climate-sensitive diseases, pointing out changes of typical epidemiological patterns linked to risk groups, local environment (the new geography of vector-borne diseases for example) and time variations. On the one hand, there is a clear relation between climate change and the socio-economic and environmental determinants of well-being and health (e.g., poverty, clean air, safe drinking water, food supplies), as well as extreme events such as floods, heat waves and hurricanes, associated with distress, as well as with loss of property (Leal Filho et al., 2016; Watts et al., 2015). On the other hand, it is very difficult to assess the extent and the nature of climate change impacts on health.

Climate change affects all regions around the world differently and developing countries in Africa are regarded as the most seriously affected (Amin and Leal Filho, 2011; Leal Filho, 2011). Globally, extreme events have been stimulating or forcing the displacement of populations. The rising sea level that has led to the destruction of cultivated fields and to the reduction of fish availability for large populations, for example, has forced local populations to change their practices (Viegas et al., 2016) or caused displacement as well as forced or voluntary migration (Carraro, 2015; Wilbanks et al., 2007). No region in the world is immune to the consequences of climate change. However, the individual characteristics and policy-making of an affected region may influence the health risks and outcomes in both ways, positively and negatively.

2.2. Climate change and health relationships: demographic and socio-economic vulnerabilities

Taking the social and demographic dynamics of populations into account, it is possible to understand the variability of their exposure to the consequences of climate change according to a population's individual characteristics like age, gender, health status, level of income, place of residence, or local policies and regulations (Watts et al., 2015). Those factors, especially when unevenly distributed, are very important to understand and explain populations' different vulnerabilities, health risks and outcomes. Ecological processes such as impacts on biodiversity loss (Castro et al., 2016), changes in disease vector ecology (Nazareth et al., 2016), as well as changes in socio-economic and demographic dynamics of populations, may modify or amplify these risks.

The consequences of climate change on human health depend on the duration, frequency and intensity of exposure to situations and settings, as well as on the vulnerability and susceptibility of exposed communities and populations. International trends have shown that women, children, the elderly, the poor and marginalized groups such as people with disabilities are, in this context, especially vulnerable (McMichael, 2003; Smith et al., 2014; Watts et al., 2015). Apart from the direct effects on human physical health, increases in the local frequency of extreme weather events such as floods, storms and heat waves – or in their severity – could increase the risk of diseases, particularly the proliferation of transmissible diseases, stress and psychiatric disorders (Leal Filho et al., 2016). For example, not only infectious disease epidemics like Ebola, mosquito-borne diseases (e.g. Dengue or Malaria) and water-borne infections (e.g. Cholera or Schistosomiasis) (Ali et al., 2016; Nazareth et al., 2016; Ojeh and Aworinde, 2016; Pereda and de Oliveira Alves, 2016), but also water scarcity and quality (Oliver and Ribeiro, 2016) are major problems in the southern hemisphere. In addition, local flooding events are responsible for habitat destruction and may favour the increase of certain diseases. The temperature rise also enhances the transmission of infectious diseases like Malaria and other diseases (Naidoo and Olaniran, 2013). Highlighting the impact of regulatory systems, a lack of piped water supply and wastewater treatment may furthermore lead to contaminated water consumption, which in turn contaminates the food chain and limits hygiene, and is responsible for virus and bacteria proliferation.

2.3. Interactions between climate, socio-economic trends and health

The World Health Organization (WHO) emphasizes the need to provide evidence for climate-related health impacts and to measure the interactions between climate change and other trends, such as poverty, that affect public health (Hales et al., 2014). Other authors furthermore emphasize the central role of community engagement (Figueiredo and Perkins, 2013). As a well-known, but also decisive example of the complex body of climate, socioeconomic trends, and health, the global food system makes a significant contribution to climate change by affecting greenhouse gas emissions (Oliveira et al., 2016) and altered transmission of infectious diseases and malnutrition from crop failures (Patz et al., 2005). Malnutrition caused by food insecurity (Nehama et al., 2016) in a framework of poverty and inequality (Aparicio-Effen et al., 2016a, 2016b; De Freitas et al., 2016; Gallo et al., 2016; Setti et al., 2016) negatively affects food production among the more vulnerable territories and populations in poor countries (Setti et al., 2016). Rising temperatures lead to droughts and water shortages, affecting crops and reducing food possibilities, further contributing to situations of malnutrition and a consequent increase in infectious diseases (NRC, 2001).

In summary, climate change may affect our health in more far-reaching ways than we may think (Leal Filho et al., 2016). Climate costs for society and economy put increasing pressure to find cost-effective solutions, mitigations, and finance adaptations. Populations adapt to the local prevailing climate via physiological, behavioural, socio-cultural and technological responses. However, extreme events often stress populations beyond those adaptation limits (McMichael et al., 2006). There is a pressing need to identify adaptation strategies, try new mitigation measures and methods, and increase resilience to climate change to reduce health risks (De Mendonca et al., 2016; Favaro et al., 2016; Leal Filho et al., 2016). Also, a closer recognition of the links between social and environmental factors has been urged – an 'eco-social' approach –as well as, relatedly, a greater co-operation between social and natural sciences (McMichael et al., 2015) in facing social inequalities in vulnerable countries that need to increase resilience to extreme events (Aparicio-Effen et al., 2016a, 2016b; Nagy et al., 2016). In this context, climate change impacts on health requires the articulation of transdisciplinary research, in the sense used by Gaziulusoy et al. (2016), that is collaboration and coordination between researchers from different disciplinary backgrounds, intersectoral and interinstitutional, where universities can play a fundamental role (Leal Filho et al., 2018).

3. Climatic change, climate variability and the spread of neglected vector-borne diseases. The case of Brazil

Influenced by the Amazon rainforest, the Brazilian Highlands and 7491 km of coastline, Brazil encompasses a climate variability presenting both tropical and temperate climate zones (Alvares et al., 2013; Central Intelligence Agency, 2017). With one of the world's largest economies and the Amazon as the planet's biggest ecosystem, Brazil indicates a high vulnerability to the impacts of climate change. During the past decades, Brazil was confronted with an uprising trend in minimum and overall surface temperature, especially targeting urbanized areas (Lucena et al., 2013), and was challenged by one of the strongest El Niño Southern Oscillation events that occurred in 2015/2016 (Caminade et al., 2017). In the future, a further rise in warming trends and an increase in the occurrence of weather extremes like floods or droughts are presumed (WHO, 2015).

Due to Brazil's various climate characteristics, insect vectors that are able to transmit infectious diseases are wide-spread (Hunter, 2003). Viruses, rickettsiae, bacteria, protozoa and parasites are vector-borne pathogens that can be passed to vertebral hosts by blood-feeding anthropods such as ticks, flies, bugs or mosquitoes (Gubler et al., 2001). In Brazil, mosquitoes, ticks, sandflies, bugs, and aquatic snails act as vectors causing a variety of diseases like Yellow fever, Dengue, Chikungunya, Zika, Leishmaniasis, Chagas disease or Schistosomiasis (WHO, 2016a). Especially mosquito-borne diseases (MBD) have become a major public health concern in both rural and urbanized areas (McMichael, 2003). Focusing on Brazil's mosquito-borne anthropods there is evidence that predominant climate conditions and weather extremes such as droughts or floods caused by El Niño can influence the seasonal occurrence of infectious diseases, likely accumulated by climate change effects (Caminade et al., 2017; WHO, 2016b).

3.1. Vectors, climate stressors and mosquito-borne diseases

After South America experienced an extensive outbreak of a hitherto neglected tropical arbovirus, the Zika virus (ZIKV), in 2015/2016, profound investigations have been needed to better understand the interaction of vector, host and pathogen, as well as crucial drivers that influence MBD epidemiology and distribution. While several countries experienced major arbovirus outbreaks, preventive measures to stop the spread of mosquito-transmitted diseases like Dengue, Zika, or Chikungunya are lacking. The main vectors for ZIKV are mosquitoes of the genus Aedes, also compatible with dengue (DENV) and Chikungunya virus (CHIKV) (Enfissi et al., 2016; Faye et al., 2013). At present Aedes aegypti and Aedes albopictus are identified as the most suitable species to transfer all three arboviruses to human beings (Abushouk et al., 2016; Leparc-Goffart et al., 2014). Zika, Dengue and Chikungunya are mostly mild and self-limited diseases causing akin flu-like symptoms such as malaise and painful discomforts (a headache, arthralgia, myalgia), often accompanied by fever (DENV, CHIKV). For all three arbovirus infections, a rash may be a specific symptom (Brasil et al., 2016; Staples et al., 2009; Wilder-Smith et al., 2010). However, each disease implicates severe complications emphasizing the burden of MBD: for Dengue, Haemorrhagic fever and Dengue shock syndrome (Wilder-Smith et al., 2010); for Zika, Microcephaly, congenital disorders and neurological complications like Guillain-Barré syndrome (Krauer et al., 2017; Schuler-Faccini et al., 2016); for Chikungunya, severely debilitating polyarthralgias and neuro-invasive complications (Staples et al., 2009). Yet there is neither an approved antiviral nor a vaccine to treat or prevent those viral infections and their complications.

3.2. Climatic and eco-environmental determinants of MBD epidemics

A better understanding of MBD ecological systems and their environment is crucial to anticipate the emergence of vector-borne epidemics. Seasonal climate determinants and weather extremes – typical of Brazilian climate diversity – can either promote or inhibit the development of MBD by making the living environment more or less suitable for vectors (Nazareth et al., 2016; Wu et al., 2016). Especially temperature, rainfall and humidity, but also wind and daylight can be important drivers by having direct and indirect impacts on mosquito species and the transmission of the carried pathogen (Gubler et al., 2001). Profound knowledge of vector ecology and transmission dynamics may enhance targeted vector control and outbreak response (Zahouli et al., 2016). According to Amui et al. (2017) as well as Jabbour (2013), integrated literature reviews provide valuable input as they present results of studies on emerging issues as well as recommendations for future research and fields of action from multiple perspectives.

Although there is general scientific consensus about changes in the epidemiology of MBD linked to climate variations (e.g. Nazareth et al., 2016; Parham et al., 2015; and Wu et al., 2016), a paucity in environmental investigations as well as analytical studies on a local scale can be seen. According to Mills et al. (2010), climate change may influence the characteristics of host and vector population in terms of their geographic distribution, population density, the prevalence of infection, and viral load in hosts and vectors. However, local climatic, environmental and ecological characteristics influencing the vector-host-pathogen interaction in a certain setting require a better understanding to improve MBD outbreak management and vector control. Combining both the findings of past and current literature reviews (looking at the interaction of climate dynamics, and vector as well as MBD development, 1994–2017), and findings derived from case studies looking at MBD emergencies in Brazil (e.g. Caminade et al., 2017; and Honório et al., 2009), this section summarizes key local climate-related parameters that may affect the probability of vector-host contact and thus need to be considered when it comes to outbreak management, preparedness and prevention of future MBD epidemics.

Based on the climate sensitivity of mosquitoes and arboviruses, changes in weather patterns and local climate can reinforce the spread of MBD in different ways. An increase in average temperature, especially minimum temperature, and prolonged rainfall are critical parameters for the widespread distribution of MBD (Becker et al., 2012) by accelerating vector and pathogen development and creating favourable living conditions. In addition, a geographical shift in weather patterns can develop new vector habitat, including a highly susceptible host population. From a climate perspective, those changes apparently influenced the latest arbovirus emergencies in Brazil, amplified by one of the strongest El Niño event in recent years (Caminade et al., 2014; Paz and Semenza, 2016; WHO, 2016b). On the other hand, weather extremes may inhibit the activity of mosquitoes and the development of carried pathogens. Rainstorms and floods can harm the vector, its eggs and larvae as well as its living habitat. Droughts and hot periods can reduce mosquitoes' activity and lifetime, forcing them to seek for suitable territories. In contrast, a critical drop in minimum temperature $<20\,^{\circ}C$ can decelerate or suspend the development of both mosquito larvae and carried pathogens (Honório et al., 2009), though the climate trend in Brazil predicts a mitigation of this natural limiting factor.

In conclusion and emphasized by the work of Muñoz et al. (2016), an assessment of climate variations hold the potential to guide MBD response measures. While an adequate epidemiological and entomological surveillance may improve outbreak detection at an early stage, predictive models using climatic and environmental information at a finer geographical scale may help to develop and implement more targeted public health measures to cope with the spread of MBD.

Nevertheless, the impact of climate remains complex, influencing both the abundance of mosquitoes and the development of mosquito-borne pathogens in a positive and negative way. In addition to climate, further determinants need to be considered that can affect the ecosystem of MBD. Human activities, living environment, health-oriented literacy and public health policies can shape the extent of an outbreak (Becker et al., 2012). Additionally, international trade and travel may proliferate the global spread of mosquitoes and their agents to any region where favourable climate conditions and a susceptible population are present (Gubler et al., 2001).

4. The way ahead: policy responses

The most effective responses to climate change are likely to be the strengthening of key functions such as environmental management, surveillance and response, and to safeguard against changes in infectious disease patterns and other hazards (Institute of Medicine, 2008). Because there is some element of unpredictability in climate variations and infectious disease

Table 1
Measures to cope with climate-related health issues (CrH) and arbovirus infections (AI) in Latin America. The estimated level of expected efficiency and difficulty in the application (from low to very high), and of the application time-frame (from short-to long-term) are presented.

Measures and Policies	Level of efficiency	Level of difficulty	Application time-frame
1. Alleviate poverty (CrH)[a,b]	Very high	Very high	Long-term
2. Universal health coverage (CrH)[a,b]	High	High	Medium- to long-term
3. Improve disease surveillance and monitoring of environmental exposures (CrH)[a,c]	High	High	Medium-term
4. Enhanced vector control (AI)[d,e]	High	Moderate	Short- to Medium-term
5. Develop targeted climate-health-specific measures (Early Warning Systems, forecasting) (CrH)[a]	High	Moderate	Short- to Medium-term
6. Extended seroprevalence studies (AI)[f]	High	High	Short- to Medium-term
7. Increase capacity for disaster preparedness and response (CrH)[a]	Moderate	High	Short- to Medium-term
8. Implement measures in other sectors interrelated with public health (CrH)[a,g]	Moderate	High	Medium-term
9. Avoiding mosquito bites with repellents and adequate clothing during AI break-out periods (AI)[h]	Moderate	High	Short-term
10. Develop vulnerability and climate-related current and future risk mapping (CrH)[a,d]	Moderate	Moderate	Short- to Medium-term
11. Vaccination against DENV (There are concerns because cross-reactivity fever could accelerate and increase outbreaks of ZIKV) (AI)[c,d,f,i,j,k]	Unclear	Moderate	Short- to Medium-term
12. Delay pregnancy - Specific for ZIKV Infections during break-out periods (AI/ZIKV)[l]	Moderate	High	Short- to Medium-term

[a] Smith et al. (2014).
[b] The Lancet Global Health (2016).
[c] Ferguson et al. (2016).
[d] Institute of Medicine (2008).
[e] IPCC (2014).
[f] Goorhuis and Grobusch (2016).
[g] NRC (2001).
[h] WHO (2016c).
[i] Dejnirattisai et al. (2016).s
[j] The Lancet Infectious Diseases (2017).
[k] Tang et al. (2016).
[l] Schuck-Paim et al. (2016).
Source: Author's expert judgment based on the reviewed literature.

outbreaks, a prudent strategy is to set a high priority on reducing people's overall vulnerability to infectious disease through strong public health measures such as vector control efforts, water treatment systems and vaccination programmes (NRC, 2001).

Because mosquito-borne diseases, like Zika, are described as "a disease of the poor and disenfranchised", particularly where "the penetration of Aedes aegypti is high" (The Lancet Global Health, 2016), overall development and health policies focused on poverty reduction and universal health coverage are key measures to cope with climate-related health issues (Smith et al., 2014), including arbovirus infections (The Lancet Global Health, 2016). While the potential of ZIKV to follow the global path of Dengue and Chikungunya initially seemed underestimated (Musso et al., 2016), recent research highlights the urgent need to learn from the latest Zika virus outbreak and avoid irreversible and unacceptable costs to human health in the future, directly addressing the responsibility of governments and the global health communities (Watts et al., 2017).

4.1. Climate-related health issues adaptation: focus on arbovirus infections

A summary of measures and policies suggested by the IPCC to reduce the adaptation deficit in climate-related public health issues (Smith et al., 2014) and of those specific for mosquito-transmitted arbovirus infections is given in Table 1. These measures are presented in a decreasing order according to their estimated levels of efficiency and applicability for Arbovirus Infections and particularly ZIKV.

If implemented, these measured may provide some support to address some of the most common problems associated with infections by arboviruses.

5. Conclusions

As this paper has demonstrated, the impacts of climate change on human health depend on a variety of variables such as the duration, frequency and intensity of exposure, as well as the vulnerability of exposed communities and populations. The data presented here illustrates the connections between climate change and the spread of vector-borne diseases in Brazil, which is exemplary of a reality seen in many developing countries. In order to address the problem, a greater focus to climate change on policy making is needed. So far, despite the vulnerability of the Brazilian population to climate change, and the limited ability of the country's health system to cope with the pressures climate change pose to it, reliable policies in this central field are very limited in their scope. Therefore, the strengthening of key areas such as environmental management and surveillance on the one hand, and changes in the ways infectious diseases are handled —on the other- are much needed.

As far as the stakeholders are concerned, there are some requirements which also need to be met, if their vulnerability is to be reduced. These are

- the need to foster more awareness on the means via which vector-borne diseases are transmitted, which may substantiate and add a greater degree of reliability to prevention efforts;
- improvements in sanitation and infra-structured are required, so as to reduce the suitability of conditions for vector proliferation;
- a deeper knowledge of the life cycles and habits of vectors such as mosquitos is necessary, so as to handle them more efficiently.

There is also a perceived need to design and employ predictive models to estimate and properly handle the future burdens in the fragile health system in Brazil, posed by infectious diseases caused by mosquitos, aquatic parasites and other vectors, under projected climate change scenarios.

References

Abushouk, A., Negida, A., Ahmed, H., 2016. An updated review of Zika virus. J. Clin. Virol. 84, 53–58. https://doi.org/10.1016/j.jcv.2016.09.012.

Alderman, K., Turner, L., Tong, S., 2012. Floods and human health: a systematic review. Env. Int. 47, 37–47. https://doi.org/10.1016/j.envint.2012.06.003.

Ali, H., Dumbuya, B., Hynie, M., Idahosa, P., Keil, R., Perkins, P., 2016. The social and political dimensions of the Ebola response: global inequality, climate change, and infectious disease. In: Leal Filho, W., Azeiteiro, U., Alves, F. (Eds.), Climate Change and Health: Improving Resilience and Reducing Risks. Springer International Publishing, Switzerland, pp. 151–170.

Alpino, T., Sena, A., Freitas, C., 2016. Desastres relacionados à seca e saúde coletiva; uma revisão da literatura científica. Ciênc. Saúde Coletiva 21, 809–820. https://doi.org/10.1590/1413-81232015213.21392015.

Alvares, C., Stape, J., Sentelhas, P., de Moraes Gonçalves, J., Sparovek, G., 2013. Köppen's climate classification map for Brazil. Meteorol. Z. 22, 711–728. https://doi.org/10.1127/0941-2948/2013/0507.

Alves, F., Caeiro, S., Azeiteiro, U., 2014. Lay rationalities of climate change. Int. J. Clim. Change Strateg. Manag. 6, 1756–8692. https://doi.org/https://doi.org/10.1108/IJCCSM-10-2013-0121.

Amin, A.Q.A., Leal Filho, W., 2011. An overview of prospects and challenges in the field of climate change in Malaysia. Int. J. Glob. Warm. 3, 390–402. https://doi.org/10.1504/IJGW.2011.044402.

Amui, L.B.L., Jabbour, C.J.C., de Sousa Jabbour, A.B.L., Kannan, D., 2017. Sustainability as a dynamic organizational capability: a systematic review and a future agenda toward a sustainable transition. J. Clean. Prod. 142, 308–322. https://doi.org/10.1016/j.jclepro.2016.07.103.

Aparicio-Effen, M., Arana, I., Aparicio, J., Cortez, P., Coronel, G., Pastén, M., Nagy, G.J., Galeano Rojas, A., Flores, L., Bidegain, M., 2016. Introducing hydro-climatic extremes and human impacts in Bolivia, Paraguay and Uruguay. In: Leal Filho, W., Azeiteiro, U.M., Alves, F. (Eds.), Climate Change and Health. Springer International Publishing, Cham, pp. 449–473. https://doi.org/10.1007/978-3-319-24660-4_26.

Aparicio-Effen, M., Arana, I., Aparicio, J., Ramallo, C., Bernal, N., Ocampo, M., Nagy, G., 2016. Climate change and health vulnerability in bolivian chaco ecosystems. In: Leal Filho, W., Azeiteiro, U., Alves, F. (Eds.), Climate Change and Health: Improving Resilience and Reducing Risks. Springer International Publishing, Switzerland, pp. 231–262.

Basagaña, X., Sartini, C., Barrera-Gómez, J., Dadvand, P., Cunillera, J., Ostro, B., Sunyer, J., Medina-Ramón, M., 2011. Heat waves and cause-specific mortality at all ages. Epidemiology 22, 765–772. https://doi.org/10.1097/EDE.0b013e31823031c5.

Becker, N., Pluskota, B., Kaiser, A., Schaffner, F., 2012. Exotic mosquitoes conquer the world. In: Mehlhorn, H. (Ed.), Arthropods as Vectors of Emerging Diseases. Springer Berlin Heidelberg, Berlin, Heidelberg, pp. 31–60. https://doi.org/10.1007/978-3-642-28842-5_2.

Benmarhnia, T., Deguen, S., Kaufman, J.S., Smargiassi, A., 2015. Review article: vulnerability to heat-related mortality. Epidemiology 26, 781–793. https://doi.org/10.1097/EDE.0000000000000375.

Brasil, P., Calvet, G.A., Siqueira, A.M., Wakimoto, M., de Sequeira, P.C., Nobre, A., Quintana, M., Mendonça, de S.B., de, M.C.L., Lupi, O., de Souza, R.V., Romero, C., Zogbi, H., Bressan, C. da S., Alves, S.S., Lourenço-de-Oliveira, R., Nogueira, R.M.R., Carvalho, M.S., de Filippis, A.M.B., Jaenisch, T., 2016. Zika Virus Outbreak in Rio de Janeiro, Brazil: clinical Characterization, Epidemiological and Virological Aspects. PLoS Negl. Trop. Dis. 10, e0004636. https://doi.org/10.1371/journal.pntd.0004636.

Butler, C.D., Harley, D., 2010. Primary, secondary and tertiary effects of eco-climatic change: the medical response. Postgrad. Med. J. 86, 230–234. https://doi.org/10.1136/pgmj.2009.082727.

Caminade, C., Kovats, S., Rocklov, J., Tompkins, A.M., Morse, A.P., Colón-González, F.J., Stenlund, H., Martens, P., Lloyd, S.J., 2014. Impact of climate change on global malaria distribution. Proc. Natl. Acad. Sci. 111, 3286–3291. https://doi.org/10.1073/pnas.1302089111.

Caminade, C., Turner, J., Metelmann, S., Hesson, J.C., Blagrove, M.S.C., Solomon, T., Morse, A.P., Baylis, M., 2017. Global risk model for vector-borne transmission of Zika virus reveals the role of El Niño 2015. Proc. Natl. Acad. Sci. 114, 119–124. https://doi.org/10.1073/pnas.1614303114.

Carraro, C., 2015. Climate change and migrations. Rev. Environ. Energy Econ. Re3.

Castro, P., Azeiteiro, U.M., Bacelar-Nicolau, P., Leal Filho, W., Azul, A.M. (Eds.), 2016. Biodiversity and Education for Sustainable Development, World Sustainability Series. Springer International Publishing, Cham. https://doi.org/10.1007/978-3-319-32318-3.

Central Intelligence Agency, 2017. South America: Brazil [WWW Document]. Libr. World Factb. URL. https://www.cia.gov/library/publications/the-world-factbook/geos/br.html (Accessed 1 13 2016).

Chirebvu, E., Chimbari, M.J., Ngwenya, B.N., Sartorius, B., 2016. Clinical malaria transmission trends and its association with climatic variables in tubu village,

Botswana: a retrospective analysis. PLos One 11, e0139843. https://doi.org/10.1371/journal.pone.0139843.
Confalonieri, U., Menne, B., Akhtar, R., Ebi, K., Hauengue, M., Kovats, R., Revich, B., Woodward, A., 2007. Human health. In: Parry, M., Canziani, O., Palutikof, J., van der Linden, P., Hanson, C. (Eds.), Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, pp. 391–431.
Dai, A., 2011. Characteristics and trends in various forms of the palmer drought severity index during 1900–2008. J. Geophys. Res. 116. https://doi.org/10.1029/2010JD015541.
De Freitas, L.E., Oswaldo-Cruz, J.C.H., Cortines, A.C., Gallo, E., 2016. Observatory of sustainable and healthy territories (OTSS) GIS: geo-information for the sustainability of traditional communities in southeastern Brazil. In: Leal Filho, W., Azeiteiro, U.M., Alves, F. (Eds.), Climate Change and Health. Springer International Publishing, Cham, pp. 353–367. https://doi.org/10.1007/978-3-319-24660-4_20.
De Mendonca, M.B., da-Silva-Rosa, T., Monteiro, T.G., de Souza Matos, R., 2016. Improving Disaster Risk Reduction and Resilience Cultures Through Environmental Education: a Case Study in Rio de Janeiro State, Brazil. In: Leal Filho, W., Azeiteiro, U.M., Alves, F. (Eds.), Climate Change and Health. Springer International Publishing, Cham, pp. 279–295. https://doi.org/10.1007/978-3-319-24660-4_16.
Dejnirattisai, W., Supasa, P., Wongwiwat, W., Rouvinski, A., Barba-Spaeth, G., Duangchinda, T., Sakuntabhai, A., Cao-Lormeau, V.-M., Malasit, P., Rey, F.A., Mongkolsapaya, J., Screaton, G.R., 2016. Dengue virus sero-cross-reactivity drives antibody-dependent enhancement of infection with zika virus. Nat. Immunol. 17, 1102–1108. https://doi.org/10.1038/ni.3515.
Enfissi, A., Codrington, J., Roosblad, J., Kazanji, M., Rousset, D., 2016. Zika virus genome from the Americas. Lancet 387, 227–228. https://doi.org/10.1016/S0140-6736(16)00003-9.
Favaro, A.K.M. do I., Maria, N.C., Cutolo, S.A., de Toledo, R.F., Landin, R., Tolffo, F.A., Baptista, A.C.S., Giatti, L.L., 2016. Inequities and challenges for a metropolitan region to improve climate resilience. In: Leal Filho, W., Azeiteiro, U.M., Alves, F. (Eds.), Climate Change and Health. Springer International Publishing, Cham, pp. 419–432. https://doi.org/10.1007/978-3-319-24660-4_24.
Faye, O., Faye, O., Diallo, D., Diallo, M., Weidmann, M., Sall, A., 2013. Quantitative real-time PCR detection of Zika virus and evaluation with field-caught Mosquitoes. Virol. J. 10 (311). https://doi.org/10.1186/1743-422X-10-311.
Ferguson, N.M., Cucunuba, Z.M., Dorigatti, I., Nedjati-Gilani, G.L., Donnelly, C.A., Basanez, M.-G., Nouvellet, P., Lessler, J., 2016. Countering the zika epidemic in Latin America. Science 353, 353–354. https://doi.org/10.1126/science.aag0219.
Figueiredo, P., Perkins, P.E., 2013. Women and water management in times of climate change: participatory and inclusive processes. J. Clean. Prod. 60, 188–194. https://doi.org/10.1016/j.jclepro.2012.02.025.
Freitas, C.M., de Ximenes, E.F., 2012. Enchentes e saúde pública: uma questão na literatura científica recente das causas, consequências e respostas para prevenção e mitigação. Ciênc. Saúde Coletiva 17, 1601–1616. https://doi.org/10.1590/S1413-81232012000600023.
Gallo, E., Setti, A.F.F., Ruprecht, T., Sobrinho, F.X., Finamore, P., Shubo, T., Machado, G.C.X.M.P., 2016. Territorial Solutions, Governance and Climate Change: ecological Sanitation at Praia do Sono, Paraty, Rio de Janeiro, Brazil. In: Leal Filho, W., Azeiteiro, U.M., Alves, F. (Eds.), Climate Change and Health. Springer International Publishing, Cham, pp. 515–532. https://doi.org/10.1007/978-3-319-24660-4_28.
Gaziulusoy, A.I., Ryan, C., McGrail, S., Chandler, P., Twomey, P., 2016. Identifying and addressing challenges faced by transdisciplinary research teams in climate change research. J. Clean. Prod. 123, 55–64. https://doi.org/10.1016/j.jclepro.2015.08.049.
Goorhuis, A., Grobusch, M.P., 2016. Zika virus: who's next? Lancet Infect. Dis. 16, 1204–1205. https://doi.org/10.1016/S1473-3099(16)30316-4.
Gronlund, C.J., 2014. Racial and socioeconomic disparities in heat-related health effects and their mechanisms: a review. Curr. Epidemiol. Rep. 1, 165–173. https://doi.org/10.1007/s40471-014-0014-4.
Gubler, D., Reiter, P., Ebi, K., Yap, W., Nasci, R., Patz, J., 2001. Climate variability and change in the United States: potential impacts on vectorand rodent-borne diseases. Environ. Health Perspect. 109, 223–233.
Hales, S., Kovats, S., Lloyd, S., Campbell-Lendrum, D., 2014. Quantitative Risk Assessment of the Effects of Climate Change on Selected Causes of Death, 2030s and 2050s.
Hales, S., Weinstein, P., Souares, Y., Woodward, A., 1999. El Niño and the dynamics of vectorborne disease transmission. Env. Health Perspect. 107, 99–102.
Haque, M.M., Rahman, A., Samali, B., 2016. Evaluation of climate change impacts on rainwater harvesting. J. Clean. Prod. 137, 60–69. https://doi.org/10.1016/j.jclepro.2016.07.038.
Herring, S.C., Hoerling, M.P., Peterson, T.C., Stott, P.A., 2014. Explaining extreme events of 2013 from a climate perspective. Bull. Am. Meteorol. Soc. 95, 1–104. https://doi.org/10.1175/1520-0477-95.9.S1.1.
Honório, N.A., Codeço, C.T., Alves, F.C., Magalhães, M.A.F.M., Lourenço-de-Oliveira, R., 2009. Temporal distribution of Aedes aegypti in different districts of rio de Janeiro, Brazil, measured by two types of traps. J. Med. Entomol. 46, 1001–1014. https://doi.org/10.1603/033.046.0505.
Huang, L.-Y., Wang, Y.-C., Wu, C.-C., Chen, Y.-C., Huang, Y.-L., 2016. Risk of flood-related diseases of eyes, skin and gastrointestinal tract in taiwan: a retrospective cohort study. PLos One 11, e0155166. https://doi.org/10.1371/journal.pone.0155166.
Hulme, M., 2014. Attributing weather extremes to 'climate change': a review. Prog. Phys. Geogr. 38, 499–511. https://doi.org/10.1177/0309133314538644.
Hunter, P.R., 2003. Climate change and waterborne and vector-borne disease. J. Appl. Microbiol. 94, 37–46. https://doi.org/10.1046/j.1365-2672.94.s1.5.x.
Institute of Medicine, 2008. Global Climate Change and Extreme Weather Events: Understanding the Contributions to Infectious Disease Emergence: Workshop Summary. National Academies Press, Washington, D.C.. https://doi.org/10.17226/12435
IPCC, 2014. Climate Change 2014 Impacts, Adaptation, and Vulnerability: Working Group II Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge. https://doi.org/10.1017/CBO9781107415379.
IPCC, 2012. Resumen para responsables de políticas"en el Informe especial sobre la gestión de los riesgos de fenómenos meteorológicos extremos y desastres para mejorar la adaptación al cambio climático. In: Field, C.B., Barros, V.R., Stocker, T.F., Dahe, Q., Dokken, D.J., Ebi, K.L., Mastrandrea, M.D., Mach, K.J., Plattner, G.-K., Allen, S.K., Tignor, M., Midgley, P.M. (Eds.), Informe especial de los Grupos de trabajo I y II del Grupo Intergubernamental de Expertos sobre el Cambio Climático. Cambridge University Press, Cambridge, New York, pp. 1–19. https://doi.org/10.1017/CBO9781107415379.
Jabbour, C.J.C., 2013. Environmental training in organisations: from a literature review to a framework for future research. Resour. Conserv. Recycl. 74, 144–155. https://doi.org/10.1016/j.resconrec.2012.12.017.
Kraemer, M.U., Sinka, M.E., Duda, K.A., Mylne, A.Q., Shearer, F.M., Barker, C.M., Moore, C.G., Carvalho, R.G., Coelho, G.E., Van Bortel, W., Hendrickx, G., Schaffner, F., Elyazar, I.R., Teng, H.-J., Brady, O.J., Messina, J.P., Pigott, D.M., Scott, T.W., Smith, D.L., Wint, G.W., Golding, N., Hay, S.I., 2015. The global distribution of the arbovirus vectors Aedes aegypti and Ae. albopictus. ELife 4. https://doi.org/10.7554/eLife.08347.
Krauer, F., Riesen, M., Reveiz, L., Oladapo, O.T., Martínez-Vega, R., Porgo, T.V., Haefliger, A., Broutet, N.J., Low, N., WHO zika causality working group, 2017. Zika Virus Infection as a Cause of Congenital Brain Abnormalities and Guillain–Barré Syndrome: Systematic Review. PLoS Med. 14, e1002203. https://doi.org/10.1371/journal.pmed.1002203.
Leal Filho, W. (Ed.), 2011. The Economic, Social and Political Elements of Climate Change, Climate Change Management. Springer Berlin Heidelberg, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-14776-0.
Leal Filho, W., Alves, F., Caeiro, S., Azeiteiro, U.M. (Eds.), 2014. International Perspectives on Climate Change, Climate Change Management. Springer International Publishing, Cham. https://doi.org/10.1007/978-3-319-04489-7.
Leal Filho, W., Azeiteiro, U.M., Alves, F., 2016. Climate change and health: an overview of the issues and needs. In: Leal Filho, W., Azeiteiro, U.M., Alves, F. (Eds.), Climate Change and Health. Springer International Publishing, Cham, pp. 1–11. https://doi.org/10.1007/978-3-319-24660-4_1.
Leal Filho, W., Morgan, E.A., Godoy, E.S., Azeiteiro, U.M., Bacelar-Nicolau, P., Veiga Ávila, L., Mac-Lean, C., Hugé, J., 2018. Implementing climate change research at universities: barriers, potential and actions. J. Clean. Prod. 170, 269–277. https://doi.org/10.1016/j.jclepro.2017.09.105.
Leparc-Goffart, I., Nougairede, A., Cassadou, S., Prat, C., de Lamballerie, X., 2014. Chikungunya in the Americas. Lancet 383 (514). https://doi.org/10.1016/S0140-6736(14)60185-9.
Lucena, A.J. de, Rotunno Filho, O.C., França, J.R. de A., Peres, L. de F., Xavier, L.N.R., 2013. Urban climate and clues of heat island events in the metropolitan area of Rio de Janeiro. Theor. Appl. Climatol. 111, 497–511. https://doi.org/10.1007/s00704-012-0668-0.
McMichael, A.J., 2003. Climate Change and Human Health: Risks and Responses. World Health Organization, Geneva.
McMichael, A.J., Butler, C.D., Dixon, J., 2015. Climate change, food systems and population health risks in their eco-social context. Publ. Health 129, 1361–1368. https://doi.org/10.1016/j.puhe.2014.11.013.
McMichael, A.J., Woodruff, R.E., Hales, S., 2006. Climate change and human health: present and future risks. Lancet 367, 859–869. https://doi.org/10.1016/S0140-6736(06)68079-3.
Meason, B., Paterson, R., 2014. Chikungunya, climate change, and human rights. Health Hum. Rights 16, 105–112.
Mills, J.N., Gage, K.L., Khan, A.S., 2010. Potential influence of climate change on vector-borne and zoonotic diseases: a review and proposed research plan. Environ. Health Perspect. 118, 1507–1514. https://doi.org/10.1289/ehp.0901389.
Muñoz, Á.G., Thomson, M.C., Goddard, L., Aldighieri, S., 2016. Analyzing climate variations at multiple timescales can guide Zika virus response measures. GigaScience 5. https://doi.org/10.1186/s13742-016-0146-1.
Musso, D., Stramer, S.L., Busch, M.P., 2016. Zika virus: a new challenge for blood transfusion. Lancet 387, 1993–1994. https://doi.org/10.1016/S0140-6736(16)30428-7.
Nagy, G.J., Coronel, G., Pastén, M., Báez, J., Monte-Domecq, R., Galeano-Rojas, A., Flores, L., Ciganda, C., Bidegain, M., Aparicio-Effen, M., Arana, I., 2016. Impacts on well-being and health by excessive rainfall and floods in Paraguay, Uruguay and Bolivia. In: Leal Filho, W., Azeiteiro, U.M., Alves, F. (Eds.), Climate Change and Health. Springer International Publishing, Cham, pp. 475–514. https://doi.org/10.1007/978-3-319-24660-4_27.
Naidoo, S., Olaniran, A., 2013. Treated wastewater effluent as a source of microbial pollution of surface water resources. Int. J. Environ. Res. Publ. Health 11, 249–270. https://doi.org/10.3390/ijerph110100249.
Nazareth, T., Seixas, G., Sousa, C.A., 2016. Climate change and mosquito-borne diseases. In: Leal Filho, W., Azeiteiro, U.M., Alves, F. (Eds.), Climate Change

and Health. Springer International Publishing, Cham, pp. 187–199. https://doi.org/10.1007/978-3-319-24660-4_12.

Nehama, F.P.J., Matavel, A.J., Hoguane, A.M., Menomussanga, M., Hoguane, C.A.M., Zacarias, O., Lemos, M.A., 2016. Building community resilience and strengthening local capacities for disaster risk reduction and climate change adaptation in zongoene (Xai-Xai district), gaza province. In: Leal Filho, W., Azeiteiro, U.M., Alves, F. (Eds.), Climate Change and Health. Springer International Publishing, Cham, pp. 369–385. https://doi.org/10.1007/978-3-319-24660-4_21.

NRC, 2001. Under the Weather: Climate, Ecosystems, and Infectious Disease. National Academies Press, Washington, D.C.. https://doi.org/10.17226/10025

Ojeh, V.N., Aworinde, S.A., 2016. Climate variation and challenges of human health in Nigeria: malaria in perspective. In: Leal Filho, W., Azeiteiro, U.M., Alves, F. (Eds.), Climate Change and Health. Springer International Publishing, Cham, pp. 171–185. https://doi.org/10.1007/978-3-319-24660-4_11.

Oliveira, B., de Moura, A.P., Cunha, L.M., 2016. Reducing food waste in the food service sector as a way to promote public health and environmental sustainability. In: Leal Filho, W., Azeiteiro, U.M., Alves, F. (Eds.), Climate Change and Health. Springer International Publishing, Cham, pp. 117–132. https://doi.org/10.1007/978-3-319-24660-4_8.

Oliver, S.L., Ribeiro, H., 2016. Water supply, climate change and health risk factors: example case of são Paulo—Brazil. In: Leal Filho, W., Azeiteiro, U.M., Alves, F. (Eds.), Climate Change and Health. Springer International Publishing, Cham, pp. 433–447. https://doi.org/10.1007/978-3-319-24660-4_25.

Parham, P.E., Waldock, J., Christophides, G.K., Hemming, D., Agusto, F., Evans, K.J., Fefferman, N., Gaff, H., Gumel, A., LaDeau, S., Lenhart, S., Mickens, R.E., Naumova, E.N., Ostfeld, R.S., Ready, P.D., Thomas, M.B., Velasco-Hernandez, J., Michael, E., 2015. Climate, environmental and socio-economic change: weighing up the balance in vector-borne disease transmission. Philos. Trans. R. Soc. B Biol. Sci. 370, 20130551–20130551. https://doi.org/10.1098/rstb.2013.0551.

Patz, J.A., Campbell-Lendrum, D., Holloway, T., Foley, J.A., 2005. Impact of regional climate change on human health. Nature 438, 310–317. https://doi.org/10.1038/nature04188.

Paz, S., Semenza, J.C., 2016. El Niño and climate change—contributing factors in the dispersal of Zika virus in the Americas? Lancet 387 (745). https://doi.org/10.1016/S0140-6736(16)00256-7.

Pereda, P.C., de Oliveira Alves, D.C., 2016. Climate impacts on dengue risk in Brazil: current and future risks. In: Leal Filho, W., Azeiteiro, U.M., Alves, F. (Eds.), Climate Change and Health. Springer International Publishing, Cham, pp. 201–230. https://doi.org/10.1007/978-3-319-24660-4_13.

Reeves, W.C., Hardy, J.L., Reisen, W.K., Milby, M.M., 1994. Potential effect of global warming on mosquito-borne arboviruses. J. Med. Entomol. 31, 323–332.

Schuck-Paim, C., López, D., Simonsen, L., Alonso, W., 2016. Unintended pregnancies in Brazil - a challenge for the recommendation to delay pregnancy due to zika. PLoS Curr. https://doi.org/10.1371/currents.outbreaks.7038a6813f734c1db547240c2a0ba291.

Brazilian Medical Genetics Society–Zika Embryopathy Task Force, 2016. Possible Association Between Zika Virus Infection and Microcephaly — Brazil Schuler-Faccini, L., Ribeiro, E.M., Feitosa, I.M.L., Horovitz, D.D.G., Cavalcanti, D.P., Pessoa, A., Doriqui, M.J.R., Neri, J.I., Neto, J.M. de P., Wanderley, H.Y.C., Cernach, M., El-Husny, A.S., Pone, M.V.S., Serao, C.L.C., Sanseverino, M.T.V., 2015. Mmwr morb. Mortal. Wkly. Rep. 65, 59–62. https://doi.org/10.15585/mmwr.mm6503e2.

Setti, A.F.F., Ribeiro, H., Gallo, E., Alves, F., Azeiteiro, U.M., 2016. Climate change and health: governance mechanisms in traditional communities of mosaico Bocaina/Brazil. In: Leal Filho, W., Azeiteiro, U.M., Alves, F. (Eds.), Climate Change and Health. Springer International Publishing, Cham, pp. 329–351. https://doi.org/10.1007/978-3-319-24660-4_19.

Smith, K., Woodward, A., Campbell-Lendrum, D., Chadee, D., Honda, Y., Liu, Q., Olwoch, J., Revich, B., Sauerborn, R., 2014. Human health: impacts, adaptation and co-benefits. In: Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., Girma, B., Kissel, E.S., Levy, A.N., MacCracken, S., Mastrandrea, P.R., White, L.L. (Eds.), Climate Change Impacts: Adaptation and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, New York, pp. 709–754.

Stanke, C., Murray, V., Amlôt, R., Nurse, J., Williams, R., 2012. The effects of flooding on mental health: outcomes and recommendations from a review of the literature. PLoS Curr. https://doi.org/10.1371/4f9f1fa9c3cae.

Staples, J.E., Breiman, R.F., Powers, A.M., 2009. Chikungunya fever: an epidemiological review of a Re-Emerging infectious disease. Clin. Infect. Dis. 49, 942–948. https://doi.org/10.1086/605496.

Tang, B., Xiao, Y., Wu, J., 2016. Implication of vaccination against dengue for Zika outbreak. Sci. Rep. 6. https://doi.org/10.1038/srep35623.

The Lancet Global Health, 2016. The right(s) approach to Zika. Lancet Glob. Health 4, e427. https://doi.org/10.1016/S2214-109X(16)30109-7.

The Lancet Infectious Diseases, 2017. Dengue — Executive Summary [WWW Document]. Dengue — Exec. Summ. URL. http://www.thelancet.com/series/dengue (Accessed 2 21 2017).

Viegas, V., Azeiteiro, U.M., Alves, F., 2016. Fostering resilience among artisanal fishers in peniche (Portugal): an exploratory study. In: Leal Filho, W., Musa, H., Cavan, G., O'Hare, P., Seixas, J. (Eds.), Climate Change Adaptation, Resilience and Hazards. Springer International Publishing, Cham, pp. 305–327. https://doi.org/10.1007/978-3-319-39880-8_19.

Watts, N., Adger, W.N., Agnolucci, P., Blackstock, J., Byass, P., Cai, W., Chaytor, S., Colbourn, T., Collins, M., Cooper, A., Cox, P.M., Depledge, J., Drummond, P., Ekins, P., Galaz, V., Grace, D., Graham, H., Grubb, M., Haines, A., Hamilton, I., Hunter, A., Jiang, X., Li, M., Kelman, I., Liang, L., Lott, M., Lowe, R., Luo, Y., Mace, G., Maslin, M., Nilsson, M., Oreszczyn, T., Pye, S., Quinn, T., Svensdotter, M., Venevsky, S., Warner, K., Xu, B., Yang, J., Yin, Y., Yu, C., Zhang, Q., Gong, P., Montgomery, H., Costello, A., 2015. Health and climate change: policy responses to protect public health. Lancet 386, 1861–1914. https://doi.org/10.1016/S0140-6736(15)60854-6.

Watts, N., Amann, M., Ayeb-Karlsson, S., Belesova, K., Bouley, T., Boykoff, M., Byass, P., Cai, W., Campbell-Lendrum, D., Chambers, J., Cox, P.M., Daly, M., Dasandi, N., Davies, M., Depledge, M., Depoux, A., Dominguez-Salas, P., Drummond, P., Ekins, P., Flahault, A., Frumkin, H., Georgeson, L., Ghanei, M., Grace, D., Graham, H., Grojsman, R., Haines, A., Hamilton, I., Hartinger, S., Johnson, A., Kelman, I., Kiesewetter, G., Kniveton, D., Liang, L., Lott, M., Lowe, R., Mace, G., Odhiambo Sewe, M., Maslin, M., Mikhaylov, S., Milner, J., Latifi, A.M., Moradi-Lakeh, M., Morrissey, K., Murray, K., Neville, T., Nilsson, M., Oreszczyn, T., Owfi, F., Pencheon, D., Pye, S., Rabbaniha, M., Robinson, E., Rocklöv, J., Schütte, S., Shumake-Guillemot, J., Steinbach, R., Tabatabaei, M., Wheeler, N., Wilkinson, P., Gong, P., Montgomery, H., Costello, A., 2017. The Lancet Countdown on health and climate change: from 25 years of inaction to a global transformation for public health. Lancet (17), 32464–32469. https://doi.org/10.1016/S0140-6736.

WHO, 2016a. Vector-borne Diseases [WWW Document]. Media Cent. URL. http://www.who.int/mediacentre/factsheets/fs387/en/ (Accessed 1 10 2017).

WHO, 2016b. El Niño May Increase Breeding Grounds for Mosquitoes Spreading Zika Virus, WHO Says [WWW Document]. Humanit. Health Action. URL. http://who.int/hac/crises/el-nino/22february2016/en/ (Accessed 8 9 2016).

WHO, 2016c. Mosquito (Vector) Control Emergency Response and Preparedness for Zika Virus [WWW Document]. Neglected Trop. Dis. URL. http://www.who.int/neglected_diseases/news/mosquito_vector_control_response/en/ (Accessed 2 17 2017).

WHO, 2015. Climate and Health Country Profile — 2015. Brazil [WWW Document]. Clim. Health Ctry. Profile — 2015 Braz. URL. http://www.who.int/iris/handle/10665/208857 (Accessed 1 13 2017).

Wilbanks, T., Romero Lankao, P., Bao, M., Berkhout, F., Cairncross, S., Ceron, J.-P., Kapshe, M., Muir-Wood, R., Zapata-Marti, R., 2007. Industry, settlement and society. In: Parry, M., Canziani, O., Palutikof, J., van der Linden, P., Hanson, C. (Eds.), Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, pp. 357–390.

Wilder-Smith, A., Ooi, E.-E., Vasudevan, S.G., Gubler, D.J., 2010. Update on dengue: epidemiology, virus evolution, antiviral drugs, and vaccine development. Curr. Infect. Dis. Rep. 12, 157–164. https://doi.org/10.1007/s11908-010-0102-7.

Wu, X., Lu, Y., Zhou, S., Chen, L., Xu, B., 2016. Impact of climate change on human infectious diseases: empirical evidence and human adaptation. Environ. Int. 86, 14–23. https://doi.org/10.1016/j.envint.2015.09.007.

Yuan, X.-C., Wei, Y.-M., Wang, B., Mi, Z., 2017. Risk management of extreme events under climate change. J. Clean. Prod. 166, 1169–1174. https://doi.org/10.1016/j.jclepro.2017.07.209.

Zahouli, J.B.Z., Utzinger, J., Adja, M.A., Müller, P., Malone, D., Tano, Y., Koudou, B.G., 2016. Oviposition ecology and species composition of Aedes spp. and Aedes aegypti dynamics in variously urbanized settings in arbovirus foci in south-eastern Côte d'Ivoire. Parasites Vectors 9. https://doi.org/10.1186/s13071-016-1778-9.