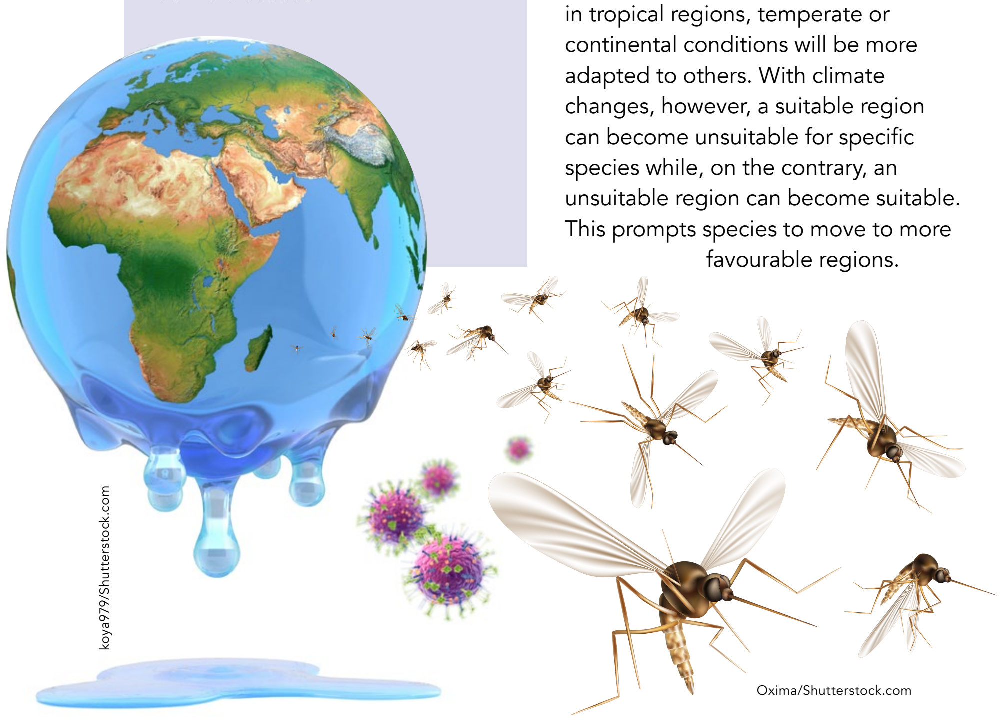
Climate change impacts the transmission of vector-borne diseases

Climate change is responsible for changes in temperature and rainfall patterns as well as more frequent extreme events such as floods. These changes may cause insect displacements to regions that are more favourable to them. This can prove to be problematic for local human populations as some of these insects carry diseases: vector-borne diseases are illnesses caused by parasites, viruses and bacteria that are transmitted by vectors such as mosquitoes, ticks and flies. Dr Florence Fouque, researcher at the World Health Organization, is passionate about understanding the effects of climate and environmental factors including climate change on the transmission of vector-borne diseases.



koya979/Shutterstock.com

Oxima/Shutterstock.com

Around the globe, climate differs from one region of the world to another. The climate of each region is defined by averages over many years of temperature, precipitation, wind and other weather-related parameters. Climate changes occur naturally at different timescales, from tens to thousands of years, though factors such as human activity can modify these changes. Over the past fifty years, Earth's climate has been affected by global warming: surface, air and ocean temperature has been increasing, resulting in the melting of glaciers and the rise of sea levels. Extreme events such as cyclones and floods have also become more frequent.

Average weather conditions greatly influence wildlife as plant and animal species live in regions that offer suitable conditions: while some species thrive in tropical regions, temperate or continental conditions will be more adapted to others. With climate changes, however, a suitable region can become unsuitable for specific species while, on the contrary, an unsuitable region can become suitable. This prompts species to move to more favourable regions.

Among these species are insects such as mosquitoes, ticks and flies that can transmit illnesses called vector-borne diseases (VBDs). Malaria, Zika virus, dengue, chikungunya, yellow fever, Japanese encephalitis, Lyme disease, typhus, leishmaniasis and sleeping sickness are examples of VBDs. Every year, VBDs cause more than 700,000 deaths. Although great progress has been achieved in the past century on the control of these infectious diseases, the environmental changes are compromising the progress and a deeper understanding of these diseases is needed. For this reason, TDR and WHO are gathering evidence on how climate change influences the geographical distribution of these insects and subsequently affects the transmission of VBDs.

VECTOR-BORNE DISEASES

A vector-borne disease involves three elements: the pathogen, the vector, and the host. Pathogens can be parasites, viruses or bacteria that cause infections either silent or symptomatic in humans and/or animals. Vectors can be mosquitoes, flies, ticks or other insect species that transmit the pathogen to a host. Hosts can be humans or livestock or other animals that become infected and eventually sick after being infected by a vector.

Insects may become infectious mainly after the ingestion of a pathogen through a bloodmeal on an infected host – for example, when a mosquito bites a sick human. Then, the pathogen develops within the insect and acts as an infectious vector when transmitting the pathogen to a non-immune host. The time required for the amplification of the pathogen in the insect is called the extrinsic incubation period (EIP). Finally, during its next bloodmeal for mosquitoes, flies and ticks, but also through other means such as defecating for bugs or being squashed for lice, the vector transmits the pathogen into another host.

Changes in temperature and precipitation affect the environment in which the VBDs are transmitted. These environments may become more or less favourable to the vectors and to disease transmission. The changes can also impact humans by prompting them to leave, or by affecting agricultural practices and housing systems.

AN IDEAL TEMPERATURE

The EIP, which corresponds to the period between the time when a vector ingests the pathogen and the time when that vector is ready to transmit the pathogen to another host, strongly depends on temperature. Consequently, temperature has a direct impact on the transmission of VBDs. For each vector and pathogen, there is an ideal temperature at which EIP is minimal; a shorter EIP is advantageous for disease transmission since vectors become infectious faster. The temperature can also affect VBDs transmission by affecting the biting behaviour, fecundity and survival of the vectors.

In the context of VBDs, the cycle of a pathogen is divided into two parts: one part taking place in the vector, the other one in the host. In the host, the pathogen will find stable and suitable temperature conditions, since the host is regulating its own temperature. Insects, however, are cold-blooded, which means that they cannot regulate their own temperature so, in the vector, the pathogen will find suitable temperature conditions only if the vector is exposed to a favourable environment. For example, dengue viruses will develop in mosquitoes and be transmitted only if exposed to temperatures within the range of 20 to 35°C.

TEMPERATURE VARIATIONS AND DISPLACEMENTS

Global warming impacts the geographical distribution of vectors involved in different VBDs. In several cases, vectors move away from the equator, towards more temperate regions.

Province of Antananarivo, Madagascar, September 2019 (Personal picture F. Fouque).
The increase of temperature was associated with an increase of malaria transmission at higher altitude. Deforestation is further exacerbating the temperature increase.

TDR and the World Health Organization are gathering evidence that climate change influences the geographical distribution of insects and affects the transmission of vector-borne diseases.

In China, for example, the changes in temperatures will have opposite effects, in the southern parts an increase of the maximum temperature will decrease malaria transmission while, in contrast, in the northern parts of the country, an increase in the minimum temperature will increase malaria transmission and a region where temperatures were previously too low will be now suitable for malaria.

Similar observations were made for the Leishmaniasis, transmitted by sand flies which are moving from south to north in Europe and from north to south in Argentina. Sand flies are consequently now found in Belgium and Germany, creating new risks of transmission in countries that are currently free of disease transmission. Likewise, in Canada, heatwaves cause the northward displacement of ticks responsible for Lyme disease.

Rift Valley, Kenya, May 2015 (Personal picture F. Fouque).
Warmer temperatures were found to affect malaria trends in highland regions of East Africa.
Reference: Alonso D, *et al.* Epidemic malaria and warmer temperatures in recent decades in an east African highland. *M Proc Biol Sci. 2011;278(1712): 1661–9.* https://doi.org/10.1098/rspb.2010.2020 *Epub 2010 Nov 10.*

THE HIGHLANDS AT RISK

Besides prompting vectors to move away from the equator, global warming also puts the highlands at risk. Colder temperatures at higher altitudes slow down or even halt the development of pathogens within the vectors, decrease the rate of reproduction, and reduce the biting rate of the vector, thus minimising or even preventing transmission. With increased temperatures, VBDs reach regions at higher altitudes.

This was observed in Rwanda, at Mount Kilimanjaro in Tanzania, in Iran, in Madagascar, in Ethiopia and in Columbia: in warmer years, malaria affects regions at higher altitudes. This implies that, with global warming, the risks of contracting malaria will increase for populations in the highlands of Africa and South America. Similarly, the city of Kathmandu in Nepal, which is above 1300m, is now affected by dengue outbreaks.

While the highlands are now at risk, these changes are beneficial to

Khett Kampong Spoe, Cambodge, March 2019 (Personal picture, F. Fouque).
Urban temperatures are changing in a drastic way due to the warming climate and consequently they are enhancing, among other factors, dengue transmission and outbreaks.

Southern Africa, January 2015, UNFPA Picture.
Rainfalls and extreme flooding have also been found to have an impact on malaria transmission.

Climate change is affecting vector-borne disease transmission more strikingly in regions at the border between affected and unaffected areas.

other regions: in the Zambezi Valley, the once common tsetse flies, that transmit sleeping sickness, have practically disappeared.

RAINFALLS AND EXTREME EVENTS
Rainfalls and the humidity of the environment also strongly influence VBD transmission. Increased rainfalls and extreme flooding are usually associated with increased risks of contracting VBDs. There is evidence of this phenomenon for malaria transmission in Uganda, Zambia and Papua New Guinea, as well as for dengue in Vietnam and in the Philippines. A tropical cyclone also favours dengue transmission in four provinces of China.

On the contrary, insects move away from regions that show a decrease in rainfall: a decrease of rain was associated with a decrease of malaria in southern coastal region of Papua New Guinea while the decrease in rainfall in the Sahelian border led tsetse flies, responsible for the sleeping sickness, to move southward.

The successive occurrence of droughts and extreme rainfalls due to the phenomenon called El Niño favours Rift Valley fever outbreaks in eastern Africa. When floods set in and mosquitoes develop, the disease affects both livestock and humans. Droughts contribute by increasing animal mortality and thus reducing herd immunity: in addition, animals that die may get replaced by other breed/species of hosts that have never faced the virus before and will therefore be highly at risk during the next flood and disease outbreak.

BORDERING AREA VULNERABILITY
Climate change is affecting VBD transmission more strikingly in regions at the border between affected and unaffected areas. These regions, once free of these diseases, become suitable for vectors living in neighbouring areas and for the transmission of VBDs to populations that are less immune and thus more at risk.

The impact can be devastating as, in these newly affected regions, public health systems can face unexpected challenges and be unprepared to provide an adequate response. In Nepal, an elimination programme aims to limit the effects of leishmaniasis in affected districts. Between 1999 and 2009, because of changes in the geographical distribution of sand flies, eleven additional districts located in mountainous areas reported cases of leishmaniasis, forcing the country to extend its elimination programme to these newly affected areas, with all the costs and logistics issues for a low-income country.

BETTER PREVENTION IS NEEDED
The consequences of climatic changes on public health are not fully understood yet, but it seems inevitable that changes in geographical distribution of the vectors and the diseases will result in strong effects. The risk of emergence of new transmission zones, including in developed countries, is great and emphasises the need to be prepared to face such events.

The Tropical Diseases Research Programme and the World Health Organization continue to work towards understanding the effects of climate change on VBD transmission, with the aim of preventing the impact on human health and public health systems more accurately. Although tendencies related to how temperature and rainfall impact VBD transmission were observed, many factors linked to weather and human activity interact, making the prediction of upcoming changes at a global scale challenging. There is therefore a need to study the impact locally to take prevention measures and mitigate the threats of epidemics.

Behind the Research

Dr Florence Fouque

E: fouquef@who.int **T:** +41 22 791 2173 **W:** www.who.int/tdr

Research Objectives

UNICEF/UNDP/World Bank/WHO Special Programme for Research and Training in Tropical Diseases (TDR) based at the World Health Organization, 20, Avenue Appia, 1211 Geneva 27, Switzerland, is a global programme of scientific collaboration that facilitates, supports and influences efforts to combat diseases of poverty.

Detail

Florence Fouque
The Special Programme for Research and Training in Tropical Diseases
World Health Organization
20, Avenue Appia
CH-1211 Geneva 27, Switzerland

Bio
Florence Fouque obtained her PhD in biology at the Polytechnical School of Zürich and completed her Post-Doctoral training at the University of Berkeley. She then joined the Pasteur Institute in 1993 as a medical entomologist and Head of Laboratories to work on different VBD transmission patterns and vectors within the International Pasteur Institutes Network. In 2007, Dr Fouque was appointed as qualified member of the French Haut Conseil de la Santé Publique and in 2014 she joined TDR as Team Leader of the Vector Environment and Society research Unit. Since then, she has been working for TDR and WHO on all aspects of VBD within the UN system.

Funding
The Tropical Diseases Research Programme, hosted at WHO and co-sponsored by UNDP, UNICEF, World Bank and WHO) has received funding from IDRC (International Development Research Center, Canada) to manage a 5-year research project on the impact of climate change on VBDs in vulnerable populations in Africa, which has given TDR the opportunity to work deeper on the subject with the selected research teams.

Collaborators
- TDR Director, John Reeder, co-author of the publication on Impact of Climate Change on VBDs.
- Bernadette Ramirez, the TDR Officer, Scientist and Manager of the IDRC project.
- All TDR staff who have contributed and are still contributing to this project and subject.

References

- Fouque F., & Reeder J. C. (2019). Impact of past and on-going changes on climate and weather on vector-borne diseases transmission: a look at the evidence. *Infectious Diseases of Poverty*, 8(1), 51. https://doi.org/10.1186/s40249-019-0565-1
- Siraj A. S., Santos-Vega M., Bouma M. J., Yadeta D., Ruiz Carrascal D., & Pascual M. (2014). Altitudinal changes in malaria incidence in highlands of Ethiopia and Colombia. *Science (New York, N.Y.)*, 343(6175), 1154–1158. https://doi.org/10.1126/science.1244325
- Ebi K. L., Ogden N. H., Semenza J. C., & Woodward A. (2017). Detecting and Attributing Health Burdens to Climate Change. *Environmental Health Perspectives*, 125(8), 085004. https://doi.org/10.1289/EHP1509
- Lord J. S., Hargrove J. W., Torr S. J., & Vale G. A. (2018). Climate change and African trypanosomiasis vector populations in Zimbabwe's Zambezi Valley: A mathematical modelling study. *PLoS Medicine*, 15(10), e1002675. https://doi.org/10.1371/journal.pmed.1002675
- Dhimal M., Ahrens B., & Kuch U. (2015). Climate Change and Spatiotemporal Distributions of Vector-Borne Diseases in Nepal--A Systematic Synthesis of Literature. *PloS One*, 10(6), e0129869. https://doi.org/10.1371/journal.pone.0129869

Personal Response

Research shows that the impact of climate change is likely to affect hard-to-reach, marginal, migrant and bordering populations more severely. What can be done to mitigate this?

" The complexity to reach these specific and vulnerable populations has several faces and we must consider all these faces to mitigate as much as possible the impact of climate change on these populations. Among important elements, some of them are mentioned herein. The first aspect is societal, we must understand why these populations are hard to reach, e.g. because of conflicts, poverty, cultural isolation, illegal and many other factors. The health system will not be able to reach them if it does not have a kind of specific approach according to the origin of the vulnerability. The second aspect is financial and links to the motivation for reaching these populations. If prioritisation of activities is done but completely forgets some small part of the populations, we will end up with small spots of transmission acting as reservoir and subsequently contaminating the larger groups again. The last element for improving the access to health for these populations is about the prevention of both the movement and the diseases. We must work on preventing these displacements as well as on preventing ecological disruptions that are forcing the movements. Climate change can be considered as one of these disruptions and all efforts to better tackle this problem are worthwhile. "