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Brazil burning! What is the potential impact of the Amazon wildfires on vector-borne and zoonotic emerging diseases? – A statement from an international experts meeting

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According to recent scientific evidence, Brazil's wildfires are linked to deforestation. The blazes are surging in a pattern typical of forest clearing, along the edges of the agricultural frontiers (Fig. 1). Historical data shows the pattern of events: chainsaws or excavators open the way, then the wildfires, and these are followed by livestock, monoculture, or other forms of economic activity [1]. By August 24th, 2019, Brazil's National Institute for Space Research (INPE) had counted more than 76,000 wildfire spots in the Brazilian Amazon, compared with 22,000 in the same period last year. The Global wildfire Emissions Database project, which includes scientists from NASA's Goddard Space Flight Center in Greenbelt, Maryland; the University of California, Irvine; and Vrije University in Amsterdam, sees the same trend, although the numbers are slightly higher [1].

The situation, especially ecologically, is critical. Brazil contains about 60% of the Amazon, the largest rainforest in the world. Several million plants, animal and insect species live in the Amazon, in addition to dwellers, and the Amazon acts as an enormous carbon sink that helps to cool global temperatures, of utmost importance in the context of climate change and global warming [2]. Forest wildfires (Fig. 1), in this scenario, release this stored carbon, causing a major impact on health. For example, high air pollution immediately. The long-term impact is more considerable and challenging to estimate. The effects will be determined by the type of change in the ecosystem (landscape, fauna, flora, environment) [3,4].

During the period August 16th-17th, 2019, a group of international experts held a meeting on Zoonoses and One Health, in Pereira, Colombia, under the auspices and networking of the Colombian Association of Infectious Diseases and its Committee on Tropical Medicine, Zoonoses and Travel Medicine. This group has analyzed the situation in Brazil and set a position regarding the potential impact of the 2019 Amazon wildfires (Fig. 1) on vector-borne and zoonotic emerging diseases.

The forest wildfire produces a sharp change of the landscape, from a tropical forest, characteristically humid; it changes towards a dry one, typical of deforestation. Previous studies have shown that landscape change, and primary deforestation, alters multiple ecological elements, e.g. phytotelmata habitat availability and mosquito production, as has been observed in the Peruvian Amazon with increasing rates of vector-borne disease transmission. Studies report that deforestation increases the risk of malaria and probably other vector-transmitted infections [5]. The ecologies of multiple transmissions of vector-borne and zoonotic diseases pose challenges for their control, especially in changing landscapes, even more during such deforestation situations [6].

After deforestation has occurred, the landscape will be modified to facilitate economic activities. Land-use changes can impact infectious disease transmission by increasing spatial overlap between people and wildlife disease reservoirs. Previous epidemics like the sizeable yellow fever epidemic, which began in Brazil in 2016 and had as vectors the *Haemagogus leucocelaenus* and *H. janthinomys*, which are wild mosquitoes [7], have been driven by landscape modifications, with forest fragments running in periurban areas, allowing enough interaction to produce such an epidemic [3,4].

Additionally, the Amazon region of Brazil, endemic for many communicable or zoonotic diseases, can, after a wildfire, can trigger a selection for survival, and with it change the habitat and behaviors of some animal species. These can be reservoirs of zoonotic bacteria, viruses, and parasites, that can adapt to suburban and urban landscapes and would increase the risk of interaction and infection leading to the emergence of diseases in new areas [8,9].

For example, with regard to the arenaviruses and hantaviruses, in rodent hosts, their geographical distribution may change, with the potential risk of increasing and representing a threat to humans [10]. Other hosts, such as birds could also transport pathogens. The situation could also help hosts to propagate diseases like Oropouche virus, a zoonotic arbovirus in which birds play an essential role maintaining sylvatic cycles [11], previously reported in areas surrounding the wildfires [12].

Human-related factors include modern life trends such as

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Fig. 1. Satellite images from the NASA's Earth Observing System Data and Information System (EOSDIS) from July 15 to August 28, 2019, showing the MODIS wildfire and Thermal Anomalies layer, able to identify active wildfire and thermal anomalies (red points). The MODIS wildfire and Thermal Anomalies product is available from the Terra (MOD14) and Aqua (MYD14) satellites as well as a combined Terra and Aqua (MCD14) satellite product. The sensor resolution is 1 km, and the temporal resolution is daily. The thermal anomalies are represented as red points (approximate center of a 1 km pixel) in the Global Imagery Browse Services (GIBS)/Worldview. Also, as a base layer, the MODIS Normalized Difference Vegetation Index (NDVI). The index is calculated based on how much red and near-infrared light is reflected by plant leaves. The index values range from −0.2 to 1 where higher values (0.3–1) indicate areas covered by green, leafy vegetation, and lower values (0–0.3) indicate areas where there is little or no vegetation. The MODIS rolling 8-day NDVI layer is available as a near real-time, rolling 8-day product (MOD13Q4N) from the Terra satellite. It is created from a rolling 8-day land surface reflectance product, MOD09Q1N. The sensor resolution is 250 m, imagery resolution is 250 m, and the temporal resolution is an 8-day product which is updated daily. Available at: https://worldview.earthdata.nasa.gov/.(For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

ecotourism, increased exposure through hunting, or owning pets. Also, certain culinary habits, industrialization sequelae such as farming/food chain intensification, globalization of trade, human intrusion into ecosystems and urbanization are relevant [8,13]. Significant alterations in political regimes, conflict with accompanying breakdown of public health and surveillance infrastructure, voluntary or involuntary immigration also impact the situation. Besides that, border controls, and hierarchy issues impacting decision-making, and scientific advances that allow easier detection of zoonotic infections and evolution of novel susceptible immunocompromised populations also play key roles [8].

Pathogen-related factors include alterations in ecosystems and biodiversity that determine the selection of local fauna, favoring the expansion of hosts or disease vectors, pressure for virulence/resistance selection and genomic variability [8], which can result in a jump in the species barrier as a determinant of the emergency/reemergence of human diseases especially zoonotic infections. This has already occurred with the virus involved in the yellow fever epidemic in the Amazon rainforest of Brazil and its neighbors. Countries, which share what is called the Pan Amazon, such as Bolivia, Colombia, Ecuador, Peru, and Venezuela have been affected by the ongoing wildfires from Brazil which are even moving close to urban and periurban areas as in Bolivia [1,2,6,14].

Likewise, water scarcity, unplanned urbanization, temperature fluctuations, among other climatic conditions, the conversion of land use, illegal mining, the consumption of wild animal meat, in addition to deforestation, are present after these wildfires of the Amazon rainforest. All of them have been associated with increases in vector-borne, water-borne and zoonotic diseases, including diarrheal diseases, hantavirus pulmonary syndrome [10], West Nile virus infection, chikungunya [3,4], leptospirosis [15], cryptosporidiosis, malaria, typhoid, cholera, lymphatic filariasis, leishmaniasis [13,16], Chagas disease, yellow fever, plague [17], among others. In the case of leishmaniasis, resolution of emerging issues will necessitate a 'One Health' approach to co-ordination of resources between human and veterinary healthcare, including the role of mass migrations of human and canine populations, with incursion into novel environments (e.g. related to deforestation) coupled with a background of poverty and poor public health infrastructure. In Chagas disease studies in Colombia, oil palm plantation establishment had the potential to impact Chagas disease transmission by increasing the distribution range of *Rhodnius prolixus*. Studies have reported *Trypanosoma cruzi* natural infection in *R. prolixus* captured in oil palms (*Elaeis guineensis*) in the Orinoco region, Colombia [18].

For arboviral diseases, viruses and vectors have adaptable to different conditions of climate change [11]. The displacement of mosquitoes, such as those species of the genus *Aedes*, could enable arboviruses to become endemoepidemic at urban and periurban areas as a consequence of the shift derived from wildfires. It is worthwhile to mention that many cities in Latin America are located in ecotones located between the classification of urban and periurban areas, today a frontier of weak definition, that allow viral geographic change [11].

In 1997/1998, slash-and-burn deforestation resulted in the formation of a severe haze that blanketed much of Southeast Asia in the months directly preceding the Nipah virus disease outbreak. That was exacerbated by a drought-driven by the severe 1997–1998 El Niño Southern Oscillation (ENSO) event, suggesting that this series of events led to a reduction in the availability of flowering and fruiting forest trees for foraging by fruitbats. This culminated in an unprecedented encroachment of fruitbats into cultivated fruit orchards in 1997/1998. These anthropogenic events coupled with the location of piggeries in orchards and the design of pigsties allowed transmission of a novel paramyxovirus from its reservoir host to the domestic pig and ultimately to the human population. In the Americas, bats, including fruitbats, would carry rabies, dengue, and other viruses and pathogens [14,19].

Deforestation of tropical forests is one cause of increasing contact between wildlife and humans [8]. However, the mechanics of disease emergence are complex and dynamic, being influenced by varying parameters that can roughly be categorized as human-related, pathogen-related, and climate/environment-related. There is a significant interplay between these factors [8]. Additionally, the loss of biodiversity constitutes a barrier to develop new drugs against communicable or zoonotic diseases. Since these bioactive principles are found in the flora of the Amazon. Less than 10% of biodiversity has been evaluated for its pharmacological potential. For example, Brazil has the most significant number of plants with active ingredients studied against malaria parasites [20].

What is going on right now in Brazil (Fig. 1), is a matter of concern for the world, including the uncertainty of future emerging and reemerging vector-borne and zoonotic diseases. Environmental, animal and human health, are connected, related and inter-dependent. A "One health" approach is of crucial importance to understand how the wildfires in the Amazon rainforest in Brazil could affect animal, human and environmental health, and for planning and executing measures to mitigate the consequences and challenges the situation imposes [9].

In addition to the situation in Brazil, let us not forget that deforestation, in other Latin American countries, and abroad, is also happening, as consequence of multiple factors and with multiple consequences including the reemergence of vector-borne and zoonotic diseases [1–3,8,12,13]. This is the case also of Colombia, Bolivia, Peru, and probably Venezuela, among others. Brazil burning will have local and global consequences.

Conflicts of interest

None.

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