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The Grass Was Greener - Climate Change, One Health, and the High Hopes to Mitigate COVID-19, Avian Influenza, and other Zoonotic Emerging Diseases

D. Katterine Bonilla-Aldana[1], Álvaro A. Faccini-Martínez[2], Darío A. Vallejo-Timaran[3], Flor de María Bocanegra-Viteri[4], Julian Ruiz-Saenz[5], Alberto E. Paniz-Mondolfi[6,7], Alfonso J. Rodriguez-Morales[4,8]*, and Jose Antonio Suárez[9]

[1]*Semillero de Investigacion en Zoonosis (SIZOO), Grupo de Investigación BIOECOS, Fundacion Universitaria Autonoma de las Americas, Pereira, Risaralda, Colombia.*
[2]*Department of Pathology, University of Texas Medical Branch, Galveston, TX, USA.*
[3]*Grupo de Investigación GISCA, Faculty of Veterinary Medicine and Zootechnics, Fundación Universitaria Autónoma de las Americas, Medellín, Antioquia, Colombia.*
[4]*Masters in Climate Change, Universidad Cientifica del Sur, Lima, Peru.*
[5]*Grupo de Investigacion en Ciencias Animales, Universidad Cooperativa de Colombia, Bucaramanga, Santander, Colombia.*
[6]*Department of Pathology, Molecular and Cell-Based Medicine, Laboratory of Microbiology, Icahn School of Medicine at Mount Sinai, New York, New York, United States of America.*
[7]*Instituto de Investigaciones Biomédicas IDB/Incubadora Venezolana de la Ciencia, Barquisimeto, Venezuela.*
[8]*Grupo de Investigacion Biomedicina, Faculty of Medicine, Fundacion Universitaria Autonoma de las Americas, Pereira, Risaralda, Colombia.*
[9]*Investigador SNI Senacyt Panamá, Clinical Research Deparment, Instituto Conmemorativo Gorgas de Estudios de la Salud, Panamá City, Panama*

*Corresponding author`s Email: alfonso.rodriguez@uam.edu.co; ORCID: 0000-0001-9773-2192

EDITORIAL
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Over the last decades, global warming has significantly affected the world's climate, negatively impacting numerous ecosystems (Cardenas et al., 2006; Beyer et al., 2021; Dupraz and Burnand, 2021). The accumulating influences of climate change, including the rise of the earth's surface temperature and sea level as well as melting glaciers among many other direct and indirect effects (Calel et al., 2020; Harvey et al., 2020), are reshaping, not only the ecological landscape of many world regions, but also setting the stage for emerging diseases sceneries. Floods, droughts, hurricanes (Zambrano et al., 2021), heat waves and surging fires across all continents (Bonilla-Aldana et al., 2019) are all part of the human-driven fingerprint that has led to climate change (Figure 1). These effects have also resulted in a massive reduction of vegetation across many regions around the globe. As the legendary British rock 'n' roll band Pink Floyd once sang in their most celebrated song "*High Hopes*", *"…the grass was greener…"* (Pink Floyd, *dixit*), framed in an environmental context these lyrics should call for a reflection on how climate change is leaving its mark on earth's landscape.

Accelerating climate change is not only affecting human health but also animal health in ways that if left uncontrolled could trigger the emergence/reemergence of climate-sensitive pathogens, vector-borne, and zoonotic diseases (Rodriguez-Morales, 2013; Chowdhury et al., 2018; Chowdhury et al., 2020) (Figure 1). Potential emerging pathogens include most importantly viruses, like the recently evolving Severe Acute Respiratory Syndrome coronavirus 2 (SARS-CoV-2) pandemic for which a number of environmental and climate-related changes appear to have paved its way from animals to human transmission (Yan Yam, 2020).

Possible causes influencing climate-related pathogen emergence include human transgression on wildlife habitats and wildlife exploitation which may lead to increased human-animal, and animal-animals interactions (Figure 1), creating opportunities for pathogens to spill over among species (Yan Yam, 2020). Additionally, the loss of biodiversity compounded by climate change reduces the interface between animals for disease transmission, which increases chances for pathogen exposure and spread to humans, and consequently, potential outbreaks (Escalera-Antezana et al., 2020), epidemics, and even pandemics, as recently seen with the SARS-CoV-2 causing the Coronavirus Disease 2019 (COVID-19) (Dhama et al., 2020).

On the other hand, the impact of environmental deleterious human activities, such as deforestation can lead to an increase or shift of selection pressures on different pathogens, particularly viruses (Kalbus et al., 2021; Laporta et al., 2021), Figure 1). Such is the case of SARS-CoV-2, whose origin remains largely unknown (Mohammed, 2021; The Lancet Infectious, 2021) although recent findings have revealed that 96.2% of its genome shares similarities with bat-

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related coronaviruses; thus, suggesting its probable origin from Chiroptera (Zhou et al., 2020; Bonilla-Aldana et al., 2021). A similar scenario was previously recorded in 1997-1998 with the emergence of the Nipah virus (Uppal, 2000; Chua et al., 2002) following an event of slash-and-burn deforestation that led to a severe haze across much of Southeast Asia and consequent bat (*Pteropus*) invasions to fruit orchards lying in close proximity to swineherds, which ultimately led to spread amongst pigs followed by cross-species transmission to humans (Breed et al., 2010; Bonilla-Aldana et al., 2019).

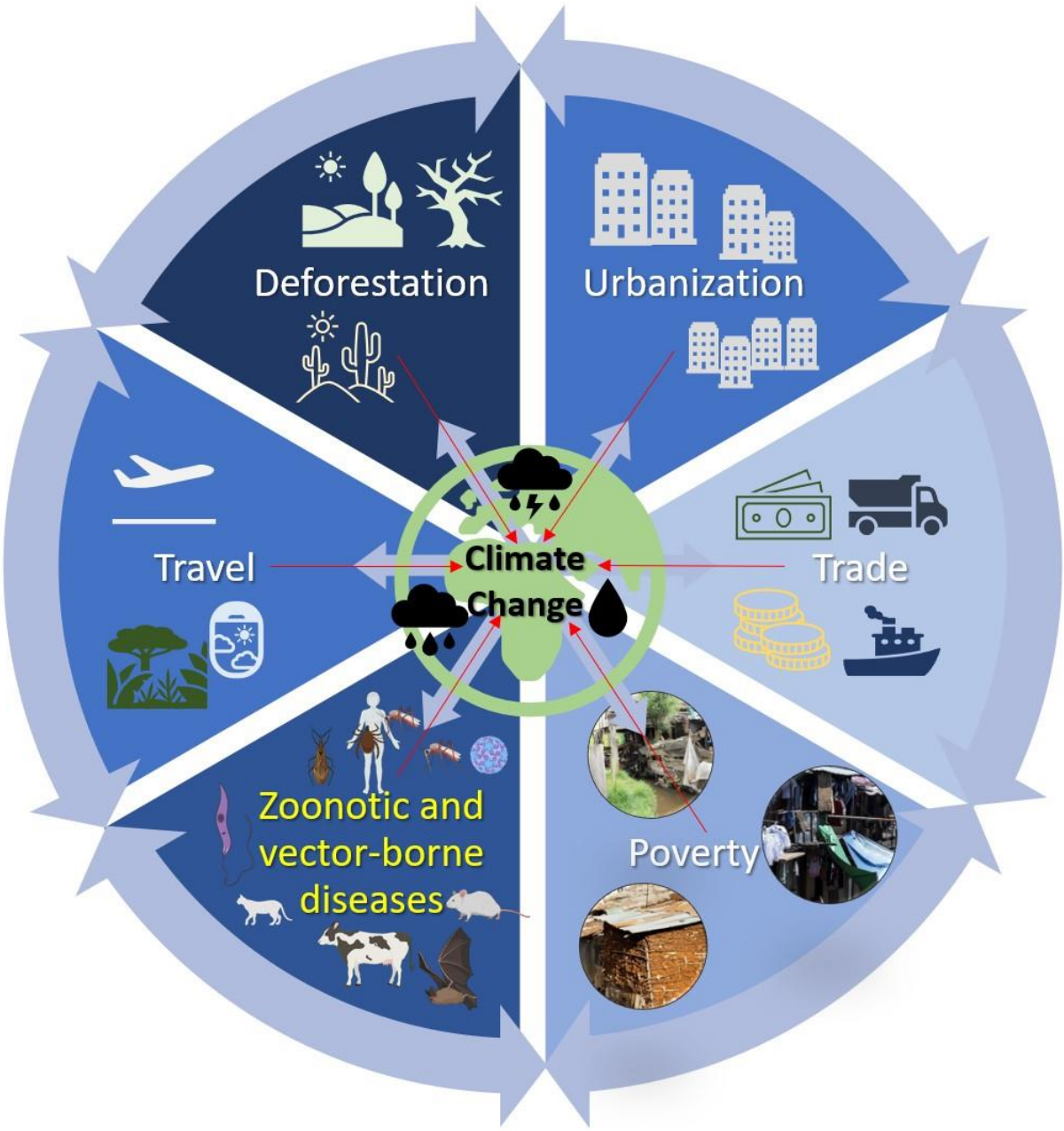

Figure 1. Some selected factors interacting with climate change, and their potential impacts on zoonotic and vector-borne diseases.

In addition, climate change can also influence the incidence and severity of multiple infectious diseases by affecting vector ecology and competency as well as host immune responses. Certain zoonotic respiratory infections may arise in previously spared geographical areas, influenced by a number of climatic causes derived from global warming (Mirsaeidi et al., 2016). An example of this includes avian influenza viruses, which are raising red flags after recent reports on the circulation H5N6, H5N8 (Bonilla-Aldana et al., 2020a), and recently H10N3 (ProMedMail, 2021b). In particular, avian influenza H5N8 has been linked to recent outbreaks in poultry farms and amongst wild birds and humans. More recently, the World Health Organization (WHO) alerted about the detection of avian influenza (H5N8) in seven poultry farm workers from Astrakhan Oblast in the Russian Federation (ProMedMail, 2021a; European Food Safety et al., 2021). Likewise, in December 2020, experts from the UK Plant Health Agency (APHA) laboratory isolated

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H5N8 influenza virus during post-mortem analysis performed on common seals (*Phoca vitulina*), a grey seal (*Halichoerus grypus*), and a red fox (*Vulpes vulpes*) from a wildlife rehabilitation center (Zambrano et al., 2021; ProMEDmail, 2021c). Now, in June 2021, a human case due to H10N3 has been reported in China (ProMedMail, 2021b).

Climate change is affecting all areas of society by negatively modulating environmental determinants of both human and animal health, and will continue to do so for generations. The current COVID-19 pandemic is probably associated with the impacts of climate change, due to land use and changes in the interactions between bats and intermediate hosts of coronaviruses. This emphasizes the importance of a One Health approach to tackle the numerous serious ongoing environmental challenges (Bonilla-Aldana et al., 2020b; Bonilla-Aldana et al., 2020c). Given the broad diversity of pathogens affecting wildlife and their continuous evolution, forecasting pathogen emergence through interdisciplinary networking has become the best strategy to reduce the risk of future outbreaks. Efforts to prevent disease emergence should also be emphasized in study areas, such as pathogen surveillance, pathogen-human interaction, and drivers of cross-species transmission. This is the only way we will be able to transit "... along the long road and on down the causeway" (Pink Floyd, *dixit*) of the multiple challenges imposed by climate change and its impact on human-animal disease ecology. Looking into the future, we have "high hopes" that humankind will manage to restore its carbon footprint while allowing to mitigate further impacts on climate change and reducing the risk of future pandemics of zoonotic origin.

DECLARATIONS

Authors' contributions

DKBA and AJRM conceived the review, developed the first draft of the manuscript. ÁAFM, DAVT, FMBV, JRS, AEPM, and JAS, critically reviewed the manuscript for relevant intellectual content. All authors have read and approved the final version of the paper.

Competing interests

All authors report no potential conflicts.

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