



## Review

## Pathways linking climate change and HIV/AIDS: An updated conceptual framework and implications for the Philippines



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## ABSTRACT

As we commemorate the 40th anniversary of the discovery of Human Immunodeficiency Virus (HIV) while fighting the ongoing COVID-19 pandemic, another global crisis - climate change - is threatening the progress achieved so far in the global fight against HIV/AIDS. The climate emergency is anticipated to generate dire health consequences worldwide in the coming decades. While the pathways that link climate change and different disease areas are better understood, the connection between climate change and HIV/AIDS is still yet to be recognized both in research and practice. In this review, we update one of the frameworks on the HIV-climate nexus described in earlier literature. Four major pathways have been identified: extreme weather events; sea level rise; changes in precipitation and temperature; and increased air pollution. These pathways impact the spectrum of HIV/AIDS-related outcomes through changes in social systems, healthcare disruption, and other climate-sensitive diseases, influenced by the social determinants of health. We also reflect on the significance of this updated framework for the Philippines, a country that is both highly vulnerable to the climate crisis and facing a rising HIV/AIDS epidemic. The framework can aid countries like the Philippines in filling gaps in research, policy, and program design to mount climate-adaptive HIV/AIDS responses. The HIV/AIDS and climate justice movements must also join forces in calling for accelerated worldwide decline in greenhouse gas emissions from all sectors to stabilize the global climate - this will benefit not just people affected by HIV/AIDS but everyone.

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## 1. Introduction

While the world is still wrestling with the COVID-19 pandemic, this year, 2021, also marks the 40th anniversary since the first cases of human immunodeficiency virus (HIV) were reported as a cluster of *Pneumocystis carinii* pneumonia among previously healthy gay men in Los Angeles [1]. Since then, there have been 36 million who have died of acquired immunodeficiency syndrome (AIDS) globally with 38 million living with it today [2]. Global efforts to halt HIV transmission have achieved significant progress in terms of decreasing new HIV infections, AIDS-related deaths, and costs for antiretroviral therapy (ART) [3]. However, the burden of HIV in some countries still remains significantly high due to limited availability of HIV prevention programs, testing services, and treatment [4].

In addition to COVID-19, the global HIV/AIDS epidemic also persists against the backdrop of another global crisis - climate change. The climate emergency is anticipated to generate dire health consequences worldwide in the coming years and decades. While the pathways that link climate change and different disease areas are better understood, the connection between climate change and HIV/AIDS is still yet to be recognized both in research and practice. Over the past decade, there have been a few attempts to describe the linkages between climate change and HIV/AIDS [5,6]. Overall, the pathways linking the two are more indirect, as there is neither plausible explanation nor evidence of climate change's direct influence on the virus itself, unlike its impacts on the behavior of pathogen-bearing mosquitoes for instance [7]. Moreover, the previously described frameworks either presented more generic pathways, such as how extreme weather events can lead to forced displacement of populations which can hamper access to HIV/AIDS treatment, or described only a select number of linkages and missed other important ones [8].

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In this review, we provide an update of the earlier frameworks described in previous academic papers and reports in gray literature that were published during the past decade. In particular, we elaborate on the framework described by Lieber et al. and add new pathways and more granular information based on recent scientific literature and emerging discourses [5]. We also reflect on the relevance of our newly-constructed framework to the Philippines, which is one of the world's most climate-vulnerable countries with the fastest rate of new HIV cases in the World Health Organization's Western Pacific Region [9,10].

## 2. Methodology

We performed a rapid literature search of academic journals in PubMed and Google Scholar between March 9 and April 9, 2021. The review was restricted to English-language academic publications from 2006 to 2021. The search terms include [“(HIV” OR “AIDS” OR “HIV/AIDS” OR “human immunodeficiency virus”) AND (“climate change” OR “global warming” OR “climate emergency” OR “natural disasters”)]. Articles were screened by title, abstract, or full-text review to identify major pathways by which HIV/AIDS and climate change interact. The initial set of themes that were found were food insecurity, air pollution, drought, flooding, and infectious diseases. A second search from April 9 to April 15, 2021 was done to look for articles linking the proposed pathways from the first search to HIV/AIDS. Search terms include [“(HIV” OR “AIDS” OR “HIV/AIDS” OR “human immunodeficiency virus”) AND (“food insecurity” OR “air pollution” OR “drought” OR “flooding” OR “infectious disease”)]. An additional search for sea level rise from August 29 to September 5, 2021 was conducted because of its significance to the Philippines which is facing one of the fastest rates of sea level rise in the world [11]. Specific pathways from the additional searches were compiled and synthesized into a conceptual framework. The framework by Lieber et al. was used as a skeleton for the updated framework [5].

## 3. Results

### 3.1. An updated conceptual framework

Fig. 1 shows the conceptual framework depicting the multiple pathways that link climate change and HIV/AIDS. This updated framework has four main features. First, by expanding on and

combining previously proposed frameworks, four major pathways driven by environmental changes generated by the climate crisis are described [5]. These pathways include extreme weather events such as droughts, storms, flooding, and heatwaves; sea level rise; changes in precipitation and temperature; and increased air pollution. Oftentimes, only the impact of extreme weather events on the delivery of HIV services is acknowledged as the main climate-related issue affecting HIV/AIDS, and other pathways are ignored. Second, the granular steps that connect major climate-related health phenomena and HIV/AIDS are identified in greater detail. As earlier mentioned, climate-related environmental phenomena do not have a direct effect on the virus or HIV/AIDS-related clinical outcomes. Instead, they create significant alterations in the proximal environment, social systems, and human behavior, which then lead to indirect effects on the HIV/AIDS epidemic [12]. While the diagram shows linear yet interconnected pathways for clarity, it is important to remember that in reality, these pathways and their different steps interact in complex and multidirectional ways.

Third, the spectrum of HIV/AIDS-related outcomes that will be impacted by different climate change pathways is elaborated. As previously discussed, climate change does not directly influence the HIV virus, but the changes that it generates in environmental and social systems eventually impact the whole sequelae of the HIV/AIDS experience from viral transmission and acquisition to disease progression and mortality [13]. Finally, the role of the social determinants of health in both increasing climate vulnerability and worsening HIV/AIDS-related outcomes is emphasized. The health impacts of both climate change and HIV/AIDS are unevenly distributed in society, and such inequalities are driven by a wide array of social stratifiers such as gender, race, employment, and geographic location, among others [14]. These social determinants operate in the different pathways of the climate-HIV nexus as well as in the different levels. An integrated, multisectoral, and equity-focused approach is therefore critical to tackling HIV/AIDS in the climate era.

This revitalized framework primarily builds on the work of Lieber et al. [5]. However, in addition to the features described above, there are a few more differences and modifications. First, this framework focused solely on the impact of climate change on HIV/AIDS, and did not include the reverse - for instance, how HIV/AIDS care can contribute to greenhouse gas emissions leading to further worsening of the climate crisis. Including this dimension will make the framework much more complicated and more difficult to be used in practice,

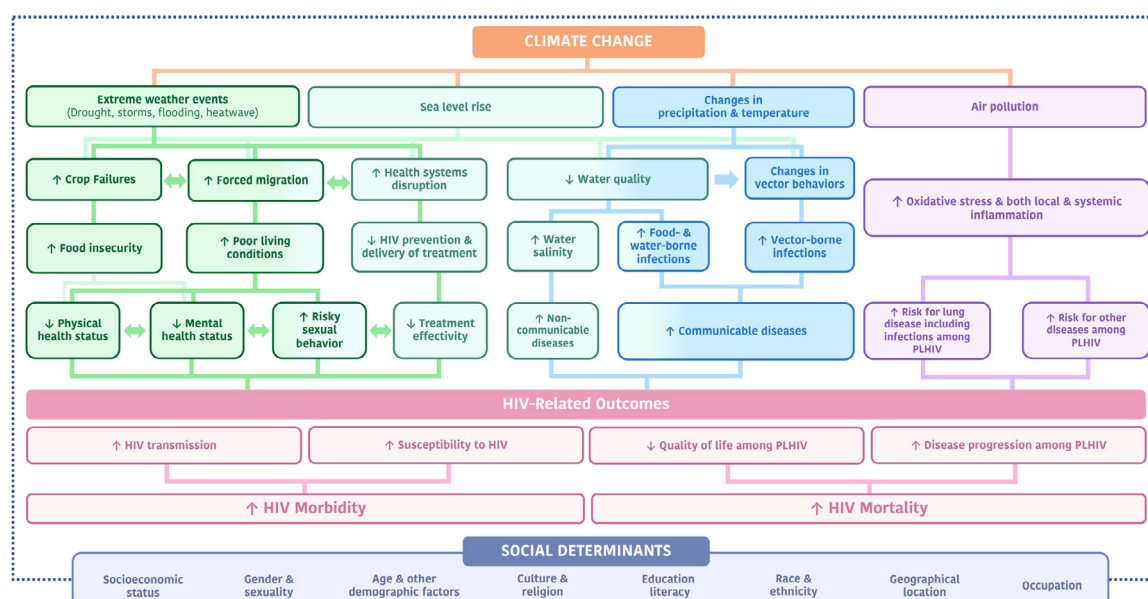


Fig. 1. Pathways Linking Climate Change and HIV/AIDS.

especially for HIV/AIDS programs in climate-vulnerable settings. It could be therefore said that this framework focuses more on climate adaptation for HIV/AIDS programs, but the important role of climate mitigation within the health sector is in no way underestimated. Moreover, other large-scale ecosystem changes such as biodiversity loss and land use change were also excluded from this framework. While these ecosystem alterations are also related to climate change in different ways, they also have their own causes and consequences and will entail the inclusion of additional pathways, making the framework much more complicated and too expansive for HIV/AIDS programming.

### 3.2. Pathways linking climate change and HIV/AIDS

#### 3.2.1. Extreme weather events

One of the major impacts of climate change is the increase in frequency and severity of extreme weather events in different regions of the world. Examples of these are droughts, storms, flooding, and heatwaves. These abrupt yet catastrophic phenomena create massive disruptions in various aspects of communities. In the case of HIV/AIDS, there are at least three main aspects where disruptions can be anticipated, which can have grave consequences for communities affected by HIV/AIDS. First, such extreme events affect food production, either by inundating agricultural lands or lowering soil moisture, which then diminishes crop yield eventually leading to food insecurity [14,15]. Reduced access to a steady supply of nutritious food is detrimental to overall physical and mental health. Malnutrition leads to a compromised immunological system, which then would result in increased susceptibility to infections among already immunocompromised patients living with HIV [16].

Extreme weather also can destroy human settlements and forcibly displace communities [5]. Climate migrants then stay in new locations, which could be temporary shelters or evacuation centers, or other host communities that oftentimes have similarly dire conditions. In these settings, there could be food shortage, lack of water, sanitation, and hygiene facilities, and limited employment, which are key proximal determinants of physical and mental health of people including those affected by HIV/AIDS. Physical space is also constrained, while overcrowding and social tensions can create the conditions for risky sexual behavior, which can contribute to increased HIV transmission. Health services in temporary settlements are very basic and limited, while the capacity to deliver care in host communities may be overwhelmed. In both situations, access to HIV prevention and treatment services are very limited, if not lacking at all.

Lastly, these extreme weather events can also erode the public health infrastructure of a community [17]. Flooding and severe storms can destroy clinics, hospitals, and transportation networks. The disruption of healthcare infrastructure can decrease access to healthcare among people living with HIV (PLHIV), including life-saving ART.

#### 3.2.2. Sea level rise

Sea level rise (SLR) is another major consequence of climate change, which especially impacts communities and infrastructure found along coastlines [18,19]. In contrast to extreme weather events, SLR is insidious, slow in onset and subtle in effects, and is primarily driven by three factors: ocean thermal expansion, melting of glaciers and ice sheets, and changes in terrestrial water storage [18]. A one-meter rise in the sea level can bring catastrophic effects such as submergence of agricultural lands, human settlements, and infrastructure. Many of the impacts of SLR on affected communities are similar to those driven by extreme weather events - food insecurity, forced displacement, and healthcare access disruption.

In addition, SLR also leads to the intrusion of saltwater into bodies of freshwater, which are an important source of drinking water to coastal communities [20]. There is growing evidence of the myriad

health impacts of consumption of highly salinized water resulting from SLR [21,22]. Rise in hypertension, preeclampsia, and kidney disease were noted among communities consuming water high in salt content due to SLR [23]. Moreover, outbreaks of water-borne, vector-borne, and food-borne diseases were also noted to increase, which threatens the health status of people, particularly those living in the coastlines [24,25,26]. While these impacts will be generally felt by all people in coastal communities, the health of PLHIVs can potentially be more harmed because of their weakened immune systems.

#### 3.2.3. Changes in temperature, precipitation, and water quality

Another major effect of climate change is the increase in ambient temperature. This in turn results in the subsequent rise in ocean heat storage and sea surface temperatures, which lead to greater evaporation of water into the atmosphere [27]. Eventually, the rate of precipitation rises as well [27].

Higher temperature and precipitation levels in turn have negative impacts on water quality in bodies of water. Studies suggest that an increase in surface water temperature causes dissolved oxygen levels to drop, phosphate levels to rise, and phytoplankton growth surges to occur, all leading to compromised water quality [28,29]. Meanwhile, increases in either the amount or frequency of precipitation also leads to soil degradation [30]. The capacity of soil to absorb nutrients, pesticides, and other substances is thereby reduced, which ultimately degrades water quality as well [31].

The interplay between changes in temperature, precipitation, and water quality creates the conditions for the emergence and spread of climate-sensitive infectious diseases. For instance, poor water quality promotes the spread of water-borne and food-borne diseases such as, but not limited to, typhoid, cholera, Shigella, leptospirosis, amoebic dysentery, schistosomiasis, Guinea worm, and viral hepatitis [32]. Compared to the general population, PLHIVs are more susceptible to contracting these climate-sensitive diarrheal pathogens as well as facing a higher risk of severe outcomes due to their weakened immune system [33,34]. Access to clean water and sanitation facilities must therefore be prioritized in areas with high prevalence of HIV/AIDS and high levels of climate vulnerability.

Meanwhile, changes in the behavior of disease vectors, particularly mosquitoes, are another effect of temperature, precipitation, and water quality alterations. For instance, high temperature accelerates the larval development of *Anopheles gambiae* s.s. mosquitoes, a vector for malaria [35]. Moreover, higher levels of precipitation are found to accelerate the population growth of mosquitoes carrying dengue, scrub typhus, and Japanese encephalitis, thereby facilitating their rapid spread [32]. Similar with water- and food-borne diseases, mosquito-borne diseases can result in more aggressive presentations of vector-borne infections in PLHIVs [36].

#### 3.2.4. Increased air pollution

Another pathway that links climate change to HIV/AIDS is air pollution. Unlike the earlier pathways, climate change does not directly cause air pollution, although the two have mutually reinforcing effects. Instead, the sources of greenhouse gas emissions, such as fossil fuel burning electricity generation and transportation, are also the same sources of air pollutants such as particulate matter, nitrogen oxides (NOx) and sulfur dioxide (SO<sub>2</sub>). Exposure to air pollution is a major risk factor for a wide range of chronic non-communicable diseases including heart disease, asthma exacerbations, chronic obstructive pulmonary disease (COPD), and lung cancer [37]. When exposed to high levels of air pollution, HIV patients can be more susceptible to acquiring these diseases as well as suffering from more severe outcomes. The main mechanism through which air pollution brings about or exacerbates cardiorespiratory diseases is through local and systemic inflammation as well as increased oxidative stress [38,39]. During HIV infection, oxidative stress is much worsened due to enhanced reactive oxygen species (ROS) production in monocytes

and reduction in total antioxidant capacity in CD4<sup>+</sup> and CD8<sup>+</sup> T-lymphocytes [40].

There is limited literature on the effects of air pollution on different organ systems of PLHIVs; hence, more research needs to be conducted. In one study, elevated ambient concentrations of PM<sub>10</sub> and NO<sub>2</sub> were shown to suppress IgM response to recombinant *Pneumocystis jirovecii* major surface glycoprotein leading to longer hospital stays [41]. Although other clinical outcomes (intensive care unit admission, intubation, or in-hospital mortality) were not found to be associated with ambient air pollution, more research is needed for this population group [41]. Among children with perinatal HIV infection, neurocognitive impairment was also linked with chronic exposure to common air pollutants [42]. Elevated subclinical vascular disease was also associated with PM<sub>2.5</sub> exposure among adolescents with perinatally acquired HIV, suggesting the amplifying role of HIV infection in the development of air pollution-induced cardiovascular insults [43]. Air pollution and HIV infection seem to exhibit independent yet synergistic pro-atherogenic mechanisms. When particulate matter is deposited on epithelial cells that line the respiratory tract, cytokine production is induced, which initiates inflammatory signaling cascades that promote atherosclerosis and thrombosis [44]. Meanwhile, HIV infection also accelerates atherosclerosis by oxidative stress, immune activation, and dysregulation of autophagy [45].

### 3.2.5. The role of social determinants of health

There is some documentation of the compounding effects of the social determinants of health in exacerbating outcomes driven by both HIV and climate change, thereby disproportionately affecting vulnerable populations [46–49]. The vulnerability of indigent groups and marginalized sectors to both HIV/AIDS and climate change emanate from inadequate adaptive capacity to respond to environmental and socioeconomic shocks, manifested in the lack of social, financial, and/or physical assets [50]. Gendered disparities are also observed both in HIV/AIDS outcomes and climate-related effects. Women and other sexual minorities in climate-vulnerable locations are disproportionately affected, especially in settings where socially-constructed gender roles determine responsibilities, access to resources, and motivations for risky sexual behaviors such as transactional sex [51]. There is also evidence suggesting that the negative effects of climate change on PLHIVs may also go the other way – poorer health translates to greater dependence on natural resources and ecosystem services, which in turn decreases the capacity of ecosystems to deliver more benefits to people [50]. This is an example of a negative feedback loop that can worsen both HIV/AIDS- and environment-related outcomes in the long run. Because of the unequal distribution of health outcomes in society as they relate to both HIV/AIDS and climate change, tackling this nexus must take into account the myriad social determinants and their vast interconnections.

## 4. Discussion

### 4.1. Case in point: HIV/AIDS and climate change in the Philippines

The previous section elucidated the myriad pathways through which climate change impacts the spectrum of HIV/AIDS-related outcomes. The international community must therefore consider climate change and its effects in the design of HIV research, services, and programs. This is especially true for countries that are gravely affected by both crises such as the Philippines. The burden of HIV in the Philippines has risen dramatically in recent years. The Joint United Nations Programme on HIV/AIDS (UNAIDS) reported that the total number of HIV infections in the Philippines has increased by 200% from 2010 to 2018, constituting the steepest rise in the Asia-Pacific region. As of the time of writing, there are a total of 53,286 PLHIVs who are presently on ART, the majority being men having sex with men, especially in urban settings [52].

From a climate perspective, the Philippines ranks 4th on the list of countries most affected by climate change from 2000 to 2019 [53]. This high vulnerability to climate change is attributed to its archipelagic geography, tropical location, level of socioeconomic development, and limited adaptive capacity of governance and its institutions. Every year, an average of 20 typhoons hit the Philippines, bringing heavy rainfall, intense flooding, and strong winds, and inflicting enormous damage to communities. Climate change is expected to increase the intensity of these typhoons [54], which can further intensify the amount of damage incurred, for instance in healthcare infrastructure, food systems, and human settlements. Meanwhile, slow-onset effects such as increasing ambient temperature and precipitation as well as sea level rise are also beginning to manifest in the Philippines, all of which can generate the aforementioned health impacts such as the rise in climate-sensitive mosquito- and water-borne diseases. Both the sudden and slow-onset impacts of climate change will have detrimental consequences for the Philippine population, including communities affected by HIV/AIDS. While the country has put in place policies that tackle the climate crisis such as the Climate Change Act and the National Climate Change Action Plan, attention to the climate impacts on the health sector remains limited, most especially for health-vulnerable populations such as PLHIV [55,56].

Direct evidence of climate change's impacts on the HIV epidemic in the Philippines – whether by creating the conditions for increased transmission, disrupting access to care, or increasing susceptibility to other diseases – is still yet to be generated. Hence, the conceptual framework described above must guide future HIV/AIDS research, policy, and program design to ensure that future HIV/AIDS response in the country is climate-adaptive. The major first step is to ensure that future iterations of the Philippines' AIDS Medium Term Plan acknowledge climate change as a pressing threat to national progress towards ending the HIV/AIDS epidemic by 2030, which is the goal articulated in the 2016 United Nations High Level Political Declaration [57,58]. Embedding climate considerations in national HIV/AIDS policy will greatly aid in setting the direction of activities of various stakeholders towards building climate resilience within the HIV/AIDS sector.

Another important task is to establish the baseline vulnerability to climate change of communities affected by HIV/AIDS. Part of this baseline is having a clear assessment of the scope of HIV/AIDS nationally and extrapolating how climate change can worsen this situation in the coming years. UNAIDS estimates that in the Philippines, only 67% of PLHIVs know their status, 55% have CD4 count lower than 200 cells/ $\mu$ L at the time of diagnosis, 32% are on ART, and 82% remain on ART 12 months after treatment initiation [10]. Despite numerous efforts in recent years especially by civil society, HIV testing is still limited in the Philippines. One study showed that the prevalence of HIV testing among Filipino women aged 15–49 is only 2.4% [59]. Low testing rate means more PLHIVs – who can be potentially affected by climate change's impacts – are not being diagnosed and provided care. Future climate catastrophes can further restrict access to limited testing and hamper case detection efforts.

Finally, specific attention to climate change's impacts on PLHIVs can usher the development of new models of care for HIV/AIDS especially in climate-vulnerable geographic areas in the Philippines. For instance, ART is becoming increasingly accessible to Filipinos, as it is already provided in more than 160 government and private treatment facilities situated around the country. However, without anticipatory planning and if supply chain management is not strengthened, ART supply may be disrupted by climate-related extreme weather events. Climate-proofed HIV/AIDS treatment programs will ensure that medication adherence is not interrupted and that disease outcomes for PLHIVs are not worsened despite being affected by such climate-induced calamities.



## 5. Conclusion

For the past forty years, much has been accomplished by the HIV scientific community and activist movement. Unfortunately, as presented above, climate change threatens to undermine the global progress that has been achieved when it comes to curbing the HIV epidemic worldwide. Moreover, climate change, whose impacts are unevenly distributed across populations, can further widen these longstanding inequalities in terms of HIV susceptibility, access to care, clinical outcomes, and quality of life. Hence, in mounting joined-up solutions to both the HIV and climate crisis, it is imperative that a strong equity and justice lens is embraced. The human rights framework, which is embraced by both the HIV and climate movements, also provides a strong foundation for collective action. Considering the HIV-climate nexus while in the middle of the COVID-19 pandemic, future health systems will need to be not only pandemic-resistant but also responsive to the healthcare needs of people affected by HIV/AIDS while also resilient to the long-term changes brought about by the climate crisis. The framework described above will serve as a guide for the next generation of researchers and practitioners who will tackle the HIV/AIDS epidemic in the face of a warming planet. Ultimately, the HIV/AIDS and climate justice movements must join forces in calling for accelerated worldwide decline in greenhouse gas emissions from all sectors in order to stabilize the global climate - this will benefit not just people affected by HIV/AIDS but everyone.

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## CRedit authorship contribution statement

**Renzo R. Guinto:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing, Supervision. **Joshua Joel F. Cahatol:** Methodology, Writing – original draft, Writing – review & editing, Visualization. **Kris Yvan Mari S. Lazaro:** Methodology, Writing – original draft, Writing – review & editing. **Anna Flora Natividad Cruz Salazar:** Methodology, Writing – original draft, Writing – review & editing, Visualization.

## Supplementary materials

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