



Climate change and extreme weather events and linkages with HIV outcomes: recent advances and ways forward

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Purpose of review

Discuss the recent evidence on climate change and related extreme weather events (EWE) and linkages with HIV prevention and care outcomes.

Recent findings

We identified 22 studies exploring HIV prevention and care in the context of EWE. HIV prevention studies examined sexual practices that increase HIV exposure (e.g., condomless sex, transactional sex), HIV testing, and HIV recent infections and prevalence. HIV care-related outcomes among people with HIV included clinical outcomes (e.g., viral load), antiretroviral therapy adherence and access, HIV care engagement and retention, and mental and physical wellbeing. Pathways from EWE to HIV prevention and care included: structural impacts (e.g., health infrastructure damage); resource insecurities (e.g., food insecurity-related ART adherence barriers); migration and displacement (e.g., reduced access to HIV services); and intrapersonal and interpersonal impacts (e.g., mental health challenges, reduced social support).

Summary

Studies recommended multilevel strategies for HIV care in the context of EWE, including at the structural-level (e.g. food security programs), health institution-level (e.g., long-lasting ART), community-level (e.g. collective water management), and individual-level (e.g., coping skills). Climate-informed HIV prevention research is needed. Integration of EWE emergency and disaster preparedness and HIV services offers new opportunities for optimizing HIV prevention and care.

Keywords

antiretroviral therapy, climate change, extreme weather events, HIV

INTRODUCTION

There is growing attention to the associations between climate change and related extreme weather events (EWE) and HIV prevention and care outcomes. Climate change and EWE impact HIV affected regions and populations. For instance, more than 54% of people with HIV globally live in Eastern and Southern Africa [1] and these regions are also at elevated risk for precipitation extremes, [2] experiencing annual drought with increased duration and intensity [3], and rainfall changes [4]. Growing evidence in Sub-Saharan Africa links EWE to HIV acquisition risks. For instance, drought and flooding are associated with HIV risks such as transactional sex [5⁶], and multiple sex partners [7⁸]. In Sub-Saharan Africa, drought is also associated with lower antiretroviral therapy (ART) adherence and worse HIV clinical outcomes among people with HIV [8⁹].

A comprehensive review of global recent literature focused on climate change, EWE, and pathways to HIV prevention and care outcomes is lacking. Reviews that have provided an important

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KEY POINTS

- Extreme weather events, such as drought and flooding, were associated with poorer HIV prevention outcomes, including reduced HIV testing, increased sexual practices that elevate HIV acquisition risks (e.g., condomless sex, transactional sex), and increased odds of recent HIV infection.
- HIV care outcomes worsened in the context of extreme weather events, including reduced viral suppression, reduced antiretroviral therapy adherence, disruptions to HIV care, and worse wellbeing (e.g., mental and physical health challenges).
- Mechanistic pathways from climate change and extreme weather events to HIV prevention and care include structural factors (e.g., damage to health clinics), resource insecurities (e.g., increased food and water insecurity), migration and displacement, and individual and interpersonal challenges (e.g., reduced access to social support).
- Climate-informed interventions, and integration of HIV services with extreme weather event emergency and disaster preparedness, are required to optimize HIV prevention and care.

foundation for understanding these linkages include a systematic review examining EWEs and disruption to HIV care services until 2023 [10], a systematic review examining drought and ART adherence in Sub-Saharan Africa (2003–2019) [9], a systematic review on climate change's health impacts on vulnerable populations in South Africa (2014–2022) [11], and scoping reviews on climate change and sexual health (1997–2022) [12] and sexual and reproductive health in low and middle-income countries (1994–2023) [13]. We searched the literature from January 2022 to August 2024 to understand recent advances in climate change, EWE and HIV prevention and care research globally. Two review authors screened findings across ten databases for relevant articles. We included empirical (qualitative, quantitative, mixed-methods) studies related to HIV and climate change, natural disasters, and/or EWEs. We also hand searched reference lists from eligible studies. We conducted thematic analysis [14] to synthesize articles through refining themes and sub-themes, organizing HIV outcomes broadly into HIV prevention and HIV care outcomes.

FINDINGS

Context and study populations

We include 22 empirical studies identified in this review, including qualitative ($n = 7$), quantitative

($n = 12$), and mixed-methods ($n = 3$) approaches. Our included studies span 29 countries, most in sub-Saharan Africa ($n = 18$) with others in the United States ($n = 2$), Puerto Rico ($n = 1$), and The Bahamas ($n = 1$). The map of countries included in our review is illustrated in Fig. 1.

There were a diversity of climate and EWE issues examined, including drought ($n = 12$), water insecurity ($n = 8$), floods ($n = 5$), seasonal weather changes ($n = 4$), hurricanes ($n = 3$), extreme heat ($n = 1$), wildfire ($n = 2$), and extreme rain ($n = 3$). Table 1 presents an overview of climate change and related extreme weather events and HIV variables examined in the included articles. What is notable, as illustrated in Table 1, is that there were no HIV prevention-related articles addressing three EWE (extreme heat; wildfires; hurricanes and other storms), and there were no specific climate-tailored HIV prevention interventions (only one intervention conducted during an EWE, but not addressing EWE specific issues). For HIV care outcomes, only one article examined extreme heat, and this was in the context of the health workforce, and one examined heavy rain.

Below, we present the key themes identified in the included studies, organized by HIV prevention-related and HIV care-related outcomes.

HIV prevention-related outcomes

Studies exploring the HIV prevention cascade focused on: sexual practices that increase HIV exposure (condomless sex: $n = 4$; transactional sex: $n = 3$; number of sex partners: $n = 2$); HIV testing ($n = 1$); HIV and sexually transmitted infections (STI) infection outcomes (recent STI: $n = 2$, recent HIV infection: $n = 3$, HIV prevalence: $n = 1$); and an HIV prevention intervention ($n = 1$).

Sexual practices that increase HIV exposure

Condom use was explored in the context of drought in a 10-country study in Sub-Saharan Africa (SSA) [15^{***}]. Using nationally representative cross-sectional data, this study found drought exposure was associated with lower likelihood of condom use during the last sexual encounter [15^{***}]. Transactional sex in the context of climate-related and EWE factors was also examined. A study of the effects of the 2015 drought in Malawi on transactional sex and HIV serostatus using population-level data [5^{*}] found that experiencing a 6-month drought doubles the likelihood of engaging in transactional sex for women relying on agriculture, while no effect was observed for women whose main livelihood was not agriculture. A mixed-methods study

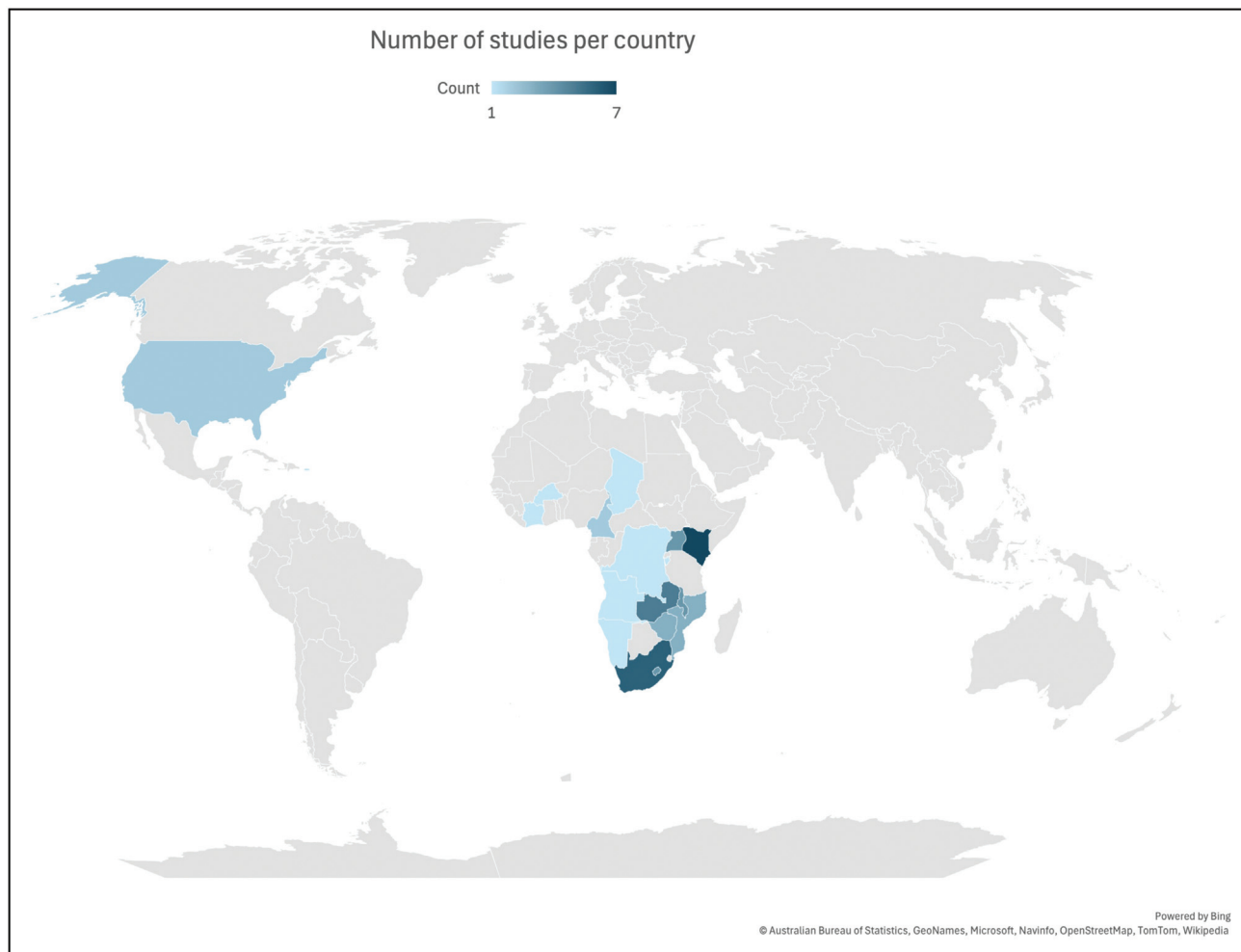


FIGURE 1. Map of countries included in this recent review on climate change, extreme weather events, and HIV.

with urban refugee youth in Kampala, Uganda corroborated this finding, noting that water insecurity was associated with transactional sex in quantitative findings, while flooding and subsequent housing insecurity were also associated with transactional sex in qualitative findings [6].

Number of sex partners was examined in association with drought and heavy rainfall; studies leveraged large, population-based data and found that both of these EWEs were associated with increased sex partners among some population groups. For instance, Epstein *et al.*'s 10 country SSA study found that, among adolescents and persons in rural areas, drought was associated with a greater number of past-year sex partners [15²²]. Nagata *et al.*'s [7²³] investigation of the association between heavy rainfall and number of sex partners used cross-sectional population-based data from 21 SSA countries over 12 years, finding an association between heavy rainfall and higher number of sex partners.

HIV testing

One study examined HIV testing in the context of drought. This 10-country study [15²²] found that respondents exposed to drought were less likely to have an HIV test in the past 12 months, and this effect was modified by sex and age, in that it was strongest among men, people in urban settings, and adolescents. Authors hypothesize multiple potential pathways from drought to reduced testing, including increased food insecurity and economic hardship, increased mental health challenges and interpersonal violence, increased migration, and impacts on health infrastructure, for instance, extreme heat during drought that can disrupt power, heating, and/or cooling, reducing ability to access testing [15²²].

HIV and STI infection outcomes

HIV and sexually transmitted infections (STI) were examined in relationship to both drought and flooding. A study of the associations between

Table 1. Overview of climate change and related extreme weather events and HIV variables examined in a review of recent articles from 2022–2024

	Drought	Floods	Extreme heat	Wildfire	Hurricane & other storms	Extreme/heavy rain	Water insecurity	Seasonal weather changes	Climate adapted /informed Intervention
HIV prevention outcomes									
Condom use (n=4)	Epstein <i>et al.</i> , 2023 [15 ^{***}] Trickey <i>et al.</i> , 2024 [16 ^{**}]	Logie <i>et al.</i> , 2024 [6]					Logie <i>et al.</i> , 2024 [6]		Deveaux <i>et al.</i> , 2022 [17]
Transactional sex (n=3)	Treibich <i>et al.</i> , 2022 [5] Trickey <i>et al.</i> , 2024 [16 ^{**}]	Logie <i>et al.</i> , 2024 [6]					Logie <i>et al.</i> , 2024 [6]		
Number of sex partners (n=2)	Epstein <i>et al.</i> , 2023 [15 ^{***}]					Nagata <i>et al.</i> , 2022a [7 ^{***}]			
HIV testing (n=1)	Epstein <i>et al.</i> , 2023 [15 ^{***}]								
HIV risk: recent STI (n=2)	Treibich <i>et al.</i> , 2022 [5 ^{**}]					Nagata <i>et al.</i> , 2022a [7 ^{***}]			
HIV prevalence, recent HIV infection (n=3)	Treibich <i>et al.</i> , 2022 [5 ^{**}] Trickey <i>et al.</i> , 2024 [16 ^{**}]					Nagata <i>et al.</i> , 2022a [7 ^{***}]			
HIV prevention intentions (n=1)									Deveaux <i>et al.</i> , 2022 [17]
HIV care related outcomes									
HIV clinical outcome: viral load (n=5)	Trickey <i>et al.</i> , 2023 [8 ^{***}]				Hernández <i>et al.</i> , 2023 [19]		Nagata <i>et al.</i> , 2022b [18] Palmer <i>et al.</i> , 2024 [29]		Cohen <i>et al.</i> , 2022 [30 ^{***}]
HIV clinical outcome: CD4 (n=4)	Trickey <i>et al.</i> , 2023 [8 ^{***}]				Hernández <i>et al.</i> , 2023 [19]		Nagata <i>et al.</i> , 2022b [18] Palmer <i>et al.</i> , 2024 [29]		Cohen <i>et al.</i> , 2022 [30 ^{***}]
HIV clinical outcome: AIDS defining illness (n=2)							Nagata <i>et al.</i> , 2022b [18]		
HIV clinical outcome: mortality among people with HIV (n=1)	Trickey <i>et al.</i> , 2023 [8 ^{***}]						Nagata <i>et al.</i> , 2022b [18]		Cohen <i>et al.</i> , 2022 [30 ^{***}]
HIV care: ART access and adherence (n=9)	Iwujii <i>et al.</i> , 2023 [20 ^{**}] Orievulu <i>et al.</i> , 2022 [22] Orievulu & Iwujii, 2022 [23]	Tran <i>et al.</i> , 2023 [25]		Saberi <i>et al.</i> , 2023 [24 ^{**}]	Hernández <i>et al.</i> , 2023 [19]		Nutor <i>et al.</i> , 2024 [21] Palmer <i>et al.</i> , 2024 [29]		Cohen <i>et al.</i> , 2022 [30 ^{***}]
HIV care: retention in care/access to care/care engagement (n=7)	Iwujii <i>et al.</i> , 2023 [20 ^{**}] Orievulu <i>et al.</i> , 2022 [22] Orievulu & Iwujii, 2022 [23] Trickey <i>et al.</i> , 2023 [8 ^{***}]	Tran <i>et al.</i> , 2023 [25]		Saberi <i>et al.</i> , 2023 [24 ^{**}]			Orievulu <i>et al.</i> , 2022 [22] Orievulu & Iwujii, 2022 [23]		Cohen <i>et al.</i> , 2022 [30 ^{***}]
HIV care: disruption to service provision/delivery/workforce (n=4)	Moran <i>et al.</i> , 2023 [26] Orievulu & Iwujii, 2022 [23]	Moran <i>et al.</i> , 2023 [26] Tran <i>et al.</i> , 2023 [25]	Moran <i>et al.</i> , 2023 [26]	Moran <i>et al.</i> , 2023 [26] Saberi <i>et al.</i> , 2023 [24 ^{**}]	Moran <i>et al.</i> , 2023 [26]			Moran <i>et al.</i> , 2023 [26]	
Wellbeing (mental, emotional, physical) and coping among people with HIV (n=10)	Beyeler <i>et al.</i> , 2023 [27] Orievulu <i>et al.</i> , 2022 [22] Orievulu & Iwujii, 2022 [23] King <i>et al.</i> , 2023 [28]	Beyeler <i>et al.</i> , 2023 [27] Tran <i>et al.</i> , 2023 [25]		Saberi <i>et al.</i> , 2023 [24 ^{**}]	Beyeler <i>et al.</i> , 2023 [27]		King <i>et al.</i> , 2023 [28] Palmer <i>et al.</i> , 2024 [29]		Cohen <i>et al.</i> , 2022 [30 ^{***}] Ouvor <i>et al.</i> , 2024 [32 ^{**}] Weiser <i>et al.</i> , 2024 [31 ^{**}]

drought and HIV transmission using population-level data from men and women aged 15–59 in Eswatini, Lesotho, Tanzania, Uganda, and Zambia [16[¶]] found that women in rural areas exposed to drought had higher odds of recent HIV infection after adjusting for demographic and sexual practices, while no effect was observed between women in urban areas or men. Authors posit that women engaged in agriculture may experience drought-related economic shocks that can lead to transactional sex-related coping with men not involved in agriculture, thus less exposed to drought's economic impacts [16[¶]]. Treibich *et al.* [5[¶]] also looked at drought and HIV and STI status in Malawi among women aged 15–49 and men aged 15–54. They found drought was associated with increased likelihood of past-12 month STI symptoms, particularly among women working in agriculture, and that the number of droughts in the past 5 years was associated with higher HIV prevalence among women and men [5[¶]]. The authors call for additional research on economic shock-coping strategies to mitigate harmful effects of drought on HIV acquisition risks.

Nagata's 21-country study [7^{¶¶}] found each year of heavy rainfall was associated with higher odds of prevalent HIV infection and past 12-month STIs. The association between heavy rainfall and HIV prevalence was greater in rural areas, among adults aged 20–29 and adults 30 and above, while it was not significant in urban areas or among adolescents [7^{¶¶}]. The authors hypothesize that the relationship between heavy rainfall and HIV prevalence may be due to the depletion of agricultural yields and resulting food insecurity leading to increased transactional sex, and reduced access to clinics due to flooding-related infrastructure damage [7^{¶¶}].

HIV prevention intervention

One study was found that examined an HIV prevention intervention conducted during an EWE. Deveaux *et al.* [17] explored factors associated with the implementation of an HIV prevention program and program outcomes in grade 6 classrooms in The Bahamas during school disruptions due to Hurricane Dorian and the COVID-19 pandemic [17]. At 6-month follow-up, students showed significant increases in HIV knowledge, self-efficacy, and intention to use condoms. The authors emphasize the importance of training and support from school administrators to help teachers implement HIV prevention programs during future natural disasters.

HIV care-related outcomes

HIV care-related outcomes explored across studies included: clinical outcomes among people with HIV (viral load: $n = 5$, CD4⁺ cell count: $n = 4$, AIDS

defining illness: $n = 2$; mortality: $n = 1$); antiretroviral therapy adherence and access ($n = 9$); HIV care (care engagement and retention: $n = 7$, workforce disruptions: $n = 4$); and wellbeing of people with HIV ($n = 10$).

Clinical outcomes among people with HIV

HIV clinical outcomes were examined during drought and water insecurity, as well as storms. A study with people with HIV across six countries in Southern Africa found lower than usual rainfall was associated with higher mortality and unsuppressed viral loads per 10 percentile decrease in rainfall rank [8^{¶¶}]. In another study in Western Kenya among people with HIV [18], each five-unit higher household water insecurity score was associated with increased likelihood of a higher viral load and AIDS defining illnesses. The authors suggest potential mechanisms for these findings include: water insecurity's effects on dehydration, fatigue, and hygiene practices that could increase opportunistic infections; and stress and mental health-related barriers to adherence and clinical care engagement [18]. Another study [19] investigated the impacts of Hurricane Maria on people with HIV who use drugs and found significant declines in viral suppression, significantly lower CD4 counts, and significantly higher viral load in posthurricane assessments compared to prehurricane.

Antiretroviral therapy access and adherence

Antiretroviral therapy (ART) outcomes were examined in relation to a range of EWE. Across studies, drought and water insecurity were linked with reduced ART adherence. For instance, an interrupted time series analysis [20^{¶¶}] in primary care clinics in rural South Africa over a 9-year period found marked decreases in ART adherence during periods of drought, with only partial recovery during wet years. This decrease in adherence during drought was worse for women than men, and for younger (15–24 years) vs. older (25–57 years) individuals [20^{¶¶}]. Another study with pregnant and postpartum women living with HIV in Greater Accra, Ghana similarly found that moderate and high water insecurity was associated with poor ART adherence [21]. Qualitative studies explored the impacts of drought on people with HIV in Kenya [18] and South Africa [22], as well as government and health workers in South Africa [23], identifying ART adherence barriers such as insufficient water to take medication, food insecurity, and migration-related challenges refilling ART.

Storms, wildfires, and flooding were also linked with ART disruptions in different global regions. A study focused on Hurricane Maria in Puerto Rico [19] found no statistically significant ART adherence

changes among the whole sample of people with HIV, but did find reduced posthurricane adherence for the sub-sample who was not virally suppressed prior to the hurricane. A qualitative study with people with HIV and their clinicians impacted by the Northern California wildfires discussed key reasons for missing ART included wildfire-related: stress and depression; altered routines; sudden evacuation process; longer travel distances for collecting medication due to road closures; and HIV-related disclosure concerns following evacuations. HIV-related disclosure concerns were driven by the lack of privacy following evacuations and HIV-related stigma, including living in a new place where people had disclosure concerns related to taking ART, highlighting the particular stigma-related challenges faced by people with HIV during wildfires [24[•]]. A qualitative study with HIV providers described how flooding in Western Kenya resulted in housing displacement and increased food insecurity that in turn produced challenges taking ART [25].

Retention in and access to HIV care

Studies looked at retention and engagement in HIV care in the context of drought, storms, and wildfires. Overall, drought was associated with reduced visits to HIV centers, such as in a 6-country study [8^{••}], as well as reduced HIV care retention in a rural South African study which found only partial recovery during wet years [20^{••}]. This reduced retention was worse for women (vs. men) and younger vs. older persons – authors hypothesize that drought can exacerbate existing social inequitable power relations such as gender inequity [20^{••}]. Thus while all people with HIV may prioritize economic survival over healthcare, this may be particularly true for women and young people [20^{••}]. A study in Puerto Rico found statistically significant reductions in access to HIV care post Hurricane Maria, and this was further reduced for persons not virally suppressed before the hurricane [19], again suggesting the impacts of EWE may be exacerbated for those with social and health disparities. Qualitative studies [22,23] in South Africa reported barriers to HIV care during drought included lack of transport fare to clinics as well as migration. Transport barriers to clinics were also noted during the Northern California wildfires [24[•]].

Workforce disruptions that interrupted HIV care were described in relation to multiple EWE. A qualitative study [26] of challenges experienced by the HIV workforce delivering care in the context of climate-related disaster events and EWE (e.g., wildfires, floods, extreme heat) in California highlighted both the resilience and adaptability of service providers in maintaining service continuity, while also

documenting service provider experiences of trauma, health risks, and workforce depletion [26]. Another study of Northern California wildfires noted HIV care barriers at the clinic level (e.g., staff shortage, clinic closures due to smoke/power disruptions/water damage) and systemic level (e.g. pharmacy closures, medication stockouts, nonfunctioning medication mail delivery) [24[•]]. HIV care delivery barriers during flooding in Western Kenya [25] and drought in South Africa [23] also include healthcare facility strain and infrastructure damage (e.g., clinic closures due to flooding, water scarcity, supply chain issues), as well as the inability to focus on meeting clients' immediate, tangible needs.

Authors provided recommendations for HIV care continuity during EWE. These included localized interventions to: mitigate effects of EWE on accessing ART through prescribing long-lasting ARTs and multimonth dispensing [8^{••}] as well as community-based medication delivery and outreach programs [25]; reduce ART refill disruptions through innovative strategies such as clinic mobile applications for medication refills and fast-tracked medication delivery [24[•]]; increase HIV care continuity with mobile pharmacies and clinics at evacuation sites [24[•]] and telehealth services [25]; build protective factors (e.g. resilience, coping) [19]; and reduce resource scarcities through programs targeting food [8^{••}] and water security [23]. Others discussed integrating HIV care guidelines and EWE emergency preparedness [8^{••},19], increasing disaster preparedness among people with HIV and service providers [26], and increasing financial support for clinics and service providers to support communities during and after climate-related events [26].

Wellbeing among people with HIV

Mental health and wellbeing challenges among people with HIV were described in relation to climate change and EWE-related events. Climate change can affect emotional wellbeing directly via losing homes and farms, such as among Kenyan smallholder farmers with HIV in a qualitative study, and well as indirectly through increased poverty, reduced social cohesion, and changes to professional and personal identity [27]. Individual adaptive coping strategies, such as changing agricultural practices, were often insufficient to manage the magnitude of disruption to their livelihoods and wellbeing [27]. Another qualitative study, conducted with people with HIV affected by Northern California wildfires, reported mental health challenges such as hypervigilance, trauma, anxiety, depression, stress, and sleep disturbances, as well as socio-economic impacts caused by housing damage and evacuation costs [24[•]]. Stress coping strategies included both

maladaptive approaches, such as substance use (i.e., opioids, alcohol) and adaptive approaches (e.g., breathing exercises, online support); importantly, wildfires disrupted established coping strategies such as accessing nature and/or socializing [24[■]].

EWE also affected physical wellbeing among people with HIV. Qualitative studies of drought in South Africa with people with HIV [22] and key informants [23] reported physical health issues linked with unclear and insufficient water access, including the inability to meet water and sanitation needs such as menstruation management and risks of water-borne infections (e.g., cholera, dysentery). Others noted drought in South Africa [28] and Zambia [29] was associated with increased food insecurity among people with HIV, and subsequent challenges with managing HIV and taking ART. Physical health challenges from wildfire effects included coughing, wheezing, worsened asthma, higher blood pressure, and exacerbated chronic obstructive pulmonary disease [24[■]].

Authors recommended policy-level strategies to support HIV management among drought-affected smallholder farmers with HIV [27] and nutrition programming for people with HIV experiencing food insecurity [28]. Community-level coping also enhanced the reliability of water sources through community contributions to maintain water and repair pumps [29].

Climate-informed interventions for people with HIV

One climate-informed intervention was reported for people with HIV. The Shamba Maisha RCT [30[■]] examined the effect of a multisectoral agricultural intervention (irrigation pump, fertilizer, seeds, pesticides, training in sustainable agriculture and financial literacy) on HIV clinical outcomes and well being among smallholder farmers with HIV in Kenya. Compared to the control group, the intervention group reported reduced food insecurity, fewer missed clinic visits, decreased depression, and increased social support and self-confidence. Although there were limited observed effects on HIV clinical indicators, this agricultural intervention offers promise for improving food security and wellbeing among people with HIV, which has important implications for HIV management. The effects of this agricultural intervention on HIV stigma were also explored, finding that intervention respondents experienced significant decreases in three dimensions of HIV stigma (internalized, anticipated, enacted) over the two-year study period compared to the control group [31[■]]. The authors suggest that this intervention improved health outcomes, social capital, and economic productivity; they posit that this in turn challenges the

assumptions that HIV leads to poverty, morbidity, and disability that drive HIV stigma [31[■]]. Indeed, qualitative interviews with women smallholder farmers who were Shamba Maisha participants noted that the coping mechanisms in this study (e.g., sharing water pumps, collectively supporting irrigation pump operation) built social cohesion, reciprocity, and community connectedness, and reduced HIV-related stigma [32[■]].

CONCLUSION

Findings from this review of recent studies on climate change, EWE, and HIV signal multiple pathways to both HIV prevention and care. These pathways, illustrated in Fig. 2, include: structural impacts of EWE (e.g., health infrastructure damage); resource insecurities exacerbated by EWE (e.g., food insecurity that presented ART adherence barriers); EWE-related migration and displacement (e.g., reduced access to HIV services); and individual and interpersonal impacts of EWE (e.g., mental health challenges, reduced social support).

There remains a dearth of climate-informed HIV prevention and care interventions, yet our findings offer ways forward for research, policy, and practice. HIV care in the context of EWE can include multilevel strategies spanning structural (e.g. food security programs), health institution (e.g., long-lasting ART, climate resilient health centers), community (e.g. collective water management), and individual (e.g., coping skills) levels. Limited research has evaluated the impact of climate-informed HIV interventions on HIV prevention, and future studies could examine long-acting PrEP, mobile pharmacies, mobile health strategies, interventions to reduce resource scarcities (e.g., food, water), and flexible service delivery for mobile and migrant people before, during, and following EWE. Building on HIV prevention and care approaches in humanitarian settings [33], self-care strategies [34] during EWE could include self-testing (e.g., HIV self-testing), self-management (e.g., long-acting ART and PrEP, over the counter postexposure prophylaxis), and self-awareness (e.g., mobile phone message information on EWE [35–37] that integrates HIV resources). Shamba Maisha [30[■]], the climate-informed agricultural intervention for people with HIV in Kenya examined in our review, for instance, could be adapted for urban settings (e.g., urban gardens) and expand to include people at elevated risk of HIV acquisition. Citizen science [38] – public participation in producing scientific research – can meaningfully engage people who are living with, and affected by, HIV in climate-related research to inform community-based science-based decision making on integrating HIV and climate programming [39].

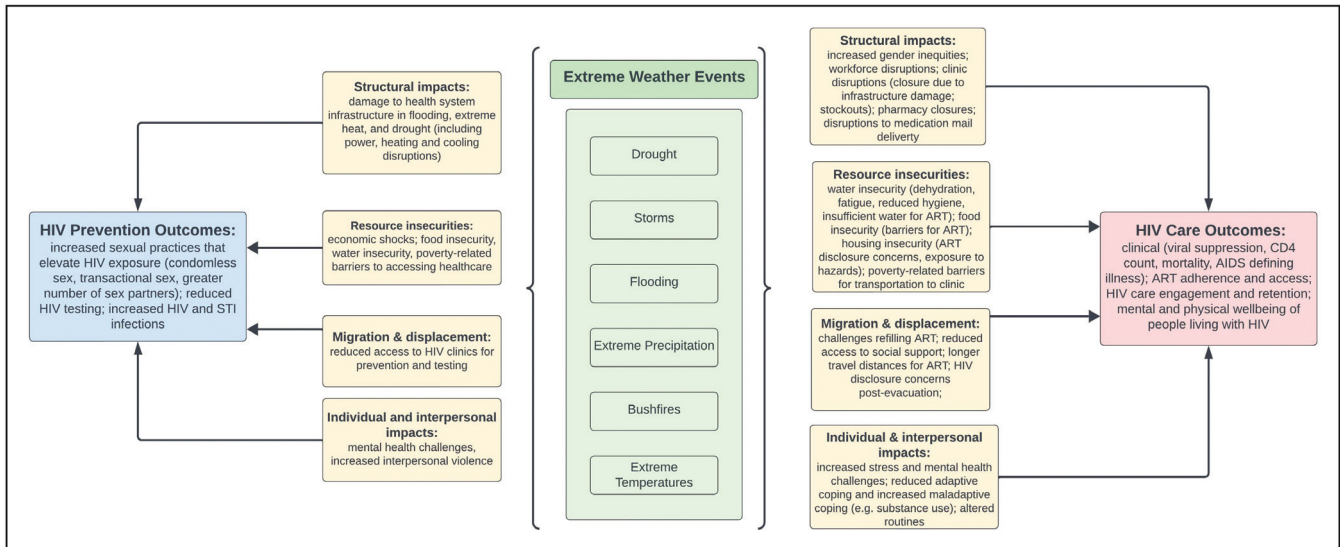


FIGURE 2. Conceptual framework of pathways from climate change and related extreme weather events to HIV prevention and care.

These potential climate-informed HIV responses spanning multiple social ecological domains are portrayed in Fig. 3.

There are five knowledge gaps that offer directions for future research. First, as detailed in Table 1,

there are evidence gaps across EWE and HIV outcomes. There is a need for HIV prevention (e.g. PrEP) and testing to be examined across a range of EWE, building on the important findings on drought-related HIV testing disruptions [15¹¹]. Researchers

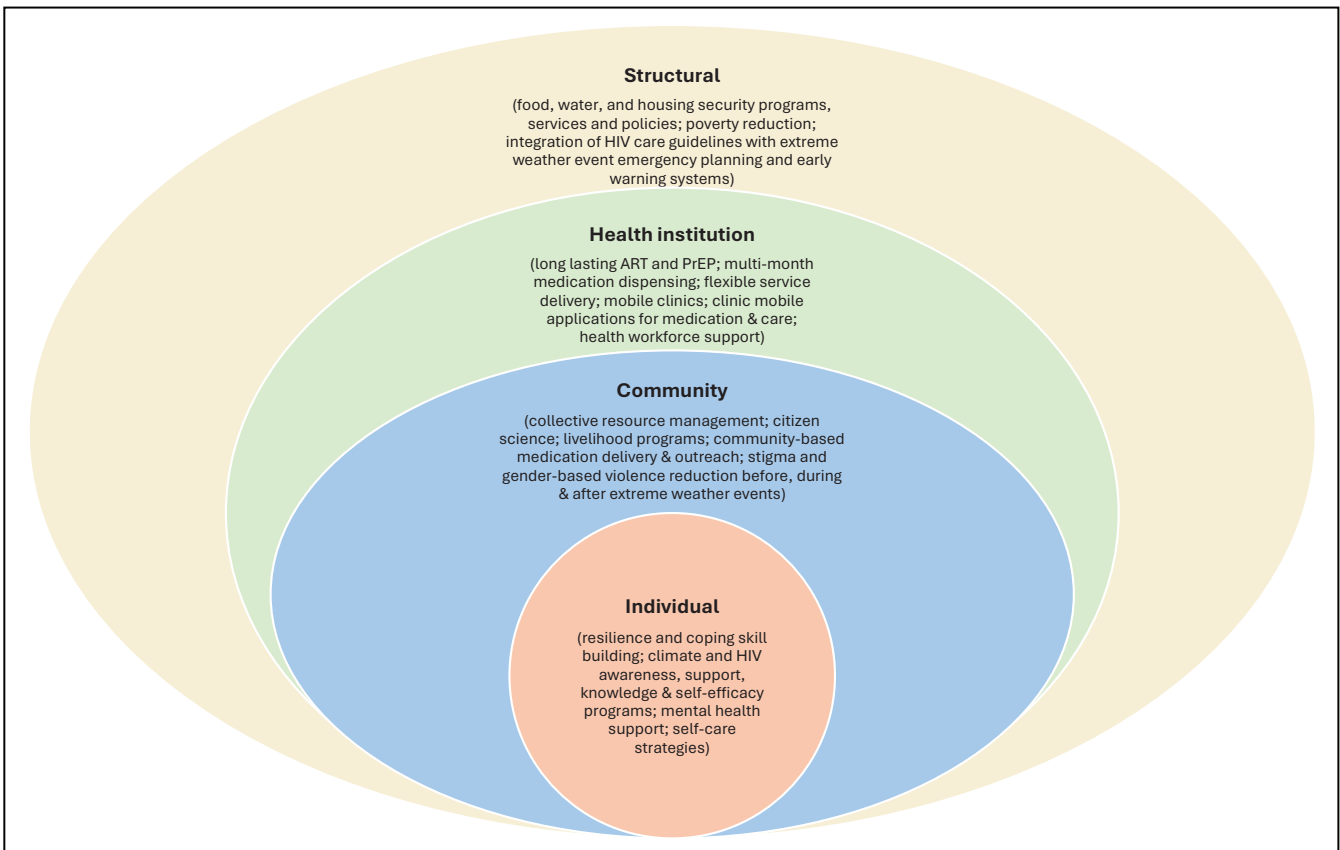


FIGURE 3. Social ecological approaches to climate-informed HIV prevention and care.

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could also explore, for instance, HIV prevention opportunities during extreme heat, wildfires, and hurricanes/storms. Second, extreme heat and HIV care remains understudied, despite its potential harms for people with HIV, including during pregnancy [13,40], heat-related illness [41], and its linkages with increased gender-based violence which already disproportionately affects people with HIV [42–44]. Third, as documented in Fig. 1, there are research gaps across global geographical regions that are highly vulnerable to the impacts of climate change and experience increasing rates of HIV, such as Middle East and Northern Africa [45]. Fourth, few studies examined the interplay between climate change, EWE, and intersecting forms of stigma. As EWE [12,46], water insecurity [47], and food insecurity [48] are associated with increased gender-based violence, research could explore associations between EWE and gender-based stigma [44]. Research could also examine associations between EWE, poverty, and HIV-related stigma, as EWEs harm livelihoods and increase poverty [49,50], and prior studies with people with HIV found poverty stigma was associated with worse HIV outcomes [51,52], and food and housing insecurity were associated with trajectories of higher HIV stigma [53,54]. Indeed, people with HIV discussed disclosure concerns as an ART barrier during EWE-related evacuations [24^a], so HIV-informed EWE planning should include intersecting stigma considerations. This includes, for instance, the need to better understand stigma experiences of sexually and gender diverse persons when accessing HIV and EWE services, including in displacement [55–58].

Finally, there remains a significant, persisting lack of knowledge of EWE and HIV among key populations, including sex workers, people who use drugs, and sexually and gender diverse persons. This is an urgent gap, as sexually and gender diverse persons are disproportionately affected by HIV and may also experience increased exposure to climate change and EWE due to social marginalization, and may be more likely to live in poverty and experience housing and water insecurity [59–62]. There are calls for gender-inclusive water and sanitation hygiene [63] and EWE [61,64,65] research. Some socially marginalized communities that are disproportionately affected by HIV may also experience water and sanitation insecurity – including people who inject drugs [66], migrants [67], Indigenous peoples [67], and people experiencing homelessness [67] – thus are vulnerable to the effects of EWE. This warrants further investigation.

Transformative and multilevel interventions [68], programs, and policy are needed to mobilize the evidence we have on climate change, EWE, and

HIV. Innovative approaches can integrate HIV services into community-based EWE emergency warning systems [35,69,70] and disaster preparedness planning [25,71] to create new opportunities for climate-informed HIV service delivery. It is critical that future climate and HIV research, programs, and policies include a diversity of EWE, affected populations, and geographies across the HIV prevention and care cascades to advance health equity and rights.

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Conflicts of interest

There are no conflicts of interest.

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