A scoping review to map research gaps and opportunities relating to heat-related health hazards in countries surrounding Lake Victoria, Africa.

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Abstract

Urban populations in sub-Saharan Africa are at rising risks of climate-related health hazards due to global climate change and uncontrolled rapid urbanization. Despite the increasing recognition of these challenges, the extent to which urban climates impact health outcomes in Africa remains poorly understood. East African countries surrounding the Lake Victoria Basin (Kenya, Uganda, Rwanda, Burundi and Tanzania) are no different, even though this region is one of the most densely populated areas in the world and a climatically unique part of the globe. In this scoping review focusing on urban climate and health-related impacts around the Lake Victoria Basin, we highlight how key research and knowledge gaps exist in the area and derive potential opportunities for future works aiming at preventing maladaptation. Using systematic search criteria over the *Web of Knowledge* and *Scopus* databases, we first selected 133 papers out of 878 that cover climate—particularly air temperature—in urban areas and related health outcomes. Following further selection criteria, we reviewed 24 papers focusing on East African cities neighboring the Lake Victoria Basin. Our bibliometric analysis shows that research on the topics of urban climate and urban health has increased since the 2010s. However, it remains limited in scope and is unevenly distributed geographically; most of the studies focus on the two large metropolises of the region, Nairobi (Kenya) and Kampala (Uganda), and other cities of the basin are underrepresented. We found an increase that explicitly examine the links between urban climate and health after 2019, with more recent studies incorporating more information on the intra-urban climate variability and the potential unequal exposures to climate hazards in cities, particularly in informal settlements. Key climate-driven health hazards in cities include heat- and cold-related mortality and morbidity, dangerous heat stress levels, exposure to critical air pollution, vector-borne diseases, water-borne diseases, and human-to-human infectious diseases. Nevertheless, major knowledge gaps on the influence of urban climate on these health hazards still remains in the area, mostly due to the characteristic climate and health data scarcity and a lack of longitudinal, intra-urban and transdisciplinary studies. We therefore argue that more integrated and interdisciplinary research should be done in the region, combining fields of urban climatology, public health, and social sciences. Data scarcity should be addressed, with a promising opportunity for the deployment of low-cost monitoring devices. This is essential to prevent potential maladaptation by expanding knowledge on how urban heterogeneity in the specific context of the Lake Victoria Basin influences unequal climate-health risks to local populations. Insights from East African countries in the region have broader relevance as similar climate-health challenges could emerge globally due to climate change and ongoing urbanization.

Introduction

Africa is often referred to as being disproportionately vulnerable from global climate change (1–3). Arguments underlying this observation regularly point at the lack of resources and infrastructure available for adapting to regional and local climate changes (4), increase in frequency of destructive and disruptive extreme weather events such as droughts, prolongated heatwaves, or flooding due to heavy rainfall (5,6), and the extension of unlivable climatic conditions around the equator and the tropics (7). On top of this, geopolitical instabilities in the region, rapidly growing populations, and uncontrolled urbanization are all expected to further amplify the impact of climate-related hazards by making African populations particularly vulnerable (8,9). In addition, climate-related health hazards are of specific concern in Africa as projected climate changes are expected to reshape current geographies of infectious diseases (10). This is due to extending climatically suitable environments for the development and the transmission of vector-borne diseases (VBDs) (11,12), changes in the seasonality of infectious diseases, including human-to-human transmission (13,4), and increases in the likelihood of water-borne epidemics due to flooding and poor water management (14). In parallel, constant increases in life expectancy across the continent may result in an increased proportion of the population aged 65 or above, who, by being at greater risk from climate-related morbidity and mortality induced by non-communicable diseases (15), may add to the public health burden.

Obviously, considering Africa as a sole entity in the face of climate change is problematic. The African continent comprises varied geographies, all characterized by specific climates that directly influence local cultures and practices (16). In addition, resources are unevenly distributed across the continent, making some countries or sub-regions more or less able to face the challenges induced by global climate change (17,18). Preparing African countries to face climate change impacts on health therefore requires more locally tailored climate adaptation rather than one-fit-for-all responses adopted based on indicators aggregated at supra-regional scales. In particular, it is paramount that adaptation strategies to single climate-related health hazards (e.g., heat stress, or water-borne epidemic of cholera) be thought holistically to prevent maladaptation to local climate changes. This means that interventions aimed at lowering the impact of climate changes on one health hazard should not amplify the risk of suffering from another health hazard.

Such a challenge is further amplified in the complex and fast-changing urban environments of Africa. The rapid and uncontrolled urbanization that the continent has experienced over recent years has indeed created specific local urban climates that are already known to affect urban populations(19). This calls for urgent interventions aimed at making cities more resilient to climate changes, in particular for the most vulnerable living in informal settlements (20). However, research on urban climate remains sparse in Africa, often limited to large global metropolises and cities of wealthier countries from North Africa and South Africa (21).

A key example of this problem is highlighted by East African countries that border Lake Victoria, and which are amongst the most densely populated areas in the world (Figure 1 and Figure 2f). In this region, also referred to as the Lake Victoria Basin – from a hydrological and geological point of view – population densities often overpass 500 pop·km^{-2} and can reach beyond 10,000 pop·km^{-2} in urban areas like Kampala, the capital city of Uganda (22). Population density is expected to grow everywhere in the area, due to the current and projected rates of urbanization and population growth. Population density is expected to particularly increase and spread along the Northern shores of the Lake Victoria, extending towards Rwanda and Burundi in the West, and the capital of Kenya, Nairobi in the coming decades (23,24). Such rapid changes can be expected to impact local land use and land cover and therefore induce changes in local climates due to changes in surface energy balances and roughness lengths.

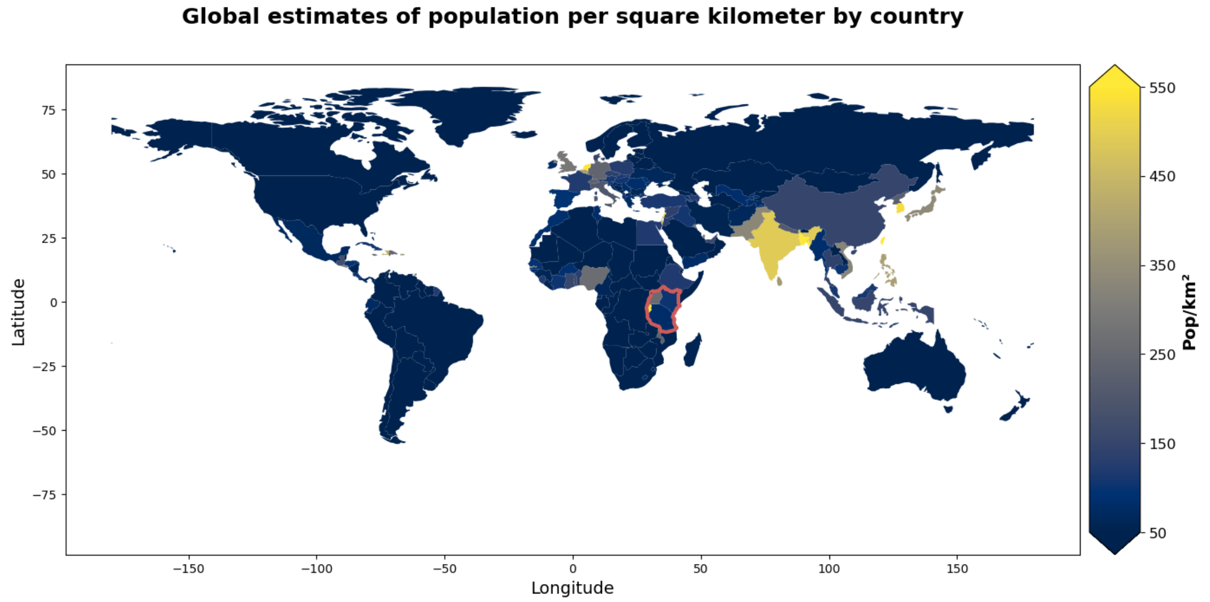

Figure 1: Population density by country for 2025 based on data pre-processed by "Our World in Data" and relying on UN WPP (2024); and UN FAO (2024) data. Contoured in red are the countries on which this review focuses. Absence of data is plotted in white.

Presently, local climate conditions are particularly modulated by the Lake Victoria and surrounding mountainous areas from the Albertine and Gregory Ridges (25,26). Lake Victoria is the second largest freshwater lake in the world and the largest lake in the tropics, covering an area of approximately 68,800 km^2 shared between three countries of East-Africa: Kenya, Uganda, and Tanzania (22,25). Impacts of Lake Victoria on the local and regional climate are well-documented and consist of regional modulations of the inter-tropical convergence zone's impacts and related dry/wet seasons (27–29), intensification of heavy thunderstorms over and along the lake (30), and land-lake interactions that result in diurnal patterns of land-lake breezes (31,32), among others. These already affect local populations by directly causing thousands of deaths of fishermen every year (33,34), potentially inducing urban flooding in informal settlements (35,36), and causing disastrous landslides (37). In addition, the rapid and uncontrolled urbanization that happens in the region could exacerbate heat-related risks in newly built-up areas, and in particular in informal settlements (38), whilst also potentially impacting the land-lake modulation of urban air pollution and cooling capacities (39). Lastly, multiple cases of urban malaria and other VBDs have been reported in cities of the Lake Victoria Basin (40,41), and recent modelling evidence showed that urban climate information helped in predicting prevalence of urban malaria (42).

Considering all of these indicators of unprecedented global and regional changes, and the heterogeneity of climate impacts on local populations, it appears that adaptation interventions in cities of the Lake Victoria Basin and East Africa should be carefully chosen. We therefore argue that urban climate and health research in the area, and by extension in other regions of Africa, should be as holistic and transdisciplinary as possible. In this study, we first performed a systematic review of the current knowledge on urban climate and health research in the area to map out current drivers of research and highlight critical research gaps. Based on the state-of-the-art, we then reflect on opportunities and challenges for future research on urban climate and health in the region to emphasize how such research could not only be positive for East African countries around Lake Victoria, but also to the rest of the world.

Literature review

To map out research opportunities and challenges in the region we decided to perform a thorough scoping review – with methodological elements in line with systematic reviews to prevent personal biases in the selection of valid papers to be included in the review. Below, we first provide methodological information and selection criteria for the review. Then, we present some bibliometric information from the selected papers. Finally, we give a summary of the current state of the art and methods employed in the urban climate and health research around Lake Victoria.

Methods and selection criteria

As explained above, urban climate research in East Africa is running behind compared to other regions of the world. Nevertheless, it may well be that knowledge on urban climate impacts on health has already been acquired in other fields of research (e.g., public health, biology, atmospheric sciences, or architecture). Therefore, we chose to keep our first selection criteria as open as possible by including all papers that **relate both urban climate and health in at least one African city**. For example, if a paper focuses on air quality because of its impact on the public health of local populations and relates it to climate variations or metrics, then the paper would be selected. If the latter part were not suggested, then the paper would be rejected.

We chose to apply this selection criteria on abstracts only to make sure that this was considered as a key output from the research to be communicated by the authors and prevent overselling titles to influence the research query. We also included abstracts that discuss African cities in a loose way, to make sure that no studies around the Lake Victoria basin are missed. As many weather variables are affected by the urban climate, we decided to focus specifically on studies that are heat-related – indicated by air temperature. Temperature is also a variable that is expected to be more likely recorded as temperature sensors are easily deployed compared to other devices (e.g., anemometers or flux towers) and low-cost sensor options to sense it in data scarce areas exist (e.g., (19,43,38)). Finally, temperature is related to many climate-related health impacts including non-communicable diseases (NCDs), changes in air quality, VBDs, water-borne diseases, and human-to-human infectious diseases (44). We therefore expect it to systematically be considered in urban climate health impact studies. This resulted in the following selection query:

> “***AB=(city OR cities OR urban) AND AB=(africa OR african OR Uganda OR Tanzania OR Kenya OR Rwanda OR Burundi) AND AB=(heat OR "heat stress" OR "heat island" OR temperature OR climate) AND AB=(health OR mortality OR disease)***”

Manuscripts were gathered on *Scopus* and *Web of Knowledge* online platforms and exported in RIS format, with the latest record obtained on the 22nd of April 2026. We included all manuscripts published until the end of 2025. This resulted in 629 potential candidates coming from *Web of Knowledge* and 798 from *Scopus*. After removing duplicates on the *Rayyan* online software, 878 manuscripts were considered. We then conducted a double-blinded selection of the manuscripts by using the inclusion criteria given above. This was achieved on the online *Rayyan* platform which allows double-blinded peer-review with options of *Include*, *Maybe*, or *Reject*. Once the two reviewers finalized their selection, conflicts and manuscripts flagged as *Maybe* were discussed and a final decision was made in agreement. There was 144 conflicts after the first round of review, showing a strong agreement in the selection process (~84 % of agreement) between the two independent reviewers.

Once the first round of selection was achieved, book chapters, opinions, books, reviews, conference, non-traceable manuscripts, preprints, and non-English manuscripts were removed. This resulted in a final selection of potential candidates consisting of 133 peer reviewed journal articles. We then decided to remove studies that were performed at global scale or that focused on more than 10 cities to make sure that the acquisition of knowledge on urban climate and health was specific to limited amounts of urban environments, ensuring no one-fit-all solution would be suggested. Finally, only studies focusing on cities embedded in countries that are part of the Lake Victoria Basin were considered. Eventually, 26 studies were included in the literature review and were used for mapping the state of the art and potential opportunities and challenges for future studies.

Bibliometric analysis

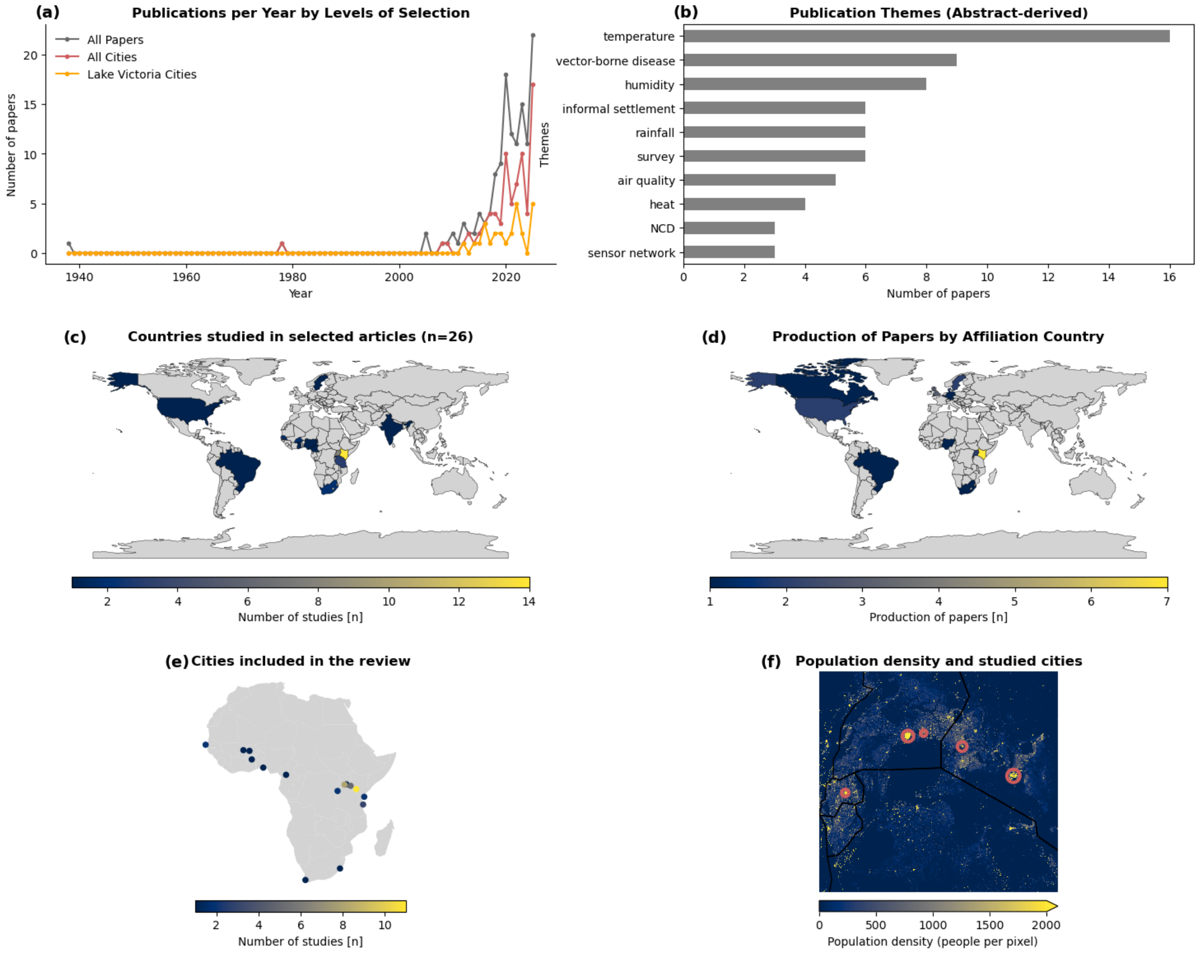

*Figure 2: Summary of the bibliometric analysis showing the location of the reviewed studies, the lead affiliation country, the recent increase in publication covering urban climate and health topics, the major thematic covered in the abstracts and the cities covered around the Lake Victoria Basin. Increase in publication per year (**a**) is shown for the whole sample of papers after first round of screening (n=133; "All Papers"), for papers that focus on urban areas (n=76; "All Cities"), and for cities that surround the Lake Victoria Basin (n=26; "Lake Victoria Cities"). The number of papers fitting each empirically derived themes are given in **b**. Number of studies per country are shown in **c**, while paper production by country based on lead author's affiliation is given in **d**. All African cities included in the review and the number of studies focusing on them are shown in **e**. The latter are also shown on the population density (pop.km^{-2}) around the Lake Victoria from the Global Human Settlement Layer counts aggregated over pixels of 1 km^{-2} (**f**); the larger the red circle the more studies (c.f. panel **e**).*

As a first way for understanding the current state-of-the-art, we performed some simple bibliometric analysis on the final sample of studies. In particular, we looked at the countries in which the first author is affiliated to understand the origin of urban climate and health research and Africa and discuss potential decolonization issues. We then looked at which countries in the region had the most studies before counting studies per city. Lastly, we screened through all abstracts and counted how many studies fell into sub-themes categories based on our own classification. This was done to define the major trends in inter-disciplinary research that relate temperature and other climate factors to health issues around the Lake Victoria basin. We also recorded the methods employed in each study to map out the usual tools employed for the study of urban climate and health issues in the region.

First of all, we found that of all papers selected based on their abstracts (n=133), 76 were specifically looking at cities and urban environments. This means that 43 % of the articles that were considered suitable for the review came out of global/large-scale (n=36) or regional/country (n=21) studies. Of the remaining 76 studies, 8 were focusing on multi-city comparisons. Within these 76 studies, 26 were focusing on at least one city in a neighboring country of the Lake Victoria Basin. Independent of the level of selection, since the 2010s, there was a rise in number of papers linking cities, climate and health, peaking in 2025 (Figure 2a). The latter shows a greater interest for the topic in recent years and an emerging field of research in the area. Most of the selected studies focused on Kenyan cities (n=14), followed by Ugandan ones (n=8); Tanzanian cities were only observed in 3 of the 26 studies and were not located around the Lake Victoria (Figure 2e and 2f). Nairobi was the most studied city in the sample (n=11), while Kampala was the 2nd with 8 studies. Several cities in sub-Saharan Africa were included in the sample as part as cross-country comparisons – in particular in West Africa (e.g., Dakar, Ouagadougou, Lagos, or Yoaunde; Figure 2e). Outside of Africa, single cities in Brazil, Jamaica, United States of America, Sweden and India were included in this review for the same reasons (Figure 1c). Interestingly, although Kenyan institutions led 7 out of the 26 studies reviewed and was the top-lead country (27 %), only 12 studies (46%) as a whole were led by African institutions and all other studies were led by foreign institutions (Figure 2d). Major themes, empirically derived from the abstracts, cover a wide-range of tools and research foci (Figure 2b). Looking at the 10 themes that are the most referred to, 20 of the 26 papers specifically refer to *temperature* and/or *heat* in their abstract, suggesting that the remaining 7 papers were more loosely incorporated in the review for their "*urban climate*" component – as explained above in the definition of selection criteria. *VBDs* are referred to in 9 papers, followed by *humidity* in 8, and *informal settlements*, *rainfall* and/or *survey*, in 6 papers, respectively. Other papers focus on *air quality*, or *non-communicable diseases*, and rely on *sensor networks*. Overall, this shows that the sample of selected studies already provides information on how temperature in cities can be linked to compounding climatic conditions, impact the risk of contraction of (non-)communicable diseases, and influence air quality. A specific focus appears to be surging in informal settlements. Lastly, different techniques seem to be employed to study the effect of urban climates on local populations and would be later discussed.

In a nutshell, this preliminary bibliometric analysis provides valuable information on the type of papers that are included in the review. However, as the sample remains small (n=26), it would be unreliable to try to map out keyword prevalence, networks of researchers, preferred journals for publication, or lead papers based on citations. It would also be unreliable to try to map research trends and gaps based on this sample alone. Below, we therefore focus the rest of the research on a detailed reporting of the content of the papers and map research gaps and opportunities in the region based on the state-of-the-art. This led to the exclusion of 2 additional papers for the following reasons: one suggested that the paper focused on an East African city around the Lake Victoria but effectively focused solely on a Brazilian city (part of a larger research group involving an East African city); the other did not refer to urban temperature or climate in the whole manuscript except as an opening sentence in the discussion. The subsequent section therefore includes 24 papers.

State of the art on urban climate and health in countries that surround the Lake Victoria Basin

In 2012, Egondi et al. (2012) were first to investigate temperature-related mortality in Nairobi and found that the specific local climate of the city, often referred to as a cold climate for the tropical latitudes, was linked to higher rates of mortality of people aged 50 or above and that periods of heat were more susceptible to lead to the death of children aged 5 or under – see Table 1 below for more information on the content of each papers mentioned in this section. This pioneering study led the foundations of climate and health knowledge in urban areas of countries that surround the Lake Victoria basin. However, their study did not consider the effect of the heterogeneous urban environment on the local climate and the resulting variety of urban climates that could explain the observed mortality.

In the following years, several studies looked into climate-related health issues within cities of Uganda and Kenya, but also missed opportunities to look at how specific urban climates may influence the outcomes of their study. For example, large cross-country studies like Sewe et al. (2018) found similar outcomes to Egondi et al. (2012) and predicted cold-related years of life lost (YLL) in Kenyan cities of Kisumu (lag 6-days) and Nairobi (lag 10-days) without using specific urban climate data. They did also notice heat-related YLL and attribute the cold-related YLL to the specific local climate of the two Kenyan cities. In fact, the city of Nouna in Burkina Faso, located at similar latitudes, only observed heat-related YLL and no cold-related ones. Further, studies showed that VBDs are a rising concern in Kenyan cities, such as: dengue, since its resurgence in 1982 (47,48), chikungunya, which recently re-emerged in Kenya (49), or malaria (50), which has always been endemic to the region and contributes to a high annual mortality burden. Optimal temperatures indeed enhance vector competence in transmission of pathogens like dengue or chikungunya (47,49,48). Other types of infectious disease outbreaks in Nairobi and Kilifi have also been related to rainfall and minimum temperatures, like *Shigellosis*, a form of bloody diarrhea particularly fatal for children below 5 (51). Some studies also focused on the increasing problems caused by increasing exposure to dangerous levels of air pollutants due to the rapid urbanization in Uganda and Kenya. For example, Kirenga et al. (2015) highlighted the dangerous levels of fine particulate matters ($PM_{2.5}$) that populations are subject to in Kampala and Jinja while showing that local variations between different environments characterized by Local Climate Zones (53) exist, but without explaining the mechanisms by which these differences surge. Gaita et al. (2016) identified 11 elements of particulate matter in Nairobi – from both anthropogenic and climatic/natural sources – that could cause harmful health impacts, including zinc (Zn) in informal settlements. They then modelled their dispersion using a simple model of the human respiratory system and found that most would stick in the head of the respiratory system. Lastly, Hashemi (2016) modelled the risk of indoor overheating in typical housing of Kampala using Energy Plus and showed that the commonly employed iron roofs are detrimental to indoor thermal comfort. Their modelling study relied on the weather file from Kisumu and did not look at locations of the housing across the built environment.

It is not before the study of Brousse et al. (2019) that studies specifically looked into urban climate's impact on health in cities of the region. They did so through the example of malaria prevalence (measured in *plasmodium falciparum* prevalence for children aged 2 to 10; $PfPR_{2\_10}$; see Table 1). Although most of their paper revolves around the development of new mapping strategies to gather urban information useful for urban climate studies in the form of LCZs, they emphasized the importance of data that accurately represent the heterogeneity of urban climates to support mapping efforts of VBDs, in that case malaria. This was later confirmed in the study by Morlighem et al. (2023) which showed that accurate information on the land use and land cover, as well as socio-economic and climatic parameters, improved the performance of spatial models of $PfPR_{2\_10}$ trained over DHS epidemiological data. Besides malaria, dengue continues to be a focal point of research in relation to urban climate and VBDs. For instance, Osalla et al. (2025) tried to estimate the impact of weather variables on the climate suitability for the development of *Aedes aegypti* vectors in Ukanda, a coastal Kenyan city. Multi-linear regressions and random forest regressors, trained on climate data derived from satellites and weekly adult/egg mosquito counts collected over a year, did however not find significant climatic influence on the vector populations. This could suggest that vectors of dengue are already fully adapted to urban environments in Kenya and are not influenced by their specific climates.

Beyond 2020, several studies investigated other climate-health indicators, such as heat-related illness or thermal discomfort. Kabano et al. (2022) demonstrated through the deployment of low-cost weather sensors and high-resolution satellite images that soil moisture plays an important role in explaining the spatial distributions of exposure to heat in Kampala – measured in air temperature or Heat Index (59) . Lower intra-urban differences of heat were observed during the wet season, and more built-up areas were found to be a greater risk of heat exposure during the days in the dry season. They also found that pervious surfaces and trees were protective of heat in Kampala, something that was also confirmed by Van De Walle et al. (2022) using *iButtons* and Normalized Difference Vegetation Index (NDVI) derived from Landsat satellites. In particular, informal settlements and densely built residential areas appear to be at high risk of heat exposure. This could again be related to the building materials employed in recently built housing, and more specifically iron roofs, as noted by Kajjoba et al. (2022). Nevertheless, measurements taken in 7 randomly selected houses of Kampala did not show records of indoor thermal discomfort following the 80 % limit of the *ASHRAE 55* standards; yet nighttime thermal discomfort was noted (61). Besides heat, compound events of heat and poor air quality could increase the health impact on urban populations (62). Using a set of 12 low-cost sensors in the Rwandan capital of Kigali, Kalisa & Sudmant (2025) found a positive correlation between air temperatures and ozone (O_3), and for nitrogen dioxide (NO_2); a negative was found for $PM_{2.5}$. As expected, higher ozone concentration was found during heatwave events but no signal was found for $PM_{2.5}$ or NO_2. Seasonality appeared to play a role whereby $PM_{2.5}$ and O_3 had higher concentrations during the wet season, and NO_2 during the dry season. Still, NO_2 and $PM_{2.5}$ concentrations were highly correlated to anthropogenic activity, sometimes overpassing the World Health Organization (WHO) guidelines by 8-fold. Such compound events are not yet properly investigated due to the characteristic data scarcity of African cities on the latter. But, low-cost weather and air quality sensors could help model the spatial spread of air pollutants at hourly timesteps and create alarm systems, as shown in Kigali (64).

Alongside quantitative research focusing on urban climate and health, many studies started using qualitative mixed-methods and questionnaire surveys to investigate how inhabitants perceive the impact of climate change and urban climates on their lives. Residents from the Keko Machunga informal settlements in Dar es Salaam (Tanzania; n=405) were, for instance, familiar with the impact of the urban heat island on their thermal discomfort and health (65). They were also testifying about their experience of extreme heat in the vast majority of respondents (78 %) and related it to climate changes. They reported skin rashes, malaria, or headaches as their top 3 heat-related health impacts. Other studies in Dar es Salaam involving mixed-methods analysis through several interviews and workshops (summing up to 68 participants) showed that residents are concerned about overheating in informal settlements and identify children as the most vulnerable population to climate-related health impacts (66). Risks of exposure to overheating noted by residents are linked to possibility of outdoor sleeping, nighttime safety allowing window opening, lack of green infrastructure, and prevention of malaria infection by bed nests. Reinforcing loops between air temperature, water management, poverty, and disease outbreaks are also identified. Similar findings were highlighted by studies in the Mukuru settlement – a settlement of ~300k inhabitants in Nairobi (Andersen et al., 2021 – n=28; Greibe Andersen et al., 2023 – n=402) where residents are particularly concerned about NCDs, respiratory and VBDs, noting food insecurity, air pollution and mental health issues too. As in Dar es Salaam, children were identified as the most vulnerable group. Past experience of a climate-related disaster (e.g., flooding) explained part of the awareness on urban climate changes and health impacts. Some confusion was however noted in causal links between air pollution or deforestation and climate change. In addition, despite an interest in knowledge acquisition and action against climate change, residents tend to note the lack of adequate governance to cope with climate-related health hazards in cities of Nairobi or Kampala. Through the example of urban agriculture, a central means for food accessibility and a potential urban green intervention to mitigate/adapt to climate change, Vidal Merino et al.(2021) showed that Kampala's regulation on urban agriculture and the existing land tenure system could lead to greater exposures to climate risk in the city. Land competition in urban areas of East Africa remains a challenge for easing urban climate adaptation in the region.

Overall, we find that urban climate and health, through the lens of air temperatures, is a recent field of study in countries that neighbor the Lake Victoria Basin. For the first half of the studied period (7 years), studies mostly focused on climate-related health issues in a city rather than connecting the specific urban climatology to the observed health outcomes (n=11). Already, studies were covering a wide-range of climate-related health hazards including heat-related mortality and morbidity, air pollution, human-to-human infectious diseases, and VBDs spread by mosquitoes, in particular. Over the second half of the studied period, studies started to relate urban climatic environments to urban health issues (n=12) – apart from two studies (Table 1). The thematic coverage remained similar, but more studies started to rely on qualitative mixed-methods to investigate how urban residents perceive or experience climate-related hazards, in particular in informal settlements. Nevertheless, estimations of the actual impact of climate-related health hazards in urban environments remain limited. More importantly, recommendations for adaptation to or mitigation of climate changes in cities are only contextual or discussion points. Studies looking at compounding events of poor air quality and heatwaves are encouraging but are not enough to prevent maladaptation of the booming cities in the area. This calls for a better definition of research objectives in the area and a mapping of current reasons that explain this research gap.

Table 1: Summary of selected manuscripts per sections covering contextual information (introduction and/or discussion), methods, key outputs (results and/or discussion), and limitations. Limitations are whether mentioned in the manuscript or identified by the reviewers. A binary variable defining whether the manuscript mentions interactions between urban climate and health at any point is given on the right-most column.

Reference	**Location(s)**	**Year**	**Contextual information**	**Methods**	**Key outputs**	**Limitations**	**Urban climate and health links**
Egoudi et al.	Nairobi (Kenya)	2012	Climate related death (both cold and hot) Nairobi has a cold climate Fuel poverty and poor indoor air quality	Time-series models to study daily weather and mortality (~60 000 cap.) from 2003 to 2008 Weather from Moi Airbase weather station	Child death is higher at high temperatures People aged 50+ are subject to greater cold mortality Increase in pneumonia at warmer temperatures NCD and pneumonia associated to rainfall (up to 30-day lag effect)	Single automatic weather stations No data on air pollution to control for compound health impacts	NO
Chepkorir et al.	Nairobi (Kenya), Kilifi (Kenya)	2014	Kenya prone to Dengue infections with first outbreaks observed in 1982 in Malindi and Kilifi Re-emergence of Dengue in East Africa Urbanization positively impacts Aedes aegypti	Collection of eggs in both cities Breeding of both populations under respective cities climate in laboratory to test vector competence Nairobi (26 °C) and Kilifi	Higher vector competence of mosquitoes from Kilifi Higher initial infection rate in mosquitoes from Nairobi Higher temperatures lead to higher infection rates in both populations	Laboratory study relying on yearly average temperatures No local weather data gathered	NO

			breeding capacity *Aedes aegypti* widely distributed in Kenya	(30 °C) yearly average temperatures reproduced in breeding environmental chambers			
Kirenga et al.	Kampala (Uganda), Jinja (Uganda)	2015	Lack of research on air pollution in developing cities of Africa due to data gap Very limited research on air pollution in Uganda Health problems related to air pollution include respiratory and cardiovascular diseases	Monitoring of gas phase pollutants and PM across different LCZ (open low-rise and sparsely bult) during two weeks (30th of June to 17th of July 2014) Meteorological data collected in one commercial site of Kampala (1 week; 30th of June to 7th of July 2014) and compared to National Weather Services' records Descriptive statistics to look at pollutants and weather variables across different land use and cities 18 sites for $PM_{2.5}$ (15 Kampala, 3 Jinja) 28 sites for NO_2 and SO_2 (22 Kampala, 6 Jinja)	No daily temperature variations during the recorded days Observed land-use and land-cover differences: highest $PM_{2.5}$ in industrial areas followed by residential with unpaved roads Records of $PM_{2.5}$ above 100 µg·m^{-3} in Kampala Higher concentrations of NO_2 in Kampala than in Jinja	Focus on short time period in the dry season only No explanations given on the underlying causes that explain the observed differences	NO
Hashemi	Kampala (Uganda)	2016	50 % of Ugandan families live in single-roomed	Model overheating likelihood in housing	Iron roofs are detrimental and cause overheating (15	Kisumu weather file for modelling Kampala	NO

			properties subject to overcrowding 60 % of the population in informal settlements Tropical climate with greatly varying rainfall and temperatures ranging between 16 °C and 30 °C Newly employed housing materials are more prone to overheating (e.g., iron roofs), especially in informal settlements	based on common housing types using modern and vernacular materials Compare iron roofs to thatch; brick walls to mud and poles; earth/soil floors to cement/concrete Building energy modelling using *Energy Plus* Use of Kisumu weather file due to lack of weather data in Kampala Tested insulation, cool white painted roofs, thatched roofs, double painted Overheating defined based on CIBSE TM52 criterion	times higher than with thatched roofs) Cool roofs and insulation prevent overheating Original thatched roofs are also beneficial compared to iron roofs Walls and flooring have low influence on overheating likelihood	Actual location not properly defined	
Gaita et al.	Nairobi (Kenya)	2016	$PM_{2.5}$ and PM_{10} is a public health problem in Africa Current and projected droughts impact air quality in Africa by increased concentrations of mineral dust	24-hour samples collected in August and September 2007 in Nairobi (17m above ground level) Characterization of PM and elemental	11 elements were characterized: Si, S, K, Ca, Ti, Mn, Fe, Cu, Zn, Br, and Pb Various origins from both natural and anthropic nature	Single site measurement in industrial area Data from 2007 and lack of recent data No relation to	NO

			Higher exposures to Zn and PM in informal settlements Lack of regulations on motor vehicles in African cities	composition to derive potential health impact Simple human body model (MPPD v2.1) to estimate deposition in respiratory systems	Higher deposition of pollutant in the head airways rather than in tracheobronchial and pulmonary systems	weather variables	
Njuguna et al.	Nairobi (Kenya), Kilifi (Kenya)	2016	Lack of research on relationship between climatic variation and diarrhea diseases (*Shigellosis*) Shigellosis can be fatal for children under 5 years Incidence of acute bloody diarrhea are influenced by temperature and rainfall Informal settlements are particularly at risk Increase of cases in Kenya over recent years	Mean monthly temperature and rainfall for Kilifi and Nairobi (Kenya Meteorological Department) Pearson correlation between weather variables and positive cases 805 participants enrolled at hospitals and in household surveys Separation between urban (Nairobi) and rural (Kilifi) participants Survey questionnaire to investigate risk factors	Rainfall positively correlated to bloody diarrhea in both urban and rural populations Peak of infection rate in April and October emphasize seasonality of pathogen transmission Minimum temperature positively associated with acute bloody diarrhea – stronger correlation in Nairobi Statistically significant risk factor variables include safe water storage, hand-washing, and presence of coliforms in main source of water	Weather data for Kilifi collected in Malindi (60 km apart) Background climates differ between Nairobi and Kilifi due to different geographies	NO
Agha et al.	Kisumu (Kenya), Nairobi	2017	Chikungunya virus re-emergence in Kenya	Egg collection in Mombasa, Nairobi and Kisumu between March	Higher infectious rate in mosquitoes from Mombasa compared to Nairobi and	No use of weather data	NO

	(Kenya), Mombasa (Kenya)		Virus mostly found in urban environments Mosquitoes species' competence on vector transmission varies between urban and rural environments Cases reported in Mombasa but not yet in Nairobi or Kisumu – need to prospect for potential vector competence Short incubation of pathogen compared to other pathogens	and April 2016 Mosquitoes hatched in laboratory (Nairobi) at constant temperature of 28 °C Specimens infected using sheep blood meals All mosquito populations are *Aedes aegypti* were put in environmental chambers set at 28 °C to compare difference in infection tilters	Kisumu (not statistically significant) All mosquito species from the three cities were competent in the transmission of Chikungunya after 5 to 7 days post exposure Lower average monthly temperatures in Nairobi could explain the lower infection rate than in Mombasa but not in Kisumu	Reference to temperature as a discussion point only No test on the vector competence based on local temperatures	
Sewe et al.	Kisumu (Kenya), Nairobi (Kenya), Nouna (Burkina Faso), Stockholm (Sweden), Philadelphia (USA), Phoenix (USA), Vadu (India)	2018	Lack of research on temperature-health associations in LMICs Lack of daily mortality data in low-income countries Infectious diseases are linked to weather variables like temperature or humidity Informal settlements are at greater risk of suffering	Cross country and city comparison of years of life lost (YLL) YLL estimated using quasi-Poisson regression on HDSS mortality data based on weather data gathered at single stations Use of daily maximum temperature data	Cold and heat related impacts on YLL in both Kisumu and Nairobi Cold-related YLL increase at lags 6 to 10 in Kisumu and at 14 days in Nairobi Warm African sites like Nouna in Burkina Faso do not observe cold-related YLL Nairobi at greater risk of cold related mortality than	No adjustment of relationship for harvesting Maximum daily temperature could underestimate cold effect	NO

			from climate-related diseases		heat-related mortality		
Okuneye et al.	Nairobi (Kenya), Lagos (Nigeria), Durban (South Africa)	2018	VBDs account for 17 % of global burden in infectious disease with malaria summing an estimated 1M a year Life-cycle of mosquitoes depend on temperature Survival rate depends on temperature and humidity	Development of mechanistic model for the development of female Anopheles Model based on temperature and rainfall Employment of a non-autonomous deterministic system to evaluate the impact of temperature and rainfall on mosquito population Weather data gathered randomly for three African cities on worldweatheronline.com	Parameters that influence the population dynamics are: successful blood meal; mortality rate of adult; natural mortality of larvae; deposition of eggs; maturation rate Peak mosquito abundance in Nairobi occurs with temperatures ranging from 20.5 °C to 21.5 °C and rainfall comprised between 50 and 120 mm	No infection of the modelled population Weather data coming from non-official source No rationale for choice of cities	NO
Agha et al.	Nairobi (Kenya), Kisumu (Kenya), Mombasa (Kenya)	2019	Dengue observed in Mombasa but not in Kisumu and Nairobi despite the presence of humans and Aedes aegypti in all areas Re-emerging disease in Kenya and yet lack of research – millions of people potentially affected in these cities	Collection of mosquitoes in indoor environments across the three cities (12 traps per city) Trap deployment for 5 consecutive days in each season (60 traps per season and city) Female count of Aedes aegypti as indicator of	Similar vector density in Kisumu and Mombasa but twice lower in Nairobi No difference in the transmission capacity between the different species Higher transmission at higher temperatures	Climatic environments exposed to mosquito population are limited to three temperatures Only consider DENV-2 and no other strains of Dengue	NO

			High DENV-2 burden in East Africa	vector density Description of vector blood meal based on DNA extraction Immature mosquitoes collected in the three cities between October and December 2016 and hatched in laboratory Mature mosquitoes infected with DENV-2 and exposed to different environmental chambers based on minimum and maximum average temperatures in the three cities (22 °C min in Nairobi; 28 °C max in Nairobi, min in Kisumu and Mombasa; 31 °C max in Kisumu and Mombasa) All mosquitoes collected in different cities exposed to the different city climates	Vector competence does not explain the transmission of DENV-2 in Kenyan cities Kisumu mosquitoes have a low rate of human blood meals compared to Mombasa (statistically significant)		
Brousse et al.	Kampala (Uganda), Dakar (Senegal)	2019	Rapid urbanization calls for more urban climate studies in SSA to provide data relevant for health	Employ large remote sensing banks of Google's Earth Engine to map cities of Africa in the form of	Low classification performance in informal settlements for LCZ (lightweight lowrise; overall	LCZ morphological parameters only evaluated in Dakar and not in Kampala	YES

			impact studies Remote sensing and urban climate modelling offer opportunities to gather relevant data at high resolution Local Climate Zones and WUDAPT program can bridge over data gap for LULC data relevant to urban climate studies Existence of past urban climate studies in SSA but not linked to health	LCZ Test of different mapping strategies based on different input parameters from multiple satellites (e.g., *Sentinel* and *Landsat*) Compare LCZ maps against morphological information gathered from very high resolution satellites Use LCZs to perform urban climate modelling (TERRA_URB; 2-week run from 1st to 15th of January 2015) that can provide climate suitability information relevant to urban malaria prevalence models	accuracy below 40 %) Sentinel 1 improve mapping of LCZ compared to default variable set relying on Landsat only NDWI and NDVI improve mapping of open low-rise (LCZ 6) Evaluation of LCZ morphological parameters in Dakar showed a systematic overestimation of building heights LCZ can inform urban climate models in SSA and help mapping climate suitability of mosquito vectors in the form of TSI (30 % increase in vectorial capacity in the city center)	Temperature Suitability Index (TSI) only modelled in its static form and for a short run of 2 weeks	
Pasquini et al.	Dar es Salaam (Tanzania)	2020	Link between human mortality/morbidity and heat in low income countries Urban heat islands are expected to increase the health burden of heat	Review of the main factors that affect urban heat exposure and vulnerability Mixed methods analysis involving structured interviews with decision makers (n=11; Sep-Oct	Respondents point to the risk of overheating in informal settlements (already experienced) Mismatch between when respondents feel warm and when temperatures are high	No employment of weather stations because of accessibility	YES

			Lack of knowledge on the unequal impact of heat in informal settlements despite known variations in vulnerability Little research in Tanzania on the topic besides occupational exposure to heat 4M inhabitants projected to 10M in 2030 Lack of health data and recording capacity	2016); climate data analysis using CMIP5 under RCP8.5 (n=15 GCMs, current (1986-2015) and future (2031-2050; 2081-2100)); structured interviews with informal settlement residents (n=12, July 2017); unstructured interviews with respondents from the health sector (n=14); 1-day stakeholder workshop with 31 participants from varied backgrounds (February 2018)	Issues of planning identified and lack of Heat Action Plan Factors that influence exposure to overheating are outdoor sleeping, nighttime safety, and malaria infection Loss of green in informal settlement but no quantification of impact Children considered most vulnerable Poor sanitation and water management link to higher health risks during hot days Reinforcing loop between temperature, water management, poverty, and disease outbreaks		
Greibe Andersen et al.	Nairoby (Kenya)	2021	Increase in NCDs projected by the WHO during the next decade resulting in 28M more death Focus on Mukuru	In-depth interviews (n=5) and focus group discussions (n=23) were conducted with 28 participants that are related to Mukuru, climate change, and	NCDs are the most commonly referred themes in the discussions (81 mentions) Food, air pollution, and VBDs are referred ~40	Small sample size in participants Confusions in causality between climate change and air quality	YES

			informal settlement in Nairobi (~300k inhabitants) projected to increase to 700k inhabitants in 2030 Lack of research on perceived risks between NCDs and climate chance in low-income countries	health Discussions conducted between March and May 2021 Independent survey development between 2 researchers Inductive approach for coding categories in NVivo	times Various NCDs mentioned by participants (e.g., diabetes, cancer, heat stroke…) and mental health as well Various infectious diseases mentioned (e.g., water borne, malaria, or respiratory) Water scarcity and safety following droughts is a key issue in informal settlements Unclear links between climate change and air pollution, or deforestation Children identified as vulnerable groups, especially during floods Desire from participants and communities to learn more about climate impacts and raise awareness		
Vidal Merino et	Kampala (Uganda),	2021	Urban agriculture is widely employed for	Scope for governance incentives for urban	Land tenure systems and uncontrolled urbanization	No collection of weather data	NO

al.	Tamale (Ghana), Cape Town (South Africa)		subsistence in cities Urban agriculture can reduce heat and climate change impacts Urban agriculture is also subject to climate changes Urban agriculture can be used as mitigation and/or adaptation strategy to climate changes in cities 50 % of households involved in urban agriculture in Kampala	agriculture using the Institutional Analysis and Development (IAD) framework Case studies (including Kampala) to report on challenges in governance that promote urban agriculture in face of climate changes Selection of case studies based on literature review in Google Scholar	lead to greater exposures to climate risks A legal framework (Urban Agriculture Ordinance, 2006) controls urban agriculture in Kampala Urban agriculture is becoming a permanent infrastructure in Kampala Urban flooding, heat, and droughts are major risk imposed to urban agriculture	No estimation of health benefits	
Bayode Adegun et al.	Dar es Salaam (Tanzania)	2022	Lack of research on individual responses to heat in informal settlements Increased average temperatures in Dar es Salaam and 50 % of the urban area is informal Evidence of greater heat exposure risk in informal settlements of Africa based on observations and field campaigns	Survey questionnaires distributed to 405 participants in the Keko Machunga informal settlement (~23k inhabitants) Questionnaire co-designed with residents and informed by literature review Survey performed during 3 months (May to July 2020)	Respondents spend whether substantial (>4 hrs) or little time (<1 hrs) outside of their houses Majority of residents experience heat stress Of 78 % respondents that have witnessed increased temperature in the settlement, 50 % relate it to climate change Residents are aware of	No weather measurement during the study	YES

				All answers were considered valid	urban climate impacts (e.g., urban heat island; heat trapping due to building density; impact of green infrastructure) Building designs influence overheating Top 3 health problems that are related to heat are: skin rashes, malaria, and headaches Behavioral change involve passive cooling strategies or going outdoors; little information seeking on official *Met Office* channels		
Corburn et al.	Nairobi (Kenya)	2022	Need for climate justice in informal settlements to address urban climate and health issues beyond the most vulnerable individuals Kenyan policies and action plans exist to cope with climate-related health issues Heat poses a major climate injustice in	Multiple surveys around climate and health in Mukuru informal settlement performed between 2015 and 2019 involving thousands of participants Survey on household level living conditions Health survey on health symptoms experienced over the past 6 months	1/3 of respondents experienced flooding in the last 6 months Water scarcity is presented as a problem already Soil pollution is more important after flooding Respondents link flooding risks to weather, climate change, and unpaved roads	Long research covering 6 years	YES

			informal settlements VBDs are impacted by increased temperatures in East Africa Compound events of heat and air pollution increase risks of CVD and respiratory NCDs in informal settlements Women are disproportionately affected Flooding increase the likelihood of infectious diseases Droughts and water accessibility unequally impact those with intermittent access to clean water Mukuru informal settlement has a population density of 111k $\text{cap}\cdot\text{km}^{-2}$ Lack of funding to run long-term community	Monthly focus group discussions between August 2017 and June 2020 Citizen scientists map infrastructures and facilities (GPS and satellite images) Environmental health data gathered by citizen scientists in the form of soil samples to measure pollution level post-flooding	Citizen prioritize better road infrastructure to prevent flooding		

			engagement research programs				
Kabano et al.	Kampala (Uganda)	2022	Tropical urban climate studies on the rise but not in SSA Lack of studies on the impact of humidity on thermal comfort in cities	Explorative regression analysis on the influence of soil moisture and land cover composition on urban climate 22 sensors deployed around Kampala during 50 days to collect air temperature and relative humidity (*dt* = 30min) Satellite derived impervious fraction, paved fraction, building fraction, tree coverage, pervious fraction (*World View 3* satellite image of 25-10-2016) Measure of thermal comfort using the Heat Index	Soil moisture is correlated to relative humidity Heat Index does not decline with greater soil moisture Greater soil moisture leads to lower urban climate differences between neighborhoods On average, most densely built location is warmer than the others Higher tree coverage is linked to lower Heat Index Trees and perviousness reduce nighttime temperature Air temperature increases slower during wet seasons when soil moisture is high in openly built environments Greatest thermal discomfort during dry	Sample location and temporal coverage	YES

					season in most built up areas		
Kajjaba et al.	Kampala (Uganda)	2022	Thermal comfort studies usually employ subjective or objective methods No building standards exist in Uganda for heat and IAQ Lack of studies on indoor thermal comfort in Uganda Iron roofs can cause increase risks of overheating Lack of studies on indoor air quality Need to study compound effects of IAQ and heat stress together	Mixed methods to assess thermal comfort involving building energy modelling, survey questionnaire, and indoor environmental sensor deployment Weather file employed in Design Builder from Kisumu Model outputs validated against measurements Seven households empirically chosen to monitor indoor air quality and overheating risks 300 participants to the survey questionnaire Kawempe I informal settlement as case study during June2019 Daily weather conditions obtained from Kawanda AWS	Measurements show CO_2 concentrations below WHO standards (450-510 ppm) Based on *ASHRAE 55* guidelines, indoor thermal comfort falls within the 80 % acceptable limit Nighttime thermal discomfort is observed $PM_{2.5}$ are ~2 times higher than the recommended WHO standards of 25 $\mu g \cdot m^{-3}$; 3 times more for PM10 (50 $\mu g \cdot m^{-3}$ threshold)	Unclear data analysis and research protocol Unclear usage of outdoor weather data Fragile assumptions around observed results	YES
Van de	Kampala	2022	Lack of research on	Deployment of 45	Early morning UHI explains	Only employ one heat	YES

Walle et al.	(Uganda)		extreme heat impacts and exposures in Africa Only 6 weather stations operational in Kampala operated by TAHMO project Kampala has one of the fastest urbanization rates in Africa Urban morphology in Kampala is linked to socio-economic factors Iron roofs often present in the built environment Mismatch between urban planning interventions against heat and land competition (tree deployment plan)	*iButtons* sensors measuring humidity and temperature across 13 sites *iButtons* deployed in groups of 3 to control for sensor inaccuracy Quantification of heat stress based on Humidex Explorative regression analysis to explain spatial distribution of heat stress across different LCZs Multi-linear regression using Ordinary Least Squares Sensor accuracies tested against official AWS at Makerere University Three periods of 42 days from August 2018 to April 2019	distribution of heat stress at time of minimum temperature Intra-urban heterogeneity of Humidex is better explained during daily maximum temperature hours Humidex strongly correlated to NDVI and impervious surface fraction Great to Dangerous thermal discomfort observed in LCZ 7 (lightweight lowrise) and LCZ 3 (compact low-rise) Some locations were exposed to dangerous heat stress for more than 50 % of the time during maximum temperature hours, but never in parks out city outskirts A difference of 6.4 °C is observed between parks/openly built and densely built center areas in the afternoon	index to estimate thermal discomfort	

					Important exposure to heat stress in informal settlements		
Greibe Anderse et al.	Nairobi (Kenya)	2023	Lack of research on climate change and health Lack of evidence on informal settlements' adaptation strategies Climate change expected to impact VBDs Mukuru informal settlement expected to have ~700k inhabitants in 2030	Survey questionnaire involving 402 participants in September 2021 (1 week) – random sampling Questionnaire designed to investigate climate change awareness, responses and feelings in Mukuru	Majority of female respondents and below 40 years old 3/4 of respondents heard of CC before and link it to the distance of the riverbed 4/5 are concerned about climate change and 9/10 about its impact on health because of the proximity of the river Communities were affected by air pollution, poor health, water quality, droughts and heat (>2/3 of respondents) Air and water quality are the major concerns Climate change affects health according to respondents More than 50 % of respondents consider	Sample biases due to social and cultural constraints (female dominated) Confusions between air quality and climate change driven impacts	YES

					respiratory diseases, infectious and VBDs to be influenced by climate change Desire to act against climate change but feel responsibility is in central institutional powers Having lived a climatic disaster could explain raised awareness		
Morlighem et al.	Kampala (Uganda), Dar es Salaam (Tanzania), Dakar (Senegal), Ouagadougou (Burkina Faso)	2023	Malaria impacted by climate change and urbanization in SSA Need to urban models of malaria that integrate climate information Epidemiological data displacement to preserve sensible information is a challenge for relating environmental factors and malaria incidence/prevalence Lack of urban malaria data	Test spatial optimization of DHS data to overcome limitations induced by data displacement Random Forest machine learning regression using satellite images and urban climate data to estimate *Pf*PR$_{2\_10}$ from DHS data Precipitation and wind speed data from WorldClim and urban climate influence modelled through LCZ maps MODIS LST used to inform	Method 2 is the best performing method for all cities including Kampala and Dar es Salaam Climatic information is considered more or less important depending on the city LCZs are not considered importance following feature importance in RF model	DHS data sampling method mostly during dry season and focusing on children Assumed stationarity of malaria, covariates and inhabitants	YES

				the model on intra-urban climatic variability Very high resolution LULC information derived from satellite imagery Control for vegetation, wetness, elevation using Landsat NDVI, NDUI and SRTM digital elevation models 2 methods to mitigate displacement influence: 1) inflate number of DHS points in all cardinal directions in a buffer zone; 2) randomly move DHS data along cardinal directions in buffer zone until best performance is achieved			
Kalisa and Sudmant	Kigali (Rwanda)	2025	Lack of studies in SSA on compound events between air quality and heatwaves Temperature more generally treated as a catalyst rather than a driver of air quality deterioration	Deployment of 12 low-cost weather stations and air quality monitoring devices across Kigali (May 2021 to December 2024) Measurements evaluated against official beta attenuation mass monitor (BAM) station	More $PM_{2.5}$ and O_3 during wet season, more NO2 during dry season O_3 linked to heatwaves but not $PM_{2.5}$ nor NO_2 Warmest heatwave event (n=6) had the best air quality respective to the	No look at other weather variables for compound events Heatwave definition	YES

			Low-cost air quality monitoring devices could address the data scarcity in SSA cities Urbanization pace in Kigali leads to greater risks related to heat and air pollution	Definition of heatwave based on thresholds of temperatures and consecutive days overpassing it – no official definition of heatwave in Rwanda	other 5 heatwaves $PM_{2.5}$ and NO_2 are correlated to anthropogenic activities (e.g., peak emissions during rush hours) WHO guidelines of 5 $\mu g \cdot m^{-3}$ in Kigali for $PM_{2.5}$ overpassed by values 8 times higher Positive correlation between temperature and O_3 and NO_2, negative for $PM_{2.5}$		
Morais et al.	Kisumu (Kenya), Yaounde (Cameroon), Bel Horizonte (Brazil), Kinmgston (Jamaica)	2025		INVALID			NO
Nizeyimana et al.	Kigali (Rwanda)	2025	Lack of monitoring systems of air quality Fast growing threat (air pollution) due to pace of urbanization	Development and testing of low-cost embarked air quality monitoring devices Early warning system development using	Better model performance for CO_2, temperature, O_3, NO_2 Poor performance of the model for PMx but expected due to local	Unclear model validation and climatic/air quality research protocol	NO

			Double the amount of $PM_{2.5}$ than WHO guidelines previously recorded Lack of spatial data and cost of official stations (~50k USD) call for low-cost options	machine learning to predict air quality at 2 hours based on weather data collected (LSTM neural network) Devices communicate through GSM/GPRS Development of a web interface for near real-time data providing to users based on ThingSpeak Cloud	influences on PM distributions (e.g., local emissions) Weather variables improve model predictions		
Ogani et al.	Kisumu (Kenya), Busia (Kenya)	2025		INVALID			NO
Osalla et al.	Ukanda (Kenya)	2025	Kenyan coasts have seen a resurgence of Dengue Dengue is endemic to urban areas in Kenya Precipitation and humidity are known to affect vectorial capacity Data scarcity of Dengue infection in Kenya Lack of research on the association between climatic factors due to	Longitudinal study of Dengue epidemiology in Ukanda from December 2021 to November 2022 (1 year) Adult mosquitoes captured weekly and eggs captured weekly to measure oviposition and hatch adult mosquitoes in laboratory Blood meal analysis based on DNA	>50k mosquitoes trapped with prevalence of Aedes aegypti (67 %) >10k of Aedes eggs Only 2 mosquitoes tested positive to DENV-2 flavivirus No clear pattern found between abundance of females and weather variables Hypothesis that no climatic	No local weather data measured in situ	YES

			absence of longitudinal studies	Daily weather variables obtained from satellite derived outputs (NASA Power) Multi-linear regression and step-wise regression to test association and importance of weather variables on abundance of female Aedes aegypti Random forest model to investigate weather impact on egg abundance	pattern means that Aedes aegypti lives all year around in the city of Ukunda		

Research gaps and opportunities to prevent maladaptation in cities that surround the Lake Victoria basin

Based on the corpus of papers reviewed in this manuscript, several research gaps related to urban climate and health are identified, mostly related to lack of resources and characteristic data scarcity in the region. For instance, several papers note a research gap in how temperatures and climate changes are affecting the health of people living in the region, and more generally, in low- medium-income countries (LMICs). This is most likely due to the lack of health and epidemiological data (e.g., daily mortality data, dengue incidence, or malaria prevalence), longitudinal studies and recording capacities (46,66,60,68,57,58). The latter is not specific to health data and is also characteristic of climate data in the region. This translates into impaired capacities for studying direct impacts of climate-related health hazards like the indoor and outdoor thermal comfort in urban areas (43,61), exposure to dangerous levels of air pollution (52,64), and compound events between air quality and heatwaves (63). More indirect hazards involving pathogens whether spread through human-to-human contaminations, water, or vectors like mosquitoes are thereby poorly studied too (51,57,58). The latter would need more research on how climate change and urbanization impact vector competence and habitat suitability for reemerging mosquito VBDs (47,49,48), something currently lacking as well.

In general, despite the existence of past urban health studies or urban climate studies in East Africa and the Lake Victoria basin (e.g., Nakamura, 1966; Jonsson et al., 2004; Egondi et al., 2015; Brousse et al., 2020; Morakinyo et al., 2026), a critical research gap exists on how urban health is influenced by urban climate and temperatures (56). Such a research gap could lead to the development of unsuitable and/or maladapted urban environments in face of climate changes; something that could also explain the lack of regulations on air quality and overheating in countries neighboring Lake Victoria, as noted by Gaita et al. (2016) or Kajjoba et al. (2022). Maladapted urban environments could result in increased climate-related health burden for the most vulnerable in the future, as viable adaptation strategies are not yet identified (66). As it stands, there is a critical lack of knowledge on the unequal impact of heat in informal settlements despite known climate and health injustices in these settlements (66,62,68). Furthermore, research on how informal settlements' residents adapt their behavior in the face of perceived exposures to climate-related health hazards are also lacking (67,65).

Our review therefore points at an urgent need for more transdisciplinary research in urban climate and health in East Africa, and more specifically in countries that neighbor the Lake Victoria Basin. We note, for instance, that several tools and techniques already exist for the study of urban climate and health impacts, but that their employment usually remains isolated and do not offer a comprehensive understanding of how the heterogeneity of urban climates translates into a variety of potential urban health outcomes. For example, Chepkorir et al.(2014), or Agha et al. (2017, 2019) compared inter-city vector competence or urban versus rural sites, but did not perform intra-city analysis. Several studies in the corpus also rely on remotely-sensed climate data or large scale GCMs rather than deploying viable low-cost weather sensors, as suggested by Kabano et al.(2022), Van De Walle et al.(2022) or Nizeyimana et al. (2025). There are known limitations in the employment of surface environmental indicators for the prediction of atmospheric phenomena in the urban canopy (74–76), or of large-scale models that do not integrate the effect of cities' heterogeneous environment on the climate (Lauwaet et al., 2015; Goodess et al., 2021; Morakinyo, et al., 2026). Besides, climate-health impact studies tend to work with single time-series of weather data to estimate the effect of heat or cold on the mortality and morbidity of cities' inhabitants (e.g., Egondi et al., 2012; Sewe et al., 2018). But these are gathered through official weather measurements that are usually located outside of the city and that therefore do not incorporate the additional burden related to the urban climate in their predictions (79,80). They also entirely miss the unequal exposures to climate-related health hazards that are experienced within urban environments around the Lake Victoria basin (19,60) . This therefore calls for more representative urban climate data in the region, something that can be obtained via urban climate models (56), or at least, via land-use land-cover data that integrate an urban climate component, like Local Climate Zones (41,57,73). Studies that engage with residents should also try to provide more quantitative data on the experienced climate (e.g., through the use of embarked sensors at the time of the interviews), as some mismatch between reported thermal discomfort and actual temperatures were already reported (66).

It is important to note that these conclusions are subject to some limitations of our scoping review. First, we assumed that temperature would be a cross-sectional weather variable that would cover the vast majority of potential climate-health hazards and that it would be sufficient for mapping the current state-of-the-art on urban climate and health research. Future research could scope for other weather variable that may influence health hazards, like rainfall or humidity. Second, we constrained our search to abstracts of peer-reviewed journal articles. Including search of keywords in title and/or other parts of the manuscript could have potentially extended the reviewed corpus. Nevertheless, this ensured that urban climate and health elements of the performed research were meant to be highlighted in the abstract, therefore strengthening the strength of the evidence. Third, personal biases are evidently impacting the selection process, but this was mitigated by having a double-blinded screening with authors based in different institutions and with different backgrounds. We thus consider that the reported evidence is adequate and reliable for understanding the current research in urban climate and health in the studied countries of East Africa.

In the end, we argue that, considering the amount of urban climate related health risks that are already faced in countries that neighbor the Lake Victoria Basin, an urgent response to address local challenges related to the characteristic data scarcity should be set by unlocking funding for the deployment of long-term monitoring systems. Data gathering should also be as comprehensive as possible and not focus solely on one aspect of urban climate or health. This way, research could start offering comprehensive adaptation solutions that do not only respond to single urban health issues. For example, responding to urban heat through the deployment of blue or green infrastructure, independent of their recorded positive impacts in the region (43,60), may be detrimental due to an increased vectorial capacity of infectious mosquitoes. Urban interventions that try to reduce the temperature in informal settlements should also consider opportunities for addressing water management challenges. For instance, interventions that prevent run-off and/or floodings could help preventing exacerbation of the risk of exposure to water-borne and/or vector-borne diseases by mitigating the impacts of flooding on water safety and breeding site availability (81,82). Further studies on compound events that affect climate-related hazards and air quality should also be integrated into the design of interventions as local air pollution is not only linked to anthropogenic activities, but also to natural processes that follow the seasonality of wet and dry seasons (83).

In summary, we identify four potential research pathways and opportunities for urban climate and health research in the region:

1. **Develop integrated climate and health datasets through long-term monitoring systems.** Many reviewed studies rely on short-term data collection, limiting the ability to assess long-term urban climate–health interactions. Addressing this requires sustained investment in high-resolution health, epidemiological, environmental, and urban climate data collection.

Low-cost sensor networks and citizen science initiatives offer promising avenues to help overcome current data scarcity.

2. **Advance intra-urban climate–health analyses beyond coarse or inter-city approaches.** Future research should better capture within-city variability by leveraging urban climate models, remotely sensed data, low-cost sensor networks, and mixed-methods approaches across diverse neighborhoods. Understanding inequalities in climate–health risks across the Lake Victoria Basin is essential, and research should not focus exclusively on informal settlements to ensure inclusive planning. Participatory approaches are also needed to capture residents' adaptive behaviors and lived experiences. Tools such as Local Climate Zones can support standardized and spatially explicit risk mapping.
3. **Strengthen transdisciplinary and systems-based approaches within a One Health / Planetary Health framework.** Research should integrate urban climate science, environmental science, public health, urban planning, governance, and social sciences. Such approaches are essential to better understand compound risks and to evaluate the cross-sectoral costs and benefits of urban climate interventions.
4. **Develop context-specific adaptation strategies that maximize co-benefits and avoid maladaptation**. Locally tailored policies should account for the multi-dimensional impacts of climate-sensitive urban design. Follow-up studies are needed to evaluate the outcomes of interventions and build evidence on both intended and unintended effects of adaptation strategies in the region.

In doing so, research in East African countries around the Lake Victoria basin could not only influence local decision-making to prevent maladaptation but could also influence adaptative and mitigative practices across the globe. In fact, geographies of climate-related health hazards are changing due to global climate change and new challenges that East African countries already experience are to be faced by countries of other regions of the world. Recent outbreaks of chikungunya epidemics in North America (84), West Nile virus in Europe (85), or dengue in France (86) just show that what was considered to be viable strategies to adapt cities to climate change in certain places may not always be so. Any knowledge acquired on these synergetic health impacts of urban climates in East Africa will therefore not only benefit local communities, but also offer viable paths for building more resilient cities across the globe.

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Generative Artificial Intelligence disclosure statement

The authors acknowledge the use of Microsoft Copilot (version GPT-5.5) for *Python* code generation and improvement, and for language check-up. No Gen AI was employed in the reviewing of the manuscripts referred to in this manuscript or in the acquisition of references.

Data and code availability statement

All input data, bibliographic records and codes for literature and data analysis can be asked to the corresponding author or the associate editor for reviewing purposes. All will be made publicly available once the reviewing process is complete.

Authors contribution

O.B. study design, literature review, literature screening, writing, analysis, figures, data management. T.E.M. literature screening, writing. C.H. project lead, writing

References

1. Adenle AA, Ford JD, Morton J, Twomlow S, Alverson K, Cattaneo A, et al. Managing Climate Change Risks in Africa - A Global Perspective. Ecol Econ. 2017 Nov 1;141:190–201. doi:10.1016/j.ecolecon.2017.06.004

2. Fonjong L, Matose F, Sonnenfeld DA. Climate change in Africa: Impacts, adaptation, and policy responses. Glob Environ Change. 2024 Dec 1;89:102912. doi:10.1016/j.gloenvcha.2024.102912

3. World Meteorological Organization. State of the Climate in Africa 2023 [Internet]. 2024 [cited 2026 May 11]. Available from: https://library.wmo.int/records/item/69000-state-of-the-climate-in-africa-2023

4. Wright CY, Kapwata T, Naidoo N, Asante KP, Arku RE, Cissé G, et al. Climate Change and Human Health in Africa in Relation to Opportunities to Strengthen Mitigating Potential and Adaptive Capacity: Strategies to Inform an African "Brains Trust." Ann Glob Health. 2024 Jan 29;90(1). doi:10.5334/aogh.4260

5. Thiery W, Lange S, Rogelj J, Schleussner CF, Gudmundsson L, Seneviratne SI, et al. Intergenerational inequities in exposure to climate extremes. Science. 2021 Oct 8;374(6564):158–60. doi:10.1126/science.abi7339

6. Adeyeri OE, Ishola KA, Ajadi SA, Ekot BC, Folorunsho AH, Ayegbusi KI, et al. Coupled climate–land-use interactions modulate projected heatwave intensification across Africa. Commun Earth Environ. 2026 Jan 7;7(1):85. doi:10.1038/s43247-025-03110-6

7. Andrews O, Quéré CL, Kjellstrom T, Lemke B, Haines A. Implications for workability and survivability in populations exposed to extreme heat under climate change: a modelling study. Lancet Planet Health. 2018 Dec 1;2(12):e540–7. doi:10.1016/S2542-5196(18)30240-7 PubMed PMID: 30526940.

8. Lwasa S, Buyana K, Kasaija P, Mutyaba J. Scenarios for adaptation and mitigation in urban Africa under 1.5 °C global warming. Curr Opin Environ Sustain. 2018 Feb 1;1.5°C Climate change and urban areas30:52–8. doi:10.1016/j.cosust.2018.02.012

9. Ogwu MC. Towards Sustainable Development in Africa: The Challenge of Urbanization and Climate Change Adaptation. In: Cobbinah PB, Addaney M, editors. The Geography of Climate Change Adaptation in Urban Africa [Internet]. Cham: Springer International Publishing; 2019 [cited 2026 May 11]. p. 29–55. Available from: https://doi.org/10.1007/978-3-030-04873-0_2 doi:10.1007/978-3-030-04873-0_2

10. Agyarko RKD, Kithinji D, Nsarhaza KB. Climate Change and the Rise of Emerging and Re-Emerging Infectious Diseases in Africa: A Literature Review. Int J Environ Res Public Health. 2025 Jun 5;22(6). doi:10.3390/ijerph22060903

11. Peterson AT. Shifting suitability for malaria vectors across Africa with warming climates. BMC Infect Dis. 2009 May 10;9(1):59. doi:10.1186/1471-2334-9-59

12. Ryan SJ, McNally A, Johnson LR, Mordecai EA, Ben-Horin T, Paaijmans K, et al. Mapping Physiological Suitability Limits for Malaria in Africa Under Climate Change. Vector-Borne Zoonotic Dis. 2015 Dec 1;15(12):718–25. doi:10.1089/vbz.2015.1822

13. Yamba EI, Fink AH, Badu K, Asare EO, Tompkins AM, Amekudzi LK. Climate Drivers of Malaria Transmission Seasonality and Their Relative Importance in Sub-Saharan Africa. GeoHealth. 2023;7(2):e2022GH000698. doi:10.1029/2022GH000698

14. Nichols G, Lake I, Heaviside C. Climate Change and Water-Related Infectious Diseases. Atmosphere. 2018 Oct 1;9(10). doi:10.3390/atmos9100385

15. Benmarhnia T, Deguen S, Kaufman JS, Smargiassi A. Review Article: Vulnerability to Heat-related Mortality: A Systematic Review, Meta-analysis, and Meta-regression Analysis. Epidemiology. 2015 Nov;26(6):781–93. doi:10.1097/EDE.0000000000000375 PubMed PMID: 26332052.

16. Morakinyo TE, E. Adeyeri O, Daramola MT, Vishal B, Ishola KA, Obe OB, et al. Multi-Country-Multi-City Characterisation of Heat Stress and Exposure in Africa. Int J Climatol. 2026 Apr 21;n/a(n/a):e70385. doi:10.1002/joc.70385

17. Nyiwul L. Climate change adaptation and inequality in Africa: Case of water, energy and food insecurity. J Clean Prod. 2021 Jan 1;278:123393. doi:10.1016/j.jclepro.2020.123393

18. Epule TE, Poirier V, Chehbouni A, Salih W, Kechchour A, Kambiet PLK, et al. A new index assessing adaptive capacity across Africa. Environ Sci Policy. 2023 Nov 1;149:103561. doi:10.1016/j.envsci.2023.103561

19. Scott AA, Misiani H, Okoth J, Jordan A, Gohlke J, Ouma G, et al. Temperature and heat in informal settlements in Nairobi. PLOS ONE. 2017 Nov 6;12(11):e0187300. doi:10.1371/journal.pone.0187300

20. Akinsanola AA, Singhai P, Taguela TN, Folorunsho AH, Adeyeri OE, Morakinyo TE, et al. A review of urban resilience to weather and climate extremes. City Built Environ. 2025 Nov 13;3(1):24. doi:10.1007/s44213-025-00063-6

21. Mhedhbi Z, Mazzega P, Gaston M, Haouès-Jouve S, Hidalgo J. Mining the Web of Science for African cities and climate change (1991–2021). Front Sustain Cities. 2023 May 3;5. doi:10.3389/frsc.2023.989266

22. Jian X, Oule H, Tront JM. World Bank [Text/HTML] [Internet]. 2018 [cited 2026 Apr 15]. Concept Project Information Document-Integrated Safeguards Data Sheet - Lake Victoria Environmental Management Project Phase Three - P165352. Available from: https://documents.worldbank.org/pt/publication/documents-reports/documentdetail/328181540137025874

23. Boke-Olén N, Abdi AM, Hall O, Lehsten V. High-resolution African population projections from radiative forcing and socio-economic models, 2000 to 2100. Sci Data. 2017 Jan 17;4(1):160130. doi:10.1038/sdata.2016.130

24. Ramon D, Heaviside C, Brousse O, Simpson C, Amuron I, Jjemba EW, et al. Projected population exposure to dangerous heat stress around Lake Victoria under a high-end climate change scenario. Environ Res Lett. 2025 Sep;20(10):104068. doi:10.1088/1748-9326/ae05b1

25. Van de Walle J, Thiery W, Brousse O, Souverijns N, Demuzere M, van Lipzig NPM. A convection-permitting model for the Lake Victoria Basin: evaluation and insight into the mesoscale versus synoptic atmospheric dynamics. Clim Dyn. 2020 Feb 1;54(3):1779–99. doi:10.1007/s00382-019-05088-2

26. Van de Walle J, Thiery W, Brogli R, Martius O, Zscheischler J, van Lipzig NPM. Future intensification of precipitation and wind gust associated thunderstorms over Lake Victoria. Weather Clim Extrem. 2021 Dec 1;34:100391. doi:10.1016/j.wace.2021.100391

27. Anyah RO, Semazzi FHM. Simulation of the sensitivity of Lake Victoria basin climate to lake surface temperatures. Theor Appl Climatol. 2004 Oct 1;79(1):55–69. doi:10.1007/s00704-004-0057-4

28. Virts KS, Goodman SJ. Prolific Lightning and Thunderstorm Initiation over the Lake Victoria Basin in East Africa. Mon Weather Rev. 2020 May 1;148(5):1971–85. doi:10.1175/MWR-D-19-0260.1

29. Vemado F, Pereira Filho AJ. Convective Rainfall in Lake Victoria Watershed and Adjacent Equatorial Africa. Atmospheric Clim Sci. 2021;11(03):373–97. doi:10.4236/acs.2021.113022

30. Thiery W, Davin EL, Seneviratne SI, Bedka K, Lhermitte S, van Lipzig NPM. Hazardous thunderstorm intensification over Lake Victoria. Nat Commun. 2016 Sep 23;7(1):12786. doi:10.1038/ncomms12786

31. Bürgesser RE, Nicora MG, Ávila EE. Spatial and time distribution of the flash rate over tropical Africa. J Atmospheric Sol-Terr Phys. 2013 Mar 1;94:41–8. doi:10.1016/j.jastp.2012.12.025

32. Thiery W, Davin EL, Panitz HJ, Demuzere M, Lhermitte S, Lipzig N van. The Impact of the African Great Lakes on the Regional Climate. J Clim. 2015 May 15;28(10):4061–85. doi:10.1175/JCLI-D-14-00565.1

33. Kiwanuka-Tondo J, Semazzi F, Pettiway K. Climate risk communication of navigation safety and climate conditions over Lake Victoria basin: Exploring perceptions and knowledge of indigenous communities. Ricart Casadevall S, editor. Cogent Soc Sci. 2019 Jan 1;5(1):1588485. doi:10.1080/23311886.2019.1588485

34. Virts KS, Goodman SJ. Prolific Lightning and Thunderstorm Initiation over the Lake Victoria Basin in East Africa. Mon Weather Rev. 2020 May 1;148(5):1971–85. doi:10.1175/MWR-D-19-0260.1

35. Arinabo D. Understanding the Evolving Nature of Urban Flood Risks in Sub-Saharan Africa: The Case of Kampala City, Uganda. In: Floods - Hydraulics and Hydrology [Internet]. IntechOpen; 2024 [cited 2026 May 12]. Available from: https://www.intechopen.com/chapters/1179231 doi:10.5772/intechopen.1005760

36. Mukwaya PI, Sengendo H, Lwasa S. Enhancing Security and Resilience of Low-Income Communities to Climate Change in Growing Cities: An Assessment of Flood Management and Planning Regimes in Kampala City, Uganda. In: Scheffran J, Brzoska M, Brauch HG, Link PM, Schilling J, editors. Climate Change, Human Security and Violent Conflict: Challenges for Societal Stability [Internet]. Berlin, Heidelberg: Springer; 2012 [cited 2026 May 12]. p. 543–57. Available from: https://doi.org/10.1007/978-3-642-28626-1_26 doi:10.1007/978-3-642-28626-1_26

37. Pietroiusti R, Vanderkelen I, Otto FEL, Barnes C, Temple L, Akurut M, et al. Possible role of anthropogenic climate change in the record-breaking 2020 Lake Victoria levels and floods. Earth Syst Dyn. 2024 Mar 18;15(2):225–64. doi:10.5194/esd-15-225-2024

38. Van de Walle J, Brousse O, Arnalsteen L, Brimicombe C, Byarugaba D, Demuzere M, et al. Lack of vegetation exacerbates exposure to dangerous heat in dense settlements in a tropical African city. Environ Res Lett. 2022 Feb 1;17(2). Located at: WOS:000745314600001. doi:10.1088/1748-9326/ac47c3

39. Brousse O, Wouters H, Demuzere M, Thiery W, Van de Walle J, van Lipzig NPM. The local climate impact of an African city during clear-sky conditions—Implications of the recent urbanization in Kampala (Uganda). Int J Climatol. 2020;40(10):4586–608. doi:10.1002/joc.6477

40. Omumbo JA, Guerra CA, Hay SI, Snow RW. The influence of urbanisation on measures of *Plasmodium falciparum* infection prevalence in East Africa. Acta Trop. 2005 Jan 1;93(1):11–21. doi:10.1016/j.actatropica.2004.08.010

41. Brousse O, Georganos S, Demuzere M, Dujardin S, Lennert M, Linard C, et al. Can we use local climate zones for predicting malaria prevalence across sub-Saharan African cities? Environ Res Lett. 2020 Dec;15(12):124051. doi:10.1088/1748-9326/abc996

42. Morlighem C, Chaiban C, Georganos S, Brousse O, Walle JV de, Lipzig NPM van, et al. The Multi-Satellite Environmental and Socioeconomic Predictors of Vector-Borne Diseases in African Cities: Malaria as an Example. Remote Sens. 2022 Oct 26;14(21). doi:10.3390/rs14215381

43. Kabano P, Harris A, Lindley S. Spatiotemporal dynamics of urban climate during the wet-dry season transition in a tropical African city. Int J Biometeorol. 2022;66(2):385–96. Located at: Scopus. doi:10.1007/s00484-020-02061-1

44. Mitchell D, Lo YTE, Ball E, Godwin JL, Andrews O, Barciela R, et al. Expert judgement reveals current and emerging UK climate-mortality burden. Lancet Planet Health. 2024 Sep 1;8(9):e684–94. doi:10.1016/S2542-5196(24)00175-X PubMed PMID: 39243784.

45. Egondi T, Kyobutungi C, Kovats S, Muindi K, Ettarh R, Rocklöv J. Time-series analysis of weather and mortality patterns in Nairobi's informal settlements. Glob Health ACTION. 2012;5:23–32. Located at: WOS:000209741600005. doi:10.3402/gha.v5i0.19065

46. Sewe MO, Bunker A, Ingole V, Egondi T, Åström DO, Hondula DM, et al. Estimated effect of temperature on years of life lost: A retrospective time-series study of low-, middle-, and high-income regions. Environ Health Perspect. 2018;126(1). Located at: Scopus. doi:10.1289/EHP1745

47. Chepkorir E, Lutomiah J, Mutisya J, Mulwa F, Limbaso K, Orindi B, et al. Vector competence of Aedes aegypti populations from Kilifi and Nairobi for dengue 2 virus and the influence of temperature. Parasit Vectors. 2014;7(1). Located at: Scopus. doi:10.1186/1756-3305-7-435

48. Agha SB, Tchouassi DP, Turell MJ, Bastos ADS, Sang R. Entomological assessment of dengue virus transmission risk in three urban areas of Kenya. PLoS Negl Trop Dis. 2019;13(8). Located at: Scopus. doi:10.1371/journal.pntd.0007686

49. Agha SB, Chepkorir E, Mulwa F, Tigoi C, Arum S, Guarido MM, et al. Vector competence of populations of Aedes aegypti from three distinct cities in Kenya for chikungunya virus. PLoS Negl Trop Dis. 2017;11(8). Located at: Scopus. doi:10.1371/journal.pntd.0005860

50. Okuneye K, Abdelrazec A, Gumel AB. Mathematical analysis of a weather-driven model for the population ecology of mosquitoes. Math Biosci Eng. 2018;15(1):57–93. Located at: Scopus. doi:10.3934/mbe.2018003

51. Njuguna C, Njeru I, Mgamb E, Langat D, Makokha A, Ongore D, et al. Enteric pathogens and factors associated with acute bloody diarrhoea, Kenya. BMC Infect Dis. 2016 Sep 6;16. Located at: WOS:000382745800003. doi:10.1186/s12879-016-1814-6

52. Kirenga BJ, Meng Q, Van Gemert F, Aanyu-Tukamuhebwa H, Chavannes N, Katamba A, et al. The state of ambient air quality in two ugandan cities: A pilot cross-sectional spatial assessment. Int J Environ Res Public Health. 2015;12(7):8075–91. Located at: Scopus. doi:10.3390/ijerph120708075

53. Stewart ID, Oke TR. Local Climate Zones for Urban Temperature Studies. Bull Am Meteorol Soc. 2012 Dec 1;93(12):1879–900. doi:10.1175/BAMS-D-11-00019.1

54. Gaita SM, Boman J, Gatari MJ, Wagner A, Jonsson SK. Characterization of size-fractionated particulate matter and deposition fractions in human respiratory system in a typical African city: Nairobi, Kenya. Aerosol Air Qual Res. 2016;16(10):2378–85. Located at: Scopus. doi:10.4209/aaqr.2016.01.0019

55. Hashemi A. Climate Resilient Low-Income Tropical Housing. Energies. 2016;9(6). Located at: Scopus. doi:10.3390/en9060468

56. Brousse O, Georganos S, Demuzere M, Vanhuysse S, Wouters H, Wolff E, et al. Using Local Climate Zones in Sub-Saharan Africa to tackle urban health issues. Urban Clim. 2019;27:227–42. Located at: Scopus. doi:10.1016/j.uclim.2018.12.004

57. Morlighem C, Chaiban C, Georganos S, Brousse O, van Lipzig NPM, Wolff E, et al. Spatial Optimization Methods for Malaria Risk Mapping in Sub-Saharan African Cities Using Demographic and Health Surveys. GeoHealth. 2023;7(10). Located at: Scopus. doi:10.1029/2023GH000787

58. Osalla J, Gouagna LC, Rotich G, Nzilani M, Safari P, Senagi K, et al. Longitudinal surveillance of Aedes aegypti (Diptera: Culicidae) in urban coastal Kenya: population dynamics, blood feeding frequency and dengue virus infection rates. Sci Rep. 2025 Jul 1;15(1):21787. doi:10.1038/s41598-025-05408-z

59. Rothfusz LP. The Heat Index “Equation” (or, More Than You Ever Wanted to Know About Heat Index). 1990 Jul 1.

60. Van De Walle J, Brousse O, Arnalsteen L, Brimicombe C, Byarugaba D, Demuzere M, et al. Lack of vegetation exacerbates exposure to dangerous heat in dense settlements in a tropical African city. Environ Res Lett. 2022;17(2). Located at: Scopus. doi:10.1088/1748-9326/ac47c3

61. Kajjoba D, Kasedde H, Olupot PW, Lwanyaga JD. Evaluation of thermal comfort and air quality of low-income housing in Kampala City, Uganda. Energy Built Environ. 2022;3(4):508–24. Located at: Scopus. doi:10.1016/j.enbenv.2021.05.007

62. Corburn J, Njoroge P, Weru J, Musya M. Urban Climate Justice, Human Health, and Citizen Science in Nairobi’s Informal Settlements. Urban Sci. 2022;6(2). Located at: Scopus. doi:10.3390/urbansci6020036

63. Kalisa E, Sudmant A. Heatwaves amplify air pollution risks in Sub-Saharan Africa. Sci Rep. 2025 Jul 21;15(1):26448. doi:10.1038/s41598-025-12210-4

64. Nizeyimana E, Hanyurwimfura D, Uwanyirigira G, Karikumutima B, Nsenga J, Mihigo IN. CleanCity IoT: A Vehicle-Mounted Platform for Real-Time Urban Air-Quality Monitoring and Forecasting in Resource-Constrained African Cities. Int J Adv Comput Sci Appl IJACSA. 2025 Dec 31;16(12). doi:10.14569/IJACSA.2025.01612100

65. Adegun OB, Mbuya EC, Njavike E. Responses to Heat Stress Within an Unplanned Settlement in Dar Es Salaam, Tanzania. Front Built Environ. 2022;8. Located at: Scopus. doi:10.3389/fbuil.2022.874751

66. Pasquini L, van Aardenne L, Godsmark CN, Lee J, Jack C. Emerging climate change-related public health challenges in Africa: A case study of the heat-health vulnerability of informal settlement residents in Dar es Salaam, Tanzania. Sci Total Environ. 2020;747. Located at: Scopus. doi:10.1016/j.scitotenv.2020.141355

67. Andersen JG, Karekezi C, Ali Z, Yonga G, Kallestrup P, Kraef C. Perspectives of local community leaders, health care workers, volunteers, policy makers and academia on climate change related health risks in mukuru informal settlement in nairobi, kenya—a qualitative study. Int J Environ Res Public Health. 2021;18(22). Located at: Scopus. doi:10.3390/ijerph182212241

68. Andersen JG, Kallestrup P, Karekezi C, Yonga G, Kraef C. Climate change and health risks in Mukuru informal settlement in Nairobi, Kenya – knowledge, attitudes and practices among residents. BMC Public Health. 2023;23(1). Located at: Scopus. doi:10.1186/s12889-023-15281-y

69. Vidal Merino M, Gajjar SP, Subedi A, Polgar A, Van Den Hoof C. Resilient Governance Regimes That Support Urban Agriculture in Sub-Saharan Cities: Learning From Local Challenges. Front Sustain Food Syst. 2021;5. Located at: Scopus. doi:10.3389/fsufs.2021.692167

70. Nakamura K. City Temperature of Nairobi. J Geogr Chigaku Zasshi. 1966;75(6):316–25. doi:10.5026/jgeography.75.6_316

71. Jonsson P, Bennet C, Eliasson I, Selin Lindgren E. Suspended particulate matter and its relations to the urban climate in Dar es Salaam, Tanzania. Atmos Environ. 2004 Aug 1;38(25):4175–81. doi:10.1016/j.atmosenv.2004.04.021

72. Egondi T, Kyobutungi C, Rocklöv J. Temperature Variation and Heat Wave and Cold Spell Impacts on Years of Life Lost Among the Urban Poor Population of Nairobi, Kenya. Int J Environ Res Public Health. 2015 Mar 1;12(3):2735–48. doi:10.3390/ijerph120302735

73. Morakinyo TE, Obe OB, Mills G, Adegun OB, Mngumi L, Mbuya E, et al. The impact of hazard indicator selection on urban heat risk assessment: evidence from two Sub-Saharan African cities. City Environ Interact. 2026 Apr 1;30:100338. doi:10.1016/j.cacint.2026.100338

74. Venter ZS, Brousse O, Esau I, Meier F. Hyperlocal mapping of urban air temperature using remote sensing and crowdsourced weather data. Remote Sens Environ. 2020 Jun 1;242:111791. doi:10.1016/j.rse.2020.111791

75. Chakraborty T, Venter ZS, Qian Y, Lee X. Lower Urban Humidity Moderates Outdoor Heat Stress. AGU Adv. 2022;3(5):e2022AV000729. doi:10.1029/2022AV000729

76. Zhan W, Bechtel B, Du H, Chakraborty TC, Kotthaus S, Krayenhoff ES, et al. Satellite-derived Land Surface Temperatures Strongly Mischaracterise Urban Heat Hazard [Internet]. arXiv; 2025 [cited 2026 May 13]. Available from: http://arxiv.org/abs/2509.16568 doi:10.48550/arXiv.2509.16568

77. Lauwaet D, Hooyberghs H, Maiheu B, Lefebvre W, Driesen G, Looy SV, et al. Detailed Urban Heat Island Projections for Cities Worldwide: Dynamical Downscaling CMIP5 Global Climate Models. Climate. 2015 May 31;3(2):391–415. doi:10.3390/cli3020391

78. Goodess C, Berk S, Ratna SB, Brousse O, Davies M, Heaviside C, et al. Climate change projections for sustainable and healthy cities. Build Cities. 2021 Sep 30;2(1). doi:10.5334/bc.111

79. Heaviside C, Vardoulakis S, Cai XM. Attribution of mortality to the urban heat island during heatwaves in the West Midlands, UK. Environ Health. 2016 Mar 8;15(1):S27. doi:10.1186/s12940-016-0100-9

80. Simpson CH, Brousse O, Taylor T, Milojevic A, Grellier J, Taylor J, et al. The mortality and associated economic burden of London's summer urban heat island effect: a modelling study. Lancet Planet Health. 2025 Mar 1;9(3):e219–26. doi:10.1016/S2542-5196(25)00025-7 PubMed PMID: 40120628.

81. Zerbo A, Delgado RC, González PA. Vulnerability and everyday health risks of urban informal settlements in Sub-Saharan Africa. Glob Health J. 2020 Jun 1;4(2):46–50. doi:10.1016/j.glohj.2020.04.003

82. Suhr F, Steinert JI. Epidemiology of floods in sub-Saharan Africa: a systematic review of health outcomes. BMC Public Health. 2022 Feb 10;22(1):268. doi:10.1186/s12889-022-12584-4

83. Nyaga EW, Giordano MR, Beekmann M, Westervelt DM, Gatari M, Mungai J, et al. Seasonal multisite low-cost sensor measurements to estimate spatial and temporal variability of particulate matter pollution in Nairobi, Kenya. Atmospheric Pollut Res. 2025 Oct 1;16(10):102630. doi:10.1016/j.apr.2025.102630

84. Handler MZ, Handler NS, Stephany MP, Handler GA, Schwartz RA. Chikungunya fever: an emerging viral infection threatening North America and Europe. Int J Dermatol. 2017;56(2):e19–25. doi:10.1111/ijd.13439

85. Sambri V, Capobianchi M, Charrel R, Fyodorova M, Gaibani P, Gould E, et al. West Nile virus in Europe: emergence, epidemiology, diagnosis, treatment, and prevention. Clin Microbiol Infect. 2013 Aug 1;19(8):699–704. doi:10.1111/1469-0691.12211

86. Zatta M, Brichler S, Vindrios W, Melica G, Gallien S. Autochthonous Dengue Outbreak, Paris Region, France, September–October 2023 - Volume 29, Number 12—December 2023 - Emerging Infectious Diseases journal - CDC [Internet]. 2023. doi:10.3201/eid2912.231472