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Review

Heat Stress Adaptation within Informal, Low-Income Urban Settlements in Africa

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Abstract: Climate projections indicate that persistent high temperatures and related heat stress will become a common experience in the future, across Africa. It is, therefore, important to understand challenges that might result from increasing extreme heat conditions, and how humans within urban centres can adapt. In this article, we provide a review that considers the experience of poor urban residents with extreme temperatures and adaptation strategies in relation to low-income, informal urban contexts in Africa. Our analysis is carried out across four focus countries: Nigeria, South Africa, Kenya, and Egypt. Only cursory insights exist in the context of informal settlements. We found that heat stress remains an overlooked topic in comparison to other climate change adaptation needs. Evidence shows that adaptation strategies varied and differed in framing, scale, and applied methods across the contexts. Adaptation strategies dominantly examine a broad variety of alternative building measures and, to a lesser degree, greening/nature-based strategies. It is important to highlight heat stress as a cross-cutting, focal topic in urban research in relation to informal settlements and generally broaden the spectrum. It is worthwhile to pay special attention to strategic actions and research designs that foresee win–win and co-beneficial options for local urban communities.

Keywords: heat adaptation; heat-resilient housing; thermal comfort; sustainable urbanism

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1. Introduction

Persistent high temperatures and related heat stress are a common occurrence across Africa. This experience often occurs at temperatures above 35 °C with high humidity, or above 40 °C with low humidity [1], and it is expected to continue and increase, particularly in cities, from 13 billion person-days between 1985 and 2005 to 45 billion person-days exposure by the 2060s, according to IPCC's Sixth Assessment Report [2]. Here, heat exposure per year (person-days refers to the annual number of days when the temperature is over 40.6 °C multiplied by the number of people exposed). It is, therefore, important to better understand challenges that might result from increasing and even extreme heat conditions due to climate change and their current and future impacts on humans within urban centres. Climate change adaptation is predominantly discussed and addressed with regard to hazards and shocks such as flooding, while increased heat stress is often overlooked, particularly in its connection between climatic and human settlement conditions. This aspect deserves keen consideration not only to harness "a basis for heat awareness and implementation of a heat warning system" [3] but also for inclusive urban planning policy and practice to turn their climate change resilience agenda also towards these increasing stresses.

Heat stress is a relevant climatic challenge that requires more in-depth fundamental and applied research, especially with regard to informal and low-income urban settlements. These communities are particularly sensitive to a changing climate, as they experience increased thermal discomfort and heat stress that is exacerbated due to the built environment conditions, socio-economic circumstances, as well as the lack of adaptation strategies and capacities. For example, in Egypt, an estimated 60% of the population lives in informality in its urban areas [4]. At the same time, Egypt is exposed to increasingly erratic weather events due to climate change. Among other climatic impacts, extreme heatwaves were recorded in July 2007 [5,6], in the summer of 2015 [7], and more recently, in August 2021 [8]. In 2015, especially in Greater Cairo, temperatures soared 67%, more likely due to anthropogenic climate change [9] and exacerbated by the urban heat island (UHI) effect. This affects vulnerable populations as "deaths were blamed on overpopulation and cramped living conditions", usually within informal settlements [9].

The analysis by Rohat et al. [10] paints a similar picture to that in Egypt for dozens of cities across western and central Africa. The grim climatic experience and projections for African cities notably follow the pattern of inequality that characterises the urban centres. Socio-economic conditions, which are reflected in the context of housing and environmental exposure, influence levels of heat vulnerability, heat stress, and associated health risks. Scholarly works from outside Africa—namely, developing countries such as India [11,12] and Indonesia [13]—affirm this correlation.

In this article, we report a review that considers heat stress experiences and adaptation strategies in relation to low-income communities within African cities. It involved accessing peer-reviewed and non-refereed publications from different online databases. The review focuses on areas categorised as slums and informal settlements in cities, as well as low-income housing within areas of cities that might not be officially regarded as informal settlements.

2. Methodology

This study is based on a review of the literature that considers or touches on heat and thermal stress in relation to low-income, informal urban contexts in Africa. The review was conducted in line with structured methodologies of aim/question formulation, literature search and screening, and eventual analysis, established by Green [14]. The primary aim is to identify the documented experience of poor urban residents with extreme temperatures and their adaptation and coping strategies. This analysis was performed across four focus countries: Nigeria, South Africa, Kenya, and Egypt. Within each country, consideration was given to the diverse urban contexts, especially larger cities. These four countries were selected to achieve geographical representation across northern, eastern, western, and southern parts of Africa. They hold the largest economies in each region. Additionally, compared with other countries in the continental subregions, a variety of scholarly works have paid attention to the nexus between climatic and human settlement issues in the selected countries. The selection was based on the availability of data, which varies within each country but often emanates from studies conducted in these countries' major cities and metropolitan areas.

Peer-reviewed publications (journal articles, conference proceedings, book chapters, books) and academic outputs (e.g., thesis/dissertations) within the last fifteen years (2007–2022) were retrieved from reputable and most prominent research databases, such as Scopus and Google Scholar. Additionally, the Egyptian Knowledge Bank (EKB) Management System—a large digital library—was accessed, given its relevance to studies in the Egyptian context. Applying the Boolean-based search logic, the keywords used to search the databases include heat stress, heat wave, thermal discomfort, adaptation, resilience, slums, informal settlements, low-income housing, Nigeria, South Africa, Kenya, and Egypt. Boolean search logic was applied in a recent review dealing with human physiological responses to heat stress by Clusiault et al. [15]. To have a concise and contextualised search, we used the Boolean search framework—combining the keywords into several formats while searching the databases. The formats used included (1) "heat" OR "heat stress" AND "Adapt" OR "Adaptation" AND "informal urban" OR "low-income urban"; (2) "*thermal comfort*" OR "thermal discomfort" AND "*low-income housing*" AND "South Africa (other countries or major cities were named as relevant)"; (3) "*heat stress*" OR "*heat wave*" AND "*informal settlements*" OR "*slums*"; (4) "*thermal comfort*" OR "*heat stress*" AND "*low-income housing*"; (5) "*heat*" AND "*resilience*" AND "*bottom-up*" OR "*policy*". Search across the databases initially yielded numerous publications. The subsequent screening of abstracts and initial content analysis led to exclusion of items that did not align with the objective of the review. After exclusion, a final set of 31 items (10 from Nigeria, 5 from Kenya, 9 from Egypt, 4 from South Africa, and 3 which are general/cross-cutting) were selected and reviewed extensively.

To understand policy-level actions, efforts on heat adaptation and thermal comfort improvement were reviewed through content analysis of selected (primary and secondary) literature such as local and international organisations' project and assessment reports, governmental reports and project proposals, and published books available in English or as English translations. Eighteen of these secondary sources in the literature from the four focus countries were accessed in course of the research. Reviewing these resources afforded engagement with state of the art on various initiatives by local communities, national organisations, international institutions, etc.

3. Results

3.1. Intra-Urban Inequality in Heat Exposure: A Challenge in Low-Income Informal Urban Communities

Within Africa, a few studies have provided empirical evidence that addresses intra-urban heat stress. While no study was found for Nigeria, literature search led to studies in South Africa, Egypt, and Kenya which affirm what international literature indicates. For example, in Durban (South Africa), a study using heat risk/stress mapping combined city-level data on heat exposure and social vulnerability, especially availability and access to basic services and infrastructure [16]. The mapping shows that "neighbourhoods most at risk of heat stress are those that lack access to water and sanitation, and have informal and traditional housing types"—essentially, informal settlements [16].

Furthermore, evidence of intra-urban exposure is available through studies conducted in Nairobi (Kenya). Ochola et al. [17] conducted an analysis of spatiotemporal gradients of temperature fields across a variety of neighbourhoods in Nairobi. The study revealed that higher mean land surface temperatures were also associated with zones that are mostly informal or areas surrounded by informal settlements. It attributed the higher heat load in built-up areas and informal settlements to the combined effect of natural and anthropogenic factors. In the same vein, Scott et al. [18] found that temperatures in informal settlements in Nairobi were higher than those recorded in the city's meteorological stations. For instance, "during the hottest summer on record in Nairobi, temperatures measured within three informal settlements [Kibera, Mathare, and Mukuru] regularly exceed temperatures at the central, non-slum monitoring station by several degrees or more … throughout the day and night" [18]. The higher exposure is linked to dense housing typologies and little vegetation in the low-income informal settlements.

Additionally, Greater Cairo (Egypt) was considered one of the densest in 1998 (an "average informal area density in Cairo reached 528 Inh/ha"), compared with 300 inhabitants per hectare in formally planned areas, and exceeding in areas such as Manshiet Nasser with 1500 inhabitants per hectare [19]. In informal settlements such as Rod El Farag density measures included 74,000 inhabitants per square kilometre [20]. In urban settings worldwide, climate exposure and heat stresses are linked to an intertwining combination of social, physical, and spatial setup [21], impacting the adaptive capacities of its inhabitants, particularly in informal settlements. A diverse housing stock leads to a variety of climate impacts to respond to; however, (spatial socio-economic) data covering this variety are still missing and understanding remain tentative [6]. A few case studies in Cairo's urban settings exist. Research by Khalil et al. [4] identified the "highest mean UHI intensity of +1.7 °C, as a direct effect of its urban structure" in the informal district of Imbaba, which has a high density of 1.900 inhabitants per hectare. Evidence of sensitivity to heat stress in informal settlements is also available through development cooperation projects (such as GIZ's Participatory Development Programme) and their accompanying assessments in four pilot neighbourhoods in Cairo [6,22] (ranging from Computer-aided data collection, surveys to qualitative assessments).

Studies from other parts of Africa confirm increased heat exposure within low-income informal settlements. These studies from Accra (Ghana) [23] and Kampala (Uganda) [24] attribute the problem to housing materials and lack of greening.

Generally, the empirical evidence on intra-urban heat stress is still inadequate to properly inform relevant understanding and actions. More studies are, therefore, needed. Nevertheless, a spectrum of various factors could be identified—ranging from the location within the city to spatial and physical setting, including settlement density and form, as well as socio-economic conditions.

3.2. Experiences and Perceptions of (Increasing) Thermal Discomfort and Heat Stress

Several studies identified the prevalence of, and increase in, thermal discomfort and actual heat stress within low-income settings in the selected African countries. In their post-occupancy evaluation of low-income housing in Abuja (Nigeria), with a hot and humid climate, Adaji et al. [25] showed that over 70% of the occupants were dissatisfied with their thermal environment. The average temperature in their case study settings was 31.7 °C. In Ibadan, Adegebo [26] found that 43% of the 400 survey respondents agreed that there is a "warmer/hotter temperature during day and night" over the preceding five years. In Nairobi, thermal discomfort is highest from January to March, and from September to November.

In Greater Cairo, Khalil et al. [4] undertook a detailed thermal comfort mapping of outdoor spaces in the informal district of Imbaba, with the help of GIS mapping. Concerning exposure, a GIZ study presented that 68% of the respondents noticed higher temperatures in the summer [27], although varying by residential area. Overall, around 75% of respondents perceived heat (in contrast to extreme cold) as the most problematic climate condition for themselves and members of their households [27].

3.3. Drivers for Increased Thermal Discomfort and Heat Stress

The problem of extreme heat is usually linked to climate change, although other significant enabling factors can include overcrowding, building inadequacies (e.g., poor ventilation, excessive solar insolation, etc.), and neighbourhood morphology, as implied in Section 3.1. For two out of the four reference countries, examples could be identified during the literature search. In particular, overcrowding seems to be a concern; for instance, occupancy rates of 3 to 7 persons per room have been recorded across slums in Nigeria [28]. In Nairobi, over half of the residents within a settlement lived in a 3.5 by 4 m room, accommodating at least five persons [29]. Regarding Egypt's Greater Cairo Region, a GIZ project baseline study covering 2800 households in four informal neighbourhoods (Ain Shams, Ezbet El-Nasr, Masaken Geziret El-Dahab, and Markaz El-Abhath) established that average occupancy rates ranged from 3 to 6 per household, an average 3.3 rooms per household, and 95% lived in apartments (as opposed to free-standing houses [27].

Moreover, the quality of the houses (e.g., wall construction material, with or without ceiling, kind of roof covering, etc.,) are contributors to the level of exposure to heat and thermal comfort. Dwellings in informal settlements are mostly built from flimsy materials with poor heat-resisting qualities. In Nairobi's Mathare Valley settlement, iron sheets are predominantly used for walls and roofs. In most cases, a ceiling is absent [29]. These materials, especially iron sheets, absorb heat when the temperature is high, making the dwelling very hot during the day and at times into the night.

In Greater Cairo, the quality of construction and building materials (the majority use brick walls and cement roofs) affects climatic performance across informal settlements. The houses are partially constructed making use of reinforced concrete skeleton frames that offer structural stability [30], but these buildings in informal areas lack adaptive quality and robustness due to lacking proper painting, plastering, or insulation [4]. Correlating challenges could be identified in a GIZ project study assessing vulnerabilities to climate change: Around 20% of youth residents interviewed (and 18% among households) acknowledged building problems, linking them to their informal nature/setup without permission (62%, and 70% among households) or ramshackle state (45%, and 29.9% among households), thus expressing fear of general safety and/or collapse (65%, and 60% among households) [27]. Buildings' sensitivities are determined by overall urban density, thermal performance of the housing units, availability and robustness of active and passive ventilation systems [5,6], and security of buildings [27].

Some studies provide helpful correlations of other drivers. For instance, one study in Egypt looked at the personal and physical factors to human thermal comfort, resulting in the analysis of clothing ensembles and their correlating insulation values for Egypt in general [31]. In Katzan [32], there was a "qualitative vulnerability and adaptation assessment among pregnant women and mothers of children under five" in three of Cairo's informal settlements. The assessment revealed drivers that, firstly, are environmental factors such as infrastructure and living conditions, which are "outside of their control". Secondly, drivers were noted that are linked to behaviour and depend on (lack of access to) resources such as time and finance, health care services, and nurseries among vulnerable groups [32]. Moreover, gaps in awareness (resulting in maladaptation practices) were identified. What feeds into the challenge of awareness is the seeming lack of noticeability of climatic impacts besides extreme heat [6]. In GIZ's four project areas, about one-fifth of the above-mentioned baseline study respondents acknowledged having heard about climate change, whereby 74% considered "climate change as an environmental challenge" [27]. However, around 41% of interviewees reportedly mentioned not knowing the reasons for climate change, while 90% stated that no action can be taken about the changing climate [27].

For some residents, heat exposure is occupational; that is, it is work-related. This situation is common among the self-employed population, resulting from working conditions in and around homes and home-based livelihood/enterprises, for example, kitchen-related activities such as frying or roasting food items and construction activities. Due to their informal and low-skill nature, it appears many of these "residents would be unable to change their work hours or locations to reduce their heat exposure" [33]. In Greater Cairo, for instance, nearby slaughterhouses [30]) and stone and marble crafting sites contribute to overall air pollution [34], thus intensifying heat-stress-related vulnerabilities.

3.4. Heat-Related Health Challenges and Associated Health-Seeking Responses

In the literature on the urban African context, heat stress is particularly presented as a health challenge. The most prominent physiological impacts reported in the literature are persistent headaches and body/skin rashes across cities in Nigeria [26,35,36]. Other notable health challenges are eczema/fungal infections and heat stroke. In extreme situations, these physiological problems result in death. In Maiduguri, northeast Nigeria, a report showed that within "one week at least 60 people died of heat stroke caused by intense heat . . . between 55 degrees and 60 °C" [37].

Heat-related health problems are complicated by poor access to adequate and affordable health care. For instance, in Nigeria's southwestern town of Ikare-Akoko, about 17.8% of residents surveyed do not have access to a health centre for care if experiencing heat-related health problems [35]. Without proper health care, the residents often resort to self-medication and local therapies such as the application of dusting powder.

In Egypt, some studies investigated the impacts of heat stress and its burden on health infrastructure [38]. Other studies investigated direct and indirect health effects of climate risks such as heat waves. Vector-borne diseases linked to increased heat in overcrowded living environments are trachoma, respiratory infections from air pollution, cardiovascular diseases, and consequently, mortalities linked to heat, malnutrition, and dehydration [32,39]. Exacerbating these challenges are insufficient health expenditures or provision of social and health services in informal settlements. In a health-related assessment focusing on pregnant women and children under five years, Katzan [32] undertook focus group interviews at three sites in Cairo. The findings of the study revealed that people's underlying and pre-existing health status determines their sensitivity to heat and environmental factors, worsening during summer. Moreover, high basic costs, insufficient sanitary conditions, and insufficient services (water availability, electricity, sewage, waste disposal) "lead to a population being more vulnerable to external factors like changing climatic conditions" [32].

3.5. Behavioural Responses to Heat Stress and Thermal Discomfort within Residential Settings

Human responses by poor urban residents within informal areas or low-income housing during high temperatures have been studied in various African contexts. The most popular responses at the personal level are opening windows/doors to allow improved airflow, shading for windows and balconies, taking a cold bath, drinking water or chilled fluids, and using hand fans or electric fans. These practices are consistent across studies conducted within low-income neighbourhoods within Nigerian cities such as Akure [40], Ikare-Akoko [35], and Ibadan [26,36], as well as Johannesburg in South Africa [41], and Cairo in Egypt [4,27,30,32]. Other practices such as sleeping outside the house and dousing oneself with water were also reported across settlements in Nairobi [29] and Greater Cairo [30]. Further coping measures reported in informal settlements in Greater Cairo include moving to less exposed rooms, wearing fewer clothes and lighter clothes [27,30].

Notably, using air-conditioners is not common within informal settlements or within low-income housing. The capital and operational costs associated with it cannot be afforded by socio-economically weak households in this context. Moreover, Jay et al. [42] criticised air conditioning as a heat-resistant strategy for vulnerable urban settings because it drives increasing demand for electricity and, at the same time, tends to remove people's stimulus for physiological and perceptual adaptation to the heat.

Box 1 summarises the above-mentioned responses and other possible individual-level behavioural responses to heat stress and thermal discomfort across informal settlements in the urban African setting. The additional indicated responses were identified from relevant literature emanating from outside the focus countries (for example, [42–44]).

Box 1. Summarised list of personal heat response strategies, based on presented literature.

- Fans—electric and manual (hand-held) fans of various types promoting heat loss through convection and evaporation. Misting fans emitting high-pressure water spray can enhance evaporative heat loss from the skin without additional sweating;
- Self-dousing—water/ice/moisture applied to the skin (e.g., with a spray bottle, napkin, or sponge); draping damp chilled towels or donning wet clothing;
- Foot immersion—immersing feet to above the ankles in cold water;
- Clothing—light-coloured clothing or protective equipment, smaller clothing, vents in clothing, etc.;
- Hydration—ingesting cold fluids;
- Activity planning—reduced outdoor activities or those during sunny hours of the day;
- Sleep location—sleeping outdoors, sleeping in less exposed rooms/areas, etc.;
- Operating building components—opening doors, windows, or curtains.

Like the drivers of thermal discomfort and heat stress (Section 3.2), the decisions to take a particular set of behavioural responses are influenced by several correlating factors. These include the level of awareness, availability of services and resources (especially electricity and water), or otherwise [44]. For example, where electricity connection is absent or unaffordable to poor urban residents, the use of electric fans or other mechanical cooling devices will be nearly impossible. When portable water is not available or is inadequate or too expensive, measures such as self-dousing, frequent baths, etc., will be difficult.

3.6. Building-Related Heat-Resistant Measures

Addressing heat stress and thermal discomfort through architectural and spatial measures has been established over the past few decades. These target improvements in the usually low-quality, non-durable, and/or poor condition of informal dwellings, regarding heat resistance or thermic relief through cooling. Table 1 shows the various measures identified from studies related to the low-income settings across different cities, with varying climatic conditions in the African reference countries. These measures are part of passive design (retrofit) strategies towards achieving improved thermal comfort. According to the reviewed studies, they are based on assessing an experimental measure through field measurement or simulation of a possible implementation of relevant measures. These ascertain how, and to what extent, can different measures make dwellings heat resistant. The presented knowledge and evidence are derived from applied research and cooperative projects. Adegun and Ayoola's [40] study provided a ranking of heat-resistant features implemented within a low-income neighbourhood in Akure, Nigeria. Installing mechanical cooling devices (ceiling and wall fans), light curtains, energy-saving bulbs, and door nets were the top building-related heat-resistant features implemented. Wall/roof insulation and lighter colouring for roofs, though with potential, were rarely implemented.

Table 1. Building-related measures to tackle heat stress and thermal discomfort in low-income housing environments.

Building Measure	Micro-Climate Benefit (Temperature Difference)	Nature of Study	Study Location	Reference
Louvre or sliding window openings	Louvre windows offer improved ventilation and indoor temperature reduction, notably in the dry season (November to April), with ≤26 °C and ≥33 °C recorded.	Field measurement	Ile-Ife, Nigeria	[45]
Vertical green structures on walls	Plants on outer walls reduce indoor temperatures by 2.3 °C on average, moving internal comfort conditions to around 90–100% of the time daily.	Experimentation, with field measurement	Lagos, Nigeria	[46]
Shading devices (such as verandas)	These can reduce the frequency of indoor thermal discomfort by 8.5–19.5%.	Validated simulation	Abuja, Nigeria	[47]
Building orientation and external shading (fins, overhang, etc.)	Adjusting room orientation can lead to a 4–6% reduction in thermal discomfort. External shading components can offer a 4% reduction in thermal discomfort.	Validated simulation	Abuja, Nigeria	[48]
Retrofit—roof insulation, fins + overhang)	These specific measures can reduce operative temperature up to 3 °C.	Simulation	Lagos, Nigeria	[49]
Retrofit (ceiling insulation, energy-efficient lighting, tree planting, etc.)	The retrofitted houses experienced a general decrease in indoor temperature (up to 4 °C) in the hottest hours.	Experimentation and field measurement	Durban, South Africa	[50]
Outer wall paintings (cool coatings)	Painted spaces had up to a 4.3 °C reduction in temperature.	Experimentation and field measurement	Johannesburg, South Africa	[51]
Retrofit—building envelope	Such measures lead to an increase in indoor thermal comfort hours by about 40%.	Simulation	Nairobi, Kenya	[52]
Passive eco-cooling with clay funnels (wall openings)	This strategy leads to average reductions in indoor temperature and humidity by 2 °C and 15%, respectively.	On-site experimentation	Greater Cairo, Egypt	[53]
Rooftop farming	Such measures decrease direct heat gain on rooftops (no quantification provided).	On-site implementation	Greater Cairo, Egypt	[54,55]
Street shading	Temporary and permanent lightweight structures reduce outdoor temperatures (no quantification provided).	On-site implementation	Greater Cairo, Egypt	[56]
Green Wall (living façade skin system)	This offers improved shading of walls and evapotranspiration and air quality.	On-site implementation (2016–2018)	Greater Cairo, Egypt	[57]

In Cairo, on the building scale, an experimental study by Dabaie et al. [58] addressed heat stress challenges by looking into the affordable low-tech indoor passive cooling systems—namely, applying commonly available shisha heads made of clay as funnels in walls. Furthermore, local building-related adaptation measures in informal neighbourhoods of the Greater Cairo Region (Ezbet El-Nasr, Masaken Geziret El-Dahab, Markaz El-Abhath, and Ain Shams) were identified within the above-mentioned GIZ-PDP project. Measures such as participatory rooftop farming, street shading, and capacity building were implemented through a pilot between 2013 and 2016 [22,54].

The heat adaptation measures implemented within the literature generally facilitated a reduction in ambient indoor temperature, promoted evaporative and convective cooling, and improved the thermal performance of material constituents of dwellings. As shown in Table 1, temperature reduction of up to 4 °C was recorded through the entire retrofit of low-income housing in Durban [50]. Repainting of building envelope also offered similar indoor temperature reduction in Johannesburg, South Africa [51].

3.7. Greening Strategies to Address Heat Stress in Informal Settlements

The prevalence of heat and thermal discomfort is linked to a low green space coverage. The presence of vegetation (trees, parks, etc.) is a significant predictor of cooler mean temperatures and lower perceived temperatures within informal settlements. Addressing heat stress and improving thermal comfort can utilise the development of green infrastructure [59]. This has been attempted in some instances, especially at the building scale (some examples are listed in Table 1).

In Mathare informal settlements (Kenya), Thorn et al. [60] noted that creepers are grown to prevent heat gain and loss in the buildings. An earlier survey within the settlement showed that planting trees is the most popular of all community proposals aimed to address heat stress and thermal discomfort [29]. Additionally, vertical greening systems proposed and implemented in Lagos (Nigeria), among other things, address heat and thermal discomfort. In Cairo, Elmaghragy [61] presented the greening of open spaces in leftover spaces within the densely populated informal district of "Al Zawya Al Hamra". The strategy was proposed to mitigate the urban heat island (UHI) effect. Verner [39] noted that the agro-ecological context in Cairo will involve greening projects that deal with urban heat through drought-resistant vegetation.

3.8. Policy Directions and Gaps

The focus countries (Kenya, Nigeria, South Africa, and Egypt) within this review are part of the global climate action community. They have committed to attending international and intergovernmental meetings such as the annual Conference of Parties (COPs), regular reporting under the UNFCCC framework, and submitting Nationally Determined Contributions (NDCs). As Non-Annex I Parties under the Kyoto Protocol, they are especially vulnerable to the adverse impacts of climate change and have a lesser burden to reduce carbon emissions while they receive funding for climate adaptation.

African countries have developed policies and programmes focused on adaptation to the changing climate at the national level and city scale. Notably, Nigeria and Kenya already have climate change laws, while South Africa has made good progress with similar legislations. These policies, legislations, etc., are evidence of general awareness and concern for climate change, its threats, and their impacts on various sectors of each country. All the countries have invested in early warning systems, health alert networks, and accompanying disease control systems [62].

In Egypt's case, while drafting its National Climate Change Strategy, it continues to submit the Intended Nationally Determined Contribution (INDC) as part of National Communications on climate change. It frames adaptation as part of resilience and list intended actions. Examples of proposed actions include raising awareness of citizens, e.g., in terms of water usage; however, building-adaptive capacities remain generally descriptive and not updated [63]. In the same vein, Nigeria's Climate Adaptation Policy, approved in 2013, seeks to increase public awareness, build capacity, and involve the private sector in addressing climate change challenges [64]. The recently developed 2012–2050 long-term vision for a low-emission development strategy in Nigeria's future reiterates these intentions [65]. The South African government launched its National Climate Adaptation Strategy in 2020.

Furthermore, responses to climate change are addressed in reports dedicated to regional concerns, e.g., as part of the Arab region or the Middle East and North Africa (MENA) which includes Egypt, and SADC which includes South Africa. They are presented in some reports by international agencies and organisations in the context of bilateral cooperation (GIZ, USAID), and within regional (UNDRR), as well as global strategies (i.e., UN-Habitat, World Bank, UNFCCC, UNDP, and OECD).

Additionally, city-level policies and action plans exist, especially in large urban centres. The City of Johannesburg released its Climate Action Plan in March 2021, while the City of Cape Town approved a similar document in May 2021. Cairo introduced the ambitious "Greater Cairo Air Pollution Management and Climate Change Project" in 2021 [66]. The Lagos State Government unveiled its five-year (2020–2025) Climate Action Plan in June 2021. These city-level documents emanated from the C40 Climate Action Planning framework which supported cities in developing countries to develop action plans by 2020 [67].

Certain gaps have been identified in the climate change policy domain. Addressing climate change adaptation across African countries remains a top–down approach [63,68], with gaps in building capacities and making relevant knowledge available. Other gaps identified by scholars include the lack of mutual in-depth knowledge between the implementing levels, represented by practitioners and civil society, and the administrative or stateside. Adequate monitoring and evaluation are also lacking in many situations. The link between climate change policies and community-based adaptation still has considerable gaps. There is a need to combine soft and hard heat adaptation measures [63], for which a distinctive gap currently exists.

Heat Stress and Urban Informality within Climate Policy

Urban Informality in climate adaptation is worth considering as a policy subject. Analysis of vulnerabilities, especially in the urban context, often acknowledges households with low incomes and weak socio-economic capacities, as well as those residing in low-cost housing and within informal settlements. Adaptation plans increasingly acknowledge these marginalised contexts, although responses may not be tailor-made for them. In Egypt, urban informality is referred to either through the word "slums" or "informal settlements". Egypt's National Adaptation Strategy uses the term "slum", while its Third National Communication on climate change [69] includes "slums" and "informal settlements". This is also the situation in Kenya's national adaptation strategy [70]. These highlight special attention needed for urban informality and low-income housing. In contrast, Nigeria's long-term vision document [65] makes no mention of either "slums" or "informal settlements", nor does it acknowledge the peculiarity of low-income housing.

Although adaptation has received increased policy attention for some time, it is usually focused on overarching intentions and goals giving concern to addressing the impacts of flooding on coastal areas and sea-level rise [71]. In general, we observed that heat stress and urban heat island effect are recognized in policy documents as effects of a changing climate, but on the level of responses and adaptation strategies to climate change, they seem to be still a niche, compared with policy and programs that deal with extreme events such as flooding. Heat stress in urban areas and the urban heat island effect are generally referred to but many times without specific reference to locational characteristics in the context of urban human settlements [63].

While national policy documents make cursory or no mentions of the informal, low-income urban housing situations, the city-level documents pay greater attention. For instance, the Cities of Cape Town [72], Johannesburg [73], and Lagos's climate action plans [74] draw attention to the context within slums and informal settlements. This means national-level documents give little consideration to low-income informal urban situations;

hence, city-level and subnational entities are better positioned to drive heat adaptation at the local level within urban communities.

4. Discussion

Regarding evidence accessed and presented so far, context-sensitive knowledge creation depends on various aspects, which are discussed further: the first is related to knowledge production, while the second is related to strategic application and commitment.

The first aspect concerns knowledge production, including data availability on the very local scale, be it information about collective actions or empirical evidence on individual vulnerabilities and strategies. This pertains to developing an understanding of heat-related exposures and related vulnerabilities, hence the need to understand specific adaptive capacities down to the household and individual scale across neighbourhoods facing comparable constraints. This requires a greater spectrum of reliable qualitative or quantitative data indoors and outdoors. The identified scarcity of data and publications in the four focus countries hints at generally less empirical evidence on the local level such as experiences and perceptions of (increasing) thermal discomfort and heat stress, compared with simulation-focused data. Regarding knowledge production on responses, there are gaps in existing heat adaptation strategies driven through collective action. For example, there is no evidence thus far on uptake or performance of "behavioural change communication" (BCC), "campaign targeting children", training of trainers, or heat hotline.

Our literature review revealed that knowledge bases differ across the different communities within one city or urban agglomeration. For instance, quantitative and qualitative data on intra-urban inequality in heat exposure are currently available on a city scale but become more challenging on a specific neighbourhood scale. Additionally, simulations of land-surface temperature I green spaces are available and tend to focus on the entire urban scale. Studies that focus on single and/or several in parallel (informal) neighbourhoods are relevant. They will help to better understand the contribution of existing green and blue spaces to the regulation of land-surface and ambient temperatures.

In contrast to a significant number of published papers investigating thermal comfort and heat stress in the built environment, fewer papers provide insight into the sensitivities and peculiar vulnerabilities of residents. Studies rather focus on quantitative and satellite data related to health impacts or focus on the response level. As stated previously, qualitative data on how increased heat and thermal discomfort are experienced and addressed are largely lacking, particularly in informal settlement contexts. This becomes especially apparent when looking at heat-related health challenges and associated health-seeking responses. There is a basis for qualitative insights into how heat stress is experienced and perceived.

This review also highlighted that the experience of vulnerabilities and adaptive capacities of vulnerable groups remains an under-researched topic. Although there may be comparable aspects in overall exposures, mutual transferability of experiences and derivation across scales and even contexts can be inherently flawed by a lack of attention to all affected community members in an urban setting. Attention should be given to the specific vulnerabilities of, for example, pregnant women, children under five, the elderly, persons with special needs, and the sick. Investigating trust-building methods is also a worthwhile strategy when conducting research or subsequently applying adaptive measures.

The second aspect concerns the strategic relation and commitment across tiers towards the application of measures and knowledge, particularly in informal settlements. Although commitment regarding climate action is expressed on the national level, policy directions and gaps persist and have been identified in the four focus countries. For instance, these particularly concern gaps between policy levels, their intermediaries (i.e., NGOs or aid organisations), and a community's reality. Adaptation projects are often predominantly implemented by funding from international donors or partnering with NGOs and interest groups from different sectors, scales, and target groups. These usually have a pilot character, but transferability and upscaling have not entered the next stage. Reasons can include the absence of initiation, funding, or the management of community-based projects by governmental actors.

Most studies focus on the larger metropolis and adaptation options in smaller to medium-size cities might look different. Exchanges among mid-sized and smaller cities and districts may be worthwhile. Moreover, knowledge and evidence can benefit from a more context-specific exchange related to heat-resistant interventions, which currently benefit from international cooperation projects. It becomes apparent that context-specific knowledge can be enriched by increased exchange and sharing of experiences—of both challenges and successes—across a variety of cities can be worthwhile. As elaborated above, such mobility of knowledge and experience concerns conversations around heat as a full-fledged climatic challenge to local communities. This then opens the opportunity for research covering a larger spectrum of challenges and opportunities—ranging from awareness to the soft and hard application of responses on the local scale and framing conditions.

Studies that investigate adaptation strategies dominantly examined a broad variety of alternative building measures and to a lesser degree greening strategies. While additional evidence is needed on the short- and long-term performance of the variety of passive and active building-related heat-resistant measures, attention should be given to green infrastructure and nature-based approaches. This will also need to pay special attention to the way they address heat-health challenges. Most of the conducted studies are cross-sectional. More longitudinal studies are also needed. It is worthwhile to increase the number of studies with comparable parameters and scale, thus allowing for comparability, exchange, and visibility.

5. Conclusions

This review leads to certain tentative conclusions while presenting some lessons for wider applicability in further research and practice. It became clear that heat stress remains an overlooked topic in comparison to other climate change adaptation needs. This is particularly with regard to the vulnerability of informal settlements across African cities for which there have only been cursory insights from the literature.

Research on urban heat stress in informal areas in the four focus countries presents a glance into the current research landscape of the past 10 years. The presented evidence shows that it varied and differed in framing, scale, applied methods, and research of concerned actors' groups across the contexts. To address the above-mentioned gaps and suggested areas for further study, it is worthwhile to highlight heat stress as a cross-cutting focal topic in urban research and practice in relation to informal settlements and generally broaden the spectrum of research within each context while encouraging exchange across similar contexts and scales, and disciplines covering different aspects. Research with this focal direction, however, requires financial resources, time resources, and potentially longer duration, as well as collaborative and circular (applied) research to build and maintain trust among all stakeholders. Hence, it is worthwhile to pay special attention to strategic research design that foresees benefits for local communities, investigating win–win and co-beneficial options during its conduction and implementation. Finally, and nevertheless, this paper is meant to provide a stimulus for further research addressing the outlined gaps in the face of increased heat stress in Africa's informal settlements. Further empirical evidence from those experiencing heat stress on an everyday basis will hopefully contribute to policy dialogues directed at addressing their needs and vulnerabilities whilst acknowledging and strengthening existing knowledge and capacities.

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