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Enhancing Urban Resilience to Extreme Heat in Zambia: Strategies and Interventions in Infrastructure Planning

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ABSTRACT

The rising frequency of extreme heat events, particularly in urban areas has emerged as a significant concern with climate change anticipated to exacerbate this phenomenon across various regions worldwide. This paper explores the critical dimensions of enhancing urban resilience to extreme heat in Zambian, elucidating strategies tailored to the country's socio-economic, geographical, and climatic characteristics. The analysis underscores the pivotal role of prioritizing green infrastructure, sustainable urban design, and community-centric approaches in mitigating the impacts of extreme heat. By emphasizing the interconnected nature of these strategies and their relevance to Zambia's diverse urban settings, the review offers tailored insights for policymakers and urban planners. Additionally, it stresses the importance of robust early warning systems and capacity-building initiatives, aligning them with the unique challenges faced by Zambian communities. This endeavour, crucial for policy-makers and researcher, contributes essential knowledge for fostering sustainable, resilient, and adaptive urban environments in Zambia and other regions faced with similar issues.

KEYWORDS

Extreme Heat; Urban Resilience; Climate Change; Infrastructure; Zambia; Strategies.

1. INTRODUCTION

The modern era has witnessed an escalating threat to urban environments posed by extreme heat events, urging the imperative for comprehensive strategies to enhance resilience. Urban areas globally are faced with the complex challenges associated with rising temperatures, leading to a critical examination of existing measures to mitigate and adapt to extreme heat (Tuholske et al., 2021; Turek-Hankins et al., 2021; Marcotullio et al., 2022). As the impacts of climate change intensify, understanding the current state of urban resilience to extreme heat becomes paramount in developing effective strategies to safeguard communities and infrastructure (Keith et al., 2019). The relevance and applicability of strategies for enhancing urban resilience to extreme heat in the Zambian context are deeply rooted in the country's distinctive socio-economic, geographical, and climatic characteristics. Zambia, characterized by a diverse landscape and varying population densities, necessitates a clear understanding of its unique urban settings (Mulenga & Campenhout, 2008; Moyo et al., 2022). From densely populated urban centres to peri-urban areas, the varied landscapes highlight the necessity of tailoring resilience strategies to suit the specific and dynamic requirements of each region. Recognizing this diversity is pivotal, as it emphasizes the need for interventions that go beyond a one-size-fits-all approach (Singh & Sharston, 2022; Hidalgo García, & Arco Díaz, 2023). Tailoring strategies to the situations of each urban setting ensures not only the effectiveness of the interventions but also their cultural, economic, and environmental appropriateness. This approach acknowledges that urban resilience is not a uniform concept but one that must adapt to the local context, accounting for the different challenges and strengths present in various parts of the country.

Climate change is imposing unprecedented challenges globally, and Zambia is no exception to the impacts of extreme heat events .The global shift towards urbanization, coupled with the escalating impacts of climate change, has positioned cities as critical battlegrounds for sustainability and resilience.

This literature review consolidates insights and aims to investigate and evaluate strategies and interventions from a range of scholarly works to provide a comprehensive overview of strategies, challenges, and infrastructure planning to enhance urban resilience in the face of rising temperatures to climate change. Research has consistently highlighted the escalating temperatures and altered precipitation patterns in Zambia (Zambia Climate Change Response Strategy, 2016). Zambia can draw inspiration from Melbourne's successful emphasis on green infrastructure. Implementing tree planting initiatives and creating green spaces are tangible actions that can significantly contribute to mitigating extreme heat in Zambian urban areas. Zambia can also draw significant benefits from Tokyo's experience in combating extreme heat. Exploring cool pavement technologies and incorporating reflective surfaces in urban planning aligns with Tokyo's successful strategies. In addition Zambia can find inspiration in Barcelona's Superblocks initiative, particularly in the exploration of pedestrian-friendly urban designs and the integration of green spaces. Creating environments that prioritize pedestrians not only contributes to environmental sustainability but also promotes healthier and more liveable urban spaces (Muelleret al., 2020). Consideration of community preferences is paramount for successful implementation in Zambia. DMMU (Disaster Management and Mitigation Unit) has played also pivotal role in addressing the challenges posed by extreme heat in Zambia. Through the implementation of early warning systems, DMMU has effectively communicated heat risks to communities, enabling them to prepare and take necessary precautions (Government of Zambia, 2021). The unit has also engaged in public awareness campaigns that educate citizens about the health impacts of extreme heat and provide practical tips for staying safe, such as hydration and creating heat-resilient living environments (Zambia Environmental Management Agency, 2020). Additionally, DMMU collaborates with local governments and organizations to strengthen community resilience by developing heat mitigation strategies, such as urban greening initiatives and the improvement of water access (World Bank, 2023). Their proactive approach not only helps communities cope with the immediate effects of extreme heat but also fosters long-term adaptations to climate change. Through these concerted efforts, DMMU demonstrates its commitment to enhancing public safety and resilience amid increasing temperature extremes in Zambia.

Despite its successes, Melbourne encountered challenges during the implementation of its urban heat management plan. Securing long-term commitment and sustained funding for green infrastructure projects posed a significant challenge (Bosomworth et al., 2013). This highlights the need for consistent financial support to maintain and expand green initiatives, emphasizing the importance of government and stakeholder commitment. Balancing the aesthetic appeal of green spaces with their functionality in heat mitigation presented a design challenge. Striking the right balance between creating visually appealing urban environments and ensuring effective heat reduction is crucial for the success of such initiatives. Engaging diverse communities also posed challenges, requiring tailored approaches to ensure inclusivity. Melbourne's experience underscores the importance of recognizing and addressing the specific needs and concerns of different demographic groups within the community.Despite Tokyo's successes in this regard, the implementation of the heat island countermeasure Plan encountered challenges. The need for continual monitoring and maintenance of water-intensive pavements, for instance, highlights the importance of ongoing commitment and resources. Balancing technological interventions with traditional urban design principles posed further challenges, emphasizing the necessity of integrating innovative solutions into existing urban frameworks. Ensuring equitable access to cooling technologies and information presented difficulties, particularly in reaching vulnerable populations who may face barriers to access.Barcelona story in implementing the Superblocks Initiative is not short of challenges. For example, resistance to changes in traffic patterns and initial scepticism from some community members (Inghirami, 2022). This highlight the importance of effective communication and engagement strategies. Balancing the needs of different neighbourhoods requires careful urban planning, acknowledging the diversity within the urban fabric. Sustaining community engagement over the long term is a common challenge in transformative projects, necessitating ongoing efforts to maintain public support and involvement.

Despite its successes, DMMU policies and measures for heat resilience encountered challenges during the implementation due to lack of funds and human resources. Inadequate climate and health data could make planning and response activities less successful. Inadequate baseline data may result in subpar vulnerability assessments. For heat-related issues, efficient decision-making and resource allocation may be hampered by institutional fragmentation and a lack of cooperation among authorities.Inadequate community engagement and participation in resilience-building initiatives may arise from low public awareness and comprehension of the dangers posed by high heat.

However, adapting these lessons to Zambia requires a clear and deliberate approach. Tailoring community engagement strategies to Zambia's context is crucial for success. Understanding local perceptions, cultural distinctions, and the specific concerns of different communities will enhance the effectiveness of resilience initiatives.

In this context, this review endeavours to contribute significantly to the existing body of knowledge by undertaking a comprehensive analysis of the current state of urban resilience to extreme heat in Zambia. By drawing upon global perspectives and experiences, the review seeks to assess the relevance and applicability of diverse strategies within the Zambian context. The synthesis of insights garnered from diverse experiences will facilitate the identification of gaps in current knowledge, allowing for a clearer understanding of the challenges and opportunities specific to Zambia. Moreover, this review does not merely aim to analyse the existing state but endeavours to be forward-looking. It aspires to propose innovative approaches that are rooted in the understanding of Zambia's unique urban landscapes. By doing so, it aims to provide a roadmap for future research and practical interventions that align with the evolving dynamics of urbanization, climate change, and extreme heat resilience. This forward-thinking approach is essential for creating adaptive strategies that can withstand the uncertainties of the future. The anticipated exploration of the intricate dynamics of urban resilience to extreme heat is poised to offer valuable guidance. Policymakers, urban planners, and researchers engaged in fostering sustainable and resilient urban environments in Zambia and beyond stand to benefit from the insights generated by this review. By bridging the gap between global perspectives and local realities, the review aims to contribute to the creation of context-specific solutions that address the unique challenges faced by Zambia while offering lessons and inspirations for other regions faced with similar challenges.

It is crucial to identify and bridge gaps in our current understanding of urban resilience to extreme heat to propel research advancements and inform effective strategies. While the existing body of knowledge is substantial, it is not without limitations. Acknowledging and rectifying these gaps is vital for achieving a more comprehensive understanding of the complex dynamics associated with extreme heat events and for refining targeted resilience measures. A notable gap exists in the limited understanding of localized heat patterns across diverse urban settings. Existing studies often generalize findings without considering distinct temperature variations within different urban landscapes. This lack of granularity hinders the development of context-specific strategies tailored to the unique challenges faced by distinct regions. Addressing this requires future research to prioritize localized climate modelling, combining high-resolution data with on-the-ground measurements to capture fine-scale temperature variations. This approach will enable a more precise assessment of heat patterns, facilitating the identification of specific vulnerabilities and the implementation of targeted interventions. Another identified gap concerns the socio-economic implications of extreme heat events on vulnerable communities. While research acknowledges that certain demographic groups are more susceptible to heat-related risks, there is a need for more in-depth investigations into the socio-economic disparities in vulnerability and adaptive capacity. Future studies should explore how extreme heat intersects with existing vulnerabilities related to income, access to resources, and healthcare. Understanding these dynamics is crucial for developing equitable and inclusive resilience strategies that address the specific needs of vulnerable populations. Moreover, a comprehensive evaluation of the effectiveness and scalability of nature-based solutions in the urban context is lacking. Although green infrastructure, such as urban forests and cool pavements, shows promise in mitigating heat stress, there is a need for long-term assessments of their ecological, social, and economic impacts. Research should delve into the sustained benefits of these interventions and explore their potential for large-scale implementation in diverse urban settings. Additionally, there is a scarcity of research on the interconnectedness between extreme heat and other climate-related hazards, such as water scarcity. Understanding how these hazards interact and influence each other is crucial for developing integrated resilience strategies that address multiple challenges simultaneously. Current knowledge often treats these hazards in isolation, overlooking the complex relationships that can exacerbate vulnerabilities and compound the impacts on urban environments.

2. MATERIALS AND METHODS

2.1. Description of Study Area

Zambia, a landlocked country in southern Africa, has been increasingly affected by extreme heat due to climate change. The study area encompasses the diverse geographical regions of the country, each experiencing unique impacts from rising temperatures.

Zambia is situated between 8° and 18° S latitude and 22° and 34° E longitude. It has a tropical climate characterized by three seasons: a cool dry season (May to August), a hot dry season (September to November), and a warm wet season (December to April). The country's climate is influenced by the Intertropical Convergence Zone (ITCZ), which brings seasonal rainfall.

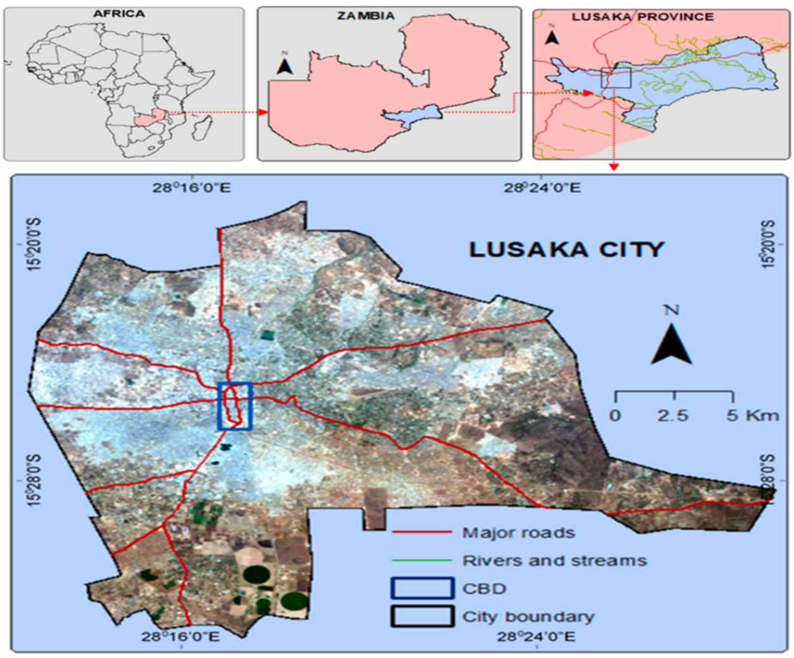

Figure 1. Location map of the city of Lusaka, showing the city centre, major roads, railway line, streams, and the current administrative city boundary.

2.2. Topography Features

Zambia's landscape varies from the high plateau regions in the south and west to the low-lying valleys in the east and north. The high plateau areas, such as the Copperbelt and Lusaka, are more susceptible to extreme heat during the hot dry season due to their lower elevation and urbanization.

2.3. Data Extraction and Analysis Methods

Data extraction was conducted systematically to capture key information from the selected studies and interventions. A structured data extraction form is developed to standardize the process, encompassing variables such as study design, geographic focus, intervention components, and outcomes. This systematic approach facilitates the synthesis of data, enabling a comparative analysis of findings across diverse sources. The analysis methods employed in this review embrace qualitative approaches, and Thematic analysis to identify recurring themes, patterns, and challenges within the selected studies.

By employing a systematic review approach, meticulous selection criteria, and rigorous data extraction and analysis methods, this methodology ensures the integrity and reliability of the review findings. It provides a solid foundation for synthesizing insights from diverse sources, contributing to a comprehensive understanding of urban resilience to extreme heat and its relevance to the Zambian context.We employ a systematic review approach to ensure the reliability and comprehensiveness of the findings based on insights from Papaioannou et al. (2016) and Munn et al. (2018). This approach provides a structured and transparent process for identifying, selecting, and synthesizing relevant literature on urban resilience to extreme heat. It minimizes bias and enhances the reproducibility of the study, aligning with the gold standard in evidence-based research. The systematic review process begins with the formulation of a well-defined research question, delineating the scope and objectives of the inquiry. A comprehensive search strategy is then devised, encompassing multiple electronic databases, academic journals, and grey literature repositories. The inclusion and exclusion criteria are meticulously established to ensure the relevance and quality of the identified studies, incorporating factors such as publication date, research design, and geographical focus.

2.4. Selection Criteria for Studies and Interventions

The selection criteria applied in this review are tailored to capture a diverse yet pertinent range of studies and interventions related to urban resilience to extreme heat, with a specific focus on their applicability to the Zambian context.For studies and interventions regarding Zambia's Disaster Management and Mitigation Unit (DMMU) focus on ensuring relevance and rigor in disaster management research. Inclusion criteria encompass various study designs, such as randomized controlled trials and qualitative research, that evaluate DMMU's effectiveness in disaster preparedness, response, and recovery.

Additionally, studies should target relevant populations, including affected communities and stakeholders, and focus on key outcomes like community resilience and stakeholder engagement.. Adhering to these criteria allows researchers to effectively assess DMMU strategies, providing valuable insights for enhancing disaster management and mitigation efforts in the country.Peer-reviewed articles, official reports, case studies, and relevant policy documents sourced from web of science (WoS), PubMed, Scopus and google scholar, among other databases are considered, encompassing multidisciplinary perspectives to provide a holistic understanding of the subject matter. Studies selected for inclusion undergo a rigorous screening process based on predefined criteria, ensuring the robustness of the evidence considered. Interventions and strategies are evaluated based on their effectiveness, scalability, and adaptability to the unique socio-economic, geographical, and climatic characteristics of Zambia. The objective is to distil insights that transcend geographical boundaries while remaining contextually relevant to the specific challenges faced by Zambian urban areas. Thus, seventy-six (76) papers were found useful for this review and were used.

3. RESULTS

3.1. Climate Impact and Vulnerability Assessment

Cities like Lusaka, the capital, and Kitwe in the Copperbelt experience significant urban heat island effects. The concentration of buildings, roads, and industrial activities, coupled with reduced green spaces, leads to higher temperatures compared to surrounding rural areas. This exacerbates heat stress for urban residents, particularly those living in densely populated informal settlements.While rural areas may not experience the same intensity of heat as urban centers, they face challenges related to agriculture and water availability. Extreme heat can lead to reduced crop yields, livestock stress, and increased evaporation rates, affecting water resources and food security. The rise in temperature increases the risk of heat-related illnesses such as heatstroke, dehydration, and cardiovascular issues.

Temperatures have warmed by 1.3°C since 1960, at an average rate of 0.29°C per decade. Since 1960, there has been an average decrease in annual rainfall of 1.9 mm per decade. There has been an increase in the frequency and intensity of drought and flooding events. Projected Weather and Climate Projections for Zambia vary across models depending on assumptions; however, the majority of climate models suggest: Annual temperature increases, above the 1970-1999 average, of 1.2-3.4°C by the 2060s and 1.6-5.5°C by the 2090s. An overall decrease in annual rainfall, and an increase in the frequency and intensity of heavy rainfall events during the rainy season.

Enhancing urban resilience to extreme heat in Zambia necessitates a holistic and adaptive approach that encompasses various strategies and interventions within infrastructure planning. Conducting an in-depth climate analysis, including an examination of historical data and future projections, serves as the foundational step for understanding the evolving climatic conditions and predicting potential extreme heat events.In the realm of infrastructure planning and design, integrating green infrastructure elements becomes pivotal. This involves not only the incorporation of green spaces, urban forests, and green roofs but also emphasizing sustainable urban design practices. These practices should encourage natural ventilation, reduce heat absorption, and incorporate cool roofs and pavements to counteract the urban heat island effect. Additionally, prioritizing energy-efficient building designs, with a focus on insulation, ventilation, and shading, contributes significantly to minimizing the need for excessive cooling in buildings

3.2. Climate Change Impact

Climate change has led to altered rainfall patterns, with some regions experiencing more frequent and prolonged droughts. This has severe implications for water availability, agriculture, and food security. Zambia is grappling with the impacts of climate change, evident in altered rainfall patterns, increased drought risk, and challenges in agriculture, affecting food security and rural livelihoods. Water scarcity and changes in hydropower availability impact energy security, while rising temperatures contribute to heatwaves with health implications. Biodiversity faces shifts, and extreme weather events pose threats to infrastructure. Vulnerable rural communities are adapting through water harvesting and crop diversification. Addressing these challenges requires a coordinated effort, involving sustainable practices, resilient infrastructure development, and international collaboration to enhance Zambia's climate resilience.

Figure 2. Extreme heat impact on the Kariba Dam as main hydro-power station in zambia

3.3. Impact on Agriculture and on Human Health

Climate change significantly impacts agriculture through rising temperatures, altered precipitation patterns, extreme weather events, and changes in pest and disease dynamics. These factors contribute to heat stress in crops and livestock, water scarcity, soil erosion, and disruptions in growing seasons. The variability in weather patterns poses challenges for farmers, affecting crop yields and economic stability. Additionally, shifts in agro-ecological zones and the expansion of pests require adaptive strategies such as crop diversification, improved water management, and the development of resilient crop varieties. Sustainable agricultural practices and collaborative efforts are crucial for mitigating climate-related risks and building resilient food systems in the face of ongoing environmental changes. Climate change poses a multifaceted threat to human health, with far-reaching impacts spanning various aspects. Rising temperatures contribute to more frequent and severe heatwaves, leading to heat-related illnesses, particularly affecting vulnerable populations. Changes in precipitation patterns influence the spread of vector-borne diseases, such as malaria and dengue fever. Disruptions in agricultural productivity, driven by climate change, contribute to malnutrition and food insecurity, affecting communities globally. Extreme weather events, including hurricanes and floods, pose immediate risks to human health through injuries and trauma. Additionally, climate change has implications for mental health, causing stress, anxiety, and depression due to the psychological impact of environmental disruptions. Air pollution exacerbated by climate change can result in respiratory issues, while waterborne diseases may rise due to contaminated water supplies. Vulnerable populations, including the elderly and those with pre-existing health conditions, face disproportionate health risks. Addressing these health challenges requires comprehensive strategies, including strengthening public health systems, adapting to changing conditions, and mitigating the root causes of climate change through international cooperation and sustainable practices. The health sector plays a crucial role in developing and implementing measures to safeguard human well-being in the face of climate-related threats.

Figure 3. Shows the Impact of Climate change on Crops such as maize the staple food in zambia

3.4. Impact on Wildlife

In Zambia, the intricate dance between climate change, the environment, and wildlife is increasingly intricate and impactful. Altered rainfall patterns, marked by irregularities and heightened drought risks, are wreaking havoc on ecosystems. The resulting water scarcity poses a direct threat to both terrestrial and aquatic habitats, jeopardizing the diverse array of species that call Zambia home. Rising temperatures further complicate matters, subjecting wildlife to unprecedented heat stress and disrupting the finely tuned balance of ecological systems. The repercussions extend beyond temperature discomfort, as heat stress challenges the behavioral and physiological adaptations of various species.

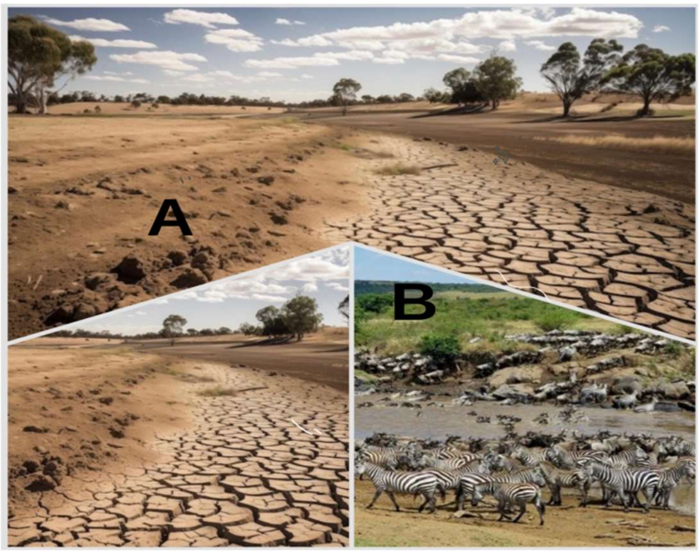

Figure 4. Shows the Impact on Wildlife A means Drought and B means Animals Migrating

3.5. Key Sector Vulnerability

Climate change poses a multifaceted challenge to Zambia's economy, impacting key sectors and exacerbating existing vulnerabilities. The agricultural sector, vital for the country's GDP, faces decreased crop yields due to erratic rainfall patterns and prolonged droughts.Food Security

Agriculture in Zambia accounts for 18-20 percent of the country's gross domestic product, employs approximately two-thirds of the country's labor force, and is a key source of livelihoods for 50 percent of the country. Approximately 12 percent of total land area is suitable for arable use and over 80 percent of the country's farmers are subsistence farmers. Most of the country's farms, located in central, south, and southwestern Zambia, have become increasingly prone to drought and have received low, unpredictable, and unevenly distributed rainfall over the last 20 years. The reliance on hydropower for electricity generation leaves the energy sector vulnerable to changes in water availability, potentially leading to energy shortages. Water scarcity affects industries, including mining and manufacturing, while extreme weather events pose risks to infrastructure, necessitating costly repairs. Zambia's tourism sector, particularly wildlife-based tourism, is susceptible to shifts in ecosystems and biodiversity caused by climate change. The burden on the healthcare system increases with the spread of vector-borne diseases, contributing to rising healthcare costs. Insurance premiums escalate due to the frequency and severity of climate-related events, impacting businesses and individuals. Rural communities, heavily dependent on agriculture, face economic disruptions that exacerbate poverty. Supply chain disruptions affect trade and commerce, hindering overall economic growth. As agricultural and livestock production are largely dependent on rainfall, the country's high rainfall variability and limited irrigation capacity make them vulnerable to climate change. The rising frequency of drought and shorter rainy seasons has led to increasing crop loss and food insecurity. Higher temperatures and greater frequency of drought may also degrade grazing land and lead to loss of livestock, with negative consequences for food security. Recorded effects of past droughts on agriculture include inundation of farmland, destruction of crops, increased malnutrition and hunger, soil erosion, reduced cultivatable land, and loss of lives

Addressing these challenges requires substantial investments in resilience, adaptation, and mitigation strategies. The economic impacts of climate change in Zambia underscore the urgency of collaborative efforts to promote sustainable practices, diversify the economy, and build resilience across sectors.

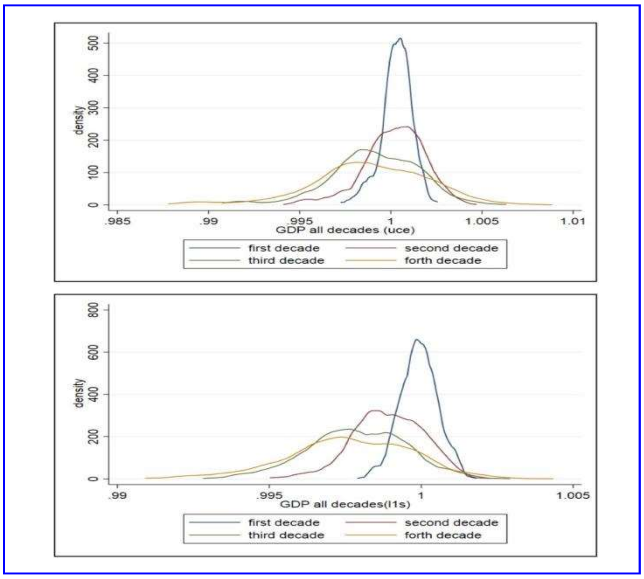

Figure 5. Impacts on climate change on total GDP by decade under unconstrained emissions (top panel) and level one stabilization (bottom panel) scenarios between 2011 and 2050.

3.6. Disaster Management and Mitigation Unit (DMMU)Assessment

Previous studies in Zambia have shown that extreme heat events are becoming more frequent and intense due to climate change, leading to increased health risks, crop failures, and economic challenges. Research indicates that effectively implemented DMMU strategies can reduce mortality rates during heat waves and enhance community resilience.

For instance, studies highlight the potential of community-based adaptation programs that not only improve immediate responses to heat but also contribute to long-term resilience through sustainable practices.

3.7. Policy and Governance Approaches

The influence of effective policy and governance on urban resilience to extreme heat is profound, encompassing a spectrum of measures that guide urban development, environmental stewardship, and community well-being (Keith et al., 2023; Meerow et al., 2022). At the core of this influence lies the formulation and implementation of policies that intricately weave climate considerations into the fabric of urban planning, zoning regulations, and building codes (Taylor et al., 2021; Allam et al., 2020). This strategic integration is pivotal in proactively addressing the challenges posed by escalating temperatures due to climate change, laying the groundwork for resilient urban landscapes (Rivero-Villar, & Vieyra Medrano, 2022; Boyd, & Juhola, 2015; Simatele, 2013; Greenwalt et al., 2018; Tanner et al., 2009). Urban planning policies that explicitly incorporate climate considerations are instrumental in shaping the physical form of cities (Boyd, & Juhola, 2015). These policies can advocate for the strategic placement of green spaces, the implementation of cool roofs and pavements, and the integration of natural shading elements (Wilkinson, & Dixon, 2016; Bosomworth et al., 2013; Hoverter, 2012). By doing so, they not only enhance the aesthetic and ecological aspects of urban environments but also contribute substantially to mitigating the urban heat island effect—a phenomenon where urban areas experience higher temperatures compared to their rural counterparts. Zoning regulations exert considerable influence over the spatial distribution of infrastructure and land use (Simwanda et al., 2020; Xu, & Wang, 2020; Simwanda, & Murayama, 2018; Hersperger et al., 2018). In the context of extreme heat resilience, well-crafted zoning policies can incentivize the development of climate-responsive buildings and neighbourhoods. For instance, zoning codes that encourage mixed land-use patterns, promoting a balance of residential, commercial, and green spaces, contribute to a more resilient and adaptable urban fabric. Building codes represent a crucial component of the policy framework, dictating the standards and specifications for construction (Ching, 2020). Policies that advocate for climate-resilient building practices, such as improved insulation, heat-reflective materials, and energy-efficient design, not only enhance the thermal comfort of indoor spaces but also contribute to overall energy conservation (Borodinecs, 2021).

A robust governance structure is indispensable for the effective implementation of these policies. Coordinated efforts among various stakeholders, including government agencies, local authorities, community organizations, and private entities, are essential to ensure a cohesive and adaptive response to heat-related challenges. Clear lines of communication, efficient resource allocation, and collaborative decision-making processes are hallmarks of effective governance structures that can navigate the complexities of urban resilience. Furthermore, policies that actively promote green spaces, sustainable transportation, and energy-efficient urban infrastructure signify a commitment to addressing the root causes of extreme heat (Qin et al., 2023; Popescu, 2022; Hassan, & Lee, 2015). Green spaces, such as parks and urban forests, not only provide cooling effects but also enhance biodiversity and improve air quality (Puplampu, & Boafo, 2021; Nero et al., 2019). Sustainable transportation policies encourage the use of eco-friendly modes of commuting, reducing carbon emissions and, consequently, heat intensification (Haq, & Schwela, 2012). Energy-efficient urban infrastructure, including smart grids and sustainable buildings, not only contributes to mitigating the urban heat island effect but also fosters long-term environmental sustainability (Verma & Singhania, 2023; Rasul & Cheng, 2023; Asarpota & Nadin, 2020).

In essence, effective policy and governance approaches act as the cornerstone of urban resilience to extreme heat. They establish the regulatory and organizational framework necessary for creating adaptive, sustainable, and liveable urban environments that can withstand the challenges presented by a changing climate. By prioritizing climate considerations and fostering collaboration among stakeholders, these approaches pave the way for a resilient urban future.

3.8. Technological Innovations in Infrastructure Planning

In enhancing urban resilience to extreme heat, technological innovations emerge as transformative tools that not only address the challenges posed by rising temperatures but also usher in a new era of adaptive and sustainable urban infrastructure planning (Argyroudis et al., 2022; Shakou et al., 2019; Tembo-Silungwe, et al., 2019). At the forefront of these innovations lies the integration of smart technologies into infrastructure planning (Musonda et al., 2023). Sensor networks and data analytics play a pivotal role by enabling real-time monitoring of heat-related parameters across urban landscapes (Ikegwu et al., 2023; Pioppi et al., 2022; Potgieter et al., 2021; Kiani et al., 2024). These technologies empower cities to gather precise and up-to-the-minute data on temperature variations, heat intensity, and other relevant metrics. The real-time information acts as a proactive early warning system, alerting authorities to potential heat stress events and facilitating prompt responses. This dynamic monitoring capability is invaluable in optimizing resource allocation, streamlining emergency response efforts, and ultimately enhancing the overall efficiency of urban systems.

One key application of technological innovation in mitigating heat stress is the integration of green infrastructure (Liu et al., 2021; Wong et al., 2021; Titz & Chiotha, 2019; Zölch et al., 2016; Norton et al., 2015; Demuzere et al., 2014). Cool roofs, which reflect sunlight and absorb less heat, permeable pavements that allow water absorption and reduce surface temperatures, and strategically planted urban forests are examples of green infrastructure elements that showcase the potential of technology to mitigate heat stress. These features not only contribute to temperature regulation but also foster environmental sustainability, improve air quality, and enhance overall urban aesthetics. Resilient infrastructure design represents another facet of technological innovation in combating extreme heat challenges (Zulu et al., 2022; de Abreu etal., 2022; Tembo-Silungwe et al., 2019; Markolf et al., 2018; Jabareen, 2013). Climate-responsive materials and construction techniques are employed to create infrastructure that can withstand and adapt to changing climatic conditions (Panarelli, 2015). These innovations ensure the longevity of urban spaces, reducing maintenance costs and the need for frequent repairs. By incorporating climate-resilient design principles, cities can future-proof their infrastructure against the impacts of temperature extremes, contributing to sustainable urban development. Moreover, the integration of Geographic Information System (GIS) technology allows for spatial analysis and mapping, aiding in the identification of heat-prone areas and vulnerable populations (Roest et al., 2023; Levin et al., 2023; Simwanda & Murayama, 2017). This data-driven approach enhances precision in decision-making, guiding targeted interventions and resource allocation where they are most needed.

Technological innovations in infrastructure planning, thus, herald a new era in urban resilience to extreme heat. From real-time monitoring through sensor networks to the integration of green infrastructure and resilient design principles, these innovations not only address immediate challenges but also pave the way for sustainable, adaptive, and technologically sophisticated urban environments. By harnessing the power of technology, cities can proactively respond to the complexities of climate change, creating resilient and liveable spaces for current and future generations.]

4. PROPOSED STRATEGIES FOR FUTURE URBAN RESILIENCE IN ZAMBIA

Urban resilience planning in the face of extreme heat in Zambia demands a forward-thinking and coordinated approach that addresses the unique challenges posed by extreme heat. From the reviewed literature, several insights are garnered and the following strategies are proposed to guide future urban resilience planning endeavours in Zambia, ensuring the creation of adaptive and sustainable urban environments.

4.1. Localized Climate Modeling and Assessment

Future resilience planning should prioritize localized climate Modeling to capture fine-scale variations in temperature across diverse urban landscapes in Zambia. Unlike broad-scale climate models, localized modelling hones in on the intricacies of temperature fluctuations at the neighbourhood or even street level, providing a granular understanding of heat patterns. The integration of localized climate modelling with on-the-ground measurements represents a significant advancement in precision and accuracy. While climate models offer valuable insights, combining these simulations with real-world data obtained from sensors and measurements ensures a clearer understanding of the specific heat dynamics experienced in different urban areas across Zambia. This fusion of modelling and empirical data creates a comprehensive and contextually rich knowledge base. The clear understanding of heat patterns derived from this localized approach serves as the foundation for tailored interventions. By recognizing the unique thermal characteristics of specific areas within urban landscapes, resilience planners can develop strategies that are not only effective in mitigating local heat stress but also contextually relevant to the socio-economic and environmental conditions of each locale. This ensures that interventions are targeted, impactful, and responsive to the specific challenges faced by different urban communities.

Moreover, the localized climate modelling and assessment approach enable a proactive stance in resilience planning. Rather than relying on generic or one-size-fits-all strategies, planners can anticipate and address heat stress based on the distinct thermal profiles of each urban area. This anticipatory approach is crucial for developing adaptive measures that pre-emptively address the vulnerabilities of specific communities, contributing to a more robust and responsive urban resilience framework. In essence, prioritizing localized climate modelling and assessment represents a paradigm shift in resilience planning, moving from generalized strategies to targeted, evidence-based interventions. This approach not only advances the scientific understanding of local heat dynamics but also empowers planners to create resilient cities that are finely attuned to the specific challenges posed by extreme heat in Zambia's diverse urban landscapes.

4.2. Inclusive Vulnerability Assessments

Acknowledging the socio-economic disparities within urban populations, future resilience planning should conduct inclusive vulnerability assessments. These assessments should go beyond traditional metrics and consider factors such as income levels, access to healthcare, and educational attainment. Traditionally, vulnerability assessments have often focused on environmental factors, such as exposure to extreme temperatures, without delving into the broader social dimensions that influence resilience. In contrast, inclusive vulnerability assessments extend beyond conventional metrics. They encompass a comprehensive examination of socio-economic factors, including income levels, access to healthcare, and educational attainment, among others. By considering these social determinants, planners gain a holistic understanding of the diverse vulnerabilities present within urban communities. Understanding how extreme heat impacts different demographic groups is a central objective of inclusive vulnerability assessments. These assessments reveal the distinct ways in which socio-economic factors intersect with environmental risks, shaping the differential experiences of heat stress among various populations. For instance, vulnerable communities with lower incomes may face challenges in accessing cooling technologies or healthcare services during heatwaves. Similarly, educational and awareness levels can influence the capacity of individuals and communities to adapt to and cope with extreme heat events.

The insights derived from inclusive vulnerability assessments serve as a compass for targeted interventions. Planners armed with an understanding of the social determinants of vulnerability can develop and implement strategies that prioritize the needs of marginalized and at-risk communities. This targeted approach is integral to fostering social equity, ensuring that resilience measures are not only effective but also contribute to the reduction of existing disparities. Moreover, fostering social equity through inclusive vulnerability assessments extends beyond the immediate benefits of climate adaptation. It aligns with broader goals of sustainable development, promoting an urban environment where all residents, regardless of socio-economic status, have equal access to resources, services, and opportunities. This holistic perspective not only strengthens the adaptive capacity of vulnerable communities but also contributes to the overall well-being and inclusivity of the urban fabric. Therefore, inclusive vulnerability assessments are a cornerstone of socially equitable urban resilience planning. By acknowledging and addressing socio-economic disparities, these assessments empower planners to create targeted interventions that prioritize the needs of the most vulnerable, fostering a resilient urban landscape that is not only environmentally sound but also socially just.

4.3. Nature-Based Solutions Integration

The integration of nature-based solutions, such as urban green spaces, cool pavements, and green roofs, should be a cornerstone of future resilience planning in Zambia. These solutions not only contribute to temperature regulation by mitigating the urban heat island effect but also enhance overall urban well-being. Urban green spaces act as natural heat sinks, while cool pavements and green roofs contribute to surface temperature reduction. Beyond temperature regulation, nature-based solutions provide recreational areas, improve air quality, and foster a sense of community, contributing to residents' overall quality of life. Emphasizing the ecological, social, and economic benefits is crucial for the long-term viability and scalability of these interventions. Ecologically, nature-based solutions support biodiversity and enhance ecosystems. Socially, they create aesthetically pleasing urban environments, promoting community interaction. Economically, these solutions reduce energy costs, enhance property values, and attract tourism and investment. Achieving success involves careful planning, species selection, and community engagement to ensure ongoing maintenance and sustainability. The integration of nature-based solutions in the Zambian urban planning is integral to building resilient, sustainable, and vibrant urban landscapes that balance human activities with the natural environment.

4.4. Integrated Multi-Hazard Planning

Recognizing the interconnected nature of climate-related hazards, future resilience planning in Zambia should adopt an integrated approach. This involves assessing the synergies and trade-offs between strategies addressing extreme heat, water scarcity, and other climate challenges. By recognizing the interdependence of these hazards, integrated planning ensures a cohesive and holistic response that maximizes the effectiveness of interventions. Rather than addressing each hazard in isolation, this approach enables a clearer understanding of how different climate-related challenges interact and influence one another within the local context of Zambia. Integrated multi-hazard planning further promotes efficiency by avoiding isolated solutions that might inadvertently exacerbate other vulnerabilities. For instance, strategies aimed at mitigating extreme heat, such as increased vegetation, may have implications for water availability. By considering these interdependencies, Zambian planners can identify win-win solutions that simultaneously address multiple challenges. This integrated approach not only enhances the resilience of urban areas in Zambia but also fosters sustainable development by recognizing the complex relationships between different environmental stressors. As climate change continues to manifest in diverse ways, this holistic planning approach becomes increasingly essential to proactively manage and adapt to the myriad challenges posed by a changing climate.

4.5. Community-Centric Approaches

Community-centric approaches are integral to the success of future resilience planning in Zambia, emphasizing the active engagement of local communities as essential participants in the decision-making process. Recognizing that communities are not passive recipients but active stakeholders, future strategies should adopt community-driven adaptation approaches. In this paradigm, residents become co-creators of solutions, contributing their local knowledge and experiences to the planning and implementation of resilience measures. This collaborative approach ensures that interventions are not only effective but also culturally, socially, and economically appropriate, aligning with the unique needs and preferences of the communities involved. Implementing community-centric approaches involves participatory processes that empower residents and foster inclusivity. Community workshops, inclusive decision-making forums, and other engagement mechanisms provide platforms for meaningful dialogue between planners and community members. Through these interactions, residents can express their concerns, share insights, and actively contribute to shaping the resilience strategies that directly impact their lives. This approach not only enhances the relevance and acceptance of interventions but also strengthens the social fabric by promoting a sense of ownership and shared responsibility. By embracing community-driven adaptation, future resilience planning in Zambia can tap into the collective wisdom of local communities, ensuring that strategies are not only technically sound but also deeply rooted in the social and cultural contexts they aim to protect and enhance.

4.6. Enhancing Early warning system

Prioritizing the development and enhancement of multi-hazard early warning systems emerges as a critical component in future resilience planning for Zambia, with a particular emphasis on the integration of various climate-related risks. Enhancing early warning systems involves bringing together data on diverse threats, including extreme heat, water scarcity, and other climate-related challenges, into a unified and comprehensive framework. This integration ensures that communities and authorities receive timely and accurate information, enabling them to respond proactively and effectively to the complex and interconnected risks associated with a changing climate. The strength of an early warning system lies in its ability to provide actionable information that facilitates targeted responses. By integrating data on multiple hazards, such as extreme heat and water scarcity, authorities can offer clearer and context-specific alerts. This approach empowers communities to take pre-emptive measures, minimizing the potential impacts of climate-related events. Moreover, a unified early warning framework facilitates a more holistic understanding of the interplay between different hazards, enabling planners and responders to anticipate and address cascading effects, thereby enhancing overall resilience. In practical terms, an enhanced early warning system equips communities and authorities with the tools to manage and mitigate the impacts of climate-related events more effectively. This includes not only timely alerts but also actionable guidance on adaptive measures and resource allocation. The integration of diverse climate-related risks ensures that responses are well-informed and tailored to the specific challenges faced by a given region. Ultimately, a robust and unified early warning system becomes a cornerstone in the broader strategy of building resilient communities and safeguarding against the multidimensional impacts of a changing climate.

4.7. Capacity Building and Education Initiatives

Capacity building and education initiatives constitute fundamental pillars in the realm of resilience planning, serving as catalysts for empowering communities to respond effectively to extreme heat events. These initiatives are integral to enhancing the adaptive capacity of communities, enabling them to proactively navigate and withstand the challenges posed by a changing climate. Educational campaigns play a pivotal role in disseminating essential knowledge about the impacts of extreme heat, adaptive measures, and the broader context of climate change. Training programs designed for community members become crucial components of capacity building, providing practical skills and tools to cope with extreme heat events. These programs can cover a range of topics, from understanding the signs of heat-related illnesses to implementing effective heat mitigation strategies. Importantly, community workshops offer interactive platforms for residents to actively engage with the information, share experiences, and collectively brainstorm strategies. This participatory approach fosters a culture of resilience, encouraging communities to take ownership of their adaptation measures and collaborate in finding context-specific solutions. The overarching goal of capacity building and education initiatives is to empower residents with the knowledge and skills needed to respond effectively to extreme heat events. This empowerment not only enhances the immediate adaptive capacity of communities but also instils a broader culture of resilience and self-sufficiency. As communities become better informed and equipped, they are more likely to take proactive measures, reducing vulnerability and minimizing the impacts of extreme heat on both individuals and the community as a whole. In essence, enhanced capacity building and education in Zambia will lay the foundation for resilient communities that are well-prepared to face the challenges posed by extreme climatic events.

4.8. Green Infrastructure and Sustainable Urban Design

Prioritizing green infrastructure and sustainable urban design principles is paramount in future planning efforts in Zambia, representing a forward-thinking approach that goes beyond mitigating extreme heat to foster overall urban sustainability. The incorporation of green infrastructure elements, such as green corridors, sustainable transportation, and energy-efficient buildings, forms a holistic strategy that not only addresses heat-related challenges but also contributes to the broader well-being of urban environments. Green corridors, characterized by interconnected green spaces, not only provide essential habitats for biodiversity but also serve as vital components in mitigating the urban heat island effect. By incorporating greenery into the urban fabric, these corridors contribute to temperature regulation, air purification, and enhanced aesthetics. Sustainable transportation initiatives, including public transit and active transportation options like cycling and walking, reduce reliance on carbon-intensive modes of transport, curbing emissions and promoting healthier, more environmentally friendly urban lifestyles. Moreover, the integration of energy-efficient buildings within sustainable urban design principles is crucial for minimizing the environmental footprint of urban areas. Such buildings incorporate design elements and technologies that optimize energy consumption, reducing the overall demand for resources. By promoting energy efficiency, future planning not only mitigates the urban heat island effect but also aligns with global efforts to combat climate change and promote ecological resilience. The emphasis on green infrastructure and sustainable urban design represents a harmonious balance between ecological integrity and urban development. These strategies prioritize the coexistence of urban environments with the natural world, recognizing the interconnectedness between human activities and the broader ecosystem. Although Zambia is still developing and may currently not have the full capacity to fully implement these, embracing these principles will ensure that future planning not only enhances the adaptability of urban areas to extreme heat but also lays the foundation for resilient, sustainable, and liveable cities that promote the well-being of both residents and the environment.

5. DISCUSSION

After examining extreme heat trends in Zambia, it is crucial to acknowledge the nation's susceptibility to the impacts of climate change, particularly in the realm of rising temperatures (Asefi-Najafabady et al., 2018; Rawlins, & Kalaba, 2020). Over recent years, Zambia has experienced observable shifts in its thermal landscape, marked by an increase in the frequency and intensity of heat-related events. Climatic data reveals a discernible warming trend, with temperatures surpassing historical averages and contributing to heightened instances of extreme heat (Kalantary, 2010; Dumenu, & Takam Tiamgne, 2020; Rawlins, & Kalaba, 2020; Libanda, 2020). The geographic diversity of Zambia introduces regional variations in heat patterns. While urban centres may encounter urban heat island effects due to concentrated human activities and infrastructure, rural and peri-urban areas may witness distinct thermal dynamics influenced by land-use patterns and natural features (Libanda et al., 2019; Libanda et al., 2019a). Understanding these localized nuances is pivotal for formulating targeted resilience strategies that align with the specific challenges faced by different regions.

Moreover, the socio-economic fabric of Zambia plays a role in exacerbating or mitigating the impacts of heat trends. Vulnerable populations, often residing in informal settlements or areas lacking adequate infrastructure, may bear a disproportionate burden of heat-related stresses (Thurlow et al., 2009; Luxon, & Pius, 2012; Ngoma et al., 2023). Concurrently, urbanization trends and industrial activities contribute to the overall heat load in urban centres (Libanda et al., 2020; Blekking et al., 2022)). Analyzing these dynamics provides a comprehensive picture of the factors influencing heat trends and aids in tailoring effective and equitable resilience measures. As climate change projections indicate a continued trajectory of warming temperatures globally (Supran et al., 20230, Zambia's vulnerability to heat-related challenges are expected to persist. This necessitates a proactive and adaptive approach to urban planning. Figure 1 depicts the annual temperature trends in Zambia.

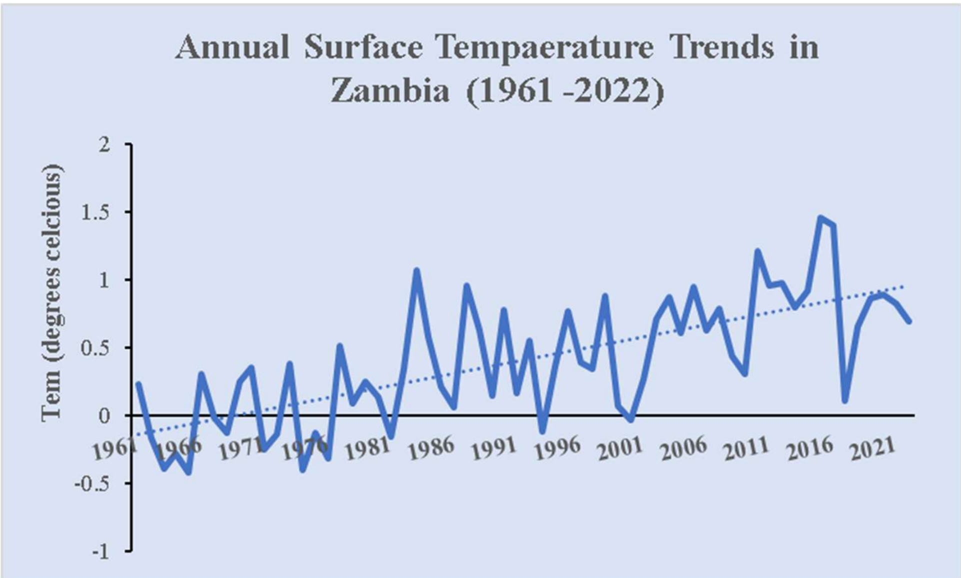

Figure 6. Trends in annual temperature in Zambia between 1961 to 2022.

Data source: Faostat.org

During the early years (1961-1980), the temperature anomalies fluctuated around the baseline, suggesting a relatively stable climate. While some years experienced warming (positive anomalies), others had cooling (negative anomalies). This variability may be influenced by natural climatic phenomena. Notably, there is no clear indication of a warming or cooling trend during this period. From the 1980s onward, a discernible warming trend emerges, with an increasing number of years exhibiting positive temperature anomalies (1981-2000). This aligns with the broader global pattern of rising temperatures attributed to human-induced climate change. The warming trend may be linked to factors such as increased greenhouse gas emissions and changes in land use, affecting Zambia's local climate. The early 2000s show a mix of positive and negative anomalies (2001-2015), indicating a degree of variability. This period may witness short-term influences, such as natural climate variability, volcanic activity, or oceanic patterns. However, the overall trend continues to show a tendency towards warmer temperatures compared to the earlier decades. In the most recent years (2016-2022), the data reveals a pronounced and sustained warming trend. Positive anomalies dominate, indicating a consistent increase in temperatures. The acceleration of this warming aligns with global concerns over the acceleration of climate change. This recent warming phase may be associated with intensifying anthropogenic influences on the climate system. Figure 2 depicts the projected seasonal cycle of daytime temperatures in Zambia from 2020 to 2039 reveals notable trends in relation to extreme heat events and their implications for urban resilience. The graph depicts categorization into the number of hot days with maximum temperatures exceeding specific thresholds, provides insights into the changing climate dynamics.

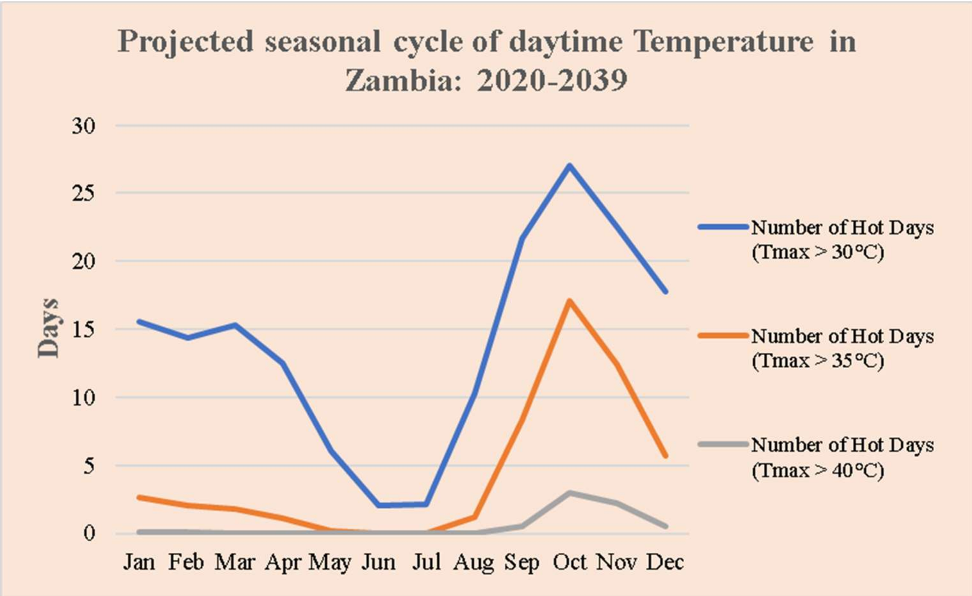

Figure 7. Projected Seasonal Cycle of Daytime Temperature Trends (2020-2039) in Zambia.

Author's design. Data source: climate change Knowledge Portal

During the months of January and February, there is a consistent number of hot days with maximum temperatures surpassing 30°C, indicating a baseline level of warmth. The occurrences of extremely hot days (Tmax > 35°C and Tmax > 40°C) are relatively limited during these months, suggesting a moderate impact on urban areas. As the seasonal cycle progresses into March and April, the number of hot days remains relatively stable, but the occurrences of extremely hot days begin to diminish. May and June mark a significant decrease in both hot and extremely hot days, highlighting a period of milder temperatures. The transition to July and August sees a slight uptick in the number of hot days, with August experiencing a notable increase. However, the occurrences of extremely hot days remain minimal during this period. September emerges as a critical month, witnessing a substantial rise in both hot and extremely hot days. This trend intensifies in October, reaching the peak of extreme heat events. The number of hot days exceeds 27, with more than 17 days surpassing 35°C and 3 days exceeding 40°C. This pattern signifies a pronounced impact on urban areas, requiring heightened resilience strategies. The trend gradually recedes in November and December, yet the number of hot days remains considerable. While extreme heat events diminish, their lingering presence underscores the need for sustained urban resilience measures.

The projected temperature trends in Zambia indicate a seasonally variable pattern of extreme heat events, with notable peaks during September and October. These fluctuations necessitate tailored resilience strategies, particularly during the peak months. Overall, the warming trends in Zambia have direct implications for urban areas. Urban heat islands (UHIs), where urban areas experience higher temperatures than surrounding rural areas, can exacerbate the impacts of rising temperatures. Urban planning, infrastructure development, and climate adaptation strategies become crucial. Furthermore, prolonged exposure to extreme heat can lead to adverse effects on human health, increase energy consumption for cooling, and strain water resources.

Finally DMMU's role in addressing extreme heat in Zambia is crucial given the increasing frequency of climate-related disasters. While there are promising strategies for enhancing resilience, the successful implementation of these solutions will depend on overcoming the identified limitations, particularly regarding resource allocation and public engagement. Future research should focus on evaluating the impact of implemented DMMU strategies, refining them based on lessons learned, and fostering a multi-agency approach for a more coordinated response to climatic challenges.

6. CONCLUSION

This comprehensive review provides profound insights into critical aspects of urban resilience to extreme heat in the Zambia context, presenting a clear understanding of strategies, lessons from successful cases, and future pathways. The review shows that intricate impact of extreme heat on urban environments necessitates sophisticated and adaptive approaches that transcend conventional mitigation measures. An in-depth analysis of strategies aimed at enhancing urban resilience underscores the pivotal importance of prioritizing green infrastructure and adopting sustainable urban design principles. The integration of elements such as green corridors, sustainable transportation, and energy-efficient buildings not only addresses heat stress but also contributes significantly to the broader realm of urban sustainability. This strategic emphasis advocates for a harmonious coexistence between urban development and ecological integrity, fostering environments that epitomize resilience and sustainability. The significance of community-centric approaches is underscored, emphasizing active community participation in the resilience planning process. Through participatory processes, workshops, and inclusive decision-making, local communities become empowered stakeholders, ensuring that resilience strategies align with their unique cultural, social, and economic contexts. This participatory approach fosters a collective sense of responsibility and ownership, thereby strengthening the social fabric of urban communities. The imperative for prioritizing early warning systems in future planning is highlighted, emphasizing the development and enhancement of comprehensive, multi-hazard systems. Integration of diverse climate-related risks into a unified framework facilitates timely and targeted responses, enabling proactive management and mitigation. This strategic focus empowers both communities and authorities to effectively navigate the challenges posed by extreme heat events. Integral to resilience planning, capacity building, and education initiatives emerge as critical components for Zambia. Equipping communities with the requisite knowledge and skills to respond to extreme heat events significantly enhances their adaptive capacity and this is critical for Zambia. Educational campaigns, training programs, and community workshops not only impart practical skills but also foster a culture of resilience and self-sufficiency. Finally, Zambia can benefit more in future resilience planning by integrating nature-based solutions, encompassing urban green spaces, cool pavements, and green roofs. Beyond contributing to temperature regulation, these solutions enhance overall urban well-being. Emphasis on the ecological, social, and economic benefits of these interventions ensures their enduring viability and scalability. In essence, this review advocates for a holistic and integrated approach to urban resilience, recognizing the interconnected nature of strategies, challenges, and community dynamics. By embracing these multifaceted considerations, Zambia’s cities can navigate the complexities of extreme heat events, working towards the realization of sustainable, resilient, and habitable urban environments.

CONFLICTS OF INTEREST

The authors declares that they have no conflicts of interest

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REFERENCES

[1] Allam, Z., Jones, D., & Thondoo, M. (2020). Cities and climate change: Climate policy, economic resilience and urban sustainability. Springer Nature.

[2] Amati, M., Stevens, Q., & Rueda, S. (2023). Taking Play Seriously in Urban Design: The Evolution of Barcelona's Superblocks. Space and Culture, 12063312231159229.

[3] Argyroudis, S. A., Mitoulis, S. A., Chatzi, E., Baker, J. W., Brilakis, I., Gkoumas, K., ... & Linkov, I. (2022). Digital technologies can enhance climate resilience of critical infrastructure. Climate Risk Management, 35, 100387.

[4] Asarpota, K., & Nadin, V. (2020). Energy strategies, the urban dimension, and spatial planning. Energies, 13(14), 3642.

[5] Asefi-Najafabady, S., Vandecar, K. L., Seimon, A., Lawrence, P., & Lawrence, D. (2018). Climate change, population, and poverty: vulnerability and exposure to heat stress in countries bordering the Great Lakes of Africa. Climatic Change, 148, 561-573.

[6] Ashie, Y. (2021). Tokyo heat island adaptation measures. Urban Climate Science for Planning Healthy Cities, 119-150.

[7] Berry, P., & Richardson, G. R. (2016). Approaches for building community resilience to extreme heat. Extreme weather, health, and communities: Interdisciplinary engagement strategies, 351-388.

[8] Blekking, J., Giroux, S., Waldman, K., Battersby, J., Tuholske, C., Robeson, S. M., & Siame, G. (2022). The impacts of climate change and urbanization on food retailers in urban sub-Saharan Africa. Current Opinion in Environmental Sustainability, 55, 101169.

[9] Borodinecs, A. (2021). Guidelines for climate proofing energy efficiency projects.

[10] Bosomworth, K., Trundle, A., & McEvoy, D. (2013). Responding to the urban heat island: a policy and institutional analysis.

[11] Boyd, E., & Juhola, S. (2015). Adaptive climate change governance for urban resilience. Urban studies, 52(7), 1234-1264.

[12] Burchell, K., Fagan-Watson, B., & Watson, T. (2017). Urban Heat: developing the role of community groups in local climate resilience.

[13] Bush, J., Ashley, G., Foster, B., & Hall, G. (2021). Integrating green infrastructure into urban planning: Developing Melbourne's green factor tool. Urban Planning, 6(1), 20-31.

[14] Ching, F. D. (2020). Building construction illustrated. John Wiley & Sons.

[15] de Abreu, V. H. S., Santos, A. S., & Monteiro, T. G. M. (2022). Climate change impacts on the road transport infrastructure: A systematic review on adaptation measures. Sustainability, 14(14), 8864.

[16] Demuzere, M., Orru, K., Heidrich, O., Olazabal, E., Geneletti, D., Orru, H., ... & Faehnle, M. (2014). Mitigating and adapting to climate change: Multi-functional and multi-scale assessment of green urban infrastructure. Journal of environmental management, 146, 107-115.

[17] Dumenu, W. K., & Takam Tiamgne, X. (2020). Social vulnerability of smallholder farmers to climate change in Zambia: the applicability of social vulnerability index. SN Applied Sciences, 2, 1-16.

[18] Fastenrath, S., Coenen, L., & Davidson, K. (2019). Urban resilience in action: The Resilient Melbourne Strategy as transformative urban innovation policy?. Sustainability, 11(3), 693.

[19] Ganoe, M., Roslida, J., & Sihotang, T. (2023). The Impact of Volunteerism on Community Resilience in Disaster Management. Jurnal Ilmu Pendidikan dan Humaniora, 12(3), 199-213.

[20] Greenwalt, J., Raasakka, N., & Alverson, K. (2018). Building urban resilience to address urbanization and climate change. In Resilience (pp. 151-164). Elsevier.

[21] Guardaro, M., Messerschmidt, M., Hondula, D. M., Grimm, N. B., & Redman, C. L. (2020). Building community heat action plans story by story: A three neighborhood case study. Cities, 107, 102886.

[22] Haq, G., & Schwela, D. (2012). Transport and environment in sub-Saharan Africa. London: Stocholm environment institute, University of York.

[23] Hartigan, M., Fitzsimons, J., Grenfell, M., & Kent, T. (2021). Developing a metropolitan-wide urban forest strategy for a large, expanding and densifying capital city: Lessons from Melbourne, Australia. Land, 10(8), 809.

[24] Hassan, A. M., & Lee, H. (2015). Toward the sustainable development of urban areas: An overview of global trends in trials and policies. Land use policy, 48, 199-212.

[25] Hersperger, A. M., Oliveira, E., Pagliarin, S., Palka, G., Verburg, P., Bolliger, J., & Grădinaru, S. (2018). Urban land-use change: The role of strategic spatial planning. Global Environmental Change, 51, 32-42.

[26] Hidalgo García, D., & Arco Díaz, J. (2023). Mitigation and Resilience of Local Climatic Zones to the Effects of Extreme Heat: Study on the City of Barcelona (Spain). Urban Science, 7(4), 102.

[27] Hoverter, S. P. (2012). Adapting to urban heat: a tool kit for local governments. Georgetown Climate Center.

[28] Hung, H. C., Yang, C. Y., Chien, C. Y., & Liu, Y. C. (2016). Building resilience: Mainstreaming community participation into integrated assessment of resilience to climatic hazards in metropolitan land use management. Land use policy, 50, 48-58.

[29] Ikegwu, A., Nweke, H., Alo, U., Anikwe, C., & Okonkwo, O. (2023). Recently Emerging Trends in Big Data Analytic Methods for Modeling and Combating Climate Change Effects.

[30] Imran, H. M., Kala, J., Ng, A. W. M., & Muthukumaran, S. (2018). Effectiveness of green and cool roofs in mitigating urban heat island effects during a heatwave event in the city of Melbourne in southeast Australia. Journal of Cleaner Production, 197, 393-405.

[31] Inghirami, P. (2022). Towards a human smart sustainable city: the case of Barcelona.

[32] Jabareen, Y. (2013). Planning the resilient city: Concepts and strategies for coping with climate change and environmental risk. Cities, 31, 220-229.

[33] Jha, A. K., Miner, T. W., & Stanton-Geddes, Z. (Eds.). (2013). Building urban resilience: principles, tools, and practice. World Bank Publications.

[34] Kalantary, C. (2010). Climate change in Zambia: Impacts and adaptation. Global Majority E-Journal, 1(2), 85-96.

[35] Keith, L., Meerow, S., & Wagner, T. (2019). Planning for extreme heat: a review. Journal of Extreme Events, 6(03n04), 2050003.

[36] Keith, L., Gabbe, C. J., & Schmidt, E. (2023). Urban heat governance: examining the role of urban planning. Journal of Environmental Policy & Planning, 25(5), 642-662.

[37] Kiani, A., Salman, A., & Riaz, Z. (2014). Real-time environmental monitoring, visualization, and notification system for construction H&S management. Journal of Information Technology in Construction, 19, 72-91.

[38] Levin, E., Beisekenov, N., Wilson, M., Sadenova, M., Nabaweesi, R., & Nguyen, L. (2023). Empowering Climate Resilience: Leveraging Cloud Computing and Big Data for Community Climate Change Impact Service (C3IS). Remote Sensing, 15(21), 5160.

[39] Libanda, B. (2020). Multi-model synthesis of future extreme temperature indices over Zambia. Modeling Earth Systems and Environment, 6(2), 743-757.

[40] Libanda, B., Nkolola, N. B., Chilekana, N., & Bwalya, K. (2019). Dominant east-west pattern of diurnal temperature range observed across Zambia. Dynamics of Atmospheres and Oceans, 86, 153-162.

[41] Libanda, B., Zheng, M., & Ngonga, C. (2019a). Spatial and temporal patterns of drought in Zambia. Journal of Arid Land, 11, 180-191.

[42] Libanda, E., Nkolola, N. B., & Chilekana, N. (2020). Human thermal comfort and urban climate of Zambia's economic and political hub: a RayMan model study. Modeling Earth Systems and Environment, 6, 1671-1682.

[43] Liu, Z., Cheng, W., Jim, C. Y., Morakinyo, T. E., Shi, Y., & Ng, E. (2021). Heat mitigation benefits of urban green and blue infrastructures: A systematic review of modeling techniques, validation and scenario simulation in ENVI-met V4. Building and Environment, 200, 107939.

[44] López, I., Ortega, J., & Pardo, M. (2020). Mobility infrastructures in cities and climate change: an analysis through the superblocks in Barcelona. Atmosphere, 11(4), 410.

[45] Luxon, N., & Pius, C. (2012). Climate change risk and vulnerability mapping and profiling at local level using the Household Economy Approach (HEA). J Earth Sci Climate Change, 3(123), 2.

[46] Marcotullio, P. J., Keßler, C., & Fekete, B. M. (2022). Global urban exposure projections to extreme heatwaves. Frontiers in Built Environment, 8, 947496.

[47] Markolf, S. A., Chester, M. V., Eisenberg, D. A., Iwaniec, D. M., Davidson, C. I., Zimmerman, R., ... & Chang, H. (2018). Interdependent infrastructure as linked social, ecological, and technological systems (SETSs) to address lock-in and enhance resilience. Earth's Future, 6(12), 1638-1659.

[48] Martinez, G. S., Imai, C., & Masumo, K. (2011). Local heat stroke prevention plans in Japan: characteristics and elements for public health adaptation to climate change. International journal of environmental research and public health, 8(12), 4563-4581.

[49] Mfitumukiza, D., Roy, A. S., Simane, B., Hammill, A., Rahman, M. F., & Huq, S. (2020). Scaling local and community-based adaptation. Global Commission on Adaptation Background Paper.

[50] Mohan, D. (2023). Enhancing capacity building initiatives at sub-national level for supporting climate change adaptation. Climate and Development, 1-8.

[51] Moyo, N., Nanyangwe-Moyo, T., Mapoma, C. C., Munkombwe, B., Phiri, M., Banda, A., ... & Qiao, X. (2022). The population of Zambia: past, present and future.

[52] Mueller, N., Rojas-Rueda, D., Khreis, H., Cirach, M., Andrés, D., Ballester, J., ... & Nieuwenhuijsen, M. (2020). Changing the urban design of cities for health: The superblock model. Environment international, 134, 105132.

[53] Mulenga, S., & Campenhout, B.V. (2008). Decomposing Poverty Changes in Zambia: Growth, Inequality and Population Dynamics. African Development Review, 20, 284-304.

[54] Munn, Z., Peters, M. D., Stern, C., Tufanaru, C., McArthur, A., & Aromataris, E. (2018). Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. BMC medical research methodology, 18, 1-7.

[55] Musonda, I., Mwanaumo, E., Onososen, A., & Moyo, T. (Eds.). (2023). Smart and Resilient Infrastructure For Emerging Economies: Perspectives on Building Better: Proceedings of the 9th International Conference on Development and Investment In infrastructure (DII-2023, 19-21 July 2023, Zambia). CRC Press.

[56] Nero, B. F., Callo-Concha, D., & Denich, M. (2019). Increasing Urbanisation and the Role of Green Spaces in Urban Climate Resilience in Africa. Environmental Change and African Societies, 265-296.

[57] Ngoma, H., Finn, A., & Kabisa, M. (2023). Climate shocks, vulnerability, resilience and livelihoods in rural Zambia. Climate and Development, 1-12.

[58] Norton, B. A., Coutts, A. M., Livesley, S. J., Harris, R. J., Hunter, A. M., & Williams, N. S. (2015). Planning for cooler cities: A framework to prioritise green infrastructure to mitigate high temperatures in urban landscapes. Landscape and urban planning, 134, 127-138.

[59] Panarelli, G. (2015). Climate responsive design. Research, strategies and assessment criteria. Technological innovation and Climate Responsive Architecture Approach in the project. HOUSING POLICIES AND URBAN ECONOMICS, 3, 92-94.

[60] Papaioannou, D., Sutton, A., & Booth, A. (2016). Systematic approaches to a successful literature review. Systematic approaches to a successful literature review, 1-336.

[61] Pioppi, B., Pisello, A. L., & Ramamurthy, P. (2022). Wearable sensing techniques to understand pedestrian-level outdoor microclimate affecting heat related risk in urban parks. Solar Energy, 242, 397-412.

[62] Popescu, S. (2022). Towards Sustainable Urban Futures: Exploring Environmental Initiatives in Smart Cities. Applied Research in Artificial Intelligence and Cloud Computing, 5(1), 84-104.

[63] Potgieter, J., Nazarian, N., Lipson, M. J., Hart, M. A., Ulpiani, G., Morrison, W., & Benjamin, K. (2021). Combining high-resolution land use data with crowdsourced air temperature to investigate intra-urban microclimate. Frontiers in Environmental Science, 9, 385.

[64] Puplampu, D. A., & Boafo, Y. A. (2021). Exploring the impacts of urban expansion on green spaces availability and delivery of ecosystem services in the Accra metropolis. Environmental Challenges, 5, 100283.

[65] Qin, Y., Ghalambaz, S., Sheremet, M., Baro, M., & Ghalambaz, M. (2023). Deciphering Urban Heat Island Mitigation: A Comprehensive Analysis of Application Categories and Research Trends. Sustainable Cities and Society, 105081.

[66] Rasul, S., & Cheng, A. Y. (2023). Policy Frameworks and Governance Structures Supporting Green City Movements. Advances in Urban Resilience and Sustainable City Design, 15(6), 37-51.

[67] Rawlins, J., & Kalaba, F. K. (2020). Adaptation to climate change: Opportunities and challenges from Zambia. African Handbook of Climate Change Adaptation, 1-20.

[68] Rezvani, S. M., de Almeida, N. M., & Falcão, M. J. (2023). Climate Adaptation Measures for Enhancing Urban Resilience. Buildings, 13(9), 2163.

[69] Rivero-Villar, A., & Vieyra Medrano, A. (2022). Governance for urban resilience in popular settlements in developing countries: a case-study review. Climate and Development, 14(3), 208-221.

[70] Roest, A. H., Weitkamp, G., Van den Brink, M., & Boogaard, F. (2023). Mapping spatial opportunities for urban climate adaptation measures in public and private spaces using a GIS-based Decision Support Model. Sustainable Cities and Society, 96, 104651.

[71] Rueda, S. (2019). Superblocks for the design of new cities and renovation of existing ones: Barcelona's case. Integrating human health into urban and transport planning: A framework, 135-153.

[72] Shakou, L. M., Wybo, J. L., Reniers, G., & Boustras, G. (2019). Developing an innovative framework for enhancing the resilience of critical infrastructure to climate change. Safety science, 118, 364-378.

[73] Shaw, R., Takeuchi, Y., Joerin, J., Fernandez, G., Tjandradewi, B. I., Wataya, E., ... & Matsuoka, Y. (2010). Climate and Disaster Resilience Initiatives: Capacity-building Program. United Nations International Strategy for Disaster Reduction (UNISDR).

[74] Simatele, D. (2013). Asset adaptation and urban food security in a changing climate: a case study of Kalingalinga and Linda Compounds in Lusaka, Zambia. In Climate Change, Assets and Food Security in Southern African Cities (pp. 110-131). Routledge.

[75] Simatele, D. (2016). Pro-poor climate change adaptation in Zambia. Climate Adaptation Governance in Cities and Regions: Theoretical Fundamentals and Practical Evidence, 267-284.

[76] Simwanda, M., & Murayama, Y. (2017). Integrating geospatial techniques for urban land use classification in the developing sub-Saharan African city of Lusaka, Zambia. ISPRS International Journal of Geo-Information, 6(4), 102.

[77] Simwanda, M., & Murayama, Y. (2018). Spatiotemporal patterns of urban land use change in the rapidly growing city of Lusaka, Zambia: Implications for sustainable urban development. Sustainable Cities and Society, 39, 262-274.

[78] Simwanda, M., Murayama, Y., & Ranagalage, M. (2020). Modeling the drivers of urban land use changes in Lusaka, Zambia using multi-criteria evaluation: An analytic network process approach. Land Use Policy, 92, 104441.

[79] Singh, M., & Sharston, R. (2022, November). Evaluating the Spatial Variation of Heatwave Intensity to Enhance Urban Resilience. In IOP Conference Series: Earth and Environmental Science (Vol. 1101, No. 2, p. 022016). IOP Publishing.

[80] Supran, G., Rahmstorf, S., & Oreskes, N. (2023). Assessing ExxonMobil's global warming projections. Science, 379(6628), eabk0063.

[81] Tanner, T., Mitchell, T., Polack, E., & Guenther, B. (2009). Urban governance for adaptation: assessing climate change resilience in ten Asian cities. IDS Working Papers, 2009(315), 01-47.

[82] Taylor, A., Siame, G., & Mwalukanga, B. (2021). Integrating climate risks into strategic urban planning in Lusaka, Zambia. Climate Risk in Africa: Adaptation and Resilience, 115-129.

[83] Tembo-Silungwe, C., Musonda, I., & Okoro, C. Proceedings for the 6th International Conference on development and investment in infrastructure-strategies for Africa: DII-2019: 24-26 July 2019, Livingstone, Zambia: Innovation in Infrastructure development and investment-is Africa ready for change?.

[84] Thurlow, J., Zhu, T., & Diao, X. (2009). The impact of climate variability and change on economic growth and poverty in Zambia.

[85] Titz, A., & Chiotha, S. S. (2019). Pathways for sustainable and inclusive cities in Southern and Eastern Africa through urban green infrastructure?. Sustainability, 11(10), 2729.

[86] Tokyo Metropolitan Government, (2005). Guidelines for Heat Island Control Measures. July, 2005 Bureau of the Environment, Tokyo Metropolitan Government

[87] Tuholske, C., Caylor, K., Funk, C., Verdin, A., Sweeney, S., Grace, K., ... & Evans, T. (2021). Global urban population exposure to extreme heat. Proceedings of the National Academy of Sciences, 118(41), e2024792118.

[88] Turek-Hankins, L. L., Coughlan de Perez, E., Scarpa, G., Ruiz-Diaz, R., Schwerdtle, P. N., Joe, E. T., ... & Mach, K. J. (2021). Climate change adaptation to extreme heat: a global systematic review of implemented action. Oxford Open Climate Change, 1(1), kgab005.

[89] Verma, A., & Singhania, R. (2023). Urban Resilience in the Face of Climate Change: Strategies for Adaptation and Mitigation. Journal of Sustainable Technologies and Infrastructure Planning, 7(1), 46-66.

[90] Wilkinson, S. J., & Dixon, T. (Eds.). (2016). Green Roof Retrofit: building urban resilience. John Wiley & Sons.

[91] Wong, N. H., Tan, C. L., Kolokotsa, D. D., & Takebayashi, H. (2021). Greenery as a mitigation and adaptation strategy to urban heat. Nature Reviews Earth & Environment, 2(3), 166-181.

[92] Xu, J., & Wang, X. (2020). Reversing Uncontrolled and Unprofitable Urban Expansion in Africa through Special Economic Zones: An Evaluation of Ethiopian and Zambian Cases. Sustainability, 12(21), 9246.

[93] Yamamoto, Y. (2006). Measures to mitigate urban heat islands. NISTEP Science & Technology Foresight Center.

[94] Zölch, T., Maderspacher, J., Wamsler, C., & Pauleit, S. (2016). Using green infrastructure for urban climate-proofing: An evaluation of heat mitigation measures at the micro-scale. Urban Forestry & Urban Greening, 20, 305-316.

[95] Zulu, E., Zulu, S. L., Chabala, M., Kavishe, N., Chifunda, C., & Musonda, I. (2022). Infrastructure design stage considerations for environmental sustainability in Zambia. Journal of Engineering, Design and Technology.