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URBAN HEAT HIGHLAND AND THERMAL DYNAMICS IN WEST AFRICA

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Abstract

Rapid urbanisation is affecting people in different ways, with some becoming more vulnerable to the impacts of climate change. Africa's cities are projected to be home to nearly 60% of the continent's population by 2050. In conjunction with climate change, these cities are experiencing critical environmental challenges, including changes in the urban thermal environment. Urban areas generally exhibit significantly higher air and surface temperatures than their surrounding rural areas, resulting in urban heat islands. However, little has been done to synthesise existing knowledge and identify the key research gaps in this area, particularly in Africa. This paper focuses on the combined effects of urbanisation and climate change on the urban thermal environment in Africa, and provides a comprehensive review of results, major advances and the dominant direction of research. Our review of 40 publications from peer-reviewed journals from 2000 to 2021 revealed that South Africa, Ethiopia and Nigeria were most frequently studied, and satellite imagery-based data and analysis were used predominantly. Results from a few studies have shown the practical implications for urban land-use planning, informal settlement management, human wellbeing and productivity, energy use, air pollution and disease spread. Integrated approaches, strengthening planning institutions, and early warning systems are proposed to address climate change. Low-

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income groups are emphasised in efforts to help people cope with heat stress. Solutions based on land use and land cover dynamics and blue–green infrastructure are mentioned but are in need of further research. Cities with similar patterns of urbanisation, geographies and climate conditions could benefit from multi-disciplinary research collaboration to address the combined impacts of rapid urbanisation and climate change.

INTRODUCTION

Global Urbanisation and Climate Change Urbanisation is a global phenomenon. The proportion of the world's population living in urban areas was only 30% in 1950 but reached 55% in 2018, and is projected to be 68% by 2050 These dramatic shifts have substantial impacts on people, the environment and development, across local, regional and global scales. Changes include air and water pollution, land use, biodiversity loss, and ecosystem degradation, while carbon emissions from cities and associated land use changes are becoming an important driver of climate change. This urban growth dynamic is not homogeneous, and urban expansion patterns differ markedly across developing countries. By 2050, the number of urban dwellers will increase by 2.5 billion, with nearly 90% of this growth happening in Asia and Africa. West Africa is experiencing rapid population growth (Figure 1), especially in the West Africa and West (Figure 2). According to the OECD, approximately 4500 new cities emerged in West Africa between 1990 and 2015. In parallel, urban populations grew by approximately 500 million people between 1990 and 2020. Urbanisation has boosted economic outcomes and living standards for many; helping hundreds of millions of people to move out of economically under-performing rural areas to benefit from better opportunities in urban centres. Cities in these countries are undergoing dramatic spatial, social, economic and environmental transformations, due to a combination of multiple factors such as resource availability, technological innovation processes, the circulation of global capital, and the impact of climate change on primary production activities. This has meant that as people have moved from rural to urban areas, many cities in West Africahave grown in an unplanned manner, with a mix of commercial centres, industrial areas, residential communities, informal settlements and agricultural lands.

Three major urban forms were detected for African cities in 2015: first, the transitional urban form, characterised by built-up sprawling urbanisation and a

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decrease in open space, as seen in Accra, Addis Ababa, Bamako, Cairo, Gombe, Ibadan, Khartoum. Kigali, Luanda, Marrakesh and Port Elizabeth. The second type of urban form is the compact-grey form. This kind of city has become even more compact and simple in shape, and includes cities such as Alexandria, Kairouan, Oyo, Tebessa. The third type is the ragged-small form, which is less irregular and complex in shape, with examples including Arusha, Beira, Nakuru and Ndola. Cities under these different urban forms are projected to experience various changes as they expand further, offering the opportunity for more sustainable planning, but also presenting a challenge. Data from the World Bank shows African cities are growing at a rate that is out of sync to real economic growth. Due to rapid rural–urban transformation and the continuous influx of rural–urban migrants, the situation limits cities' ability to reduce poverty and provide improved standards of living. Despite the economic gains made for many who moved to urban centres, millions of people in the cities of West Africalack access to resources and facilities to meet their essential needs, such as shelter, water, food, health, and education. Over 59% of the urban population in sub-Saharan West Africais estimated to be living in informal settlements. While the fact that cities are perceived to offer more economic opportunities still pulls many people to live in cities. However, doing so increases their exposure to climate impacts.. West Africais particularly vulnerable to climate change and extreme temperature increases have been recorded in most of the continent. The rising rate of temperature increases is higher than at the global level, and even double that of some areas. Africa's climate is highly diverse and variable. Patterns of temperatures and precipitation are being altered by climate change, with increased probability and magnitude of extreme events, such as floods, heatwaves, droughts and storms. Changes in annual temperature and precipitation patterns have been nuanced and variable, with increasing and decreasing trends in different subregions. Lower precipitation and higher temperatures will likely reduce crop productivity in large parts of the continent. In West Africa, particularly in the Sahel, prolonged dry seasons, shorter wet seasons, and less regular rainfall are contributing to an increase in migration and displacement. Lack of structural transformation in Africa's agriculture inhibits responses to climate change. Events such as the intense outbreak of desert locust (Schistocerca gregaria) across several West AfricaAfrican countries from the end of 2019 to early 2020, posed a major threat to food security and livelihoods in addition to the challenge of direct climate change impacts. With few livelihood options in rural areas, climate change in combination with related challenges like

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food insecurity creates another factor that can push rural migrants to urban areas. West Africa's coastal cities face especially worrying risks as a result of climate change. "Storm surges and rain-triggered floods are damaging cities, setting back development, and generating the spread of disease that has killed thousands and displaced millions in Benin, Ivory Coast, Senegal, and Togo".

Materials and Methods

The aim of this paper is to identify gaps in the literature and opportunities for further research on the combined effects of urbanisation and climate change on the urban thermal environment Africa. To do this, we asked: (1) What is the geographic spread and scale of focus in investigations into the combined effects of urbanisation and climate change on the urban thermal environment? (2) Against the background of climate change and rapid urbanisation, what are the specific drivers of changes to the urban thermal environment in Africa? (3) How have urban thermal environment change related risks been studied in Africa? (4) Targeting on urban thermal environment changes, how have the adaptation strategies for different groups been studied in Africa?

The study area of West Africa consists of 10 nations made up of Benin, Burkina Faso, Chad, Ivory Coast, Ghana, Liberia, Niger, Nigeria, Senegal and Togo (Figure 1). Located along the Lower Coastal Belt and the Sahel North West Zone, the region stretches through a 4,771,810 km2 area from Senegal to Nigeria. In 2018, the study area had a population of over 345 million people; as shown in Table 1. The region has ample potentials in agriculture, but still lags when it comes to regular food access for the populace depending on the season, the geopolitical circumstances of the area in question and conditions of the ecozone. Given the large swath of areas in the zone, the diverse ecology and the pressures from the teeming population and changing climate, the food security situation in some of the places can no longer be dismissed as an issue.



Fig. 1: Map Showing West Africa

In order to explore the urban thermal environment from a wider viewpoint and gather various conceptualizations from diverse fields of research, a semi-

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systematic literature review approach was used for this paper. We decided against undertaking a systematic literature review, as that only addresses a particular question or looks into a critical factor in the research field and was considered too restrictive Following the Collaboration for Environmental Evidence 2018 guidelines [62,93], Web of Science was searched for the period 2000 and 2021. The year 2000 was selected as the earliest point in the literature search given increased international attention on sustainability issues that were associated with the Millennium Development Goals (MDGs) [94]. The MDGs evolved to become the Sustainable Development Goals (SDGs) in 2015 and have a deadline for their achievement of 2030 [94]. Terminology related to urban thermal environments include air urban heat island, urban cool island, temperature. Thus, the search terms "urban heat island" or "UHI" or "urban cooling" or "urban heat" or "urban thermal" or "urban temperature" or "urban climate" or "city temperature" or "city climate", combined with "urbanisation" or "urbanization" or "land use" or "urban growth" or "urban expansion" or "urban development" or "urban densification.

Results and Discussion

Study Distribution

Urban Thermal Environment Studies at Regional Scales:

Urbanisation processes and climate change were associated with the urban thermal environment. Increased temperatures were described in most sampled articles. The focus of most research at a continental level was the combined effect of climate change and urbanisation processes for African cities' thermal environments associated with projections under different shared socio-economic pathways (SSP). Under the "sustainability" pathway (SSP 1) and low relative levels of climate change (RCP 2.6), the potential number of urban dwellers exposed to heat waves by 2100 will be 310 million (ranging from 111 to 608 million) excluding the extra heat from UHI. Under SSP 4 ("inequality") with climate impacts under RCP 4.5, the high-end exposure level will reach 2.0 billion including extra heat from UHI For 173 large African cities, and depending on the different SSPs considered, urban dwellers' under the extreme heat across the continent are predicted to increase 20–52 times, reaching between 86 and 217 billion person-days per year by the 2090s].The most exposed cities will be located in Western and West Africa Africa, while exposure in several West African cities will

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increase over 2000 times from the current level by the 2090s Other authors suggested that further warming of 1.5 C may double or even triple the climate change impacts that are currently experienced in African cities . Smith and Parnell indicated that rapid population growth combined with weak urban management capacity exposed African cities to the threat of ecosystem deterioration and climate change, which might seriously affect health conditions for urban dwellers. In general, the synergistic interaction between dangerous heat and rapid urban population growth in African cities has rarely been experienced during the historical period but will potentially pose significant impacts on the future urban thermal environment and cause/exacerbate heat stress.

Table 1. City-scale studies about urbanisation and climate change on urban thermal environment change.

City Name	Country	Study Period	Major Data	Data Processing Tools	Study Result
		1991,			
Accra	Ghana	2002,2017(Landsat)	Landsat, In-situ	QGIS	**SUHI increasing**
		1980–2017(in-situ)			
Akure	Nigeria	2000–2018	Google Earth, Landsat	ArcGIS 10.5	**SUHI increasing**
Bobo-Dioulasso	Burkina Faso	1991–2013	Google Earth, Landsat	Ilwis 3.8	**LST increasing**
			Google Earth,		**Surface**
Bo Town	Sierra Leone	1998–2015	Landsat,	GIS (No specified)	**temperature**
			Meteorological data		**increasing**

Source: Field Survey, 2023

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Sierra Leone, Bo Town, Sierra Leone, all detected increases during their study periods. For surface temperature based on local meteorological data, Bo Town, Sierra Leone were all found to have increased during their study period. Studies at regional scales tend to use data from climate models and remote sensing estimation and projection. Research at the city scale generally is based on re-mote sensing data, especially the Landsat and MODIS products for analysing LST and LULC. When considering urbanisation processes and the impacts of climate change on the urban thermal environment, changes through time were found in most study cities. Such changes commonly included an increase in UHI magnitude and intensity, and absolute changes in temperatures. Unlike air UHI which is more often studied globally. SUHI research dominates most studies in Africa. This is partly be-cause of the historical data scarcity that therefore hampers air UHI research. One drawback of this is that the resolution of climate models and remote sensing outputs tends not to be fine enough to identify some of the differences in urban land cover. Along with low-cost measurement equipment for local data collection, it is more achievable to synthesise remote sensing data and fieldwork data to describe the thermal complexity of urban environments. The impacts of climate change and urbanisation processes on the urban thermal environment have been described at the continental scale, and some cities have seen detailed analyses from different aspects. However, there have been few com-prehensive analyses across multiple cities with different altitudes, locations and different climate zones.

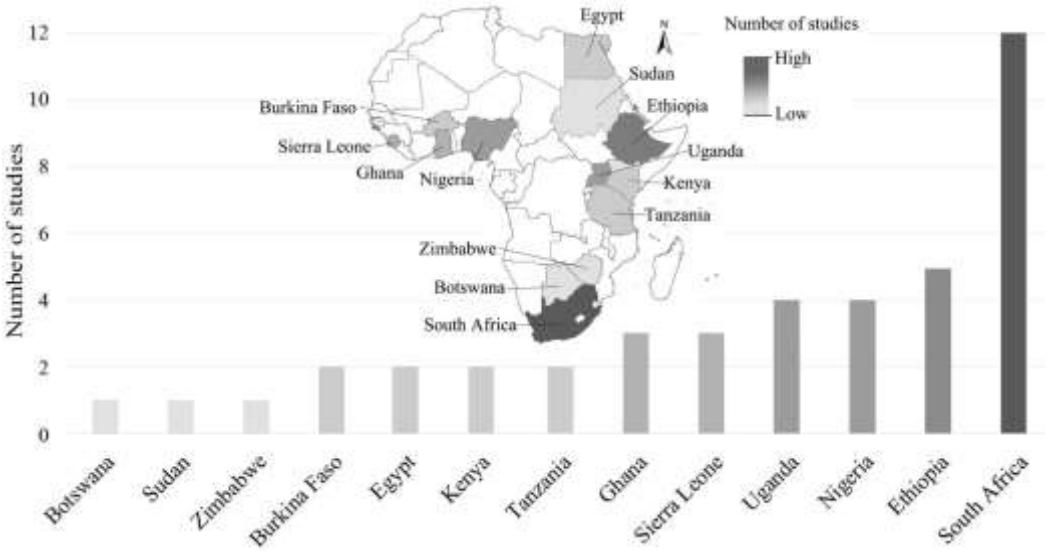

Figure 4. Distribution map of cities identified in the literature review.

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Drivers of Changes to the Urban Thermal Environment

Urban thermal environment dynamics were associated with land use and land cover(LULC) changes as well as seasonal variations. Climate change was noted to play a role in exacerbating or bringing about heat stress and other disasters, particularly increasing disaster vulnerability of low-income urban dwellers.

Land Use and Land Cover (LULC) 75.5% of green spaces lost between 1984 and 2016. This contributed to a 1.0 C and 2.0 C temperature increase, largely attributed to LULC changes and climate change. findings reveal that impervious surfaces and vegetation have experienced changes between 2003 and 2013. Although urban expansion is consideredas a starting point for growth and prosperity, these changes have caused ecological and hydrological disturbances, further increasing water insecurity in urban areas. In Akure, Nigeria, the built-up area increased from 4094 to 12,779 hectares between 2000 and 2018, at the expense of vegetated land. The observed difference in maximum and minimum temperatures between 2000 and 2018 was found to be 27.9 C. The author explained this potential because of the paucity of satellite image samples due to cloud contamination . The urban temperature in Kano Metropolis, Nigeria increased from 26.0 C in the 1980s to 27.7 °C in 2018. This nearly 2.0 °C temperature increase followed the expansion of the city from 39 km^2 in 1986 to 256 km^2 in 2018 with growing aggregation of daytime high temperatures from 1985–2010. The rise in minimum night-time temperature (1.5 C) in the city centre has also been observed between 1960 and 2001. Related to urban climate change prediction of UHI formation under A2 (a scenario under increasing global population, accompanied by a disjointed and slow economic growth) and B2 (a scenario under a continuous basis population growth, accompanied by an intermediate level of economic growth) emission scenarios, the night- time SUHI will be more intense in the winter/dry season period within the city.

Conclusion

Climate change and rapid urbanisation are combining to quickly change urban thermal environments in Africa, with implications for the long-term sustainability of cities, and the health of their residents. Despite this, there

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are still substantial evidence and research gaps. Here we highlight four key issues.

There is a significant research gap in understanding spatial and temporal variationsin SUHI across different climate zones. This requires more in-depth and interdisciplinarystudies towards urban thermal environment regulation and land resource utilization in diverse urban settings under different climatic conditions.

Our review has identified a strong geographic bias, with most studies conducted in South Africa. Due to the emergence of dangerous heat conditions combined with rapid urban population growth, cities in West Africa and West Africa therefore require more attention. As these regions are also most threatened and vulnerable to climate change, fast urban development can drastically intensify the eventual impacts.

Research that quantifies the relationships among built-up area density, configuration, and vegetation on the urban thermal environment in African cities is still limited. This is important because patterns of urban land cover and land use changes are critical factors that influence mitigation or intensification of the UHI.

Although the advantages of blue–green infrastructure include improving urban cli- mate resilience, we found few studies that investigated the practical role of blue–green infrastructure in regulating the urban thermal environment, and mitigating UHI. This means that we still do not know details of the thermal performance of blue–green infras-tructure in Africa. From climate-induced flooding, droughts, heat waves to sea level rise, coastal erosion and storm surges. Even though previous work in West Africa has attempted to reorient unsustainable urbanisation patterns, our findings highlight that research effortsneed to focus more strongly on the urban thermal environment, particularly because the current pace of urbanisation offers a very time-limited opportunity if development is to happen sustainably within the context of global climate change. Further improved understanding of the urban thermal environment is urgently needed for urban resilienceand sustainability.

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