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Investigating the major causes of morphological transformations in the CBD of Accra and the impact on urban heat island intensity.

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INVESTIGATING THE MAJOR CAUSES OF MORPHOLOGICAL TRANSFORMATIONS IN THE CBD OF ACCRA AND THE IMPACT ON URBAN HEAT ISLAND INTENSITY

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Tropical urban sites are constantly under the threats of the adverse effects of urban heat island (UHI) - a situation which is aggravated by climate change. Urban morphology comprises a large set of factors that play an important role in modifying urban climate and, consequently, the potential energy demand and supply in cities. Ghana has since independence, experienced a rapid population growth, which has resulted in the urbanisation of many of its towns. The influx of people into the urban areas means there is a high demand for more housing, commercial and other infrastructural developments. For Accra however, this drive has resulted in drastic reduction in urban greenery. The aim of this study is to investigate the main causes of morphological transformations that have occurred in Accra over the past few decades, with the view to identifying possible measures for UHI mitigation. This study employs a mixed-methods research approach. First, to gain an in-depth understanding of the underlying causes of the morphological transformation the city has undergone, qualitative data are gathered through desktop studies and face-to-face semi-structured interviews with some experienced Ghanaian built environment professionals. The quantitative study involves the collection of weather data from selected monitoring points in the city. Upon analysing the qualitative data, other major causes of the morphological transformations that have emerged include poor enforcement of development control, non-adherence to building regulations; inadequacies in the existing building regulations; architects and building designers lacking the motivation for sustainable design etc. It is evident that areas with large expanse of hardscapes and significantly reduced greenery are experiencing high UHI intensities. Recommendations include measures which address the identified challenges as well as urban regeneration.

Keywords: urban heat island, urban morphology, morphological transformation

INTRODUCTION

In the course of history, cities have been developing, and their physical characteristics have undergone various transformations as a result of varying events (Aliakbari *et al.,* 2011). Sanders (2008) describes urban morphology as a way of investigating and designing urban form which takes into consideration both physical and spatial components of an urban setting, with particular reference to plots, streets, blocks,

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buildings and various open spaces, all of which are essential elements which shape the changing process of city development. Urban morphology establishes a link between urban spaces and physical elements which are shaped by socio-economic factors (Mirmoqtadaei *et al.,* 2006). High rate of urbanisation in the 21st century has had adverse effects on the microclimatic conditions, with resultant increase in urban air temperature (Karteris *et al.,* 2016; Salman and Baofeng, 2018). The influx of people into the urban areas means there is a high demand for more housing, commercial and other infrastructural developments. Unfortunately, this drive always results in drastic reduction in urban greenery. Constant changes to urban morphological characteristics, for example, the introduction of hard materials such as concrete and asphalt, have led to the storage and eventual release of large amount of solar radiation into the urban spaces. As a result, the air within the urban environment has become warmer (Rizwan, Dennis and Chunho, 2008; Gago *et al.,* 2013; Salman and Baofeng, 2018).

The population of Ghana has since independence, grown rapidly - a situation which has culminated in the rapid urbanisation of several towns across the country (GSS, 2014). This development was fuelled by policies put in place by the colonial masters, which have been sustained through the post-independence era, as well as consequences of rural-urban migration and natural population increase. The city has been experiencing increasing temperature which causes thermal discomfort for users of both indoor and outdoor environments. In effect, heat build-up in the city results in significant energy demand due to high dependence on artificial ventilation. Climate is attributed to its fast-growing population that has increased the demand for housing and other infrastructural developments.

Study Area

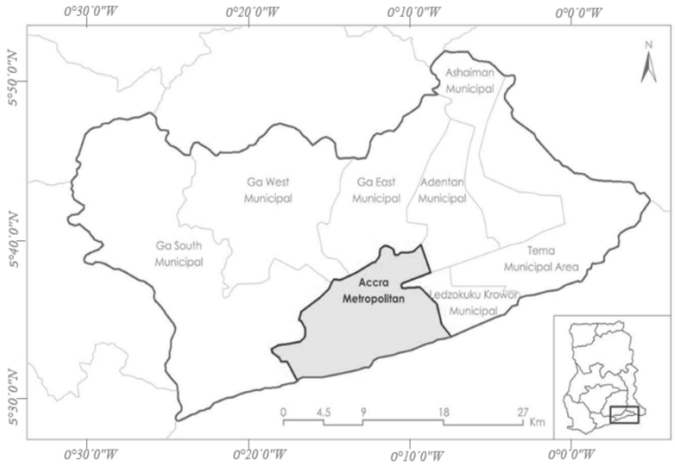

Figure 1: Map of Greater Accra Metropolitan Area showing the study area; Modified after Owusu (2013)

With findings from the study, proper mitigation measures and strategies could be developed that will ultimately culminate in effective long-term planning. This is against the backdrop that, "to help the urban dwellers cope with heat, it is extremely important to understand how cities have developed, and how they are to be redesigned for people to easily adapt to increased heat" (Hajat, O'Connor and Kosatsky, 2010).

The study aims at understanding the effect of the city's morphological transformations on its climate. The study employs a mixed-methods research approach by making use of both qualitative and quantitative data. First, it investigates the underlying causes of the city's morphological transformation using qualitative data. The impact of the

morphological transformations on the city's climate is explored by quantitatively assessing the city's historical temperature data as well as the urban heat island intensity dynamics that exist at present. To adequately access the impact of the city's morphological changes on urban heat island, both quantitative and qualitative data are triangulated to ascertain the correlation between them.

Ghana has a total population of over 25 million (Ghana Statistical Service, 2014) and is found on the west coast of Africa. On the east, it shares a boundary with The Republic of Togo, and on the west and north, with La Cote D'Ivoire and Burkina Faso respectively. Ghana has 16 regions and 212 districts (GOG, 2019). The country basically experiences wet and dry seasons. In general, the country records average annual temperatures above 24 °C (GEPA, 2001). Figure 1 shows the location of the study area.

An obvious impact following the introduction of the liberalization program in the country during the 1990s was the boom in the establishment of multinational businesses in Accra. Currently, the city hosts the head offices of almost 700 companies (Grant, 2001). Accra has been experiencing substantial urban growth and globalization, and the associated increase in economic opportunities in the city has led to the potential for land cover and land use change (Lambin *et al.,* 2001; Auch, Taylor and Acevedo 2004).

Demography and Land Use

The Accra Metropolis has a population of about 1.7 million (Owusu 2013). The population is projected to be 10.5 million by 2040 (Ghana Statistical Service, 2012). The central and eastern parts of the CBD are characterized by formal buildings, dotted with civic and mixed-use (mainly civic-commercial) developments. In the west are extremely busy commercial areas with a major market, street shops and street vending points, though the latter has been officially outlawed. There are few residential buildings in the CBD, most of which are official. In the country, 80% of employment is informal (Baah-Boateng and Ewusi, 2013).

RESEARCH METHOD

Various researchers (Wei *et al.,* 2016 and Jin, Cui, Wong and Ignatius, 2018) have investigated the impact of urban morphology on climate urban areas of Shanghai and Jurong East (Singapore) by grouping selected sites in the respective study areas into distinct configurations, using morphological parameters such as sky view factor, building plot ratio and vegetation cover. Aiming at establishing the correlation between morphology and microclimate, such studies have often been carried out through field measurements. This study partly draws from the field measurement approach; however, to gain a deeper understanding of the phenomenon historically, it also investigates events that have culminated in the morphological changes that have occurred in Accra through desktop studies. This is an aspect which has hardly been considered by previous researchers. To fill this gap, this study employs both qualitative and quantitative research methods in a sequential manner.

The first stage involves the qualitative study, which involves a desktop investigation into the major factors that have contributed to the morphological transformation Accra has undergone since the post-colonial period. It includes descriptive analyses of historic land use changes in Accra. It also involves face-to-face semi-structured interviews with some Ghanaian built environment professionals, through which an in-depth understanding of the main causal factors of the recent changes to the city's land

use pattern and physical characteristics. The second phase of the study involves a weather measurement campaign across selected monitoring points within different local climatic zones in the CBD. Findings from both qualitative and quantitative data are then triangulated and discussed. For this study, the classification of the local climate zones (LCZs) has been done based on Stewart and Oke's (2012) method, which makes use of multiple observation data. It relies on current Landsat images and aerial photographic images. Table 1 shows a summary of the locations and the respective built types of the identified LCZs in the study area.

Table 1: LCZs identified in the study area - based on Stewart and Oke (2012)

LCZ	Locations	Built Types
LCZ1	Cedi House, National Theatre, Airport City	Compact high-rise
LCZ2	Shangri-La Hotel	Compact mid-rise
LCZ3	Awoshie, Baah-Yard, Kwashieman	Compact low-rise
LCZ4	Supreme Court-Public library, Attah Mills High Street, City Hotel, Novotel-Movenpick, Ministries-Ind. Square, Advantage Place, Jubilee House	Open high-rise
LCZ5	37 Military Hospital, PWD-Barnes Rd., Adabraka Polyclinic, Accra Ridge Hospital, Electoral Commission	Open mid-rise
LCZ6	Arko Agyei Interchange Anyaa	Open low-rise
LCZ9	Lands Commission, Anyaa NIC	Sparse low-rise

Consequently, a comparative analysis of the averaged weather measurements obtained at the study area and the historic weather data is done. There is a further analysis to ascertain possible correlations between the dynamics in both the historic weather and the historic land use/land cover characteristics and climate.

RESULTS

Secondary Data

Historical developments in the urbanisation of Accra

According to Songsore (2003), following the fall of the Western Sudan trade routes, a string of coastal towns including Accra, developed to handle the new trading activities that took place between West Africa and the Europeans across the Atlantic Ocean. Accra, being one of the major coastal towns at the heart of the booming trading activities, experienced a new urban system. The colonial administrators and the Europeans inhabited the well-planned low-density areas which were properly planned with provision for good sanitation, recreation and various spatial needs. Strict adherence to regulatory building standards were ensured and therefore, only buildings built of stone, concrete, brick and metal roofing were permitted (GSS, 2014). Due to the prevailing hot weather in Accra and Ghana in general, these well-planned low-density areas were made to have substantial greenery to make them cool and serene. Unfortunately, not much effort was made to accommodate the indigenous population in similar settlements. The indigenous population lived in unplanned areas with poor sanitation - areas described by Grant and Yankson (2002) as “mass thatched buildings arranged in a haphazard manner and separated by crooked streets. Over the years, the indigenous migrants from the rural areas also settled in the fringes or the peri-urban areas such as Nima and Accra New Town. Due to racial segregation policies by the colonial rulers, these areas fell outside the officially planned jurisdiction of Accra and as a result were unregulated. With time, these areas developed as squatter settlements which have been difficult to regulate.

Urban planning in Ghana and the major bottlenecks

A plethora of planning and urban management laws have been in place in the post-independence era. The absence of clearly defined policy direction on urban development has been the bane of the myriad of challenges that have confronted urban governance in post-colonial Ghana. The situation has further been worsened by poor institutional coordination by key government institutions such as the ministries, the metropolitan, municipal and district assemblies, coupled with the lack of enforcement planning regulations and laws. Consequently, Accra, just as several other towns and cities in Ghana, has experienced haphazard and unplanned developments, with certain precincts being fragmented (GSS, 2014).

Natural Increase

Natural population increase has undoubtedly accounted for the fast-urban growth Accra has experienced. The interplay between births and deaths determines the rate at which the population of any geographical area grows naturally such that, where births far exceed deaths, the population grows rapidly and in no time, may exceed the threshold population for an urban area (GSS, 2014). As it has been difficult to provide official residential accommodation and commercial spaces for the large number of poor in-migrants, several illegal structures such as squatter settlements, have emerged as interstices within certain parts of the city, thereby reducing green and open spaces.

Changes in land use pattern of Accra

A study by Addae and Natascha (2019) on land use pattern in the Accra area has revealed that built up areas have been expanding at an alarming rate, taking over most of the city's open and green spaces. Through the study, it was discovered that the vegetative cover (grassland and forest) depleted substantially between 1991 and 2015. As shown in figure 2, grassland which used to be the most dominant land cover type changed from 50.5% in 1991 through 54.8% in 2000 and reduced to 46% in 2015. The same period saw the forest cover changing from 34.2% through 21.5% before reducing to drastically to 6%. It is evident from the figure that built-up areas virtually doubled from 11.8% to 20.6% between 1991 and 2000 and again from 20.6% to 44.4% between 2000 and 2015. The study further revealed that 733 ha (i.e. 0.5% of the land cover) of the bare land transformed into built-up spaces. Water bodies did not experience any significant change within the period.

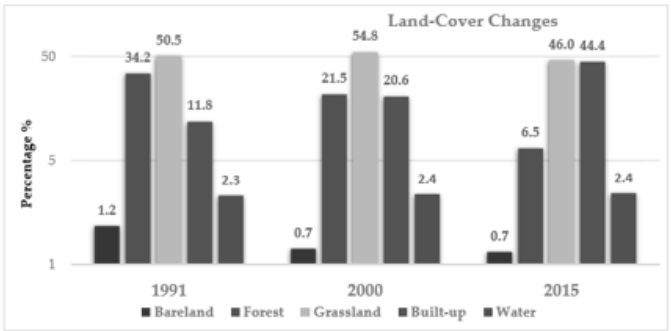

Figure 2: Land-use type percentage coverage from 1991 to 2015 Source: Addae and Natascha (2019)

Primary Data - Qualitative Findings

The qualitative data was gathered by purposively sampling local built environment professionals who are very knowledgeable in matters relating to the urbanization of

Accra as well as the research topic. All the interviewees are Ghanaians who have lived and worked in Accra for 15 to 25 years and are therefore very familiar with the city's physical characteristics and historic land use issues. The qualitative study focused on the major causes of urban transformation in Accra in the past 3 to 4 decades. The description of each of the interviewees is presented in table 2.

Table 2: Detailed description of interviewees (Author generated)

Interviewee	Assigned code name	Years of experience	Profession	Location
01	RP/UP/01	25-30	Physical Planner	Accra
02	RP/AP/02	15-20	Architect Planner	Accra
03	RP/PP/03	15-20	Physical Planner	Accra
04	RP/ARC/04	25-30	Architect	Accra
05	RP/UP/05	15-20	Architect-Planner	Accra

The questions used were designed to allow the researcher to explore the major factors that have contributed to the transformation of the morphology of the city. The method of analysis used was "content analysis". Findings from the qualitative study are presented under 4 main themes.

Factors contributing to rapid urban growth of Accra

This theme explored the main factors that have contributed to the rapid urban growth Accra has experienced over the past three to four decades. Whilst 50% of the participants further pointed to natural population, another 50% opined that booming economic activities of the city following the introduction of the Structural Adjustment Program in the 90's and the discovery of oil. Interviewee RP/PP/03 added that people have just been building and the city keeps sprawling with developments which have no greenery, due to lack of development control.

Planning of Accra and its response to growth over time

This theme was meant to ascertain the effectiveness of the planning of Accra in response to the rate at which it has grown over the years. It became evident that half of the participants believed that to some extent, there were some planning policy provisions, but the pace of urbanisation and the associated developments were not well managed. While acknowledging that there are planning challenges, participant RP/UP/01 further indicated that, the transformation was an expected result of urbanisation, as there was a need for additional spaces to meet growing demands. Research participants RP/UP/01 and RP/ARC/04 opined that projections used in planning the city centre did not adequately cater for the rapidly expanding commercial activities, and in effect, the areas earmarked for residential developments had been engulfed by commercial developments. RP/AP/02 attributed the phenomenon to lack of implementation of concrete measures by the planning authorities to contain the growth of the city, subsequent to the exit of the colonial masters.

Causes of changes to green spaces in Accra

In interrogating the extent of changes to green spaces, all the interviewees were asked to shed more light on the main causes of the said changes. Research participant RP/UP/01 attributed the reduction in green spaces in the city to lack of awareness on the part of the public. He indicated that the level of ignorance among the public is so endemic that most people see trees as nuisances which should not stand in the way of developments. Interviewee RP/AP/02 on the other hand, identified the demand for mid to high-density housing as a major cause of reduction in green spaces in the core of Accra, particularly around Labone and Cantonments. This point was corroborated

by the view held by RP/PP/03. In the view of interviewee RP/ARC/04, migration of rural dwellers to Accra means that more spaces will be required for both economic activities and residential accommodation. He also pointed to the lack of implementation of planning policies as a major contributory factor to the continuous depletion of greenery in the city

Challenges with land use plan

The purpose of the question for this theme was to ascertain the main problems confronting the implementation of the existing land use of the city. Research participant RP/AP/02 indicated that various institutions that must be interested in the city's land use planning matters have over the years been working in isolation. He posited that the physical and spatial planning sector has not been working in collaboration with the road sector, and as a result, there is no harmony in the implementation of the city's land use map. He also averred that the planning authority has been developing good land use plans over the years, but implementation has always been a challenge. Interviewee RP/ARC/04 points to the phenomenon of developments done in inordinate manner as a major challenge to the implementation of land use plan in the city. He attributes the cause of the haphazard developments to lack of provision of housing for the urban poor in the planning of the city. Interviewee RP/ARC/04 further viewed the attitude of the citizenry as a big challenge, because most residents build without recourse to appropriate building materials, the adherence to building regulations, the use of qualified design and other built environment professionals.

FINDINGS

Analysis of Accra's Meteorological Data for 1987-2016

Climate data for Accra over the last 30 years (GMA, 2017) covering the Accra weather show that the period between November and early May is generally warm. Average maximum temperatures are usually above 30°C. Given that urban heat island is directly proportional to temperature, this study has focused on meteorological data from November to May. The data (GMA, 2017) for the period, January 1987 to December 1996 showed that the temperature range for November to May was 27°C to 34.5°C, while monthly maximum temperatures between 30 and 36.1 were recorded for the same months in the last decade (i.e. 2007 to 2017). It is evident that the temperature of Accra has been rising gradually over the years.

Mobile survey

For the mobile survey, important landmarks identified in the different LCZs were chosen as the monitoring points. Figure 3 shows a mapping of the routes used.

The mobile traverse covered several parts of the survey area. It started from a sparsely built area near Anyaa and moved through Awoshie, a compact low-rise area, then through Tetteh-Quarshie Interchange to Accra Airport City Park which is a compact high- rise area and various locations in the CBD. Figure 4 depicts mobile traverse measurements taken between the reference location and the CBD of Accra.

At Anyaa-NIC, which is the reference location (in LCZ9), the average air temperature and the relative humidity International were 29.5 °C and 61% respectively. The temperature increased by 0.5 °C whilst the relative humidity dropped by 3% after a ten-minute drive into Kwashieman (in LCZ3). The relative humidity further dropped by 10.5% upon reaching Shangri-La Hotel, which is within LCZ2 and in proximity to the Kotoka Airport.

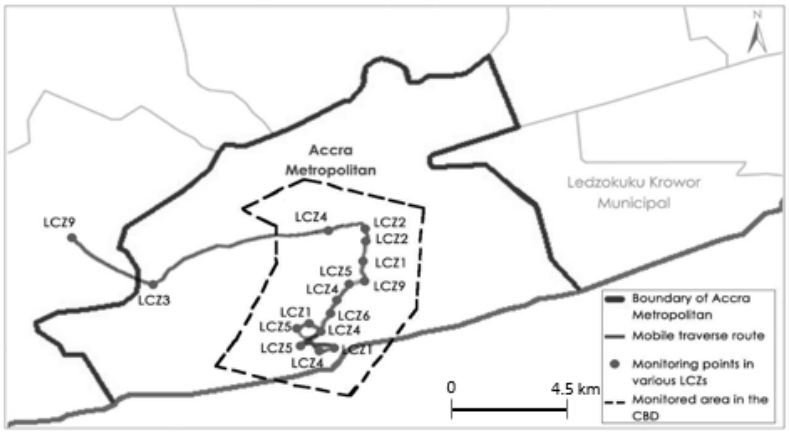

Figure 3: Map depicting traverse routes and monitoring points

At Shangri-La, the air temperature had increased to 33.5 °C, which meant that there was a significant increase of +3.5 °C from Kwashieman. The second phase of the mobile traverse covered monitoring points within the core of the CBD. The areas covered were: Airport City (LCZ1), Lands Commission (LCZ9), 37 Military Hospital (LCZ5), Jubilee House (LCZ4), Arko Agyei Interchange (LCZ6), Novotel Hotel (LCZ4), PWD (LCZ5), Supreme Court (LCZ4), Ministries (LCZ4), National Theatre (LCZ1), Advantage Place (LCZ4), Ridge Hospital (LCZ5) and the Electoral Commission Head Office (LCZ5). Using the average temperature recorded at the reference location (i.e. 29.5 °C), the urban heat island intensity (UHII) levels obtained for the various monitored locations have been plotted against the actual air temperature and relative humidity values, and these are depicted in Figure 4.

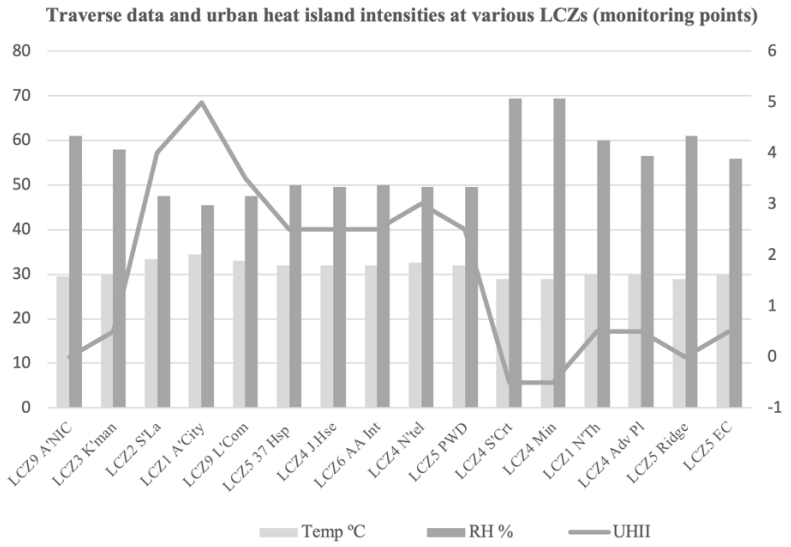

Figure 4: Graph of traverse data between Anyaa and the CBD of Accra. (Author generated)

DISCUSSION

Studies have shown that significant transformations to the physical characteristics of a city could ultimately affect its microclimate significantly. Sadly, researchers have hardly considered the chronology of events that can be attributed to such transformations. For researchers to gain in-depth understanding of the contexts they study and thus bridge research the gap, this study has assessed the phenomenon by considering both historical perspective and data from field measurements.

Although Accra has undergone significant morphological transformation, to date, most of the areas that were well-planned by the early Europeans still have green spaces which promote environmental cooling, while the peripheral areas that were abandoned created many challenges for successive governments. Findings from interviews identified a myriad of reasons accounting for the morphological transformation which include: earlier planning projections inadequately catering for expanded commercial activities; level of ignorance of public on benefits of green spaces; lack of coordination by institutions responsible for planning and developments; lack of provision of accommodation for the urban poor which has resulted in haphazard developments; inability of the planning authorities to effectively implement land use plans over the years. This clearly implies that there is a need for institutional reforms and a sustained public education on planning issues. It is evident from the studies by Addae and Natascha (2019) as well as the analysis of the 30-year climate data (GMA, 2017) that, due to continuous vegetative depletion, the climate of Accra has been changing over the years. The mobile traverse measurements showed how the effect of city's transformed morphology on the local climate. Areas with substantial greenery in most cases, recorded comparatively lower temperatures and higher humidity and the opposite was the case for areas with sparse or no vegetative cover. Consistent with Xiaofang *et al.,* (2012), mobile traverse carried out in the CBD of Accra revealed that the climate of each LCZ is significantly affected by its built-type and vegetative cover.

Due to the limited number of the weather sensors available, it was not possible to undertake stationary measurements in the different LCZs simultaneously to validate the mobile survey data. For future studies, additional sensors could be procured.

CONCLUSION

Using both secondary and primary sources, this study has revealed that factors that have contributed to the urbanization of Accra and the morphological transformations over time include: planning policies implemented during the colonial era, booming economic activities in the city, various challenges with the implementation of land use plan, others. The study has revealed that vegetative cover in Accra has depleted significantly and has mainly been taken over by built-up spaces. The quantitative study has highlighted the effect of urbanization on the local climate of the city. It is evident from the study that daytime temperatures of densely developed areas in the city (especially LCZ1 and LCZ2) are considerably higher in comparison with those of open and sparse low-rise areas (i.e. LCZ6 and LCZ9). The built-up spaces within the CBD which have substantial vegetative cover were found to be cooler than those with either little or no vegetation. There is therefore a clear indication that the transformed morphology of Accra has had a significant impact on the local climate.

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