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Research Article

Climate-Adaptive Zoning and Heat-Relevant Urban Morphology: A Field-Based Assessment of Regulatory Compliance and Built Form in Abuja, Nigeria

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Abstract

This study examines the extent to which current zoning regulations and observed regulatory compliance correlate with heat-relevant urban morphology in specific areas of Abuja, Nigeria. A documented analysis of planning tools, built-form measurement, and organised field observation are all part of a mixed-methods comparative case design. Rather than measuring thermal performance or urban heat island intensity, the approach relies on morphological indicators rather than laboratory equipment or remote sensing. Stratified purposive sampling was used to select three districts, Garki II, Wuse Zone 5, and Maitama, which represent high-density residential, commercial and mixed-use, and low-density residential typologies. Consistent morphological disparities are revealed by data collected at 36 transect stations. Deeper street canyons, increased impervious surface coverage, setback problems, inadequate regulatory compliance, and excessive construction density are all exhibited in Garki II and Wuse Zone 5. The greatest height-to-width ratio in Wuse Zone 5 was 2.57, and the impervious surface coverage was almost 85%. Garki II, on the other hand, had a mean front setback of 4.08 m, compared with the required 6 m. Maitama has the best physical profile and combines a low-density typology with higher compliance. There is no claim of causal attribution to compliance alone because density, land-use classification, and compliance all vary. A three-part typology of misalignment is used in the study to identify flaws in enforcement and regulatory design. The results provide a transportable approach for climate-responsive planning research throughout Africa.

Keywords: Climate-responsive urbanism; urban heat island; heat-relevant morphology; zoning regulations; development control; Abuja.

Highlights

- Field assessment of 36 sites reveals distinct heat-relevant urban morphologies across Abuja.
- Wuse Zone 5 recorded a maximum street canyon ratio of 2.57 and 85% impervious surface cover.
- Regulatory enforcement and climate-responsive zoning reforms are essential for urban heat adaptation.

1. Introduction

Urban form and the thermal environment are inseparable concerns in contemporary city planning, with close to 70 per cent of the world population projected to reside in cities by 2050 (United Nations, 2022). In view of this, rapidly expanding constructed environments are more exposed to the effects of climate change than the regulatory systems controlling them were designed to address. The urban heat island (UHI) effect, characterised by consistently higher temperatures in built-up areas relative to their rural surroundings, is one of the most notable examples of this mismatch. In tropical cities, surface temperature differences often exceed 3–6°C under peak conditions (Chakraborty & Lee, 2022; Manoli et al., 2023).

In Sub-Saharan Africa, rapid and poorly managed urbanisation is creating constructed environments whose shapes are linked to conditions detrimental to public health, energy security, and human comfort, as established in the literature. Nigeria is one of the nations on the continent that is urbanising fastest, with urban growth consistently outpacing planning capacity (Bayode & Siegmund, 2023; OECD et al., 2025). Abuja is a very instructive example. The city was constructed according to a comprehensive master plan, but its development trajectory has deviated significantly from the environmental principles embedded in the plan. The built form is now visible in several important zones, which the literature links to deteriorated thermal conditions. The claim made here is that this result is more than just the result of unbridled growth. Fundamentally, it is a regulatory issue: planning tools that are not updated to account for the thermal realities of the ecosystems they regulate and are applied inconsistently.

Setback requirements, green space provisions, plot coverage ratios, and zoning codes are more than just land management tools. They are the primary tools that influence cities' thermal characteristics at scale. The methodical incorporation of climate projections into these tools has been repeatedly called for by academics and climate scientists (Berardi & Jafarpur, 2020; Filho et al., 2021). In African cities, there is still little integration of climate knowledge into urban regulation tools, despite growing awareness of the need. According to Akinkunmi and Matsubara (2026), Nigeria's zoning rules and master plans, including those for Abuja, were created under planning traditions that paid little regard to microclimatic effects and have undergone little change in light of current climate projections.

This study examines the relationship between zoning laws, observed compliance, and heat-relevant urban morphology in three areas in Abuja that were specifically chosen in order to close that gap. By doing this, it adds to both the broader policy discussion on climate-responsive urbanisation in Sub-Saharan Africa and the empirical literature on urban heat in Nigerian cities. The study characterises the physical drivers of urban thermal behaviour and their regulatory roots, but it does not quantify the thermal output itself. It is crucial to clarify up front what the design can and cannot offer. The study aims to analyse the relationship between current zoning regulations, their observed enforcement, and the heat-relevant urban morphology of selected districts in Abuja, in order to provide evidence-based suggestions for incorporating climate projections into master planning and zoning instruments as a basis for climate-responsive urbanism. From this aim, four objectives follow:

- I. To critically analyse the theoretical underpinnings of climate-responsive urbanism and investigate how master planning and zoning serve as tools for controlling urban thermal conditions.

- II. To characterise the current zoning laws in the three districts of Abuja that were chosen, with a focus on factors that directly affect temperature: land use classification, building coverage, setbacks, height restrictions, and green area ratios.
- III. To assess the built-form and surface features that the literature identifies as determinants of urban thermal behaviour through organised field observation and physical Measurement, and to determine how regulatory configurations, observed compliance, and the resulting morphology correspond.
- IV. To develop targeted, evidence-grounded recommendations for reforming Abuja's planning and zoning framework so that it incorporates climate projections and promotes climate-responsive urbanism in Sub-Saharan African cities.

The purpose of Objective III is to focus on morphology instead of thermal outcome. Temperature cannot be determined using the instrument-free approach employed here, and the goal has been stated appropriately. The contribution of this study rests on four points, each qualified by the note that no exhaustive systematic literature search was conducted to establish primacy. First, to the authors' knowledge, it is among the first systematic, field-based, cross-district comparisons of zoning regulation and built morphology in Abuja that is explicitly framed around thermally relevant built form. The majority of Nigeria's current research is based on citywide remote sensing, which cannot account for district-level variations or be linked to specific regulatory characteristics. Second, the study is immediately repeatable in many African planning contexts that lack specialised equipment, since it employs a deliberately low-cost, instrument-free methodology grounded in verified proxy methods. Third, it advances a three-part misalignment typology, non-compliance, regulatory gap, and regulatory inadequacy, that distinguishes failures of enforcement from failures of regulatory design. Fourth, instead of reiterating general calls for climate-sensitive planning, it compares each conclusion to five recorded African regulatory precedents and translates them into concrete, actionable reform ideas. The antecedents show that the required regulatory tools already exist within similar African governance institutions and can be applied to Abuja; no economic costing of these reforms was conducted, nor is any claimed.

2. Literature Review

This review is organised around five themes: the urban heat island phenomenon in tropical and Sub-Saharan African cities; the physical link between urban morphology and microclimate; climate-responsive urbanism as a governance paradigm; African regulatory precedents for climate-responsive zoning; and the field-based methods used in urban climate research where instrumentation is scarce. The review is intentionally critical. Rather than cataloguing what is known, it identifies where the evidence is strong, where it is methodologically constrained, and where the gap that this study addresses actually lies. Except for foundational methods or texts, the literature reviewed was published between 2017 and 2026. The review was conducted purposely rather than as an exhaustive systematic search, a point returned to in Section 4.6.

2.1. Urban Heat Islands in Tropical and Sub-Saharan African Cities

There is a broad consensus that tropical cities have land surface temperatures 3 to 6 degrees Celsius higher than those of their rural surroundings, and that one of the main causes of this disparity is the loss of vegetation. Santamouris (2020) found that overheating

occurred in more than 400 major cities worldwide, primarily in areas lacking vegetation. In contrast, Manoli et al. (2023) demonstrated how vegetation coverage directly affects land surface temperatures in tropical cities. In particular, Koko et al. (2021) discovered a positive relationship between land surface temperature (LST) and increases in built-up areas. Conversely, vegetation cover showed an inverse relationship with LST, linking the intensification of surface urban heat islands to urban growth and vegetation loss.

The methodological tension within this body of work is important for the present study. The evidence for African and tropical UHI is overwhelmingly derived from satellite remote sensing of land surface temperature. Remote sensing is excellent at mapping where a city is hot, but it has two limitations that matter here. It does not measure conditions at the pedestrian level where comfort is truly felt, nor can it independently attribute that heat to the particular regulatory parameters that created the built form. This is the exact analytical space that a field-based, regulation-linked study can occupy, which is why the current work purposefully deviates from the prevalent remote sensing methodology. Equally significant is the corollary that the current study inherits the mirror-image limitation: it is able to attribute form to regulation but is unable to quantify the heat outcome. Instead of being interchangeable, the two methods work well together.

2.2. Urban Morphology and Regulatory Parameters as Determinants of Thermal Performance

The Sky View Factor affects the exchange of long-wave radiation in the street canyon; a lower SVF, associated with a higher H:W ratio, may reduce the cooling effect of radiative cooling. In addition, street orientation and vegetation influence the thermal effects of the canyon geometry (Chen et al., 2024). While impervious building footprints store and reradiate heat that vegetated surfaces would otherwise dissipate through evapotranspiration, higher building density retains more heat (Berardi & Jafarpur, 2020). 32 studies synthesised by Wong et al. (2021) found that requiring developments to have 20 to 30 per cent green coverage reduced ground temperatures by 2-9°C. Lastly, setbacks control the airflow that ventilates the canyon, as well as the width available for street trees.

This literature clearly implies that the tools required to control urban thermal climate are already present in traditional planning systems. The lack of scientific understanding of how morphology generates heat is the deficit. It is the conversion of that understanding into legally binding regulations. Because it places the issue in governance rather than physics, this reframing is essential to the current investigation.

2.3. Climate-Responsive Urbanism as a Governance Paradigm

A growing body of literature (Berardi & Jafarpur, 2020; Filho et al., 2021) makes the case for using climate projections as legally enforceable planning inputs. This work is, in theory, convincing. However, it is conspicuously lacking in the operational details necessary to make such principles enforceable in particular institutional situations, especially in Sub-Saharan Africa. Thermal performance should be evaluated in conjunction with structural or fire safety compliance, according to valid arguments. They rarely, however, outline the review cycles, enforcement procedures, or numerical thresholds necessary to make the idea feasible in a metropolis like Abuja. In order to address this, the current study compiles specific, quantifiable, and procedurally defined reforms from the documented antecedents that are analysed below. It then uses field data to determine which of these reforms Abuja needs most.

2.4 African Regulatory Precedents for Climate-Responsive Zoning

The belief that climate-responsive development control is a luxury of high-income environments is a common and waning concept in African urban climate policy debates. The data does not support this. Rwanda, South Africa, Morocco, Kenya, and Ethiopia are at least five African countries that have implemented documented, climate-responsive regulations that directly affect Abuja. They are useful to this study in two ways: first, they show administrative viability in African governance frameworks; second, they provide the specific numerical standards by which the inadequacies in the FCDA Development Control Manual (2007) are evaluated in Section 7.

The Kigali Master Plan 2050 Zoning Regulations (City of Kigali, 2020) are the most directly comparable instrument. In the Medium Rise Residential District (R3), building coverage is capped at 50 per cent of the plot area, at least 20 per cent of the plot must be landscaped, and minimum setbacks are specified, all of which are enforced through a digital permitting system (BPMIS). Abuja's FCDA, by contrast, permits up to 60 per cent coverage in Garki II and requires only that a small number of trees be planted, with no digital enforcement equivalent. The most institutionally developed system is found in South Africa, where all new construction must adhere to the SANS 10400-XA standard, which mandates solar water heating, insulation, and efficient HVAC. In response to heat accumulation, the framework also establishes minimum Solar Reflective Index (SRI) criteria for roofs and pavements. The FCDA Manual does not offer a comparable material performance requirement and only evaluates permeability based on dimensions.

Morocco has the best empirical foundation in Africa for the control of urban canyon geometry. Compact canyons can increase street-level air temperature by as much as 6°C, and relying on street orientation alone can produce differences in the Universal Thermal Comfort Index of up to 15°C, according to research carried out in Marrakesh (Ab elhafez et al., 2022). This finding is meaningful in two ways: first, it shows that canyon geometry plays a role, and second, it implies that orientation may be the main driver. Bare ground had the strongest association with higher temperatures ($r = 0.86$), with an average difference of 3.98°C between green and bare areas across the city, as inferred from surface temperature analysis (Gourfi et al., 2022). Morocco's National Urban Policy now requires that planning documents incorporate nature-based solutions and include mandatory green space (OECD, 2025). With its National Building Code 2024, which replaced a framework that had not changed since 1968 and introduced climate-zone-differentiated performance standards (National Construction Authority, 2024; FSD Kenya, 2024), Kenya offers the most transparent institutional reform pathway in Anglophone Africa. This logic is directly applicable to Nigeria's own climatic diversity. With the Addis Ababa Corridor Development Project lowering local temperatures by 2°C to 3°C and the national urban land plan designating 30% of urban land for green and shared public use at the district level, Ethiopia offers the best-documented example of intentional UHI mitigation through green infrastructure (Allafrica, 2025; Negesse et al., 2024).

Table 1 compares these precedents to the FCDA standards for comparable zone types and highlights the precise clauses that are either missing from or insufficiently detailed in the current Abuja instrument. Every gap found here directly relates to a reform created in Section 7 and provides the source of the suggested numerical threshold.

Table 1. African comparative regulatory parameters: reference standards versus the FCDA Development Control Manual.

Jurisdiction / instrument	Key climate-responsive provision	Quantitative benchmark	Equivalent FCDA position (gap)
Rwanda: Kigali Master Plan 2050 (2020)	Coverage cap with mandatory landscaping; digital permitting (BPMIS)	R3: max 50% coverage; min 20% landscaped; 5 m plot separation	60% coverage permitted (Garki II); only a nominal tree count required; no digital enforcement
South Africa: SANS 10400-XA / SANS 204; Green Star SA	Mandatory material performance; cool roof and cool pavement SRI minimums	SRI minimums for roofs and paving; mandatory insulation and solar water heating	No reflectance, albedo, or material performance standard; dimensional assessment only
Morocco: Marrakesh studies; National Urban Policy (2025)	Regulated canyon geometry; orientation guidance; mandatory nature-based solutions	H:W limits; up to 15°C UTCI variation by orientation; mandatory parks and green space	No H:W limit, no orientation guidance, no statutory nature-based solutions
Kenya: National Building Code 2024	Climate-zone-differentiated performance; renewable integration; life-cycle assessment	Performance standards keyed to climate zones; multi-scale green guidelines	2007 manual; no climate zone logic; no performance criteria invoked under the 1992 Act
Ethiopia: Addis Ababa CDP; urban land management plan	District-level green allocation; continuous green corridors; minimum patch size	30% urban land to green use; min patch approx. 4.5 ha; 2 to 3°C cooling	Green provision only at plot scale; no district standard, corridor, or patch minimum

Sources: City of Kigali (2020); SANS 10400-XA / SANS 204; Gourfi et al. (2022); National Construction Authority (2024); FCDA (2007); Federal Republic of Nigeria (1992).

2.5 Field-Based Methods in Urban Climate Research

When evaluating urban areas without access to sophisticated instruments, field-based approaches have a long and proven track record. The method usually entails taking transects through a study area and documenting the physical characteristics that control its thermal behaviour. When direct temperature measurement is not practical, built-environment parameters can be used as stand-ins for thermal performance. This approach is well-established and especially suitable in African settings where instrumentation is scarce (Koko et al., 2021). The current design is based on three methodological lineages: Van de Walle et al.'s methodical pedestrian observation. (2021), where the unit of interest is a continuous streetscape rather than a discrete population; the urban canopy layer field measurement of Aslam and Rana (2022), formalised in the Local Climate Zone system of Aslam & Rana (2022), which derives urban thermal character from easily accessible geometric and surface-cover data; and the document analysis method described by Morgan (2022), which views pre-existing documents as a valid source of qualitative data for systematic analysis.

2.6 Synthesis and Knowledge Gap

Across all five themes, the same gap is present. There are strong examples from Africa demonstrating climate-oriented policy reform, and there is a substantial body of physical science explaining how zoning parameters affect thermal performance. However, as far as the authors are aware, no field-based study has connected zoning parameters to quantifiable morphological patterns at the district level in Abuja or, more generally, throughout Nigerian cities. Existing work in Nigeria either relies on remote sensing, which cannot be meaningfully aligned with the zoning system, or examines conditions at the city scale, thereby obscuring the district-level differences that the present study aims to uncover. This study addresses that gap, while postponing complementary work on thermal quantification to later research.

3. Conceptual Framework

3.1. Climate-Responsive Urbanism

Climate-responsive urbanism reframes the relationship between climate research and urban governance. Rather than focusing on earlier sustainability approaches centred on emissions reduction, it highlights the spatial, morphological, and regulatory aspects of climate adaptation. It maintains that climate projections should be treated as inputs to planning that guide and constrain the legislative arrangements governing land use and the built environment, rather than being addressed only reactively after development has already occurred (Filho et al., 2021). The physical processes by which urban form influences microclimate are well documented. These include the Sky View Factor (SVF), the street height-to-width (H:W) ratio, the thermal mass of construction materials, and evapotranspirative cooling provided by vegetated surfaces. What climate-responsive urbanism contributes is a governance requirement: to translate these physical relationships into legally enforceable provisions, so that thermal performance assessment becomes a mandatory element of planning approval in the same way that structural and fire safety compliance already are (Berardi & Jafarpur, 2020; Manoli et al., 2023).

3.2 Urban Heat Islands and the Role of Zoning

The best researched example of climate-insensitive urban development is the urban heat island effect. Zoning regulations have a significant influence on their drivers, including decreased ventilation, altered radiation budgets, and the substitution of thermally absorbent, impermeable cover for vegetated surfaces (Chakraborty & Lee, 2022). The percentage of a site's sealed surface that absorbs heat is determined using plot coverage ratios. Green area ratios control evapo-transpirative cooling potential. The urban canyon's geometry is determined by building placement and height restrictions, which in turn regulate how solar radiation reaches the ground and how air flows through the street. Floor area ratios control development density and thus the amount of anthropogenic heat released.

Two qualifications frame the use of these parameters in the present study. The first is that the relationship between morphology and thermal outcome is probabilistic rather than deterministic. Canyon geometry is one term in a larger expression that also includes street orientation relative to the solar path and to the prevailing wind, the albedo and thermal mass of facade and paving materials, canopy shading, anthropogenic heat release, and moisture availability. The overall effect is time-dependent and context-dependent because a deep canyon suppresses nocturnal long-wave release while reducing daytime solar access at ground level. Therefore, morphological indicators do not predict temperature; rather, they identify configurations linked to increased heat vulnerability. The fact that these parameters are choices rather than inherent limitations is the second qualification. They are set by legislators and planners, who have the authority to alter them. These choices were made in Abuja, as in many similar African cities, without giving their thermal effects enough thought (Koko et al., Olatunde and Momoh, 2019; 2021). This presents a chance for focused regulatory reform as well as a likely contributing factor to the current urban heat stress.

3.3 Climate Projections and the Planning Horizon

The mismatch between the service life of urban infrastructure, which is typically 50 to 100 years, and the timescales over which climate conditions are changing is a major challenge for climate-responsive planning. Buildings authorised by current zoning regulations will continue to operate under significantly more stringent circumstances in the future. In the

medium-emissions pathway of the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (SSP2-4.5), West African cities are expected to see mean temperature increases of 1.5°C to 2.5°C above current levels by mid-century, together with more frequent and more intense extreme heat events (IPCC, 2021). For Abuja, the regulatory reforms undertaken now will determine the resilience of the city's built environment throughout this period of climatic intensification (Filho et al., 2021).

4. Methodology

4.1 Research Approach

The study uses a qualitative-led, mixed-methods research design, organised as a comparative multi-district case study. Three well-established methods are combined: systematic field observation, physical Measurement of the built form, and document review of planning instruments. No remote sensing software, geographic information system tools, or laboratory instruments were employed. Instead, all data was collected in the field through survey forms, a tape measure, a measuring wheel, a clinometer, photography, and official documents. No thermometer, pyranometer, anemometer, or globe thermometer was used, and no thermal or comfort variables are reported.

This design was chosen for two reasons. First, it's a reflection of an epistemological preference for close engagement with the built environment, and, critically, it preserves the replicability of the work for planners and researchers across Sub-Saharan Africa who lack specialist equipment. Second, each of the three methods is well validated. Field observation follows systematic transect-based approaches, involving structured observations along defined routes (Van-Ewalle et al., 2021). Physical Measurement draws on Local Climate Zone approaches that use readily obtainable characteristics of urban morphology and surface cover to characterise urban environments and their thermal condition (Aslam & Rana, 2022). Documentary review follows established qualitative document analysis procedures to systematically examine existing regulatory and institutional texts (Morgan, 2022). The design trades thermal precision for regulatory attribution and replicability; the findings should therefore be interpreted in light of this methodological trade-off.

4.2 Study Area

Nigeria's Federal Capital Territory, Abuja, was established as the country's capital in 1991 after being purpose-planned in the late 1970s. The International Planning Associates' master plan, which the Federal Capital Development Authority (FCDA) enforces, is the basis for its development. FCDA development control standards, which outline allowed uses, maximum building heights, setbacks, and necessary green spaces, are used to categorise each district according to its assigned land-use function. With a dry season from November to March and a wet season from April to October, Abuja has a tropical savanna climate (Köppen Aw). The dry season and the re-monsoon transition are when thermal stress peaks, with mean temperatures ranging from 25°C to 30°C. The connection between zoning and urban thermal behaviour is particularly important for resident comfort and adaptability due to high building density and progressive vegetation loss (Chakraborty & Lee, 2022; Koko et al., 2021).

4.3 District Selection Strategy

To avoid the typological and locational biases that would result from selecting only districts already known to be thermally stressed, districts were selected using stratified purposive sampling. The strategy focuses on districts that collectively encompass all of Abuja's zoning classifications. Three axes, which include functional land use, geographic distribution across the city's sectors, and morphological character, were used to stratify the selection process, as shown in Figure 1.

THREE-AXIS STRATIFICATION FRAMEWORK

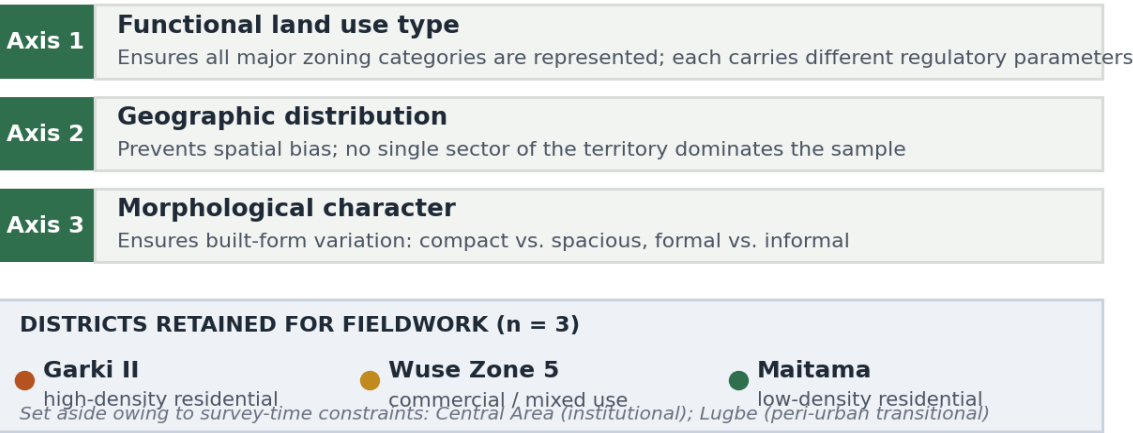


Figure 1. The three-axis stratification framework guiding district selection: functional land use type, geographic distribution, and morphological character.

Five candidate districts were initially profiled against these axes. Owing to constraints on survey time, three were retained for fieldwork, and two were set aside, while preserving the maximum variability and differentiation in zoning characteristics. The retained districts are Garki II (high-density residential), Wuse Zone 5 (commercial and mixed use), and Maitama (low-density residential). Central Area (institutional land use) and Lugbe (peri-urban transitional) were set aside and are recommended for future work. Table 2 presents a comparison of all five candidates, and Figure 2 shows their relative distribution across the territory.

Table 2. Stratification comparison of the five candidate districts across the three selection axes.

District	Axis 1: functional land use	Axis 2: geographic sector	Axis 3: morphological character	A priori morphological expectation	Study status
Garki II	High-density residential	South-central	Compact formal fabric with dense infill; narrow secondary streets	High heat vulnerability	Retained
Central Area	Institutional and civic	Central	Monumental low-coverage blocks with extensive paved forecourts	Moderate to high	Set aside
Wuse Zone 5	Commercial and mixed use	North-central	Near-continuous commercial frontage on narrow carriageways	High heat vulnerability	Retained

Maitama	Low-density and special residential	North-east	Spacious formal plots, wide streets, mature perimeter planting	Low heat vulnerability	Retained
Lugbe	Peri-urban transitional	South-west	Irregular growth, partly outside formal development control	Moderate	Set aside

Note: the *a priori* expectation column records the morphological character anticipated at the design stage from land-use designation alone; it was not used to weight or interpret the field data. Source: Authors, from FCDA district designations.



Figure 2. Schematic locational diagram of the five candidate districts within the Abuja Federal Capital Territory. P1 (Garki II), P2 (Wuse Zone 5) and P3 (Maitama) were retained; Central Area and Lugbe were set aside. Source: Authors' schematic; relative positions are indicative and the diagram is not to scale.

4.3.1 Sampling design and its justification

The field sample consists of 36 observation points, with 12 in each district. These sites are spaced 50 meters apart along a single pedestrian transect in each district. Six plot-level setback and coverage records, as well as four street cross sections per district, are included in the sample. Because of the sample's small size and intended use, its rationale is stated explicitly here rather than implied. A continuous transect of roughly 550-600 m is produced by 12 points spaced 50 m apart. This transect is long enough to cover an entire block sequence within the sub-zone bearing the district's dominant regulatory designation, yet still walkable in an hour-long observation session. Fewer points would not have covered a full block sequence; more would have necessitated either a second session, which would have involved different solar conditions, or a second observer, which would have added another source of estimation variance. To prevent the same frontage from being recorded twice and to ensure that subsequent points fall on different plots, a 50 m interval was chosen to approximate the plot-frontage module observed in Garki II and Wuse Zone 5. When the unit of interest is a continuous streetscape rather than a discrete population, fixed-interval sampling along a route rather than random point selection follows the systematic pedestrian survey convention of Gehl and Svarre (2013)

The transect was designed to go through the sub-zone in each district that most closely matches the dominant regulatory designation listed on the FCDA district sheet. The goal of this planning was to maintain the route's continuous walkability and public accessibility while incorporating both a primary and secondary street in the local hierarchy. Particularly in Maitama, the routes were restricted by gated compounds, ongoing construction sites, and diplomatic frontages with security restrictions. As a result, rather than representing the district as a whole, the transects show each district's accessible public streetscape.

Setback and coverage were recorded at six of the twelve points in each district, namely those where the plot boundary and street line were both physically accessible and a safe standing position existed for the tape and the measuring wheel. Cross-sections for the H:W ratio were taken at four locations per district, namely, where the canyon was continuous on both sides for at least one plot length and where a clear clinometer reading was possible from a measured horizontal offset. Both sub-samples are therefore availability-constrained rather than random, which is a recognised limitation (Section 4.6) and the reason that plot-level results are reported with their ranges rather than with inferential statistics.

To compare the districts under a common synoptic condition, all three transects were walked on 7 June, 2026, under clear skies. The absence of temporal replication is the primary compromise. Because the geometric and surface-cover variables change over months and years rather than hours, this restriction is acceptable. However, it limits the observational variables, particularly the availability of shade, which depends on the time of day and is therefore covered in Section 5. District-specific sessions differed: Wuse Zone 5 was surveyed in the late morning, Maitama in the late morning and early afternoon, and Garki II in the early afternoon. Analytical generalisation in the case-study sense, that is, generalisation to the theoretical claim that regulatory configuration and compliance shape the relevant morphology, is supported by the resulting sample. Statistical generalisation to Abuja as a whole is not supported, and neither explicit nor implicit significance testing is mentioned.

4.4 Data Collection Methods

Three methods, each requiring no specialist instrumentation, were applied in the field. Fieldwork was carried out on 7 June 2026, with twelve observation points surveyed in each district at 50 m intervals, across mid-morning and mid-afternoon sessions. Every district underwent a systematic observational survey using a grid walking schedule. The percentage of street frontage occupied by buildings, the predominant pavement and ground surfaces (paved, unpaved, grass, planted, or bare earth), the presence, density, and canopy cover of trees, the compliance of observed setbacks with mandatory requirements, and the availability of pedestrian shade at the time of observation were among the variables that were recorded. Photographs were used to support observations, which were methodically recorded on specially created survey forms. Physical characteristics were measured using a tape measure, a measuring wheel, and a clinometer to estimate building height from angle measurements. The recorded parameters were building setbacks from the plot and street lines; street width and the resulting height-to-width (H:W) ratio of the streetscape; building coverage on sampled plots; and tree dimensions and canopy spread.

4.4.3 Measurement and estimation procedures

The process for each is described here, along with the approximate uncertainty associated with it, since some reported values are visual estimates rather than instrument readings.

The Building height was determined using a clinometer. Each result was cross-checked against the visible storey count at a nominal 3 m per suspended floor, and the two had to agree within one storey with an estimated uncertainty of ± 1 m. The wheel was used to measure the horizontal distance between the observer and the building's face; the clinometer was used to measure the angle to the roofline; and the height was calculated as the product of that distance and the tangent of the angle, plus an eye height of 1.6 m.

The width of the Street was measured in a single run perpendicular to the carriageway, kerb to kerb using the measuring wheel. The estimated error is ± 0.2 m.

The H:W ratio was derived, not quantified. It is calculated by dividing the kerb-to-kerb street width by the mean of the two facing building heights. The values presented here reflect the built canyon at the kerb line rather than the entire facade-to-facade section, as the denominator excludes the front setback strip. The effective facade-to-facade aspect ratio is lower than the reported figure in areas with generous setbacks, such as Maitama; this convention is applied uniformly across all three districts and is stated because it affects comparisons with studies that use facade-to-facade width.

The Front setback were measured with the tape from the plot street line, or from the kerb face where no boundary marker was present, to the nearest permanent building face. Where a perimeter wall stood forward of the building, it was recorded separately and not treated as the building face—estimated uncertainty: ± 0.2 m. Building coverage was estimated, not measured. The plot frontage was measured with a wheel and used as a scale unit to visually assess the plot depth and building footprint from the street. Values were recorded in 5-percentage-point bands and are reported as the midpoint of each band. Rear extensions not visible from the public realm are a known source of downward bias. Estimated uncertainty ± 10 percentage points.

The Impervious surface cover was estimated visually within an approximate 25 m radius of each observation point, in 5-percentage-point bands, and recorded on the survey form. The district figure is the mean of the twelve-point estimates. A single observer recorded all points, and no inter-rater reliability check was possible, so the figures are indicative. Estimated uncertainty ± 10 percentage points.

The bare earth was estimated as the proportion of the non-carriageway pedestrian zone at each point that was unsealed and unvegetated, using the same banding and the same uncertainty as impervious cover. The frontage build-out was estimated as the proportion of the street-facing plot width occupied by the building, judged against the measured frontage. The Shade level was recorded on a three-point ordinal scale describing the proportion of the pedestrian zone in shadow at the moment of observation: low, below roughly 25 per cent; medium, roughly 25 to 60 per cent; high, above roughly 60 per cent. Because shade is a function of solar altitude, this variable is not directly comparable between districts surveyed in different sessions and is used only within districts. The canopy spread was measured with the tape as the maximum crown diameter where the ground beneath the crown was accessible, and paced where it was not—estimated uncertainty ± 0.5 m for taped trees and ± 1.5 m for paced trees. Table 3 records the status of every reported variable so that measured, derived, and estimated quantities are not conflated in the reading of Section 5.

Table 3. Status, procedure, and uncertainty of the reported field variables.

Variable	Status	Procedure	Approximate uncertainty
Front setback (m)	Measured	Tape from street line to building face	±0.2 m
Street width (m)	Measured	Measuring wheel, kerb to kerb	±0.2 m
Building height (m)	Measured	Clinometer angle and measured offset; cross-checked on storey count	±1 m
Canopy spread (m)	Measured / paced	Tape where accessible, pacing otherwise	±0.5 m to ±1.5 m
H:W ratio	Derived	Mean facing height divided by kerb-to-kerb width	±0.15 (propagated)
Building coverage (%)	Estimated	Visual judgement against measured frontage; 5-point bands	±10 pp
Impervious cover (%)	Estimated	Visual judgement within approx. 25 m radius; 5-point bands	±10 pp
Bare earth (%)	Estimated	Visual judgement of pedestrian zone; 5-point bands	±10 pp
Frontage build-out (%)	Estimated	Visual judgement against measured frontage	±10 pp
Shade level	Ordinal observation	Three-point scale, time-of-observation specific	Not comparable between sessions
Tree presence	Observed	Binary record at each point	Nil

Source: Authors' field protocol, 7 June 2026.

The Nigerian Urban and Regional Planning Act 1992, sections 27 to 34 and 47 to 63, which provide the legal foundation for enforcing development control, the Abuja master plan and its subsequent FCDA modifications, FCDA district land use zoning maps and their color legend, and the FCDA district development control sheets that specify permitted land use, maximum plot coverage, setbacks, maximum height, and required landscaping were all examined in the third method. Table 4 displays the combined regulatory parameters for each of the three districts.

Table 4. FCDA zoning regulatory parameters for the three study districts.

Parameter	Garki II (high-density residential)	Wuse Zone 5 (commercial / district centre)	Maitama (low-density / special residential)
Land use designation	High-density residential (plot < 750 m ²)	Commercial district centre (mixed-use corridor)	Low-density residential / SRP (plot 1500 to 5000 m ²)
Master plan colour code	Dark brown	Blue	Medium / light brown
Max plot coverage	60%	50% (max)	40%
Min front setback	6 m (mandatory)	6 m	9 to 12 m (min 6 m)
Min side / rear setback	3 m (side and rear)	4 m (side and rear)	3.5 to 8 m side; 3 to 6 m rear
Max building height	4 suspended floors	3 to 5 floors	2 floors (low density); 4 to 6 floors (SRP)
Mandatory soft landscaping	20% soft landscaping; 4 trees min.	Hard and soft landscaping of entire unbuilt space	20 to 30% soft landscaping; 10 trees min. (SRP)
Floor area ratio	Not specified	Not specified	Not specified
Thermal performance standard	None	None	None
Statutory authority	Planning Act 1992 (s.27 to 34); FCDA Manual 2007	Planning Act 1992 (s.27 to 34); FCDA Manual 2007	Planning Act 1992 (s.27 to 34); FCDA Manual 2007

Source: FCDA Development Control Manual (2007); Abuja master plan zoning maps; Federal Republic of Nigeria (1992).

4.5 Analysis Framework

Comparison is the first step in analysis. Each district's field-based morphological profile is compared to its regulatory prescription to determine whether the built environment's actual characteristics and the regulations' requirements are aligned or not. The patterns that link regulatory configurations to physical conditions of thermal relevance are then

revealed through cross-district comparison. Qualitative observations of surface material, shade, and vegetation condition give the measured data more depth for interpretation.

The entire paper employs a single analytical typology. Every misalignment case falls into one of three categories:

- I. Category A, non-compliance: a measured parameter that is in conflict with an established regulatory standard.
- II. Category B, regulatory gap: no regulation at all deals with a parameter that is thermally relevant.
- III. Category C, regulatory inadequacy: a rule is in place and is followed, but it is still insufficient given the state of the climate today and in the future.

These three categories reduce to two higher-order failure modes, and the relationship between the two levels is fixed and applied consistently in Sections 5 to 8. Category A constitutes failure of enforcement, in which the rule is adequate but is not applied. Categories B and C together constitute a failure of regulatory design, in which the rule is either absent or present but insufficient. The three-part typology is the working instrument of the analysis; the two-part distinction is the policy conclusion that follows from it, because the two modes call for different remedies, stronger enforcement in the first case and new performance standards in the second. Earlier references in this paper to two failure modes should be read in this sense and not as a competing scheme.

4.6 Scope and Limitations

The limitations of this design are substantial and are stated in full because they bound the claims that Sections 5 to 8 are entitled to make. The study records no air temperature, surface temperature, humidity, wind speed, radiant temperature, or thermal comfort index. It therefore cannot compute UHI intensity in degrees, rank the districts by measured thermal performance, or verify that the morphological differences it records translate into the temperature differences predicted by the literature. All statements about heat in this paper concern built form that the literature associates with heat vulnerability.

All fieldwork was conducted on 7 June 2026. There is no seasonal coverage, no dry-season comparison, and no repeat visit to test the stability of the observational estimates. June falls within the wet season, when vegetation is at or near its annual maximum, which may render the vegetated-surface estimates more favourable than those from a dry-season survey. The three transects were walked in different sessions. Shade availability, which depends on solar altitude and azimuth, is consequently not comparable between districts, and the observational record of surface appearance may also be affected. Only the geometric and material variables are treated as cross-comparable. A small sample consists of twelve cross-sections, eighteen measured plots, and thirty-six observation points. The plot and section sub-samples may be biased toward publicly visible, street-fronting development because they were chosen based on accessibility considerations rather than at random. As a result, no inferential statistics are provided. In order to cover a range of morphologies, three districts were specifically chosen. Two of the five profiled candidates were excluded due to survey time constraints rather than analytical considerations, and they are neither a representative nor a random sample of Abuja's districts. The three districts differ simultaneously in land-use designation, permitted density, plot size, building typology, tenure, institutional presence, and observed compliance. The design cannot separate the contribution of compliance from the contribution of typology, and no such separation is claimed.

A single observer's visual assessments of impervious cover, bare ground, building coverage, and frontage build-out are recorded in 5-percentage-point bands; there is no inter-rater reliability check and an estimated uncertainty of roughly ± 10 percentage points. District-to-district variations in these variables that are less than roughly 10 percentage points should not be regarded as significant. There were no records of street orientation, paving and facade albedo, material thermal mass, ventilation, or anthropogenic heat release. The main reason the H:W results are viewed as indicators rather than predictions is that each alters the relationship between canyon geometry and thermal outcome. Because the review in Section 3 was done on purpose rather than using a documented systematic search protocol, the novelty claim in Section 1.2 is qualified rather than absolute. The reforms proposed in Section 7 have not been costed. No capital cost, compliance cost, administrative cost, or cost-benefit assessment was undertaken, and the feasibility claims made for them rest on their adoption elsewhere in Africa rather than on any economic analysis conducted here. The study's contribution is found in the regulatory and morphological domains. It reveals the connections between zoning regulations, enforcement, and the physical factors that determine thermal conditions, and it then suggests changes to development control. In order to test the method's general applicability, future research can add a quantitative thermal layer by taking temperature readings at the same locations and expanding it to other Nigerian and African cities.

5. Findings

5.1 Overview

The results below are based on field survey data gathered on 7 June, 2026, in all three districts. For every district, the same order is used to convey the regulatory benchmark, a summary of the structured observations, the physical measurement findings with their ranges, and a regulatory and morphological assessment using the three-category misalignment typology described in Sections 4.5. After that, a cross-district comparison is used to merge the patterns. Measured numbers and visual estimations are distinguished in the text that follows Table 3.

5.2 Garki II: High-Density Residential

According to the FCDA Development Control Manual (2007), Garki II is a high-density residential area. A maximum of four suspended levels, a minimum front setback of six meters, side and rear setbacks of three meters, and a maximum site coverage of sixty per cent are among the pertinent requirements. The district boundary is depicted in Figure 3, and the twelve observation sites (GA2-01 to GA2-12) are plotted along the surveyed transect in Figure 4.



Figure 3. Garki II district boundary map (Google Maps satellite imagery, annotated by the authors). Red boundary = full district extent; yellow = primary sub-zones surveyed. Source: Authors, June 2026.

Twelve points were observed during the afternoon session (12:30 to 13:30, clear skies). The dominant surface was asphalt carriageway along the primary transects, with an estimated 40 per cent bare earth (± 10 pp) and only limited planted and grassed cover. Shade was recorded as low at seven of the twelve points and high at three, where scattered mature canopy trees were present; as noted in Section 4.4.3, this ordinal record is specific to the early-afternoon session and is not compared with the other districts. Ten of the twelve points had at least one tree. Setback compliance was poor: three points were non-compliant, four partially compliant, and five compliant, and frontages were generally built out to a high degree. Six sampled plots had a mean front setback of 4.08 m, which is less than the required 6 m. Individual values ranged from 1.5 m to the full 6 m standard. Three plots met the standard, one was partially compliant at 4 m, and two were obviously non-compliant at 2 m and 1.5 m. Four street cross-sections had a mean H:W ratio of 1.32, with each section at or above 1.0 and a maximum of 1.67 at section S3 (GA2-04), where a 10 m building height faced a 6 m street width. A cluster of plots was estimated to have about 48% building coverage, with the mean estimated building coverage across six plots being 44% (± 10 pp), within the 60% maximum. The canopy spreads of five trees were measured, with a mean of 6.3 meters and a range of 2.5 to 10 meters.



Figure 4. Garki II field survey transect point map (GA2-01 to GA2-12). Orange pins indicate 50 m interval observation points. Source: Authors, 7 June 2026.

Non-compliance with setbacks, a Category A failure, is Garki II's main misalignment. A mean setback of 4.08 m instead of the necessary 6 m eliminates the area where street trees could be planted, which is how a dimensional rule serves a microclimatic function, and reduces the pedestrian buffer by about a third. The associated surface condition, an estimated 40 per cent bare ground in the pedestrian zone, is the condition the literature associates with daytime sensible heat storage and evening re-radiation (Gourfi et al., 2022; Wong et al., 2021), although no temperature was recorded here and no such effect is measured. The mean H:W of 1.32, which suggests relatively contained canyon geometry and restricted sky exposure, cannot be used to draw inferences regarding pedestrian thermal comfort because the impacts of H:W vary with direction, vegetation, and other microclimatic factors (Chen et al., 2024). The Category A failure to enforce the Manual's requirement of four trees per plot is made worse by the Manual's lack of a canopy coverage standard (Category C).

5.3 Wuse Zone 5: District Centre Commercial Corridor

Wuse Zone 5 is classified in the FCDA Manual as a district centre commercial corridor, with 50% plot coverage, a 6 m front setback, 4 m side and rear setbacks, and a maximum building height ranging from three to five stories. The unbuilt portion of each plot must be landscaped with both hard and soft elements. The district boundary is shown in Figure 5, and the twelve observation points (WZ5-01 to WZ5-12) that span the southern mixed sub-zone and the northern commercial block are presented in Figure 6. Twelve points were observed during the afternoon session (12:30 to 13:30, clear skies). The dominant surface was an asphalt carriageway along the primary transects, with an estimated 40 per cent bare earth (± 10 pp) and only limited planted and grassed cover. Shade was recorded as low at seven of the twelve points and high at three, where scattered mature canopy trees were present; as noted in Section 4.4.3, this ordinal record is specific to the early-afternoon session and is not compared with the other districts. Ten of the twelve points had at least one tree. Setback compliance was poor: three points were non-compliant, four partially compliant, and five compliant, and frontages were generally built out to a high degree.



Figure 5. Wuse Zone 5 district boundary map (Google Maps satellite imagery, annotated by the authors). Red boundary = full district extent; yellow = sub-zones surveyed. Source: Authors, June 2026.



Figure 6. Wuse Zone 5 field survey transect point map (WZ5-01 to WZ5-12). Yellow pins indicate 50 m interval observation points. Source: Authors, 7 June 2026.

Across six sampled plots, the mean front setback was 11.1 m, which nominally exceeds the 6 m requirement; however, the values form a strongly bimodal distribution, so the mean is not a meaningful summary. Setbacks varied from 1.5 m to 27 m, with a median of 10 m. Two large commercial developments were setback 27 m and 15 m, respectively, whereas two plots at 1.5 m and 3 m were clearly non-compliant. The mean H:W ratio across four cross-sections was 1.93, the highest of the three districts, with a section range of 1.71 to 2.57 and a maximum at WZ5-04. All four sections shared the same 7 m kerb-to-kerb width, so the variation arose entirely from building heights ranging from 12 m to 18 m. The mean estimated building coverage was 35.7 per cent (± 10 pp), within the 50 per cent maximum, but the height violations mean that the effective floor area and thermal mass exceed regulatory intent. Five isolated trees were measured, with canopy spreads up to 18 m and a mean of 13.4 m. However, they were too sparsely distributed along the transect to form a continuous shaded corridor at pedestrian level.

The most consequential misalignment in Wuse Zone 5 is the building height violation at WZ5-01 to WZ5-03, a Category A failure that drives H:W ratios beyond what the permitted floor count would allow. The section ratio of 2.57 at WZ5-04 describes a deep canyon in which sky view is heavily restricted, a configuration associated with reduced sky exposure and altered radiative and airflow conditions within the canyon (Chen et al., 2024; Feteha & ElDeeb, 2024); whether those effects occur here, and with what magnitude, was not measured, and the outcome would also depend on the orientation and materials of this particular street, neither of which was recorded. The mandatory landscaping requirement is, in practice, not applied, as evidenced by an estimated 45 per cent bare ground in the pedestrian zone, a further Category A failure compounded by the absence of any shade or canopy standard in the Manual (Category B).

3.2. 5.4 Maitama: Low-Density Residential

Low-density housing plots (1500–2500 m²; maximum coverage 40%; front setback 6 m; side setbacks 3.5 m; maximum two stories) and Special Residential Plots (2500–5000 m²; maximum coverage 40%; front setback 9–12 m; side setbacks 4–8 m; four–six stories) are the two residential types found in Maitama. 30% of the landscaping must be soft. The twelve observation points along the transect from Gana Street to Aguiyi Ironsi Street are plotted in Figure 7.

Twelve points were surveyed across late-morning and early-afternoon sessions. Trees were present at every observation point, and mature canopy cover was the defining physical characteristic of the district. Surface materials were estimated as dominated by paved surfaces (50 per cent), with substantial grassed (20 per cent) and planted (20 per cent) cover and only 10 per cent bare earth confined to median strips, the most vegetated surface mix of the three districts; all four figures carry an uncertainty of about ± 10 percentage points. Shade was recorded as high at two points and medium at the remaining ten. Setback compliance was predominantly strong, with nine of twelve points compliant. The British Embassy, which has the lowest frontage build-out in the study at an estimated 30%, is part of the institutional and diplomatic corridor covered by the transect. This indicates diplomatic security setbacks rather than any climate-related provisions. According to the surveyor, the zone is a highly regulated area with mature perimeter landscaping, no unofficial encroachment, and strict adherence to the master plan..

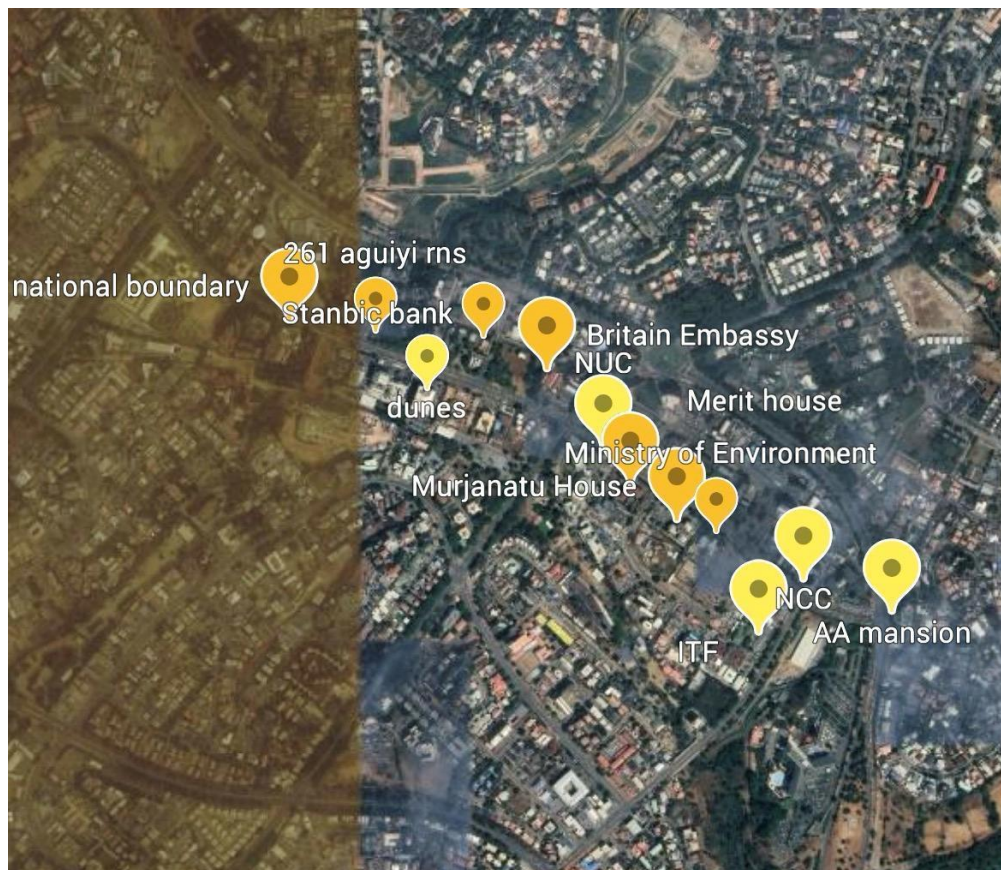


Figure 7. Maitama field survey transect point map. Yellow pins indicate 50 m interval observation points along the institutional and diplomatic corridor. Source: Authors, 7 June 2026.

The mean front setback across six sampled plots was 13.3 m, above the Special Residential Plot minimum of 9 to 12 m, with five of the six sampled plots meeting the criterion. Only the National Universities Commission plot showed deviation, with an estimated 48 per cent coverage against the 40 per cent maximum. The mean H:W ratio across four cross-sections was 0.92, with a section range of 0.75 to 1.14, well below Garki II (1.32) and Wuse Zone 5 (1.93). Uniform street widths of 22 m against building heights of 16.5 m to 25 m produced lower H:W ratios than the narrow 7 m commercial streets of Wuse Zone 5, indicating comparatively greater sky exposure; however, the thermal implications of this geometry depend on orientation, vegetation and other microclimatic conditions (Chen et al., 2024); it is worth noting that one of the four sections nonetheless exceeded 1.0, so the district is not uniformly open. Three large Mahogany and Neem trees were recorded along Aguiyi Ironsi Street, with canopy spreads ranging from 12 to 18 m and a mean of 16.7 m.

Maitama displays the highest regulatory compliance and the most favourable morphological profile of the three districts. The built-form configuration that the literature links to reduced heat vulnerability is created by generous setbacks, low building coverage, a moderate canyon ratio, and a high estimated proportion of vegetated surface: limited heat storage in impervious surfaces, room for evapotranspirative cooling, and an open sky view. There are two requirements that must be met. First, compliance is not the only factor contributing to this morphology. The generous frontages of Maitama, a low-density district of large plots with an institutional and diplomatic character, reflect plot economics, prestige, security requirements, and a permitted coverage ceiling of 40%, as well as developer compliance; these contributions cannot be distinguished by the design. Second, even where the outcome is favourable, it is a by-product of dimensional compliance rather than of any explicit thermal intent, since the FCDA framework states no thermal

performance standard at all. That is a Category C observation, and it is the reason Maitama should be read as a demonstration that the existing dimensional rules are capable of producing favourable morphology, not as evidence that they are designed to. The single compliance deviation, the coverage exceedance at the National Universities Commission plot, is a Category A failure.

5.5 Comparative Summary

Table 5 compares the three districts' measured and estimated morphology to their regulatory parameters, labelling each variable's status and reporting ranges and means. The geometric contrast is shown as comparable street sections in Figure 8, which is based on field measurements and is drawn to a standard scale. The pattern is recurring. The built-form characteristics that the literature links to increased heat vulnerability are present in districts that combine lower compliance with higher permitted density. On the other hand, the district that combines low permitted density with strong compliance shows the opposite. Due to height violations, near-total impervious dominance, and deep-canyon ratios, Wuse Zone 5 has the most constrained geometry. At a lower canyon ratio, Garki II documents a different combination of extensive bare earth, sparse vegetation, and widespread setback shortfalls. Maitama is unique across all measured variables. It is important to emphasise that the three districts differ in land use, density, and compliance, and that these differences are in form rather than measured temperature.

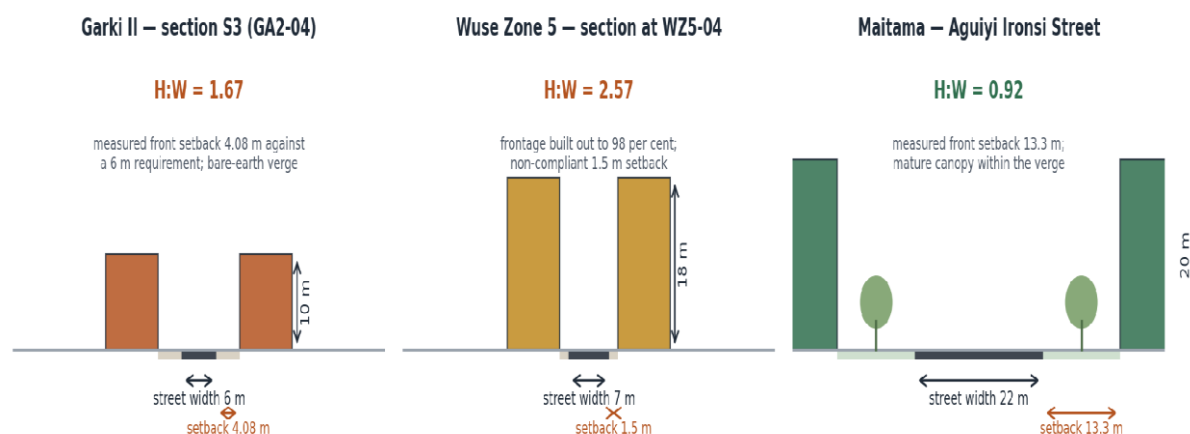


Figure 8. Comparative street cross-sections are drawn to a common scale from the field measurements, showing carriageway width, measured front setback, building height, and the derived H:W ratio for one representative section in each district. Note that the H:W ratio is computed on kerb-to-kerb width, so the wide Maitama setbacks reduce the effective facade-to-facade aspect ratio further than the stated figure suggests. Source: Authors, from field data of 7 June 2026.

Table 5. Cross-district morphological comparison: field measurements and estimates against FCDA regulatory parameters.

Parameter	Status	Garki II (high density)	Wuse Zone 5 (commercial)	Maitama (low density)
Mean front setback (m)	Measured	4.08 (range 1.5 to 6.0)	11.1 (range 1.5 to 27; median 10)	13.3 (five of six $\geq$ 9 m)
Required front setback (m)	Regulatory	6.0	6.0	9 to 12
Setback compliance	Measured	Mixed: 3 of 6 non-compliant or partial	Mixed: 2 of 6 non-compliant	Largely compliant: 5 of 6
Mean H:W ratio	Derived	1.32 (range 1.0 to 1.67)	1.93 (range 1.71 to 2.57)	0.92 (range 0.75 to 1.14)
Canyon geometry class	Derived	All sections at or above 1.0	All sections above 1.7	Three of four sections below 1.0
Mean building coverage (%)	Estimated ± 10 pp	44 (cluster to 48)	35.7	33.3 (one plot at 48)

Max permitted coverage (%)	Regulatory	60	50	40
Mean canopy spread (m)	Measured	6.3 (range 2.5 to 10)	13.4 (up to 18)	16.7 (up to 18)
Tree presence (% of points)	Observed	83	75	100
Dominant surface material	Estimated ± 10 pp	Asphalt with approx. 40% bare earth	Asphalt with approx. 45% bare earth	Paved 50% with 20% grass and 20% planted
Impervious surface (%)	Estimated ± 10 pp	75	85	50
Shade at time of survey	Ordinal, within-district only	Low (early afternoon)	Low to medium (late morning)	Medium (late morning to early afternoon)
Composite morphological profile	Interpretive	Several indicators associated with heat vulnerability	Most indicators associated with heat vulnerability	Few indicators associated with heat vulnerability

Note: the composite profile row is an interpretive summary of the morphological indicators recorded above it. It is not a measure of thermal performance, and the districts have not been ranked by any measured thermal variable. Source: Field surveys, 7 June 2026; FCDA Development Control Manual (2007).

6. Discussion

6.1 Regulatory Configurations and Heat-Relevant Morphology

Table 5 compares the three districts' measured and estimated morphology to their regulatory parameters, labelling each variable's status and reporting ranges and means. The geometric contrast is shown as comparable street sections in Figure 8, which is based on field measurements and is drawn to a standard scale. It is a recurring pattern. The built-form characteristics that the literature links to increased heat vulnerability are present in districts that combine lower compliance with higher permitted density. On the other hand, the district that combines low permitted density with strong compliance shows the opposite. Due to height violations, near-total impervious dominance, and deep-canyon ratios, Wuse Zone 5 has the most constrained geometry. At a lower canyon ratio, Garki II documents a different combination of extensive bare earth, sparse vegetation, and widespread setback shortfalls. Maitama is unique across all measured variables. It is important to emphasise that the three districts differ in land use, density, and compliance, and that these differences are in form rather than measured temperature.

The study's main hypothesis is supported by the cross-district comparison in its morphological form: the built-form parameters that the literature identifies as governing urban thermal behaviour vary systematically with the regulatory regime applied to a district and with the degree to which that regime is enforced, and the mismatch between intended regulation and realised morphology produces specific, recognisable configurations of heat vulnerability. Wuse Zone 5 has a comparatively dense and enclosed urban configuration, as evidenced by the mean canyon ratio of 1.93 and the estimated 85%. Although the resulting thermal effect varies with climatic context and street orientation, increasing H:W generally reduces sky view and can change radiative cooling and airflow within the canyon (Chen et al., 2024). With an H:W of 2.57, the section at WZ5-04 is one of the more limited geometries documented for tropical commercial streets, and the almost complete lack of vegetated ground surface eliminates the evapotranspirative cooling that Wong et al. (2021) linked to a decrease in peak surface temperature of 2°C to 9°C. The geometry and surface cover are established by the current data; the temperature consequence was not observed here and is deduced from the literature.

Garki II attains a comparable morphological profile via a different route. Setbacks averaging 4.08 m, rather than the required 6 m, eliminate the planting strips that would otherwise moderate the street, resulting in an estimated 40 per cent bare ground in the

pedestrian zone, alongside a mean H:W of 1.32. Maitama, finally, shows that the existing dimensional rules are capable of producing a favourable morphology even in the complete absence of any explicit climate-responsive intent: a mean H:W of 0.92, a mean setback of 13.3 m, an estimated building coverage of 33.3 per cent, and a high vegetated surface proportion, with mature Mahogany and Neem canopies along Aguiyi Ironsi Street.

It does not follow that compliance produced these differences. The three districts were selected precisely because they differ in land-use designation and density, and those differences are inseparable from the differences in compliance. Maitama's regulatory ceiling on coverage is 40 per cent, where Garki II's is 60 per cent, so part of the observed coverage gap is written into the rules rather than into their enforcement. Its plots are two to seven times larger, which makes a 13 m setback economically tolerable in a way that it is not on a plot below 750 m². Its institutional and diplomatic occupancy brings security setbacks, resourced grounds maintenance, and a mature planting stock accumulated over decades. Its 22 m street widths are a master plan inheritance, not a development control outcome. Conversely, the commercial economics of Wuse Zone 5 create a direct financial incentive to build out frontages and add floors that residential Maitama does not face. Compliance is therefore one term among several covarying terms, and a three-case design cannot isolate it. The defensible claim is the conditional one: where the dimensional rules are complied with, as in Maitama, the resulting morphology is of the kind the literature associates with lower heat vulnerability; and where they are not, as in Garki II and Wuse Zone 5, it is not. Establishing the independent effect of compliance would require comparison of compliant and non-compliant sites within a single density and land-use typology, which is a direction for further work.

The H:W ratio is treated here as an indicator rather than a determinant. A high ratio reduces sky view and therefore constrains long-wave release at night. However, it also shades the street during the day, and the dominant effect depends on latitude, season, time of day, street orientation relative to the solar path, prevailing wind, facade and paving albedo, thermal mass, canopy cover, and anthropogenic heat release. The Marrakesh evidence makes the point directly: orientation alone was associated with UTCI variations of up to 15°C (Abdelhafez et al., 2022), a range comparable to or greater than that explained by geometry alone. Orientation was not recorded in this survey. The 7 m canyon at WZ5-04 could therefore be materially cooler at pedestrian level during the middle of the day than the open 22 m street in Maitama, while being warmer at night, and nothing in the present data set distinguishes these possibilities. What the H:W results support is the identification of streets whose geometry warrants regulatory attention and subsequent thermal measurement; they do not support a ranking by thermal outcome.

6.2 Compliance, Enforcement, and Regulatory Intent

The recurring problem across the three districts is the disconnection between what the rules require and what is actually built. The FCDA Development Control Manual (2007) contains reasonable dimensional rules for low- and medium-density residential development, and the Maitama case shows that those rules are compatible with a favourable morphology. In that sense, the deficiency exposed in Garki II and Wuse Zone 5 is a deficiency of enforcement rather than of drafting. The height violations in Wuse Zone 5 occur at three of twelve points, but drive the canyon ratio well beyond what the permitted floor count would allow. At the same time, the setbacks in Garki II are individually less dramatic but more widespread, affecting three of six sampled plots directly and a further four of twelve observation points partially. Both illustrate the enforcement limitations discussed in the literature (Adamu et al., 2025), in which post-development inspection does not take place, and developers encroach on setbacks and add floors regardless of the permit issued.

6.3 Regulatory Adequacy under Projected Climate Conditions

Even under full compliance, the FCDA Manual exhibits structural weaknesses relative to the climate conditions projected in Section 2.3. Under the IPCC AR6 SSP2-4.5 scenario, West African cities are projected to experience mean temperature increases of 1.5°C to 2.5°C in the coming decades (IPCC, 2021). Sections 47 to 63 of the Nigerian Urban and Regional Planning Act 1992 already empower the Development Control Department to enforce through stop-work notices, demolitions, and penalties, so the statutory authority exists. What is missing is the substance. The Manual sets no thermal performance standard keyed to projected climate: there is no minimum SVF, no mandatory canopy coverage ratio, no high-albedo or permeable surface requirement, and no periodic review of standards against updated climate data. Moreover, a 20 to 30 per cent soft landscaping provision is unlikely to offset the heat load associated with 50 to 60 per cent coverage ratios in commercial and high-density areas. However, the present data cannot quantify the extent of that offset. Table 6 summarises how the three misalignment categories manifest across the districts, and how they aggregate into the two failure modes defined in Section 4.5.

Table 6. Misalignment typology applied across the three study districts.

Misalignment category	Failure mode	Garki II	Wuse Zone 5	Maitama
Category A: non-compliance	Enforcement	Widespread setback shortfall (mean 4.08 m against 6 m); unenforced tree requirement	Building height violations (WZ5-01 to 03); landscaping requirement not applied	Isolated coverage exceedance (NUC plot, estimated 48% against 40%)
Category B: regulatory gap	Regulatory design	No canopy coverage standard	No H:W limit; no shade or canopy standard	Limited; framework largely adequate dimensionally
Category C: regulatory inadequacy	Regulatory design	No thermal performance standard	Landscaping rule too vague to be enforceable	Favourable morphology arises from dimensional compliance, not from thermal design
Recorded morphological profile	—	Several indicators associated with heat vulnerability (approx. 40% bare ground; mean H:W 1.32)	Most indicators associated with heat vulnerability (mean H:W 1.93, peak 2.57; approx. 85% impervious)	Few such indicators (mean H:W 0.92; vegetated surface mix; continuous canopy)

Note: the final row summarises recorded built form only. No thermal variable was measured, and the districts are not ranked by thermal performance.

6.4 What the Evidence Supports

The evidence supports three claims. First, that regulatory standards in Abuja are unevenly enforced, and that the pattern of non-enforcement is systematic rather than incidental. Second, the built form of the surveyed districts differs sharply in exactly those parameters that the urban climate literature identifies as governing thermal behaviour. Third, the FCDA Development Control Manual contains no provision that directly addresses thermal behaviour, so that, where the outcome is favourable, it is favourable only incidentally. The evidence does not support a claim that any district is measurably hotter than another, that compliance alone accounts for the observed differences, or that the reforms proposed in Section 7 will deliver a quantified degree of cooling in Abuja. Those claims require the thermal measurement campaign identified in Section 8 to be the next priority.

7. Implications and Recommendations

The following reforms, derived from the misalignments identified above, are addressed to the FCDA Department of Development Control, the Abuja Metropolitan Management Council, and the Federal Ministry of Housing and Urban Development. A distinction should be drawn between the two components of each recommendation. The field data identify where a standard is needed, which parameter is failing, and whether the failure is due to enforcement or regulatory design. The numerical thresholds themselves are not derived from the Abuja field data. They are transferred from the African regulatory precedents reviewed in Section 3.4 and from the empirical thresholds reported in the reviewed literature, and each is attributed to its source below and in Table 7. They should be understood as benchmark values for a first regulatory draft, requiring local calibration and pilot testing against Abuja conditions before adoption. No economic costing, compliance-cost estimate, or cost-benefit appraisal of these reforms was undertaken in this study. The current ancillary requirement of four to ten trees per plot is unenforced, leaving an estimated 40 to 45 per cent of the ground bare in Garki II and Wuse Zone 5. A mandatory minimum canopy coverage should be introduced for all high-density residential and commercial development, expressed as canopy coverage rather than tree count and verified at post-occupancy certification. A threshold of 15 per cent of plot area is proposed, set below the 20 per cent landscaped-area requirement of the Kigali R3 district (City of Kigali, 2020) and below the 20 to 30 per cent green coverage range that Wong et al. (2021) associate with ground temperature reductions of 2°C to 9°C, in recognition of the smaller plots and higher permitted coverage in Abuja's high-density zones. The value is a policy transfer, not a field-derived optimum. The 6 m front setback is widely breached, with an average of 4.08 m in Garki II. Rather than increasing the dimension, the standard should be redefined as a climate-functional setback that incorporates not only the access path but also a minimum 2-m-wide permeable planting strip. The 2 m figure is the practical minimum width for a street tree pit and root run in the referenced landscaping provisions of the Kigali instrument, and the reform follows Kigali's logic of pairing a dimensional standard with a mandatory landscaped function rather than leaving the setback as space. There is currently no H:W regulation, and Wuse Zone 5 records a mean H:W of 1.93 with a peak of 2.57.

A maximum H:W ratio of 1.5 is proposed for future commercial development. The value indicates a relatively enclosed canyon geometry within the commercial district. However, its implications for pedestrian thermal comfort cannot be established from H:W alone, given the influence of orientation, vegetation and surface characteristics (Chen et al., 2024), and below the compact canyon conditions that the Marrakesh studies associate with street-level air temperature increases of up to 6°C (Abdelhafez et al., 2022). Where buildings already exceed the threshold, street-level tree planting should be a mandatory condition of any redevelopment. Given the strength of the orientation effect reported in the same Marrakesh work, the H:W limit should be accompanied by orientation guidance rather than applied as a standalone geometric rule. Following SANS 10400-XA and Green Star SA in South Africa, the Manual should mandate a minimum SRI of 29 for flat roofs in commercial and high-density zones, which is the established ASHRAE 90.1 and US EPA Energy Star minimum rather than a value derived here, with an aspirational SRI of 78 or above for commercial buildings over 1000 m². The same logic should apply to paving, requiring light or permeable concrete with an SRI of 29 or above in place of unspecified asphalt.

Santamouris (2020) reports that raising the roof SRI from 10 to 78 can lower surface temperature by up to 28°C, with a district-level ambient benefit of 0.3°C to 0.5°C. Those

figures are drawn from that source and are not projections for Abuja. The reform targets the estimated 85 per cent impervious coverage recorded in Wuse Zone 5. Following Ethiopia's district-level green allocation and Morocco's statutory nature-based solutions requirement, the vague landscaping requirement should be replaced by a two-tier mandatory provision: a minimum permeable surface ratio of 25 per cent of plot area for commercial development and 15 per cent for high-density residential, and a bioswale or equivalent linear bioretention system in the front setback of all commercial plots above 500 m². The 25 per cent figure is set between the Kigali landscaped-area requirement of 20 per cent and the upper bound of the 20-30 per cent range reported by Wong et al. (2021); it is a benchmark transfer rather than a locally optimised value. Permeable materials should be defined explicitly in the Manual and should exclude sealed asphalt and brushed concrete.

Where ground-level land is scarce, as in Wuse Zone 5, green roofs are often the only feasible way to add vegetated cover without reducing developable area. Following Green Star SA, a minimum green roof provision of 30 per cent of roof area is proposed for new commercial and institutional developments above 2000 m², using extensive systems with native vegetation. Where this is not technically feasible, an equivalent area of ground-level permeable planting or bioswale should be permitted by consent. The 30 per cent threshold follows the South African precedent and has not been tested against Abuja construction practices or roof-loading conventions. No mechanism currently updates development control standards in the light of climate data, which is the defining Category C failure of the present framework. A mandatory five-yearly climate review of all zoning schedules and development control standards should be established by the FCDA, in collaboration with the Nigerian Meteorological Agency, to assess whether coverage, setback, height, and green area provisions remain adequate in light of the latest IPCC projections, with any adjustments gazetted within 12 months. The review logic follows Kenya's National Building Code 2024, which replaced a framework that had stood unrevised since 1968; the five-year interval is proposed as a working cycle aligned to the IPCC assessment rhythm rather than as a value established by evidence. Finally, because non-compliance in Garki II and Wuse Zone 5 reflects weak enforcement during and after construction, mandatory post-construction inspection of setbacks, floor counts, and green area provision should be a precondition of occupancy certification, and the records should be digitised and made publicly available, drawing on the BPMIS model used in Kigali. Of all the reforms proposed here, this is the one most directly supported by the field evidence, since it addresses the Category A failures that the survey documents rather than importing a numerical threshold from elsewhere.

Table 7. Recommendations mapped to triggering findings, threshold provenance, and misalignment categories.

Recommendation	Triggering finding (this study)	African precedent	Provenance of the numerical threshold	Misalignment addressed
15% mandatory canopy cover	Estimated 40 to 45% bare ground; tree rule unenforced	Kigali landscaping rule	Set below Kigali's 20% landscaped requirement and Wong et al. (2021) 20 to 30% range; not field-derived	A and C
Climate-functional setback with 2 m planting strip	Mean setback 4.08 m against 6 m (Garki II)	Kigali setback rule	Retains the existing 6 m dimension; the 2 m strip follows Kigali's paired dimensional and landscaping logic	A
H:W ratio limit of 1.5	Mean H:W 1.93, peak 2.57 (Wuse Zone 5)	Marrakesh canyon studies	Indicates relatively enclosed canyon geometry; thermal-comfort implications depend on orientation,	B

						vegetation and surface characteristics (Chen et al., 2024); not field-derived	
SRI roof and pavement standard (29 minimum, aspirational)	Estimated impervious surface (Wuse Zone 5)	85%	SANS 10400-XA; Green Star SA			ASHRAE 90.1 and US EPA Energy Star minimum, cited via SANS; benefit figures from Santamouris (2020)	B and C
25% permeable surface and bioswale	Landscaping rule not applied; estimated 45% bare earth		Ethiopia; Morocco nature-based solutions			Set between Kigali's 20% and the upper bound of Wong et al. (2021); not field-derived	A and C
30% green roof for large developments	Ground-level land scarce; high frontage build-out		Green Star SA			Direct transfer of the South African provision; untested against Abuja roof loading practice	B and C
Five-yearly climate review	No standard update mechanism in the 2007 Manual		Kenya National Building Code 2024			Interval proposed to align with the IPCC assessment cycle; not evidence-derived	C
Post-construction inspection and digital records	Height and setback violations across two districts		Kigali BPMIS			Procedural, not numerical; directly supported by the field evidence	A

Note: no economic costing, compliance-cost estimate, or cost-benefit appraisal of these reforms was undertaken. Feasibility rests on their documented adoption in the cited jurisdictions.

8. Conclusion

This study set out to examine the relationship between FCDA zoning regulations, their enforcement, and the heat-relevant urban morphology of three districts of Abuja. Using a field-based methodology combining transect observation, physical measurement of built form, and analysis of the FCDA Development Control Manual (2007), it offers what is, to the authors' knowledge, among the first systematic district-level comparisons of regulation and morphology in the Federal Capital Territory.

Two findings stand out—the first concerns compliance. Regulatory standards are enforced very unevenly across the three districts: Maitama recorded compliance at five of six sampled plots and nine of twelve observation points, while Garki II recorded a mean front setback of 4.08 m against a 6 m requirement, and Wuse Zone 5 recorded height violations at three consecutive frontage points. The pattern is systematic rather than incidental, and it corresponds to the absence of post-construction inspection identified in the documentary review—the second concerns morphology. The three districts differ sharply in precisely those built-form parameters relevant to thermal behaviour: canyon aspect ratios of 0.92, 1.32, and 1.93; estimated impervious cover of 50, 75, and 85 per cent; and mean canopy spreads of 16.7, 6.3, and 13.4 m. Wuse Zone 5 exhibits the greatest concentration of indicators associated with heat vulnerability, and Maitama the fewest.

These are findings about built form and its regulatory origins, not about temperature. No air or surface temperature and no comfort variable was measured, so no district is described here as measurably hotter than another, and no urban heat island intensity is reported. Nor can the morphological differences be attributed to compliance alone: the three districts differ simultaneously in land-use designation, permitted density, plot size, and institutional character, and a three-case design cannot separate these covarying influences. The defensible conclusion is conditional. Where Abuja's existing dimensional standards are complied with, they can produce built form with characteristics associated with lower heat vulnerability, as Maitama demonstrates; where they are not complied with, these characteristics are less evident.

The regulatory implication follows from the misalignment typology applied throughout. Category A failures, non-compliance, are failures of enforcement, and they are the dominant problem in Garki II and Wuse Zone 5. Categories B and C, regulatory gap and regulatory inadequacy, are failures of regulatory design. They affect all three districts equally, since the Manual contains no canopy standard, no sky view or aspect ratio provision, no material reflectance requirement, and no mechanism for revising standards against climate projections and distinguishing the two modes matters because they call for different remedies: inspection and record-keeping in the first case, new performance standards in the second. Section 7 sets out reforms of both kinds, with the numerical thresholds drawn from documented African precedents rather than from the field data reported here.

The study is limited to three districts, a single survey day, and a small, availability-constrained sample, and several of its surface-cover figures are visual estimates with an uncertainty of about 10 percentage points. The priority for further work is therefore the thermal layer: air and surface temperature measurements at the same 36 points, across seasons and the diurnal cycle, would test whether the morphological contrasts reported here correspond to differences in temperature. Recording street orientation, surface albedo, and ventilation alongside those measurements would allow the canyon geometry results to be interpreted properly rather than indicatively. A design that compares compliant and non-compliant sites within a single density typology would isolate the effect of enforcement that the present comparison cannot. The method itself is the wider contribution: it is readily applied by planners, requires no specialist instrumentation, and remains consistent with accepted approaches to the field characterisation of urban form.

Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflict of interest

Generative AI Statement

The authors produced figures 1, 2, and 8. In an earlier version of this manuscript, the schematic figures were generated using generative artificial intelligence tools; following peer review, the authors have redrawn them from the underlying study data, and the tabular content formerly presented as an image is now provided as Table 2. The satellite imagery in Figures 3-7 was obtained from Google Maps and annotated by the authors. The authors take total ownership of the thoughts, ideas, arguments, analysis, and synthesis presented in this work. All interpretations of the field data, all conclusions, and all recommendations are the authors' own.

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