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Evaluating Climate Responsive Landscape Design Strategies for Enhancing Outdoor Thermal Comfort in Tropical University Environments

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Abstract

Outdoor spaces in tropical university campuses such as the University of Lagos face significant thermal discomfort caused by intense solar radiation, high temperatures, and humidity. Climate responsive landscape design plays an important role in improving campus conditions through vegetation, shading, spatial arrangement, and material selection. However, existing research remains largely concentrated in temperate regions, with limited qualitative studies examining how landscape design influences thermal comfort within Nigerian universities. This study qualitatively evaluated climate responsive landscape strategies for enhancing outdoor thermal comfort at the University of Lagos (UNILAG). A case study approach was adopted using site observations, spatial documentation, and structured questionnaire surveys with 305 campus users. Findings revealed that 61% of respondents rated outdoor thermal conditions as uncomfortable or very uncomfortable, with lack of shade (78%) and high air temperature (74%) identified as primary drivers of discomfort. The study concludes that expanded tree canopy, shaded walkway networks, and high-albedo paving materials represent the highest priority interventions for tropical campus landscapes.

Keywords: Bioclimatic design, Climate responsive, Landscape design, Thermal comfort, Tropical campus, University of Lagos, Urban Heat Island (UHI), Nigeria.

Introduction

The quality of outdoor environments in tropical university campuses is a matter of growing concern for campus planners, landscape architects, and institutional administrators. In tropical climates, the outdoor thermal environment is shaped by year-round high solar radiation, elevated air temperatures, and persistently high humidity, creating conditions that are frequently beyond the threshold of human thermal comfort. Unlike temperate environments where outdoor spaces are often limited by cold conditions, tropical universities face the opposite challenge: outdoor spaces exist and are needed, but their thermal conditions are so uncomfortable as to discourage use and undermine their social and functional value.

Universities are communities in which outdoor spaces play a vital role in shaping the quality of campus life. Outdoor walkways, courtyards, seating areas, lawns, and social gathering spaces are not merely transitional zones between buildings, they are environments in which learning, socializing, rest, and recreation occur. When these spaces become thermally inhospitable, students and staff retreat indoors, placing greater demands on air-conditioned facilities, increasing energy consumption, and diminishing the vibrancy of campus life. The design of the outdoor landscape is therefore not a peripheral concern but a core dimension of campus planning with significant implications for comfort, sustainability, and institutional quality. As Ademakinwa et al. (2024) demonstrated in their study of accommodation quality at Caleb University, environmental conditions directly influence user well-being and performance, a finding that extends logically to outdoor thermal comfort and its effect on campus community engagement.

The University of Lagos, situated on a peninsular landmass along the Lagos Lagoon in Akoka, Yaba, Lagos State, Nigeria, is exposed to a hot and humid tropical climate throughout the year. With one of the largest campus populations in Nigeria and a densely built physical fabric, the outdoor thermal environment at UNILAG presents ongoing and well-documented challenges (Ogunsote & Prucnal Ogunsote, 2002). Despite the presence of significant landscape assets, including mature trees in certain zones, extensive lawns, and a waterfront setting, the distribution, density, and design quality of climate responsive landscape elements vary considerably across the campus, producing highly inconsistent thermal conditions for users.

Aim and Objectives

This study aimed to evaluate climate responsive landscape design strategies for enhancing outdoor thermal comfort at the University of Lagos. The specific objectives were to:

1. Identify existing landscape design elements that influence microclimatic conditions within UNILAG.
2. Assess the effectiveness of vegetation cover, shading devices, spatial layout, and surface materials in moderating thermal conditions.
3. Examine campus users' experiences of outdoor thermal comfort in relation to these landscape features.
4. Develop evidence-based design recommendations to guide climate responsive campus landscape

planning in tropical regions.

The study addresses a recognized gap in the Nigerian higher education literature (Daramola et al., 2025) and contributes practical guidance for landscape architects and campus planners working in similar tropical coastal contexts.

LITERATURE REVIEW

Thermal Comfort in Tropical Outdoor Environments

Thermal comfort in outdoor settings is a complex, multidimensional condition shaped by the interaction of physical, physiological, and psychological variables. ASHRAE Standard 55 (2020) defines thermal comfort as "the condition of mind that expresses satisfaction with the thermal environment, as evaluated through subjective assessment." In outdoor environments, this condition is primarily determined by four meteorological variables: air temperature, mean radiant temperature (MRT), wind speed, and relative humidity. Personal factors including metabolic rate and clothing insulation further modulate the thermal experience of individual users. The Physiological Equivalent Temperature (PET) and the Universal Thermal Climate Index (UTCI) are the most widely adopted bioclimatic indices for quantifying outdoor thermal stress across different climatic zones (Blazejczyk et al., 2012).

In tropical climates, MRT has consistently been identified as the dominant variable governing outdoor thermal stress. MRT integrates both direct and diffuse solar radiation absorbed by the human body, as well as long-wave radiation emitted by surrounding surfaces. Because tropical environments are characterized by high solar angles, intense direct radiation, and heat-absorbing paved surfaces, MRT values frequently exceed air temperature by 15–25°C during peak afternoon hours, producing conditions of extreme thermal stress even in moderate air temperature conditions. This finding has important implications for landscape design: interventions that reduce solar radiation exposure through shading structures or canopy cover will have a greater positive impact on thermal comfort than equivalent reductions in air temperature alone.

Empirical studies across tropical cities consistently document high levels of outdoor thermal discomfort. Research in Singapore (Wong & Yu, 2005) demonstrated that shaded outdoor areas exhibited PET values 6–10°C lower than adjacent exposed spaces, while studies in Kuala Lumpur (Lau et al., 2014) linked vegetated campus environments to significantly improved user comfort ratings. Within the Nigerian context, Ogunsote and Prucnal Ogunsote (2002) documented the thermal characteristics of Lagos's coastal climate, establishing the baseline climatic conditions against which outdoor comfort interventions must be evaluated. Studies at Nigerian universities, including research at Obafemi Awolowo University (Adegun & Adedeji, 2017), have confirmed that campus landscape quality is strongly correlated with user-reported thermal comfort and outdoor space utilization rates.

Climate Responsive Landscape Design Strategies

Climate responsive landscape design is an integrative approach that applies ecological, bioclimatic, and spatial principles to the planning and design of outdoor environments, with

the goal of moderating microclimatic conditions and improving human comfort. The approach encompasses a range of strategies that address the dominant variables of outdoor thermal stress: solar radiation, surface heat gain, air movement, and humidity.

Vegetation and tree canopy represent the most effective and multipurpose climate responsive landscape strategy available to designers. Trees reduce solar radiation reaching ground and human surfaces through direct canopy shading, while simultaneously cooling the surrounding air through the process of evapotranspiration the release of water vapour through leaf surfaces. Studies have shown that tree-shaded areas can reduce surface temperatures by up to 20°C compared to exposed surfaces (Shashua-Bar & Hoffman, 2000), and can reduce PET values by 4–8°C in tropical outdoor spaces. The cooling benefit of trees extends beyond the immediate canopy area, with evapotranspirative cooling detectable over distances of 20–30 metres from tree groups. The selection of appropriate species is critical: trees with large, dense canopy spreads and high leaf area indices provide the greatest thermal benefit and should be prioritized in tropical campus planting programmes.

Green infrastructure encompassing shrubs, groundcovers, lawns, bioswales, green roofs, and green walls extends vegetative cooling to the broader campus fabric. Daramola et al. (2025) specifically demonstrate the role of green roofs in filtering urban air and moderating rooftop thermal environments in dense urban settings, confirming that vertical and horizontal green surfaces contribute measurably to reducing the urban heat island effect and improving air quality in campus environments. Lawn and groundcover vegetation similarly reduce surface temperatures through evapotranspiration and by replacing heat-absorbing hard surfaces with cooler, permeable alternatives.

The relationship between environmental quality and user outcomes has been further established by Adeyemi et al., (2024), who demonstrated that housing and spatial conditions significantly influence academic deliverables. By extension, the thermal quality of outdoor campus spaces directly affects student and staff comfort, satisfaction, and willingness to engage with the outdoor environment.

Water features provide a complementary cooling mechanism through the evaporative cooling of water surfaces. Fountains, channels, ponds, and mist systems introduce latent heat exchange into the outdoor microclimate, with studies reporting ambient air temperature reductions of 1–3°C in the immediate vicinity of active water features (Shashua-Bar et al., 2009). While the spatial extent of water-cooling effects is limited, their concentration at key gathering and seating points can meaningfully improve comfort at the locations where users spend the most time outdoors.

Surface material selection is a frequently underestimated but highly significant determinant of outdoor thermal comfort. Conventional paving materials including dark concrete, asphalt, and clay brick typically have low solar reflectance (albedo) values, absorbing 70–90% of incident solar radiation and re-radiating it as long-wave thermal energy. This significantly elevates MRT and worsens thermal conditions in adjacent spaces. Cool paving materials with high albedo values, as well as permeable paving systems that retain moisture and support

evaporative cooling, can substantially reduce surface temperatures and improve comfort conditions across large paved areas.

Shading structures including pergolas, canopies, tensile shade sails, and covered walkways provide immediate and reliable protection from direct solar radiation in areas where tree canopy cannot be established rapidly. While they lack the evapotranspirative cooling benefit of vegetation, shading structures can achieve comparable reductions in MRT and represent an important short- to medium-term intervention strategy for campuses undergoing landscape improvement. Spatial configuration and building orientation also influence outdoor thermal comfort by determining the flow of wind through campus spaces: layouts that preserve ventilation corridors and avoid creating stagnant air pockets can significantly enhance comfort through convective cooling, particularly during the hot dry season.

Gap in Literature

Despite the volume of international research on outdoor thermal comfort and urban landscape design, the majority of studies are concentrated in temperate regions, East Asian cities, or large metropolitan public spaces. Context-specific empirical research examining how landscape design strategies perform in Nigerian university campus environments, particularly in tropical coastal settings like Lagos remains scarce. Most existing Nigerian studies focus on building-level thermal performance rather than outdoor landscape conditions, leaving a significant gap in the evidence base for campus landscape planning and design. Furthermore, the review would benefit from greater inclusion of empirical studies from other Nigerian climatic zones, including the semi-arid north, the derived savanna of the Middle Belt, and the rainforest belt of the south-south, to establish a comparative national context and to test the transferability of landscape design interventions across Nigeria's diverse climatic regions. This study directly addresses that gap, building on the broader green infrastructure literature (Daramola et al., 2025) and international thermal comfort research to develop localized, evidence-based design guidance for UNILAG and comparable tropical university campuses.

METHODOLOGY

Research Design

The study adopted a mixed-method research design, combining observational spatial analysis of campus landscape conditions with structured questionnaire surveys of campus users. This approach reflects established practice in outdoor thermal comfort research, where physical conditions and user perceptions are understood as complementary dimensions of the same phenomenon neither fully capturing the complexity of thermal comfort experience in isolation.

Study Area

The study area was the main campus of the University of Lagos, Akoka, Lagos State, Nigeria (Latitude 6.52°N, Longitude 3.39°E). The campus occupies approximately 838 hectares on a coastal peninsula bounded by the Lagos Lagoon to the north and east. Lagos has a tropical wet and dry climate (Köppen classification Aw), with mean annual temperatures ranging from

24°C to 32°C, mean relative humidity of 75–85%, and mean annual rainfall of approximately 1,600 mm. The dry season (November to March) is characterized by intense solar radiation and high temperatures driven by harmattan conditions, while the wet season (April to October) brings elevated humidity and intermittent cloud cover. Both seasonal conditions present distinct thermal comfort challenges for outdoor campus users.

Questionnaire Survey

A total of 350 structured questionnaires were distributed to purposively sampled campus users across all major outdoor space types, including walkways, courtyards, open lawns, seating areas, sports areas, and waterfront zones. A total of 305 questionnaires were returned fully completed, representing a response rate of 87%. The questionnaire was pilot-tested with 20 campus users prior to full administration, and minor revisions were made to improve clarity.

Sampling was designed to achieve representation across user categories (undergraduate students, postgraduate students, academic staff, non-academic staff, and visitors), faculties, and times of day (morning, afternoon, and evening). The questionnaire was organized into six thematic sections: respondent profile (Section A); usage of outdoor spaces (Section B); perception of thermal comfort (Section C); assessment of climate responsive landscape design strategies using a five-point Likert scale (Section D); adaptive behaviour in response to heat (Section E); and preferred improvement strategies (Section F).

Likert scale responses were coded from 1 (Strongly Disagree) to 5 (Strongly Agree). Percentage agreement scores represent the combined proportion of respondents selecting "Agree" or "Strongly Agree." Open-ended responses were analyzed using thematic coding in NVivo 14.

Field Observations

Concurrent field observations were conducted across all major campus zones to systematically document existing landscape conditions, including tree canopy density and distribution, provision and condition of shading structures, surface material types, presence and accessibility of water features, and the spatial configuration of buildings and open spaces relative to prevailing wind directions. Field observations were conducted during the dry season (February–March 2025) between 10:00 and 16:00 hours to capture peak thermal stress conditions. Observational data were recorded through field notes, spatial mapping, and photographic documentation using a structured inventory checklist developed for this study.

To contextualise the subjective thermal comfort responses of survey participants, published meteorological data for Lagos for the February to March 2025 survey period were consulted. According to recorded climatic data for Lagos (Latitude 6.52°N), the survey period coincided with the hottest phase of the dry season. Mean daily maximum air temperatures for February 2025 ranged from approximately 29°C to 34°C, with peak afternoon temperatures on the warmest days reaching 35°C to 36°C. Mean relative humidity during this period ranged from 76% in March to 78% in February, reflecting the characteristically warm and humid coastal conditions of Lagos at this time of year (Weather Atlas, 2025; Climates to Travel, 2025). Field

observations and questionnaire administration were deliberately concentrated between 10:00 and 16:00 hours, the period during which air temperatures and solar radiation intensities are at their daily maximum. These documented ambient conditions are consistent with the high levels of thermal discomfort reported by survey respondents and provide objective climatic context that corroborates the subjective perception data collected during the study. While site-specific instrumented measurements of air temperature, mean radiant temperature (MRT), and humidity at individual campus locations were not undertaken as part of this study, the published meteorological record establishes that the survey was conducted under conditions of objectively significant thermal stress, lending validity to the discomfort responses reported by campus users.

Data Analysis

Quantitative questionnaire data were analyzed using descriptive statistical techniques including frequency counts, percentages, mean scores, and cross-tabulations using IBM SPSS Statistics (Version 26). Qualitative responses from open-ended questions were subjected to thematic analysis to identify recurring patterns and specific spatial concerns expressed by respondents. All findings are presented through narrative analysis supported by summary tables.

Ethical Considerations

Participation in the questionnaire survey was voluntary, and informed consent was obtained from all respondents. Anonymity and confidentiality were maintained throughout data collection and analysis.

Methodological Limitations

No instrumented microclimate measurements (e.g., air temperature, MRT, humidity) were collected; therefore, thermal comfort assessments are based entirely on user perception data rather than quantified bioclimatic indices such as PET or UTCI. Furthermore, questionnaire data were collected primarily during the dry season (February–March 2025) and may not fully capture thermal comfort perceptions during the wet season, when humidity levels are significantly higher.

FINDINGS AND DISCUSSION

Respondent Profile and Outdoor Space Usage

The study surveyed 305 campus users across a range of outdoor zones and times of day. The sample comprised 54% male respondents and 42% female respondents, with 4% preferring not to specify gender. The dominant age group was 21–25 years (43%), consistent with the predominantly young adult profile of a university campus. Undergraduates accounted for the largest user category (52%), followed by postgraduate students (28%), academic staff (10%), non-academic staff (8%), and visitors (2%). In terms of duration of campus use, 38% had been using UNILAG outdoor spaces for 1–3 years, 29% for 4–6 years, and 19% for more than six

years, indicating a predominantly experienced and established user base with detailed familiarity with campus thermal conditions.

Sixty-one percent of respondents reported using outdoor spaces on a daily basis, with a further 24% using them several times per week. Only 15% reported occasional or rare use, confirming that outdoor spaces are central to campus life for the overwhelming majority of users. Walkways were the most frequently used space type (87%), followed by open lawns (64%), seating areas (61%), courtyards (53%), waterfront areas (42%), sports areas (38%), and parking areas (27%). The high use of walkways reflects the fundamental role of pedestrian movement in campus life and underscores the critical importance of thermal conditions along circulation routes. Relaxation (74%) and movement between buildings (71%) were the most commonly cited purposes of outdoor space use, with studying and reading (48%), social interaction (62%), and recreation (43%) also frequently reported.

A particularly significant finding was that 58% of respondents identified the afternoon period (10am–4pm) as their primary time of outdoor space use. This period coincides precisely with peak solar radiation and maximum daily temperatures, creating a direct and persistent conflict between patterns of user demand and outdoor thermal comfort conditions. This temporal mismatch reinforces the urgency of landscape design interventions that can moderate afternoon heat stress across the campus's most heavily used outdoor zones.

Perception of Thermal Comfort

Table 1: Overall Outdoor Thermal Comfort Rating (n=305).

Comfort Rating	Frequency (n)	Percentage (%)
Very Comfortable	10	3%
Comfortable	49	16%
Neutral	61	20%
Uncomfortable	102	34%
Very Uncomfortable	83	27%

The findings reveal a predominantly negative assessment of outdoor thermal conditions at UNILAG, with a combined 61% of respondents rating the outdoor environment as uncomfortable or very uncomfortable. Only 16% of respondents reported comfortable conditions, while 20% were neutral. These results are consistent with broader research on outdoor thermal comfort in tropical Nigerian environments and confirm the existence of a significant and widespread thermal comfort deficit in the outdoor spaces of the university campus.

When asked specifically about their thermal sensation during hot periods, 62% of respondents described feeling very hot, 28% reported feeling hot, and only 7% described feeling slightly warm and 3% comfortable indicating near-universal thermal stress among outdoor users during peak conditions. The primary environmental factors identified as contributing to this discomfort were: lack of shade (78% of respondents), high air temperature (74%), poor air movement (61%), excessive paved surfaces (57%), insufficient vegetation (54%), and heat radiated from surrounding buildings (43%). This pattern of responses closely aligns with

established research on tropical outdoor thermal stress, confirming that solar radiation exposure through both direct irradiation and surface-mediated MRT elevation is the dominant source of discomfort.

Notably, 82% of respondents reported that they actively avoided certain outdoor areas on campus specifically because of excessive heat. The most commonly cited avoided zones were the main campus boulevard, exposed inter-faculty walkways, parking areas, and open plazas between academic buildings. All areas characterized by extensive paved surfaces, minimal tree canopy, and limited shade provision. This pattern of spatial avoidance has direct functional consequences: it reduces the effective outdoor circulation network available to campus users, concentrates pedestrian flows in a smaller number of shaded routes, and diminishes the social and recreational function of exposed outdoor spaces.

Assessment of Landscape Design Strategies

Table 2: User Assessment of Climate Responsive Landscape Elements (n=305)

Statement	% Agree / Strongly Agree	% Disagree / Strongly Disagree	% Neutral
Sufficient trees provide shade on campus	22%	61%	17%
Vegetation improves comfort levels	83%	7%	10%
Shaded walkways are adequate	19%	68%	13%
Water bodies improve outdoor comfort	76%	9%	15%
Building orientation allows good airflow	31%	48%	21%
Paving materials increase heat	79%	8%	13%

Note: Percentage agreement combines "Agree" and "Strongly Agree" responses. Percentage disagreement combines "Disagree" and "Strongly Disagree."

The data reveal a consistent and significant gap between users' recognition of the value of climate responsive landscape elements and their satisfaction with the current provision of these elements at UNILAG. While 83% of respondents agreed or strongly agreed that vegetation improves comfort levels, the highest endorsement of any strategy assessed only 22% felt that existing tree shade on campus was currently adequate. This discrepancy of 61 percentage points represents the most striking finding and confirms a severe and widely perceived deficit in tree canopy provision relative to campus needs.

Shaded walkway adequacy received the lowest satisfaction rating of any element, with only 19% of respondents agreeing that covered walkways were adequate and 68% disagreeing. This finding identifies the provision of shaded pedestrian infrastructure as the single most urgent landscape intervention need on campus, and is consistent with the finding that walkways are the most heavily used outdoor space type. The finding that 79% of respondents agreed that paving materials on campus increase heat reinforces the significant role of surface material choice in driving thermal discomfort and supports the case for widespread replacement of conventional dark-surfaced paving with high-albedo alternatives. This albedo effect warrants closer technical scrutiny. The existing dark concrete and asphalt surfaces prevalent across the UNILAG campus typically exhibit solar reflectance (albedo) values in the range of 0.05–0.20,

meaning they absorb 80–95% of incident solar radiation and re-radiate it as long-wave thermal energy, substantially elevating mean radiant temperature (MRT) in adjacent spaces. By contrast, high-albedo paving materials, such as light-coloured interlocking concrete pavers (albedo ≥0.35) or exposed aggregate concrete, can reduce surface temperatures by 10–15°C and lower MRT in adjacent spaces by 3–8°C under peak tropical solar conditions (Santamouris et al., 2011). This differential in surface thermal performance provides a strong technical justification for the prioritization of high-albedo resurfacing as a rapid-impact intervention on the campus's most heavily exposed paved areas. The relatively low agreement score for building orientation and airflow (31%) suggests that the existing spatial configuration of buildings impedes natural ventilation in a significant proportion of campus zones, warranting targeted spatial analysis as part of any future landscape masterplanning exercise.

Water bodies were recognized as comfort-enhancing by 76% of respondents, the second highest endorsement after vegetation yet waterfront access at UNILAG is currently confined to a relatively small area of the campus periphery. This finding underscores the potential of water features to enhance comfort in key campus gathering spaces and supports the expansion and improvement of water feature provision as a high-value landscape strategy.

Adaptive Behaviour and Preferred Improvement Strategies

The study examined how campus users adapt their behaviour in response to outdoor thermal discomfort. The most frequently reported adaptive strategies were: moving to a shaded area (69%), moving indoors (61%), reducing time spent outdoors (54%), changing route to use shaded paths (52%), and using an umbrella (23%). Only 8% reported continuing their outdoor activity without adaptation, indicating a very high degree of climate sensitivity among campus users and a strong latent demand for improved shaded outdoor environments.

The proportion of users who move indoors in response to heat discomfort (61%) is a particularly significant finding. This adaptive response effectively transfers the thermal comfort burden from outdoor landscape to indoor mechanical cooling systems, with direct implications for campus energy consumption. The fact that 52% of users alter their routes to find shaded paths further demonstrates that shading provision is already operating as a structuring force in outdoor campus movement an informal and suboptimal response to a deficit that should be addressed through systematic landscape design intervention.

Table 3: Preferred Outdoor Thermal Comfort Improvement Strategies (Multiple Response, n=305)

Improvement Strategy	% of Respondents Selecting
More trees / expanded canopy	91%
Pergolas and canopy structures	84%
Improved ventilation corridors	71%
Increased lawn and green spaces	68%
Cool / reflective paving materials	63%
Water features	57%
Green roofs and walls	44%

Table 3 shows that tree planting (91%) and pergolas and canopy structures (84%) were the most strongly endorsed improvement strategies, reflecting the clear primacy of shade provision in users' improvement priorities. Ventilation corridor improvement (71%), expanded green spaces (68%), and cool paving materials (63%) were also strongly supported, pointing to a broad and multi-dimensional improvement agenda. The 44% endorsement for green roofs and walls, while lower than other strategies, reflects growing awareness of green infrastructure as a campus comfort tool, a trend supported by the evidence presented in Daramola et al. (2025).

DESIGN RECOMMENDATIONS

Based on the findings of this study, the following integrated landscape design recommendations are advanced for the University of Lagos. These strategies are grounded in both the empirical evidence generated through this survey and the broader body of international research on climate responsive outdoor design in tropical environments. They are organized in order of priority, reflecting the urgency of user need and the potential scale of thermal comfort improvement.

Tree Canopy Expansion and Vegetation Programme

A comprehensive, campus-wide tree planting programme should be established as the highest priority landscape intervention at UNILAG. The programme should target all primary pedestrian routes, courtyards, open lawns, seating areas, and building forecourts, with a strategic goal of achieving minimum 40–50% canopy coverage over all major outdoor circulation zones. Locally adapted species with large canopy spreads, rapid growth rates, and proven performance in the Lagos coastal climate should be prioritized, including Terminalia mantaly (Madagascar Almond), Khaya senegalensis (African Mahogany), Azadirachta indica (Neem), Ficus benjamina (Weeping Fig), and Milicia excelsa (Iroko). Planting should be integrated with purpose-designed tree pits, root barriers, and irrigation systems to ensure establishment success in paved environments. The programme should be phased over a 5–10 year implementation timeline, with priority zones receiving immediate attention.

Shaded Walkway Network

A continuous, campus-wide network of shaded pedestrian walkways should be developed connecting all major academic, administrative, residential, and recreational zones of the campus. This network should be designed as a dual-phase intervention: in the short term (0–3 years), lightweight pergola and tensile canopy structures should be installed along the highest priority and most heavily used pedestrian routes, providing immediate solar shelter while tree canopy matures. Pergola structures should be designed to accommodate climbing plant species including Bougainvillea spectabilis, Thunbergia grandiflora, and Petrea volubilis to develop organic shade coverage over time. In the medium to long term (3–10 years), the maturing tree canopy programme will progressively replace the need for structural shading along established routes. The shaded walkway network should be designed to achieve contiguous shade

coverage along all principal pedestrian routes exceeding 100 metres in length, eliminating the long stretches of exposed pathway currently experienced by campus users.

Surface Material and Cool Paving Strategy

The replacement of conventional dark concrete and asphalt paving surfaces with high-albedo, permeable, or thermally improved alternatives should be embedded as a standard requirement in all new campus construction and major resurfacing projects. Recommended materials include light-coloured interlocking concrete pavers with a minimum solar reflectance value of 0.35, exposed aggregate concrete, and permeable block paving systems that retain surface moisture and support evaporative cooling. All large paved areas should be designed with integrated planted verges, tree pits, and bioswale channels to break up continuous heat-absorbing hard surfaces and introduce localized vegetation cooling. The current use of dark tarmac surfaces in high-footfall zones such as the main boulevard and faculty forecourts should be identified as an early priority for resurfacing intervention.

Water Feature Integration and Waterfront Enhancement

The campus waterfront landscape along the Lagos Lagoon should be comprehensively enhanced and activated as a primary outdoor thermal comfort zone. This should include the provision of shaded waterfront seating areas, landscaped promenades with integrated planting, and water channels and cascades at key access points. Key courtyards and public gathering spaces across the main campus should be provided with ornamental fountains, shallow reflecting pools, or mist systems to leverage the evaporative cooling benefits of water in high-use areas. All water features should incorporate sustainable water management systems, including rainwater collection, filtration, and recycling infrastructure, to minimize potable water demand and support year-round operation.

Ventilation Corridors and Green Infrastructure

A campus microclimate analysis should be commissioned to map prevailing wind directions, identify existing and potential ventilation corridors, and locate areas of stagnant air and heat accumulation. Campus development guidelines should be updated to protect identified wind access corridors from obstruction by new buildings or landscape elements, and to require wind tunnel or CFD assessment for major new developments. Green roofs and green walls should be incorporated into all future low-rise campus building projects as standard practice, consistent with the demonstrated thermal and air quality benefits documented by Daramola et al. (2025). Green walls on south and west facing building facades the most solar-exposed surfaces offer particular potential for reducing building surface temperatures and moderating the thermal environment of adjacent outdoor spaces.

Priority Intervention Zones

Based on the combined evidence of user survey responses and field observation, the following campus zones are identified as priorities for immediate landscape improvement intervention:

- Main campus boulevard and primary pedestrian spine the most heavily used route on campus, currently characterized by extensive exposed paving, minimal tree canopy, and no structural shading. Urgent installation of pergola structures and commencement of intensive tree planting required.
- Faculty of Engineering and Faculty of Science courtyards large, heavily paved outdoor areas with high student footfall and very limited vegetation or shading provision.
- Student Centre and food vendor areas high-concentration social gathering spaces currently lacking adequate shade, resulting in users eating and socializing in conditions of significant thermal stress.
- Main Gate to Sports Centre corridor a long, exposed pedestrian route with no canopy coverage, traversed by large numbers of students daily.
- Faculty of Arts and Faculty of Social Sciences outdoor areas south-facing open spaces with limited existing vegetation and significant heat absorption from adjacent paved surfaces.

Summary of Recommendations

Table 4: Summary of Recommendation

Priority	Recommendation	Estimated Cost	Responsible Body	Timeline
1	Tree canopy expansion	Medium	Estates Department	5–10 years
2	Shaded walkway network	High	Estates / Works	0–3 years (temporary), 3–10 years (permanent)
3	Cool paving strategy	High	Estates Department	Ongoing
4	Water feature integration	Medium	Estates / Landscape Unit	3–7 years
5	Ventilation corridors / green infrastructure	Low–Medium	Planning Unit	Ongoing

CONCLUSION

This study has demonstrated that outdoor thermal discomfort is a significant, widespread, and practically consequential challenge at the University of Lagos. With 70% of campus users reporting uncomfortable or very uncomfortable thermal conditions, and 82% actively avoiding certain outdoor spaces due to excessive heat, the existing outdoor landscape at UNILAG is falling substantially short of providing the thermally comfortable environment that a large and active campus community requires. The primary drivers of this deficit: inadequate tree canopy coverage, insufficient shaded walkway infrastructure, extensive heat-absorbing paved surfaces, and limited water feature provision are well understood and, crucially, addressable through targeted climate responsive landscape design intervention.

The integrated design recommendations advanced in this study, spanning expanded tree canopy, a continuous shaded walkway network, high-albedo paving, water feature integration, and green infrastructure provide a practical and evidence-based foundation for a comprehensive Climate Responsive Campus Landscape Master Plan for UNILAG. To make the tree planting recommendations immediately actionable for campus management, the following indigenous and locally-adapted tropical species are proposed as a priority planting list for UNILAG: Terminalia mantaly (Madagascar Almond), wide-spreading canopy, fast growth, tolerant of coastal conditions; Khaya senegalensis (African Mahogany), large evergreen canopy, high shade density, low maintenance; Azadirachta indica (Neem), drought-tolerant, rapid canopy establishment, medicinal value; Ficus benjamina (Weeping Fig), dense shade, suitable for walkway canopy corridors; Milicia excelsa (Iroko), large forest tree, excellent long-term canopy density; and Albizia lebbeck (Woman's Tongue), wide spreading canopy, nitrogen-fixing, well-suited to Lagos coastal soils. These species are all proven performers in the Lagos coastal climate, offer optimal canopy density, require low maintenance once established, and are available through Nigerian nurseries and forestry agencies. These strategies are mutually reinforcing: together they address the full range of thermal stress variables: solar radiation, surface MRT, air movement, and humidity that drive outdoor discomfort in tropical coastal environments. Implementing them would not only substantially improve the outdoor experience for the UNILAG community but would also reduce the campus's reliance on energy-intensive indoor air conditioning, enhance biodiversity and ecological quality, and strengthen the university's identity as an institution committed to environmental sustainability.

The study is subject to certain limitations. The absence of instrumented microclimate measurements means that the thermal performance of specific landscape interventions cannot be quantitatively predicted with precision, and the reliance on user perception data introduces subjectivity. Additionally, questionnaire data were collected primarily during the dry season (February–March 2025) and may not fully capture thermal comfort perceptions during the wet season, when humidity levels are significantly higher. Future research should incorporate air temperature and MRT measurements, PET or UTCI calculations, and computational fluid dynamics simulations to provide quantitative validation of the design recommendations advanced here. Longitudinal post-occupancy evaluation of implemented landscape improvements would further strengthen the evidence base for climate responsive campus design in the Nigerian context. Comparative studies spanning multiple Nigerian university campuses would support the development of generalizable design standards and guidelines for tropical academic outdoor environments, a contribution that would serve the wider higher education sector in West Africa and beyond.

REFERENCES

Adegun, O. B., & Adedeji, Y. M. D. (2017). Review of green infrastructure in the context of urbanization: Issues of sustainability in Nigerian cities. Future Cities and Environment, 3(1), 1–10.

Ademakinwa, O. O., Onamade, A. O., Adewumi, B. J., Adenubi, O. O., & Alagbe, O. A. (2024). Impact of accommodation on job performance at Caleb University, Imota-Lagos State, Nigeria. Caleb International Journal of Development Studies, 7(1). https://doi.org/10.26772/cijds-2024-07-01-013

Adeyemi, B. A., Ademakinwa, O. O., & Adeyemi, I. S. (2024). Housing as a stimulus to students' academic deliverables: A study of Federal University of Technology, Akure. International Journal of Research and Innovation in Applied Science, 9(3), 493–505.

ASHRAE. (2020). ASHRAE Standard 55: Thermal environmental conditions for human occupancy. American Society of Heating, Refrigerating and Air Conditioning Engineers.

Blazejczyk, K., Epstein, Y., Jendritzky, G., Staiger, H., & Tinz, B. (2012). Comparison of UTCI to selected thermal indices. International Journal of Biometeorology, 56(3), 515–535.

Climates to Travel. (2025). Lagos climate: Seasons and monthly averages. Retrieved from https://www.climatestotravel.com/climate/nigeria/lagos

Daramola, A. D., Dayomi, M., Ademakinwa, O. O., & Babamboni, A. (2025). The role of green roofs in urban air filtration. International Journal of Latest Technology in Engineering, Management & Applied Science, 14(8), 211–217.

Lau, S. S. Y., Gou, Z., & Liu, Y. (2014). Healthy campus by open space design: Approaches and guidelines. Frontiers of Architectural Research, 3(4), 452–467.

Ogunsote, O. O., & Prucnal Ogunsote, B. (2002). Defining climatic zones for architectural design in Nigeria: A systematic delineation. Journal of Environmental Technology, 1(1), 1–14.

Santamouris, M., Synnefa, A., & Karlessi, T. (2011). Using advanced cool materials in the urban built environment to mitigate heat islands and improve thermal comfort conditions. Solar Energy, 85(12), 3085–3102.

Shashua-Bar, L., & Hoffman, M. E. (2000). Vegetation as a climatic component in the design of an urban street: An empirical model for predicting the cooling effect of urban green areas with trees. Energy and Buildings, 31(3), 221–235.

Shashua-Bar, L., Pearlmutter, D., & Erell, E. (2009). The cooling efficiency of urban landscape strategies in a hot dry climate. Landscape and Urban Planning, 92(3–4), 179–186.

Wong, N. H., & Yu, C. (2005). Study of green areas and urban heat island in a tropical city. Habitat International, 29(3), 547–558

Weather Atlas. (2025). Climate and monthly weather forecast Lagos, Nigeria. Retrieved from https://www.weather-atlas.com/en/nigeria/lagos-climate