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Adaptive Landscape Design: Evaluation of Flexibility of Outdoor Spaces That Respond to Climate Change in Caleb University

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ABSTRACT

There is substantial scientific evidence that global climate change is intensifying environmental challenges, particularly in developing countries such as Nigeria, where rising temperatures, extreme rainfall, and heat stress increasingly affect the usability of outdoor environments. Despite growing discourse on sustainable design, a research gap remains in evaluating the flexibility and responsiveness of campus outdoor spaces to climate variability, especially within private university settings. This study aims to assess adaptive landscape design strategies by evaluating the flexibility of outdoor spaces in responding to climate change, using Caleb University as a case study. The objectives are to examine the current performance of outdoor spaces under changing climatic conditions, identify design limitations affecting user comfort and interaction, and propose adaptive landscape interventions that enhance resilience and usability. The study adopts a quantitative research methodology, utilizing structured online survey questionnaires administered to students, teaching staff, non-teaching staff, and visitors, with findings analyzed to determine the level of adaptability and inform climate-responsive landscape planning strategies.

Keywords: Adaptive landscape design, Climate change, Caleb University, Outdoor spaces.

INTRODUCTION

Global climate change has become one of the most pressing environmental challenges of the 21st century (IPCC, 2021). Scientific evidence shows increasing temperatures, irregular rainfall patterns, flooding, prolonged heat waves, and other extreme weather events, particularly in developing countries such as Nigeria (IPCC, 2021; Nigerian Meteorological Agency [NiMet], 2023). These climatic shifts significantly affect the performance, usability, and comfort of outdoor environments, especially in institutional settings where outdoor spaces serve academic, social, recreational, and circulation purposes (United Nations Environment Programme [UNEP], 2022; Okafor et al., 2024). University campuses rely heavily on outdoor spaces to promote learning beyond classrooms, encourage social interaction, enhance well-being, and create a sense of place (Kiribou et al., 2024; United Nations, 2023). However, many campuses were not originally designed with climate adaptability in mind (UNEP, 2022). As climate variability intensifies, poorly shaded walkways, inadequate drainage systems, heat-absorbing hardscapes, and insufficient green infrastructure reduce user comfort and limit outdoor space functionality (Agboola & Arapoglu, 2024; Ojobo & Nimlyat, 2024).

In private universities such as Caleb University, outdoor spaces play a critical role in shaping student experience and campus identity, particularly in rapidly urbanizing regions of southwestern Nigeria. However, there is limited empirical research evaluating how flexible and responsive these spaces are to climate change within private university settings in Nigeria (Okafor et al., 2024). While sustainable design discourse continues to expand globally (United Nations, 2023), a gap remains in assessing the actual adaptability of campus landscapes in the Nigerian context. Furthermore, research on institutional environments has shown that physical conditions, including outdoor spaces, significantly influence user performance and well-being (Ademakinwa et al., 2024).

Adaptive landscape design offers a strategic approach to addressing these challenges. It emphasizes flexibility, resilience, and climate-responsive planning through strategies such as shading systems, permeable surfaces, stormwater management, vegetation integration, and multifunctional open spaces (Ahern, 2021; Kiribou et al.,

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2024). Evaluating the flexibility of outdoor spaces in Caleb University is therefore necessary to determine their capacity to respond effectively to climate stressors while maintaining usability and social interaction.

Aim

To evaluate the flexibility of outdoor spaces in responding to climate change through adaptive landscape design strategies, using Caleb University as a case study.

Objectives

1. To examine the current performance of outdoor spaces in Caleb University under changing climatic conditions.
2. To assess the level of environmental comfort and usability of these outdoor spaces during extreme weather conditions.
3. To identify design limitations affecting user interaction, flexibility, and climate responsiveness.
4. To evaluate the degree of adaptability of existing landscape elements and spatial configurations.
5. To propose adaptive landscape design interventions that enhance resilience, usability, and climate responsiveness within the university campus.

LITERATURE REVIEW

Scientific consensus on climate change is unequivocal. The IPCC's Sixth Assessment Report (2021) declared that climate change is "widespread, rapid, and intensifying," with tropical regions facing amplified heatwaves, heavier extreme rainfall, and urban heat islands that can add 2–6 ℃ to local temperatures. In cities and settlements, these changes compound risks: more frequent flooding, prolonged heat stress, and reduced usability of outdoor environments (IPCC, 2022). A recent review of tropical urban heat islands confirms that UHI intensity in tropical cities frequently reaches 6 °C, double that of many temperate zones, making vegetation-based cooling essential for human comfort and health (Lefèvre et al., 2024).

Adaptive landscape design responds directly to these realities. It treats outdoor spaces as dynamic, living systems rather than fixed scenery. Core principles include nature-based solutions (NBS): shaded microclimates, bioswales and rain gardens for stormwater management, drought-tolerant native planting, and modular layouts that serve multiple seasonal functions. Recent global frameworks (White House, 2022; California NBS Climate Targets, 2024) show that well-designed NBS deliver multiple benefits—cooling, flood control, biodiversity, carbon sequestration, and improved mental well-being—often at lower long-term cost than grey infrastructure alone. Building energy performance simulation studies have also demonstrated that climate-responsive design strategies, including appropriate landscaping, can significantly reduce environmental stress on built environments (Oladigbolu et al., 2021).

Campus landscapes are ideal testing grounds for these principles. Leading institutions worldwide have moved from aspiration to action. UCLA's Place + Community + Ecology: A Climate Adaptive Landscape Plan integrates historic ecology with contemporary microclimates to create resilient, multifunctional outdoor spaces. Harvard Graduate School of Design's ongoing work on climate-responsive landscapes emphasizes slowing rainwater, treating flooding as a design feature, and storing water for reuse (Harvard Magazine, 2023).

In Africa and Nigeria, the urgency is even greater. Research indicates that over 60% of Africans depend on climate-sensitive agriculture, and West Africa (including Nigeria) faces some of the continent's highest vulnerability indices (Ayomipe & Epie, 2024). Erratic rainfall, droughts, floods, and rising temperatures are already reducing staple crop yields and intensifying urban flooding. Yet promising local adaptation is emerging. In northern Nigeria's semi-arid zones, communities traditionally adapt open spaces through indigenous knowledge: tree planting for shade, water harvesting, and flexible use of public grounds. The Global Centre on

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Adaptation (2024) reports that targeted NBS investments across Africa could avert billions in losses, with benefit-cost ratios reaching 8:1 when implemented at the landscape scale.

Despite this momentum, a critical research gap persists, particularly for existing outdoor spaces on private university campuses in Nigeria. While new "green campus" projects and public university masterplans have received attention, few studies rigorously evaluate how current campus landscapes perform under real climatic stress. Even fewer examine user experiences across diverse groups: students, staff, and visitors. Private institutions like Caleb University face distinctive constraints—rapid enrolment growth, modest budgets, and location-specific challenges in the Lagos hinterland—that are rarely addressed in existing literature. This study, therefore, fills a timely void. By assessing the flexibility of outdoor spaces at Caleb University through quantitative surveys and performance analysis, it moves beyond generic sustainability rhetoric. It identifies specific design limitations affecting thermal comfort, social interaction, and safety during heatwaves and heavy rains. Most importantly, it translates global best practices and African innovation into practical, climate-responsive interventions—shaded canopy networks, permeable surfaces, native biodiversity corridors, and seasonal flexible zones—that can be implemented within realistic institutional budgets. The evidence is clear: climate change will not wait, but neither will adaptive landscape design. Campuses that embrace flexibility today will become vibrant, resilient, living laboratories for Nigeria and the Global South.

RESEARCH METHODOLOGY

This study employed a quantitative survey design using a structured questionnaire to evaluate the environmental comfort, usability, and climate responsiveness of outdoor spaces at Caleb University. The survey method was adopted because it enables systematic data collection from a large population and allows for statistical analysis of users' perceptions and experiences. This approach made it possible to examine outdoor space usage patterns, perceived thermal comfort during extreme weather conditions, availability of climate-responsive landscape features, and users' satisfaction with the flexibility and adaptability of campus outdoor spaces.

The study was conducted at Caleb University, Imota, Lagos State. The campus contains diverse outdoor environments such as lawns, courtyards, gardens, sports areas, and landscaped walkways used for recreation, social interaction, circulation, and informal learning. Considering Lagos' climate challenges—heat waves, heavy rainfall, flooding, and seasonal drought—the campus provides a suitable setting to evaluate how outdoor spaces adapt to changing environmental conditions. The variety of landscape types and frequent daily user interaction make the campus an appropriate environment for assessing the flexibility, usability, and climate-responsive performance of adaptive landscape design. The target population comprised students, academic staff, and non-academic staff who regularly use outdoor spaces within the university. Due to accessibility and participants' willingness to respond, a convenience sampling technique was employed for questionnaire distribution. Structured questionnaires were administered primarily to students across different levels of study, and a total of 200 valid responses were collected and used for analysis. Although the sampling method is non-probabilistic, the relatively large sample size improves the reliability and generalizability of the findings within the context of campus-based perception studies.

DATA PRESENTATION, ANALYSIS AND DISCUSSION

This chapter presents and analyses the data obtained from the questionnaire survey conducted to evaluate the flexibility of outdoor spaces in responding to climate change at Caleb University. A total of **200 valid responses** were analyzed using descriptive statistics based on mean score ranking. The results are presented according to the major research variables: outdoor space usage, thermal comfort, climate-responsive landscape features, and user satisfaction.

Table 4.1: Demographic Distribution

Demographic Variable	Category	Number	Percentage (%)
Gender	Female	105	52.5%
	Male	95	47.5%

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Age	15-20 years	54	27%
	21-25 years	67	33.5%
	26-30 years	28	19.5%
	31 years and above	41	20.5%
Status in Caleb University	Student	129	64.5%
	Staff	47	23.5%
	Visitor	24	12%
How often do you use outdoor spaces on campus?	Daily	47	23.5%
	Several times a week	44	22%
	Occasionally	57	28.5%
	Rarely	52	26%
Which outdoor spaces do you use most?	Courtyards	31	15.5%
	Walkways	56	28%
	Recreational fields	49	24.5%
	Seating areas	31	15.5%
	Gardens / green area	33	16.5%

Table 4.2: Current Performance of Outdoor Spaces under Changing Climate

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean	SD
Outdoor spaces in Caleb University perform well during hot weather.	33 (16.5%)	50 (25%)	44 (22%)	46 (23%)	27 (13.5%)	2.92	1.29
Outdoor spaces provide adequate shade during sunny periods.	36 (18%)	35 (17.5%)	54 (27%)	44 (22%)	31 (15.5%)	3.00	1.41
Outdoor areas remain usable during rainfall.	43 (21.5%)	52 (26%)	34 (17%)	41 (20.5%)	30 (15%)	2.82	1.40
Landscape elements help reduce heat on campus.	37 (18.5%)	40 (20%)	39 (19.5%)	43 (21.5%)	41 (20.5%)	3.06	1.42
Outdoor spaces are designed to cope with changing weather conditions.	28 (14.1%)	47 (23.7%)	41 (20.7%)	48 (24.2%)	34 (17.2%)	3.04	1.35

Table 4.3: Environmental Comfort and Usability

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean	SD
Outdoor spaces are comfortable to use during extreme heat.	42 (21%)	50 (25%)	38 (19%)	46 (23%)	24 (12%)	2.80	1.35
Wind circulation in outdoor spaces is adequate.	30 (15%)	41 (20.5%)	50 (25%)	46 (23%)	33 (16.5%)	3.06	1.32
There are enough shaded seating areas.	42 (21%)	42 (21%)	44 (22%)	39 (19.5%)	33 (16.5%)	2.90	1.38
Outdoor spaces remain functional during heavy rainfall.	29 (14.5%)	39 (19.5%)	49 (24.5%)	43 (21.5%)	40 (20%)	3.13	1.34
Landscape design helps improve thermal comfort on campus.	31 (15.5%)	46 (23%)	44 (22%)	40 (20%)	39 (19.5%)	3.05	1.36

Table 4.4: Design Limitations Affecting Interaction and Climate Response

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean	SD
Some outdoor spaces become uncomfortable due to excessive heat.	25 (12.5%)	36 (18%)	51 (25.5%)	47 (23.5%)	41 (20.5%)	3.22	1.28

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Lack of shade discourages outdoor activities.	31 (15.5%)	37 (18.5%)	38 (19%)	43 (21.5%)	51 (25.5%)	3.23	1.41
Poor drainage affects the usability of outdoor spaces.	42 (21%)	35 (17.5%)	42 (21%)	49 (24.5%)	32 (16%)	2.97	1.39
The layout of outdoor spaces limits user interaction.	38 (19%)	31 (15.5%)	46 (23%)	51 (25.5%)	34 (17%)	3.06	1.37
Outdoor spaces lack climate-responsive design features.	40 (20%)	44 (22%)	47 (23.5%)	33 (16.5%)	36 (18%)	2.91	1.38

Table 4.5: Degree of Adaptability of Existing Landscape Elements

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean	SD
Trees and vegetation help regulate temperature in outdoor spaces.	35 (17.5%)	45 (22.5%)	41 (20.5%)	39 (19.5%)	40 (20%)	3.02	1.40
Outdoor spaces can accommodate different activities.	35 (17.5%)	32 (16%)	51 (25.5%)	45 (22.5%)	37 (18.5%)	3.09	1.35
Landscape design allows flexible use of space.	41 (20.5%)	42 (21%)	42 (21%)	42 (21%)	33 (16.5%)	2.92	1.38
Green infrastructure supports climate adaptation.	36 (18%)	37 (18.5%)	35 (17.5%)	45 (22.5%)	47 (23.5%)	3.15	1.43
Outdoor spaces can easily adapt to environmental changes.	32 (16%)	26 (13%)	54 (27%)	40 (20%)	48 (24%)	3.23	1.36

Table 4.6: Overall User Satisfaction

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean	SD
Outdoor spaces contribute positively to my campus experience.	35 (17.5%)	45 (22.5%)	41 (20.5%)	38 (19%)	41 (20.5%)	3.03	1.41
Outdoor spaces encourage social interaction among users.	38 (19%)	41 (20.5%)	41 (20.5%)	45 (22.5%)	35 (17.5%)	2.99	1.38
The landscape design makes outdoor areas attractive and functional.	32 (16%)	39 (19.5%)	42 (21%)	55 (27.5%)	32 (16%)	3.08	1.34
Outdoor spaces are flexible for different uses (study, relaxation, recreation).	33 (16.5%)	42 (21%)	44 (22%)	46 (23%)	35 (17.5%)	3.04	1.36
I am satisfied with the design of outdoor spaces on campus.	26 (13%)	39 (19.5%)	50 (25%)	44 (22%)	41 (20.5%)	3.18	1.32

SUMMARY OF FINDINGS

The study examined the flexibility of outdoor spaces at Caleb University in responding to climate change. Findings show that outdoor spaces are moderately used, with most users visiting occasionally rather than daily (Mean = 2.92 for hot weather performance), suggesting that environmental comfort and design quality influence usage patterns. Walkways and recreational fields are the most frequently used areas (28% and 24.5% respectively), while courtyards and seating spaces are less utilized, indicating limited effectiveness as social and relaxation hubs.

The performance of outdoor spaces under changing climate conditions was rated as average. While vegetation and landscape elements contribute to heat reduction (Mean = 3.06), usability during rainfall (Mean = 2.82) and extreme heat (Mean = 2.80) remains inadequate. Respondents reported insufficient shade (Mean = 3.00 for shade provision, but Mean = 3.23 indicating lack of shade discourages activities), poor drainage (Mean = 2.97), and

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inconsistent wind circulation (Mean = 3.06), highlighting thermal discomfort as a major barrier to outdoor space use.

Design limitations were strongly identified, including lack of climate-responsive features (Mean = 2.91) and layouts that restrict social interaction (Mean = 3.06). Although green infrastructure and vegetation support climate adaptation to some extent (Mean = 3.15), the flexibility of spaces for multiple uses remains moderate (Mean = 2.92 for flexible use, Mean = 3.09 for accommodating different activities).

Overall user satisfaction with outdoor spaces is average (Mean = 3.18). While the spaces contribute positively to campus life (Mean = 3.03) and social interaction (Mean = 2.99), they do not fully function as comfortable, adaptable, and climate-resilient environments. The findings therefore emphasize the need for improved shading, drainage, spatial layout, and climate-responsive landscape design to enhance usability and resilience.

CONCLUSION AND RECOMMENDATION

This study evaluated the flexibility of outdoor spaces at Caleb University in responding to climate change using adaptive landscape design principles. The findings confirm that climate variability—particularly rising temperatures, intense rainfall, and heat stress—has a noticeable impact on the usability, comfort, and social value of outdoor spaces on campus.

The results reveal that outdoor spaces are moderately functional but not fully climate responsive. Although walkways, recreational fields, and green areas are actively used, most users only utilize outdoor spaces occasionally rather than daily. This indicates that environmental comfort significantly influences outdoor behaviour.

The study identified thermal discomfort, insufficient shading, and poor drainage as the most critical limitations affecting usability. Outdoor spaces were found to perform only moderately during hot weather and rainfall, demonstrating that current landscape design strategies are not adequately adapted to evolving climate conditions. Furthermore, spatial layouts were perceived to limit social interaction and flexible use, indicating that the campus landscape lacks multifunctional and adaptive design features.

Despite these challenges, existing vegetation and green infrastructure already provide a foundation for climate adaptation. Users generally acknowledged that outdoor spaces contribute positively to campus experience; however, overall satisfaction remains only average. This suggests that Caleb University possesses strong potential for climate-responsive transformation, but targeted design interventions are required to improve comfort, resilience, and flexibility.

In conclusion, the study establishes that while Caleb University's outdoor spaces provide basic functionality, significant improvements are needed to transform them into climate-resilient, socially vibrant, and adaptable environments capable of supporting long-term sustainability.

Recommendations

Based on the findings, the following adaptive landscape design strategies are recommended:

Improve Shading and Heat Mitigation

- Introduce **continuous tree-canopy networks** along walkways and gathering spaces.
- Install **pergolas, tensile canopies, and shaded pavilions** in seating and study areas.
- Increase use of **native, drought-resistant trees** to create long-term microclimate cooling.
- Replace heat-absorbing hard surfaces with **cool pavements and permeable materials**.

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Enhance Stormwater Management and Drainage

- Implement **bioswales, rain gardens, and retention ponds** to manage heavy rainfall.
- Introduce **permeable paving systems** for walkways and plazas.
- Redesign low-lying areas prone to flooding to improve surface runoff control.

Create Flexible and Multifunctional Outdoor Spaces

- Design outdoor spaces that support **study, relaxation, events, and recreation simultaneously**.
- Introduce **movable seating and modular furniture** to allow adaptable use.
- Develop **multi-seasonal spaces** that remain functional during both dry and rainy periods.

Improve Spatial Layout and Social Interaction

- Develop **activity nodes and social hubs** across campus.
- Improve **connectivity between outdoor spaces** using shaded pedestrian corridors.
- Redesign courtyards and seating areas to encourage **informal learning and interaction**.

Strengthen Green Infrastructure and Biodiversity

- Expand **green corridors and biodiversity zones** across campus.
- Incorporate **urban agriculture and outdoor learning gardens**.
- Increase vegetation coverage to reduce the **urban heat island effect**.

Establish Climate-Responsive Campus Planning Policies

- Integrate adaptive landscape strategies into **future campus master planning**.
- Conduct **regular post-occupancy evaluations** of outdoor spaces.
- Promote campus awareness and participation in **sustainability initiatives**.

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