Green Infrastructure and Climate Change Adaptation in University Campuses: Nature-based solutions for Resilience

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Abstract

Innovative and sustainable methods are desperately needed to increase environmental resilience, especially on college campuses where climate change poses an increasing threat. With an emphasis on nature-based solutions (NBS) as a clever solution to these environmental issues, this study delves deeply into the role that green infrastructure plays in assisting campuses in mitigating climate change. Vegetated swales, rain gardens, permeable pavements, urban forests, and green roofs are examples of green infrastructure. These features all contribute to improving microclimates, controlling storm water, preserving biodiversity and advancing ecological sustainability. The study investigated how integrating these natural solutions into campus planning and design can help organizations better understand the effects of climate change, such as flooding, extreme heat and air pollution. Using a quantitative approach, data were garnered through a questionnaire and analyzed with ordinal regression. The study revealed no significant impact of the current state of green infrastructure and climate change adaptation in some selected University campuses in the Niger-Delta region in Nigeria. More so, the study finds that critical infrastructure challenges of implementing green infrastructure do not significantly impact climate change adaptation in some selected University campuses in the Niger Delta region. However, the study showed that green infrastructures on campus sustainability have an effect on climate change adaptation in some selected University Campuses.

Keywords: Green Infrastructure, Adaptation, Sustainability, Nature-Based Solutions, University Campuses, Niger Delta, Climate Change.

1. Introduction

Extreme heat, flooding, poor air quality and water shortages are just a few of the problems that universities face due to climate change. They are especially at risk since they are centers of knowledge and densely populated areas. According to Grimm et al. (2023), green infrastructure and nature-based solutions (NBS) are becoming popular as sustainable, multidimensional ways to increase campus resilience because of the pressing need to address these environmental issues. Yang et al. (2024) opined that green roofs, urban forests, permeable pavements, bioswales, rain gardens and vegetated buffers provide a nature-focused approach to managing climate risks while providing additional ecological, educational and social benefits. Henderson et al. (2017) emphasize on not depending on just technological solutions to address climate change, universities must adopt ecosystem-based approaches that support sustainability objectives. University campus projects serve as living laboratories, encouraging interdisciplinary cooperation and providing students with chances to get involved and educated about sustainability (Samuels et al, 2024). As part of larger climate action plans, universities in developed and developing nations are beginning to implement NBS, albeit progress varies because of a lack of policy framework, financial obstacles and knowledge gaps (Grimm et al, 2023).

The integration of green infrastructure can fulfil national and international commitments to the Sustainable Development Goals (SDGs), particularly Goal 11(Sustainable Cities and Communities), Goal 13(Climate Action) (Seddon et al, 2020). Universities have a special chance to set an example for climate resilience by incorporating nature-based solutions into their operational and physical frameworks, as they are responsible for developing the next generation of leaders (Lakshmisha et al., 2024). Many university campuses still rely on traditional grey infrastructure, such as concrete drainage systems, impermeable surfaces, and energy-intensive buildings with little flexibility to adapt to climate threats, even as hubs for innovation and sustainability advocacy (Bressane et al., 2024). Campuses are frequently unprepared to handle the environmental issues resulting from climate variability and catastrophic weather occurrences (Garre, 2024). GI address environmental concerns and offers benefits like increased biodiversity, cleaner air, improved student wellbeing and educational opportunities (Grimm et al., 2023). However, they are still not widely included in the design and infrastructure construction of university campuses, especially in low and middle-income nations, where a lack of awareness, policy gaps, and resource limitations hampers innovation. According to Calabrese et al. (2023), few empirical studies have been done on how well NBS and green infrastructure support academic environments' resilience to climate change. Campuses continue to experience frequent environmental vulnerabilities, resource inefficiencies, and lost chances for climate leadership without strategic implementation and evidence-based frameworks (Yang et al., 2024). Thus, it is imperative to look into how universities might use nature-based solutions to improve environmental resilience, lower risks associated with climate change, and set an example for sustainability (Vazin et al., 2024). This study seeks to evaluate the Green infrastructure and climate change adaptation in selected public universities in the Niger Delta region. The objectives are to:

1. Examine the current state of green infrastructure that has been implemented in the campuses of the selected universities.
2. Identify the critical challenges of implementing green infrastructure in the campuses of the selected universities.
3. Analyze the impact of green infrastructures on campus sustainability in the selected universities.

According to Dhyani and Krishnaswamy (2025), ecological services and biodiversity co-benefits are frequently underestimated, in contrast to energy and water efficiency, which have obvious financial advantages. Adeshina et al. (2024) stated that the authority of the University of Lagos could work with the local people to enhance the riparian buffers and green corridors within the river profile for both parties. Abimbola and Agboola (2023) suggested that GI improved by adding features like lighting, thoughtful space design, and comfortable seating. Metos et al. (2023) highlighted using nature to enhance resilience. Solutions that integrate ecosystems offer a range of benefits, including regulating temperatures and providing various ecosystem services. Akinwale et al. (2025) found that students often used green spaces for leisure activities. To direct researchers and campus planners toward integrated, evidence-based NBS strategies, the review synthesizes theoretical underpinnings, empirical findings, methodological approaches, and gaps (Aghaloo et al., 2024). GI provides essential ecosystem services in urban areas and is a component of larger Nature-based Solutions (NBS) initiatives that are inspired by, supported by, or modelled after nature to address societal challenges with multifunctional benefits and these initiatives collectively support climate-change adaptation and enhancing the resilience ability of a social-ecological system, like a university campus, to absorb disturbances (Pochodyła et al., 2022; Sharma et al., 2024). Ogbonna et al. (2020) suggested that strengthening institutional frameworks and capacities to produce favourable environmental outcomes is necessary to increase climate resilience in and around the Niger Delta's coasts, riverbanks, and lakeshores. Yoshino and Asahiro (2025) conducted tree growth and landscape greening in Coastal Urban areas: The case of Hakata port in Fukuoka City, Japan. Findings showed that the main tree species in the green space at Fukuoka City's port include Machilus Thunbergii, Morella rubra, and Pasania edulis. Effiong (2025) looked into climate justice within land use planning and examined the possibilities and challenges of integrating nature-based solutions in Nigeria. The findings highlighted Nigeria's intricate planning regulations and land use policies and how these relate to natural solutions for adapting to climate change.

The Social-Ecological Systems (SES) Resilience Theory is based on the understanding that ecological systems, which include natural resources, biodiversity, and ecosystem services and human systems, which include society, governance, and institutions, are intricately intertwined and constantly co-evolving. Given the diversity of management structures and environmental awareness levels in Nigerian universities, where many campuses face severe heat stress, heavy rainfall, poor drainage, a lack of funding, and maintenance issues, the SES framework's emphasis on adaptive governance, stakeholder engagement, and context-specific solutions is extremely pertinent. When used in research, the SES framework can support a conceptual model that maps social (staff, students, policies, governance) and ecological (green roofs, wetlands, trees) components. This allows for the analysis of both ecological impacts (such as cooling and runoff reduction) and social impacts (such as awareness and willingness to maintain GI over time). Terdoo et al (2025) carried out research on Exploring the Role of Nature-Based Solutions in Reducing CO2 Emissions and Supporting Urban Climate Resilience in Nigeria. The results showed notable sectoral variations in Nigerian implementation.

2. Materials and Methods

The survey method was used for the investigation, and it included using a questionnaire. To draw deductions and conclusions, and generalize findings from a sample to the population, survey research is justified in this way. However, the University of Uyo (UNIUYO), University of Calabar (UNICAL), Federal University of Technology, Akure (FUTA), Rivers State University (RSU), Niger Delta University (NDU), Yenogoa and Ambrose Alli University (AAU), Ekpoma were the main subjects of the study. The population consisted of stakeholders of the selected universities mentioned above, which were estimated to be 186,039. Using the sample size calculation approach proposed by Krejcie & Morgan (1970), the sample size for the study was 385 stakeholders from selected university campuses across the Niger Delta. Israel (2013) stated that the sample size should be increased by 10 to 30% of the questionnaires to account for potential errors that may arise when administering the surveys. In this study, the population was based on judgment and distributed to the selected universities. 446 questionnaires were administered to the respondents across the universities, but only 417 questionnaires, representing 93.5% were returned. Data were collected from the 417 respondents through purposive, cluster, and simple random selection techniques. Furthermore, because the population is heterogeneous, the study used a basic random sampling technique. Essentially, bias or the lack of systematic variance is why this technique was chosen. With these samplings, each member of the population has an independent and equal probability of being selected for the sample. The data obtained throughout the research is the only source used in this work to test the hypotheses. The study made use of primary data. However, 75 questionnaires were distributed at FUTA, 82 questionnaires were administered at UNIUYO, 97 questionnaires were administered at UNICAL, 77 questionnaires were administered to the respondents at AAU, 48 questionnaires were administered to the NDU Community, and 67 questionnaires were administered to the community of RSU. The questionnaire was a structured, closed-ended questionnaire. To ensure validity, the questionnaire was reviewed by 10 academics, and pilot testing was carried out with a group consisting of sixty respondents from the three selected universities, distributing 20 questionnaires to each of the respondents. Cronbach's Alpha was used to evaluate the questionnaire's reliability. The variables were tested independently to check if the questionnaire to be used for the study is reliable enough. All variables have a figure above 0.7. Ordinal Regression was utilized to analyze the data from the 417 (four hundred and seventeen) questionnaires that were returned.

3. Results and Discussion

Table 1 Model Fitting Information

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	2634.164			
Final	2585.744	48.420	3	.000

Link function: Logit.

Source: Author (2025)

The model fitting data, or goodness of fit statistics, is displayed in Table 1 above. The table makes it abundantly evident that the fit is far better than it was for the null model. Since our Alpha level (0.05) is higher than the P-value and indicates a significant difference between the intercept-only model and the final model, the model thus demonstrated a strong match. This means that Green infrastructure is related to climate Change Adaptation in University campuses either positively or negatively.

Table 2 Goodness-of-Fit

	Chi-Square	df	Sig.
Pearson	11233.576	11085	.159
Deviance	2526.003	11085	1.000

Link function: Logit.

Source: Author (2025)

Table 2 above indicates a satisfactory match because the P-value (1.00) is higher than the Alpha level (0.05). This indicates that the fitted (assumed) model and the observed data are significantly different.

Table 3 Pseudo R-Square

Cox and Snell	.135
Nagelkerke	.135
McFadden	.023

Link function: Logit.

Source: Author (2025)

Table 3 above shows the value of Nagelkerke R-Square to be 0.13, meaning that there has been a 13% improvement in the prediction of the outcome based on the Predictors (Green infrastructure) is in comparison to the null model. This means that the 13% deviation in the dependent variable (Climate Change Adaptation in University campuses) is explained by the deviation in the Independent Variable.

Table 4 Parameter Estimates

		Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
Threshold	[ISS = 1.00]	-1.741	.468	13.816	1	.000	-2.658	-.823
	[ISS = 1.10]	-.968	.416	5.430	1	.020	-1.783	-.154
	[ISS = 1.20]	-.234	.391	.359	1	.549	-1.001	.532
	[ISS = 1.30]	.151	.385	.153	1	.695	-.603	.905
	[ISS = 1.40]	.690	.381	3.288	1	.070	-.056	1.436
	[ISS = 1.50]	1.039	.380	7.465	1	.006	.294	1.785
	[ISS = 1.60]	1.418	.382	13.784	1	.000	.669	2.166
	[ISS = 1.70]	1.730	.384	20.283	1	.000	.977	2.483
	[ISS = 1.80]	2.018	.387	27.192	1	.000	1.259	2.776
	[ISS = 1.90]	2.251	.390	33.383	1	.000	1.488	3.015
	[ISS = 2.00]	2.708	.396	46.750	1	.000	1.931	3.484
	[ISS = 2.10]	2.901	.399	52.872	1	.000	2.119	3.683
	[ISS = 2.20]	3.135	.403	60.538	1	.000	2.345	3.925
	[ISS = 2.30]	3.350	.407	67.826	1	.000	2.553	4.147
	[ISS = 2.40]	3.466	.409	71.821	1	.000	2.664	4.268
	[ISS = 2.50]	3.622	.412	77.250	1	.000	2.814	4.429
	[ISS = 2.60]	3.851	.417	85.308	1	.000	3.034	4.669
	[ISS = 2.70]	3.950	.419	88.778	1	.000	3.128	4.772
	[ISS = 2.80]	4.055	.422	92.457	1	.000	3.229	4.882
	[ISS = 2.90]	4.122	.423	94.780	1	.000	3.292	4.952
	[ISS = 3.00]	4.943	.450	120.880	1	.000	4.061	5.824
	[ISS = 3.10]	4.986	.451	122.049	1	.000	4.102	5.871
	[ISS = 3.20]	5.078	.455	124.412	1	.000	4.186	5.971
	[ISS = 3.30]	5.406	.472	131.386	1	.000	4.482	6.331
	[ISS = 3.40]	5.471	.475	132.453	1	.000	4.540	6.403
	[ISS = 3.50]	5.689	.489	135.155	1	.000	4.730	6.648
	[ISS = 3.60]	5.954	.510	136.401	1	.000	4.955	6.953
	[ISS = 3.80]	6.172	.530	135.587	1	.000	5.133	7.211
	[ISS = 3.90]	6.444	.561	132.157	1	.000	5.345	7.543
	[ISS = 4.00]	6.610	.582	128.786	1	.000	5.468	7.751
	[ISS = 4.10]	7.039	.653	116.135	1	.000	5.759	8.320
	[ISS = 4.40]	7.341	.717	104.748	1	.000	5.935	8.747
	[ISS = 5.00]	8.463	1.101	59.131	1	.000	6.306	10.620
Location	WM	-.087	.098	.782	1	.377	-.279	.105
	ST	-.178	.140	1.621	1	.203	-.452	.096
	FTI	1.124	.168	44.492	1	.000	.794	1.454

Link function: Logit.

Source: Author (2025)

Table 4 above shows a negative Parameter Estimate between the current state of green infrastructure and the climate change adaptation in some campuses. This means that for every on-unit increase in the state of green infrastructure that has been implemented, there is a predicted decrease of -.087 in the Log odds of being a lower level on climate change adaptation in campuses. The P-value (0.37) is greater than our Alpha level (0.05), which means that there is no significant impact between the current state of green infrastructure and climate change adaptation. Also, Table 4 above shows a negative Parameter Estimate between the critical infrastructure challenges of implementing green infrastructure and the climate change adaptation in campuses. The coefficient value shows that for every one-unit increase in critical infrastructure challenges of implementing green infrastructure, there is a predicted decrease of -.178 in the Log odds of being a lower level on the climate change adaptation in campuses. Also, the P-value (0.20) is greater than our Alpha level (0.05), meaning that the critical infrastructure challenges of implementing green infrastructure do not have a significant impact on climate change adaptation in campuses. Table 4 above reveals a positive Parameter Estimate between green infrastructures on campus sustainability and climate change adaptation. Hence, for every one-unit increase in procurement fraud, there is a predicted increase of 1.124 in the Log odds of being a higher level on the green infrastructures on campus sustainability and climate change adaptation. Also, our P-value (0.00) is less than our Alpha level (0.05), which means that green infrastructures on campus sustainability have an impact on climate change adaptation in some campuses.

Table 5 Test of Parallel Lines[a]

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Null Hypothesis	2642.294			
General	.000[b]	2642.294	256	.000

Source: Author (2025)

The parallel line test is shown in Table 5 above. The location parameters (slope coefficients) in the table are the same for all answer categories, according to the null hypothesis. As a result, this test for null hypotheses explains why the chances for every explanatory variable remain constant across various outcome variable thresholds.

3.1 Major findings

Study shows that there is no statistically significant impact of the degree of climate change adaptation on the selected university campuses in the region and the current condition of green infrastructure (GI). This implies that although some aspects of green infrastructure, like tree cover, green spaces, drainage systems, and environmentally friendly campus layouts, exist to varying degrees, they are not yet operating at a scale or effectiveness that can significantly aid in the results of climate change adaptation. Study revealed that current GI initiatives on these campuses are frequently dispersed, badly maintained, or carried out without a well-thought-out plan for climate adaptation. The study highlighted a crucial gap: GI alone does not equate to successful climate change adaptation unless it is carefully planned, maintained, and integrated with larger campus sustainability frameworks. In order to maximize GI's contribution to boosting resilience in academic settings, it also emphasizes the necessity of capacity building, policy alignment, and resource allocation. Also, it turns out that the challenges of putting green infrastructure (GI) into action do not significantly impact how well universities in the region adapt to climate change. This means that even with major hurdles like limited funding, lack of expertise, policy gaps, maintenance issues, and low engagement from stakeholders, these factors do not seem to play a huge role in shaping the current state of climate adaptation at these schools. Many campuses are finding workaround solutions like leaning on donor-funded projects, using makeshift maintenance, or implementing smaller initiatives to tackle some of these challenges. But these tactics often lack sustainability and do not really tie GI programs to measurable climate adaptation benefits. This suggests that while the implementation challenges are relevant to the bigger sustainability conversation, other elements like institutional policy goals and availability of tailored adaptation programs.

The findings indicated that the hurdles presented by deploying GI do have a statistically significant effect on climate change adaptation among the selected university campuses. This means that, despite facing challenges like funding shortages, lack of technical skills, inconsistent policy enforcement, minimal stakeholder awareness, and maintenance troubles, these obstacles are not the main factors affecting adaptation results on campus. Despite these challenges, some institutions have managed to implement climate-related policies, often using various methods such as donor-funded initiatives, community collaborations, small-scale nature-based solutions, or integrating with broader sustainability efforts. In the near term, the capacity to adapt may be more strongly influenced by other aspects, such as the range of institutional climate policies, additional funding sources, and how well adaptation measures are woven into campus planning.

4. Conclusion

The study findings revealed that the current state of green infrastructure on these campuses does not affect how well they adapt to climate change. Likewise, the challenges of putting in place crucial green infrastructure also did not have a significant impact on their adaptation capacity. Essentially, these results suggest that the main drivers of climate resilience in the institutions studied are not about facing implementation hurdles or simply having GI elements in place. Rather, institutional policy priorities, the incorporation of climate action into strategic campus planning, the availability of focused adaptation programs, and access to outside technical and financial assistance seem to have a greater influence on climate change adaptation. Although, there is potential for green infrastructure to be a successful nature-based solution for reducing the effects of climate change, its contribution to the universities under study is still underutilised because of its dispersed implementation, poor maintenance, and lack of a systematic connection to adaptation goals. The lack of statistically significant correlations should not be taken as proof that resilience-building and green infrastructure are unrelated. Instead, it emphasizes how universities must abandon discrete, aesthetically motivated GI initiatives in favour of comprehensive, well-coordinated plans that specifically incorporate ecological systems into institutional adaptation frameworks. Stronger governance frameworks, consistent funding, stakeholder involvement, and the alignment of campus green initiatives with quantifiable climate adaptation objectives are all necessary to achieve this. The transformation of nature-based solutions from symbolic gestures into useful, resilience-enhancing assets for the campus environment and the larger community ultimately necessitates a change from passive adoption to proactive, policy-driven, and scientifically informed deployment in order to increase the role of green infrastructure on campuses.

When planning and implementing green infrastructure, universities should take a strategic, goal-oriented approach. Rather than being created purely for aesthetic reasons, GI projects should be planned and run with specific adaptation goals like flood control, heat reduction, biodiversity preservation, and water conservation. To do this, campus-specific green infrastructure master plans must be created, incorporated into institutional climate policies, and evaluated for resilience using performance metrics. Universities should invest in technical staff capacity building, obtain diversified funding (including collaborations with the government, non-governmental organizations, and private donors), and fortify governance and coordination frameworks for GI implementation. For adaptation efforts to be integrated into larger institutional culture and planning rather than relying exclusively on infrastructure projects, climate change adaptation strategies should also be formalized within academic curricula and operational policies. Universities should not ignore these obstacles since they can impede long-term sustainability, even though the statistical results indicate that implementation difficulties are not the primary factor influencing climate adaptation. In order to plan and maintain green infrastructure, institutions should proactively simplify policy frameworks, enhance interdepartmental coordination, and develop technical capacity. The creation of specialised sustainability departments at each university, backed by steady funding and employee development, would guarantee that green infrastructure projects are methodically connected to climate resilience objectives rather than carried out separately.

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