

CLIMATE HAZARD EXPOSURE, INFRASTRUCTURE VULNERABILITY AND DEVELOPMENT OF A CAMPUS CLIMATE RESILIENCE INDEX FOR POLYTECHNICS IN SOUTH-WEST NIGERIA

ODEYEMI F. G.¹, SURU W. P.¹ and APATA C. O.²

¹Department of Surveying and Geoinformatics, Federal Polytechnic Ede, Osun State, P.M.B 231, Nigeria.

²Department of Quantity Surveying, Federal Polytechnic Ede, Osun State, P.M.B 231, Nigeria.

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ODEYEMI F. G., SURU W. P. and APATA C. O.

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Abstract

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Abstract

Climate change is intensifying flooding, extreme heat and windstorms that threaten infrastructure and operations in Nigeria. This study assessed climate hazard exposure and infrastructure vulnerability across polytechnic campuses in South-West Nigeria and developed a campus climate resilience index. An assessment-and-index-development design combined geospatial, field and survey methods. Hazards were mapped for six campuses, exposure was assessed by geolocating buildings, services, roads and critical assets, and vulnerability was assessed through audit and survey of sensitivity and adaptive capacity. A composite index was built from weighted, normalised indicators and validated through sensitivity analysis and expert appraisal. Flooding was the most significant hazard (24.6% of campus areas), followed by extreme heat (18.4%) and windstorms (12.8%). Exposure was highest for roads and drainage (62.4%), followed by buildings (48.6%) and utilities (42.8%). Overall, 58.4% of infrastructure had low adaptive capacity, with inadequate drainage (72.6%), poor maintenance (64.2%) and lack of early warning systems (58.4%) as key gaps. The Campus Climate Resilience Index (CCRI) ranged from 0.44 to 0.62 (mean 0.53). Experts rated it highly for robustness (3.60), relevance (3.80) and usability (3.40). The study provides a hazard and vulnerability assessment and a validated index to support climate resilience planning in Nigerian polytechnics.

Keywords: climate hazard; infrastructure vulnerability; resilience index; polytechnic campuses; climate adaptation; Nigeria

Introduction

Climate change is intensifying the hazards to which institutions are exposed, and in Nigeria these include worsening flooding, extreme heat and damaging windstorms that threaten infrastructure, operations and safety (Echendu, 2020). Research has documented that Nigeria is highly vulnerable to climate change impacts, with flooding affecting over 3 million people annually and causing billions of naira in damages. Studies have shown that the frequency and intensity of extreme weather events in Nigeria have increased in recent decades, with the 2022 floods being the worst in over a decade, affecting 34 of the 36 states and displacing over 1.4 million people. Polytechnic campuses, with their buildings, services, roads and grounds, are exposed to these hazards, yet their exposure and the vulnerability of their infrastructure are seldom assessed,

leaving institutions unable to anticipate or manage climate risk. Research on climate resilience in Nigerian institutions has been limited, with most studies focusing on communities, agriculture, or urban areas rather than institutional campuses.

Climate risk is understood as the intersection of hazard, exposure and vulnerability, and assessing it requires characterising each. Hazard describes the climate-related events and trends; exposure describes the people, assets and infrastructure in harm's way; and vulnerability describes their susceptibility to harm and lack of capacity to cope, so that resilience depends on all three (Intergovernmental Panel on Climate Change, 2022). The IPCC framework has been widely adopted for climate risk assessment, providing a structured approach that can be applied at multiple scales. Research has emphasised that understanding vulnerability requires considering both sensitivity, the degree to which a system is affected by climate hazards, and adaptive capacity, the ability of the system to adjust to and cope with those hazards. Applying this framing to campuses provides a structured basis for assessment, enabling institutions to identify where their infrastructure is most at risk and what capacities they need to build.

Composite indices are a well-established means of measuring and comparing vulnerability and resilience. By combining exposure, sensitivity and adaptive-capacity indicators into a single, transparent measure, indices such as social-vulnerability and resilience indices allow places or assets to be compared, hotspots identified and resources prioritised, informing decision-making (Cutter et al., 2003; Notre Dame Global Adaptation Initiative, 2024). The social vulnerability index developed by Cutter et al. (2003) has been widely applied and adapted for different contexts, demonstrating the utility of composite indices for understanding differential vulnerability. Research has demonstrated that composite indices can effectively communicate complex information to decision-makers and support resource allocation for adaptation. A campus-scale index would give institutions a comparable, actionable measure of their climate resilience, enabling them to benchmark their performance, track progress over time, and prioritise investments in resilience-building measures.

Despite growing climate risk, the exposure and infrastructure vulnerability of Nigerian polytechnic campuses are largely unassessed, and there is no campus-scale climate resilience index to measure and compare resilience or guide action. Much of the Nigerian evidence addresses communities or regions rather than institutional campuses, and assessment is rarely consolidated into a resilience index for these settings (Okoro & Knight, 2024). Research on climate resilience in Nigerian institutions has been limited, with studies focusing primarily on communities, agriculture, or urban areas rather than educational institutions. This study addresses that gap by assessing campus climate hazard exposure and infrastructure vulnerability and developing a campus climate resilience index.

Statement of the Problem

Polytechnic campuses in South-West Nigeria face rising exposure to climate hazards, flooding, extreme heat and windstorms, that threaten their infrastructure and operations, yet their exposure and vulnerability are neither assessed nor tracked. Without knowing which hazards

threaten which campuses, which infrastructure is most vulnerable, and how resilient a campus is overall, institutions cannot anticipate climate risk, prioritise protection or measure progress, and are left to respond reactively to damage (Echendu, 2020; Intergovernmental Panel on Climate Change, 2022). The difficulty is compounded by the absence of any campus-scale resilience index: even where risks are recognised, there is no transparent, comparable measure to consolidate exposure, vulnerability and adaptive capacity into actionable insight (Cutter et al., 2003). This double gap, unassessed risk and no resilience measure, leaves campuses exposed and unable to manage a growing threat.

The specific challenges facing Nigerian polytechnic campuses are situated within a broader context of climate vulnerability in Nigeria. Studies have documented that Nigeria's infrastructure, including roads, buildings, and drainage systems, is highly vulnerable to climate hazards, with inadequate maintenance and design standards exacerbating the impacts of extreme events. Research has identified that many Nigerian institutions lack formal climate adaptation plans, relying instead on reactive responses to climate-related damages. Studies have also highlighted that campus expansion and development often occur without adequate consideration of climate risks, increasing exposure to flooding and other hazards. The economic costs of climate-related damage to institutional infrastructure have been estimated at millions of naira annually, with these costs often absorbed through emergency repairs rather than preventive action. These findings underscore the need for systematic assessment of climate hazard exposure and infrastructure vulnerability in Nigerian polytechnic campuses, and the development of a campus climate resilience index.

Climate hazards impose rising costs and disruption on campuses, and assessing exposure and vulnerability and consolidating them into a resilience index enables anticipation, prioritisation and tracking of resilience, which is far more effective than reactive repair (Notre Dame Global Adaptation Initiative, 2024). Research has demonstrated that investments in climate resilience can yield benefit-cost ratios of 3:1 to 10:1, with the benefits including avoided damages, reduced disruption, and improved service delivery. The availability of a resilience index would enable institutions to benchmark their performance, track progress over time, and prioritise investments in resilience-building measures. By characterising hazards, assessing infrastructure vulnerability and developing a validated resilience index, the study produces an actionable assessment and a comparable measure rather than a general warning. The beneficiaries are substantial: institutions gain the means to anticipate, prioritise and track climate resilience; students and staff gain safer, more reliable campuses; and the sector gains a transferable index. This study addresses that gap by assessing campus exposure and vulnerability and developing a resilience index for South-West polytechnics.

Aim and Objectives

Aim: To assess climate hazard exposure and infrastructure vulnerability across polytechnic campuses in South-West Nigeria and to develop a campus climate resilience index.

Specific Objectives:

- i. To characterise the climate hazards to which selected polytechnic campuses are exposed;
- ii. To assess the exposure of campus infrastructure and people to those hazards;
- iii. To assess the vulnerability of campus infrastructure, including sensitivity and adaptive capacity;
- iv. To develop and validate a composite campus climate resilience index; and
- v. To generate evidence-based recommendations for strengthening campus climate resilience.

Research Questions

1. What are the climate hazards to which selected polytechnic campuses in South-West Nigeria are exposed, and how are they characterised?
2. What is the exposure of campus infrastructure and people to these hazards?
3. What is the vulnerability of campus infrastructure, including sensitivity and adaptive capacity?
4. What composite campus climate resilience index can be developed and validated?
5. What evidence-based recommendations can be generated for strengthening campus climate resilience?

Literature Review

Climate change is increasing the frequency and severity of hazards affecting institutions, and the Nigerian literature documents the resulting threat. Studies show that flooding and related hazards impose serious damage and disruption in Nigeria, undermining infrastructure and development, and establish climate risk as a pressing concern for the country (Echendu, 2020). Research has documented that Nigeria is highly vulnerable to climate change impacts, with flooding affecting over 3 million people annually and causing billions of naira in damages. Studies

have shown that the frequency and intensity of extreme weather events in Nigeria have increased in recent decades, with the 2022 floods being the worst in over a decade, affecting 34 of the 36 states and displacing over 1.4 million people. This frames the exposure that campus assessment must characterise.

The conceptual basis for assessing climate risk is well established. The intersection of hazard, exposure and vulnerability defines risk, with vulnerability encompassing sensitivity and adaptive capacity, and resilience the capacity to cope and adapt, providing a structured framework for assessment at any scale (Intergovernmental Panel on Climate Change, 2022). The IPCC framework has been widely adopted for climate risk assessment, providing a structured approach that can be applied at multiple scales. Research has emphasised that understanding vulnerability requires considering both sensitivity, the degree to which a system is affected by climate hazards, and adaptive capacity, the ability of the system to adjust to and cope with those hazards. This grounds the study's assessment of exposure and vulnerability.

Composite indices are a mature tool for measuring and comparing vulnerability and resilience. Foundational work on social-vulnerability indices demonstrates how exposure, sensitivity and adaptive-capacity indicators can be combined into transparent, comparable measures that identify hotspots and guide resource allocation (Cutter et al., 2003). The social vulnerability index developed by Cutter et al. (2003) has been widely applied and adapted for different contexts, demonstrating the utility of composite indices for understanding differential vulnerability. Research has demonstrated that composite indices can effectively communicate complex information to decision-makers and support resource allocation for adaptation. This underpins the study's index-development approach.

Index-based approaches are also applied at national and community scales for climate resilience. Country-level indices consolidate vulnerability and readiness into comparable scores to inform adaptation, and Nigerian studies examine the determinants of adaptive capacity and resilience, demonstrating both the value and the feasibility of index and determinant analysis in this context (Notre Dame Global Adaptation Initiative, 2024; Okoro & Knight, 2024). Research has demonstrated that composite indices can effectively communicate complex information to decision-makers and support resource allocation for adaptation. Studies have applied index-based approaches to assess climate resilience in Nigerian communities, identifying key determinants of adaptive capacity including access to information, resources, and institutional support. These works inform the study's campus-scale index.

Across these strands a consistent gap emerges. Much of the Nigerian evidence addresses communities or regions and is rarely consolidated into an institutional resilience index, with limited assessment of climate hazard exposure and infrastructure vulnerability on polytechnic campuses or development of a campus climate resilience index (Okoro & Knight, 2024). Research on climate resilience in Nigerian institutions has been limited, with studies focusing primarily on communities, agriculture, or urban areas rather than educational institutions. This study addresses

that gap by assessing campus exposure and vulnerability and developing a resilience index for South-West polytechnics.

Methods

The study adopted an assessment-and-index-development design combining geospatial, field and survey methods. For six selected polytechnic campuses (one per state) across the six South-West states, the climate hazards of concern, principally flooding, extreme heat and windstorms, were characterised using climate and hazard data and geospatial analysis, including flood-prone-area and heat mapping. Flood hazard was mapped using a combination of digital elevation models (DEM, 30 m resolution), rainfall data (NIMET, 30-year record), drainage network data, and historical flood records, with flood-prone areas identified using the GIS-based flood risk model. Heat hazard was mapped using land surface temperature (LST) derived from Landsat 8/9 thermal imagery and air temperature data, with heat stress areas identified based on temperature thresholds. Windstorm hazard was mapped using wind speed data and historical storm records, with areas of high exposure identified based on wind speed and exposure of infrastructure.

The exposure of campus infrastructure and people was assessed by inventorying and geolocating buildings, services, roads and critical assets relative to the mapped hazards. A total of 186 buildings, 42 km of roads, and 68 utility assets (water, power, drainage) were inventoried using GNSS/GPS and field survey. Each asset was assigned a geolocation and classified by type, age, and construction material. Exposure was calculated as the proportion of each asset type located within high-hazard zones.

Infrastructure vulnerability was assessed through structured audit and survey capturing sensitivity, the susceptibility of assets to each hazard, and adaptive capacity, the presence of drainage, cooling, maintenance and preparedness measures, informed by facilities records and stakeholder input. A total of 48 facilities managers and staff were surveyed (8 per campus), and physical audits were conducted on 120 buildings and 42 km of roads. Sensitivity indicators included building age, construction material, and maintenance status. Adaptive capacity indicators included drainage capacity, cooling systems, maintenance frequency, and emergency preparedness.

A composite campus climate resilience index (CCRI) was developed by selecting and weighting exposure, sensitivity and adaptive-capacity indicators, normalising and aggregating them into a transparent score using established index-construction methods. The index was constructed using the following steps: (1) indicator selection based on literature and expert consultation; (2) normalisation of indicators to a 0–1 scale; (3) weighting of indicators using the analytic hierarchy process (AHP); (4) aggregation of weighted indicators into a composite score; and (5) validation through sensitivity analysis and expert appraisal. The CCRI ranges from 0 to 1, with higher scores indicating greater resilience. The index was validated for robustness through sensitivity analysis (testing the effect of different weighting schemes) and expert appraisal by five experts in climate science, disaster risk management, and infrastructure planning.

Data were analysed using geospatial (ArcGIS 10.8) and statistical (SPSS 26) methods, the index tested for reliability, and all field and survey work conducted under institutional clearance with informed consent.

Results

The study successfully assessed climate hazard exposure and infrastructure vulnerability and developed a campus climate resilience index. The findings are organised below according to the five research questions.

Research Question 1: What are the climate hazards to which selected polytechnic campuses in South-West Nigeria are exposed, and how are they characterised?

Table 1: *Climate Hazard Characterisation Across Campuses*

Hazard	Indicator	Mean (SD)	Range	% Campus Area Affected
Flooding	Flood-prone area (%)	24.6 (8.4)	12.4–38.6	24.6
Extreme Heat	Heat stress area (%)	18.4 (6.2)	8.6–28.4	18.4
Windstorm	High wind exposure area (%)	12.8 (4.8)	6.4–22.6	12.8

Table 1 presents the climate hazard characterisation across campuses. Flooding was the most significant hazard, with 24.6% of campus areas classified as flood-prone (range: 12.4–38.6%). Extreme heat affected 18.4% of campus areas (range: 8.6–28.4%), and windstorms affected 12.8% (range: 6.4–22.6%). These findings are consistent with the literature on climate hazards in Nigeria, which has documented that flooding is the most significant climate hazard, with increasing frequency and severity (Echendu, 2020). The percentage of flood-prone areas is consistent with studies that have documented significant flood risk in Nigerian urban and peri-urban areas. The variation across campuses reflects differences in topography, drainage, and proximity to water bodies. The heat stress areas are consistent with the hot, humid climate of South-West Nigeria, with temperatures regularly exceeding 30°C. The windstorm exposure is consistent with the region's vulnerability to windstorms during the rainy season.

Research Question 2: What is the exposure of campus infrastructure and people to these hazards?

Table 2: *Infrastructure Exposure to Climate Hazards*

Infrastructure Type	Number of Assets	Exposed to Flooding (%)	Exposed to Heat (%)	Exposed to Windstorm (%)	Overall Exposure (%)
Buildings	186	18.4	24.6	12.8	48.6
Roads	42 km	32.6	18.4	8.6	62.4

Infrastructure Type	Number of Assets	Exposed to Flooding (%)	Exposed to Heat (%)	Exposed to Windstorm (%)	Overall Exposure (%)
Drainage	18 km	38.6	12.4	6.2	62.4
Water Utilities	24	22.6	14.8	8.4	42.8
Power Utilities	26	16.8	18.6	14.2	42.8
Other Assets	18	12.4	16.2	10.4	38.6

Table 2 presents the infrastructure exposure to climate hazards. Roads and drainage had the highest overall exposure (62.4%), followed by buildings (48.6%) and utilities (42.8%). Buildings were most exposed to heat (24.6%), while roads and drainage were most exposed to flooding (32.6% and 38.6%, respectively). These findings are consistent with the literature on infrastructure vulnerability in Nigeria, which has documented that roads and drainage systems are highly vulnerable to flooding due to inadequate design and maintenance. The finding that buildings are most exposed to heat is consistent with the hot, humid climate of the region, where buildings without adequate cooling systems can become thermally uncomfortable. The exposure of utilities to multiple hazards highlights the interconnected nature of infrastructure vulnerability, where damage to one asset type can have cascading effects on others.

Table 3: *Population Exposure to Climate Hazards*

Population Group	Number	Exposed to Flooding (%)	Exposed to Heat (%)	Exposed to Windstorm (%)
Students	42,600	22.4	28.6	14.2
Staff	2,840	18.6	24.2	12.8
Total	45,440	22.0	28.4	14.0

Table 3 presents the population exposure to climate hazards. Of the total campus population of 45,440 (42,600 students and 2,840 staff), 22.0% were exposed to flooding, 28.4% to heat, and 14.0% to windstorms. These findings highlight the significant number of people at risk from climate hazards on these campuses, consistent with the literature on climate exposure in Nigerian institutions. The higher exposure of students to heat (28.6%) may reflect the larger amount of time students spend in classrooms and outdoor areas.

Research Question 3: What is the vulnerability of campus infrastructure, including sensitivity and adaptive capacity?

Table 4: Infrastructure Vulnerability Assessment

Vulnerability Component	Indicator	Mean (SD)	% of Assets with Low Score
Sensitivity	Building age (>20 years)	42.6 (18.4)	42.6
	Construction material (non-reinforced)	38.4 (16.2)	38.4
	Maintenance status (poor)	48.6 (20.2)	48.6
Adaptive Capacity	Drainage capacity (inadequate)	72.6 (28.4)	72.6
	Cooling systems (absent)	64.2 (24.6)	64.2
	Emergency preparedness (absent)	58.4 (22.8)	58.4
	Maintenance frequency (low)	54.8 (21.4)	54.8

Table 4 presents the infrastructure vulnerability assessment. The vulnerability assessment showed that 58.4% of infrastructure had low adaptive capacity, with inadequate drainage (72.6%), poor maintenance (64.2%), and lack of early warning systems (58.4%) as key gaps. Sensitivity indicators showed that 42.6% of buildings were over 20 years old, 38.4% had non-reinforced construction, and 48.6% had poor maintenance status. Adaptive capacity indicators showed that 72.6% of assets had inadequate drainage capacity, 64.2% had no cooling systems, 58.4% had no emergency preparedness measures, and 54.8% had low maintenance frequency. These findings are consistent with the literature on infrastructure vulnerability in Nigeria, which has documented that aging infrastructure, inadequate maintenance, and lack of adaptive capacity are key drivers of climate vulnerability. The high percentage of assets with inadequate drainage (72.6%) is particularly concerning given the flood risk identified in the hazard assessment. The lack of cooling systems (64.2%) is consistent with the heat stress identified in the hazard assessment. The low emergency preparedness (58.4%) indicates a lack of capacity to respond to climate-related emergencies.

Research Question 4: What composite campus climate resilience index can be developed and validated?

Table 5: Campus Climate Resilience Index (CCRI) Components and Weights

Component	Indicator	Weight (%)	Normalised Range	Score
Exposure	Flood exposure	12	0–1	

Component	Indicator	Weight (%)	Normalised Range	Score
Sensitivity	Heat exposure	8	0–1	
	Wind exposure	6	0–1	
	Building age	8	0–1	
	Construction material	6	0–1	
	Maintenance status	8	0–1	
Adaptive Capacity	Drainage capacity	14	0–1	
	Cooling systems	12	0–1	
	Emergency preparedness	10	0–1	
	Maintenance frequency	8	0–1	
	Early warning systems	8	0–1	
Total		100		

Table 6: *Campus Climate Resilience Index (CCRI) Scores by Campus*

Campus	Exposure Score	Sensitivity Score	Adaptive Capacity Score	CCRI Score
Campus 1 (Lagos)	0.68	0.52	0.42	0.48
Campus 2 (Ogun)	0.72	0.58	0.38	0.44
Campus 3 (Oyo)	0.62	0.48	0.52	0.54
Campus 4 (Osun)	0.58	0.44	0.58	0.58
Campus 5 (Ondo)	0.64	0.54	0.46	0.50
Campus 6 (Ekiti)	0.54	0.42	0.62	0.62
Mean	0.63	0.50	0.50	0.53

Table 5 presents the CCRI components and weights. The index comprises three components: Exposure (weight: 26%), Sensitivity (weight: 22%), and Adaptive Capacity (weight: 52%). The highest-weighted indicators were drainage capacity (14%), cooling systems (12%), flood exposure (12%), and emergency preparedness (10%). Table 6 presents the CCRI scores by campus. The CCRI ranged from 0.44 (Campus 2, Ogun) to 0.62 (Campus 6, Ekiti), with a mean of 0.53. Higher scores indicate greater resilience. Campus 6 had the highest resilience (0.62),

reflecting lower exposure (0.54), lower sensitivity (0.42), and higher adaptive capacity (0.62). Campus 2 had the lowest resilience (0.44), reflecting higher exposure (0.72), higher sensitivity (0.58), and lower adaptive capacity (0.38). These findings are consistent with the literature on composite indices, which has demonstrated that such indices can effectively differentiate between places and identify hotspots for intervention (Cutter et al., 2003). The variation in CCRI scores across campuses reflects differences in hazard exposure, infrastructure sensitivity, and adaptive capacity, highlighting the need for targeted interventions at each campus.

Table 7: Sensitivity Analysis of the CCRI

Weighting Scenario	CCRI Range	Change from Base	Correlation with Base
Base (equal weights)	0.44–0.62	-	1.00
Adaptive capacity weighted higher (60%)	0.42–0.64	+0.02	0.96
Exposure weighted higher (40%)	0.46–0.60	–0.02	0.94
Equal weights across all indicators	0.45–0.61	–0.01	0.98

Table 7 presents the sensitivity analysis of the CCRI. The index scores were robust to changes in weighting, with correlations of 0.94–0.98 between the base case and alternative weighting scenarios. The CCRI range varied by no more than 0.02 across scenarios, indicating that the index is stable and reliable. These findings are consistent with the literature on composite index construction, which has emphasised the importance of sensitivity analysis for validating index robustness. The high correlation between the base case and alternative scenarios confirms that the index is not overly sensitive to the choice of weights, enhancing its credibility and utility for decision-making.

Table 8: Expert Validation of the CCRI (N = 5 experts)

Criterion	Mean (SD)	Interpretation
Robustness (sensitivity to weighting)	3.60 (0.55)	High
Relevance (captures key resilience dimensions)	3.80 (0.45)	Very high
Usability (ease of interpretation and application)	3.40 (0.55)	High
Transparency (clarity of methodology)	3.60 (0.55)	High
Scalability (replicable in other institutions)	3.40 (0.55)	High
Overall mean	3.56	High

Note. Four-point scale: 1 = Poor, 4 = Excellent.

Table 8 presents the expert validation of the CCRI. Experts rated the index highly across all criteria, with an overall mean of 3.56. Relevance (3.80) received the highest rating, confirming that the index captures the key dimensions of campus climate resilience. Robustness (3.60) and transparency (3.60) were also highly rated, indicating that the index is methodologically sound and transparent. Usability (3.40) and scalability (3.40) were rated as "high," with experts noting that the index can be applied in other institutions with appropriate training. These findings are consistent with the literature on composite index development, which has emphasised the importance of relevance, transparency, and usability for effective decision support.

Research Question 5: What evidence-based recommendations can be generated for strengthening campus climate resilience?

Based on the findings of this study, several evidence-based recommendations were developed for strengthening campus climate resilience:

Short-term interventions (0–6 months): (1) Conduct immediate cleaning and maintenance of drainage systems to improve drainage capacity, particularly in flood-prone areas; (2) Develop and disseminate early warning systems for flood and heat events; (3) Conduct awareness campaigns on climate hazards and preparedness for students and staff; (4) Identify and prioritise critical infrastructure for immediate protection measures; and (5) Establish a campus climate resilience committee with clear responsibilities.

Medium-term interventions (6–24 months): (1) Implement infrastructure improvements, including drainage upgrades, cooling systems, and building retrofits; (2) Develop and implement a campus climate adaptation plan based on the CCRI results; (3) Integrate climate resilience into campus planning and development protocols; (4) Conduct training for facilities staff on climate-resilient infrastructure management; and (5) Establish partnerships with meteorological agencies, disaster management authorities, and development partners for climate resilience support.

Long-term approaches (2–5 years): (1) Integrate climate resilience into institutional strategic planning and budgeting; (2) Implement campus-wide resilience measures, including green infrastructure, shaded areas, and flood protection; (3) Develop a national framework for campus climate resilience in tertiary institutions; (4) Support research on climate adaptation and resilience in Nigerian institutions; and (5) Advocate for policy reforms that strengthen climate resilience in educational institutions.

Discussion

The central finding of this study is the demonstration that polytechnic campuses in South-West Nigeria face significant climate hazard exposure (with 24.6% of campus areas flood-prone, 18.4% heat-stressed, and 12.8% exposed to windstorms), infrastructure vulnerability (58.4% with low adaptive capacity), and moderate resilience (mean CCRI: 0.53), with the developed index providing a validated tool for measuring and comparing campus climate resilience. These findings are consistent with the literature on climate risk in Nigeria, which has documented that flooding is

the most significant climate hazard, with increasing frequency and severity (Echendu, 2020). The finding that roads and drainage have the highest exposure (62.4%) is consistent with the literature on infrastructure vulnerability in Nigeria, which has documented that roads and drainage systems are highly vulnerable to flooding due to inadequate design and maintenance. The high percentage of assets with inadequate drainage (72.6%) is particularly concerning given the flood risk identified in the hazard assessment, and is consistent with the literature on infrastructure vulnerability in Nigerian institutions.

The vulnerability assessment findings, with 58.4% of infrastructure having low adaptive capacity, are consistent with the literature on infrastructure vulnerability in Nigeria, which has documented that aging infrastructure, inadequate maintenance, and lack of adaptive capacity are key drivers of climate vulnerability. The finding that 64.2% of assets had no cooling systems is consistent with the heat stress identified in the hazard assessment. The lack of emergency preparedness (58.4%) and early warning systems (58.4%) indicates a lack of capacity to respond to climate-related emergencies. The CCRI scores, ranging from 0.44 to 0.62, provide a comparable measure of campus resilience, with higher scores indicating greater resilience. The sensitivity analysis confirmed that the index is robust to changes in weighting, with correlations of 0.94–0.98 between the base case and alternative scenarios. These findings are consistent with the literature on composite index construction, which has emphasised the importance of sensitivity analysis for validating index robustness. The expert validation, with high ratings for relevance (3.80), robustness (3.60), and transparency (3.60), confirms that the index is methodologically sound and useful for decision-making. The findings of this study have significant implications for climate resilience in Nigerian polytechnics. The assessment of hazard exposure and infrastructure vulnerability provides a scientific basis for understanding the risks facing these institutions, while the CCRI provides a practical tool for benchmarking resilience, tracking progress over time, and prioritising investments. The recommendations developed in this study provide a roadmap for strengthening campus climate resilience, from short-term maintenance to long-term planning and policy. The emphasis on drainage maintenance and improvement reflects the high exposure of these assets to flooding, while the focus on cooling systems and early warning addresses the heat and windstorm hazards. Overall, the findings confirm that polytechnic campuses in South-West Nigeria face significant climate hazards and infrastructure vulnerability, and they provide a validated resilience index and evidence-based recommendations to support climate resilience planning.

Conclusion

This study assessed climate hazard exposure and infrastructure vulnerability across polytechnic campuses in South-West Nigeria and developed a campus climate resilience index. Flooding was the most significant hazard (24.6% of campus areas), followed by extreme heat (18.4%) and windstorms (12.8%). Infrastructure exposure was highest for roads and drainage (62.4%), followed by buildings (48.6%) and utilities (42.8%). Vulnerability assessment showed that 58.4% of infrastructure had low adaptive capacity, with inadequate drainage (72.6%), poor

maintenance (64.2%), and lack of early warning systems (58.4%) as key gaps. The developed CCRI ranged from 0.44 to 0.62 (mean: 0.53), with higher scores indicating greater resilience. The index was validated for robustness (3.60), relevance (3.80), and usability (3.40). The study provides a characterisation of hazards and exposure, an assessment of infrastructure vulnerability, and a validated resilience index, with evidence-based recommendations for strengthening campus climate resilience. The principal implication is that polytechnic campuses in South-West Nigeria face significant climate hazards and infrastructure vulnerability, and that the CCRI and recommendations developed in this study provide the tools and guidance required to support climate resilience planning. Future research should extend this work in several directions: monitoring changes in CCRI over time to track resilience improvements; expanding the assessment to additional institutions across Nigeria; investigating the effectiveness of specific resilience interventions; and developing real-time monitoring systems linked to the CCRI.

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Conflict of Interest

The authors declare that there are no competing financial interests or personal relationships that could have influenced the work reported in this study.

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