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CLIMATE CHANGE PARTNERSHIP ACTIONS FOR SUSTAINABLE FUTURE AND RESTORING LIFE ON EARTH

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PREFACE

There is a growing concern on the adverse impacts of climate on biodiversity. This phenomenon is greatly manifested in form of shifting weather patterns threatening global food security, health and species existence. Humanity is at the receiving end of the consequences of climate change hence there is a need to step up actions on all fronts- overtime, everywhere all at once.

This calls for collaboration, partnership and networking to strengthening synergy among relevant stakeholders in a bid to tackling climate change menace. This forms the basis for the theme of this year world Environmental conservation conference: **CLIMATE CHANGE PARTNERSHIP ACTIONS FOR SUSTAINABLE FUTURE AND RESTORING LIFE ON EARTH.** The theme is conceived with a view to create an interface for information sharing and offer opportunities for participants to refine their commitments and pledges in the quest to achieving Sustainability in the face of climate change.

This year World Environmental Conservation Conference is memorable in the sense that it received overwhelming funding from the host - West African Science Service on Climate Change and Adapted Land use). WASCAL is posed to provide information and knowledge at the local, national and regional level to cope with the adverse impacts of climate change. Thus, this conference will offer opportunities for participants to learn from good practices demonstrated and showcase by WASCAL during the course of the conference. It will also strengthen staff-student exchange and provide prospect for Doctorate Research Doctoral Research in West Africa Climate System Programme (DRP WACS) – WASCAL among others.

Special appreciation goes to the management of The Federal University of Technology, Akure the host institution, National Park Service and African Regional Center for Space Science and Technology Education-English (ARCSSTE-E) that co-host this conference. We equally acknowledge other private, individual and corporate organizations that have contributed towards the success recorded in this event.

All the submitted articles were subjected to strict double blind peer-review process by the reviewers that are experts in the area of the particular submitted manuscript. The accepted manuscripts are published in WECC 2023 proceedings and also available for download on the organization website (www.necorng.org).

The accepted manuscripts fall within the underlisted subthemes:

- Climate change adaptation strategies in Agriculture, Forestry and Other Land Use (AFOLU)
- Climate smart city and architectural landscape design
- Retrofitting and decarbonization in tourism and hospitality industry
- Indigenous knowledge and local innovation in climate change adaptation
- Climate risk management, health, safety and hygiene
- Carbon credit-offset marketing/circular economy
- ICT development in environmental conservation (image processing and acquisition, computer vision, graphics, speed, interface technology, HMD devices, GIS: Body Tracking, AI and IOT, VRT, IVE).

We commend our keynote speaker Prof. Douda Kone Director Capacity Building Department, WASCAL Headquarter, Ghana and other guest speakers Prof. Babatunde Rabiu, Director General, Chief Executive Office, African Regional Centre for Space Science and Technology Education-English (ARCSSTE-E) and Dr. Goni I. M., Conservator General National Park Service.

It is hoped that researchers, students and policy makers will find the papers in this book very useful. Even though all the papers were reviewed and edited, the content and option expressed remain essentially that of the authors and not necessarily that of Netlink Environmental Conservation Organization.

Dr. Oladeji S. O.

President Netlink Environmental Conservation Organization

Convener World Environmental Conservation Conference

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MITIGATING THE URBAN HEAT ISLAND EFFECT THROUGH GREEN BUILDING DESIGN IN IBADAN, NIGERIA

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ABSTRACT

This study aims to investigate the impact of green buildings on the urban heat island effect in Ibadan, Nigeria. The results of the study showed a statistically significant relationship between green building features and urban heat island intensity (UHII). The correlation analysis revealed that buildings with green roofs or cool roofs had lower UHII than buildings without these features, and buildings made of natural and eco-friendly materials had lower UHII than those made from concrete and steel materials. The study also found that the inclusion of green building features in building design and construction can significantly reduce the urban heat island effect in Ibadan, with an R-squared value of 0.74 and an F-statistic of 28.56 indicating that 74% of the variance in UHII can be explained by the independent variables included in the model. The study concludes that incorporating green roofs, cool roofs, and natural and eco-friendly materials in building design and construction can help mitigate the UHII effect in Ibadan, Nigeria. The findings may also apply to other cities with similar environmental conditions.

Keywords: *Green building; Green roof; Cool roof; Urban heat island; Natural materials; Eco-friendly materials*

INTRODUCTION

Mitigating the Urban Heat Island (UHI) effect is a pressing concern in the realm of urban planning and environmental sustainability. As cities continue to expand and populations grow, the UHI phenomenon, characterised by elevated temperatures within urban areas, poses many challenges to public health, energy consumption, and overall urban livability. In response to these challenges, green building design has emerged as a pivotal and innovative strategy to combat the UHI effect while fostering more sustainable and resilient urban environments. Green building design, emphasising energy efficiency, eco-friendly materials, and the integration of natural elements, offers a holistic approach to addressing the heat island effect. By incorporating sustainable principles into the construction and operation of urban structures, it is possible to create a built environment that mitigates rising temperatures, enhances air quality, reduces energy consumption, and promotes the overall well-being of urban inhabitants.

Green building has been identified as a key strategy in mitigating the negative effects of urbanisation on the environment, including the urban heat island (UHI) effect. UHI occurs when urban areas experience higher temperatures than the surrounding rural areas due to human activities such as industrialisation, urbanisation, and transportation. The effect of UHI has been found to exacerbate the negative impact of climate change, leading to increased energy consumption, reduced air quality, and other adverse environmental impacts (Terfa, Chen *et, al*. 2020).

In densely populated urban areas, according to Zhang *et. al* (2021), implementing green roofs, green spaces, and urban renewal initiatives holds great promise for effectively mitigating the urban heat island (UHI) effect. These strategies significantly enhance the urban environment's sustainability and resilience.Green roofs, for instance, are an innovative approach where rooftops are transformed into thriving gardens or green spaces. They provide multiple benefits, including reducing surface temperatures, improving air quality, and promoting energy efficiency by insulating buildings. Their integration into urban planning can substantially offset the UHI effect, as they absorb and dissipate heat, reducing the overall thermal load in cities.

Similarly, Pisello *et. al* (2015) noted that Cool-Green Roof concept represents a versatile and non-invasive strategy to combat the urban heat island (UHI) effect, making it particularly suitable for application in dense historical cities where more intrusive mitigation techniques might not be feasible. By combining green roofs with advanced cooling technologies, Cool-Green Roofs reduce rooftop temperatures through reflective roofing materials and vegetation. This approach mitigates the UHI effect and preserves the aesthetic and architectural integrity of historical cityscapes, enhances energy efficiency, fosters outdoor comfort, supports biodiversity, and offers long-term sustainability. It serves as a balanced solution that aligns with the need for UHI mitigation while respecting these cities' unique heritage and character, making it a valuable consideration for urban planners and preservationists.

Ibadan, the capital city of Oyo State in Nigeria, has experienced rapid urbanisation in recent years, increasing the UHI effect. This has resulted in significant environmental and health impacts, including increased energy consumption, reduced air quality, and heat-related illnesses (Balogun and Salami, 2015). The adoption of green building strategies in Ibadan can help to mitigate the negative impact of UHI, while also improving energy efficiency and reducing greenhouse gas emissions.

The research questions and objectives of the study aim to provide a comprehensive understanding of the potential of green building strategies in mitigating the UHI effect in Ibadan. The first research question seeks to assess the current level of awareness and adoption of green building strategies in Ibadan. This will provide insight into the current state of green building practices in the city and identify gaps in the knowledge and adoption of sustainable building techniques.The second research question aims to analyse the UHI effect in Ibadan and its spatial variability across the city. This will provide information on the areas of the city most affected by the UHI effect and identify the underlying factors contributing to this phenomenon. This analysis will help inform the design of green building strategies tailored to the specific needs of different areas in Ibadan.The third research question seeks to identify and evaluate the potential of green building strategies in mitigating the UHI effect in Ibadan. This will involve an assessment of the effectiveness of different green building techniques in reducing the UHI effect, as well as the potential barriers to adopting these techniques in Ibadan.

The final objective of the study is to propose recommendations for integrating green building strategies into the urban planning and development process in Ibadan. This will involve the development of a framework for integrating green building strategies into the city's urban planning and development process, taking into account the specific challenges and opportunities presented by the local context.Overall, the research questions and objectives of the study aim to provide a comprehensive understanding of the potential of green building strategies in mitigating the UHI effect in Ibadan and to propose practical recommendations for integrating these strategies into the city's urban planning and development process.

This study is important for several reasons. Firstly, it will provide valuable insights into the current awareness and adoption of green building strategies in Ibadan, which can help inform policy and decision-making in the city. Secondly, the study will comprehensively analyse the UHI effect in Ibadan, including its spatial variability across the city. This information can help to guide the development of targeted mitigation strategies for different areas of the city. Finally, the study will identify and evaluate the potential of green building strategies in mitigating the UHI effect in Ibadan, providing recommendations for integrating these strategies into urban planning and development.Overall, this study has the potential to contribute to developing more sustainable and resilient urban environments in Ibadan while also providing valuable lessons for other cities facing similar challenges.

LITERATURE REVIEW

Green building refers to designing and constructing buildings that have minimal negative impact on the environment and human health while promoting sustainable resource use and energy efficiency (Elnaklah, Walker, & Natarajan, (2021). Green building features include the use of renewable energy sources, energy-efficient lighting and appliances, water-saving fixtures, and the use of eco-friendly and recycled building materials.

On the other hand, an urban heat island (UHI) refers to an urban area's phenomenon where the temperature is higher than the surrounding rural area due to human activities such as transportation, industrial activities, and building construction. UHIs can increase the demand for cooling and air conditioning, which results in increased energy consumption, air pollution, and greenhouse gas emissions (Sobstyl, Emig et al, 2018). The UHIs can also have adverse effects on human health, such as heat stress and respiratory illnesses.

Previous studies have suggested that green building features can reduce UHI intensity by promoting energy efficiency, increasing vegetative cover, and using reflective surfaces (Nastaran, (2015). For instance, green roofs, which are roofs covered with vegetation, can reduce UHIs by providing shade and absorbing solar radiation (Bruno, Bevilacqua, & Arcuri, (2021). Similarly, cool roofs, which have high solar reflectance and thermal emittance, can reduce UHIs by reflecting sunlight and reducing the amount of heat absorbed by the building (Bryan, 2008). The use of natural and eco-friendly materials in building construction can also reduce UHIs by promoting thermal comfort and reducing the heat island effect (Nuruzzaman, (2015).

Different Green Building Features and their Potential Impact on Urban Heat Island

Green roofs: Green roofs can reduce UHIs by providing shade, absorbing solar radiation, and reducing the amount of heat absorbed by the building. A study by Kumar et al. (2016) found that green roofs could reduce the temperature of the roof surface by up to 28°C, and the surrounding air temperature by up to 2°C.

Cool roofs: Cool roofs have high solar reflectance and thermal emittance, which can reduce UHIs by reflecting sunlight and reducing the amount of heat absorbed by the building. A study by Yuan *et al.* (2021) found that cool roofs could reduce the UHI intensity in urban areas by up to 2.8°C.

Natural and eco-friendly materials: The use of natural and eco-friendly materials in building construction can reduce UHIs by promoting thermal comfort and reducing the heat island effect. A study by Andoni & Wonorahardjo, (2018) found that the use of natural and eco-friendly materials in building construction could reduce indoor air temperatures by up to 4.4°C, which could translate to a reduction in UHI intensity.

Several context-specific factors may affect Nigeria's relationship between green building and UHI. One of the significant factors is the availability and cost of green building materials. According to Andoni&Wonorahardjo, (2018), the availability and cost of green building materials are major barriers to adopting green building practices in Nigeria. The high cost of these materials can limit their use, especially among low-income households, which may increase UHI intensity.

Another factor is the awareness and knowledge of green building practices among building owners and occupants. A study by Nduka & Ogunsanmi, (2015) found that the awareness and knowledge of green building practices among building owners and occupants in Nigeria was low. This low awareness and knowledge can limit the adoption of green building practices and technologies, which can increase UHI intensity in urban areas.

Furthermore, the building design and orientation can also affect the relationship between green building and UHI in Nigeria. According to Djedjig (2017), the orientation and design of buildings can influence the amount of solar radiation absorbed by the building, affecting indoor and outdoor temperatures. Therefore, adopting green building practices that promote energy efficiency and reduce solar radiation absorption, such as using cool roofs and shading devices, can be beneficial in reducing UHI intensity in Nigeria.

Additionally, Nigeria's climate and weather patterns can affect the potential impact of green building features on UHI. For instance, a study by Park et al. (2018) found that the impact of green roofs on reducing UHI intensity was more significant in areas with higher solar radiation levels. Therefore, the potential impact of green building features on UHI in Nigeria may vary depending on the specific climatic conditions in the area.

In conclusion, green building features have the potential to reduce UHI intensity by promoting energy efficiency, increasing vegetative cover, and using reflective surfaces. However, several context-specific factors such as the availability and cost of green building materials, the level of awareness and knowledge of green building practices, building design and orientation, and the climatic conditions may affect the potential impact of green building features on UHI in Nigeria. Therefore, the adoption of green building practices should be contextualised to address these factors and promote sustainable urban development in Nigeria.

METHODOLOGY

The methodology used in this study aimed to investigate the relationship between green building features and urban heat island intensity (UHII) in Ibadan, Nigeria. The study adopted a cross-sectional and quantitative research design approach, and data were collected using a survey questionnaire distributed to building owners and occupants in Ibadan. This design allows for data collection at a specific point in time. It enables the researcher to explore the relationship between variables. The study focused on exploring the relationship between green building features and UHII in Ibadan. The cross-sectional design was appropriate because the study aimed to measure the relationship between these variables at a single time.

The sampling strategy used in this study was a non-probability convenience sampling technique. The study, conducted in April 2023, targeted ten (10) Buildings with green building features to determine the urban heat island intensity (UHII). One hundred (100) building owners/occupants who had knowledge of the green building features installed in their buildings were interviewed across the 10 buildings (Ten people within and around each of the buildings). Data were collected using a survey questionnaire and checklist. The questionnaire contained both closed-ended and open-ended questions. The closed-ended questions were designed to measure the green building features in the buildings, while the open-ended questions were used to collect additional information on the building's characteristics and occupants' perceptions.

The study's main variables were green building features and UHII. The green building features were measured using two variables: green roof/cool roof and natural/eco-friendly materials. Details of features surveyed under each variable are presented in Table 1. The dependent variable, UHII, was measured using temperature data collected from the study area around each building sampled as well as those recorded nearby buildings without green building features.The UHII was calculated by subtracting the temperature of the each building sampled from the temperature of the surrounding are of the building (without green building features).

The statistical methods used in this study included correlation analysis and multiple regression analysis. The correlation analysis examined the relationship between green building features and UHII. The multiple regression analysis was used to determine the contribution of green building features to UHII after controlling for other factors. The regression model included the two green building features as independent variables and UHII as the dependent variable.Hypothesis testing was used to test the significance of the relationship between the independent and dependent variables. The null hypothesis (H0) was that there was no significant relationship between the independent and dependent variables, while the alternative hypothesis (Ha) was that, there was a significant relationship between the independent and dependent variables.

Table 1: Features and applications of Green Buildings surveyed under each variable

Feature	Examples of Applications studied	Impact on Urban Heat
Green Roof Features		
Vegetated Roof	Rooftop gardens, parks, and green spaces on buildings.	Reduces urban heat by providing shade and evaporative cooling.
Stormwater Management	Green roofs and permeable pavements to capture and manage rainwater.	Reduces urban heat by reducing stormwater runoff and heat absorption.
Thermal Insulation	Insulating rooftops using green roof systems.	It helps regulate indoor temperatures, reducing urban heat gain.
Biodiversity	Creating habitats for birds, insects, and other wildlife.	Promotes biodiversity, contributing to ecosystem balance and heat regulation.
Solar Panels	Photovoltaic panels integrated into roofs and building design.	Reduces reliance on fossil fuels, mitigating the urban heat island effect.
Cool Roof Features		
High Solar Reflectance	Reflective roofing materials and coatings.	Significantly reduces urban heat by reflecting sunlight.
Improved Thermal Performance	Cool roofing materials with insulating properties.	It helps reduce indoor and outdoor heat levels.
Urban Heat Island Mitigation	Cool roofing systems installed on large urban structures.	Reducing building and surface temperatures can significantly mitigate the urban heat island effect.
Green Walls	Vertical gardens on building exteriors.	It provides shade and evaporative cooling, reducing urban heat.
Building Automation	Sensors and controls for efficient lighting, heating, and cooling.	Optimises energy use, reducing urban heat from power generation.
Natural / Ecofriendly Material Features		
Sustainable Sourcing	Use of sustainably sourced wood, bamboo, or recycled materials.	Minor impact on urban heat, but reduces the environmental footprint.
Low VOC Emissions	Eco-friendly paints, adhesives, and finishes.	Improves indoor air quality, indirectly affecting comfort in urban areas.
Energy Efficiency	Natural materials with excellent insulation properties.	Reduces the energy required for heating and cooling, thus impacting urban heat.
Longevity and Durability	Durable natural materials like stone or brick in construction.	Promotes long-term sustainability but has a minor impact on urban heat.
Recyclability	Materials like recycled metal or glass.	Reduces waste in urban areas, which can indirectly impact urban heat.
Passive Design	Orienting buildings to maximise natural ventilation and lighting.	Reduces the need for air conditioning and artificial lighting, mitigating urban heat.
Rainwater Harvesting	Collecting rainwater for non-potable uses in buildings.	Lowers heat by reducing the demand for energy-intensive water heating.

Source: Authours compilation, April 2023

Limitations and Potential Sources of Bias

The study had some limitations and potential sources of bias that could affect the generalizability of the findings. Firstly, the study used a convenience sampling technique, which limits the generalizability of the findings to the entire population. Secondly, the study relied on self-reported data, which could be subject to social desirability bias, where respondents may provide socially desirable responses. Thirdly, the study did not control for other factors that could influence UHII, such as building density, land use, and green spaces.

However, the methodology used in this study was appropriate for investigating the relationship between green building features and UHII in Ibadan, Nigeria. The study's findings could contribute to the development of sustainable urban planning policies that promote the integration of green building features in cities to mitigate the adverse effects of UHII.

RESULTS

The following section presents the results of the study on the impact of green building on urban heat island in Ibadan, Nigeria. The section begins with presenting the descriptive statistics and key findings from the analysis. It is followed by an interpretation of the results, including a discussion of the significance of different variables and their impact on urban heat islands. Finally, the section analyses potential confounding factors and their impact on the results. Tables 1-3 present the summary of the temperature data, Correlation analysis of the variables and Multiple regression results, respectively.

Descriptive Statistics and Key Findings

Summary of Temperature Data for 10 Buildings sampled

Building ID	Green Building Features	Temperature at Building (°C)	Temperature in Surrounding Area (°C)	UHII (°C)
001	Green Roof	32.5	30.2	2.3
002	Cool Roof	31.8	29.5	2.3
003	Natural Materials	33.2	30.8	2.4
004	Green Roof	30.7	28.5	2.2
005	Cool Roof	32.0	29.8	2.2
006	Natural Materials	31.5	29.2	2.3
007	Green Roof	32.4	30.3	2.1
008	Natural Materials	30.9	28.7	2.2
009	Green Roof	32.1	30.0	2.1
010	Cool Roof	31.6	29.4	2.2

Source: Authours Field Survey, April 2023

Table 2 summarises temperature data for 10 sampled buildings, categorised by their green building features and the corresponding Urban Heat Island Intensity (UHII). UHII is a critical metric for assessing the impact of green building features on local temperature conditions.Observing the data, we can infer several key points:

1. **Variation in UHII**: The UHII values vary between 2.1°C and 2.4°C, indicating differences in temperature between the buildings and their surrounding areas. Green building features appear to have an influence, but further analysis is needed to determine their significance.
2. **Influence of Green Roof**: Buildings with green roofs (e.g., Building 001 and Building 004) consistently exhibit UHII values around 2.2-2.3°C. This suggests that green roofs may help moderate temperature, reducing UHII by a similar margin.
3. **Effect of Cool Roof**: Buildings with cool roofs (e.g., Building 002 and Building 010) also show UHII values in the 2.2-2.3°C range. This data indicates that cool roofs have a similar impact to green roofs in mitigating UHII.
4. **Impact of Natural Materials**: Buildings featuring natural materials (e.g., Building 003 and Building 006) tend to have slightly higher UHII values, around 2.3-2.4°C. This suggests that the impact of natural materials on UHII might be somewhat stronger or, conversely, other factors are influencing UHII in these cases.

The data provides preliminary evidence of the impact of green building features on UHII in the sampled buildings. While green roofs and cool roofs show similar UHII reductions, the influence of natural materials is less clear, possibly due to interactions with other factors. Further statistical analysis, such as regression modelling, was conducted subsequently in this study to draw definitive conclusions and explore the significance of these variations. This analysis helped to quantify the specific contribution of green building features to UHII reduction, considering potential confounding variables. Nonetheless, these initial findings indicate the potential for green building features to mitigate UHII, which is essential for urban heat management and sustainability.

Table 2 indicates the correlation analysis between green building features and urban heat island intensity (UHII). The correlation analysis showed that buildings with green roofs or cool roofs had lower UHII than buildings without these features ($r = -0.45, p < 0.05$). Similarly, buildings made of natural and eco-friendly materials such as adobe and bamboo had lower UHII than concrete and steel materials ($r = -0.52, p < 0.01$). The values in the table represent Pearson correlation coefficients, which range from -1.00 to 1.00. A correlation coefficient 1.00 indicates a perfect positive correlation, meaning that as one variable increases, the other also increases. A correlation coefficient of -1.00 indicates a perfect negative correlation, meaning that as one variable increases, the other variable decreases. A correlation coefficient of 0 indicates no correlation between the variables.

Table 2: Correlation analysis between green building features and urban heat island intensity (UHII)

	UHII	**Green Roof/Cool Roof**	**Natural/Eco-Friendly Materials**
UHII	1.00		
Green Roof/Cool Roof	-0.45*	1.00	
Natural/Eco-Friendly Materials	-0.52**	-0.37*	1.00

*p < 0.05, **p < 0.01

Source: Authours Fields work, April 2023.

In this table, the UHII variable has a correlation coefficient of 1.00 with itself, as expected. The correlation coefficient between UHII and Green Roof/Cool Roof is -0.45, indicating a moderate negative correlation. This means that as the presence of green roofs and cool roofs increases in a building, the UHII decreases. The correlation coefficient between UHII and Natural/Eco-Friendly Materials is -0.52, indicating a moderate negative correlation. This means that as the use of natural and eco-friendly materials in a building increases, the UHII decreases. The correlation coefficient between Green Roof/Cool Roof and Natural/Eco-Friendly Materials is -0.37, indicating a moderate negative correlation. This means that as green and cool roofs increase in a building, the use of natural and eco-friendly materials also tends to increase. These correlation coefficients suggest a statistically significant relationship between green building features and UHII in Ibadan, Nigeria. The negative correlation coefficients between green building features and UHII suggest that incorporating these features in building design and construction can help to mitigate the UHII effect in the city.It is important to note that correlation does not necessarily imply causation. While these correlation coefficients suggest that green building features are associated with lower UHII, other factors may contribute to the relationship between these variables. Further analysis, such as multiple regression, can help to determine the extent to which these green building features affect UHII while controlling for other factors.

Inferences drawn from this table include that incorporating green roofs and cool roofs and using natural and eco-friendly materials can help mitigate UHII in Ibadan, Nigeria. The negative correlation coefficients suggest that increasing the presence of these green building features can significantly reduce UHII in the city. Policymakers and planners can use this information to promote these features in building design and construction to help mitigate the effects of urbanisation on the urban environment.It is important to note that while these findings are specific to Ibadan, Nigeria, they may also apply to other cities with similar environmental conditions. Future research can investigate the impact of green building features on UHII in other cities to determine the generalizability of these findings.

Table 3 presents the results of the multiple regression analysis of green building features on UHII. The model had a good fit with an R-squared value of 0.74 and an F-statistic of 28.56, indicating that 74% of the variance in UHII can be explained by the independent variables included in the model. The multiple regression analysis indicated that including green building features in building design and construction can significantly reduce the urban heat island effect in Ibadan. The results showed that the model had a good fit (R-squared = 0.74, F = 28.56, $p < 0.001$). The regression coefficients showed that the green roof and cool roof variables had a negative and statistically significant impact on UHII ($\beta = -0.29, p < 0.05$), as did the natural and eco-friendly materials variables ($\beta = -0.36, p < 0.01$).

Table 3: Multiple regression analysis of green building features on UHII

	β	**SE**	**t**	**p-value**
Green Roof/Cool Roof	-0.29	0.12	-2.44	0.017
Natural/Eco-Friendly Materials	-0.36	0.10	-3.54	0.002
Constant	2.95	0.49	6.02	<0.001
R-squared	0.74			
F-statistic	28.56			
p-value	<0.001			

Note: SE = standard error

The regression coefficients indicate the strength and direction of the relationship between each independent and dependent variable. The variable for green and cool roofs had a negative regression coefficient of -0.29, indicating that buildings with green roofs or cool roofs had a lower UHII than buildings without these features. The coefficient was statistically significant ($p < 0.05$), indicating that this relationship was not due to chance.

Similarly, the variable for natural and eco-friendly materials had a negative regression coefficient of -0.36, indicating that buildings made of adobe or bamboo had lower UHII than those made from concrete and steel materials. This coefficient was also statistically significant ($p < 0.01$), indicating that this relationship was not due to chance.
The constant term in the model was 2.95, indicating the expected value of UHII when all independent variables are set to zero. The coefficient was statistically significant ($p < 0.001$), indicating that there were other factors beyond the green building features that were contributing to UHII.

The multiple regression analysis indicates that including green building features in building design and construction can significantly reduce the urban heat island effect in Ibadan. The variables for green roof and cool roof, as well as natural and eco-friendly materials, had a significant negative impact on UHII. The data analysis generally revealed a statistically significant relationship between green building features and urban heat island in Ibadan, Nigeria. This suggests that policymakers, planners, and other stakeholders should consider incorporating green building features to mitigate the urban heat island effect in Ibadan.

Interpretation of Results

The study's results support the hypothesis that green building features significantly impactthe urban heat island in Ibadan, Nigeria. The findings show that buildings with green roofs or cool roofs and those made of natural and eco-friendly materials have a lower UHII compared to buildings without these features. This suggests that incorporating these green building features in building design and construction can help reduce the urban heat island effect in Ibadan and other similar cities.

The negative correlation between green building features and UHII suggests that these features can help to mitigate the effects of urbanisation on the urban environment. Green roofs and cool roofs can help to reduce the amount of solar energy absorbed by buildings, which can, in turn, reduce the amount of heat radiated back into the environment. Similarly, buildings made of natural and eco-friendly materials can help reduce the amount of heat absorbed by buildings, which can reduce the amount of heat radiated back into the environment. The multiple regression analysis further supports the hypothesis that green building features significantly impact urban heat island in Ibadan, Nigeria. The results indicate that the inclusion of green roof, cool roof, and natural and eco-friendly materials variables in building design and construction can significantly reduce UHII in the city. The model had a good fit, suggesting that these variables explain a significant proportion of the variance in UHII.

Analysis of Potential Confounding Factors

Several potential confounding factors could have influenced the results of the study. For example, the location and orientation of buildings, the presence of trees and other vegetation, and the type of urban fabric could have affected the UHII readings. However, the study controlled for these factors by selecting sample points that were similar in terms of their built environment characteristics and by using standardised UHII measurement techniques.
Another potential confounding factor is the impact of human behaviour on UHII. For example, the use of air conditioning units and vehicular traffic could have affected the UHII readings. However, the study controlled for these factors by selecting sample points that were similar in terms of their usage patterns and by conducting the measurements during similar times of the day and week to minimise the impact of human behaviour.

Despite these efforts, it is important to acknowledge that there may still be other factors that were not controlled for and may have influenced the results of the study. For example, the study did not account for the impact of building density or the use of reflective surfaces in the surrounding built environment. Future studies could consider these factors to further refine our understanding of the relationship between green building features and urban heat islands.
Overall, the results of this study suggest that green building features significantly impactthe urban heat island in Ibadan, Nigeria. The incorporation of green roofs, cool roofs, and natural and eco-friendly materials in building design and construction can help to mitigate the effects of urbanisation on the urban environment and reduce the UHII in the city. These findings have important implications for urban planning, policy, and sustainability and highlight the need to promote green building practices in cities facing similar environmental challenges.

DISCUSSION

The findings of this study have several important implications for urban planning, policy, and sustainability in Ibadan, Nigeria. The study aimed to examine the impact of green building features on the urban heat island effect, and the results demonstrate that such features can significantly reduce the intensity of the UHI in built-up areas.Overall, the findings of this study are consistent with previous research that has shown the importance of green building features in mitigating the UHI effect. The results suggest that buildings with green roofs or cool roofs, and those made of natural and eco-friendly materials such as adobe and bamboo have a lower UHI than buildings without these features or concrete and steel materials.

Therefore, green building features can be seen as a viable strategy for reducing the UHI effect in cities like Ibadan. This has important implications for urban planning and policy, as it suggests that encouraging green building features can play a key role in creating more sustainable and livable cities.One potential policy implication of this study is the need for incentives and regulations that promote green building features in new constructions and renovations. For example, tax breaks or subsidies could be offered to developers who incorporate green building features into their designs, while regulations could be implemented to ensure that all new constructions meet certain sustainability standards.

Another important implication of this study is the need for more research into the effectiveness of different green building features in reducing the UHI effect. While this study found that several specific features were effective, further research is needed to determine which features are most effective in different contexts and how they can be combined to create optimal UHI reduction strategies.

Despite the important implications of this study, several limitations must be taken into account. One limitation is the relatively small sample size of the study, which may limit the generalizability of the results. Additionally, the study was conducted in a specific location (Ibadan, Nigeria), and the findings may not be directly applicable to other cities or regions.

In conclusion, this study has shown that green building features can significantly reduce the intensity of the UHI effect in built-up areas and that promoting the use of such features can be an important strategy for creating more sustainable and livable cities. Further research is needed to explore the most effective UHI reduction strategies and address this study's limitations. Nonetheless, the findings of this study have important implications for urban planning and policy. They can contribute to efforts to create more sustainable and resilient cities.

CONCLUSION

The study aimed to investigate the impact of green building features on urban heat islands in Ibadan, Nigeria. The findings suggest that incorporating green building features such as green roofs, cool roofs, and natural and eco-friendly materials in building design and construction can significantly reduce UHII in the city. The study's contribution to green building and urban heat island lies in its emphasis on incorporating green building features as a sustainable solution to reduce the UHII effect in urban areas.

The study's main findings indicate that including green building features in building design and construction can help reduce the urban heat island effect in Ibadan and other similar cities. Green roofs and cool roofs can help reduce the amount of solar energy absorbed by buildings, which can reduce the amount of heat radiated back into the environment. Similarly, buildings made of natural and eco-friendly materials can help reduce the amount of heat absorbed by buildings, which can reduce the amount of heat radiated back into the environment.

The study recommends that policymakers, planners, and other stakeholders consider incorporating green building features in building design and construction as a sustainable solution to reduce UHII in urban areas. Such measures can help mitigate urbanisation's effects on the urban environment, enhance the liveability of cities, and promote sustainable urban development.

The study suggests that future research should focus on the effectiveness of different green building features in reducing UHII in different Climatic zones and the cost-effectiveness of these measures. Further research could also investigate the impact of different building orientations, urban forms, and land use patterns on UHII in different urban contexts.

In conclusion, the study's findings emphasise the importance of incorporating green building features as a sustainable solution to reduce UHII in urban areas. The incorporation of green building features can help to mitigate the effects of urbanisation on the urban environment and promote sustainable urban development. The study's findings can inform policymakers, planners, and other stakeholders in their efforts to promote sustainable urban development and enhance the liveability of cities.

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