Effect of Vegetation on Outdoor and Indoor Temperatures of Some Households in Benin City, Nigeria

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ABSTRACT

The absence of vegetation on building site leads to increase in outdoor and indoor temperatures of buildings. This study therefore assessed the effect of vegetation on the microclimate of buildings in five zones of Benin City in Edo State, Nigeria. The objective is to identify building sites with vegetation and building sites without vegetation and measure their outdoor and indoor temperatures. 550 questionnaires were administered across the five zones in the study area, 489 completed and retrieved, giving a completion rate of approximately 89% success from the field survey. The findings of this study shows that there was a significant relationship between outdoor and indoor temperatures and presence of vegetation on building site in the study area. Nonetheless, there was no significant relationship between outdoor temperature and presence of vegetation on some building sites; the effect of evaporative cooling is not significant in some of these sites having both vegetation and concrete ground covers. This could be as a result of diffusion of cool air and hot air on these sites with both vegetative and concrete pavements ground cover. It is recommended that landscape element like trees and shrubs be planted along the concrete pavements to shade them from direct sunlight. The study also recommends that, building development approval be given only for proposed designed building's site plans that integrate vegetation, while compliance should be monitored by respective government agency during building development stage, and existing sites without vegetation, owners, should be encouraged to plan vegetation around their buildings.

Keywords: Vegetation, indoor temperature, outdoor temperature.

INTRODUCTION

The drive for urban development has often resulted in the large-scale clearance of natural vegetation to create new towns, replacing green cover with paved streets, buildings, and non-climate-responsive designs. Inadequate integration of buildings with their surrounding environment has contributed to elevated air temperatures, high relative humidity, and poor ventilation in many cities worldwide (European Union, 2011; Helbling & Meierrieks, 2022; Kamal-chaoui & Robert, 2009). These human activities have directly or indirectly accelerated climate change, posing major challenges for architects and urban planners and prompting a global shift toward energy-efficient building policies (Iwaro & Mwasha, 2010; Ochedi & Taki, 2022; United Nations, 2010). The incorporation of trees and other vegetation around buildings provides shading that reduces solar heat gain while offering additional benefits such as wind sheltering, evaporative cooling, and improved air quality (Abdel Aziz, 2014; Mari et al., 2019). This shading effect is also evident in everyday situations, such as when vehicles parked under tree canopies remain cooler. In the same manner, by shielding buildings from direct solar radiation, vegetation creates measurable differences between outdoor and indoor temperatures, delivering multiple positive impacts within the urban environment.

Vegetation, comprising trees, shrubs, creepers, and ground covers such as grasses and lawns, plays a vital role in moderating both outdoor and indoor building temperatures by providing shade from solar radiation, cooling the air through evapotranspiration, and enhancing ventilation (Fadamiro & Adedeji, 1998; Shibu, Manicham, Chinnasamy & Prasanth, 2022). The relationship between vegetation and building temperatures is closely linked to the effects of solar radiation, which directly influences the earth and its built environment through heat transmission processes. As a result, buildings are designed to offer thermal insulation against heat gain or heat loss, depending on prevailing weather conditions. This approach is rooted in the broader objective of reducing energy consumption for cooling or heating, thereby reinforcing the importance of scientific research in addressing global warming.

Benin City, in Southern Nigeria, experiences a hot climate with average temperatures ranging from 27 °C to 29 °C and relative humidity levels between 82% and 83% (Eyefia & Efe, 2014; Floyd et al., 2016). In hot climate regions such as Benin City, two sustainable strategies for reducing outdoor and indoor building temperatures are the proper integration of buildings with their environment (e.g., orientation) and the use of vegetation for shading. These approaches are not only highly effective for cooling but also enhance the aesthetic quality of buildings (Mohammad, Yakubu, Ahmad, Aisha & Abubakar, 2013). Vegetation influences urban microclimates directly by shading surfaces and modifying wind speeds, and indirectly through evapotranspiration, which regulates solar radiation and the exchange of stored heat between urban surfaces (Akbari, Davis, Dorsano, Huang & Winett, 2009; Debnath, Wang, Peters & Menon, 2021). Similarly, Alamah, George, and Penny (2018) emphasized that vegetation affects urban climates and building energy use by providing shade, reducing and channeling wind speeds, and thereby altering the thermal interactions between buildings and their surroundings.

Landscaping plays a crucial role in balancing the capacity of nature to adapt to human activities through processes such as recycling, creating green spaces, and reforestation. For instance, when trees are planted around buildings, their canopies provide shade for walls and roofs, thereby reducing exposure to direct solar radiation—an especially important function in hot and humid climates (Qunshan, Jiachuan, Zhi-Hua & Elizabeth, 2018). Trees mitigate solar heat gain through shading, reflection, convection, and heat absorption, while also cooling the surrounding environment through evapotranspiration (Abdel Aziz, 2014; Alamah et al., 2018; Mari et al., 2019). The resulting cool air is dispersed by wind, creating an overall cooling effect.

In cold climates, the density and location of trees and shrubs influence wind speed. By reducing wind velocity, a carefully planned landscape conserves energy by limiting air infiltration into buildings and minimizing heat loss. Conversely, in warm and humid tropical climates, sparsely planted trees can channel breezes into buildings, providing natural ventilation and relief from high vapor pressure. Large deciduous trees with spreading branches are particularly effective at maintaining airflow while offering shade. Similarly, grasses and lawns generate evapotranspiration, further cooling the surrounding environment. Through thoughtful planning, landscaping can reduce the amount of solar radiation reaching building surfaces and prevent reflected heat from entering indoor spaces. Overall, trees, shrubs, and grasses collectively lower air temperatures near buildings while enhancing thermal comfort (Abdel Aziz, 2014; Alamah et al., 2018; Mari et al., 2019).

Historically, prior to the 19th century, Benin City's physical landscape was dominated by evergreen vegetation. This natural cover played an important role in releasing moisture into the atmosphere, which, combined with prevailing winds, helped cool the environment through evapotranspiration. Today, however, widespread deforestation and the replacement of vegetation with built infrastructure have significantly altered the city's natural environment (Eyefia & Efe, 2014; Floyd et al., 2016). These changes have contributed to pressing environmental challenges, including rising temperatures, reduced humidity, and elevated levels of air pollution (Okhakhu, 2010). Such conditions have created thermal discomfort in many parts of the city, particularly along areas such as Akpakpava, Igun, Uselu, Iyaro, and Airport Roads, where commercial and industrial activities—including the use of generator sets, firewood, sawmills, and manufacturing processes—emit carbon monoxide and other pollutants during combustion of wood and sawdust (Efe & Eyefia, 2014). This has intensified the thermal differences between urban and rural areas.

In addition, Benin City's rapid urbanization, high population density, and commercial activities have further contributed to urban heat build-up. The increased use of air conditioners and modern building materials has altered the city's natural thermal balance. These activities modify the surface properties of the environment, disrupting energy and water cycles and intensifying the warming of the city's urban canopy (Omogbai, 1985; Efe, 2006). Moreover, many of these human activities have progressed with little regard for the ecological role of vegetation, despite its well-documented benefits in mitigating urban climates through shading and the provision of thermal comfort for both indoor and outdoor spaces (Obi & Chendo, 2014).

METHODOLOGY

This study employed a cross-sectional design to survey households in Benin City, Edo State, Nigeria. Benin City spans all or parts of four Local Government Areas (LGAs): Ikpoba-Okha, Oredo, Egor, and Ovia North East. As the capital of Edo State, the city serves as a major transit hub for human and vehicular movement between the southwestern and northern regions of Nigeria, as well as to the southeast and other parts of the south-south (Atimati & Sokeimieibi, 2019; Ikhile, 2012). It is also the largest urban centre in Edo State (World Bank, 2017).

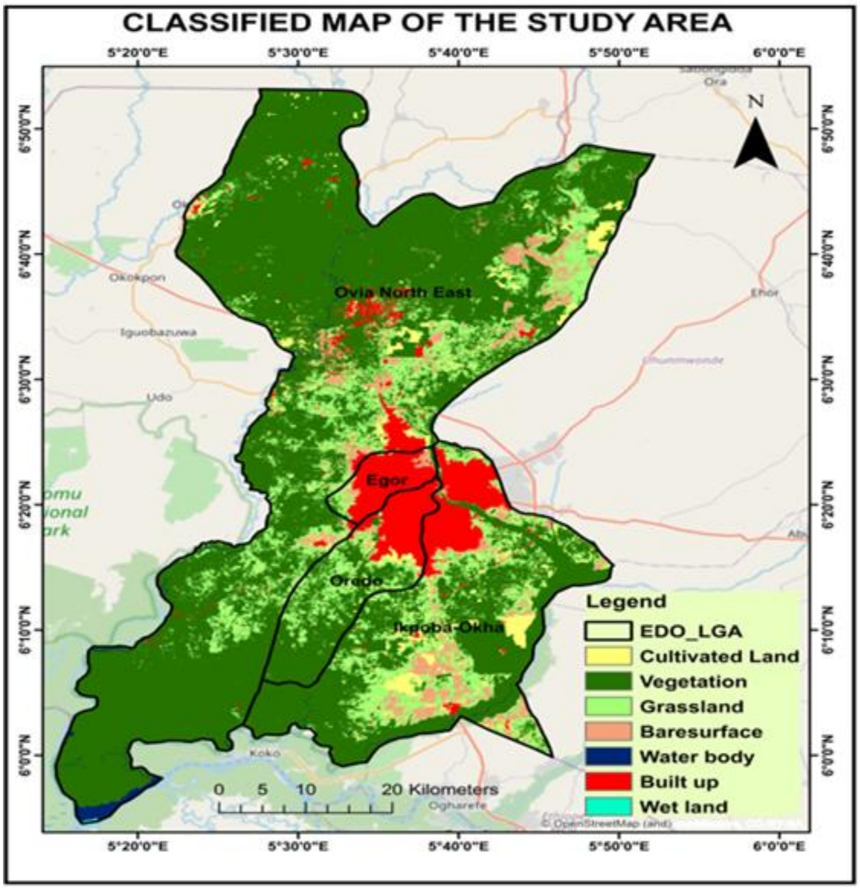

Figure 1: Classified map of Benin City, Edo State, Nigeria.

Source: National Space Research and Development Agency (NASRDA), Abuja, Nigeria (2023)

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The survey was conducted across five purposively selected zones in the city: Ikpoba Hill, Government Reservation Areas (G.R.A), Ekehuan, Uselu, and Ugbowo. Using an online sample size calculator (Maple Tech International, 2021), the minimum required sample size was determined to be 384 houses. However, to enhance representativeness, a total sample of 550 houses was used. Within each zone, two streets were randomly selected, and all houses where the owner or an authorized representative granted consent for entry and data collection were included until the target sample was reached. Data on building features and housing characteristics were collected using a structured questionnaire administered to owners or their representatives. Indoor and outdoor temperatures were measured with a thermohygrometer (Federal Institute of Technology in Lausanne, 2020). For indoor measurements, the device was placed vertically, ensuring no contact with walls or objects. Outdoor measurements were taken on vegetated surfaces, bare ground, and concrete/interlocking tiles within each property. Temperature readings were recorded with a precision of 0.1 °C.

Data analysis was conducted using SPSS version 25 (International Business Machines, 2020), with the level of statistical significance set at $p < 0.05$. Housing features were summarized using frequencies and proportions; analysis of variance (ANOVA) was employed to compare mean indoor and outdoor temperatures; and chi-square tests were used to assess associations between housing features and the zones in which they were located. Verbal informed consent was obtained from all participants, and the collected data were de-identified and treated with strict confidentiality.

RESULTS

The study zones and the number of completed questionnaires are shown in table 1. The proportion of completed questionnaires ranged from 80% to 96% per zone with a total proportion of 88.9% response rate achieved.

Table 1: Administered and Retrieved Questionnaires

Neighbourhood/Zones	Administered Questionnaires	Completed and Retrieved Questionnaires	Percentage Retrieved (%)
Ikpoba Hill	110	100	90.91
GRA	110	88	80.00
Uselu	110	106	96.36
Ugbowo	110	90	81.82
Ekehuan	110	105	95.45
Total	**550**	**489**	**88.91**

Source: Author’s field survey, 2020.

Table 2 shows that less than half of houses surveyed had flowers/shrubs, lawns, or grasses in their compounds. About 20% of compounds had lawns/grasses covering only 10% of the plot area. The predominant tree type in 47.4% of houses surveyed was evergreen, while deciduous trees were found in 52.6% of the houses.

Table 2: Presence of Vegetation around Houses

Variable	Frequency (N=489)	Percent
Presence of flowers/shrubs		
Yes	217	**44.4**
No	272	55.6
Proportion of total area covered by flowers/shrubs		
10%	117	23.9
20%	36	7.4

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30%	32	6.5
40%	28	5.7
Above 40%	4	0.8
No flowers/shrubs	272	55.6
Presence of lawns or grasses		
Yes	194	**39.7**
No	295	60.3
Proportion of total area covered by lawns or grasses(n=194)		
10%	100	20.4
20%	44	9.0
30%	38	7.8
40%	11	2.2
Above 40%	1	0.2
No lawn or grasses	295	60.3
Presence of trees		
Yes	228	**46.6**
No	261	53.4
Type of trees (n= 228)		
Evergreen	108	47.4
Deciduous	120	52.6

Source: Author's field survey, 2020.

Table 3. shows that houses built on 30metres x 30metres land size in the zones were found most in GRA (36.4%) while Uselu has the least with 14.2% (Appendix 3). The observed difference was significant (X^2= 73.629, df= 16, P<0.001).

Table 3: Comparative Analysis of Zones with Plot Size

Zone	**Plot size of land (Metre)**					**Total**	**Statistics**
	15x15	**15X30**	**30X30**	**30X45**	**30X60**		
Ikpoba	9	55	31	4	1	100	X^2= 73.629
	9.0%	55.0%	31.0%	4.0%	1.0%	100.0%	df= 16
GRA	4	40	32	10	2	88	P< 0.001
	4.5%	45.5%	36.4%	11.4%	2.3%	100.0%	
Uselu	22	65	15	2	2	106	
	20.8%	61.3%	14.2%	1.9%	1.9%	100.0%	
Ugbowo	5	54	20	3	8	90	
	5.6%	60.0%	22.2%	3.3%	8.9%	100.0%	
Ekehuan	27	58	18	2	0	105	
	25.7%	55.2%	17.1%	1.9%	0.0%	100.0%	

Source: Author's field survey, 2020.

Table 4 shows that there were slightly higher mean air temperatures on vegetated site and natural ground than on concrete/interlocking tiles for buildings with vegetation. However, the differences were not statistically significant (F= 0.830, p = 0.371; F= 1.164, p = 0.287; and F= 0.652, p= 0.429 respectively).

Table 4: Comparison of Outdoor Air Temperatures (°C) with Vegetation

Presence of vegetation*		**Air temperature on vegetated site**	**Air temperature on natural ground**	**Air temperature on concrete/ interlocking tiles**
Yes	Mean	26.5906	27.0962	25.4450
	Std. Deviation	2.00010	2.17434	2.45398
	Median	26.7000	25.8000	25.9200
No	Mean	25.9100	26.3364	26.1586
	Std. Deviation	1.67428	1.34035	1.69543
	Median	26.0000	25.9000	25.8500
Statistics	**F****	0.830	1.164	0.652
	Sig.	0.371	0.287	0.429

*Presence of lawns/grasses or trees**F: Coefficient of analysis of variance (ANOVA) Source: Author's field survey, 2020.

Table 5 shows t-test analysis of the relationship between various temperature parameters around houses. There were statistically significant differences between air temperatures of natural ground and concrete ground with houses that have vegetation showing lower mean temperatures (p = 0.001, CI: -0.67-2.19; p= 0.001, CI; -1.45-1.63 respectively). The table also shows that mean surface temperature at concrete ground was significantly lower for houses with vegetation compared to houses without vegetation (p = 0.018, CI; -3.95-0.05). Overall, mean indoor temperature was significantly lower for houses with vegetation than those without vegetation (p= 0.035, CI; -0.47- 0.27).

Table 5: T-test analysis of relationship between vegetation and house temperature measurements

Variable	**Vegetation (Yes/No)**	**Mean**	**SD**	**F**	**Sig**	**t**	**95% CI**	
							Lower	Upper
Air temperature at vegetated site	Yes	26.60	2.00	2.05	.164	.91	-.85	2.22
	No	25.91	1.67			.96	-.79	2.15
Air temperature at natural ground	Yes	26.10	2.17	11.96	.001	1.08	-.67	2.19
	No	26.34	1.34			1.33	-.41	1.93
Air temperature at concrete ground	Yes	25.26	2.43	16.59	.001	.13	-1.45	1.63
	No	25.87	1.17			.112	-1.71	1.90
Surface temperature at vegetated site	Yes	26.07	1.20	1.24	.276	-.33	-1.09	.79
	No	26.22	1.08			-.34	-1.08	.77
Surface temperature at natural ground	Yes	28.40	10.29	0.92	.341	.70	-4.16	8.53
	No	26.22	1.16			1.13	-1.78	6.15
Surface temperature at concrete ground	Yes	25.25	0.17	6.94	.018	-2.07	-3.95	.05
	No	27.20	1.84			-3.90	-3.02	-.88
Indoor temperature	Yes	26.14	0.60	4.64	.035	-.53	-.47	.27
	No	27.24	0.86			-.52	-.49	.29

Source: Author's field survey, 2020.

Table 6 shows that the mean indoor temperature of houses with vegetation was significantly lower than that of houses without vegetation (F= 14.684, p= 0.042). On the other hand, there was no statistically significant

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difference between the mean outdoor temperature of houses with vegetation and that of houses without vegetation (F= 0.042, p= 0.840).

Table 6: Relationship between Vegetation and Indoor and Outdoor Temperatures

Presence of vegetation		Indoor temperature	Outdoor temperature	Count
Yes	Mean	26.0680	26.0844	228
	Std. Deviation	0.97156	1.20702	
No	Mean	26.9440	26.1750	261
	Std. Deviation	0.60214	1.09638	
Total	Mean	26.5060	26.1232	489
	Std. Deviation	0.91415	1.14070	
F	F	14.684	0.0001	
Sig.	Sig.	0.042	0.840	

F: Coefficient of analysis of variance (ANOVA). Source: Author’s field survey, 2020.

Table 7 shows that majority of the respondents (85.1%) were using ceiling fans as means of cooling, while 80.6% of respondents practice sitting outside the house to cool themselves. Majority of respondents (97.1%) had no need for heating while 87.1% of respondents were reported experiencing hotter days than night during the dry season. This clearly shows higher percentages of respondents use one form of cooling methods while 97.1% do not require to heat their buildings even in cold weather. This is an indication of the absence of vegetation covers in most buildings surveyed.

Table 7: Cooling and Heating Practices

Variable	Frequency (N= 489)	Percent
Means of cooling		
Air conditioner (AC)	61	12.5
Ceiling fan	416	85.1
Hand fan	9	1.8
Sit under tree	2	0.4
Sit in verandah	1	0.2
Sit outside to cool self		
Yes	394	80.6
No	95	19.4
Use hand fan to cool self when outside		
Yes	270	55.2
No	219	44.8
Use of hand fan when in verandah		
Yes	312	63.8
No	177	36.2
Method of heating room when weather is cold		
Room heater	12	2.5
Chimney	2	0.4
Don't heat	475	97.1
Hotter time in dry season		
Day time	426	87.1

Night time	63	12.9
Hotter time in wet season		
Day time	70	14.3
Night time	419	85.7

Source: Author’s field survey, 2020.

DISCUSSION OF RESEARCH FINDINGS

Table 1, the study area was divided into five different zones. In each zone, 80% to 96% of the questionnaires were completed — so the lowest response rate for a zone was 80%, and the highest was 96%. When looking at all zones combined**,** the overall response rate was 88.9% successful**.** Generally, the survey got a very high participation rate, with almost 9 out of 10 people responding overall, and no zone falling below 80% participation.

Table 2 indicates that fewer than half of the surveyed houses had flowers, shrubs, lawns, or grasses within their compounds. Approximately 20% of the compounds had lawns or grasses covering only about 10% of the plot area. Among the houses surveyed, 47.4% had predominantly evergreen trees, while 52.6% featured deciduous trees, which shade their leaves during dry season (harmattan)

This suggests that a large proportion of buildings in the study areas have been cleared of vegetation to accommodate residential and commercial development. Such clearance has exerted significant pressure on local flora and fauna while also increasing solar radiation absorption and heat retention by built surfaces, thereby intensifying indoor cooling energy demands (Jie, 2017; Fineschi & Loreto, 2020). These results are consistent with the findings of Ikyaagba et al. (2023), who highlighted the crucial role of vegetation in mitigating urban heat island effects. Likewise, Okhakhu (2010), in a study of Benin City, observed that the city’s green ecosystem has been disrupted by the widespread adoption of modern building materials—such as cement, glass, marble, steel, aluminum roofing sheets, tar, stone, and heavy security wires—which are highly efficient at absorbing and storing solar energy.

The study also revealed that over half of the surveyed houses had no trees within their compounds, leaving buildings directly exposed to sunlight and thereby increasing the demand for cooling energy. This observation is consistent with the findings of Haque, Tai, and Ham (2004) regarding the extent and impact of energy consumption in South Carolina, USA. In the study area, the absence of vegetation on some building sites may be attributed to limited space, where a high proportion of plot sizes measure less than 30 m × 30 m across all five zones. Furthermore, most property owners have developed more than 50% of their plot area as shown in Table 3, leaving insufficient space for car parking, tree planting, lawns, flowers, or shrubs. The results also indicate that some houses combine vegetation with concrete pavement or interlocking tiles, as shown in Table 4, which can elevate relative humidity and reduce the cooling benefits of vegetation. This is reflected in the recorded mean air temperatures: 26.59 °C for vegetated sites, 27.10 °C for natural ground, and 25.45 °C for concrete/interlocking tiles as shown in Table 5. Similarly, the results in Table 6, with p-values of 0.042 for indoor temperatures and 0.084 for outdoor temperatures, suggest that vegetation on building sites helps lower both indoor and outdoor thermal conditions in the study area. These outcomes are consistent with the findings of Alamah (2012) and Alamah et al. (2018), who reported comparable thermal benefits of vegetation in Malaysia, a tropical climate similar to that of Benin City. Overall, the analysis indicates a significant relationship between the presence of vegetation on building sites and the moderation of both indoor and outdoor temperatures in the study area.

Table 7 examines cooling and heating practices, which shows that during the dry season, most respondents (87.1%) experienced the hottest period during the daytime. The surveyed environment consistently high temperatures, especially during the dry season, making cooling methods essential and heating largely unnecessary suggests a lack of vegetation, as trees help lower surrounding air temperatures through evapotranspiration (Akbari et al., 2009; Santamouris, 2001). The widespread use of ceiling fans and the practice of sitting outdoors indicate that indoor conditions can become uncomfortably warm. The fact that almost all respondents do not require heating, even in cooler weather, implies that the area retains heat effectively—likely due to a lack of vegetation cover, which would otherwise help regulate temperature by providing shade and cooling through evapotranspiration. This absence of vegetation could be contributing to a localized heat island effect around the buildings.

Furthermore, Table 7 reveal that most respondents experienced hotter nighttime temperatures during the wet season. This is largely due to absence of vegetation to cover surfaces from absorbing heat, while the increase in cloud cover typically observed in this period has the opposite effect at night—trapping heat emitted from the earth's surface and reemitting it back, thereby raising surface temperatures (McMullan, 2007). This phenomenon highlights the need for further research into the role of vegetation in influencing the amount of heat retained by clouds and reemitted to the earth at night.

CONCLUSION AND RECOMMENDATION

The rapid replacement of vegetated areas with asphalt, buildings, and other hard surfaces, combined with Nigeria's inadequate power generation, underscores the need to explore alternative approaches for conserving and reducing energy consumption in buildings. To meet this challenge, integrating energy-efficient strategies into building design and construction should be prioritized by architects, developers, and property owners. This study highlights the effectiveness of vegetal shading in lowering both outdoor and indoor temperatures, thereby reducing energy use while enhancing the overall quality of the built environment. Consequently, there is a pressing need for stronger awareness campaigns and the formulation of policies by government that make the incorporation of vegetal shading a fundamental requirement for development approval.

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