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Hindrances to the Utilization of Climate Responsive Architecture Principles for Residential Design in Northeast Nigeria

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Abstract— Thermal comfort plays a major role in the perception of the interior environment, and it must be achieved in order to maintain occupant health as well as ensure productive living. Increasing temperatures in Northeast Nigeria as a result of the effects of climate change makes the achievement of thermal comfort more important and similarly, more challenging. With the domestic building sector consuming 55% to 60% of Nigeria's energy between 1996 and 2005, Climate Responsive Architecture provides a twofold solution as it allows a building to achieve thermal comfort by utilizing minimal energy and consequently, can contribute to the slowing of climate change effects through significantly reduced energy emissions. This study assesses architects' use of principles of Climate Responsive Architecture (CRA) in residential design in Northeast Nigeria with the aim of ranking the factors hindering the implementation of CRA principles. Through the use of field surveys directed at practicing architects in the region, it concluded that other than the use of vegetation, architects rarely implement several passive design principles due to the following factors by rank; Lack of client awareness for importance of climate responsive architecture, socio-cultural needs, client preference, bad perception of local/traditional building materials, lack of knowledge on principles of climate responsive architecture and high cost perception of using climate responsive architecture principles. The study suggests creating awareness for the need for climate responsive architecture in the public domain as well as establish its significance in student curricula, in order to educate on its value in improving thermal comfort and reducing the building sector's carbon footprint.

Index Terms— Climate Change, Climate Responsive Architecture, Hindrances, Passive Cooling, Residential, Sustainability, Thermal Comfort,

1 Introduction

HOUSING, first and foremost, incorporates all environments that provide man the capacity to live and grow in direct response to the simultaneously existing biological material and his physical needs. For a house to properly deliver its optimal goal, it must have the minimum facilities that are required for human physical health and emotional wellbeing [1]. Olotuah (2003) expatiates that Housing is a progression that creates conditions in which a higher percentage of man's life activities occurs therein and is a reflection of the economic, social and cultural values of a society [2]. Mabogunje (1978) states that the fundamental purposes of housing are that they provide shelter for the execution of performances in the realm of social activities, safety, space, security, privacy, among other rationales that stimulate good health and dignified living conditions [3].

The climate of any region is fundamental to the forms of architecture that propagate. Imaah (2008) notes that the science of building has proven that the wall is used for its thermal quality to react to environmental conditions, therefore, local builders' utilization of readily available local building materials like tempered clay and timber are to be expected [4]. In the same vein, Fatiregun (1999) states that the environment, followed by social factors determines the emergent differing architectural solutions that are seen in Nigeria's pre-colonial traditional setting. The climate factor emphasizes and influences any socio-cultural factors that directly regulate types of available building materials which defined the nature of the structures that manifest. He further states that religious and philosophical leaning of individual communities and their social order alongside culture subsequently influenced the forms, spatial layout of buildings as well as their process of construction [5].

Opoko (2001) lists the components that led to the development of building methods as climate, technology, socio-economic and traditional building materials. As further reported by the author, traditional building materials utilized in a simple, but innovative way demonstrates a reflection of local builder's expertise. Opoko concludes that effective building forms have developed over time in order to facilitate the attainment of high comfort levels both within and outside of the built environment without recourse to the use of external artificial methods [6].

Thermal comfort therefore is one of the primary requirements of housing in its attempt to adapt to the prevailing climate and provide a relationship between the internal and external environment that generates a comfortable and conducive lifestyle to the occupants. The role of the architect in the delivery of a stable environment cannot be understated. Through design, the architect controls form, space, layout, openings and materials, having a major effect on the lifestyle of any building's residents. Poorly designed buildings will result in unsatisfactory living for the occupants and likewise, the use of thoughtful design provides a positive impact on the

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life of occupants.

2 LITERATURE REVIEW

2.1 Thermal Comfort and Climate Responsive Architecture in the Context of Climate Change

A major indicator of a building's indoor climate, thermal comfort encompasses individual factors that influence the satisfaction gained by building occupants from the immediate environment the building provides. Thermal comfort is defined as a "condition of mind that expresses satisfaction with the thermal environment" [7]. It is the condition of thermal neutrality, where the occupant of a space does not feel too hot or too cold. Not only is it a potential health hazard, the dissatisfaction of occupants with their thermal environment can negatively impact on the ability of occupants to function effectively and productively in their daily lives. When designing buildings, the physiological functions of the human body must be considered. With regards to comfort, the physiological factors that affect the regulation of human temperature are of primary importance. The internal temperature of the body must be kept within the narrow range approximately between 15°C (59°F) and 30°C (86°F). and in order to maintain this thermal comfort level, various methods of climate control are often employed. Any fluctuations from this range of values is a sign of illness, where a rise of 5°C or a drop of 2°C from average body temperature can lead to death [8].

According to Szokolay (2014), there are two main factors that influence the perception of thermal comfort within a space. These are; measurable environmental/climatic elements and; subjective/personal human factors (as shown in Table 1) [9]. In order to achieve proper thermal comfort, Szokolay (1980), (2014) states that firstly, the deep-body temperature must be higher than the skin temperature due to the direction of heat flow from the deep-body to the skin and secondly, the temperature of the environment must be lower than the skin temperature for heat to be dissipated from the skin surface to the environment [9], [10].

TABLE 1
SUMMARY OF FACTORS AFFECTING THERMAL COMFORT

OBJECTIVE FACTORS (MEASURABLE)	SUBJECTIVE FACTORS
Surface, Air temperature	Metabolic rate
Wind Speed, Direction	Clothing
Humidity	State of Health
Solar radiation	Acclimatization

Source: Adapted from [9], [11]

Szokolay (2014) reports that the human factors affecting thermal comfort are subjective and non-measurable [9]. This means that they may differ from one individual to another, depending on activity, clothing and their state of health. Pertinent to this study are the environmental factors, whose direct influence on buildings affect perception of thermal comfort. The relationship between these factors and architecture is important in producing an environment that is thermally comfortable for habitation, and healthy living.

2.2 Climate Change

As stated by Griffiths (2015), researchers have revealed as far back as 1940 that the first signs of climate change began to manifest in the Tropical regions – specifically Africa, southeast Asia and Australia [12]. Drake (2014) further adds that scientists began investigating global climates as early as the 1870s. and recognized the earliest signs of climate change in the afore-mentioned regions due to the fact that their climates feature a small range of temperatures, as typically seen in tropical climates. Therefore, the increase in temperatures and further environmental changes which indicated the idea of global warming, were easily determined [13].

Climate change has a set of highly distinctive implications for Africa, whose climate is likely to be affected more adversely than the climate of other regions. Furthermore, this problem is compounded by the greater exposure of Africa's its economy to variations in climate [14]. In contrast to this severe exposure to these effects, Africa's role in carbon emissions and overall climate change is a typically minor. This is because its economic activity in the past, has contributed a minimal amount to the amassed global stock of carbon. Its current activity also accounts for a trivial proportion of global emissions. Conway (2005) adds that the African continent is not a driver of the change in climate, yet is a serious victim [15]. According to Collier (2008) future predictions suggest that its contribution to emissions will continue to be marginal [14]. However, Thiele (2013) states that this is no longer the case, with rapid urbanization and increase of industrial capacity in the tropical regions increasing Africa's contribution to carbon emissions [16]. In other regions across the world, the principal adverse effects of global warming are projected to occur in the future and are uncertain in their severity and scale. Hence, the primary concern for these regions is how to reduce their carbon emissions. In tropical regions however, many of the adverse effects are already manifesting. Therefore, the primary concern for these regions concern the adaptation to the changing climate, as well as mitigation of the deteriorating conditions.

The African continent is distinctive in the manifestation of the effects of climate change. Firstly, there is recorded evidence that shows Africa is warming faster than the global average, with its mean annual temperatures rising, and this phenomenon is highly likely to continue, especially in the more arid regions [17]. Secondly, as a result of Africa's vertically expansive landmass that stretches from approximately 35°N to 35°S, there is no single continent-wide climate effect. Climate change effects vary wildly according to the particular location within the continent. Some parts of the continent will become drier while others become wetter, and some areas may derive an economic benefit, while most regions remain adversely affected.

2.2.1 Climate Change in Hot Semi-arid region of Northeast Nigeria

Northeast Nigeria covers a vast portion of the country comprising about a third of the Nigeria's land mass, with a total area of 268,423 square kilometers. This region is situated Nigeria between 9°-14°N and 8°-15°E [18]. Politically, the zone comprises of six states namely, Adamawa, Bauchi, Borno, Gombe Taraba and Yobe. Of these states, only Bauchi and Gombe do not share borders with international communities.

Fig. 1. Map of Nigeria showing Northeast states. Source: Wikipedia

The zone is bounded in the north by Niger Republic, in the northeast by the lake Chad and Chad Republic and to the east by Cameroun. It naturally experiences an acute dryness of the soil, which does not strongly support flourishing growth of grass and other forms of biodiversity in the extreme limited regions. However, locations such as those around river valleys and floodplains, around riverbeds, mountains and highlands allow the thriving growth of trees which supports arable farmland as well as animal husbandry. With a projected population of 23,558,674, this region constitutes 13.5% of Nigeria's total population. The agriculture practicing peoples of the region comprise sedentary arable farmers and migratory herdsmen, who are mostly members of the Fulani ethnic group. The majority ethnic languages spoken here are Hausa, Fulani and Kanuri, there are however, about 200 other ethnic groups that can be found here, among which are the Bachama, Jukun, Tiv, Kutep, etc. [19].

The climate of this region is controlled by two prevailing airmasses which are; the hot dry Tropical Continental airmass (cT) that blows from the Sahara in the north, associated with the cool, dry and dusty Northeast Trades referred to as the Harmattan, prevailing for 6-9 months of the year and the moist Tropical Maritime airmass (mT) which is associated with the southwest winds prevails for 3-6 months. While the latter brings about the short rainy season, the former is predominantly responsible for the region's semi-arid dry climate. The type of vegetation found here is that of the tropical Savannah. In the southern sub-region, Guinea Savannah (parkland) vegetation type can be found. Moving northwards, this steadily merges into the Sudan Savannah. In the northernmost end is the Sahel Savannah, whose areas are gradually being overtaken by desert encroachment. Toward the eastern border, Montane vegetation can be found in the highland plateau regions of Adamawa and Taraba.

The temperature in this region ranges from a low of 19°C during the harmattan period to an average of 23°C in the cooler highland regions and an average temperature of 32.2°C in

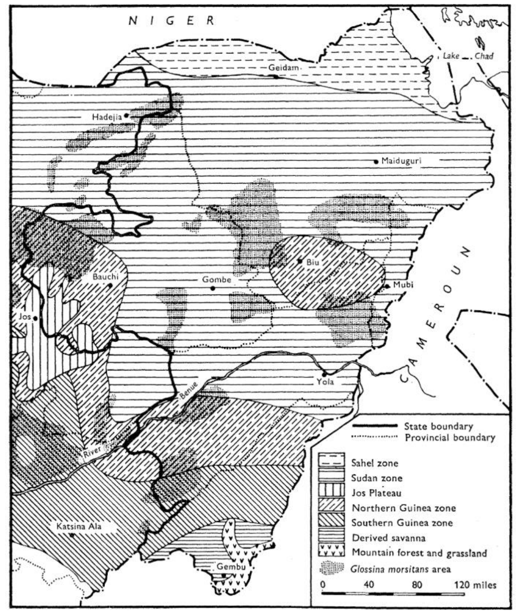

Fig. 2. Climate classification Map of Northeast Nigeria. Source; [20]

the Sahel areas, with maximum temperatures exceeding 43°C. The two air masses (mT and cT) converge along a slanting surface which is known as the Intertropical Discontinuity (ITD). It is the movement of the ITD towards the north of the country in August (between latitude 21 to 22°N) that marks the height of the rainy season in the region while its retreat to the southern part in January/February (at around 6°N) marks the peak in the dry season.

2.2.2 Effects of Climate Change in Northeast Nigeria

As a result of increased temperatures, there are increased occurrences of excessive death of people and farm animals from heat exhaustion, water related diseases like cholera, diarrhea and skin diseases), respiratory and inflammatory diseases such as cough and asthma, cataract and skin cancer. The frequency of reduced volumes of waterbodies often leads to a concentration and densification of people along the locations of the few remaining water resources. This further exacerbates the pollution and overuse of the remaining waterbodies. Additionally, the increasing daily temperatures will mean a northward migration of mosquitoes carrying malaria fever, which will then spread from its native tropical region to the warm temperate region as the sporogony of the protozoa that causes malaria accelerates from about 25 days at 10°C to 8 days at 32°C [21].

Another impact of climate change is the worsening of extreme weather events like drought, flood, thunderstorms rainstorms, windstorms and landslides among others. Odjugo (2008) observes that not only did the magnitude and frequency of wind and rainstorms increase, they also took 199 lives and destroyed property worth N85.03 billion in the region between 1992 and 2007 [22].

Climate change has already begun to, and will continue to produce negative impacts on agriculture and food security. As greenhouse gas emissions rise to service increasingly rising populations of the country, this would increase the risk of hunger to millions. Odjugo (2008) further notes that climate change has led to a shift in the types of crops cultivated in northeast Nigeria [22]. Odjugo quotes Ahmed (1978) revealing that in 1978, guinea corn followed by groundnut, then maize, were the preferred crops cultivated by farmers. Due to increasing temperatures, the decreasing amount of rainfall and a season caused by climate change, by 2007, the farmers shifted to the production of millet followed by maize then beans as a means of adaptation [23]. Another major impact in agriculture in Northeast Nigeria is the reduction of arable lands. Desert encroachment carrying along desert sand dunes is depleting farmers of their farmlands and grazing range. Additionally, the frequent droughts and reduced rains lesser rains have started shortening the growing season thereby causing crops failure and food shortage. It has been shown that drought, desert encroachment and coastal inundation have started affecting the country's ecosystem leading to ecological destabilization due to climate change impact in the semi-arid region of Northern Nigeria.

The region is witnessing an ever-increasing reliance on high energy intensity methods of construction, and high energy use in the life cycle of contemporary buildings in the region, coupled with increased construction of housing to cater for the rapidly urbanizing population, it is critical to curb the impact of the construction industry on the enviornment. Energy-efficiency and thermal comfort must serve as the primary tools in guiding climate change adaptation as well as delivering optimum indoor climates. Furthermore, it is important to design resilient contemporary housing which provides adequate thermal comfort without the need for mechanical systems. Increasing temperatures across the region means a heavier task is placed on the human body to regulate temperatures to ensure thermal comfort in indoor environments, thus it is of critical importance to place the onus on the shelter itself, to do the bulk of the work in ensuring human thermal comfort.

2.3 Climate Responsive Architecture as a Solution

Climate-responsive architecture is defined as architecture that aims to achieve thermal and visual comfort of building occupants using little to no non-renewable energy sources by incorporating the elements of the local climate in design effectively [24]. Similarly, the phrase "bioclimatic approach to architectural regionalism" as seen in Olgyay (1963) emphasizes the importance of the interactions of living organisms and the local climate through the form and fabric of the building [25]. In contemporary times, climate responsive design has become a crucial step in achieving more sustainable buildings. Climate responsive design principles therefore, are necessary for building design as a starting point for architectural conception with response to the immediate climate in mind. Akande (2015) concluded that between 1996 and 2005, the domestic sector was responsible for over half (55% - 61%) of energy consumption in Nigeria. Furthermore, the study states that the most significant contributors to energy use in Nigerian houses are space cooling, lighting and other daily activities like cooking and household appliances [26]. Space cooling is associated with the relationship between indoor climate, outdoor climate and thermal comfort, with many studies revealing that there is a constant need for space cooling in houses [27], [28], [29]. As found by Olaniyan (2013), building occupants are subject to thermal discomfort caused by high temperatures for most of the year in Nigeria and the most widely used solution is mechanical cooling, which is powerd by electrical energy in both urban and rural areas. Furthermore, the buildings most likely to run these mechanical cooling systems are observed to be contemporary [27].

Studies by Haruna (2018) in Jimeta, Northeast Nigeria show that building forms, their orientation, openings to floor area ratio, fenestration and landscaping have direct impact on the average room temperature of residential buildings [29]. Additionally, Danja et al (2020) suggest that designing with climate responsive principles significantly improves the indoor environment quality and livelihood of building occupants [30]. Additionally, studies by [31], [32] [26], [11] all suggest the use of passive design principles of climate responsive architecture to ensure thermal comfort in Nigerias houses.

2.3.1 Passive Methods/Principles of Achieving Climate-responsive Architecture

Building Orientation

Akande (2010) reports that in this region, proper orientation is not given major consideration when designing buildings, suggesting that buildings that are properly oriented take advantage of solar radiation and prevailing wind [32]. Gut (1997) suggests that while designing, the longer axis of a building should be laid along the east-west direction for minimum solar heat gain by the building envelope [8]. Studies by Wong (2004) in examining the effectiveness of passive climate control methods such as building orientation for houses in Singapore conclude that the cooling load can be reduced by 8% to 11% by following this orientation [33].

Floor plan zoning

As stated by Gut (1997), the spatial layout of rooms depends on the function they serve and according to the time of the day they are in use [8]. Where building orientation as suggested by Wong (2004) cannot be achieved, such as on sites where the opposite sides are longer, the study states that west face will need significant attention as it heats up in the afternoon and therefore, the plan should be organized in such a way that the rooms on this side are not usually inhabited frequently in the morning and afternoon. Therefore, placement of bedrooms on the east side is adviced, as during the morning and early afternoon hours, they remain unused. Gut (1997) also suggests that rooms which see frequent use for most times of the day, such as living rooms should be located on the northern face. Moreover, other auxiliary spaces such as the storage should be located on the disadvantaged, western sides. Rooms that have high internal heat load, such as kitchens, should be detached from the most frequently used spaces, and if the kitchen is used in morning and midday hours, it can be similarly located on the west face [8].

Shading

Solar gain through openings such as windows and doors, as well as on the opaque walling fabrics increase the surface temperature of the building envelope and contributes to the heating of the interior environment [34]. Studies by Danja et al (2020) suggest that the provision of shading devices on buildings has the capacity to reduce heat gain signifcantly [30]. Shading can be provided through various means, including the use of dedicated shading devices, nearby structures, and vegetation. External shading devices are considered the most effective in general, since they significantly reduce the amount of radiation passing through the building envelope into the interior space. Odimegwu (2019) suggests using a properly oriented high-pitched roof which can afford self shading as a simple yet effective shading technique. There is the possibility that shading design often conflicts with natural day lightening, leading to reduced day light penetration due to over shading. This could result in increasing demand for artifcial lighting, which subsequently offsets any energy savings made from reduced heat gains. Odimegwu states that such a conflict can be resolved by using interior surfaces of high reflective values, light shelves to reflect daylight into the deeper interior spaces, and moveable shading devices, such as louvers, which will permit occupants to achieve their desired middle ground between natural lighting and shading [34].

Building materials

Materials used in modern buildings tend to obstruct the flow of air, necessitating the use of mechanical ventilation. In Nigeria, most buildings are built using cement blocks and studies show that this material absorbs and retains heat over the course of the day and radiates it at nighttime, creating an unsuitable thermal environment. In recent times, the use of traditional materials has received widespread promotion, with research being done into investigating its efficiency and sustainability for achieving good indoor climate [26], [28], [32]. The claim is that previously, traditional buildings in Northeast Nigeria have been directly influenced by environmental elements i.e climate, construction materials and the prevailing culture of the people [35]. As stated by Danja (2014), these traditional buildings maintain some passive and cost-effective solutions to the climate of the region but as a result of the rise in popularity of contemporary architecture, these passive solutions are no longer utilized especially in urban areas [36]. According to Muazu (2017), the preference today to build a house with contemporary construction materials (porous concrete blocks, ceramic blocks) instead of natural materials (bamboo, hempcrete clay, etc.) is as a result of people's lack of knowledge about the advantages of building with these natural materials [37]. Mud brick or adobe is a material that is composed of between 20%-30% clay, commonly found in many rural areas of Nigeria. Although much of the buildings made out of adobe are mainly as a result of how cheap they are to build, Akande (2010) suggests that they also serve the function of facilitating a good indoor temperature and are used due to the high temperatures seen in the northeast [32]. Moreover, it is advised to avoid dark hues and utilize white or brightly colored surface finishes in order to reflect intense solar radiation [38].

Vegetation

According to Akande (2010), Landscaping is an under utilised element of domestic architecture despite its relative cheap cost and effective results in the improvement of year-round comfort and energy efficiency [32]. Studies by Raeissi (1999) on proper tree plantation for energy saving conclude that cooling loads can be reduced by 10%- 40% through proper tree plantation [39]. Odimegwu (2019) cites studies by Parker (1981) which conclude that average temperature of walls which are shaded by plants can be 5°C to 15°C less than that of unshaded walls, depending on plant types, layout and local climates. Similarly, a roof garden can attain temperature 10°C to 30 C below that of bare roof surface depending on the roof construction, planting details and surrounding conditions. In Nigeria, the rapid growth of vegetation can be harnessed as a passive design element either vertically or horizontally for use in patios, pergolas, screens, atriums, flower pots, etc. in order to create cooling microclimates.

Other methods of passive cooling such as the employment of enclosed courtyards, cooling pools and wind catchers and stack ventilaion have been promoted as methods to passively provide suitable thermal comfort without resorting to mechanical methods.

2.3.2 Inadequacies in thermal comfort

The challenge presented by climate change and global warming means that Climate responsive architecture must be used to satisfy two different purposes. Since climate change as reported earlier has resulted in harsher environmental conditions, this form of architecture firstly, is a solution to provide a conducive indoor thermal environment for living. Secondly, since the methods which are used to achieve this level of thermal comfort are passive in nature, this means that the construction industry produces considerably less impact on the environment throughout the lifecycle of the built environment. The increased use of local materials produces less carbon waste from industrially produced materials, large transport machines, and the use of passive methods reduces the need for mechanical cooling which requires the intense consumption of energy burning of fossil fuels that negatively impacts the environment.

The responsibility of the architect therefore goes beyond just building drawings. He plays a major role from the initial concept stage of a project to the official handover, through building maintenance, management, reuse as well as eventual demolition. The architect has the capacity to impact the way occupants use a building and is a major player in determining the thermal comfort level of interior environments. Consequently, this means the architect also takes responsibility for buildings with poor thermal performance.

Studies undertaken in the hot dry region of Nigeria have shown that a large number of houses have interior temperatures beyond the thermal comfort requirements, with high temperatures observed in the region's residential and non-residential architecture [29], [32], [40], [41]. With the importance ascribed to climate and site responsive design, it is

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not clear why these principles are not adopted. This paper seeks to evaluate the hindrances to the use of climate responsive architecture in the light of increasing temperatures as a result of climate change

3 METHODOLOGY

3.1 Research Design

This study is targeted at the professionals working in the built environment, specifically architects, who are responsible for the first building design decisions. A purposive sampling technique was used to select research participants across the six states in the Northeast region of Nigeria These are Adamawa, Bauchi, Borno, Gombe, Taraba, Yobe States.

A survey methodology was adapted for this study, with its main objective; 'to assess and rank the factors hindering the implementation of climate responsive principles in the region's residential Architecture.' Literature review provided the fundamental theoretical context for the study, while simultaneously serving as a source of secondary data. It also forms the basis for the structuring of interviews conducted to participants. The information gleaned from the interviews provided the premise for a questionnaire survey. These surveys, alongside the interviews serve as the primary data sources for the study.

3.2 Research Questions

Q1. What passive climate responsive architecture principles are utilized by architects in the region?

Q2. What are the hindrances to the implementation of passive climate responsive architecture principles in the region?

3.3 Data Collection

For the research questions raised, an objective approach is needed to provide well rounded answers. This was tackled by initially conducting interviews based on reviewed literature. The answers from the conducted interviews provide the basis for creating a questionnaire. The self-filled questionnaire was distributed to selected architects with working experience in the region, and was designed with a five-point Likert scale which required respondents to answer questions by selecting one of the following; strongly agreed, agreed, neutral, disagree and strongly disagree. The selected architects for interview have had more than 10 years working experience in the region and answered the following open-ended questions;

Do you think there is a need to design climate responsive architecture?

To what extent do architects in the region design with these climate responsive principles in mind? (Building orientation, Floor plan zoning, Shading, Building materials, Vegetation, Courtyards, Stack ventilation/wind catcher)

What are the hindrances to the implementation of climate responsive principles in design of houses?

The interview was conducted for 6 architects, each from a State in the Northeast Region. The interviewed architects are represented as A1, A2, A3, A4, A5, A6.

3.4 Results and Discussions

3.4.1 Interview

From the conducted interviews, all architects concluded that there is an important need to design according to the climate, as corroborated by existing literature. Moreover, there was a general consensus that many of the above mentioned passive responsive principles are not usually all employed in the design phase of houses in the region. However, one or two principles may be used in a house.

A2:*" I don't think you can find a house with all these principles employed together, it's very rare you know. Usually, you'll see a house with a few plants around, or you'll find that they use overhanging eaves to shade the windows"*.

A5:*" Most times you can design verandah around the house, but building orientation or floor plan zoning is not the norm for some particular reasons You can also find some landscaping that improves the cooling. Also, it is hard to see a newly built house made of mud in the towns, maybe in the village you will see more"*.

The Interviews provided valuable insights as to why there is little use of climate responsive. The interviewed architects provided several reasons which can be categorized into the following factors that hinder the use of climate responsive principles in design:

Lack of Client awareness on sustainability

The interviewed architects suggest that there is not enough awareness among clients to the importance of sustainability in design, thermal comfort and daily life.

Lack of information on methods of climate responsive architecture

The curriculum in universities does not provide prospective architects with up to date information on how to utilize climate responsive principles, make performance analysis, produce various design iterations based on thermal comfort and environment.

Socio-Cultural factors

Factors such as the separation of public from private space, and the hierarchy of space order as influenced by religion and culture make it difficult to enforce floor plan zoning.

High Cost perception of Climate responsive architecture solutions

Sometimes, the belief is that the use of these principles can come with additional costs such as those for simulation analyses fees, cost for more building materials and cost for landscaping. Furthermore, clients believe that such design principles will cost more money to include.

Bad Perception of Traditional materials

Construction materials such as mud and timber are seen as substandard, with poor quality and are not related with luxury, reliability, durability or performance.

Client's Preference/choice

Clients who the final say belongs to, often want particular choices, layouts and aesthetics that override any passive design ideas suggested by architects.

3.5 Questionnaire

A total of 80 questionnaires were distributed among practicing architects in the six states within the study region. The questionnaires involve statements that were to be evaluated on a typical Likert scale, using a range of values from 1 = strongly agree and 5 = strongly disagree. A total of 71 questionnaires were returned, representing an 89% response rate which is found to be adequate to provide a basis for empirical study.

3.5.1 Respondent's profile

TABLE 2
RESPONDENT'S GENDER

Respondents	Frequency	Percent
Male	65	91.5
Female	6	8.5
Total	71	100.0

Respondent's gender profile shows a relative absence of female architects in the profession
Source: Authors

TABLE 3
RESPONDENT'S YEARS OF EXPERIENCE

Years of Experience	Frequency	Percent
1 to 5 years	19	26.8
6 to 10 years	21	29.6
More than 10 years	31	43.7
Total	71	100.0

Analysis of respondent's years of experience shows that 43% of respondent architects had more than 10 years' experience in the field, with 29.6% having between 6 to 10 years work experience. This allows the study to gain insight from experienced professionals in the field.
Source: Authors

3.5.2 Respondent's Utilization of CRA Principles

As seen in Table 4, A mean score closer to 1 (Strongly Agree), represents the most utilized CRA principle by respondents while the closer a value is to 5 (Strongly Disagree), the less a CRA principle is utilized. Statistical Computation shows that respondent architects make use of Vegetation more than any other CRA principle, followed by Shading techniques. Furthermore, respondent architects use Cooling pools the least, followed by the use of Stack Ventilation/wind catcher, Floor Plan Zoning, Building Orientation and a Courtyard. A mean value above 3 represents a lack of use of the CRA principles, and therefore the above-mentioned 5 principles are rarely used by architects in the region.

The lack of use of a cooling pool can be attributed to the avoidance of situating stagnant bodies of water that will permit the breeding of malaria carrying mosquitoes.

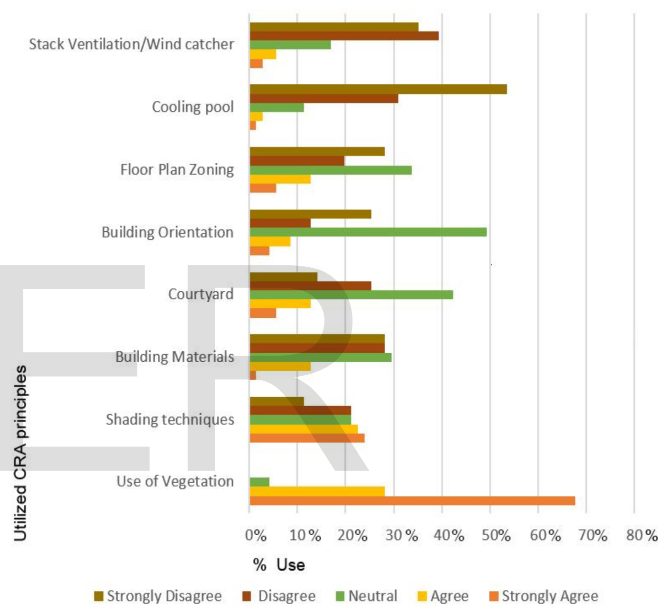

Fig. 3. Clustered bar graph showing respondents' level of utilization of climate responsive architecture principles.

Source: Authors

TABLE 4
RESPONDENT'S USE OF PRINCIPLES OF CLIMATE RESPONSIVE ARCHITECTURE (CRA)

	Use of Vegetation	Shading techniques	Building Materials	Courtyard	Building Orientation	Floor Plan Zoning	Cooling pool	Stack Ventilation/Wind catcher
Mean	1.37	2.73	3.69	3.30	3.46	3.52	4.32	3.99
Std. Deviation	.567	1.341	1.064	1.047	1.093	1.194	.891	1.007

Analysis of respondent's perception on their use of CRA principles shows that respondents use Vegetation the most, while they use Cooling pools the least.
Source: Authors

TABLE 5
RESPONDENT'S RANKING OF THE FACTORS HINDERING USE OF PRINCIPLES OF CLIMATE RESPONSIVE ARCHITECTURE (CRA)

	Lack of client awareness for the importance of CRA	Lack of knowledge on methods of CRA	Client preference	Socio-cultural needs	High Cost perception of using CRA principles	Bad perception of local/traditional materials
Mean	1.62	2.15	1.68	1.66	2.21	1.97
Std. Deviation	.704	1.142	.713	.716	1.054	1.095
Rank	1st	5th	3rd	2nd	6th	4th

Respondent's ranking of the factors hindering the use of CRA principles puts Lack of client awareness for the importance of CRA as the most hindering factor.
Source: Authors

3.5.3 Respondent's Ranking of Hindrances to the use of CRA Principles

As shown in Table 5 above, a mean score closer to 1 represents that respondents strongly agree with a variable as the most hindering factor for CRA principle utilization. Respondents rank lack of client awareness for the importance of climate responsive design as the biggest factor hindering the utilization of CRA principles. Socio-Cultural needs, followed by Client preference rank 2nd and 3rd respectively. This suggests that clients lack sufficient awareness about the importance of CRA principles, in agreement with studies by Obia (2016) in South-South Nigeria, who observed that only 13.5% of architects sampled had clients who asked them to incorporate green architecture in their design [42]. It also agrees with studies by Allu (2015) that respondents are not very knowledgeable on the relationship between climate change and buildings [43]. This paper further ranks the lack of knowledge on methods of CRA principles utilization as the 5th most important factor hindering the utilization of Climate responsive architecture principles in the Northeast Region. While this may rank low relative to the other factors, it still is an important hindrance as the difference seen between the respondents ranking of factors is very close, suggesting that all the suggested factors offer significant hindrances to the utilization of Climate responsive architecture principles in Northeast Nigeria.

3.6 Conclusion

Thermal comfort in any building is of paramount importance, and it is becoming increasingly difficult to achieve thermal comfort passively due to increasing temperatures as a result of climate change in Northeast Nigeria. The use of principles of climate responsive architecture has a twofold effect, improving the thermal comfort of the interior environment while reducing the energy requirements, and subsequently emission impacts of the built environment. As seen in this study, besides the use of vegetation such as trees, plants and various landscaping, principles of CRA are rarely used in this region by architects. This is largely as a result of a lack of awareness of the importance of using these principles to passively cool buildings, as well as a general lack of awareness on the impacts of the domestic sector on the climate. The preferences of clients, socio-cultural needs as well as high cost perception of CRA principles also pose a major hindrance to the use of these passive principles. These hindrances appear to all stem from a general lack of awareness of the relationship between climate and buildings. It is important therefore to generate awareness for the importance of Climate responsive architecture in this region, which is experiencing rapid urbanization and population growth. Public campaigns and government initiatives must be set up to ensure the populace has adequate knowledge on the subject. Moreover, architects, whose responsibility it is to provide good shelter, should be educated sufficiently on the use of CRA principles.

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