Greening Vernacular Building Projects in Northern Nigeria

II Danja¹, Wang Xinping¹, SG Dalibi³, Mukhtar Alkali², L U Inuwa⁴ and Anvar Safarov²

¹Institute of Regional and Urban Development, School of Architecture, South East University, Nanjing China.
²School of Architecture, South East University, Nanjing China.
³Institute of Project Management, Hohai University Nanjing, China.
⁴Business School, Nanjing University of Information Science and Technology

*danjaiah@yahoo.com

Abstract: The concept of green building has extended its boundaries over the past decades as it now involves several other disciplines. Greening takes advantage of available human and natural resources, including solar access, wind patterns, accessible, and affordable construction materials. The introduction of some specific green ideas and features into vernacular buildings in northern Nigeria will not only improve the living condition of the building occupants but can also sustain, and preserve the traditional practices while also introducing new innovative design ideas into vernacular architectural traditions, thereby, saving the vernacular architecture of such regions. Geographical factors such as solar radiation and the problem of the Tropical Continental Air mass (CT) locally known as the harmattan wind, which significantly affects the daily usage of the residents. This study recommends the use of some selected green building concepts into the vernacular architectural practices in northern Nigeria with the view of identifying the impact of the proposed features on the performance of vernacular buildings in Northern Nigeria. Proposed concepts were integrated into a prototype of the existing buildings. Reviewed literature is used to determine the adaptable features, and An energy simulation using Autodesk Insight, an add-in of Revit software, and Autodesk flow simulation software are used to assess their effects on such buildings. The result shows that the adopted ideas will significantly improve the indoor environment quality and the entire livelihood of the building occupants.

1. Introduction

The concept of green building has extended its boundaries over the past decades as it now involves several other disciplines. Previous studies have defined a green building as a building process that is harmless to human health and environment by attempting to safeguard air, water, and earth by using eco-friendly materials and construction practices [1]; the foundation of sustainable construction and refer to a structure that is resource-efficient in term of economy, utility, durability, and comfort [2-3]; buildings with combination of energy and water efficiency systems, daylighting strategies, indoor environment quality (IEQ) system and efficient building envelope system that is efficient to the extent that it constitutes both a comfortable living condition, and a positive impact to building occupants and the immediate environment.
[4]; and as a building or structure that enhances resource savings, environmental protection, pollution reduction, while administering a comfortable, healthy, and efficient living space for the people, as it exists compatibly with nature [5-7]. Therefore, designing an environmentally friendly building that satisfies the human livelihood condition by taking advantage of available human and natural resources, including solar access, wind patterns, accessible, and affordable construction materials, is well within the concept of green building.

The introduction of these green concepts and features into vernacular buildings (VB) in northern Nigeria will not only improve the living condition of the building occupants but can also sustain, and preserve the traditional practices while also introducing new innovative design ideas into vernacular architectural traditions, thereby, saving the pre-existing vernacular architecture of these regions. Danja et al. define vernacular architecture (VA) as a shelter or building constructed according to ethnicity, culture, religion, environment, constrained by climatic factors, and local sourcing of available building materials of a region [8]. The traditional architecture of Hausa-Fulani in northern Nigeria are among the most alluring of the medieval ages owing to their bright, colorful, and elaborating engraving symbols designed into building facades [9]. They also exude a unique ambiance, and can be found in varying sizes and shapes and, a tradition of exquisite architecture has continuously blossomed in the area over the centuries [10].

Fatty stated that only innovation and evaluation of new ideas would save the architecture of the tropics [11]. These entail the introduction and integration of innovative design concepts and ideas into architectural practices of the regions. Geographical factors such as solar radiation cause a significant rise in temperature in the Savannah region, which affects the IEQ of the buildings; in some cases, the buildings with thicker walls absorb and stores a lot of heat from passive solar radiation and transfer it to the buildings at night. This heat transfer makes a living inside the rooms unbearable at night, especially in summer. The amount of absorbed solar radiation also causes crumbling, wear, and tear of the walls.

There is also the problem of the Tropical Continental Air mass (CT) locally known as the harmattan wind, originating from North Africa, which crosses the Sahara Desert into West Africa to Nigeria. This dusty air mass affects the regular daily activities of the building occupants by forcing them to abandon the courtyards and move into their rooms, especially during harmattan [12]. There is also the problem of water scarcity, especially in the dry season, as building occupants need to travel kilometers to neighboring villages to fetch water for daily uses. The combination of these challenges further consolidates the problems faced by VB in Northern Nigeria. Hence, the need to introduce green concepts, features, and practices regarding such structures.

This study aims to introduce some selected green building (GB) features into the vernacular architectural practices in northern Nigeria with the view of identifying the impact of the proposed features on the performance of VB in northern Nigeria. To achieve the research aim and adequately address the research problems, the proposed concepts will be integrated into a prototype of the existing buildings.

1.1 Methodology
Reviewed literature will be used to determine some of the adoptable GB features that can enhance the human living condition of the occupants of VB in northern Nigeria. This research adopted the use of the wind-catcher system, Shading and extended roof eaves, Natural shading and windbreakers, and stormwater harvesting. An energy simulation using Autodesk Insight, an add-in of Revit software, and Autodesk flow simulation software would be used to determine the effect of these adopted features on VB in northern Nigeria.
2. Literature Review

2.1 The climate of Northern Nigeria
Like most countries in West Africa, the climate of Nigeria is characterized by active latitudinal zones, that progressively become drier the further north one advances from the coast. Rainfall, therefore, serves as the crucial climate variable in Nigeria with an alternation of dry and wet seasons. Rain in the region is controlled by moisture-laden northward-moving air from the coast of the Atlantic, and dry continental air from the North African landmass [13]. Northern Nigeria is covered by the Savanna region (Sahel, Guinea, and Sudan Savanna). The Savanna climate type has alternating Wet and dry seasons. The rainfall in this region is varying with an unpredictable onset and lasts about five months in a year, especially between May and October. The rainfall intensity is mostly high between July and August [14]. The dry season in the region is mainly from December to March with Harmattan, a continental tropical air mass (CT) loaded with dust from the Sahara Desert dominating the season. The airmass originates from North Africa and moves across the Sahara Desert into West Africa to northern Nigeria carrying dirt, limiting visibility, and blocking sun rays in the region [15]. The temperature in Northern Nigeria can reach as high as 44° C before the beginning of the rainy season and drop to a relatively harsh low of 6° C during the intrusion of cold air from the Sahara Desert [12].

2.2 Typical Building Prototype
The building is located at 12°28′N7°59′E in Dadin Kwarar village of Kusada Local Government at the Northern part of Katsina State in Daura Senatorial Zone. The building is a traditional courtyard house commonly built in the region following the Islamic style of architecture. The house is divided into two parts joined by the central courtyard; the front part is opened to the public while the inner part is private. Figures 1-4 show the typical building prototype and its layout.

![Figure 1. Floor plan of building prototype](source: Author, 2017)

![Figure 2. Function layout of building prototype](source: Author, 2017)
2.3 Adoptable Features and Design Considerations

The VBs in Northern Nigeria are green because they are designed and built using eco-friendly locally available building materials. Due to the geography of the region, this study will adopt the systems of Windcatcher, Natural shading, and windbreakers. Shading and extended roof eaves, Stormwater harvesting into the VB in northern Nigeria.

2.3.1 Wind Catcher. The windcatcher is an intelligent utilization of wind energy, which makes an increase in building thermal comfort in a tropical region viable. The significant advantage of the wind towers is that they are passive systems, requiring no power for their operation [16]. This system exhibits the harmony of the natural environment and architectural design as it conserves energy and operates base on sustainability principles [17]. The windcatcher is an element of Iranian architecture used to direct the wind into the interior spaces of a building to increase the thermal comfort for occupants. The system is mostly a combination of inlet and outlet openings serving as a channel through which air circulates in and out of a building or structure [18].

2.3.2 Natural Shading and Windbreakers. Previous studies showed that the solution of using trees around buildings to reduce energy consumption is efficient. It was confirmed that the cooling effects of trees vary with the kind of tree and individual trees of the same family [19]. The major impact factor of trees affecting the cooling demands of buildings may include tree height, the distance between trees and buildings, tree canopy density, and tree species [20]. A study conducted in Akure city in the south-western part of Nigeria on the effect of tree shading on two similar buildings shows a significant difference between indoor-outdoor temperature. The tree-shaded building shows a peak of 2.4°C, while the unshaded building exceeds 5.4°C [21]. Therefore, the Use of trees as natural shadings and windbreakers can increase the thermal comfort of VB in northern Nigeria as well as protect them from the tropical continental air mass. This study will adopt...
the planting Neem tree, also known as “Darbejiya” in the Hausa language. Neem tree is evergreen and can reach a height of 15m and can survive in regions of high temperature; it also possesses medicinal properties that can be useful to the residents and their locale.

2.3.3 Shading and Extended Roof Eaves. In Northern Nigeria, passive solar radiation is transmitted to the exposed building envelope directly; this significantly affects the thermal comfort of the buildings. There are various forms of affordable external shading systems that are effective for different seasons and different building orientations. Horizontal shadings like roof eaves and roof overhangs are more suitable for protection against passive solar radiation if strategically installed while fins and other vertical shading systems are ideal for protection against both rain and passive solar radiation. This study will adopt the use of external horizontal shading into the proposed building prototype. A roof overhang will be installed in front of the building envelope. The installation of this overhang will provide the necessary protection for the building against passive solar radiation and provide shade for the building occupants.

2.4. Adopting the Proposed Features and Design Considerations

A study survey conducted by [22] on the VA of northern Nigeria shows that the heat gain through passive solar radiation and inadequate ventilation are some of the primary factors affecting the IEQ of the VB. The building's thick walls absorb most of the solar radiation during the day and transfer it into the interior spaces at night. Additionally, the lack of proper ventilation mechanisms further exacerbates this challenge. In an urban setting, a direct solution would be to provide air conditioning units to cool the space when required. However, this is an energy-intensive cooling system that is unattainable for the rural poor. It becomes essential to create a simple and affordable solution that improves the IEQ of the buildings. These, all together, according to Dalibi et al. [23] is essential and discard any hindrance to GB features.

2.4.1. Wind Catcher. Autodesk flow simulation software is used to test the effect of adopting a wind catcher system into VB in northern Nigeria. An airflow simulation around a simplified model of the house on-site was run, as shown in figure 5, to visually show the poor ventilation in the buildings.

![Figure 5. Prototype building model on site](Source: Author, 2019)
During the summer months, the prevailing wind direction is from the west. However, the western ends of the bedrooms have no window openings, which means that if the doors are closed, which they typically are for privacy, there is little to no air circulation, as shown by the simulation of the rooms present condition in figure 6.

By adding windcatcher, extending the roof eaves, and adding an opening or a window on the western walls of the bedrooms, the indoor thermal comfort of the rooms will be remarkably improved. As shown in figure 7 below, the extended roof eaves wills serve as a mechanism for trapping moving air, which will then be tunneled into the freshly created opening on the western wall into the bedrooms. By making the openings on the windward side of the bedrooms smaller and increasing the size of those in the leeward side, the higher air pressure on the windward side would force air through, thereby creating cross ventilation. The addition of a windcatcher allows the warm air from inside the building to escape while the cooler air replaces it through the stack effect.

Figure 6. Air circulation in typical building prototype(Source: Author 2019 )
Figure 7. Air circulation after the extension of roof eaves, adding another opening and windcatcher (Source: Author, 2019)
2.4.2. Shading and Extended Roof Eaves. Autodesk Insight, an energy simulation add-in of Revit software is used to analyze the typical building prototype for one year (from 1st of January 2010 to 31st December 2010) to ascertain the effect of extending the roof eaves and the level of insulation needed on the façade and roof of the building.

Figure 8: Rate of absorbed solar radiation by typical building prototype(Source: Author, 2019)

Figure 8 shows the rate of the absorbed passive solar radiation by the typical building prototype. The roof is the highest absorber of the radiation, then followed by the courtyard and the walls. Extending the roof eaves reduces the amount of the absorbed radiation by the building interiors, walls, and the courtyards, as shown in figure 9.

Figure 9. Rate of absorbed radiation after the extension of roof eaves(Source: Author, 2019)

Figure 9 shows that extending the roof eaves significantly reduces the amount of the absorbed passive solar radiation by building walls and courtyards.

2.4.3. Natural Shading and Windbreakers. Planting a row of trees along the western and eastern facades (areas of the building that receive direct sunlight) as shading mechanisms will further reduce the amount of absorbed solar radiation and improve the environmental quality of the buildings, as shown in figure 10
below. It can also block the amount of dust carried by Harmattan wind in the dry season, thereby serving as a windbreaker. However, it is imperative to make sure that the planted trees have their leaves and branches above the roof section so as not to disrupt the airflow through the windows.

Figure 10. The planting of neem trees along the western and eastern facades significantly reduces the amount of radiation absorbed by the buildings (Source: Author, 2019)

2.4.4. Storm Water Harvesting. The study area lies in the Sahel Savannah region of Nigeria; dry season is an annual occurrence. Also, the remote location of the village means it does not have access to potable water pipelines, which means that residents have to rely on previously dug wells and existing streams as their source of water in dry seasons. Figure 11 shows that stormwater can be harvested to reduce the problems of access to potable water.

Figure 11: Harvesting stormwater during the rainy season to overcome the problem of access to clean water in the dry seasons. (Source: Author, 2019)

A simple gutter equipped with a fine mesh filter to the drain is added to collect rainwater from the rooftop and transfer it into a partially buried clay pot typically used in the region to store water and keep it ready for future uses.

3. Conclusion
Designing an environmentally friendly building that satisfies the human livelihood condition by taking advantage of available human and natural resources, including solar access, wind patterns, accessible, and affordable construction materials, is critical to saving vernacular architectural practices in northern Nigeria. The introduction of these green concepts and features into VB will not only improve the living condition of the building occupants but can also sustain and preserve the traditional practices while also introducing new innovative design ideas into vernacular architectural traditions, thereby saving the VA of such regions. The
result from the simulations shows that incorporating the proposed design concepts and features into traditional architectural practices will significantly improve the living condition of the building residents. The addition of windcatcher, extension of the roof eaves, and adding an opening or a window on the western walls of the bedrooms, will improve the indoor thermal comfort of the rooms, and use of natural shading and windbreakers as shading mechanisms will further reduce the amount of absorbed solar radiation by building walls and courtyards thus improving the environmental quality of the buildings. Furthermore, harvesting stormwater during the rainy season would help in overcoming the problem of access to clean water in the dry seasons. Despite the result of the simulation, it is imperative to incorporate the adopted features practically to realize their impact on VB in Northern Nigeria.

Acknowledgement
This research is funded by National Key R&D Program of China (No. 2016YFE0201000): Research Cooperation and Exemplary Application in Planning of Overseas Industrial Parks.

Reference
[1] Roy Madhumita, 2008, Dept. of Architecture, Jadavpur University, Kolkata, India, “Importance of green architecture today.”
[2] U.S Green Building Council, How to achieve certification, accessed: February 21, 2012, available: http://www.usgbc.org/Display-Page.aspx?CMSPageID=1991,2012.
[3] Environmental Protection Agency (EPA), GREEN BUILDING, available at http://www.epa.gov/greenbuilding/publishabout.htm.
[4] Salisu Gidado Dalibi (2012): Cost Impact Assessment of Green Buildings in China (A Case Study of a few Selected Green Building Projects in Shanghai, China). MSc Thesis submitted to Hohai University Nanjing-Jiangsu Province of China.
[5] MOC 2006. Evaluation standard for green building (GB/T 50378-2006). One ed.: MoC.
[6] LI, Y. &CURRIE, J. (2011). Green Buildings in China: conception, codes, and certification. Available: http://www.institutebe.com/InstituteBE/media/Library/Resources/Green%20Buildings/Issue_Brief_Green_Buildings_in_China.pdf [Accessed Feb 11,2012].
[7] Yujun Liu (2012): Green Building Development in China: A policy-Oriented Research With a Case Study of Shanghai. Master’s Degree Thesis in Environmental Studies and Sustainability Science submitted in partial fulfillment of the requirements for Lund University International Master’s Program in Environmental Studies and Sustainability Science.
[8] I. Danja, Xue Li, and S.G. Dalibi (2017a). Vernacular Architecture of Northern Nigeria: A Review. International Journal of Scientific & Engineering Research, Volume 8, Issue 3, March-2017 ISSN 2229-5518.
[9] Kano chronicle, 1970-72 accessed 10/29/16.
[10] I. Danja, Xue Li, and S.G. Dalibi (2017 b). Vernacular Architecture of Northern Nigeria in the Light of Sustainability. 2017 International Conference on Sustainable Development & Green Building (ICSDGB 2017) Suzhou, China
[11] Fatty, H., 2006. Natural energy and Vernacular Architecture. In: Jencks, C. and K. Kroopf, (Eds.), Theories and Manifestoes of Contemporary Architecture. 2nd Edn., John Wiley and Sons Ltd., Sussex, pp: 144-145.
[12] URL: https://en.wikipedia.org/wiki/Geography_of_Nigeria accessed 8/1/2018.
[13] URL: http://www.geography site.co.uk/pages/countries/climate/nigeria_climate.html. Accessed 8/1/2018.
[14] Anselm E.O, & O.F Ati., 2010, *The influence of rainfall on Hausa traditional architecture*. Research Journal of applied science, engineering, and technology. Maxwell Scientific organization, 2010.

[15] URL: https://en.wikipedia.org/wiki/Geography_of_Nigeria accessed 8/1/2018.

[16] Maryam Hossein Ghadiri, and Mahmud Dehnavi: *the effect of plan size in wind catcher on its ventilation rate*. Proceedings of TheIIER-Science Plus International Conference, Kuala Lumpur Malaysia, 18th October 2014, ISBN: 978-93-84209-57-5.

[17] M.K. Pirnia, Windcatcher, Journal of Art and Architecture, 10(1), 1971, 30-34 [1].

[18] Mahmud Dehnavi, Maryam Hossein Ghadiri, Hossein Mohammadi, Mahdiar Hossein Ghadiri. *Study of Wind Catchers with a square plan: Influence of physical parameters*. International Journal of Modern Engineering Research (IJMER). Vol.2, Issue.1, Jan-Feb, 2012 pp-559-564.

[19] L. Shashua-bar, M.E. Hoffman, Vegetation as a climatic component in the design of an urban street, EnergyBuild. 31 (2000) 221-235.

[20] F.C. Jan, C.M. Hseih, M. Ishikawa, Influence of street tree density on transpiration in a sub-tropical climate, Environ. Nat. Res. Res. 2 (2012).

[21] T.E. Morakinyo, A.A. Balogun, O.B. Adegun, Comparing the effect of trees on the thermal condition of two typical urban buildings, Urban Clim. 3 (2013) 76-93.

[22] I Danja. Vernacular Architecture of Northern Nigeria. A Thesis Submitted to Southeast University For the Academic Degree of Master of Architecture (2018) 22-24.

[23] S. G. Dalibi, J. C. Feng, L. Shuangqin, A. Sadiq, B. S. Bello, and I. I. Danja, “Hindrances to Green Building Developments in Nigeria’s Built Environment: ‘the Project Professionals’ Perspectives,” in *IOP Conference Series: Earth and Environmental Science*, 2017.