SUSTAINABLE LANDSCAPING AND GREEN HOUSING IN TROPICAL CLIMATES: A CASE STUDY OF AKURE, NIGERIA

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Abstract

The need for green housing is generally acknowledged by architects in Nigeria and there have been many attempts to enlighten professionals about the consequences of global warming and why we must adapt to the current demands of sustainability. However, architects are often at a loss when it comes to implementation of these ideals in the Nigerian context. This paper defines green building and green housing in tropical climates and identifies the objectives of going green. The advantages and benefits of green housing are specified as including improvement of indoor air quality, increase in energy efficiency and waste reduction. The paper also discusses sustainable landscaping in tropical countries and recommends practices that support sustainable environments in which all plants, animals and other forms of life are able to exist in an ecosystem without any exterior aid or interference. The paper aims to formulate a strategy for development of tools for green housing and sustainable landscaping of residential areas in Akure and has the specific objectives of creating ideal models for green housing and sustainable landscaping in Akure and in Nigeria in general. Using averages of long term climatic data collected from climatological station in Akure and the thermal index proposed by Martin Evans, the thermal stress (comfort conditions) in Akure are defined. With this basic definition of the climatic context, an attempt was made at proposing ideal models for green housing and sustainable landscaping of residential areas in Akure. The procedure for defining rating scales using the Building Research Establishment Environmental Assessment Method (BREEAM) was discussed in detail and the applicability of the system in Nigeria was analyzed with concrete proposals for amendments to improve accuracy in the Nigerian environment. The ideal model proposed for sustainable landscaping of residential areas in Akure concentrates on which climatic variables (sol-air temperature, the air temperature, the relative humidity, wind speed and direction as well as surface absorptivity and reflectance). The hard and soft landscaping elements that can be used to achieve this control include trees and shrubs, lawns and flowerbeds, pools and ponds, mulches, walls and fences, steps and paving. In conclusion, the paper recommends detailed analysis of climatic data, determination of the thermal stress and cooling loads in major Nigerian cities using current software and models and the empirical comparison
of various green rating scales with the aim of creating a hybrid system that will be most accurate and effective in determining the sustainability of existing and proposed housing units.

**Keywords:** climate, comfort, green housing, environment, sustainable landscaping.

1. **INTRODUCTION**

Housing has been universally accepted as a basic essential human need that comes only after food and clothing. Housing in all its ramifications is more than mere shelter since it embraces all the social services and utilities that make a community or neighbourhood a liveable environment. It is the total environment in which man lives and grows. Man’s strive for increased comfort and financial independence, the densification of congested urban areas, increase in traffic levels and the growing electric smog problem due to new communication technologies all cause ever rising stress levels in individuals and the society at large. These human activities cause various environmental problems including air and water pollution, generation of domestic and industrial waste, emergence of slums and global warming with attendant negative effects on quality of life and health standard of the citizenry.

The concept of sustainable development can be traced to the energy crisis and the environmental pollution concern in the 1970s ([Mao et al.](#), 2009). The green building movement in the United States of America originated from the need for more energy efficient and environmentally friendly construction practices. There are a number of motives to building green, including environmental, economic, and social benefits. However, modern sustainability initiatives call for an integrated and synergistic design to both new construction and in the retrofitting of existing structures. Also known as sustainable design, this approach integrates the building life-cycle with each green practice employed with a design-purpose to create a synergy amongst the practices used. This energy design or energy conscious design can be achieved through intelligent design and use of materials and technology (Adedeji and Folorunso, 2008). This paper documents the analysis of the climate and human comfort conditions of Akure, the capital of Ondo State in Nigeria and proposes ideals models for sustainable landscaping and green housing for ameliorating green house effects and thermal stress in tropical environments.

2. **GREEN HOUSING IN TROPICAL CLIMATES**

Green building (also known as green construction or sustainable building) is the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle ([Bauer et al.](#), 2009). Starting from siting to design, construction, operation, maintenance, renovation, and deconstruction, this practice expands and complements the classical building design concerns of economy, utility, durability, and comfort ([U.S. Environmental Protection Agency](#), 2009b).

Green building brings together a vast array of practices and techniques to reduce and ultimately eliminate the impacts of new buildings on the environment and human health. It often emphasizes taking advantage of renewable resources e.g., using sunlight through passive solar, active solar and voltaic techniques and using plants and trees for reduction of rainwater run-off. Many other techniques, such as using packed gravel or permeable concrete instead of conventional concrete or asphalt to enhance replenishment of ground water, are used as well.

While the practices, or technologies, employed in green building are constantly evolving and may differ from region to region, there are fundamental principles that persist from which the
method is derived: siting and structure design efficiency, energy efficiency, water efficiency, materials efficiency, indoor environmental quality enhancement, operations and maintenance optimisation and toxic waste reduction (U.S. Environmental Protection Agency, 2009a). The essence of green building is an optimization of one or more of these principles. Also, with the proper synergistic design, individual green building technologies may work together to produce a greater cumulative effect.

Although new technologies are constantly being developed to complement current practices in creating greener structures, the common objective is that green buildings are designed to reduce the overall impact of the built environment on human health and the natural environment by:

1. Efficiently using energy, water and other resources; 
2. Protecting occupant health and improving employees’ productivity and 
3. Reducing waste, pollution and other environmental degradation.

Green housing is fundamentally the basis of green living and green building. This means that the lifestyle of the homeowner, design and functionality of the house influence the degree of green housing anticipated. There are a wide variety of options to be chosen from in order to “green” a building. These includes reducing energy use and converting to alternative energy solutions, reducing water use, choosing an environmentally friendly location for houses, designing homes with green building materials and increasing recycling.

3. ADVANTAGES AND BENEFITS OF GREEN HOUSING

Green building practices aim to reduce the environmental impact of new buildings. Buildings account for a large amount of land use, energy and water consumption, and alteration of the environment. Considering the statistics, reducing the amount of natural resources buildings consume and the amount of pollution given off is seen as crucial for future sustainability (U.S. Environmental Protection Agency, 2009b). Benefits derivable from green housing can be categorized into two. These are environmental benefits and economic benefits. The environmental benefits include improving air and water quality; protecting the biodiversity and the ecosystem of our planet and conserving natural resources such as natural gas and fossil fuels (Greg et al., 2003). Economic benefits include lower energy consumption with energy saving electrical appliances, lightning bulbs, home designs and locations; and through green energy solutions such as solar panels and wind turbines which generate electricity independently from utility companies. Additionally, green housing increases the value of a home.

Green buildings can be used to achieve the following:

3.1. Improvement of Indoor Air Quality

Improvement of Indoor Air Quality (IAQ) seeks to reduce volatile organic compounds (VOC) and other air impurities such as microbial contaminants. Choosing construction materials and interior finish products with zero or low emissions will improve IAQ because many building materials emit toxic gases. These gases can have a detrimental impact on occupants' health and productivity as well (Lee & Guerin, 2009).

3.2. Increase in Energy Efficiency

Green buildings often include measures to reduce energy use. To increase the efficiency of the building envelope, (the barrier between conditioned and unconditioned space), they may use
high-efficiency windows insulation in walls, ceilings, and floors. Another strategy, passive solar building design, is often implemented in low-energy homes. Personal temperature and airflow control over the HVAC system coupled with a properly designed building envelope will aid in increasing a building’s thermal quality. Designers orient windows and walls and place awnings, porches, and trees (Simpson, 2002) to shade windows and roofs during the wet season while maximizing solar gain in the dry season. In addition, effective window placement (day lighting) can provide more natural light and lessen the need for electric lighting during the day. Solar water heating further reduces energy loads. Creating a high performance luminous environment through the careful integration of natural and artificial light sources will improve the lighting quality of a structure (National Institute of Building Sciences, 2010)

3.3. Waste Reduction
Green architecture also seeks to reduce waste of energy, water and materials used during construction. During the construction phase, one goal should be to reduce the amount of material going to landfills. Well-designed buildings also help reduce the amount of waste generated by the occupants as well, by providing on-site solutions such as compost bins to reduce matter going to landfills. To reduce the impact on wells or water treatment plants, several options exist. Waste water from sources such as dishwashing or washing machines, can be used for subsurface irrigation, or if treated, for non-potable purposes, for example, to flush toilets and wash cars. Rainwater collectors are used for similar purposes.

4. SUSTAINABLE LANDSCAPING IN TROPICAL COUNTRIES
A sustainable landscape is designed to be both attractive and in balance with the local climate and environment and it should require minimal resource inputs such as fertilizer, pesticides and water. Sustainable landscaping begins with an appropriate design that must be functional, cost-efficient, visually pleasing, environmentally friendly and maintainable. It pays close attention to the preservation of limited and costly resources, reducing waste and preventing air, water and soil pollution. Also, compost, fertilization, pest control measures that avoid or minimize the use of chemicals, integrated pest management using the right plant in the right place, appropriate use of turf, irrigation efficiency and or water-wise gardening are all components of sustainable landscaping. A sustainable environment is the one in which all plants, animals and other forms of life are able to exist in an ecosystem without any exterior aid or interference (Sustainable Landscape Designs (2010); White, 2010).

Sustainable landscaping includes a diversity of practices that have developed in response to environmental issues. These practices are used in every phase of landscaping, including design, construction, implementation and management of residential and commercial landscapes (Loehrlein, 2009)

Sustainable landscaping can be achieved by the adoption of the following:
1. Reduction of storm water run-off through the use of bio-wastes, rain gardens and green roofs and walls (Rowe et al, 2006).
2. Reduction of water use in landscapes through design of water-wise garden techniques (sometimes known as xeriscaping (Krizner, 2008).
4. Landscape irrigation using water from showers and sinks, known as gray water (Melby, & Cathcart, 2002).
5. Integrated Pest Management techniques for pest control.
6. Creating and enhancing wildlife habitat in urban environments.
7. Permeable paving materials to reduce storm-water run-off and allow rain water to infiltrate into the ground and replenish groundwater rather than run into surface water (Kerkhoff, 2006).
8. Use of sustainably harvested wood, composite wood products for decking and other landscape projects, as well as use of plastic lumber (Weber, 2006).
9. Recycling of products, such as glass, rubber from tires and other materials to create landscape products such as paving stones, mulch and other materials.
10. Soil management techniques, including composting kitchen and yard wastes, to maintain and enhance healthy soil that supports a diversity of soil life.
11. Integration and adoption of renewable energy, including solar-powered landscape lighting.

5. RESEARCH METHODOLOGY

The aim of the research is to formulate a strategy for development of tools for green housing and sustainable landscaping of residential areas in Akure. The specific objectives are:

- To create an ideal model for green housing in Akure and in Nigeria in general and
- To create an ideal model for sustainable landscaping in Akure and in Nigeria in general.

5.1. Data Collection

The data used for the research was collected from various meteorological stations in Akure by postgraduate students as an assignment for the course "ARC 810: Applied Climatology" during the year 2007. The data was analyzed using Microsoft Excel. Inconsistent and suspicious data were ignored, while missing data were compensated for. This data was compared for consistency with the data archives of the Meteorology Department, Federal University of Technology, Akure. Detailed hourly and daily climatic data for Ilesha, Osun State, was obtained from Meteonorm, the global solar radiation database and this helped as a guide in identifying values that were significantly out of range. The literature review was based on library and Internet searches.

5.2. Determination of thermal stress

The thermal stress was determined using procedures established by Ogunsote in earlier studies and the Evans scale.

6. THE CLIMATE OF AKURE

The building of a model for green housing and sustainable landscaping in Akure requires a good understanding of the climatic conditions and thermal stress (comfort conditions) in Akure. What is required is not only collection and analysis of long term climatic data, but also extensive studies of the comfort conditions, heat loads and occupant behavioural patterns during different seasons of the year using various architectural models. Given the recent advances in
development of green rating systems and software for assessment of thermal comfort, it became evident that detailed climatic data will be required to build a refined model. Meanwhile, only limited climatic data was available for Akure. The data collected had many missing variables, and sometimes there was no data available for some years. Even some of the data appeared suspicious and require validation and confirmation. The data available was however averaged, obviously misleading data discarded and missing variables were compensated for to give a general idea of the climatic conditions in Akure as presented in table 1.

From the data available, Akure enjoys a moderate tropical climate with maximum temperatures rarely rising above 33°C and minimum temperatures rarely falling below 20°C. Relative humidity is also moderate with maximum relative humidity rarely rising above 86% and minimum relative humidity rarely falling below 40%. There is some form of precipitation throughout the year, even though there are distinct wet and dry seasons. There is usually more than six hours of sunshine, even during the rainy season.

Table 1: Average Climatic Conditions in Akure (1983-2004).

<table>
<thead>
<tr>
<th></th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Monthly Maximum Temperature (°C)</td>
<td>32.1</td>
<td>33.5</td>
<td>33.4</td>
<td>32.3</td>
<td>31.6</td>
<td>29.0</td>
<td>29.0</td>
<td>28.2</td>
<td>29.1</td>
<td>30.4</td>
<td>32.2</td>
<td>31.4</td>
</tr>
<tr>
<td>Mean Monthly Minimum Temperature (°C)</td>
<td>17.9</td>
<td>20.0</td>
<td>21.7</td>
<td>22.0</td>
<td>21.1</td>
<td>20.8</td>
<td>20.2</td>
<td>20.1</td>
<td>20.2</td>
<td>20.6</td>
<td>21.2</td>
<td>19.8</td>
</tr>
<tr>
<td>Mean Daily Maximum Relative Humidity (%)</td>
<td>66.3</td>
<td>65.1</td>
<td>75.9</td>
<td>78.4</td>
<td>79.6</td>
<td>83.2</td>
<td>86.6</td>
<td>85.8</td>
<td>84.6</td>
<td>79.2</td>
<td>75.2</td>
<td>70.7</td>
</tr>
<tr>
<td>Mean Daily Minimum Relative Humidity (%)</td>
<td>43.6</td>
<td>40.0</td>
<td>48.2</td>
<td>54.0</td>
<td>56.5</td>
<td>59.1</td>
<td>62.8</td>
<td>64.1</td>
<td>61.4</td>
<td>60.3</td>
<td>50.0</td>
<td>43.2</td>
</tr>
<tr>
<td>Precipitation (mm)</td>
<td>10.9</td>
<td>33.5</td>
<td>65.6</td>
<td>79.1</td>
<td>154.4</td>
<td>169.5</td>
<td>209.9</td>
<td>245.7</td>
<td>178.8</td>
<td>180.3</td>
<td>49.0</td>
<td>34.1</td>
</tr>
<tr>
<td>Hours of Sunshine</td>
<td>7.9</td>
<td>8.1</td>
<td>7.4</td>
<td>8.4</td>
<td>8.1</td>
<td>7.5</td>
<td>6.9</td>
<td>6.3</td>
<td>7.6</td>
<td>7.6</td>
<td>8.0</td>
<td>7.6</td>
</tr>
<tr>
<td>Mean Wind Velocity (m/s)</td>
<td>0.9</td>
<td>1.1</td>
<td>1.2</td>
<td>1.1</td>
<td>1.1</td>
<td>1.1</td>
<td>1.2</td>
<td>1.1</td>
<td>1.2</td>
<td>1.1</td>
<td>1.1</td>
<td>1.1</td>
</tr>
</tbody>
</table>

Source: Analysis of data collected from weather stations in Akure by FUTA students.

7. COMFORT CONDITIONS IN AKURE

Studies conducted by Ogunsote & Prucnal-Ogunsote (2003) indicate that the comfort limits and the method proposed by Evans (1980) are the most effective for the determination of thermal stress for the Nigerian climate. This method uses the air temperature and the relative humidity to establish the thermal stress. See Table 2.

Table 2. Comfort limits proposed by Evans.

<table>
<thead>
<tr>
<th>Relative humidity (%)</th>
<th>Day comfort limits (°C)</th>
<th>Night comfort limits (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 30</td>
<td>29.5 – 32.5</td>
<td>27.5 – 29.5</td>
</tr>
<tr>
<td>30 – 50</td>
<td>28.5 – 30.5</td>
<td>26.5 – 29</td>
</tr>
<tr>
<td>50 – 70</td>
<td>27.5 – 29.5</td>
<td>26 – 28.5</td>
</tr>
<tr>
<td>70 – 100</td>
<td>26 – 29</td>
<td>25.5 – 28</td>
</tr>
</tbody>
</table>

Source: Evans (1980).
These limits were used to determine the comfort conditions (thermal stress) in Akure. The day thermal stress was obtained by comparing the mean monthly maximum temperature with the day comfort limits using the mean monthly minimum relative humidity. Note that the maximum temperature is used with the minimum relative humidity because both readings are taken in the early afternoon. The night thermal stress is obtained by comparing the mean monthly minimum temperature with the night comfort limits using the mean monthly maximum relative humidity. The thermal stress is categorised as shown in Table 3:

Table 3. Categories of thermal stress.

<table>
<thead>
<tr>
<th>Category of thermal stress</th>
<th>Conditions</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very cold</td>
<td>Temperature less than 5 degrees below the lower comfort limit</td>
<td>--</td>
</tr>
<tr>
<td>Cold</td>
<td>Temperature below the lower comfort limit but more than 5 degrees below the lower comfort limit</td>
<td>-</td>
</tr>
<tr>
<td>Comfortable</td>
<td>Temperature within the comfort limits</td>
<td>0</td>
</tr>
<tr>
<td>Hot</td>
<td>Temperature above the upper comfort limit less than 5 degrees above the upper comfort limit</td>
<td>+</td>
</tr>
<tr>
<td>Very Hot</td>
<td>Temperature more than 5 degrees above the upper comfort limit</td>
<td>++</td>
</tr>
</tbody>
</table>

The climatic data, comfort limits proposed by Evans and this categorization were used to determine the thermal stress in Akure as shown in Table 4.

Table 4. Human Comfort Conditions (Thermal Stress) in Akure.

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
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</tr>
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<td>33.4</td>
<td>32.3</td>
<td>31.6</td>
<td>29.0</td>
<td>29.0</td>
<td>28.2</td>
<td>29.1</td>
<td>30.4</td>
<td>32.2</td>
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<td>22.0</td>
<td>21.1</td>
<td>20.8</td>
<td>20.2</td>
<td>20.1</td>
<td>20.2</td>
<td>20.6</td>
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<td>19.8</td>
</tr>
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<td>75.9</td>
<td>78.4</td>
<td>79.6</td>
<td>83.2</td>
<td>86.6</td>
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</tr>
<tr>
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<td>48.2</td>
<td>54.0</td>
<td>56.5</td>
<td>59.1</td>
<td>62.8</td>
<td>64.1</td>
<td>61.4</td>
<td>60.3</td>
<td>50.0</td>
<td>43.2</td>
</tr>
<tr>
<td>Day Thermal Stress</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Night Thermal Stress</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
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</tr>
</tbody>
</table>

From this analysis, human comfort conditions in Akure are satisfactory and there are no extremes of cold or hot discomfort. Hot discomfort in the day is often followed by cold or very cold discomfort in the night, thereby giving room for amelioration of thermal stress through the use of building materials with high thermal capacity and long time lag.

This analysis however does not take many variables, such as the globe temperature and wind speed, into consideration. There is need for a more detailed and accurate estimation of the thermal stress and also a specification of the thermal capacity and time lag of recommended
building materials that will be required to maintain the environmental variables within the comfort limits.

8. IDEAL MODEL FOR GREEN HOUSING IN AKURE

A model green house in Akure must necessarily meet the minimum requirements for sustainable building in the specific climatic, technological and social-economic environment of Akure. To determine if the model meets such a standard, a green rating system must be used to assess the building. Although there are many rating systems for green architecture and sustainable design around the world, none have been adopted in Nigeria (Prucnal-Ogunsote et al, 2010). These rating systems include the Building Research Establishment Environmental Assessment Method (BREEAM) in the UK, the Leadership in Energy and Environmental Design (LEED) in the USA, Green Star in Australia, and Haute Qualité Environnementale (HQE) in France.

8.1. The Building Research Establishment Environmental Assessment Method (BREEAM)

BREEAM is a voluntary measurement rating for green buildings that sets the standard for best practice in sustainable design and is used to describe a building's environmental performance. It addresses wide-ranging environmental and sustainability issues and enables developers and designers to prove the environmental credentials of their buildings to planners and clients. It uses a straightforward scoring system, has a positive influence on the design, construction and management of buildings, and sets and maintains a robust technical standard with rigorous quality assurance and certification (Building Research Establishment Ltd., 2010 & Wikipedia, 2010). There are minimum levels of performance across 7 key issues:

- Energy efficiency/CO₂
- Water efficiency
- Surface water management
- Site waste management
- Household waste management
- Use of materials
- Lifetime homes (applies to Code Level 6 only)

The procedure for assessment is described in a 300-page document (British Research Establishment, 2010b) and it may not be possible to go into details in such a short paper. Table 5 shows a simplification of this procedure. Each of the issues (C) is awarded a credit (E), from which a percentage point score (F) is obtained by multiplying the credits awarded (E) by the weighted value of each credit (B). The total percentage point score is then found by addition.

The total percentage point score is used to find the code level (star rating) of the building using table 6. A code level is awarded on the basis of achieving both a set of mandatory minimum standards and a minimum overall score. For most of the issues within the code assessment, developers and designers can choose standards to suit a given site and development. This offers flexibility in achieving the standards.
Table 5: Calculation of Star Rating of Buildings using BREEAM.

<table>
<thead>
<tr>
<th>Categories (Category weighing factor)</th>
<th>Weighted value of each credit</th>
<th>Issue</th>
<th>Available credits</th>
<th>Credits awarded</th>
<th>$F = B \times E$</th>
<th>Percentage point score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy and CO2 emissions (36.4%)</td>
<td>1.26</td>
<td>Dwelling emission rate (M)</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Building fabric</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Internal lighting</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Drying space</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Energy labelled white goods</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>External lighting</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Low or zero carbon (LZC) technologies</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cycle storage</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Home office</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water (9%)</td>
<td>1.5</td>
<td>Indoor water use (M)</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>External water use</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Materials (7.2%)</td>
<td>0.3</td>
<td>Environmental impact of materials (M)</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Responsible sourcing of materials – basic building elements</td>
<td>6</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Responsible sourcing of materials – finishing elements</td>
<td>3</td>
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<td></td>
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<tr>
<td>Surface Water Run-off (2.2%)</td>
<td>0.55</td>
<td>Management of Surface Water Runoff from developments (M)</td>
<td>2</td>
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<tr>
<td></td>
<td></td>
<td>Flood risk</td>
<td>2</td>
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<td></td>
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<tr>
<td>Waste (6.4%)</td>
<td>0.91</td>
<td>Storage of non-recyclable waste and recyclable household waste (M)</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Construction waste management (M)</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Composting</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Pollution (2.8%)</td>
<td>0.7</td>
<td>Global warming potential (GWP) of insulants</td>
<td>1</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>NOx emissions</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Health and Well-being (14%)</td>
<td>1.17</td>
<td>Daylighting</td>
<td>3</td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sound insulation</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Private space</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Lifetime homes (M)</td>
<td>4</td>
<td></td>
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<tr>
<td>Management (10%)</td>
<td>1.11</td>
<td>Home user guide</td>
<td>3</td>
<td></td>
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<tr>
<td></td>
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<td>Considerate constructors scheme</td>
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<td></td>
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<td></td>
<td>Construction site impacts</td>
<td>2</td>
<td></td>
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<td></td>
<td></td>
<td>Security</td>
<td>2</td>
<td></td>
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<tr>
<td>Ecology (12%)</td>
<td>1.33</td>
<td>Ecological value of site</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Ecological enhancement</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Protection of ecological features</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Change in ecological value of site</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Building footprint</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: (M) denotes issues with mandatory elements. Source: Adapted from British Research Establishment (2010b).
Table 6: Relationship between Total percentage points score and Code Level (Star rating).

<table>
<thead>
<tr>
<th>Total percentage points score (equal to or greater than)</th>
<th>Code Levels</th>
<th>Star rating</th>
<th>Comparison with other standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>36</td>
<td>1</td>
<td>1-star</td>
<td>Above regulatory standards</td>
</tr>
<tr>
<td>48</td>
<td>2</td>
<td>2-star</td>
<td>Similar standard to BRE’s EcoHomes GOOD level</td>
</tr>
<tr>
<td>57</td>
<td>3</td>
<td>3-star</td>
<td>Broadly similar standard to BRE’s EcoHomes VERY GOOD level</td>
</tr>
<tr>
<td>68</td>
<td>4</td>
<td>4-star</td>
<td>Current exemplary performance</td>
</tr>
<tr>
<td>84</td>
<td>5</td>
<td>5-star</td>
<td>Exemplary performance with high standards of energy and water efficiency</td>
</tr>
<tr>
<td>90</td>
<td>6</td>
<td>6-star</td>
<td>Aspirational standard based on zero carbon emissions for the dwelling and high performance across all environmental categories</td>
</tr>
</tbody>
</table>

Source: Adapted from British Research Establishment (2010b).

8.2. Applicability of BREEAM in Akure and Nigeria Generally

Using a green rating system such as BREEAM to define a model for green housing in Akure requires certain adjustments for the country's specific climatic, technological and social-economic environment. The guide gives detailed instructions for assessment and provides examples of common scenarios and options. For example, for internal water usage in the water category, the following tables and guides are provided.

- A table showing exceptions for post-construction stage assessment.
- A table showing credits to be awarded based on the number of litres consumed per person per day.
- A table showing evidence required to demonstrate compliance.
- A table for calculation of water consumption based on type of fittings, equipment or installation.
- Detailed assessment methodology for both design and post-constructional stages.
- Extensive notes, checklists, examples of cases of non-compliance, examples of special cases, etc.

It is necessary to study these details for each of the issues and make adjustments as necessary. Furthermore, the rating system should be modified to be more accurate in Nigeria in the following ways:

- The system was designed for temperate climates. For tropical climates, there should be more emphasis on natural ventilation, protection from driving rain, sun-shading, protection from pests and vermin and greater emphasis on drainage. Provision of outdoor living space should also be included in the hot and dry climatic design zones in the country.
- The system is complex and time consuming. Simplifying the procedures, even if results will be less accurate, will encourage professionals to use the system.
9. **IDEAL MODEL FOR SUSTAINABLE LANDSCAPING OF RESIDENTIAL AREAS IN AKURE**

Landscaping can be used to control several aspects of the microclimate of residential buildings. According to Ogunsote & Prucnal-Ogunsote (2004), the climatic variables that can be regulated include solar radiation (sol-air temperature), air temperature, relative humidity, wind speed and direction; and glare.

9.1. **Sol-Air Temperature Control**

Ventilated shading provided by trees, shrubs and climbers can be used for the control of radiant temperature, and reduction of air, ground and surface temperature. Ventilated shading reduces the amount of solar radiation reaching ground and wall surfaces, thereby reducing the sol-air temperature, which is an indication of the globe temperature. Climbers with or without trellis can be used to cover surfaces exposed to the sun.

9.2. **Air Temperature Control**

The air temperature control achieved through landscaping is a direct result of reduction in sol-air temperatures by ventilated shading. Ventilated shading is accompanied by evapotranspiration, a process whereby plants take water from the soil and lose the water by evaporation through the leaves. This causes cooling just like sweating causes cooling in humans, with the latent heat of evaporation taken from the surrounding air.

9.3. **Humidity Control**

Plants in general increase the humidity of the site. They can therefore increase the thermal comfort during hot, dry seasons, although the plants have to be watered regularly. The plants take water from the soil, and when this water evaporates from the leaves it increases the relative humidity while lowering the air temperature. Pools and ponds behave in a similar manner. Water evaporating from the surface increases relative humidity while reducing air temperature.

9.4. **Control of Air Velocity and Wind Speed**

Plants are used to reduce wind speed and to increase the velocity of stagnant and slow-moving air. Windbreakers in the form of rows of trees are a very effective way of reducing wind speed and filtering dust. The almond tree effect induces air movement under and around trees even when there is relative calm in unplanted areas.

9.5. **Control of Wind Direction**

Landscaping can be used to direct wind away from the building, or towards the building. Fences, walls, hedges and trees can be combined to form an obstruction that will deflect the wind above the building. This can be useful when protecting the building from the cold harmattan wind. The more common use of trees however, is to channel air flow towards living space. While trees allow a portion of the wind to pass through them, some wind is deflected above and below the trees. The wind forced to flow beneath the trees increases air movement in living space. On larger plots groups of trees can also be used to channel the wind in a particular direction.
9.6.  **Control of Surface Absorptivity and Reflectance (Albedo)**

Landscaping can be used to control the rate at which surfaces absorb and reflect solar radiation. The use of lawns, plants, colour and careful selection of pavement materials can control the proportion of solar radiation absorbed to that reflected (Wilmers, 1991).

9.7.  **Seasonal shading**

The choice of plants can be used to control the amount of shading in different seasons. Summarily, there are two types of climate in Nigeria: the warm humid (such as is found in Akure), and the composite climates. The composite climates have warm humid, hot dry and cold seasons. Seasonal shading usually involves full shading in the hot, wet season. In the dry, cold season trees are used to block the cold northern wind while allowing the sun in from the South. The cold season wind can be blocked by plant material, especially thick evergreens and plants with heavy foliage. A good design will have planting with deciduous trees on the South, which cool the air in the hot season and drop their leaves to let in precious sunlight in the cold season (Caudill et al, 1974).

9.8.  **Pollution control**

Plants are very effective in controlling levels of pollution. They absorb dangerous gases like carbon dioxide that are associated with the urban heat island. They also reduce the levels of other pollutants, especially from automobiles. Buffer zones planted with trees are used for separating industrial areas from residential areas. The tree belts in Northern Nigeria help reduce the dust content of the harmattan winds.

9.9.  **Glare Control**

Direct glare can be prevented by using trees to block off the relevant portions of the sky while indirect glare can be prevented by planting flowers, shrubs and grass on surfaces that would normally reflect light into the building.

9.10.  **Fresh Air and Fragrance**

Plants produce oxygen and fragrances, which combined with the almond tree effect, create the refreshing atmosphere of gardens. While the freshness of the air and fragrance may not be measurable by climatic variables, the improvement in the microclimate is unquestionable.

10.  **LANDSCAPE ELEMENTS FOR MICROCLIMATE CONTROL**

Microclimate control can be achieved by hard and soft landscaping elements. Soft landscaping elements refer to vegetation while the hard landscaping elements are all other elements including simple structures, steps, paving, garden furniture, walls and fences.

10.1.  **Soft landscaping elements**

Trees and shrubs

Trees and shrubs are the most significant in the provision of shade and the control of relative humidity and air movement. They contribute more to the attainment of thermal comfort than any other element. Ventilation is affected by plant materials. Air crossing hard reflective or absorptive surfaces like parking lots and sidewalks is warmed, but air passing through trees and
plants will be cooled (Caudill et al, 1974). See Plate 1. Tree leaves are arranged to catch as much of the sun as possible. In the process, they provide the best possible shade. This shading is far superior to that provided by a roof or a wall. While a roof may provide full shading, the roof heats up in the process and hot air is trapped under the roof causing discomfort. The roof also radiates heat, causing further discomfort. A tree on the other hand filters the radiation, with the upper leaves receiving most radiation and thus becomes hotter. The leaves at the bottom receive less radiation and are much cooler and hence radiate less heat. The tree also allows air to rise through the leaves to the top of the tree, thereby preventing hot air from being trapped under the tree (Ogunsote & Prucnal-Ogunsote, 2004).

![Plate 1: A residential building in Alagbaka GRA, Akure landscaped with shrubs and trees](image)

Source: Field Survey (2010).

**Lawns and Flowerbeds**
Lawns and flowerbeds are used to reduce ground temperature and to prevent glare. Vegetation generally improves air freshness and fragrance. See Plate 2.

**Pools and ponds**
These water bodies are used for humidification and evaporative cooling.
Mulches
Mulch is a protective covering over the roots of trees and bushes to retain moisture and kill weeds. Mulches include straw, fallen leaves or plastic sheeting. Others are gravel, wood chipping, rotting leaves and grass. Mulches can be used to reduce surface and air temperatures by reducing the heat absorbed by the ground.

Trellises and climbers
A trellis is a light framework of crossing strips of wood, plastic, et cetera used to support climbing plants and it is often fastened to a wall. This can be used to provide shade on western walls, or used as free standing elements to block out the Western sun.


10.2. Hard landscaping elements

Walls and fences
Walls are used to deflect the wind, and they can also be used to channel the wind. Walls are usually solid, while fences are made from stakes, rails, wire, netting, et cetera. Fences thus allow some wind to flow through them, even when they have climbers.
Steps and paving
The choice of the surface finishing, material and construction of steps and paving can play a significant role in the reduction of ground temperature. The use of asphalt in parking lots without any form of shade is a primary source of discomfort.

Slopes and barriers
The use of slopes and barriers to direct airflow can be very effective on sites with significant variations in the topography.

Stones and boulders
Stones and boulders can be arranged to direct airflow and to provide shade.

10.3. Outdoor living space
Outdoor living spaces occupy that region between the house and the garden. These are conditioned outdoor spaces. They are partly garden, partly house. They are partially protected from the elements, yet open to nature. They include courtyards (courts), patios, corridors, terraces, balconies, loggias and porches (verandas). Outdoor living space can be considered a part of the landscape and its design can significantly impact on the indoor comfort conditions.

10.4. Plant Selection in Landscaping
Most of what makes a landscape unsustainable is the amount of inputs required to grow a non-native plant on it. A local plant, which has adapted to local climate conditions, will require less work on the part of some other agent to flourish. Also, by choosing native plants, certain problems with insects and pests can be avoided because these plants will be adapted to deal with any local invader. By choosing the right kind of local plants, money can be saved on pest control and watering. See Plate 3.

11. CONCLUSION AND RECOMMENDATIONS
The development of ideal models for green housing and sustainable landscaping of residential areas in Akure will require extensive data collection and analysis. The human comfort conditions (thermal stress) for various seasons and times of the day need to be determined in greater detail. Also, the cooling loads imposed on buildings need to be determined using current models and software. Given the proliferation of green rating systems, there is need to encourage the adaptation and use of the various systems by professionals, and to eventually identify the ones that are most accurate and effective in Nigeria. The development and use of a green rating system will involve cooperation by all stakeholders in the building industry, and even though legislation and embodiment of such rating systems in the national building code is inevitable, this process should preferably be driven by persuasion and market forces. Going green should be seen not only to be better, healthier and more responsible; it should mean more greenbacks, even if only in the long run.

12. REFERENCES


