RESEARCH PROPOSAL

Greenery Effects on Thermal Comfort of Students in North-eastern Nigerian Universities

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MAY 2018
1.0 Research Topic:

Greenery Effects on Thermal Comfort of Students in North-eastern Nigerian Universities

2.0 Research Aim

The aim of this research is to evaluate the influence of tree canopies and groundcovers on students’ thermal comfort in Nigerian universities, within the context of North-Eastern region.

3.0 Research Objectives

The following objectives will be observed in order to achieve the research aim;

i. To identify available greenery systems, elements, their characteristics and students perception of them with regards to their thermal comfort in the north-eastern region of Nigeria.

ii. To examine the thermal comfort situations in relation to existing vegetation on campuses in the north-eastern region of Nigeria and its challenges on academic activities.

iii. To evaluate effects and performance of tree canopies and groundcovers on thermal comfort in the context of North-eastern Nigeria climate.

4.0 Assumptions

4.1 It is assumed that the campus environments in north-east Nigerian universities are not conducive to learning and student’s wellbeing due to the excessive solar
radiation and the diurnal change in temperature. Consequently, convert the atmosphere into a harsh environment.

4.2 Thermal properties of surfaces around a human body have an influence on his thermal comfort (Shashua-Bar, Pearlmutter, & Erell, 2011). Therefore, it is assumed that an increase in vegetation density on campuses in the north-east Nigerian universities will help tremendously in improving the thermal comfort of students on such campuses.

5.0 Hypothesis

H₀  Vegetation density and canopy size do not have positive effects on students’ thermal comfort on campuses in the north-east Nigerian universities.

H₁  Vegetation density and canopy size have positive effects on students’ thermal comfort on campuses in the north-east Nigerian universities.

6.0 Research Questions

6.1 What are the local greenery elements available on campuses located in north-east Nigeria?

6.2 What are the perceptions of students of such campuses on greenery in relation to their thermal comfort?

6.3 What is the thermal comfort situation on campuses in the north-east Nigerian universities considering the existing vegetation set-up?

6.4 To what extent greeneries will influence the thermal comfort of a student on campuses in the north-east Nigerian universities?
Figure 1: Research methodology chart
7.0 Problem Statement

In the past few years globally, there was severe climatic changes and conditions, be it in the form of low annual precipitation serious floods, landslides along with greater degrees of earthquakes, which were not been experienced before (Kakoty, 2017). Consequently, the thermal behavior of our environments changed drastically due to the experienced climatic change. Global warming became the most disturbing phenomenon nowadays (Mitchell, 2017). Some countries planned for mitigating the global warming as can be seen at the Paris climate conference in December 2015. Precisely, 195 nations including Nigeria were the world's first countries took universal action plan to mitigate climate change by subduing global warming to at least 2°C (Mitchell, 2017).

Furthermore, it has been studied that higher percentage of the global warming over the last five decades was from the activities of human, and it will continue to influence the thermal condition of the environment. Consequently, the global mean air temperatures will continue rising to a higher degree (Ezeabasili 2013). In the same vein, vegetation was removed and replaced with roads, buildings, pedestrian walkways and other hard surfaces (Amorim & Dubreuil, 2017) which makes the environment overheated. Additionally, Climatic change, excessive rise in temperature and the global warming turn out to be an environmental issue (Nasir, Ahmad, Zain-Ahmed, & Ibrahim, 2015). Consequently, most of the developed countries find it very difficult to compensate the replaced vegetation due to frequent and massive development of buildings and other related infrastructure. Similarly, in Nigeria, vegetation is replaced with academic and administrative buildings on the campuses, the percentage of roads and pedestrian walkways are also increased over that of the vegetation.

Many students on campus were suffered from many physiological disorders due to an excessive rise in outdoor temperature during the summer period (Xi, Li, Mochida, & Meng, 2012). Correspondingly, students on the north-east Nigerian university campuses suffered most because of the thermal environment of the region. Therefore, with the excessive rise in temperature and change in climatic conditions, demand for improved microclimate is always at the forefront than previous decades (Nasir et al., 2015).
Nigeria is one of the tropical countries with utmost higher temperature with less and sparse vegetation across its lands, precisely the north-eastern part of the country. Consequently, the absence of vegetation gives room to the exposed ground surfaces to absorb heat from direct solar radiation and in turn radiate the heat back to the human body which makes it psychologically and physiologically very uncomfortable to human wellbeing. Academic campuses are places where a conducive environment is required for proper learning and other academic activities. Above all, in north-east Nigerian universities, thermal comfort is the most influential factor that determines the conduciveness of the campus environments. Therefore, efforts have to be made in order to gain maximum comfort through the greenery.

The north-east region is one of the six geographical zones in Nigeria, comprising of six states as Bauchi, Borno, Adamawa, Gombe, Taraba and Yobe states. The region has a total number of fifteen (15) universities with more than twenty campuses, with an average of fifteen thousand enrolled students per a university. Indeed, more than two hundred and twenty-five thousand students are under the threat of excessive solar radiation and harsh weather condition. Consequently, students’ learning process and activities under such environmental conditions will be prostrating. Evidently, the figures below show the condition of the universities that are located in the north-east region with no or sparse vegetation. Hence, it results in students’ thermal dissatisfaction on the campus.

![Abubakar Tafawa Balewa University, Senate Bldg.](image1)

![Abubakar Tafawa Balewa University, Main Gate](image2)

Figure 2: Abubakar Tafawa Balewa University, Senate Bldg.

Figure 3: Abubakar Tafawa Balewa University, Main Gate
8.0 Research Gap

Researches on thermal comfort were mostly conducted on building indoors that are mostly mechanically ventilated, few were conducted on the influence of greenery on outdoor thermal comfort on university campuses (Xi et al., 2012). Furthermore, researches on thermal comfort were mostly geared towards residential buildings, offices and or public open spaces. Based on the literature reviewed none was conducted on the influence greenery on students’ thermal comfort. University campuses in north-east Nigeria have a temperature difference of its microclimate environment up to 30°C in a day. In addition, the campuses have an average students' enrollment of fifteen thousand per university but have no any empirical and scientific study to improve the quality of such students' life.
Table 1. Indicating the observed gap.

<table>
<thead>
<tr>
<th>S/N</th>
<th>AUTHOR</th>
<th>TITLE</th>
<th>AREA</th>
<th>LOCATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(Nasir et al., 2015)</td>
<td>Human Comfort in an Urban Area: Role of tree shade</td>
<td>Outdoor Spaces</td>
<td>Malaysia</td>
</tr>
<tr>
<td>2</td>
<td>(Lu et al., 2017)</td>
<td>Cooling effects of an urban parks</td>
<td>Outdoor Spaces</td>
<td>China</td>
</tr>
<tr>
<td>3</td>
<td>(Takakura, Kitade, &amp; Goto, 2000)</td>
<td>The cooling effect of greenery cover over a building</td>
<td>Experimental model</td>
<td>Japan</td>
</tr>
<tr>
<td>4</td>
<td>(Kawashima, 1990)</td>
<td>Effect of Vegetation on Surface Temperature.</td>
<td>Outdoor Spaces</td>
<td>Japan</td>
</tr>
<tr>
<td>5</td>
<td>(C. L. Tan, Wong, &amp; Jusuf, 2014)</td>
<td>Effects of vertical greenery on mean radiant temperature impact of greenery in an institutional campus in the tropics</td>
<td>Outdoor Spaces</td>
<td>Singapore</td>
</tr>
<tr>
<td>6</td>
<td>(Nyuk Hien Wong et al., 2007)</td>
<td>Greener evaluation on campus master plan</td>
<td>Campus</td>
<td>Singapore</td>
</tr>
<tr>
<td>7</td>
<td>(N. H. Wong et al., 2008)</td>
<td>Vertical Greenery System</td>
<td>Building Corridors</td>
<td>Singapore</td>
</tr>
<tr>
<td>8</td>
<td>(Jaafar, Said, Reba, &amp; Rasidi, 2013)</td>
<td>Impacts of Vegetation on Heating and Cooling</td>
<td>Residential</td>
<td>U.S.A.</td>
</tr>
<tr>
<td>9</td>
<td>(Che &amp; Ng, 2013)</td>
<td>effect of downtown greenery on thermal comfort</td>
<td>Outdoor Spaces</td>
<td>Hong Kong</td>
</tr>
<tr>
<td>10</td>
<td>(Nyuk Hien, Puay York, &amp; Yu, 2007)</td>
<td>Thermal performance of extensive rooftop greener systems</td>
<td>Indoor</td>
<td>Singapore</td>
</tr>
<tr>
<td>11</td>
<td>(Nyuk Hien Wong &amp; Jusuf, 2010)</td>
<td>Microclimate condition along a green pedestrian</td>
<td>Campus</td>
<td>Singapore</td>
</tr>
<tr>
<td>12</td>
<td>(Kaufmann et al., 2003)</td>
<td>The effect of vegetation on surface temperature:</td>
<td>Outdoor Spaces</td>
<td>North America</td>
</tr>
<tr>
<td>13</td>
<td>(Prez et al. 2014)</td>
<td>Vertical Greenery Systems (VGS) for energy saving in buildings: A review</td>
<td>Review</td>
<td>Spain</td>
</tr>
<tr>
<td>14</td>
<td>(H. Tan, Chen, Shi, &amp; Wang, 2014)</td>
<td>Development of green Campus campus</td>
<td>Campus</td>
<td>China</td>
</tr>
<tr>
<td>15</td>
<td>(Farid, Ahmad, Raub, &amp; Shaari, 2016)</td>
<td>Occupants’ Improved Quality of Life</td>
<td>Building facades</td>
<td>Malaysia</td>
</tr>
<tr>
<td>16</td>
<td>(Buyadi, Mohd, &amp; Misni, 2013)</td>
<td>Urban Microclimate</td>
<td>Outdoor Spaces</td>
<td>Malaysia</td>
</tr>
<tr>
<td>17</td>
<td>(Montacchini, Tedesco, &amp; Rondinone, 2017)</td>
<td>User comfort, health and behavior</td>
<td>Campus</td>
<td>Italy</td>
</tr>
<tr>
<td>18</td>
<td>(Jaafar et al., 2013)</td>
<td>Impact of Vertical Greener System on Internal Building Corridors in the Tropic</td>
<td>Office Buildings</td>
<td>Malaysia</td>
</tr>
<tr>
<td>19</td>
<td>(Morakinyo, Adegun, &amp; Balogun, 2016)</td>
<td>Indoor and outdoor thermal comfort</td>
<td>Campus</td>
<td>Nigeria</td>
</tr>
<tr>
<td>20</td>
<td>(Nasir, Ahmad, &amp; Ahmed, 2012)</td>
<td>Psychological Adaptation of Outdoor Thermal Comfort in Shaded Green Spaces</td>
<td>Outdoor Spaces</td>
<td>Malaysia</td>
</tr>
<tr>
<td>21</td>
<td>(Xi et al., 2012)</td>
<td>Outdoor thermal environment and thermal comfort</td>
<td>Campus</td>
<td>China</td>
</tr>
<tr>
<td>22</td>
<td>(Shashua-Bar et al., 2011)</td>
<td>The influence of trees and grass on outdoor thermal comfort</td>
<td>Campus</td>
<td>Israel</td>
</tr>
<tr>
<td>23</td>
<td>(Buyadi, Mohd, &amp; Misni, 2015)</td>
<td>Vegetation’s Role on Modifying Microclimate of Urban Resident Buildings</td>
<td>Residential</td>
<td>Malaysia</td>
</tr>
<tr>
<td>24</td>
<td>(Othman &amp; Sahidin, 2016)</td>
<td>Vertical Greening Façade as Passive Approach in Sustainable Design</td>
<td>Office Buildings</td>
<td>Malaysia</td>
</tr>
</tbody>
</table>
As can be seen in the table above, all the reviewed literature that studied the contribution of greenery on thermal comfort were mostly concentrated on Asian countries, America and some part of Europe. Very few tried to carry out their studies on tropical regions of Nigeria and other African countries.

9.0 Research Background

University Campuses in North-Eastern Nigeria require a higher percentage of greenery due to the impact of thermal environmental. Notably, campuses as a place for learning and other academic gathering require a highly conducive environment. Most especially in the aspects of human thermal comfort (Montacchini et al., 2017; N. H. Wong et al., 2007; Nyuk Hien Wong & Jusuf, 2008). As such, greeneries lower the ambient temperature of outdoor environments (C. L. Tan et al., 2014; Nyuk Hien Wong & Jusuf, 2008). Similarly, vegetation density plays a significant role in the human thermal balance, to be in a comfortable range (Nasir et al., 2015). Furthermore, environments that are within or in close proximity to greenery have a high tendency of surface temperature reduction (C. L. Tan et al., 2014; N. H. Wong et al., 2007). In the same way, the impact of greenery on human thermal comfort does not only influence the outdoor thermal environment but also the indoor spaces (Jaafar et al., 2013). Additionally, grasses as a ground cover have a great influence in preventing heat transfer into indoor spaces (Nyuk Hien Wong & Jusuf, 2008). Generally, (Jaafar et al., 2013; Kawashima, 1990; McPherson et al., 1988; Nasir et al., 2015; Takakura et al., 2000; C. L. Tan et al., 2014; N. H. Wong et al., 2007; Nyuk Hien Wong & Jusuf, 2008) identified the roles and influence of greenery in mitigating the impacts of Urban Heat Island (UHI) effects. Consequently, UHI bring about the higher demand of electricity for Heating, ventilation, and Cooling (HVAC) in order to gain a high level of thermal comfort (Li, Menassa, & Kamat, 2017; Nikdel, Janoyan, Bird, & Powers, 2018; Omer, 2008).

The world energy demand in a building was estimated at 39% in the year 2008 and further increased to 40% between the year 2008 to 2030 (Salleh, Kandar, & Sakip, 2016). Likewise, in Nigeria alone, the energy consumption in a building was about 65% in 2014 (Oyedepo, 2014). Therefore, there is the need for energy efficiency strategies in order to lower its demand worldwide (Gutierrez-Aliaga & Williams, 2016; Kapsalaki & Leal, 2011; Serghides, Dimitriou, Kyprianou, & Papanicolas, 2017). Hence, researchers found that greenery serves as one of the
fundamental tool for changing our environment to be energy efficient (Jaafar et al., 2013; Montacchini et al., 2017; Pérez, Coma, Martorell, & Cabeza, 2014; Takakura et al., 2000; N. H. Wong et al., 2007; Nyuk Hien Wong et al., 2010). Moreover, energy savings were achieved in many climatic conditions using tremendous greenery treatments (Meier, 1990).

The north-eastern part of Nigeria as a tropical region is identified with hot weather, wet summer, low humidity, and little diurnal change in temperature (Farauta, Egbule, Idrisa, & Agu, 2011; International & Journal, 2013). As such, the campuses situated in this region of Nigeria are the most affected environments with thermal dissatisfaction due to solar radiation and excessive rise in temperature of about 42°C in late May. Indeed, human thermal comfort within campuses in north-east Nigeria is one of the notable factors that influence students’ performance on our university campuses (Almeida, Ramos, & De Freitas, 2016; Shan, Zhou, Chang, & Yang, 2016). For this reason, greeneries on the campuses in north-east Nigeria need be fully embarked upon, in order to mitigate the over-heating of our campus environments for effective and conducive learning atmosphere. Thus, the present situation of greenery on campuses in this region is not sufficient for students’ thermal comfort improvement. This research is aimed at evaluating the influence of tree canopies and groundcovers on students’ thermal comfort in Nigerian universities, within the context of North-Eastern region.

Figure 8: Showing north-eastern states in the red portion
The north-eastern part of Nigeria has fifteen universities located within the six states in the region, out of which only two are private universities while the remaining thirteen are public universities.

**Table 2. University locations across the six states of the North-east Nigeria**

<table>
<thead>
<tr>
<th>S/N</th>
<th>University</th>
<th>Acronyms</th>
<th>Year of Establishment</th>
<th>Category</th>
<th>Location (State)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Abubakar Tafawa Balewa University</td>
<td>ATBU</td>
<td>1980</td>
<td>Public</td>
<td>Bauchi</td>
</tr>
<tr>
<td>2</td>
<td>Bauchi State University Gadau</td>
<td>BASUG</td>
<td>2011</td>
<td>Public</td>
<td>Bauchi</td>
</tr>
<tr>
<td>3</td>
<td>Federal University Kashere</td>
<td>FUK</td>
<td>2011</td>
<td>Public</td>
<td>Gombe</td>
</tr>
<tr>
<td>4</td>
<td>Gombe State University</td>
<td>GSU</td>
<td>2004</td>
<td>Public</td>
<td>Gombe</td>
</tr>
<tr>
<td>5</td>
<td>Gombe State University of Science and Technology Kumo</td>
<td>GSUST</td>
<td>2017</td>
<td>Public</td>
<td>Gombe</td>
</tr>
<tr>
<td>6</td>
<td>American University of Nigeria Yola</td>
<td>AUN</td>
<td>2003</td>
<td>Private</td>
<td>Adamawa</td>
</tr>
<tr>
<td>7</td>
<td>Modibbo Adama University of Technology Yola</td>
<td>MAUTECH</td>
<td>1988</td>
<td>Public</td>
<td>Adamawa</td>
</tr>
<tr>
<td>8</td>
<td>Adamawa State university Mubi</td>
<td>ADSU</td>
<td>2002</td>
<td>Public</td>
<td>Adamawa</td>
</tr>
<tr>
<td>9</td>
<td>Federal University wukari</td>
<td>FUW</td>
<td>2011</td>
<td>Public</td>
<td>Taraba</td>
</tr>
<tr>
<td>10</td>
<td>Taraba State University Jalingo</td>
<td>TSU</td>
<td>2008</td>
<td>Public</td>
<td>Taraba</td>
</tr>
<tr>
<td>11</td>
<td>Kwararafa University Wukari</td>
<td>KUW</td>
<td>2005</td>
<td>Private</td>
<td>Taraba</td>
</tr>
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<td>12</td>
<td>University of Maiduguri</td>
<td>UNIMAID</td>
<td>1975</td>
<td>Public</td>
<td>Borno</td>
</tr>
<tr>
<td>13</td>
<td>Borno state University Maiduguri</td>
<td>BSUM</td>
<td>2016</td>
<td>Public</td>
<td>Borno</td>
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<tr>
<td></td>
<td>University Name</td>
<td>Abbreviation</td>
<td>Year</td>
<td>Type</td>
<td>State</td>
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</tr>
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<td>14</td>
<td>Federal University Gashua</td>
<td>FUG</td>
<td>2013</td>
<td>Public</td>
<td>Yobe</td>
</tr>
<tr>
<td>15</td>
<td>Yobe State university</td>
<td>YSU</td>
<td>2006</td>
<td>Public</td>
<td>Yobe</td>
</tr>
</tbody>
</table>

Figure 9: Showing the map location for north-east Nigerian Universities
10.0 Theoretical Framework

- Thermal Comfort

Thermal comfort can be defined as a situation whereby individuals prefer neither cooler nor warmer thermal environment (Nasir et al., 2012). In the context of north-east Nigeria microclimates, thermal comfort can be seen as the main indicator to describe human’s subjective experience of temperature in his environments. It indicates the impact of solar radiation, air velocity, volume and direction, air temperature and relative humidity on the thermal sensations.

Many a time due to the harshness of the regions' microclimate environment, the human body finds it difficult to balance for cold or hot environmental thermal conditions through thermoregulation, thermal discomfort arises and the actual environment is perceived to be too cold or too warm. The comfort temperature should be between 23°C to 26°C, while the humidity of the atmosphere is between 30% to 60%, predicted Mean Vote PMV is between -0.5 to 0.5 for PPD<10%, while airspeed $V_a < 0.25$ m/s (Nematchoua et al. 2014). As described by Nematchoua et al. (2014), the air temperature in north-east Nigeria is mostly higher than the comfort temperature of 23°C to 26°C. In the months of May to July, the temperature rises to 42°C, which normally gives room for thermal discomfort to the students on campuses in the region.

Human thermal comfort in our environment is not only for human wellbeing, but it maximizes his productivity (Nematchoua et al. 2014). Similarly, it has been shown that the productivity will be increased by 15% when occupants are satisfied with their thermal environments (Abiodun 2014). Consequently, without improving the students' thermal comfort on the campuses, their academic performance will definitely be declined and resulted in an educational drawback.

- Greenery

Greenery is embraced not only for aesthetic purposes but for many reasons in the context of sustainable built environment and ecological wellbeing. Consequently, greenery serves as one of the fundamental tools for improving thermal comfort. As such, vegetation plays a significant role in influencing the microclimate environment of cities and improve the thermal load of buildings
(Nyuk Hien et al., 2007; Tong et al., 2017; Nyuk Hien Wong et al., 2010). Furthermore, greeneries contribute a lot to the environment by providing the required fresh air and absorb the polluted one, improving thermal comfort, retaining water, preserving soil and improving quality of life (Nasir et al. 2015). The thermal comfort cooling effect of dense greenery extends beyond the greenery area (Lu et al. 2017). Greenery has a vital influential factor in the microclimate of outdoor environment as well as the indoor thermal condition (Tan, Wong, and Jusuf 2014)

As reviewed in the related articles, greeneries are placed into three categories based on their plantation, propagation and uses for improving thermal comfort on campuses; Ground cover vegetation, vertical greenery system and rooftop garden. In the north-east region of Nigeria, the predominant native tree is the neem tree (Azadirachta indica), which is normally called a “Dalbejiya” in the Hausa local language. Trees with wider canopy and ground cover vegetation are generally adopted in the region due to the nature of the built environment and its microclimate.

Figure 10: Showing the predominant native tree in the north-east Nigerian Universities
• **Ground Cover Vegetation**

Vegetation is not only perceived as the means of providing pedestrians with pleasurable and aesthetic visions but also for other important aspects of life, such as shade provision against direct solar radiation, echo level reduction, air quality improvement, and mitigation against the effects of Urban Heat Island (Chen & Ng, 2013). Dense vegetation with mature trees provides a higher level of thermal comfort than the young ones (Nyuk Hien Wong & Jusuf, 2010). Similarly, it was found that greening the environment is the easiest and the most effective way in improving thermal comfort on campus (Nyuk Hien Wong & Jusuf, 2010).

Land surface temperature (LST) is always sensitive to ground cover greenery and the moisture in soils (Buyadi et al., 2013). Additionally, evapotranspiration process by green ground covers reduce surrounding air temperature by absorbing up to 85% of the heat from solar radiation (Misni, 2013).

Vegetation along the side of roads and dense tree plantations in open spaces and urban parks within a residential area help in modifying the microclimate of the environment by its shadow effects and evapotranspiration process at day and night time (Buyadi et al., 2015). In the same way, strategic placement of vegetation can immensely reduce the temperatures in and around a building (Meier, 1990).

• **Effects of Vegetation on Direct Solar Radiation**

In a hot microclimate environment, vegetation around a built environment can improve energy balance as well as cooling energy requirements of the built environment by protecting all building envelopes and other outdoor environments from the effects of direct solar radiation as well as reflections from surrounding surfaces (Nasir et al., 2015). The air temperature in an environment can be low when good shading provided by a dense tree canopy, which in turn prevent incoming solar radiation (Nyu Hien Wong & Jusuf, 2010). Similarly, the canopy of a mature tree can lower the intensity of solar radiation to less than 150W/m² unlike the canopy of a young tree which, may reduce it to less than 300W/m² (Nyu Hien Wong & Jusuf, 2010).
The temperature exchange between the human body and the radiant temperature due to solar radiation played the most vital role in the human thermal environment and comfort (Xi et al. 2012). Furthermore, the air temperature in a greenery environment is reduced by up to 4°C (Nasir et al., 2015). Similarly, Misni (2013) stated that the species of vegetation is very vital when selecting for thermal comfort issue, their character with regards to the canopy and shed they provide as well as their appearance and its acclimatization with the local weather and climatic conditions.

- **Tree Sheds and Canopies**

Tree canopies and sheds reduce ground surface radiation due to lower surface temperature (Tan et al., 2014). Similarly, the tree shades and canopies provide a conducive environment for open space activities and recreations (Nasir et al. 2015). In a densely populated campus vegetation can help in lowering air temperature and provision of canopies (Tan et al., 2014). Furthermore, tree canopies found to improve the human thermal balance while performing outdoor activities, as well as improving the outdoor thermal condition of the built environment by reducing the direct solar electromagnetic waves on building facades (Nasir et al. 2015)

- **Evapotranspiration**

Evapotranspiration is a combination of the words evaporation and transpiration. It refers to the process of water (moisture) moving from the soil and the plant and entering the earth's atmosphere. Evapotranspiration is really two processes: the evaporation of water from the soil, and the transpiration of moisture from the plant’s surfaces. With this process, clouds and rain eventually occur. Consequently, By plants evapotranspiration, solar radiation can be changed to latent heat which does not change or increase the temperature of the environment (Takakura et al., 2000). Likewise, The higher percentage of moisture content in the atmosphere and the rise in temperature in the tropical hot regions create discomfort and lower the activities within outdoor spaces (Nasir et al., 2015)
Lack of evapotranspiration surfaces contributes to the increase in campus temperature. Therefore, to increase evapotranspiration on-campus environment is by increasing the amount of greenery in the campus environment (Takakura, Kitade, and Goto 2000).

- **Campus Greenery and General Layout**

Campus as a place for learning and other daily academic activities, it requires conducive learning environment, the microclimate improvement of the campus outdoor environment is the first step to ensure conducive learning environment. Meanwhile, Only a few research were conducted on campus outdoor thermal comfort in the tropic regions (Xi et al., 2012). As is can be seen, none was conducted on north-east Nigerian university campuses. In an effort to improve the microclimate of the campus outdoor and indoor spaces, previous researchers discovered the influence of greenery environment in mitigating the effects of excessive temperature rise in tropical regions (Nasir et al. 2015). Similarly, such efforts when adopted in the north-east Nigerian university campuses will equally mitigate the effects of excessive temperature rise. Otherwise, lack of vegetation and evapotranspiration surfaces contributes to the increase in campus temperature (Takakura et al., 2000). The species of vegetation is very vital when selecting for thermal comfort issue. Equally, their character with regards to their density, canopy and the shed they provide as well as their acclimatization with the local weather and climatic conditions (Misni, 2013).

The two factors that influence the climate of campus are the campus geometry and its surfaces (Xi et al., 2012). Likewise, The tree shades and canopies provide the conducive environment for academic activities and recreations (Nasir et al., 2015). Whereas, the absence of vegetation on-campus environment gives room for campus users to suffer from many physiological disorders due to an excessive rise in outdoor temperature during the summer period.

The ratio of the height of a built structure and its offset between adjacent structures affect the campus geometry and it influences the direct solar radiation and air velocity (Xi et al., 2012). Meanwhile, the Vegetation can lower thermal load of a building and reduce energy consumption for cooling the indoor (Tan et al., 2014). Similarly, Nasir et al. (2015) stated that, in a hot microclimate environment, vegetation around a built environment can improve energy balance as
well as cooling energy requirements of the built environment by protecting all building envelopes from the effects of direct solar radiation as well as reflections from surrounding surfaces.

11.0 Scope of Study

The study intends to evaluate the effects of greenery on-campus user thermal comfort in the context of the north-eastern region of Nigeria. In a general term, greenery consists of ground covers, tree canopies, vertical greenery system and rooftop gardens, but for the purpose of this study, emphasis will be only on groundcovers and tree canopies, the analysis will be on the local grass and tree species. Furthermore, the study will be conducted on student's thermal comfort in an academic area of the campuses. The study will be conducted on two university campuses out of the fifteen universities located in north-east Nigeria. The campuses are selected mainly due to their geographical locations. The first university, which is Abubakar Tafawa Balewa University Bauchi (ATBU), is located in the semi Sahara arid zone, while the other university, which is University of Maiduguri (UNIMAID), is located in the Sahara zone. Secondly, ATBU is located in a zone whereby the temperature there is lower than the remaining parts of the region, while UNIMAID is located in a zone whereby its temperature is higher than other parts of the region. Finally, ATBU is located in a zone whereby it has a higher annual precipitation, while UNIMAID is located in a zone whereby the annual precipitation is lower than the remaining parts of the region.
Figure 11: Study Area (1) Abubakar Tafawa Balewa University (ATBU), Bauchi

Figure 12: Study Area (1)
Figure 13: Study Area (2) University of Maiduguri (UNIMAID), Borno State

Figure 14: Study Area (2)
Academic area of the campuses are selected for this study because, students spent most of their day time in the academic zone. Furthermore, in the day time is when the microclimate of the environment turns to be harsh due to temperature rise. Similarly, the output needed from students is on academic performance. Therefore, the academic microclimate environment needs to be improved for better results.

12.0 Methodology

This study is aimed at employing field survey; the survey will be in three stages, the experimental survey, the questionnaire survey, and the field observation.

12.1 Experimental Survey:

The experimental survey is expected to answer research question three and four. The experimental survey is employed in order to measure three of the thermal comfort parameters on site. The parameters to measure are; the air temperature, the air velocity, and the relative humidity. Furthermore, the measurement is expected to cover a period from the month of June 2018 to August 2018. The survey is expected to yield a good result because, in north-east Nigeria, the higher temperature is experienced in the months of May, June, and July while a higher percentage of humidity is normally experienced in the months of August and September.

Table 3. Equipment for measuring parameters on site

<table>
<thead>
<tr>
<th>S/N</th>
<th>NAME</th>
<th>IMAGE</th>
<th>SPECIFICATION</th>
<th>USES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>U23 – 002 HOBO Data Logger</td>
<td><img src="image.png" alt="Image" /></td>
<td>*42,000 measurements *-40° to 70°C / 0 to 100% measurement range, *Waterproof housing *Accuracy ±0.21°C, ±2.5%</td>
<td>Measure Temperature and Relative Humidity</td>
</tr>
</tbody>
</table>
2 U-4 Optical Base Station

*Operating temperatures range of 0 to 50°C (32 to 122°F).
*Cable length 183 cm (6 ft.)
*Offloads full 64K logger in 30 seconds

Transfer data from U23 – 002 logger to computer

3 UX100 – 011 HOBO Data Logger

*84,650 measurements
*-40°C to 70°C / 1% to 95% measurement range,
*Flexible mounting option

Measure Temperature and Relative Humidity

4 M-RSA Solar Radiation Shield

*Height: 152 mm (6.0 inches); 165 mm (6.5 inches) with bracket
*Width: 210 mm (8.3 inches)
*Depth: 187 mm (7.4 inches);

Protecting Data loggers against external solar radiations

5 MASTECH MS6252B Digital Anemometer

*-20°C to 80°C / 0% to 95% measurement range,
*Storage -10°C to 50°C / 0% to 85%

Measure Temperature, Relative Humidity, Air Velocity and Air Volume.
Temperature and Relative Humidity Measurements

The data logger will be placed in four (4) measurement points on each site; each data logger is to be placed in a solar radiation shield in order to protect the measurements from any interference from solar radiation. The loggers will be situated at 2.0 meters from the ground level, it will be done in order to avoid any interference with radiations from ground surfaces and to have an air temperature of the human height.

The logger will be set to record measurements for an interval of 5 minutes for the period of four weeks for each point; all the four points will be taken concurrently for the entire four weeks. UX100 – 011 HOBO Data Logger is going to be used for this assignment due to its higher measurements storing capacity (84,650 measurements).

A security man is expected to be employed for the period of data measurements in order to secure all the experimental equipment.
• **Air Velocity Measurement**

The air velocity is one of the four variables to measure for the purpose of this study; anemometer will be used to measure the air velocity. Daily air velocity will be recorded for the period of four weeks; normally the changes in air velocity of a particular area are not significant.

• **Radiant Temperature**

The radiant temperature as one of the four variables can be derived from a formula as shown below (Johansson, Thorsson, Emmanuel, & Krüger, 2014)

\[
T_{mrt} = \left( (T_g + 273.15)^4 + \frac{1.1 \times 10^8 V_a^6}{\epsilon D^{0.4}} x (T_g - T_a) \right)^{1/4} - 273.15 \quad \text{equation - 1}
\]

Whereas;

- \(T_{mrt}\) = The mean radiant temperature (°C)
- \(T_g\) = The globe temperature (°C)
- \(T_a\) = The air temperature (m/s)
- \(D\) = The globe diameter (m)
- \(\epsilon\) = The globe emissivity (no unit)

The standard recommended globe diameter \(D= 0.15\)m, and the globe emissivity \(\epsilon = 0.95\)

\[
T_{mrt} = \left( (T_g + 273.15)^4 + 2.5 \times 10^8 V_a^6 (T_g - T_a) \right)^{1/4} - 273.15 \quad \text{equation - 2}
\]
• **Location Coordinates Measurements**

GPS machine is to be used in locating and capturing the study area coordinates. The coordinates are commonly expressed as latitude and longitude. The GPS divides the earth into latitude lines, which shows how far north or south of the equator a location is, and longitude lines, which indicate how far east or west of the prime meridian a location is.

Under this system, an exact location on the earth's surface can be expressed as a set of numbers. The latitude and longitude of the Empire State Building, for example, is expressed as N30° 34.9064', W083° 59.0735'. The location may also be expressed in a numbers-only format, per 40.748440, -73.984559. With the first number indicating latitude and the second number representing longitude (the minus sign indicates "west"). Being numeric-only, the second means of notation is the most commonly used for inputting positions into GPS devices.

After the measurements taken, GIS software will be used in order to analyze the percentage of the built environment, the vegetation percentage and the percentage of undeveloped portions. Furthermore, the software will be used to map up the location for the reader to see physically the existing situation of the study area.

• **Aerial coverage**

Aerial photographs will be captured by the use of an aerial drone for further references. These photographs will be used in a discussion session when details of the measurement points need to be shown in relation to the adjoining features.

**12.2 Questionnaire Survey**

Based on the stated objectives of this research work, the first objective is to be achieved by the use of questionnaire survey questionnaire, which is expected to target students as the unit of analysis. The survey questionnaire will be divided into three sections; the first section will be towards the demographic study of the respondent, the second section will be on the respondents’
experience on the thermal condition of their campus environments, while the last section will be on the respondents’ knowledge and perception on greenery.

Three hundred questionnaire booklets will be produced and for three hundred respondents (students), one hundred and fifty questionnaires for each of the two targeted campuses. The hybrid design of the survey questionnaire (Paper and electronic survey) is going to be adopted in order to give the respondents' alternative way of answering the survey questions. Consequently, a web link will be provided on the questionnaire booklet for easy access to the alternative electronic web questions.

**Table 4. Data collection**

<table>
<thead>
<tr>
<th>S/n</th>
<th>Research Questions</th>
<th>Research Objectives</th>
<th>Source of Data</th>
<th>Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>RQ1. What are the local greenery elements available on campuses located in north-east Nigeria?</td>
<td>RO1</td>
<td>Questionnaire, Field observation, Experimental survey</td>
<td>Existing vegetation (its availability and percentage on site)</td>
</tr>
<tr>
<td>2</td>
<td>RQ2. What are the perceptions of students on greenery in relation to their thermal comfort?</td>
<td></td>
<td>Questionnaire</td>
<td>Students' perception of thermal comfort and campus greenery</td>
</tr>
<tr>
<td>3</td>
<td>RQ3. What is the thermal comfort situation on campuses in the north-east Nigerian universities considering the existing vegetation set-up?</td>
<td>RO2</td>
<td>Experimental survey</td>
<td>Relative humidity, Air temperature, Air velocity, Radiant temperature</td>
</tr>
<tr>
<td>4</td>
<td>RQ4. To what extent greeneries will</td>
<td></td>
<td>Experimental survey</td>
<td>Relative humidity, Air temperature</td>
</tr>
</tbody>
</table>

26
<table>
<thead>
<tr>
<th>Question</th>
<th>RO3</th>
</tr>
</thead>
</table>
| influence the thermal comfort of students on campuses in the north-east Nigerian universities? | Air velocity  
Radiant temperature |

### 12.3 Data Analysis

All data collected on site will be analyzed with analysis and simulation software prior to the result interpretations and discussions. Arc GIS, SPSS, and Envi-Met Simulation software are going to be employed for the analysis.

- **Arc GIS**

Arc GIS is going to be used for area mapping and estimation for the percentage of the built environment, the vegetation percentage and the percentage of undeveloped portions. Longitudinal and latitudinal GPS coordinates are the measured variables to be used for the Arc GIS.

- **SPSS Software**

The Statistical Package for the Social Sciences (SPSS) is a software package used in statistical analysis of data. It was developed by SPSS Inc. and acquired by IBM in 2009. In 2014, the software was officially renamed IBM SPSS Statistics. The SPSS is going to be used for the analysis of the filled questionnaires.

- **Envi-Met Simulation Software**

Envi-Met is the most accepted and validated software for simulating the outdoor environment, which relates surface greenery, air temperature and the outdoor microenvironment (Lu et al.
Consequently, in this research work, Envi-met simulation software is going to be used during data analysis to validate the measured data. Additionally, the software will be used to simulate the outdoor microclimate of the study area in relation to existing and other future scenario greeneries for the thermal comfort of students and other campus users.

The measured thermal comfort parameters to be used in the simulation are; air velocity, humidity, air temperature and radiant temperature. Another parameter which is expected to be used in the simulation is the Leaf Area Index (LAI) of the local vegetation that can survive the climate and the soil nature of north-east Nigeria, in order to create same vegetation in the simulation software because of the default vegetation are not tropical plants.

Table 5. Data analysis

<table>
<thead>
<tr>
<th>S/ n</th>
<th>Research Questions</th>
<th>Research Objectives</th>
<th>Source of Data</th>
<th>Analysis tool</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>RQ 1. What are the local greenery elements available on campuses located in north-east Nigeria?</td>
<td>RO1</td>
<td>• Questionnaire • Field observation • Experimental survey</td>
<td>• SPSS • Nvivo • Arc GIS</td>
</tr>
<tr>
<td>2</td>
<td>RQ 2. What are the perceptions of students on greenery in relation to their thermal comfort?</td>
<td></td>
<td>• Questionnaire</td>
<td>• SPSS</td>
</tr>
<tr>
<td>3</td>
<td>RQ 3. What is the thermal comfort situation on campuses in the north-east Nigerian universities considering the existing vegetation set-up?</td>
<td>RO2</td>
<td>• Questionnaire • Experimental survey • Derived equations</td>
<td>• SPSS • Envi-met Simulation software</td>
</tr>
<tr>
<td>4</td>
<td>RQ 4. To what extent greeneries will influence the thermal</td>
<td></td>
<td>• Experimental survey</td>
<td>• Envi-met Simulation software</td>
</tr>
</tbody>
</table>
comfort of students on campuses in the north-east Nigerian universities?

RO3  • Derived equations

13.0 Significance of the Research

Considering the number of university campuses in north-east Nigeria, with an average students' enrollment of fifteen thousand per university, empirical and scientific study is required to improve the quality of such students' life. Consequently, at the end of this research work, critical studies and analysis will evaluate the influence of tree canopies and groundcovers on the students’ thermal comfort in the context of north-eastern microclimate.

14.0 Anticipated Findings

A Campus is a place for learning and other recreational activities for students. Therefore, it requires conducive environment, the microclimate improvement of the campus outdoor environment is the first step to ensure conducive atmosphere, therefore this study anticipates the findings below;

i) Many local vegetation types and species will be identified, its character, how and to what extent will it influence human comfort in the context of north-east Nigeria climatic condition.

ii) Existing greenery/vegetation percentage on the campuses in north-east Nigeria universities is not sufficient to improve thermal comfort of students on such campuses.

The few existing vegetation on the campuses were not optimally utilized for outdoor microclimate enhancement due to lack of empirical and scientific studies on how, where and when to plant and maintain them based on the existing climate and soil nature.
15.0  RESEARCH SCHEDULE

<table>
<thead>
<tr>
<th>MONTHS</th>
<th>YEAR 1</th>
<th>YEAR 2</th>
<th>YEAR 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SEMESTER – 1</td>
<td>SEMESTER – 2</td>
<td>SEMESTER – 3</td>
</tr>
<tr>
<td>1</td>
<td>Literature review</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Conference / Journal Papers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Research Proposal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Data Collection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Data Analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Interpretation of results</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Chapter Writing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Submission of First Draft</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Submission of Corrected Draft</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>VIVA VOCE</td>
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