# Prevalence of Landscaping as a Means of Passive Cooling in Hot Climates: a Case Study

**Muhammad Babale Girei[1], Yakubu Aminu Dodo[2*], Ahmed Yahaya Abdul[3], Aisha Haladu Bornoma[4] & Abubakar Sarkile Kawuwa[5]**

[1 3 4&5]Department of Architecture, Modibbo Adama University of Technology, Yola, Nigeria
[2] Department of Architecture, Faculty of Built Environment, Universiti Teknologi Malaysia

*dyaaminu@yahoo.com, +60166486703

***Abstract***- Landscaping can improve the micro climate of the immediate surroundings of a building; by modifying the microclimate around a building making the building sustainable. Yola has a very hot climate which makes it necessary to have mechanical cooling systems in the buildings but due to power shortage and the need to conserve energy, it becomes necessary to have proper landscaping, since the hotter weather occupies the major part of the year. This research is trying to find out whether there is prevalence of proper landscaping to enhance passive cooling in Yola especially within Modibbo Adama University of Technology (MAUTECH) Yola. Literatures were reviewed to analyze and determine existing conditions of buildings while physical observation of surroundings and the climatic data was also gotten from meteorological stations taken into consideration with data recorded over a period of time. A large number of buildings and their immediate surroundings were designed without the provision of landscaping**.** Landscaping is major aspect of passive cooling technique in which if Architects and Designers apply to buildings whether they are new or retrofitted buildings, would enhance and maintain the comfortable internal conditions as well as the immediate environment.

***Index Terms***-climate; landscaping; passive cooling; sustainable &shading

## I. INTRODUCTION

This paper is all about landscaping which can be used to enhance a passive cooling system. The use of vegetation to shade a house is a cooling technique that can be very effective. A well-placed plant can deliver effective, cool shade, as well as add to the aesthetic value of a building. As well as shade, plants are also effective for cooling because they absorb the heat. Since leaves are generally dark and coarse they reflect very little light, they make ideal solar radiation controllers. Photosynthesis is the way plants convert light into nourishment. During photosynthesis, a process known as evapo-transpiration occurs, in which large amounts of water vapour escape through the leaves. The water vapour cools the air passing by it, thus providing a source of cool air for the building [1].

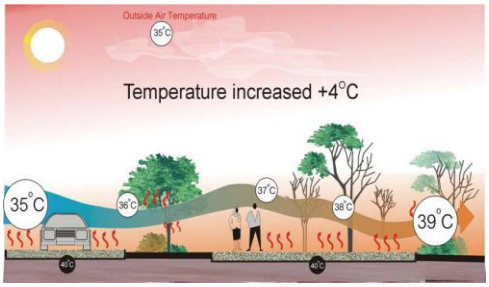
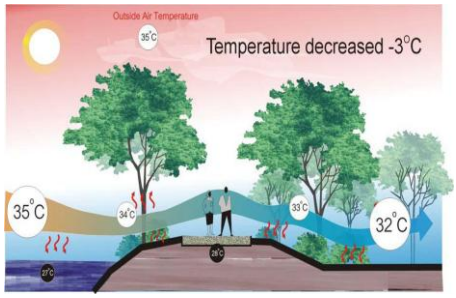
Strategic planting of trees, shrubs and vines about a building and on structures such as pergolas and beam overhangs can, along with urban form, help to modify the microclimate. When correctly applied, the need for internal and external shading devices can be greatly reduced. Selective planting can shade not only windows and other apertures but also whole facades and roofs, reducing conductive as well as radioactive heat gains. [1]Also stated that by using deciduous trees and vines shading is provided only when needed. Through the use of evergreens, shading can be provided year-round. Vegetation can also be used to reduce ground reflection and, through evapotranspiration, the ambient air temperature. Evergreen shrubs and ground cover are useful for preventing or reducing reflection from roads, paved areas and buildings. Evergreens are also effectively used as wind barriers. Deciduous species are particularly suitable for temperate climates. The shading effect of vegetation depends heavily on the plant type (trees, shrubs or vines), species, and age. These factors define the leaf type and the density of the vegetation. In the case of deciduous plants, the density changes from season to season.

[1]records that vegetation affects the internal temperature and cooling load of buildings in various ways as follows: Tall trees and pergolas situated a short distance from walls and windows will provide shade without significantly reducing ventilation; Vines on walls and high shrubs close to walls will provide shade but also reduce the wind speed next to the walls;

The air temperature adjacent to the building's external façade is decreased, thus reducing conductive and infiltration heat gains; Vegetative ground cover around a building reduces reflected solar radiation and long wave radiation emitted toward the walls from the surrounding area, thus lowering the solar and long wave heat gain; Vegetation on the eastern and western sides of a building can

provide effective protection from solar radiation. During peak summer days the average temperature of walls shaded by trees or a combination of trees and shrubs can be reduced by up to 150K. Planted courtyards can provide a store of coolness in a building. The courtyard acts like a well of cold air, as the cool air of the desert night sinks and is trapped in the courtyard, providing a reservoir of coolness during the day. All the rooms opening into the courtyard benefit from this coolness [2].

Table 1 Temperature increase and decrease [3]

| | |
|---|---|
|  |  |
| Too much hard surfaces like concrete paving and asphalt increases heat gain. | Vegetation and trees in particular effectively shade and reduce heat gain. They increase humidity level. They also cause pressure differences thereby increasing and decreasing air speed or directing air flow. They can, therefore, direct air into a building or deflect it away. |

## II. MATERIALS AND METHODS

Yola has a tropical climate which is that of the hot semi-humid type. The characteristics of the climatic elements are explained below:

*A. Wind:*The dominant wind direction between 2004 and 2010 is North West (NW) according to [4].

*B. Temperature:*Air temperature characteristics are typical of the West African Savannah climate. Temperature in this climatic region is high almost throughout the year because of high radiation income which is relatively evenly distributed throughout the year. However there is usually a seasonal change in temperature as depicted in table 1.0. There is a gradual increase in temperature from January to April. The seasonal maxima usually occur in April. There is a distinct drop in temperature at the onset of rains due to the effect of cloudiness. A slight increase after the cessation of rains (October to November) is common before the onset of harrmattan in December when the temperature drops further. Maximum temperature reaches up to 40 °C particularly in April while minimum temperature can be as low as 18°C between December and January (Table 1.0). Mean monthly temperature is 27.8°C.

*C. Relative Humidity*: The seasonal variation in RH of the site is shown in Table 1.0 Between January and March RH is extremely low (20-30%). It starts increasing as from April and reaches the peak (about 80%) in August and September. This is due to the influence of the humid maritime air mass which covers the whole state during this time. Relative humidity starts to decline again as from October following the cessation of rains.

*D. Sunshine:*The monthly distribution pattern (Table 1.0) shows that the period from January to April has a mean monthly sunshine hour of 220. There is a decline in sunshine hours between May and September due to increasing cloudiness all over the state. The mean during this period is about 207 hours. The mean sunshine hours increases again to 255 for the period between October and December. The amount of sunshine hours is 2750per annum.

*E. Evaporation:*the monthly distribution of pan A evaporation in Yola. The rate of evaporation is generally high in Yola due to the high insolation. The monthly distribution pattern is similar to that of sunshine and Temperature which show significant decrease during the rainy season.

Table 2Average Climatic Conditions in Yola (Latitude 09° 16') [5]

| ***MONTH*** | **T max °C** | **T min °C** | **T mean °C** | **R.H %** | **R'fall mm** | **Evaporation mm** | **Sunshine** |
|---|---|---|---|---|---|---|---|
| ***JAN*** | 33.9 | 18.4 | 26.1 | 30 | 0 | 269.5 | 234 |
| ***FEB*** | 37.0 | 20.4 | 28.7 | 27 | 0 | 294.6 | 217.0 |
| ***MAR*** | 39.4 | 27.3 | 29.3 | 33 | 4.8 | 334.9 | 205 |
| ***APR*** | *39.6* | *26.9* | *33.3* | *44* | *40.3* | *282.0* | *224* |
| ***MAY*** | *36.6* | *25.4* | *31.0* | *58* | *138.8* | *209.5* | *238* |
| ***JUN*** | *33.9* | *24.2* | *29.1* | *69* | *127.2* | *142.0* | *222* |
| ***JUL*** | *31.4* | *23.4* | *27.4* | *79* | *192.5* | *138.8* | *184* |
| ***AUG*** | *30.9* | *23.4* | *27.2* | *79* | *215.2* | *134.4* | *187* |
| ***SEP*** | *31.2* | *23.2* | *27.2* | *77* | *147.4* | *115.4* | *202* |
| ***OCT*** | *33.8* | *23.2* | *28.5* | *66* | *42.1* | *160.7* | *248* |
| ***NOV*** | *35.5* | *19.7* | *27.6* | *44* | *2.7* | *226.4* | *263* |
| ***DEC*** | *34.3* | *18.1* | *26.2* | *34* | *0* | *262.0* | *255* |
| ***YEAR*** | | | | | *910.8* | | |

Source: authorsfield work (2011)

Twenty buildings were selected within Modibbo Adama University of Technology Yola to access their effectiveness in applying passive cooling. Various landscaping techniques will be used to analyze the case studies stating the extent to which these techniques are applied. A score will be allocated to show how effective these techniques are as shown below:

Table 3 selected photographs of buildings used for the various case studies

| | | | |
|---|---|---|---|
|  *Computer Department* |  *Administrative Block* |  *Geology Department* |  *Senate Building* |
|  *Geography Department* |  *Demonstration* |  *Biotech Complex* |  *Sch. of Mgt. & Info Tech* |
|  *Lecture Theatre 3&4* |  *Library* |  *Architecture Department* |  *Abuja* |
|  *Lecture Theatre 1&2* |  *School of Science* |  *Clinic* |  *Student Centre* |

Source: authorsfield work (2011)

Table 4 Extent to which landscaping is applied with the respective score.

| EXTENT TO WHICH LANDSCAPING IS APPLIED | SCORE |
|---|---|
| **VERY HIGH** | 5 |
| **HIGH** | 4 |
| **MODERATE** | 3 |
| **LOW** | 2 |
| **VERY LOW** | 1 |
| **NOT AVAILABE** | 0 |

Source: authorsfield work (2011)

The landscaping techniques to be considered are shown below with acronyms assigned to each variable to simplify data tabulation; these variables were examined in each case study to know the extent to which they are applied.

*F. Landscaping using plants:*Shading with trees on all façade (TR SHD E); Shading with trees on all façade (TR SHD W); Shading with trees on all façade (TR SHD N); Shading with trees on all façade (TR SHD S); Shading with lawns on all façade (LWN E); Shading with lawns on all façade (LWN W); Shading with lawns on all façade (LWN N); Shading with lawns on all façade (LWN S). Higher ratio of vegetation cover to hard surfaces such as concrete paving tarred roads, sand (VEG COVER).

## III. RESULTS

From the case studies, a summary of the various applied techniques of passive cooling, their performance rating, whether they perform well or not are shown in Tables 5.0. The prevalence of some landscaping techniques is indicated in table 5.0. It will be observed that shading with trees on all the facades has a mean score of 2. Use of green lawn on all facades has a mean score of 1 as there is a few trace of grass lawn. Trees are few and scattered while absent in some structures. According to [1], during peak summer days the average temperature of walls shaded by trees or a combination of trees and shrubs can be reduced by up to 150K. Climbing vines can reduce the temperature by up to 120K. Looking at the combined landscaping techniques no building scored up to 50%, the highest score was from only two buildings with only 38% which is not good. Shading especially with plants is one of the most important passive cooling techniques as it can eliminate the need for the other techniques if properly applied. According to [6], when a building's internal and solar gains are sufficiently reduced, a *lean acclimatization concept* can be developed. Direct sun can generate the same heat as a single bar radiator over each square meter of a surface. Shading can block up to 90 percent of this heat [7]. All the buildings have either tarred road, concrete paving, sand or a combination of all these landscape elements with few traces of grass lawn in some cases. This modifies the micro-climate by making it hotter since these hard surfaces absorb solar radiation and reflects it to the building. Trees are few and scattered while absent in some structures.

According to [2], trees can reduce air temperatures around them by up to 5°C. Directly underneath trees the cooling is even better – up to a huge 14°C cooler.

## IV. DISCUSSION

Yola's climate has a diurnal range of 7-8 high mass construction can cause thermal discomfort unless carefully designed, well shaded and insulated. High thermal mass paving materials like stone, cement or ceramic pavers, gravel, bitumen accumulate heat while the sun is on them, and radiate that heat back at night, heating up the air over them both during the day and for some time after sunset. Some of these materials have reflective tendencies, reflecting sunlight up into nearby windows. Groundcover and low growing

plants do not store heat, instead having some cooling effect on nearby air by shading the soil beneath them and transpiration. Architects should keep paths and driveways shaded, or at least far enough away from the building that they can't reflect much heat and light into it, and plant groundcover at the base of walls.Desirable wind direction in Modibbo Adama University of Technology (MAUTECH) Yola is South-West trade winds so a short deflector on the lee side of the fenestrations will divert some breeze into the building.

Also an undesirable wind like the North-East trade winds blowing at an angle to a building can be turned away by a deflector on the windward side of a fenestration. Trees and shrubs on the east and west can be a great way to reduce heating during sunrise and sunset, providing shade during all but the middle few hours of the day.

Table 5Case studies showing green landscaping performance

| | **BUILDING** | **TR SHD W** | **TR SHD E** | **TR SHD N** | **TR SHD S** | **LWN W** | **LWN E** | **LWN N** | **LWN S** | **VEG CVR** | **TOTAL SCORE 45** | **% SCORE** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | **PG SCHOOL** | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | **13** | **29%** |
| 2 | **OBA ADETONA HALL** | 3 | 3 | 3 | 3 | 1 | 1 | 1 | 1 | 1 | **17** | **38%** |
| 3 | **ADMIN BLOCK** | 2 | 2 | 0 | 2 | 1 | 1 | 1 | 1 | 1 | **11** | **24%** |
| 4 | **SENATE BUILDING** | 3 | 3 | 3 | 3 | 1 | 1 | 1 | 1 | 1 | **17** | **38%** |
| 5 | **GEOGRAPHY DEPT** | 0 | 3 | 3 | 3 | 1 | 1 | 1 | 1 | 3 | **16** | **36%** |
| 6 | **DEMO SECONDARY SCHOOL** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | **9** | **20%** |
| 7 | **BIOTECH COMPLEX** | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 2 | **11** | **24%** |
| 8 | **SCHOOL OF MGT & INFO TECH** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | **9** | **20%** |
| 9 | **LECTURE THEARTRE 1&2** | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | **11** | **24%** |
| 10 | **ARCH DEPT** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | **9** | **20%** |
| 11 | **KABIR UMAR HALL BLOCK E** | 2 | 2 | 2 | 0 | 1 | 1 | 1 | 1 | 1 | **11** | **24%** |
| 12 | **ABUJA HALL** | 3 | 2 | 3 | 2 | 1 | 1 | 1 | 1 | 1 | **15** | **33%** |
| 13 | **LECTURE THEARTRE 3&4** | 2 | 2 | 3 | 0 | 1 | 2 | 3 | 0 | 1 | **14** | **31%** |
| 14 | **SCHOOL OF SCIENCE** | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | **2** | **4%** |
| 15 | **CLINIC** | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | **4** | **9%** |
| 16 | **STUDENT CENTRE** | 3 | 3 | 2 | 2 | 1 | 0 | 0 | 0 | 1 | **12** | **27%** |
| 17 | **GEOLOGY DEPT** | 3 | 3 | 2 | 2 | 1 | 0 | 0 | 0 | 1 | **12** | **27%** |
| 18 | **COMPUTER** | 3 | 3 | 2 | 2 | 1 | 0 | 0 | 0 | 1 | **12** | **27%** |
| 19 | **CHEMISTRY DEPT** | 3 | 3 | 0 | 2 | 0 | 0 | 0 | 0 | 1 | **9** | **20%** |
| 20 | **LIBRARY** | 3 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 1 | 8 | 18% |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **MEAN** | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 11 | 25% |
| | **SD** | 0.97 | 0.94 | 1.04 | 0.92 | 0.48 | 0.56 | 0.7 | 0.49 | 0.54 | 2.0 | 8.5 |

Source: authorsfield work (2011)

A canopy of trees with a lower level of shrubs and bushes, a wall or fence, to block low-angled rays is most effective. Architects should lay more emphasis on getting climatic data, carryout extensive site analysis and also learn from performance of existing buildings within the area before embarking on their design. It is very important for them to use winter and summer sunrise/sunset points for the site latitude to decide the appropriate length and placement oftree lines on the east and west facades.

## V. CONCLUSIONS

The paper attempted to establish the extent to which landscaping is used to enhance passive cooling techniques are applied in MAUTECH Yola which revealed that Architects have knowledge of passive cooling techniques but they concentrate more on aesthetics and functionality. Vegetation and trees in particular effectively shade and reduce heat gain. They increase humidity level. They also cause pressure differences thereby increasing and decreasing air speed or directing air flow. They can, therefore, direct air into a building or deflect it away. Plants, shrubs and trees absorb radiation in the process of photosynthesis.

As a result they actually cool the environment. Trees can be used to cut off the east-west sun. Too much hard surfaces like concrete paving and Asphalt increases heat gain and therefore should be minimized around the building. Plants cool air temperatures as their leaves cast shade which makes air beneath them cooler as it is not heated directly by sunlight. They also cool air temperatures by transpiration which is releasing water from pores underneath leaves which cools relatively dry air by evaporation. In order to benefit from this this effect is to have ventilation pathways – the pathways air travels into a building either by directly blowing in or by suction – pass through a garden belt, a mix of trees and shrubs.

This should not too dense; otherwise a windbreak effect will result. The effect to aim for is shade rather than a wall of plants [17] Building clients should also be educated on the importance and benefits of passive cooling especially with green landscape elements as it will enhance users comfort and cut down energy cost from mechanical cooling.

## ACKNOWLEDGMENT

A part of this work was partly the first author master thesis; the authors would like to also acknowledge and thank the International Doctorial Fellowship (IDF) initiated by Universiti Teknologi Malaysia and Educational Trust Fund (ETF) Nigeria for contributing to this research work.

## REFERENCES

[1] B. Givoni,*Passive and Low Energy Cooling of Buildings*. John Wiley & sons, 2001.
[2] United States department of Energy 2008.*landscaping*, Retrieved March 01, 2012 from http://www.eere.energy.gov/consumer/yourhome/landscaping/index.cfm/mytopic=11940.
[3] S. Boonyatikarn, *Sustainable Architecture: Experiences from Thailand.* Shinawatra University Thailand,2004.
[4] Upper Benue River Basin Development Authority, 2010. *Yola Climatic data*. UBRBDA meteorological station.
[5] Geography department meteorological station, FUT Yola 2010. *Yola Climatic data*.
[6]C.F.Reinhart, et al 2001. *Passive cooling of buildings*. Retrieved March 01, 2009 from http://www.esu.com.sg/pdf/ passive cooling of building.pdf
[7]A. Olgyay, and V. Olgyay, *Solar Control and Shading Devices.*Princeton University Press, Princeton, NJ,1951.