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Research Article

Reducing Energy Consumption through Landscaping

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Abstract: In tropical regions where the sun is constantly high in the sky are experiencing intense solar radiation throughout the year. The urban areas where less vegetation is found are most impacted which lead to among others, the urban heat island phenomenon. Global temperature rise increases cooling load, thus, more energy is consumed. Careful planning of exterior spaces can help reduce energy consumption for cooling by reducing the adverse impact of some climatic factors and increasing vegetation. Strategically placed vegetation around a building has long been recognised as a means of cooling. It can reduce temperatures and humidity through shading, evapotranspiration and wind channeling. Thus, manipulating the building envelop and ambience. Two buildings in the same area with similar orientation were considered, pictures and readings were taken on site using data loggers. One of the buildings had more paved surfaces while the other had more green surfaces, temperature and humidity readings were taken simultaneously and compared. It was discovered that the building with more green surfaces maintained a lower temperature and higher humidity as compared with the building with more paved surfaces.
Keywords: Landscaping, temperature, humidity, ambience.

INTRODUCTION

Landscaping form an integral part of the built environment and contribute immensely to enhance passive performance of buildings. For instance, Bernatzky [1]; Anumah [2] identified benefits of urban green structures as cooling hot air by evapo-transpiration, shading the ground and walls, reducing the radiant temperature, control of wind velocity and direction, filtering dust and noise.

The energy used in residential buildings is dependent on a number of variables, such as climate, surrounding vegetation, orientation, structure and construction materials. Of these, climatic factors have the most influence on the energy use in buildings. By controlling or manipulating the microclimate, it is possible to control the energy used for heating and cooling [3]. A microclimate space begins directly around an individual building, and spreads to its neighbors until its reach takes in a small community as a neighborhood area. In an individual building, a microclimate boundary can be created by manipulating the building envelope and ambience [4]. The planning and development of exterior spaces can reduce the energy consumption of buildings by reducing the impact of some climatic factors. If the microclimatic condition around the building is similar to the desired interior conditions, little or no extra energy is required. Contrarily, if the microclimate is significantly different from the desired interior conditions, more energy may be required for heating or cooling. Awareness and knowledge of the potential of vegetation to modify microclimate could produce an alternative of quantifying the energy saving potential of landscaping [5].

One mistake in designing the built environment is in terms of landscaping. The choice and use of ground covers and the use of polished surfaces like bare earth, asphalt, sand and concrete which become excessively hot due to solar radiation there by increasing the air temperature in and around the building envelope making it uncomfortable for occupants.

Climatic factors affecting thermal performance

Climate is the integration of weather conditions in respect to the characteristics of a certain geographical location over a period of time [6]. The Köppen system classification of climate recognizes five major climatic types; which are tropical climate, dry climate, temperate, continental and polar. This paper focuses on the tropical climate (which includes places located at 15-degree north and south of the equator characterized by dry and wet seasons with high relative humidity and temperature with problems like low air quality for internal spaces and glare). This contributes to high energy usage for cooling in buildings as users try to get the right comfort zone [7]. Architects are interested in the aspects of climate that can increase human comfort and reduce energy needs.

CONDUCTION

Conduction involves the transformation of kinetic heat in a solid mass. This is the process of heat transfer from warmer to cooler molecules within a solid material. The primary heat transfers paths between a building and the external environment through conduction are through walls, roofs, doors (opaque conduction) and windows (glazed conduction).

CONVECTION

Convection represents the transfer of heat by circulation or movement of hot particles to cooler areas. This is a very important mechanism in the building design, as air movement is necessary to:

- Moderate internal temperatures.
- Reduce the accumulation of moisture, odours and other gases that can increase during occupied periods.

Air movement in buildings can be 'enhanced' (for example driven by fans), or 'natural' resulting from pressure differences from one part of a building to another.

RADIATION

Radiation occurs without the involvement of a physical substance as the medium. Thermal radiation involves the interchange of electromagnetic waves between surfaces of different temperatures [8]. The sun transfers its heat to the surface of the Earth by radiation through space to the Earth's atmosphere. The ozone layer, atmospheric particles, condensing water vapour and dust acts as a filter for solar radiation, thus, reduces its intensity at the Earth's surface. In buildings, radiant heat transfer is the energy exchange between surfaces by electromagnetic waves across space. The radiation wave is transmitted through space until it strikes an opaque surface, where it is partly absorbed. The absorbed radiation increases the vibration of the surface molecules, and thus raises the temperature of the material where the absorption took place.

Air temperature

Air temperature is the ambient temperature indicated by a thermometer exposed to the air, but sheltered from direct solar radiation, 1.5–2m above ground [9]. Season, latitude, the amount of cloud cover, and the time of year are some of the main factors that determine air temperature [10]. Generally, the coldest air temperature during the course of the day is usually just before sunrise, while the hottest is two hours after noon. The air temperature then starts to decrease and continues to do so through the night. Krigger and Dorsi [11] state that air temperature which is one of the most important factors in determining heating and cooling energy use is the most noticeable characteristic of climate. Outdoor temperatures vary according to the season, weather and time of day.

WIND

Wind has a great influence on building design and their thermal performance. It affects the convective heat exchanges of a building envelope and the air infiltration [12]. It's necessary to avoid the effect of winter wind which increases the infiltration heat loss and utilizing the summer wind in encouraging ventilation [13]. Many factors affect the wind at the local level such as topography, vegetation and buildings configuration [14].

Humidity

Humidity is the presence of water vapour in the atmosphere. It is measured in either relative terms (relative humidity) or absolute terms (dewpoint temperature). According to Oughton & Hodkinson [15], levels of between 40 and 70% relative humidity are considered to be the limits of acceptability for humidity, with 45 to 65% humidity being the levels for optimum comfort. Relative humidity is the ratio between the actual amount of water vapour in the air and the maximum amount of water vapour that the air can hold at that air temperature. This measurement is taken with a psychomotor. Relative humidity of between 40 and 70% does not have a major impact on thermal comfort. In some spaces, such as office areas, humidity is usually kept between these ranges.

Vegetation

This is the overall plant cover (trees, shrubs, grasses) within an area. Vegetation is one naturally occurring phenomena. It is rich and provides an excellent means of improving microclimate. Its surfaces do not heat up and they provide efficient shading at almost no cost [7]. They can also reduce the external temperature of a building surrounding through evapotranspiration; compound word used to define evaporation and transpiration [16].

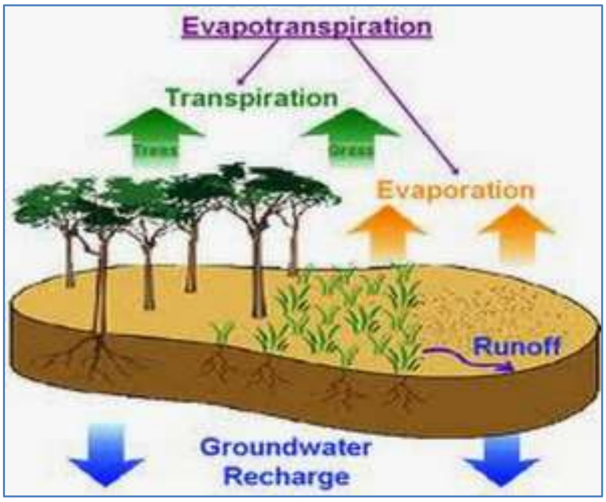

Fig-1

Hard surfaces are almost inevitable around buildings, but they should be minimal to reduce the outdoor temperature. When hard surfaces are heated and these surfaces are surrounded by shrubs, instead of a significant increase in the ambient temperature, the ambient temperature remains cooler as a result of shading provided by plant foliage and moisture that they retain in the soil. Trees can have a canopy large enough to provide shade roofs and walls, which can reduce the amount of solar radiation reaching a house. Solar radiation is also absorbed by the tree canopy, generating evapotranspiration that cools the leaves and surrounding air. Air movement then disperses this cool air resulting in an overall cooling effect. Trees and shrubs can be planted to funnel or deflect wind away from or towards specific areas, as both vertical and horizontal concentrations of foliage can modify air movement patterns.

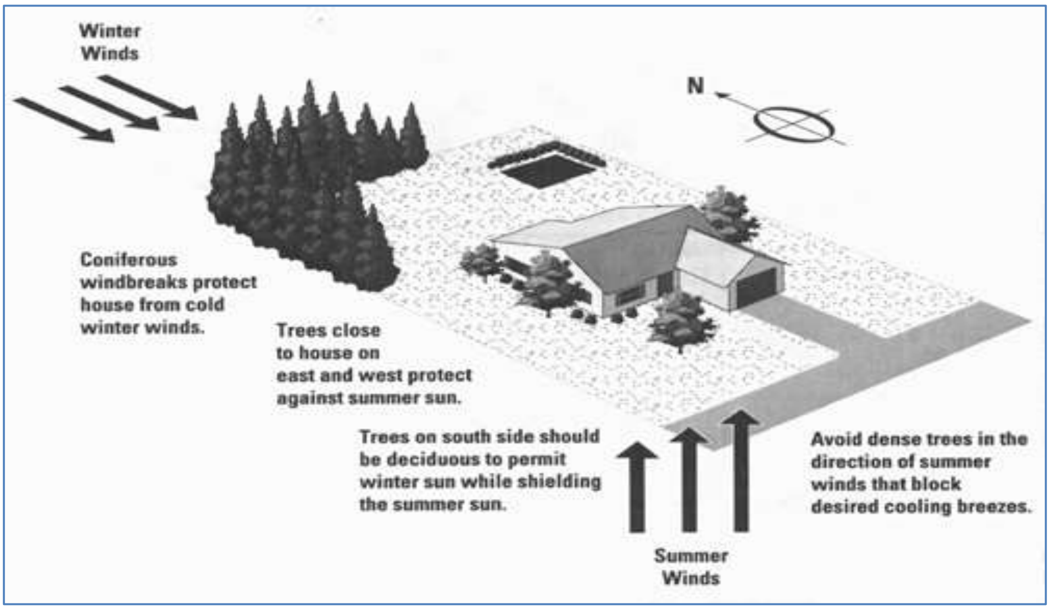

Fig-2

Dense clusters of trees can reduce wind speed compared to an area devoid of trees. By reducing wind velocity, a landscape aimed at assisting with energy conservation slows air infiltration into a building. In hot-humid tropical climates wind should be channeled for cooling and to provide relief from high vapour pressure. A few large trees with spreading branches can allow breezes to reach a building, and keep the area cool.

Shading

Trees and vegetation are most useful as a mitigation strategy when planted in strategic locations around buildings or to shade pavement in parking lots and on streets. Researchers have found that planting deciduous trees or vines to the west is typically most effective for cooling a building, especially if they shade windows and part of the building's roof. To achieve efficient shading trees have to be placed strategically. For example, at 40°N Latitude the sun is at a low angle in the morning and late afternoon. To counter these evergreen trees should be placed facing southeast and southwest of the building. The best locations for deciduous trees are on the south and east sides of a house [17]. Conversely, at 40°S the most effective landscape planting strategy is to block the summer setting sun by planting dense deciduous trees and shrubs on the west and northwest sides of a house. The trees will cast long shadows that can effectively shade areas of houses, which are otherwise difficult to protect from the sun's heat at this time of the day. When these trees drop their leaves in the winter, sunlight can reach the house to assist with heating. Trees with high, spreading crowns can be planted to the south area to provide maximum summertime roof shading. In the tropics, shrubs and other low growing foliage provide shade during the morning and late afternoon when the sun is low in the sky. Shrubs planted close to the house will shade walls and windows. Vines are generally very fast growing and require little space. They are also a source of shade for a building.

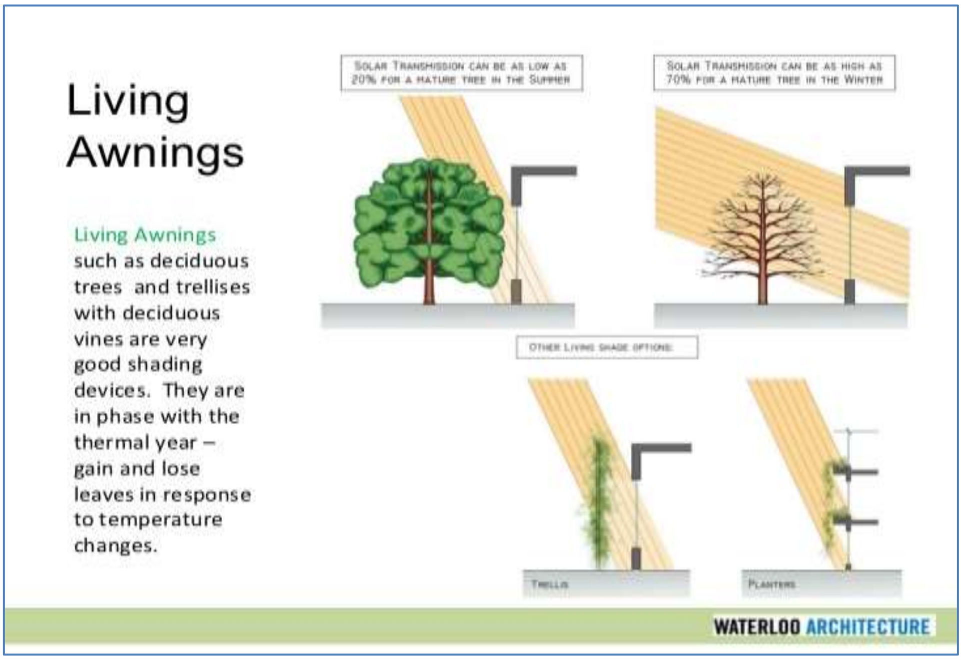

Fig-3

METHODOLOGY

This research was basically by review of relevant documented data and field work. The field work entails taking of pictures and measurements of air temperature and relative humidity from the exterior of houses simultaneously (two houses in the same location during similar weather conditions to ensure they could be accurately compared). This data was automatically recorded at three hours intervals by temperature-humidity data logger and WBTS Heat stress meter.

RESULTS AND FINDINGS

The studied area is Gura top area of Rayfield in Jos south local Government Area of Plateau state (latitude 9.54N and longitude 8.53E). The area is predominantly residential. Two residential buildings are selected and studied with consideration to the landscaping. One of the buildings is having more vegetation while the other is sparse and has more hard surfaces.

The field work and data collection of this study took place from the 7th to 14th of January, 2019 where data loggers were used to take reading of temperature and relative humidity of the two surroundings simultaneously.

Fig-4: Satellite image showing location of the two-case study
Source: google earth pro version 8.32

Case study one

Case study one is the surrounding landscape of a bungalow, the building is 12 years old. The landscape nature around the building comprises of the soft and the hard elements, with the hard element restricted to the walk ways and parking. The soft element dominates the landscape with mostly lawn and conical and fountain trees planted close to the building envelop where openings are located.

Fig-5: Showing the landscape nature of case study one
Author's field survey, 2019

CASE STUDY TWO

Case study two is the surrounding landscape of yet another bungalow where the nature of landscape has predominantly the hard elements. Inter-locking concrete tiles covered more than 50% of the surrounding with few shrubs around the walls of the building.

Fig-6: Showing the surrounding landscape of case study two
Author survey, 2019

Analysis

The two-surrounding house in this case study had differences in their architecture and landscape design, each house around them followed the construction trends of the time they were built. Weather data measurement taken for the ambient air included solar air temperature and relative humidity, both of which can influence the thermal performance of the house.

Table-1: showing temperature data collected around the two buildings at 3hours interval

DAYS	LANDSCAPE TYPES	6am	9am	12pm	3pm	6pm	9pm	12am	3am
MON	Hard Landscape(°C)	23.8	29.4	35.1	33.3	31.4	24.6	22.3	20.9
	Soft Landscape(°C)	21.9	27.7	33.6	31.2	28.8	21.9	20.1	19.2
TUE	Hard Landscape(°C)	24.1	29.7	34.9	33.1	30.7	24.3	22.7	22
	Soft Landscape(°C)	22.4	26.8	32.2	30.7	28.4	22.6	21.3	19.9
WED	Hard Landscape(°C)	22.9	24.5	35.1	36.8	32.5	24.2	22.7	20.6
	Soft Landscape(°C)	20.6	23	32.5	31.5	29.1	22.7	20.2	19.7
THUR.	Hard Landscape(°C)	24.3	25.8	36.6	34.2	30.4	23.8	21.9	21.4
	Soft Landscape(°C)	22.2	23.6	33.4	30.8	29.7	21.6	20.2	18.9
FRI.	Hard Landscape(°C)	23.7	26.7	36.1	33.9	31.2	24.5	21.2	21.8
	Soft Landscape(°C)	22.4	24.1	34.2	31.8	28.7	21.9	18.8	19.3
SAT.	Hard Landscape(°C)	22.9	25.6	34.4	33.1	29.7	23.6	20.9	18.5
	Soft Landscape(°C)	21	22.8	32.6	30.9	27.8	21.4	18.1	17.2
SUN	Hard Landscape(°C)	21.3	24.5	33.9	33.1	27.8	23.4	20.3	18.1
	Soft Landscape(°C)	20	22.5	32.2	30.7	24.4	21.1	18.3	16.9

Source: Authors survey, 2019

Case study 1 is referred to in the table as soft landscape while case study 2 is hard landscape.

Table-2: showing relative humidity data collected at interval of 3hours.

DAYS	LANDSCAPE TYPES	6am	9am	12pm	3pm	6pm	9pm	12am	3am
MON	Hard landscape (%)	95.4	88.6	72.5	64.7	73.1	83.5	84.8	89.1
	Soft landscape (%)	97.2	92.9	74.8	67.9	75.2	86.3	88.9	94.7
TUE	Hard landscape (%)	92.1	85.3	69.7	62.6	71.1	80.8	82.1	87.4
	Soft landscape (%)	95.4	88.6	72.5	64.7	73.1	83.5	84.8	89.1
WED	Hard landscape (%)	83.7	79.8	65.9	62.8	68	77.2	83.5	84.9
	Soft landscape (%)	85.4	82.6	69.2	66.1	71.4	80.3	86.6	88.5
THUR.	Hard landscape (%)	95.4	88.6	72.5	64.7	73.1	83.5	84.8	89.1
	Soft landscape (%)	97.2	92.9	74.8	67.9	75.2	86.3	88.9	94.7
FRI.	Hard landscape (%)	88.1	82	65.9	61.2	67.4	76.7	78.6	83.9
	Soft landscape (%)	92.1	85.3	69.7	62.6	71.1	80.8	82.1	87.4
SAT.	Hard landscape (%)	92.1	85.3	69.7	62.6	71.1	80.8	82.1	87.4
	Soft landscape (%)	95.4	88.6	72.5	64.7	73.1	83.5	84.8	89.1
SUN	Hard landscape (%)	92.3	88.6	72.5	64.7	73.1	83.5	87.6	89.1
	Soft landscape (%)	94.6	92.9	74.8	67.9	75.2	86.3	91.8	94.7

Source: Authors survey, 2019

Table-3: showing the daily mean temperature of the two studied surroundings.

	days						
Types of landscape	Mon.	Tues.	Wed.	Thur.	Fri.	Sat.	Sun
Hard landscape (°C)	27.6	28.1	27.4	27.5	27.2	26.8	26.4
Soft landscape (°C)	25.1	25.0	24.2	24.4	24.0	23.7	23.2

Source: Authors survey, 2019

From the data collected, it was discovered that case study 1 (soft landscape) had lower temperature as compared to case study 2(hard landscape). There was a variation of about 3°C meaning that the surrounding vegetation had influence in the reduction of the immediate ambient temperature of that surrounding. It can be said that the vegetation in case study 1 modified the micro climate by a3°C reduction in temperature.

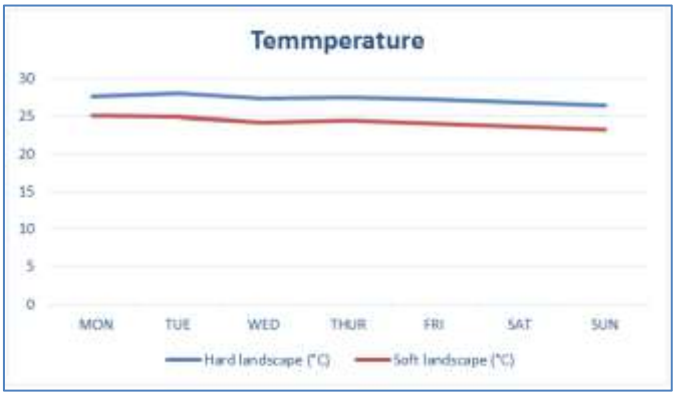

Fig-6: Graph showing the results of the mean temperature of the studied surrounding

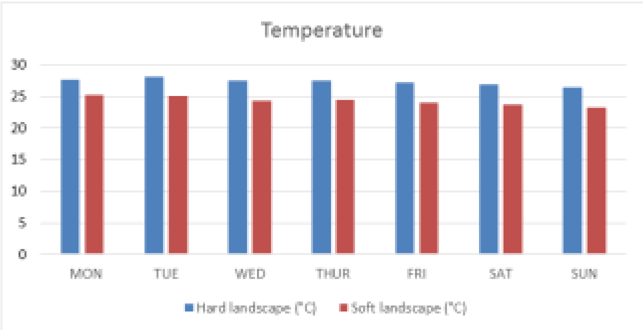

Fig-7: Graph showing temperature variation of soft and hard landscape surroundings

Table-4: Showing the daily mean relative humidity of the two studied surroundings.

	days						
Types of landscape used	Mon.	Tues.	Wed.	Thur.	Fri.	Sat.	Sun
Hard landscape (%)	76.4	76.2	77.0	76.3	78.3	77.6	78.1
Soft landscape (%)	87.7	86.1	87.3	86.9	87.4	86.9	87.8

Source: Authors survey, 2019

The 3hours interval measurements of relative humidity around the two houses were taken from beside their exterior walls. The figures show that evapotranspiration was influenced by the amount, placement and size of plants around the house. Case study 1 had higher RH levels, especially during the mornings, and these slightly declined from noon. This was because dense vegetation helps to control the moisture content through the evapotranspiration process.

The different amounts of vegetation around the two houses produced different microclimates. Having a large amount of vegetation can modify net radiation, sensible heat, latent heat and heat storage. From the analysis, it was discovered that there is a variation of 10% of the relative humidity of the surroundings. It can therefore be concluded that the vegetation in case study 1 modified the microclimate by 0 10% rise in relative humidity.

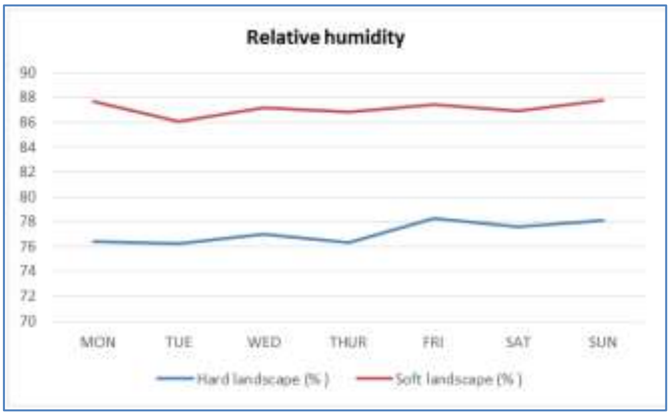

Fig-8: Graph showing the variation in the relative humidity of the different landscape pattern

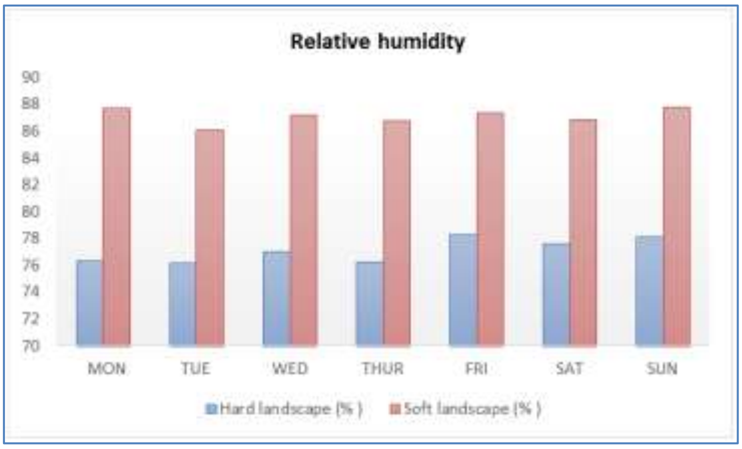

Fig-9: Graph showing the variation in the relative humidity of the different landscape pattern

The results from the ambient conditions of the two study houses showed that air temperature, relative humidity, and wind speed were influenced by the surrounding vegetation. The intensity of the global solar radiation and cloud cover contributed to a microclimate effect in the case study areas. However, the surrounding vegetation exerted a direct influence by shading and channeling wind, and indirectly through evapotranspiration.

SUMMARY

In the study areas, the two houses and surroundings had similar styles of architecture, and had similar methods of building construction. The majority of trees, shrubs, and groundcover surrounding the well landscaped hose were situated in strategic locations on the east and west sides of the houses, where they received direct solar radiation. They also had little number of plants located on the north and south side, which could reduce diffuse solar radiation. From the data collected and the analysed results it was discovered that the building that was well soft landscaped had an advantage over the building with more of the hard landscape elements in term of decrease in the surrounding temperature of the two areas. Adequate numbers and sizes of trees, supported by shrubs, and groundcover located in strategic positions around a building can increase the energy saving potential of a house, particularly during the peak load time of the day. These plants will help to cool the ambient air temperatures, and help decrease air-conditioning use.

CONCLUSION AND RECOMMENDATION

The results of this study shows that the planting pattern in tropical landscape designs and styles have different effects on the ambience of the buildings studied. The house with the strategic landscape design achieved the lowest temperature in the exterior surrounding of the house; low temperatures, high humidity and moderate wind combined to create a cool and comfortable living environment. Trees, shrubs, vines and groundcover play an important role in directly creating this by cooling the environment. The surrounding plant and trees also play a key role in evapotranspiration, thus, giving a cooler ambience.

Green plants and shrubs have shown great importance in terms of improving the micro climate of an environment to meet occupants' thermal comfort. The following are hereby recommended:

1. Plants should be employed in landscaping of buildings as they can reduce and in some cases eliminate the use of HVAC due to their energy saving potentials.
2. The use of hard landscape elements like inter-locks, asphalt, tar and concrete surfaces around a building should be minimized as they increase the immediate temperature of that surrounding by creating what is known as urban heat island which affects the ambient temperature of the immediate environment.
3. A natural environment and its features most especially the greens, are the driving force to any sustainability in terms of the built environment, so in cases of planning and construction of buildings the green environment should be put in place in order to harness the potentials it has to offer.

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