THE INFLUENCE OF VEGETATION ON MICROCLIMATE IN HOT HUMID TROPICAL ENVIRONMENT-A CASE OF ENUGU URBAN.

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ABSTRACT: *Controlling direct solar radiation and increasing wind velocity to its Optimum capacity are part of planning strategies employed in the design of urban open spaces especially in hot humid tropical environment. Vegetation has the ability to reduce excessive air temperature through sunlight interception. Its geometric configuration influences the amount of solar radiation, air temperature, humidity and wind velocity on microclimate of a given area. Panning strategies aimed at reducing solar heat through application of vegetation were discussed. It also discussed the problem of thermal heat stress affecting the residents of Enugu Urban. The results were analyzed and solutions recommended.*

KEYWORDS: Open Space, Planning Strategies, Solar Radiation, Tropical Environment, Urban Microclimate.

INTRODUCTION

According to United Nations (2010), World Bank, (2009), more than half of the world's population lives in the urban areas. Urbanization trend poses new millennium challenges in both industrialized and developing countries. One of these challenges is thermal heat stress resulting from climate change. The hot humid tropical environment of Enugu is characterized with high intensity of solar radiation and low wind velocity during the hot season. The rapid development activities taking place within the past decade will in no doubt lead to urban heat island effect and plant destruction among other environmental damages. Due to the recent climate change phenomenon, the city dwellers are experiencing continuous problems of heat stress, thus the problem of thermal comfort in urban quarters needs to be addressed. Vegetation is an essential element of urban space planning. Benefits derived from its application include amelioration of urban microclimate through sunlight interception, shading, and control of wind velocity, as well as air purification by absorption and control of noise pollution. (Yu & Hien, 2006).

Reducing solar heat and increasing and controlling wind direction are part of planning strategies aimed at bringing thermal comfort within acceptable standards for urban dwellers living in the city. This paper therefore aims to discuss planning strategies to be adopted in reducing solar heat through the application of vegetation in the study area. Emphasis was layed on the effects of vegetation configuration and location for improving microclimate of the area.

CONCEPTUAL FRAMEWORK

According to David, (2009), vegetation increases the oxygen and moisture in the air, absorbs sun's radiation, gives shade, cools the surrounding environment and generally improves the microclimate of a given area. According to Thornson et al, (2004), thermal conditions are influenced by buildings, surfaces conditions, open space obstacles and tree canopies causing climate from very hot to cool in the hot season. Therefore, taking into account of psychological issues, and thermal variations, microclimate guidelines should be studied so as to develop planning strategies in order to ensure outdoor human comfort in future urban design.According to Chandler, (2001), different climatic effects occur within a general pattern under the influence of local conditions. The overall weather patterns form a framework which is influenced by local and regional geographic factors. These in turn can produce a climate influenced by buildings and their surrounding elements within urban setting.

Chandler classified climate into different level; viz:
Macro-climate: Climate obtained by using data from a number of standardized sites over a large area such as country, continent, and oceans.
Microclimate: encompasses large areas with fairly uniform conditions which are influenced by air masses moving over earth surface within parameters that characterize a localized area with a geographic scale between 1m2-100m2. The main factors that influence microclimate include surface temperature, relative humidity, wind speed, solar radiation and precipitation.

Odeleye, (1989), posits that climate either macro- and micro- climate is the sum of characteristic meteorological phenomena in the atmosphere which are modified by topographic conditions of the earth and by changes which civilization has made to its surface. He went further to define microclimate as that found in a more limited space, whether a room, a street, town or small landscape while macroclimate is that found in a much larger space such as over a country, region, oceans or continents. On thermal comfort, Nervis, (1963), Giovani, (1969), considered the physiological aspect of thermal sensation generally recognized that heat gained or lost by the body to its environment is directly related to the temperature of the surroundings, humidity, wind velocity, radiant temperature of the surroundings and type of activity.

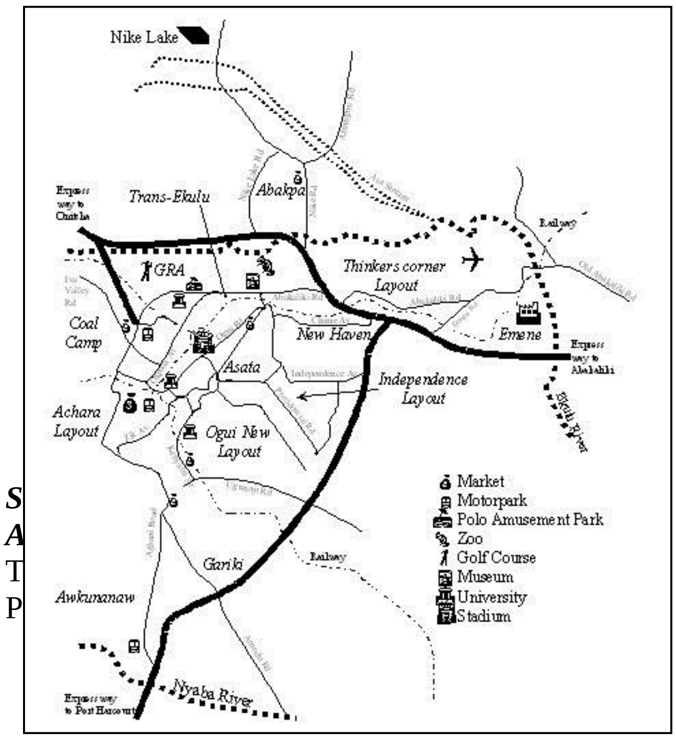
AREA OF THE STUDY

Enugu literally means *hilltop* in Igbo Language because of the dominant feature of Udi Hill. The hilltop towers about 207m above sea level. Enugu State is called Coal City state because of the discovery of coal in commercial quantity in Enugu Urban in 1909 by British explorers. The State boarders with Ebonyi State to the east and Anambra State to the west, Benue and Kogi States to the northeast and northwest respectively, while Abia and Imo States border to the South.

Enugu State is found between longitudes 7^0E and 7, 45^0E and latitudes 6,00^0N and 7,00^0N of equator. This makes Enugu to fall within the tropic zone and its vegetation is dominated by tropical rainforest with derived savannah. The city has tropical humid savannah climate. The humidity is highest between the months of March and November. The whole area records mean daily temperature of 26.70C.The two dominant seasons are the dry and rainy seasons. The average annual rainfall in Enugu is 2000 millimeters. Another significant weather condition that affects the city is the Harmattan brought by dusty North-East trade wind between the months of December and January. Generally, Enugu is hot throughout the year like the rest of Nigeria. (Table 1). The teren is made up of groups of dome shaped and flat top hills and ridges forming saucer shaped depressions in different locations. Development westwards is restricted by ridged scarpland, therefore urban expansion progresses southwards towards Agbani and eastwards towards Abakaliki. The main towns of the state include Enugu Urban, Udi, Oji and Nsukka

Urban. The population of Enugu urban was put at 717,201 according to 2006 National Population Commission and the population density was 6400/km2. (Table1). Enugu Urban, the Study Area is found between latitudes 6.24^0N and 6.30^0N and longitudes 7.24^0E and 7.32^0E. Enugu Urban borders, on the east by Nkanu East Local Government Area, on the west, by Udi Local Government, on the north by Igbo Etiti and Isi-Uzo Local Government Areas, and Nkanu West Local Government Area on the south. There are 20 prominent residential layouts in Enugu Urban. They include Abakpa, Trans-Ekulu, GRA, Nike, Ogui, Asata, New Hevan, Obiagu, Ogbete, Iva Valey, Independence Layout, Achara Layout, Ugwuaji, Maryland, Awknawnaw, Uwani, Agbani, Coal Camp, Amochi and Idaw River Layouts. The Study Area falls within the Humid Tropical Area of Eastern Nigeria.

Fig 1: Map of Enugu State Local Government Area and Enugu Urban



LOCAL GOVERNMENT AREA	MALES	FEMALES	TOTAL
Enugu East	131,214	145,905	277,119
Enugu North	118,895	123,245	242,050
Enugu South	93,758	104,274	198,032
Total	343,867	373,424	717,201

SOURCE: National Population Commission (2006)

Table II: Climate Data for Enugu.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Record High ^{o}c	37	37	40	37	34	33	32	31	31	34	34	36	40
Average High ^{o}c	34	35	35	34	32	31	30	30	30	37	33	33	32
Daily Mean	27	29	29.5	29	27.5	27	26	26	26	26.5	27.5	26.5	27
Average Low ^{o}c	20	23	24	24	23	23	22	22	22	22	22	20	22
Record low ^{o}c	13	18	20	21	21	20	20	19	21	19	13	12	12
Precipitation in mm	19	15	70	130	217	252	242	237	292	201	12	8	1.695
Average precipitation days	1	1	4	7	12	14	16	15	18	12	1	1	102
Mean monthly sunshine hours	186	174	183	183	186	153	118	118	123	174	219	217	2034

Source: The weather Network

AIM AND OBJECTIVE OF STUDY:

The aim of this paper is to discuss planning strategies to be adopted in reducing solar heat stress in Enugu Urban using vegetation application.

The objective of the study is;

- To evaluate the use of vegetation in addressing the problem of heat stress in Enugu urban.
- To assess the level of heat stress and its associated discomfort among the residents of the area.
- To evaluate climate/microclimate regime in the study area.

MATERIALS AND METHODS:

The methodology used is field survey. The study was carried out between the hottest months of February and March and June and July, the rainy season months for 2010 and 2011. Different sites were selected as experimental sites in areas with vegetation cover in **GRA, Independence Layout and University of Nigeria, Enugu Campus (UNEC),** while a reference station was created in down town areas without vegetation cover made up of **Abakpa Nike, Uwani Awknaunau**. Temperature readings were also taken under the selected shade trees and outside them at chosen locations both in open spaces and at street levels. The reports were reviewed and the results presented and discussed. Tree selection was based on their availability, canopy foliage, height and specie. The resultant data were analyzed in order to assess the thermal comfort level in Enugu urban, using Bioclimatic Index as posited by Tzenkova et al, (2000).

Table III: Mean Monthly Temperature Reading

Month	**Control Temperature (Without Tree)**	**Under Tree Temperature**	**Temp. Reduction**
February	30.5^{o}c	24.5^{o}c	6^{o}c
March	33.0^{o}c	28.6^{o}c	5.4^{o}c
June	29.6^{o}c	18.8^{o}c	10.8^{o}c
July	28.8^{o}c	19.5^{o}c	9.3^{o}c
Feb-July	30.4^{o}c	22.9^{o}c	7.5^{o}c

Table IV: Mean Radiant Temperature under Different shade Trees.

S/N	**Shade Tree**	**Mean Radiant Temp.**
1	Mango Tree	16°c
2	Guava Tree	18°c
3	Coconut Tree	26°c
4	Flame of the Forest.	20°c
5	Masquerade Tree	25°c
6	Melina Tree	18°c
7	Palm Tree	25°c
8	Cashew Tree	13°c

Table V: Thermal Comfort Index

S/N	**Thermo-Hydrometric Discomfort Index**	**DI°c**
1	Comfort level (No discomfort)	24°c
2	Discomfort under 50% of population	21-24°c
3	Discomfort by over 50% of population	24-27°c
4	Discomfort by over 50% of population	27-29°c
5	Stressed by Total population	80-82°c
6	Existence of State of Medical Emergency	>82°c

Source: Tzenkova et al (2000)

RESULTS AND ANALYSES

The mean monthly radiant temperature for dry season months February & March were 30.5oC 33.0oC respectively and for the rainy season June & July amounts to 29.6oC and 28.8oC respectively. Temperature reading under tree shades also gave24.5oC and 28.6oC for February and March and for June and July, the readings were 18.5oC and 19.5oC. On the average, the dry season months the dry season months, February and March had 30.4oC while under shade tree temperature gave 22.9oC. It is important to note that under shade temperatures were taken under different shade trees to determine their effects on thermal heat reduction. (Fig.111). It should be noted that all temperature readings were taken as monthly average. The highest temperatures were recorded on coconut tree 26oC, Palm tree 25oC, and Masquerade tree, while lower temperatures were recorded on cashew tree 13oC, Mango tree
(Table v) was analyzed and thermal comfort index indicates that 63% of the trees produced shades with resultant reduction in temperature within **comfort or no discomfort** levels.

DISCUSSION

The Problems of Thermal stress of Open Spaces in Hot Humid Tropical Environment:

According Mansy, (2006), Soegiyanto, (1998), the hot humid climatic zone experiences high air temperature of a range between 27^0C-32^0C as a result of high intensity of solar radiation coupled with low wind velocity of approximately 1-2m/s.According to Scudo et al, (2004), a relationship exists between direct solar radiation with ratio of height of the surrounding building and width of open space (H/W ratio). It follows that when H/W ratio is low; the intensity of solar radiation on urban open space becomes high. According to Huang, (2008), radiation effects on concrete surfaces increases the surrounding air temperature in the surrounding urban open space, resulting to urban heat island effects. This condition creates uncomfortable outdoor environment for the urban dwellers as a result of heat stresses. Low wind velocity as earlier stated has also been identified as another factor accompanying heat stress. It is necessary to device means of optimum utilization of wind velocity and direction inorder to address the problem. This study observed that reducing direct solar radiation to the bearest minimum and increasing wind velocity to an optimum level can be employed as planning strategy to reduce air temperature with resultant reduction to heat intensity in the urban areas thereby creating thermal comfort for urban dwellers. The study also observed that microclimate can be modified by the use of vegetation.

Mitigation of Urban Heat Island Effect with Vegetation:

Trees and vegetation cool the air by providing shade and by means of evapotranspiration (the evaporation of water from leaves). Shade reduces the amount of solar radiation transmitted to the underlying surfaces thereby keeping them cool. Shaded walls may be (5^0C-20^0C) cooler than the peak surface temperature of unshaded surfaces. These cooler walls decreases the quantity of heat intake transmitted to the building interior, thus lowering or reducing air conditioning costs. Cooler surfaces also lessen the heat island effect by reducing heat transfer to the surrounding air temperature.Minimizing direct solar radiation and optimizing wind velocity are essential factors employed in the design of urban open spaces. Vegetation has the ability to reduce environmental heat stresses. Its form and configuration that is its geometry can influence solar radiation, air temperature, humidity and wind of a selected site.

Relevant Literature on the Subject:

According to Yu & Hein, (2006), in hot humid tropical area characterized by high intensity of solar heat and low wind velocity, vegetation can provide various environmental benefits such as amelioration of urban microclimate by shading the sun radiation and controlling wind velocity, and also by reduction of air pollution through absorbtion of the pollutants as well as reduction of noise. According to Katzchner, (2002), reduction of solar glare and wind control are strategies that help to create thermal comfort within the microclimate of urban living areas and open spaces.

Vegetation and Solar Radiation Link:

Plant or tree geometry, that is its crown structure, shape, height and width (dimension), leaves condition were observed to reduce amount of solar radiation reaching the desired area.

According to scudo, (2001), leaves of trees allow 20% of radiation to be transmitted through them and about 55% absorbed while 25% reflects back. It follows then that the process of evaporation increases relative humidity and air temperature. This according to Hiroaka, (2002), is that solar radiation absorbed by leaves of trees is re-transmitted by the process of evapotranspiration.

Vegetation and Thermal Comfort Link:

According to Nervis & Hardy, (1963 revised 2007), the sensation of comfort or lack of discomfort is a complex subjective reaction resulting from a combination of physical, psychological and physiological phenomena. In a hot humid environment l, an absence of thermal discomfort results in part, when the human body is able to dissipate to its surroundings all of the heat it receives, including that generated by metabolism without sensibly sweating. He went further to posit that there is always a small amount of heat lost by evaporation in the form of moisture diffusion through the skin known as *insensible perspiration* and through evaporation from the respiratory system. Cooling effect by vegetation influence had been recorded in the past by researchers such as Zahoor (1997), Saxena, (2001), Vineet et al, (2001), Hiraoka, (2002), Matzarakis (2002), Hien et al, (2006), Wallace, (2007), and others.

Zahoor, (1997), carried an experience in Pakistan and found out that vegetation has significant influence to local temperature and was effective in reducing air temperature to about 6-7^{0}F . Saxena in (2001), by computer simulation also observed that temperature on residential neighbourhood surrounded by considerable number of trees has 1.34 ^{0}F lower than without vegetation. In the same vein, Hiroaka (2002), observed through computer simulation the air temperature distribution of around 10m height single tree and obtained the range of maximum reduced air temperature at about 25 meter away from the tree, though this is partially influenced by wind velocity and direction.

Vinet et al, (2001), observed significant drop of temperature at 1p.m around green area. Mayer and Matzarakis (2002), as well as Hien et al (2006), in Singapore which lies within humid tropic climate observed high temperature differences between densely covered green areas and sparsely covered green area to be as high as 4 oC at 1p.m. A key factor determining a tree cooling effect according to this study is its transmittance, the fraction of radiant energy that having entered the trees canopy, some amount of light being absorbed by the leaves and used for photosynthesis, some amount being reflected back into the atmosphere and some amount was being transmitted to the grass or ground below. Another way trees and vegetation cool the air according to this study, is by absorbing water through their roots and evaporating it through leaf pores using heat from the air to convert it to water vapour. A mature tree with 9 metre crown transpires 40 gallons of water per day. Evapotranspiration has the ability to reduce hot day temperature of 1oC – 5oC and add moisture to the air. A re-radiation effect of concrete surfaces according to Huang, (2008), increases the surrounding air temperature in the surrounding urban area. The issue of optimizing wind velocity and direction in hot humid tropical environment as mentioned earlier is a design challenge that needs to be addressed. In general, increase of wind velocity provides more comfort to pedestrians in urban open spaces. Air movement has proved to incorporate lower air masses which have the tendency to provide refreshing sensation for pedestrians in the urban areas Part of the design strategies is to direct winds to necessary areas they are required, Corbella & Magathaes, (2008). Abundance of trees which is a characteristic of the rainforest in the study area would allow this effect to take place if they are properly utilized.

Vegetation Influence in Urban Microclimate:

According to Scudo, (2001) leaves from tree canopy have the tendency to allow light from tree canopy to pass through them, and about 55% absorbed while 25% is reflected. The absorbed 55% can be re-transmitted by the process of evapotranspiration according to Hiroaka, (2002).

Vegetation and Energy Reduction:

The effectiveness with which trees provide shade and save energy according to this study depends on their density, shape (geometry) and placement (distance), the dimensions of the shading building, the position of the sun in the sky and whether a tree keeps its leaves all year round also determined overall energy savings. Gomez Monoz et al, (2010), observed that the effect of tree shadowing buildings is found to reduce heating loads and concluded that trees have beneficial effect in energy savings. It follows that the emerging economic value of tree shadows in hot climate urban areas and cities. This calls for the development of an appropriate simulation of numerical method of establishing relative advantages on energy savings relating to building envelops. The results demonstrated that large trees have potentials to provide 70% shade during hot or warm seasons. Heisler, (1986), performed an experiment with a mid-sized sugar marple tree (Acer Saccharum marsh) and observed reduced irradiance in its shade on a south facing wall by about 80% when in leaf and by almost 40% when leafless. The percentage reductions varied with the fraction of diffuse radiation, (DR) and could be approximated by regressions with DR' as independent variable. Pandit et al, (2010) opined that trees cast shades on homes and buildings thereby lowering the indoor temperatures and thus reducing demand for power to cool the buildings during hot times of the year. They developed a statistical model that indicated savings generated by shade-producing tree in a sub-urban environment. Escobedo et al, (2011), observed that Gainesville's urban trees reduce its energy use year round by shading buildings and providing evaporative cooling effects, saving air conditioning costs during the warm months and block icy winter winds during cold months. It implies that the knowledge of the size of a given building and sizes and positions of the trees near it will enable a researcher to place economic value on the trees based on the amount of reduction and increases in energy use in the building.

Vegetation and Wind Control:

Smart (2011), developed concepts of grapevine canopy microclimate by considering how solar heat levels are affected due to high absorption by wind. According to Scudo, (2002), vegetation influenced the direction of wind movement by means of obstruction and deflection, guidance and filtration depending on tree geometry, height, canopy permeability and crown cover. Thus it is structural characteristics of the vegetation that is the controlling factor for air movement. In the same vein, Stathopoulos et al, (1994), observed that a single row high density windbreak vegetation reduced air infiltration by about 60% when planted approximately four tree heights away from the building. The writer observed that the efficiency of windbreakers process is dependent on the direction of dominant winds. The two dominant trade winds, North-East and South-West trade winds play important roles in this context.

The parameters typically associated with microclimate include conventional variables such as air temperature, atmospheric humidity, solar insulation fluxes, Wind speed and Wind direction. In all the residential layouts in the study area, only GRA boasted high percentage of vegetation cover, followed by Independence Layout and pockets of vegetation around Ogui New Layout, The rest lacks standard vegetation cover.

Other factors affecting microclimate were also identified to include National environmental factors such as topography, sun angle exposure, latitude, soil type, vegetation cover and other meteorological factors such as cloud cover, regional precipitation, high altitude, wind characteristics.

Relationship to Climate Change:

Temperature was identified as the fundamental parameter for assessing trends in climate change in the study area. The concept of urban heat island effect has been well documented by the local meteorologist but the issue is whether increased intensity of a given urban heat island over the past decades will bias temporal trends of temperature in Enugu urban. In order to elucidate this issue, the writer has intended to research on a much more complete picture to microclimate where sensors will be placed. The role of vegetation in urban microclimate control strategy in the study area was observed to have positive effects such as shading effects, surface temperature reduction through absorbtion and reflection, ground temperature reduction by reflection and absorbtion of urban heat island especially during the night, and controlling wind effect through blockages and re-direction if properly positioned.

To provide proper shadow effect, the vegetation density needs to be high enough but not too high as to create wind obstruction.Shading by vegetation was identified to be dependent on the vegetation density configuration that is its shape, height and canopy position, distance from the shaded structure, building relation to the position of the sun.Tree shading has the ability to reduce thermal heat through solar energy interception. Shading was observed in the study area to reduce afternoon temperature at both street and open space levels. Our result indicates reduction of average temperature of February and March, the hottest months by 6oC and 5.4oC respectively. 10.8oC and 9.3oCfor June and July respectively. Complete shading by trees eliminates about 70% of solar energy falling on the canopy.

CONCLUSION AND RECOMMENDATIONS

Climate, culture and economy have through the ages been one of the major determinants of architecture and buildings. Physical environment is considered in this study as very essential in provision of comfortable living environment because it relates to comfortable conditions which embrace human sensations such as thermal, visual, aural and nuisance value of the environment. The problems affecting thermal comfort in Enugu were identified.

This can be resolved by a way of configuration, positioning, orientation and adaptation of vegetation.

Further research on the subject matter is also being carried out by the writer who is of the opinion that positive results are expected.

However the following recommendations are proposed;

- The dynamics of urbanization process should not be allowed to destroy urban vegetation which has been preserved because of the potentials to enhance human comfort in Enugu urban. Such actions have been going on within the past decade as one can witness the destruction of Enugu zoological garden, the popular Polo Park and the greenbelt separating G.R.A and Artisan

Quarters by forces of urbanization. Such actions would have gone through due consultation and environmental impact assessment.

- Forest Department should be resurrected in all urban centers in view of total neglect to tree preservation laws.
- It is important for human dwellers to take step to protect and enhance urban trees and garden parks etc in order to address community environmental human health concerns.
- Unshaded parking lots can become extremely hot and contribute to both the urban heat island effect and increased pollution.

Designers in Enugu and other urban areas should ensure that newly constructed or reconstructed parking (e.g. Shoprite Shopping Mall Parking lot) be shaded by incorporated tree planting.

- Urban Planners to use top-down remote sensing or bottom-up-on-the ground tree survey to existing tree canopies in the urban and suburban areas in view of identifying and documenting different types of vegetation in the urban areas both public (street trees, parks etc) and private (residential, commercial and industrial areas).
- Planners should use remote sensing imagery RSI and geographic information systems GIS analysis to identify locations and areas with community priorities such as wildlife, botanical and zoological gardens in view of their need for preservation.
- Planners to institutionalize urban tree goals in planning regulations and bye laws.

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