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RESEARCH ARTICLE

INFLUENCE OF SKY VIEW FACTOR ON TEMPERATURE VARIABILITY IN URBAN JIMETA, NIGERIA

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ABSTRACT

Urban geometry has complex influence on the micro climate of the urban environment. The most important geometric effect is that of the sky view factor (SVF). This study has investigated the influence of Sky view factor on urban micro climate of the city of Jimeta, Nigeria. A total of 6 study sites were selected within the metropolis with theYola international airport's meteorological station as the control station. Data on the land use and land cover (LULC) categorization, sky view factor, temperature and altitude were collected from these sites and analyzed using the appropriate methods. The data were obtained for two seasons and analyzed. Findings reveal that of the 6 sites, Ribadu square has the highest SVF value of 0.0919. This means that over 90% of its sky is open and unobstructed by either trees and/or buildings. The lowest record was obtained at Gwadabawa with a SVF of 0.75516, meaning that over 75% of the sky in Gwadabawa is devoid of obstruction by any object. The difference between the highest and lowest SVF in the area is 0.1634 revealing that there is no wide variation in the sky view factor within the study area. The mean value of SVF for the study area stands at 0.8752, which signifies that, generally speaking, about 87% of the sky in Jimeta metropolis is visible. This gives rise to a temperature variation of about 0.85^{0}C between the studied sites, with Nasarawo having the highest mean value of 28.5^{0}C and Ribadu square the least (27.65^{0}C) temperatures. Meanwhile, the control site has the mean value of 26.85^{0}C, which is not very far from the values within the city centre. This suggests therefore, that the effect of SVF is not well pronounced in the town, compared to results of other studies in Nigerian cities like Kano (Abdulhamid 2011) and Onitsha (Nduka 2010). A correlation test result between SVF and temperature reveals that there was a positive relationship between SVF and temperature in April and a negative in August in the study area. However, differences in temperatures, though not significant, from one study site to another for the different seasons and at different times were observed. The temperature characteristics revealed a significant spatio-temporal variation for the two seasons in the study area.

INTRODUCTION

Sky view factor (SVF) refers to the ratio of radiation received by a planar surface from the sky to that received from the entire hemispheric radiating environment (Wu *et al*., 2013). It is a dimensionless measure between zero and one, representing totally obstructed and free spaces respectively (Oke, 1988). If SVF is measured to be one, it means that the radiation, which is released by a surface, is totally received by the sky, while a value of zero means that the radiation is completely blocked by obstructions. Urban areas are known to experience dramatic anthropogenic land use changes with resultant effects manifesting in geometrical characteristics of varying shapes and sizes. As a consequence, urban environments modify the energy and water balance which often results in higher urban temperatures compared to the relatively natural surroundings.

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Very often, there are also variations in temperatures within the city setup as a result of variations in the heights, intensity, orientations, construction materials and sizes of the city geometries (buildings). The sizes, heights and orientation of city buildings constitute city canyon geometry. The canyon geometry of urban areas is an important factor contributing to intra-urban temperature variation below roof level (Oke, 1981; Eliasson, 1996). Sky view factor (SVF) is often used to describe urban geometry. Several techniques have been proposed to estimate SVF. These include first, the analytical methods, which use equations and geometrical characteristics as input to determine SVF. For instance, Oke (1981) proposed a method to estimate SVF of the centre point of symmetric canyon of infinite length and Johnson and Watson (1984) extended the method and established expressions for nonsymmetrical canyons of finite length. The second method is the Numerical models methods, which is developed for the SVF estimation in the built or schematic design phase of urban environment. Teller *et al* (2001), Gal *et al* (2009) and Cheng (2012) all employed this method as means of calculating SVF with a view to determining its effect on urban environment. The third method is the fisheye photographic methods which project the hemispherical environment onto a circular plane, and the image is processed manually or by computer to determine SVF. For instance, Steyn (1980) and Brown *et al* (2001) made use of this method to determine SVF in Vancouver and Salt Lake City respectively. Gal *et al* (2007) maintained that the third method above is particularly well suited for urban environments and it is also a common way of SVF determination. This is because, according to them, the SVF values of the methods (BMSky-view) are suitable for checking the errors of the vector-based method. It is based on this that the authors chose to use this technique to demonstrate its validity in the tropical African city. Most importantly, the photographic technique was used particularly because it suites Jimeta urban environment where buildings differ in size, shape and vegetation. Interestingly, Zemba (2010) has established that the process of urbanization in Jimeta has tremendously changed the physical surroundings which in turn induce alterations in the energy regime near the surface. Most of these alterations are seen through the increasing rate of air pollution; increase in temperature; building spacing, heights, orientations, and the materials used; decrease in vegetation layering; increasing population density; and land use distributions.

Similarly, Adebayo and Zemba (2003) using dry and wet bulb thermometers in ten selected sites in Jimeta discovered that relief, population density, anthropogenic activities and seasons of the year influence the microclimatic conditions of the city. The study also shows that unlike Ibadan (Oguntoyinbo, 1981), there was no significant relationship between urban heat island (UHI) development and altitude. Zemba *et al* (2010) further reported that significant land use and land cover change has taken place in Jimeta, leading to increase in urban temperature by about 4^0C from 1986 to 2008. High rise buildings have also sprang up in recent times, especially along Mohammed Mustapha way and Atiku Abubakar Street of the city. Furthermore, more buildings can be seen springing up and zinc and asbestos roofing sheets giving way to aluminum roofing sheets and resulting to changes in the radiation characteristics of the surface in Jimeta. All of these are indications that urban heat island effect is pronounced in Jimeta city; the extent to which its distribution is determined by sky view factor is what remains to be known. It is in line with this that this study was designed to demonstrate the validity of a new technology – Thermochron i-button in Jimeta, Nigeria.

The study area

The study area is Jimeta metropolis that constitutes the greater part of Yola North local government area of Adamawa State, Nigeria. It is situated between latitude $9^0$14’ and $9^0$17’N and longitude $12^0$24’ and $12^0$38’E (Fig. 1). The study area has an approximate land area of 231.6 km^2 (Zemba, 2010). It falls within the tropical climate and has mean monthly sunshine hours of about 220 from January to April (Adebayo, 1999). This decreases to a mean value of 207 hours between May and September due to increasing cloudiness. The mean sunshine hours increases again to about 255 from the period between October and December. Approximately, the average sunshine hours per annum in Jimeta is 2750. Temperatures are generally high almost throughout the year. The weather is marked by a gradual increase in temperature from January to April due to increasing receipt of solar radiation. The temperature reaches its maximum by April with over 45^0C sometimes (Zemba 2006). At the beginning of the rainy season, temperatures drop due to the effect of cloudiness. At the end of rainy reason (October), slight increase in temperature is usually experienced before the harmattan dust comes in around December. Zemba (2003) reported that the minimum temperature value for the area can be as low as 15^0C between December and January. The selected site of the study area are, Nasarawo (Market), Ribadu Square, Gwadabawa, Karewa, Demsawo and Dougirei. The selection of the sites was based on their suitability in meeting up with the characteristics of different thermal climate zones.

MATERIALS AND METHODS

The data for this study largely involved field exercise. GARMIN 12 GPS was used to locate the coordinates of strategic points within the study area during field survey. In the course of the survey, the Thermal Climate Zones (TCZ) was delineated, considering their suitability in matching the estimated properties of the different sites in the study area. The most important properties considered in this process, are built surface fraction and surface thermal admittance. Temperature is the climatic data that was used in this research. This is because it is the most widely held variable for determining the nature and intensity of urban heat island within an urban area (Oke, 1982). The method involves the use of instruments to determine both vertical and horizontal component of the air parcel above the urban area. The canyon geometry of urban areas is an important factor contributing to intra-urban temperature variation below roof level (Oke, 2006; Eliasson, 1996). Hence, this was investigated as a way of assessing the variability in the temperature of the city.

To achieve this, the analysis of SVF was adopted and its evaluation was carried out using Steyn (1980) method from BM Sky view software. The Fisheye lens was placed on a digital camera facing the sky using a tripod with a height of 10m from the ground. The readings were carried out early before sunrise in each of the selected sites to avoid compromise of the results. The readings were taken in April and August representing dry and rainy seasons respectively. The readings were simultaneously taken at 1900 hours GMT for all the seven stations, including the control site, using field assistants. The meteorological data of Yola international airport was used as control site. The distribution of the sky view was calculated along all sites selected in Jimeta, and the Fish eye photographs were used to determine the sky view factor for the temperature stations. Analysis of variance (ANOVA) was determined using SPSS package to determine whether there is significant difference among different TCZ during the 2 distinct seasons studied. The variables used are the mean air temperature from each of the six stations in the wet and dry seasons. Correlation Analysis through the SPSS package was used to determine if there is significant relationship between air temperature and sky view factor, at different times during wet and the dry season.

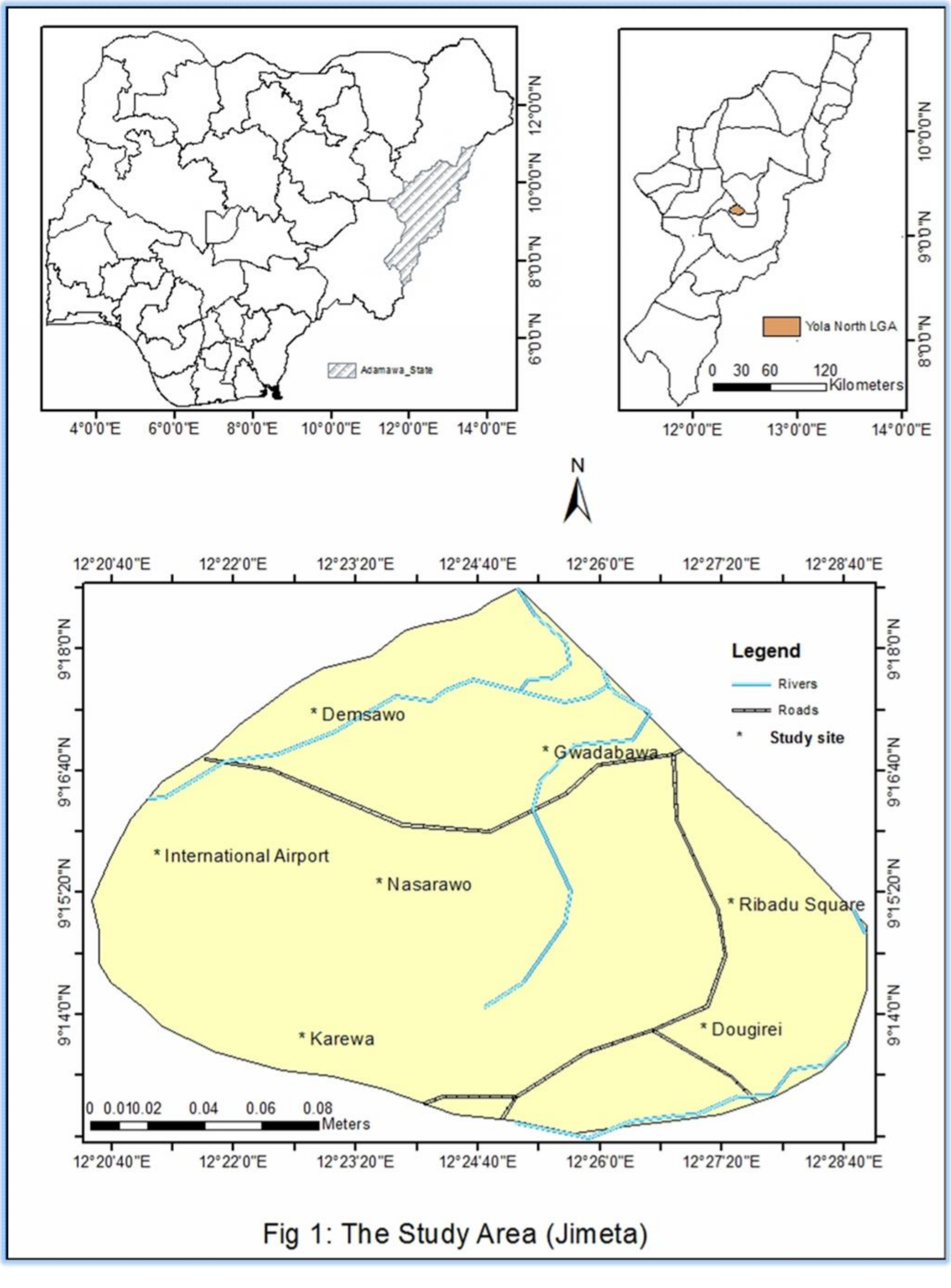

Fig 1: The Study Area (Jimeta)

The variables used are the mean air temperature for the six sites and the results of sky view factor of each of the site.

RESULTS AND DISCUSSION

Canyon Geometry of the Study Area

The result of the canyon geometry of all the selected sites in Jimeta as in Table 1 indicates that the site with the highest SVF is Ribadu Square. Going by the value (0.919), it means that over 90% of the sky in Ribadu Square is open and unobstructed by vegetation and buildings.

Table 1: Results of the Canyon Geometry (SVF) of Study Sites

S/n	Site	Category	SVF
1	Airport	Control site	0.906612
2	Demsawo	TCZ 3	0.871792
3	Gwadabawa	TCZ 8	0.755516
4	Nasarawo	TCZ 2	0.905699
5	Ribadu Square	TCZ 9	0.918971
6	Karewa	TCZ 7	0.830422
7	Dougirei	TCZ 5	0.896221
	Mean		0.875257

Source: Fieldwork, (2012)

This allows a free flow of radiation in and out of the land surface. The lowest value of SVF was observed at Gwadabawa with 0.75516. This means that just about 75% of the sky is not obstructed by any standing objects in Gwadabawa. The difference in SVF between Ribadu Square and Gwadabawa sites is 0.1634. This value means that there is no wide variation in the sky view factors between the selected sites in Jimeta. The mean sky view factor for the study area is 0.8752, which generally speaking reveals that up to 87% of the sky is visible in Jimeta-Yola Metropolis as at the time of this research. Based on the selected sites and period of this research, it reveals that Sky View Factor is not well pronounced in Jimeta compared to other studies like Abdulhamid (2011) and Nduka (2010) on SVF in Nigerian cities.

The Sky View Factor (SVF) of the Study Area

Very often, a temperature variation in urban setup has been attributed to varying factors relating to surface characteristics. The most important of these factors have to do with the size, shape, orientation, surface materials and human activities within the city. The sizes, height, shape and orientation of urban structures, which constitute the urban geometry, has been discovered to play a significant role in the prevailing temperature characteristics of urban Jimeta. The result in Table 2 has revealed that Gwadabawa has the highest temperature (29.7^0C) in April, while it ranks 5^{th} in the value of temperature in August. This result reveals the fact that it falls within a high settlement density area having too congested buildings with narrow streets. Nasarawo is another high settlement density area and is ranked 2^{nd} in terms of temperature. This is followed by Karewa/Demsawo, Dougirei and Ribadu square. Ribadu square has the lowest temperature probably because it is an open ground with high sky view factor.

In August (rainy season), Nasarawo produced the highest temperature of 27.7^0C, followed by Demsawo, Karewa, Dougirie, Gwadabawa and Ribadu square (Table 2).

Table 2. SVF versus Temperature of the Study Sites

Station	SVF	April Temperature	August Temperature	Average Temperature
Airport	0.906612	28.1	25.6	26.85
Demsawo	0.871792	29.1	27.5	28.30
Gwadabawa	0.755516	29.7	27.0	28.35
Nasarawo	0.905699	29.3	27.7	28.50
Ribadu Square	0.918971	28.7	26.6	27.65
Karewa	0.830422	29.1	27.3	28.20
Dougirei	0.896221	29.0	27.2	28.10

The mean values for the two seasons indicate that Nasarawo has the highest while Ribadu square has the lowest value. These values seem to portray true reflections of what these areas are in terms of urban structures and canyon geometry. Nasarawo, Gwadabawa and, to some extent, Demsawo are high settlement density areas with compacted and high-rise buildings with relatively low sky view factors. Karewa and Dougirie on the other hand, are low density zones with well-planned and wide streets. Ribadu square is an open field used for public functions and has the highest sky view factor, meaning that the area is void of high-rise structures that can obstruct sky view. The airport, which was used as a control suburban site has the highest open sky view factor and the lowest temperature. This is not surprising considering the fact that apart from it being a suburban site, it is also devoid of tall vegetation cover and built-up structures.

Table 3. Results of Correlation Analysis Between Temperature and SVF

Season	Variables tested	Température	SVF
Dry (April)	Tempt Pearson correlation	1	.244
	Sig. (2 –tailed)		.598
	N	7	7
	SVF Pearson correlation	.244	1
	Sig. (2 –tailed)	.598	
	N	7	7
Rainy (August)	Tempt Pearson correlation	1	-.067
	Sig. (2 –tailed)		.886
	N	7	7
	SVF Pearson correlation	-.067	1
	Sig. (2 –tailed)	.886	
	N	7	7

Statistical Results

The result of Pearson Product Moment Correlation analysis between temperature and Sky View Factor across all sites selected (Table 3) reveals that there is positive correlation in April while negative correlation exists in August, between temperature and SVF in the study area. The result shows that the correlation values are not significant in both April and August. Generally, over 88% of the sky view in Jimeta as revealed from this research is open; hence the incoming solar radiation is easily released through long wave radiation. Only little heat is trapped within the canyons, resulting in the quick cooling of the environment in Jimeta.

Conclusion

Sky View Factor from this research is seen to be a significant factor for understanding the micro thermal climate in Jimeta street canyons. This research has shown that there is relationship between temperature and sky view factor. The sky view of Jimeta, according to the finding of this research, is over 88% open. This means that the incoming solar radiation is can easily finds its way back to the atmosphere through long wave radiation. This by implications means that, all other things being equal, only little heat is trapped within the canyons in Jimeta. The sky view factor SVF is therefore not pronounced in Jimeta as at the time of this research compared to other Nigerian cities. This is true because Jimeta, generally, is least developed in terms of the intensity of city structures compared to other cities like Lagos, Kano, kaduna and so on.

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