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AN ASSESSMENT OF THE CHARACTERISTICS AND DISTRIBUTION OF MICROCLIMATIC ELEMENTS IN ENUGU URBAN

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Abstract

This paper examined the characteristics and distribution of microclimatic parameters in Enugu Urban. The data were obtained from Nigerian Meteorological Agency (NiMet). Descriptive and inferential analytical techniques were employed for data analysis. Correlation analysis was employed to determine the degree of linear association among the microclimatic elements. The result shows that annual rainfall is clustered around 1200mm and 1900mm. The skewness and kurtosis of annual rainfall estimate show positive kurtosis of 0.17. The distribution result of maximum temperature is clustered around 29.1°C and 33.9°C with a mean of 32.0°C and a standard deviation of 0.7°C. The close spread indicates that the series are not volatile. From the skewness and kurtosis statistics, it is shown that the series is negatively skewed and has an excess kurtosis of about 4.98. The result also shows that the minimum rainfall was 760.09mm, recorded in the year 1983 while the maximum was 2070.10mm in the year 2012. The minimum temperature of the area ranges between 21.6°C to 24.5°C with a mean value of 22.4°C and a standard deviation of 0.5°C. The minimum value of wind speed is 2.70 knots while the maximum value is 6.90knots. The series is skewed to the left and without excess kurtosis. The relative humidity in the area stood at an average of 57.32% with a standard deviation of 2.39%, indicating the non-volatile nature of the data series. The minimum value for the period was 51.0% seen in 2015 while the maximum was 63.0% observed in 2008. The characteristics result of sunshine for the study period shows that the sunshine values (in hours) per day ranges from 5.1 to 5.8 having a mean value of 5.4 and associated standard deviation of 0.2. The series are normal, positively skewed and without excess kurtosis. The correlation analysis result shows that there is no multicollinearity problem among the variables. Rainfall interacts negatively and insignificantly with temperature, sunshine and wind speed, and positively with relative humidity. There is also a significant negative link between relative humidity and sunshine. The study therefore, reveals some evidence of urban heat island and recommends urban forestry and tree planting. It also suggests increasing the albedo of surfaces as a good mitigating measure.

Keywords: Microclimatic Elements, Distribution, Characteristics, Urban Heat Island, Urban Climate

INTRODUCTION

Over the years, there has been growing interest in urban energy and microclimate issues as both represent important factors in achieving sustainability and mitigating global climate change effects (Gaitani et al., 2011). Today, over 50% of the world's population lives in urban areas, and this number is expected to continue rising particularly in developing nations (United Nations, 2008). International Energy Agency in 2008 stated that approximately two-thirds of the world's primary energy is consumed by cities. This urban growth has caused significant changes in the radiant balance of the urban space, the convective heat exchange between the ground and the buildings, the air flowing above the urban area and the heat generation within the city (Gaitani et al., 2011).

These changes in the urban morphology bring about so many mishaps in the urban microclimate. The main consequence of these effects is the difference in values of air temperature between urban and rural areas (Landsberg, 1981; Oke, 1987, Gaitani et al., 2011). This urban heat island (UHI) phenomenon, with daytime air temperatures higher than the surrounding rural areas, is present in many cities around the world (Taha, 1997; Santamouris, 2007; Adinna, Enete, & Okolie, 2009; Kataokaa, Matsumotob, Ichinoseb, & Taniguchic, 2009). Urban Heat Island is the characteristic warmth of urban areas compared to their outskirts (Balogun, Balogun, & Adeyewa, 2012). It is also often referred to as the increase of air temperature in the near-surface layer of the atmosphere within cities relative to their surrounding countryside (Voogt, 2002). Onwuadiochi, Igu, Enete, and Ozoemene (2020) modeled the trends and causal interaction among key selected microclimatic elements in Enugu Urban and explained the evidence of urban heat island in the study. They therefore recommended urban forestry, proper urban planning and increasing the albedo of surfaces as good mitigating measures.

Taha (1997) and Enete (2015) found that the UHI is a result of the changes in surface albedo and vegetation cover owing to urbanization. As controlled by different assemblages of energy exchange processes, the characteristics of UHI can vary from place to place and from time to time (Arnfield, 2003). Cities modify materials, structure and energy balance of the surface and almost all properties of the urban atmospheric environment compared to the natural surroundings. Thus, owing to the artificial factors, a local climate (Urban Climate) develops, and this means of modification to the pre-urban situation. This climate is as a result of the construction of buildings, as well as the emission of heat, moisture and pollution related to human activities (Unger, Savic, & Gal, 2011).

In their assertions, (Clarke, 1972; Akbari, 1992; EPA, 2019) highlighted some effects of UHI in the city's environment and quality of life. These include causing heat related health problems by contributing to general discomfort, respiratory difficulties, heat cramps and exhaustion, non-fatal heat stroke, and heat-related mortality. According to Eurosurveillance (2005), an estimated 22080 excess deaths occurred in England, Wales, France, Italy and Portugal during and immediately after the heat waves of summer of 2003. Additionally, heat islands worsens air quality because the rate of photochemical ozone production is accelerated at higher temperatures and the emissions of ozone precursors are increased (Stathopoulou, Mihalakakou, Santamouris, & Bagiorgas, 2008). Fossil fuel power plants that emit greenhouse gases, particularly CO_2, which contributes to global climate change contributes immensely to the interruption of urban microclimate (Taha, 1994; Sarrat, Lemonsu, Masson, & Guedalia, 2006).

Mitigating the heat islands effect is therefore a key element to achieving sustainability in a city and it can be done by improving the urban microclimate (Gaitani et al., 2011). This paper, therefore, aims at comprehensively explaining the microclimatic characteristics and their distribution in Enugu Urban. Some mitigating measures for improving the microclimate and rehabilitating the urban areas were also proffered.

LITERATURE REVIEW

Theoretical Framework

The Systems Theory

The Systems Theory is the theory on which the study situates. A system is a unified whole (working body) that consists of interdependently functioning elements (Jiwan, Siddiqui, & Bansal, 2020). An element is a very basic part of a unified whole. For example, the human body is a biological system involving various elements (parts) like cells, tissues, blood, bones and muscles. These elements (parts) are functioning interdependently. Likewise, the Earth itself is the largest system which is made of lithosphere, hydrosphere, atmosphere and biosphere. The biosphere is the largest ecosystem made of interconnected sub-systems (both terrestrial and aquatic ecosystems) viz., forest, grassland, desert, ocean, lake, pond etc. These systems vary greatly in size and scale ranging from microscopic to micro, meso and macro (Jiwan et al., 2020). A system is a functioning whole with various sub-systems interlinked with each other. The system, contrary to chaos, is the name of order. In other words, it is the way, sequence in which the various components or phenomena are organized into a whole, into a totality (Rana, 2015).

Edobor and Bello (2016) see system as made up of objects with components, attributes or parts that interact like the biological system in terms of material exchange. This interaction is responsible for the kind of relationship that exists. They asserted that a system (subsystem) may be part of another system (super system) and a break in any part of a system will surely affect the entire super system. They also stated that man is a major component of the earth or environmental system and he acts as an agent of change through his interactions. Their study revealed that man's activities as well as his relationship with the environment are largely responsible for the observed pattern of human endeavours and impacts such as climate change and associated diseases, urbanisation, erosion, flooding, deforestation, movement and transportation.

Pidwirny (2006), stated that one common conclusion of scientific inquiry is that the world of nature is often very complex and argued that to understand this complexity; scientists usually try to envisage the phenomena of nature as simplified versions of reality known as a system. He further defined a 'system' as a collection of interrelated parts that work together by way of some driving processes. According to Mondal (2015), a system where one or more of the functionally important variables are spatial may be described as a geographical system. Meteorologists, Climatologists and Geographers are primarily interested in studying systems whose most important functional variables are spatial circumstances, such as location, distance, extent, sprawl and density per areal unit.

The system's approach can be suggested as a way or a method of comprehending the world as a whole (Rana, 2015). The modern emphasis on system as an explicit item for analysis may be seen as a part of a general change in emphasis from the study of very simple situations in which the interactions are few, to situations in which there are interactions between very large numbers of variables (Rana, 2015). A system is not merely the assemblage of various components; rather it is the functioning of those components together and independently as well (Cook and Johnson, 1969; Husain, 1993; Onokerhoraye, 1994). The 'whole' is greater than the parts and any little change leads to the various corresponding changes in the whole system (Husain, 1993). For instance, continuous flow of smoke and gases from the factories and mills have greatly increased the amount of carbon dioxide in the atmosphere; and this increase has disturbed the ecological balance of CO_2 already present in the atmosphere (Rana, 2015). As a result, there is decrease in the total amount of rainfall, increase in the temperature, urban heat island, increase in air pollution and proliferation of public health diseases.

The essential features of a system define its basic functional characteristics in terms of its environment, behaviour, state of existence, information and organisation. All are interrelated (Harvey, 1969). The environment of a system is the whole of which the system is only a part. For example, urban health system has its environment in the biosphere. The changes in this environment bring about direct changes in the values of the elements contained in the system under examination. Environment changes from system to system, even of the same time, because it is not the time more considered here, rather it is the manner or way in which the elements are combined and functioning together (Rana, 2015).

This flexible approach to the concept of environment in systems analysis is particularly useful to meteorology and geography, because it has made considerable use of the notion of the environment. It is useful at this juncture to clarify the usual meaning of the terms 'open' and 'closed' systems. The open system interacts with the environment. It means that an open system is not isolated from its environment, but exchanges materials or energies with it. A closed system, on the other hand, operates without any kind of exchange with the environment (Rana, 2015).

The behaviour of system simply refers to flows, stimuli, and responses, inputs and outputs, and the likes (Husain, 1993; Rana, 2015). We can examine both the internal behaviour of some system or its transactions with the environment. A study of the internal behaviour accounts for a study of functional 'laws' that connect behaviour in various parts of the system (Rana, 2015). Most analyses of behaviour tend to concentrate on the latter aspect. For instance, a system has one or more of its elements related to some aspect of the environment, and the environment undergoes a change. Then, at least one element in the whole system is affected and the effects are transmitted throughout the system until all connected elements in the system are affected. This constitutes a simple stimulus-response, or input-output system without feedback to environment. In other words, the behaviour of a system is described by its flows that connect the inputs (stimulus) with the outputs (responses) (Rana, 2015; Jiwan et al., 2020).

In general, the state of a system may be thought of as the values which the variables take on within the system at any particular point of time (Davies, 1972; Rana, 2015; Jiwan et al., 2020). Now it is possible for the variables to take on a large number of values, so that the term 'state' is often used in a more restricted sense to refer to any well defined condition or property that can be recognized if it occurs again. It is therefore useful to differentiate between the 'transient' and 'transitional' states and the various types of 'equilibrium' states, which have distinctive properties (Davies, 1972; Rana, 2015; Jiwan et al., 2020). 'Equilibrium' refers to a system that maintains some kind of balance instead of being in a 'transient' or ever-changing state. 'Homeostasis' implies that the balance is at a fixed point or level. A 'steady state' is an equilibrium that does not depend on a fixed point or level (Davies, 1972; Rana, 2015; Jiwan et al., 2020).

Morphogenesis is the process that leads to changes in a system's form, structure, or state, so that it comes to exist at a new and more complex level of equilibrium (Rana, 2015). Normally, we can recognize two kinds or categories of equilibrium, viz. stable and dynamic equilibrium. The stable equilibrium includes both homeostasis and steady states, as defined above. In a homeostatic social system, there is always activity, but it does not alter (change) the balance between the system's components. A social system that was in a steady state would be equally stable, but it would also change – in an orderly way. Dynamic equilibrium refers to the process by which a slight disturbance engenders constant change throughout the system (Rana, 2015; Jiwan et al., 2020).

The twin concepts of organization and information are exceedingly important in systems analysis. They provide the necessary concepts for discussing certain aspects of behavior of systems in a general or objective way. The concept of organization can best be examined by way of an example. Consider a system, containing 'n' elements, that behaves in such a way that if we know the value of one element in the system we can predict the values of all the others. Such a system is highly organized. Consider a similar system in which even though we know the values of '1-to-n' elements, we still cannot predict the value of the 'nth' element. Such a system is disorganized. Information may be regarded as the measure of the amount of organization (as opposed to randomness) in the system (Rana, 2015).

The term 'entropy' and 'negentropy' are closely related to the organization and information in the system. Entropy is often referred to as a measure of disorder or disorganization. Basically it is an expression for the degree to which energy has been unable to perform the work. It states that systems can only proceed to a state of increased disorder (Davies, 1972; Rana, 2015; Jiwan et al., 2020). Negative entropy or Negentropy, on the other hand, is a measure of order (Rana, 2015). Any closed system tends to increase its entropy and will finally approach the inert (inactive) state of maximum entropy. An open system, on the other hand, can maintain a fairly low level of entropy, by interacting with its environment. As a result, it will tend to develop a more complex structure (Davies, 1972; Rana, 2015).

The Urban Atmosphere

The functioning of the urban atmosphere and the cycling of materials are embedded on the mechanisms of the Systems Theory. Observations of atmospheric conditions and processes in cities provide the cornerstone for advances in the understanding of urban climates and are crucial to improving the performance of urban atmospheric models (Grimmond, 2006). Probably, the most compelling focus of climate research in built-up areas remains studies of the urban heat island (Arnfield, 2003). The majority of citizens live in urban areas that dominate the economy and energy use. People living in these areas can affect the balance of nature since the gradual increase in the earth's surface temperature is caused predominantly by human activity (Bozkurt, 2016). Humans cause the emission of gases such as carbon dioxide through exhaust from cars and power plants. If this negative effect continues, climate change due to global warming is inevitable (Bozkurt, 2016).

People living in urban areas have ecological impacts on the environment because of land used for housing, traffic and industrial areas (Bochow, Peisker, Segl, & Kaufmann, 2006). Human activities like the burning of fossil fuels and deforestation intensify the greenhouse effect (Bozkurt, 2016). Increasing concentrations of greenhouse gases cause global warming, ocean acidification, smog pollution, and ozone depletion (Bozkurt, 2016). The greenhouse gases include CO_2, methane, nitrous oxides and Chlorofluorocarbons (CFCs). These and other greenhouse gases absorb infrared terrestrial radiation preventing it from escaping to space thus warming the earth's atmosphere (Ayoade, 2004).

Cities have often been blamed for generating most of the world's greenhouse gas emissions, and contributing disproportionately to global climate change (Dodman, 2009). Referring specifically to climate change, the Executive Director of the United Nations Centre for Human Settlements (UN Habitat) has stated that cities are "responsible for 75 percent of global energy consumption and 80 percent of greenhouse gas emissions"; while the Clinton Foundation suggests that cities contribute "approximately 75 percent of all heat-trapping greenhouse gas emissions to our atmosphere, while only comprising 2 percent of land mass" (Satterthwaite, 2008).

The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report of 2007 unequivocally states that the earth's climate system has been undergoing warming over the last fifty years. Projected future global averaged surface warming (for the decade 2090-99 relative to 1980-99) ranges from 1.1° to 6.4°C, whilst sea level rise (for the same period) is predicted at 18 to 59cm (Intergovernmental Panel on Climate Change, 2007). Mean temperatures are likely to increase, mean precipitation will fluctuate, and mean sea-level will rise; extreme rainfall events and tropical cyclones are likely to be more frequent and intense, leading to flooding (both riverine and storm surge). Population changes and ecological changes may result in increased exposure to disaster risk. Changes in means will intensify the stresses faced by poor urban residents on a day-to-day basis, and may reduce or deplete their stocks of assets and resources they require to face occasional extreme events; while increases in the intensity of these extreme events will have significant implications for the households, livelihoods and lives of people.

Specifically in relation to urban areas, the IPCC report states that "climate change is almost certain to affect human settlements, large and small, in a variety of significant ways" (Willbanks et al., 2007). Climate change is likely to exacerbate many of the risks faced by low-income urban residents – the IPCC also states that "poor communities can be especially vulnerable, in particular those concentrated in relatively high-risk areas" (Willbanks et al., 2007). The dense concentration of urban populations can increase susceptibility to the disasters that are likely to become more frequent and more intense as a result of climate change. The proportion of disaster-related deaths and injuries that occur in urban areas in low- and middle-income nations is likely to grow, in part because an increasing proportion of the world's population live and work there (and almost all the world's population growth anticipated in the next few decades is likely to occur in urban areas in low- and middle-income nations) (Satterthwaite, 2007). Climate change is likely to increase the number of serious injuries and deaths from disasters in urban areas significantly – and many cities in low- and middle-income nations are at high risk from climate change (Satterthwaite, Huq, Reid, Pelling, & Romero, 2007).

MATERIALS AND METHOD

The Study Area

Enugu urban area is located between latitudes $6^0.21^1$N and $6^0.30^1$N of the equator and longitude $7^0.26^1$E and $7^0.37^1$E of the Greenwich Meridian and covers an area of about 145.8sqkm(Fig. 1). The 2006 National Census recorded the population of Enugu urban as 770,000persons (NPC, 2006). Its 2016 projection, ten years after, was 920,000.

Under relief, its topography is divided into the escarpment and lowland zones. The geology of the urban area is dominated by two formations namely; the lower coal measure (Mamu formation) and false Bedded sandstone (Ajalli formation) (Ezenwaji, Awuh and Onwuadiochi, 2018; Ezenwaji et al., 2019). The climate is categorized as wet and dry according to the Koppen's climate classification system. This system is characterized by marked wet and dry seasons. Annual Rainfall is usually about 1700mm but can be as high as 2000mm, while daily temperature all through the year is usually high between 28^0C and 33^0C. The high temperature of 33^0C or more are experienced in dry season around the month of March (Ezenwaji, Awuh and Onwuadiochi, 2018).

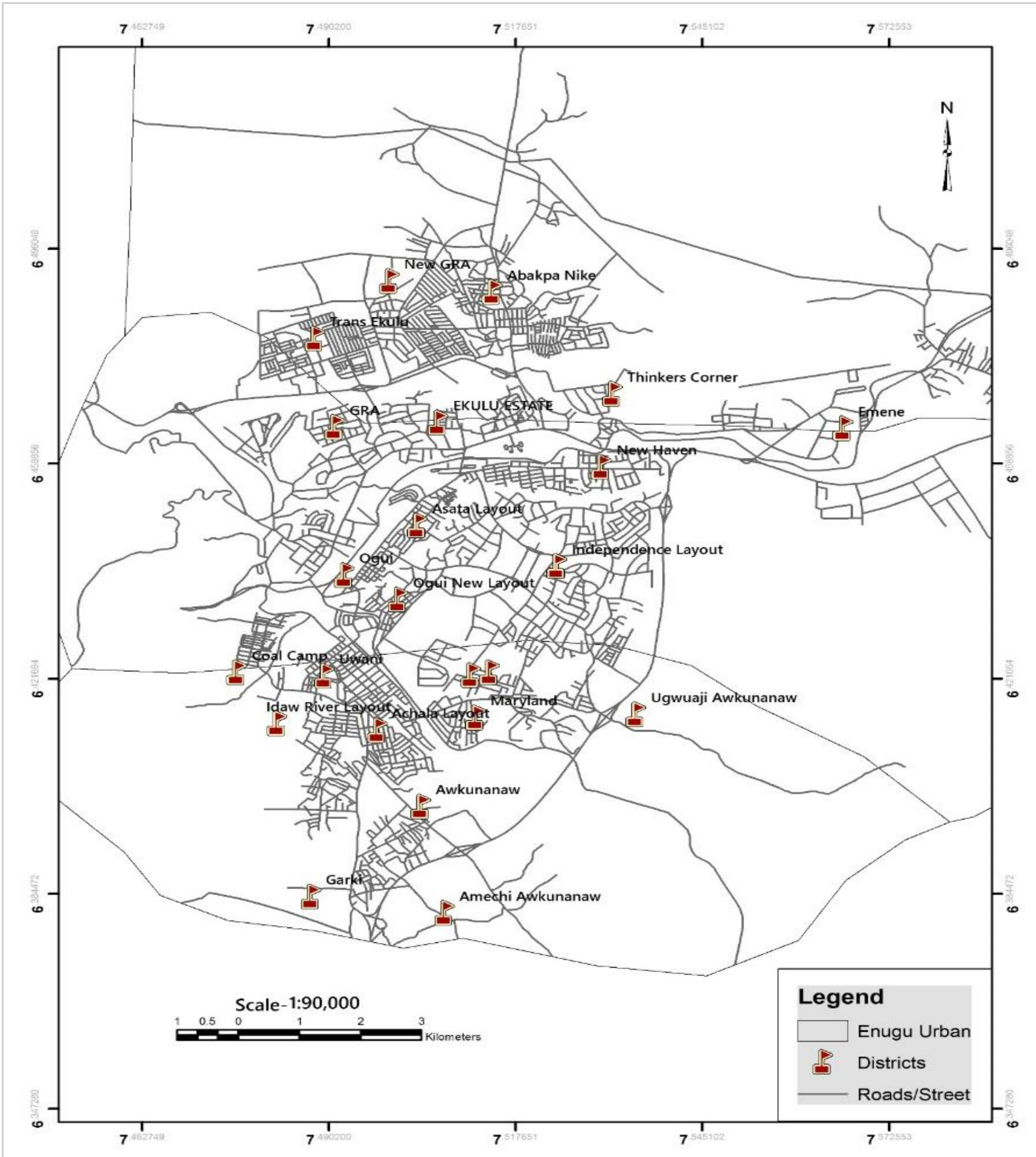


Fig. 1: Map of Enugu Urban

The entire urban area is drained by three principal rivers namely Asata which is a tributary of Ekulu, while Ekulu empties unto river Nyaba in the southern areas of the town. All the rivers have their sources in the escarpment east of the town, and flows eastwards in the Cross-River Basin. The vegetation is mainly the Guinea Savanna, which was derived from the original tropical rainforest vegetation of the area that was destroyed as a result of urbanization and other anthropogenic activities, leaving outliers of forest in some localities, especially as deity forest in the traditional home areas of Nike people.

Data Collection

The data needed for this study were rainfall, maximum temperature, minimum temperature, wind speed, relative humidity and sunshine data recorded at Akanu Ibiam International Airport, Enugu, Enugu State from 1971 to 2018. The study predominantly relied on secondary sources. The data were obtained from the Nigerian Meteorological Agency (NiMet).

Data Analysis

To achieve the target of this study, descriptive and inferential analytical techniques were employed. Specifically, descriptive estimation methods such as mean, standard deviations, skewness, kurtosis, and Jarque-Bera goodness of fit test were used to describe the data series over the period. The standard deviation provided estimate of spread out of the data while skewness and kurtosis were used to summarize the extent of symmetry and tail thickness of the distribution of the data series for the period of study. The essence of these analyses was to ascertain whether parametric or non-parametric tools are appropriate for further estimation.

The Jarque and Bera (1987) test of normality was given by:

$$JB = \frac{\hat{S}^2(x)}{6/T} + \frac{(\hat{K}(x)-3)^2}{24/T} \qquad (1)$$

Where,

x represents the parameter of interest

$\hat{S}_{(x)}$ and $\hat{K}_{(x)}$ are estimates of the skewness and kurtosis respectively.

The skewness $(S_{(x)}) \sim N\left(0, \frac{6}{T}\right)$ while the kurtosis $(K_{(x)}) \sim N\left(0, \frac{24}{T}\right)$

The JB statistic is asymptotically distributed as Chi-squared random variable with 2-degrees of freedom. In this test, the null hypothesis (Ho) of normality is rejected if the p-value of JB statistic is less than the specified significance level; otherwise Ho is upheld.

Correlation Analysis: This technique was employed to determine the degree of linear association among the microclimatic elements in Enugu Urban. Particularly the Pearson's method was employed due to the nature of data collected. The correlation coefficients between the pairs of microclimatic parameters are worked out and arranged in the form of a correlation matrix below:

		p_1	p_2	p_3	p_4	p_5	p_6
	p_1	p_1^2					
	p_2	p_{21}	p_2^2				
Parameters	p_3	p_{31}	p_{32}	p_3^2			
	p_4	p_{41}	p_{42}	p_{43}	p_4^2		
	p_5	p_{51}	p_{52}	p_{53}	p_{54}	p_5^2	
	p_6	p_{61}	p_{62}	p_{63}	p_{64}	p_{65}	p_6^2

Where, p_{ij} is computed as:

$$r = \frac{Cov\ (M,N)}{\sqrt{(Var\ (M))(Var\ (N))}} = \frac{\sum_{i=1}^{T}[(M - \bar{M})(N - \bar{N})]}{\sqrt{\left[\sum_{i=1}^{T}(M - \bar{M})^2\right]\left[\sum_{i=1}^{T}(N - \bar{N})^2\right]}} \quad (2)$$

Where,

r is the correlation coefficient,

$Cov\ (M, N) = \sum_{i=1}^{T}[(M - \bar{M})(N - \bar{N})]$ is the covariance of M and N series,

$Var\ (M) = \sum_{i=1}^{T}(M - \bar{M})^2$ is the variance of M series,

$Var\ (N) = \sum_{i=1}^{T}(N - \bar{N})^2$ is the variance of N series

T = Total number of observations,

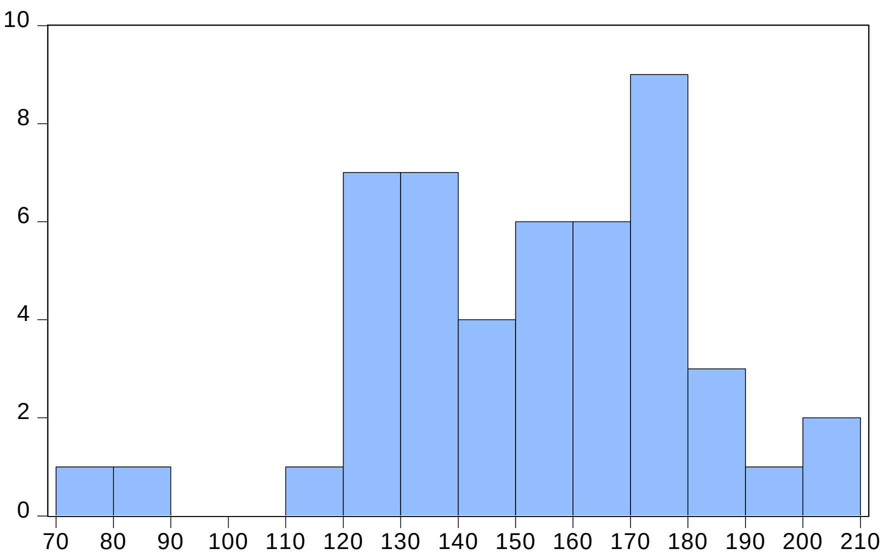
$\bar{M}$ and $\bar{N}$ and mean values of series of M and N values,

M and N are variables of interest.

All the statistical analysis were carried out using the E-views 10 analytical package.

RESULTS AND DISCUSSION

The analysis of the numerical as it concerns this study began with descriptive statistics. The descriptive statistics as earlier highlighted explained the behaviour of the various microclimatic parameters used in the study. The descriptive statistics results are as presented in figs. 1 to 6:



Series: RAINFALL__MM_	
Sample 1971 2018	
Observations 48	
Mean	152.0640
Median	155.3060
Maximum	207.1030
Minimum	76.09200
Std. Dev.	27.98443
Skewness	-0.403386
Kurtosis	3.170410
Jarque-Bera	1.359840
Probability	0.506658

Fig. 1*: Characteristics of Rainfall in Enugu Urban (1971-2018)*

From the descriptive statistics result in figure 1, it is shown that annual rainfall in Enugu urban is clustered around 1200mm to 1900mm and are not highly volatile (Std. Dev. = 270.98mm). The result also shows that the minimum rainfall for the period was 760.09mm, recorded in the year 1983 while the maximum was 2070.10mm in the year 2012. From the descriptive presentation of pattern of annual rainfall distribution within the period, it is observed that rainfall in Enugu urban exhibits a random pattern.

The skewness and kurtosis estimate shows that the distribution of rainfall in the area is skewed to the left and leptokurtic (i.e., having excess positive kurtosis of 0.17). However, as confirmed by the Jarque-Bera test, the rainfall distribution is normal in Enugu urban (p=0.5067>0.05).

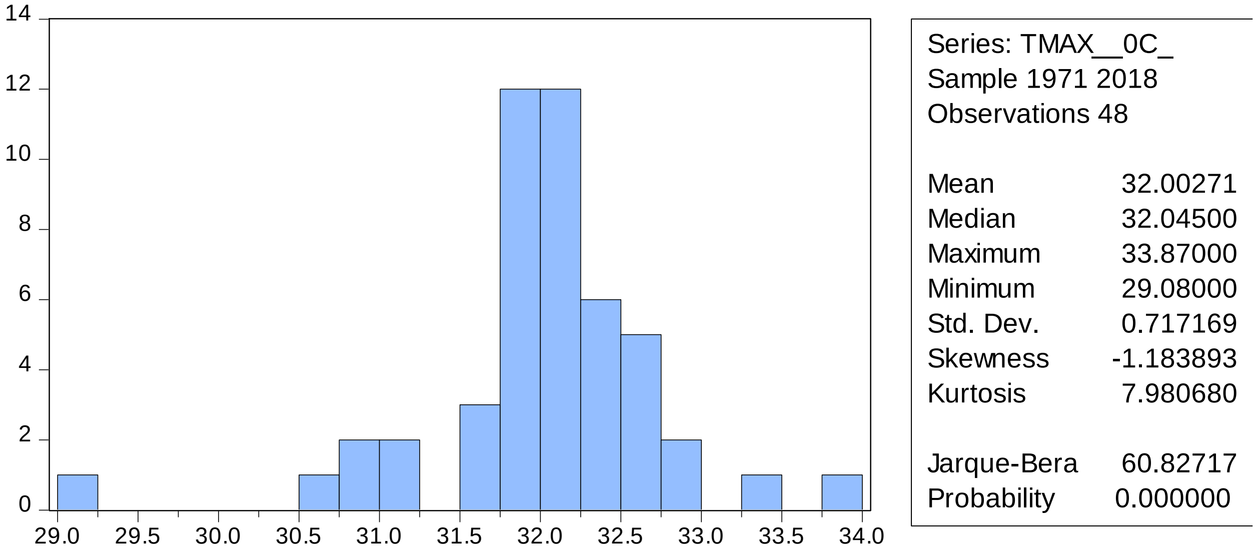


Fig. 2*: Characteristics of Maximum Temperature in Enugu Urban (1971-2018)*

The distribution result of maximum temperature (in ^{o}C) over the period is clustered around 29.1^{o}C to 33.9^{o}C with mean of 32.0^{o}C and a standard deviation of 0.7^{o}C. The close spread indicates that the series are not volatile. From the skewness and kurtosis statistics, it is shown that the series is negatively skewed and has an excess kurtosis of about 4.98. This is quite bad and however confirmed by the Jarque-Bera goodness of fit test as not normal.

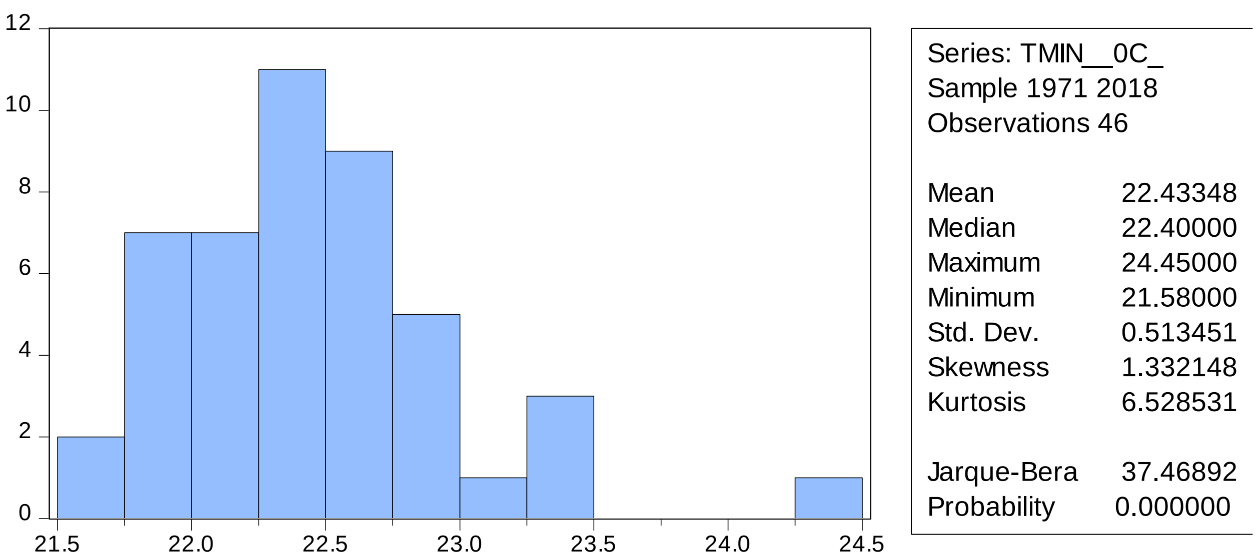


Fig. 3*: Characteristics of Minimum Temperature in Enugu Urban (1971-2018)*

The minimum temperature of the area ranges between 21.6°C to 24.5°C with mean value of 22.4°C and a standard deviation of 0.5°C. The series is positively skewed and have excess kurtosis of about 3.53. The Jarque-Bera test result provided that the series is not normally distributed. The standard deviation is small indicating a high predictive nature of the dataset.

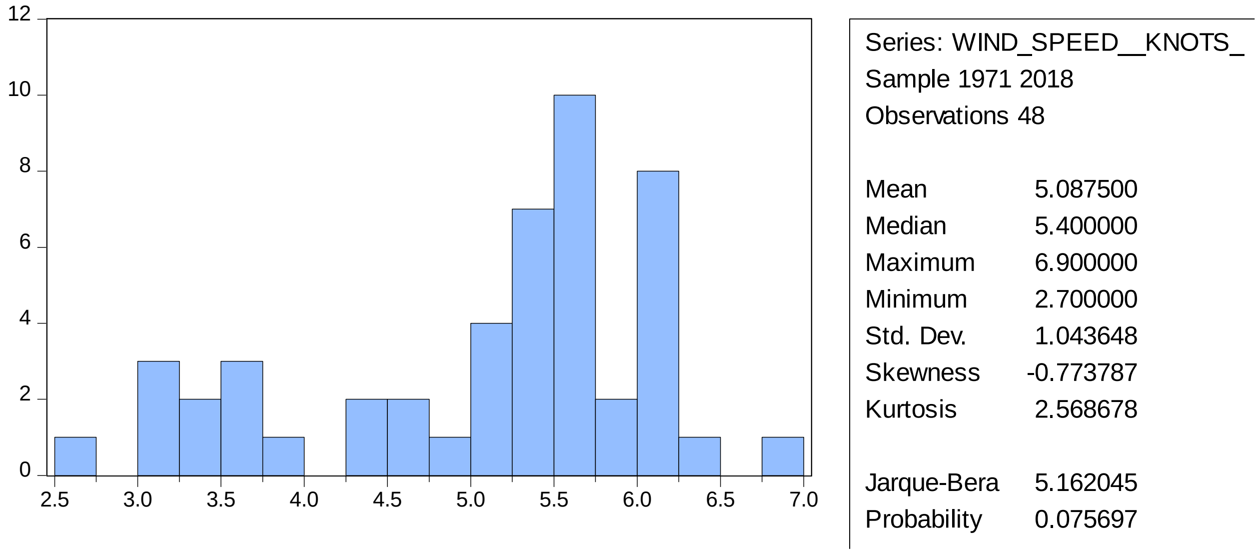


Fig. 4*: Characteristics of Wind Speed in Enugu Urban (1971-2018)*

Fig. 4 shows the characteristics of the wind speed for the study period. The minimum value is 2.70knots while the maximum value is 6.90knots. The series is skewed to the left and without excess kurtosis. As shown by the Jarque-Bera statistics with a coefficient value of 5.16 and associated probability value of 0.0757>005, the distribution is normal and smooth.

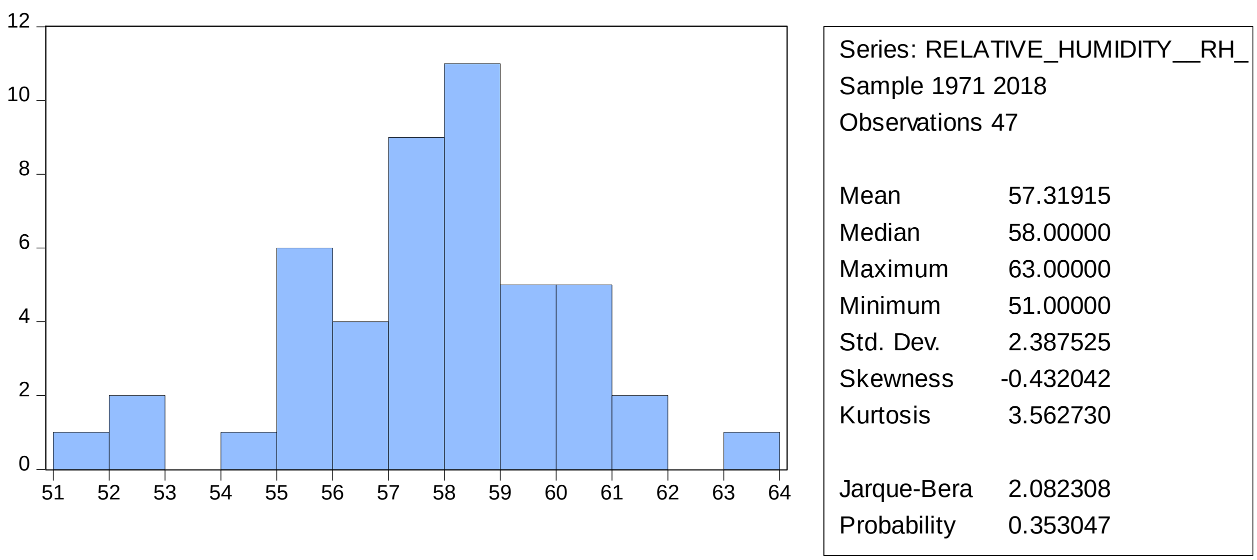


Fig. 5*: Characteristics of Relative Humidity in Enugu Urban (1971-2018)*

From figure 5 above, relative humidity in the area stood at average of 57.32% with a standard deviation of 2.39%, indicating non-volatile nature of the data series. The minimum value for the period was 51.0% seen in 2015 while the maximum was 63.0% observed in 2008. The distribution of the series is negatively skewed and has excess kurtosis (k>3). Since the excess kurtosis is negligible, the series maintains a normal and smooth shape (prob. (JB-stat) = 0.3530>0.05).

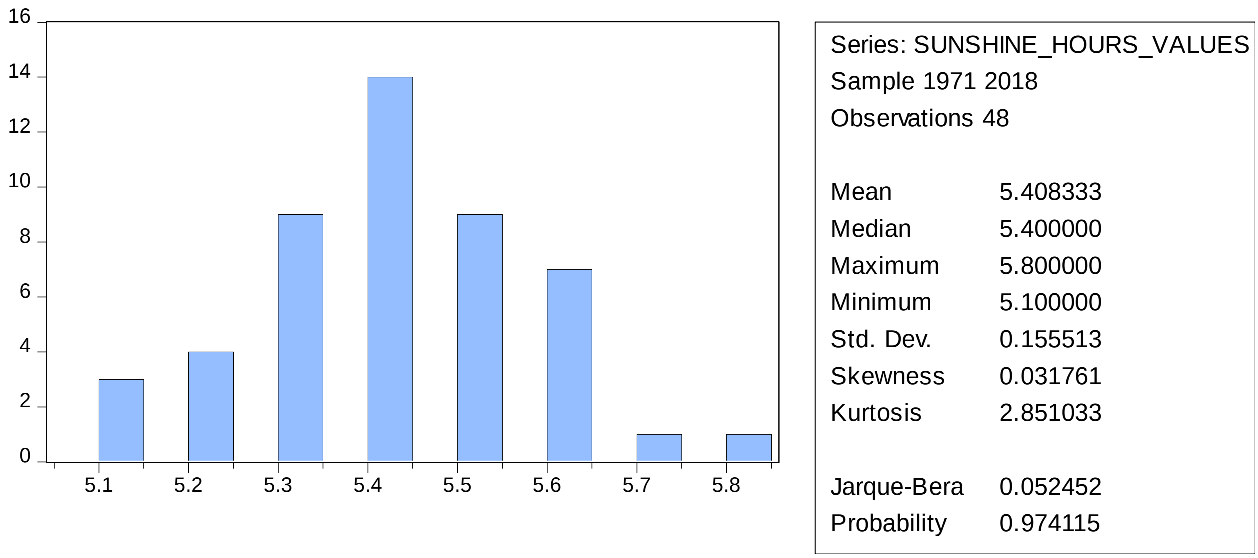


Fig. 6: *Characteristics of Sunshine Values in Enugu Urban (1971-2018)*

The characteristics of sunshine for the study period are presented in fig. 6. The descriptive result shows that for the period under investigation, the sunshine values (in hours) per day ranges from 5.1 to 5.8 having a mean value of 5.4 and associated standard deviation of 0.2. The series are normal, positively skewed and without excess kurtosis.

Correlation Analysis amongst the selected microclimatic elements in Enugu Urban

The correlation matrix of the microclimatic elements in the study area is shown in table 1.

Table 1: Correlation matrix of the microclimatic parameters

Sample: 1971 – 2018
Included observations: 45
Balanced sample (listwise missing value deletion)

Correlation t-Statistic Probability	RAINFALL	T_{MAX}	T_{MIN}	WIND SPEED	RELATIVE HUMIDITY	SUNSHINE
RAINFALL	1.000000					

T_{MAX}	-0.101667	1.000000				
	-0.670147	-----				
	0.5063	-----				
T_{MIN}	-0.145816	0.164808	1.000000			
	-0.966510	1.095700	-----			
	0.3392	0.2793	-----			
WIND SPEED	-0.329779	0.083377	0.078662	1.000000		
	-2.290651	0.548653	0.517426	-----		
	0.0269	0.5861	0.6075	-----		
RELATIVE HUMIDITY	0.072006	-0.079024	-0.129181	-0.168119	1.000000	
	0.473406	-0.519818	-0.854256	-1.118346	-----	
	0.6383	0.6059	0.3977	0.2696	-----	
SUNSHINE	-0.176557	0.220251	-0.000975	0.239060	-0.429936	1.000000
	-1.176241	1.480640	-0.006392	1.614433	-3.122616	-----
	0.2460	0.1460	0.9949	0.1137	0.0032	-----

Source: Author's computation using E-views 10 package

The correlation analysis result shows that there is no multicollinearity problem among the variables. From the result, there is a significant negative relationship between rainfall and wind speed, indicating that increase in rainfall decreases wind speed in the study area. There is also a significant negative link between relative humidity and sunshine. Rainfall interact negatively and insignificantly with temperature, sunshine, and positively with relative humidity. This implies that high rainfall leads to low temperature, and sunshine, and on the other hand, high relative humidity. The wind speed is reduced by relative humidity and triggered by sunshine and temperature, while high sunshine sets the temperature high. High relative humidity is absorbed by high temperature.

CONCLUSION/RECOMMENDATION

The characteristics and distribution of microclimatic variables in Enugu Urban reveal some indication of the city's urban heat island. The average annual maximum temperature is 32°C, which demonstrates this. The city's morphology, chlorofluorocarbons and other gases and pollutants in the atmosphere, and a lack of trees all contribute to the rise in temperature. Rainfall which is generally torrential is concentrated between 1200 and 1900mm. The correlation analysis reveals that there is no no multicollinearity problem among the variables. Rainfall interacts negatively and insignificantly with temperature, sunshine, and wind speed, but positively with relative humidity, according to the research. Furthermore, there is a strong negative correlation between relative humidity and sunshine. The study therefore, recommends urban forestry and tree planting in the study area. It also suggests increasing the albedo of surfaces as a good mitigating measure. All these would help to forestall the effects of urban heat island in the area.

Increasing the albedo of surfaces such as roofs and pavements and urban forestry will drastically reduce the cooling energy use in buildings and lower the ambient air temperature through evapotranspiration. Vegetation covers reduce cooling energy demand by blocking the sun's radiation. Also, as stated by Enete and Ogbonna (2018), another adaptation and mitigation strategy is building institutional capacity. This entails;

- Improve capacity of institutions to develop, regulate, enable and sustain strategies and policies targeted at

(a) Improving building design and performance
(b) Improving energy efficiency of appliance and equipment
(c) Reducing Green House Gas (GHG) emissions and
(d) Encourage energy saving and green behavior among city residents. Providing appropriate services and infrastructure.

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