TEMPORAL ASSESSMENT OF LINKAGE BETWEEN INFRASTRUCTURAL PROVISIONS AND TEMPERATURE VARIATIONS IN OWERRI METROPOLIS, SOUTHEASTERN NIGERIA

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Abstract

Spatial and temporal variation and swings in temperature is to a large extent influenced by local activities of the population. This fact relates to the alteration of forcing and changes in environmental systems through land use and land cover dynamism. The resultant effect manifests in alteration of the local meteorological parameters of the area, leading to variation in local climatic events of worrisome dimensions. Owerri has a spate of land use and land cover conversions and change, for transport and other infrastructural facilities. Data from the study came from remotely sensed data, and examined against variation of relevant meteorological indices between 1986 and 2000. The coverage of infrastructural LU/LC in 1986 rose from 438.04km^2 to 543.88km^2 in 2000. This show that about 105.84 sq. km (80.5%) increase in infrastructural LU cover the area between 1986 and 2000 while annual mean coverage is about 7.56 sq. km or about 5.8% increase annually. A test of homogeneity in means variance of LU/LC classes in 1986, 1991, 2000 and 2005 using the single factor ANOVA was computed. The results showed significant variation in LU/LC at $P < 0.05$ confidence level using single factor ANOVA, such that $F_{cal17.14} > F_{crit\ 4.08}$ between 1986 – 2005. Another test of homogeneity in means variance (with Temperature in 1986, 1991, 2000 and 2005) using single factor ANOVA showed that $F_{cal\ 3715} < F_{crit\ 4.17}$ at $P < 0.05$ revealed heterogeneity. The results showed that some measure of heterogeneity exist between built environment and rise in the urban temperature in 2005.

***Key words*: Land Use, Climate Variation, Land Cover, Infrastructure**

Introduction

Transportation infrastructure is treated as an integral part of the infrastructural base of Owerri metropolis in this study, which argues that Land Use (LU) change for transportation, forces climate swings, variations and changes in local, regional and global contexts. Pielke Sr *et al* (2002) argue that policy related quantification of human influences on climate has focused largely on changes in atmospheric composition to which transportation is a major contributor. Several studies also have revealed the alarming proportions in use at LU and Land Cover (LC) have influenced the global environmental change of urban environments. These studies have demonstrated that LU and LC changes provide additional major forcing of climate through changes in the physical properties of the land surface. Tropical LU changes have been shown in Chase *et al* (1996, 2000), and summarized in Claussen (2002), to have an effect on the climate system similar to that from El Nino event. Moreover, since thunderstorms preferentially form over land (Lyons, 1999), the role of the tropical land surface should be expected to have a greater effect on global climate than implied by its per cent areal coverage of the earth's surface alone. These issues are involved in LU and LC conversions as well as its changes manifest over time because changes in vegetation modify the surface heat fluxes directly.

Thus, regional landscape changes can result from alterations to surface fluxes elsewhere in the world through nonlinear feedbacks within the atmosphere's global circulations (Chase *et al*, 2000). These regional scale LC conversions modify, and on the aggregate, cause global or regional, macro or micro changes in weather conditions of diverse dimensions and proportions through tele-connections (Avissar, 1995; Pielke, 2001a; Claussen, 2002). Specifically, the conversions for, and imposition of infrastructure can influence the climate system of built environments in several parts of the world [Pielke Sr *et al* 2002, Veldkamp and Fresco, 1996]. The alterations of the tropical landscapes, primarily the conversion of forests to agriculture or pasture, changes the partitioning of solar insolation into its sensible and latent turbulent heat forms (Pielke Sr *et al*, 2002). Therefore, the less transpiration associated with the agricultural and pasture regions results in less thunderstorm activity over the landscape. Lawton *et al* (2001) illustrates the significant regional effects that tropical deforestations have on the ecological environment of adjacent mountains. Similarly, the impacts of carbon on the climate system are seen in terms of radiative forcing and perturbations on the earth's radiation budget prior to feedbacks from the rest of the climate system (Pielke Sr *et al*, 2002).

Apart from these, there is the effect of land-surface albedo change which can be quantified in terms of radiative forcing (Hansen, *et al* 1997; Betts, 2001), which has elaborately been used in attempts to compare the global significance of historical LU change with that of other drivers of climate change and variation (IPCC, 2001).

The reviewed studies, invariably, contend that the changing landscape can significantly affect local weather more acutely than long-term climate change. In particular, LC change can influence microclimatic condition, including temperature, evapotranspiration and surface run-off. Commonly, a rise in the mean annual temperature is a manifestation of climate variation in the long-run traceable to land use changes. Ojo (1986) and Walker and Steffen (1997) admitted that land use is the dominant forcing of global change, and observed regional variations and swings in the climate system. Njoku, (2010) recognizes the need to monitor and measure the rate of land conversions for infrastructure and vice versa, because these activities raise the radiative forcing and thus affect the mean annual temperature. Consequently, land use changes bring short-term unexpected variations or perturbations in the climate system and affect the global warming potential.

In the tropics, land use change has been shown to impact on apparent variation in the weather and climate system [Chase *et al*, 1996, 2000 and Claussen, 2002]. This is achieved through the carbon cycle and the energy budget [Pielke Sr *et al*, 2002]. The potency lies in the fact that land cover provides a major forcing of climate through changes in the physical properties of the land surfaces. In areas of intensive human-induced land use changes such as urban areas, the local radiative – forcing change caused by surface albedo may actually be greater than that due to all the well-mixed anthropogenic GHGs together [IPCC, 2001; Betts, 2000 and Pielke, 2001b]. Besides, the alteration of the landscape changes, the partitioning of solar insolation into its sensible and latent turbulent heat forms leads to rise in the mean annual temperature of the locality. Apart from these, Chase *et al*, [2000] point out that regional landscape change can as a result in alterations to surface fluxes through non-linear feedbacks within the atmosphere's global circulation.

Studies by Njoku (1992) and Njoku *et al*, (2006) have documented the regional patterns of land use change and conversions for transportation and other infrastructural facilities between 1986 and 2000 for northwestern Nigeria and then for Owerri by Njoku (2010) and Njoku *et al* (2010). These studies showed significant rises in the aggregate conversions in favour of infrastructural class, rose from 438.04 sq. km to 543.88 sq. km between 1986 and 2000, with a mean conversion rate of about 7.56 sq. km per [5.8%] annum for Owerri and environs.

This apparent rate of conversion and the fear expressed by Chase *et al* [1996, 2000] and Claussen, [2002] as well as Pielke Sr *et al* [2002] spurred the writing of this study. Consequently, this study examines the association between infrastructural land use conversion and temperature variation in Owerri and environs (See Figure 1).

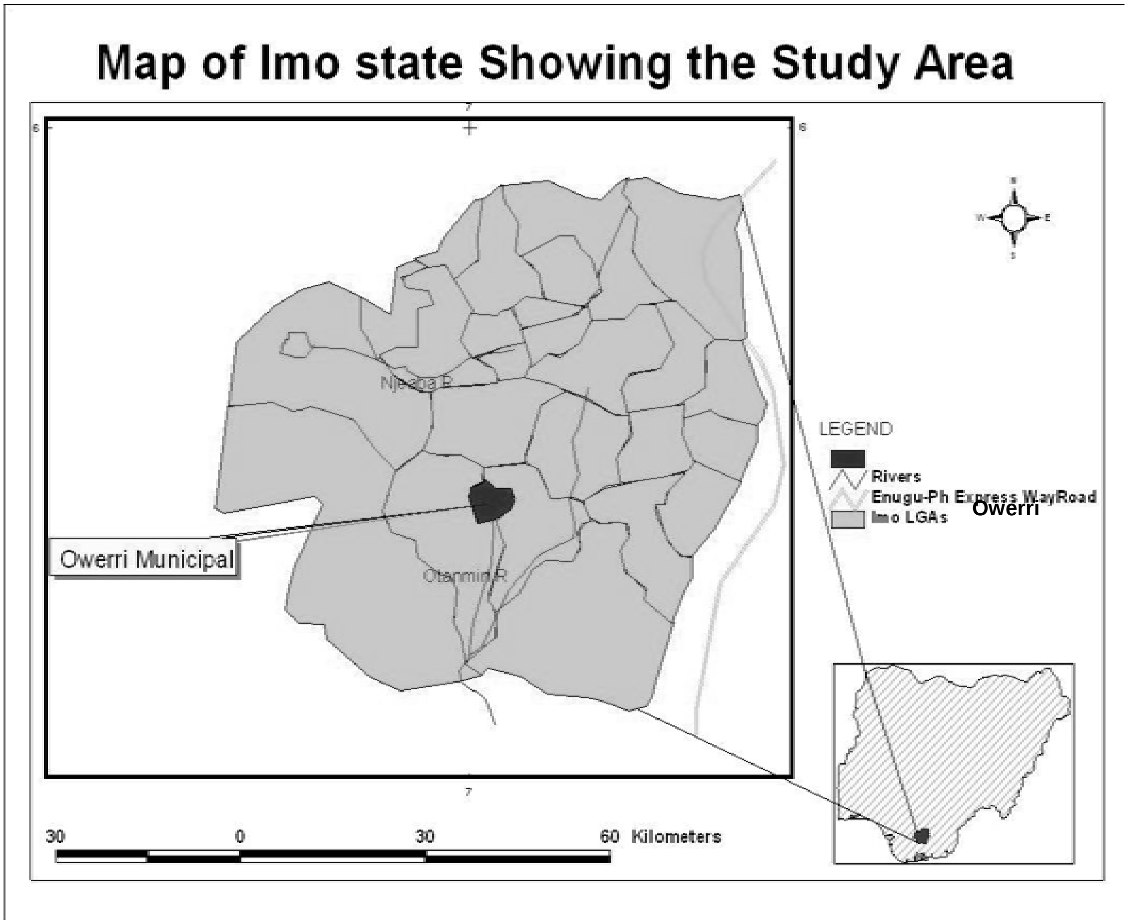

***Figure 1*: A Map of Imo State, showing Owerri as the study area**

LU/LC Forcing of Climate Variation and Change

Commonly, carbon is the index used to measure the human intervention in the earth's climate system. Impacts on climate are compared in terms of radiative forcing, which can be considered as disturbances to the earth's radiation budget prior to feedbacks from the rest of the climate system. Several studies, Hansel *et al*, [1997] and Betts [2001] assent that the effects of land surface albedo change can be qualified in terms of radiative forcing. Studies by Lenton [2000] and Esatman *et al* [2001a, b] argue in favour of biogeochemical feedbacks in conjunction with an increased CO_2 radiative warming produced amplified regional and global warming response and suggest cooler daytime and warmer nighttime in response to greater plant growth in a doubled – CO_2 atmosphere. These amply show that the removal of vegetal cover raises the albedo of a site and subsequently, the temperature of the region at large. Also, abundant soil moisture in the soil lowers the albedo and so is the ambient temperature and vice versa. In areas where the soil is impervious or the land is paved, there is reduction in soil moisture and a rise in diurnal mean annual temperature. Further to these, the presence of drought and hydrological feedbacks associated with LU/LC change locally, has a direct impact on the source/sink capabilities of the terrestrial ecosystem [Pielke, *et al*, 2010]. Studies show that LU/LC changes have implications for the climate system, especially these changes related to the removal of vegetal cover and reduction of soil moisture content. It is on this premise that the spate of LU/LC change for infrastructural provision has been seen by Njoku, (2006) as a contributor to the rising mean annual temperature of Owerri on temporal and spatial contexts.

Materials and Methods

Description of study Area

Owerri lies between latitude $5^{o}25^{'}$N and 5^{o} $34^{'}$ N and longitude $6^{o}7^{'}$E and $7^{o}06^{'}$E covering an area of approximately 5,792.72 km^2 and a population of about 401, 875 in 2006 [NPC, 2006] with an annual growth rate of 2.83%. Owerri, a closely-settled, built-up area is the administrative capital of Imo State of Nigeria. Owerri metropolis is within the humid tropics, and is characterized by high temperature and rainfall regimes with a mean maximum temperature of about 32^{0}C and a mean minimum of about 21^{0}C [Njoku, 2006]. Recent studies (Nnaji, 1998, 1999 and FGN, 2003) indicate a declining trend in rainfall characterized by large spatial and temporal variations. The area lies in the rainforest belt of Southeastern Nigeria characterized by low land tropical rainforest. Owerri lies within the densely populated region of Southeastern Nigeria. The growth rate of the population, its size structure, density, spatial distribution and urbanization characteristics, rapid socio-economic activities are critical factors of the environment which are likely to affect temperature change.

Data Requirements

Data used for the study were Landsat Thematic Mapper [TM] of 1986 and 1991 and Enhanced Thematic Mapper plus [ETM+] of 2000 and 2005 satellite imageries and the temperature data of corresponding years. These data were used for LU/LC classification, identification and statistical change analysis of static features captured by the imageries. The LU/LC classes were identified through a combination of their image characteristics, previous LU/LC patterns as well as previous potential changes, since the trend, regularity and patterns were identified for the conversion process. Image classification was achieved through preparation of a confusion matrix. The relationship between temperature and the built environment, using the coupled graph, was achieved using correlation analysis, student to test and analysis of variance.

The study sought to determine the relationships between LU/LC change and temperature swings or variation and change in local or regional context. Temperature data of 1986, 1991, 2000 and 2005 were correlated and compared with the rates of change in conversion dynamics. These were correlated with the proportions of built, vegetation, cultivated and water in the corresponding years, using correlation analysis and single factor ANOVA.

Results and Discussion

The transportation and other infrastructural environments were identified and delineated on TM 1986, 1991 and ETM+ 2000 and 2005 (Njoku, 2010 and Njoku *et al* 2010). There were also observed varying degrees of spectral signatures on the generated imageries and variations in the settlement class. Land areas and features were assigned different spectral signatures to represent changes from one sub class to another. The coverage of infrastructural LU/LC in 1986 rose from 438.04km^2 to 543.88km^2 in 2000. This showed that about 105.84 sq. km (80.5%) increase in infrastructural LU covered the area between 1986 and 2000 while annual mean coverage is about 7.56 sq. km or about 5.8% increase annually within the study period. Compared with other LUs, the conversion of forest class to the infrastructural class was about 42.79 km^2. This was due mainly to urbanization and land development as a result of population increases and provision of infrastructural development for the near-two decades. Summary of the LU/LC change analysis between the periods, 1986 and 2000 is presented on Table 1.

The study showed that there were LU/LC conversions, from one type to the other, between 5 classes. These areas appeared on TM 86 as forest vegetation and on ETM+ 2000 as infrastructural. This conversion from forest vegetation to infrastructural represents about 42.79 sq. km. The summary of changes on the infrastructural class is presented on Table 2.

Table 1: Land use and Land cover Change in Owerri, 1986 - 2000

LU/LC Classes	TM [86 Classified]	ETM+ 2000 [Classified]	Area in Km^2
Vegetation Δ Forest Vegetation	Forest Vegetation	Forest Vegetation	1097.46
Vegetation Δ Built up	Forest Vegetation	Built up	42.79
Vegetation Δ Water Body	Forest Vegetation	Water Body	0.63
Vegetation Δ Cultivation	Forest Vegetation	Cultivation	290.38
Built up Δ Forest Vegetation	Built up	Forest Vegetation	15.29
Built up Δ Built up	Built up	Built up	331.15
Built up Δ Water Body	Built up	Water Body	0.56
Built up Δ Cultivation	Built up	Cultivation	91.04
Eroded Surface Δ Forest Vegetation	Bare/Eroded Surface	Forest Vegetation	0.02
Eroded Surface Δ Built up	Bare/Eroded Surface	Built up	20.35
Eroded Δ Cultivation	Bare/Eroded Surface	Cultivation	1.58
Water Body Δ Forest Vegetation	Water Body	Forest Vegetation	3.19
Water BodyΔ Built up	Water Body	Built up	3.35
Water Body ΔWater Body	Water Body	Water Body	1.49
Water BodyΔ Cultivation	Water Body	Cultivation	1.50
Cultivation Δ Forest Vegetation	Cultivation	Forest Vegetation	444.32
CultivationΔ Built up	Cultivation	Built up	150.78
Cultivation Δ Water Body	Cultivation	Water Body	0.95
Cultivation Δ Cultivation	Cultivation	Cultivation	295.89
Δ = changed to		**Total Area**	**2792.72**

Adapted from Njoku (2010)

There were conversions between 5 classes. Specifically, these were areas which appeared on TM 86 as forest vegetation and on ETM+ 2000 as infrastructural. This conversion from forest vegetation to infrastructural represents about 42.79 sq. km. The summary of changes on the infrastructural class is presented on Table 3.

Table 2: Summary of the changes on the infrastructural class of Owerri, 1986 – 2000

LU and LC Classes	TM 86[Classified]	ETM +2000[Classified]	Area in km^2
Built up **Δ** Forest Vegetation	Built up	Forest Vegetation	15.29
Built up **Δ** Built up	Built up	Built up	331.15
Built up **Δ** Water Body	Built up	Water Body	0.56
Built up **Δ** Cultivation	Built up	Cultivation	91.04
Δ = changed to	**Total**		438.04

Adapted from Njoku, (2010)

LU/LC dynamics and climate variation and change in Owerri

The descriptive statistics showed wider variation between the LU/LC and temperature during the study period. This is presented on Table 3.

Table 3: Descriptive Statistics

Parameters	Minimum	Maximum	Range	Mean	S E
Bare surface	4.01	21.96	17.95	12.6	4.84
Cultivation	544.08	891.94	347.88	745.13	81.81
Forest Vegetation	1204.75	1560	355.25	1393.54	73.6
Built up	438.04	788.95	530.91	570.7	76.6
Water body	3.11	9.53	6.42	6.42	1.77
Temp 1 (1986)	24.9	27.9	3.00	26.2	0.65
Temp 2(1991)	25.3	28.4	3.1	26.9	0.637
Temp 3 (2000)	25.6	28.0	2.4	26.92	0.5
Temp 4 (2005)	25.3	27.0	1.7	25.9	0.3

Source: **Fieldwork, 2010**

From Table 3, the built up areas range from 438.04 sq.km to 788.95 sq.km at $P < 0.05$. The correlation analysis matrix on Figure 4 was used to show the effect of LU/LC on the temperature of the 4 years. There was largely no significant correlation between the LU/LC classes and the meteorological data for the 4 years.

Table 4: Correlation matrix (r) of the LU/LC classes

	Bare surfaces	Cultivation	Forest vegetation	Built up	Water body
Temp 1(1986)	0.87	0.66	-0.63	-0.36	0.84
Temp 2(1991)	0.79	0.59	-0.44	-0.33	0.75
Temp 3(2000)	0.84	0.63	-0.56	-0.34	0.80
Temp 4(2005)	0.67	0.55	0.004	-0.45	0.61

Source: **Fieldwork, 2010**

The studentized't' test of significance was done with a pair of variables to determine the significance of each LU/LC class on each meteorological variable. The results showed no significance.

A test of homogeneity in means variance of LU/LC classes in 1986, 1991, 2000 and 2005 using the single factor ANOVA was computed. The results showed significant variation in LU/LC at $P < 0.05$ confidence level using single factor ANOVA, such that $F_{cal17.14} > F_{crit\ 4.08}$ between 1986 – 2005. A further structure of group means, of predictor and independent variables, using means plots utilized built up as predictor variables. The results revealed that 1986 and 1991 were most responsible for the observed heterogeneity. Of the 4 years studied, the plots shown on Figures 2, 3 and 5 indicated that in 1986 (438.04sq.km) and 1991 (511.94 sq. km) built up showed most variation against bare surfaces, cultivation and water body. However, in the forest vegetation (Figure 4) in 2000 (543.88 sq. km) was most responsible for the observed variation.

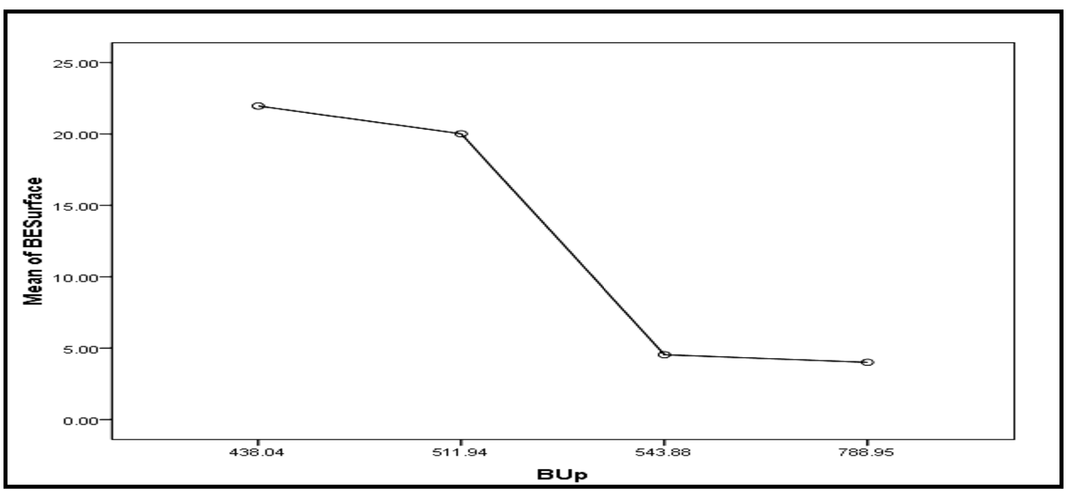

Figure 2: **Means plot of built up against bare surface LU and LC classes**

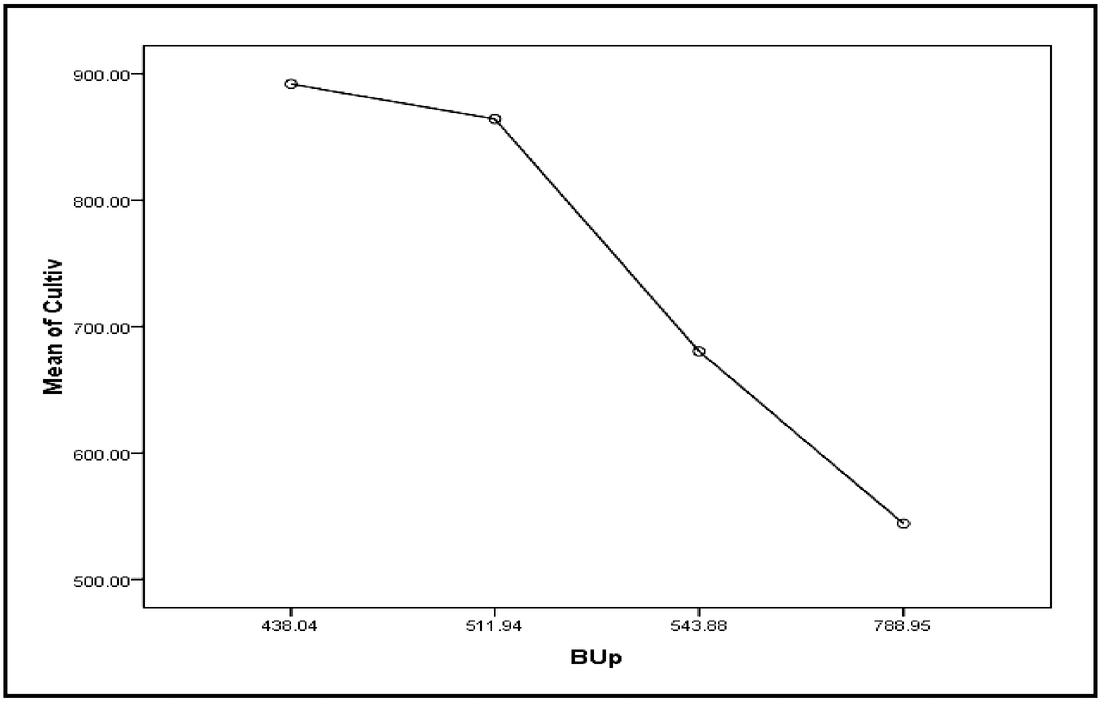

Figure 3: **Means plots of built up against cultivation**

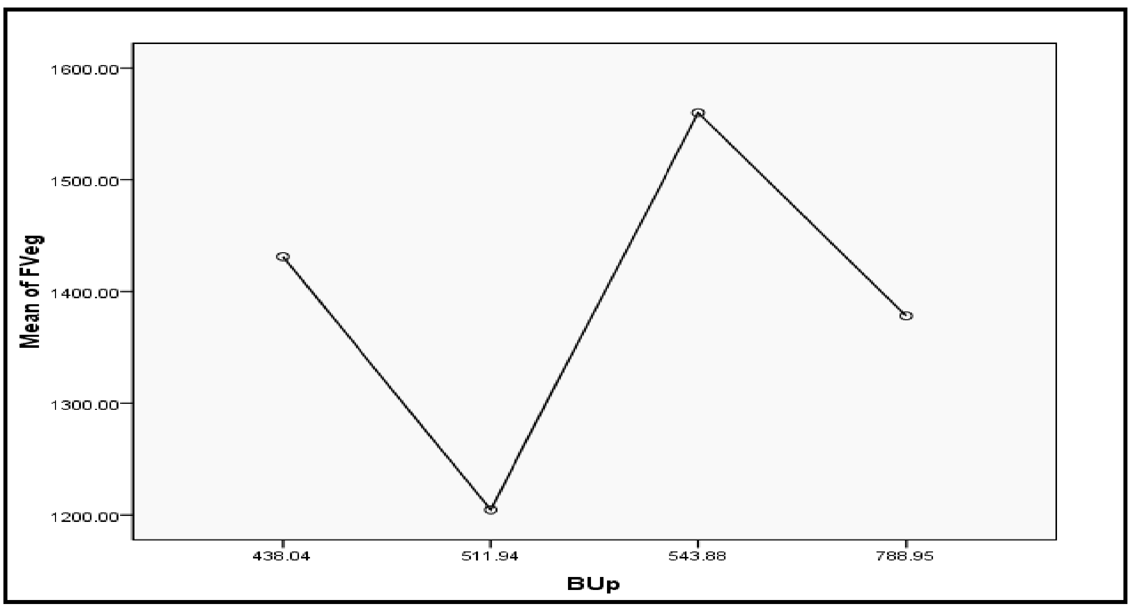

Figure 4: **Means plots of built up against forest vegetation**

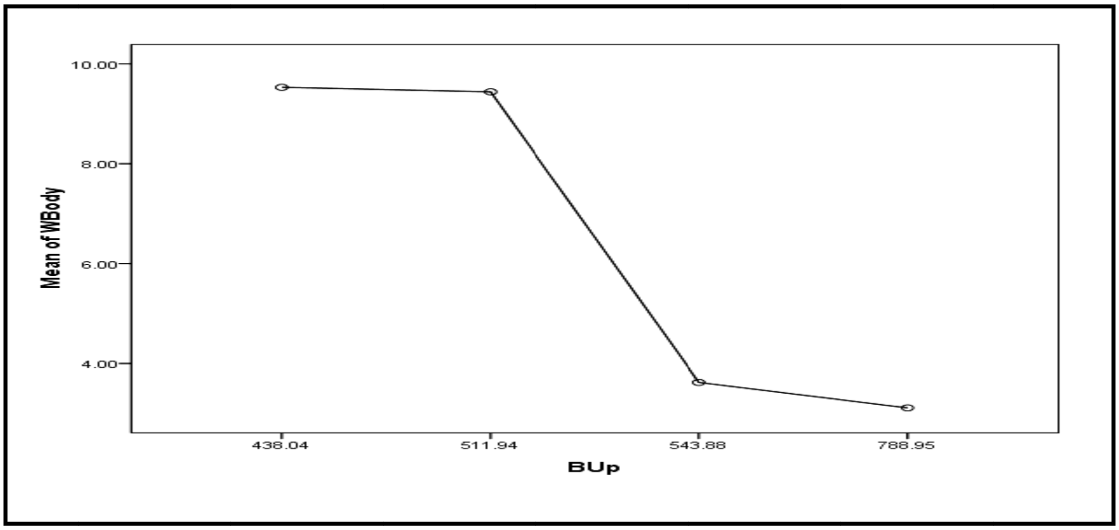

Figure 5: **Means plots of built up against water body**

Another test of homogeneity in means variance (with Temperature in 1986, 1991, 2000 and 2005) using single factor ANOVA showed that $F_{cal\ 3715} < F_{crit\ 4.17}$ at $P < 0.05$ revealed heterogeneity. The means plots presented on Figures 6 – 8 suggests that 2005 (27.90^{0}C) had greatest influence on the observed variation, while Figures 9 and 10 showed LU/LC classes and annual variations in maximum temperature for Owerri and environs between 1986 and 2005.

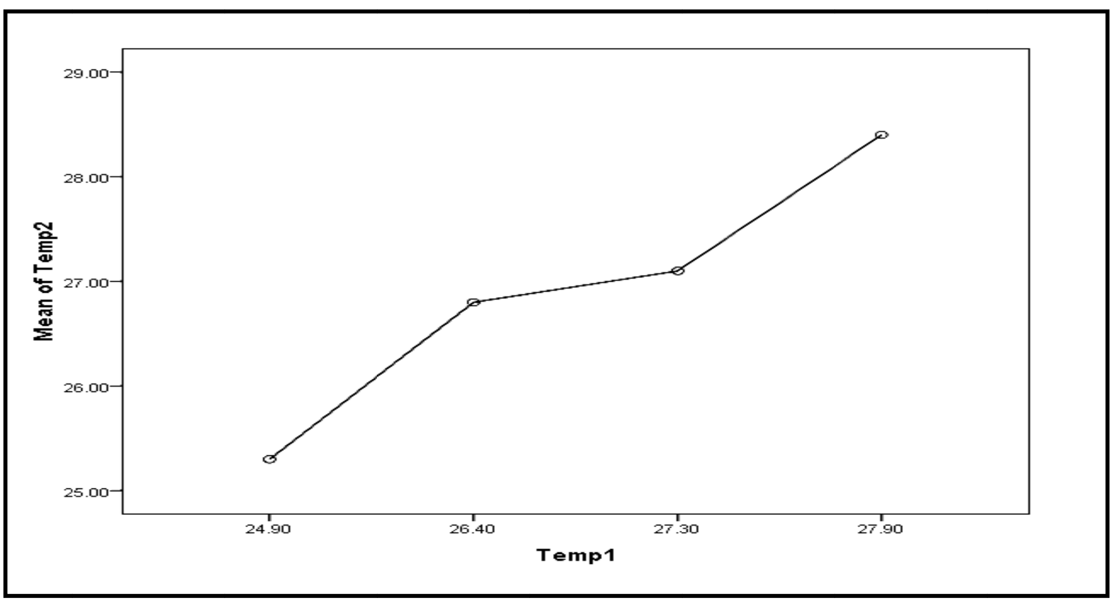

Figure 6: Means plots of maximum temperature for 1986 against maximum temperature of 1991

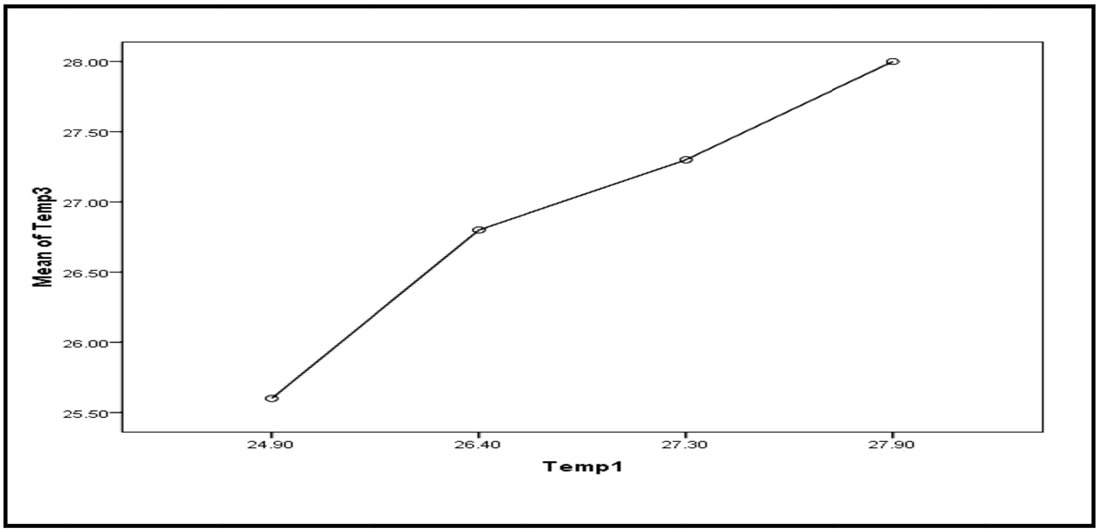

Figure 7: Means plots of maximum temperature for 2000 against maximum temperature of 2005

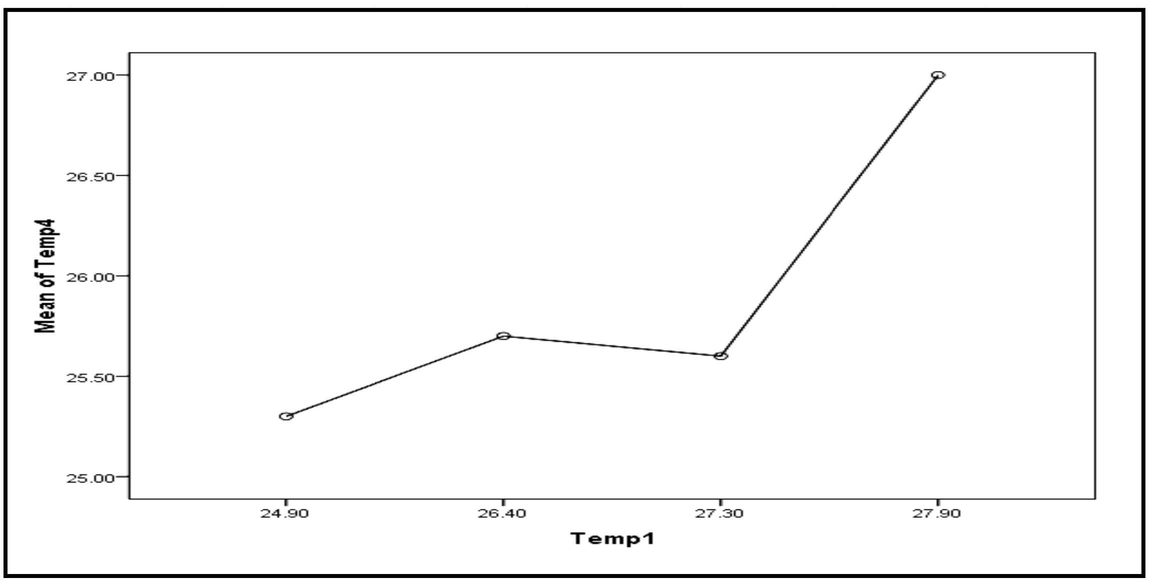

Figure 8: Means plots of maximum temperature for 1986 against maximum temperature of 2005

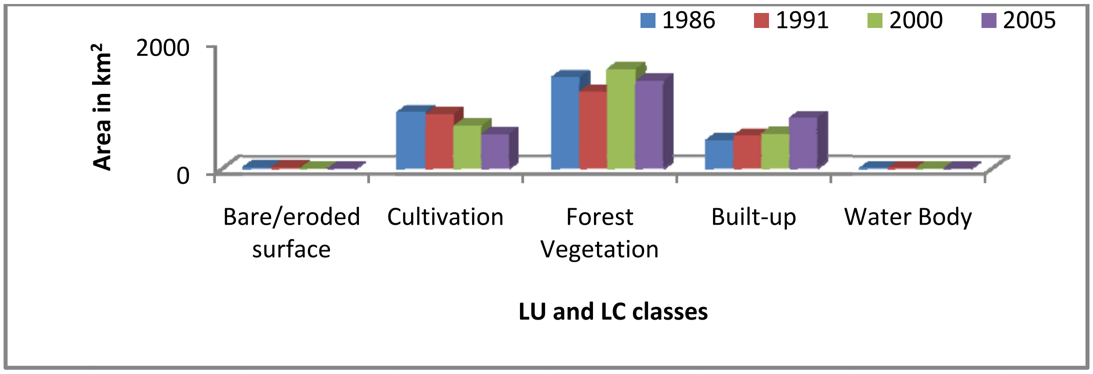

Figure 9: Coverage of LU and LC classes during the study period

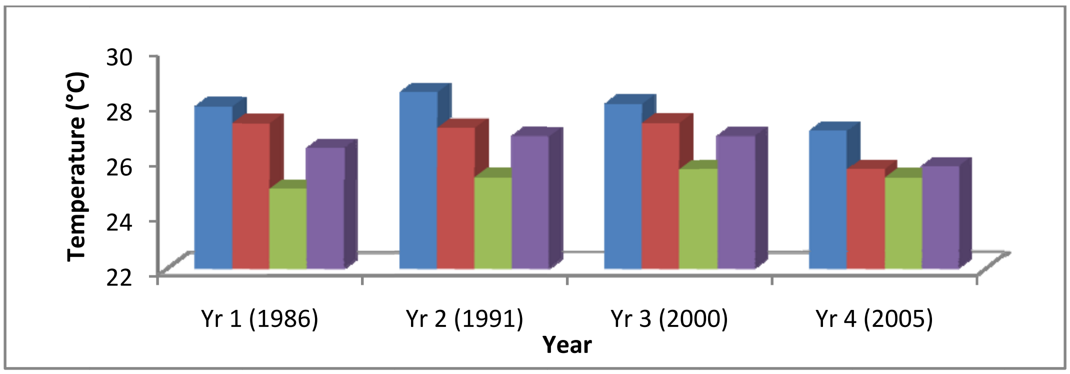

Figure 10: Annual variations in maximum temperature of Owerri and environs

Conclusion

It is common knowledge that LU and LC dynamism bears consequences on the regional temperature and climate variation and change. The results showed that some measure of heterogeneity exist between built environment and rise in the urban temperature in 2005. The coverage of infrastructural LU/LC class rose from 438.04km^2 in 1986 to 543.88km^2 in 2000. This showed mean annual coverage of 7.56km^2 or about 5.8% increase within the study period. If this continues in the long-run, Owerri metropolis and environs may be experiencing rise in temperature as outcome of LU/LC change in favour of infrastructure. Therefore, temporal and spatial land use and cover change for transport and other infrastructural development may be contributory to the swings in the urban climate being experienced in Owerri, Imo State. It is therefore recommended that the spate of this change be monitored and/or carried out with minimum destruction to vegetal cover, which can greatly influence temperature of the area.

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