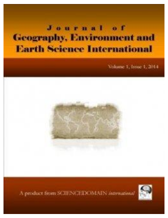

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The Effects of Urbanization on Micro-climate of Minna Urban Area

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Authors' contributions

This work was carried out in collaboration between all authors. Author SRF initiated the research, its design and managed the literature review section with the manuscript draft. Author DDB worked on the study data, performed the trend analysis and wrote the variables relationships in the discussion section and author OK wrote the abstract, managed the reference section and organization of the study. However, all authors have read and approved the final manuscript.

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ABSTRACT

This study deals with the interrelationship between urbanization and micro-climate of Minna city. The paper examined and analyzed the effect of urbanization on the city's micro-climate using recorded annual average temperatures and the population figures as bases for calibration. The researchers considered a period of 24 years (1991-2014) in which population data for 1991 and 2006 were obtained and used to project for the missing years. In the like manner the existing temperature records as variables were graphically contrived using correlation and regression statistics to analyzing the trend values of variables. The time series analysis revealed that the city average temperature has a positive relationship at significant value of 0.000 and at t-value of 104.075. However, there were gentle positive relationship between the city population density and its mean temperature. Population growth rate was estimated at 2.8% and with an increase in the city population from 230,169 to 436,887 within the period of 24years (1991-2014). Trends analysis revealed a rise in population density which in turns has impact on the temperature of the city. The

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researchers from the study concluded that a weak relationship exist between population density and average temperature of Minna at 12% degree of relationship and other elements of microclimate (e.g. relative humidity etc) are been affected at 88% due to other factors. The study recommended the use of automobiles such as tricycle, motorcycle and generator which have less capacity for releasing less carbon monoxide (Co) and also encouraged trees planting which has the benefit of abating high temperature at day time.

Keywords: Environment; micro climate; Minna city; population density; temperature; urbanization.

1. INTRODUCTION

For over three centuries most human settlements of the world have undergone noticeable transformation from just being naturally rural communities to some levels of civilization and urbanism. By definition, urbanization is the process in which the number of people living in cities increases compared with the number of people living in rural areas. In real sense a country is considered to be urbanized when over 50% of its population lives in urban places. Amongst the first countries to become urbanized were Great Britain and some European countries. Their urbanization was relatively slow, allowing governments' time to plan and provide for the needs of increasing urban populations. Urbanization is most rapid in Third World countries, some of which are among the first-ten world's largest cities. From UN-Habitat 2006 annual report, majority of people worldwide will be living in towns or cities for the first time by the middle of 2007 (Urban Millennium) and by estimation 93% of urban growth will occur in Asia and Africa.

The negative implications of the spurt urban growth on cities climate in particular is a concern for many researchers and governments of most nations [1,2]

Micro-climate in the context of urban centers and in this study refers to as Urban Heat Islands (UHI) has been studied since the 1800's when Luke Howard discovered that the urban center was warmer at night than the surrounding countryside [3]. Micro-climate studies improve the understanding of urban climatology, environmental change, and human-environment interactions that affect the quality of human life. Research has shown that the encroachment of urbanization into agricultural lands leads to higher temperatures at night, presenting as a contribution to some of the climate change issues [4]. A microclimate is a local atmospheric zone where the climate differs from the surrounding area. The term may refer to areas as small as a few square feet (for example a garden bed) or as large as many square miles. Microclimates exist, for example, near bodies of water which may cool the local atmosphere, or in heavily urban areas where brick, concrete, and asphalt absorb the sun's energy, heat up, and reradiate that heat to the ambient air: the resulting urban heat island is a kind of microclimate [5].

Cities micro climate change could result from both high per-capita transportation emissions and industrial smog/smoke which are common incidences in industrial cities of the world. In general, older cities that developed on the basis of manufacturing and trade, and before the invention of the automobile, have higher population density, more effective public transit systems, and lower per-capita transportation emissions compared with newer cities [6].

For the sustenance and dynamism of livelihood, every growing society is characterized by the erection of either permanent or temporary structures for the purpose of shelter which ranks second in the necessity of life [7]. The continuous quest for housing has tremendously increased urbanization and the built environment resulting in various environmental impacts and environmental degradation which is recently being traced to human activities with construction projects works taking a lion's share. Environmental Impact are used to describe some implications of human activities on the environment [8,9,10,11]. At the highest level, this includes the study of interactions among all forms and activities of the environment. In many fora Environmental Impact refers to effects of human activities on his environment [12,13].

It is widely accepted that economic activities and urbanization go hand in hand; however, the impact of urbanization on climate change has adverse effects and is yet to be acknowledged by many. Urbanization is an extreme way that human activities have changed the land cover according to their needs and desire.

In the light of the discussion, this study aims at analyzing the effect of urbanization on micro-climate of Minna and its environs. This hope to be achieved through the following objectives;

i. To examine the effect of population density on temperature of Minna and its environs.
ii. To compute the city climate change that has occurred over the years (1991 - 2014) using Temperature as an index of change.
iii. To examine the rate of changes in population density for the city of Minna over the years.

2. THE STUDY AREA BACKGROUND

The research area, Minna city, is one of the Nigeria's States (Niger State) administrative headquarters. The growing city has a population of 350, 287 [14] and occupies a land area of about 6,784 square kilometers. Minna city is located between Latitude 09^0 $4^0 17^I 0.63^{II}$ N and Latitude 09^0 3^0 $59^I 0.72^{II}$ N on one hand and between Longitude 06^0 30^I 0.32^{II} E to Longitude 06^0 36^1 34.05^{II} N on the other hand (Fig. 1). Basically, Minna lies in the middle belt of Nigeria and falls within the temperate humid which coincides appropriately with the tropical hinterland and Guinea savannah zone of the country (Fig. 1). Minna city lies on lowland and shares border in the east by Paida hill stretching eastwards towards Maitumbi and essentially savannah and quite conducive for farming. It shares borders Wushishi and Gbako to the west, Shiroro to the North, Paikoro to the East and Katcha to the south.

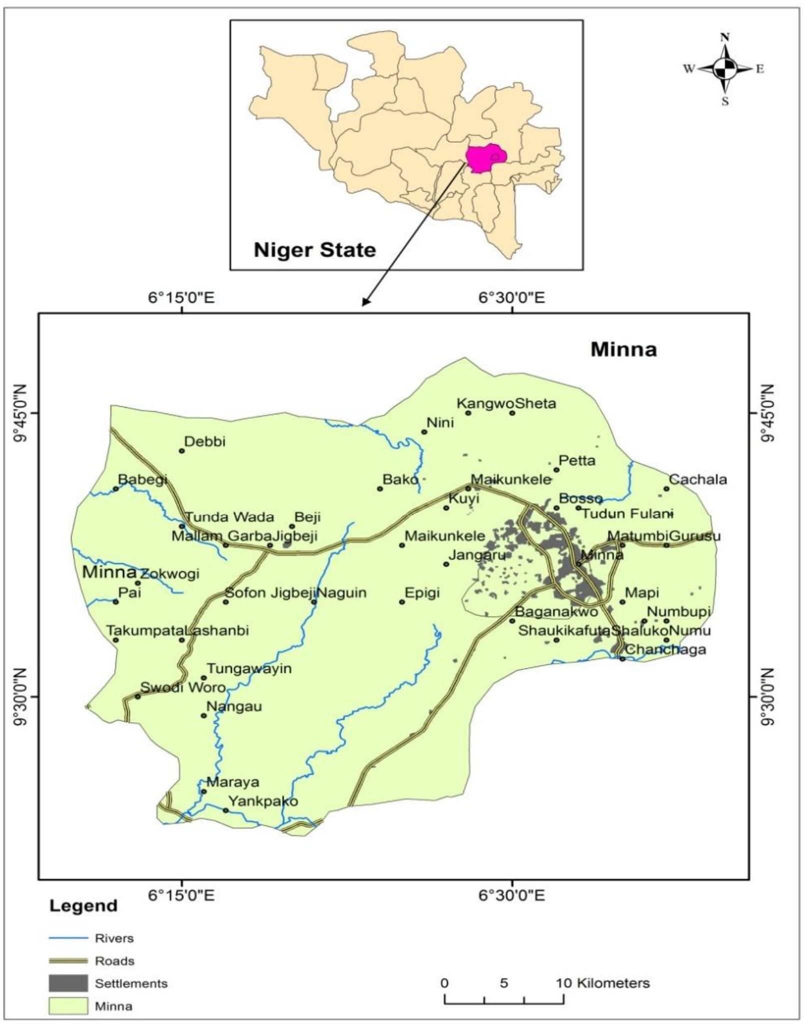

Fig. 1. Niger State map showing Minna Urban area

Source: Survey and GIS Department, Bells University of Technology, Ota (2016)

Minna is located within the tropical hinterland and the tropical continental climate of Nigeria (North and the sub-equatorial south climate regions). It therefore falls under the tropical continental wet and dry climate based on the Koppen classification scheme. The town has an annual mean precipitation of 1300mm taken from an exceptionally long record of 50 years. The highest mean monthly rainfall is in September with almost 300 mm. the rainy season stars on average between 11th and 20th April, and last between 190 and 200 days. Temperature rarely falls below 22ºC. The peak are 40ºC around February/March) and 35^{O}C within the two months of November and December. See details of 24 years (1991-2014) temperature trend in Appendix 1.

The geological structure of the city depicts a steep sloping rock outcrop on the north and eastern edge. The entire land area is characterized by some undulating topographies. In the real sense, land beyond the presently developed strip is suitable for development but that requires much careful planning to keep abase construction cost of culverts, bridges, embankments and drainage works. To the north over the hills, there are some developable lands but intersperse with poor land spaces. To the south the land offers reasonable development possibilities but is curtailed by the Chanchaga River. There is a major drainage channel fed by many minor drainage flows from the centre of the town south-west wards. At some other locations, these drainage channels flood large areas of low lying terrain especially after heavy downpour [15].

The vegetation cover of the city area consists of open savanna grassland interspaced with short trees characterized by baled brand leafed with some up to 16.5 meters in height. The Fadamas of the larger rivers support open savanna with occasional streams covered with dense riparian wood lands or gallery forest. The grasses often measured between 0.8 to 3.5 meters high.

3. LITERATURE REVIEW

The process of urbanization involves human activities that tend to alter chemical composition of the atmosphere, the thermal and hydrological properties of the earth's surface as well as the aerodynamic roughness parameters. For instance, marshes are drained, local vegetation is removed and soil is turned as natural surfaces are replaced by more impervious surfaces such as pavements, tarred roads and building roofs. Other human activities that encourage generation of green house gases such as building industries and increasing the number of automobiles are taking place in urban areas. These bring about increase in urban temperature compared with its rural areas the phenomenon termed "Urban Heat Island" (UHI) [16].

While an urban centre is an agglomeration of people that are organized around non-agricultural activities, urbanization has bee seen as the agglomeration of people in relatively large number at a particular spot of the earth surface [17,18]. Another school of thought believes the term is not about the population size, but that certain conditions like modernization, physical and economic development, as well as the heterogeneity in occupation muat be satisfied [16]. There is high rural-urban drift in Nigeria because of the inequalities, in terms of infrastructural facilities, services, social amenities and heterogeneity economic activities in favor of urban centres [19].

Urbanization is a global phenomenon that has transformed and continues to alter landscapes and the ways in which societies function and develop [20]. Cities offer the lure of better employment, education, health care, and culture; and they contribute disproportionately to national economies [21]. The United Nations Habitat (2006) describes urbanization as the increased concentration of people in cities rather than in rural areas. In other words, urbanization is the outcome of social, economic and political developments that lead to urban concentration and growth of large cities, changes in land use and transformation from rural to metropolitan pattern of organization and governance. It usually finds expression in outward expansion of the built-up area and conversion of prime agricultural lands into residential and industrial uses. This is a noticeable occurrence when a nation is still developing.

Reviewed literature suggests three features which distinguish the current trend of global urbanization. Firstly, it is taking place mainly in developing countries; secondly it is occurring rapidly and thirdly the severance of its occurrence and impact appear unevenly distributed across the globe, as [22] has observed.

The relationship between urbanization and climate change are obvious. Man's activities relate principally to where he lives, works and his movement from place to place, consumption as well as the usage of technologies, all affect heat emissions in the city [23]. Moreover, [24] has observed Nigeria is experiencing global warming at the rate far higher than the global mean temperatures. In Nigeria, the mean increase in temperature from 1971 to 2008 is 1.78ºC, compared to the global mean increase in temperature of 0.74ºC since instrumental global temperature measurement started in 1860. Climate change could lead to incessant flood occurrence, harsh temperature, poor agricultural productivity, and human health diseases - through skin reactions and respiratory ailment among other challenges.

Increase in population brings about increase in size of urban area. World Urbanization Prospects 2005 annual report described 20th century as witnessing the rapid urbanization of the world's population as the global proportion of the urban population rose dramatically from 13% (220 million) in 1900 to 49% (3.2 billion) in 2005. This has resulted in the shifting of residential area outward a process called suburbanization. Various authors at different times have emerged with different terminology to describe the formation of such new points of concentration outside downtown. For instance, [25] called it network city while [26] described it as postmodern city. The negative influence of the rapid urban growth on climate is a concern for many researchers.

According to [27], urban microclimate is the climate develops over a city and modified by variation in aspect, shape and form of the ground, soil moisture and surface vegetation. [28] stressed that the most pronounced and locally far reaching effects of man's activities on microclimate have been in cities. For instance it was discovered that smog is formed faster in cities because of the hot weather. Almost every city in the world is between 1 - 4^{0}C hotter than its surrounding areas. For every degree rise in temperature electricity generation rises by 2% - 4% and smog production increases by 4% - 10%. [29] generally find out that human induced changes in landuse such as urbanization among others affect both local and regional climate and even large scale atmosphere circulations.

Ilham [30] whose research work focuses on influence of population density on urban heat island reveals that the population density of city is proportional to the records of temperature taken during the survey. His findings shows a continuous increase of Kuala Lumpur population density, from 670 to 6085 (1980) and from 2000 to 6429 (2004). Consequently the intensity of the UHI of the city increased from 4.0^{o}C in 1985 to 5.5^{o}C in 2004. Thus, there is a proportional relationship between the population density and the UHI of the city of Kuala Lumpur. Therefore, the study concludes that, the UHI of the city of Kuala Lumpur is proportional to the population density of the city. The study also concludes that, the population density affects the urban heat island of the city and contributes to the increase in the intensity of the urban heat island of the city of Kuala Lumpur, Malaysia. The study shows that, although the overall population density of the city increases, that of the city centre decreases, while the nucleus of this UHI is the city centre. Therefore, it is difficult to conclude that the intensity of the UHI is inversely proportional to the population density of the city centre. Nevertheless, it is possible to conclude that, the increase in the intensity of the UHI is not only related to the population density of the city centre, it is actually affected by other different factors and human activities. The study finds that, the commercial, road and rail reserves lands of the city is proportional to the intensity of the UHI, while the open space and recreational, residential, institutional, and agricultural/ fishery/ forest lands is inversely proportional to the intensity of the UHI of the city [30].

Olarewaju 31] carried out the strength of relationships with correlation and regression analysis, between the variables of population growth and temperature shows that positive relationship exists between population growth and temperatures but with variation in strength. The implication is that as population rises temperature also scale up proportionally.

Review on work done by Tahir and team made us understand that both natural increase (population growth) and net migration are the major contributory factors to urban growth [32, 33]. Kim et al. used observational data from 2003 to 2005 to investigate the changes in the local thermal environment associated with the restoration of an inner-city stream in Seoul, Korea. They estimated that after the stream was restored, the near-surface temperature averaged over the stream area dropped by 0.4◦C, with the largest local temperature drop being 0.9◦C [34].

Hou et al. developed a method of near-surface air temperature (NSAT) retrieval that employs

Landsat Thematic Mapper images and examined the spatial relationship between NSAT and urban wetlands. They discovered that wetlands have an obvious influence on atmospheric temperature, which decreases as the distance from the wetland increases. Kochi is a fast-growing urban region in coastal South India interlaced by a network of canals and wetlands that is a part of the Vembanad Lake system [35].

Ifatimehin et al. [36], clarify that there are several impacts of urbanization on the micro-climate. There will be no meaningful development in the absence of urbanization; therefore urbanization has several adverse effects on environment existing in different places across the globe. Micro-climate study simply involves measuring the change in local weather conditions over a period of time in a small area. The Humidex formula has played a useful role in this regards. The equation is as follows:

$$H = T + (0.5555 * (E – 10)) \quad (1)$$

Where: H = humidex; T = temperature (ºC); E = relative humidity

4. MATERIALS AND METHODS

Basically the secondary data were used in this study and that include the climatic data and population data which are retrieved from relevant journals, textbooks, academic reports, newspapers, magazines, encyclopedia, etc. The climatic data is the temperature variables (element) of the study area while the population data is the population density variable of the study area.

The Secondary data were collected from the relatively longer records of meteorological data provided by the specific weather station (NIMET) network, Minna which was used to analyse the temperature of the city.

Data were further analyzed by means of engaging linear regression and trend analysis method; the various results obtained from the analysis of the effect of urbanization on microclimate of the study area were graphically presented using the SPSS (version 7.0).

In obtaining objective one, linear regression analysis was carried out to examine the effect of population density on temperature of Minna and its environs in order to show how strong the relationship between population density and temperature of Minna. Temperature is the dependent variable which represents “Y” coordinate while population density is the independent variable which stands for “X” coordinate. Statistical Package for Social Science (SPSS) software was engaged to carry out the analysis. The research adopts the use of hypothesis in its verification as follows:

1. Alternative hypothesis- This states that there is a significant relationship between the temperature and population density of Minna.
2. Null hypothesis- This states that there is no significant relationship between the temperature and population density of Minna.

In obtaining objective two, trend analysis was carried out using Microsoft excel. In doing this, the Microsoft excel sheet was used to calculate the average mean of the temperature by dividing the years into integers of four (4) with six (6) years in each integer. This was then plotted against the temperature and the trend value was obtained. The analysis was carried out to compare the changes that have occurred within the study area using temperature as an index of change. However, to ensure simple and accurate computation, the analysis was presented in forms of graphs and tables.

In obtaining objective three, that is examining the rate of change in population density of the city of Minna over the years, time series analysis was carried out. This exhibits the trend analysis of the population density using Minitab software package.

5. RESULTS AND DISCUSSION

Table 1 provides both the average temperature of Minna and its population density for a period of 24years (1991-2014) on one hand and the yearly percentage change in the population change on the other hand. Basically, they ware employed to analyze the actual effect of urbanization on micro-climate of the urban area of Minna which helped depict the relationship between the two variables of average temperature – called dependent variable (Y) and the population density called independent variable, X.

Studies carried out in other places have also included other variables like precipitation, Relative humidity, and pressure as modification elements for microclimate phenomena. The basis for this depends on the issues under investigation. Some researchers focus on the impact of micro climates on fauna and floral ecology, others basically on agriculture or forest zone. In most recent research on the microclimate regulation function of urban wetland of Xixi (China), Wei Zhang and his team analyzed the influence of a suburb wetland's urbanization process on the local climate through contrast observations of the protected wetland area and the former wetland area in Xixi wetland [37]. Lokoja (Nigeria) has maintained a monthly mean temperatures maximum of around 33.7°C and 22.7ºC as its lowest minimum over the past decades [38].

From Table 1, it is apparent that Minna urban population density maintains a progressive yearly increase unlike the annual average temperature, that are constantly subject to variation. Population density progressive rise is expected in the growing city where there is daily influx of people from the surrounding towns and villages resulting in a correspondence physical expansion of the built area. All these to a significant extent helped to increase the warm effect arising from Minna microclimate particularly the temperature. Evidently, the percentage change of Minna population density in 24 years is quite revealing, with the lowest at 1.5% between 2013 and 2014. However, the highest percentage change was between 1999 and 2000, when 4.7% change over the previous year was achieved. Average temperature record also was at its peak in 2009 (33.9ºC), two other years – 1998 and 2014 were warmer at 33.93ºC and 33.9ºC respectively, than other years within the 24 years period under consideration.

The obtained results upon the engagement of correlation and regression model are shown in Table 2 and Table 3.

Table 1. Average temperature and population density from 1991-2014

Year	AVE. TEMP (^{0}c) =Y	POP DEN(per/km^2) =X	% Change Pop. Den
1991	33.19	34	n.a
1992	32.86	35	2.9
1993	33.58	36	2.8
1994	33.34	37	2.7
1995	33.65	38	2.6
1996	33.63	39	2.6
1997	33.61	40	2.5
1998	33.93	41	2.5
1999	33.53	42	2.5
2000	33.47	44	4.7
2001	33.58	45	2.2
2002	33.5	46	2.2
2003	33.83	47	2.1
2004	33.24	49	4.2
2005	33.67	50	2
2006	32.86	52	4
2007	33.14	53	1.9
2008	33.38	55	3.7
2009	33.97	56	1.8
2010	33.83	58	3.5
2011	33.84	59	1.7
2012	33.54	61	3.3
2013	33.7	63	3.2
2014	33.9	64	1.5

Source: Author's computation 2015

From Table 2, it becomes clear that the t-value (that is, a test for significance) 104.075 for the constant is greater than the significance value 0.000 which reveals that there is a positive relationship between the population density and the temperature. In like manner, the t-value (test for significance) at 1.713 for the population density (independent variable) is greater than the significance value 0.97. This also points to the fact that population density has a positive implication on the average temperature.

Table 2. The coefficients of the regression model

Model		Unstandardized coefficients		Standardized coefficients	T	Sig.
		B	Std. error	Beta		
1	(Constant)	32.993	.317		104.075	.000
	POP	.011	.007	.346	1.731	0.97

Table 3. The model summary of the correlation and regression analysis

Model	R	R square	Adjusted R square	Std. error of the estimate
1	.346[a]	.120	.080	.29421

a. Predictors: Constant, POP

This result is a true reflection of common trends across major cities with high population concentration, or with compact development and/or high atmospheric pollution rate which usually arise from automobile and industries. Minna has no industries but investigation around the city revealed some forms of indiscriminate burning of bushes/fossils. The numbers of automobile has increased tremendously in the past two decades thereby helping to increase the level of atmospheric carbon monoxide. This is felt more along the major linear (ribbon) road between Bosso to Chanchaga, measuring over 10 kilometres, and the impact of obnoxious carbon monoxide are usually felt few metres away from the point of disperse.

The linear regression equation, given as: $y = 32.993 + 0.011x$ where ‘y’ is the dependent variable (average temperature) and ‘x’ the independent variable (population density). From Table 3, it could be examined that the correlation coefficient (R) is 34.6% implying that there is a positive relationship between the two variables. The degree of relationship (R^2) at 12% means that there is a weak relationship between the two variables. It also shows that urbanization (population density) has 12% influences on average temperature while other elements of urbanization fittingly account for the remaining 88%.

From the analysis it becomes obvious that the significant value is less than the B-value 0.11 which portents that the null hypothesis is rejected while the alternative hypothesis is accepted. The alternative hypothesis states that *there is a significant relationship between population density and temperature.*

From the Fig. 2, the average temperature is not constant even as the population density increases constantly. The population density increases every year from 34 person /km^2 in the year 1991 to 64 person /km^2 in the 2014 while the temperature varies at the rang of 32.86ºC to 33.97ºC. The value of the trend line analysis which is R^2= 0.121 portrays that there is a positive correlation between the population density and temperature of Minna but with a weak relationship.

The trend reveals that in 1991(base year), the population density of Minna city was 34 person /km^2 while the temperature was 33.19^0C. By the year 1996, the population density increased to 39 person /km^2. Likewise the temperature increased to 33.63ºC from 33.17ºC in 1991 with a temperature difference of 0.44ºC. This reveals clearly that an increase in population density brings about an increase in temperature of Minna within six years (1991-1996).

Again, within the period 1997-2002, the temperature fluctuated at a high bearable level of

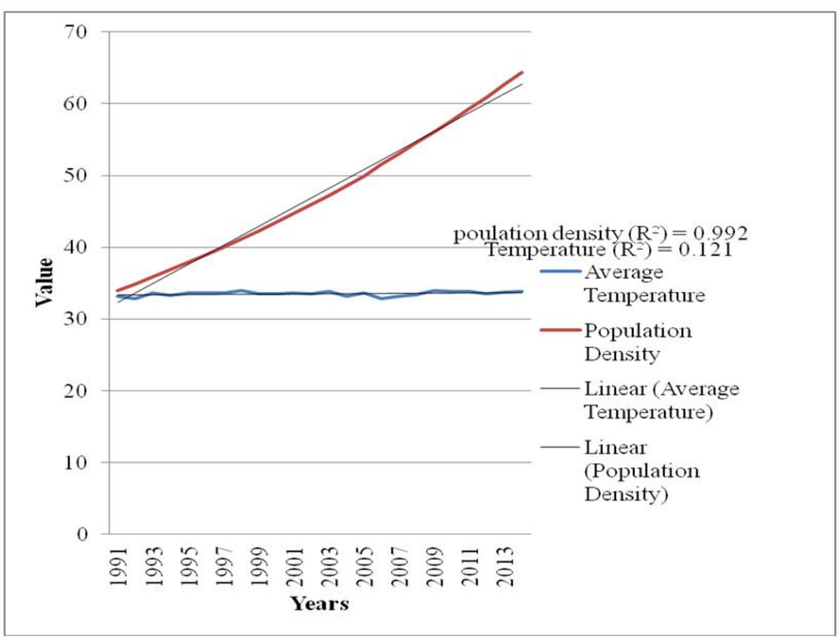

Fig. 2. The trend analysis of population density and temperature of Minna (1991- 2014)

33.93ºC (1998) while the population density maintains high rise from 40 person /km^2 to 46 person /km^2. The fluctuating temperature indicates that within six years period, the increase in population density does not really affect the temperature of Minna. The trend subsists through the period from 2003-2008, with the highest temperature of 33.83ºC in 2003.

In another six years period (2009 – 2014), the population density increases from 56 person /km^2 to 64 person /km^2 but with a slight decline in average temperature from 33.97ºC to 33.54ºC in year 2012, thereafter it manifests a minor rise to 33.7ºC and 33.9ºC in 2013 and 2014 respectively.

Table 4. Minna average temperature (1991-2011) in 6 rolling years segmentation

S/N	Year	AVE. temperature
1	1991-1994	33.24
2	1995-1998	33.71
3	1999-2002	33.52
4	2003-2006	33.40
5	2007-2010	33.58
6	2011-2011	33.75

Source: Author's computation, 2015

Observably, from this disclosure, it is evident that the increase in population density which is a subset element of urbanization has a lesser influence on the average temperature of Minna. This is due to the all time prolonged and unabated human activities on the land resulting to a drastic change in the land cover.

The effects of the city urbanization process essentially are re-shaping of the town components through the modification of the radiation receipt, development of layers of buildings and changing of the local land cover making it a different character from the surrounding areas. All these brought about changes in the temperature of Minna.

The average temperatures of Minna in three roll up years (1991-2011) are shown in Table 4 and graphically presented in Fig. 3.

Fig. 3 depicts an outcome of the changes that occurred over the study area from the year 1991-2014 using temperature as an index of change. Urbanization has brought changes to the average mean temperature of Minna. The chart however shows a mild correlation between the average mean temperature and the years with a level of significance R^2=0.322.

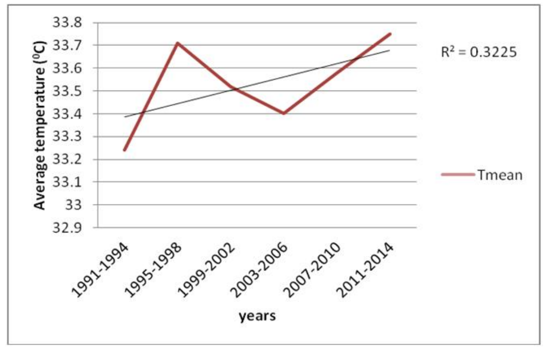

Fig. 3. Average mean temperature against the segmented years

The results obtained through the chart can be interpreted as follows:

- In the year 1991-1994 the average mean temperature of Minna was 33.24ºC. As urbanization continues to take place, the temperature has an increased value of 0.47ºC in 1995-1998 which makes the temperature of that year to increase to 33.71ºC.
- In 1999-2002 there was a decrease in average mean temperature to about 33.52ºC due to the urbanization that occurred and the planting of trees which absorbs some of the solar heating and released of green house gases. Likewise in 2003-2006 the temperature also falls to 33.40ºC.
- From 2007-2010 the average mean temperature rises again to 33.58ºC due to deforestation for the purpose of building settlements and industries.
- Also in 2011-2014 the temperature continues to increase, and able to attain 33.75ºC due to the high population density of Minna which increased from 34 person /km^2 1991 to 64 person /km^2 in 2014

Table 5 provides the rate of change that took place for 24 years in Population Density of Minna city (1991 to 2014). The observable correlation between population growth and population density is a natural trend in any growing urban area, the inverse may occur in an emergency situation of city decline, where industries and economic activities are folding up or are bring relocated to other cities in the same region.

Table 5. Minna population growth and population density (1991-2014)

Year	Population growth (persons)	Population density (person/km2)
1991	230,169	34
1992	236,614	35
1993	243.239	36
1994	250,050	37
1995	257,051	38
1996	264,248	39
1997	271,647	40
1998	279,254	41
1999	287,073	42
2000	295,111	44
2001	303,374	45
2002	311,868	46
2003	320,601	47
2004	329,577	49
2005	338,805	50
2006	350,287	52
2007	360,095	53
2008	370,178	55
2009	380,543	56
2010	391,198	58
2011	402,151	59
2012	413,412	61
2013	424,987	63
2014	436,887	64

Source: Author's computation, 2015

From Table 5 it is observed that the city population growth is directly proportional to its population density, which implies that as urbanization takes place population growth increases at the rate of 2.8% which in turn increases the population density from 34 person /km^2 (in 1991) to 64 person /km^2 (in 2014) which almost doubled the size of the previous year.

Fig. 4 reflects the trend analysis of population density of the study area from 1991-2014. Observably, the population density grew from 34 pers/km^2 in 1991 to 64 per/km^2 in year 2014, with the growth rate of approximately 2.8%. This is also confirmed from the trend line equation which indicates a positive trend (y=1.3191x+31.178). The resultant effect of the obvious growth led to rapid urbanization in the study area and the implications of this on the micro climate of Minna cannot be underscored.

The urbanization trend that has been examined over the years revealed a tangible growth of the population - from 230,169 people (in 1991) to 436,867 (in 2014) and forecasted to reach 658,950 persons by year 2064 (i.e, 50 years forecast). It is pertinent to assume that the increase in the city's population density may not significantly affect the average temperature of Minna ambience, nonetheless the activities which the people engage with bring that to bear, such as farming activities, deforestation and bush burning. According to the operational equation of the trend analysis used in forecasting the future population, the research affirms that when the population of Minna could attains 658,950. At this time most people will be engaging in varying activities in order to enjoy better life, consequently, such activities will bring about increases in the temperature of the town and its neighborhoods.

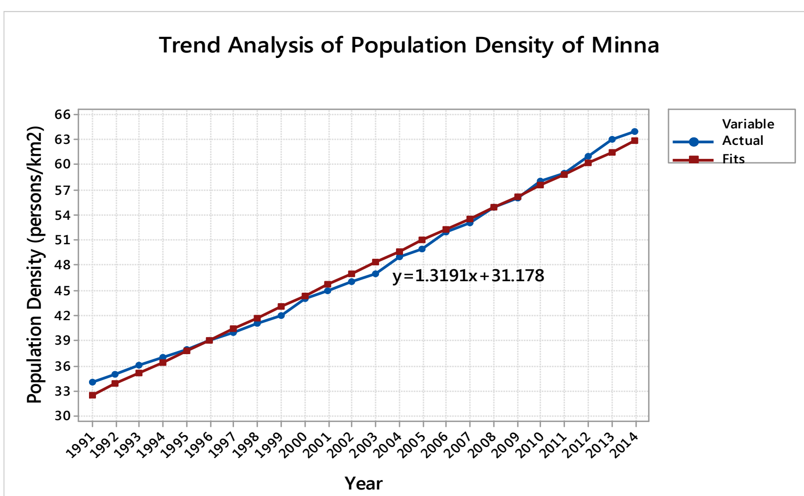

Fig. 4. Trend analysis of population density of Minna

6. CONCLUSION

From this study it could be deduced that population density has a slight effect at 12% on the average temperature of Minna city, meaning that other factors and human activities together have 88% effect on the temperature of the city. In all these, practical action will go a long way to improving the city urbanization process and its micro climate sustainability. Therefore, utilizing these findings the study hereby suggests an immediate action to help reduce urban heat island intensity of the city through the following ways:

- Government policy intervention by enforcing land use regulations in order to compel adherence to proper housing plan and construction.
- Enlightenment and awareness programme on the danger of urbanization the on human inhabitants and the environment.
- Trees planting and city greenery project/scheme (turning of open areas into green areas or small parks) thereby helping to create cool effects to the city.
- Reducing solar emission through efficient management of the land covers on critical surfaces and increasing the amount of vegetation/ open water at a higher rate than the profusion of hardcore and asphalt cover. This no doubt will discourage higher volumetric heat capacities and greater rates of latent heat influx, thereby lowering air temperatures.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX 1

Minna air temperature values in degree celsius (ºc) 1991 – 2014

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1991	35.5	37.4	37.6	35.6	31.4	29.7	29	30.8	30.1	31.7	35.4	34.1
1992	34.9	36.5	37.3	34.9	33.2	30.3	27.3	28.7	29.5	32.2	34.2	35.3
1993	33.5	36.8	36.6	37.6	34.9	31.3	29.7	29.4	30.7	32.5	34.6	35.3
1994	34.3	37.1	39.2	36.1	33.6	31.3	30.1	28.7	29.8	31.2	34.5	34.2
1995	34.2	37	38.9	37.2	33.6	31.9	30.3	29	30.6	32	34.4	34.7
1996	36.2	37.6	38.3	37.6	33.4	30.5	29.2	28.5	29.9	31.5	35	35.8
1997	38.8	36.8	37.1	35.4	32.2	30.8	29.6	30.2	30.8	31.7	34.9	35
1998	34.7	38.8	38.5	38.4	33.7	31.4	29.5	28.6	29.9	31.9	36.3	35.5
1999	35.4	37	38.3	37	34.2	31.4	29.1	28.6	29.5	31.3	35.7	34.9
2000	35.7	34.8	38.1	37.3	35.1	30.6	29.2	28.9	30.2	31.5	35.4	34.8
2001	34.8	36.1	38.9	36.3	33.7	30.9	29.1	28.3	29.5	33	36	36.4
2002	33.5	37	38.6	35.8	35.7	32	29.9	29.4	29.2	31.3	34.7	34.9
2003	35.3	38.2	39	36.6	34.7	31.2	29.8	28.8	29.8	31.8	35.5	35.2
2004	34.8	36.7	37.6	37.6	33.5	31	29.2	29	29.9	30	34.8	34.8
2005	33.7	38.3	39.4	37.6	33.7	31.4	29.4	28.8	30.5	31.5	35.1	34.6
2006	35.7	37.5	38.4	31.9	31.5	30.1	28.5	30.1	31.3	30	34.7	34.6
2007	33.7	37.2	38.2	36	32.8	30.3	29.5	28.2	30	31.7	34.7	35.4
2008	32.7	35.6	38.6	36.4	33.2	31.9	29.5	28.6	30.3	32.2	36	35.6
2009	35.7	37.8	39.2	35.2	33.9	31.8	30.9	29.8	30.5	31.5	34.6	36.7
2010	36.5	38.7	38.8	38.1	33.8	31.4	29.4	29.2	29.9	29.9	34.5	35.8
2011	34.7	37.4	39.3	37.2	33.4	31.4	30.7	29.4	30.3	31.4	35.5	35.4
2012	35	37.4	39.3	36.4	32.7	31	29.1	28.2	29.8	31.7	35.5	36.4
2013	36	37.7	38.8	35.4	32.9	30.5	29.4	29	30.7	32.3	36.1	35.6
2014	36.1	37.8	38.1	35.8	33	31.4	30.3	29	30.9	33	36.4	36.1

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